MRWC

# MERRIMACK RIVER WATERSHED COUNCIL

## 2022 WATER QUALITY REPORT

**Ferry Park**

West Newbury

# EXECUTIVE SUMMARY


The Merrimack River Watershed Council's volunteer water quality monitoring program collects water quality data at 13 sites along the main stem of the Merrimack River, from Manchester, NH to Newburyport and Salisbury, MA. Data on pH, salinity, total dissolved solids, conductivity, and temperature were collected once or twice a month between January and December 2022. For all monitoring sites, the conditions for pH, salinity, total dissolved solids, conductivity, and temperature were within recommended limits for human use and/or are supportive of aquatic ecosystems.

In addition to the physical parameters above, grab samples were collected and analyzed for fecal indicator bacteria once a month or twice a month at each site. This sampling schedule allowed to test for bacteria presence more regularly through the recreational months of the year. The presence and concentration of *E. coli* and *Enterococcus* (two types of fecal indicator bacteria) show whether and to what extent a water body has been contaminated with fecal matter. The presence of fecal contamination in local water bodies (from stormwater runoff, illicit sewer connections and legal CSOs) presents a serious threat to both human and ecological communities. Although conditions in the Merrimack are safe most of the time, occurrences of high bacteria levels suggest that recreational activities, such as swimming or boating, may be unsafe at certain times.

Rainfall records show that 2022 was a relatively dry year, with the Newburyport region experiencing a wetter July than normal, but still within the yearly average.

During our regular monitoring program, 27 out of 177 *E. coli* samples (15%) were elevated, indicating that the water was unsafe for recreational use, while for *Enterococcus*, 31 samples out of 125 samples (23%) were elevated, indicating that the water was considered unsafe for recreational use. Most of the elevated samples occurred during dry weather events for *Enterococcus*, but the opposite for *E. coli*. This could indicate another contamination source aside from CSOs at some sites. However, further investigation is needed to determine issues at specific locations. Our work includes working with scientists at the Boston University School of Public Health to model water quality conditions in the river and to get a better understanding of the health risks associated with CSO events.

MRWC is using these data to work towards solutions that will improve the conditions in the watershed. This will help municipalities develop watershed-based plans including green infrastructure projects to capture stormwater runoff and reduce nonpoint source pollution, and advocating to ensure upcoming federal money reaches our communities to improve combined sewer systems.

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# HOW TO USE THIS REPORT

This report is written to provide information in a scientific format, but that is approachable for the general audience. Depending on your purpose for viewing the report, you may read the report from start to finish, or visit each of the standalone sections to find only the information you are looking for. Below is a guide to each section.

## Introduction

This section provides information about how we run our program and why, including explanations on where bacteria in the Merrimack come from, and how we work to understand them with our sampling program.

## Environmental Conditions

This section explains the conditions within the watershed during 2022 that provide context for our sampling. This includes how much rain fell and streamflow patterns in the river in 2022 and how that compares to other years, as well as how much CSO volume contributed to the river and where. By understanding the context within which we collected data, we can draw better conclusions about our findings.

## 2022 Monitoring Program Results

This section provides and explains all of the data we collected in 2022 for all sites along the Merrimack River. Each physical/chemical parameter (pH, specific conductivity, salinity, total dissolved solids, and temperature) is described in a two-page summary. Bacteria conditions for the entire Merrimack are described in an eight-page summary.

## Regional Profiles

If you only want to learn about bacteria conditions in the area where you live, skip to this section. Here we interpret bacteria results in five regions by grouping our sampling sites and analyzing results according to where those sites are located relative to known potential contributions of bacteria to the river, such as large urban areas and CSO outfalls.

# INTRODUCTION

## Who is MRWC

The Merrimack River Watershed Council (MRWC) was founded in 1976 to address the issue of pollution in the Merrimack River. At the time, the river turned green, red, or orange, depending on the color dye that was used in the mills that day. While the dyes are gone, the river still faces significant threats. Current issues that directly impact water quality in the Merrimack are related to increased human activities across the watershed and aging sewer infrastructure, which can alter physical, chemical, and bacteria conditions in the Merrimack River.

## Collecting Data to Improve Decision Making

MRWC monitors water quality at sites along the main stem of the Merrimack River, from Manchester, NH to Newburyport and Salisbury, MA. We collect data on pH, salinity, total dissolved solids, conductivity, temperature, and concentrations of two types of fecal indicator bacteria. **While there are many types of bacteria, we sample for Escherichia coli (*E. coli)* and *Enterococcus* – these are called indicator bacteria (FIB) and they tell us if the river has been contaminated with fecal matter and to what extent.** We care about fecal contamination specifically because it presents a serious threat to both human and ecological communities and can make people sick. High fecal indicator bacteria (FIB) levels indicate that recreational activities, such as swimming or boating, may be unsafe. **Throughout this report we will use "bacteria" for brevity but are referring to the fecal indicator bacteria of *E. coli* and *Enterococcus.***

### What about drinking water?

The Merrimack River is the second-largest surface-based drinking water source in New England, with more than 600,000 people getting their drinking water from the river. However, drinking water is heavily treated and it is unlikely that water coming out of the tap from city supplied water will be contaminated with bacteria. A study by the US Geological Survey did not find contaminants at reportable levels in treated drinking water, despite finding some in source water on the Merrimack. This suggests that water treatment methods are working correctly to eliminate contaminants from CSOs in drinking water.[30]

While we know there are periods when bacteria concentrations in the river are higher than the level considered safe for recreation[25], we also recognize that concentrations are below this level much of the time. There is still a major gap in understanding when, where, and for how long the river is unsafe to use after CSOs, rain events, or when snow is melting. The river monitoring program at MRWC aims to fill that gap in understanding. By collecting data consistently, we can better understand how changing environmental conditions and increasing human impacts affect the water quality of the Merrimack River. We use our data to inform residents about the conditions of the Merrimack; advocate for the right solutions to improve conditions; inform the development of regulations; remediate pollution hot spots; support litigation against polluters; and promote pollution reduction projects.

***What is a CSO combined sewer overflow (CSO)?***

*A combined sewer system collects rainwater and wastewater into one pipe. Under normal conditions, it transports all of this water to a sewage treatment plant before discharging into a water body, keeping our rivers clean. Sometimes, during heavy rainfall and snowmelt, the volume of the combined storm and wastewater can exceed the capacity of the system and it discharges directly to nearby water bodies.* ***Learn more at merrimack.org/cso***

## Understanding Sources of Bacteria

Bacteria in the Merrimack typically come from three sources: nonpoint sources (like stormwater runoff), CSOs, and illicit sewer connections. By collecting water quality data over time and at different sites, we can see trends in bacteria concentrations that may help us to understand the source. While this sounds relatively simple, the process of identifying the source of contamination is complex. Bacteria concentrations vary greatly, and any given location in the river might receive bacteria from more than one source. Bacteria also flow downstream with the current (which can move fast some days and slower others), and rainfall is a driver for both nonpoint sources and CSOs, making these sources hard to differentiate. The methods we use to quantify bacteria only count living bacteria. Water temperature, exposure to light, salinity and other environmental conditions can affect how quickly bacteria die off – those that are not living are not counted. These conditions are constantly changing, making it difficult to compare the results of one day of sampling to another during data analysis.

To see trends in the data and determine the source(s) of bacteria, a large dataset is required. To build this dataset, MRWC collects samples at the same locations every two weeks, year-round, and will continue to monitor for many years into the future. Already, we can see trends in the data as outlined in this report, and we are working with communities to resolve known and suspected sources of fecal contamination. For example, we know CSOs happen because of rain events. Sites that have high bacteria concentrations during both wet and dry weather conditions are likely impacted by an illicit sewer connection, which contributes bacteria to the river whether or not it is raining. In 2020, we found that our sample site in Methuen falls in this category. The EPA recently investigated the area, found the source of pollution, and has been working with the City of Methuen to fix this issue. This demonstrates how impactful data collection can be.

# BACTERIA SOURCES IN THE MERRIMACK RIVER

## NONPOINT SOURCES:

When rain runs over the land into rivers, it picks up and carries bacteria and other pollution. This might be animal waste from wildlife, your dog, or manure spread on agricultural fields. Wildlife that live in/on the Merrimack contribute fecal matter directly into the river.

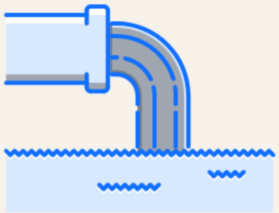
In natural environments, rain falls on vegetated areas and seeps into the soil. As the water flows to the river, some pollutants and bacteria can be filtered out of the water by natural processes.

In urban areas, rainwater and snowmelt runs over parking lots and other impervious surfaces, where this natural filtration process doesn't happen.

## POINT SOURCES:

### Combined Sewer Overflows

Combined Sewer overflows (CSOs) occur when the combined sewer system that collects rainwater runoff, domestic sewage, and industrial wastewater into one pipe overflows.



Under normal conditions, these systems transport all the water to a sewage treatment plant. When the system works, it is best for the environment and our water bodies because it treats both stormwater and wastewater.

During heavy rainfall and snowmelt, the volume of combined storm and wastewater can exceed the capacity of the system. When this occurs, untreated stormwater and wastewater discharge directly into the Merrimack River.

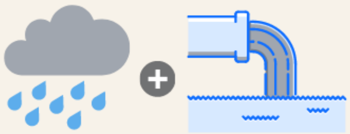
### Illicit sewer connections

Illicit sewer connections are when older septic system or sewer pipes are leaking or directly flowing into the river.

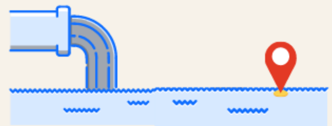
# HOW DO WE TRY TO UNDERSTAND SOURCES OF BACTERIAL CONTAMINATION IN OUR RIVER?

| OBSERVATION IN MONITORING DATA | LIKELY SOURCE OF BACTERIA |
|---|---|

### Time

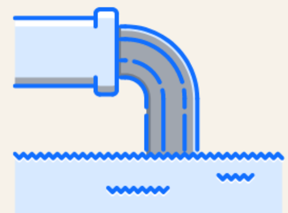


### Space



High bacteria levels after a known CSO event at sites downstream of a CSO outfall are likely caused by that that outfall. However, since nonpoint source pollution also occurs when it rains, we can't know whether high levels of fecal indicator bacteria are caused 100% by nonpoint pollution or a CSO outfall.

### CSO



### Time

### Space

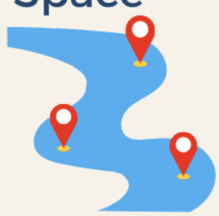
High bacteria levels during all weather events at the same site consistently, are likely caused by an illicit sewer connection.

### Illicit connection

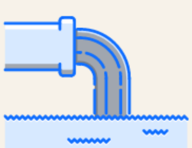
### Time

### Space

and



or



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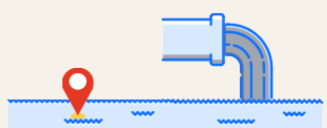
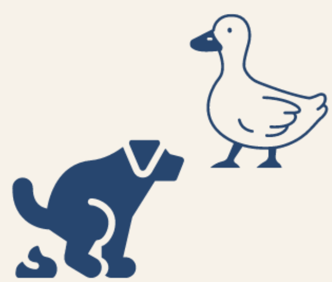


High bacteria levels during or after rainstorms (without a CSO) anywhere in the river or high levels after a CSO at sites upstream of a CSO outfall, are likely caused by nonpoint source pollution.

### Nonpoint source



# Monitoring Approach: Volunteer Powered

MRWC's water quality monitoring program relies on community science. All data are collected by community members who are trained by MRWC staff scientists to gather quality-controlled data in a standardized and reliable way. Each volunteer signs up for a six-month commitment, taking samples monthly at their assigned site (once monthly November-March due to ice conditions in the river and twice monthly in the remaining months). Each volunteer receives a 1.5-hour training session along with a testing kit. Volunteers are responsible for calibrating, using, cleaning, and storing their kit.

MRWC volunteers currently collect water quality data at 13 sites on the main stem of the Merrimack River: 11 sites in MA and 2 sites in NH (See Figure 1 and Table 1). These locations were selected based on a variety of criteria, including their location upstream or downstream of cities (and known CSOs), proximity to popular recreation areas (for activities such as swimming, kayaking, motor boating, and fishing), and the safety of our volunteers when accessing the river.

Of these 13 sites, there are freshwater monitoring locations, which are not influenced by ocean water, and brackish (estuarine) monitoring locations, which experience changing salinity and streamflow due to the tides. Freshwater monitoring locations begin at West Newbury, MA and continue upstream to Manchester, NH, while the brackish monitoring sites begin at the mouth of the river and continue up to Deer Island in Amesbury, MA.

However, tidal influence can be seen as far upstream as the Essex Dam in Lawrence, as the downstream tides can increase water volume upstream, creating a tide-like situation. To ensure that we are monitoring freshwater, we collect water samples within two hours before low tide to ensure that we are monitoring what contaminants are coming downstream, rather than what is coming in from the ocean.

***13 monitoring locations***

***36 volunteers and back-up volunteers***

***Samples collected every 1 to 2 times per month***

***182 samples analyzed in 2022***

*Table 1. Key aspects of MRWC water quality monitoring sites*

| Site | Site Abbreviation | Site Type | Collection Location | GPS Coordinates |
|---|---|---|---|---|
| Manchester - Merrimack Foot Bridge | MMFB | Freshwater | Bridge | 42.979072, -71.469388 |
| Manchester - USGS Gauge | MUG | Freshwater | Shore | 42.948027, -71.463148 |
| Lowell - Pawtucket Blvd | LPB | Freshwater | Shore | 42.6411911, -71.3460007 |
| Lowell - Hunts Falls Bridge | LHFB | Freshwater | Bridge | 42.64649, -71.29923 |
| Dracut - Gravel Pit | DGP | Freshwater | Shore | 42.66614, -71.2417 |
| Lawrence - Bashara Boathouse | LBB | Freshwater | Dock/Shore | 42.6922158, -71.1773753 |
| Methuen - Riverview Blvd | MRB | Freshwater | Shore | 42.7273583, -71.1290352 |
| Haverhill - Lincoln Ave Bridge | HLAB | Freshwater | Bridge | 42.7642673, -71.0345758 |
| West Newbury - Ferry Park | WNFP | Freshwater | Shore | 42.8101931, -70.9963550 |
| Amesbury - Deer Island | ADI | Brackish | Shore | 42.8348062, -70.9068175 |
| Newburyport - Road Bridge | NBRB | Brackish | Bridge | 42.815705, -70.872899 |
| Newburyport - Plum Island | NPIL | Brackish | Dock/Shore | 42.816798, -70.820559 |
| Salisbury Beach State Reservation | SBSR | Brackish | Shore | 42.8218847, -70.8212684 |

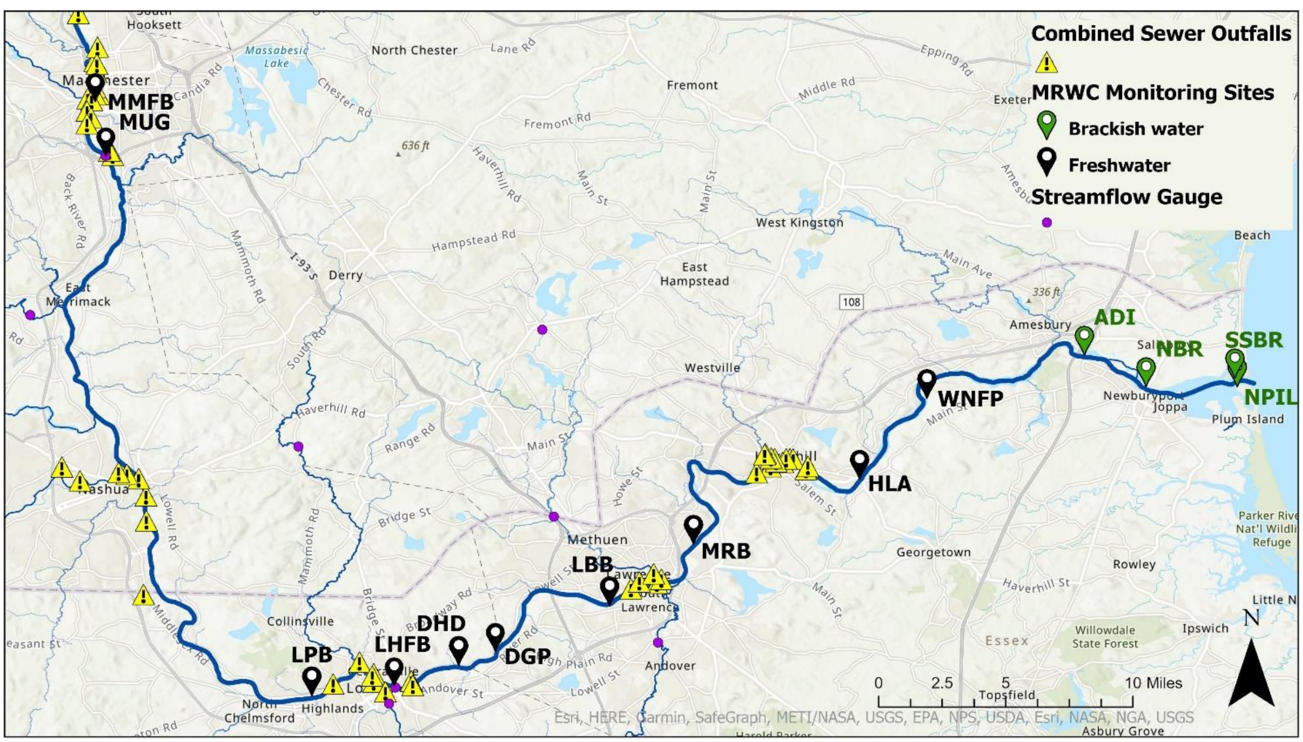



*Figure 1. Map of the MRWC water quality monitoring sites.*

## Field Methods

Water samples and water quality data are collected twice monthly at each site. The river sample is collected either from a bridge, using a rope and bucket, or from the riverbank, obtaining the sample an arm's length into the river. Five physical and chemical water quality measurements are recorded on site using a handheld Pocket Pro+ Multi 2 Tester: 1) pH, 2) conductivity, 3) total dissolved solids (TDS), 4) salinity, and 5) temperature. Prior to testing, the meters are calibrated to ensure accuracy.

At each site, three readings for the physical and chemical properties are collected to ensure precision of the measurements. At brackish sites, volunteers are trained to properly dilute samples and adjust measurement calculations accordingly since the salinity at the most downstream sites can exceed the maximum reading level of the meters. The volunteers then record the measurements on datasheets provided by MRWC, along with observations about the ambient conditions and any nearby activity that may impact the sample.

After collecting the physical and chemical parameters, a grab sample is collected in a sterile sample bottle with a sodium thiosulfate preservative. Once collected, the samples are stored on ice and transported to the MRWC office, where they are then transported to an EPA-approved laboratory for analysis. After large CSO events that occur early in the week (see below for more information on this), volunteers may also be asked to collect daily grab samples for up to four days at all sites to track bacteria levels after CSO events.

After sampling, the datasheets and the bacterial data from the laboratory are reviewed by MRWC staff for reasonableness and completeness before being entered into the MRWC water quality database. The results in that database form the foundation for this report.

***Quality Assurance Project Plan***

*Our field and lab methods follow our Quality Assurance Project Plan (QAPP) which was approved by the EPA and MassDEP. Within our QAPP, we use approved standard operating procedures for sample collection, parameter measurements, and sample analysis.*

*MRWC maintains a partnership with the EPA Region 1 Laboratory, which analyzes all samples collected in our program. The EPA Region 1 laboratory report their results as most probable number per 100 milliliters (MPN/100 mL). However, other labs can report their results as colony forming units per 100 milliliters (CFU/100 mL). These two units are considered interchangeable and only indicate the lab procedure used to determine the results.*

# ENVIRONMENTAL CONDITIONS

Many conditions in the natural and human-made environment contribute to the water quality of the Merrimack River. These conditions influence changes in water quality parameters over time and space and should always be taken into account when interpreting water quality data.

## Rainfall

Rainfall has a large impact on river flows and water quality conditions. In vegetated places in the Merrimack River Watershed, rain falls on the ground and either absorbs into the soil or runs off directly into the river, carrying sediments, nutrients, and bacteria with it. In urban areas, there is very little soil to absorb the rain, so it often flows over paved surfaces into stormwater infrastructure. In most towns and cities, this untreated stormwater runs directly into the river, carrying with it everything that it picks up along the way. However, five regions along the Merrimack have combined sewer systems, which operate differently. In these systems, both stormwater and sewage flow to the wastewater treatment plant and are treated before being discharged into the river. If it rains enough or there is enough snowmelt to overwhelm the system, a CSO occurs, causing a mix of stormwater and sewage to flow directly into the river untreated or partially treated.

Rainfall is measured daily at various rainfall gauges across the region. These gauges are maintained by the National Oceanic and Atmospheric Administration. For this analysis, we selected 5 stations along the Merrimack River in Concord and Manchester, NH and Lawrence, Haverhill, and Newburyport, MA, combined daily values to determine the annual and monthly values, and then compared those values between 2022 and 2021[1].

### Total Rainfall

Rainfall records from 2022 showed a highly dry year, with a 16% decrease in the total average rainfall from 2021. The most downstream site in Newburyport, MA, however, had the only increase in rainfall between years with a 6% increase indicating that the lower watershed received significantly more rain than normal. Further up in the watershed experienced much less rainfall than normal, with Lawrence, MA receiving nearly half the amount of rain that it had experienced the previous year, while Manchester, NH showed little difference from last year (Table 2).

*Table 2. Rainfall data from 5 stations in the Merrimack.*

| Rainfall Station Name | Elevation (m) | Total Rainfall in 2022 (in) | Total Rainfall in 2021 (in) | % Difference |
|---|---|---|---|---|
| CONCORD AIRPORT, NH | 103.1 | 39.9 | 44.0 | -9.3% |
| MASSABESIC LAKE, NH | 77.1 | 44.7 | 45.3 | -1.3% |
| LAWRENCE, MA | 15.2 | 31.3 | 53.5 | -41.5% |
| HAVERHILL, MA | 6.1 | 37.5 | 53.7 | -30.2% |
| NEWBURYPORT, MA | 16.8 | 55.7 | 52.4 | +6.3% |
| **Average** | | **41.8** | **49.8** | **-16.1%** |

## Monthly Rainfall

When comparing the monthly rainfall amounts in Newburyport, the 2022 monthly values show a very high peak in July and a moderate peak in September, both of which are much greater than the 10-year and long-term averages for the sites. The monthly total for July 2022 was 11.8 inches, where the previous highest recorded rainfall in July was 10.7 inches in 1982. This is not a record-breaking number, and though high for this year, the amount of rainfall received in July is not a concern at this time (Figure 2).

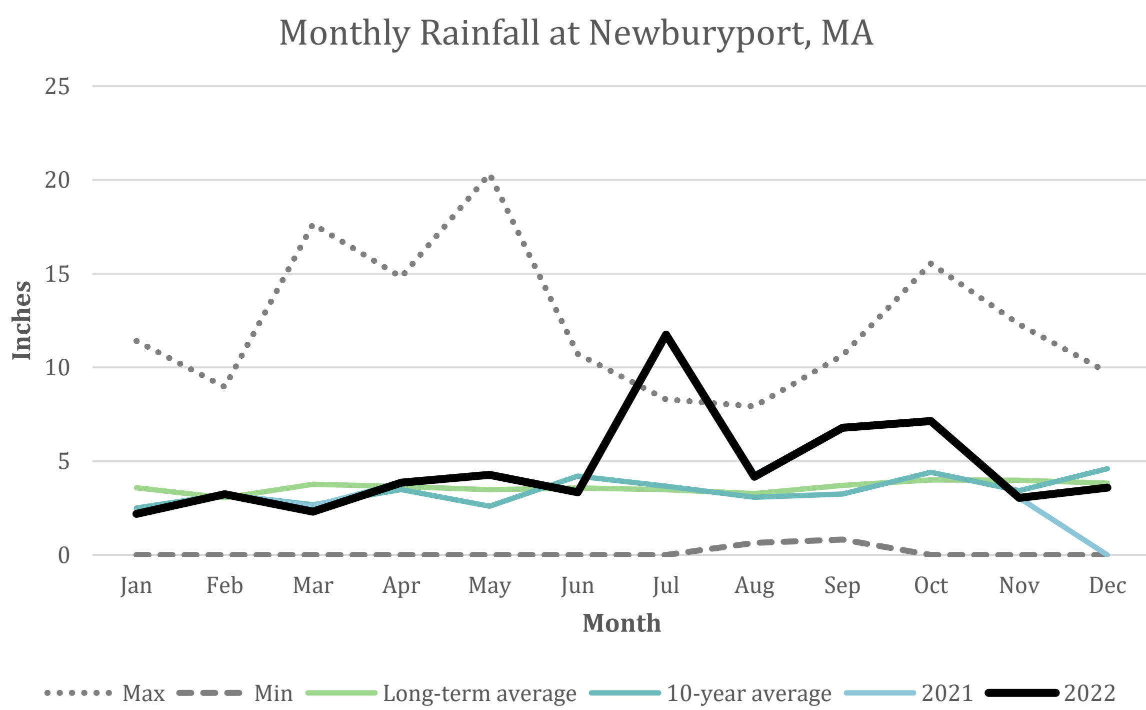



*Figure 2. Average monthly rainfall at Newburyport, MA rainfall station*

## CSO Events Driven by Rainfall

Heavy rainfall causes CSO events in the Merrimack River. Rainfall intensity is the amount of rain that falls in a set time period, usually measured in inches per hour. Combined sewer systems vary in how they respond to rainfall. In Haverhill, for example, rainfall intensity is a good predictor of whether a CSO event will occur or not (Figure 3, left). In Lowell, for example, total rainfall is a better predictor (Figure 3, right). Once a larger dataset is available, further analysis of these patterns could lead to predictions of whether a CSO will occur and where it will occur given rain conditions.

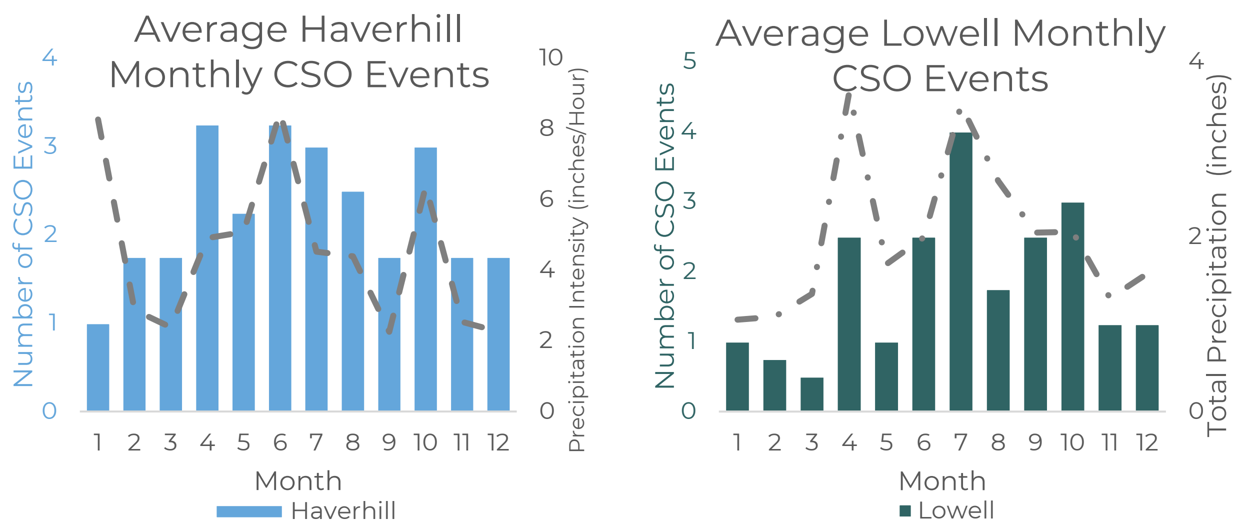



*Figure 3. Average monthly (numeric calendar year order) CSO events and rainfall intensity at Haverhill (left, averaged over 2019-2022) and average monthly CSO events and total rainfall at Lowell (right, averaged over 2019-2022).*

# Streamflow

Streamflow, or the amount of water moving through the river at a certain location, is closely linked to snow melt and rainfall. Once rainfall and snowmelt carry bacteria from the source to the river, streamflow determines how quickly it will move downstream. There are two gauges in the Merrimack that measure streamflow, one in Manchester, NH and one in Lowell, MA. For this report, we analyzed the streamflow in Lowell, MA because it has a longer period of record.

In 2022, the streamflow was higher in the winter months than in the historical maximum average (Figure 4). This is most likely due to ice, as the formation of ice can cause discharge values to appear higher than normal. Therefore, it can be assumed that the higher flow in December through March is attributed to melting ice from higher than average temperatures rather than higher than normal precipitation.

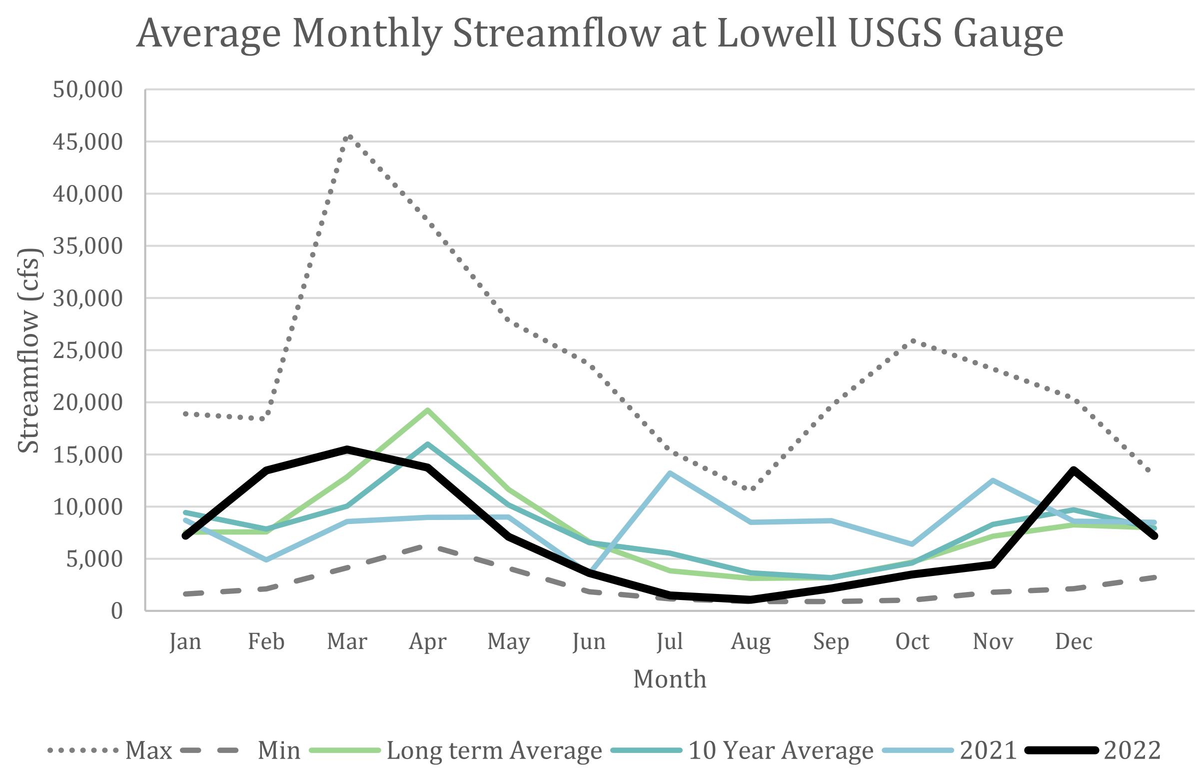



*Figure 4. Average monthly streamflow at the USGS Gauge in Lowell, for different time periods.*

## Combined Sewer Overflows

CSO volumes can fluctuate annually depending on the rainfall and any changes made to combined sewer systems. CSO discharge volume also varies from event to event due to factors like rainfall intensity, rainfall duration, and soil saturation. There are five areas with combined sewer systems on the mainstem of the Merrimack River: Manchester and Nashua in NH, and Lowell, Greater Lawrence Sanitary District (GLSD), and Haverhill in MA.

Based on CSO volume data reported by wastewater treatment facilities in each of the five areas from 2014 to 2022, the year 2022 saw a lower volume of CSOs into the Merrimack with a total of 452 million gallons (Figure , Table 3)[2–5]. This is nearly half the volume of CSOs from 2021, with the lowest occurring in 2015 (Table 3). On average, Manchester and Lowell each contribute an average of 218 million gallons per year, each making up an average of 41% of the total CSO volume (Figure , Table 3). Nashua contributed the lowest annual average with 15 million gallons (Figure , Table 3).

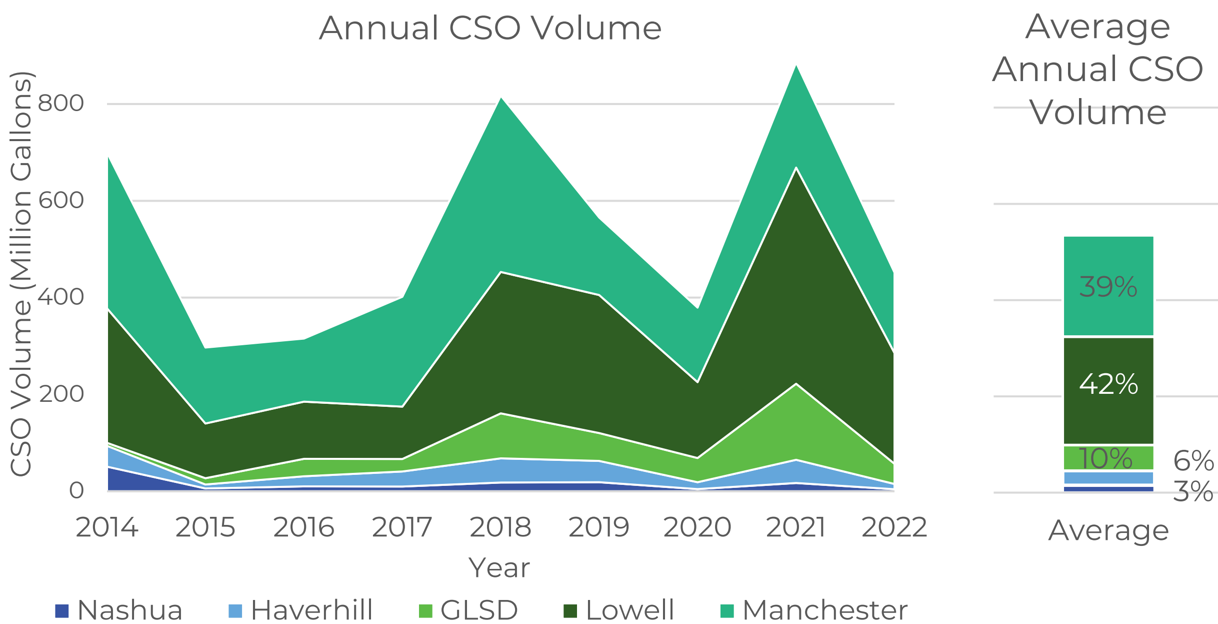



*Figure 5. Average Annual CSO volume from the five combined systems on the Merrimack over 8 years (left) and the average percent contribution from the five systems for 2022 (right).*

In terms of the number of CSO events in each year, Haverhill is the largest contributor historically, contributing 38% of the total CSO events each year (32 events on average, Figure ). Haverhill typically has frequent but small volume events compared to Lowell or GLSD, which have less frequent but larger events. In 2022, we estimated that Haverhill contributed less CSO events with higher volumes than in 2021 (Figure ). Manchester is not included in the CSO event analysis because the city does not report individual events and only reports total annual volumes twice per year, without the dates the CSOs occurred.

*CSO data can be accessed two ways. You can be alerted about CSOs when they are occurring via email. Currently, you must sign up for notifications from each wastewater treatment facility individually. You may also download reports about all CSO events in a month, quarter or year, depending on the facility.* ***All CSO data used in this analysis are available in the appendix.***

***Find out how to access data from wastewater facilities at our website: merrimack.org/cso***

*Table 3. Annual CSO volume by year and combined sewer system.*

| | | | Total Annual CSO Volume (million gal) | | | |
|---|---|---|---|---|---|---|
| **Year** | **Haverhill** | **GLSD** | **Lowell** | **Nashua** | **Manchester** | **Total** |
| 2014 | 43 | 6 | 278 | 51 | 322 | **701** |
| 2015 | 8 | 13 | 113 | 6 | 157 | **296** |
| 2016 | 21 | 36 | 118 | 10 | 131 | **316** |
| 2017 | 31 | 26 | 108 | 10 | 227 | **401** |
| 2018 | 50 | 93 | 292 | 18 | 364 | **816** |
| 2019 | 44 | 58 | 285 | 19 | 160 | **565** |
| 2020 | 14 | 50 | 157 | 5 | 154 | **380** |
| 2021 | 48 | 157 | 447 | 17 | 217 | **886** |
| 2022 | 11 | 42 | 229 | 4 | 116 | **452** |
| **Average** | **30** | **53** | **225** | **15** | **211** | **535** |
| **Percent** | **6%** | **10%** | **42%** | **3%** | **39%** | |

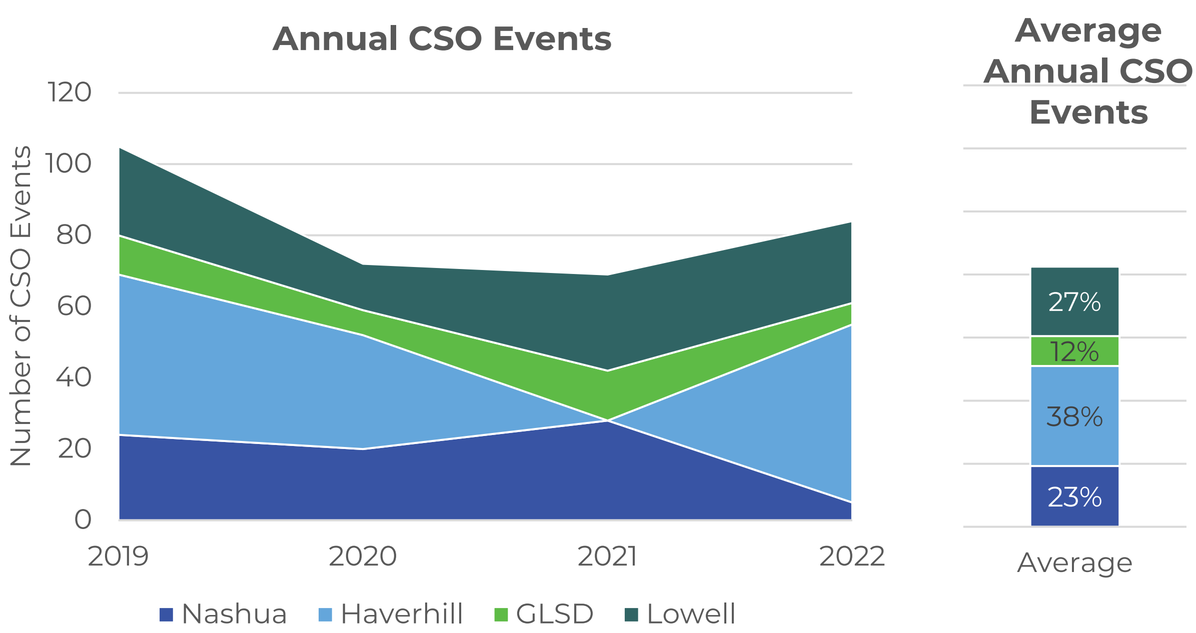



*Figure 6. Average annual number of CSO events from four combined systems on the Merrimack for the past 4 years.*

Monthly trends in CSO volumes are a result of a variety of factors: how much it rains (total precipitation), how hard it rains (intensity) and how long it rains (duration). No single factor fully explains the monthly trends of CSO volumes. We see the highest cumulative volumes in

CSO discharges in the spring (April), when long lasting heavy spring storms occur and summer to early fall (July to September) when short, but heavy thunderstorms occur (Figure ). 2022 was a relatively dry year compared to 2021, and the number and volume of CSOs that occurred were slightly lower than average. September saw a drastic increase in precipitation, which triggered more CSOs than the rest of the year, with Lowell being the largest contributor at almost 93 million gallons released. While precipitation in January, February, and March is historically made up of snow, warmer temperatures from climate change may cause increased rainfall and snowmelt events (and thus CSO events and volumes) in the winter months. Importantly, more intense storms like those seen in July 2021 are predicted to become more common[6,7].

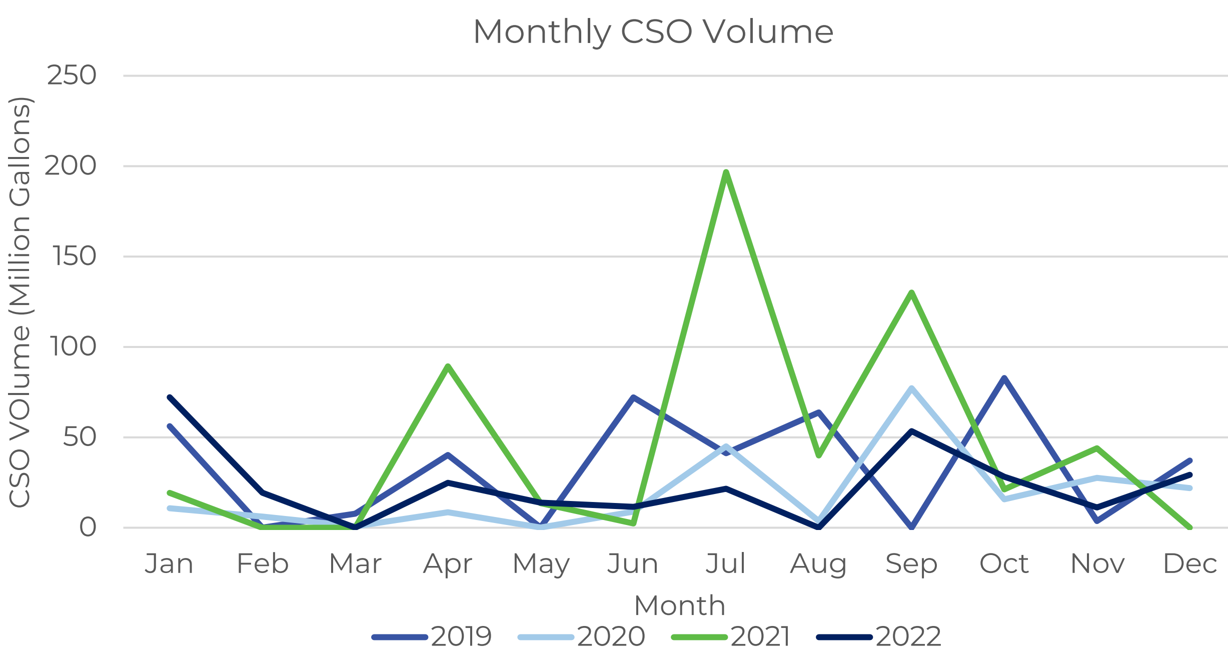



*Figure 7. Monthly CSO volume for 2019-2022 from Nashua, Lowell, GLSD and Haverhill combined sewer systems on the Merrimack. Manchester does not report on individual CSO events, they only release total volumes twice per year, and therefore were not included.*

## 2022 MONITORING PROGRAM RESULTS

The next section reviews the different parameters MRWC measures as part of our water quality monitoring program. It includes information and context about each parameter as well as a review of the conditions in the Merrimack River in 2022.

**Data Dashboards**

Want to see all the data we collected this year on the Merrimack? Or see results at a specific monitoring site? Check out our new interactive dashboards! Go to **merrimack.org/science/water-quality-monitoring-program**

# pH

**What is pH?**

- pH is a measurement of how basic or acidic water is, or more specifically, the concentration of hydrogen ions in water; pH has no units
- pH ranges from 0 (most acidic) to 14 (most basic), with 7 being neutral
- pH is based on a logarithmic scale, so a pH of 5 is 10 times more acidic than a pH of 6 and a pH of 9 is 10 times more basic than a pH of 8

**Why is it important?**

- Water that is too basic or too acidic can negatively impact aquatic plants and wildlife, causing stress and reducing their overall growth, reproduction, and survival rates, and can lead to a reduction in biodiversity[8,9]
- Water with pH that is too high or too low can also corrode water pipes and make it harder to treat drinking water[8]

**What changes pH values?**

- The background pH in waterbodies is influenced by the types of rocks and soils present in a watershed. For example, streams in areas that have soils with high levels of carbonate often have slightly basic pH.[8]
- Human activities, such as mining runoff, industrial pollution, and the burning of fossil fuels, can cause a decrease in pH, making waters more acidic[8–10]
- Industrial pollution dumped directly into the river can also affect the pH.
- The pH of seawater typically has a range between 7.5 and 8.5, freshwater between 6 and 8, and natural precipitation around 5.6. However, due to the acidification of atmospheric water from coal fired power plants in the Midwest, rainwater in New England has a pH between 4.5 and 4.7.[8–10]

**What are important values for environmental and human health?**

- The US EPA suggests a pH range of 6.5 to 9 to support aquatic organisms[9]
- Between 6.5 and 8.5 is often considered ideal for drinking water for people[11]

**What were the conditions in the Merrimack River in 2022?**

For most monitoring sites, the median (average) pH conditions in the Merrimack River are within the EPA's water quality criteria of between 6.5 and 9 (Table 4). Some sites that measured values below the 6.5 value (meaning these samples were more acidic than typical water values) could be attributed to equipment error, as the probes used to measure water quality parameters typically take longer to adjust (which volunteers are trained to modify their normal procedures to accommodate) when sampling in colder weather. One concerning measurement occurred at the Newburyport Road Bridge, which read much lower at 5.1. We attributed this error to the probe, however, it is important to note that there was only one reading taken on this sampling day, as opposed to the required three for precision.

In addition to the low reading at Newburyport at the Road Bridge, Lawrence Boathouse, Dracut Gravel Pit, Hunts Falls Dam in Lowell, Pawtucket Blvd in Lowell, Lincoln Ave Bridge, and the Merrimack Foot Bridge in Manchester each had at least one reading that was below 6.5, most likely due to probe issues. These readings, while low, are also not low enough to warrant concern and appear to be short-lived events unlikely to cause any impacts to aquatic species.

*Table 4. Minimum, maximum and median pH measurements from all monitoring activities 2022.*

| Site | Water Type | River Mile | Min pH | Max pH | Median pH |
|---|---|---|---|---|---|
| Manchester - Merrimack Foot Bridge | Freshwater | 70.55 | 6.42 | 8.06 | 6.98 |
| Manchester - USGS Gauge | Freshwater | 67.86 | 6.33 | 8.69 | 7.09 |
| Lowell - Pawtucket Blvd | Freshwater | 47.75 | 6.34 | 7.70 | 7.04 |
| Lowell - Hunts Falls Bridge | Freshwater | 43.00 | 6.30 | 7.56 | 7.05 |
| Dracut - Gravel Pit | Freshwater | 34.00 | 6.27 | 7.63 | 7.02 |
| Lawrence - Bashara Boathouse | Freshwater | 29.02 | 6.27 | 8.65 | 6.65 |
| Methuen - Riverview Blvd | Freshwater | 26.20 | 6.78 | 8.10 | 7.43 |
| Haverhill - Lincoln Ave Bridge | Freshwater | 16.24 | 6.37 | 7.92 | 7.33 |
| West Newbury - Ferry Park | Freshwater | 12.43 | 7.09 | 8.74 | 7.41 |
| Amesbury - Deer Island | Brackish | 5.67 | 6.72 | 8.14 | 7.39 |
| Newburyport - Road Bridge | Brackish | 3.47 | 5.10 | 7.88 | 6.95 |
| Newburyport - Plum Island | Brackish | 0.74 | 6.76 | 8.87 | 7.36 |
| Salisbury - Beach State Reservation | Brackish | 0.72 | 7.20 | 8.05 | 7.44 |

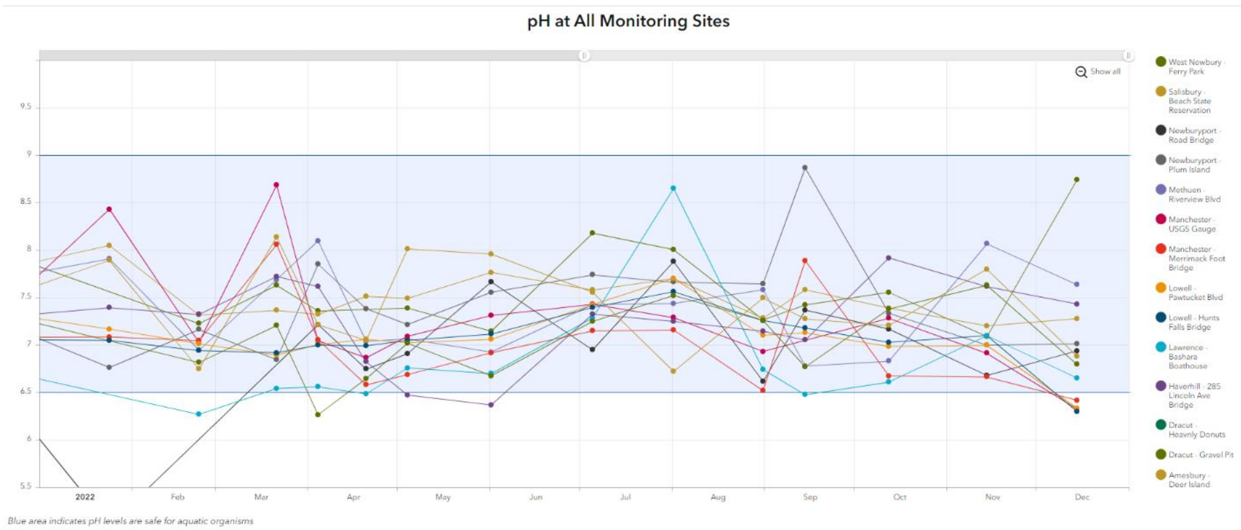



*Figure 8. pH measurements from all monitoring activities in 2022. Use the online dashboard to see site-specific results: merrimack.org/science/water-quality-monitoring-program*

# Specific Conductivity

**What is specific conductivity?**

- Specific conductivity (often referred to as conductivity for short) is a measure of water's ability to conduct electricity, measured in micro-Siemens per centimeter (µS/cm) at 25˚C
- Conductivity is dependent on the amount of positive and negative ions in the water, usually due to the presence of dissolved salts
- Conductivity is closely linked to salinity and total dissolved solids

**Why is it important?**

- Rivers and streams usually have a relatively consistent conductivity value that is unique to that water body, and any significant change in conductivity measurements may indicate pollutants entering the river[12]
- Background levels of conductivity are dependent on the surrounding geology, with clay soils increasing conductivity and granite bedrock reducing it[12]

**What changes conductivity?**

- Agricultural runoff and sewage leaks may increase conductivity, while oil spills or other organic compounds may decrease conductivity[12]

**What are important values for environmental or human health?**

- Freshwater rivers in the US typically range between 50 and 1,500 µS/cm, with levels for supporting good mixed fisheries between 150 and 500 µS/cm[13]
- Industrial wastewater can measure 10,000 µS/cm or more[12,13], while seawater can measure 55,000 µS/cm or more[12]

**What were the conditions in the Merrimack River in 2022?**

The average conductivity of the freshwater sites in the Merrimack River are within the suggested range for supporting good mixed fisheries (Table 5, Figure ). There were a couple of samples above 500 µS/cm at the Methuen Riverview Blvd site, but they were still within the typical range for freshwater streams and rivers, with the soil and geology the most likely cause of lower conductivity within the watershed.  The Methuen site, between 2021 and 2022, shows consistent high conductivity, which MRWC will monitor over the next few years to determine if there is an issue that needs to be addressed, or if this is normal for the site.

The brackish sampling sites had samples up to 619,233 µS/cm. However, all samples above 10,000 µS/cm had salinities greater than 1 ppt, which indicates that the increased conductivity was likely due to the presence of seawater and not industrial pollutants.

*Table 5. Minimum, maximum and median specific conductivity from all monitoring activities in 2022.*

| Site | Water Type | River Mile | Min Cond (µS/cm) | Max Cond (µS/cm) | Median Cond (µS/cm) |
|---|---|---|---|---|---|
| Manchester - Merrimack Foot Bridge | Freshwater | 70.55 | 77.03 | 179.33 | 108.03 |
| Manchester - USGS Gauge | Freshwater | 67.86 | 90.73 | 169.50 | 117.27 |
| Lowell - Pawtucket Blvd | Freshwater | 47.75 | 107.23 | 270.00 | 219.40 |
| Lowell - Hunts Falls Bridge | Freshwater | 43.00 | 116.63 | 250.00 | 169.47 |
| Dracut - Gravel Pit | Freshwater | 34.00 | 124.07 | 370.00 | 194.37 |
| Lawrence - Bashara Boathouse | Freshwater | 29.02 | 144.33 | 406.00 | 222.67 |
| Methuen - Riverview Blvd | Freshwater | 26.20 | 183.30 | 678.33 | 406.17 |
| Haverhill - 285 Lincoln Ave Bridge | Freshwater | 16.24 | 169.27 | 379.00 | 241.00 |
| West Newbury - Ferry Park | Freshwater | 12.43 | 177.33 | 361.67 | 235.67 |
| Amesbury - Deer Island | Brackish | 5.67 | 158.77 | 4,990.00 | 240.50 |
| Newburyport - Road Bridge | Brackish | 3.47 | 42.27 | 24,376.67 | 1,663.17 |
| Newburyport - Plum Island | Brackish | 0.74 | 5,056.67 | 619,233.33 | 9,701.67 |
| Salisbury - Beach State Reservation | Brackish | 0.72 | 142.67 | 1,1723.33 | 6,353.33 |

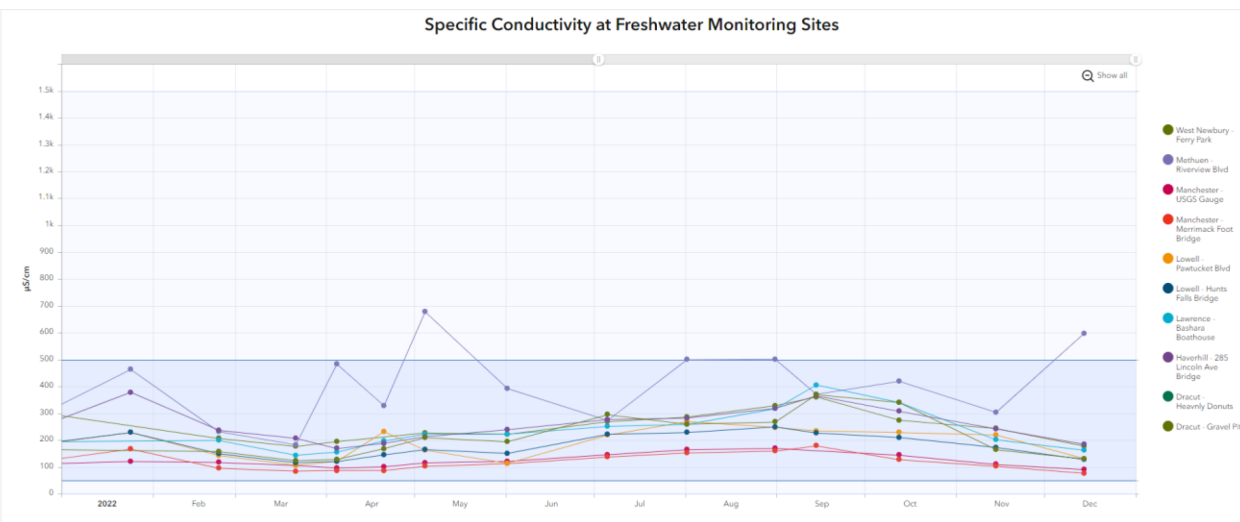



*Figure 9. Conductivity measurements from all monitoring activities in 2022. Use the online dashboard to see site-specific results: merrimack.org/science/water-quality-monitoring-program*

# Salinity

**What is salinity?**

- Salinity is the amount of dissolved salts in the water, measured in parts per thousand (ppt)
- Salinity is closely linked with conductivity and total dissolved solids

**Why is it important?**

- Measuring salinity can help determine how far the tides flow up the Merrimack River
- Salinity levels impact the types of aquatic species that live in different parts of the river[14]

**What changes salinity?**

- Increases in salinity are most commonly caused by saltwater mixing with a freshwater body (like during high tides in an estuary), and salinity can decrease through dilution when a large volume of freshwater is added to a water body (such as during heavy rainfall or snowmelt)
- Salinity can also increase in terminal river basins and lakes as freshwater evaporates and leaves behind natural salts, which can build up over time
- In smaller streams and tributaries to the Merrimack, salinity can increase due to runoff from road salts used in the winter

**What are important values for environmental or human health?**

- Freshwater habitats typically have a salinity value of less than 0.5 ppt[12,14]
- Brackish water habitats (a mix of freshwater and ocean water) typically have a salinity value between 0.5 and 17 ppt[12,14]
- Ocean water typically has a salinity value around 30 to 35 ppt[12,14]

**What were the conditions in the Merrimack River in 2022?**

All freshwater monitoring sites have an average salinity of 0.2 ppt or less, with the highest single recording of 0.4 ppt at Methuen - Riverview Blvd. This is within the normal range for freshwater sources. The brackish sites have slightly higher average values, with the highest reading of 37.77 ppt at Plum Island in Newburyport. Water quality testing is usually scheduled within two hours prior to low tide so high tide conditions, which would increase salinity at some sites, are not represented in these data.

*Table 6. Minimum, maximum and median salinity from all monitoring activities in 2022.*

| Site | Water Type | River Mile | Min Salinity (ppt) | Max Salinity (ppt) | Median Salinity (ppt) |
|---|---|---|---|---|---|
| Manchester - Merrimack Foot Bridge | Freshwater | 70.55 | 0.04 | 0.09 | 0.06 |
| Manchester - USGS Gauge | Freshwater | 67.86 | 0.04 | 0.09 | 0.06 |
| Lowell - Pawtucket Blvd | Freshwater | 47.75 | 0.05 | 0.14 | 0.11 |
| Lowell - Hunts Falls Bridge | Freshwater | 43.00 | 0.06 | 0.12 | 0.08 |
| Dracut - Gravel Pit | Freshwater | 34.00 | 0.06 | 0.19 | 0.09 |
| Lawrence - Bashara Boathouse | Freshwater | 29.02 | 0.01 | 0.20 | 0.11 |
| Methuen - Riverview Blvd | Freshwater | 26.20 | 0.10 | 0.36 | 0.20 |
| Haverhill - 285 Lincoln Ave Bridge | Freshwater | 16.24 | 0.01 | 0.20 | 0.13 |
| West Newbury - Ferry Park | Freshwater | 12.43 | 0.09 | 0.18 | 0.12 |
| Amesbury - Deer Island | Brackish | 5.67 | 0.08 | 2.53 | 0.12 |
| Newburyport - Road Bridge | Brackish | 3.47 | 0.10 | 37.12 | 0.52 |
| Newburyport - Plum Island | Brackish | 0.74 | 4.76 | 35.77 | 19.19 |
| Salisbury - Beach State Reservation | Brackish | 0.72 | 6.27 | 29.00 | 14.03 |

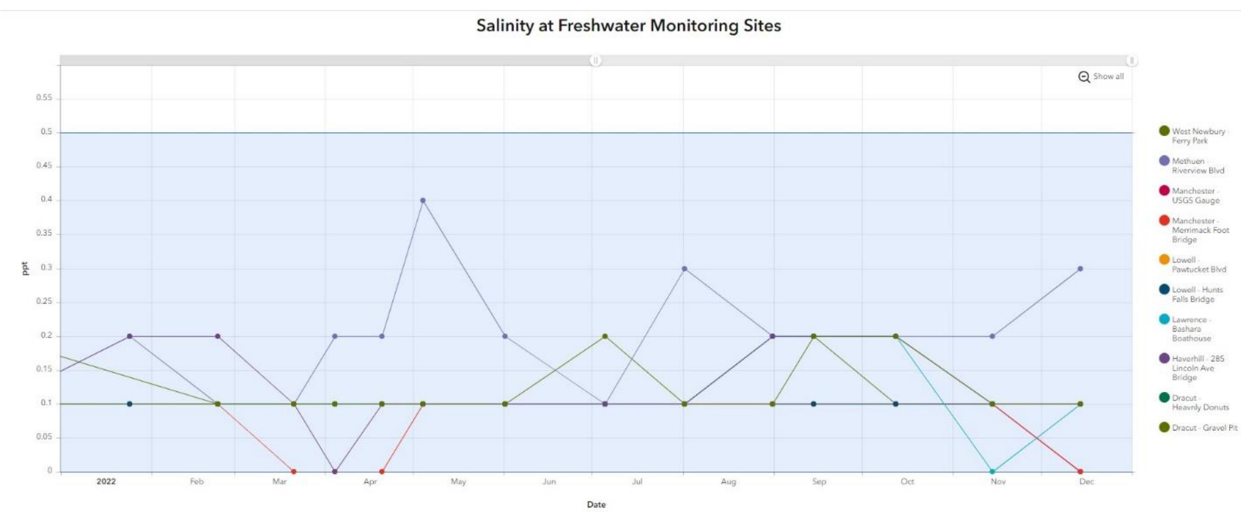



*Figure 10. Salinity measurements from all monitoring activities in 2022. Use the online dashboard to see site-specific results: merrimack.org/science/water-quality-monitoring-program*

# Total Dissolved Solids

**What are total dissolved solids (TDS)?**

- TDS are the amount of all ions and solids in water that are less than 2 microns (0.0002 cm) in length, measured in milligrams per liter of water (mg/L)
- TDS includes positive and negative ions, dissolved salts, and dissolved organic matter

**Why is it important?**

- If TDS levels are too high or too low, this could impact an organism's ability to move up and down in the water column, as well as limit the growth and lifespan of aquatic species[15,16]

**What changes total dissolved solids?**

- Heavy rains and large amounts of industrial and/or agricultural runoff from the watershed can temporarily increase total dissolved solids[12]
- However, high levels of total dissolved solids in freshwater during a dry period can be a sign of point source pollution[12]

**What are important values for environmental or human health?**

- There is no EPA recommendation for TDS limits for aquatic species, but TDS measurements over 1,000 mg/L in freshwater could impact fish reproduction[17]
- TDS values over 500 mg/L require secondary treatment before being used as drinking water for humans[15]

**What were the conditions in the Merrimack River in 2022?**

All freshwater sites in the Merrimack are well below the 1,000 mg/L threshold, with the exception of Hunts Falls Bridge in Lowell. In June, the level of TDS was nearly 10,000 mg/L. This is most likely due to a sudden spike in rain after drought conditions. Looking at the rest of the data, we suspect that this reading is an outlier and that the indicating the levels of TDS do not threaten freshwater aquatic species. Measurements at brackish sites are much higher, as would be expected with the introduction of ocean water. However, any aquatic species living in this zone are tolerant of changes in TDS and these elevated levels are not of environmental concern.

*Table 7. Minimum, maximum and median total dissolved solids from all monitoring activities in 2022.*

| Site | Water Type | River Mile | Min TDS (mg/L) | Max TDS (mg/L) | Median TDS (mg/L) |
|---|---|---|---|---|---|
| Manchester - Merrimack Foot Bridge | Freshwater | 70.55 | 54.60 | 133.00 | 76.87 |
| Manchester - USGS Gauge | Freshwater | 67.86 | 63.53 | 86,033.33 | 82.70 |
| Lowell - Pawtucket Blvd | Freshwater | 47.75 | 76.37 | 83,066.67 | 159.17 |
| Lowell - Hunts Falls Bridge | Freshwater | 43.00 | 82.73 | 107,666.67 | 136.33 |
| Dracut - Gravel Pit | Freshwater | 34.00 | 88.77 | 263.00 | 131.17 |
| Lawrence - Bashara Boathouse | Freshwater | 29.02 | 102.43 | 338.33 | 160.33 |
| Methuen - Riverview Blvd | Freshwater | 26.20 | 129.50 | 507.67 | 279.17 |
| Haverhill - 285 Lincoln Ave Bridge | Freshwater | 16.24 | 125.00 | 259.00 | 160.50 |
| West Newbury - Ferry Park | Freshwater | 12.43 | 123.00 | 256.67 | 168.17 |
| Amesbury - Deer Island | Brackish | 5.67 | 113.00 | 3,603.33 | 294.83 |
| Newburyport - Road Bridge | Brackish | 3.47 | 150.50 | 32,916.67 | 11,841.67 |
| Newburyport - Plum Island | Brackish | 0.74 | 8,916.67 | 39,633.33 | 22,416.67 |
| Salisbury - Beach State Reservation | Brackish | 0.72 | 0.00 | 34,566.67 | 17,550.00 |

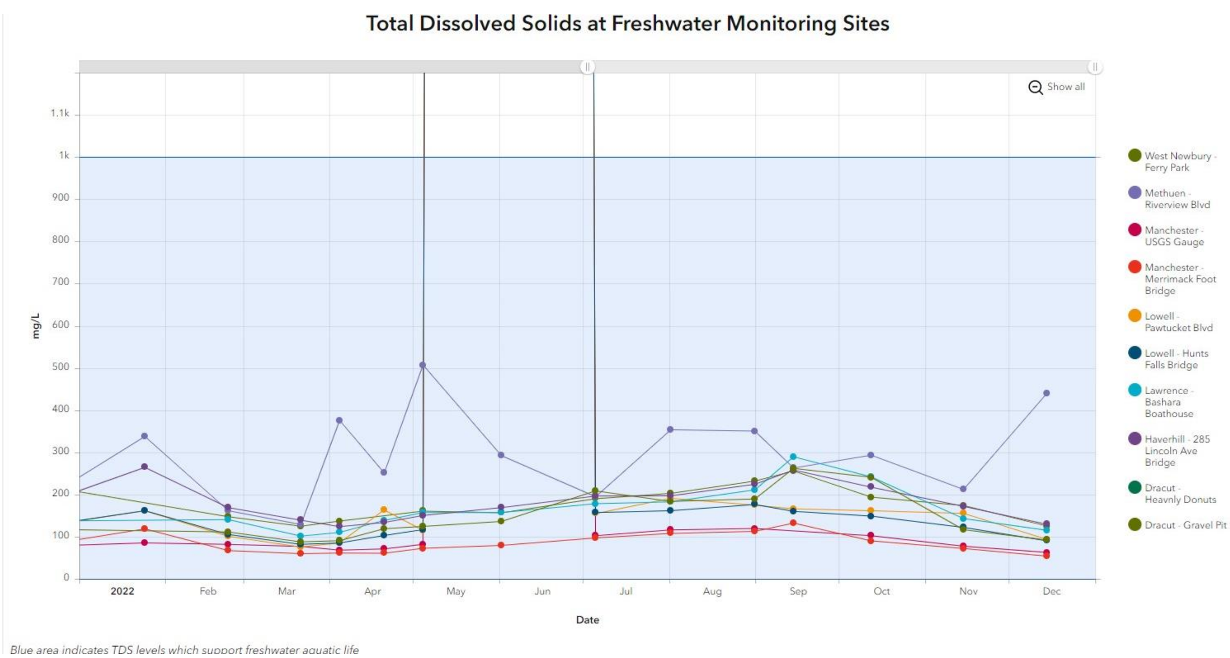



*Figure 51. Total dissolved solids measurements from all monitoring activities in 2022. Use the online dashboard to see site-specific results: merrimack.org/science/water-quality-monitoring-program*

# Temperature

**What is temperature?**

- Temperature is a measurement of thermal energy, measured in degrees Celsius (˚C) or degrees Fahrenheit (˚F)

**Why is it important?**

- Aquatic plants and wildlife species have a preferred temperature range[18]
- Water bodies with higher temperatures contain less dissolved oxygen, which is important for aquatic organisms[18,19]
- Water bodies with high temperatures may also result in higher levels of toxicity from heavy metals[19]

**What changes temperature?**

- Temperatures naturally fluctuate with the seasons and can be influenced by tides containing ocean water
- Human actions, such as building dams, running thermoelectric power plants, and cutting down riparian forests, can increase the temperature of rivers and water bodies[19]

**What are important values for environmental or human health?**

- Cold water fish species, such as brook trout and salmon, cannot tolerate long-periods of water that is 20˚C (68˚F) or higher[20,21]
- Warm water fish species found on the Merrimack River, such as Atlantic Sturgeon and American Eel, can tolerate temperatures up to 25˚C (77˚F), and sometimes higher[22,23]

**What were the conditions in the Merrimack River in 2022?**

Comparing all monitoring sites, the near surface temperatures (water samples collected just under the water surface) are quite similar (Table 8). The brackish sites may have a slightly warmer temperature in the winter months due to the influence of ocean water coming in with the tides, which is often warmer than the freshwater during these months. During the spring, fall, and winter, the Merrimack River is cool enough to be able to support cold water fisheries (Figure ). However, during the warm summer months of June through September the average temperatures rise above 20˚C, meaning that any cold-water fish species in the main stem of the Merrimack will need to find cold water tributaries for refuge areas. While the mainstem of the Merrimack is not considered cold-water fishery habitat, it does serve as an important corridor for fish moving between tributaries. It should also be noted that the samples were taken near the surface of the water, which tends to be warmer due to heating from the sun.

*Table 8. Minimum, maximum, and median temperature from all monitoring activities in 2022.*

| Site | Water Type | River Mile | Min Temp (˚C) | Max Temp (˚C) | Median Temp (˚C) |
|---|---|---|---|---|---|
| Manchester - Merrimack Foot Bridge | Freshwater | 70.55 | 1.30 | 26.83 | 11.37 |
| Manchester - USGS Gauge | Freshwater | 67.86 | 1.80 | 25.47 | 10.53 |
| Lowell - Pawtucket Blvd | Freshwater | 47.75 | 1.87 | 27.20 | 12.00 |
| Lowell - Hunts Falls Bridge | Freshwater | 43.00 | 2.37 | 25.80 | 11.17 |
| Dracut - Gravel Pit | Freshwater | 34.00 | 3.33 | 26.53 | 13.07 |
| Lawrence - Bashara Boathouse | Freshwater | 29.02 | 1.27 | 26.50 | 13.07 |
| Methuen - Riverview Blvd | Freshwater | 26.20 | 5.13 | 27.10 | 13.73 |
| Haverhill - 285 Lincoln Ave Bridge | Freshwater | 16.24 | 3.03 | 27.20 | 13.20 |
| West Newbury - Ferry Park | Freshwater | 12.43 | 2.83 | 27.10 | 13.03 |
| Amesbury - Deer Island | Brackish | 5.67 | 1.50 | 25.53 | 11.85 |
| Newburyport - Road Bridge | Brackish | 3.47 | 3.13 | 24.77 | 13.53 |
| Newburyport - Plum Island | Brackish | 0.74 | 0.00 | 21.37 | 10.83 |
| Salisbury - Beach State Reservation | Brackish | 0.72 | 4.07 | 19.10 | 11.65 |

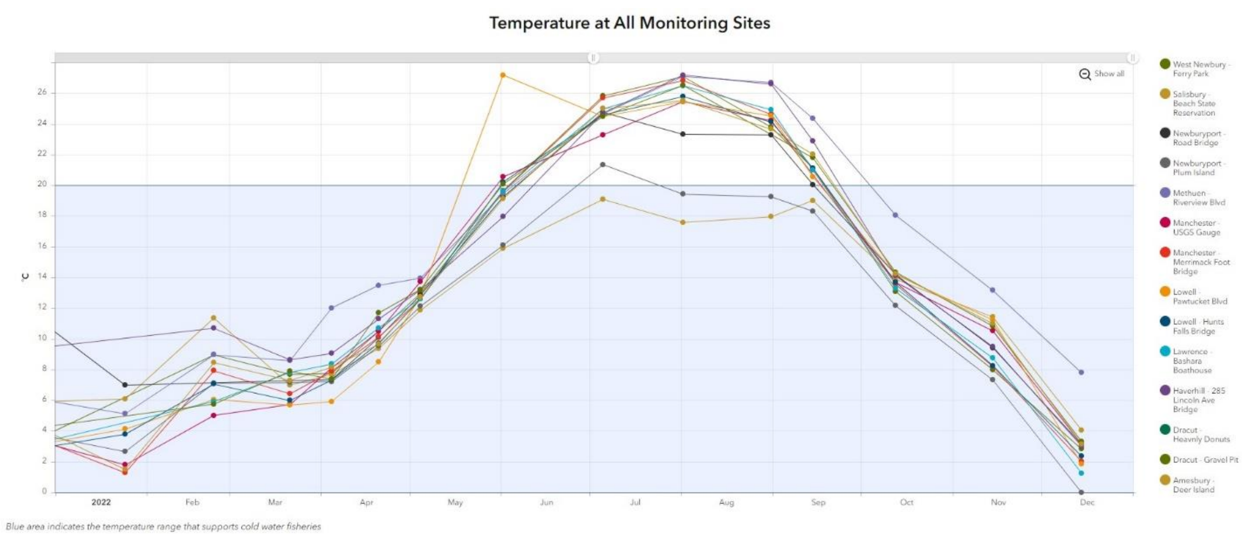



*Figure 12. Temperature measurements from all monitoring activities in 2022. Use the online dashboard to see site-specific results: merrimack.org/science/water-quality-monitoring-program*

# Bacteria – *Escherichia coli* (*E. coli*) and *Enterococcus*

**What are pathogens and fecal indicator bacteria?**

- Pathogens are disease-causing microorganisms, which can be bacteria (single-celled organisms), viruses, fungi, or protozoa
- Two common bacteria used in water quality monitoring are *Escherichia coli* (*E. coli*) and *Enterococcus*, which are found in the gut and feces of warm-blooded animals.
- While *E. coli* and *Enterococcus* themselves are not particularly dangerous to humans, they often indicate the presence of more harmful pathogens such as norovirus and *Cryptosporidium*, which can make people sick.
- The source of fecal contamination is very important. Fecal contamination from human sources (e.g., sewage from an illicit connection or CSO) is likely to contain more pathogens that will have a greater impact on human health than fecal contamination from non-human sources (e.g., birds, wildlife, and farm animals).[24]
- *E. coli* is an indicator of health impacts for humans in freshwater samples, while *Enterococcus* can be used as an indicator in freshwater and brackish samples.[25]

**Why are they important?**

- When humans come in contact with pathogens, they can cause illnesses ranging from gastrointestinal impacts such as vomiting and diarrhea to infections, and even death, with the very young, the very old, and those with weakened immune systems at greatest risk [26,27]
- A wide variety of pathogens can cause illness in humans and animals, but *E. coli* and *Enterococcus* are commonly found, relatively easy to monitor, and have been shown to correlate with cases of gastrointestinal illness among swimmers in waterbodies contaminated with human-sourced fecal matter.[28]

**What changes bacteria concentrations?**

- The concentration of bacteria measured at a specific site on a given day is influenced by many factors such as concentration from nearby sources, dilution, streamflow, dispersion, sedimentation, temperature, decay/die off, and tides. ***Learn more on our website: merrimack.org/cso.***

**What are important values for environmental or human health?**

- NH and MA have their own state standards for water and environmental quality, and they do not align completely in numerical value or in theoretical approach, making them difficult to compare. Therefore, in this report, the monitoring results have been compared to a national standard: the US EPA's 1986 Ambient Water Quality Criteria for Bacteria[29].

- The US EPA's 1986 Ambient Water Quality Criteria for Bacteria sets a standard for safe bacteria levels for designated beach areas (or "safe for recreational use" in this report): a maximum value of 235 CFUs/100 ml for *E. coli* in freshwater samples and 61 CFUs/100 ml for *Enterococcus* in freshwater and brackish samples.[29]

**What were the conditions in the Merrimack River in 2022?**

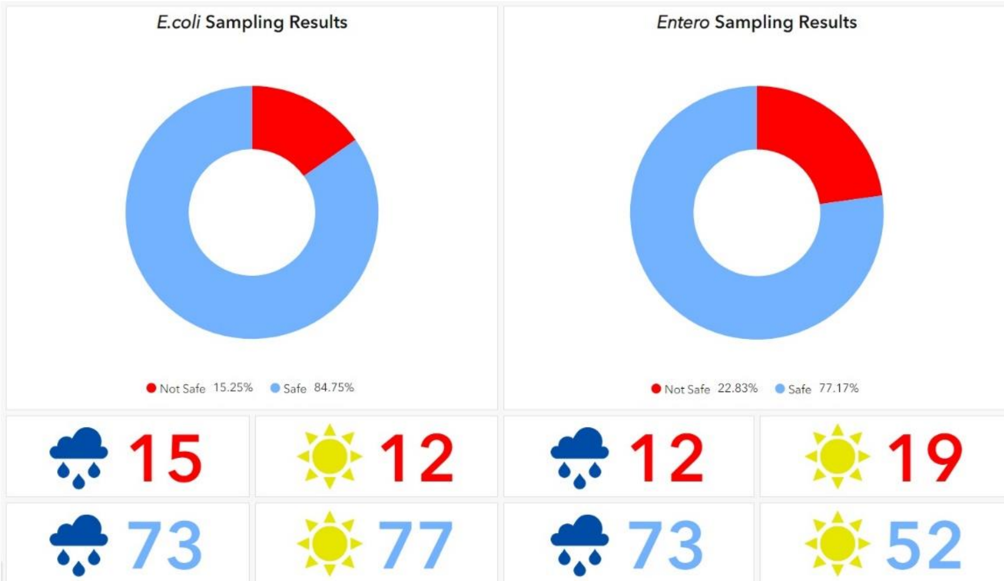
In 2022, MRWC collected data on *E. coli* and *Enterococcus* at all sites. Because *Enterococcus* is a better indicator of fecal coliforms in brackish water, we focused only on *Enterococcus* and not *E. coli* in the most downstream sites. We also used several water quality parameters to assess the overall health of the river. All available bacteria and water quality data can be viewed on the MRWC Bacteria Monitoring Dashboard.
This year, MRWC only conducted regular monitoring (where samples are collected once monthly) and did not participate in CSO event monitoring. Each bacterial monitoring sample was also classified according to precipitation conditions at the nearest NOAA rainfall gauge; it is considered wet weather conditions if it rained at least 0.1 inches within 72 hours of the sampling day, and dry conditions if it rained less than 0.1 inches. Our analysis of conditions has separated these types of monitoring to showcase the results of each monitoring effort, as well as different environmental conditions.

**Regular Monitoring Program**

Results from our regular monitoring program include all regularly scheduled sampling days. It may happen that some of these days did follow rain or CSO events and are still included in this dataset. The purpose of this data set is to provide an unbiased view of the river's conditions, so sampling days are not selected based on weather, but are prescheduled at the beginning of the year.

During our regular monitoring program, 27 out of 177 *E. coli* samples (15%) were considered unsafe for recreational use, while for *Enterococcus*, 50 samples out of 219 samples (23%) were considered unsafe for recreational use (

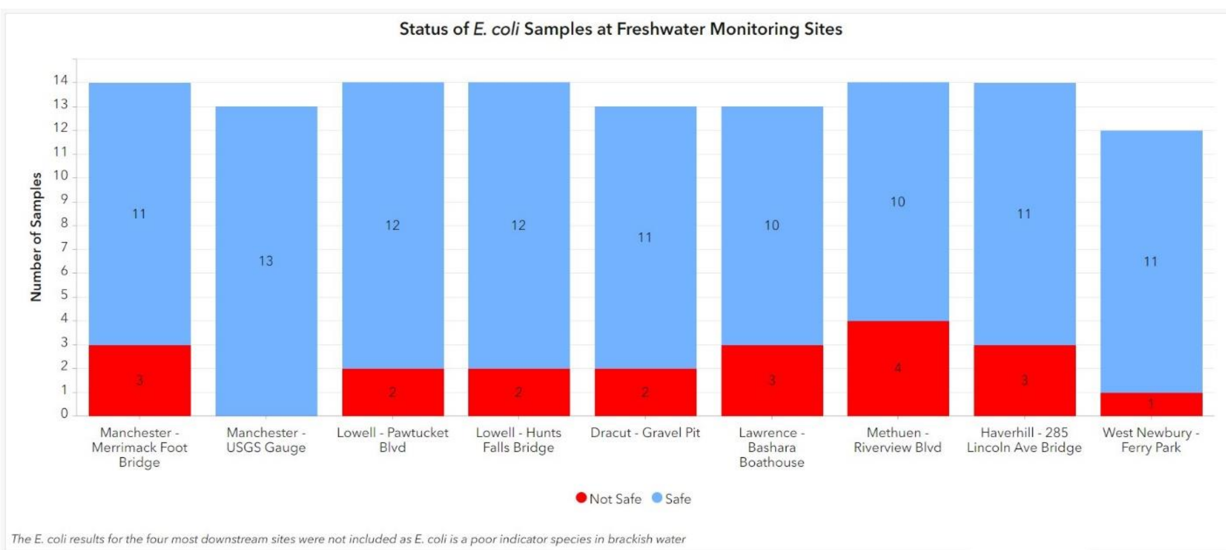
Figure ). Most of the samples indicating unsafe conditions occurred during dry weather events for *Enterococcus*, but the opposite for *E. coli*. This could indicate the presence of a contamination source other than CSOs at some sites, most likely nonpoint-source pollution or stormwater runoff.



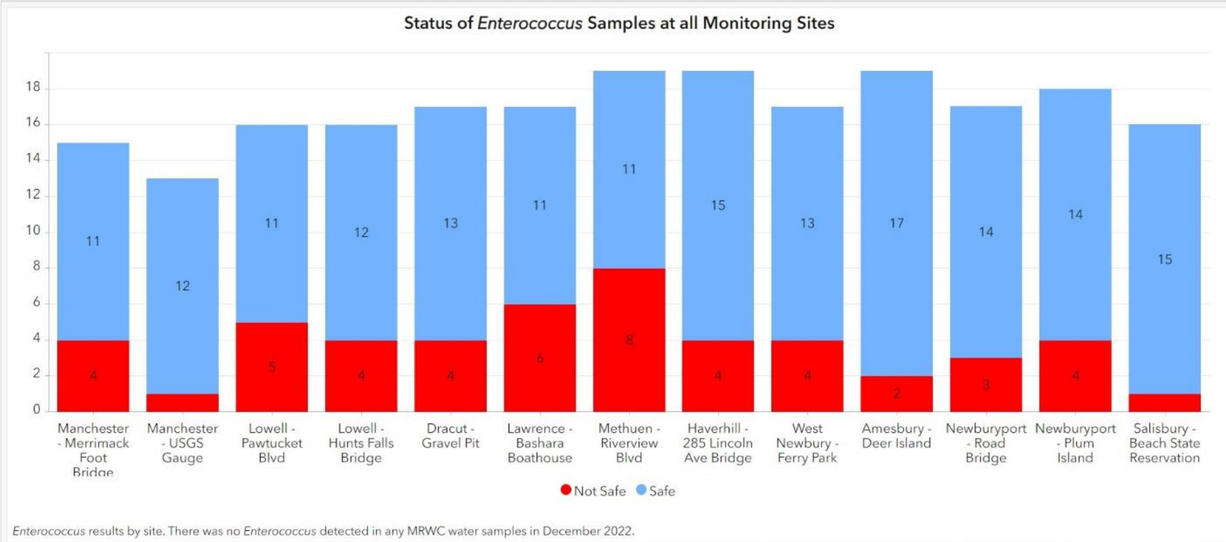

The circle graphs indicate safe (blue) and unsafe (red) samples at each site, relative to the EPA limit for recreational use. The number below the circle charts show the percentage and count of samples that are safe and unsafe, and whether they occurred during wet or dry weather conditions.

*Figure 13. Summary of E. coli concentrations for all freshwater sites and Enterococcus concentrations for all brackish water sites for regular monitoring program samples in 2022.*

Looking at these results by monitoring site, the data show that most samples are considered safe throughout the Merrimack but there are unsafe samples at each site (Figure ). It is worth noting that Manchester USGS Gauge and Salisbury Beach State Reservation each had only one unsafe sample during regular monitoring activities, while Methuen had the highest number of unsafe samples. This is interesting due to the high conductivity and salinity also found at this site. Further site-specific analyses on potential reasons are provided in the regional profiles section.



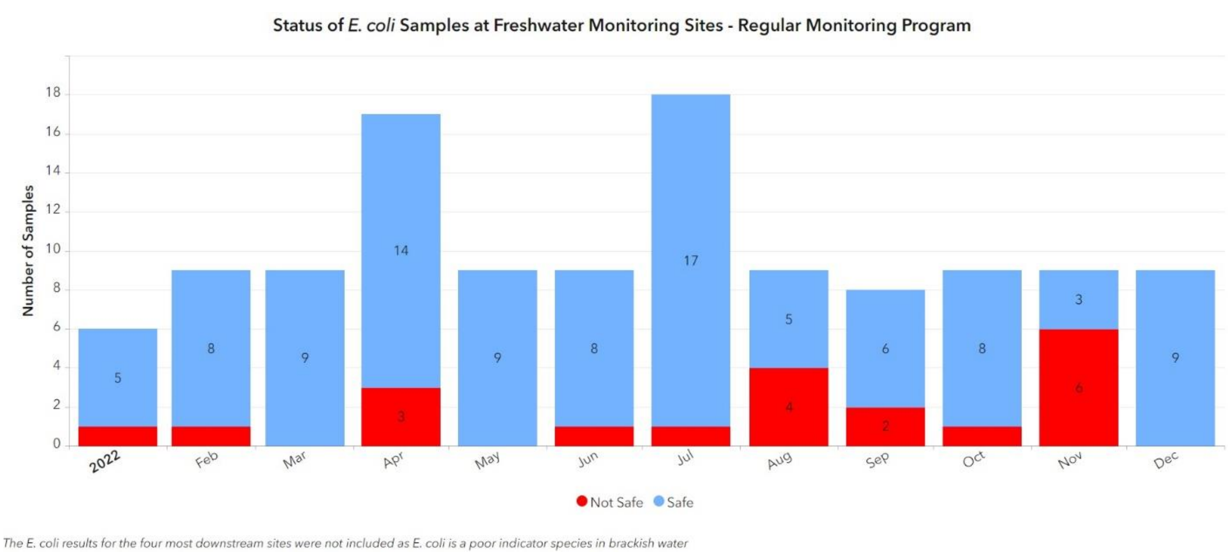

(a)



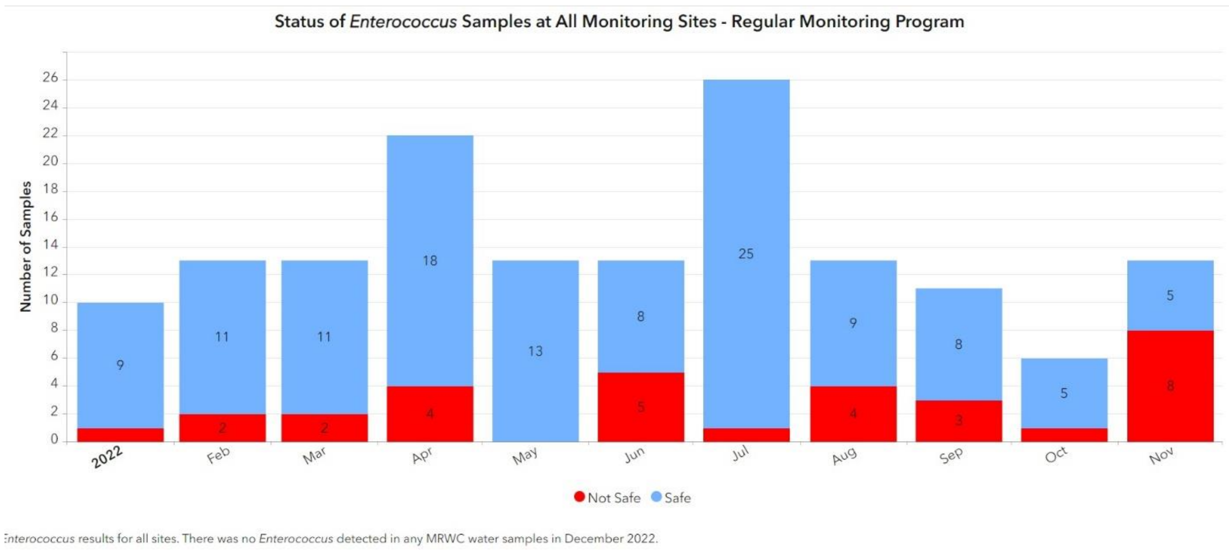

(b)

*Figure 14. Number of safe and not safe samples by monitoring site for E. coli at freshwater monitoring sites (a) and Enterococcus monitoring sites (b) in 2022.*

Looking at these results by month, most samples were within the safe limit during spring and early summer (Figure ). However, during the June, August, and November there were more unsafe samples than other months. It is important to note that in May through early August in 2022, Massachusetts experienced a drought. The low bacteria concentrations that occurred in June and July during a time of recreation are most likely due to lack of rain events.




(a)



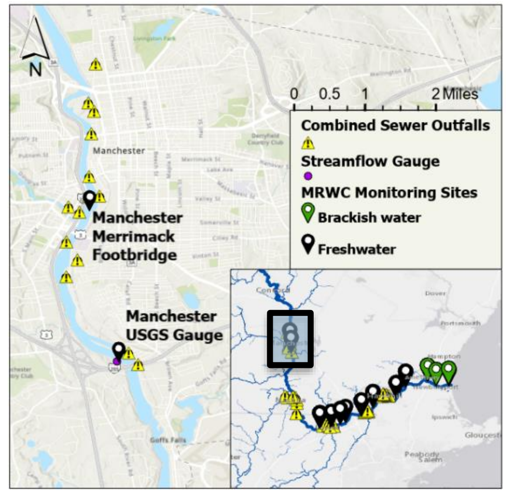

(b)

*Figure 15. Number of safe and not safe samples by month for E. coli at freshwater monitoring sites (a) and Enterococcus all monitoring sites (b) in 2022.*

# REGIONAL PROFILES

By grouping each of the sites into regions, we can better understand the potential impacts cities and towns within those regions and upstream of them may have on bacteria concentrations. Each regional profile shares information on our monitoring locations, CSO infrastructure, and an analysis of the bacteria data for that region.

# Greater Manchester, New Hampshire




## Monitoring Sites

- Merrimack Foot Bridge (river mile 70.6)
- USGS Gauge (river mile 67.9)

## Known CSO Infrastructure

- Manchester has 15 CSO outfalls
- Manchester contributes the second largest volume of CSOs to the Merrimack compared to all other combined systems on the Merrimack (average of 221 million gallons per year)
- The Merrimack Foot bridge site, the most upstream site of our monitoring network, is downstream of some CSO outfalls, and upstream of other outfalls
- The USGS Gauge site is located at the USGS streamflow gauge and downstream of all but one CSO outfall
- Site selection is based on a variety of factors, with access to the river being the biggest limitation. These sites are located where they are due to the limited number of access locations and bridges with sidewalks crossing the Merrimack in this area.

## Water Quality in the Greater Manchester Region

Overall, 21% of the samples collected in greater Manchester have *E. coli* levels that were above the safe limit (Figure 6) and 31% of the samples collected have *Enterococcus* levels that were above the safe limit (Figure 17). The more downstream site at Manchester – USGS Gauge (MUG) had zero unsafe *E. coli* samples while the more upstream site of Merrimack Foot Bridge (MMFB) had unsafe concentrations. The site at the USGS gauge also had a much lower concentration of *Enterococcus* than the upstream site at the bridge.

Manchester is the most upstream combined sewer system which means these sites are only influenced by Manchester CSO events. The city has an interactive map which shows the location and status of the CSO's in the area, as well as a CSO notification system that sends out alerts when a CSO is activated, as well as a list of how many gallons are released by each outfall. However, the city does not report which dates the CSOs occur on. When looking at the June $1^{st}$ sampling event during dry weather, we see that there was a CSO that occurred in the Greater Lowell Region on May $28^{th}$. Since Manchester is directly above Lowell, and due to weather system movements, we can therefore interpret that there was also a CSO in the Greater Manchester Region and that the unsafe levels of *E. coli* and *Enterococcus* were likely due to residuals from the May $28^{th}$ CSO event.

In summary, the majority of samples in this area are safe. However, the data suggests bacteria may persist in the system for at least 72 hours after a rainstorm, which is important to note for recreational purposes.

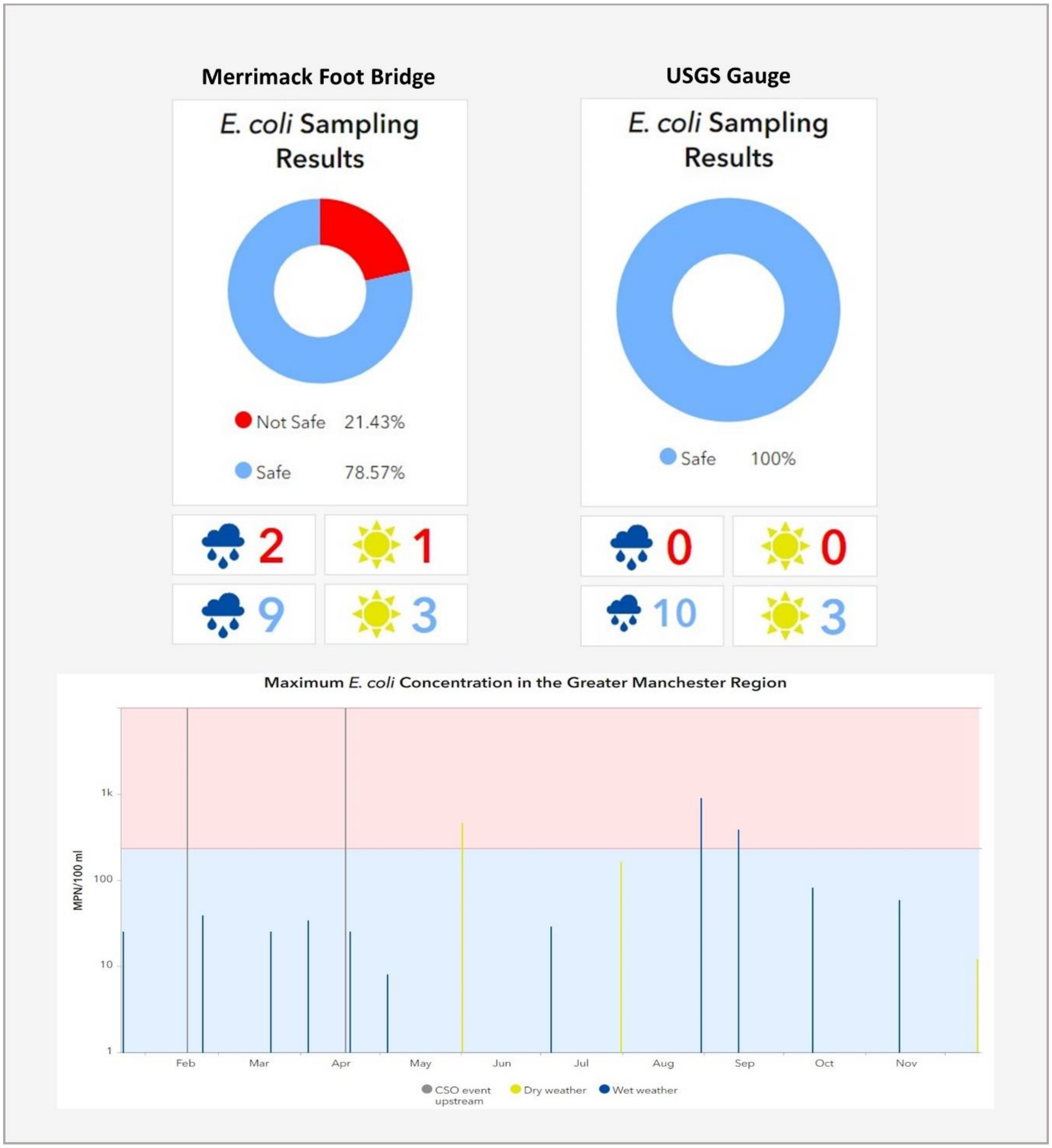



*Figure 16. Results of E. coli sampling at the sites within the Greater Manchester region.*

*The circle graphs at the top indicate safe (blue) and unsafe (red) samples at each site. The number below the circle charts show the percentage and count of samples that are safe and unsafe, and whether they occurred during wet or dry conditions. The time series shows the maximum concentration samples collected on each sampling day in this region.*

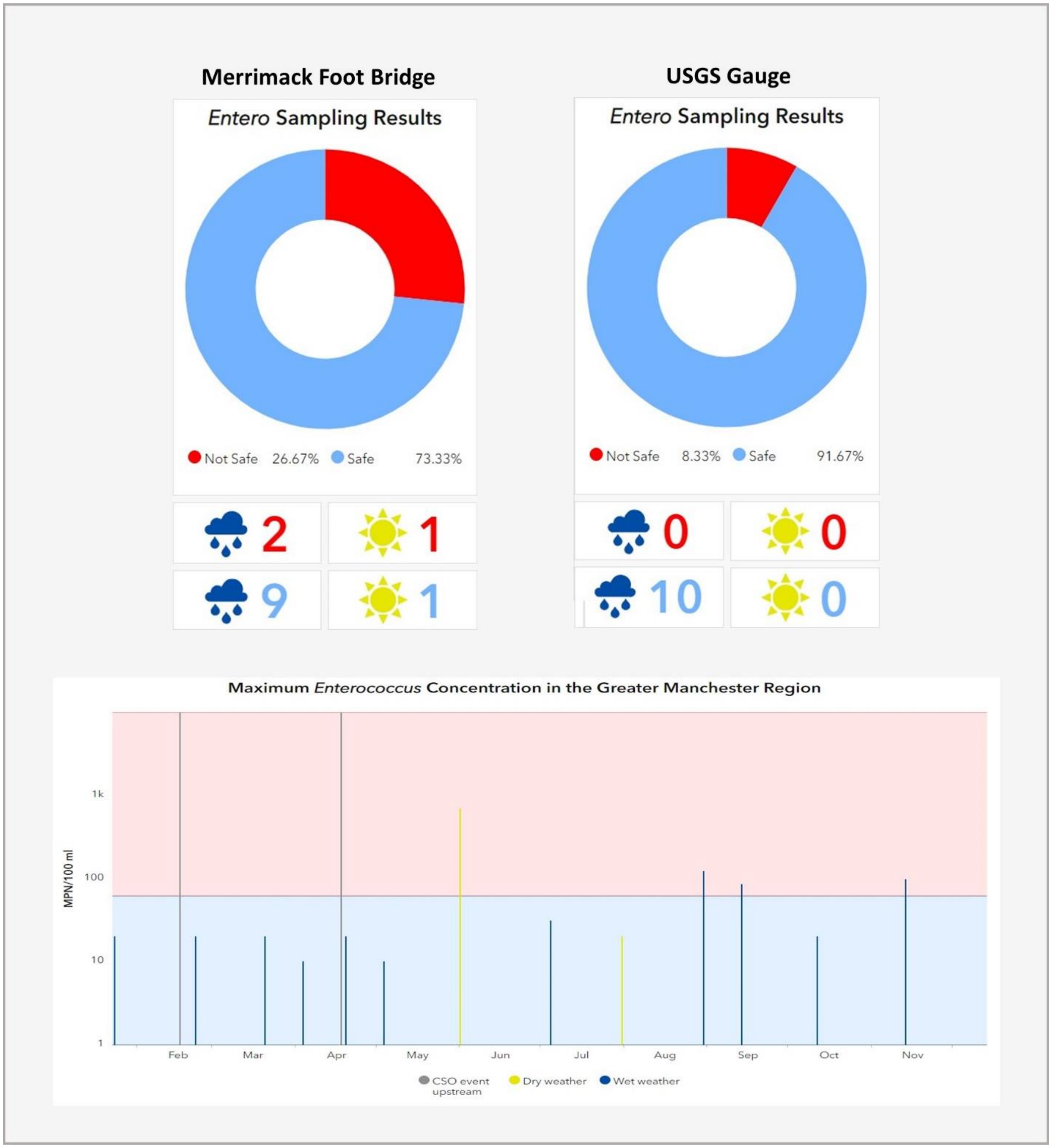
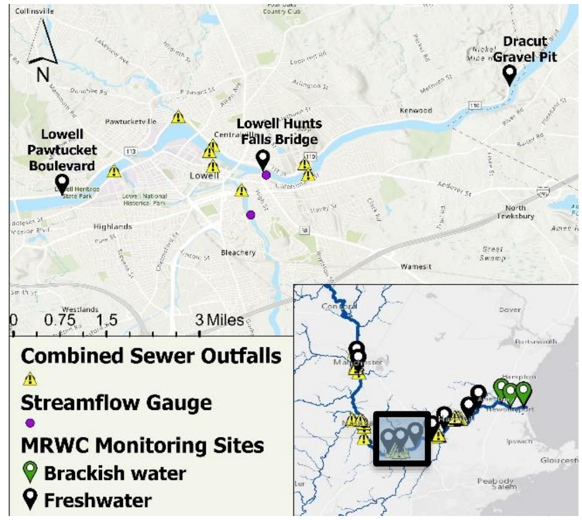



*Figure 17. Results of Enterococcus sampling at the sites within the Greater Manchester region.*

*The circle graphs at the top indicate safe (blue) and unsafe (red) samples at each site. The number below the circle charts show the percentage and count of samples that are safe and unsafe, and whether they occurred during wet or dry conditions. The time series shows the maximum concentration samples collected on each sampling day in this region.*

## Greater Lowell, Massachusetts




### Monitoring Sites

- Lowell Pawtucket Boulevard (river mile 47.8)
- Lowell Hunts Falls Bridge (river mile 43)
- Dracut Gravel Pit (river mile 34)

### Known CSO Infrastructure

- The Lowell Regional Wastewater Utility has 8 CSO outfalls
- Greater Lowell is one of the largest contributors to Merrimack each year in terms of CSO volume (average of 222 million gallons per year)
- The Pawtucket Boulevard site is downstream of all Manchester and Nashua CSO outfalls
- The Hunts Falls Bridge site is downstream of all of Manchester and Nashua CSO outfalls and most of Lowell's CSO outfalls, and located at the USGS streamflow gauge, just downstream of the confluence of the Concord River
- The Dracut site is downstream of all Manchester, Nashua and Lowell CSO outfalls

### Water Quality in the Greater Lowell Region

We found that 15% of samples collected in this region were above the safe limit for *E. coli* (Figure 18) and that 27% of samples were above the safe limit for *Enterococcus* (Figure 19).

There were two instances where both *E. coli* and *Enterococcus* levels were unsafe. One occurred in April, which was collected during wet weather, and another occurred in November, which was collected during dry weather. While the unsafe conditions during wet weather is to be expected, the dry weather unsafe conditions tells us some additional information. It is important to note that this sample date occurred 3 days after a CSO was recorded upstream in Manchester.

*E. coli* levels were unsafe in 17% of samples collected and *Enterococcus* levels were unsafe in 43% of samples collected during wet weather conditions. 15% of unsafe *E. coli* and *Enterococcus* samples were collected within three days of a CSO occurring upstream.

In summary, just because there is rain or a CSO upstream, it does not mean the river is unsafe to use in this location. After significant rain events, however, bacteria levels in this region may stay unsafe for up to three days.

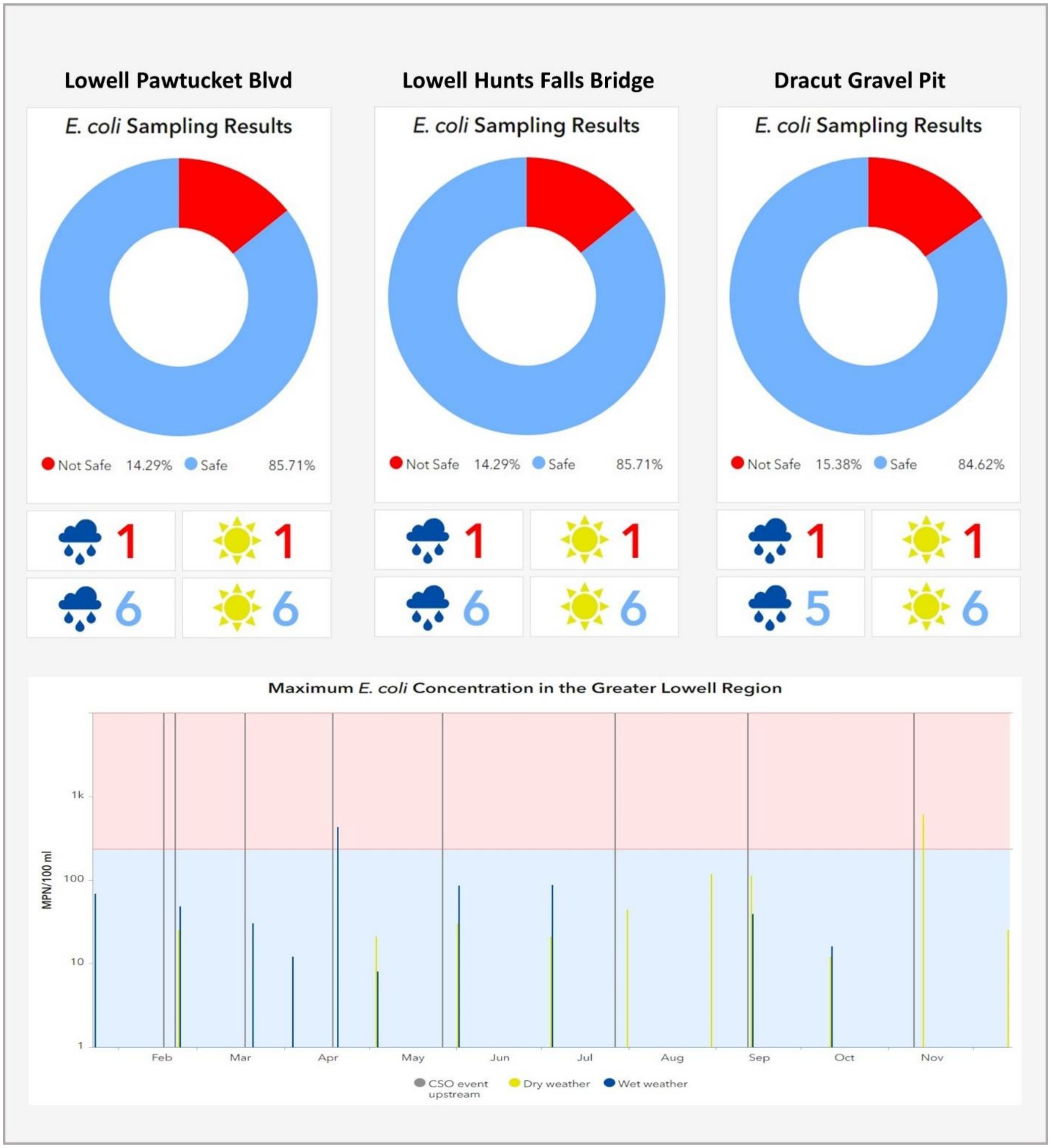



*Figure 18. Results of E. coli sampling at the sites within the Greater Lowell region.*

*The circle graphs at the top indicate safe (blue) and unsafe (red) samples at each site. The number below the circle charts show the percentage and count of samples that are safe and unsafe, and whether they occurred during wet or dry conditions. The time series shows the maximum concentration of samples collected on each sampling day in this region, relative to upstream CSO events shown by grey lines (since daily CSO event data is not available for Manchester, it is therefore assumed that all CSO events occurring upstream of Lowell are from Nashua, NH).*

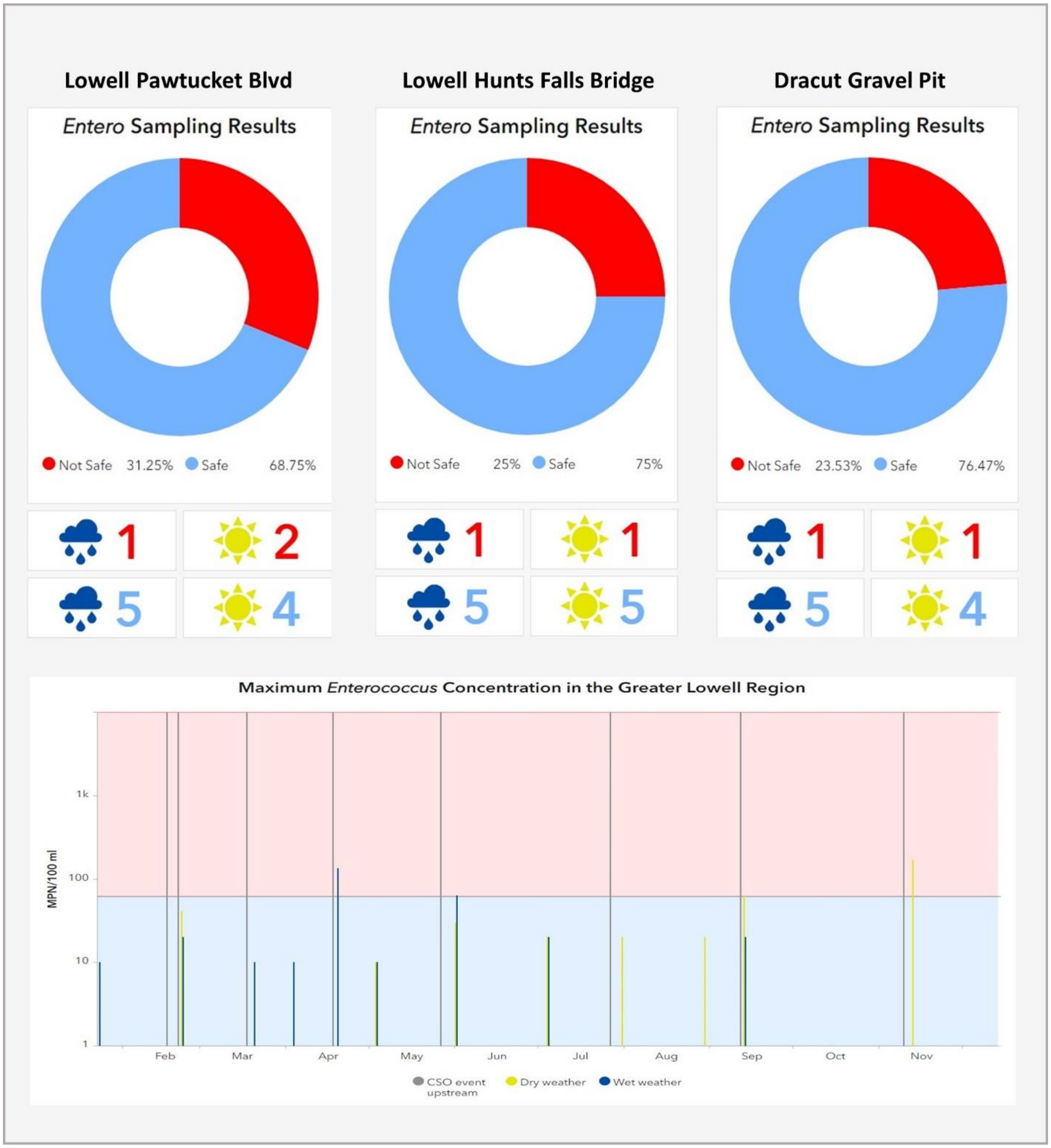
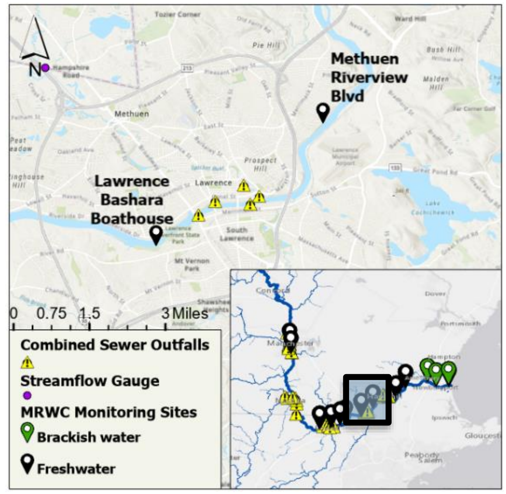



*Figure 19. Results of Enterococcus sampling at the sites within the Greater Lowell region.*

*The circle graphs at the top indicate safe (blue) and unsafe (red) samples at each site. The number below the circle charts show the percentage and count of samples that are safe and unsafe, and whether they occurred during wet or dry conditions. The time series shows the maximum concentration of samples collected on each sampling day in this region, relative to upstream CSO events shown by grey lines (since daily CSO event data is not available for Manchester, it is therefore assumed that all CSO events occurring upstream of Lowell are from Nashua, NH).*

## Greater Lawrence, Massachusetts




### Monitoring Site Names

- Lawrence Bashara Boathouse (river mile 29)
- Methuen Riverview Boulevard (river mile 26.2)

### Known CSO Infrastructure

- The Greater Lawrence Sanitary District (GLSD) has 5 CSO outfalls
- GLSD contributes the third largest volume of CSOs to the Merrimack each year compared to the other combined systems in the watershed (average of 53 million gallons per year)
- The Lawrence Bashara Boathouse Sampling Site is located upstream of all GLSD CSO outfalls, and the Methuen Riverview Boulevard site is located downstream of all GLSD CSO outfalls
- Both sites are located downstream of all Manchester, Nashua, and Lowell CSO outfalls

### Water Quality in the Greater Lawrence Region

In Greater Lawrence, 26% of samples analyzed for *E. coli* were above the safe limit (Figure 20) and 39% of samples collected for *Enterococcus* were above the safe limit (Figure 21). Of the unsafe *E. coli* samples, three were collected from the Lawrence site, and four were collected from the Methuen site. Of the *Enterococcus* samples, six were collected from Lawrence and eight were collected from Methuen.

Methuen is downstream of five GLSD CSO outfalls. However, CSOs alone do not fully explain the high concentrations found in Methuen nor the difference in concentrations when compared to the Lawrence site. There was one sample day in which there was neither wet weather, nor a CSO event that occurred upstream. On October 12$^{th}$, Methuen had levels of both *E. coli* and *Enterococcus* that were not safe. We do know of an illicit sewer connection upstream of our Methuen sampling site, which likely is contributing to some of these high concentrations. However, because not all samples collected during dry weather were high, stormwater from the urban areas upstream may also be contributing to the high concentrations at this site.

In summary, it is likely that a combination of sources of bacteria are contributing to bacteria contamination at the Methuen site, leading to more frequent unsafe conditions here than most other sites that we monitor. The Lawrence site is safe a large percentage of the time, except following CSOs that occur upstream.

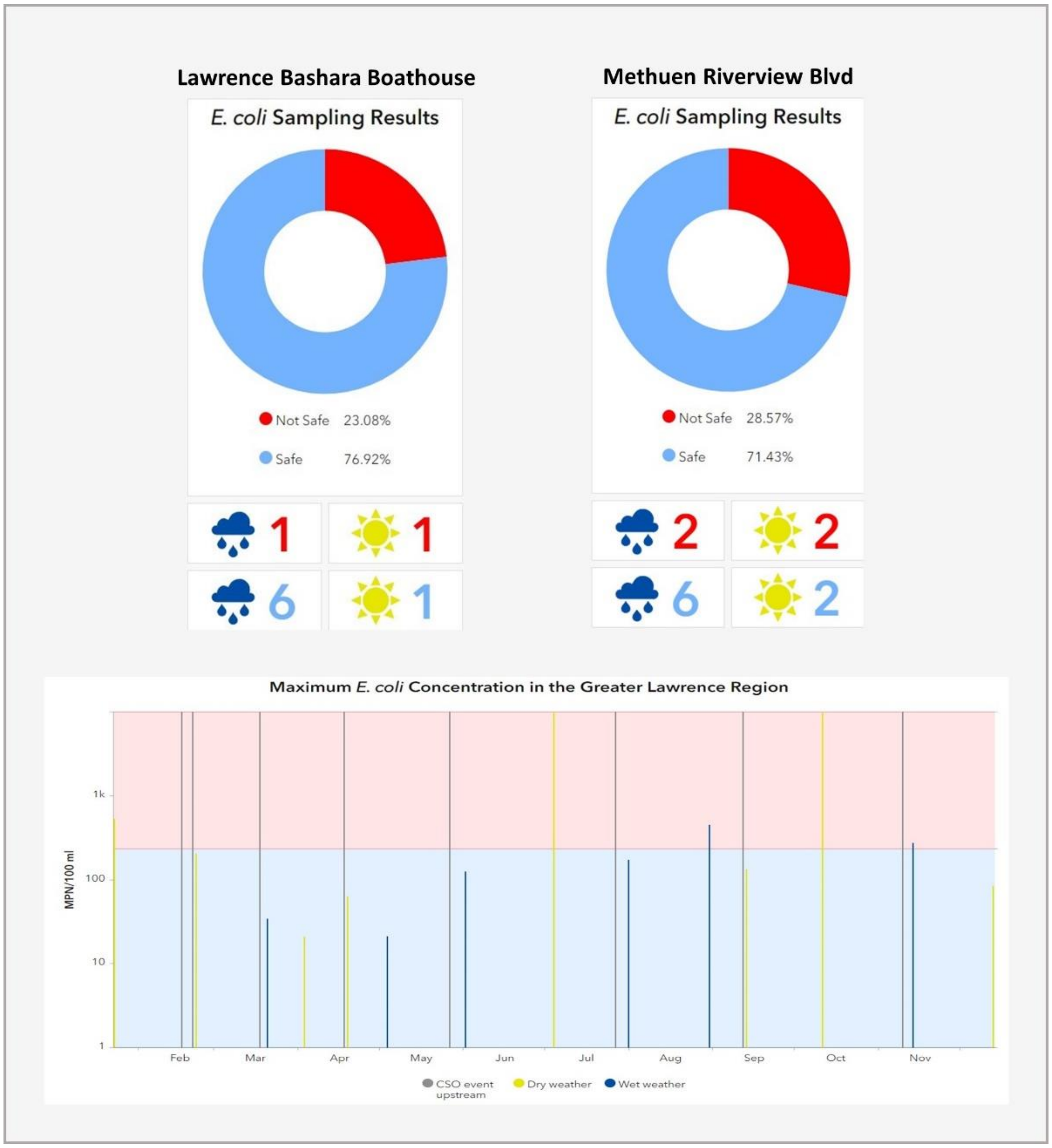



*Figure 20. Results of E. coli sampling at the sites within the Greater Lawrence region.*

*The circle graphs at the top indicate safe (blue) and unsafe (red) samples at each site. The number below the circle charts show the percentage and count of samples that are safe and unsafe, and whether they occurred during wet or dry conditions. The time series shows the maximum concentration of samples collected on each sampling day in this region, relative to upstream CSO events shown by grey lines (since daily CSO event data is not available for Manchester, it is therefore assumed that all CSO events occurring upstream of Lowell are from Nashua, NH).*

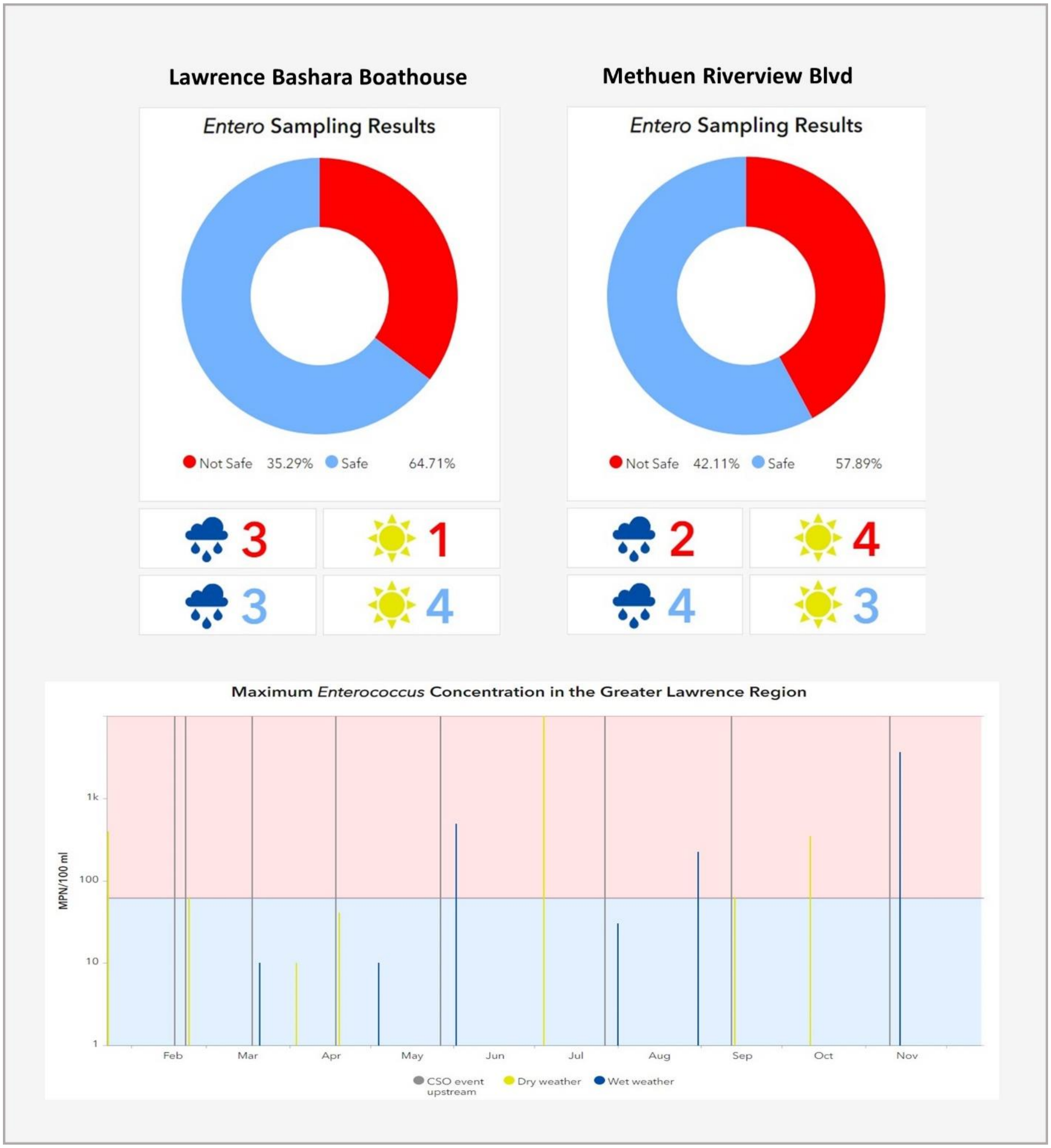


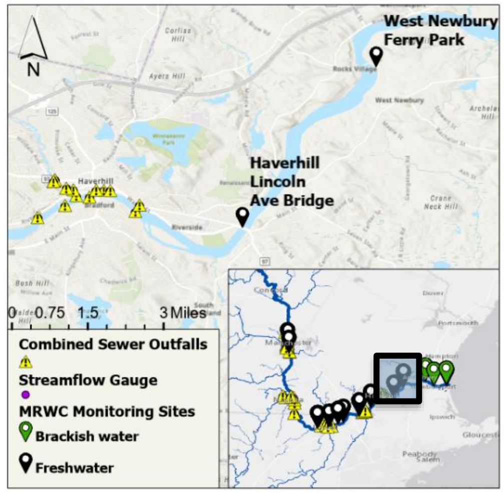

*Figure 21. Results of Enterococcus sampling at the sites within the Greater Lawrence region.*

*The circle graphs at the top indicate safe (blue) and unsafe (red) samples at each site. The number below the circle charts show the percentage and count of samples that are safe and unsafe, and whether they occurred during wet or dry conditions. The time series shows the maximum concentration of samples collected on each sampling day in this region, relative to upstream CSO events shown by grey lines (since daily CSO event data is not available for Manchester, it is therefore assumed that all CSO events occurring upstream of Lowell are from Nashua, NH).*

# Greater Haverhill, Massachusetts

## Monitoring Site Names

- Haverhill Lincoln Avenue Bridge (river mile 16.2)
- West Newbury Ferry Park (river mile 12.4)




## Known CSO Infrastructure

- Haverhill has 14 CSO outfalls
- Haverhill contributes the greatest number of CSO events per year on average, but contributes the second lowest volume compared to the other combined systems (average of 33 million gallons per year)
- Both the Haverhill and West Newbury monitoring sites are downstream of all Haverhill CSO outfalls

## Water Quality in the Greater Haverhill Region

In the Greater Haverhill region, 15% of *E. coli* samples were above the safe limit (Figure 22) and 22% of samples collected for *Enterococcus* were above the safe limit (Figure 23). All of the unsafe *E. coli* and *Enterococcus* samples collected from Haverhill were collected during wet weather conditions and/or within 3 days following a CSO event in Haverhill and either GLSD or Lowell. Haverhill has the greatest number of CSO events per year compared to all other combined sewer systems on the Merrimack. But while they are frequent, they are significantly smaller than those from GLSD or Lowell.

There were three instances (March 21st, June 2nd, and August 31st) where the *Enterococcus* samples were considered unsafe, but the *E. coli* samples were considered safe at the West Newbury Ferry Park site. Since *E. coli* is not viable in salt water, and, while the West Newbury Ferry Park site is considered freshwater, it is close enough to the coast that it could be somewhat tied to the tides, which could explain these results.

In the past, our volunteers and staff have noticed that there are several flocks of birds that typically spend time in the river upstream of this site. This region also has some agricultural land along the river, among other potential sources of nonpoint source pollution. Further research is needed to determine whether the geese or other human-related sources are contributing to these high concentrations at the West Newbury site.

It is also important to note that construction began at this site for bridge maintenance sometime in the late summer. While this seemed to have little effect on most of the data collected, we did see a spike in bacteria concentration at the time the construction began. More data will need to be collected after the construction is completed to determine what effects the bridge maintenance had on the water quality.

In summary, concentrations at the Haverhill site are most often within safe limits, except when there is sufficient rain to trigger a CSO in Haverhill *and* either Lowell or Lawrence. High bacteria concentrations at the West Newbury site require further investigation.

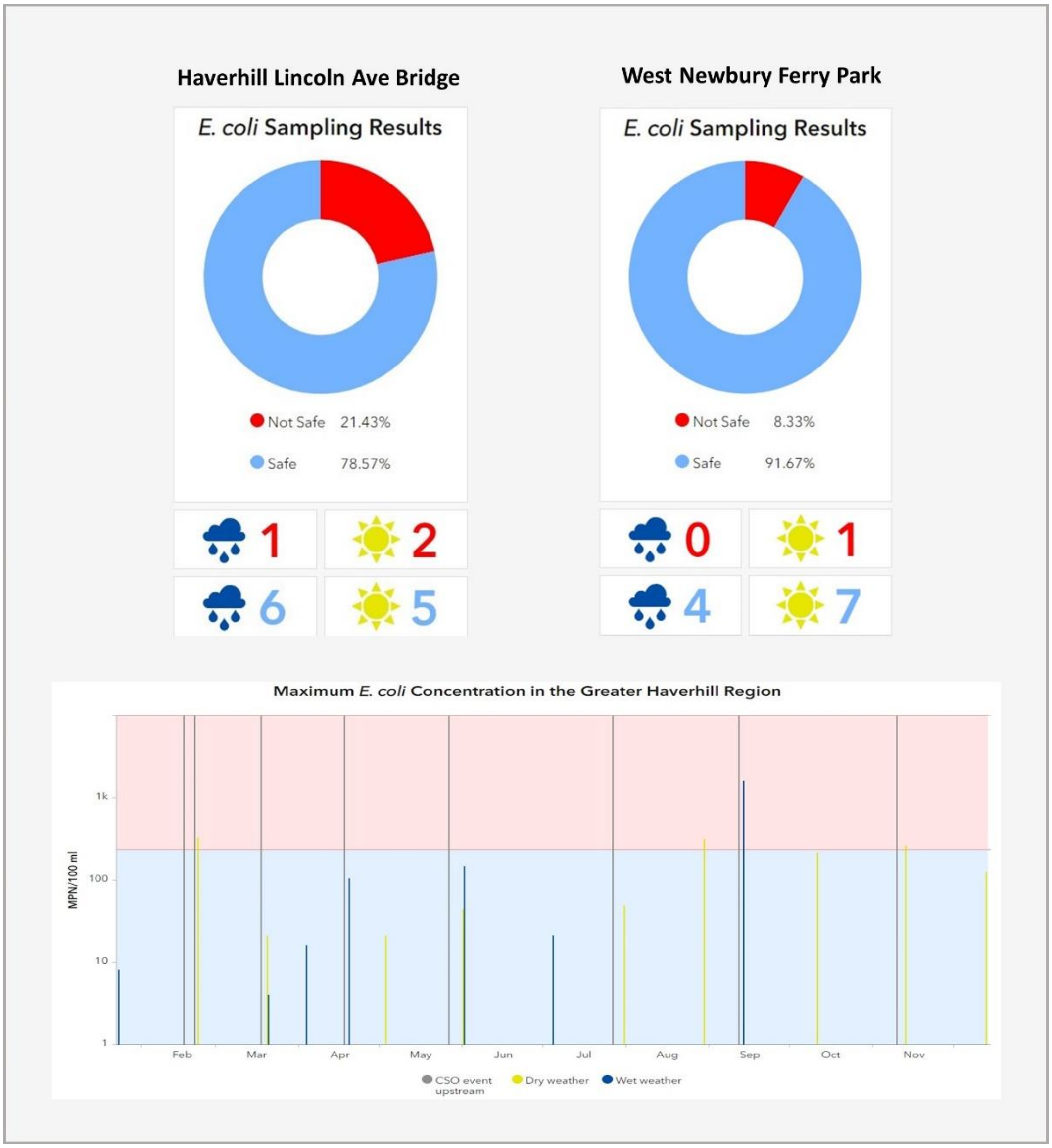



*Figure 22. Results of E. coli sampling at the sites within the Greater Haverhill region.*

*The circle graphs at the top indicate safe (blue) and unsafe (red) samples at each site. The number below the circle charts show the percentage and count of samples that are safe and unsafe, and whether they occurred during wet or dry conditions. The time series shows the maximum concentration of E. coli from samples collected on each sampling day in this region, relative to upstream CSO events shown by grey lines (since daily CSO event data is not available for Manchester, it is therefore assumed that all CSO events occurring upstream of Lowell are from Nashua, NH).*

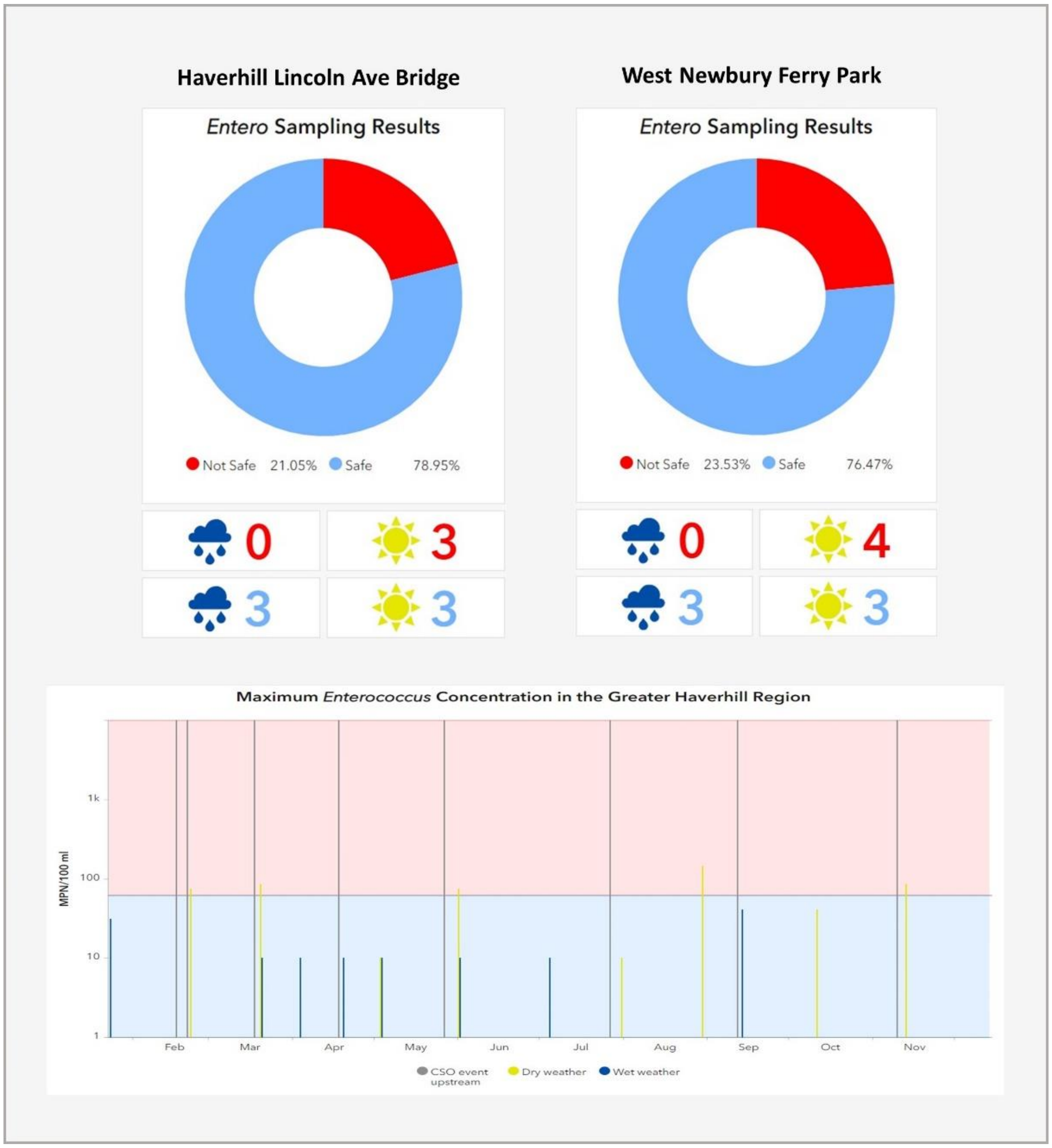


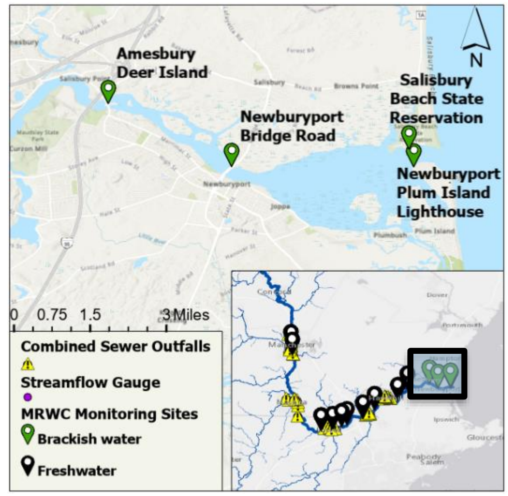

*Figure 23. Results of Enterococcus sampling at the sites within the Greater Haverhill region.*

*The circle graphs at the top indicate safe (blue) and unsafe (red) samples at each site. The number below the circle charts show the percentage and count of samples that are safe and unsafe, and whether they occurred during wet or dry conditions. The time series shows the maximum concentration of Enterococcus from samples collected on each sampling day in this region, relative to upstream CSO events shown by grey lines (since daily CSO event data is not available for Manchester, it is therefore assumed that all CSO events occurring upstream of Lowell are from Nashua, NH).*

# Coastal Region, Massachusetts

## Monitoring Site Names

- Deer Island (river mile 5.7)
- Newburyport Road Bridge (river mile 3.5)
- Plum Island (river mile 0.7)
- Salisbury Beach State Reservation (river mile 0.7)




## Known CSO Infrastructure

- There are no combined sewer outfalls within this region. All sites within this region are downstream of all CSO outfalls contributing to the mainstem of the Merrimack
- These sites may also be influenced by separated sewer systems, where stormwater flows directly to the river untreated during all rain events.

## Water Quality in the Coastal Region

*Enterococcus* is a more reliable indicator of fecal contamination in brackish water than *E. coli*. At these sites, average salinity during our sample collection ranged from 0.08 to 22.3 ppt, so we use *Enterococcus* as the indicator for fecal contamination (Figure 24). Our sampling protocol is such that samples in this region are collected within 2 hours before low tide (as the tide is going out).

In the coastal region, 14% of samples were above the safe limit for *Enterococcus (Figure 24)*. Of the samples above the safe limit, half were collected during wet weather sampling, and the other half were collected during dry weather, but at least three days after a CSO event occurred upstream.

There are no CSO outfalls in this region. However, this region is downstream of all CSOs on the mainstem of the Merrimack. This suggests that there is an obvious impact of CSOs, or rain events large enough to trigger CSOs, on bacteria concentrations at least three days following CSO events.

In summary, it is difficult to pull apart the influence of CSO contributions and wet weather contributions in this region because these sites are downstream of all CSO outfalls and close to the Haverhill CSOs, which experience a CSO almost every time it rains.

Overall, the majority of samples collected in this area are within safe limits for *Enterococcus*, suggesting it is typically safe to recreate in the river in these areas. However, rain and CSO events likely contribute to high concentrations for approximately three days following a CSO event.


*Figure 24. Results of Enterococcus sampling at the coastal sites.*

*The circle graphs at the top indicate safe (blue) and unsafe (red) samples at each site, relative to the EPA limit for recreational use (61 MPN/100 mL for Enterococcus). The number below the circle charts show the percentage and count of samples that are safe and unsafe, and whether they occurred during wet or dry conditions. The time series shows the maximum concentration of Enterococcus from samples collected on each sampling day in this region, relative to upstream CSO events shown by grey lines (since daily CSO event data is not available for Manchester, it is therefore assumed that all CSO events occurring upstream of Lowell are from Nashua, NH).*

# DATA QUALIFICATIONS

To ensure the integrity of the data we collect, our program has quality assurance in place. Each sampling day, volunteers are required to collect three two field duplicate parameter readings. Field blanks make up 10% of the total samples collected, and at the start of each new six-month commitment for volunteers, all volunteers collect a field blank so that any additional training or investigation can be implemented immediately.

We have experienced challenges with the Hach Pro meters, especially in colder weather. To make sure that the meter probes are reading accurately, we make sure that each is calibrated before every test day. We use 7.00 pH standard and 1413 µS/cm Conductivity standard. If there is an issue with the calibration, then the information is recorded, and the data can be adjusted or discarded as needed. Volunteers with take-home monitoring kits are trained on how to calibrate their machine. MRWC also produced a video walk-through of calibration for volunteers.

# DATA-DRIVEN SOLUTIONS FROM MRWC

While these data allow us to better understand what percentage of samples are safe or unsafe, there is more work to be done to better understand if we can make better correlations between rain events and CSO events, as well as their influence on the river's water quality. While Massachusetts is required to alter the public if a CSO event occurs[31], we would like to investigate not just if it rained within 3 days of sampling, but how much and where, and if that determines whether the river is safe or unsafe for recreational use. Similar analysis is still needed for CSO events - not just if one happened upstream, but how large it was, how long it lasted, and how far away it was from the sampling site - and if those factors can determine how safe or unsafe the bacteria levels are.

While understanding when to avoid the river is important, we would prefer Merrimack enthusiasts didn't have to avoid the river at all! We are working on a variety of approaches to reduce bacteria sources and prevent them from reaching the Merrimack in the first place. We are coordinating with municipalities to develop watershed-based plans and implement green infrastructure which will capture stormwater runoff and mitigate nonpoint source pollution before it reaches the Merrimack and its tributaries. These practices can also be used to reduce flooding and make our communities more climate resilient.

We are in a pivotal moment for infrastructure improvements in our country. Not since the Clean Water Act in 1972 has the federal government invested so much money in repairing our infrastructure, water and sewer infrastructure included. We are advocating to ensure the money from future federal and state funding reaches our communities. We are hopeful that this influx of funding, combined with the awareness we have been building around CSOs, will begin to bring solutions to the Merrimack.

# ACKNOWLEDGEMENTS

MRWC would like to thank our amazing 2022 volunteers for spending their early mornings collecting data and grab samples in the Merrimack. After these samples are collected, the EPA Region 1 Laboratory processes our samples free of charge. Rain or shine, warm or cold, our dedicated volunteers and partners at the EPA make this program a success!

MRWC would also like to thank our technical reviewers for their comments and suggestions to improve this report: Jill Carr, MassBays National Estuaries Partnership; Dr. Beth Haley and Professor Wendy Heiger-Bernays, Boston University School of Public Health.

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- Essex County Community Foundation, through the Dee & King Webster Foundation
- Greater Lowell Community Foundation
- NH Charitable Foundation
- MassDEP Water Quality Monitoring Grant
- Merrimack Conservation Partnership
- MassBays Healthy Estuaries Grant Program
- National Fish and Wildlife Foundation 5 Star Grant
- The Theodore Edson Parker Foundation
- The Rogers Family Foundation
- The Fuller Foundation
- New England Biolabs Foundation
- Volunteer NH
- Stevens Foundation
- Cell Signaling
- Bank of M & T, Amplify Fund
- Dorr Foundation

Thank you to these partners and our donors for their ongoing support of our water quality monitoring program!

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# APPENDIX

| Daily Combined Sewer Overflow Volumes (Gallons) | | | | |
|---|---|---|---|---|
| **Date** | **Haverhill CSO Volume[2]** | **GLSD CSO Volume[3]** | **Lowell CSO Volume[5]** | **Nashua CSO Volume[4]** |
| 1/17/2022 | 4,092,890 | 14,220,000 | 51,400,000 | 2,468,000 |
| 2/3/2022 | 893 | - | - | - |
| 2/4/2022 | 324,744 | - | 18,170,000 | 481,000 |
| 2/18/2022 | 17,789 | - | - | - |
| 2/22/2022 | 1,058 | - | 370,000 | - |
| 3/7/2022 | 3,179 | - | - | - |
| 3/12/2022 | 6,923 | - | - | - |
| 3/19/2022 | 61,466 | - | - | - |
| 3/24/2022 | 3,313 | - | - | - |
| 4/8/2022 | 62,194 | - | 20,000 | - |
| 4/19/2022 | 3,260,465 | 5,610,000 | 14,980,000 | 933,100 |
| 5/15/2022 | 60,341 | - | - | - |
| 5/16/2022 | 112,054 | 2,390,000 | 3,400,000 | - |
| 5/28/2022 | 219,975 | - | 7,690,000 | - |
| 6/1/2022 | - | - | 590,000 | - |
| 6/9/2022 | 172,516 | 3,210,000 | 6,570,000 | - |
| 6/29/2022 | - | - | 1,020,000 | - |
| 7/6/2022 | 107,463 | - | - | - |
| 7/14/2022 | 92,549 | - | - | - |
| 7/19/2022 | 117,000 | 510,000 | 11,010,000 | - |
| 7/21/2022 | - | - | - | 295,000 |
| 7/28/2022 | - | - | 9,390,000 | - |
| 9/5/2022 | 43,666 | - | 37,500,000 | - |
| 9/13/2022 | 106,906 | - | 180,000 | - |
| 9/19/2022 | 131,595 | - | 12,690,000 | - |
| 9/22/2022 | 313,981 | - | 2,440,000 | - |
| 10/13/2022 | 95,480 | - | - | - |
| 10/14/2022 | 52,705 | - | 7,740,000 | - |
| 10/17/2022 | 499,767 | - | 1,400,000 | - |
| 10/18/2022 | - | 15,700,000 | 2,630,000 | - |
| 10/24/2022 | 42,960 | - | - | - |
| 11/11/2022 | 21,476 | - | 4,740,000 | - |
| 11/16/2022 | - | - | 6,370,000 | - |
| 11/27/2022 | 14,943 | - | - | - |
| 11/30/2022 | 31,612 | - | - | - |
| 12/7/2022 | 22,775 | - | - | - |
| 12/16/2022 | - | - | 900,000 | - |
| 12/23/2022 | 678,860 | - | 27,610,000 | 83,000 |