Responses to Review#2

Comment 1: *However, since the dilution model results will inform shellfish growing area classification and support potential decision-making processes, it is crucial to ensure that the simulated dilution maps are accurate and able to quantify the uncertainties. For example, is it possible to evaluate the model simulated 1:1,000 contour with observations, such as Rhodamine dye injections as described in True (2008), the reference provided by Dr. Chen, and quantify the uncertainty in the spatial location of the 1:1,000 contour?*

Response: We believe that dye tracers are the most effective tool for validating the spatiotemporal distribution of wastewater treatment plant (WWTP) diluted water. While previous dye experiments were conducted at the Plymouth outfall, none have taken place at the New Bedford and Fairhaven outfalls.

As an alternative, we propose first applying our model to the Plymouth outfall, using data from the past dye experiments for validation. Given the significant variability in the local marine environment, it is essential that the validation experiment occurs during the same period as the dye release. Unfortunately, since our priority has been to address concerns related to the outfalls in the North River, Scituate, and New Bedford/Fairhaven, we have not received funding to conduct such a model validation experiment.

It should be noted that our model was configured based on insights from our past dye experiments. We have conducted extensive tests to evaluate the convergence of the tracer model through comparisons with dye releases, demonstrating the sensitivity of the spatiotemporal variability of the diluted tracer to model resolution. At a regional scale, such as Georges Bank, convergence can be achieved with model resolutions approaching 100 meters, as detailed in our provided paper. In our research on predicting the initial spread of radionuclides from the Fukushima Dai-ichi Nuclear Power Plant, we found that a model resolution of approximately 5 meters is necessary to accurately capture the plant's infrastructure and align with observational data.

The WWTP model has also been utilized by FVCOM users in other states, where configurations around 100 meters have effectively reproduced WWTP effluent dilution. For the Massachusetts coast, the 3-4 meters' resolution we employed in the WWTP model is sufficient to achieve convergence of the dye tracer from the outfall.

We hope to secure funding to conduct a dye experiment for the New Bedford and Fairhaven outfalls, or at least at one of these two locations. Such an experiment would provide us with a valuable dataset for solid model validation.

QS. 1: Tracer-tracking model:

Could Dr. Chen and his team provide more information on how they implemented the tracer-tracking model? For example, what is the concentration of the passive tracer, and does it vary with *the discharge rates of the WWTP? How was the 1:1000 contour defined, considering it appears inconsistent with the 0.1% dye concentration in their plots in Document 02?*

Answer: The wastewater from the WWTP is injected at the outfall using the discharge volume rate, with an assumed concentration of the passive tracer fixed at a unit value of 1.0. While the discharge volume can vary, the concentration of the passive tracer remains constant at this unit level when it is injected.

The 1:1000 contour is defined as a line representing a concentration of 1/1000 of the initial tracer concentration. The simulation aims to address the question: If the WWTP injects wastewater with a fixed unit concentration, how does this concentration change relative to its initial value of 1.0 as it disperses? To determine the actual concentration in the water column at the outfall, one can multiply the known chemical concentration of the WWTP discharge water by the model-simulated concentration.

Regarding the 0.1% dye concentration, it represents a dilution of 1/100, rather than 1/1000. If Document 02 is indeed a report, it may contain a typographical error.

QS.2: Surface versus bottom dye concentrations:

The surface concentration around the WWTP outfall is much higher than at the bottom, where the WWTP pipe is located. While Dr. Chen and his team have provided explanations such as the energetic vertical mixing and the interaction of the laminar flow from the WWTP pipe and oceanic currents, I wondered if the WWTP pipe generated laminar flow has been reproduced in the model. Additionally, are there observation data to validate the much higher surface concentration than the bottom source region?

Answer: Thank you for your insightful question. In our model experiment, the WWTP wastewater was injected as a point source at the bottom, and we did not simulate a physical pipe structure. Consequently, the model does not explicitly resolve the laminar flow within the pipe. Instead, we treat the wastewater as a tracer that immediately interacts with the surrounding ocean water upon discharge.

Unfortunately, we were unable to locate observational data on WWTP wastewater concentrations specifically around the New Bedford and Fairhaven outfalls that could be used to validate our model results regarding the higher surface concentrations. However, in our previous assessments for the outfall in Boston Harbor conducted for the Massachusetts Water Resources Authority (MWRA), we did have nutrient data that provided a basis for validating the FVCOM-UG-RCA water quality model. The model demonstrated robustness in capturing observed nutrient concentrations in that setting.

The design used for the Boston Harbor outfall was applied to the New Bedford and Fairhaven outfalls, based on the assumption that the validated numerical approach is applicable to other outfalls as well.

We also hope to conduct surveys to measure WWTP concentrations and spreading around the New Bedford and Fairhaven outfalls in the future. This could be carried out effectively if funding is secured, and such data would provide a solid basis for validating our model.

QS. 3: WWTP contaminant decay rate:

Is it necessary to consider the decay rate of contaminants discharged from WWTP? To what extent does the decay of tracer affect the accuracy of the simulated contour lines at 1:1,000 and 1:100,000?

Answer: Yes, it is necessary to consider the decay rate of contaminants discharged from the WWTP when modeling their behavior in the environment. The decay of the tracer can significantly affect the accuracy of the simulated contour lines at both the 1:1,000 and 1:100,000 concentrations, particularly over time and distance. A higher decay rate would lead to a quicker reduction in concentration, thereby impacting the delineation of these contour lines.

We first want to clarify that the dilution simulation results serve as an alternative reference for the Division of Marine Fisheries (DMF). However, the final decision, to our understanding, is based on integrating this model data with additional chemical and biological data analyses conducted by DMF. We also assume that the decay rate of contaminants and other relevant factors have been considered in the final assessment by DMF.

To simulate the decay rate of contaminants in modeling, it is necessary to incorporate a water quality model that considers both biological and chemical processes. We have developed the Northeast Coastal Ocean Acidification Model (NeBEM), which was initially validated in Massachusetts Bay, incorporating the Boston Harbor outfall. In comparisons with UG-RCA, a water quality model used to assess the impact of the MWRA outfall in Boston Harbor, we found that NeBEM yielded more promising results. We could utilize NeBEM to address the reviewers' comments if additional funding is available to support the necessary personnel.

***Suggestions for additional model validations**:*

(1) If observations of temperature, salinity, and velocity are available near the New Bedford and Fairhaven WWTPs or within New Bedford Sound (which receives effluent from the majority of the 26 WWTPs), it would be beneficial to evaluate how well the model simulates these variables, as well as stratifications and local circulations.

Response: We concur with the reviewer that these measurements could serve as a reference for validating the model at the local outfall scale.

(2) I would also recommend evaluating the simulated passive dye distribution. Conducting realistic dye release experiment could be one option, as demonstrated by Chen et al. (2008) in their study at Georges Bank and by True (2018) in a tidal estuary in Maine. Both studies used FVCOM model to simulate dye dispersion. A realistic dye release could be implemented within the model domain, considering the logistical or resource requirement, or directly from the New Bedford pipe (if

feasible). This would allow for testing whether the observed surface dye concentrations are higher than those at the source at the bottom, as suggested by the model simulations. Additionally, besides releasing realistic dye from the WWTP pipe, another approach to verify the high surface concentration would be to collect vertical water samples to measure concentrations associated with the dilution process originating from the WWTP pipe.

Response: This is a great suggestion, and we completely agree that it is a necessary step. Given the challenges in assessing the impact of model uncertainties on the WWTP-diluted water simulation, we believe that conducting dye tracer studies is the most effective approach for validating the spatiotemporal distribution of wastewater treatment plant (WWTP) diluted water. This was successfully done for the Plymouth outfall in the past and should also be done for the New Bedford and Fairhaven outfalls.

Comments on the usage of this model for decision-making

To establish shellfish classification areas

First of all, I believe this model could be a valuable tool to establish shellfish classification areas, given the already achieved good model performance and many applications of FVCOM in studying material transport process. However, before applying the model to establish shellfish classification areas, I would suggest (1) enhancing confidence in the model simulated hydrodynamics (temperature, salinity, stratification and circulation) in the regions that near the WWTPs; (2) evaluating the module simulated dilution map with realistic dye studies or other concentration measurements to assess the accuracy of the simulated passive tracer; (3) analyzing the spatial uncertainty associated with the model-generated concentration contours, such as those at a 1:1,000 scale, to understand the reliability of the predictions. By undertaking these additional evaluations, I think this model could be a useful and reliable tool to inform the establishment of shellfish classification areas.

Response: To address the first suggestion, we plan to conduct surveys to measure temperature, salinity, and circulation in the vicinity of the WWTPs. This can be accomplished through collaboration with Professor Micheline Labrie, Director of the Coastal System Program (CSP) at the School for Marine Science and Technology (SMAST), UMass Dartmouth. The CSP has a long-standing record of conducting field measurements for nitrogen removal in eutrophic estuaries in Massachusetts.

For the second and third suggestions, we can collaborate with Professor Miles Sundermeyer at SMAST/UMass Dartmouth, who specializes in dye experiments in marine environments. Comparing model outputs with empirical dye results is the most effective way to estimate spatial uncertainty. This will be feasible contingent on executing the dye experiment.

All these efforts require additional sufficient personnel support.

To predict the short-term impact of rainfall events and CSO discharges

Dr. Chen and his team have been operating NECOF for many years and have validated the atmospheric forcings from WRF. Therefore, I believe it is technically feasible for their group to incorporate the Mass Coastal-FVCOM model into their forecasting system to predict the short-term impact of rainfall events. My question is: how fast can the forecast run be completed, given the very short time step and fine grid cells used in the Mass Coastal-FVCOM model. This will also depend on the forecast duration and the available computational resources.

The flooding/drying capability, as detailed in Document 03, indicate that model can simulate areas that are periodically flooded by tide or occasionally inundated by extreme storm conditions. However, I lack experience with the FVCOM model and am unsure how FVCOM handles the CSO discharges and its overall model stability. In addition to measuring the discharge from CSO, it would be important to measure the concentration of contaminates to inform the concentration of the released passive dye, rather than assuming a concentration of 1 (as mentioned in Document 03). Furthermore, evaluating the model simulated hydrodynamics in regions where CSO discharges occur, comparing the simulated dilution maps against available observations, and identifying potential uncertainties associated with model configurations would be important.

Responses: The NECOFS forecast operation has indeed incorporated the Mass Coastal-FVCOM model with a resolution of approximately 10 meters. The WWTP model used for the Massachusetts coast is a modified version of the Mass Coastal-FVCOM model, with a refined local grid around individual WWTP outfalls of about 4 meters. It takes approximately 3-4 computational hours to complete a 5-day forecast using the Mass Coastal-FVCOM model. We anticipate that the 5-day forecast using the updated version with WWTP data could be completed in around 6 hours, which is about 1-2 hours longer than the current model.

As mentioned earlier, the dilution simulation results will serve as an alternative reference for the Division of Marine Fisheries (DMF). However, it is our understanding that the final decision will be based on a combination of our model data and additional chemical and biological analyses conducted by the DMF. We could implement a similar strategy to convert the WWTP simulation into a continuous 24/7 forecast operation, which would provide the DMF with real-time dilution maps reflecting the temporospatial variability of WWTP effluent. The DMF manager could then integrate the model data with their own information (e.g., concentrations of contaminants and their decay rates) to produce a real-time assessment of contaminant dispersion.