# Estimation of the Sewage Water Dilution from Wastewater Treatment Plants in New Bedford and Fairhaven, Massachusetts

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## Executive Summary

A joint team, the University of Massachusetts-Dartmouth and the Massachusetts Division of Marine Fisheries, established a high-resolution (up to ~4 m) unstructured-grid, Finite-Volume Community Ocean Model (FVCOM) for the Massachusetts coast (Mass Coastal FVCOM). The model domain resolves the coastal ocean, rivers, and intertidal wetlands, and was configured with the 1.0 m × 1.0 m resolution LIDAR bathymetry. The Mass Coastal FVCOM was run through one-way nesting with the Northeast Coastal Ocean Forecast System (NECOFS) and driven by the assimilated atmospheric forcing at the surface from the Weather Research and Forecast model (WRF). The model was ramped up from the initial condition from December 15 to December 31, 2020. The simulation was done from January 1 to December 31, 2021, including freshwater discharged from 26 rivers and outfall discharges from the Wastewater Treatment Plants (WWTPs) from New Bedford and Fairhaven. Dilution maps were created to project the monthly and seasonal mean contaminant coverage areas in the New Bedford and Fairhaven regions. The model results show that the spreading and covered area of the WWTP diluted water varied significantly from month to month. The contaminant spreading was greater during winter through spring and less significant during summer through fall, even though the WWTP discharges were most prominent in the fall. Although the outfalls were located at the bottom, the WWTP-diluted water occupied a larger area at the sea surface than at the bottom. At the sea surface, the dilution region of the WWTP effluent reached a maximum in March and a minimum in July. The diluted water concentration was higher around the Fairhaven coast than around New Bedford, even though the WWTP discharge in Fairhaven was 5-6 times smaller.

## 1. Introduction and Background

New Bedford and Fairhaven, located on the western coast of Buzzard Bay, Massachusetts, are the most productive fishing ports over the U.S. coast (Fig. 1). Buzzard Bay is a shallow coastal region with a mean water depth ranging from ~5 m in the inner area to 20 m in the outer exit. The bay is dominated by semi-diurnal tidal currents, well-mixed during winter and stratified during summer. Two wastewater treatment plant (WWTPs) outfalls are located on the western coast of Buzzard Bay. One is at the bottom 944 m offshore on the southern coast of New Bedford, and another is within New Bedford Harbor, 300 m offshore of Fairhaven coast. The Environmental Protection Agency (EPA) made a comprehensive assessment of the impact of New Bedford sewage treatment facilities on the coastal marine environment in 1991 (EPA-FEIS, 1991). Moored meters were deployed in outer and inner New Bedford Harbor to measure dissolved oxygen (DO), nitrogen, and chlorophyll-a. The observations showed that the DO depression decreased offshore due to energetic ocean current flushing and biophysical interactions. The outfall at the offshore site could avoid the local accumulation of contaminants, reducing the nitrogen concentration and the risk of DO violation in the outer region of New Bedford Harbor.

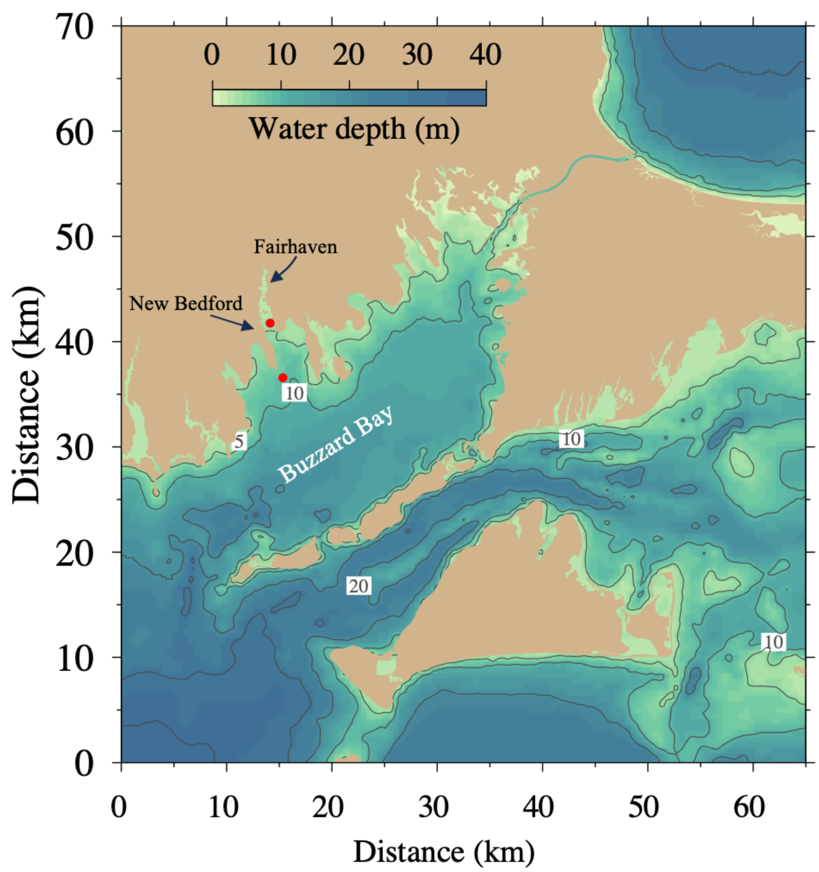



*Fig. 1: Geometries of Buzzard Bay, including New Bedford and Fairhaven. The image is the water depth. The red dots are the outfall location off the New Bedford and Fairhaven coasts.*

However, no efforts have been made to simulate the spreading and covered area of contaminant dilution from either outfall at New Bedford or Fairhaven coast. The sewage contains toxic microorganisms. The New Bedford Harbor is flushed or drained by the semidiurnal $M_2$ tidal currents almost twice daily. This flushing and draining process is significantly altered by surface winds, especially during storms. Although the outfall at the offshore site on the southern coast of New Bedford could reduce the local contaminant accumulation, the WWTP effluent could carry these contaminants to the surrounding water areas, enlarging its covered areas. The water exchange in New Bedford Harbor and Buzzard Bay goes through a narrow navigation passage where the Fairhaven bridge is located. The contaminants from Fairhaven outfall could be accumulated locally due to the inefficient water exchange through that passage.

We, the Marine Ecosystem Dynamics Laboratory, School for Marine Science and Technology (SMAST), University of Massachusetts-Dartmouth (UMASS-D), have established a high-resolution (up to ~4 m) WWTP effluent assessment model for the Massachusetts coast (named Mass Coastal-FVCOM). This work was accomplished by collaborating with the Massachusetts Division of Marine Fisheries (MDMF) through a Massachusetts Marine Fisheries Institute (MFI), a cooperative venture between the SMAST/UMASSD and MDMF. The model was developed using the unstructured grid, Finite Volume Community Ocean Model (FVCOM) (*Chen et al*., 2003, 2006, 2013a). The unstructured triangular grid used in FVCOM is advantageous for resolving complex coastal geometry. This model was robust for tracking the discharges of the Yarmouth WWTP in Casco Bay, Maine (True, 2018) and the North River, MA (Chen et al., 2022a).

This report summarizes the major findings from the numerical simulation of the WWTP effluents from the New Bedford and Fairhaven outfalls. The simulation used the Massachusetts coastal WWTP effluent assessment model (Mass Coastal-FVCOM). Mass Coastal FVCOM was run through one-way nesting with the Northeast Coastal Ocean Forecast System (NECOFS) and driven by the assimilated atmospheric forcing at the surface from the Weather Research and Forecast model (WRF). The model was run from January 1 to December 31, 2021, including freshwater discharged from 26 rivers and discharges from New Bedford and Fairhaven WWTP outfalls.

The report is organized as follows. Section 2 describes the model, data, and numerical experiment designs. Section 3 presents the dilution maps for the case considering the outfall discharges from New Bedford and Fairhaven WWTPs and the case considering only the Fairhaven WWTP outfall. Section 4 highlights the model validation experiments. Section 5 summarizes the primary finding, followed by suggestions for future works.

## 2. The Model, Data, and Numerical Experiment Designs

### 2.1 Mass Coastal-FVCOM and the numerical experiment design

Mass Coastal-FVCOM was developed by configuring FVCOM to the Massachusetts coast. The FVCOM version used in this trace-tracking experiment employed $\sigma$- transformation in the vertical and non-overlapping, unstructured triangular grids in the horizontal. The vertical eddy viscosity was produced by the Mellor and Yamada level-2.5 turbulent closure scheme (*Mellor and Yamada*, 1982). The horizontal diffusion coefficients were specified using the Smagorinsky eddy parameterization (*Smagorinsky*, 1961). The FVCOM is solved numerically by a finite-volume flux calculation with the discretization of the integral form of the governing equations at the non-overlapping, unstructured triangular grid node (tracer variables) and centroids (horizontal velocities) (Chen et al., 2003). The triangular grid approach in FVCOM provides the flexibility to make the mesh fit well with irregular coastlines and geometries. The flux calculation accurately represents the volume mass conservations in individual control volumes for water properties. The discretization, time integration, and coding structure of FVCOM were described in detail in the FVCOM user manual (Chen et al., 2013a). Mass Coastal-FVCOM simulates the flooding/drying process using unstructured-grid wet/dry point treatment algorithms (*Chen et al*., 2003, 2013, and 2022b). Numerical singularity due to a zero depth in the σ-coordinates was avoided by adding a viscous sublayer with a 5-cm thickness in the equations. The criteria determining the wet or dry conditions in individual grid cells are based on the total water depth at the triangle's nodes and cells. A detailed discussion of this unstructured grid wet/dry point treatment technique was given by *Chen et al*. (2003, 2022b), and an example of the WWTP dilution water simulation was done

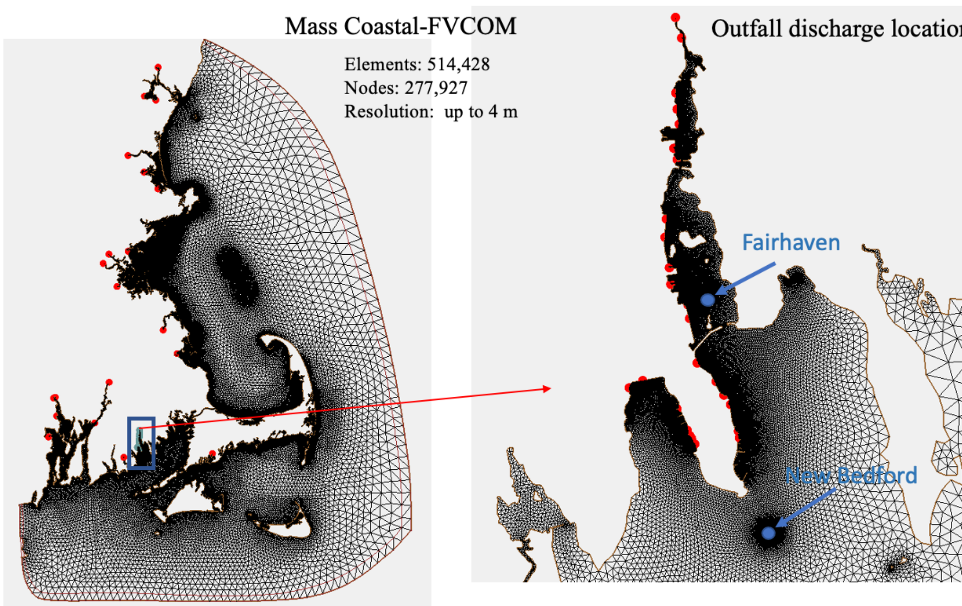



*Fig. 2: The Mass Coastal-FVCOM grid (left) and the outfall discharge locations (right). Red dots: the locations of 26 wastewater outfall sites along the New Bedford coast. Filled blue dots: the WWTP outfall locations in New Bedford and Fairhaven. Red dots: the locations of the USGS river discharge locations.*

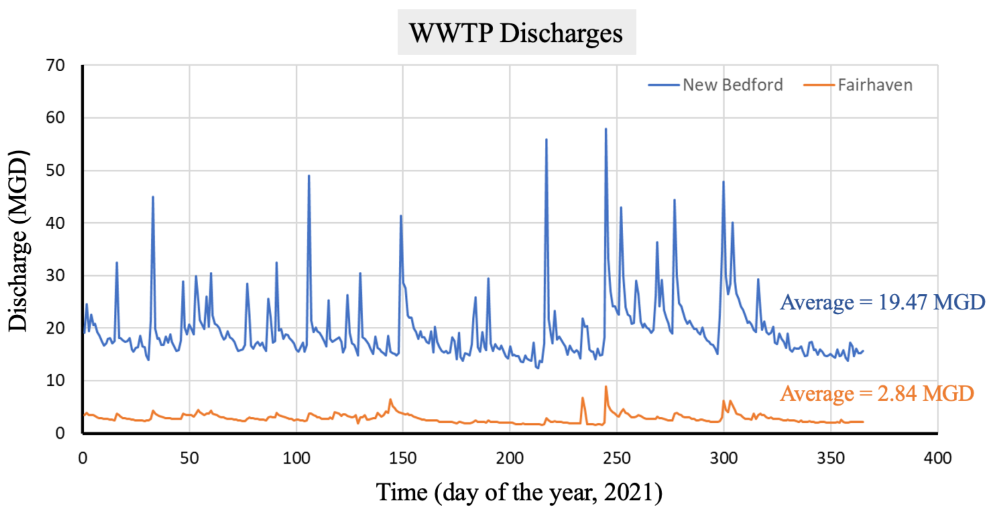
for the North River in Scituate, MA, in 2022 (Chen et al., 2022a).

The computational domain of Mass Coastal-FVCOM covered the entire Massachusetts coast, estuaries, and wetlands (Fig. 2). The domain was meshed using a non-overlapping unstructured triangular grid with a horizontal resolution up to ~ 4 m. It contains a total of 514,428 elements and 277,927 nodes. A uniform sigma coordinate transformation with eleven levels was used in the vertical, corresponding to a vertical resolution of 2.0 m or less over the shelf and 0.5 m or less in the river and intertidal salt marsh. The 1-m resolution LIDAR bathymetry set up the mean water depth. The time step was 0.3 sec for the internal mode, with an internal-to-external time step ratio of 5. This ratio was determined based on the stability analysis results (*Chen et al.*, 2022b). The initial and open boundary conditions were provided by NECOFS hindcast simulation fields, and the surface atmospheric forcing was specified using the 2021 assimilated WRF hindcast field, including wind, heat flux, and precipitation via evaporation. The WRF assimilation results were validated via wind measurements at meteorological buoys available in the region from the Chesapeake Bay to the Nova Scotian shelf. A total of 26 rivers were included in the computational domains. The freshwater discharges from those rivers were specified using the USGS daily records.

Two types of experiments were done. The first experiment included New Bedford and Fairhaven WWTP discharges simultaneously. To distinguish the impacts of the Fairhaven WWTP from the New Bedford WWTP, we re-run the tracer-tracking model for December 2021 by only considering the Fairhaven WWTP discharge only. It is a month showing the worst environmental impact in the New Bedford Harbor.

### 2.2 WWTP daily discharge data

The MDMF collected the 2021 daily discharge data from New Bedford and Fairhaven WWTPs (Fig. 3). The discharge rate from the New Bedford WWTP outfall varied significantly from month to month, ranging from 12.4 to 57.9 MGD. The discharge rate from the Fairhaven WWTP was about seven times smaller, with a change in a range of 1.6 to 8.9 MGD. The discharge rate from New Bedford WWTP outfall exhibited a maximum in autumn, about 4.6 to 6.1 MGD higher than in spring, summer, and winter. The discharge rate from the Fairhaven outfall remained stable throughout the year, with a seasonally averaged difference of only 1.0 MGD. The yearly mean discharge rates at these two WWTP outfalls were 19.5 and 2.8 MGD, respectively.




| WWTP Discharge (MGD) | Spring | Summer | Fall | Winter |
|---|---|---|---|---|
| New Bedford | 18.93 | 17.49 | 23.55 | 18.16 |
| Fairhaven | 3.25 | 2.22 | 3.24 | 2.77 |

*Fig.3: The daily discharge rates from the New Bedford and Fairhaven WWTP outfalls. The table summarized the seasonally averaged discharge rates at these two sites.*

## 3. Model Results

### 3.1. Covered areas of the WWTP contaminant

We have created the monthly and seasonally averaged surface and bottom dilution maps to show the spreading areas of the WWTP contaminant with concentrations of 100:1, 500:1, 1000:1, and 1500:1. Two types of maps were created with regional and local domains shown in Fig. 4. The regional domain map covered the entire Buzzard Bay, including Narragansett Bay and a portion of Nantucket Sound. The small domain map covers the New Bedford and Fairhaven areas, with concentrations of 20:1, 30:1, 40:1, 50:1, 100:1, 200:1, 400:1, 600:1, and 1000:1. The data used to create the dilution map was based on the hourly Mass Coastal-FVCOM-simulated tracer concentrations. The monthly model outputs, dilution maps, and animations were organized and saved into an external drive. It can be accessed by contacting Dr. Liuzhi Zhao through his email: lzhao@umassd.edu.

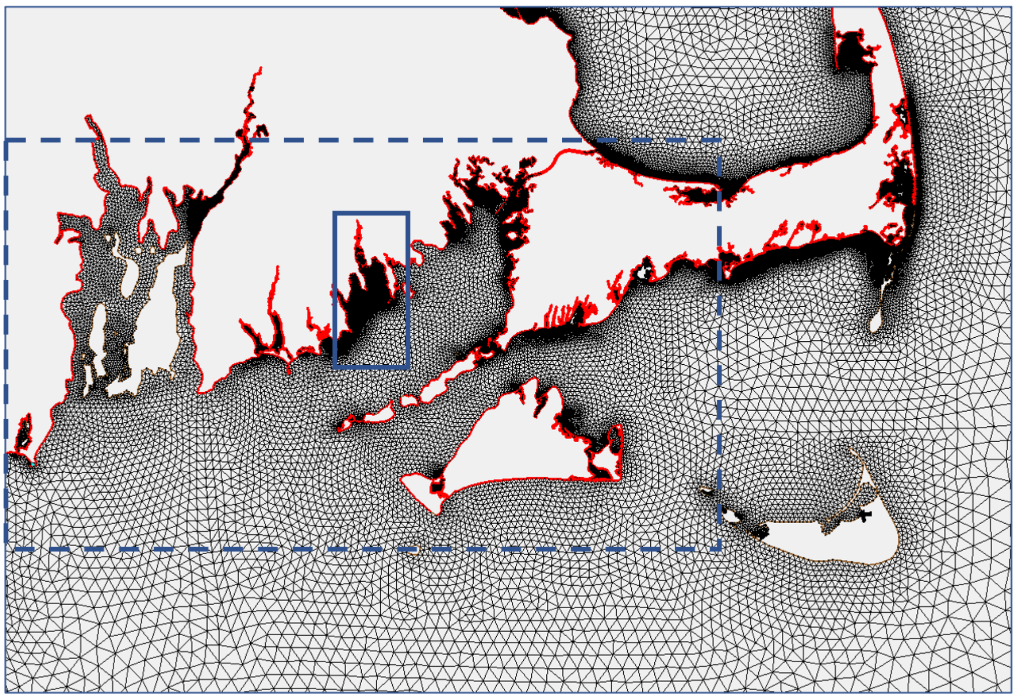


*Fig. 4: The regional and local domains used to display the WWTP dilution coverage areas with concentrations of 100:1, 500:1, 1000:1, and 1500:1.*

The WWTP dilution over the New Bedford and Fairhaven coasts was mainly driven by the advection and mixing due to strong semidiurnal tides and winds. This region was flushed by tidal currents twice daily. The dominant semidiurnal $M_2$ tidal current amplitude was ~11-12 cm/s at the New Bedford WWTP site and ~15 cm/s at the Fairhaven WWTP site. There was no wind measurement data available in this region in 2021. The closest wind measurement was at NOAA buoy#44020 in Nantucket Sound, but the wind direction sensor did not work well. According to the wind speed and direction records on buoy#44013 in Massachusetts Bay, this area prevailed strongly varying winds, northwesterly to southwesterly in winter and spring, southwesterly in summer, and southeasterly in autumn (Fig. 5). The maximum wind exceeded 12 m/s, a peak of >15-20 m/s, occurring in winter, spring, and autumn, even though the occurrence frequency was only in a range of ~2-5%.

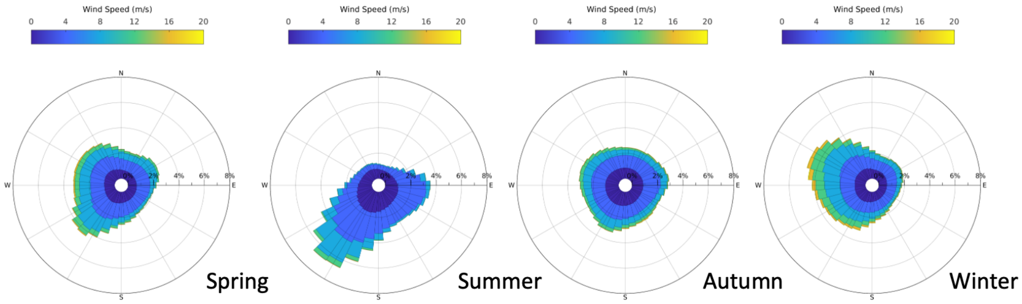



*Fig.5: The wind rose plots for spring, summer, autumn, and winter. Colors: wind speed; the circles with percentage labels: the occurrence frequency of the wind. The wind data are from the hourly records at buoy#44013 from January 1 to December 31, 2021.*

**Seasonally mean dilution maps**. The spreading and covered area of the WWTP diluted water varied significantly from month to month. Taking the 1000:1 contour line as a boundary to measure the WWTP effluent-affected area, the model results indicated that the impact of the WWTP effluent on the local marine environment was more significant in winter through early spring and less influential in summer through autumn. Figures 6-9 show the seasonal-mean distribution of the diluted water at the surface and bottom in the region. In 2021, the New Bedford and Fairhaven coast waters were vertically well mixed during winter. The 1000:1 contour covered a large area throughout the water column in Buzzard Bay, bounded by the cross-bay lines between Westport Point and Naushon Island on the south and Ram Island and Uncatena Island on the north. The high concentration of diluted water, bounded by a 20:1 contour, occurred at the surface about 1.5-2.0 km around the New Bedford outfall site, but it did not appear at the bottom. The dynamical analysis implied that energic vertical mixing brought the WWTP water quickly from the bottom to the surface. Meanwhile, the interaction of the laminar flow from the WWTP pipe and oceanic currents resulted in a divergent flow field at the bottom. This divergence enhanced the horizontal advection and diffusion to mix the outfall effluent with the surrounding water. The Fairhaven WWTP outfall was located within the New Bedford Harbor. The narrow navigation passage connecting the harbor to Buzzard Bay is only ~106.5 m wide. Due to inefficient water exchange through this passage, the northern area of the New Bedford and Fairhaven coast was full of contaminant water with a concentration of 30:1 or higher, and the highest concentration occurred on the Fairhaven side.

In spring, the water became stratified in the southern Buzzard Bay. The boundary of the 1000:1 dilution line pushed back toward the New Bedford coast at the surface and bottom, but the covered area, bounded by the 1000:1 contour line, was much smaller at the bottom. The distribution of the diluted water around the New Bedford outfall was like that in winter, but the concentration was much lower. The 1000:1 line covered an area only 7-8 km from the outfall. The water quality condition around the Fairhaven outfall slightly improved, but most regions of New Bedford harbor were still full of contaminant water bounded by the 30:1 dilution line.

In summer, the weaker winds significantly reduce the spatial spreading of the WWTP contaminants in Buzzard Bay. The 1000:1 contour line shrank back to the western coast, with the yearly lowest concentration in the region. Especially at the bottom, the contaminant water, bounded by the 1000:1 dilution line, only covered an area about 3 km away from the southernmost tip of New Bedford. In the Fairhaven coastal region, a high concentration of contaminant water was trapped around the outfall area, even though the pollution condition in the northern area and on the New Bedford side was significantly improved.

In autumn, the distribution of the WWTP diluted water was like what was found in spring. Both spring and autumn were the transition periods. The former was from well-mixed to stratified conditions, and the latter from stratified to well-mixed environments. The only difference was in the contaminant concentration around the Fairhaven outfalls, which was higher in autumn than in spring.

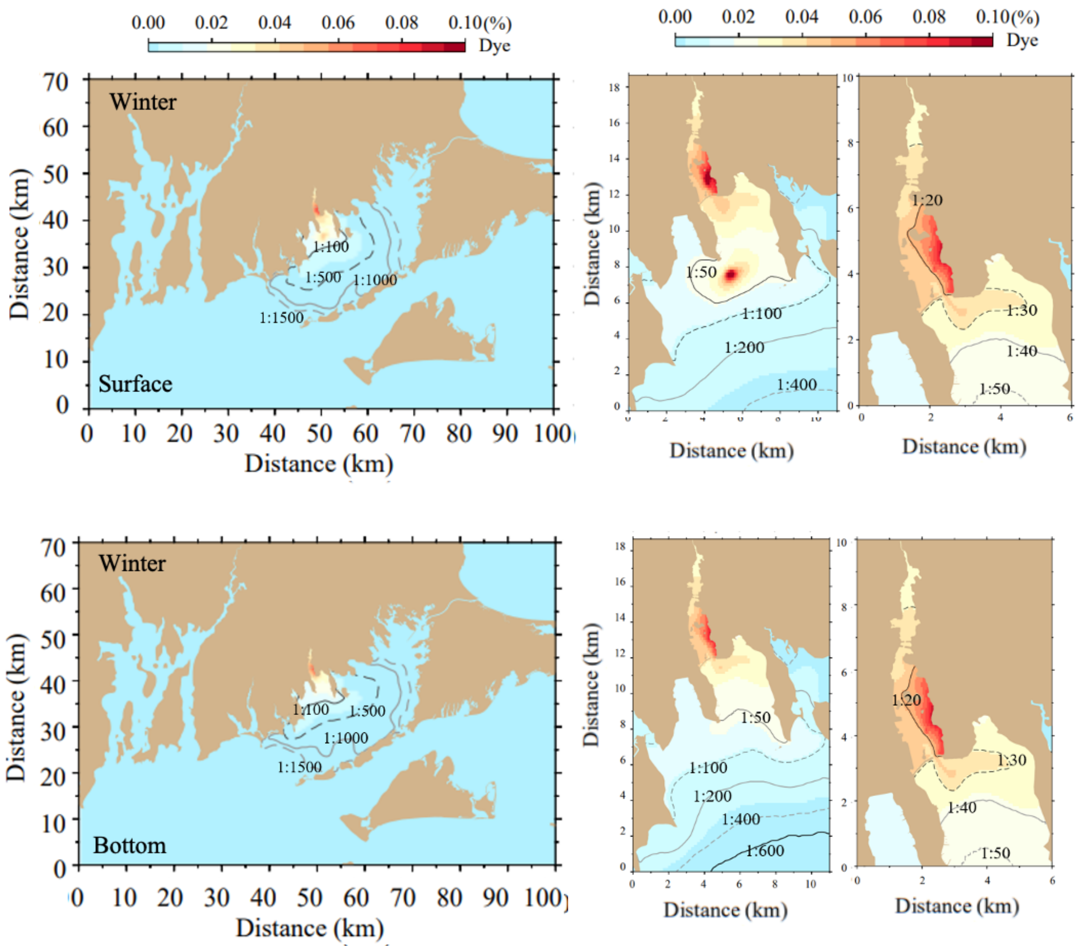



*Fig. 6: The wintertime distributions of the WWTP diluted water at the sea surface (upper panels) and bottom (lower panels) for the case with combined Fairhaven and New Bedford outfall discharges. The winter season included December, January, and February 2021.*

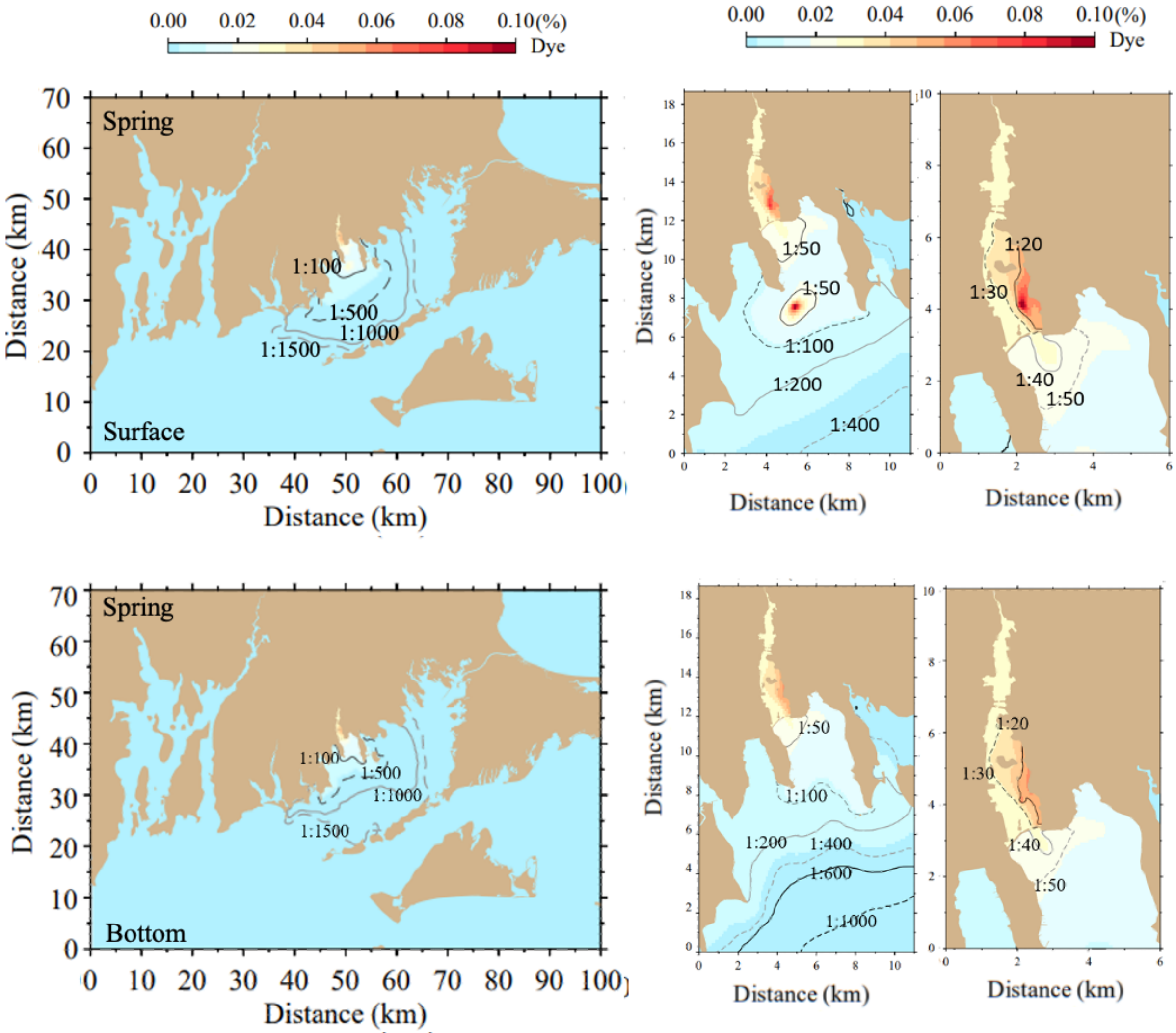



*Fig. 7: The springtime distributions of the WWTP diluted water at the sea surface (upper panels) and bottom (lower panels) for the case with combined Fairhaven and New Bedford outfall discharges. The winter season included March, April, and May 2021.*

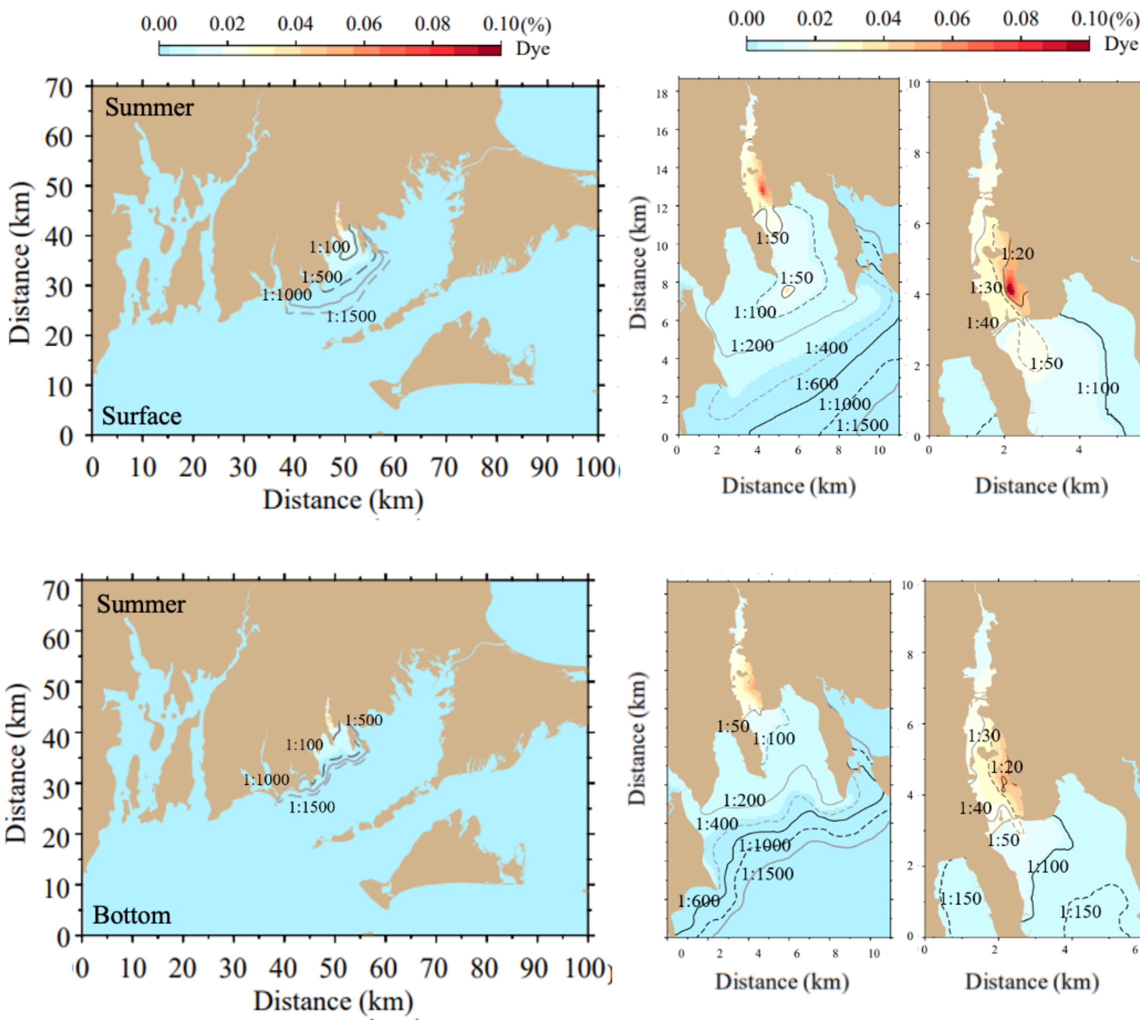



*Fig. 8: The summertime distributions of the WWTP diluted water at the sea surface (upper panels) and bottom (lower panels) for the case with combined Fairhaven and New Bedford outfall discharges. The winter season included June, July, and August 2021.*

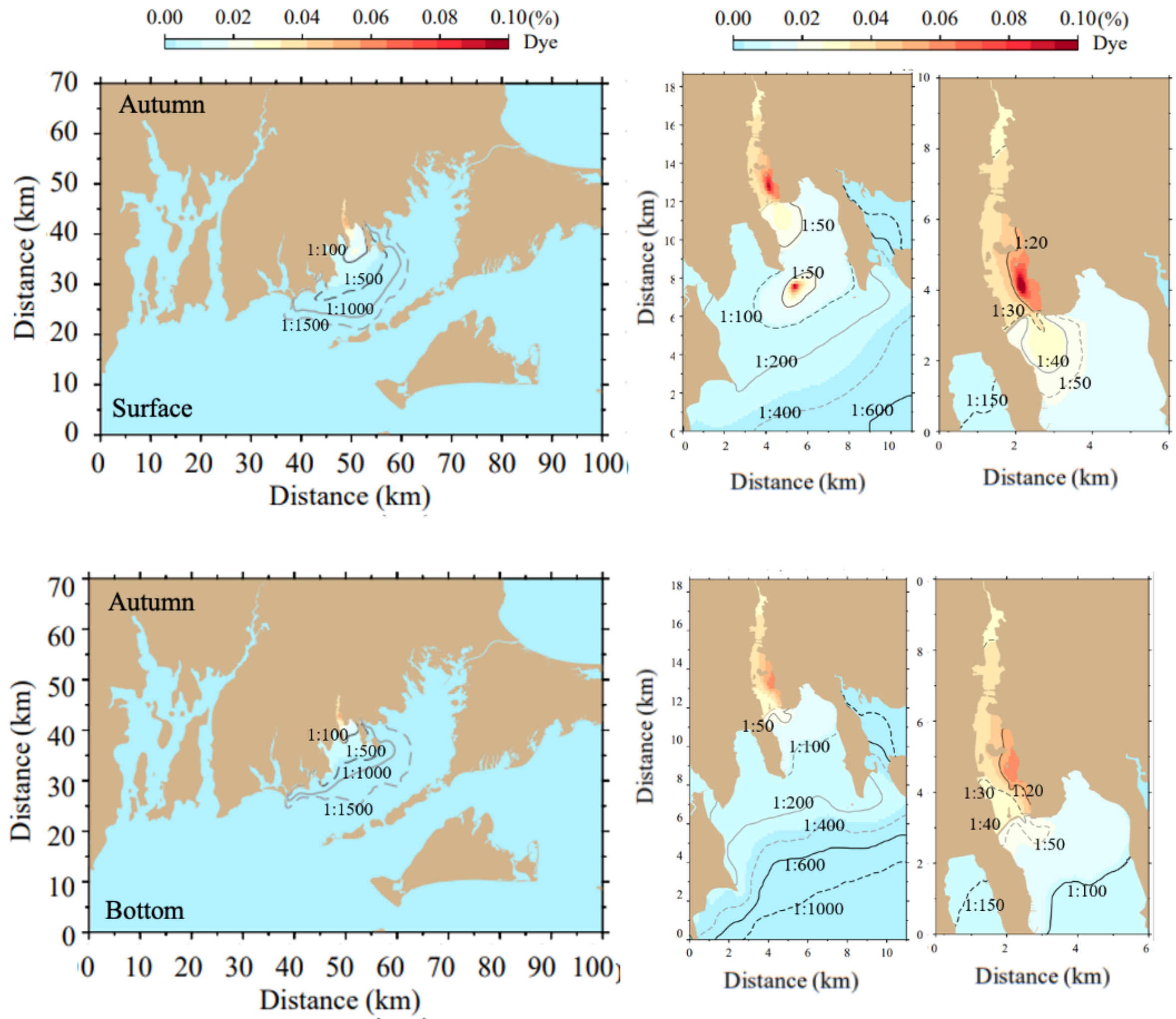



*Fig. 9: The autumntime distributions of the WWTP diluted water at the sea surface (upper panels) and bottom (lower panels) for the case with combined Fairhaven and New Bedford outfall discharges. The winter season included September, October, and November 2021.*

**Maximum and minimum dilution maps**. In 2021, the maximum and minimum spreading areas of WWTP diluted waters in Buzzard Bay occurred in March and July, respectively. The monthly-averaged discharge rates in March were 19.65 MGD at the New Bedford outfall and 3.02 MGD at the Fairhaven outfall. Compared with the winter condition, the 1000:1 contour line in March extended northward to Charles Neck Point, covering Nyes Cove and Aucoot Cove on the western side of Buzzard Bay (Fig. 10). The 500:1 contour line extended eastward throughout the water column, reaching the bay's eastern coast. The distributions of the surface and bottom WWTP diluted waters in July were similar to the summer seasonal mean condition, except for a slightly smaller area bounded by 1000:1 contour lines throughout the water column (Fig. 11).

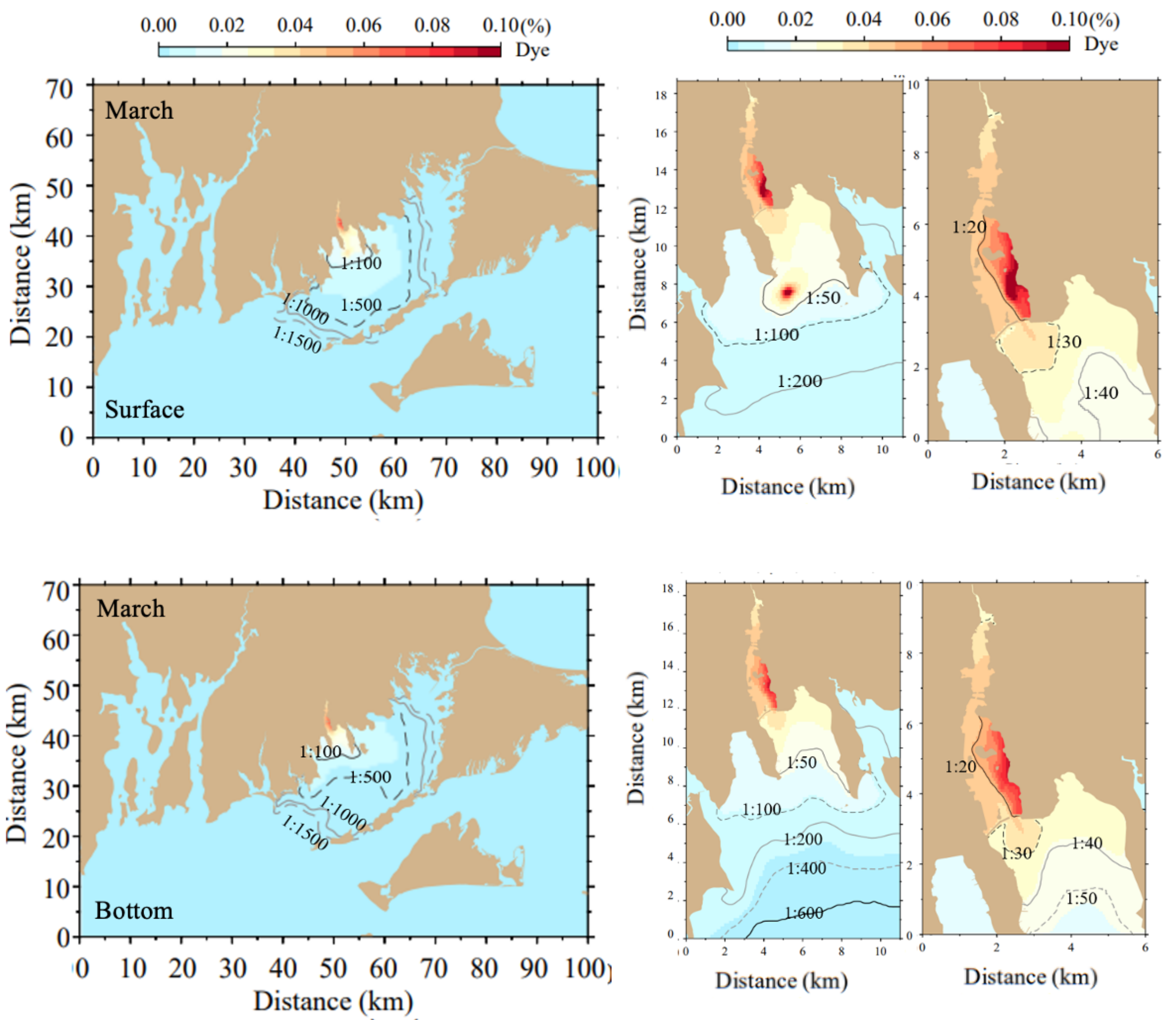



*Fig. 10: The monthly-averaged distributions of the WWTP diluted water at the sea surface (upper panels) and bottom (lower panels) for March 2021. The simulation was done with combined Fairhaven and New Bedford outfall discharges.*

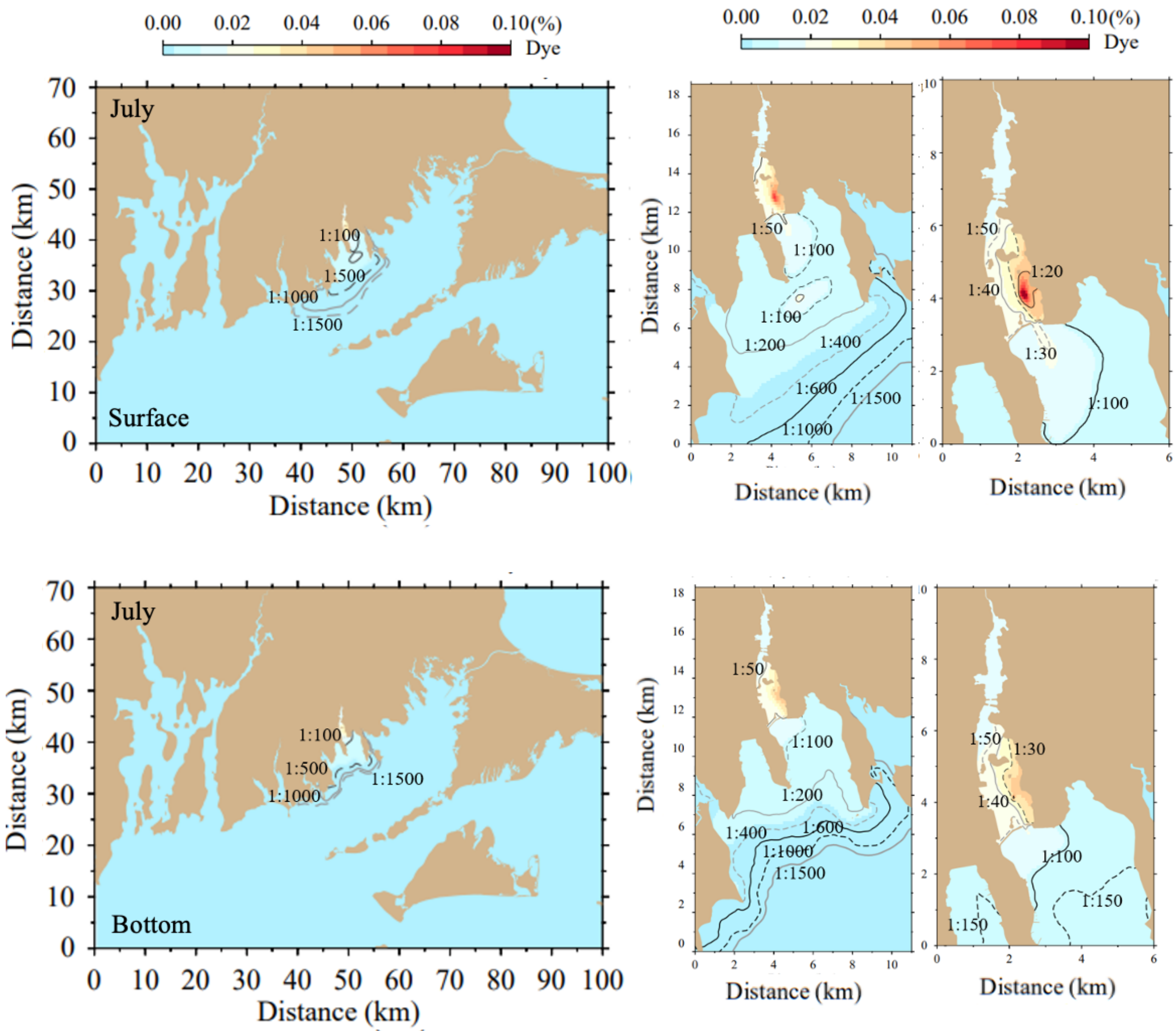



*Fig. 11: The monthly-averaged distributions of the WWTP diluted water at the sea surface (upper panels) and bottom (lower panels) for July 2021. The simulation was done with combined Fairhaven and New Bedford outfall discharges.*

### 3.2. The maximum influenced area of the Fairhaven WWTP effluent

The dilution maps presented in Figs. 5-11 considered both the New Bedford and Fairhaven WWTP outfalls. Since the diluted water from the New Bedford outfall could be advected northward to New Bedford Harbor, those maps could not distinguish the maximum influenced area by the Fairhaven outfall discharge. The 2021 simulation showed that the most significant impact of the Fairhaven WWTP effluent on the New Bedford harbor environment occurred in December. Choosing this month as an example, we examined the maximum influence area of the Fairhaven outfall by running the model with the only Fairhaven outfall discharge. The discussion was carried out by comparing the dilution maps for the cases with only Fairhaven outfall and combined Fairhaven and New Bedford outfall discharges. We named the only Fairhaven outfall discharge case “Case-F” and the combined Fairhaven and New Bedford outfall discharge case “Case-NF.”

The simulation results from Case-F showed that the diluted water from the Fairhaven outfall could be advected into the southern area of Buzzard Bay in winter. At the sea surface, the 1000:1 contour line reached the bay's western coastal region, ~3 km from Nashawena Island, and bounded by West Island Town Beach on the north and Westport Point Horseneck Beach on the south (Fig. 12: upper-left). Comparing Case-F with Case-NF suggested that the combined Fairhaven and New Bedford outfall discharges enlarged the covered area of the WWTP contaminant in Buzzard Bay (Figure 12: lower-left). Meanwhile, it increased the contaminant concentration around the Fairhaven outfall. At the bottom, the influence of the Fairhaven outfall discharge on the water quality in Buzzard Bay was mainly concentrated along the western coast, even though the 1000:1 contour line could still extend to West Island on the north and Westport Point on the south (Fig.13: upper-left). Like the surface, adding the New Bedford outfall discharge enlarged the covered area of the WWTP diluted water in Buzzard Bay and increased the contaminant concentration in the New Bedford Harbor area (Fig. 13: lower-left).

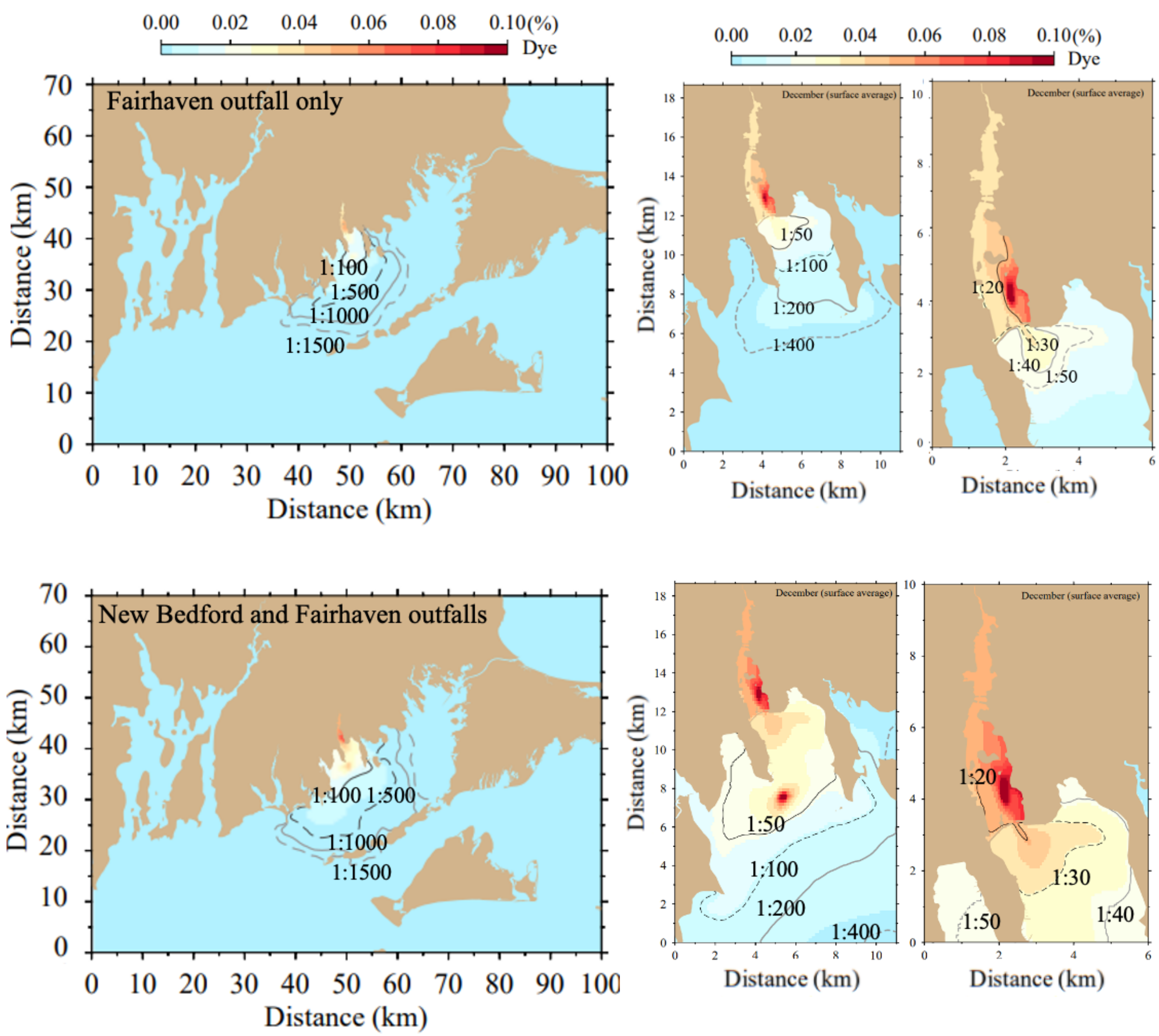



*Fig.12: The distributions of the WWTP diluted water at the sea surface for the case with the only Fairhaven outfall discharge (upper panels) and combined Fairhaven and New Bedford outfall discharges (lower panels). The model simulation was conducted for December 2021.*

The Fairhaven outfall discharge led to the WWTP contaminant accumulation in New Bedford Harbor north of the Fairhaven bridge (Fig. 12: upper-right). The whole region was full of the WWTP diluted water bounded by 30:1 or higher. The highest concentration was on the Fairhaven coast, where the concentration ratio exceeded 10:1, relatively higher at the surface and lower at the bottom (Figs 12-13: upper-right). The combined Fairhaven and New Bedford outfall discharges made the water quality much worse in the New Bedford Harbor area, where the whole region was full of WWTP contaminants with a concentration ratio of 20:1 or higher (Figs. 12-13: lower-right).

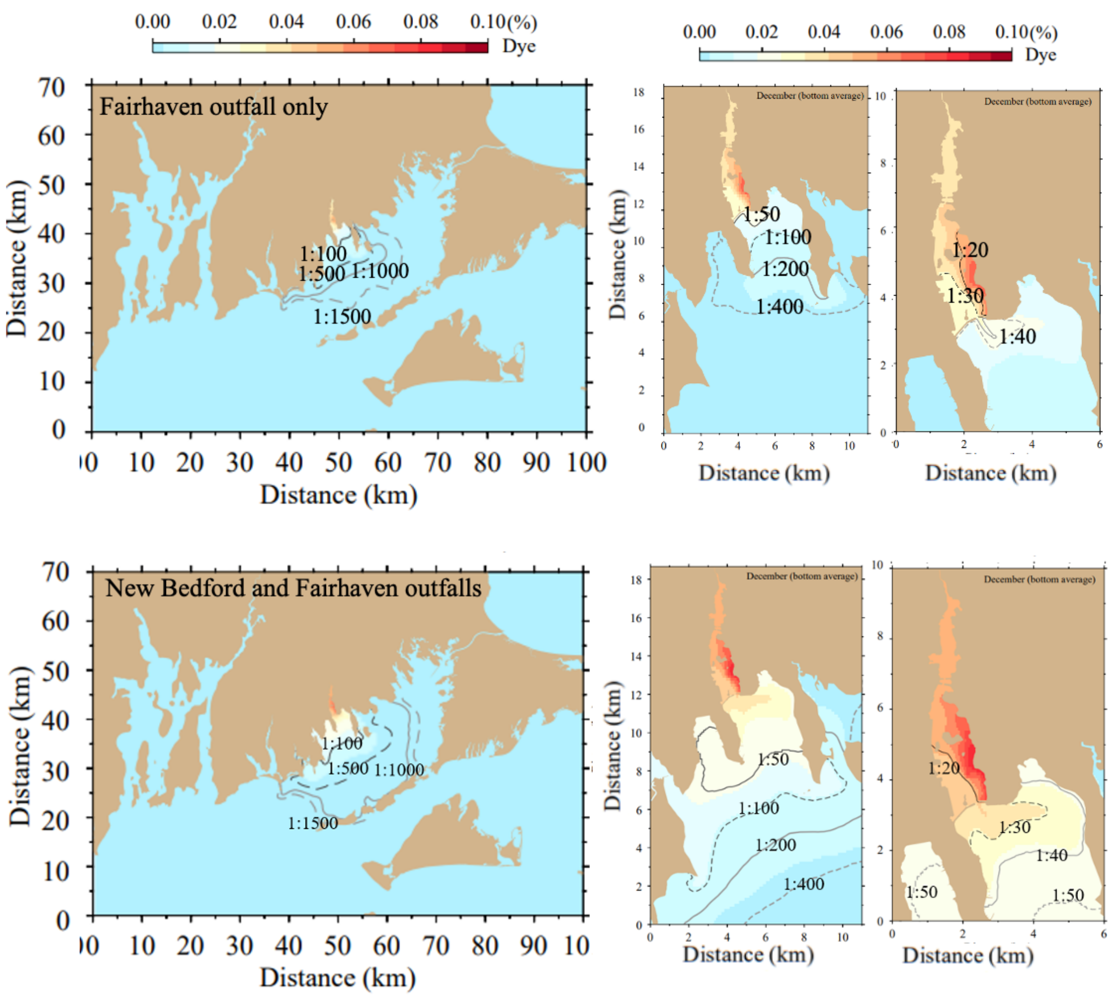



*Fig.13: The distributions of the WWTP diluted water at the bottom for the case with the only Fairhaven outfall discharge (upper panels) and combined Fairhaven and New Bedford outfall discharges (lower panels). The model simulation was conducted from December 1 to 31, 2021.*

## 4. The Model Validation

Mass Coastal-FVCOM is a subdomain model nested with NECOFS. NSCOFS has been validated by comparing the results with many available observations over the last 41 years (1978-2018), including 1) water levels (*Chen et al.*, 2011), 2) stratification (*Li et al.*, 2015), 3) currents (*Sun et al.*, 2016, *Cowles et al.*, 2008), 4) hurricanes, extratropic storms, surges, and coastal inundations (*Beardsley et al*., 2013; *Chen et al*., 2013b; *Sun et al*., 2013; *Li et al*., 2020; *Li and Chen*, 2022), and 5) the sea level rise impacts on storm-induced coastal inundations (*Zhang et al*., 2020b; *Chen et al*., 2020). In this WWTP dilution assessment experiment, we updated bathymetries in the nearshore, wetland, and rivers in Mass Coastal-FVCOM using the 1.0 m × 1.0 m resolution LIDAR data. A tidal validation was conducted to ensure the model's capability of capturing the tidal currents and elevation in the region.

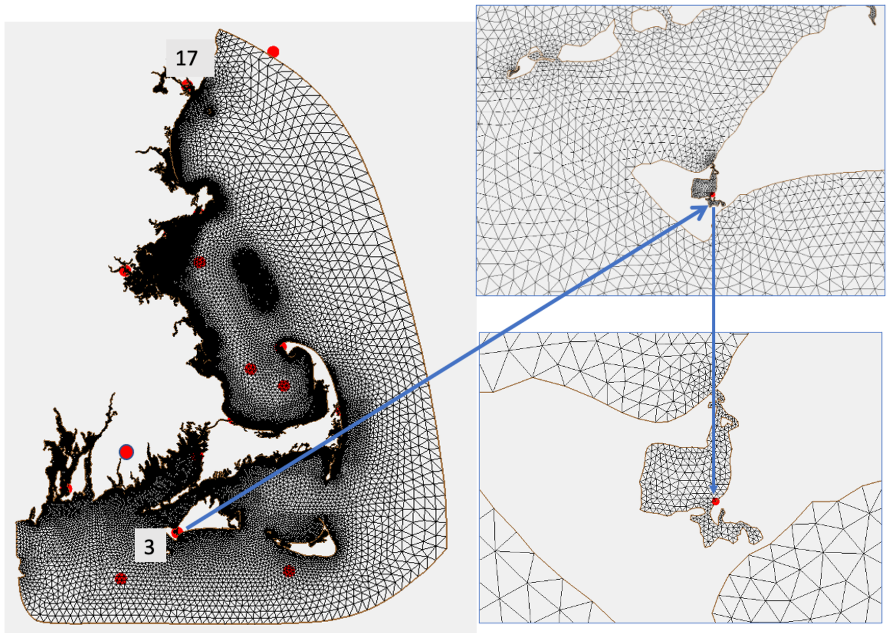



*Fig. 14: Locations of tidal gauges in the Mass Coastal-FVCOM domain (red dots). Numbers 3 and 17 are two tidal gauges discussed in the report.*

There were 18 tidal gauges in the Mass Coastal-FVCOM computational domain (Fig. 14). The model accurately reproduced semidiurnal and diurnal tides in the region. The scatter plots of simulated via observed amplitudes and phases show a good agreement between the model and observations, except at tidal gauges numbered 3 and 17 (Fig. 15). Excluding tidal gauges #3 and 17, the root-mean-square error (RMSE) was about 4.5 cm in amplitude and 6.1° in phase for the $M_2$ tidal constituent, 2.3 cm and 5.4° for the $N_2$ tidal constituent, and 1.3 cm and 8.9° for the $S_2$ tidal constituent. The tidal gauge #3 is located at the southern coast of Menemsha Pond over Martha's Vineyard, where the high-resolution LIDAR bathymetry data was unavailable. The significant RMSE found at that site was mainly due to poor resolving of local bathymetry. The tidal gauge #17 was located at the entrance of Great Bay, New Hampshire. Similarly, the large RMSE at that site was likely due to the inaccuracy of local bathymetry. Since these two tidal gauges were far from Buzzard Bay, they did not affect the tidal simulation results around the New Bedford and Fairhaven outfall regions.

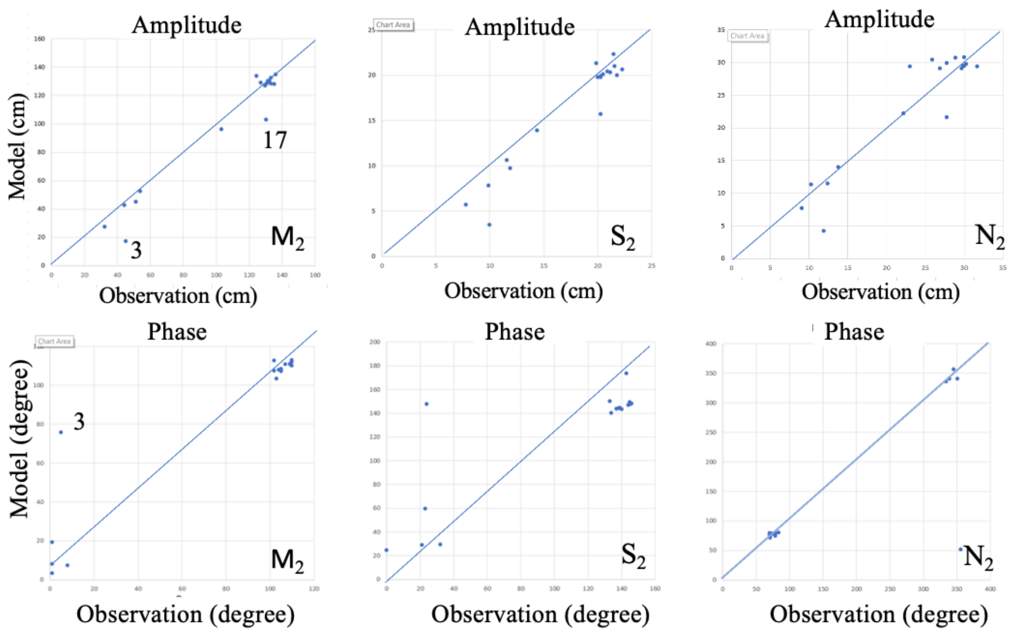



*Fig.15: The scatter plot of simulated via observed tidal amplitudes and phases for $M_2$, $S_2$, and $N_2$ tidal constituents. A total of 18 tidal gauges (see Fig. 14) were included.*

## 5. Summary and Suggestions

A high-resolution Mass Coastal-FVCOM was developed and applied to assess the impact of the New Bedford and Fairhaven WWTP outfalls on the local shellfish environment in Buzzard Bay. The model domain covered the coastal ocean, rivers, and intertidal wetlands with a horizontal resolution of up to ~ 4.0 m. The model grid was upgraded with the 1.0 m × 1.0 m resolution LIDAR bathymetry. Mass Coastal-FVCOM was driven by the assimilated atmospheric forcing at the surface from the Weather Research and Forecast model (WRF). The open boundary condition was specified through one-way nesting with the Northeast Coastal Ocean Forecast System (NECOFS). The land boundary condition included freshwater discharges from 26 rivers. The freshwater discharges from those rivers were specified using the USGS daily measurement records.

The model was ramped up from the initial condition over December 15-31, 2020. The simulation was done from January 1 to December 31, 2021, including freshwater discharged from 26 rivers and outfall discharges from New Bedford and Fairhaven WWTPs. The dilution maps were created to project the monthly and seasonal mean contaminant-covered areas in Buzzard Bay, including the New Bedford and Fairhaven regions. The model results show that the spreading and covered areas of the WWTP diluted water varied significantly from month to month. The contaminant spreading was more significant during winter through spring compared with summer and autumn, even though the WWTP discharges were the largest in the autumn. Although the outfalls were located at the bottom, the WWTP-diluted water occupied a larger area at the sea surface than at the bottom. The maximum covered area at the sea surface occurred in March, and the minimum was in July. The diluted water concentration was higher around the Fairhaven coast than around New Bedford, even though the WWTP discharge from the Fairhaven outfall was 5-6 times smaller. A validation was carried out for semidiurnal and diurnal tidal elevations. The results demonstrated that Mass Coastal-FVCOM was accurate enough to reproduce the tidal flushing in the region.

It should be pointed out that there were 26 wastewater outfall sites along the New Bedford coast. Due to the unavailability of discharge data at these outfall sites, the WWTP dilution assessment only considered the outfall discharges from the New Bedford and Fairhaven WWTPs. An assessment should be carried out by taking these outfall sites into account. Meanwhile, the model simulation results suggested that the WWTP diluted water spreading varied significantly with the wind intensity and directions. We should establish Mass Coastal-FVCOM for a forecast model system to monitor the daily temporospatial variability of the WWTP diluted water in the region. The Marine Ecosystem Dynamics Modeling Laboratory has operated a Northeast Coastal Ocean Forecast System (NECOFS) since 2007. It is straightforward to add Mass Coastal-FVCOM into the NECOFS operations.

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