City of Lynn & Town of Swampscott, MA

King's Beach UV Pilot Study

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INTRODUCTION

Background

The City of Lynn (Lynn) and Town of Swampscott (Swampscott), in collaboration with the project team, conducted a full-scale pilot study (Pilot) at King's Beach from June to August 2025 to evaluate the effectiveness of ultraviolet (UV) disinfection on bacteria-contaminated stormwater which currently discharges onto King's Beach from both communities through two parallel drainage culverts at the municipal border near the intersections of Eastern Avenue, Lynn Shore Drive, and Humphrey Street. UV disinfection is a proven technology used primarily at wastewater treatment plants to inactivate bacteria; this pilot's primary objective was to test its applicability for a stormwater application.

OVERVIEW OF PILOT STUDY

In June 2025, the City of Lynn and Town of Swampscott launched a two-month full-scale pilot study to assess the effectiveness of ultraviolet (UV) disinfection in treating bacteria-contaminated stormwater discharged onto King's Beach via two drainage culverts at their municipal border.

Objectives:

1. **Evaluate UV disinfection performance** under dry and wet weather conditions.
2. **Gain operational experience** with a UV technology.
3. **Improve public access** to King's Beach during the pilot period.

Key Findings:

- **Effective during dry weather.** UV treatment significantly reduced bacteria levels in stormwater during normal flow conditions.
- **Limited during wet weather.** The effectiveness of UV dropped in the first 24 hours due to increased turbidity in the flow.
- **Improved beach access.** UV treatment contributed to fewer beach closures, though other environmental factors could also be in play.
- **Operational challenges.** Maintenance and engineering issues must be addressed before implementing a permanent UV facility.

In 2024, Lynn and Swampscott performed laboratory-scale testing of UV using collimated beam testing and found that the technology was effective at inactivating bacteria in stormwater discharging to King's Beach to safe levels for recreation. The full-scale Pilot offered the opportunity to test the capability of treating stormwater at a larger scale and for an extended period with this environmentally friendly, chemical-free technology.

This Memorandum summarizes the results and findings from the UV Pilot which was operated for approximately 2 months (59 days) during the 2025 beach season from June 20th to August 17th. The UV Pilot was designed to operate continuously during dry and wet weather (with the exception of large rainfall events) and convey and treat flows up to approximately 5 million gallons per day (mgd). This includes all dry weather flows as well as all wet weather flows from rainfall events less than approximately 0.25 inches in depth. For rainfall events greater than 0.25 inches, the system was designed to remain on but would not be able to treat all flows. For events greater than 0.8 inches, the system was planned to be shut down until the conclusion of the storm to avoid capacity issues in the Swampscott culvert. For large events greater than 2 inches, the weir walls were to be removed to reinstate the full original conveyance capacities of both culverts.

Project Team

As noted, the UV Pilot was a collaborative effort by Lynn, Swampscott, and its partners. The UV Pilot Team (Team) consisted of the following along with their roles and responsibilities:

- City of Lynn Staff: Equipment and contractor procurement; operational support; public outreach and engagement
- Town of Swampscott Staff: Equipment and contractor procurement; operational support; public outreach and engagement
- Lynn Water and Sewer Commission (LWSC): Operation and maintenance support; system monitoring
- Local Volunteers: Sampling support; data reporting; system monitoring
- Kleinfelder: Design and operational support; data analysis and reporting

Project Objectives

The objectives of the UV Pilot established during the project planning process are listed below:

- **Objective 1:** Determine the effectiveness of UV disinfection at reducing bacteria in stormwater discharging to King's Beach during dry and wet weather conditions.

- **Objective 2:** Gain operational experience with a UV disinfection system.

- **Objective 3:** Provide greater access to King's Beach to the residents of Lynn and Swampscott during the operational period of the pilot.

Project Setup

The UV Pilot was staged at the intersection of Humphrey Street, Ocean Street, and Eastern Avenue straddling the municipal boundary between Lynn and Swampscott. The UV Pilot equipment consisted of one UV treatment system, five electric pumps and associated piping, two 3-foot high weir walls (one in each culvert), and one diesel generator. The Team researched obtaining a temporary electrical connection from National Grid to use instead of a diesel generator, but the timeframe to obtain this connection could not be accommodated in the UV Pilot schedule.

All system components were enclosed by 6-foot tall temporary fencing with jersey barriers included on all boundaries facing the roadways. Visual screening and sound blankets were affixed to all fencing that surrounded noise-making equipment. A site schematic is shown in **Figure 1** and photographs of the site in **Figure 2** and **Figure 3**.

A process flow diagram is demonstrated in **Figure 4.** The water from both culverts was isolated by the 3-foot tall weir walls. The pumps lifted the water from each culvert to grade and conveyed it to the influent side of the UV treatment system. Once in the UV system, the water from both culverts combined and then flowed by gravity through an array of UV lights and into the effluent chamber. From there, the treated water was discharged by gravity back into the Swampscott culvert downstream of the weir wall.

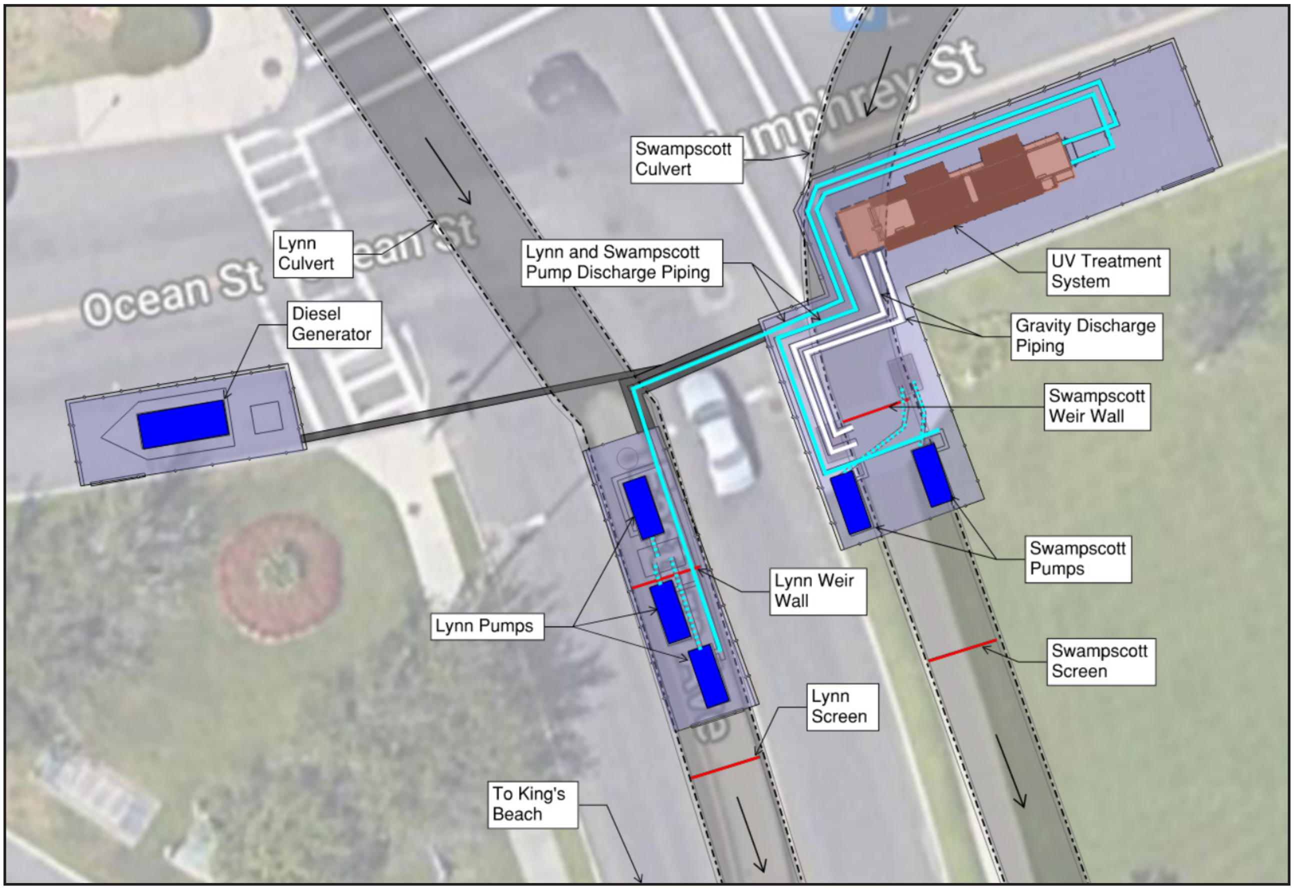

Figure 1. UV Pilot Site Plan

Figure 2. Aerial Photo of UV Pilot Site

Figure 3. UV and Pumping Systems Being Installed at the Pilot Site

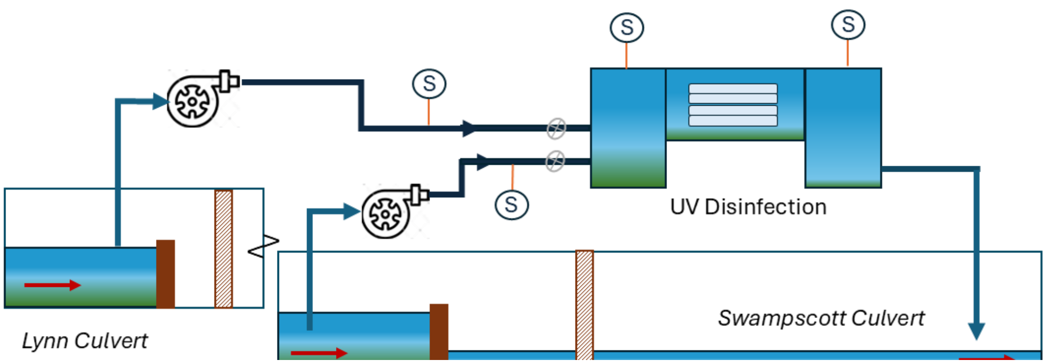

Figure 4. UV Pilot Process Flow Diagram

SAMPLING AND TESTING PROCEDURES

Overview

A daily sampling and testing program was conducted for the full duration of the UV Pilot when the system was operational. The program was managed and conducted by the Town of Swampscott and a team of local volunteers. The sampling was conducted once per day by two volunteers during low tide conditions. The sampling locations and testing parameters are described below.

The UV Pilot was operational from June 20th to August 17th (59 days); however, due to various operational issues encountered throughout the summer, as well as the down time required for regular maintenance, there were 6 days when the system was fully offline and 14 additional days when the system was partially offline. Sampling was not conducted on days when the system was fully offline. When possible, sampling was performed on days when the system was partially offline if timing permitted. The total number of fully operational days is 39 days and total number of full and partial operational days is 53. Of the 53 full and partial operational days, there were 41 dry weather days and 12 wet weather days. Wet weather days were defined as any days when measured rainfall was greater than 0.10 inches per Environmental Protection Agency (EPA) guidance.[1] For the purposes of our analysis, wet weather days include an additional 24 hours beyond the end of the event to take into account the residual impact of wet weather on flow quantity and quality in the Lynn and Swampscott culverts.

In **Figure 5** below, the qualifying rainfall periods are highlighted with their totals annotated at the top. The full and partial offline days are highlighted in orange and yellow respectively. These features for rainfall events and offline days are shown for reference in many of the plots included in the **Data and Results** section of the memo.

Sampling Locations

There were five daily sampling locations, as shown in **Figure 6** and **Figure 7.**

- Locations #1 and #2 represent the untreated stormwater from the individual Lynn and Swampscott culverts. Samples were taken from ports installed on the pump discharge pipes.
- Location #3 represents the combined untreated stormwater from Lynn and Swampscott. The water from both culverts were mixed in the influent tank of the UV treatment system.
- Location #4 represents the combined treated stormwater from Lynn and Swampscott. The sample was taken from the effluent tank of the UV treatment system.
- Location #5 represents a sample taken at King's Beach in the ocean at approximately 3 feet of depth. The sample was taken on the Swampscott side of King's Beach roughly in alignment with the access ramp.

[1] *Refer to EPA National Pollutant Discharge Elimination System (NPDES) guidance 40 CFR 122.21(g)(7)(ii)*

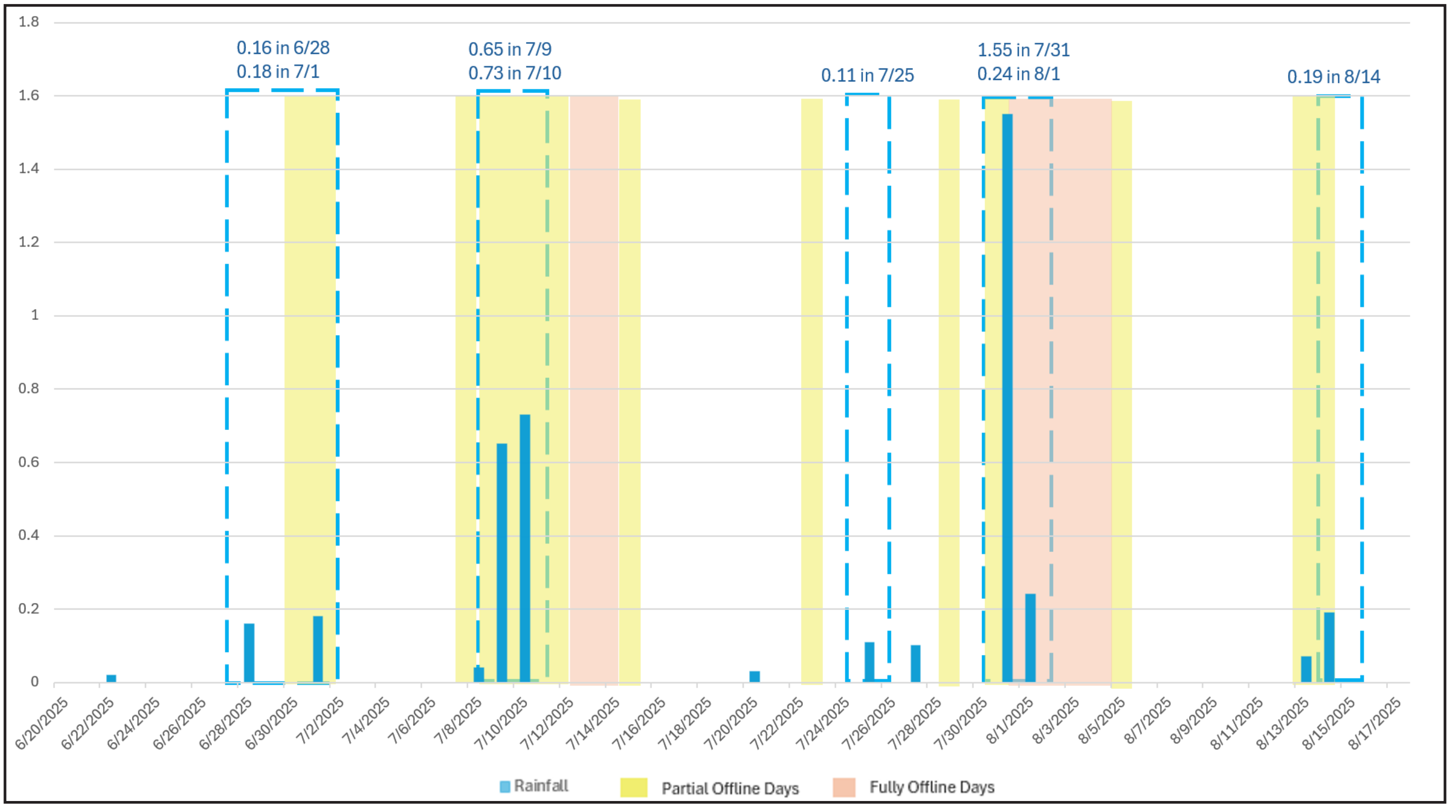

Figure 5. Rainfall and Offline Days

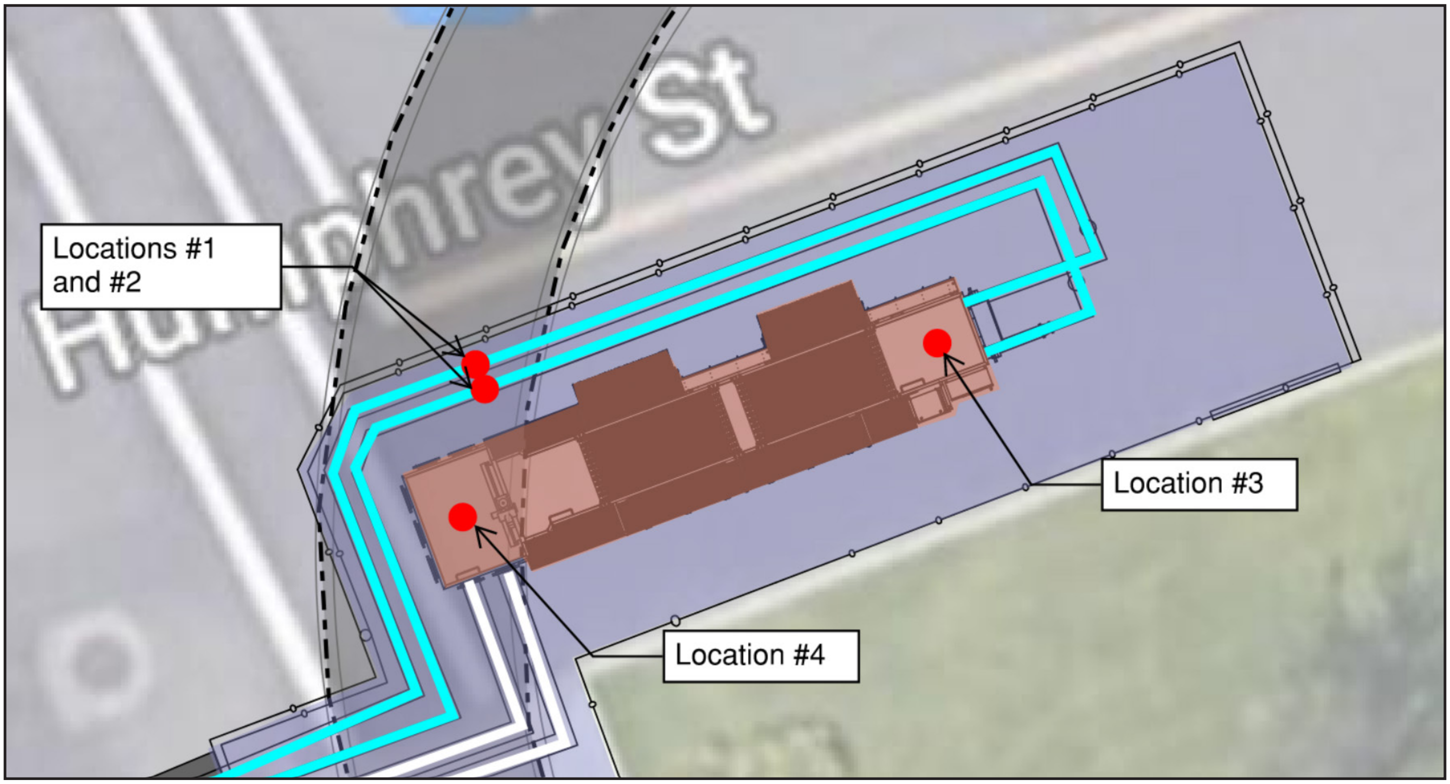

Figure 6. Daily Sampling Locations #1-4

Figure 7. Daily Sampling Location #5

Testing Parameters

All testing was completed in-house by the UV Pilot sampling team. Most tests were performed on site using probes and field kits. Bacteria tests were performed in a laboratory space provided by the Town of Swampscott using an EPA approved IDEXX Tecta testing machine. **Table 1** below lists the sampling parameters and testing methods.

Daily bacteria testing was conducted at all five sampling locations. However, the remaining parameters were only tested at the combined influent and effluent tanks of the UV treatment system (Locations #3 and #4). These two locations were considered the most critical to capture for the pilot as they demonstrate the water quality before and after UV disinfection.

Table 1. UV Pilot Sample Parameters and Test Methods

Sample Parameter	Test Method
Bacteria (Enterococcus)	IDEXX Tecta Lab Test
UV Transmittance (UVT)	Real Tech Probe Field Test
Turbidity	YSI Pro DSS Multiprobe Field Test
Total Chlorine	Hach DR900 Colorimeter Field Test
Ammonia	Hach Test Strips Field Test
Temperature	YSI Pro DSS Multiprobe Field Test
Conductivity	YSI Pro DSS Multiprobe Field Test
pH	YSI Pro DSS Multiprobe Field Test

To ensure data quality, all staff received hands-on training on the field and laboratory equipment prior to performing sampling, and all equipment was calibrated by staff per manufacturer recommendations prior to each use.

The pilot data collected for bacteria (enterococcus), UVT, and turbidity is discussed in the body of the memo. The data collected for the other sample parameters (total chlorine, ammonia, temperature, conductivity, and pH) is included in **Appendix A.**

Other Data Sources

Rainfall

Rainfall data for the UV Pilot project was taken from the LWSC's Sanderson Avenue rain gauge, which is an existing monitoring point maintained by Flow Assessment Services. The rainfall data is provided in 5-minute increments. The rain gauge is located approximately 1,800 feet (0.34 miles) in a northwest direction from the UV Pilot.

Tidal Data

Tide data was sourced from the National Oceanic and Atmospheric Association (NOAA) Boston Harbor tide gauge available in up to 1-min increments. The data was referenced frequently to ensure sampling occurred during low tide.

Department of Conservation and Recreation/Department of Public Health

Water quality sampling data is published by the Massachusetts Department of Conservation and Recreation (DCR) and Department of Public Health (DPH). DCR/DPH samples are typically taken at King's Beach at four locations, including three in the ocean on the Lynn side and one at the mouth of the Lynn outfall. The DCR/DPH results from the three ocean samples are then used to determine beach status and whether water quality necessitates a closure. The DCR/DPH data collected concurrent with the pilot duration is discussed in more detail in the **King's Beach Water Quality** section.

Air Quality

Air quality data measuring particulate matter (less than 2.5 micrometers in diameter) was collected throughout the duration of the summer by three PurpleAir sensors installed in the vicinity of the project area. Two sensors were installed in close proximity to the UV Pilot equipment, most notably the diesel generator. The third sensor was installed at the Swampscott Town Hall approximately 0.25 miles from the UV treatment equipment to serve as control/background data. The third sensor was installed to control for external factors, such as wildfires, that may impact air quality. The air quality data is included in **Appendix B.**

DATA AND RESULTS

Baseline Data

The daily bacteria data for the water within the Lynn and Swampscott culverts is shown on a logarithmic scale along with daily rainfall totals in **Figur**e **8**. The single-sample DPH threshold for enterococcus bacteria at ocean beaches is shown for reference as a dashed red line, 104 CFU / 100 mL.[2] Note that culvert samples were not taken when dry weather flows were too low in the culvert for the pumps to be operating. This happened in both culverts at various times throughout the UV Pilot, but more frequently in the Swampscott culvert. Borders are shown around the designated wet weather periods that will be referenced in subsequent plots; there were 5 wet weather periods of varying volumes over the course of the pilot.

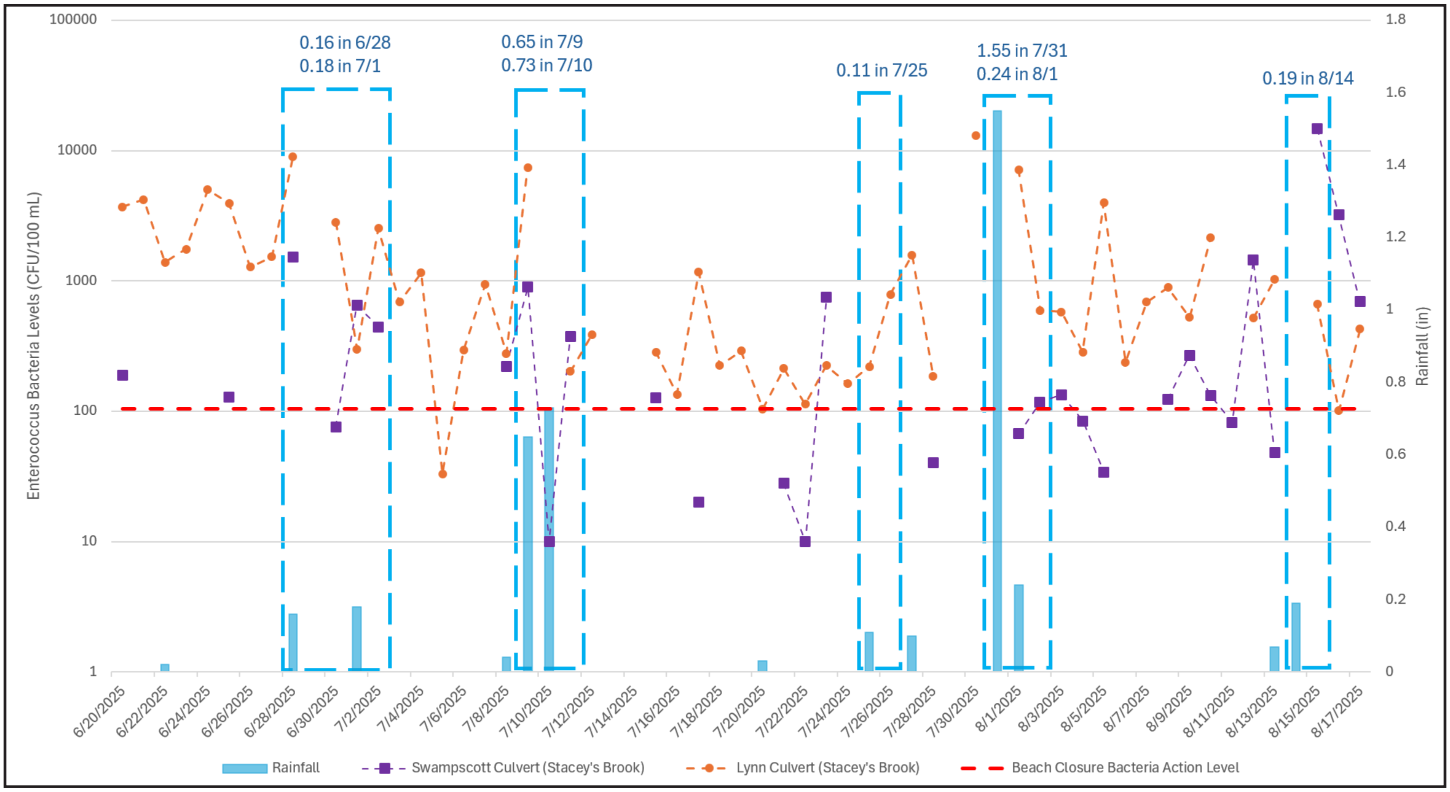

Figure 8. Individual (Untreated) Culvert Bacteria Results and Rainfall

Figure 8 represents the typical concentrations of bacteria in the water flowing through the Lynn and Swampscott culverts out to King's Beach. This data was collected as background information to better understand the typical water quality patterns in each culvert. While the data is not pertinent independently to the objective of determining the effectiveness of UV treatment, it does indicate that the water quality in both culverts is highly variable. It also indicates that the bacteria concentrations in both culverts exceed the DPH threshold the majority of the time.

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[2] *Colony Forming Units (CFU) per 100 milliliters is the typical unit referenced for bacterial concentrations in stormwater.*

UV Treatment Results

Bacteria

The daily enterococcus bacteria data from the influent and effluent chambers of the UV treatment system is shown on a logarithmic scale in **Figure 9**. The data represents the bacteria results from the combined Lynn and Swampscott culvert flow both before and after UV treatment. The single-sample DPH threshold for enterococcus bacteria at ocean beaches of 104 CFU / 100 mL is shown for reference as a red dashed line. Bacteria results that were below the detection limit of 10 CFU / 100 mL are shown as 5 CFU / 100 mL, which is consistent with DPH / DCR reporting practices. As presented in the **Sampling and Testing Procedures** section, wet weather periods are outlined in blue with rainfall totals listed above and fully and partially offline periods are highlighted in red yellow respectively. Note that samples were taken during most of the days when the system was partially offline if the timing of operation allowed.

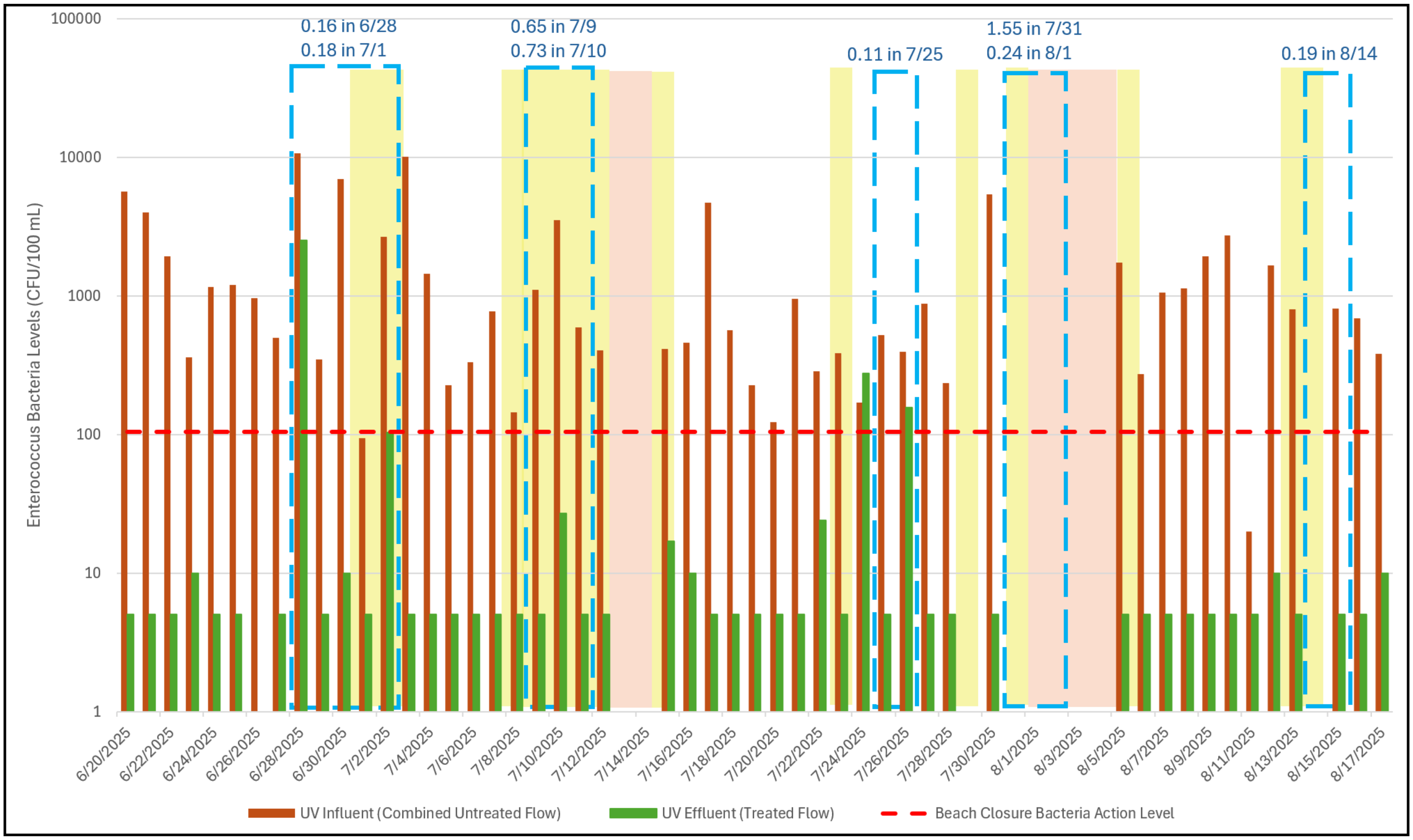


Figure 9. Bacteria Results Before and After UV Treatment

Figure 9 demonstrates the consistent effectiveness of UV treatment at reducing bacteria concentrations to below the DCR/DPH threshold. There was only one dry weather day (July 24) during pilot operation when the threshold was not met. On this date, the effluent bacteria concentration was actually higher than the influent. The cause of this result is unknown but appears to be an outlier and can possibly be attributed to the accumulation of organic debris in the UV effluent tank.

Additionally, there were two wet weather days (June 28 and July 26) that were sampled when the threshold was not met. The June 28 exceedance was within the first 3 hours of a storm event, a period that is sometimes referred to as the "first flush." The first flush is the period at the beginning of the storm when the majority of the solids, debris, and contaminants that have accumulated in the culvert during the previous stretch of dry weather are flushed out in the higher flows. The July 26 exceedance was the morning after the wet weather that occurred in the late afternoon on July 25. Both exceedances occurred within the first 24 hours of the event, and the June 28 sample is significantly higher because it occurred during the first flush. All results taken on subsequent days from these events are below the DPH threshold, indicating that UV regains effectiveness within about 24 hours after the beginning of the storm.

UV Transmittance and Turbidity

Turbidity is a measure of the clarity of the water, while UV Transmittance (UVT) is a measure of the ability of light to penetrate the water to inactivate the target bacteria. They are related parameters; low turbidity and high UVT are ideal conditions for UV treatment. For reference, typical UV treatment systems at wastewater treatment plants are designed for 55-65% UVT. The daily UVT and turbidity data taken from the influent chamber of the UV treatment system is shown in **Figure 10**. Based on the full set of data collected, the average UVT of the combined Lynn and Swampscott flow is approximately 87.5%. This is a very favorable UVT and would result in a smaller overall system needed to meet the same treatment levels as a flow with lower UVT. Again, wet weather periods are highlighted in blue and full and partial offline periods in red and yellow.

Figure 11 compares the daily rate of bacteria reduction with UV against the turbidity data collected, similar to **Figure 10** but instead using bacteria reduction as an indicator of UV performance. By comparing the actual bacteria results with the turbidity, it is even more apparent how the clarity of the water impacts the performance of UV.

Figure 10 and **Figure 11** illustrate that the conditions of the combined Lynn and Swampscott flows are consistently conducive to UV treatment as the water is largely clear (low turbidity and high UVT). The only notable exceptions are during wet weather periods on June 28, July 26, and July 31, attributable to a large amount of particulates being washed down the drainage system. It's clear that the effectiveness of UV treatment is compromised during these conditions. However, the charts show that the clarity of the water returns to treatable levels within about 24 hours after the beginning of the storm.

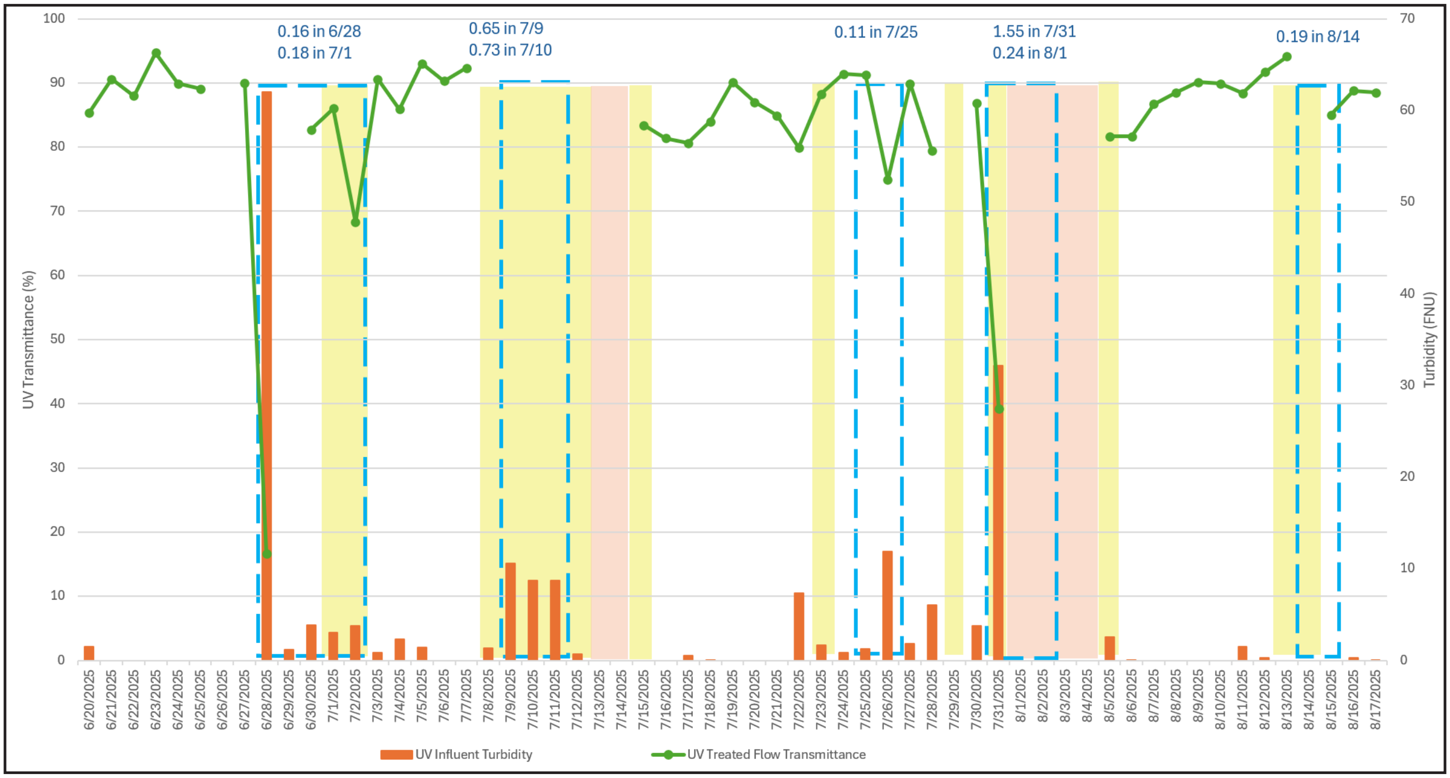


Figure 10. UV Transmittance and Turbidity Results

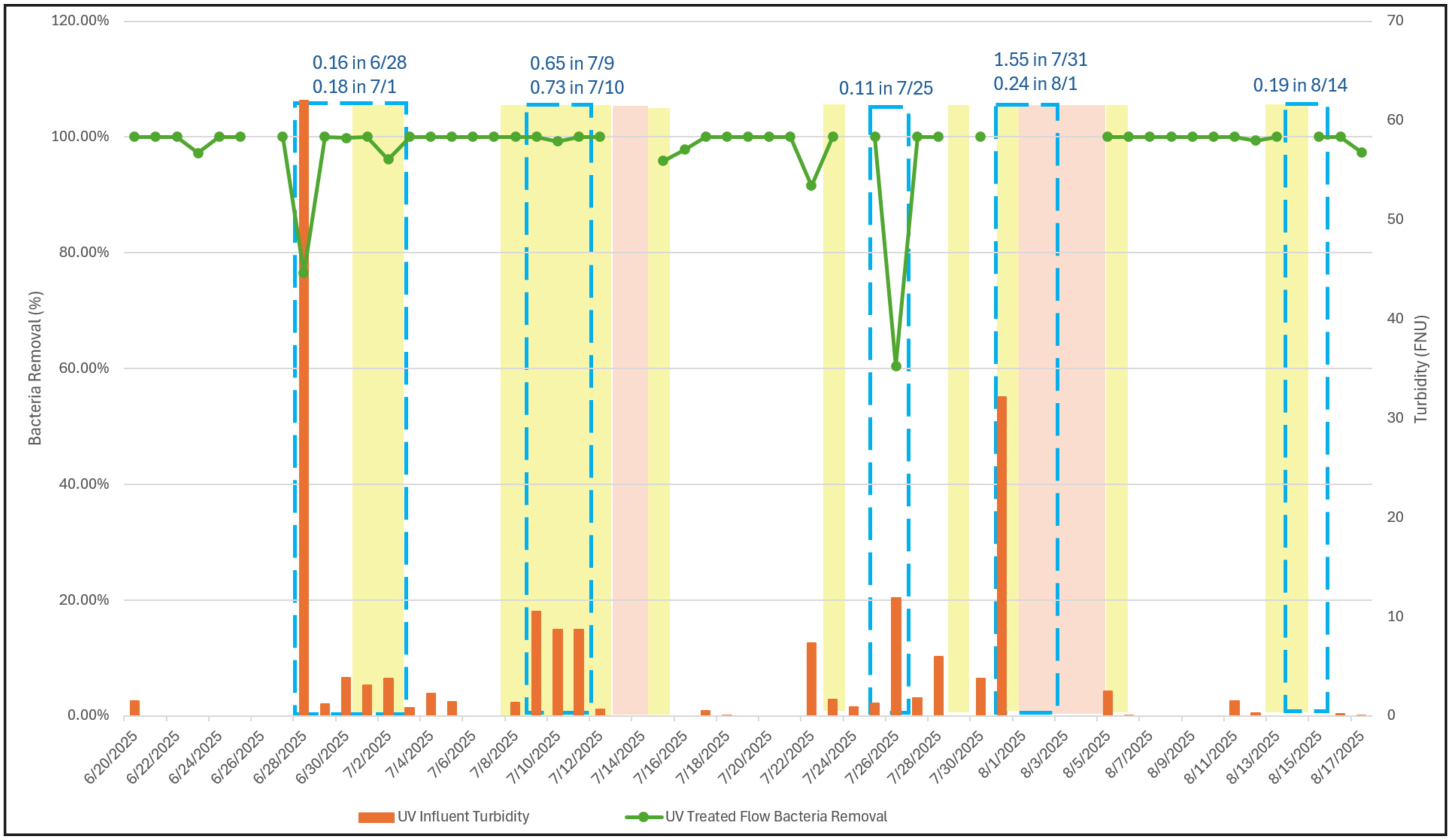


Figure 11. Turbidity and Bacteria Reduction

King's Beach Water Quality

DCR/DPH Results

During the entire 2025 beach season, DCR/DPH performed daily sampling for enterococcus bacteria at King's Beach as part of their statewide water quality testing program. Samples are taken at four locations, including three in the ocean on the Lynn side of King's Beach. The three ocean samples are taken in the vicinity of Eastern Avenue, Kimball Road, and Pierce Road. The Eastern Avenue sample is roughly in line with the two large stormwater culvert outfalls from Lynn and Swampscott that are the subject of this report. The Kimball Road and Pierce Road samples are in proximity to other smaller stormwater outfalls owned and maintained by DCR. The remaining sample is typically taken at the mouth of the Lynn outfall; however, through coordination with the UV Pilot team, this sample was taken at the mouth of the Swampscott outfall during the pilot operation period.

The DCR/ DPH sample results at the three ocean locations determine the beach closures for King's Beach. The sample taken at the mouth of the Lynn or Swampscott outfall is taken for informational purposes but has no impact on beach closure. *A single sample result at any of the three ocean locations greater or equal to 104 cfu/100 mL results in a beach closure for the entire beach.* Because of the incubation period involved in the laboratory bacteria tests, the beach closures are posted the day following when the sample was taken. Additionally, DCR/DPH calculate a running geomean of the bacteria results from the past five samples for all three ocean locations. There is a separate threshold of 35 cfu/100 mL for the 5-sample geomean[3] calculation. If the combination of the 5-sample geomeans of all three ocean locations (15 data points) exceeds this threshold, this also results in a beach closure.

Due to the design of DCR/DPH's sampling program and the triggers used to close King's Beach, the days that King's Beach is open or closed do not necessarily correlate to the effectiveness of the UV technology to inactivate bacteria. **Figure 12** displays the DCR/DPH individual sample results from the Eastern Avenue sample location for the period of pilot operation. The results from the other two sample locations at Kimball Road and Pierce Road are not presented to isolate for the impact on water quality in the vicinity of the UV Pilot. Similarly, the geomean calculation is not shown as this calculation factors in the Kimball Road and Pierce Road results.

The DCR/DPH sample results indicate several instances of exceedances throughout the summer. The individual sample results that exceed the 104 CFU / 100 mL threshold appear to mostly correspond to wet weather periods; however, there are several exceptions where exceedances occurred during dry weather, like the three data points in early August (August 6, 11, and 12). Conversely, there are several periods of wet weather when there were no exceedances, such as the July 25 event and the July 31 event.

[3] *Geomean is n^{th} root of the product of n sample results.*

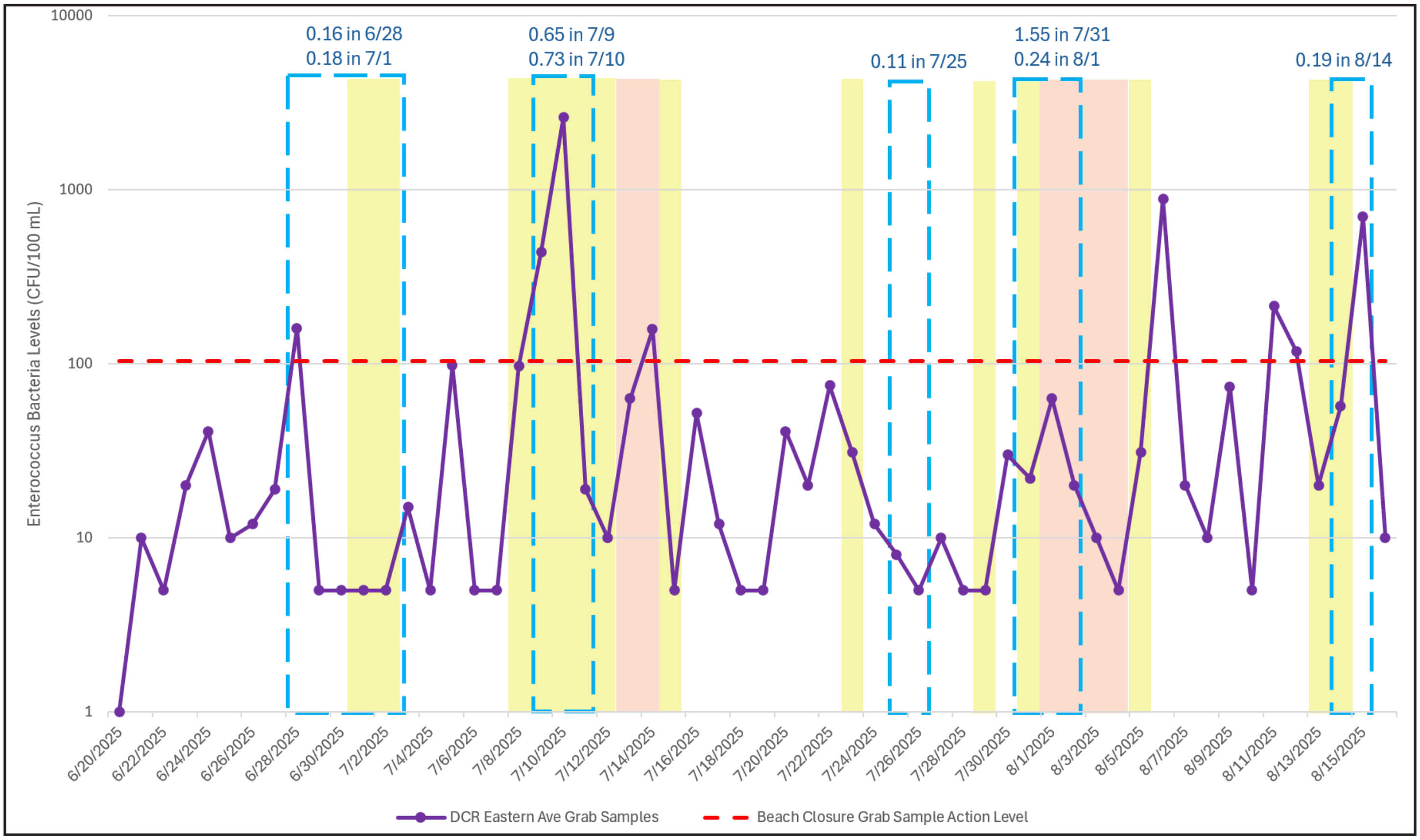


Figure 12. DCR/DPH Eastern Avenue Individual Sample Results

Historical Analysis of Exceedances

To better understand the potential impact of the UV Pilot on Eastern Avenue individual sample exceedances, historical data from the past 5 years was analyzed for the same duration that the pilot was operational. The Kimball Road and Pierce Road results, as well as the geomean calculation are not considered to isolate for the impact on water quality in the vicinity of the UV Pilot. **Table 2** includes the dates of June 20 to August 17 for each year from 2021 to 2025. Data includes the number of exceedances at the Eastern Avenue sample locations, total rainfall, and number of wet weather days. Exceedances include the number of single sample results over the 104 CFU / 100mL threshold. The data is subdivided into months and totaled for the entire period. Additionally, a plot with the exceedances and wet weather days for each year is included in **Figure 13.** Note that the 2025 data includes the full 59-day operational period including days when the pilot was partially and fully offline.

Month	Exceedances During Study Period	Exceedance (%)	Total Rainfall (in)	Number of Wet Days During Study Period
June 2021	2	18.18%	1.78	3
July 2021	15	48.39%	9.40	21
August 2021	6	35.29%	2.91	5
2021 Total	**23**	**38.98%**	**14.09**	**29**
June 2022	4	36.36%	0.99	2
July 2022	15	48.39%	0.81	4
August 2022	12	70.59%	0.75	2
2022 Total	**31**	**52.54%**	**2.55**	**8**
June 2023	7	63.64%	0.47	3
July 2023	25	80.65%	8.81	16
August 2023	11	64.71%	2.48	4
2023 Total	**43**	**72.88%**	**11.76**	**23**
June 2024	6	54.55%	2.63	9
July 2024	15	48.39%	1.57	8
August 2024	12	70.59%	3.67	12
2024 Total	**33**	**55.93%**	**7.87**	**29**
June 2025	1	9.09%	0.18	2
July 2025	3	9.68%	3.39	8
August 2025	4	23.53%	0.5	4
2025 Total	**8**	**13.56%**	**4.07**	**14**

Table 2. Eastern Avenue Bacteria Exceedances (above 104 CFU / mL) and Wet Weather 2021-2025

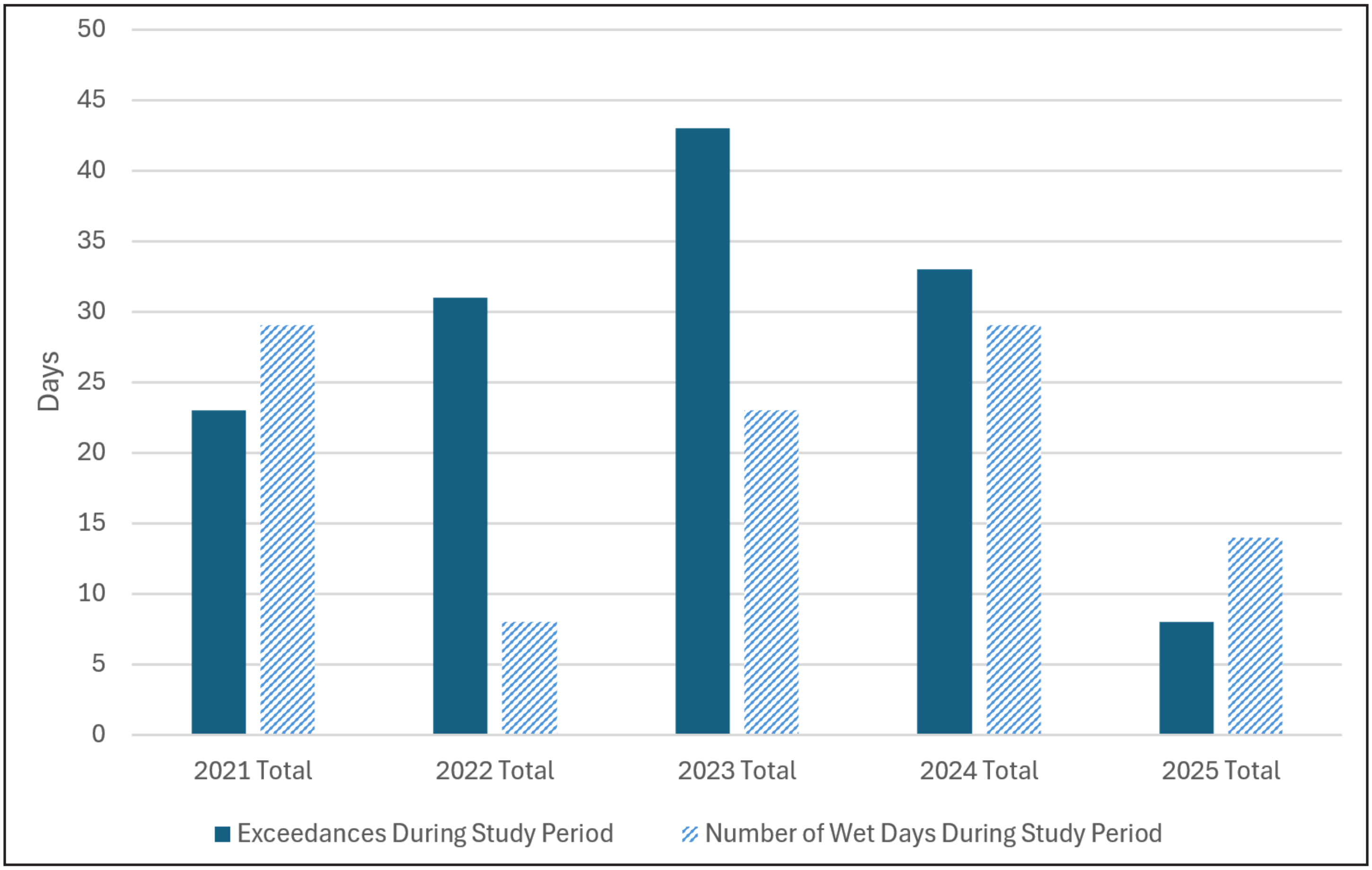


Figure 13. Eastern Avenue Bacteria Exceedances (above 104 CFU / mL) and Wet Weather 2021-2025

Many factors may contribute to the concentration of bacteria in the ocean at the Eastern Avenue testing location at King's Beach. However, when comparing the exceedances in 2025 during the UV operation to the previous 4 summers, it had a meaningful impact. Note that as mentioned above, these totals do not account for days when the UV pilot was partially and fully offline. The period of UV operation was significantly drier than previous summers apart from 2022, which had a similar number of wet weather days. However, there were only 8 counted exceedances at Eastern Avenue in 2025 compared to 31 in 2022.

Culvert Effluent Results

The DCR/DPH results taken at the mouth of the Lynn or Swampscott outfall are not used to determine beach closures. However, the results are useful to help understand what was ultimately coming out of the outfalls. As previously mentioned, the UV Pilot team coordinated with DCR/DPH to advise them of the pilot program and that treated flows would be discharged solely through the Swampscott culvert. When operational, no flow should have been discharging through the Lynn outfall. DCR/DPH utilizes a third-party company to perform the sampling and they were advised of the pilot; however, the UV Pilot team cannot verify where exactly the samples were taken each day. For the purposes of this discussion, it is assumed that the samples were taken from the Swampscott culvert when the UV Pilot was operational. **Figure 14** plots the DCR/DPH culvert results against the UV effluent results. Theoretically, the two sets of results should match on the days that the pilot was fully operational since the only flows discharged through either outfall should be treated. There are no pipe connections in either culvert between the weir walls and the outfalls. **Figure 14** displays a comparison of the two sets of results.

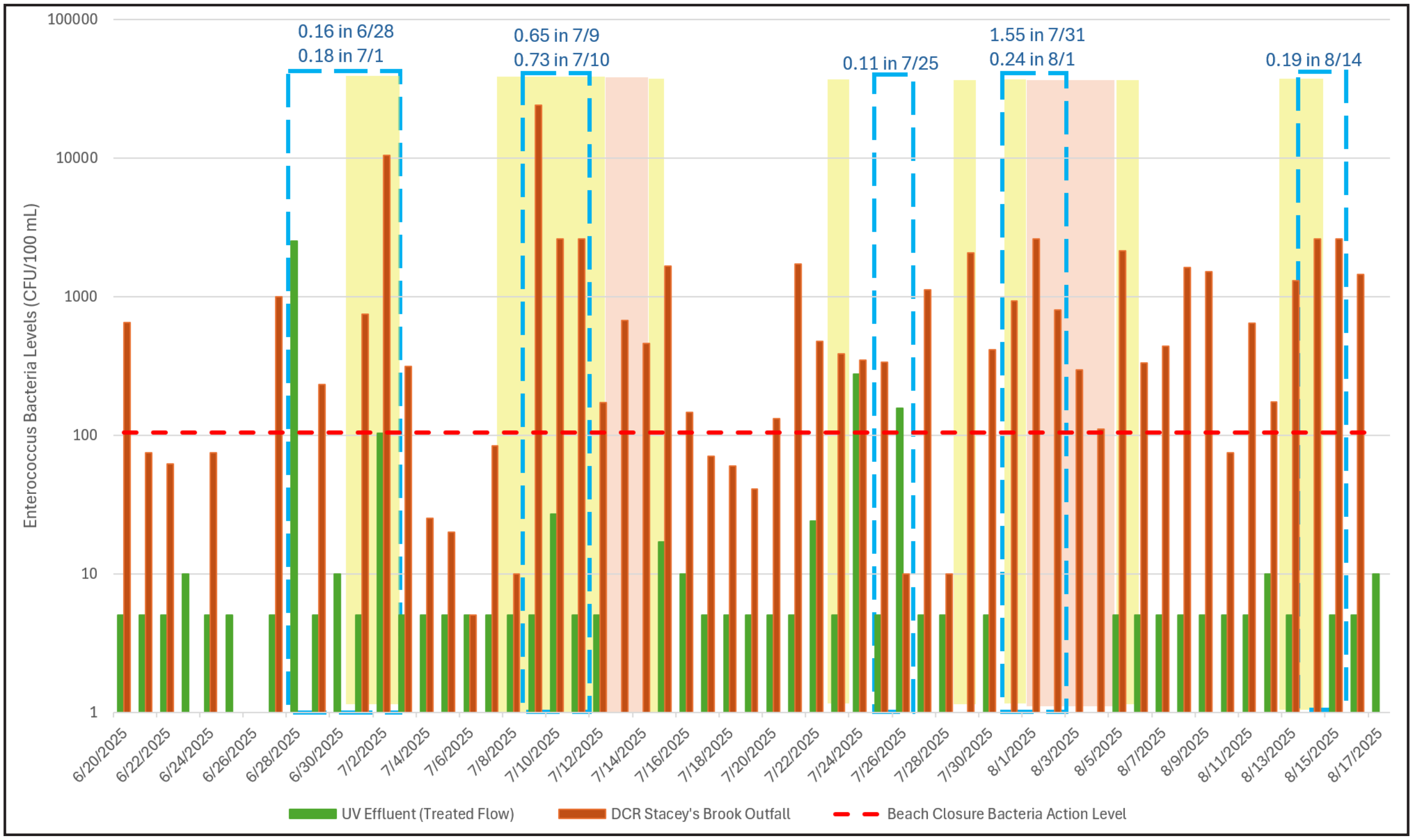


Figure 14. UV Effluent and DCR/DPH Outfall Bacteria Results

As shown in **Figure 14**, the DCR/DPH results are consistently higher than the UV effluent results. Even when accounting for the days when the pilot system was partially or fully offline, the end of pipe results are consistently higher than the flow leaving the UV treatment system. Setting aside the timing, test method, and potential for human error, there are several potential explanations for this. First, it's possible that the weir walls were not fully sealed around the sides or the bottom of the culverts and allowed some portion of flow from one or both of the culverts to bypass treatment and flow directly to the outfall. Second, it's possible that the accumulated sand, seaweed, algae, and debris piled up in the culverts between the weir walls and the outfall created pools of stagnant water that grew bacteria. The challenges with cleaning these portions of the culverts are discussed further in Section 4. Neither of these potential explanations were tested during pilot operation so it is not possible to state for certain the reason(s) for the discrepancy in results shown in **Figure 14**.

OPERATIONAL PERFORMANCE AND FINDINGS

In addition to the effectiveness of UV treatment, another key objective of the UV Pilot was to gain a better understanding of the operation of a UV treatment system. At a high level, the UV disinfection itself presented the lowest operational and maintenance related issues. The bigger challenge operationally came from the influence of tidal / oceanic flows and first flush conditions within the stormwater culverts. Several operational challenges of the UV Pilot system are summarized below along with potential design considerations that could mitigate those challenges in a full-scale system.

Tidal and Ocean Impacts

Tidal and ocean impacts were expected prior to the UV Pilot due to the proximity of the ocean and the high tides that intrude up the culverts. During most high tides, the peak water level exceeded the height of the 3-foot weir walls. However, the extent of the tidal impacts was greater than expected. At the initial startup of the pilot, the pumps became critically clogged within one day due to large amounts of seaweed being washed up and over the weir walls. Incidentally, the initial startup occurred shortly after a large Nor'easter offshore that likely increase the volume of seaweed washing up on King's Beach. The startup had to be temporarily paused until a solution was identified to reduce seaweed washup. Ultimately, metal screens with 0.5-inch openings were installed in both culverts downstream of the weir walls to protect the pilot equipment from seaweed. The screens helped significantly and the pilot would not have been successful without them; however, seaweed issues persisted throughout the pilot. **Figure 15** shows a view of the screen from the upstream perspective.

Figure 15. Culvert Screen Installed to Manage Seaweed

Regular maintenance was conducted to remove seaweed from the pumps, piping, UV system, and screens to ensure equipment could operate continuously. Additionally, regular beach raking (2-3 times per week) was completed on the Swampscott side of King's Beach to clear seaweed and debris. However, the beach raking did not include the Lynn side of King's Beach or the area right in front of the outfalls since this area falls under DCR's jurisdiction. Over the course of the summer, the volume of seaweed deposited on the beach varied widely. It's likely that ocean currents, storms, and other external factors offshore have a strong impact on seaweed levels; yet it's clear that seaweed is a persistent issue and must be accounted for in a permanent UV facility. **Figure 16** is an image of the Swampscott outfall full of seaweed taken during the UV Pilot. Swampscott had to remove this seaweed with backhoe.

Figure 16. Seaweed Buildup in Swampscott Outfall

Besides seaweed, the high tides also brought algae, organic debris, and sand into the pilot system. While these proved to be less significant hurdles than seaweed, they still required regular maintenance. Over time, the UV influent and effluent tanks accumulated debris (seaweed, algae, and organic debris) at the bottom, which had to be cleaned out periodically. Separately, sand washed up from high tide piled up significantly in both culverts between the screens and the outfalls. Sand buildup was more significant in the Lynn culvert as there was no flow discharged during normal operation. Sand levels fluctuated, but in general, made access to the culvert from the ocean side extremely difficult. The sand also impacted flows and water levels in the culverts since the piles created pools of stagnant water that discharged slowly or only when additional flows from upstream were introduced. Cleaning of this section of culvert would be time consuming and tedious with limited access, not to mention that the sand and debris would likely return at the next high tide. **Figure 17** shows the Lynn culvert approximately half full of sand and debris during the UV Pilot.

Overall, the UV Pilot encountered significant impacts from regular high tides, necessitating metal screening to be added, requiring frequent and regular maintenance to remove seaweed, algae, and organic debris, and complicating access and hydraulics in the culverts. However, despite the operational and maintenance challenges, UV appeared to maintain its effectiveness in the presence of tidal impacts. To reduce the tidal impacts in a permanent facility, engineered solutions such as tide gates could be considered to more effectively protect the culvert from high tides and associated debris.

Figure 17. Sand Buildup in Lynn Outfall

Wet Weather Impacts

Wet weather impacts on UV Pilot operation were observed throughout the summer. As discussed in the **Data and Results Section,** wet weather, especially at the start or first flush of the event, brought with it large amounts of solids and debris down the culverts from street runoff, catch basins, and other stormwater inlets. In addition to natural debris, such as leaves, sticks, and sediment, there was a significant amount of trash observed in the culverts, including plastic bottles, aluminum cans, toys, and personal items. **Figure 18** is a picture of debris floating in the culvert upstream of the weir wall after a wet weather event. The large debris usually had to be removed from the culverts and the UV influent and effluent tanks after the storm. In a permanent UV facility, additional engineering controls could be installed upstream of the treatment system to reduce the amount of solids and debris, such as screens, sediment forebays, or other pretreatment systems.

Additionally, as expected, wet weather was observed to increase flow rates in the culverts and raise water levels. The 3-foot weir walls and the metal screens installed as part of the pilot contribute head loss to the culvert flows, which has a significant impact when flow rates are high (e.g. wet weather conditions). During the pilot, head loss and backup were observed to be caused by clogging/blinding of the screens, particularly on the Swampscott side that was receiving the discharged UV effluent.

Figure 18. Wet Weather Debris in Culvert

The clogging/blinding of screens was mostly caused by seaweed and other debris getting stuck in the screen mesh. Lynn and Swampscott performed regular cleaning of the screens, especially prior to a wet weather event to reduce the risk of backup; however, the cleaning did not remove all the debris. The cleaning was difficult given the limited access to the screens and the pooled water and sand accumulated on both sides. In a permanent UV facility, further hydraulic analyses should be conducted on the culverts. However, in a permanent facility the flow could be diverted to a side channel for treatment to limit the impact on the natural flow in the drains and reduce the risk of head loss and backup in the culverts.

Monitoring and Controls

The equipment used in the UV Pilot relied largely on manual monitoring and controls, which limited reliability and adaptability. The pumps were equipped with level floats for activation and Variable Frequency Drives (VFDs) that automatically controlled the flow rates for the pumps on each culvert, as shown in **Figure 19**. However, there were no automatic alarms to alert any issues (e.g. clogging, temperature, vibration, etc.). There was also no way to monitor or control the pumps remotely. To obtain the full suite of desired monitoring and controls for the pump package, the cost would be prohibitive for a temporary "pilot" setup. A permanent facility could be set up with continuous monitoring and SCADA controls.

Figure 19. Flow Meter on Pump Discharge

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

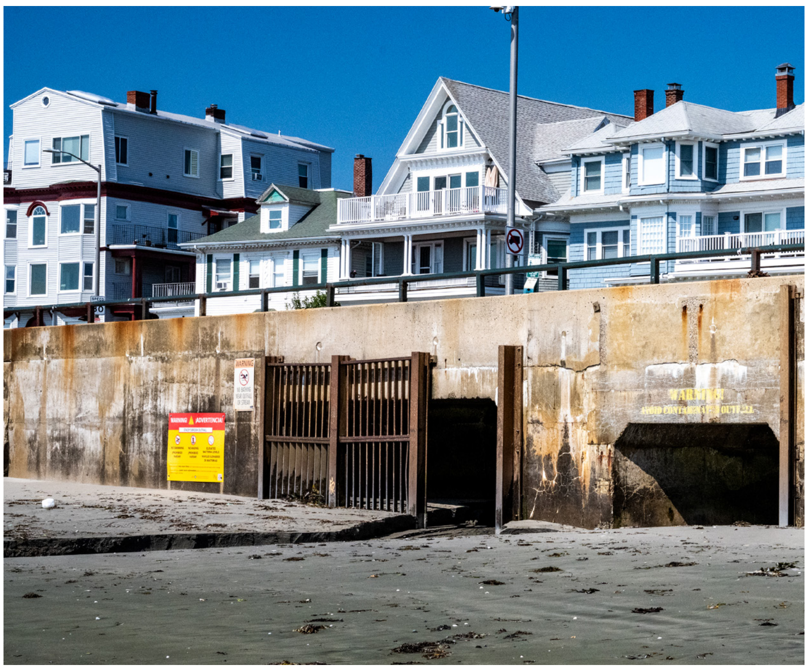
Overall, the UV Pilot was effective and successful in meeting the objectives originally set out by the UV Pilot Team. Key takeaways from the UV Pilot testing include:

- UV effectively treats day-to-day dry weather stormwater flows from the Lynn and Swampscott culverts.
- The effectiveness of a UV system is reduced during wet weather events, particularly in the first 24 hours, due to increased turbidity in the flow.
- UV can reduce the number of days King's Beach is closed during a summer season even though there are other factors affecting beach closures beyond the discharges from the subject outfalls.
- There are numerous operation and maintenance challenges that need to be addressed with engineering controls in the design of a permanent facility.

Recommendations

Lynn and Swampscott need to determine whether or not to proceed with next steps toward implementation of a permanent UV stormwater treatment system. Should the decision be made to pursue a permanent facility, the next steps would include the following:

1. **Additional Data Collection:**
    a. <u>Conduct continuous flow and level monitoring</u> in both culverts for up to 12 months to increase the understanding of the dry and wet weather hydraulics and seasonal variability.
    b. <u>Perform targeted wet weather testing for UVT and turbidity</u> throughout multiple additional storms to supplement the data collected during the UV Pilot and increase the understanding of the duration of suppressed UV effectiveness during various types of wet weather.
    c. <u>Perform sediment analysis of material deposits</u> in the Lynn and Swampscott culverts within the approximately 50 feet from the mouth of the outfalls to test for bacteria and other contaminants.
2. **Feasibility Study and Preliminary Design:**
    a. <u>Refine initial UV facility concept</u> developed during the 2023 King's Beach Study, including sizing, capacity, and configuration.
    b. <u>Preliminary design of tide gates, screening, and pre-treatment systems</u> to mitigate operation and maintenance challenges.
3. **Permitting and Coordination with Regulators:**
    a. <u>Engage regulators to discuss results of UV Pilot</u> and next steps towards a permanent UV facility.
    b. <u>Review permitting requirements and begin compiling permit documentation</u> and coordinating with relevant agencies.
4. **Siting Analysis and Public Outreach:**
    a. <u>Review potential sites for a permanent UV facility and perform public outreach</u> to narrow down to a recommended location.
5. **Funding Approach:**
    a. <u>Refine cost estimate and identify potential funding source(s) and approach(es)</u> for a permanent UV facility.



Acknowledgements

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APPENDIX A

ADDITIONAL UV PILOT WATER QUALITY DATA

APPENDIX A: ADDITIONAL UV PILOT WATER QUALITY DATA

Total Chlorine

Outside of the sample data relevant to the UV Pilot objectives, several other water quality parameters were tracked for informational purposes. Daily total chlorine measurements shown in Figure A.1 were taken from each culvert. The total chlorine concentrations in both culverts are higher than what would typically be expected from stormwater flows. The concentrations also appear to increase during wet weather periods. Though the exact source of chlorine is unknown at this time, it is possibly coming from a leak in a potable water main in either Lynn or Swampscott that is contributing to these elevated concentrations. This was investigated during the early part of the pilot but no definitive sources were identified.

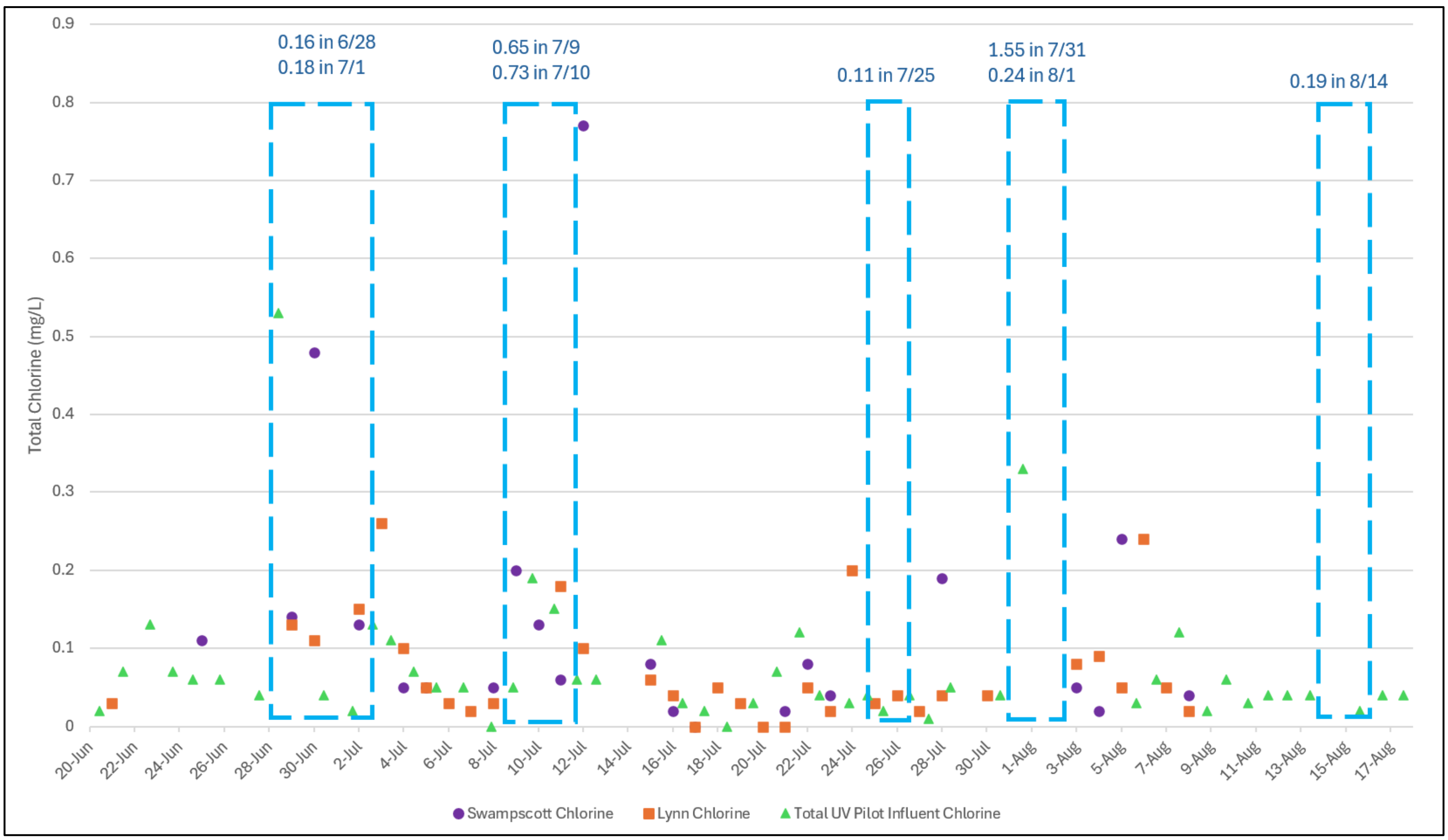

Figure A.1 - Total Chlorine Concentrations from Lynn and Swampscott

Ammonia

Daily ammonia measurements shown in Figure A.2 were taken from the combined untreated flow into the UV treatment system. Ammonia is a chemical indicative of sanitary sources and is a common sample parameter used to identify illicit sources in a stormwater system. Ammonia can also be harmful to aquatic ecosystems. The data shows that the ammonia concentrations in the Lynn and Swampscott culverts are consistently low but elevate significantly during the beginning of wet weather events.

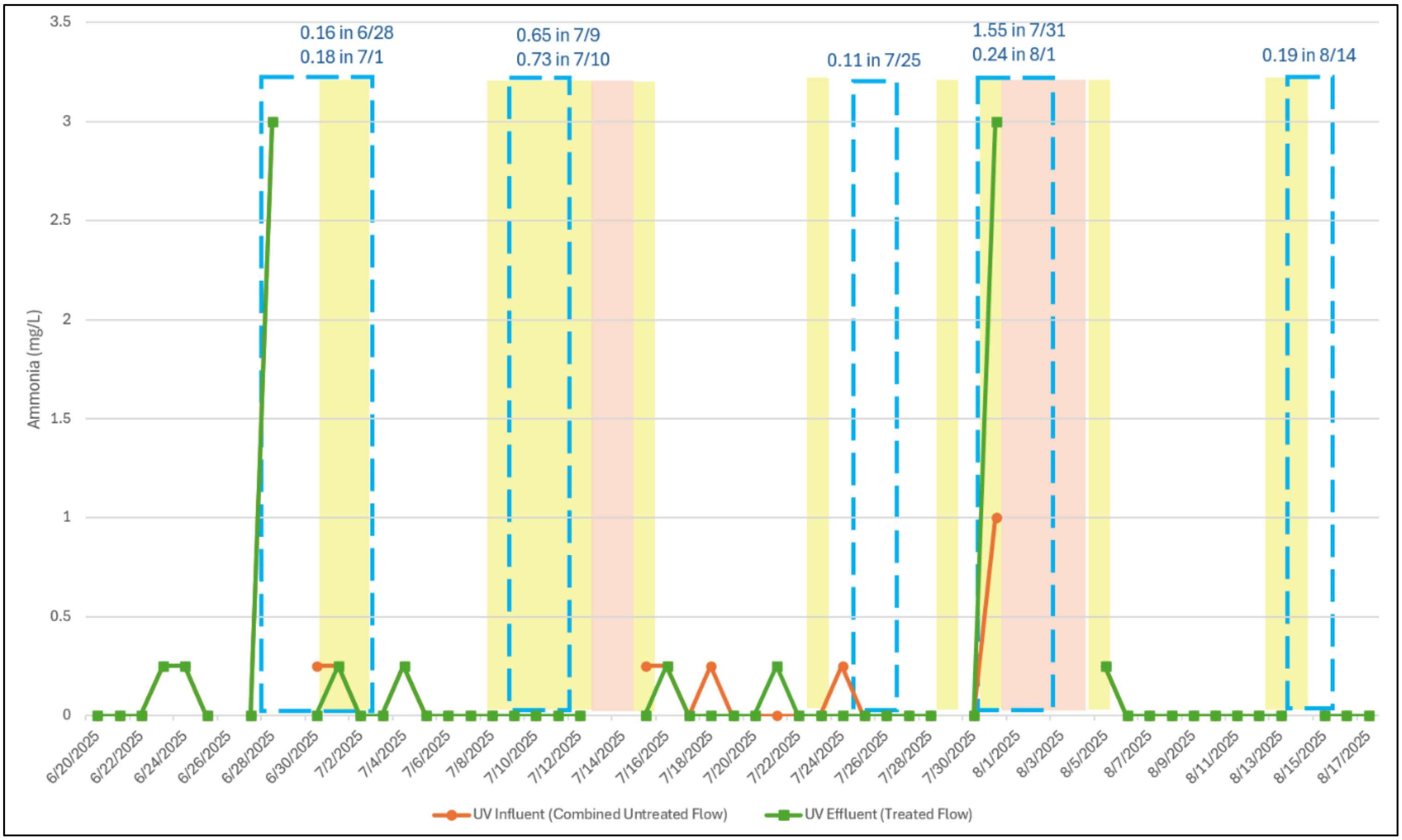

Figure A.2 - Ammonia Concentrations in UV Pilot Influent and Effluent

Temperature

Daily water temperature readings in degrees Fahrenheit were taken of the combined flows from Lynn and Swampscott are shown in Figure A.3. Water temperature is typically representative of environmental conditions such as air temperature, rainfall, and land use. The data shows water temperatures fluctuations from approximately 61-72 degrees Fahrenheit over the duration of the pilot. It appears that higher temperatures were logged during wet weather events and lower temperatures during wet weather.

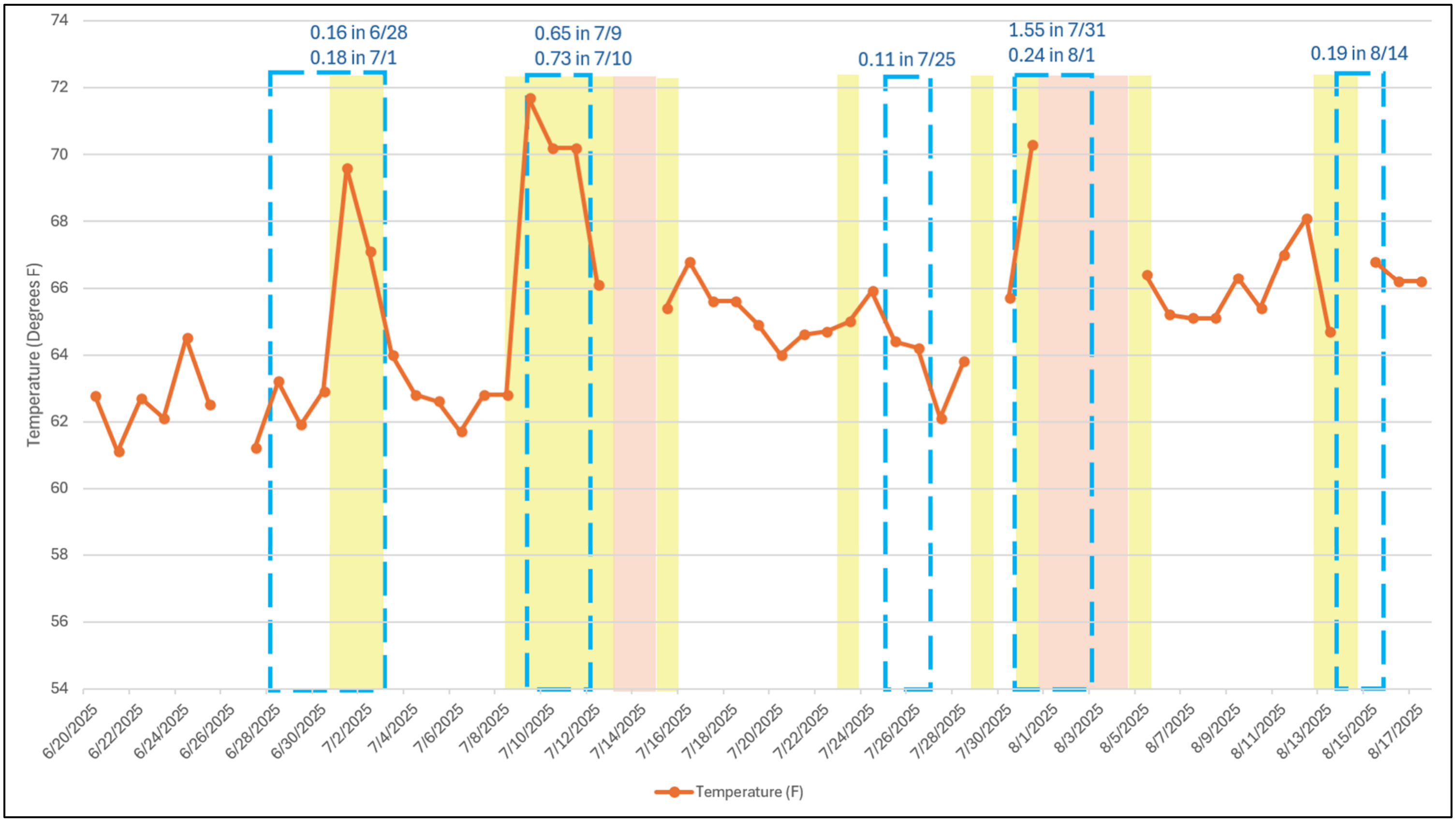

Figure A.3 – Temperature Readings of Lynn and Swampscott Combined Flows

Conductivity

Daily conductivity readings taken from the combined flows from Lynn and Swampscott are shown in Figure A.4. The units are in millisiemens per centimeter. Conductivity measures the concentration of dissolved ions, like salts and metals. Overall, the conductivity readings from Lynn and Swampscott are higher than typical stormwater systems, but this is likely a result of saltwater intrusion from the ocean.

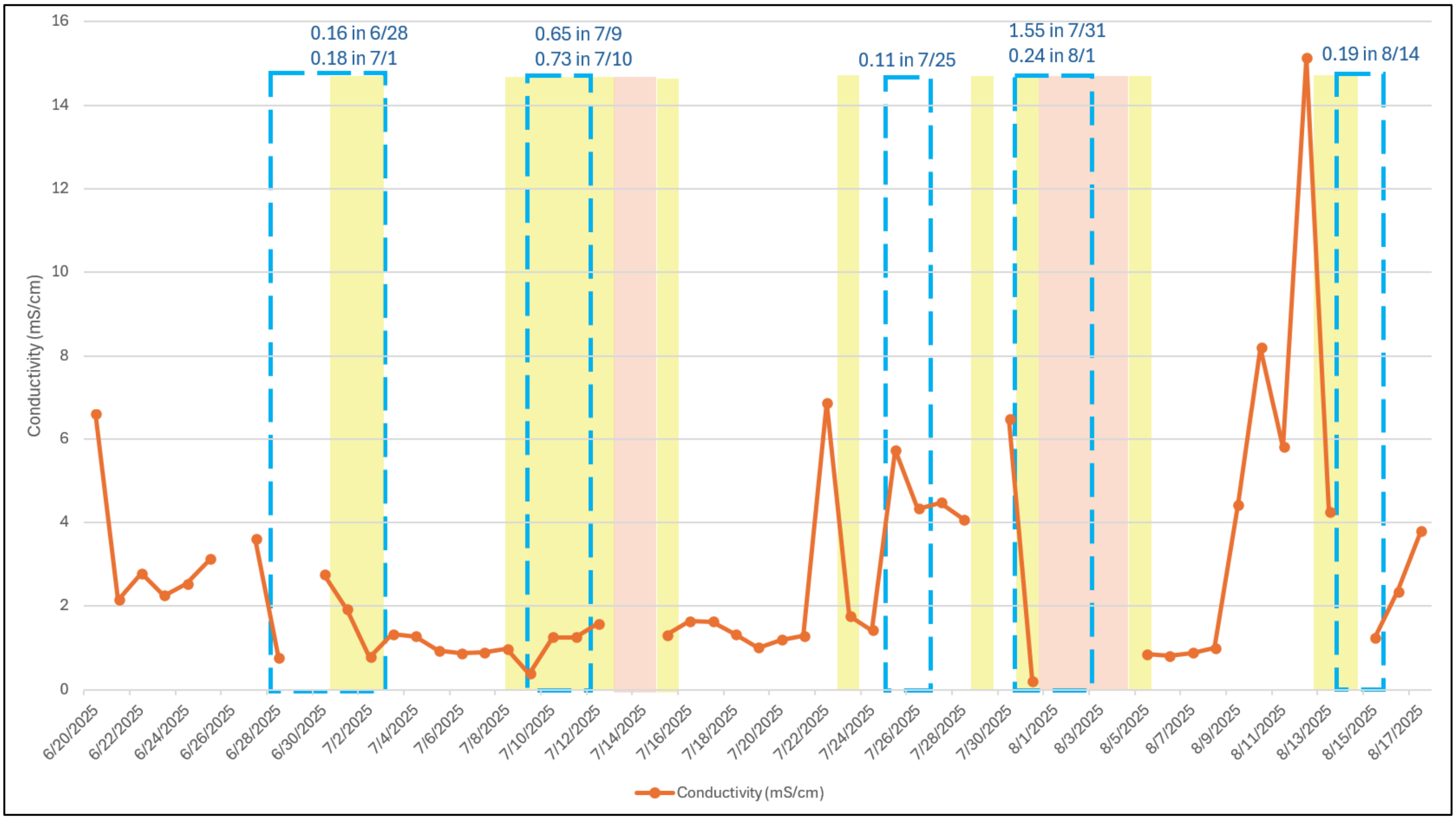

Figure A.4 - Conductivity Readings from Lynn and Swampscott Combined Flows

pH

Daily pH readings taken from the combined flows from Lynn and Swampscott are shown in Figure A.5. PH levels in stormwater above or below 7.0 can indicate influences of pollutants with acidic or basic materials. Based on the results shown in Figure A.5, the pH in Lynn and Swampscott flows is pretty close to neutral and fluctuates between approximately 6.4 to 7.5.

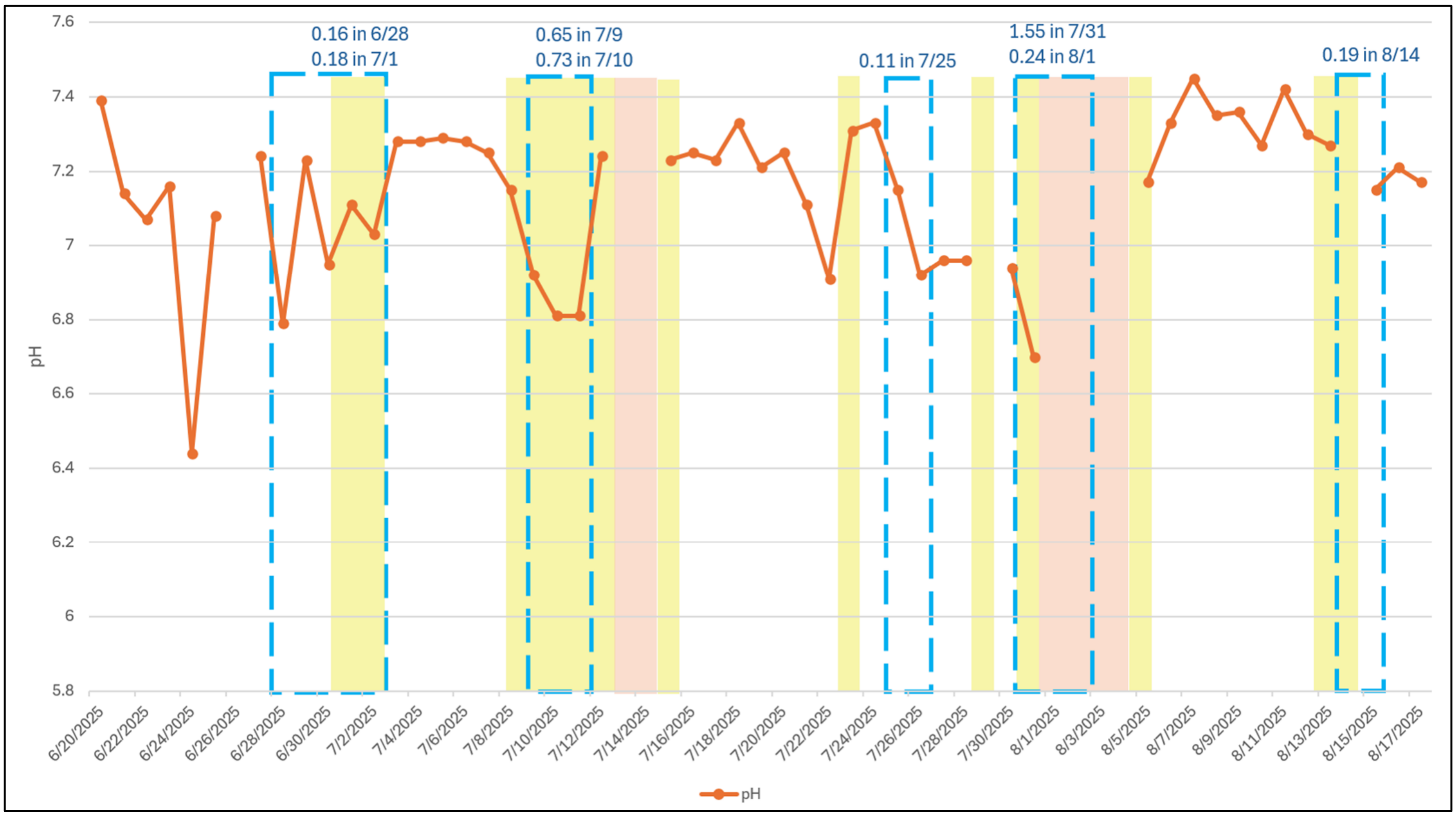

Figure A.5 - pH Readings from Lynn and Swampscott Combined Flows

APPENDIX B

AIR QUALITY DATA

APPENDIX B: AIR QUALITY DATA

Air quality data measuring particulate matter (less than 2.5 micrometers in diameter / pm2.5) was collected throughout the duration of the summer by three PurpleAir sensors installed in the vicinity of the project area. Two sensors were installed in close proximity to the UV Pilot equipment, most notably the diesel generator. These were located at private properties at 2 Humphrey Street and 27 Ocean Street. The third sensor was installed at the Swampscott Town Hall approximately 0.25 miles from the UV treatment equipment to serve as control/background for external factors, such as wildfires, that may impact air quality. The daily average particulate matter concentration in parts per million (ppm) for each sensor is shown in Figure B.1 for the duration of the pilot operation from June 19 to August 18, 2025.

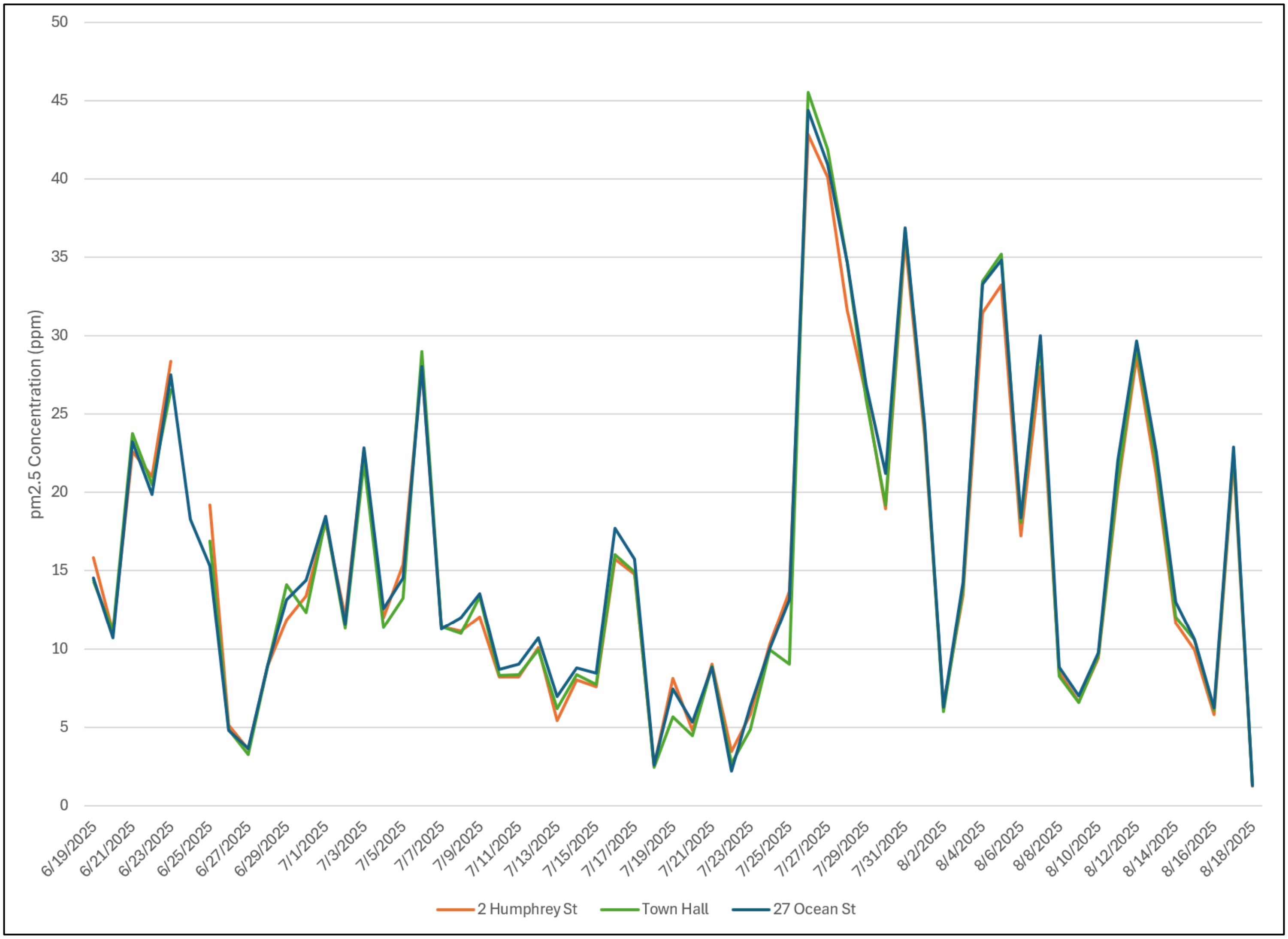

Figure B.1 - Air Quality Data

The air quality data shown in Figure B.1 does not appear to indicate elevated particulate matter in the two sensors located near the UV Pilot project site. There are daily variations across all three sensors, but these are likely due to external environmental and meteorological factors that impact air quality.

APPENDIX C

UV PILOT KINGS BEACH TESTING

APPENDIX C: UV PILOT BEACH TESTING

The UV Pilot sampling team collected samples at King's Beach during the operational period of the pilot. the samples were collected on the Swampscott side of the beach just east of where the two culvert outfalls discharge. The sampling team collected the samples during low tide conditions; however, they were not taken at the same time as the DCR/DPH samples. Figure C.1 compares the sampling team's results with the DCR/DPH results taken at the Eastern Avenue testing location.

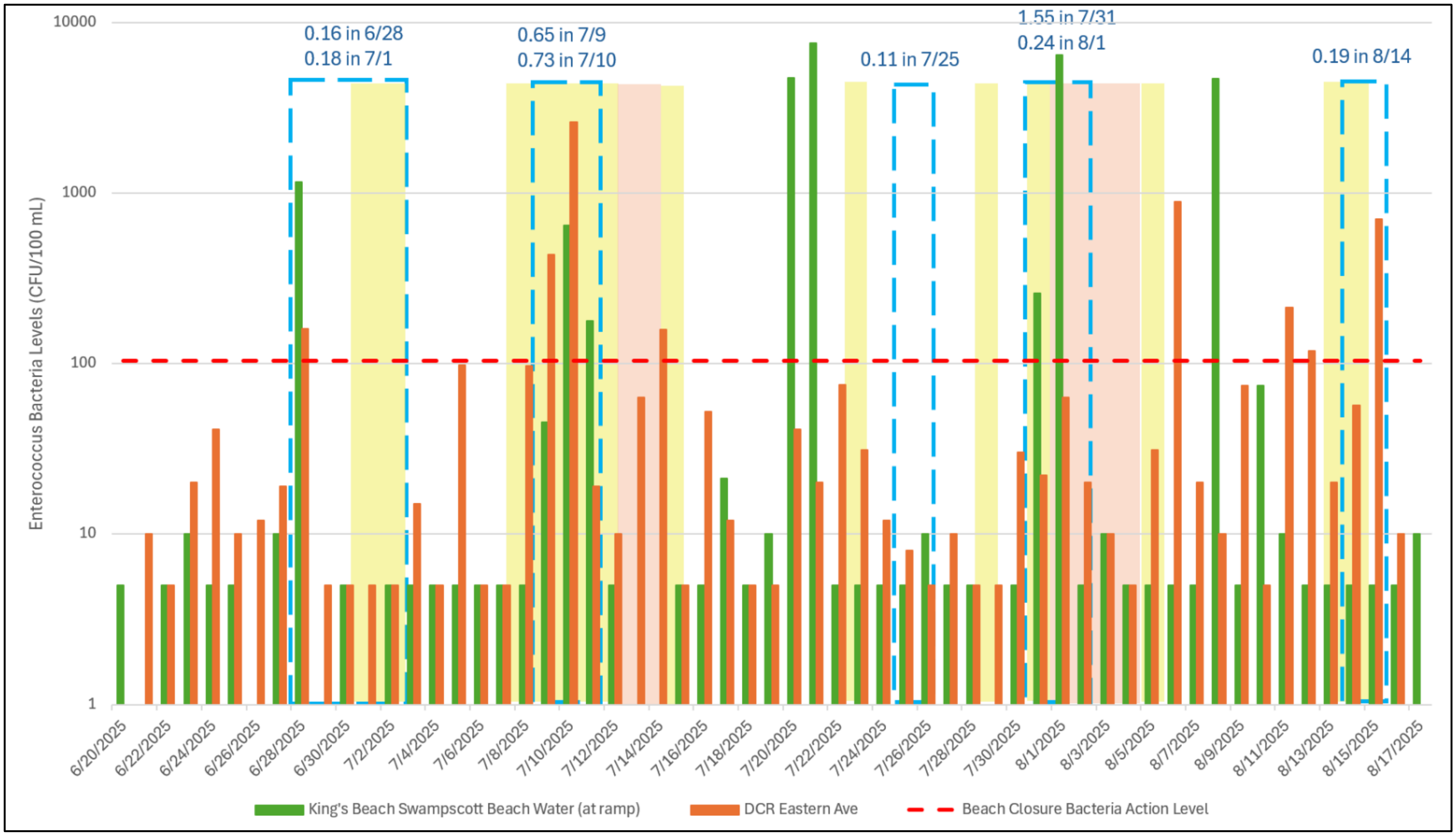

Figure C.1 - UV Pilot and DCR/DPH Beach Testing Results

Figure C.1 shows that while the two sets of results are highly variable, there is some correlation observed. Both sets of data align fairly well during the beginning of the testing period between June 20 and July 11. Both sets show extended periods where the bacteria concentrations are below the DCR/DPH threshold as well as exceedances above the threshold during the beginning of the first two wet weather periods. However, later in the testing period, there is more variation. There are several instances when the UV Pilot samples returned results above the DCR/DPH threshold while the DCR/DPH samples were below. In other instances, the opposite is observed. Overall, there are many factors that may contribute to the variability between these two datasets, including location, timing, and test method among others.