Attachment A

Assessment of Water Quality at the Miami Beach Park View Canal to Identify Sources of the Fecal Indicator Bacteria, Enterococci

DRAFT REPORT
Submitted on January 20, 2023

Authors

Larissa Montas, Ph.D.
Afeefa Abdool-Ghany, M.S.
Yutao Chen, M.S.
Erik Lamm
Ashley Quijada
Rivka Reiner
Hekai Zhang, M.S.
Helena Solo-Gabriele, Ph.D., P.E.

University of Miami, Coral Gables, FL
Department of Chemical, Environmental, and Materials Engineering

Submitted to:

City of Miami Beach (c/o Lindsey Precht)
1700 Convention Center Drive
Miami Beach, FL 33139

This page left intentionally blank

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

Figures throughout the document depicting sanitary sewer structures owned or operated by the City are exempt from public disclosure per 119.071(3)(b)1 Florida Statute. The figures depicted in black have been redacted per the Statute.

EXECUTIVE SUMMARY

The Park View Canal (PVC) is a secondary canal with limited flow located within Biscayne Bay, an area of known degraded water quality. Within this context, the water quality at the PVC is also degraded as documented by elevated levels of the fecal indicator bacteria (FIB), enterococci. Monitoring of the waterway by the City of Miami Beach (CMB) was initiated April 2019 as part of a stormwater management program designed to inform decision-making. Although the site is not part of the Florida Department of Health (FDOH) Healthy Beaches Program, its levels are compared to recreational beach levels to provide a basis for comparison.

Since the initiation of sample collection by the CMB, levels of enterococci have exceeded the FDOH recommended 70 most probable number (MPN) per 100 mL recreational swimming threshold 90% of the time, with occasional values (9.5%) exceeding 10,000 MPN/100 mL. Given these elevated enterococci levels, the PVC was closed to the public for safety concerns and several studies were initiated by the CMB to evaluate sources of enterococci to the PVC. Testing by CMB during 2020 and 2021 showed that the FIB could be attributed to dog and bird waste. Since prior studies had not identified one source or solution, the CMB contracted with the the University of Miami to conduct an evaluation of historical data provided by the CMB and implement a sample collection program aimed at identifying the geographic location of the source and to better understand the conditions by which enterococci enter the waterway. The sample collection program included intense spatial sampling (many samples collected around Parkview Island within a short period of time), intense temporal sampling (hourly sample collection at the PVC for 48 hours), sample collection within the stormwater conveyance system catch basins and wells, and sample collection to evaluate distributions of enterococci with increasing water depth at the PVC.

Results show that antecedent rainfall was the main predictor of poor water quality within the PVC. Approximately 329,000 m^2 of catchment area contributes rainwater runoff to nine outfalls that discharge directly to the PVC. The sample collection program showed dramatic increases in enterococci levels during and after a storm event. Sediments collected from the banks of the waterway and from the surface and bottom of catch basins were characterized by levels of enterococci up to several hundreds of thousands per gram. Water collected from catch basins and drainage wells frequently exceeded 10,000 MPN/100 mL with some samples testing above the 241,960 MPN/100 mL detection limits. However, samples collected from the CMB groundwater monitoring wells screened at a depth of 35 feet were characterized by low levels of enterococci suggesting that deeper groundwater does not contribute to the elevated levels of enterococci. In addition, the ambient water in the PVC is more saline than rainfall resulting in a surface layer (or freshwater lens) that floats on top of the saltier water. This freshwater that is found at the top surface of the water at the PVC frequently exceeds detection limits for enterococci. Therefore, levels measured are highly sensitive to the method of sample collection. The distribution in enterococci with depth (with very high levels at the upper surface) likely has confounded the interpretation of earlier data given potential differences in how (and at what depth) samples may have been collected.

Given these results, **the primary source of enterococci to the PVC was identified as waste deposited on surfaces that drain towards the PVC**. When it rains, the stormwater washes surfaces (streets, roof tops, gutters) and in the process picks up FIB that are on these surfaces. This runoff containing the FIB from the stormwater catchment area (from Parkview Island extending east to Collins Avenue) is then carried to the PVC through the stormwater conveyance system creating the freshwater lens described above that contains very high levels of enterococci that floats on the surface of the PVC. Specific sources of FIB to freshwater runoff have been identified from visual observations as fecal matter from animals inclusive of dogs, iguanas, racoons, and feral birds. Sources also include waste from homeless populations that live within the stormwater catchment area and who do not have access to sanitation facilities. Trash and seepage from garbage containers and commercial bins are also sources of FIB that contribute towards the contamination of surface runoff as well as contaminated sediments found on the streets and along the waterway banks. Although a specific leaking sanitary sewer was not identified, the results of this study do not exclude the possibility of sanitary sewage from contributing to the elevated levels of FIB. The sanitary sewer system is aging and needs upgrades as recognized by the CMB and for which funding is needed. This aging sanitary sewer system along with the stormwater conveyance system are located just above the groundwater or within the top few feet of the groundwater and there is a possibility of leakage from the aging sanitary sewer system impacting shallow groundwater which in turn can be picked up by the stormwater conveyance system and carried towards the PVC.

In efforts to address the elevated FIB levels at the PVC, we recommend that CMB develop a comprehensive management plan to reduce the fecal loads to the waterway. This plan (portions of which have been implemented throughout the course of this study) includes provision of extensive outreach services to the homeless in the area, continuing with aggressive education programs to minimize dog fecal waste throughout the stormwater catchment, and management of non-native feral animals. Trash on streets should continue to be minimized through street sweeping, code enforcement, educational outreach, and clean up. Leakage from trash bins should continue to be minimized by maintaining covers and frequent trash pickup. Efforts should continue to assess the possibility of leaks from aging sewer pipes. In the longer term, plans are recommended for upgrading the storm and sanitary infrastructure. For stormwater, efforts should focus on developing conveyance systems to treat the first flush and the possibility of providing a treatment system for trash and sediment removal. Plans underway should be implemented that upgrade the sanitary sewer system as soon as possible given the age of the system and the possibility of leaks. The physical constraints to flow within the PVC also contributes to the elevated levels, and efforts should also focus on improving water flow through the removal of debris/trash and possible dredging.

As described in further detail in the last chapter of this report (see page 77), the CMB has initiated many actions to address FIB contamination. In brief these actions have included a public education program to encourage dog owners to pick up waste and provision of outreach services for homeless populations. Actions have also included increased sweeping (by hand and mechanically) of the streets, more frequent cleaning of the stormwater conveyance system to remove trash, and more frequent trash pickup. The CMB has existing programs in place to inspect gravity mains to identify potential leaks on Parkview Island and the CMB is committed to fixing leaks as they are found. The CMB has applied for $11.5M in funding from the NOAA Transformational Habitat Restoration and Coastal Resilience Grant to provide funding for shoreline improvements in the PVC and other shoreline areas in Miami Beach. Most significantly the CMB has received a $10M Florida Resilient grant to develop design alternatives for a North Shore D and Towncenter Neighborhood Improvement Project which includes a proposed stormwater conveyance system that will replace the existing stormwater pipe network from between 69th and 73rd streets and from the PVC to Collins Avenue to the east. The new stormwater conveyance system is currently projected to include new catch basin structures, manhole structures, conveyance piping, injection wells (to treat the first flush), and up to two stormwater pump stations. The City procured Hazen and Sawyer to complete Water and Sewer Master Plans (2019) that have identified and prioritized critical projects that must be completed in a timely manner. The water and sewer capital improvements received $122M in funding to implement the prioritized critical projects. Although the CMB recognizes that a lot of work is to be done in long-term planning, it has initiated work through its Stormwater Master Plan Update and Capital Improvement Plan that will identify critical needs to be addressed by the City over the next 10 years. The plan will take several criteria into consideration including stormwater flooding, tidal flooding, water quality issues, and resident complaints. The Stormwater Master Plan Update will be completed and presented to City Commission in November of 2023.

Overall, the intent of this report is to consolidate available data, report on sampling aimed at identifying enterococci sources, and summarize the initiatives taken by CMB. Our hope is that this document will assist in further establishing communications with the community in efforts to best address water quality issues associated with the PVC. A CMB community meeting scheduled for late January 2023, aims to initiate discussions given the results from this report, and request feedback and support from community members in establishing action plans.

LIST OF ACRONYMS

CFU: Colony Forming Units

CMB: City of Miami Beach

FDEP: Florida Department of Environmental Protection

FDOH: Florida Department of Health

FIB: Fecal Indicator Bacteria

GIS: Geographic Information System

KL: Kayak Launch

KLW: Kayak Launch Waterway (used interchangeably with PVC)

MF: Membrane Filtration

MPN: Most Probable Number

PVC: Park View Canal

PVI: Park View Island

TPTV: Ten Percent Threshold Value

UM: University of Miami

CHAPTER I

MOTIVATION, OBJECTIVES, AND BACKGROUND

CHAPTER I

MOTIVATION, OBJECTIVES, AND BACKGROUND

This chapter focuses on describing the motivation and objectives (Section I.1) and the project background for this study, including target levels for enterococci and fecal coliform (Section I.2), general categories of enterococci sources (Section I.3), and general conditions of the Park View Canal (Section I.4)

I.1 MOTIVATION AND OBJECTIVES

The Park View Canal (PVC) at the City of Miami Beach (CMB) (GPS: 25˚ 51' 31.20" N. 80˚ 07' 33.00" W for the Launch) located near 73 Street and Dickens Avenue (Figure I.1) has a history of elevated levels of fecal indicator bacteria (FIB).

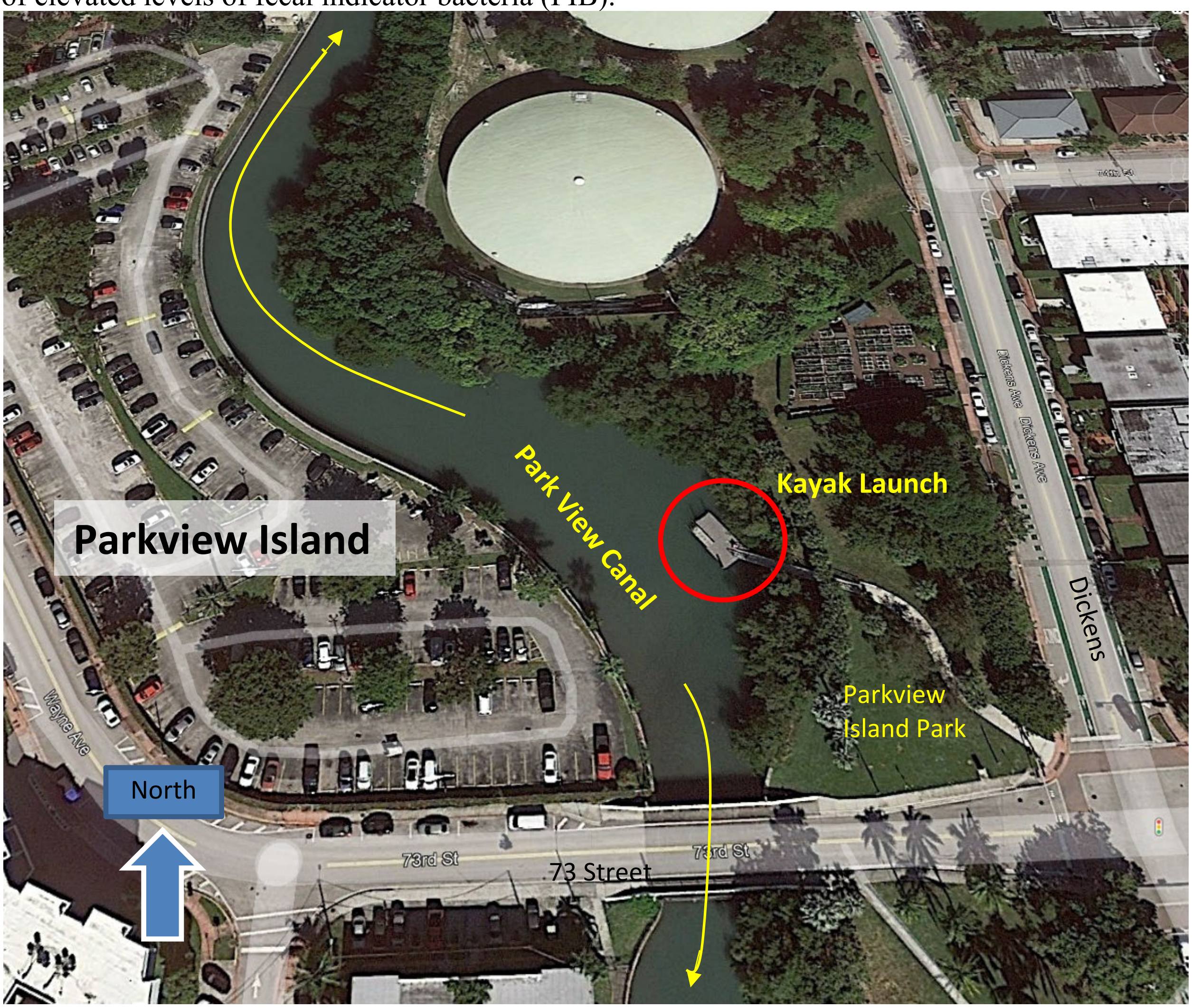


Figure I.1: The PVC emphasizing the location of the Kayak Launch (25˚ 51' 31.20" N. 80˚ 07' 33.00" W), near 73 Street and Dickens Avenue Miami Beach, FL. Basemap from Google Earth.

In recent years several sewage leaks, at various locations in the CMB (see Figure III.3 in Chapter III), have resulted in sewage impacting the bay and connected waterways. In October 2018, city inspectors discovered cracks in a wastewater pipe under the bridge to La Gorce Island, located 1.3 km to the south of the PVC study area (MNT 2018). The leak lasted approximately 16 hours during which 800 gallons of raw sewage discharged into the bay. On July 31, 2019, a wastewater pipe at 5th Street and Michigan Avenue was accidentally drilled by a contractor causing a leak of 780,000 gallons of untreated sewage over two days, of which an estimated 390,000 gallons discharged into the bay (MNT 2020). That following year, on March 4 and 5, 2020, the City experienced back-to-back major sewer main breaks, one of which impacted the immediate vicinity of the Kayak Launch within the PVC. The first occurred on March 4 near Lincoln Road (located about 5 miles south from the PVC) when a drilling company accidentally drilled into a 42-inch sanitary sewer main (PV ISA 2021). The flow from this main was diverted to other pipes in the system causing pressure shifts which then caused two additional breaks on March 5, 2020 (WLRN 2020). These additional two breaks emphasize the weakness of the existing aging infrastructure and the need for its upgrade. One of the two breaks occurring on March 5, was located at 28 Street and Pine Tree Drive and the second of the two breaks was located at 72nd Street and Harding Avenue, which is located 1500 feet east of the PVC. This pipe break at Harding Avenue spilled an estimated 665,000 gallons of untreated sewage towards the PVC. Overall, an estimated total of 1.4 million gallons of raw sewage spilled into various waterways as a result of these three breaks.

As part of cleanup efforts, the water quality of waterways receiving wastewater from the aforementioned breaks was tested for FIB. On March 6, 2020 water quality measurements at the PVC indicated that enterococci concentrations were 345 times the acceptable State and Federal value for safe swimming. Although, within days after the spill most waterways tested below the FDOH advisory levels (including the sites of the original March 4 break plus the other site at Pine Tree Drive), the PVC has not tested consistently within regulatory levels.

Although the March 2020 spill focused attention on the water quality of the PVC, this site was being monitoring prior to the spill, since April 17, 2019. This earlier monitoring was part of a stormwater management program designed to inform decision-making. At the time during 2019, CMB was in the process of identifying priority areas within Miami Beach for possible installation of stormwater pump and treatment stations. The CMB has installed at other locations stormwater pump stations fitted with treatment systems designed to remove trash and grit (via vortexer).

The March 2020 sewage leak set forth discussions by city officials, residents, and other stakeholders on the time for onset of water quality deterioration and enterococci contamination at the PVC (PV ISA 2021). Considerations put forward by residents emphasized a slow degradation in water quality over several years with the water slowly changing color, occasional odors, algae blooms, and a fish kill during April 2020, about a month after the sewage leaks. Monitoring data collected at the PVC prior to the March 2020 sewage break are of particular interest as they can provide some insight on whether deterioration of the waterway coincided with the March 2020 sewer break.

Discussions by residents, CMB officials, and other stakeholders also centered on whether the enterococci in the PVC were generated by human or animal sources, in particular dogs. The presence of dog feces adjacent to stormwater inlets, and at the Park View Island Park, was proposed as one possible source for the elevated enterococci levels. Opposing views pointed at the CMB's sewage infrastructure as the possible source, citing that the 50- to 70-year-old sanitary sewer infrastructure was failing, possibly leaking sewage that ended up in the bay and waterways (MNT 2020).

When the FIB at the PVC did not decrease to below regulatory levels (following the March 2020 sewage leaks) the CMB contracted to have samples analyzed for Microbial Source Tracking (MST) markers. MST microbial markers are specialized molecular analyses that further identify which species (humans, dogs and/or birds) are contributing fecal waste to the waterway. Thus, MST can be used to link the elevated enterococci levels with an animal species. Five sets of samples were collected (October 13, 2020; November 5, 2020; June 15, 2021; September 2, 2021; September 24, 2021). Three first three sets (collected on October 13, 2020, November 5, 2020, and June 15, 2021) indicated a dominance of dog markers. The set collected on June 15, 2021, although dominated by dog marker, showed some evidence of human marker. The set collected subsequently on September 2, 2021 showed no significant contributions from animals. The last set collected on September 24, 2021 showed a dominance of bird markers with some contributions from dogs. As a result of these MST sampling efforts, the CMB developed an educational campaign to encourage dog owners to properly dispose dog waste. The CMB constructed facilities with doggie bags and garbage bins with signage at the park area that leads to the PVC (Parkview Island Park) to encourage proper disposal of dog waste and thus reduce contamination of runoff by dog fecal matter.

Despite the implementation of these measures focused on dog waste removal, the levels of FIB at the PVC remained elevated. Given these continued elevated levels of FIB, Surfrider Foundation initiated its own MST study (JV 2022). Three samples were collected in the PVC on July 14, 2022, one at the Kayak Launch, one to the north, and one to the south (Figure I.2). Results from the Surfrider Foundation study suggest that the fecal indicator bacteria levels in the waterway come from human and dog sources. The human marker was found in 2 out of 3 replicates at the south end, and in one replicate at the Kayak Launch. However, human was not detected at the North end. The average number of copies detected for the Human01 assay were almost double at the south (477 per 100 mL) end than at the Kayak launch (257 per 100 mL). This southern area also coincides with the storm sewer conveyance line along 72 Street which is in-line with the location of the March 5, 2020, line break at Harding Avenue and 72 Street. Given these data, the sample collection plan developed for this current study takes this information into account by first establishing a spatially intense sampling effort to confirm the geographic location of enterococci sources along the entire perimeter of Parkview Island to identify the location of hot spots in the area.

[redacted]

Figure I.2: Location of Surfrider Foundation Study Sampling Sites Shown in Blue Dots Relative to Storm and Sanitary Infrastructure at Parkview Island.

Concurrent with the water quality monitoring programs describe above, the CMB has conducted a comprehensive set of studies of the area in attempts to isolate potential sources of FIB. In addition to the efforts at reducing the impacts from dog waste, CMB has conducted extensive studies evaluating the sanitary sewer system, inclusive of smoke testing, camera inspections, and acoustic testing to identify potential leaks. With the exception of the large sewer main break of March 5, 2020, it is our understanding that leaks identified were minor. For cases where leaks have been identified the City has taken corrective action where possible. Corrective actions can be taken by CMB in the public right-of-way but not on private properties. The CMB continues to evaluate the area for potential sources of FIB inclusive of sanitary sewage but has yet to identify a source that explains the persistent elevated levels of enterococci in the PVC.

The **objective** of this project was to identify the source of the elevated levels of enterococci to the PVC. Source in the context of this study focused on understanding, "**From where the enterococci are coming from?**"

We used targeted sampling and measurements to identify the type of water (fresh versus marine) and geographic location of the source. For example, by collecting many samples along the entire extent of the PVC in a short period of time (intense spatial sampling) we identified hot spots in the waterway and used this information to identify infrastructure that could be conveying enterococci towards these hotspots. Likewise, by collecting many samples at a single location over 48 hours, we identified environmental and hydrometeorological parameters associated with high enterococci levels.

We did not use Microbial Source Tracking (MST) as part of the current study. Prior MST studies by the CMB and the Surfrider Foundation have documented that the source comes from humans, dogs, and birds. The next step was to understand, "**How enterococci from humans, dogs, and birds enter the waterway?**"

Therefore, we designed the study to better isolate potential sources to specific geographic areas and types of water (fresh water coming from the land vs. marine water). To identify the source and potential transport pathways to the PVC, we have categorized our analysis into four subtasks as follows. Two subtasks focus on evaluating existing information and two focus on efforts associated with the team's visit and sampling of the sites.

(1) Evaluate Existing Historical Water Quality Data Available through the City of Miami Beach (Chapter II)
(2) Evaluate Existing Stormwater Conveyance Infrastructure in the Vicinity of the PVC (Chapter III)
(3) Provide Qualitative Assessment from Visual Inspections at the Site (Chapter IV)
(4) Conduct Targeted Sample Collection Efforts to Identify Sources (Chapter V). These efforts included:
    - Intense Spatial Sampling at the PVC
    - Sediment and Stormwater System Catch Basin Sampling
    - Intense Temporal Sampling (Autosampler) at the PVC
    - Depth Sampling Within Waterway, Catch Basins and Wells

We used the information provided by (1) to (4) above, to propose recommendations for approaches to reduce enterococci contributions to the PVC as described in Chapter VI.

I.2 TARGET LEVELS FOR ENTEROCOCCI

Fecal indicator bacteria, enterococci and fecal coliform, are frequently used to establish safety guidelines for use of a water body. Over the years guidelines have transitioned away from fecal coliform to other FIB such as enterococci (used predominantly for marine waters) or *E. coli* (used predominantly for freshwater). The PVC is a marine water and therefore the enterococci guidelines would be the most applicable. Since CMB historical data are available for both fecal coliform and enterococci, this section will describe the guideline levels for both FIB.

In Florida, two agencies set guidelines for FIB in recreational waters, the Florida Department of Health (FDOH) and the Florida Department of Environmental Protection (FDEP). The FDOH, through the Florida Healthy Beaches Program, provides guidelines for recreational bathing beaches and has a centralized reporting website that lists a recreational water as good, moderate, or poor quality (See: https://www.floridahealth.gov/environmental-health/beach-water-quality/index.html). The FDOH lists a water as good quality when enterococci levels are less than 36 enterococci per 100 mL, moderate quality when levels are between 36 and 70 enterococci per 100 mL, and poor quality when enterococci levels exceed 70 per 100 mL. Beach "advisories" are issued when two consecutive samples exceed 70 per 100 mL. The FDOH guideline is based upon the U.S.

Environmental Protection Agency (U.S. EPA) guidelines (U.S. EPA 2012).

Historically the FDOH had used fecal coliform for establishing beach closures. Fecal coliforms were recommended earlier by the U.S. EPA for both freshwater and marine water (U.S. EPA, 2017). From August 2000 through June 2002, FDOH would issue closures when fecal coliform exceeded 800 CFU/100 mL. This was adjusted to 400 per 100 mL, which was in effect from July 2002 until June 2011. After June 2011, fecal coliform was dropped from FDOH sampling (Kelly et al. 2018).

Similarly, the FDEP also has guidelines established for enterococci. The FDEP regulates surface waters of the state according to their designated uses and thus the surface waters of the state are separated into one of six classes. The classes that most closely align to the current uses of the PVC are Class III and Class III – Limited (See, https://floridadep.gov/dear/water-quality-standards/content/surface-water-quality-standards-classes-uses-criteria). These are defined as:

- Class III: Fish Consumption, Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife
- Class III – Limited: Fish Consumption, Recreation or Limited Recreation, and/or Propagation and Maintenance of a limited population of fish and wildlife.

The bacteriological criteria for both classes as documented in the Florida Administrative Code (F.A.C. 2016) is the same and listed as: Most Probable Number (MPN) or Membrane Filtration (MF) counts shall not exceed a monthly geometric mean of 35 nor exceed the Ten Percent Threshold Value (TPTV) of 130 in 10% or more of the samples during any 30-day period. Monthly geometric means shall be based on a minimum of 10 samples taken over a 30-day period.

Historically, prior to 2016 (F.A.C. 2013) the FDEP had recommended fecal coliform for Class III and Class III-limited designated waters. The fecal coliform standards for both classes were listed as: MPN or MF counts shall not exceed a monthly average of 200, nor exceed 400 in 10% of the samples, nor exceed 800 on any one day. Monthly averages shall be expressed as geometric means based on a minimum of 10 samples taken over a 30-day period.

A summary of the threshold values as established by the FDOH and FDEP is given by the following table. When evaluating enterococci levels based upon single sample analyses the general practice has been to use a threshold value of 70 per 100 mL to designate the quality of a beach site. For subsequent discussion purposes the value of 70 will be used as the target threshold for assessing the microbial quality of the PVC.

Table: I.1: Target Guideline Levels for Fecal Indicator Bacteria as Listed by the FDOH and FDEP

Fecal Indicator Bacteria	**FDOH Beach Recreational Standards**	**FDEP Class III standards**
Enterococci (current)	• Good quality < 36 per 100 mL • Moderate quality between 36 and 70 per 100 mL • Poor quality > 70 per 100 mL	• Geometric mean < 36 per 100 mL, • 10% of samples within a 30-day period < 130 per 100 mL
Fecal coliform (historical, 2003 to 2011)	• Beach closures issued > 400 per 100 mL	
Fecal coliform (historical, before 2002)	• Beach closures issued > 800 per 100 mL	
Fecal coliform (historical, before 2016)		• Monthly average < 201 per 100 mL, 10% samples < 401 per 100 mL, Single day sample < 801 per 100 mL

I.3 GENERAL CATEGORIES OF ENTEROCOCCI SOURCES

Many beach and other marine bathing sites periodically exceed FIB guideline levels, and the cause of exceedances is difficult to identify. Pollutants including pathogenic and non-pathogenic microbial organisms such as FIB, nutrients and chemical compounds originate from a single place or from many places all at once. In the context of marine recreational water quality, single or point sources are normally related to individual discharges to a marine water body at spatially discrete locations, for example a leaking wastewater tank in a boat or a building discharging polluted waters directly through a pipe. Multiple sources or non-point sources are normally associated with areas of greater spatial scale and thus the contribution of each discrete location, to the total amount of pollutants discharged is more difficult to calculate. For example, urban street sediments contain trace amounts of toxic chemicals from vehicular engine exhaust emissions, different compounds which end up on the streets and other urban areas through atmospheric deposition (a process whereby minute particles in the atmosphere free fall to the ground and deposit on surfaces), and microorganisms from trash, human waste and dog feces among others. For example, rainwater runoff washes away street sediments, flows downhill and streams to a marine waterbody along various stretches of shoreline.

Identifying the source of elevated enterococci bacteria in a marine water body is especially difficult for areas impacted by non-point sources of enterococci and other fecal indicator bacteria. The first step in the process is to identify the source of the bacteria (in terms of geography or location) and to then evaluate the transport processes into the water column. Non-point sources of enterococci to the marine environment can include shoreline sediments and stormwater run-off through shoreline banks. Particularly, in South Florida, shoreline sediments have been associated with microbe sources to the water column (Solo-Gabriele et al. 2000, Desmarais et al. 2002, Enns et al. 2012). Sources of microbes to sediments include direct input from humans, animals including mammals, birds and reptiles (Wright et al. 2009). Point sources of microbes to the marine environment include stormwater outfalls, roof drains and other drains connected to private property and accidental direct discharge from marine vessels.

The process of source identification is confounded by microbial persistence and multiplication in the marine environment. South Florida local environmental factors are exceptionally suited for microbe persistence over moderate to long periods of time, and microbe regrowth and multiplication (depending on site-specific conditions). Of note, microbe multiplication is different for different types of indicator bacteria. For example, bacteria can be split into two primary groups (Gram-positive or Gram-negative) based upon the structure of their cellular membranes. Studies have shown Gram-positive microorganisms such as enterococci may survive in water with higher salinity concentrations than groups of bacteria which are Gram-negative such as fecal coliforms.

The elevated levels of fecal indicator bacteria (FIB) at the PVC are observed for both enterococci and fecal coliform, although enterococci are more elevated. In sanitary sewage, the opposite holds true, where fecal coliform is typically at levels of 10^6 MPN per 100 mL whereas enterococci is typically at levels of 10^5 per 100 mL (Roca et al. 2019). So, the fact that enterococci at the PVC is higher than fecal coliform suggests that there may be differential die-off or regrowth of enterococci in the environment. Regrowth has been documented to occur in shallow sediment side slopes of water bodies in areas characterized by high organic matter and shade (Solo-Gabriele et al. 2000, Desmarais et al. 2002), in stormwater drain biofilm (Skinner et al. 2010), and high bacterial densities have been detected in algae, vegetation, including submerged vegetation and marine wrack (Abdool-Ghany et al. 2022, Whitman et al. 2003, Grant et al. 2001, Badgley et al. 2010). Thus, understanding microbial persistence and regrowth in the marine environment, particularly how and where they can survive in the water column, is not only important in the interpretation of measured bacterial levels, but also in conceiving a sampling plan designed to answer the questions of where the bacteria are coming from and how they enter the water column.

I.4 GENERAL CONDITIONS OF THE PVC

Several conditions have been identified that are particular to the study area and that provide insights into the possible transport mechanisms of the bacteria into the PVC as well as environmental conditions that might favor the regrowth and accumulation of FIB in the waterway. The PVC is located within Biscayne Bay. It is well documented that water quality in Biscayne Bay has been degrading (BBTF 2020), especially in the northern regions of the bay where the PVC is found. Degradation of Biscayne Bay has been attributed to concentrated freshwater inputs at canal inlets to the bay which erode sediments and carry pulses of nutrients that encourage algal blooms and resultant seagrass die offs. The PVC resides within the degraded northern Biscayne Bay. In addition to lying within a degraded Bay area, it is a waterway within a waterway, with significant restrictions to natural water flows. The PVC branches off from the main waterway located east of Normandy Shores Island and west of Park View Island. The PVC is connected to a network of waterways that run north to south (Tatum, Biscayne Point and Normandy Waterway N-S) and east to west (Normandy Waterway E-W)

(Figure I.3). Most of the waterways in this network have direct access to Biscayne Bay, however the PVC does not. It is important to note that the waterway has bends in the longitudinal direction (Northeast and Southeast banks of Park View Island) that impede the natural circulation of the water which is mainly driven by tides. Studies have shown that the degree of water circulation impacts the levels of FIB within waterways. Other studies have shown that ocean facing beaches in the State of Florida have better water quality than bay facing beaches (Kelly et al. 2018). The PVC is on the bay side of Miami Beach on a narrow waterway within another narrow waterway, thereby greatly limiting tidal flushing of the waterway and allowing for the accumulation of FIB. Other waterway characteristics include its relatively shallow depth, its numerous bends, and the mangroves and shallow banks along its edge which have been shown to allow for FIB persistence and growth (Desmarais et al. 2002). Additionally, the area is very highly urbanized with significant sanitary and storm sewer systems. The following sections of this report provide details on measured PVC depth in the longitudinal direction and also observed shoreline types (mangroves, retention walls, exposed sediments, and others).

Figure I.3: Map showing locations of 1) Park View Canal, 2) Biscayne Point Waterway, 3) Tatum Waterways, 4) Normandy Waterway N-S, and 5) Normandy Waterway E-W.

CHAPTER II

ANALYSIS OF HISTORICAL DATA

CHAPTER II
ANALYSIS OF HISTORICAL DATA

This analysis is based upon the considerable amount of data collected and shared through the CMB. The focus of this initial analysis is to evaluate trends of enterococci data to date (Section I.1), evaluate hydrometeorological data and predict tidally driven water level changes at the PVC (Section II.2), and use the information derived to evaluate correlations between environmental factors and enterococci and fecal coliform levels (Section II.3).

I.1 ENTEROCOCCI LEVELS AT THE PVC

The PVC has been monitored monthly for FIB since April 17, 2019. Monitoring consists of collecting a water sample, at approximately the same location in the vicinity of the Kayak Launch Pad within the PVC, followed by laboratory analysis to measure the Most probable Number of enterococci per 100 mL (MPN/100 mL). We compiled sampling data, corresponding to the time period from April 2019 to October 2022, and found that enterococci levels for samples collected in the vicinity of the Kayak Launch pad have exceeded the 70 MPN/100 mL FDOH regulatory threshold, by factors of 10, and 100. Some samples had enterococci concentrations above the detection limit of 24,196 MPN/100 mL (Figure II.1). This analysis suggests that enterococci levels have continued to remain elevated following the March 4 and 5, 2020 sewer leaks. There is no discernable difference in water quality before or after the March 2020 sewage spill. Levels of enterococci at the PVC were consistently elevated prior to this spill.

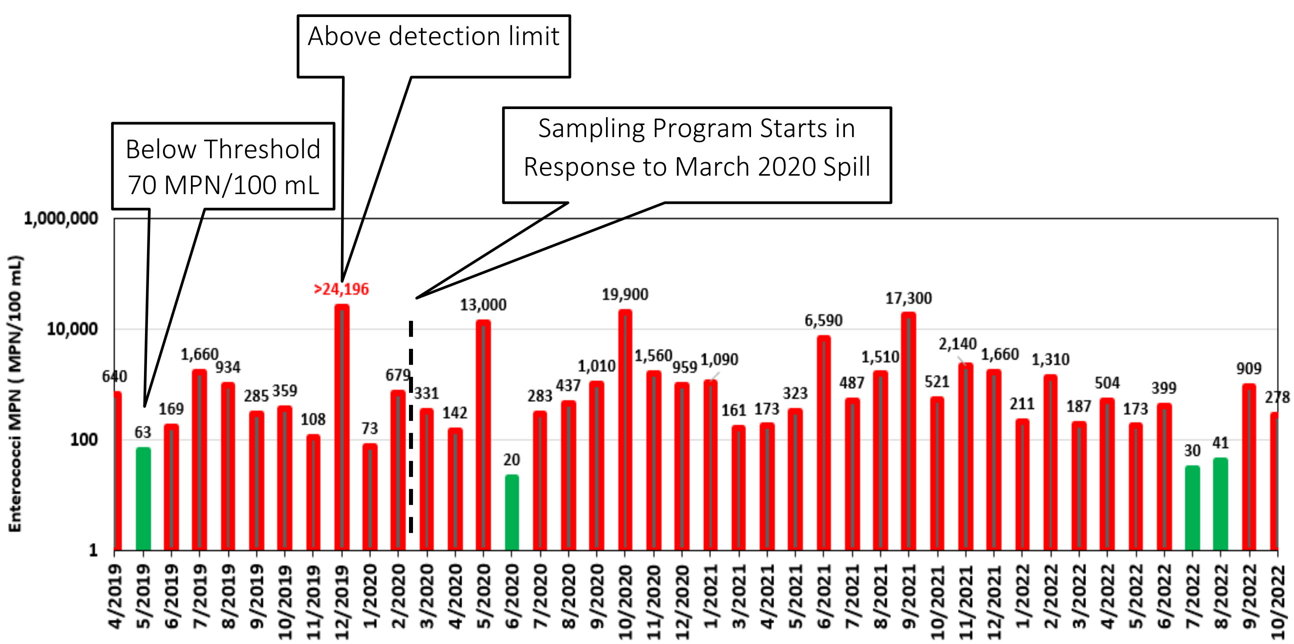


Figure II.1: Results from Monthly Enterococci Measurements at PVC from 4/2019 to 10/2022. Green bars correspond to data points within the 70 MPN/100 mL recommended recreational level whereas red bars correspond to data points which exceed this level. Note the data are plotted on a logarithmic scale due to the wide range of measurements.

To further describe the exceedances at the PVC, enterococci levels from the CMB record were converted to exceedances above the 70 MPN/100 mL advisory threshold for each year.

Table II.1: Percent of Exceedances of 70 MPN/100 mL Threshold per Year

Year	Number of Exceedances	Number of Measurements	% Exceed
2022	8	10	80%
2021	11	11	100%
2020	11	12	92%
2019	8	9	89%

Since the monitoring program started in 2019, the fraction of the time the PVC waterway has exceeded the 70 MPN/100 mL threshold has been at or above 80%, with the highest number of exceedances observed for year 2021 when all samples collected exceeded the regulatory threshold 70 MPN/100 mL. For the entire period of record evaluated (April 2019 to October 2022) the PVC exceeded the 70 MPN/100 mL threshold 90% of the time.

II.2 RAINFALL, GROUNDWATER, AND TIDAL FLUCTUATIONS

The first step of preliminary historic data analysis involved compiling available environmental data including hydrometeorological data of rainfall, tides, and groundwater. The objective of the analysis was to document the locations of available data. These data were used in the subsequent section to determine possible associations between hydrometeorological data and enterococci.

Rainfall data were compiled from several sites located north, south, and east of the PVC, for the period 2019 to date (Figure II.2). A total of 8 rainfall stations were identified (Table II.2). Tidal data were compiled from the National Oceanographic and Atmospheric Administration's (NOAA) Tides and Currents repository. NOAA does not have a tidal station located on Parkview Island. Five NOAA stations located north and south of the study area (Figure II.2, Table II.3) were used in the preliminary analysis. The team examined data from multiple tide stations surrounding Parkview Island which included:

- Indian Creek Golf Club station, the closest station, located north of Parkview.
- Haulover Pier station, oceanside and located northeast of Parkview.
- Miami Beach station, oceanside and located south of Parkview.
- San Marino Island, south of Parkview, but northwest of the Miami Beach station.
- Virginia Key station. Has hourly tidal prediction and measurement data which is not available at the other sites that are closer.

NOAA provides tidal predictions for four of these five stations. The NOAA data consists of only four data points available per day corresponding to low and high tides. The team obtained the tidal data ranging from May 2020 to September 2020 from each station to explore any discernible patterns that could correlated with the high enterococci and coliform levels.

In addition to the first four stations listed above, the team also utilized data from the Virginia Key tidal station, which has available information for both the hourly predicted and verified (measured) tidal heights (See Figure B.4, Appendix B for a comparison). This station is the furthest south from Parkview Island, but the data is useful in providing tides at shorter time scales (hourly) and understanding how the verified tides can often deviate from the predicted heights.

Table II.2: Rainfall gauging stations in vicinity of the PVC

Rain Station Name	Period of Record	Measure-ment Frequency	GPS Coordinates		URL for Station and/or Stations Description
			N	W	
Farrbetter - KFLMIAMI60	2019-Present	15 mins	25.864	-80.129	Weather Underground https://www.wunderground.com/dashboard/pws/KFLMIAMI60 (KFLMIAMI60)
Miami Beach - KFLMIAMI89	2019-present	5 mins	25.835	-80.129	Weather Underground https://www.wunderground.com/dashboard/pws/KFLMIAMI89 (KFL MIAMI 89)
Surfside – KFLMIAMI583	2019-present	5 mins	25.814	-80.129	Weather Underground https://www.wunderground.com/dashboard/pws/KFLMIAMI583 (KFL MIAMI 583)
Miami Beach U.S. Coast Guard	Previous 30 days	Intermittent readings (5-15)	25.77157	-80.14556	LocalConditions.com https://www.localconditions.com/weather-miami-beach-coast-guard-station-florida/fl300/past.php (Coast Guard)
WS1	2019-present	30 mins	25.792967	-80.135582	City of Miami Beach Station 1, City Hall - 1700 Convention Center Drive, Miami Beach, FL 33139
WS2	2019-present	30 mins	25.81467	-80.128312	City of Miami Beach Station 2, 40 W 42 St, Miami Beach, FL 33140
WS3	2019 present	30 mins	25.85753	-80.12296	City of Miami Beach Station 3, 501 72nd St, Miami Beach, FL 33141
S27_R	2019 - present	15 mins	25.85	-80.19	https://apps.sfwmd.gov/WAB/EnvironmentalMonitoring/index.html

Table II.3: NOAA tidal stations in the vicinity of the PVC. Tidal information used in this project for all stations (except Virginia Key) are predictions.

Tidal Station Name	Period of Record	Measurement Frequency	GPS Coordinates		URL for Station
			N	W	
Indian Creek Golf Club, Biscayne Bay	Not available	3-4 predictions per day (2 high tide and 2 low tide)	25.8750	-80.1433	https://tidesandcurrents.noaa.gov/stationhome.html?id=8723094
Haulover Pier, N. Miami Beach	07/14/1981 – 09/22/1992 *	3-4 predictions per day (2 high tide and 2 low tide)	25.9033	-80.1200	https://tidesandcurrents.noaa.gov/stationhome.html?id=8723080
Miami Beach	06/01/1931 – 07/25/1981 *	3-4 predictions per day (2 high tide and 2 low tide)	25.7683	-80.1317	https://tidesandcurrents.noaa.gov/stationhome.html?id=8723170
Virginia Key, Biscayne Bay	01/28/1994 – Present	Hourly	25.7314	-80.1618	https://tidesandcurrents.noaa.gov/stationhome.html?id=8723214
San Marino Island	Not available	3-4 predictions per day (2 high tide and 2 low tide)	25.7933	-80.1633	https://tidesandcurrents.noaa.gov/stationhome.html?id=8723156

*Period of record for verified data

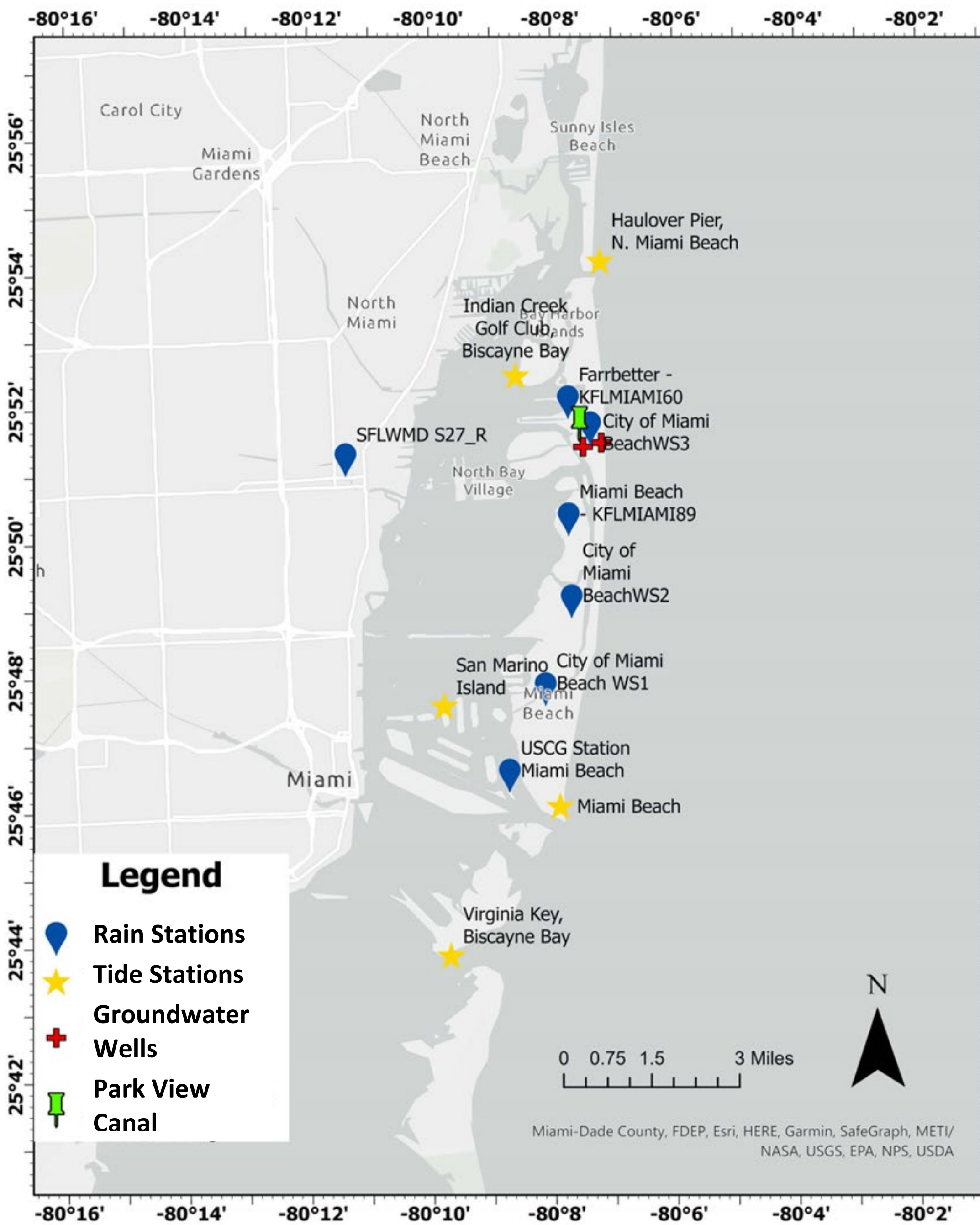


Figure II.2: Map showing locations of the rainfall, groundwater and tidal stations. The green pin shows the location of the Park View Canal, the blue drops show the locations of the weather stations, the yellow stars show the location of the NOAA tide stations, and the red crosses show the location of the City of Miami Beach monitoring wells. Of note, KFLMIAMI60 and KFLMIAMI583 are very close to one another and only KFLMIAMI60 is shown explicitly above.

The two closest groundwater monitoring stations are called Parkview Park and North Beach Bandshell (Figure II.2, Table II.4). These stations are owned and maintained by the CMB. At each station there is a cluster of three wells screened at shallow, intermediate, and deep depths.

Table II.4: Groundwater monitoring stations closest to the PVC

Groundwater Monitoring Station Name	Period of Record	Measurement Frequency	GPS Coordinates		Description of Station
			N	W	
Parkview Park (PVP)	9/2/2019-present	Hourly	25.8572428	80.1248966	Shallow well screened at 25-35 feet, intermediate well at 85 to 95 feet, and deep well at 200 to 210 feet
North Beach Bandshell (NSP)	9/2/2019-present	Hourly	25.8583060	80.1198783	Also called North Shore Park. Shallow well screened at 30-40 feet, intermediate well at 95 to 105 feet, and deep well at 195 to 205 feet

Preliminary analysis was conducted to assess the relationships between rainfall, tide and groundwater data and the dates coinciding with the PVC FIB measurements. Of note CMB provided FIB data from a series of catch basin sampling efforts. The results from these catch basin sampling efforts were plotted as "heat maps" by CMB. For the data analysis, first, a time series plot of rainfall events was superimposed with markers corresponding to heat map peaks in FIB concentrations (Figure B.1, Appendix B). Second, tidal data for each of the five NOAA tide stations were plotted with the dates corresponding to FIB peaks (Figure B.2, Appendix B). Third, groundwater data for the two monitoring wells were plotted in a similar manner (Figure B.3, Appendix B). Finally, a time series plot for the precipitation, tide and groundwater data and FIB peaks was generated to explore trends across all three environmental parameters (Figure II.3). Results for the preliminary analysis show that no obvious relationships were observed between the environmental parameters and the catch basin water heat map FIB peaks occurring at the different dates.

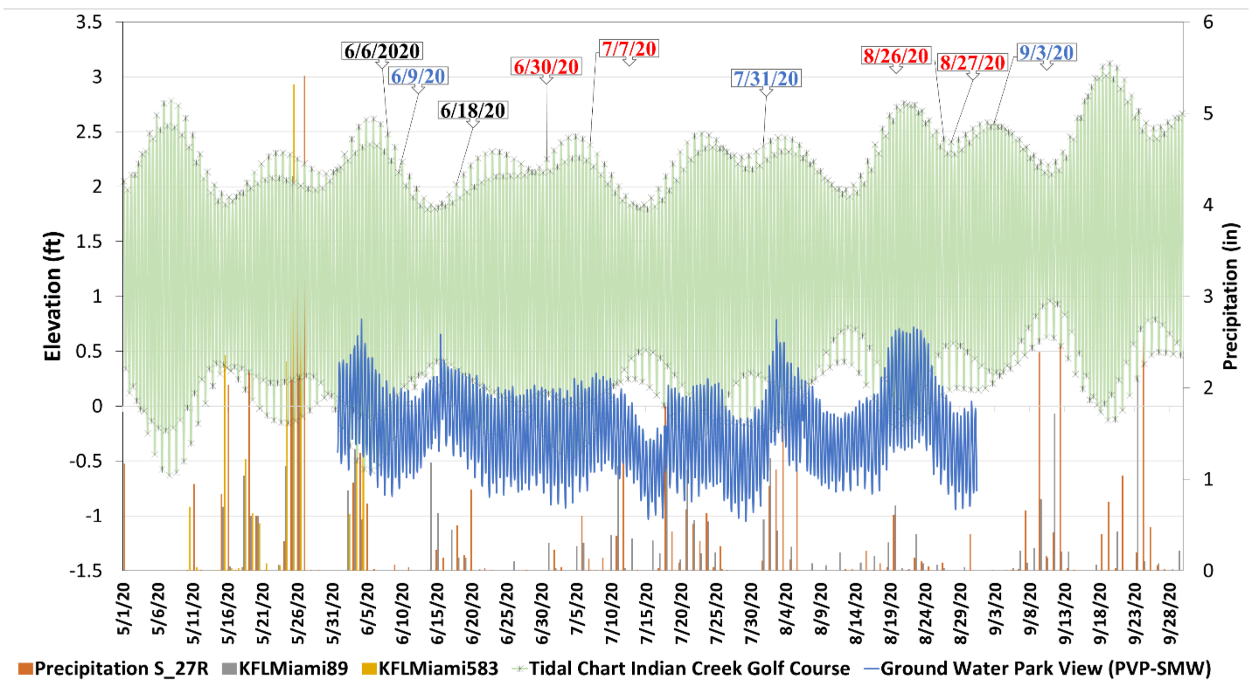


Figure II.3: Time series plot of rainfall, tides and groundwater superimposed on dates and peak enterococci levels measured in catch basins.

Following the preliminary analysis of historic data, on July 24, 2022 we visited the study area to measure the tidally driven changes in water levels over an 8-hour period at the Kayak Launch Pad within the PVC. We measured the change in water levels during ebb tide (transition from high to low tide). The tidal data from the Kayak Launch, Indian Creek Golf Club station, and Virginia Key station were plotted in one graph to compare differences in tidal times. Through this analysis, we determined that the Kayak Launch high and low tides closely match the tides at Virginia Key. The low tide at the Kayak Launch lagged the Virginia Key low tide by approximately 17 minutes (Figure II.4). From this information, we compiled a table of estimated tidal times for the Kayak Launch for the all the subsequent months of this study. The estimated low and high tides were then used to determine the dates of the intense sampling activity as described in the following sections.

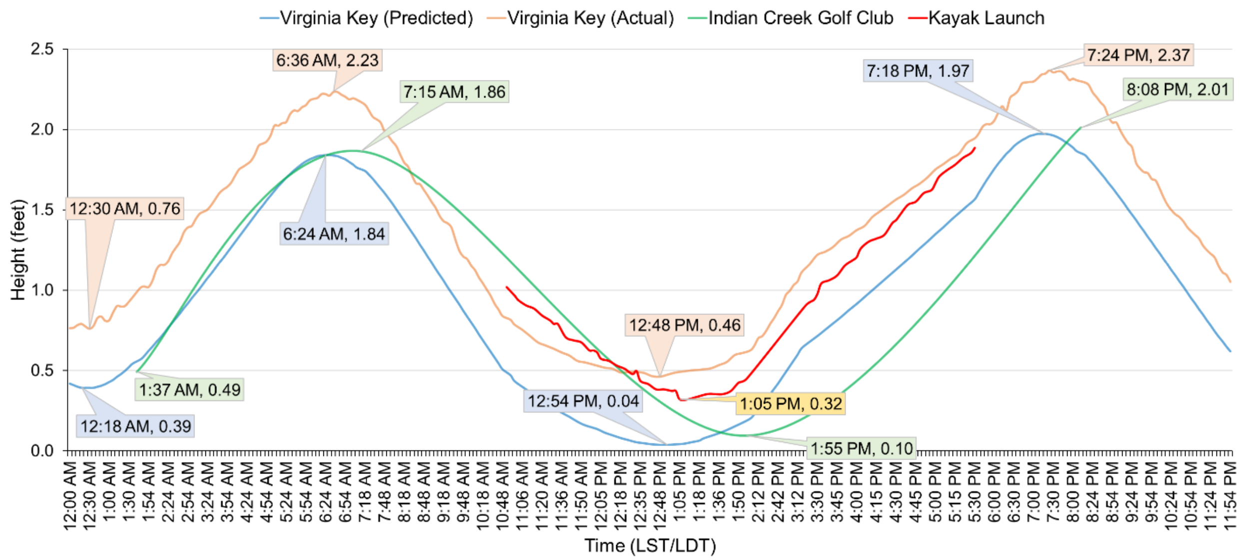


Figure II.4: Measured tidal data at the Park View Canal on July 24, 2022, and tide predictions at the NOAA tidal stations located at Indian Creek Golf Club and Virginia Key stations. The data labels represent the high and low tides.

II.3 RELATIONSHIP BETWEEN HISTORIC ENTEROCOCCI LEVELS, RAINFALL, TIDES, AND PHYSICOCHEMICAL PARAMETERS

Available enterococci data were combined with available rainfall, tidal, and physicochemical parameters data to evaluate whether environmental conditions could be used to explain the enterococci levels. In addition to the heat map comparisons described in the prior section, two additional sets of data were evaluated. These included the monthly enterococci data collected from the PVC (described in more detail below, section II.3.a), plus one additional historical data set focused on catch basin monitoring results (see section II.3.b). These catch basin measurements included multiple measurements of FIB daily (3 to 4 measurements per day at a site) over the course of three days.

II.3.a Further evaluation of monthly enterococci data collected from the PVC

Along with the measurement of enterococci, additional parameters were measured monthly (April 2019 to October 2022) as provided through CMB. These additional parameters included total nitrogen, total phosphorus, salinity, field specific conductance, field temperature, pH, dissolved oxygen, and turbidity. Additionally, cumulative precipitation for different time periods prior to the time of sample collection (6-hours, 12-hours, 24-hour, 48-hours) and tidally driven water elevations were also compiled. Rainfall corresponded to Miami Beach Station, WS3. Missing data points were filled in with data from data collected from the South Florida Water Management District Station S27_R. Tidal data corresponded to the NOAA Station located at Virginia Key. Details about the rainfall and tidal stations are available in section II.2. A listing of the enterococci and additional water quality data used in this analysis are provided in Appendix B (See Table B.1).

To evaluate changes between enterococci and the environmental and physicochemical parameters, exploratory data analysis was conducted by computing Pearson's correlations and Spearman's ranked correlations for all compiled (4/17/2019 to 10/17/2022) data to evaluate the changes between the enterococci and the environmental and physicochemical parameters (Table II.5). Correlations were considered significant at 95% confidence limits for p-values less than 0.05. Statistically significant Spearman correlations ($|r_s|>0.3$, $p<0.05$) were found between enterococci levels and salinity plus 6 hr, 12 hr, 24 hr and 48 hr antecedent rainfall. The strongest relationship was observed for 24 hr antecedent rainfall ($r_s = 0.75$). Results for Pearson's correlation show that statistically significant correlations ($|R|>0.38$, $p<0.05$) were found between enterococci levels and salinity, fecal coliforms, pH and 6 hr, 12 hr, 24 hr and 48 hr antecedent rainfall. The strongest relationship was observed for 24 hr antecedent rainfall ($R = 0.53$). It is interesting to note that a negative relationship was observed between enterococci and salinity. That is the higher the salinity, the lower the concentration of enterococci. Conversely, the lower the salinity (or higher freshwater content), the higher the concentration of enterococci.

Results from multiple linear regression (using SPSS software) again confirmed that rainfall, in particular 24-hour antecedent rainfall, was the primary parameter correlated with enterococci. Although the model was set up to evaluate multiple parameters, 24-hour rainfall was by far the parameter that contributed the most towards explaining the variability of the enterococci levels. The model developed (Equation II.1) relates P (24-hour antecedent rainfall) to enterococci levels in units of MPN/100 mL as follows:

$$\text{Enterococci (MPN/100 mL)} = 1006 + 3634 \times P \qquad \text{(Equation II.1)}$$

Table II.5: Correlation between the enterococci in samples collected monthly from Miami Beach from 4/17/2019 to 10/17/2022 with other physical chemical parameters (water level, tide cycle, total nitrogen, total phosphorus, salinity, fecal coliforms, field specific conductance, field temperature, pH, dissolved oxygen, turbidity and cumulative precipitation (6-hour, 12-hour, 24-hour, 48-hour)) based on both Pearson's and Spearman's analysis. Yellow indicates a significant correlation ("*" indicates a p-value < 0.05, "**" indicates a p-value < 0.01).

		Total Nitrogen, Kjeldahl (mg/L)	Total Phosphorus (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	Field Specific Conductance (umhos/cm)	Field Temperature (°C)	Field pH	Dissolved Oxygen (mg/L)	Turbidity (NTU)	6-hour Precipitation (in)	12-hour Precipitation (in)	24-hour Precipitation (in)	48-hour Precipitation (in)	Water Level (ft)
Pearson Correlation: Enterococci (MPN/100 mL)	Correlation Coefficient (R)	-0.088	0.174	-.442**	0.183	-.384*	-0.070	-0.124	-0.027	0.059	.439**	.688**	.750**	.578**	0.064
	p-value	0.606	0.290	0.003	0.251	0.012	0.663	0.434	0.866	0.713	0.004	0.000	0.000	0.000	0.685
Spearman correlation: Enterococci (MPN/100 mL)	Correlation Coefficient (Rs)	-0.059	0.065	-.313*	.485**	-0.235	-0.143	-.385*	-0.075	-0.049	.381*	.421**	.527**	.457**	-0.060
	p-value	0.730	0.694	0.044	0.001	0.133	0.372	0.012	0.636	0.760	0.013	0.006	0.000	0.002	0.706
Sample size		37	39	42	41	42	41	42	42	41	42	42	42	42	42

II.3.b Catch Basin Measurements During Three Consecutive Days

During April 19, 20, and 21, 2021, three combinations of outfalls and upstream catch basins were sampled (Figure II.5). The three outfalls were labeled as Outfalls OT1, OT4, and OT7. Catch basins feeding into these outfalls included:

- US1A and US1B feeding OT1,
- US4A, US4B, and US4C feeding OT4, and
- US7A and US7B feeding OT7

At each of these sites, three samples were collected on April 19, four samples on April 20, and four samples on April 21. The data were combined with rainfall and tidal data. Rainfall measurements came from Miami Beach Stations WS3 (see section II.2 for details about this station). Tidal data was interpolated from the Virginia Key NOAA tide station.

Time series plots of the data show that the enterococci concentrations in the waterway were low during April 19. It rained overnight from April 19 to the 20^{th}. On the following day, the enterococci levels were very high throughout, exceeding detection limits (Figure II.6). Interesting patterns in the enterococci variation were observed at 12 noon on April 20 which was observed for both the OT1 and OT4 system. These patterns were observed at extreme low tide (Figure II.7) where oscillations appear to have occurred in the relative levels of enterococci between the outfalls and the catch basins. The coincidence of these oscillations is striking and suggests shifting of water sources possibly between the outfalls and the catch basins at these times.

Spearman and Pearson's correlation analysis (Table II.6), identified prior rainfall, specifically 48 hour antecedent rainfall, as the most strongly correlated rainfall parameter. Pearson correlation coefficients between enterococci and 48-hour rainfall were as high as 0.92 to 0.98 for catch basins US1A, US1B, US4C, and US7B (Figure II.8).

Figure II.5: Sampling locations of the upstream (US) and outfall (OT) shown in the blue and red circles within the map.

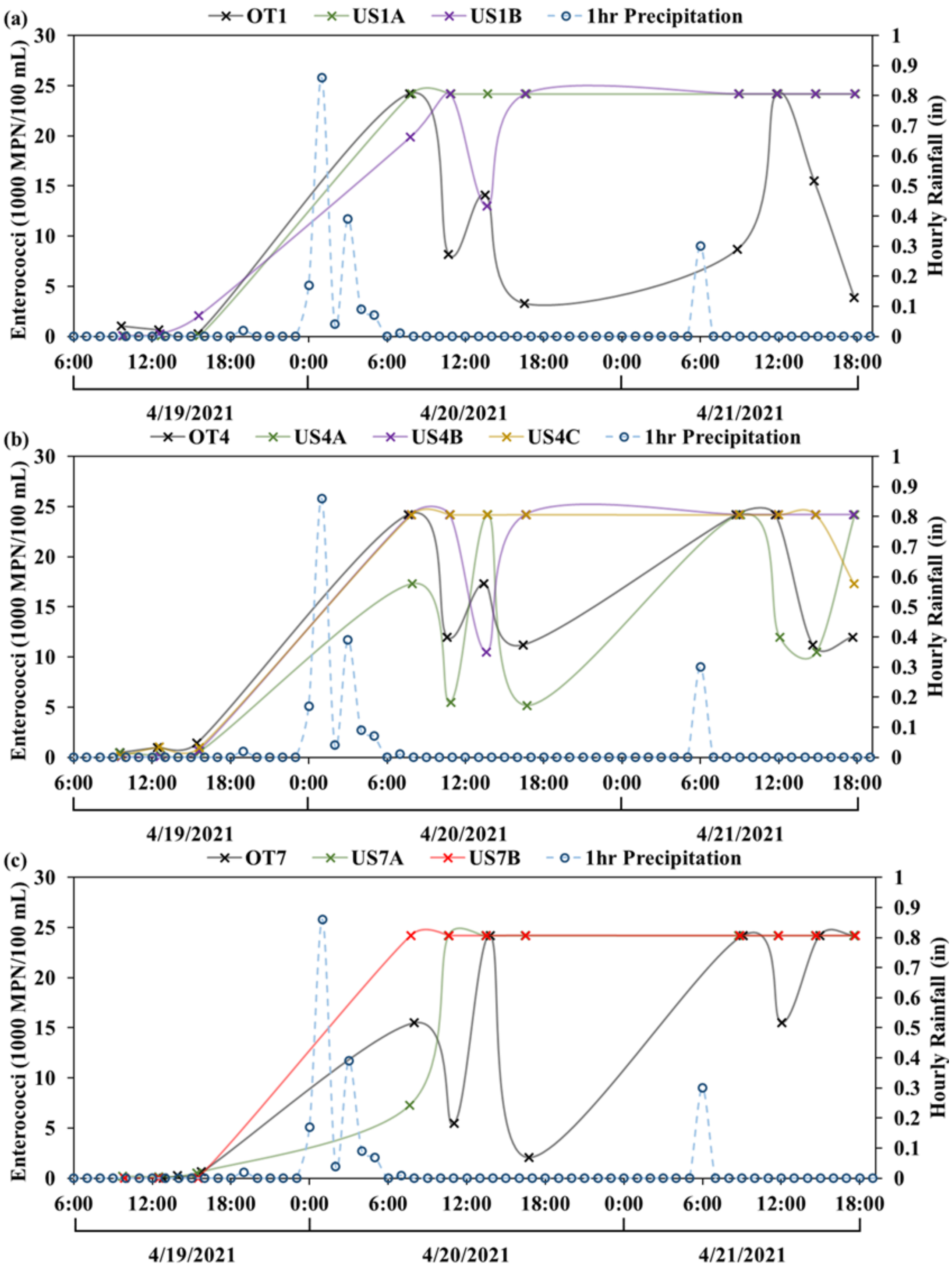


Figure II.6: Concentration of enterococci in the outfall (OT) and upstream (US) and hourly rainfall based on the time series. Panel (a) includes outfall and upstream for the first location; Panel (b) includes outfall and upstream for the fourth location; Panel (c) includes outfall and upstream for the seventh location.

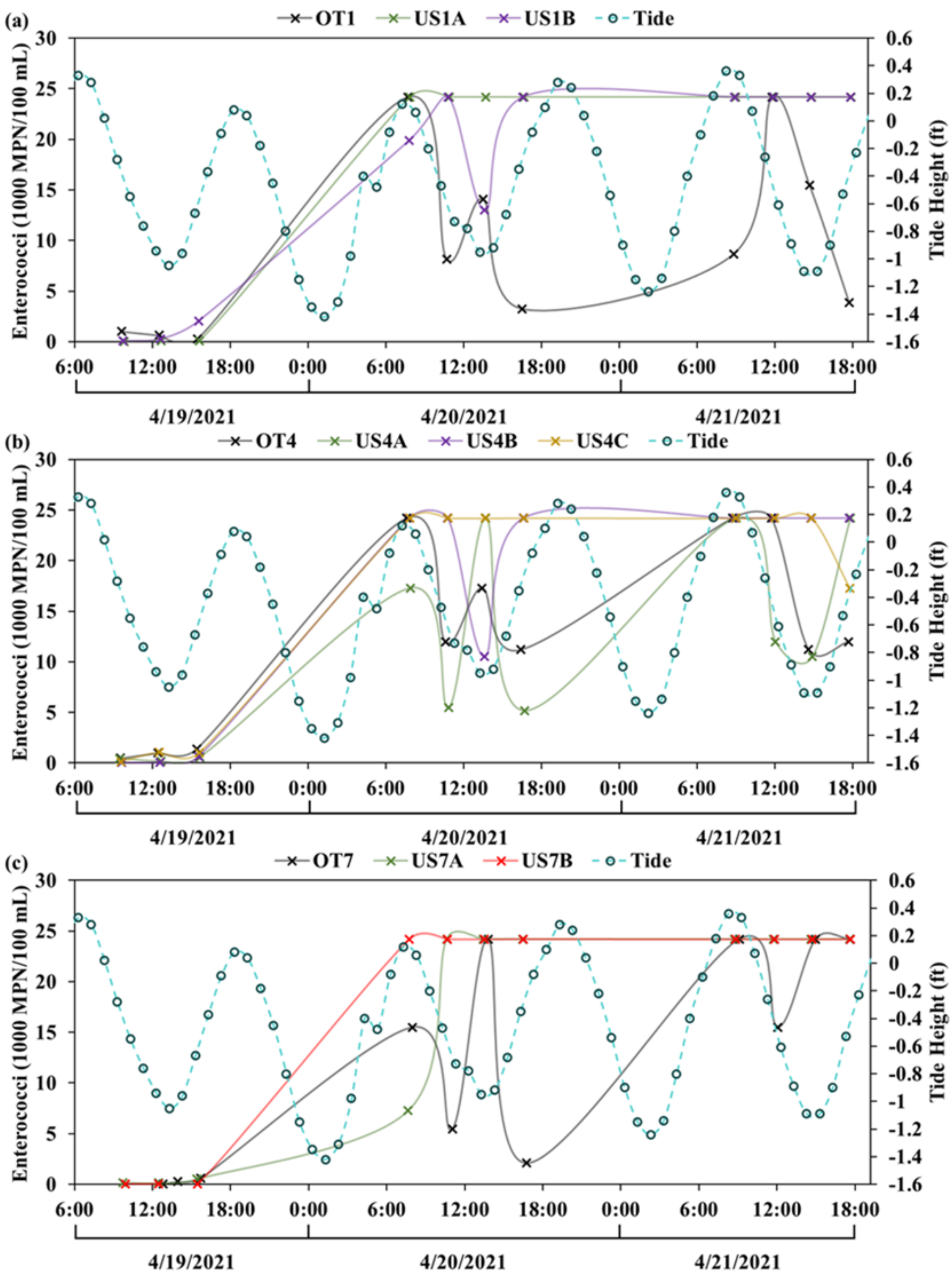


Figure II.7: Concentration of enterococci in the outfall (OT) and upstream (US) and height of sea tide based on the time series. Panel (a) includes outfall and upstream for the first location; Panel (b) includes outfall and upstream for the fourth location; Panel (c) includes outfall and upstream for the seventh location.

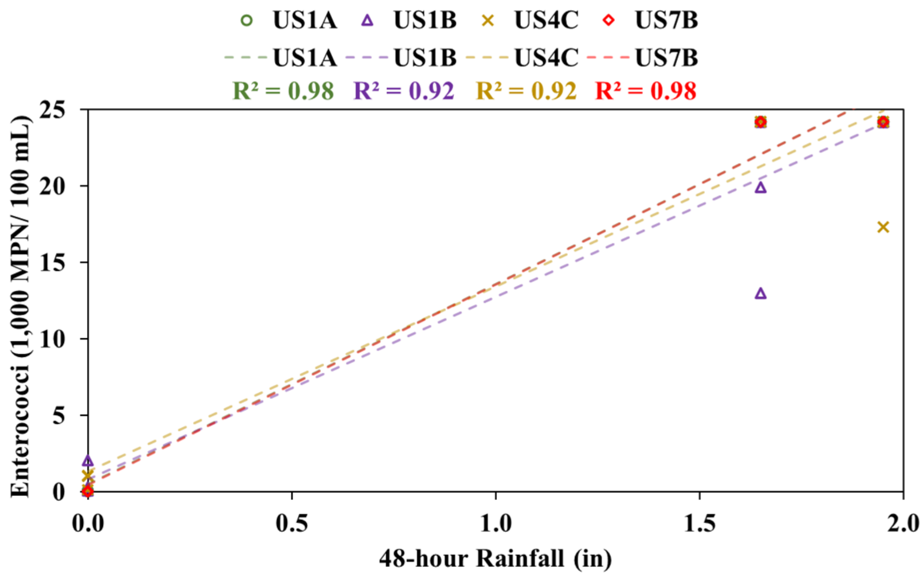


Figure II.8: Linear correlation between enterococci in the upstream samples (US1A, US1B, US4C, and US7B) and 48-hour cumulative precipitation prior to the sampling time based on the Pearson's analysis (R^2).

Table II.6: Correlation between the enterococci in the samples of outfall (OT) and upstream (US) and height of sea tide or cumulative precipitation based on both Pearson's and Spearman's analysis. Yellow indicates the significant correlation (p-value < 0.05). Red indicates the strong linear correlation (Pearson's $R^2 > 0.9$).

Sample ID	Correlation w/ Enterococci	Tide Height	1h Rainfall	6h Rainfall	12h Rainfall	24h Rainfall	48h Rainfall
OT1	Pearson's R (p-value)	0.139 (0.684)	0.548 (0.081)	0.536 (0.089)	0.549 (0.080)	0.356 (0.283)	0.630 (0.038)
	Pearson's R^2	0.019	0.300	0.287	0.302	0.127	0.397
	Spearman's rank (p-value)	0.137 (0.689)	0.451 (0.164)	0.633 (0.037)	0.816 (0.002)	0.579 (0.062)	0.695 (0.018)
OT4	Pearson's R (p-value)	0.526 (0.097)	NA	0.634 (0.036)	0.478 (0.137)	0.427 (0.190)	0.824 (0.002)
	Pearson's R^2	0.276	NA	0.402	0.228	0.182	0.679
	Spearman's rank (p-value)	0.426 (0.192)	NA	0.800 (0.003)	0.811 (0.002)	0.640 (0.034)	0.640 (0.034)
OT7	Pearson's R (p-value)	0.220 (0.516)	NA	0.264 (0.434)	0.145 (0.671)	0.095 (0.780)	0.775 (0.005)
	Pearson's R^2	0.048	NA	0.069	0.021	0.009	0.601
	Spearman's rank (p-value)	0.270 (0.422)	NA	0.146 (0.669)	0.606 (0.048)	0.485 (0.131)	0.795 (0.003)
US1A	Pearson's R (p-value)	0.260 (0.440)	NA	0.281 (0.403)	0.452 (0.163)	0.602 (0.050)	0.987 (< 0.001)
	Pearson's R^2	0.068	NA	0.079	0.204	0.362	0.974
	Spearman's rank (p-value)	0.326 (0.327)	NA	0.612 (0.046)	0.839 (0.001)	0.825 (0.002)	0.647 (0.031)
US1B	Pearson's R (p-value)	0.325 (0.329)	NA	0.236 (0.485)	0.364 (0.271)	0.439 (0.176)	0.961 (< 0.001)
	Pearson's R^2	0.106	NA	0.056	0.133	0.193	0.924
	Spearman's rank (p-value)	0.233 (0.491)	NA	0.350 (0.291)	0.493 (0.123)	0.525 (0.097)	0.861 (0.001)
US4A	Pearson's R (p-value)	0.326 (0.328)	NA	0.397 (0.227)	0.198 (0.559)	0.259 (0.442)	0.737 (0.010)
	Pearson's R^2	0.106	NA	0.158	0.039	0.067	0.543
	Spearman's rank (p-value)	0.284 (0.397)	NA	0.356 (0.283)	0.651 (0.030)	0.525 (0.097)	0.758 (0.007)
US4B	Pearson's R (p-value)	0.372 (0.260)	NA	0.340 (0.307)	0.428 (0.189)	0.451 (0.164)	0.942 (< 0.001)
	Pearson's R^2	0.138	NA	0.115	0.183	0.204	0.887
	Spearman's rank (p-value)	0.284 (0.397)	NA	0.537 (0.089)	0.645 (0.032)	0.647 (0.031)	0.825 (0.002)

Table II.6: (Continued). Correlation between the enterococci in the samples of outfall (OT) and upstream (US) and height of sea tide or cumulative precipitation based on both Pearson's and Spearman's analysis. Yellow indicates the significant correlation (p-value < 0.05). Red indicates the strong linear correlation (Pearson's $R^2 > 0.9$).

Sample ID	Correlation w/ Enterococci	Tide Height	1h Rainfall	6h Rainfall	12h Rainfall	24h Rainfall	48h Rainfall
US4C	Pearson's R (p-value)	0.212 (0.531)	NA	0.310 (0.354)	0.504 (0.114)	0.648 (0.031)	0.958 (< 0.001)
	Pearson's R^2	0.045	NA	0.096	0.254	0.420	0.918
	Spearman's rank (p-value)	-0.010 (0.978)	NA	0.201 (0.554)	0.581 (0.061)	0.729 (0.011)	0.608 (0.047)
US7A	Pearson's R (p-value)	0.068 (0.844)	NA	-0.101 (0.767)	0.168 (0.621)	0.407 (0.214)	0.912 (< 0.001)
	Pearson's R^2	0.005	NA	0.010	0.028	0.166	0.832
	Spearman's rank (p-value)	0.105 (0.758)	NA	0.195 (0.565)	0.581 (0.061)	0.647 (0.031)	0.825 (0.002)
US7B	Pearson's R (p-value)	0.277 (0.409)	NA	0.294 (0.380)	0.460 (0.154)	0.602 (0.050)	0.988 (< 0.001)
	Pearson's R^2	0.077	NA	0.087	0.212	0.362	0.976
	Spearman's rank (p-value)	0.475 (0.140)	NA	0.269 (0.424)	0.561 (0.073)	0.828 (0.002)	0.649 (0.031)

CHAPTER III

ANALYSIS OF EXISTING WATER CONVEYANCE INFRASTRUCTURE

CHAPTER III

ANALYSIS OF STORMWATER AND WASTEWATER CONVEYANCE INFRASTRUCTURE

The CMB provided access to images of the stormwater and sanitary sewer infrastructure. Key elements of this infrastructure as they may relate to PVC water quality are provided below.

III.1 STORMWATER CONVEYANCE SYSTEM

An analysis of Geographic Information System (GIS) data for the stormwater infrastructure shows that 9 outfalls discharge stormwater directly to the PVC whereas over 45 stormwater outfalls discharge to waterways that are connected to the PVC on the north, south, and east (Figure III.1). The six outfalls located on the east banks of the waterway, discharge stormwater from their corresponding catchment areas located on the main island of Miami Beach. The three outfalls located on the west bank of the waterway, discharge stormwater from the catchment areas located in Park View Island. The catchment area to the east includes 1 through 5 and partial areas for 9 through 12. These areas combined consist of approximately 253,443 m^2 of mixed-use urban area (commercial and residential) whereas catchment areas 6 to 8 are comprised of 75,650 m^2 residential areas (Table III.1). It is important to note, that all three of the Park View Island outfalls discharge to the PVC and no outfalls are observed on the west part of the island. Thus, a total of 329,093 m^2 of catchment area discharges stormwater to the PVC. Contaminants on surfaces that may be washed away by stormwater run-off, such as roofs, street sediments, soot from vehicles, litter, and animal feces may eventually end up in the waterway.

In summary, the PVC is also directly impacted by stormwater run-off along the shoreline, stormwater discharge through outfalls connected to the conveyance system that transports run-off from several catchment areas, and indirectly by stormwater discharges to surrounding areas (through connecting waterways to the north and west) (Figure III.1).

Figure III.1: Stormwater catchment area for PVC shown by heavy blue lines on right panel. Locations of stormwater outfalls are shown by red ovals. This map does not show private outfalls. Total catchment area (catchments 1 to 8 and partial areas for 9 to 12) that discharges stormwater to the PVC is approximately 329,000 m^2.

Table III.1: Catchment areas in CMB connected to stormwater conveyance system with discharge locations in PVC

ID	Location	Basin ID	Project Name	Proportion of Basin in Catchment	Area (m^2)
1	CMB	HU-72ST-DICK	North Shores	100%	25,973
2	CMB	HU-74ST-DICK	North Shores	100%	45,651
3	CMB	HU-73ST-DICK	North Shores	100%	62,464
4	CMB	HU-75ST-DICK	North Shores	100%	33,753
5	CMB	HU-75ST-OUTF	North Shores	100%	10,632
6	PVI	HU-75ST-GARY	NA	100%	47,368
7	PVI	HU-73ST-WAYN	NA	100%	1,5491
8	PVI	HU-74ST-GARY	NA	100%	1,2791
9	CMB	HU-75ST-HARD	North Shores	25%	10,650
10	CMB	HU-74ST-HARD	North Shores	50%	18,000
11	CMB	HU-73ST-HARD	North Shores	50%	30,943
12	CMB	HU-71ST-ABBT	North Shores	25%	15,377

III.2 SANITARY SEWER SYSTEM

Likewise, an analysis of the GIS data for the sanitary sewer infrastructure shows sewer force mains (sanitary sewers under pressure) along the south leg of the PVC and 72nd street, as well as along the northeast perimeter of the PVC and along Dickens Avenue. A siphon is located on the Northeast bend of the canal (Figure III.3). A high density of sanitary sewer force mains was observed under the Miami Beach Parking lot located between 72nd and 73rd street. Lateral connections from residential properties to gravity pipes are also observed throughout the area.

The location of the March 5, 2020, sewage main break is shown by the yellow star (Figure III.3). As noted prior, the location of sewer leak at 72nd street and Harding Ave. is approximately 1,500 feet away from the PVC. It is estimated that following the March 5, 2020, sewer leaks, about 665,000 gallons of untreated sewage streamed to the PVC.

The analysis of existing infrastructure suggests that the PVC may potentially be impacted by,

- Sewage overflow at times of flooding due to heavy rainfall or King Tides
- Non-point discharge through leaking or failing wastewater sewer infrastructure

In the event of failing wastewater pipes, wastewater may impact the PVC through the stormwater conveyance systems via tidally driven groundwater fluxes to the PVC. Further details are provided in the following section.

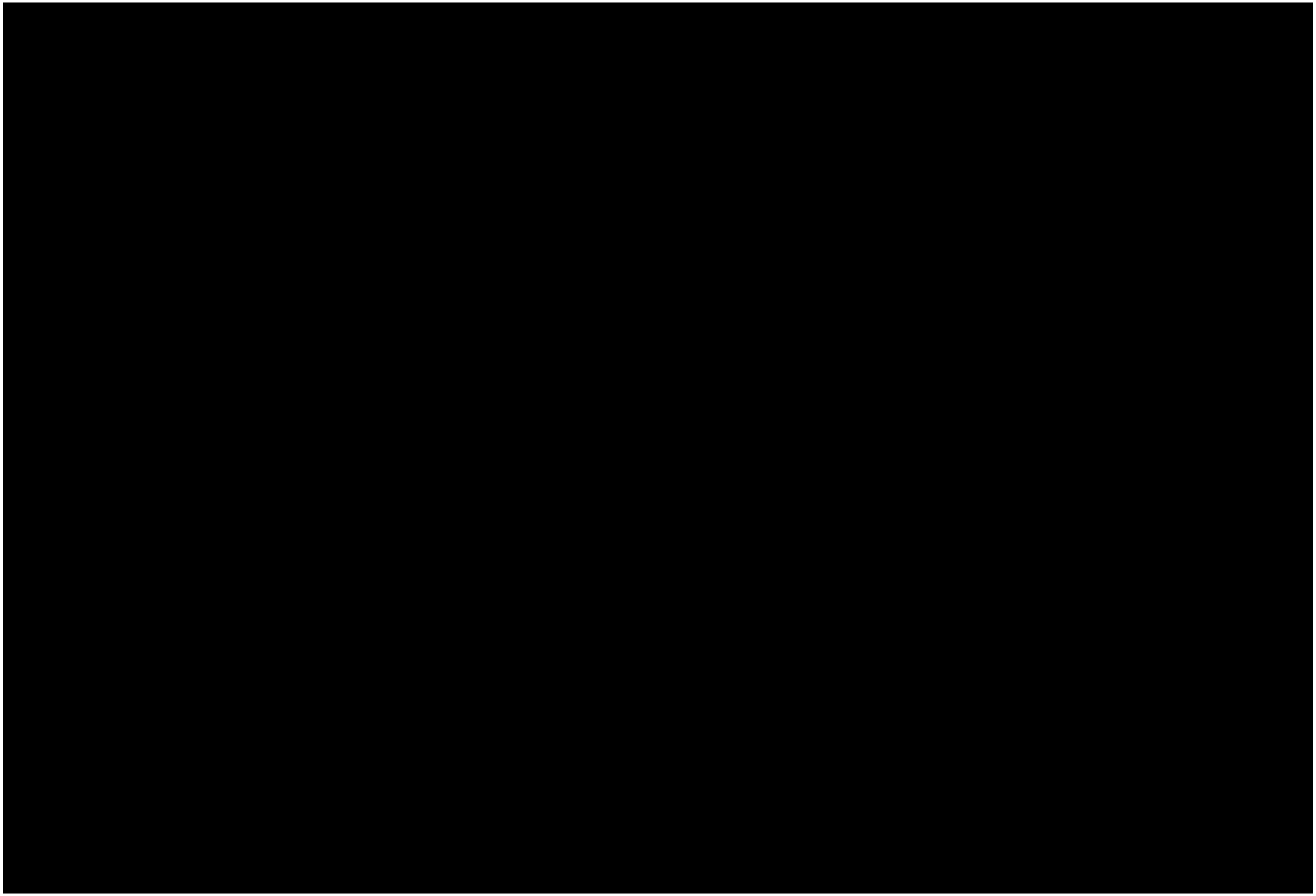


Figure III.3: Locations of sanitary sewer force mains are shown by the dark brown lines. Locations of sewer gravity mains are shown by the beige lines. The siphon on the northeast bend of the KYW is indicated by the orange-brown line.

III.3 EVALUATION OF BOTH SYSTEMS

The tidal and groundwater level variations at the PVC are particularly important, given the multitude of sanitary sewer system infrastructure in the area, the elevated FIB levels measured in both the stormwater system and in the waterway, and the potential for cross contamination from the sanitary to the groundwater and stormwater conveyance system. There are significant locations where the sanitary and the stormwater conveyance system overlap (e.g., see Figure III.4) thereby emphasizing the possibility of water exchange between the two systems. To assess how the groundwater levels in the vicinity of the PVC are influenced by tides, plots of groundwater levels at the nearby Parkview Park monitoring well and tidal predictions at the PVC were generated (Figure III.5). Results show a clear relationship whereby, the groundwater levels are tidally influenced.

[redacted]

Figure III.4: Locations of areas where the storm conveyance system and sanitary sewer system overlap along 73rd Street.

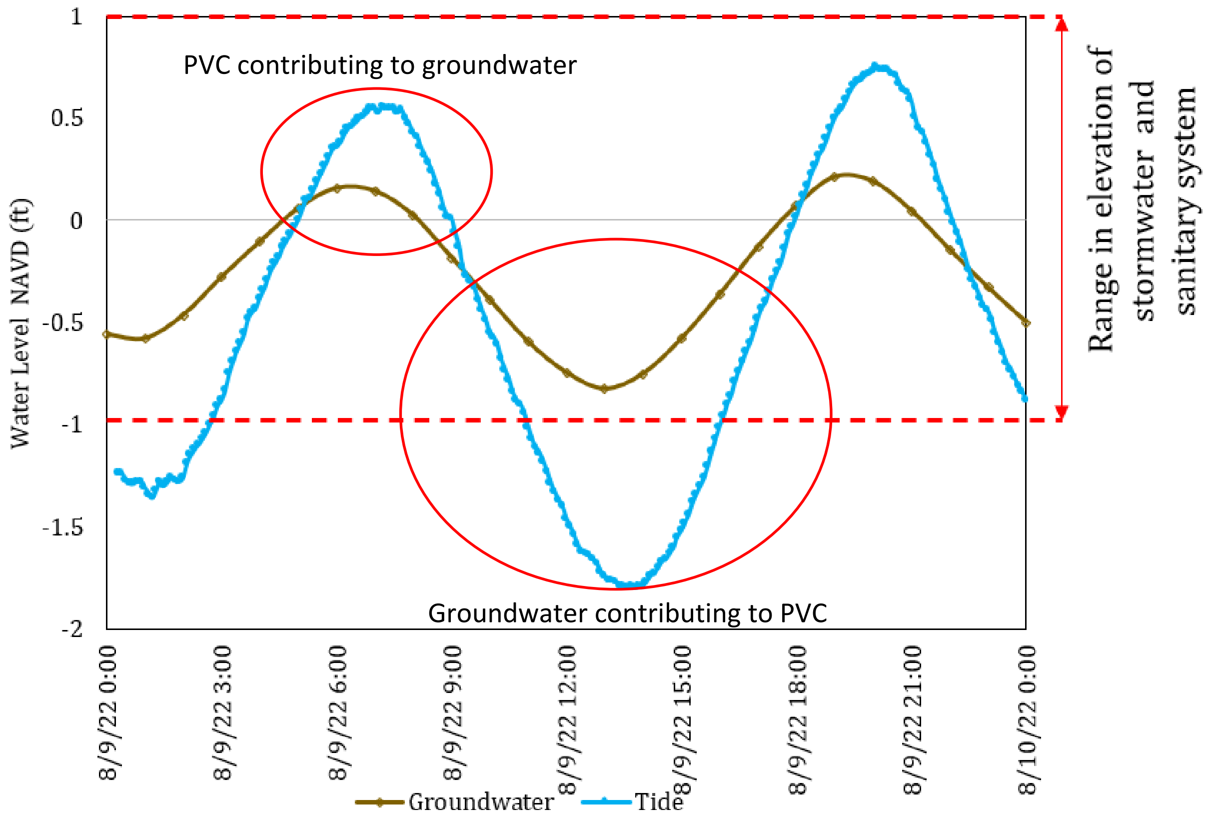
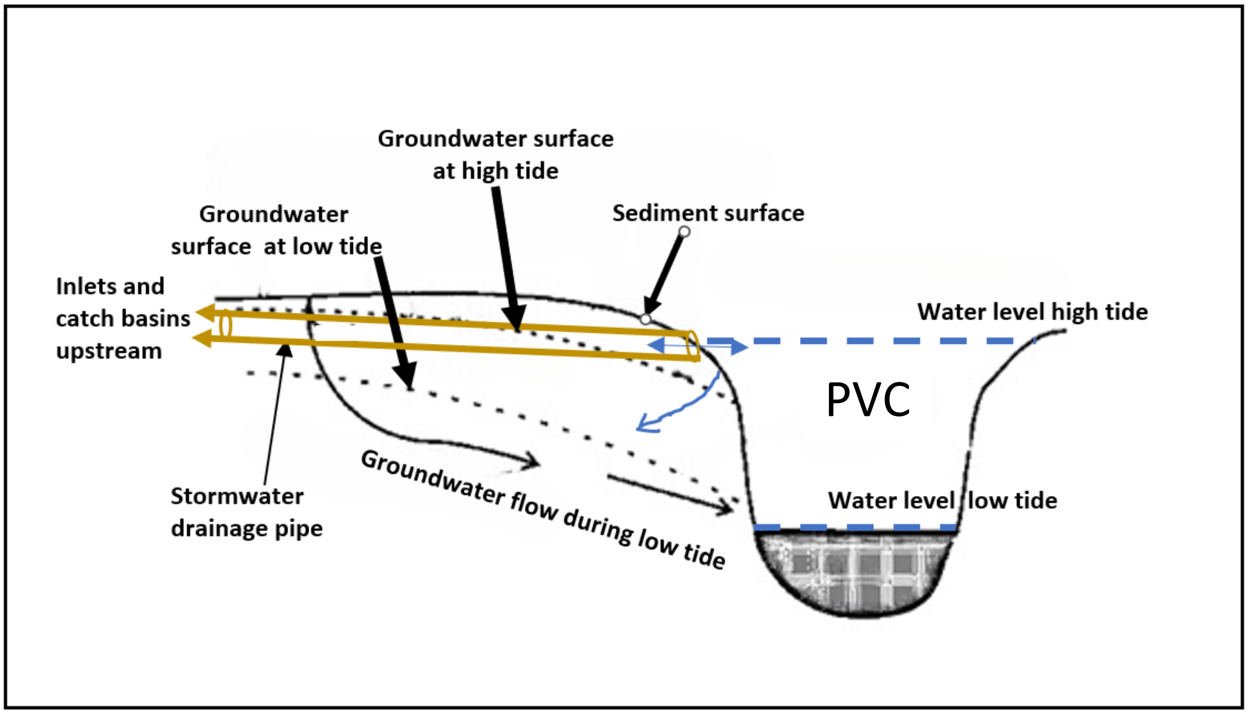


Figure III.5: Estimated tidally driven water levels at PVC and measured groundwater elevation at Parkview Island Park monitoring well.

During high tide, the elevation of the marine water at the PVC is higher than the groundwater elevation. Since water flows from high elevation to low elevation, during high tide water generally flows from the PVC towards the groundwater. This flow into the groundwater system can be facilitated by the stormwater conveyance system acting as a perforated pipes that permits unrestrained flow from the PVC to the shallow groundwater. However, during low tide, the elevation of the groundwater is higher than the marine water at the PVC. Again, water flows downhill. At times of low tide, groundwater flows into the PVC, from the landside to the waterway. (Figure III.5). This flow direction is again facilitated by the stormwater conveyance system where the perforated pipes serve as unrestrained conduits linking the groundwater to the PVC.



tidally driven fluxes. At the land-marine water interface, one potentially important pathway for non-point pollution from land to the sea is groundwater (Burnett et al. 2006). Submarine groundwater discharge is an ubiquitous coastal process. It involves the flow of fresh groundwater, re-circulated marine water, or a composite of both (Swarzenski et al. 2004). In some urban locations it has been shown to be an important source of nutrients and has been indirectly linked to high concentrations of FIB (Boehm et al. 2003, Boehm et al. 2004, Izbicki et al. 2012, Russell et al. 2013). In the event of a leaking sewer gravity main, sewer force main, or laterals at multiple residential units, the wastewater could potentially contaminate the groundwater and eventually contaminate the PVC through tidally driven groundwater fluxes. It is important to note that the hypothesis that the wastewater sewer is not impacting the groundwater has not been proved. Further details and suggested studies are provided in Section VI of this report.

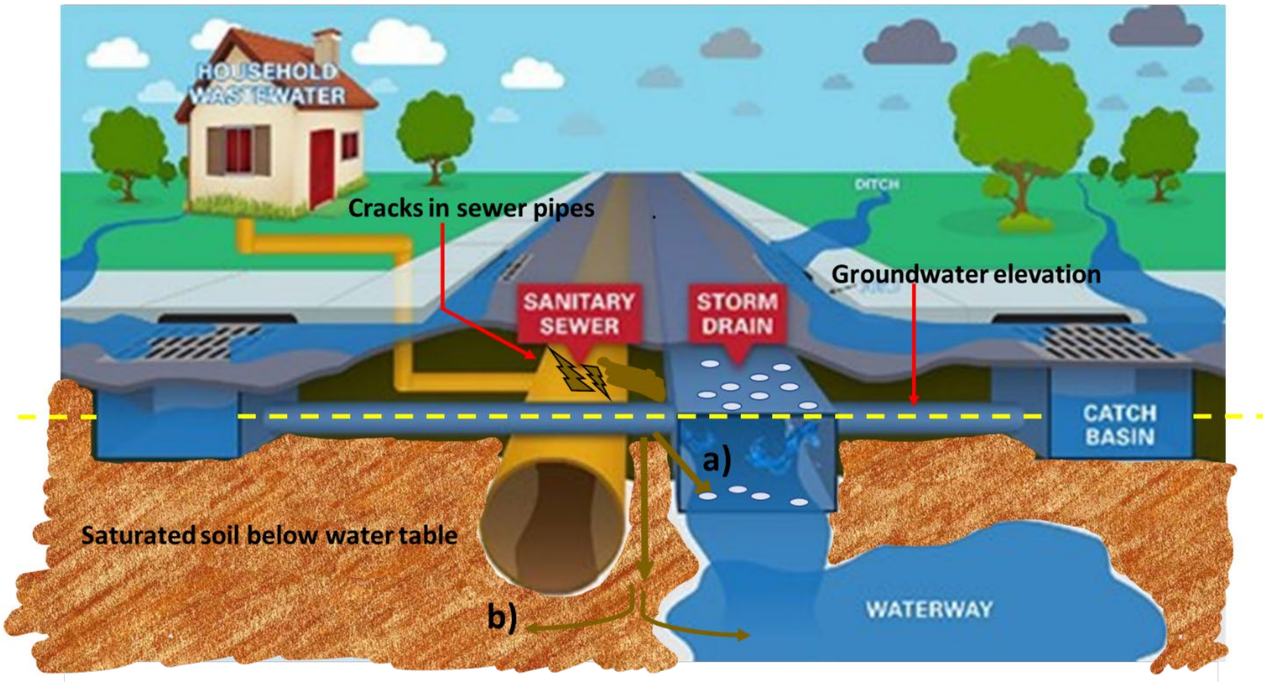


Figure III.7 Flow diagram showing possible water pathways into and out of conveyance system. a) emphasizes the possibility of leaks from the sanitary sewer contaminating groundwater and flowing into the perforated pipes of the storm conveyance system, b) emphasizes the possibility of leaks from the sanitary sewer contaminating groundwater that flows directly to the waterway.

CHAPTER IV

OBSERVATIONS DURING VISUAL INSPECTIONS

CHAPTER IV

OBSERVATIONS DURING VISUAL INSPECTIONS

As part of sampling efforts, the research team had the opportunity to visit the catchment area and conduct qualitative assessments of the study area. These qualitative assessment took place during site visits aimed at gathering samples and data. They included inspections by foot from the land side and by water via boat and paddle board inspections of the PVC. Our team was present in the field during mostly dry conditions but they were also present during rain events. A detailed summary of these visits along with photographs taken is given in Appendix D. Below is a table that summarizes the main sources of "visible" contaminants during our sampling efforts.

Table IV.1: Potential Fecal Sources Observable During Field Visits. See Appendix D for details and photos from field visits.

Categories of Potential Sources Fecal Sources Observable During Field Visits	Details of Source
1. Animals feces	• Dogs • Roosters • Iguanas • Racoons • Rats
2. Animal feeding stations	• Parkview Island Park Adjacent to the Kayak Launch. The feeding station attracks feral animals that release feces in the area.
3. Homeless	• Bridge from PVI to Elementary School • Bridge from PVI to Dickens Avenue • Shoreline in vicinity of Parkview Island Park (hammock and mosquito net in mangrove area) • West of community garden

Table IV.1 (continued): Potential Fecal Sources Observable During Field Visits. See Appendix D for details and photos from field visits.

Categories of Potential Sources Fecal Sources Observable During Field Visits	Details of Source
4. Trash in waterway	Observed on all inspection days (source of FIB and limits circulation) • Plastic bags • Soda cans • Large plastic items • Landscaping debris • Animal feces floating in waterway • White foam
5. Trash and debris in curbs	• Food packages, cans, cigarettes, plastic bags etc. • Dirt and leaves
6. Trash bins from commercial establishments	• Leaking leachate
7. Very little green space in stormwater catchment areas	• Limits percolation of run-off which limits natural contaminant removal
8. High population density	• High population density suggests more human associated sources of FIB within a smaller area. Thus the system will need to rely more on engineered systems to facilitate contaminant removal as natural attenuation and dilution is not sufficient to handle the density.
9. Shaded embankments with natural soils	• Shaded soil embankments are known to harbor high levels of FIB due to shade and wetting and drying cycles which encourages FIB persistence and growth
10. Eroding channel embankments	• Sediments from shoreline containing high levels of bacteria can enter waterway as part of tidal changes in water levels or through rainfall-runoff
11. Stormwater outfalls	• Source during rainfall-runoff and evaluated through sampling as part of this study

CHAPTER V

SAMPLING EFFORTS

CHAPTER V

SAMPLING EFFORTS

Sampling efforts included: 1) intense spatial sampling (Section V.1), 2) sediment and catch basin sampling (Section V.2), 3) intense temporal sampling using an autosampler (Section V.3), and 4) depth sampling within the waterway, catch basins, and wells (Section V.4). The timeline for sample collection efforts are illustrated on the following time line superimposed on the rainfall record (Figure V.1a). Of note August through early Septnmber (includes the first three sampling events) corresponded to a relativley dry sampling period (August and early September). The sample collection during September 16th (intense sampling during low tide) corresponded to a wet period. A small rainfall event was observed during the hourly (over 48 hours) sampling event.

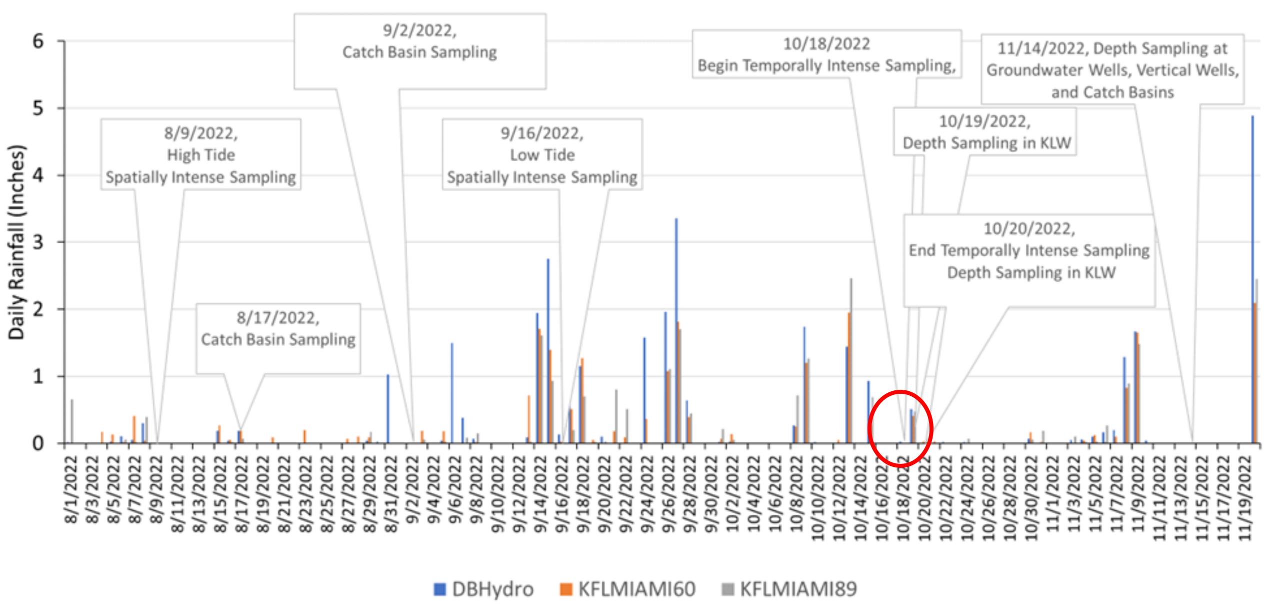


Figure V.1a: Sample collection timeline superimposed on daily rainfall record. Of note, low tide spatial sampling occurred during an antecedent wet period. Period corresponding to the hourly sampling period (over 48 hours) is highlighted by a red circle.

All of the analyses initiated as part of the current study through the University of Miami were performed using the Most Probable Number (MPN) method based upon the use of chromogenic substrates (Enterolert-18, IDEXX Industries), their standardized well system (Quantitray-2000), and incubation temperatures consistent with enterococci measurements (41.5 ºC for 24 hours ± 2 hours). This method was chosen given the wide range of enterococci measurements documented historically in the PVC. The MPN approach provides the broadest range of detection (from 1 to 2419.6 counts) for a single analysis, thereby increasing the chances of direct measurements of concentrations. In this study, dilutions of 10:1 were preferentially used thereby providing analytical ranges between 10 and 24,196 MPN per 100 mL.

All PVC samples were collected in pre-sterilized Whirlpak bags by collecting samples from the water's surface with the exception of: a) depth samples from the PVC which were collected with sterile pipettes (new each time) attached to tubing and a hand pump, and b) 48 hour samples were collected using a pump set with a purge cycle and collection into sterile bags (new each time). For catch basin, vertical wells, and groundwater monitoring wells samples were collected in sterilized 500 mL bottles by either pumping water using a peristaltic pump (new tubing used each time) or by attaching bottles to a weighted bottle holder on the end of a rope. Early catch basin sampling (August and September) was conducted using the weighted rope method. Later sampling documented the sampling depth more precisely through pumping water from a specified depth.

V.1 INTENSE SPATIAL SAMPLING

The next step following our preliminary data analysis and visual inspections was to identify the location of the enterococci hot spots in the Kayak Launch area within the PVC. To this end, a spatially intense sample collection program was conducted. The program included a series of transects that cut across the canal at locations of interest to the north and south of the Kayak Launch area. The spatially intense sampling was conducted at extreme high tide and at extreme low tide, with all samples collected as quickly as possible to get a snapshot of the enterococci distribution across the entire length of the waterway surrounding Park View Island (Figure V.1).

We conducted our first spatially intense sampling effort on August 9 very early in the morning, targeting high tide. We systematically collected 50 water samples along the transects, which are ordered locations along the waterways around Park View Island. A greater number of samples were collected on the east side of the PVC. Transects L through R show the location of 28 sample collection points, that is 4 samples per transect. Of note, transects M to O show sample collection points in the vicinity, to the north and south of the Kayak Launch location (Figure V.1b). We also collected one sample per transect along the Normandy Waterway N-S (Transects A to F), at the intersection of the PVC with Biscayne Point Waterway (Transect G), Tatum Waterway (Transect H). One sample was also collected near the outfall located in the Tatum Waterway (Transect I). In addition to collecting water samples for analysis of enterococci concentrations, at each point along transects, we also measured the waterway depth, and a suite of physical chemical parameters including dissolved oxygen, pH, temperature and salinity.

The second spatially intense sampling was conducted on September 16 very early in the morning targeting low tide. We collected 50 water samples along the same transects as on August 9, 2022. Two additional samples were also collected: a sample was collected from an unidentified outfall that was discharging water a few meters east of transect K4, and a duplicate sample was collected at transect N2 which is closest to the Kayak Launch pad. During the September 16 sampling effort, we also measured physical chemical parameters.

The collection of a high number of samples in a short period of time during high tide and during low tide, enabled a "snapshot" of the bacteria distribution within the waterways around the island. Additionally, the results from the intense spatial sampling provided information on the spatial changes in the enterococci levels in the PVC with respect to the levels in the adjoining waterways. We also compared differences in environmental parameters measured during high and low tide to gain insights into the tidal and groundwater influences on water quality. These insights provided a better understanding of the underlying transport and fate mechanisms driving the different levels of FIB in the waterway and complemented the spatial analysis. Final analysis of the results for the intense spatial sampling coupled with the analysis of environmental parameters are provided in the following paragraphs.

On both sampling days, the first sample was collected at Transect A, and the last sample was collected at Transect S, as the boat transporting our team travelled in a counterclockwise direction around Parkview Island. Enterococci concentrations measured on August 9, during high tide, ranged from 52 MPN/100 mL to 4,611 MPN per/100 mL (Figure V.2). Several samples measured below the 70 MPN/100 mL threshold value, including the sample collected at Transect A, and several samples collected just before exiting the waterway on the south leg of the PVC. Sampling results show, a well-defined spatial pattern, of increasing enterococci concentrations, in the counterclockwise direction starting along the north leg of the PVC, and through the PVC East and moving south. This trend of increasing concentration, peaked in the vicinity of the Kayak launch Pad, along transects N through O. Three hotspots were identified, where the highest enterococci concentrations were measured at transect N1 (4,611 MPN/100 mL), at transect P3 (2,064 MPN/100 mL) and transect O1 (1,785 MPN/100 mL) (Figure V.4, panel a).

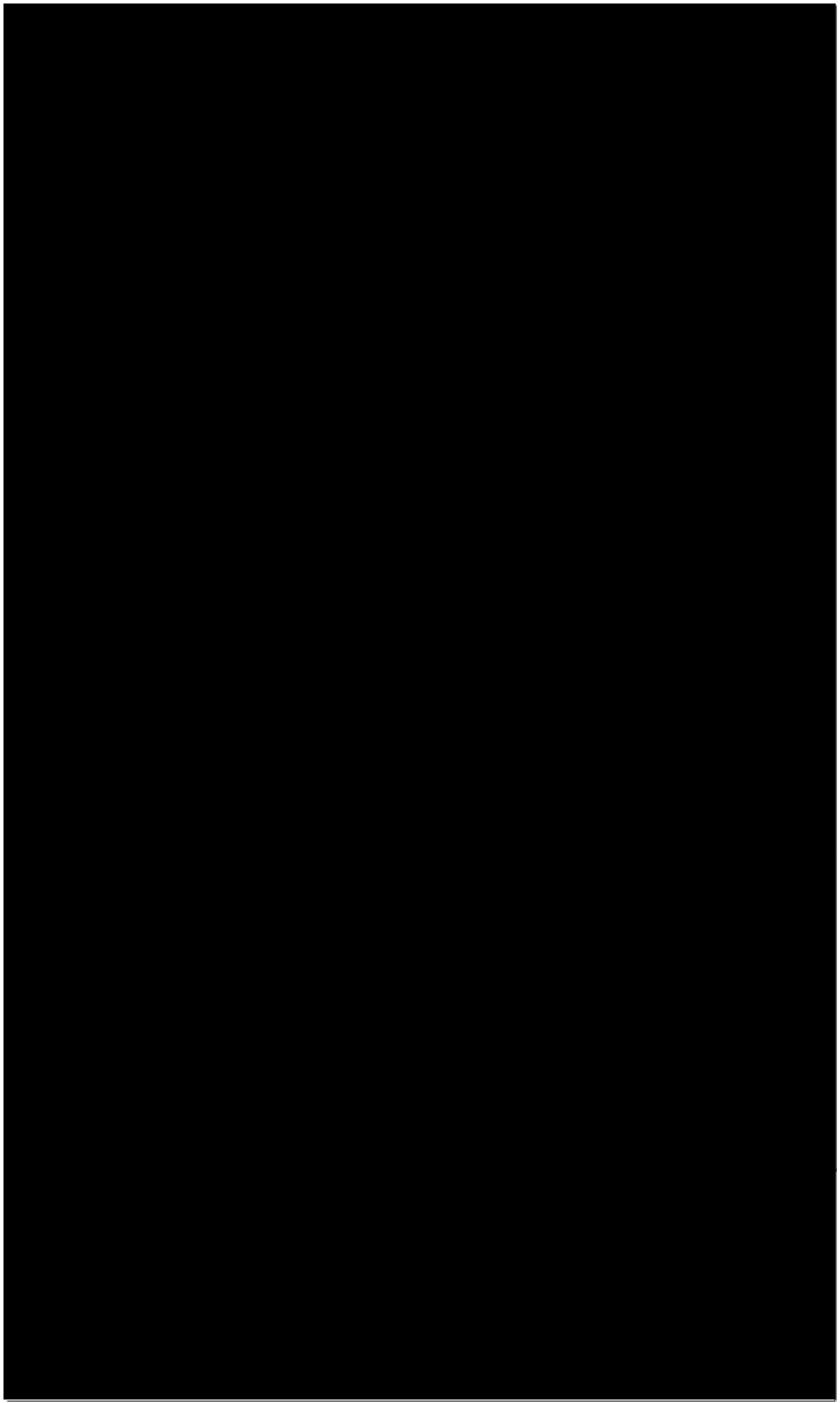


Figure V.1b: Map showing transects with sampling locations for intense spatial sampling activity conducted on August 9th and September 16th. Red points show the location of the stormwater outfalls, green lines show the location of the stormwater mains, orange line on the northeast bend of the canal shows the location of the siphon, brown lines show the location of the sanitary sewer system force and gravity mains.

Figure V.2: Map showing measured concentrations of enterococci at the PVC during **high** tide (August 9, 2022). Hotspots shown by large pink and purple circles.

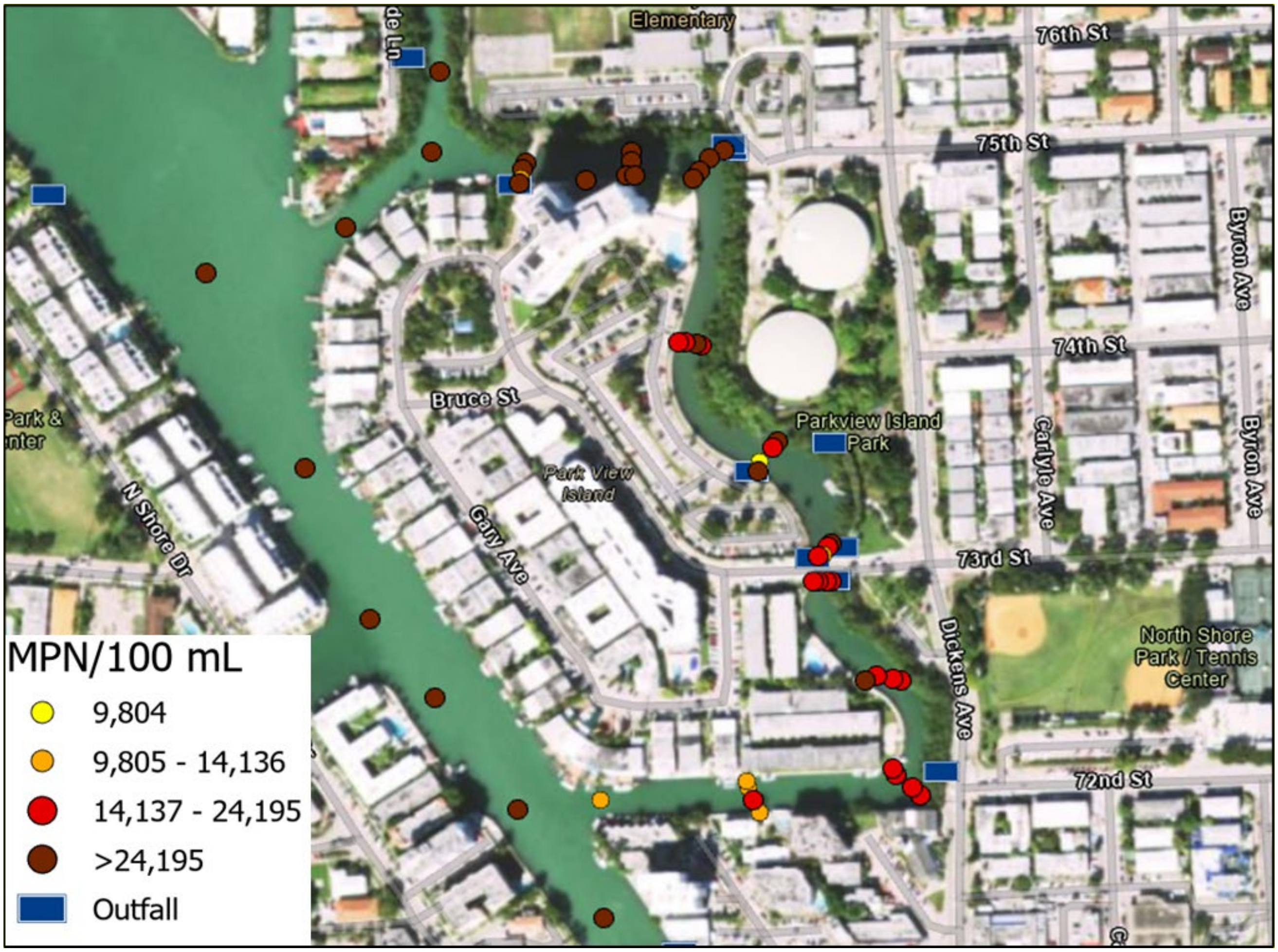


Figure V.3: Map showing measured concentrations of enterococci at the PVC during **low** tide (September 16, 2022).

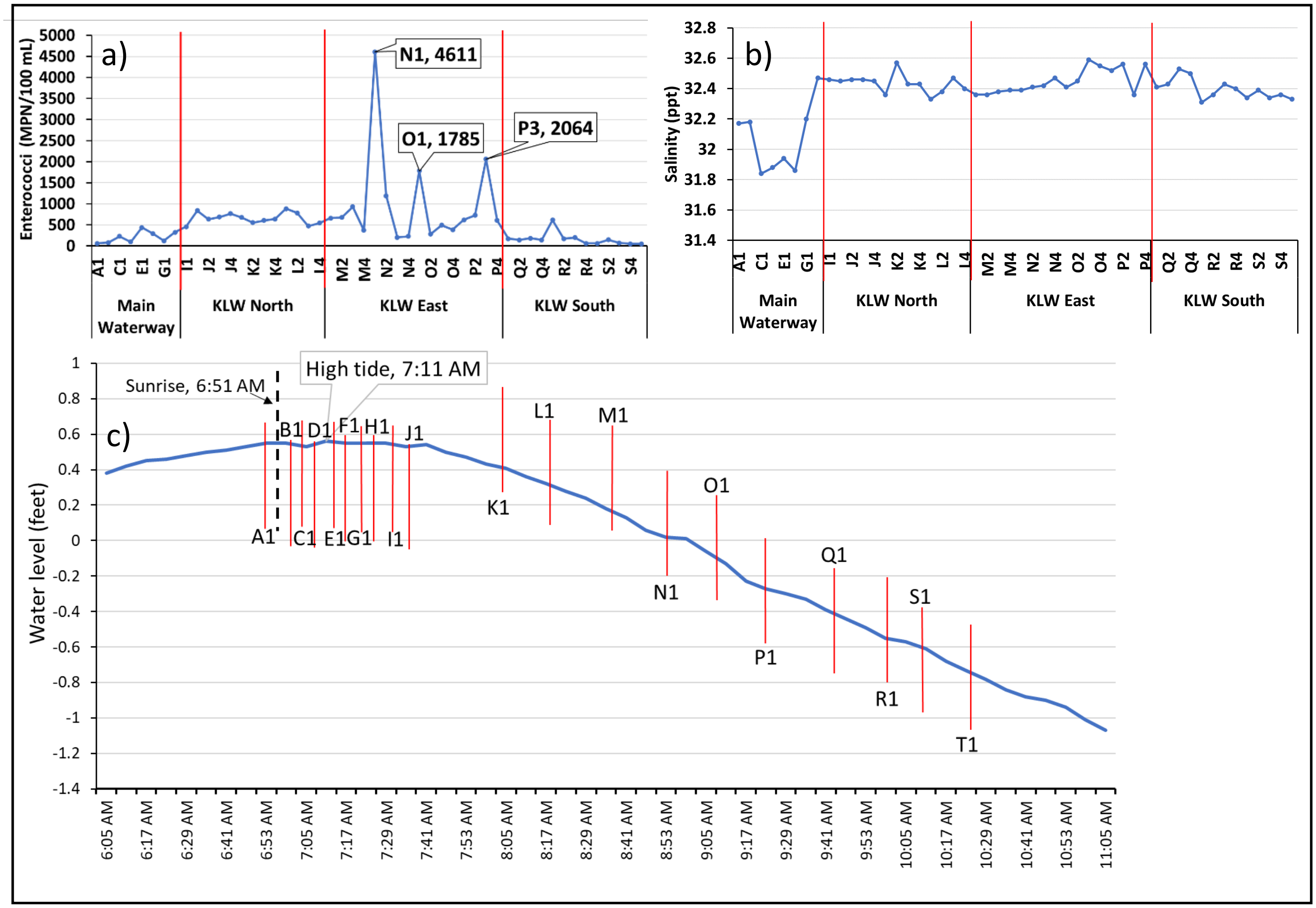


Figure V.4: Panel a) August 19th (high tide) enterococci levels around the perimeter of Parkview Island, Panel b) salinity measurements along PVC. Panel c) water levels (NAVD) during sampling activities.

This trend reverses upon entering the PVC South, where lower enterococci concentrations with values like those in the main waterway were observed. In general, higher salinity concentrations were measured along the PVC North and East, than along the main waterway of Normandy Waterway N-S and the PVC South. The change in salinity between the main waterway and the PVC is surprising since both the main (31.8 ppt) and PVC North (32.4-32.6) waterways were measured during extreme high tide. This change in salinity could provide insights into the tidal flushing mechanisms that affect the PVC.

Enterococci concentrations measured on September 16, during low tide, ranged from 9,804 MPN/100ml to over the 24,196 MPN /100 mL detection limit value (Figure V.5). None of the samples measured below the 70 MPN/100 mL threshold value. Several samples measured at the lower end of the range for that day (9,804 to 14,136 MPN/100 mL). These samples were located at transects J and N, and along the PVC South. This lower range is two to seven times higher than the peaks identified on August 19.

Sampling results from September 16 show, a spatial pattern opposite to that observed during August 19, with increasing enterococci concentrations upon exiting the PVC. All samples collected along the main waterway measured above the detection value of 24,195 MPN/100 mL. All samples, except for one, collected along the PVC North also measured above the detection limit. However, samples collected in the PVC East had lower enterococci concentrations with 7 samples measuring within the 9,804-14,136 MPN/100 mL range, and 15 samples measuring within the 14,137 to 24,196 MPN/100 mL range. Only five samples in the PVC East had concentrations above the detection limit. These five samples were collected at transects M, N and Q, in the same general area as for the peaks observed on August 19. Similarly, to high tide sampling on August 19, during the low tide sampling on September 16, the lowest concentrations were observed along the PVC South. To emphasize, these “lower concentrations” observed on September 16 were much higher than the peaks observed during high tide sampling conducted on August 19. The source of enterococci was much more pronounced on September 16 than on August 19. We believe that the very high levels observed on September 16th were due to the antecedent wet period during which the stormwater conveyance system had discharged stormwater shortly prior to sampling. This is consistent with the hypothesis that the primary source of enterococci are wastes deposited on surfaces that are washed into the PVC by the stormwater conveyance system.

A change in salinity levels was observed during low tide sampling, whereby the measured salinity values (26.8 to 30.3 ppt) during low tide were lower than values measured during high tide (31.8 to 32.6 ppt). This observation suggests that the extremely high levels of enterococci are associated with freshwater. It is possible that during low tide, tidal flushing forced freshwater from the PVC out to the main waterway, thereby explaining the reversal in observed spatial concentration trends. The study is located in North Biscayne Bay. Tidal flow between North Bay and the ocean is through Baker’s Haulover Inlet. Our team (Dr. Larissa Montas) observed that during the ebb tide cycle, currents in the PVC North were moving west. However, during the flood tide cycle, currents in the PVC were moving east. However, during the ebb tide cycle, currents in the PVC East were in general moving south and not north. This suggests that greater tidal flushing occurs through the PVC South than through the PVC North. It is possible that tidal flushing through the PVC North is limited by the sharp 45 degree angles created by Biscayne Point Island and flows from the waterways to the north. In contrast, water exiting the PVC South could flow to the main waterway with less impedances.

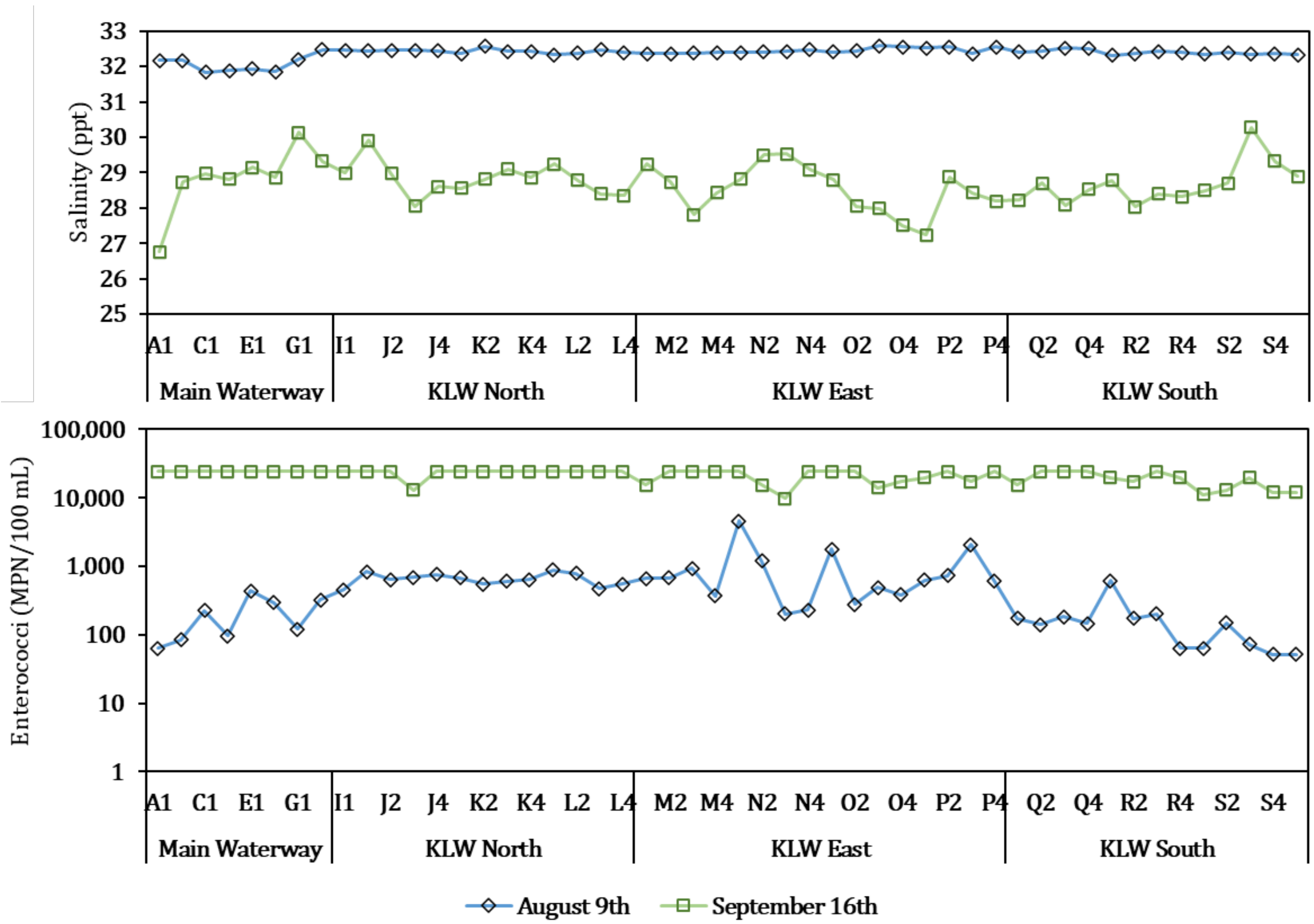


Figure V.5: Results from spatially intense sampling around the perimeter of Parkview Island, comparing the results from the August 19th sampling event (high tide) and the September 16th sampling event (low tide). Top panel compares salinity and lower panel compares enterococci.

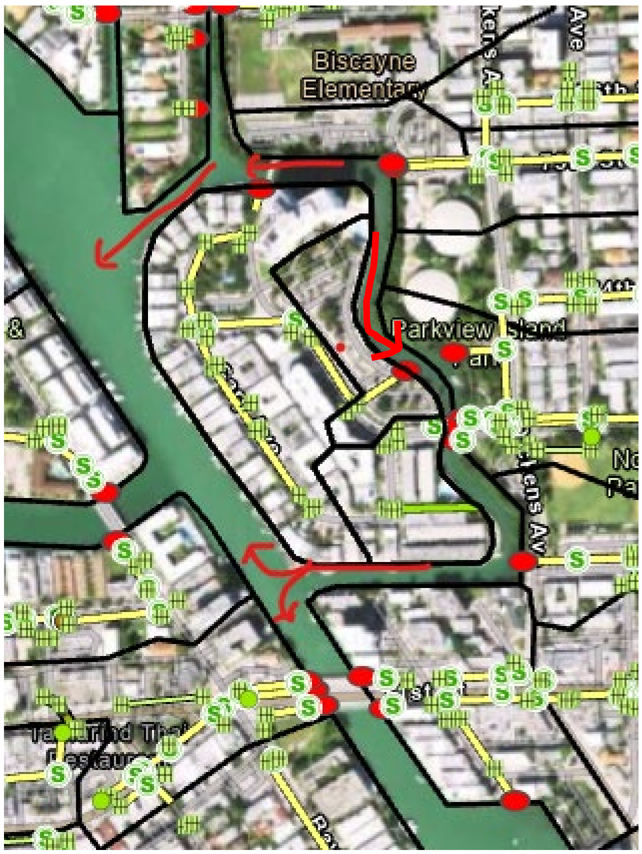


Figure V.6: Schematic of conceptualized tidal flushing during ebb tide, with more tidal flushing towards the south of Parkview Island. It is possible that tidal flushing through the PVC North is limited by the sharp 45-degree angles created by Biscayne Point Island and flows from the waterways to the north. In contrast, water exiting the PVC South could flow to the main waterway with less impedances.

V.2 SEDIMENT AND CATCH BASIN SAMPLING

Following our scouting visits, and the evaluation of sanitary and stormwater infrastructure GIS data, we decided to evaluate the waterway slope sediments and stormwater and sediments within the catch basins. Sampling took place on two dates, August 17 and September 2, 2022.

On August 17 we conducted sampling activities targeting the stormwater sewer infrastructure. We focused our efforts on sampling stormwater inlets and catch basins located along the two gravity pipes leading to the stormwater outfalls that discharge north and south of the Kayak Launch Dock. These two gravity pipes run along 73rd street and 74th street. We also sampled sediments along the waterway banks, right next to the outfall discharge during low tide by scraping the upper 1 inch of sediments using a sterile spoon and placing the sample into a sterile Whirlpak bag. Specifically, sediments next to the outfall north of the Kayak Launch dock (NS1, Figure 6), sediments next to the outfall south of the Kayak Launch dock (NS3, Figure 6), and sediments on the banks in front of the Kayak Launch dock (NS2, Figure 6). We also collected water samples at locations directly across from the sediment sampling locations to allow for comparison between the FIB levels measured in the sediments and along the stormwater gravity pipes discharging to the outfalls. Three water samples were collected north, south and adjacent to the Kayak Launch pad (NW1, NW2, and NW3, Figure V.7).

Six locations were selected for catch basin sampling. These locations included three along 73rd Street and three along 74th Street. At each location sampling of the catch basins on August 17th consisted of:

- Collecting sediment samples (top sediments) near the inlets (ST1 to ST6, Figure V.7) by using a sterile scoopula to scrape sediments from the top of the catch basins and place them within sterile Whirlpak bags,
- Removing the inlet grate and collecting water samples directly from the catch basin (W1 to W6, Figure V.7) by attaching pre-sterilized polypropylene bottles to a weighted bottle holder on the end of a rope and lowering the bottle into the catch basin, and
- Using an Ekman dredge to collect available sediments at the bottom of the catch basin (SB1 to SB6, Figure V.7) and transferring these sediments using a sterile spoon into sterile Whirlpak bags. Of note, no sediments were available at WB3 nor at WB4.

For the second sampling of the stormwater catch basins conducted on September 2nd, the sampling program was expanded. We decided to conduct a catch basin analysis by sampling locations close to the force mains of the sanitary sewer infrastructure located along Harding and Collins Avenues, plus locations as far away as possible from the force mains and high-density gravity sanitary sewer infrastructure to evaluate whether proximity to the sanitary sewer infrastructure was associated with enterococci levels.

Three sites were identified as being as far away as possible from the pressurized sanitary infrastructure (i.e., “far away” sites). These three sites form a triangle around the main study area. Specifically, these sites were located at the far upstream end of the sanitary sewer gravity system on Parkview Island (southwest side of the island, site 7), on 77th Street between Byron and Abbot (site 8), and on the corner of 71st Street and Byron (site 9). Site 7 is located upstream of the two gravity sewer pipes on Park View Island (Figure V.8). Site 8 is not adjacent to any gravity sanitary sewer main and in addition is not connected to the stormwater conveyance system (Figure V.8). Finally, site 9 is also as far away as possible to a sanitary sewer force main and is connected to the stormwater gravity pipe that discharges directly to the main waterway away from Park View Island (Figure V.8). Six additional sites were chosen given their close proximity to the wastewater force mains (i.e., "close" sites) under the Miami Beach Parking Lot between Collins and Byron and 72nd and 73rd Street (Sites 10, and 12 through 16). Of note, the majority of the catch basins in close proximity to the pressurized sewer infrastructure were inspected but several (as indicated in Figure V.8 bottom panel) contained no water and therefore were not sampled. In addition, a sample labeled as site 11 was collected from the PVC waterway from the Kayak Launch to provide a comparison to the levels observed from the catch basins.

Results from the waterway shoreline sampling show enterococci in the range from 2,000 to 360,000 MPN per g. The site that had the highest levels in the shoreline sediment was the site located immediately adjacent to the Kayak Launch. As observed from the visual inspection at this site, this is where the animal feeding station was located and where iguana feces were commonly found along the banks.

Results from the catch basin sampling show that top sediments and bottom sediments were characterized by enterococci levels that would exceed 1,000 MPN per gram with values reaching several hundreds of thousands MPN per gram (800,000 MPN/g). Site 4 which had the highest levels of enterococci in the catch basin water (>240,960 MPN/100 mL) also had high levels of enterococci in the top sediments (650,000 MPN/g) suggesting that the top sediments (sediments from the curbs on the street) serve as a significant source of enterococci. Visual inspection of the areas contributing runoff towards the curb in this area showed leaking garbage dumpsters and dumpsters without covers. Bottom sediments in the catch basins were also elevated suggesting that these also serve as a concentrated source of enterococci. The site with the highest level of enterococci in the bottom sediment was also the catch basin where considerable trash was visible within the catch basin.

Overall results from shoreline and catch basin sampling suggest that major sources of enterococci to the catch basins are runoff and sediments potentially contaminated by animal feces, trash, and liquids from garbage dumpsters.

Figure V.7: Map showing locations for intense catch basin sampling conducted on August 17th. The August 17th sampling focused on both the water and sediments. Red ovals show the location of the stormwater outfalls, yellow squares show the location of the stormwater inlets and catch basins. Dark brown lines and light brown lines show the location of the wastewater force mains and gravity lines, respectively. Yellow squares, yellow and blue triangles show the locations of the catch basins, sediment, and waterway water sampled on August 17th.

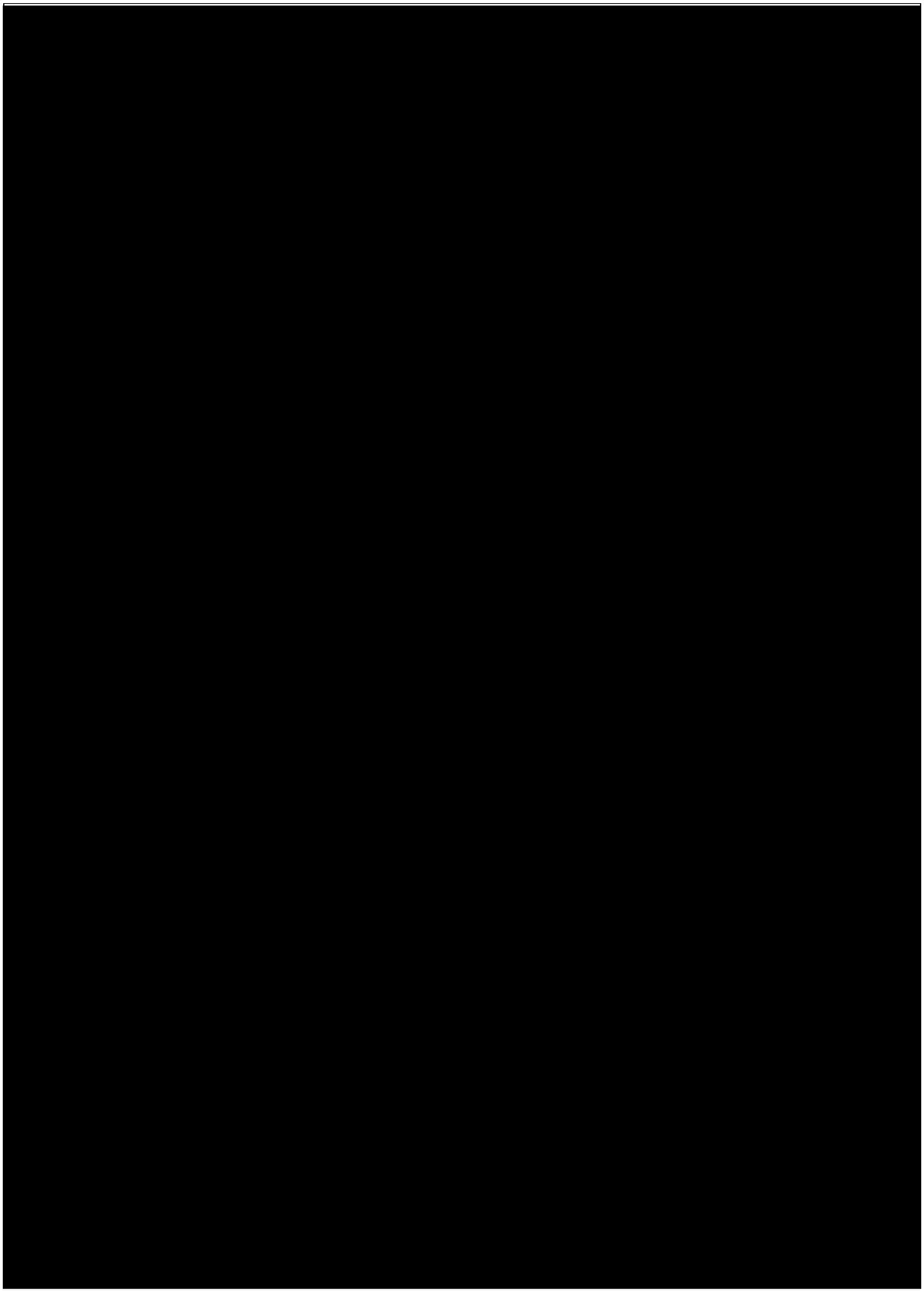
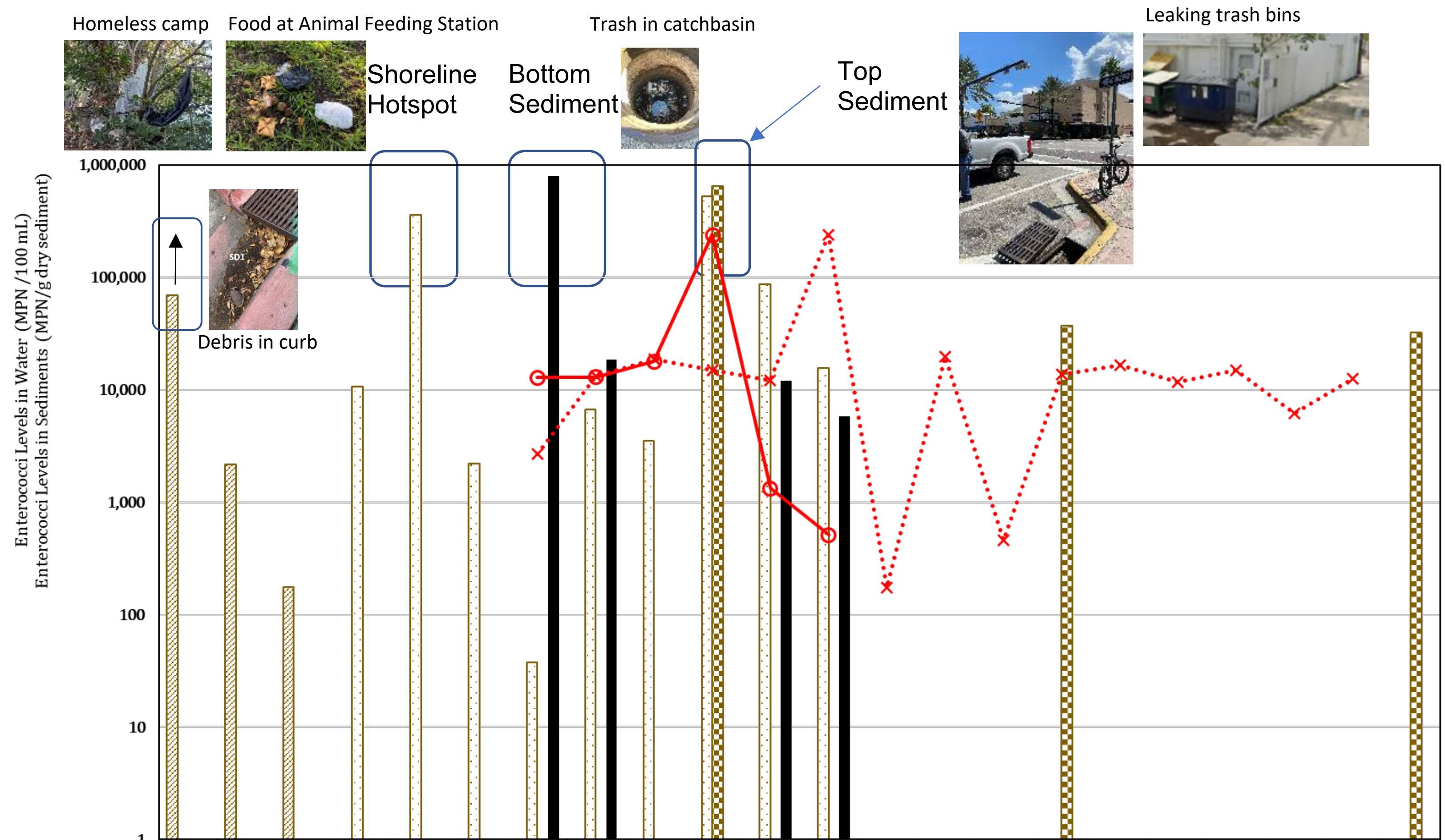


Figure V.8: Panel a) Map showing locations for intense catch basin sampling conducted on September 2nd. On September 2nd sampling focused on water only. “Far-away” sites from the pressurized sanitary infrastructure are shown as 7, 8 and 9. “Close” sites are shown as 10, 12 to 16. Panel b) Details of “far-away sites given in middle panel. Panel c) Details of “close” sites along with location of catch basins with no water are provided in the lower panel



	SD1	SD2	SD3	S1	S2	S3	1	2	3	4	5	6	7	8	9	10	12	13	14	15	16	4R
8/9 Top Sediments	>69,355	2,158.	174.5																			
8/17 Top Sediments				10,704	359,886	2,212	38	6,709	3,526	526,092	87,023	15,743										
9/2 Top Sediments										654,063						37,135						32,467
8/17 Bottom Sediments							798,013	18,751			12,042	5,787										
8/17 Catch Basin Water							12,873	13,053	17,968	241,960	1,327	512										
9/2 Catch Basin Water							2,718	13,393	18,868	14,923	12,248	241,960	173	19,648	463	13,753	16,768	11,730	14,978	6,240	12,528	

Figure V.9: Results from sediment and water sampling of channel banks and catch basins (August 17 and September 2). Sediment results shown by bar plots and water results shown by lines.

V.3 INTENSE TEMPORAL SAMPLING USING AN AUTOSAMPLER

Prior efforts have been completed to collect bacteria data on a daily basis and also several times per day. The results show that the enterococci levels are highly variable between days and between fractions of a day. The lack of trends indicates that the temporal time scale of sampling is too coarse. In other words, sample collection should occur on shorter time scale (such as hourly) in order to capture trends in enterococci concentrations. Given the need to collect samples from one location over shorter time scales, an autosampler (ISCO 6712) was installed at the Kayak Launch (in an enclosure to avoid vandalism) which collected samples every hour over the course of 48 hours (from October 18 at 7 am to October 20, 2022, at 6 am). Samples were retrieved 2 times per day (once every twelve hours) in individual pre-sterilized containers. In addition, an EXO3 sonde fitted with water temperature, pH, salinity, dissolved oxygen, and turbidity sensors was also deployed outside of the enclosure and attached to the floating dock in the waterway such that the instrument maintained a constant depth from the water's surface. The EXO3 sonde (Xylem Inc.) was set to record data every one minute. Similarly, the nozzle used for the autosampler was also suspended from the floating dock such that it too maintained a constant depth, screened at a depth from 6 inches to 12 inches below the water's surface. Upon processing of the hourly samples, the remaining sample was used for additional water quality measurements (water temperature, pH, salinity, dissolved oxygen, and turbidity) using an YSI Pro DSS sonde (YSI Inc).

In addition to direct measurements, additional hydrometerologic data were collected. This included rainfall, tidal heights, and solar radiation. Rainfall was consolidated from three stations, Miami Beach, Farrbetter, and Coast Guard Station (more details about these stations is given in Section II.2). Tidal heights were interpolated from the NOAA station at Virginia Key. Solar Radiation was also available at the NOAA station at Virginia Key.

Results show a very strong response of enterococci to rainfall. During the 48-hour sampling period no rain was detected for the first 31 hours with the exception of 0.01 inch detected at the Miami Beach rain gauge at 2 pm on October 18 and 0.01 inch detected at the Coast Guard rain gauge at 2 am on October 19. Starting at 1 pm on October 19, rainfall was detected across multiple rain gauging stations, with 0.41, 0.38, and 0.34 inches recorded at the Farrbetter, Miami Beach, and Coast Guard stations respectively (see Figure V.10).

Prior to the rainfall period (prior to 1 pm on October 19) the enterococci levels at the PVC were less than 1800 MPN/100 mL, ranging from 228 to 1,730 MPN/100 mL. Upon the initiation of rainfall, the enterococci levels increased considerably to values above detection limit (>24,200 MPN/100 mL). The response to rainfall was striking. These results confirm earlier analysis of the historical data which showed strong correlations between enterococci levels and antecedent rainfall.

A weaker relationship was observed with tidal height. Prior to the rainfall event, in general, there was a general trend of higher enterococci concentrations during low tide and lower enterococci concentrations during high tide. During low tide, the primary source of water to the river would be groundwater (see Section III.3 for further explanation). At high tide the primary source would be ocean water pushing water back up into the waterway system. The Pearson correlation (R) between enterococci and tidal height was computed as 0.81 (R^2=0.66) (Figure V.11). These results suggest that shallow groundwater may be a source of enterococci to the PVC. However, compared to the impacts from rainfall, the impacts from groundwater are more subtle.

Among the water quality parameters (as measured from the actual sample using a YSI probe), a significant Pearson correlation was observed between enterococci and salinity (R=0.88, R^2=0.78) (Figure V.12). No significant correlations were observed between water quality measured from the waterway with the EXO3 (Figure V.13). These results suggest that water quality is highly site specific and thus water quality results from actual samples is more indicative of enterococci levels compared to ambient water quality in the vicinity of where samples were collected.

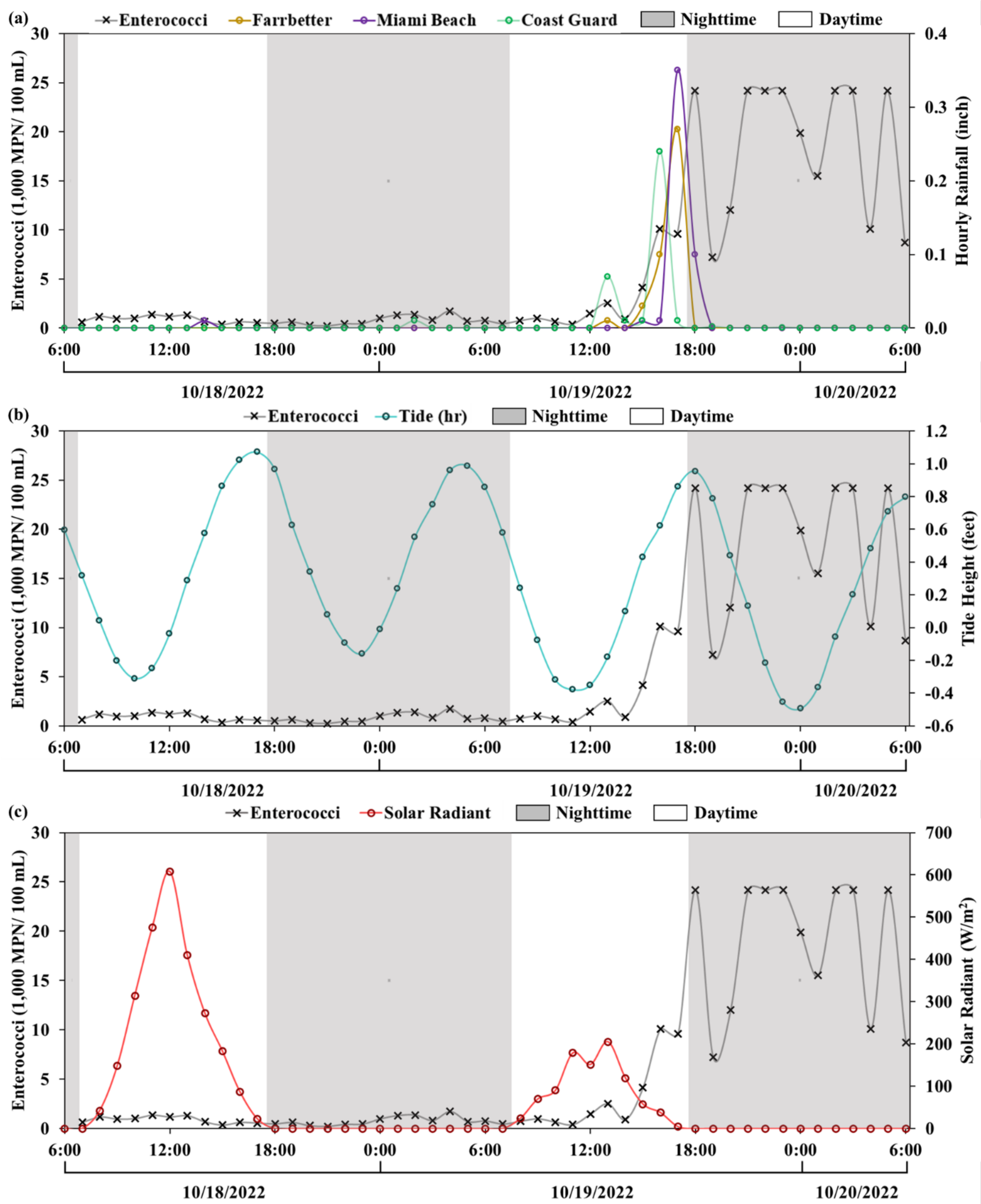


Figure V.10: Enterococci concentration at the KLW during the 48-hour sampling effort along with: Panel (a) hourly rainfall from three closest weather stations; Panel (b) tidal height; and Panel (c) solar radiation. White and grey background indicated daytime and nighttime during the sampling, respectively.

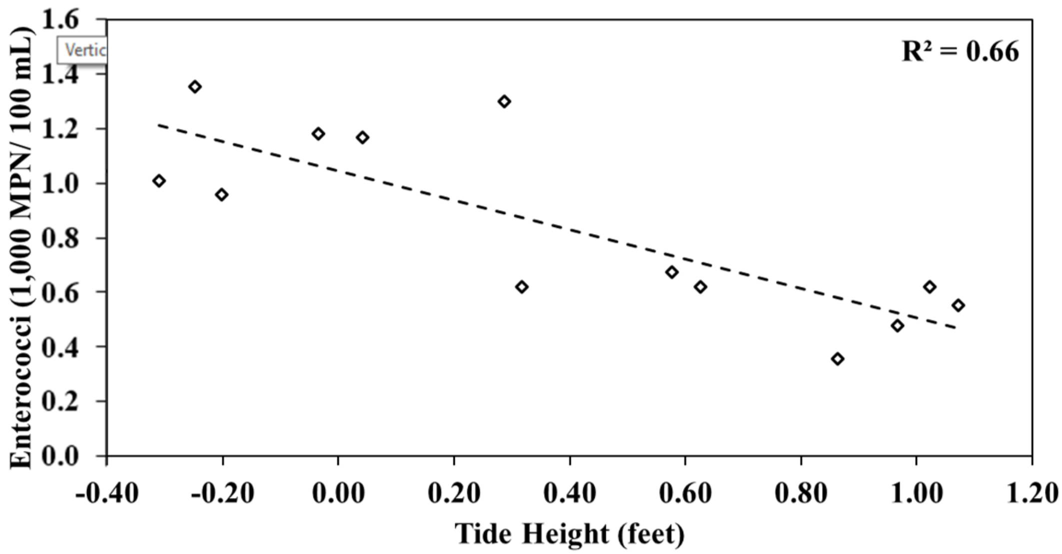


Figure V.11: Linear correlation between the concentration of enterococci and height of tide (water level) from 7:00 to 19:00 on Oct. 18, 2022.

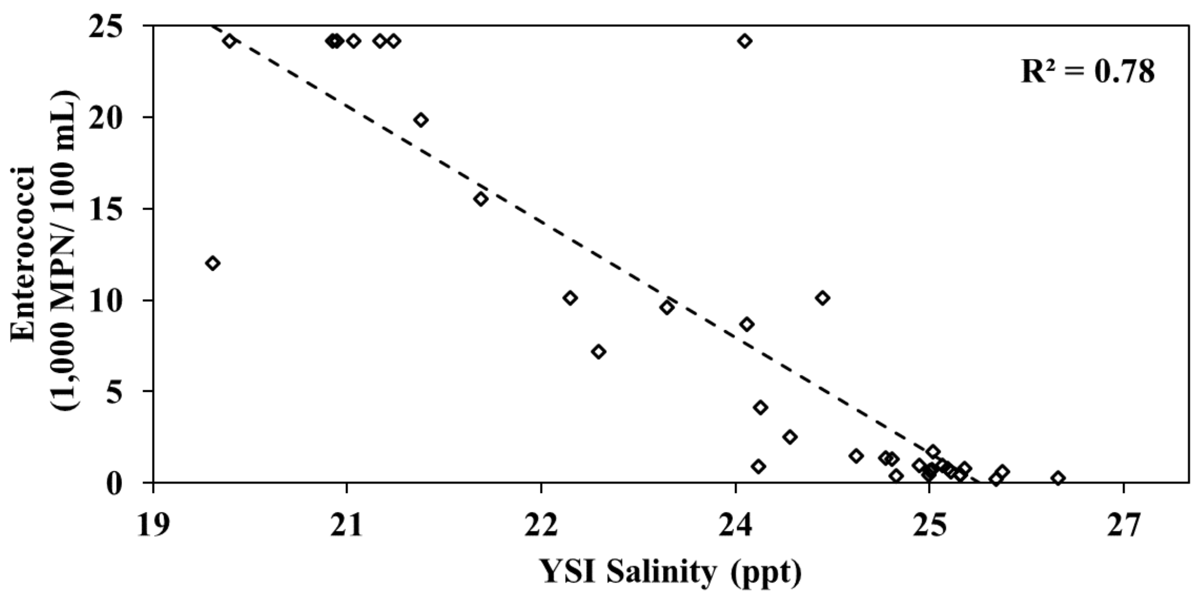


Figure V.12: Linear correlation between the concentration of enterococci and YSI salinity from 19:00 on Oct. 18, 2022, to 6:00 on Oct. 20, 2022.

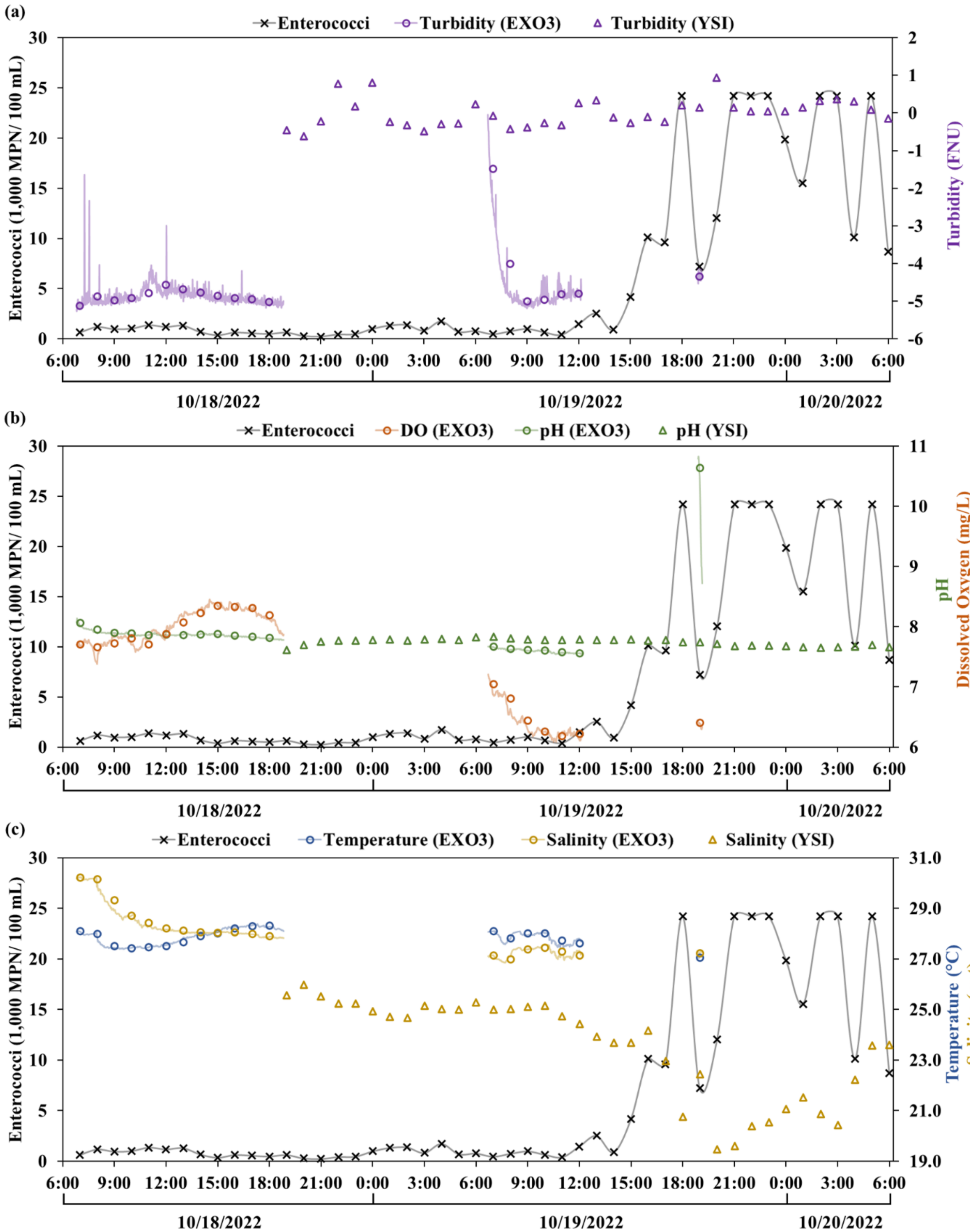


Figure V.13: Enterococci concentration at the KLW during the 48-hour sampling effort with related physical chemical parameters: Panel (a) includes turbidity; Panel (b) includes pH and dissolved oxygen; and Panel (c) includes temperature and salinity.

V.4 DEPTH SAMPLING WITHIN THE WATERWAY, CATCH BASINS, AND WELLS

Variations in enterococci levels and water quality with depth were evaluated: a) within the waterway, b) within catch basins, c) within vertical drainage wells, and d) within groundwater monitoring wells. In addition to collecting samples for enterococci measurements, a YSI probe was used in the field to measure temperature, pH, salinity, dissolved oxygen, and turbidity with depth. After the samples were process for enterococci, the YSI probe was used again in the laboratory to measure the same parameters from the samples that were collected.

For the waterway, samples were collected on two occasions, October 19 at 7 pm, and October 20 at 6:30 am. These were collected at depths of 0.5 inch (just below the water's surface using a sterile pipette) and from depths of 1, 2, 3, 4, and 5 feet from the kayak floating dock (GPS 25º 51' 31.19", 80º 07' 32.95"). Results show a strong gradient in enterococci with depth (Figure V.14). The highest levels (above 19,000 MPN/100 mL) were observed in the surface samples with decreases in enterococci concentrations with depth. The enterococci concentration of the deepest samples collected at 5 foot depth measured at 1200 to 1700 MPN/100 mL. This trend was observed consistently during both sampling efforts. In terms of water quality, temperature was observed to increase with depth with temperatures in the 23 to 25 ºC range at the surface and near and above 27 ºC at depth. Similarly, salinity was observed to increase from 16 to 20 ppt near the surface to near 27 ppt at depth. pH also increased with depth from 7.4 to 7.7.

The density of water is dependent upon its temperature and salinity. For example, for the October 19 sampling date, the density of the very top surface water is estimated at 1,010 kg/m^3 (temperature of 25.10 ºC and salinity of 16.82 ppt). The density of the water at depth on that day was 1017 kg/m^3 (temperature 27.60 ºC and salinity of 26.91 ppt). Essentially the fresher water containing the higher levels of enterococci is floating over the saltier water with lower levels of enterococci. Apparently, there is a density gradient vertically in the waterway that tends to maintain the waters with the higher enterococci levels near the surface. The fresh water that tends to float at the surface of the waterway tends to have high enterococci concentrations, lower salinity, lower temperature, and lower pH.

For the catch basins, sites included:

- Site W4 located at Collins and 73 Street (GPS 25º 51' 30.81"N, 80º 07' 15.62"W)
- Site W6 located at Dickens and 73 Street (GPS 25º 51' 29.98"N, 80º 07' 32.30"W)
- Site W8 located at 77 Street between Byron and Abbott (south side of road) (GPS 25º 51' 43.53"N, 80º 07' 24.40"W)

Two samples were collected from each site, one from the surface (top) and one at depth (bottom). Results for the catch basins (Figure V.15) showed that enterococci was generally lower at W4 (360 to 1930 MPN/100 mL), which had been a hot spot during earlier sampling rounds. Levels above detection limits (>24,200 MPN/100 mL) were observed for both samples collected at W8 and for the top sample collected at W6. W6 was the only site among the three that had a depth beyond 1.5 feet (7 ft) and the enterococci levels at depth were at 930 MPN/100 mL, lower than at the surface. Water quality at each site was distinct with the shallower sites (W4 and W8) showing more uniformity. The deepest site (W8) showed distinct trends in the vertical direction. At W8 there was evidence of a fresher water lens within the top foot characterized by lower salinity, lower pH, and higher temperatures.

For the vertical drainage wells, sites included:

- Site V1 located near the Kayak Launch (GPS 25º 51’ 29.99”N, 80º 07’ 32.23”W)
- Site V2 located at Ocean Terrace and 73 Street (GPS 25º 51’ 31.07”N, 80º 07’ 10.68”W)
- Site V3 located at Harding and 74 Street (GPS 25º 51’ 34.14”N, 80º 07’ 20.24”W)

Similar to the catch basins, two samples were collected from each site, one from the surface (top) and one at depth (bottom). Results for the vertical drainage wells (Figure V.16) indicate that V2 had the highest enterococci levels (>17,000 MPN/100 mL). This site also had very low salinities even at depth, and the lowest levels of dissolved oxygen and temperatures.

For the groundwater monitoring wells, sites included:

- Site G1 located at North Beach Bandshell (GPS 25.8583060, -80.1198783)
- Site G2 located at Parkview Park southwest corner (GPS 25.8572133, -80.1249013)

Unlike the other sites evaluated, enterococci levels at the groundwater wells (Figure V.17) were very low. Three of the four measurements were below the detection limit of 10 MPN/100 mL whereas one site measured at 20 MPN/100 mL. In general salinity increased with depth at the groundwater monitoring wells with a freshwater lens observed within the top 10 feet. Turbidity, dissolved oxygen, and pH decreased with depth. Overall, the enterococci levels at the groundwater monitoring wells were different than at the catch basins, vertical drainage wells, and waterway. The low levels of enterococci may be attributed to the deep screening depth of the wells (about 35 feet) and the fact that they do not receive direct stormwater discharges.

Correlations between enterococci and water quality parameters showed Pearson and Spearman significant correlations with pH (R>0.56) when the catch basin, vertical drainage wells, and groundwater monitoring wells were considered (W4, W6, W8, V1, V2, V3, G1, G2) (Table V.1). When only the catch basin and vertical well sites were considered Pearson correlations were significant for pH (R=0.63) and Pearson correlations were significant for salinity (r_s=-0.60) (Table V.2).

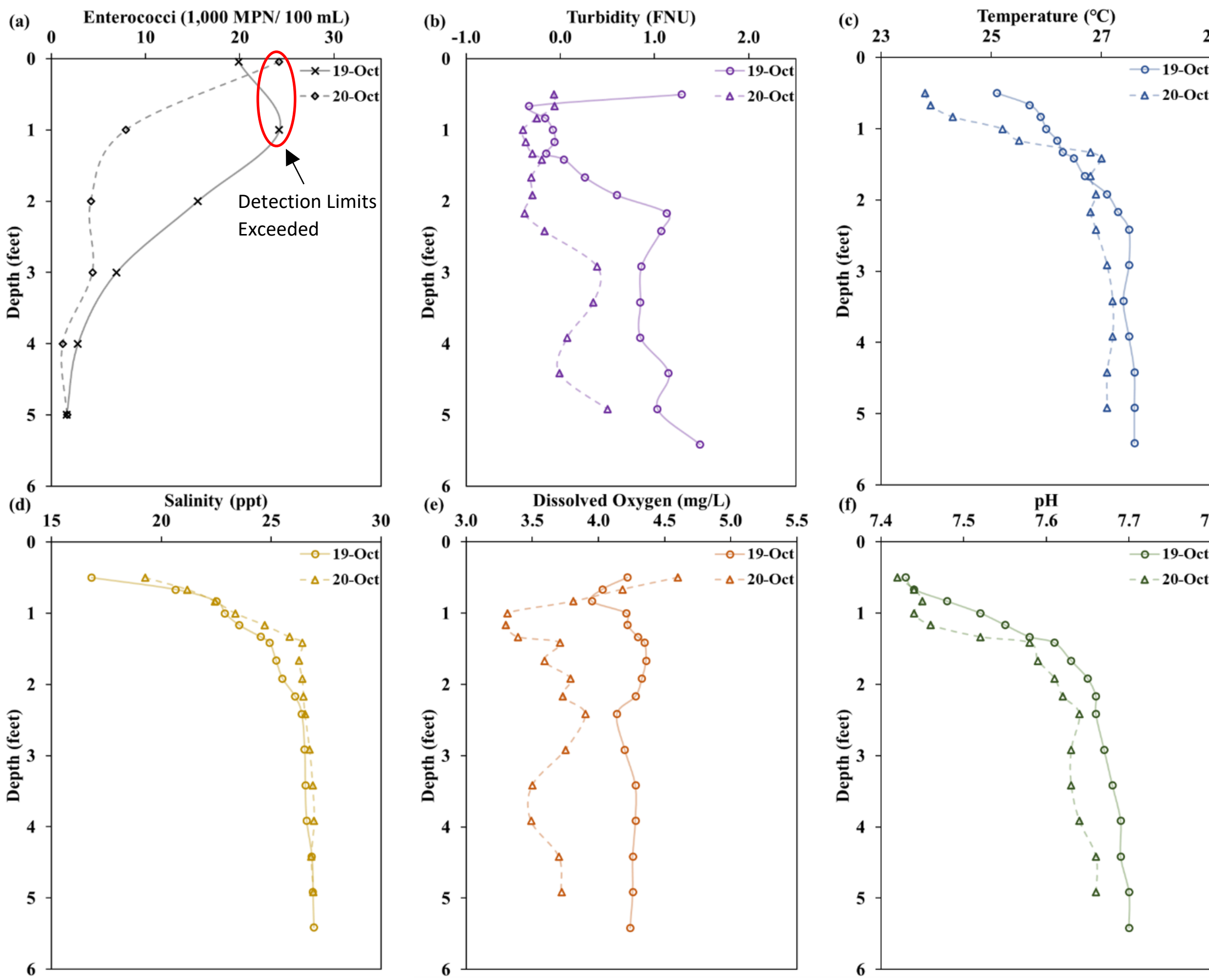


Figure V.14: Measurements versus depth at the KLW. Panel (a) enterococci concentrations; Panel (b) turbidity; Panel (c) temperature; Panel (d) salinity; Panel (e) dissolved oxygen; and Panel (f) pH.

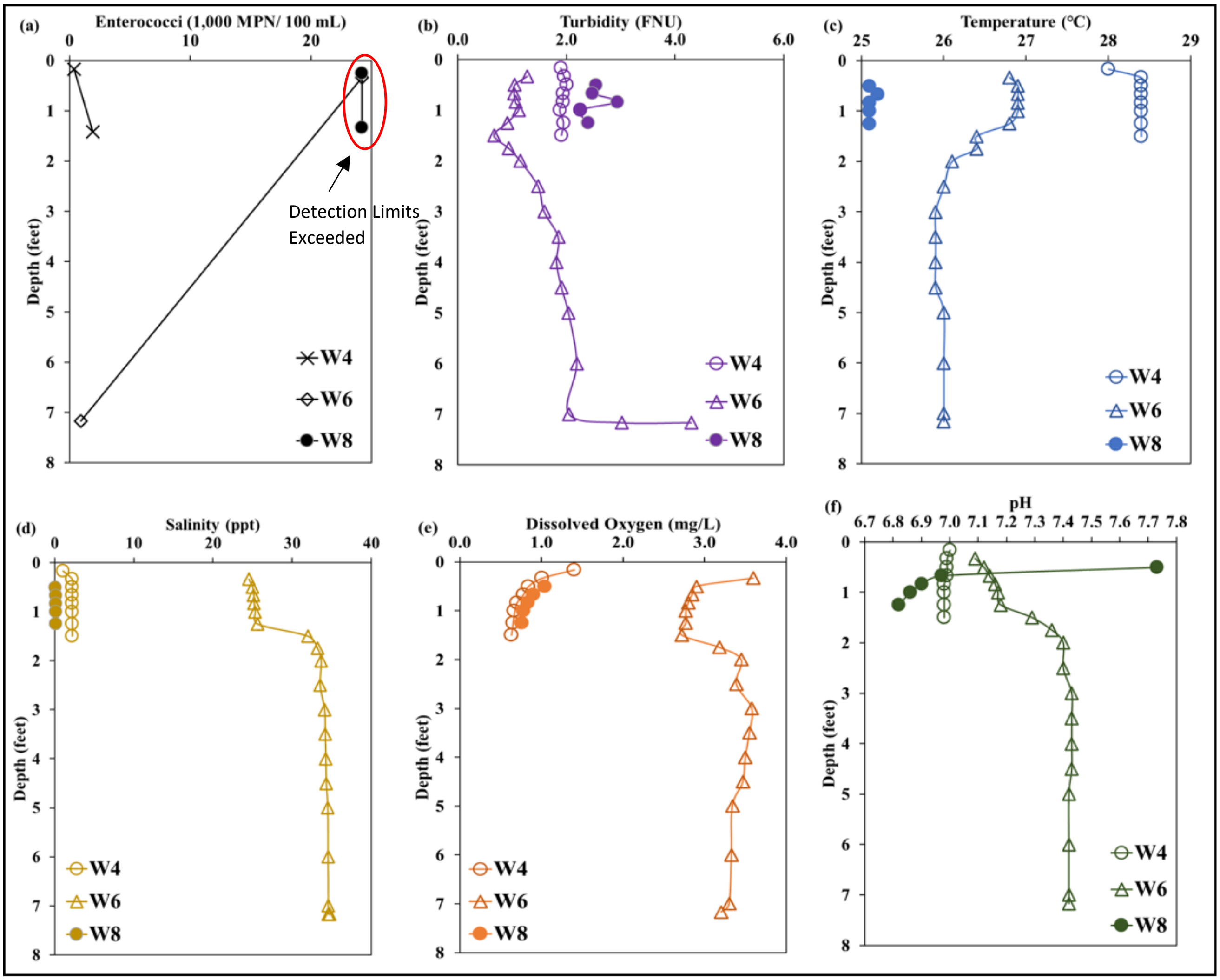


Figure V.15: Catch basin measurements (W4, W6 and W8) collected on November 14, 2022. Panel (a) enterococci concentration; Panel (b) turbidity; Panel (c) temperature; Panel (d) salinity; Panel (e) dissolved oxygen; and Panel (f) pH.

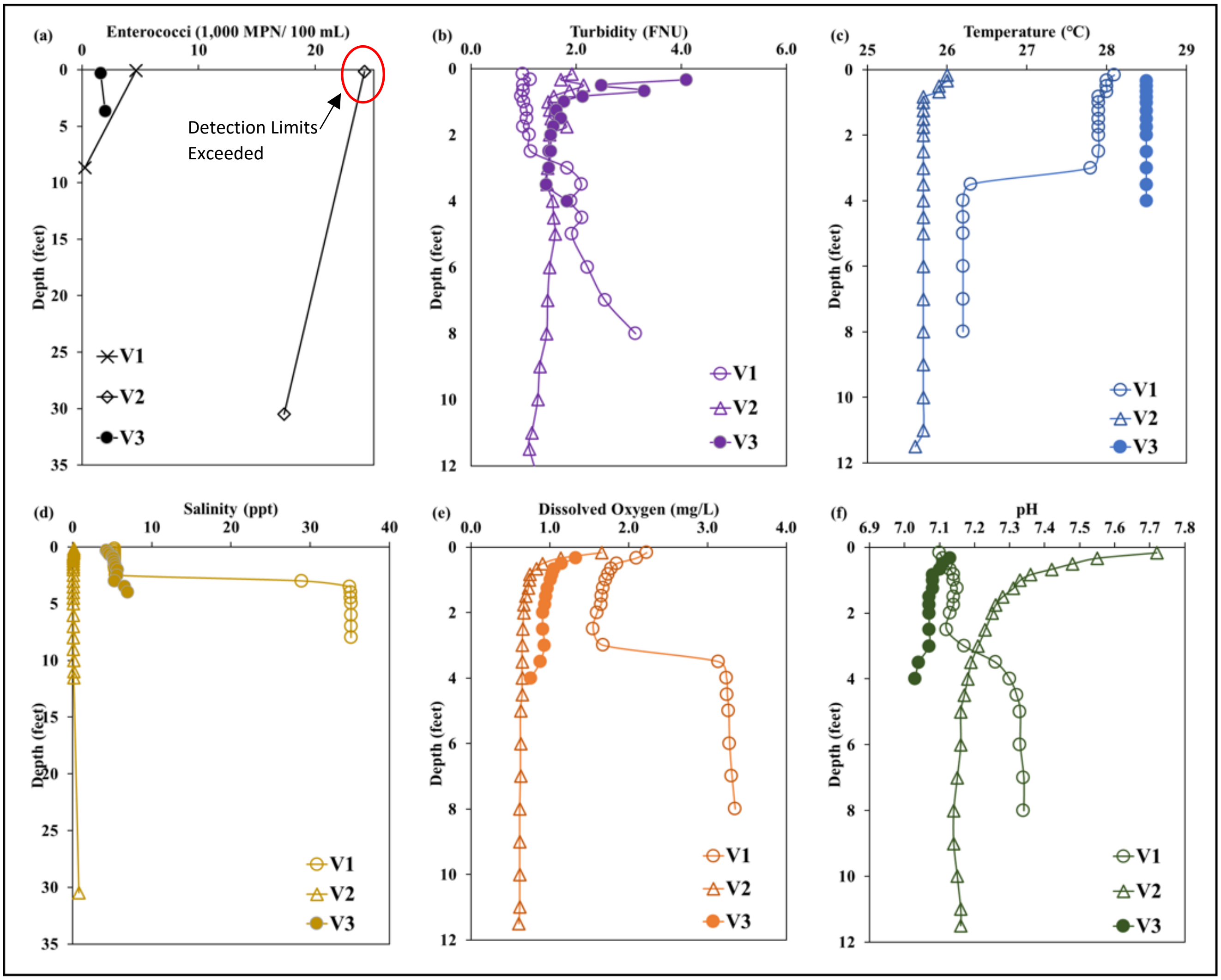


Figure V.16: Vertical drainage wells measurements (V1, V2 and V3) collected on November 14, 2022. Panel (a) enterococci concentration; Panel (b) turbidity; Panel (c) temperature; Panel (d) salinity; Panel (e) dissolved oxygen; and Panel (f) pH.

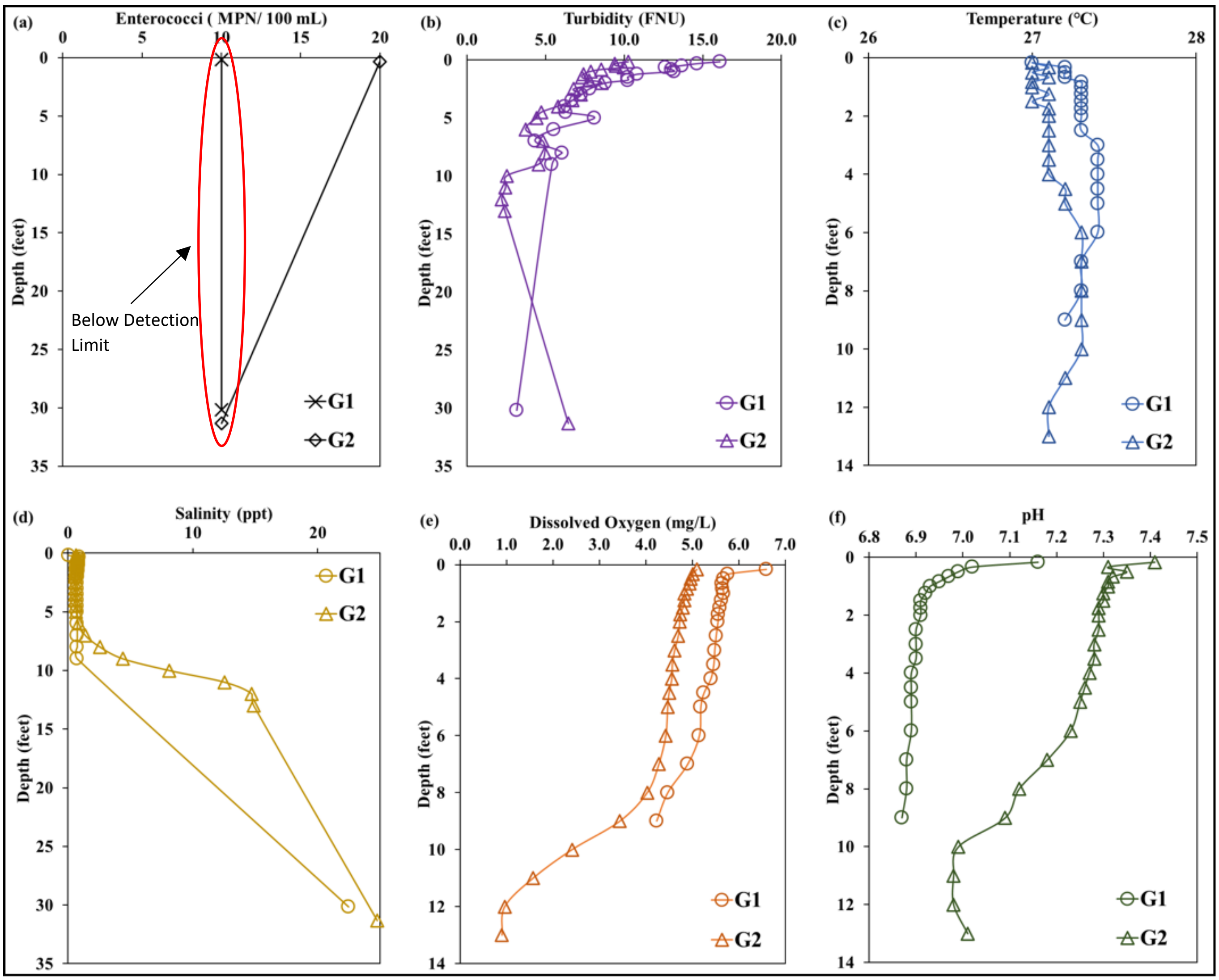


Figure V.17: Groundwater measurements at stations G1 (Bandshell) and G2 (Parkview Island) collected on November 14, 2022. Panel (a) enterococci concentration; Panel (b) turbidity; Panel (c) temperature; Panel (d) salinity; Panel (e) dissolved oxygen; and Panel (f) pH.

Table V.1: Correlation between the enterococci in samples collected for Miami beach from November 14, 2022 with other physical chemical parameters (field temperature (℃), dissolved oxygen (mg/L), salinity (ppt), field pH and turbidity (NTU)) based on both Pearson's and Spearman's analysis. Yellow indicates the significant correlation (p-value < 0.05). All sites for Table 4, including all top and bottom samples each site for groundwater and stormwater (W4, W6, W8, V1, V2, V3, G1,G2,).

		Field Temperature (℃)	Dissolved Oxygen (mg/L)	Salinity (ppt)	Field pH	Turbidity (NTU)
Pearson Correlation: Enterococci (1000 MPN/100 mL)	Correlation Coefficient (R)	0.038	-0.184	-0.275	.673**	-0.376
	p-value	0.889	0.496	0.303	0.004	0.151
Spearman correlation: Enterococci (1000 MPN/100 mL)	Correlation Coefficient (Rs)	-0.096	-0.349	-0.378	.569*	-0.373
	p-value	0.723	0.185	0.149	0.021	0.155
Sample size		16	16	16	16	16

Table V.2: Correlation between the enterococci in samples collected for Miami beach from November 14, 2022 with other physical chemical parameters (field temperature (℃), dissolved oxygen (mg/L), salinity (ppt), field pH and turbidity (NTU)) based on both Pearson's and Spearman's analysis. Yellow indicates the significant correlation (p-value < 0.05). All sites for groundwater and stormwater including all top and bottom samples each site for stormwater (W4, W6, W8, V1, V2, V3).

		Field Temperature (℃)	Dissolved Oxygen (mg/L)	Salinity (ppt)	Field pH	Turbidity (NTU)
Pearson Correlation: Enterococci (1000 MPN/100 mL)	Correlation Coefficient (R)	0.150	0.031	-0.300	.626*	-0.406
	p-value	0.643	0.923	0.343	0.029	0.190
Spearman correlation: Enterococci (1000 MPN/100 mL)	Correlation Coefficient (Rs)	0.219	-0.142	-.599*	0.249	-0.402
	p-value	0.493	0.659	0.040	0.435	0.195
Sample size		12	12	12	12	12

CHAPTER VI

OVERALL ASSESSMENT AND RECOMMENDATIONS

CHAPTER VI

OVERALL ASSESSMENT AND RECOMMENDATIONS

VI.1 SUMMARY

Results from this study indicate that the primary source of enterococci to the PVC is waste deposited on surfaces of the areas draining towards the waterway. When it rains, the rainwater washes surfaces (streets, roof tops, gutters) and in the process picks up FIB that are on these surfaces. This runoff containing the FIB is then carried to the PVC through the stormwater conveyance system. These sources and mode of conveyance to the waterway were identified through the historical analysis of the data which showed the strongest correlations between enterococci and 24-hour antecedent rainfall. This was confirmed from the 48-hour sampling effort at the PVC which showed a striking increase in enterococci within the waterway immediately after a rainfall event, with sustained high levels of enterococci for many hours after the rainfall event. Sources of enterococci to runoff include all waste that is found on the streets within the catchment (Parkview Island plus areas to the east to Collins Avenue) including waste from domestic (dogs) and feral (iguanas, racoons, and birds) animals plus waste from homeless populations that live within the catchment and do not have access to sanitation facilities. Trash was frequently found in the catch basins and flowing during storms from the storm conveyance system to the waterways. Plus uncovered trash dumpsters and leaking trash bins were observed to contribute towards the streets and thus ultimately washed into the storm conveyance infrastructure. Roof drains which flow towards the storm conveyance system can also serve as sources of enterococci. All these sources of enterococci are absorbed by the sediments which can be flushed into the storm conveyance system and ultimately impact the PVC.

Although FIB on street surfaces was found to be the primary source of enterococci, this does not discount the possibility of sanitary sewage leaks from contributing to groundwater contamination. There is evidence that groundwater is contaminated and that it enters the waterway during low tide, regardless of storm conditions. The groundwater influence is at a lower level compared to the extreme impacts observed during storms from surface runoff. The source of groundwater contamination can be surface runoff (FIB from the street surfaces) or from sanitary sewer leaks. Samples collected from within catch basins and vertical drainage wells show that the upper surface of the groundwater in areas that are designed to receive surface runoff are contaminated with high levels of enterococci, frequently exceeding levels of detection (>24,200 MPN/100 mL). In contrast groundwater in areas that are not impacted by surface runoff have low levels of enterococci (<20 MPN/100 mL). The extremely high levels of enterococci were usually found at the very top water surface of the catch basins, at the top of the vertical wells, and at the very top of the surface waters of the PVC. These extremely high levels of enterococci were fresher and thus float at the surface due to its lower density (because of its lower salinity). Deeper groundwater and water from the ocean that enters the PVC tends to be saltier and thus denser, denser than the freshwater that contains the extremely high levels of enterococci. As a result a freshwater lens of lower density water that contains very high levels of enterococci floats at the surface of the PVC. We believe this floating freshwater lens observed within the PVC is produced by the waters that are conveyed by the stormwater infrastructure.

However, both surface runoff and sanitary sewage are freshwaters. Because of the timing of the extreme enterococci levels, runoff contaminated by FIB found on surfaces within the catchment is considered to be the major source at this time. However, we cannot discount the possibility of wastewater contributions where leaks in the sanitary sewer system result in wastewater floating at the surface of the groundwater which can then enter the PVC through the stormwater conveyance system (See Figure VI.1 for conceptual diagram).

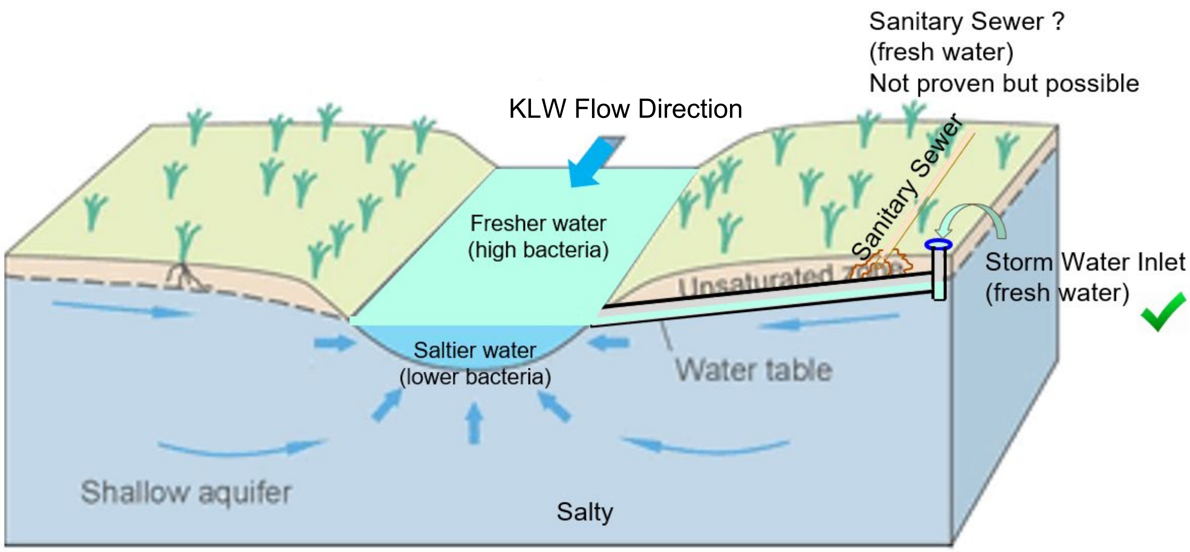


Figure VI.1: Conceptual illustration of stormwater conveyance system carrying freshwater with high levels of enterococci towards the PVC. High levels of enterococci were found in the catch basin waters and catch basin sediments. The stormwater conveyance system is designed to carry surface runoff from storm events towards the PVC. Although no sanitary sewage leaks were found as part of this study, the study cannot discount the possibility of sanitary sewage impacting the upper layers of the groundwater which are connected to the storm conveyance system.

VI.2 DETAILED RECOMMENDATIONS

The prior sections have identified the stormwater conveyance infrastructure as the conduit by which high enterococci levels enter the PVC. The stormwater conveyance infrastructure that discharges at the PVC, collects runoff from a large area (329,000 m^2) comprising a wide range of contributing factors (street sediments, roof run-off, animal feces, trash) which originate in the vicinity of the PVC, Park View Island, and Park View Island Park and in areas farther away. Other factors detailed in Chapter IV, such as animals and human settlements, potentially contribute to the elevated levels as well. Finally, tidally driven groundwater fluxes could potentially contribute to the high concentrations of enterococci.

Inputs of FIB in the stormwater conveyance system were identified in prior sections of this study which detail elevated FIB concentrations in top sediments, bottom sediments and in the catch basin water. Likewise, prior sections detail elevated FIB concentrations in shoreline sediments. These inputs are visible and the following sub-sections set forth recommendations aimed at reducing the impact from these inputs.

Other processes which may play a role in the elevated enterococci levels are not visible and are more difficult to address. We observed evidence of elevated FIB, in the hundreds to thousands MPN/100 mL, in the waterway during low tide not impacted by stormwater flows. This suggests that groundwater may be contaminated with FIB even during times between storm events. This could potentially explain why enterococci levels, remain elevated during the dry season, and on days with no antecedent rainfall. More work is needed to evaluate if tidally driven groundwater fluxes to the waterway are contributing (to a lesser degree than the outfalls) to the elevated enterococci levels. A confounding factor encouraging the accumulation of FIB is limited tidal flushing coupled with persistence and multiplication of enterococci in the PVC and surrounding sediment banks.

VI.2.a Reduce Inputs of FIB to Stormwater Conveyance System

The catchment contributing towards the PVC is highly urbanized with a significant amount of impervious area with disproportionately small areas available for natural treatment or attenuation of contaminants carried by runoff. Due to this situation, the catchment is unable to naturally cleanse itself and will rely on human intervention or actions to reduce levels of FIB in runoff that is carried towards the PVC. Below are recommendations for actions that can be taken to reduce FIB inputs to the waterway.

- Within the catchment, excessive sediments and debris were observed in the curbs and gutters that lead towards the underground stormwater conveyance system. These sediments and debris have very high levels of enterococci and should be removed. Studies should be conducted to benchmark street-sweeping frequency against other nearby communities and any increases in sweeping frequency should be tied to a budget requests and action to assure longer term sustainability. In response to this observation, the CMB has taken a two-pronged approach as a short-term solution. The CMB sanitation team has since increased the frequency of hand crew cleanings from once a week to twice a week. These crews clean debris from sidewalks, gutters, and the right of way. In addition to hand crew cleaning, the CMB has increased the frequency of mechanical street sweeping on Parkview Island, with considerations given to increase the frequency of street sweeping for catchment areas to the east.

- Trash was frequently found within the stormwater conveyance system. Trash is a source of FIB as it contains feces plus it contains nutrients needed for FIB to grow. Efforts should focus on increasing trash pickup and minimizing the amount of trash that enters the stormwater infrastructure. In response the CMB sanitation team has increased the cleaning of public litter cans to twice day from once a day (7 days a week).
- To further address trash, trash filters should be explored at curb and gutter inlets. If this is not feasible, trash racks with the stormwater system can also be considered. With the inclusion of filters and rack comes the possibility of increased flooding if the racks and filters become blocked. The feasibility of the installation of filters and racks should consider their potential contributions towards flooding. It is our understanding that the CMB has explored filters at catchbasins and their initial assessment indicate that such filters contribute towards flooding. A better alternative identified by the CMB is the inclusion of trash racks at pump stations since they can be more easily maintained to prevent blockage by debris. Another alternative is to install bar racks upstream of the outfalls, which would require further exploration.
- Leakage from trash bins should be eliminated by enforcing that trash dumpsters be covered and liquid leakage from the dumpsters be redirected away from storm drains. Redirection towards grassy areas that provide some treatment is one possibility. In addition, considerations should be given towards minimizing leaks from trash dumpsters by lining the trash bins. In high volume locations, additional trash receptacles may need to be added to handle the amount of trash generated. In response, the CMB has increased the frequency of cleaning public litter cans and has added rain domes to the public trash bins to minimize leakage from trash cans.
- Reduce animal sources by eliminating animal feeding stations and improving management of invasive wild animals such as iguanas, racoons, and non-native birds (e.g., roosters). In response to this observation, the animal feeding station at Parkview Park was removed (but it then returned). The CMB is committed to addressing this situation through increased vigilance of the area and by enforcing park hours of operation. The CMB is in the process of developing signs to discourage feeding wild animals.
- CMB has initiated a strong campaign to encourage dog owners to remove pet waste. The signage and availability of doggie bags and waste bins is prevalent at Parkview Island Park. Extending this signage throughout the catchment area including areas extending east through to Collins Avenue and Ocean Terrace would be beneficial.
- CMB public education efforts are commendable as evidenced by its easy-to-use web site (https://www.miamibeachfl.gov/engagementtoolbox/) and mobile apps used for communications purposes. Such efforts should continue and expand to further emphasize proper disposal and covering of trash and proper disposal of yard debris away from the waterway. Fertilizer use, especially in areas that drain towards the waterway, should be discouraged as these fertilizers provide nutrients which may allow bacteria to proliferate. Businesses in the area should continue to be informed of ways to reduce their potential to

pollute stormwater. In response, the CMB has initiated efforts to add signage about fertilizer use within the catchment including within the community garden area.

- Encourage further public participation in identifying and reporting potential sources of contamination to the waterway. During a sampling event, a community member informed the team of live-aboard boats in the area which could potentially serve as a source of bacteria if the waste from the boats is not disposed via pump out stations. Assuming that this is in fact the case within the PVC, a public education campaign for live aboard boat owners of the availability of pump out stations could help encourage proper disposal of waste. In response to this recommendation, the CMB is developing a public education campaign to engage the community champions and building managers in efforts to minimize sources of contamination to the waterway.
- Evaluate improve sanitation opportunities for homeless through either rehabilitation of the homeless (e.g., Lazarus project), relocation to places that have proper sanitation, or provision of sanitation facilities. The CMB should continue with its strong homeless outreach services. Outreach occurs two to three times per week at Parkview Park to offer services to homeless populations.
- Evaluate the stormwater conveyance system for its ability to treat the first flush of rainfall-runoff. Modern stormwater conveyance systems are required to treat the first inch or so of stormwater prior to discharge to a receiving water body. The stormwater conveyance system should be comprehensively evaluated for its ability to treat the first flush of contaminants. Common ways to treat the first flush involve letting the first portion of the rainfall-runoff enter a detention area where particulates settle. Other designs are based upon the use of grassy swales to retain the first flush. Given the lack of space for stormwater retention, consideration should be provided towards replacing impervious areas with pervious systems that allow for some runoff treatment.

  Along these lines, the CMB was awarded a $10M Florida Resilient Grant for the design of a Neighborhood Improvement Project (North Shore D and Towncenter Neighborhood Improvement Project) which includes a proposed stormwater conveyance system that will replace the existing stormwater pipe network from 69th street to the south to 73rd street to the north and from the PVC to the west to Collins Avenue to the east. The stormwater conveyance system is currently projected to include new catch basin structures, manhole structures, conveyance piping, injection wells (to treat the first flush), and up to two stormwater pump stations. The stormwater pump stations will be configured to include upstream water quality filtration and treatment to treat the first flush of contaminants in the form of bar racks and vortex water quality structures. Additionally, energy dissipation structures will be constructed downstream of the pump stations prior to discharge into adjacent canals to prevent damage to the existing plant life and canal bottom. The stormwater system will also be fitted with back flow prevention devices where needed to prevent backflow of tidal waters into the stormwater system. The scope of this project also includes the replacement of adjacent potable water and sanitary sewer conveyance, distribution, and transmission systems. The aerial potable water and sanitary sewer pipe crossings at the 71st street bridge over the PVC will be replaced with subaqueous crossings under the scope of this project. This project is currently in negotiation and is projected to start design early 2023.
- Additionally, the City has a Blue-Green Infrastructure Concept Plan that was adopted by City Commission. All Neighborhood Improvement Projects must consider proposing

blue-green stormwater infrastructure such as swales, bioswales, injection wells, permeable pavement, rainwater harvesting, tree canopy, etc. The North Shore D and Towncenter Neighborhood Improvement Project will incorporate blue-green infrastructure where feasible. Given the limited space for stormwater retention facilities to treat the first flush, more highly engineered systems should be considered inclusive of bar racks (for trash removal) and vortexers (for coarse sediment removal). If elevated levels of enterococci persist even with these measures, alternative methods to treat the runoff can include active disinfection process through UV disinfection. However, UV disinfection systems are expensive, require considerable maintenance, and are effective only for low turbidity waters. It is unclear whether the rainfall-runoff from the catchment area would be suitable for UV disinfection, but the possibility should be explored. In addition to the approaches described in the above bullet, one alternative that has been implemented by CMB is the inclusion of a vortexer called the Hydrodefender. This device adds 1 foot of head (causes water to back up by 1 foot) which may be excessive in areas prone to flooding. This can be addressed by placing the Hydrodefender downstream of pumps. This way the pumps can provide the 1 foot of pressure needed to minimize impacts on flooding.

- Focus on illicit connections and their removal. Illicit connections are those that are not composed of stormwater. They flow during dry weather due to connections with other sources of water and examples can include water from car washing, clothes washing, and inadvertent cross connections with sanitary sewage. The CMB is currently working with the legal authority (County/DERM) on illicit discharges from outfalls. A list of illicit connections is provided biannually to DERM and CMB continues to actively notify the environmental regulatory authorities. Connections prior to 1984 (when DERM established) have been grandfathered. It is our understanding that these grandfathered connections can only be legally addressed when the facility with the connection goes through its 40-year recertification. In the meantime, the CMB will continue to refer these connections to DERM, and will press the county for a resolution.

VI.2.b Reduce Impacts of Stormwater Discharge in the PVC

- The hydrology of the PVC should be explored further to better understand its water circulation during and after storms and during the cyclical ebb and flow of the tides. The waterways on the north end of the PVC (Biscayne Point) are anecdotally believed to limit flushing of water from the PVC to the north. The hydrodynamics of the area should be explored to better assess areas with restricted circulation.
- One option to improve circulation is dredging of the PVC, particularly at the north and south intersections with the Biscayne Point Waterway and the Main Waterway (Normandy N-S). Additionally, circulation along the northeast and southeast bends could be improved by dredging at depth angles that limit the deposition of sediments. The CMB is currently exploring potential dredging to improve water circulation. The CMB has identified funding ($500,000) for bathymetric and geotechnical surveys of the PVC.
- Removal of trash from the PVC waterway. If dredging is not an option, at least the removal of trash from the bottom and along the banks of the PVC should be explored. At

low tide, near the banks of the PVC trash was observable from the water's surface and the trash should be removed as it serves as a source of resistance to water flow.

- To limit the erosion of sediments and transport of trash by runoff along the shoreline we recommend that the shoreline be protected by increasing vegetation cover, inclusive of mangroves and other plant species which act as deterrents to the public accessing the PVC through any point other than the Kayak Launch pad. CMB is developing plans for an improved living shoreline that can provide additional treatment of direct runoff to the waterway while improving the area's ability to maintain a healthy ecosystem.

  To address this issue, the CMB acquired Cummins Cederberg to conduct a Nature Based Shoreline Assessment (CCI 2021) that selected the most viable locations for living shorelines within the sites of CMB-owned seawalls. Ten locations where identified, two of which are directly adjacent to the the PVC. Given the recommendations from the Cummins Cederberg report, the CMB has applied for \$11.5M (with \$1.5M match) in funding from the NOAA Transformational Habitat Restoration and Coastal Resilience Grant. The Cummins Cederberg study showed that the 2,460-foot shoreline along the PVC is densely packed with mangroves. The living shoreline project will remove invasive vegetation, repair and rehabilitate damaged seawalls, and mitigate coastline erosion. Awards for this grant should be announced early 2023 and the design would commence shortly thereafter.

VI.2.c Continue Searching for Sanitary Sewer Leaks

- The CMB has conducted considerable work towards identifying potential sources of FIB to the stormwater system impacting the PVC and issues have been corrected when found. Efforts include water sampling, sanitary sewer inspections, stormwater conveyance system inspections. Sampling has been conducted to evaluate source tracking markers (through Source Molecular) and via a contract to ESciences which included an evaluation of the catch basins. Work has also been extensive in evaluating potential cross connections between the sanitary sewer and storm conveyance system. Techniques used include evaluation of the proximity of the systems through GIS and evaluation of construction drawings, dye testing, camera testing, acoustical testing, and smoke testing. For example, the CMB has been conducting work towards reducing infiltration and inflow into the sanitary sewer system (Hazen 2022a). The focus has been on rehabilitating manholes, gravity mains, and laterals. Techniques utilized include night flow isolation, camera inspections, manhole inspections, and smoke testing. A study specific to Parkview island (Hazen 2022b) found multiple gravity sewer pipes in need of cleaning and repair. These pipes have been repaired by lining the sewers to reduce leaks. This study focused on gravity sewers within the public right-of-way and did not evaluate the integrity of sewer laterals on private property. Although the work has been extensive through CMB, additional efforts are recommended below.
- Focus on rehabilitating areas with excessive infiltration and inflow as identified through Hazen 2022a. The area south of 72 Street has been identified as one such area. Continue with plans to line sanitary sewer pipes known to have excessive infiltration. To address this, as mentioned above, the CMB was awarded a \$10M Florida Resilient Grant for the

design of a Neighborhood Improvement Project (North Shore D and Towncenter Neighborhood Improvement Project). The scope of this project also includes the replacement of potable water and sanitary sewer conveyance, distribution, and transmission systems from 69th street to the south to 73rd street to the north and from the PVC to the west to Collins Avenue to the east. The aerial potable water and sanitary sewer pipe crossings at the 71st street bridge over the PVC will be replaced with subaqueous crossings under the scope of this project. The infrastructure identified as critical due to age, infiltration, or other criteria will be addressed within this project scope. This project is currently in negotiation and is projected to start design early 2023.

- Evaluate new technologies to identify potential sanitary sewer leaks. It is our understanding that CMB is currently working with companies who can provide innovative leak detection services (e.g., Asterra which is currently in procurement).
- Characterize the groundwater to surface water pathway. Additional sampling of the upper surface of the groundwater is recommended to evaluate the extent of enterococci contamination. The direct push technology currently being implemented at other locations in Miami Beach should be explored for gathering shallow groundwater samples within the top centimeters of water table at various locations close to and away from the sanitary sewer system. Assessment of groundwater sample data should take into account the direction of groundwater flow.

VI.2.d Quantify Tidally Driven Groundwater Discharge

- In order to understand the interaction of tidal fluctuations in the PVC and nearshore groundwater zones we recommend activities to assess the groundwater flow direction and vertical and horizontal hydraulic gradients in order to develop a robust conceptual site model. Such information can be integrated into a model that would allow for a better assessment of contaminant (microbe) fate and transport.
- More accurately document the hydraulic gradient between the adjacent groundwater and surface water.
- To better characterize the hydrology, set up a surveying benchmark to provide a reference for water elevations at the Kayak Launch pad. An ideal benchmark can be a marker of known elevation on the piling that supports the Kayak Launch.
- Recommend groundwater sampling to evaluate potential sanitary sewer contamination. Direct push technology (Res 2022) can be potentially used to obtain samples which can be then analyzed for indicators of sanitary sewage. Indicators of sanitary sewage, in addition to the FIB (e.g., enterococci) can include chemical indicators of human waste such as caffeine, sucralose, and acetaminophen.

VI.2.e Develop a Long-Term Comprehensive Plan for Stormwater (and Sanitary) System Improvements

- It is our understanding that the CMB has initiated work with consultants for a design to improve stormwater management in the area by re-routing stormwater towards a centralized treatment system that would be designed to remove trash and coarse particulates using vortex separators. The plan, as described above (through the $10M Florida Resilient Grant), includes the integration of injection wells that would provide additional treatment for the first flush of stormwater. Such a system would be similar to the one designed for first street which receives stormwater from Alton Road and Washington Avenue. The treatment system elements include water quality wells, bar screens, vortex separator, and an energy dissipator structure. Assuming that this system is effective (by measuring water quality in and out of the system), this process should be considered for treating PVC stormwater.

- Benchmark plan against those developed for other communities. The Florida Keys have been successful at improving coastal water quality through a comprehensive 20-year plan which aimed at improving both sanitary and stormwater infrastructure. For example, the main goal of the 2001 stormwater master plan (CDM 2001) for Monroe County was water quality protection and improvement. This report provides an excellent summary of stormwater best management practices listing both structural (JEA 2020) and nonstructural stormwater controls. A hierarchy is provided in terms of actions that can be taken from low cost to higher cost.

  Although the CMB recognizes that a lot of work is to be done on long-term planning, it has initiated some work through its Stormwater Master Plan Update and Capital Improvement Plan that will identify critical needs to be addressed by the City over 10 years. The plan will take several criteria into consideration including stormwater flooding, tidal flooding, water quality issues, and resident complaints. The Stormwater Master Plan Update will be completed and presented to City Commission in November of 2023.

  The City acquired Hazen and Sawyer to complete Water and Sewer Master Plans (2019a,b) that have identified and prioritized critical projects that must be completed in a timely manner. Projects for the capital improvement plans were based on specific criteria: the sanitary sewer system was evaluated based on capacity, probability of failure (useful life), and consequence of failure (cost of repair, social/health impacts, and environmental impacts). The water and sewer capital improvements received $122M in funding to implement.

VI.3 SUMMARY OF RECOMMENDATIONS

Overall, a comprehensive plan should be developed for the PVC that address both short term and long term improvements in water quality. In the short term, efforts should focus on management of feral animals within the catchment, continued aggressive education programs to minimize dog fecal waste and other waste sources throughout the stormwater catchment, and facilitating improved sanitary conditions for the homeless. Minimizing trash on the streets, capturing trash prior to entering the waterway, reduction of seepage from trash bins, and increased street sweeping should also be considered. Efforts should be continuous for assessing the possibility of sewer leaks. Of interest would be to explore the extent of enterococci contamination at the surface of the groundwater by documenting groundwater gradients in the area coupled with sampling of the shallow groundwater. Such an approach may help to pinpoint areas with possible sanitary sewage leaks.

In the longer term, plans are recommended for upgrading the storm and sanitary infrastructure. For stormwater, efforts should focus on developing conveyance systems to treat the first flush and the possibility of providing a treatment system for trash removal, sediment reduction, and possibly disinfection. Plans should also be put into place to upgrade the sanitary sewer system given the age of the system and the possibility of leaks. The lack of circulation within the PVC also contributes to the elevated levels, and efforts should also focus on better understanding the hydrology of the PVC and improving water flow through the removal of debris/trash and possible dredging.

ACKNOWLEDGMENTS

This project was funded by the City of Miami Beach. We thank the City of Miami Beach Public Works teams who provided available data and logistical support during sampling efforts. We also thank the many interested parties who have shared their insights with us in efforts to better understand the cause of the elevated enterococci levels.

REFERENCES AND PERTINENT LITERATURE

Abdool-Ghany, A.A., Sahwell, P.J., Klaus, J., Gidley, M.L., Sinigalliano, C.D., Solo-Gabriele, H.M., 2022. Fecal indicator bacteria levels at a marine beach before, during, and after the COVID-19 shutdown period and associations with decomposing seaweed and human presence. Sci Total Environ. 2022 Dec 10;851(Pt 2):158349. doi: 10.1016/j.scitotenv.2022.158349. Epub 2022 Aug 27. PMID: 36041612.

Badgley, B.D., Thomas, F.I.M., Harwood. V.J., 2010. The effects of submerged aquatic vegetation on the persistence of environmental populations of Enterococcus spp. Environ. Microbiol. 42: 1271–1281

Biscayne Bay Task Force (BBTF), 2020. A Unified Approach to Recovery for a Healthy & Resilient Biscayne Bay, Biscayne Bay Task Force Report and Recommendations, June 2020.

Boehm, A.B., Shellenbarger, G.G., Paytan, A., 2004. Groundwater discharge: potential association with fecal indicator bacteria in the surf zone. Environmental Science & Technology, 38(13), pp.3558-3566.

Boehm, A.B., Fuhrman, J.A., Mrse, R.D., Grant, S.B., 2003. Tiered approach for identification of a human fecal pollution source at a recreational beach: case study at Avalon Bay, Catalina Island, California. Environmental Science & Technology, 37, 673–680.

Burnett, W.C., Aggarwal, P.K., Aureli, A., Bokuniewicz, H., Cable, J.E., Charette, M.A., Kontar, E., Krupa, S., Kulkarni, K.M., Loveless, A., Moore, W.S., Oberdorfer, J.A., Oliveira, J., Ozyurt, N., Povinec, P., Privitera, A.M.G., Rajar, R., Ramassur, R.T., Scholten, J., Stieglitz, T., Taniguchi, M., Turner, J.V., 2006. Quantifying submarine groundwater discharge in the coastal zone via multiple methods. Science of the Total Environment 367, 498–543.

Camp Dresser & McKee, Inc. (CDM), 2001. Monroe County Stormwater Management Master Plan.

Cummins Cederberg, Inc. (CCI), 2021. Nature Based Shorelin Assessment, City of Miami Beach. CCI Miami, FL.

Desmarais, T.R., Solo-Gabriele, H.M., and Palmer, C.J., 2002. Influence of Soil on Fecal Indicator Organisms in a Tidally Influenced Subtropical Environment. Applied and Environmental Microbiology, 68(3): 1165-1172. http://dx.doi.org/10.1128/AEM.68.3.1165-1172.2002

Enns, A.A., Vogel, L.J., Abdelzaher, A.M., Solo-Gabriele, H.M., Plano, L.R.W., Gidley, M.L., Phillips, M.C., Klaus, J.S., Piggot, A.M., Feng, Z., Reniers, A.J.H.M., Haus, B.K., Elmir, S.M., Zhang, Y., Jimenez, N.H., Abdel-Mottaleb, N., Schoor, M.E., Brown, A., Khan, S.Q., Dameron, A.S., Salazar, N.C., and Fleming, L.E., 2012. Spatial and Temporal Variation in Indicator Microbe Sampling is Influential in Beach Management Decisions, Water Research, 46: 2237-2246. http://dx.doi.org/10.1016/j.watres.2012.01.040 PMID: 22365370

Grant, S. B; Sanders, B. F; Boehm, A. B; Redman, J. A; Kim, J. H; Mrše, R. D; Chu, A. K; Gouldin, M; McGee, C. D; Gardiner, N. A; Jones, B. H; Svejkovsky, J; Leipzig, G. V; Brown, A. Generation of enterococci bacteria in a costal saltwater marsh and its impact on surf zone water quality. Environ. Sci. Technol. 35: 2407–2416

Hazen and Sawyer (Hazen), 2019a. City of Miami Beach Sewer System Master Plan.

Hazen and Sawyer (Hazen), 2019b. City of Miami Beach Water System Master Plan.

Hazen and Sawyer (Hazen), 2022a. City of Miami Beach Sanitary Sewer Evaluation Survey, Phase I, preliminary sewer system survey, sewer system analysis, and corrective action plan,

Hazen and Sawyer (Hazen), 2022b. Parkview island Gravity Sewer Video Review – Part 1, Technical Memorandum.

Izbicki, J.A., Swarzenski, P.W., Burton, C.A., Van De Werfhorst, L.C., Holden, P.A., Dubinsky, E.A., 2012. Source of fecal indicator bacteria to groundwater, Malibu Lagoon, and the nearshore ocean, Malibu, California, USA. Annals of Environmental Science, 6, 35–86.

Jonah Ventures (JV), 2022. Report prepared for bwtf@miami.surfrider.org, BatchID = JVB1755. info@jonahventures.com.

Jones Edmunds & Associates (JEA), 2020. Updated Manual of Stormwater Management Practices, Prepared for Monroe County Department of Planning & Environmental Resources, Key Largo, FL

Kelly, E. A., Feng, Z., Gidley, M. L., Sinigalliano, C. D., Kumar, N., Donahue, A. G., Reniers, A. J. H. M., and Solo-Gabriele, H. M., 2018. Effect of Beach Management Policies on Recreational Water Quality. Journal of Environmental Management, 212: 266-277. doi:10.1016/j.jenvman.2018.02.012 PMID: 29448181

Miami New Times (MNT), 2018. Horrible Biscayne Bay Pollution Worsened by 800-Gallon Sewage Leak. Story written by Jessica Lipscomb and published on November 27, 2018. https://www.miaminewtimes.com/news/biscayne-bay-polluted-by-800-gallons-of-poop-from-miami-beach-city-says-10926772

Pace Analytical, 2020. Report of Laboratory Analysis, Pace Project Number: 35593582. Submitted by Brad Smith to Elizabeth Wheaton on December 7, 2020.

Pace Analytical, 2021. Report of Laboratory Analysis, Pace Project Number: 35600623. Submitted by Brad Smith to Elizabeth Wheaton on January 11, 2021.

Park View Island Sustainable Association (PV ISA), 2021. Miami Beach's Dirty Little Secret – The Park View Island Canal. Story written by Valentina Palm and published on March 17, 2021, credit: FIU/South Florida Media Network.
https://www.parkviewisland.com/miamibeachsdirtylittlesecret

RES Florida Consulting (RES), 2022. Proposal for Sewer and Groundwater Sampling for the West Avenue Sewer Extension Permit Miami Beach, Miami Dade County, Florida. E Science

Roca, M. A., Brown, R., Solo-Gabriele, H. M. 2019. Fecal indicator bacteria levels at beaches in the Florida Keys after Hurricane Irma. Marine Pollution Bulletin, 138, 266-273. http://doi.org/10.1016/j.marpolbul.2018.09.036

Russell, T. L., Sassoubre, L. M., Wang, D., Masuda, S., Chen, H., Soetjipto, C., Hassaballah, A., Boehm, A. B., 2013. A coupled modeling and molecular biology approach to microbial source tracking at Cowell Beach, Santa Cruz, CA, USA. Environmental Science & Technology, 47, 10231–10239.

Skinner, J.F., Kappeler, J., Guzman, J. 2010. Regrowth of Enterococci & Fecal Coliform in Biofilm. Stormwater. Published on July 1, 2010. Available at: https://www.stormh2o.com/bmps/article/13005530/regrowth-of-enterococci-fecal-coliform-in-biofilm

Solo-Gabriele, H., Wolfert, M, Desmarais, T., and Palmer, C., 2000. Sources of E.coli to a Sub-Tropical Coastal Environment. Applied and Environmental Microbiology, 66(1): 230-237. http://dx.doi.org/10.1128/AEM.66.1.230-237.2000

Swarzenski, P.W., Burnett, B., Reich, C., Dulaiova, H., Peterson, R., Meunier, J., 2004, Novel geophysical and geochemical techniques used to study submarine groundwater discharge in Biscayne Bay, Florida: U.S. Geological Survey Fact Sheet 2004–3117, 4., https://doi.org/10.3133/fs20043117.

Whitman, R.L., Shively, D.A., Pawlik, H, Nevers, M.B., Byappanahalli, M.N. 2003. Occurrence of Escherichia coli and enterococci in Cladophora (Chlorophyta) in nearshore water and beach sand of Lake Michigan. Appl. Environ. Microbiol. 69: 4714–4719

WLRN Miami, South Florida 91.3 FM, 2020. Miami Beach Lost Half Its Sewage Capacity. Age Was Partly to Blame. Story written by Jenny Staletovich and published on March 10, 2020. https://www.wlrn.org/environment/2020-03-10/miami-beach-lost-half-its-sewage-capacity-age-was-partly-to-blame

Wright, M.E., Solo-Gabriele, H.M., Elmir, S., Fleming, L.E. 2009. Microbial load from animal feces at a recreational beach, Marine Pollution Bulletin, 58(11): 1649-1656. http://dx.doi.org/10.1016/j.marpolbul.2009.07.003 PMID:19664785

APPENDICES

APPENDIX A

INITIAL REVIEW OF PRIOR DATA

APPENDIX A
INITIAL REVIEW OF PRIOR DATA

Review of Data Provided during April 2022

Access to a shared drive was facilitated through the City of Miami Beach (Mariana Evora). This drive included a set of folders. A brief assessment of what was observed in each folder (each subheading is a folder name) is provided below. Recommendations for additional information is provided.

Groundwater Wells

A map of groundwater wells is provided in the folder called, "Groundwater Wells." The nearest groundwater well is "Parkview Park (PVP)". Physical Chemical data is provided for this site (GPS 25.85723264751922 -80.12488156557083, located on Google Earth to be on the southwest corner of the baseball fields, See Figure A1 below). Results show salinities in the 25 to 29 psu range. Recommendation: As part of a preliminary reconnaissance – collect a sample of this groundwater to determine whether it is impacted fecal indicator bacteria.

Figure A.1: Location of groundwater well for which data were included in the shared folder. Background image from Google Earth.

Heat Maps (data not verified)

The heat maps clearly indicate that the storm drain system has extremely high levels of fecal indicator bacteria on frequent occasions. Results between enterococci and fecal coliform are consistent with one another. Below in Table A1 is a very quick review of the data. Recommendation: As part of a preliminary reconnaissance – in addition to collecting a sample from the Kayak Launch, collect a sample of surface water at the outlet of each of the outfalls at low tide, at the point where it enters the canal with the Kayak Launch. Record date and time and tie back to tidal stage.

Table A.1: High level summary of heat maps of storm drainage system.

Sampling Date	**Enterococci (estimated units of counts per 100 mL)**	**Fecal coliform (estimated units of counts per 100 mL)**
June 9, 2020	hundreds	double digits to hundreds
June 18, 2020	hundreds to tens of thousands	double digits to hundreds
June 30, 2020	double digits to hundreds	double digits to hundreds
July 7, 2020	hundreds to above detection limits*	
July 31, 2020	hundreds to thousands	hundreds
August 26, 2020	above detection limits	above detection limits
August 27, 2020	hundreds to above detection limits	hundreds to above detection limits
September 3, 2020	hundreds to above detection limits	hundreds to above detection limits

*Detection limits >24196 counts per 100 mL.

Photos

The photos include views of the canal and sewage pipe that runs under the bridge at 857 Michael Street (Figure A2). Recommendation: As part of a preliminary reconnaissance – collect a sample from the sediments under the mangroves (at low tide) to determine whether it is impacted fecal indicator bacteria.

Figure A.2: Photo of canal where kayak launch is located and photo of pipe under bridge at 857 Michael Street.

Sanitary and Storm Sewer Maps in the Area

The maps emphasize that there is a very intricate network of storm and sanitary sewers with the possibility of cross-over between the two. In another folder the locations of the cross-overs have been identified. There is a very large sewer main connection from the mainland passing at 72nd Street equivalent (Figure A.3). To complement the comprehensive map in the file called "North Beach Sewer Overview,pdf", images "4A", "4B", and "5" provide additional details. These detailed maps provide locations of storm drain outfalls at the canal where the Kayak Launch is located. Recommendation: Add sample collection IDs to these maps. In the folder called "Water Quality Results" there are data corresponding to locations called OT-2, OT-4, OT-7, US-1A, US-1B, etc… which do not have GPS coordinates nor location descriptions. The results at these locations show very high (enterococci >24,196 MPN/100 mL). Efforts are needed to determine when these sites are contributing to the Kayak Launch location. But first we need to know where these sites are located relative to the storm drain system.

Figure A.3: Storm and sanitary sewer network emphasizing the location of large sewer main that crosses the Parkview Canal at 72nd Street. Image from file "North Beach Sewer Overview.pdf", City of Miami Beach.

Siphon Inspection

The siphon is located at Park View Island and 75th Street and is defined by manhole A and B. On June 9th, 2020 the Public Works Operations Division conducted a dye test on a siphon that crosses the canal. From this test there were no visible traces of dye in the waterway and the dye was seen coming out the siphon's downstream manhole. On July 20, 2020 the siphon was inspected by camera with no visible signs of leakage. Recommendation: Location of siphon needs to be clearly identified on the maps. GPS coordinates for manhole A and B are needed.

Smoke Testing

Many recommendations were made by the consultant to minimize leaks from a December 2020 inspection of the sanitary sewer system. Recommendation: Document whether these recommendations have been addressed and conduct another smoke test to follow up.

Test Results

This folder includes results from two sets of studies: one from Microbial Source Tracking and another from a bay-wide water quality study.

Microbial Source Tracking

Microbial Source Tracking found evidence of dog inputs in a groundwater well and at the Kayak Launch on October 13, 2020, and again at the Kayak Launch on November 5, 2020. There was no strong evidence of human sources. These results are very interesting in that it would point the source away from sanitary (human) sewage towards runoff. Of interest would be to test the water in the storm drains for human and dog markers, especially when values are above detection limits for fecal indicators.

Bay Wide Water Quality Results

The "Test Results" folder also contains physical chemical, nutrient, and fecal indicator bacteria data for the sites shown in the following map (Figure A.4) (Pace Analytical 2020, 2021) for the months of November 2020 and December 2020. The site within the PVC is site 69. The next two closest sites are sites 70 and 79. When reviewing the data in these reports only data for site 79 was available. This site is located to the southwest of the PVC within a larger more open section of the bay (Figure A.4). From the summary of results (Table A.2) the fecal indicator bacteria levels were high on November 2020 which is surprising given that this area is much more highly flushed. Of particular interest is that for this site the dissolved oxygen level was very low (0.96 mg/L) and the ammonia was high (1.3 mg/L) which suggests a source of biochemical oxygen demand (possibly wastewater).

Of note is that since the provision of the November and December 2020 reports, the consolidated data was provided by the CMB for the PVC (site 69). This consolidated data for the entire period of record (monthly from April 2019 to October 2022, summarized in Table B.1 in the appendix) was evaluated for correlations in Section II.3.a of the report (page 26). Results showed in section II.2.a that antecedent rainfall was the primary predictor of enterococci levels (more rain more higher enterococci). Salinity and specific conductivity also contributed towards correlations with enterococci (higher salinity or specific conductivity corresponded to lower enterococci). No significant correlations were observed with nutrients, nitrogen and phosphorus.

Table A.2: Summary of water quality results from site 79, site closest to the PVC.

Site 79 Water Quality Parameter	**November 2020 (page 25 of report)**	**December 2020 (page 27 of report)**
Enterococci, MPN/100 mL	490	10
Fecal Coliform, CFU/100 mL	1750	175
Salinity, ppt	7	7
Dissolved Oxygen, mg/L	0.96	0.24
Nitrogen as Ammonia, mg/L	1.3	1.3
Nitrogen as Total Kjeldahl Nitrogen, mg/L	1.5	1.5
Nitrogen as NO_2 plus NO_3, mg/L	0.033 U	0.033 U
Phosphorous as P total, mg/L	0.19	0.099

In addition, when evaluating data at other sites farther to the south, results show that dissolved oxygen levels are more in line with what would be expected from waters not impacted by wastewater (>5 mg/L). Of note errors were found in the dissolved oxygen levels in the November 2020 report for site 38 (p. 14, quoted at 640 mg/L) and for site 80 (p. 21, quoted at 599 mg/L). It is possible that a decimal place was missed. Recommendation: Go back to consultant to get dissolved oxygen levels corrected. In future measurements, include measures of physical chemical parameters including dissolved oxygen. Dissolved oxygen can be analyzed almost instantly in the field and can be used to track back towards a source of biochemical oxygen demand. There is the possibility that it can be used to guide where to collect samples for fecal indicator bacteria.

Water Quality Results

The folder called water quality results contains many files. The files include comparative fecal indicator bacteria results between two laboratories (Pace Analytical and Florida Spectrum). The results between the laboratories are consistent. The data in the file called "2021 Kayak Launch Results.xlsx" shows that enterococci values tend to be higher than the fecal coliform values (whereas in sewage the opposite is observed). The results also show that levels of fecal indicator bacteria are chronically elevated. The folder also has several files that have results for enterococci and fecal coliform at sites called "OT-1, OT-4, OT-7, US-1A, US-1B, US-4A, etc.." showing that the fecal indicator bacteria at these sites are chronically elevated with days showing extraordinarily high values above 24,196 MPN/100 mL. Recommendations: The locations of these sites (OT-1, etc..) need to be provided and mapped relative to the Kayak Launch. The sources of fecal indicator bacteria to these sites need to be evaluated further. Also, the impact of discharges from these sites should also be evaluated further.

Additional files in this folder are data analysis files. For example, "Copy of WQ Sampling Results…" is the data used to plot the heat maps in the "heat maps folder". The folder contains a file called "Kayak Launch Water Quality Evaluation" that evaluates multiple samples collected during the same day but spread out in intervals of three hours. These results are interesting but do not show a distinct trend except that some sites have higher levels than others. Recommendation: Plot the data in "Copy of WQ Sampling Results …" in time series and using box and whisker plots. In the time series include measures of tide to see if there is a pattern in time. The box and whisker plots can be used to evaluate whether the values at one location are different than at another location.

Interestingly this folder also has results from Microbial Source Tracking and in the file called 'Source & FIB.xlsx." From this file there is also evidence, especially for the data in column AF corresponding to September 24, 2021, that birds may be contributing towards the elevated fecal indicator bacteria levels.

Figure A.4: Map showing locations of sampling sites for Bay-Wide Water Quality Study. From City of Miami Beach in folder called "Test Results" and file called "Current WQ Sampling Locations.pdf".

Main Folder

In the main folder there were two files, one called "Timeline" and another called "Water Quality Evaluation_Project Status….pdf". The timeline was very helpful. Of particular attention was the summary of the fecal indicator data collected during March 2020 (Table A.3). These results show that the fecal indicator bacteria are highly variable. The extremely elevated levels were observed March 6, and then 6 days later on March 12, then another 5 days later on March 17. Tides shift over time and perhaps this periodicity may be associated with a tidal height coinciding with a specific tide level. Recommendation: Plot bacteria data super-imposed on a plot that illustrates tidal height. Start with a time series plot and proceed to X-Y plots.

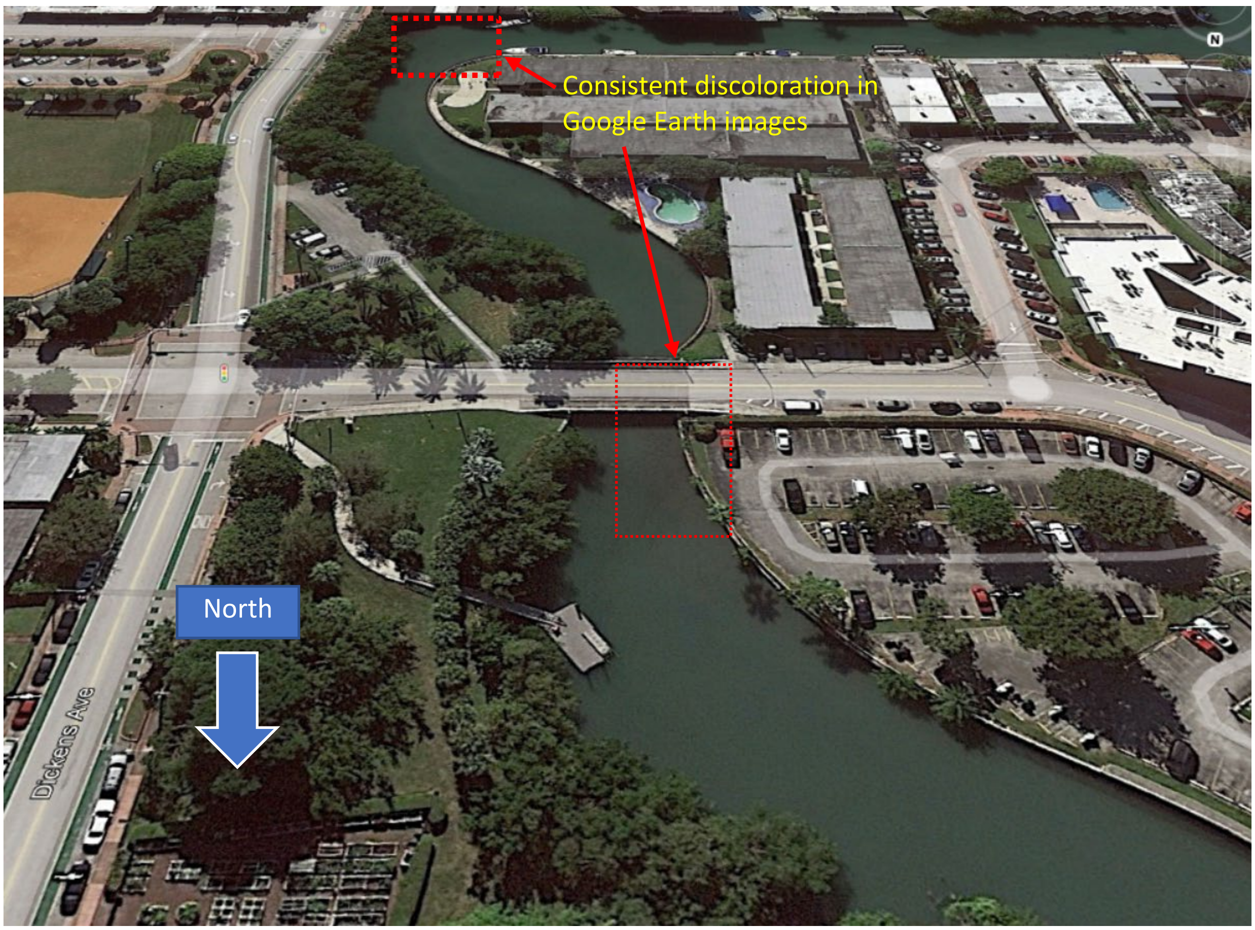
Table A.3: Fecal indicator bacteria results from daily sampling at the Kayak Launch. Data from "Timeline.docx" file located in the main folder.

Collection location	Collection Date	Parameter	Results
Kayak Launch	March 6th, 2020	Fecal Coliform MPN	TNTC
Kayak Launch	March 6th, 2020	Enterococci MPN	>24196
Kayak Launch	March 7th, 2020	Fecal Coliform MPN	2000
Kayak Launch	March 7th, 2020	Enterococci MPN	146
Kayak Launch	March 8th, 2020	Fecal Coliform MPN	818
Kayak Launch	March 8th, 2020	Enterococci MPN	355
Kayak Launch	March 9th, 2020	Fecal Coliform MPN	280
Kayak Launch	March 9th, 2020	Enterococci MPN	98
Kayak Launch	March 10th, 2020	Fecal Coliform MPN	32
Kayak Launch	March 10th, 2020	Enterococci MPN	146
Kayak Launch	March 11th, 2020	Fecal Coliform MPN	53
Kayak Launch	March 11th, 2020	Enterococci MPN	134
Kayak Launch	March 12th, 2020	Fecal Coliform MPN	TNTC
Kayak Launch	March 12th, 2020	Enterococci MPN	1500
Kayak Launch	March 13th, 2020	Fecal Coliform MPN	320
Kayak Launch	March 13th, 2020	Enterococci MPN	408
Kayak Launch	March 16th, 2020	Fecal Coliform MPN	120
Kayak Launch	March 16th, 2020	Enterococci MPN	279
Kayak Launch	March 17th, 2020	Fecal Coliform MPN	TNTC
Kayak Launch	March 17th, 2020	Enterococci MPN	624
Kayak Launch	March 18th, 2020	Fecal Coliform MPN	204
Kayak Launch	March 18th, 2020	Enterococci MPN	275
Kayak Launch	March 19th, 2020	Fecal Coliform MPN	106
Kayak Launch	March 19th, 2020	Enterococci MPN	272

In addition to evaluating the data in the shared folders, Google Earth maps were reviewed over time.

Visual Inspection of Google Earth Maps

Review of Google Earth maps of the Kayak Launch area shows that the launch is first seen in May of 2017. Images since 2013 show a consistent darker colored water to the west of the launch, north of 73 street. The clearest recent image is dated January 2021 (Figure A5). Recommendation: Conduct a detailed sampling program collecting samples along perpendicular transects. See Phase 1c and Figure 2 in the main report.



APPENDIX B

HISTORICAL DATA

APPENDIX B

HISTORICAL DATA

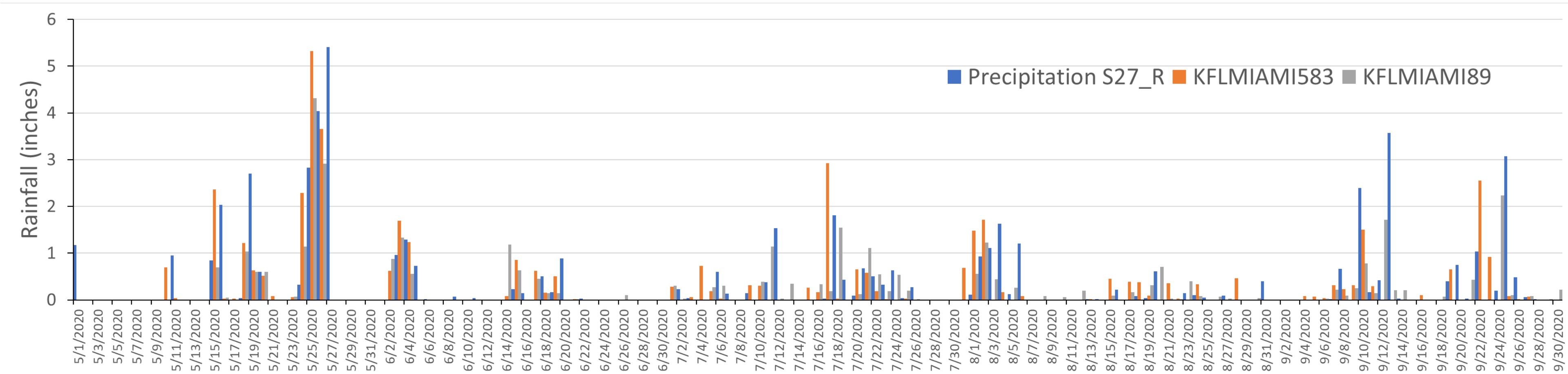


Figure B.1: Time series plot of rainfall data from three different gauges and the dates of the elevated FIB levels as shown in the heat maps. Rainfall data were collected from three different stations located throughout Miami Beach (Surfside (KFLMIAMI583), Miami Beach (KFLMIAMI89), and S27_R). Sampling dates from the heat maps were 6/6/2020, 6/9/2020, 6/18/2020, 6/30/2020, 7/7/2020, 7/31/2020, 8/26/2020, 8/27/2020, 9/3/2020.

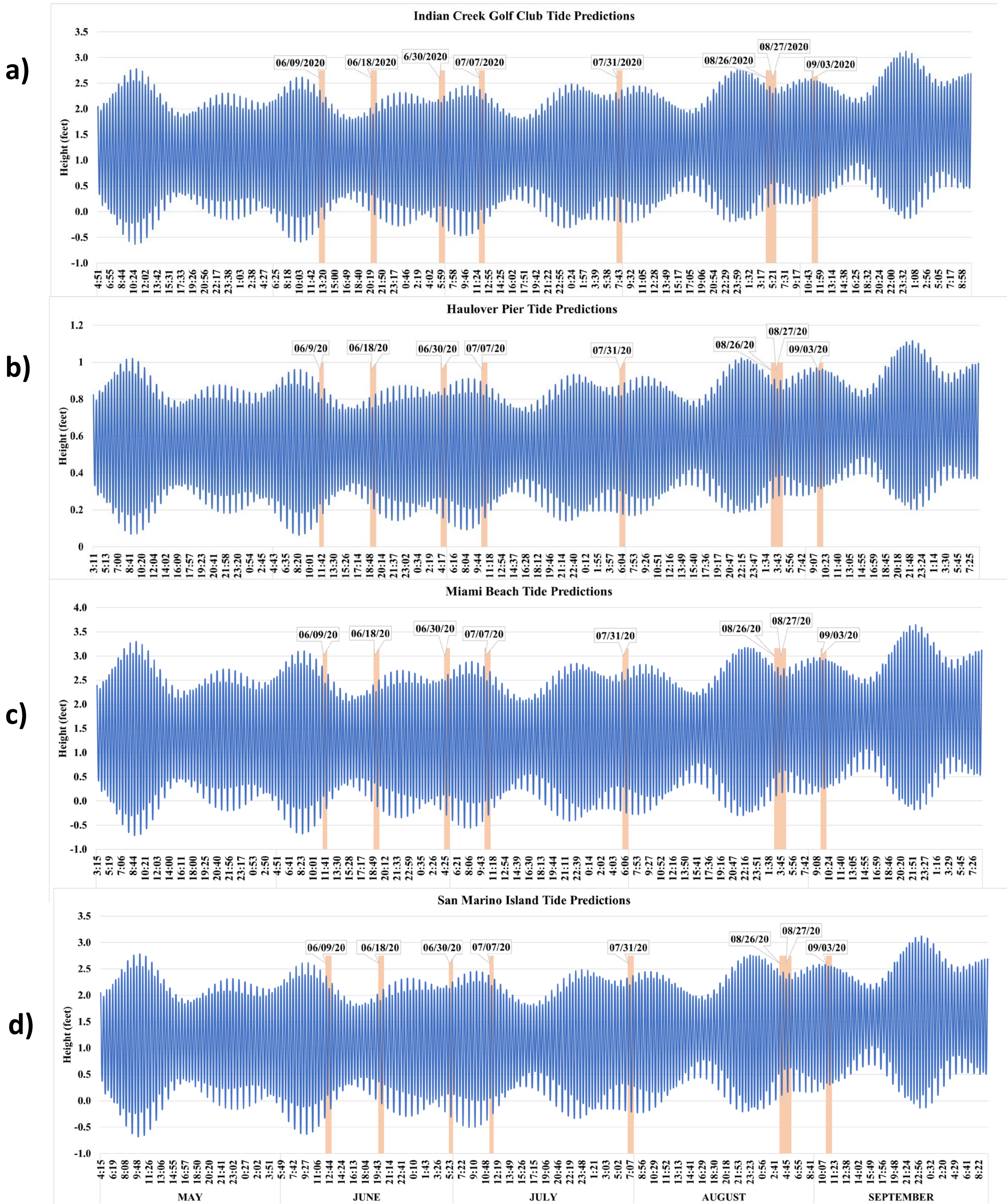


Figure B.2: Time series plots for four NOAA tidal station for the months of May to September. Stations correspond to: Indian Creek (panel a), Haulover (panel b), Miami Beach (panel c), and San Marino Island (panel d). The dates from the heat maps are highlighted in orange.

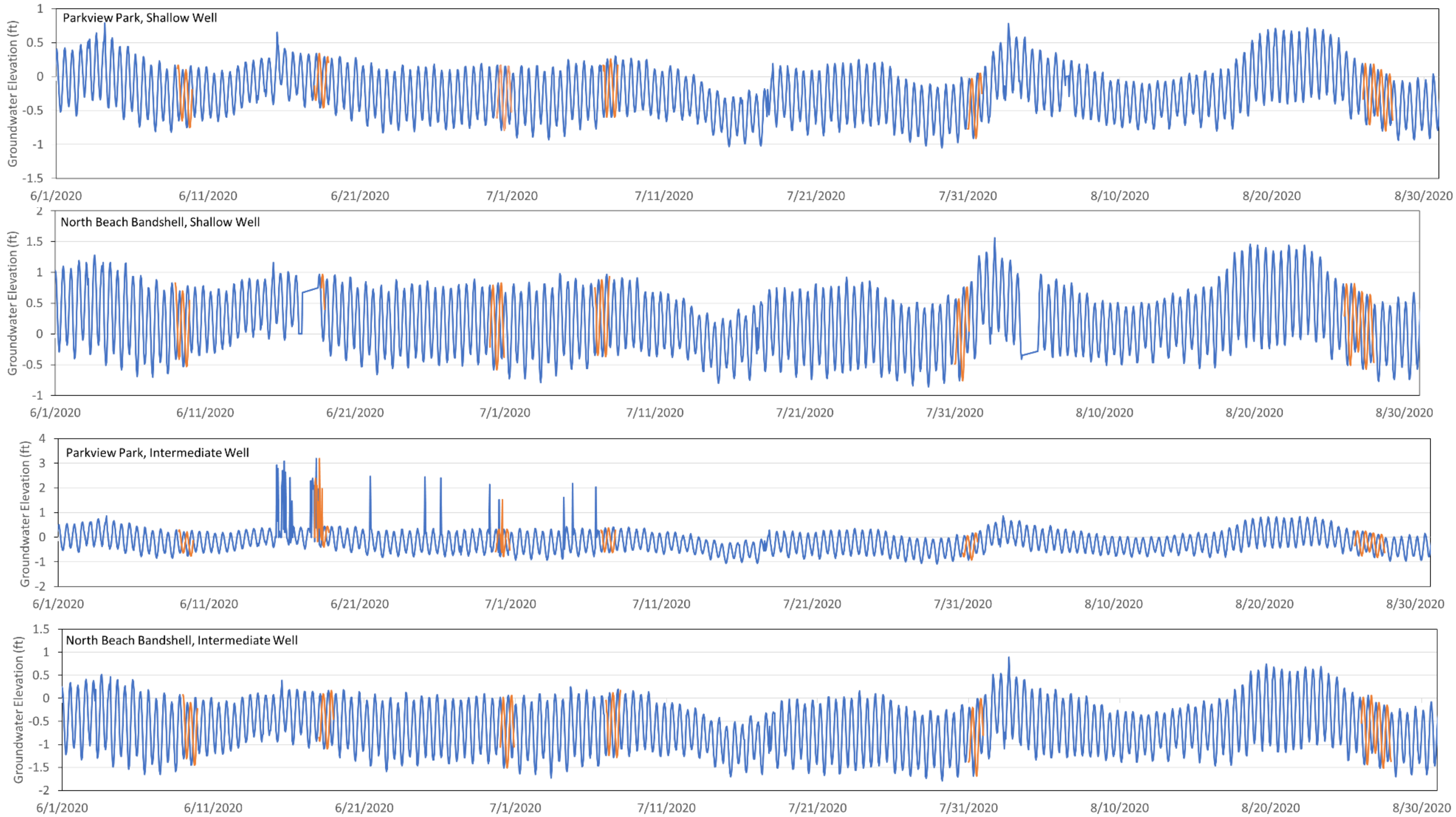


Figure B.3: Time series plot of groundwater data from the Parkview Park and North Beach Bandshell groundwater monitoring well. Dates of heat maps are highlighted for the months June, July and August 2020. The horizontal straight lines correspond to missing data.

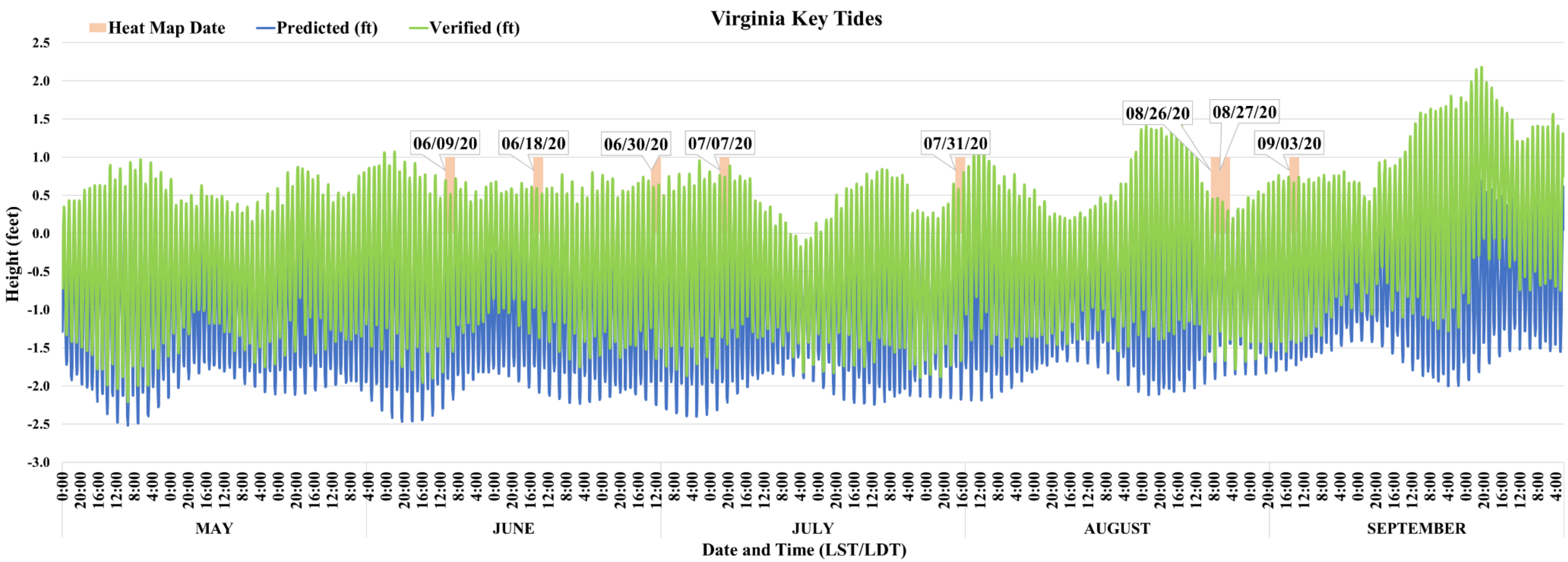


Figure B.4: Virginia Key predicted and verified tides, dates from Heat Maps with FIB peaks

Table B.1: Concentration of enterococci in samples collected monthly from Miami Beach from 4/17/2019 to 10/17/2022 with other physical chemical parameters record including water level, tide cycle, total nitrogen, total phosphorus, salinity, fecal coliforms, field specific conductance, field temperature, pH, dissolved oxygen, turbidity and cumulative precipitation (6-hour, 12-hour, 24-hour, 48-hour)

Date	Time	Enterococci (MPN/100 mL)	Total Nitrogen, Kjeldahl (mg/L)	Total Phosphorus (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	Field Specific Conductance (umhos/cm)	Field Temp (°C)	Field pH	Dissolved Oxygen (mg/L)	Turbidity (NTU)	6-hour Precipitation (in)	12-hour Precipitation (in)	24-hour Precipitation (in)	48-hour Precipitation (in)	Water Level (ft)	Tide Cycle[1]
4/17/201	11:10AM	640	0.09	0.04	28.2	125	51835	27.7	7.95	5.20	7.50	0.00	0.00	0.00	0.01	-0.95	ebb
5/20/201	11:03AM	63	0.21	0.04	27.4	25	57304	29.9	8.02	5.36	N/A	0.00	0.00	0.00	0.00	0.38	ebb (high
6/27/201	10:56AM	169	0.34	0.04	20.8	400	42	30.8	8.03	6.95	1.28	0.00	0.00	0.00	0.00	-1.45	ebb (low
7/29/201	11:51AM	1660	0.27	0.03	15.8	402	39339	30.9	8.04	7.05	2.66	0.00	0.00	0.00	0.01	-1.09	ebb (low
8/13/201	11:58AM	934	0.09	0.04	15.8	92	39940	32.8	7.99	5.21	3.29	0.01	0.01	1.27	2.12	-0.49	ebb
9/25/201	11:10AM	285	0.31	0.04	25.2	157	48284	29.4	7.85	4.63	2.92	0.00	0.00	0.00	0.00	-0.7	ebb (low
10/16/20	9:26AM	359	0.33	0.06	20.1	430	40327	28.0	8.10	4.60	3.60	0.00	0.00	0.00	0.00	1.19	flow (high
11/19/20	11:10AM	108	0.18	0.032	15.8	20	32796	23.7	7.72	7.32	3.78	0.00	0.00	0.00	0.00	1.02	flow
12/23/20	10:19AM	24196	0.23	0.059	10.8	600	15542	22.3	7.89	5.79	9.43	0.01	6.01	6.01	6.01	-0.55	ebb
1/15/202	11:15 AM	73	0.290	0.040	17.9	270	27936	24.9	7.84	5.10	6.24	0.00	0.00	0.00	0.03	-0.080	flow (high
2/3/2020	11:22 AM	679	0.350	0.042	22.6	112	44060	21.9	7.77	6.19	2.53	0.00	0.00	0.00	0.37	-0.960	flow
3/17/202	10:36 AM	331	0.330	0.055	36	260	54600	25.0	8.11	4.87	16.40	0.00	0.00	0.00	0.00	-1.490	ebb (low
4/14/202	10:06 AM	142	0.290	0.044	36.3	92	54081	28.0	8.06	6.67	6.44	0.00	0.00	0.00	0.00	-1.720	flow (low
5/26/202	10:23 AM	13000	0.370	0.040	14.4	50	21901	26.1	7.78	5.85	4.36	0.03	0.18	3.88	6.30	0.320	flow (high
6/23/202	10:38 AM	20	0.290	0.027	27.2	50	39714	30.2	8.25	6.63	1.92	0.00	0.00	0.01	0.04	0.380	flow (high
7/29/202	10:40 AM	283	0.270	0.034	28	340	43117	31.2	8.30	5.26	4.66	0.00	0.00	0.00	0.00	-1.850	ebb (low
8/14/202	11:15 AM	437	0.254	0.056	29.3	570	47804	31.9	7.95	3.88	4.46	0.00	0.01	0.02	0.04	-1.270	ebb (low
9/22/202	10:55 AM	1010	0.390	0.034	30.2	1320	45718	29.9	7.98	4.23	8.14	0.00	0.00	0.78	1.07	1.030	flow
10/13/20	10:47 AM	19900	0.280	0.028	23.7	600	38537	29.5	7.88	4.30	1.33	0.00	0.00	0.40	0.44	-0.650	ebb
11/18/20	10:37 AM	1560	0.290	0.033	26	142	38528	26.3	8.02	5.74	2.80	0.00	0.00	0.00	0.00	1.250	flow (high
12/21/20	11:15 AM	959	0.310	0.055	31.8	96	44107	23.1	8.15	5.69	1.60	0.00	0.00	0.00	0.00	-0.220	flow
1/28/202	10:48AM	1090	0.370	0.041	32.9	110	49340	23.6	7.87	5.97	2.07	0.00	0.00	0.00	0.00	-0.460	Ebb
3/29/202	11:05AM	161	0.360	0.031	36.8	145	51203	27.4	8.21	4.30	9.58	0.00	0.00	0.00	0.00	0.510	Ebb (high
4/30/202	11:02AM	173	0.310	0.023	36.2	20	50654	28.1	8.29	5.72	3.18	0.00	0.00	0.00	0.00	0.080	flow (high
5/25/202	10:55AM	323	0.170	0.029	36.3	114	55252	N/A	8.15	6.81	6.38	0.00	0.00	0.00	0.00	-0.590	ebb
6/16/202	10:41AM	6590	N/A	N/A	28.5	600	40968	28.0	7.97	3.45	3.80	0.00	0.07	1.27	1.54	-0.840	flow
7/14/202	11:00AM	487	0.320	0.030	28.8	300	40390	26.3	7.97	3.71	6.00	0.00	0.06	0.73	5.46	-0.380	flow (high
8/16/202	10:47AM	1510	N/A	N/A	26.3	2100	45122	29.6	8.02	4.48	5.49	0.00	0.00	0.04	0.41	-1.570	flow (low
9/22/202	11:50AM	17300	0.270	0.022	26.2	N/A	43811	30.2	7.93	5.55	8.56	0.91	0.91	1.14	1.14	0.750	Ebb (high
10/28/20	10:29AM	521	0.340	0.007	29.6	670	44383	27.9	7.81	3.80	2.09	0.00	0.00	0.00	0.00	-0.670	flow (low
11/15/20	10:45AM	2140	0.460	0.011	29.4	770	45049	24.2	7.05	7.10	4.11	0.00	0.00	0.00	0.00	-0.670	ebb (low
12/22/20	10:26AM	1660	0.300	0.011	33.1	440	48650	21.4	7.72	5.01	7.80	0.00	0.00	0.09	0.13	0.750	flow (high

[1] Verified water levels and tide cycle, from NOAA Virginia Key station, at the same date and time the enterococci samples were collected.

Table B.1(Continued): Concentration of enterococci in samples collected monthly from Miami Beach from 4/17/2019 to 10/17/2022 with other physical chemical parameters record including water level, tide cycle, total nitrogen, total phosphorus, salinity, fecal coliforms, field specific conductance, field temperature, pH, dissolved oxygen, turbidity and cumulative precipitation (6-hour, 12-hour, 24-hour, 48-hour)

Date	Time	Enterococci (MPN/100 mL)	Total Nitrogen, Kjeldahl (mg/L)	Total Phosphorus (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	Field Specific Conductance (umhos/cm)	Field Temperature (°C)	Field pH	Dissolved Oxygen (mg/L)	Turbidity (NTU)	6-hour Precipitation (in)	12-hour Precipitation (in)	24-hour Precipitation (in)	48-hour Precipitation (in)	Water Level (ft)	Tide Cycle[1]
1/18/2022	11:30AM	211	N/A	0.010	32.4	58	48410	20.6	8.06	6.33	2.07	0.00	0.00	0.00	0.24	-0.270	ebb
2/25/2022	10:28AM	1310	0.250	0.010	34	38	51157	25.5	7.92	3.25	4.49	0.00	0.00	0.00	0.00	-1.410	flow (low tide)
3/28/2022	10:48AM	187	N/A	N/A	35.4	92	29107	23.5	7.87	5.54	2.24	0.00	0.00	0.00	0.00	-1.010	ebb
4/25/2022	10:17AM	504	N/A	0.009	38.1	114	53469	26.5	8.14	6.54	5.76	0.00	0.00	0.00	0.00	-1.170	ebb (low tide)
5/19/2022	10:37AM	173	0.300	0.007	37.2	147	55355	29.4	8.14	4.59	5.37	0.00	0.00	0.00	0.00	0.400	flow (high tide)
6/14/2022	10:38AM	399	0.280	0.008	25	430	35575	30.8	8.05	2.71	0.21	0.01	0.01	0.01	0.01	0.230	ebb (low tide)
7/18/2022	10:53AM	30	0.370	0.013	34.6	20	46892	29.2	10.48	3.13	8.25	0.00	0.00	0.00	0.10	-0.400	flow
8/11/2022	10:54AM	41	0.410	0.011	35.5	62	48079	27.9	7.26	5.38	19.80	0.00	0.00	0.00	0.00	-0.260	ebb
09/15/2022	11:09	909	0.410	0.018	31.1	28	48077	26.7	7.59	5.78	6.17	0.00	0.00	1.67	2.03	0.580	high
10/17/2022	10:48 AM	278	0.420	0.011	29.9	184	47485	28.5	8.17	7.43	4.19	0.00	0.00	0.01	0.14	-0.040	low tide

[1] Verified water levels and tide cycle, from NOAA Virginia Key station, at the same date and time the enterococci samples were collected.

Table B.2: Enterococci, height of tide, and cumulative rainfall of each sampling location based on time series.

Date	Time	Enterococci (MPN/100mL)	Tide (ft)	1h Rainfall (in)	6h Rainfall (in)	12h Rainfall (in)	24h Rainfall (in)	48h Rainfall (in)
OT1								
19-Apr	9:38	1,010	-0.37	0.00	0.00	0.00	0.00	0.00
19-Apr	12:31	627	-0.97	0.00	0.00	0.00	0.00	0.00
19-Apr	15:30	292	-0.61	0.00	0.00	0.00	0.00	0.00
20-Apr	7:43	24,196	0.09	0.01	0.60	1.63	1.65	1.65
20-Apr	10:43	8,160	-0.58	0.00	0.02	1.63	1.65	1.65
20-Apr	13:31	14,100	-0.94	0.00	0.00	0.60	1.65	1.65
20-Apr	16:31	3,260	-0.29	0.00	0.00	0.02	1.65	1.65
21-Apr	8:50	8,660	0.34	0.00	0.30	0.30	0.30	1.95
21-Apr	11:49	24,196	-0.45	0.00	0.04	0.30	0.30	1.95
21-Apr	14:42	15,500	-1.09	0.00	0.00	0.30	0.30	1.95
21-Apr	17:46	3,880	-0.39	0.00	0.00	0.05	0.30	1.95
OT4								
19-Apr	9:32	471	-0.35	0.00	0.00	0.00	0.00	0.00
19-Apr	12:26	988	-0.96	0.00	0.00	0.00	0.00	0.00
19-Apr	15:25	1,400	-0.63	0.00	0.00	0.00	0.00	0.00
20-Apr	7:38	24,200	0.10	0.00	0.59	1.63	1.65	1.65
20-Apr	10:36	12,000	-0.55	0.00	0.02	1.63	1.65	1.65
20-Apr	13:26	17,300	-0.95	0.00	0.00	0.60	1.65	1.65
20-Apr	16:25	11,200	-0.31	0.00	0.00	0.03	1.65	1.65
21-Apr	8:45	24,196	0.35	0.00	0.30	0.30	0.30	1.95
21-Apr	11:44	24,196	-0.42	0.00	0.06	0.30	0.30	1.95
21-Apr	14:37	11,200	-1.09	0.00	0.00	0.30	0.30	1.95
21-Apr	17:41	12,000	-0.41	0.00	0.00	0.07	0.30	1.95
OT7								
19-Apr	12:49	31	-1.00	0.00	0.00	0.00	0.00	0.00
19-Apr	13:55	262	-0.99	0.00	0.00	0.00	0.00	0.00
19-Apr	15:43	624	-0.54	0.00	0.00	0.00	0.00	0.00
20-Apr	7:59	15,500	0.08	0.00	0.56	1.63	1.65	1.65
20-Apr	11:03	5,480	-0.67	0.00	0.01	1.62	1.65	1.65
20-Apr	13:47	24,200	-0.94	0.00	0.00	0.58	1.65	1.65
20-Apr	16:45	2,100	-0.22	0.00	0.00	0.02	1.65	1.65
21-Apr	9:06	24,196	0.34	0.00	0.30	0.30	0.30	1.95
21-Apr	12:03	15,500	-0.53	0.00	0.00	0.30	0.30	1.95
21-Apr	14:57	24,196	-1.09	0.00	0.00	0.30	0.30	1.95
21-Apr	17:35	24,200	-0.44	0.00	0.00	0.09	0.30	1.95
US1A								
19-Apr	9:50	41	-0.43	0.00	0.00	0.00	0.00	0.00
19-Apr	12:41	84	-0.98	0.00	0.00	0.00	0.00	0.00
19-Apr	15:37	63	-0.57	0.00	0.00	0.00	0.00	0.00
20-Apr	7:52	24,200	0.09	0.00	0.57	1.63	1.65	1.65
20-Apr	10:54	24,196	-0.63	0.00	0.01	1.63	1.65	1.65
20-Apr	13:42	24,196	-0.94	0.00	0.00	0.58	1.65	1.65
20-Apr	16:39	24,196	-0.25	0.00	0.00	0.02	1.65	1.65
21-Apr	8:59	24,196	0.34	0.00	0.30	0.30	0.30	1.95
21-Apr	11:57	24,196	-0.49	0.00	0.01	0.30	0.30	1.95
21-Apr	14:51	24,196	-1.09	0.00	0.00	0.30	0.30	1.95
21-Apr	17:53	24,196	-0.35	0.00	0.00	0.03	0.30	1.95

Table B.2 (Continued): Enterococci, height of tide, and cumulative rainfall of each sampling location based on time series.

Date	Time	Enterococci (MPN/100mL)	Tide (ft)	1h Rainfall (in)	6h Rainfall (in)	12h Rainfall (in)	24h Rainfall (in)	48h Rainfall (in)
US1B								
19-Apr	9:44	85	-0.40	0.00	0.00	0.00	0.00	0.00
19-Apr	12:37	292	-0.98	0.00	0.00	0.00	0.00	0.00
19-Apr	15:34	2,060	-0.59	0.00	0.00	0.00	0.00	0.00
20-Apr	7:48	19,900	0.09	0.00	0.58	1.63	1.65	1.65
20-Apr	10:49	24,196	-0.61	0.00	0.01	1.63	1.65	1.65
20-Apr	13:38	13,000	-0.94	0.00	0.00	0.59	1.65	1.65
20-Apr	16:35	24,196	-0.27	0.00	0.00	0.02	1.65	1.65
21-Apr	8:55	24,196	0.34	0.00	0.30	0.30	0.30	1.95
21-Apr	11:53	24,196	-0.47	0.00	0.03	0.30	0.30	1.95
21-Apr	14:47	24,196	-1.09	0.00	0.00	0.30	0.30	1.95
21-Apr	17:50	24,196	-0.37	0.00	0.00	0.04	0.30	1.95
US4A								
19-Apr	9:30	465	-0.34	0.00	0.00	0.00	0.00	0.00
19-Apr	12:40	199	-0.98	0.00	0.00	0.00	0.00	0.00
19-Apr	15:40	583	-0.56	0.00	0.00	0.00	0.00	0.00
20-Apr	7:56	17,300	0.08	0.00	0.57	1.63	1.65	1.65
20-Apr	10:53	5,500	-0.63	0.00	0.01	1.63	1.65	1.65
20-Apr	13:43	24,196	-0.94	0.00	0.00	0.58	1.65	1.65
20-Apr	16:44	5,170	-0.23	0.00	0.00	0.02	1.65	1.65
21-Apr	9:03	24,196	0.34	0.00	0.30	0.30	0.30	1.95
21-Apr	12:04	12,000	-0.53	0.00	0.00	0.30	0.30	1.95
21-Apr	14:54	10,500	-1.09	0.00	0.00	0.30	0.30	1.95
21-Apr	17:50	24,196	-0.37	0.00	0.00	0.04	0.30	1.95
US4B								
19-Apr	9:38	41	-0.37	0.00	0.00	0.00	0.00	0.00
19-Apr	12:36	74	-0.97	0.00	0.00	0.00	0.00	0.00
19-Apr	15:34	643	-0.59	0.00	0.00	0.00	0.00	0.00
20-Apr	7:49	24,196	0.09	0.00	0.57	1.63	1.65	1.65
20-Apr	10:47	24,196	-0.60	0.00	0.01	1.63	1.65	1.65
20-Apr	13:36	10,500	-0.94	0.00	0.00	0.59	1.65	1.65
20-Apr	16:36	24,196	-0.26	0.00	0.00	0.02	1.65	1.65
21-Apr	8:55	24,196	0.34	0.00	0.30	0.30	0.30	1.95
21-Apr	11:55	24,196	-0.48	0.00	0.02	0.30	0.30	1.95
21-Apr	14:47	24,196	-1.09	0.00	0.00	0.30	0.30	1.95
21-Apr	17:44	24,196	-0.40	0.00	0.00	0.06	0.30	1.95
US4C								
19-Apr	9:35	141	-0.36	0.00	0.00	0.00	0.00	0.00
19-Apr	12:33	1,040	-0.97	0.00	0.00	0.00	0.00	0.00
19-Apr	15:37	1,000	-0.57	0.00	0.00	0.00	0.00	0.00
20-Apr	7:53	24,196	0.08	0.00	0.57	1.63	1.65	1.65
20-Apr	10:50	24,196	-0.61	0.00	0.01	1.63	1.65	1.65
20-Apr	13:39	24,196	-0.94	0.00	0.00	0.59	1.65	1.65
20-Apr	16:40	24,200	-0.25	0.00	0.00	0.02	1.65	1.65
21-Apr	8:59	24,196	0.34	0.00	0.30	0.30	0.30	1.95
21-Apr	12:00	24,196	-0.51	0.00	0.00	0.30	0.30	1.95
21-Apr	14:50	24,200	-1.09	0.00	0.00	0.30	0.30	1.95
21-Apr	17:47	17,300	-0.38	0.00	0.00	0.05	0.30	1.95

APPENDIX C

SAMPLE COLLECTION TIMELINE AND DATA TABLES

APPENDIX C
SAMPLE COLLECTION TIMELINE AND DATA TABLES

Table C.1 : Sample Collection Timeline

Date	Location	Activities
6/11/2022	• Parkview Island Park and adjoining streets • Kayak Launch Pad	**Scouting visit**
7/24/2022	• Kayak Launch Pad • Park View Canal banks, shoreline and surroundings	**Scouting visit**, • Water level elevation measurements at Kayak Launch Pad
8/09/2022	• Normandy Shores waterway (N-S), Park View Canal north, east and south • Kayak Launch Pad • Park View Canal banks, shoreline sediments and surroundings	**Spatially Intense Sampling:** • high tide sampling by boat • Measurement of a suite of environmental parameters with YSI probe • Water level elevation measurements at Kayak Launch pad • Shoreline sediment sampling
8/17/2022	• Kayak Launch Pad • Park View Canal banks, shoreline sediments and surroundings • 74th and 75th streets between Dickens and A1A	**Stormwater catch basin sampling:** • Marine water in vicinity of stormwater discharge • Shoreline sediments in vicinity of stormwater discharge pipe • Top sediments adjacent to inlet, • Basin water, basin bottom sediments
9/2/2022	**Sites in study area:** • 74th and 75th streets between Dickens and A1A **Background sites:** • Gary Ave & Raymond Street on Parkview Island • 77th street between Byron and Abbott • 71rst street and Byron Ave **Sites in the vicinity of wastewater sewer infrastructure:** • Miami Beach Parking lot located between 72nd and 73rd street • 72nd street and 73rds street between Dickens and A1A	**Stormwater catch basin sampling:** • Top sediments adjacent to inlet, • Basin water

Table C.1 (continued) : Sample Collection Timeline

Date	Location	Activities
9/16/2022	• Normandy Shores waterway (N-S), Park View Canal north, east and south • Kayak Launch Pad • Park View Canal banks, shoreline sediments and surroundings	**Spatially Intense Sampling**: • Low tide sampling by boat • Measurement of a suite of environmental parameters with YSI probe
10/18/2022 to 10/20/2022 - Site visits approximately every 12 hours starting at 5: 00 am on 10/18/2022 and ending at 7:00 am on 10/20/2022.	• Kayak Launch Pad	**Temporally Intense Sampling:** • Hourly sampling of top 10 cm of water column adjacent to Kayak Launch Pad • Measurement of a suite of environmental parameters with YSI probe
10/19/2022 and 10/20/2022	• Kayak Launch Pad	Vertical Measurements of Water Column: • Samples collected at 0.5 inch then in 1-foot intervals • Measurement of environmental parameters with YSI probe
11/14/22	• Parkview Park • North Beach Bandshell	Groundwater sampling Vertical well sampling Catch basin water sampling

Table C.2: Environmental parameters, physicochemical parameters, and measured enterococci concentrations for high tide sampling on August 9, 2022.

Sample ID	Sample Date	Sample Time	Latitude (N)	Longitude (W)	Depth (Feet decimals)	Temp (°C)	DO (mg/L)	Salinity (ppt)	pH	Turbidity (NTU)	Enterococci (MPN/100 mL)
A1	8/9/2022	6:49 AM	25.8563184	-80.1271770	10.42	31.1	6.19	32.17	7.89	2.3	63
B1	8/9/2022	6:55	25.8569200	-80.1276828	12.00	31.2	6.24	32.18	8.04	2.17	85
C1	8/9/2022	6:59	25.8575344	-80.1281636	14.58	30.9	5.77	31.84	8.09	1.28	228
D1	8/9/2022	7:03	25.8579687	-80.1285361	14.17	30.9	5.93	31.88	8.07	0.83	96
E1	8/9/2022	7:09	25.8587981	-80.1289130	14.67	31.1	6.05	31.94	8.14	1.5	439
F1	8/9/2022	7:13	25.8598674	-80.1294867	16.00	30.9	6.00	31.86	8.13	1.02	295
G1	8/9/2022	7:18	25.8601156	-80.1286710	12.00	30.8	6.19	32.20	8.13	0.35	122
H1	8/9/2022	7:21	25.8605303	-80.1281583	13.08	30.9	5.81	32.47	8.11	0.95	327
I1	8/9/2022	7:27	25.8609629	-80.1281091	9.67	30.9	5.74	32.46	8.13	0.79	457
J1	8/9/2022	7:33	25.8604635	-80.1276108	9.92	31.0	5.28	32.45	8.06	1.31	842
J2	8/9/2022	7:50	25.8604312	-80.1276242	10.25	31.0	5.30	32.46	8.07	1.29	637
J3	8/9/2022	7:53	25.8603817	-80.1276383	4.25	31.1	5.36	32.46	8.09	1.52	689
J4	8/9/2022	7:56	25.8603509	-80.1276421	4.17	31.0	5.34	32.45	8.08	1.41	767
K1	8/9/2022	8:01	25.8605233	-80.1269827	5.50	31.0	5.31	32.36	8.09	1.11	677
K2	8/9/2022	8:07	25.8604686	-80.1269847	8.00	31.1	5.53	32.57	8.10	1.76	556
K3	8/9/2022	8:10	25.860391	-80.1270200	5.75	31.1	5.56	32.43	8.10	1.55	609
K4	8/9/2022	8:13	25.86039	-80.1269700	4.50	31.1	5.52	32.43	8.10	1.85	644
L1	8/9/2022	8:15	25.8605288	-80.1264439	3.33	31.0	5.53	32.33	8.11	2.14	884
L2	8/9/2022	8:18	25.8604786	-80.1265244	4.25	31.1	5.55	32.38	8.11	2.72	784
L3	8/9/2022	8:24	25.8604151	-80.1265903	7.42	31.1	5.60	32.47	8.11	1.77	473
L4	8/9/2022	8:30	25.8603724	-80.1266291	5.50	31.1	5.64	32.40	8.12	1.85	548
M1	8/9/2022	8:34	25.8594608	-80.1265879	6.75	31.1	5.34	32.36	8.09	1.32	663
M2	8/9/2022	8:37	25.8594626	-80.1266158	6.83	31.1	5.38	32.36	8.09	1.35	676
M3	8/9/2022	8:42	25.8594753	-80.1266803	6.50	31.1	5.43	32.38	8.10	1.84	933
M4	8/9/2022	8:44	25.8594712	-80.1267133	4.42	31.1	5.49	32.39	8.10	1.69	373
N1	8/9/2022	8:51	25.858924	-80.1261444	7.75	31.2	5.41	32.39	8.11	1.65	4,611
N2	8/9/2022	8:53	25.8588905	-80.1261676	7.25	31.1	5.51	32.41	8.11	1.91	1,191
N3	8/9/2022	8:55	25.8588145	-80.1262487	5.33	31.2	5.73	32.42	8.13	2.37	203
N4	8/9/2022	8:57	25.8587618	-80.1262598	2.58	31.3	5.72	32.47	8.12	2.22	231

Table C.2 (continued): Environmental parameters, physicochemical parameters, and measured enterococci concentrations for high tide sampling on August 9, 2022.

Sample ID	Sample Date	Sample Time	Latitude (N)	Longitude (W)	Depth (Feet decimals)	Temp (°C)	DO (mg/L)	Salinity (ppt)	pH	Turbidity (NTU)	Enterococci (MPN/100 mL)
O1	8/9/2022	9:06	25.8583645	-80.1258331	3.67	31.1	5.39	32.41	8.10	1.81	1,785
O2	8/9/2022	9:10	25.8583454	-80.1258505	3.75	31.3	5.50	32.45	8.09	2.99	279
O3	8/9/2022	9:14	25.8583039	-80.1258763	3.58	31.4	5.51	32.59	8.10	4.63	496
O4	8/9/2022	9:17	25.8582934	-80.1259095	2.58	31.3	5.56	32.55	8.11	2.75	388
P1	8/9/2022	9:21	25.8581557	-80.1258348	18.00	31.2	5.32	32.52	8.08	4.45	624
P2	8/9/2022	9:26	25.8581554	-80.1258574	4.75	31.3	5.37	32.56	8.09	4.01	727
P3	8/9/2022	9:29	25.8581543	-80.1259121	4.25	31.2	5.35	32.36	8.10	2.19	2064
P4	8/9/2022	9:32	25.8581567	-80.1259337	4.50	31.3	5.44	32.56	8.10	4.36	609
Q1	8/9/2022	9:42	25.8576120	-80.1254248	8.33	31.2	5.62	32.41	8.11	2.17	173
Q2	8/9/2022	9:43	25.8576171	-80.1254713	11.17	31.2	5.62	32.43	8.11	3.2	142
Q3	8/9/2022	9:50	25.8576374	-80.1255726	6.83	31.4	5.57	32.53	8.11	4.71	185
Q4	8/9/2022	9:53	25.8576142	-80.1256349	3.00	31.4	5.74	32.5	8.12	4.31	146
R1	8/9/2022	9:58	25.8569812	-80.1253133	1.25	31.2	5.83	32.31	8.13	1.4	617
R2	8/9/2022	10:00	25.8570254	-80.125364	4.33	31.2	5.56	32.36	8.11	2.26	173
R3	8/9/2022	10:03	25.8570933	-80.1254534	7.42	31.3	5.76	32.43	8.12	3.26	201
R4	8/9/2022	10:05	25.8571271	-80.1254725	3.58	31.4	5.84	32.4	8.13	3.27	63
S1	8/9/2022	10:09	25.8568891	-80.1262559	3.75	31.3	5.9	32.34	8.13	1.66	63
S2	8/9/2022	10:13	25.8570321	-80.1263211	8.00	31.3	5.87	32.39	8.13	2.28	148
S3	8/9/2022	10:16	25.8569639	-80.1262934	8.08	31.3	5.97	32.34	8.14	1.38	73
S4	8/9/2022	10:19	25.8570690	-80.1263333	4.25	31.3	5.98	32.36	8.13	1.4	52
T1	8/9/2022	10:23 AM	25.8569656	-80.1271906	10.33	31.3	5.98	32.33	8.14	1.47	52

Table C.3: Environmental parameters, physicochemical parameters, and measured enterococci concentrations for low tide sampling on September 16, 2022.

Sample ID	Sample Date	Sample Time	Latitude (N)	Longitude (W)	Temp (°C)	DO (mg/L)	Salinity (ppt)	pH	Turbidity (NTU)	Enterococci (MPN/100 mL)
A1	9/16/2022	7:36 AM	25.8563184	-80.1271770	28.9	4.53	26.76	7.82	0.15	>24,196
B1	9/16/2022	7:43 AM	25.8569200	-80.1276828	29.7	5.56	28.73	8.01	-0.24	>24,196
C1	9/16/2022	7:52 AM	25.8575344	-80.1281636	30.0	5.38	28.97	8.1	-0.09	>24,196
D1	9/16/2022	7:53 AM	25.8579687	-80.1285361	30.1	5.27	28.82	8.1	-0.14	>24,196
E1	9/16/2022	7:56 AM	25.8587981	-80.1289130	30.3	5.18	29.15	8.08	0.05	>24,196
F1	9/16/2022	8:00 AM	25.8598674	-80.1294867	30.3	5.16	28.87	8.08	0.80	>24,196
G1	9/16/2022	8:04 AM	25.8601156	-80.1286710	30.9	4.9	30.13	8.05	0.70	>24,196
H1	9/16/2022	8:06 AM	25.8605303	-80.1281583	30.5	4.77	29.32	8.05	0.40	>24,196
I1	9/16/2022	8:09 AM	25.8609629	-80.1281091	30.4	5.46	28.99	8.07	0.10	>24,196
J1	9/16/2022	8:13 AM	25.8604635	-80.1276108	30.9	4.75	29.91	7.99	1.48	>24,196
J2	9/16/2022	8:15 AM	25.8604312	-80.1276242	30.5	4.85	28.98	8.06	1.00	>24,196
J3	9/16/2022	8:17 AM	25.8603817	-80.1276383	30.6	4.74	28.05	8.00	0.92	12,997
J4	9/16/2022	8:19 AM	25.8603509	-80.1276421	30.7	4.79	28.61	8.04	14.05	>24,196
K1	9/16/2022	8:24 AM	25.8605233	-80.1269827	30.3	4.41	28.56	7.97	0.07	>24,196
K2	9/16/2022	8:26 AM	25.8604686	-80.1269847	30.5	4.68	28.81	8.03	-0.16	>24,196
K3	9/16/2022	8:30 AM	25.8603910	-80.1270200	30.4	5.21	29.1	8.06	0.46	>24,196
K4	9/16/2022	8:31 AM	25.860390	-80.1269700	30.5	5.13	28.87	8.09	1.56	>24,196
L1	9/16/2022	8:37 AM	25.8605288	-80.1264439	30.4	3.17	29.24	7.63	4.72	>24,196
L2	9/16/2022	8:40 AM	25.8604786	-80.1265244	30.4	3.58	28.78	7.86	2.39	>24,196
L3	9/16/2022	8:42 AM	25.8604151	-80.1265903	30.3	5.08	28.4	8.03	0.28	>24,196
L4	9/16/2022	8:44 AM	25.8603724	-80.1266291	30.1	4.69	28.35	8.01	3.15	>24,196
M1	9/16/2022	8:48 AM	25.8594608	-80.1265879	30.5	4.31	29.25	7.99	1.01	15,531
M2	9/16/2022	8:50 AM	25.8594626	-80.1266158	30.2	4.92	28.73	8.07	-0.11	>24,196
M3	9/16/2022	8:53 AM	25.8594753	-80.1266803	30.1	4.89	27.81	8.06	0.25	24,196
M4	9/16/2022	8:55 AM	25.8594601	-80.1267784	30.2	4.73	28.43	8.03	0.95	24,196
N1	9/16/2022	8:58 AM	25.8589240	-80.1261444	30.7	3.44	28.81	7.91	0.28	>24,196
N2	9/16/2022	9:03 AM	25.8588905	-80.1261676	31.1	3.64	29.5	7.94	1.32	15,531
N3	9/16/2022	9:05 AM	25.8588145	-80.1262487	30.7	4.55	29.53	8.02	2.97	9,804
N4	9/16/2022	9:07 AM	25.8587536	-80.1262658	30.8	4.65	29.08	8.03	8.66	>24,196
O1	9/16/2022	9:12 AM	25.8583645	-80.1258331	30.6	4.38	28.8	8.01	2.75	>24,196
O2	9/16/2022	9:15 AM	25.8583454	-80.1258505	30.5	4.31	28.05	7.99	1.92	24,196
O3	9/16/2022	9:17 AM	25.8583003	-80.1288860	30.8	4.03	27.98	7.96	40.52	14,136
O4	9/16/2022	9:19 AM	25.8582934	-80.1259095	30.5	4.25	27.51	7.99	5.07	17,329
P1	9/16/2022	9:23 AM	25.8581557	-80.1258348	30.5	3.95	27.24	7.96	23.54	19,863
P2	9/16/2022	9:27 AM	25.8581554	-80.1258574	30.6	4.23	28.88	7.97	9.42	24,196
P3	9/16/2022	9:29 AM	25.8581543	-80.1259121	30.6	4.37	28.43	7.99	5.06	17,329
P4	9/16/2022	9:31 AM	25.8581567	-80.1259337	30.6	4.31	28.2	7.98	4.41	24196

Table C.3 (continued): Environmental parameters, physicochemical parameters, and measured enterococci concentrations for low tide sampling on September 16, 2022.

Sample ID	Sample Date	Sample Time	Latitude (N)	Longitude (W)	Temp (°C)	DO (mg/L)	Salinity (ppt)	pH	Turbidity (NTU)	Enterococci (MPN/100 mL)
Q1	9/16/2022	9:34 AM	25.8576120	-80.1254248	30.5	4.15	28.22	7.97	1.69	15,531
Q2	9/16/2022	9:35 AM	25.8576171	-80.1254713	30.6	4.28	28.71	7.99	3.55	24,196
Q3	9/16/2022	9:38 AM	25.8576374	-80.1255726	30.7	4.14	28.09	7.98	2.37	24,196
Q4	9/16/2022	9:40 AM	25.8576142	-80.1256349	31.0	4.39	28.53	8.00	2.85	>24,196
R1	9/16/2022	9:44 AM	25.8569812	-80.1253133	30.8	3.70	28.79	7.94	4.26	19,836
R2	9/16/2022	9:46 AM	25.8570254	-80.1253640	30.3	4.08	28.03	7.97	1.94	17,329
R3	9/16/2022	9:48 AM	25.8570933	-80.1254534	30.8	4.15	28.4	7.98	2.18	24,196
R4	9/16/2022	9:50 AM	25.8571271	-80.1254725	30.7	4.05	28.32	7.99	0.45	19,836
S1	9/16/2022	9:53 AM	25.8568891	-80.1262559	30.8	3.54	28.49	7.93	1.09	11,199
S2	9/16/2022	9:55 AM	25.8570321	-80.1263211	30.7	3.81	28.71	7.95	1.18	12,997
S3	9/16/2022	9:57 AM	25.8569639	-80.1262934	31.3	3.72	30.28	7.97	1.4	19,836
S4	9/16/2022	9:59 AM	25.8570690	-80.1263333	31.1	3.66	29.32	7.96	1.41	12,033
T1	9/16/2022	10:02 AM	25.8569656	-80.1271906	30.6	4.32	28.9	8.06	0.25	12,033

Table C.4: Measured enterococci concentrations in waterway sediments, catch basin top sediments, catch basin bottom sediments, catch basin water, and roof drain sediments. Sampling locations are shown in Figure V.8.

Location	8/9 Top Sediments	8/19 Top Sediments	8/19 Bottom Sediments	9/2 Top Sediments	8/19 Catch Basin Water	9/2 Catch Basin Water
SD1	>69,355.7	NM	NA	NM	NA	NA
SD2	2,158.3	NM	NA	NM	NA	NA
SD3	174.5	NM	NA	NM	NA	NA
S1	NM	10,704	NA	NM	NA	NA
S2	NM	359,886	NA	NM	NA	NA
S3	NM	2,212	NA	NM	NA	NA
1	NM	38	798,013	NM	12,873	2,718
2	NM	6,709	18,751	NM	13,053	13,393
3	NM	3,526	NA	NM	17,968	18,868
4	NM	526,092	NA	654,063	> 241,960	14,923
5	NM	87,023	12,042	NM	1,327	12,248
6	NM	15,743	5,787	NM	512	> 241,960
7	NM	NM	NM	NM	NM	173
8	NM	NM	NM	NM	NM	19,648
9	NM	NM	NM	NM	NM	463
10	NM	NM	NM	37,135	NM	13,753
12	NM	NM	NM	NM	NM	16,768
13	NM	NM	NM	NM	NM	11,730
14	NM	NM	NM	NM	NM	14,978
15	NM	NM	NM	NM	NM	6,240
16	NM	NM	NM	NM	NM	12,528
4R	NM	NM	NM	32,467	NM	NA

NM -not measured. NA – Not applicable.

Table C.5: Enterococci concentration in samples collected from PVC on Oct. 19 and 20, 2022 versus water depth coupled with measurements of physical chemical parameters including temperature, dissolved oxygen, salinity, pH, and turbidity.

Depth	Temperature (°C)		Dissolved Oxygen (mg/L)		Salinity (ppt)		pH		Turbidity (FNU)		Enterococci (MPN)	
feet	10/19/22	10/20/22	10/19/22	10/20/22	10/19/22	10/20/22	10/19/22	10/20/22	10/19/22	10/20/22	10/19/22	10/20/22
0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	19,863	> 24,196
0.50	25.10	23.80	4.22	4.60	16.82	19.28	7.43	7.42	1.29	-0.07	NA	NA
0.67	25.70	23.90	4.03	4.18	20.66	21.19	7.44	7.44	-0.33	-0.06	NA	NA
0.83	25.90	24.30	3.95	3.81	22.52	22.45	7.48	7.45	-0.16	-0.25	NA	NA
1.00	26.00	25.20	4.21	3.31	22.90	23.37	7.52	7.44	-0.08	-0.40	> 24,196	7,915
1.17	26.20	25.50	4.22	3.30	23.55	24.70	7.55	7.46	-0.06	-0.37	NA	NA
1.33	26.30	26.80	4.30	3.39	24.53	25.83	7.58	7.52	-0.15	-0.30	NA	NA
1.42	26.50	27.00	4.35	3.71	24.94	26.42	7.61	7.58	0.04	-0.20	NA	NA
1.67	26.70	26.80	4.36	3.59	25.23	26.26	7.63	7.59	0.26	-0.31	NA	NA
1.92	27.10	26.90	4.33	3.79	25.52	26.42	7.65	7.61	0.60	-0.30	NA	NA
2.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	15,531	4,198
2.17	27.30	26.80	4.28	3.73	26.09	26.47	7.66	7.62	1.13	-0.38	NA	NA
2.42	27.50	26.90	4.14	3.90	26.40	26.54	7.66	7.64	1.07	-0.17	NA	NA
2.92	27.50	27.10	4.20	3.75	26.53	26.75	7.67	7.63	0.86	0.39	NA	NA
3.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6,910	4,360
3.42	27.40	27.20	4.28	3.50	26.56	26.89	7.68	7.63	0.85	0.35	NA	NA
3.92	27.50	27.20	4.28	3.49	26.62	26.96	7.69	7.64	0.85	0.07	NA	NA
4.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2,812	1,211
4.42	27.60	27.10	4.26	3.70	26.86	26.83	7.69	7.66	1.15	-0.01	NA	NA
4.92	27.60	27.10	4.26	3.72	26.91	26.93	7.70	7.66	1.03	0.50	NA	NA
5.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1,594	1,674
5.42	27.60	NA	4.24	NA	26.95	NA	7.70	NA	1.48	NA	NA	NA

Table C.6: Enterococci concentration, water quality measurements, and ambient conditions during 48 hours of hourly consecutive sampling at the PVC. Water quality parameters measured included temperature, dissolved oxygen, salinity, pH, and turbidity. Ambient conditions included tidal height and solar radiation (as measured at the Virginia Key NOAA station. The EXO3 sonde readings occurred directly from the waterway and the YSI sonde readings were taken directly from the samples after the aliquot was removed for enterococci measurements.

Date	Time	Enterococci	Temperature (EXO3)	DO (EXO3)	Salinity (EXO3)	Salinity (YSI)	pH (EXO3)	pH (YSI)	Turbidity (EXO3)	Turbidity (YSI)	Tide (feet)	Solar Radiant
		MPN/100 mL	°C	mg/L	ppt	ppt			FNU	FNU	feet	W/m^2
10/18/22	7:00	620	28.10	7.70	30.21	NA	8.07	NA	-5.12	NA	-0.63	0
10/18/22	8:00	1,169	27.99	7.66	30.15	NA	7.95	NA	-4.88	NA	-0.88	43
10/18/22	9:00	958	27.51	7.72	29.31	NA	7.90	NA	-4.97	NA	-1.09	148
10/18/22	10:00	1,010	27.43	7.81	28.71	NA	7.88	NA	-4.92	NA	-1.20	314
10/18/22	11:00	1,354	27.46	7.71	28.43	NA	7.86	NA	-4.79	NA	-1.18	476
10/18/22	12:00	1,182	27.52	7.88	28.20	NA	7.87	NA	-4.56	NA	-1.00	608
10/18/22	13:00	1,301	27.67	8.07	28.11	NA	7.86	NA	-4.68	NA	-0.70	410
10/18/22	14:00	676	27.90	8.23	28.05	NA	7.87	NA	-4.77	NA	-0.36	273
10/18/22	15:00	359	28.01	8.35	28.04	NA	7.88	NA	-4.86	NA	-0.04	184
10/18/22	16:00	622	28.21	8.33	28.05	NA	7.85	NA	-4.92	NA	0.20	87
10/18/22	17:00	554	28.30	8.31	28.00	NA	7.83	NA	-4.95	NA	0.27	23
10/18/22	18:00	480	28.31	8.19	27.90	NA	7.81	NA	-5.01	NA	0.16	0
10/18/22	19:00	620	NA	NA	NA	25.56	NA	7.61	NA	-0.45	-0.09	0
10/18/22	20:00	285	NA	NA	NA	25.99	NA	7.70	NA	-0.62	-0.39	0
10/18/22	21:00	228	NA	NA	NA	25.51	NA	7.75	NA	-0.22	-0.69	0
10/18/22	22:00	428	NA	NA	NA	25.24	NA	7.77	NA	0.78	-0.92	0
10/18/22	23:00	457	NA	NA	NA	25.24	NA	7.77	NA	0.18	-1.01	0
10/19/22	0:00	985	NA	NA	NA	24.92	NA	7.78	NA	0.80	-0.93	0
10/19/22	1:00	1,320	NA	NA	NA	24.71	NA	7.79	NA	-0.24	-0.70	0
10/19/22	2:00	1,374	NA	NA	NA	24.66	NA	7.77	NA	-0.32	-0.41	0
10/19/22	3:00	823	NA	NA	NA	25.14	NA	7.79	NA	-0.48	-0.12	0
10/19/22	4:00	1,726	NA	NA	NA	25.02	NA	7.80	NA	-0.30	0.11	0
10/19/22	5:00	703	NA	NA	NA	25.00	NA	7.78	NA	-0.28	0.19	0
10/19/22	6:00	768	NA	NA	NA	25.27	NA	7.82	NA	0.24	0.10	0

Table C.6 (Continued): Enterococci concentration, water quality measurements, and ambient conditions during 48 hours of hourly consecutive sampling at the PVC. Water quality parameters measured included temperature, dissolved oxygen, salinity, pH, and turbidity. Ambient conditions included tidal height and solar radiation (as measured at the Virginia Key NOAA station. The EXO3 sonde readings occurred directly from the waterway and the YSI sonde readings were taken directly from the samples after the aliquot was removed for enterococci measurements.

Date	Time	Enterococci	Temperature (EXO3)	DO (EXO3)	Salinity (EXO3)	Salinity (YSI)	pH (EXO3)	pH (YSI)	Turbidity (EXO3)	Turbidity (YSI)	Tide (feet)	Solar Radiant
		MPN/100 mL	°C	mg/L	ppt	ppt			FNU	FNU	feet	W/m^2
10/19/22	7:00	459	28.09	7.04	27.13	24.99	7.67	7.83	-1.48	-0.08	-0.15	0
10/19/22	8:00	743	27.82	6.81	26.99	25.02	7.63	7.81	-4.01	-0.42	-0.47	24
10/19/22	9:00	982	28.01	6.44	27.37	25.10	7.62	7.79	-5.00	-0.38	-0.79	70
10/19/22	10:00	651	28.00	6.26	27.45	25.16	7.60	7.78	-4.96	-0.27	-1.06	90
10/19/22	11:00	397	27.73	6.19	27.28	24.74	7.57	7.78	-4.82	-0.32	-1.22	179
10/19/22	12:00	1,459	27.62	6.22	27.15	24.43	7.56	7.79	-4.79	0.26	-1.19	152
10/19/22	13:00	2,513	NA	NA	NA	23.92	NA	7.78	NA	0.34	-0.99	205
10/19/22	14:00	911	NA	NA	NA	23.68	NA	7.78	NA	-0.12	-0.67	119
10/19/22	15:00	4,160	NA	NA	NA	23.69	NA	7.79	NA	-0.26	-0.31	58
10/19/22	16:00	10,112	NA	NA	NA	24.17	NA	7.77	NA	-0.10	0.03	38
10/19/22	17:00	9,606	NA	NA	NA	22.97	NA	7.78	NA	-0.24	0.25	4
10/19/22	18:00	24,196	NA	NA	NA	20.75	NA	7.74	NA	0.20	0.30	0
10/19/22	19:00	7,215	27.06	6.40	27.24	22.44	10.64	7.74	-4.35	0.14	0.15	0
10/19/22	20:00	12,033	NA	NA	NA	19.46	NA	7.71	NA	0.94	-0.13	0
10/19/22	21:00	24,196	NA	NA	NA	19.59	NA	7.68	NA	0.15	-0.46	0
10/19/22	22:00	24,196	NA	NA	NA	20.39	NA	7.69	NA	0.05	-0.79	0
10/19/22	23:00	24,196	NA	NA	NA	20.55	NA	7.69	NA	0.04	-1.02	0
10/20/22	0:00	19,866	NA	NA	NA	21.07	NA	7.68	NA	0.04	-1.10	0
10/20/22	1:00	15,531	NA	NA	NA	21.53	NA	7.66	NA	0.15	-0.98	0
10/20/22	2:00	> 24,196	NA	NA	NA	20.86	NA	7.65	NA	0.32	-0.72	0
10/20/22	3:00	24,196	NA	NA	NA	20.42	NA	7.66	NA	0.36	-0.39	0
10/20/22	4:00	10,112	NA	NA	NA	22.22	NA	7.67	NA	0.31	-0.07	0
10/20/22	5:00	24,196	NA	NA	NA	23.57	NA	7.70	NA	0.09	0.18	0
10/20/22	6:00	8,704	NA	NA	NA	23.59	NA	7.66	NA	-0.15	0.27	0

Table C.7: Concentration of enterococci in 48 hours sampling from the PVC based on time with weather and water characteristics including height of tide, solar radiant and hourly rainfall from three adjacent weather stations (Farrbetter, Miami Beach, and Coast Guard).

Date	Time	Enterococci (MPN/100 mL)	Tide (feet)	Solar Radiant (W/m^2)	Hourly Rainfall (inch)		
					Farrbetter (25.86°N, 80.13°W)	Miami Beach (25.83°N, 80.13°W)	Coast Guard (25.77°N, 80.15°W)
10/18/22	7:00	620	0.32	0	0	0	0
10/18/22	8:00	1,169	0.04	43	0	0	0
10/18/22	9:00	958	-0.20	148	0	0	0
10/18/22	10:00	1,010	-0.31	314	0	0	0
10/18/22	11:00	1,354	-0.25	476	0	0	0
10/18/22	12:00	1,182	-0.04	608	0	0	0
10/18/22	13:00	1,301	0.29	410	0	0	0
10/18/22	14:00	676	0.58	273	0	0	0
10/18/22	15:00	359	0.86	184	0	0.01	0
10/18/22	16:00	622	1.02	87	0	0	0
10/18/22	17:00	554	1.07	23	0	0	0
10/18/22	18:00	480	0.97	0	0	0	0
10/18/22	19:00	620	0.63	0	0	0	0
10/18/22	20:00	285	0.34	0	0	0	0
10/18/22	21:00	228	0.08	0	0	0	0
10/18/22	22:00	428	-0.09	0	0	0	0
10/18/22	23:00	457	-0.16	0	0	0	0
10/19/22	0:00	985	-0.01	0	0	0	NA
10/19/22	1:00	1,320	0.24	0	0	0	NA
10/19/22	2:00	1,374	0.55	0	0	0	0
10/19/22	3:00	823	0.75	0	0	0	0.01
10/19/22	4:00	1,726	0.96	0	0	0	0
10/19/22	5:00	703	0.99	0	0	0	0
10/19/22	6:00	768	0.86	0	0	0	0
10/19/22	7:00	459	0.58	0	0	0	0
10/19/22	8:00	743	0.24	24	0	0	0
10/19/22	9:00	982	-0.08	70	0	0	0
10/19/22	10:00	651	-0.32	90	0	0	0
10/19/22	11:00	397	-0.38	179	0	0	0
10/19/22	12:00	1,459	-0.35	152	0	0	0
10/19/22	13:00	2,513	-0.18	205	0	0	0
10/19/22	14:00	911	0.10	119	0.01	0	0.07
10/19/22	15:00	4,160	0.43	58	0	0	0.01
10/19/22	16:00	10,112	0.62	38	0.03	0.01	0.01
10/19/22	17:00	9,606	0.86	4	0.1	0.01	0.24

Table C.7 (Continued): Concentration of enterococci in 48 hours sampling from Miami Beach based on time with weather and water characteristics including height of tide, solar radiant and hourly rainfall from three adjacent weather stations (Farrbetter, Miami Beach, and Coast Guard).

Date	Time	Enterococci (MPN/100 mL)	Tide (feet)	Solar Radiant (W/m^2)	Hourly Rainfall (inch)		
					Farrbetter (25.86°N, 80.13°W)	Miami Beach (25.83°N, 80.13°W)	Coast Guard (25.77°N, 80.15°W)
10/19/22	18:00	24,196	0.96	0	0.27	0.35	0.01
10/19/22	19:00	7,215	0.79	0	0	0.1	0
10/19/22	20:00	12,033	0.44	0	0	0	0.002
10/19/22	21:00	24,196	0.13	0	0	0	0
10/19/22	22:00	24,196	-0.22	0	0	0	0
10/19/22	23:00	24,196	-0.45	0	0	0	0
10/20/22	0:00	19,866	-0.49	0	0	0	0.001
10/20/22	1:00	15,531	-0.37	0	0	0	NA
10/20/22	2:00	> 24,196	-0.06	0	0	0	NA
10/20/22	3:00	24,196	0.20	0	0	0	NA
10/20/22	4:00	10,112	0.48	0	0	0	NA
10/20/22	5:00	24,196	0.71	0	0	0	NA
10/20/22	6:00	8,704	0.80	0	0	0	NA

Table C.8: Water quality parameters including field temperature (℃), dissolved oxygen (mg/L), salinity (ppt), field pH and turbidity (NTU) for catch basins (W4, W6, and W8) sampled on November 14, 2022.

Sample ID	Depth (feet)	Field Temperature (℃)	Dissolved Oxygen (mg/L)	Salinity (ppt)	Field pH	Turbidity (NTU)
W4	0.17	28	1.4	1.03	7	1.9
	0.33	28.4	1.01	2.2	6.99	1.96
	0.50	28.4	0.84	2.21	6.99	2.01
	0.67	28.4	0.78	2.21	6.99	1.94
	0.83	28.4	0.7	2.21	6.98	1.94
	1.00	28.4	0.67	2.21	6.98	1.88
	1.25	28.4	0.65	2.21	6.98	1.95
	1.50	28.4	0.63	2.21	6.98	1.91
W6	0.33	26.8	3.6	24.5	7.09	1.28
	0.50	26.9	2.9	24.98	7.12	1.05
	0.67	26.9	2.85	25.13	7.14	1.04
	0.83	26.9	2.8	25.18	7.16	1.06
	1.00	26.9	2.77	25.3	7.17	1.12
	1.25	26.8	2.77	25.59	7.18	0.91
	1.50	26.4	2.72	32	7.29	0.67
	1.75	26.4	3.18	33.2	7.36	0.94
	2.00	26.1	3.45	33.66	7.4	1.15
	2.50	26	3.39	33.52	7.4	1.48
	3.00	25.9	3.58	34.09	7.43	1.59
	3.50	25.9	3.55	34.18	7.43	1.85
	4.00	25.9	3.5	34.25	7.43	1.82
	4.50	25.9	3.47	34.3	7.43	1.91
	5.00	26	3.34	34.49	7.42	2.04
	6.00	26	3.33	34.53	7.42	2.19
	7.00	26	3.3	34.56	7.42	2.05
	7.17	26	3.2	34.55	7.42	3.02
	7.17			34.73	7.11	4.3
W8	0.50	25.1	1.04	0.07	7.73	2.54
	0.67	25.2	0.9	0.13	6.97	2.48
	0.83	25.1	0.83	0.13	6.9	2.94
	1.00	25.1	0.78	0.13	6.86	2.26
	1.25	25.1	0.76	0.13	6.82	2.4

Table C.9: Water quality parameters including field temperature (℃), dissolved oxygen (mg/L), salinity (ppt), field pH and turbidity (NTU) for vertical wells (V1, V2, and V3) sampled on November 14, 2022.

Sample ID	Depth (feet)	Field Temperature (℃)	Dissolved Oxygen (mg/L)	Salinity (ppt)	Field pH	Turbidity (NTU)
V1	0.17	28.1	2.23	5.31	7.1	0.99
	0.33	28	2.1	5.31	7.11	1.13
	0.50	28	1.85	5.31	7.12	1
	0.67	28	1.78	5.31	7.13	1
	0.83	27.9	1.74	5.31	7.14	0.96
	1.00	27.9	1.71	5.31	7.14	1.01
	1.25	27.9	1.68	5.31	7.15	1.06
	1.50	27.9	1.66	5.32	7.14	1.06
	1.75	27.9	1.65	5.34	7.14	1
	2.00	27.9	1.6	5.4	7.13	1.11
	2.50	27.9	1.55	5.48	7.12	1.14
	3.00	27.8	1.68	28.92	7.17	1.83
	3.50	26.3	3.14	34.98	7.26	2.1
	4.00	26.2	3.24	35.11	7.3	1.9
	4.50	26.2	3.25	35.14	7.32	2.11
	5.00	26.2	3.27	35.16	7.33	1.92
	6.00	26.2	3.28	35.17	7.33	2.22
	7.00	26.2	3.31	35.16	7.34	2.55
	8.00	26.2	3.35	35.16	7.34	3.13
V2	0.17	26	1.66	0.15	7.72	1.92
	0.33	26	1.14	0.13	7.55	1.71
	0.50	25.9	0.91	0.13	7.48	2.14
	0.67	25.9	0.83	0.12	7.42	1.87
	0.83	25.7	0.75	0.12	7.36	1.57
	1.00	25.7	0.74	0.12	7.33	1.47
	1.25	25.7	0.73	0.12	7.31	1.5
	1.50	25.7	0.7	0.12	7.28	1.52
	1.75	25.7	0.67	0.11	7.26	1.82
	2.00	25.7	0.67	0.11	7.25	1.5
	2.50	25.7	0.66	0.11	7.23	1.5
	3.00	25.7	0.65	0.11	7.21	1.46
	3.50	25.7	0.65	0.11	7.19	1.45
	4.00	25.7	0.65	0.11	7.18	1.55
	4.50	25.7	0.65	0.11	7.17	1.57
	5.00	25.7	0.63	0.11	7.16	1.6
	6.00	25.7	0.63	0.12	7.16	1.5
	7.00	25.7	0.63	0.12	7.15	1.46
	8.00	25.7	0.62	0.12	7.14	1.44
	9.00	25.7	0.62	0.12	7.14	1.31
	10.00	25.7	0.62	0.13	7.15	1.27
	11.00	25.7	0.62	0.13	7.16	1.16
	11.50	25.6	0.61	0.15	7.16	1.11
V3	0.33	28.5	1.33	4.26	7.13	4.1
	0.50	28.5	1.15	4.44	7.11	2.48
	0.67	28.5	1.05	4.69	7.1	3.3
	0.83	28.5	1.03	5.07	7.08	2.13
	1.00	28.5	1.01	5.15	7.08	1.77
	1.25	28.5	0.97	5.25	7.08	1.63
	1.50	28.5	0.95	5.35	7.07	1.71
	1.75	28.5	0.94	5.41	7.07	1.57
	2.00	28.5	0.91	5.66	7.07	1.52
	2.50	28.5	0.91	5.63	7.07	1.52
	3.00	28.5	0.93	5.3	7.07	1.48
	3.50	28.5	0.88	6.6	7.04	1.43
	4.00	28.5	0.76	6.97	7.03	1.83

Table C.10: Water quality parameters including field temperature (°C), dissolved oxygen (mg/L), salinity (ppt), field pH and turbidity (NTU) for groundwater monitoring wells (G1 and G2) sampled on November 14, 2022.

Sample ID	Depth (feet)	Field Temperature (°C)	Dissolved Oxygen (mg/L)	Salinity (ppt)	Field pH	Turbidity (NTU)
G1	0.17	27	6.59	0.04	7.16	16.1
	0.33	27.2	5.76	0.88	7.02	14.64
	0.50	27.2	5.67	0.86	6.99	13.68
	0.67	27.2	5.64	0.85	6.97	12.61
	0.83	27.3	5.65	0.86	6.95	13
	1.00	27.3	5.67	0.86	6.93	13.18
	1.25	27.3	5.63	0.81	6.92	10.81
	1.50	27.3	5.59	0.79	6.91	10.21
	1.75	27.3	5.56	0.77	6.91	10.24
	2.00	27.3	5.55	0.76	6.91	8.8
	2.50	27.3	5.51	0.74	6.9	7.8
	3.00	27.4	5.48	0.74	6.9	7.27
	3.50	27.4	5.46	0.73	6.9	6.68
	4.00	27.4	5.4	0.73	6.89	6.23
	4.50	27.4	5.25	0.73	6.89	6.29
	5.00	27.4	5.18	0.73	6.89	8.11
	6.00	27.4	5.15	0.73	6.89	5.52
	7.00	27.3	4.9	0.73	6.88	4.32
	8.00	27.3	4.47	0.73	6.88	6.04
	9.00	27.2	4.23	0.73	6.87	5.4
	30.17	N/A	N/A	22.48	6.84	3.15
G2	0.17	27	5.1	0.65	7.41	10.26
	0.33	27.1	5.01	0.61	7.31	9.41
	0.50	27	4.96	0.63	7.35	9.45
	0.67	27.1	4.94	0.61	7.32	9.96
	0.83	27	4.89	0.59	7.31	8.55
	1.00	27	4.83	0.58	7.31	7.86
	1.25	27.1	4.83	0.58	7.3	7.4
	1.50	27	4.8	0.57	7.3	7.3
	1.75	27.1	4.74	0.56	7.29	7.77
	2.00	27.1	4.73	0.56	7.29	8.56
	2.50	27.1	4.7	0.55	7.29	6.79
	3.00	27.1	4.62	0.54	7.28	7.25
	3.50	27.1	4.57	0.54	7.28	6.7
	4.00	27.1	4.56	0.55	7.27	5.8
	4.50	27.2	4.5	0.58	7.26	4.74
	5.00	27.2	4.47	0.64	7.25	4.41
	6.00	27.3	4.43	0.86	7.23	3.73
	7.00	27.3	4.28	1.37	7.18	4.81
	8.00	27.3	4.03	2.56	7.12	4.95
	9.00	27.3	3.44	4.4	7.09	4.55
	10.00	27.3	2.41	8.11	6.99	2.52
	11.00	27.2	1.57	12.55	6.98	2.45
	12.00	27.1	0.96	14.71	6.98	2.2
	13.00	27.1	0.9	14.86	7.01	2.4
	31.33	N/A	N/A	24.74	6.95	6.44

Table C.11: Enterococci concentrations for samples collected on November 14th , 2022 based on sample location and depth (Top (T) or bottom (B)) with other physical chemical parameters including field temperature (℃), dissolved oxygen (mg/L), salinity (ppt), field pH, turbidity (NTU), enterococci (MPN/100 mL).

Sample ID	Date	Field Temperature (℃)	Dissolved Oxygen (mg/L)	Salinity (ppt)	Field pH	Turbidity (NTU)	Enterococci (MPN/100 mL)
G1-T	11/14/2021	20.1	5.83	0.71	6.82	18	10
G1-B	11/14/2021	20.5	4.05	22.48	6.84	3.15	10
G2-T	11/14/2021	20.4	5.9	0.52	7.25	6.05	20
G2-B	11/14/2021	20.4	3.63	24.74	6.95	6.44	10
W4-T	11/14/2021	20.1	1.6	2.26	7.12	19.27	364
W4-B	11/14/2021	20.3	1.74	2.28	7.1	11.52	1927
W6-T	11/14/2021	20.4	4.67	25.1	7.03	3.29	24196
W6-B	11/14/2021	20.8	4.91	34.73	7.11	4.3	934
W8-T	11/14/2021	20.4	3	0.23	7.53	4.43	24196
W8-B	11/14/2021	20	3.1	0.23	7.31	4.58	24196
V1-T	11/14/2021	19.6	4.06	5.19	7.06	3.56	4611
V1-B	11/14/2021	19.6	4.34	34.79	7.13	4.03	238
V2-T	11/14/2021	20.3	3.8	0.19	7.85	3.9	24196
V2-B	11/14/2021	20.3	3.57	0.81	7.7	4.73	17327
V3-T	11/14/2021	20.2	4.5	4.02	7.22	4.8	1616
V3-B	11/14/2021	20.5	4	6.83	7.07	5.43	1989

APPENDIX D

DETAILS FROM VISUAL INSPECTIONS

APPENDIX D
DETAILS OF VISUAL INSPECTIONS

SCOUTING VISITS BY SEQUENCE OF VISIT

Helena Solo-Gabriele, Ph.D., from the University of Miami research team visited the PVC Kayak Launch site on June 11, 2022. During Dr. Solo-Gabriele's visit she observed suspected dog feces near stormwater catch basin inlets on the street and sidewalk that contribute towards the site (Figure D.1 , a and b). Although the area has dog waste disposal stations with bags available along with educational signs (Figure D.1, c and d), feces were still observed. Observations of dog walkers in the area indicate that about half pick up after their dogs. In addition, in the park area that leads to the kayak launch, animals besides dogs were observed that could potentially contribute fecal waste. These additional animals included iguanas and different types of birds. She observed a flock of pigeons, a wading bird, and a rooster (Figure D.2). The number and the diversity of the birds in the area was unusual. The area where the birds congregated had a stored lawn chair in the tree plus a cup and water tray which appeared to possibly serve as a possible bird or animal feeding station. During her visit she took photographs from the base of the kayak launch and observed the riverbanks in the area which had a considerable amount of rip rap, in addition to uncovered sediment. The mangrove canopy extended several feet into the water from the banks (Figure D.3). This is of significance as shade limits sunlight inactivation of microbes that may be in the wateway.

Erik Lamm from the University of Miami research team visited the PVC Kayak Launch site on July 24, 2022, to measure the tidally driven changes in water levels over an 8-hour period and scout for potential sampling locations. Various sampling locations were identified during the reconnaissance mission on July 24th. These locations were either exposed during low tide or only submerged by a few centimeters of water. Easy access was identified from within the canal. The sample locations varied in vegetation. The majority are in areas with an abundance of mangroves, which might provide an ideal environment for bacteria growth. Another location is near a stormwater outfall, which might isolate the stormwater system as a source. Other locations are on the bends of the canal where natural beaches with shallow water form during low tide. The southern bend is next to a large building that borders the canal (Figure D.4, a to d). The northern bend is directly above the sanitary sewer system siphon. The results from this scouting visit were used to inform the selection of the sampling transects detailed in the subsequent section of this report.

On August 9, 2022 the University of Miami research team employed a two pronged approach whereby Larissa Montas, Ph. D., and Rivka Reiner deployed by boat with CMB staff from the boat ramp located on Purdy Avenue and navigated to the Normandy Isles waterway N-S and the PVC while Dr. Helena Solo-Gabriele, Ph.D., deployed to the Kayak Launch pad. As the boat approached the Normandy Isles Waterway and the PVC, Larissa Montas observed trash floating in both waterways, including plastic trash bags, miscellaneous plastic items of varying size and dog feces floating on the water surface (Figure D.5, a and b). She also observed trash and leaves were accumulated against the retaining walls and below the docks connected to several homes along the PVC North. Where the trash had accumulated a white foam covered the water surface and higher concentration of suspended solids were observed (Figure D.6, a and b). Additionally, during the visual inspection she observed small to medium size cracks in the retaining wall along the perimeter of Parkview Island. On the landside of the waterway's banks shoreline types varied from sediment shoreline with dense mangrove canopy that extended approximately one to three meters over the water surface, exposed sediments showing signs of erosion, sediment shoreline reinforced with human-made walls, and residential units with overhanging docks and a retaining wall extending to an undetermined depth (Figure D.7, a to e).

Dr. Montas observed three homeless camps during the marine water sampling and site inspection by boat. She identified three homeless camps: one in the PVC North under the bridge leading from PVI to Biscayne Beach Elementary School, a second camp was located under the bridge leading from PVI to Dickens Ave, and a third camp was located on the shore of PVC East in the vicinity of Park View Island Park (Figure D.8, a , b and c). During this trip Dr. Solo-Gabriele who was at the Kayak Launch Pad observed a homeless camp on the west side of the community garden (see Figure D.8, panel d).

On August 17, Dr. Helena Solo-Gabriele, Dr. Larissa Montas and Erik Lamm conducted sampling activities at the PVC, PVI Park and along the stormwater conveyance infrastructure. Three water samples and three sediment samples were collected at the hot-spot locations identified during the high tide sampling. Dr. Montas observed what appeared to be animal feces at one of the shoreline sediments sampling locations. A homeless camp identified prior (hammock and mosquito net) appeared to have been moved to another sampling location. The shoreline sediments at the location directly across the PVI park had a foul odor. That same day, Dr. Solo-Gabriele led the team efforts on sampling the stormwater conveyance infrastructure with the support from the Public works Department, CMB. The team sampled stormwater inlets and catch basins located along the two gravity pipes leading to the stormwater outfalls that discharge north and south of the Kayak Launch pad. These two gravity pipes run along 73rd street and 74th street. In general, the manholes and catch basins located closest to the PVI Park and downflow of the commercial areas along Collins Ave., were full of trash. For these basins the water color was dark grey to black and a foul odor was noted. In particular, sites W1 and W2 had the most trash, with the team noticing an odor similar to sulfur, emanating from W2. Other basins, like site W5, were cleaner and the water appeared to have less suspended sediments. In terms of general observations of the top sediments adjacent to the inlets, there was high variability in the color, grain size and apparent organic content. For example sediments at location W1, appeared similar to dry grey ash or very fine sand. Sediments at location W4 had a similar appearance while sediments at location W5 were full of dry organic matter and the grain size was larger than for the two other locations (Figure D.9, a, b and c).

On September 2, Dr. Larissa Montas and Erik Lamm conducted sampling activities at 16 locations along the stormwater sewer infrastructure. These sampling activities were an effort to sample stormwater sewer catch basins and wells that were located along the 74th and 73rd Street gravity pipes and very close to the sanitary sewer infrastructure, locations within PVI, and locations that were far away from the PVC and as far away as possible form the sanitary sewer. The team observed similar conditions to those recorded on August 17. Several differences were noted. In particular, the catch basin at locations W1 and W2 had been cleaned by city contractors. Please refer to Section V.2 for further details on measured changes in enterococci concentrations in the catch basin water.

On September 16, 2022 the University of Miami research team comprised of Dr. Larissa Montas and Yutao Chen, deployed by boat with CMB staff from the boat ramp located on Purdy Avenue and navigated to the Normandy Isles waterway N-S and the PVC. A heavy storm impacted the CoMB the night before. Significant amounts of trash were observed on the water surface in main waterway and PVC. Discoloration was observed at water surface, as well as areas where a greenish color was observed at water surface. Large quantities of trash (water bottles, soda cans, plastic wraps, large plastic items including a dish pan and a bucket) were observed on sediment banks, covering bottom sediments and on the water surface was well. In particular, along the shallow banks of the north and south bend, she observed that the waterway's bottom sediments were completely covered by trash. Signs of erosion were observed along some of the exposed sediment shoreline, where it was evident that run-off had 'carved" small gullies into the sediment banks (Figure D.10, a, b and c).

On September 21, 2022, Helena Solo-Gabriele met with CMB public works staff to discuss the enclosure location for the autosampler. It was raining very heavily during this visit. Helena Solo-Gabriele along with CMB staff went out in the rain (with umbrellas) to discuss the location for the enclosure. They stood over the 73 Street outfall to discuss possible installation there. During this observation, water from the storm conveyance system wsa carrying trash into the waterway. The discharge of bags and broken up pieces of plastic were observed coming out of the storm conveyance system. Also, flows coming from smaller private outfalls were observed to have been discolored.

Helena Solo-Gabriele collected all samples with the assistance of Hekai Zhang and CMB staff from the Kayak Launch pad which resulted in five trips to the station during dark hours. During this time she observed manatees and iguanas swimming in the PVC. It was very lightly raining during the October 19 evening pick up (about 7 pm). She also interviewed the CMB staff the day before and after the rain to get their insights on when the rainn started prior (between 2 and 4 pm immediately prior to the October 19 evening pickup) based upon CMB staff near the site at the time.

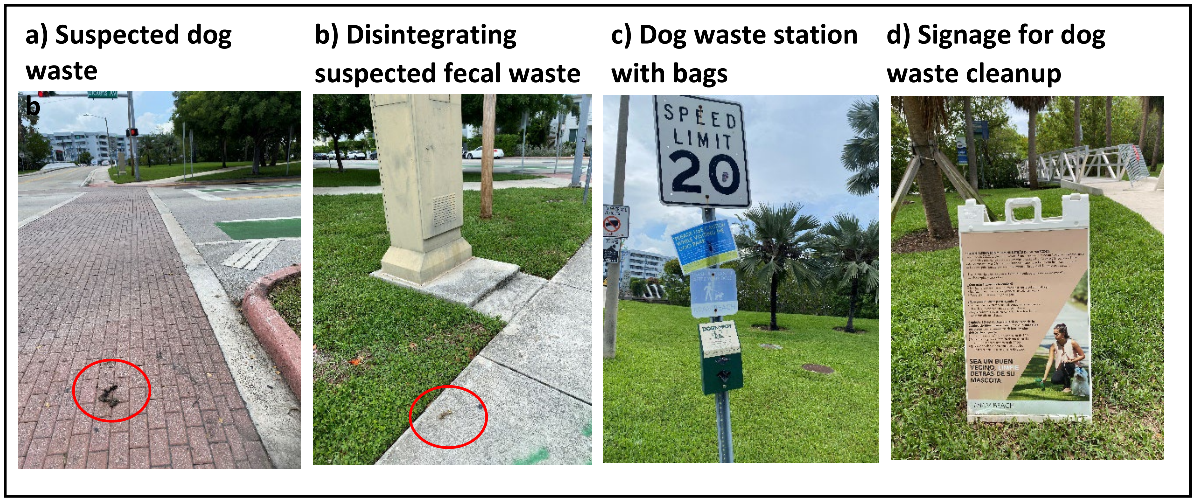


Figure D.1: Suspected dog feces and doggie disposal stations and educational materials (Photos taken June 11, 2022)

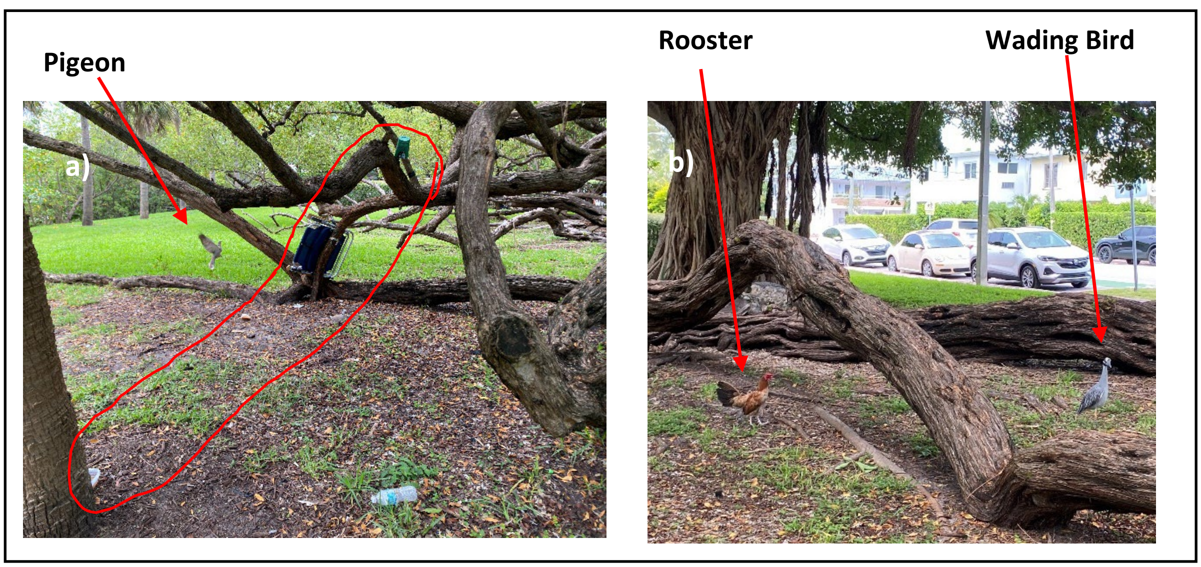


Figure D.2: Birds in park area that leads to the PVC Kayak Launch. Lawn chair, cup and water tray circled in red. At the time of the visit there was a flock of pigeons observed at the site which scattered prior to the photo (Photos taken June 11, 2022)

Figure D.3: Mangrove canopy at PVC, extending several feet from the banks providing shade and potential protection against UV light which is known to inactivate microbes

Figure D.4: Locations along the PVC with shallow water during low tide which are more highly influenced by channel bank sediments. Channel bank sediments have been shown to have elevated levels of enterococci.

Figure D.5: Animal feces and a doggie bag with feces floating on the water surface

Figure D.6: Water showing discoloration and white foam

Figure D.7: Shoreline types along PVC varies from sediment shoreline with dense mangrove canopy, exposed sediments showing signs of erosion, sediment shoreline reinforced with human-made walls, and a retaining wall extending to an undetermined depth

Figure D.8: Pictures of homeless encampments that were found immediately adjacent to the PVC. These encampments were located: a) underneath the bridge from PVI to Biscayne Shores Elementary School, b) bridge from PVI to Dickens Ave, c) mangroves in the vicinity of the park adjacent to the PVC Kayak Launch, and d) immediately west of the community garden area adjacent to Park View Island park.

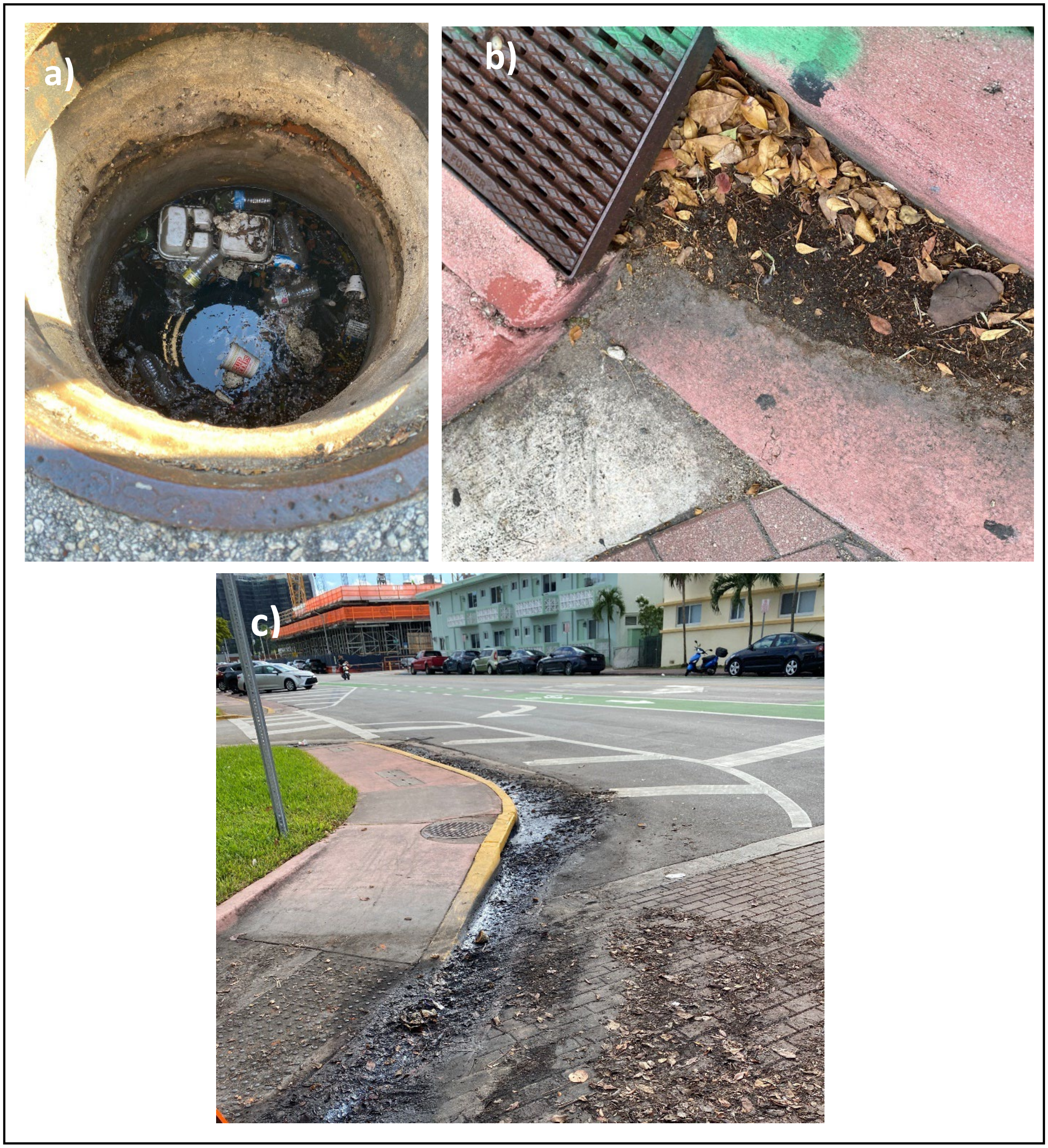


Figure D.9: Trash and debris within stormwater conveyance system. a) Catch basin with trash, b) Top sediments near inlet, c) Black sediments near curb gutter

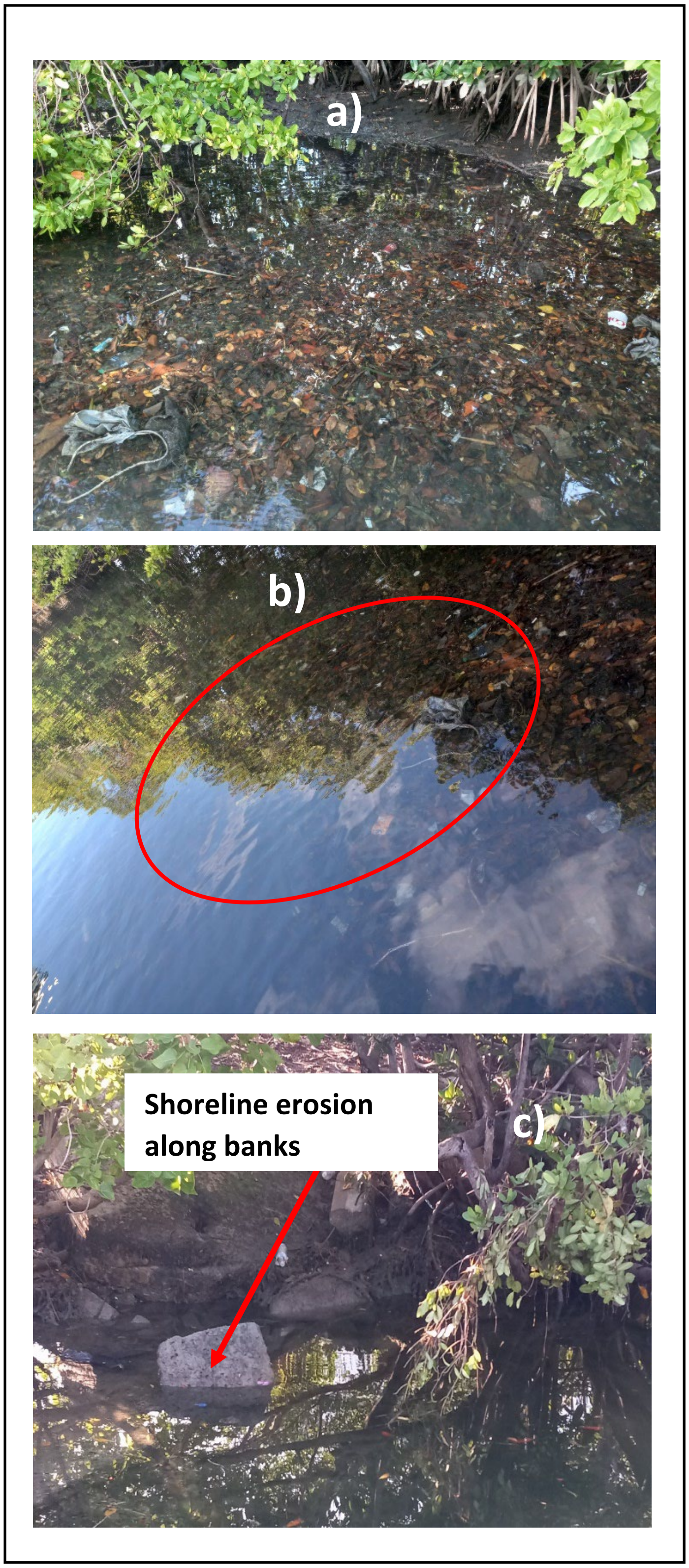


Figure D.10: Shoreline details. a) and b) Shallow banks exposed during low tide are covered with trash. c) Shoreline showing signs of erosion. At the shallow banks trash covered the sediment bottom