Assessment of Currents in Inner Harbour

Submitted to

Port Authority of Jamaica

By

SMITH WARNER INTERNATIONAL
COASTAL ENVIRONMENT

June 2009

Table of Contents

Introduction

Coming out of the meeting held with NEPA and PAJ on April 17th 2009, there were concerns that even though the hydrodynamic model displayed reasonable results outside of the inner harbour, NEPA was not convinced that the model was capable of accurately simulating currents inside the inner harbour where the dinoflagellates actually reside. NEPA therefore requested that additional data collection be carried out within the inner harbour to determine the existing current speeds and direction during a spring and neap tidal cycle.

This new data collected should then be used in the hydrodynamic model to see if the model predicts similar current speeds and directions as indicated previously. If the model then adequately predicted the currents and directions, further modeling of a typical flood condition would be investigated in relation to salinity and sedimentation concentrations within the inner harbour.

Data Collection

The location of the current meter is shown in Figure 1. It was deployed in approximately 1.9 meters of water depth. The current meter was attached to an aluminum frame and placed as close to the sea floor as possible.

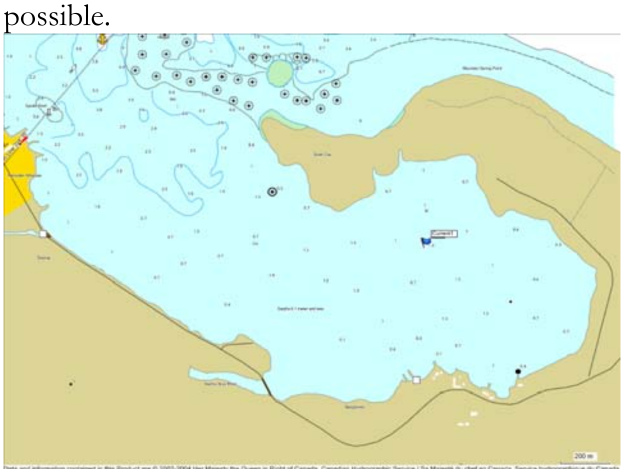
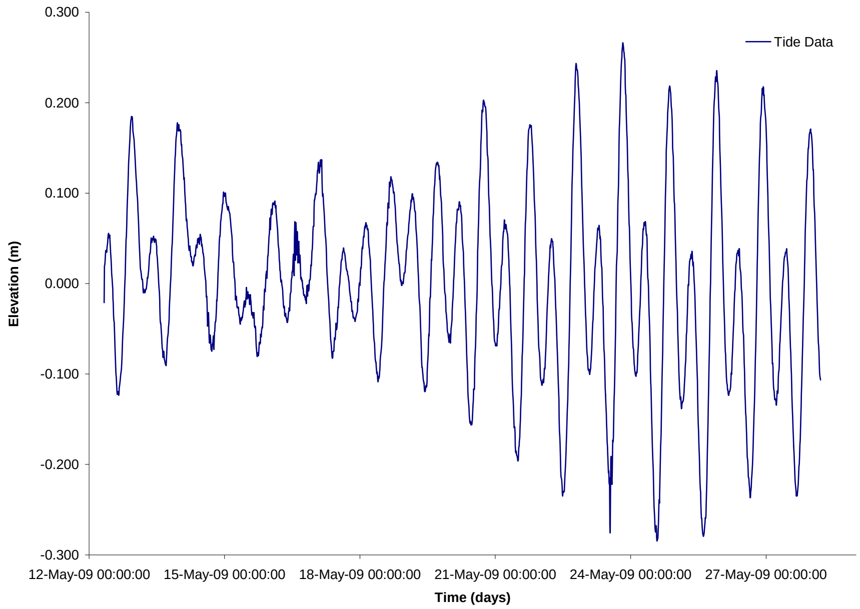
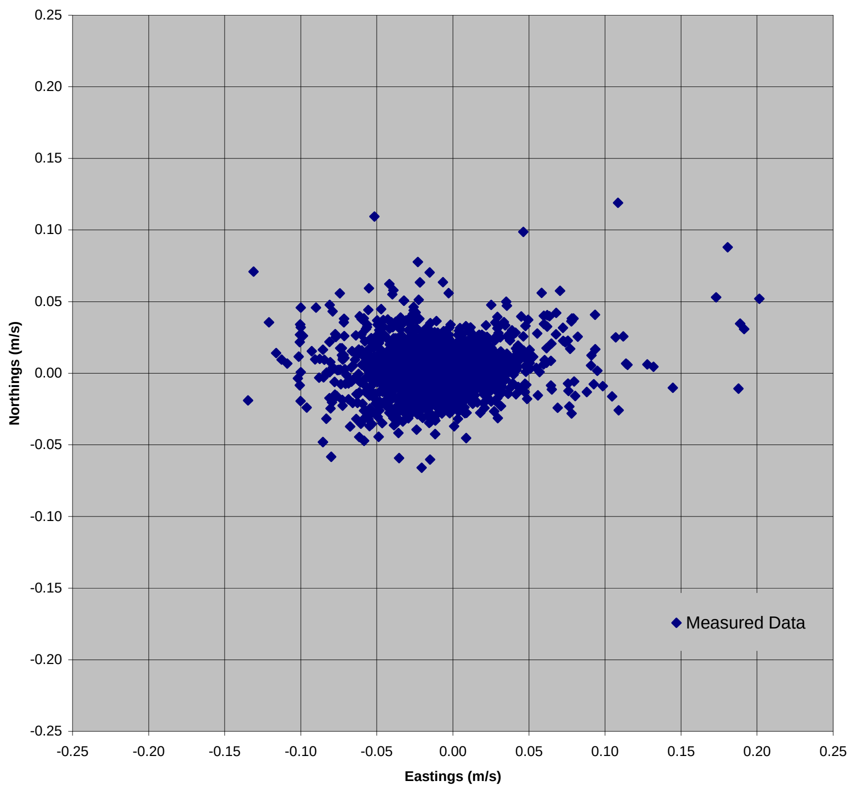


Figure 1 Location of current meter



This plot shows the measured tides and indicates the presence of Spring and Neap tides with a maximum range of approximately 0.6m. The tide signal also reveals a semi-diurnal tide, meaning that there are two highs and two lows per day, often of unequal magnitude

Figure 2 Measured tides



This scatter plot shows the main flow moving in an east-west direction with an average speed of around +/- 0.10 m/s. There are some outliers that have speeds up to 0.20 m/s in the easterly direction. Some peak flow speeds of around 0.14 m/s also occur in the westerly direction. The measured flow in the north-south direction is minimal with speeds of +/- 0.05m/s.

Figure 3 Scatter plot of measured currents

Figures 4 to 6 show the correlation of the current speeds in the main (East-West) direction with the tide, river flow and wind data. Figure 7 shows the correlation between sea temperature and river flow. These plots are presented in order to confirm our understanding of the main forces that influence the hydrodynamics of the inner bay.

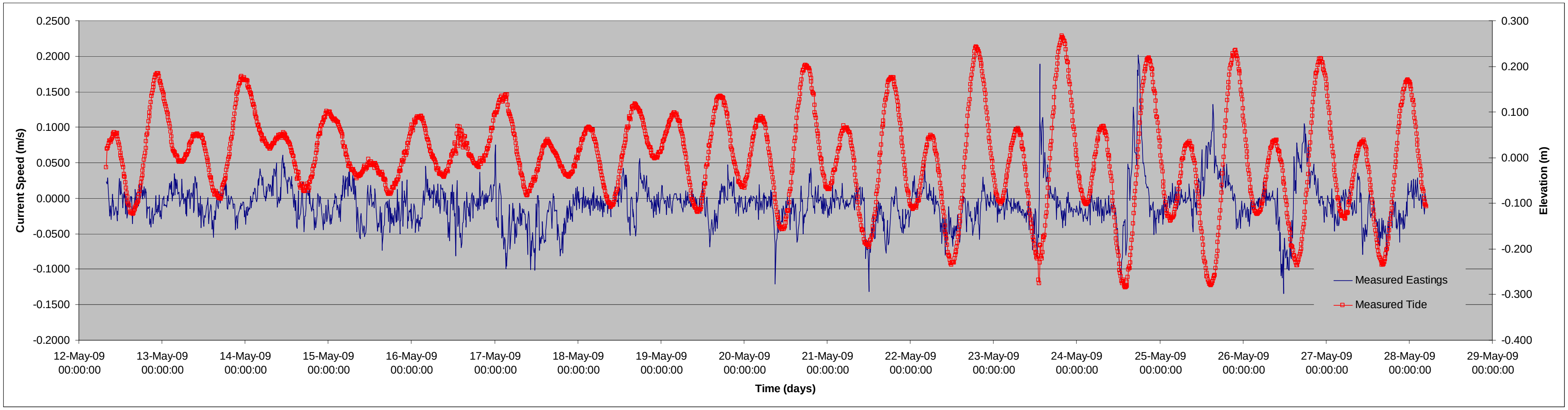


Figure 4 Measured Tide vs Measured Eastings currents

It can be seen from Figure 4 that the tidal cycle has the strongest influence on the current speeds and directions within the inner bay. During rising tides, there is a tendency for the currents to move in a positive direction, which means that the water body is moving to the east, and vice versa for when the tide is falling. However, there are some instances when the tide is falling yet the flow is positive or showing a rising tide current direction. This means there are other forces acting upon the water body that might have the same amount of influence as the tides.

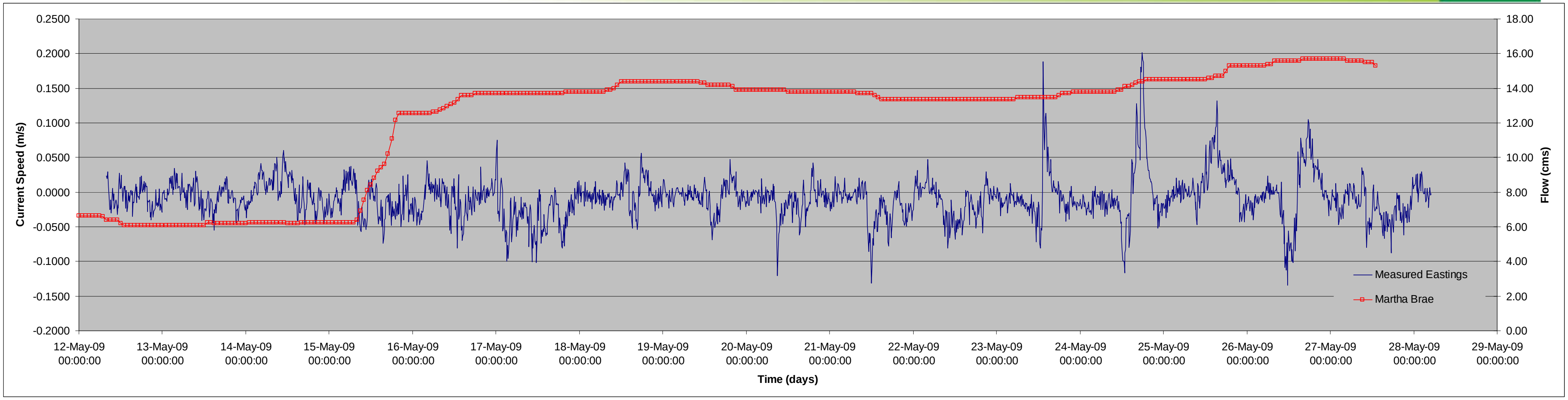


Figure 5 Measured River Flow vs Measured Eastings currents

Figure 5 shows the measured river flow data and the current speed data. This shows that the river flow basically has very little influence on the magnitude and direction of the currents within the inner bay under normal flow conditions. This measurement period represents "base flow" of approximately 6.0 m^3/s until May 15th, and then a period of sustained river flow approximately twice the base flow.

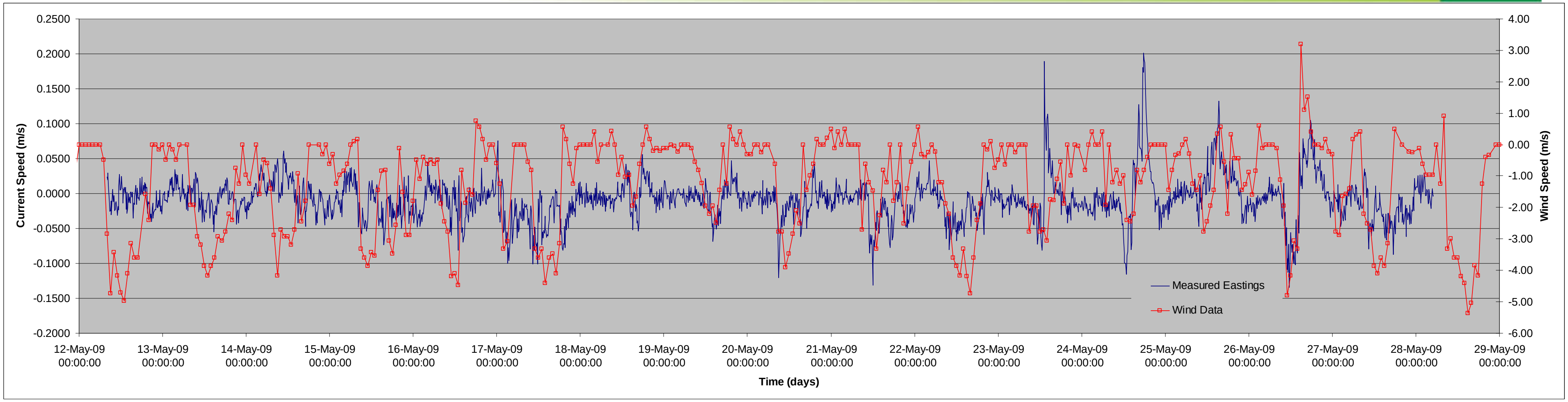


Figure 6 Wind Speed vs Measured Eastings currents

Figure 6 shows the measured wind from Montego Bay and the current speeds. It appears from this comparison that the effect of the wind is of significant importance within the inner bay. It shows that the wind effect was stronger than the tidal effect around the May 25^{th} as that was during a falling tide and the flow at this location was moving in a positive or easterly direction.

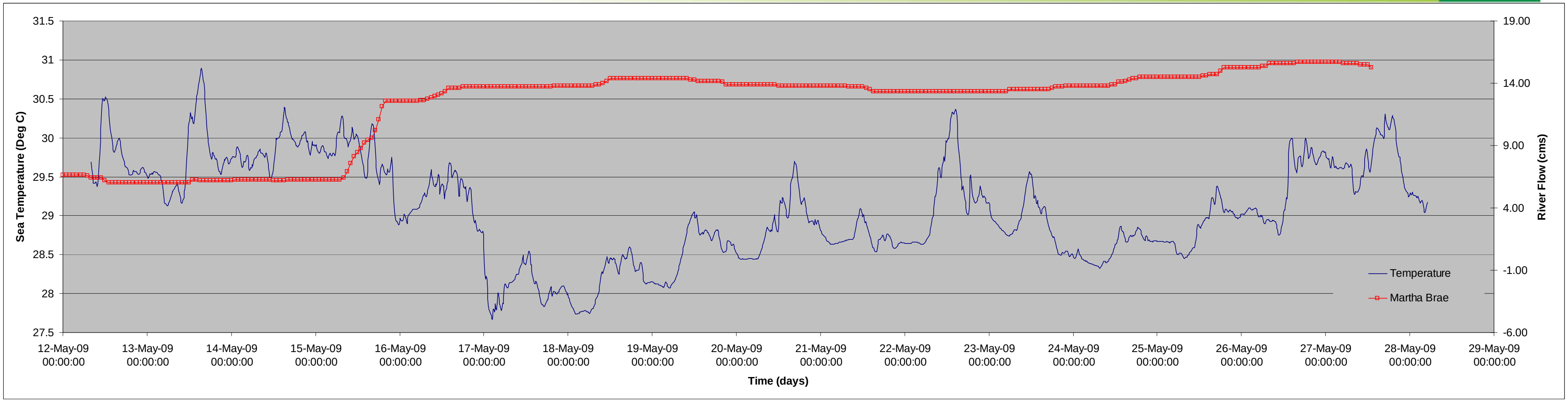


Figure 7 Measured river flow vs Measured Sea Temperature

Figure 7 shows the effect the river flow has on the sea temperature. The data shows that as the river flow increases, the sea temperature starts to fall. The lag between the increase in flow and the drop in temperature relates to the time required for lateral and vertical mixing of the cooler fresh water with the warmer waters of the inner bay. As there was very little influence of the river flow on the current speeds, it appears that the main impact of river flow is on the water temperature within the inner bay.

Drogue tracks were measured during the deployment of the current meter. Shown below is a photo of one of the drogues being deployed in the inner bay. A GPS was attached to the drogues in order to have continuous tracking of the drogue so as to have a better understanding of the spatial movement of the water mass in the bay

Figure 8 Drogues being deployed in the inner bay

Figure 9 shows the drogue tracks for May 12th 2009. The first deployment occurred in the morning when a falling tide was occurring. As seen below, Drogue 1 traveled a shorter distance than Drogue 2. This may have been because the underwater portion of Drogue 1 was closer to the sea surface than Drogue 2, which means it could have been more influenced by the wind. Drogue 2 shows some gyre effects occurring near the entrance of the Falmouth harbour. The first deployment was retrieved around 1:00pm as shown below. A second deployment was done in order to capture a rising tide, however, only the start of the rising tide was caught as the drogues were retrieved at around 4:20pm.

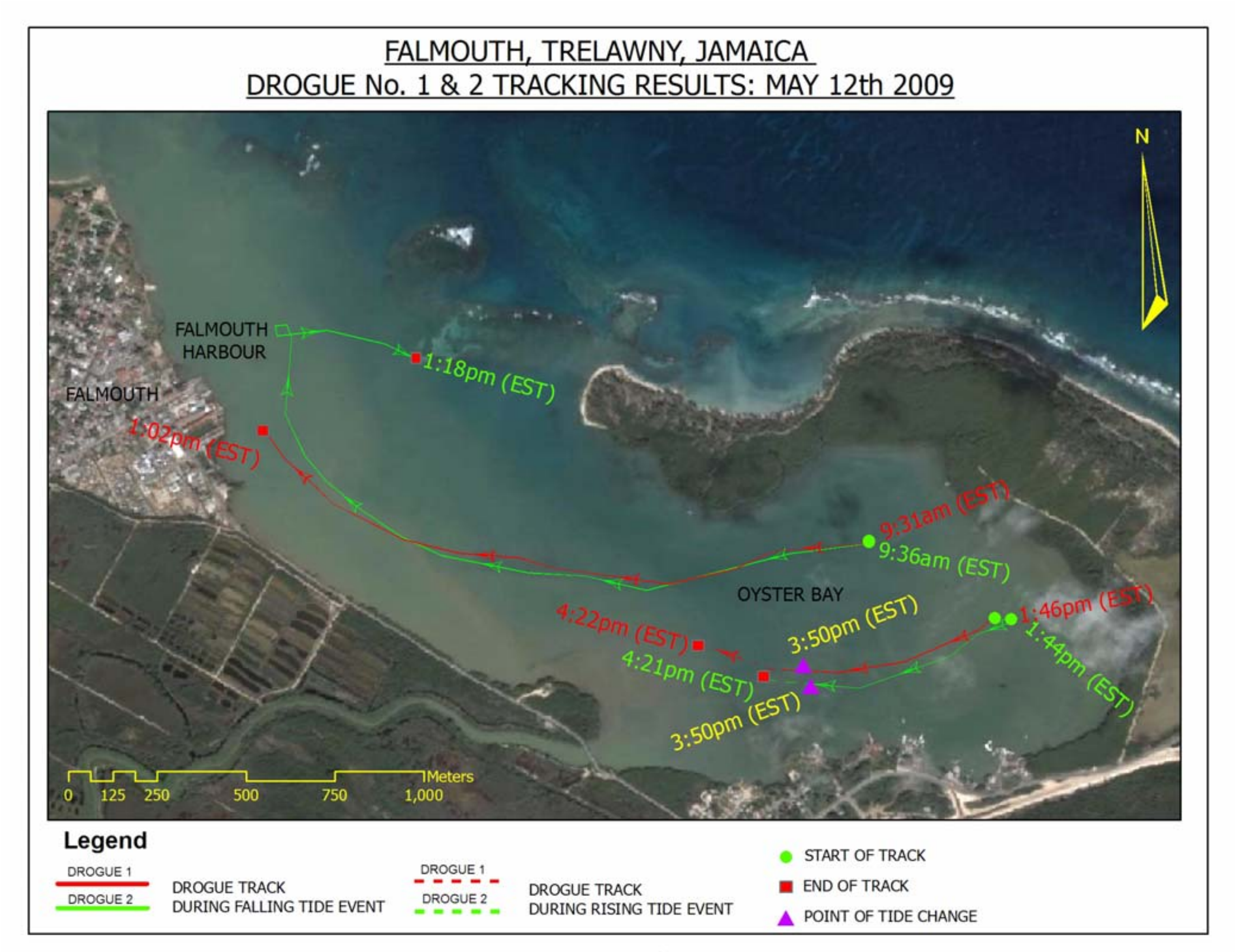


Figure 9 **Drogue tracks on May 12th 2009**

Hydrodynamic Modeling of New Data

The hydrodynamic model RMA was run using the tides, wind and river flow values that were measured. The purpose of this was to determine if the model that was calibrated using data collected in the Falmouth Harbour entrance is able to produce reliable predictions within the inner bay. The only changes that were done to the model involve the use of the tide data, the river flow data and the wind data.

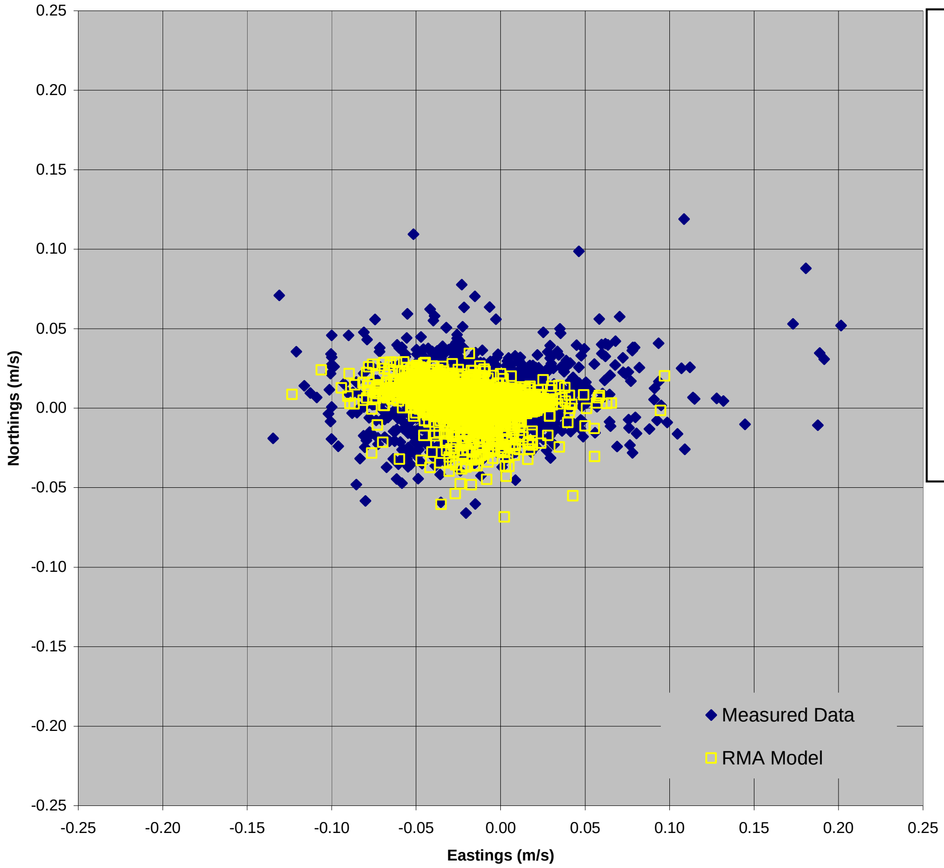


Figure 10 shows the scatter plots of both the measured and modeled currents. The model seems to capture the main flow speeds much better than the cross flow and seems to underestimate the peaks in the measured data.

Figure 10 Scatter Plot showing measured and modeled current speed and directions

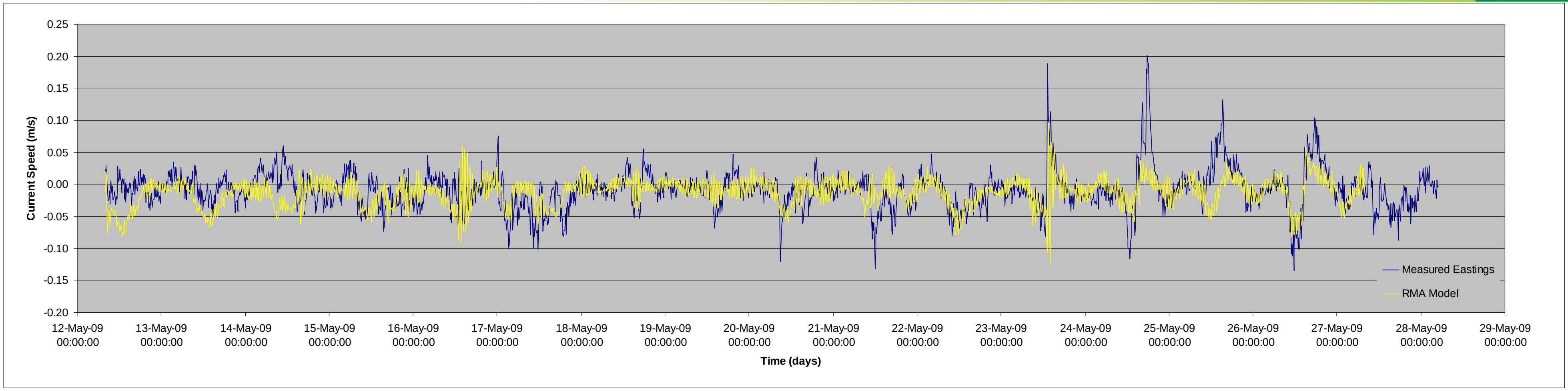


Figure 11 Measured data versus RMA 10 in the Eastings direction (m/s)

Figures 11 and 12 show the time series plots of both the Easting and Northing current speeds for measured and modeled currents. The hydrodynamic model tends to follow the measured data in both phase and direction, however, it seems to underestimate the peaks of the measured data. This underestimation could be due to high friction values within this area. In the Northing direction, the model also underestimates the peak flows, however, it falls within the general current speeds.

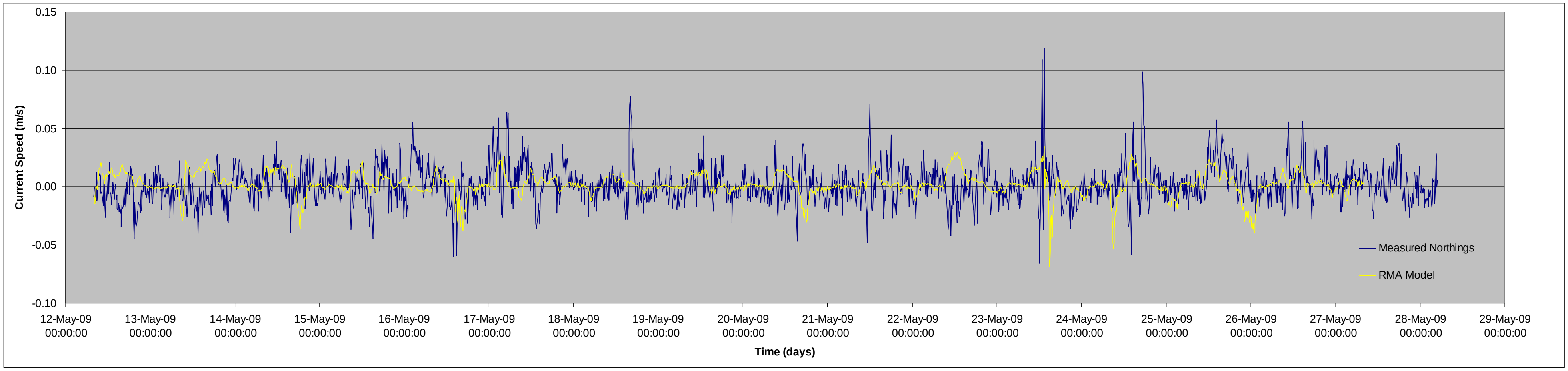


Figure 12 Measured data versus RMA 10 in the Northing direction (m/s)

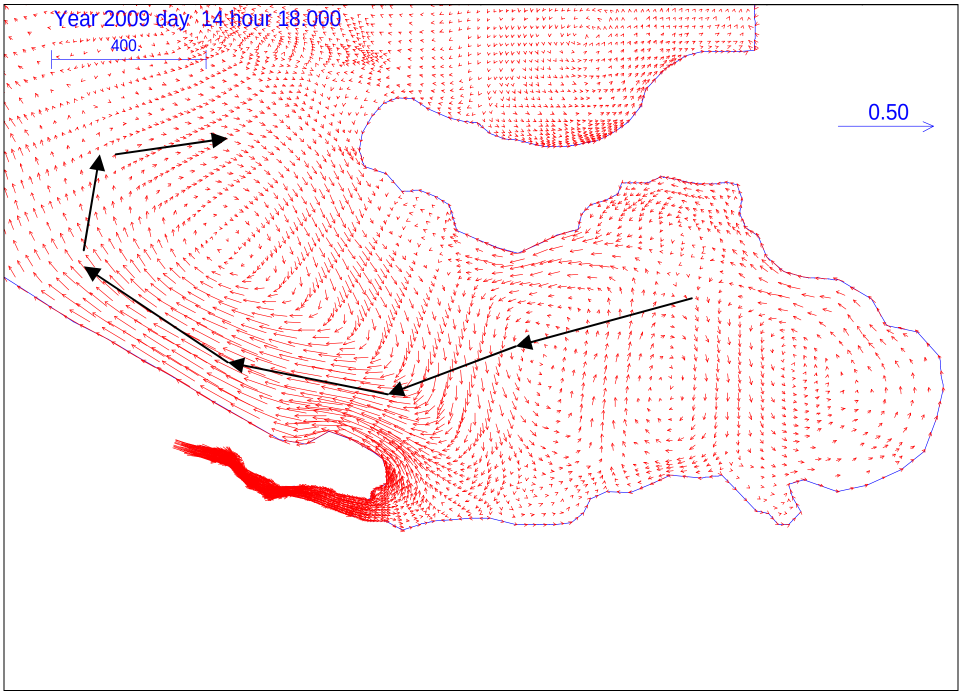


Figure 13 Comparison of hydrodynamic model and Drogue No. 2 (May 12, 2009)

Figure 13 shows a drogue track comparison alongside the model. Both the drogue and the model display the gyre effects which seem to occur within the bay. This quite clearly demonstrates the spatial capability of the hydrodynamic model. Figure 14 shows that the hydrodynamic model is able to predict stratification within the inner bay as a typical salinity profile was extracted from the model and compared against measured data.

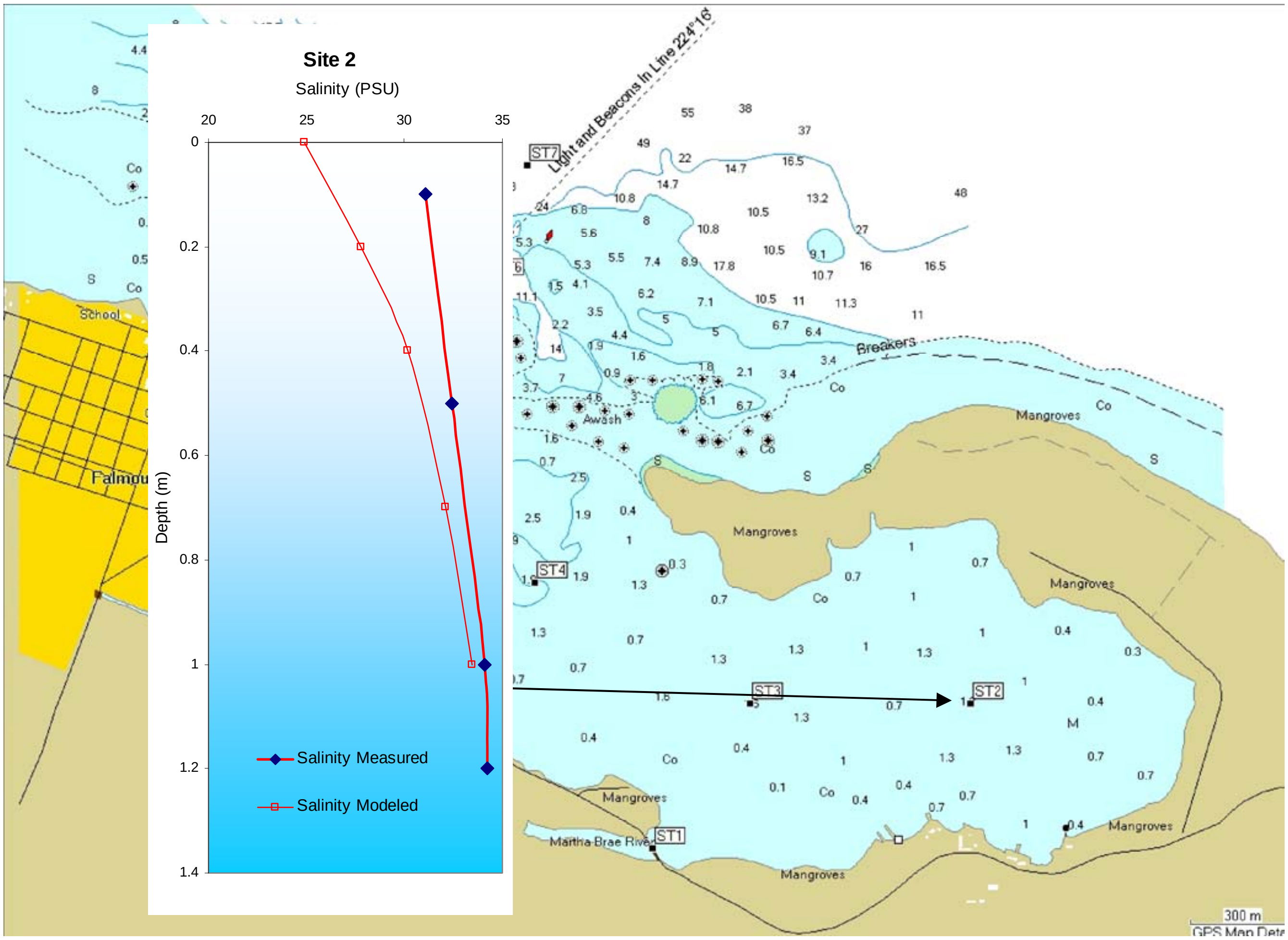


Figure 14 **Sites where measured salinity was recorded**

Overall, the performance of the model in simulating the dynamics of the outer and inner harbour is within expected limits from a physical standpoint. The model is shown to be capable of simulating both the inner and outer harbour, therefore the findings and conclusions drawn in previous reports are considered to be substantiated.

Flood Event and Time to Return to Normal Conditions (Salinity)

Using the verified model, the next step was to investigate the change in retention time that the proposed pier and the proposed pier with vessels would have on the existing conditions. A typical tide signal was used in this investigation along with a typical mean river flow and wind conditions. The model was allowed to stabilize over a period of 3 to 4 days to establish typical salinity stratification and then a flood event of 40 m^3/s was applied over a period of one day. The model then continued to run until the average conditions were reestablished as shown in Figure 15.

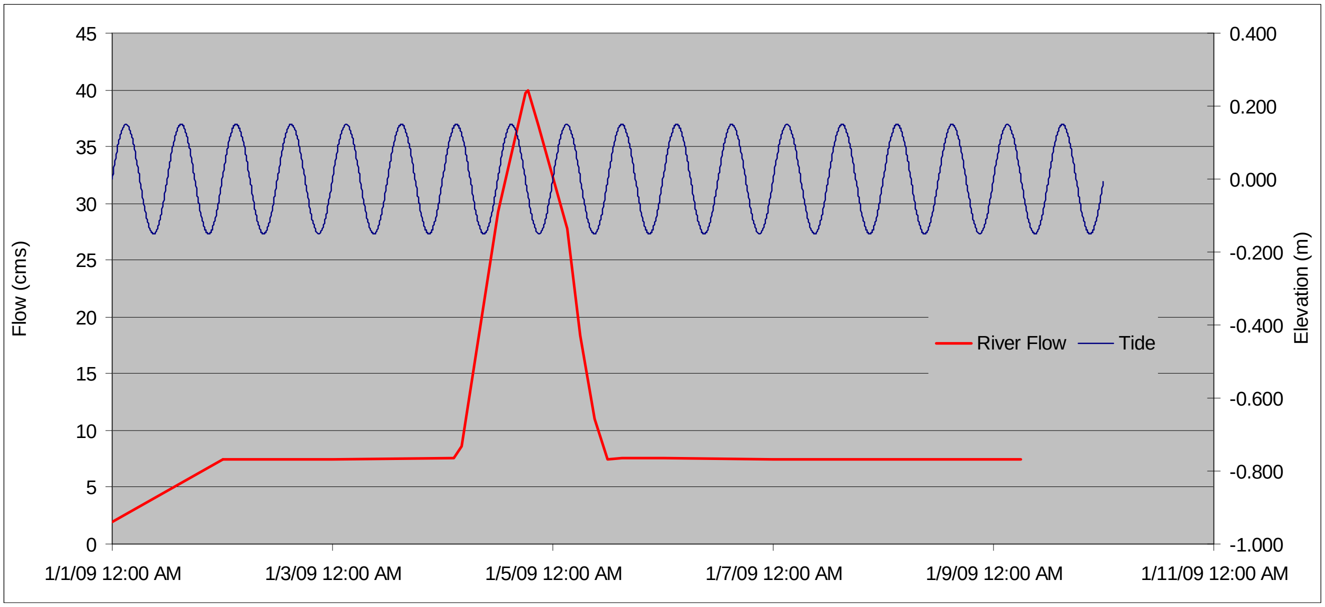


Figure 15 Tide and river flow model input conditions

These conditions were run for all three scenarios and results were extracted at three locations to make comparisons. The locations were the northern location of the inner bay, the eastern location of the inner bay and a central location within the inner bay as shown in Figure 16. For each location the surface layer and the bottom layer were compared to determine if the proposed conditions had an adverse effect on the stratification within the harbour.

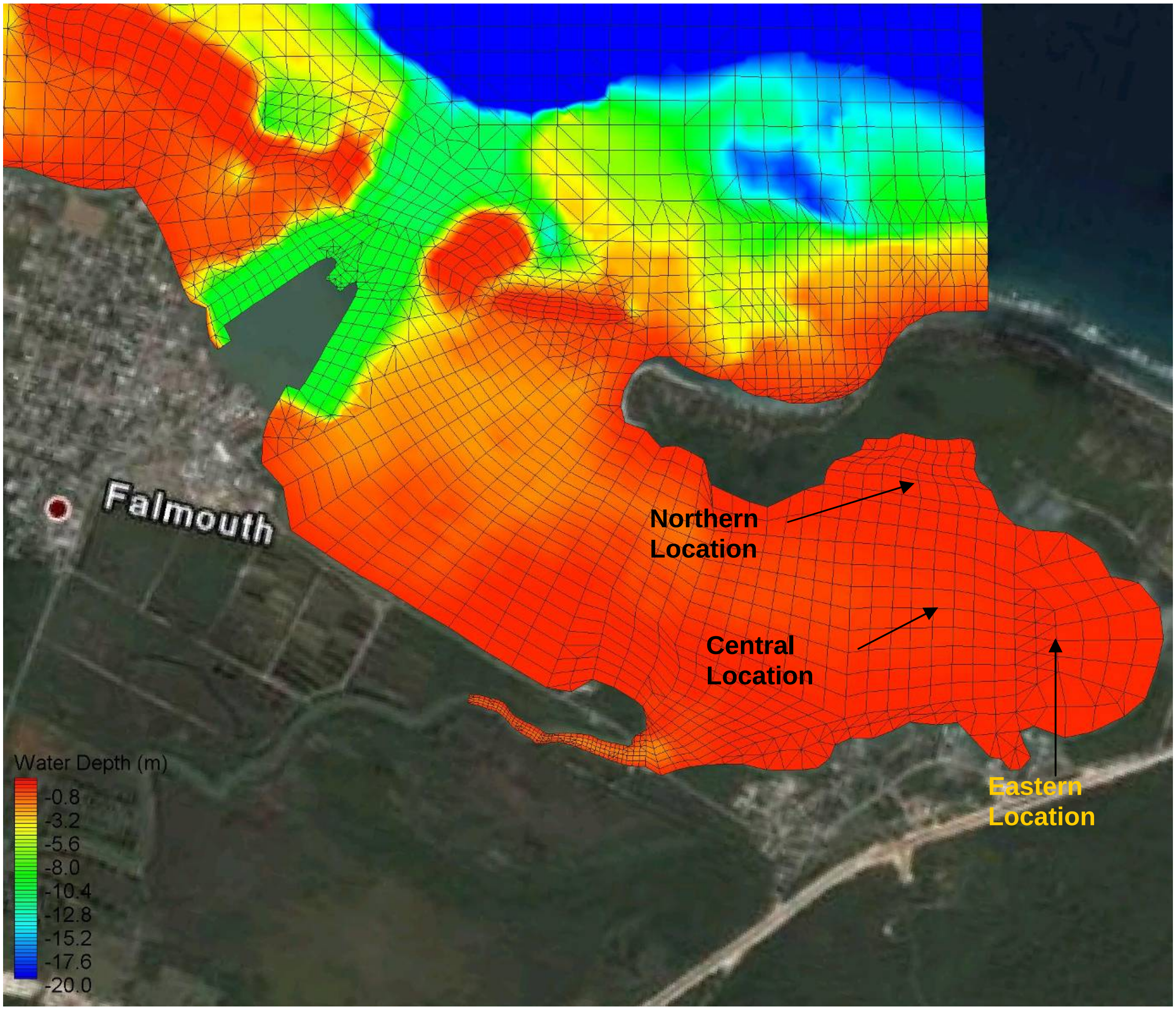


Figure 16 Locations chosen for salinity comparisons

Figures 17 and 22 show the salinity concentrations at the three locations where the *dinoflagellates* reside. The model shows that the salinity decreases significantly as expected during the flood event. The model also shows that the differences in salinity between the different scenarios are small and short in duration.

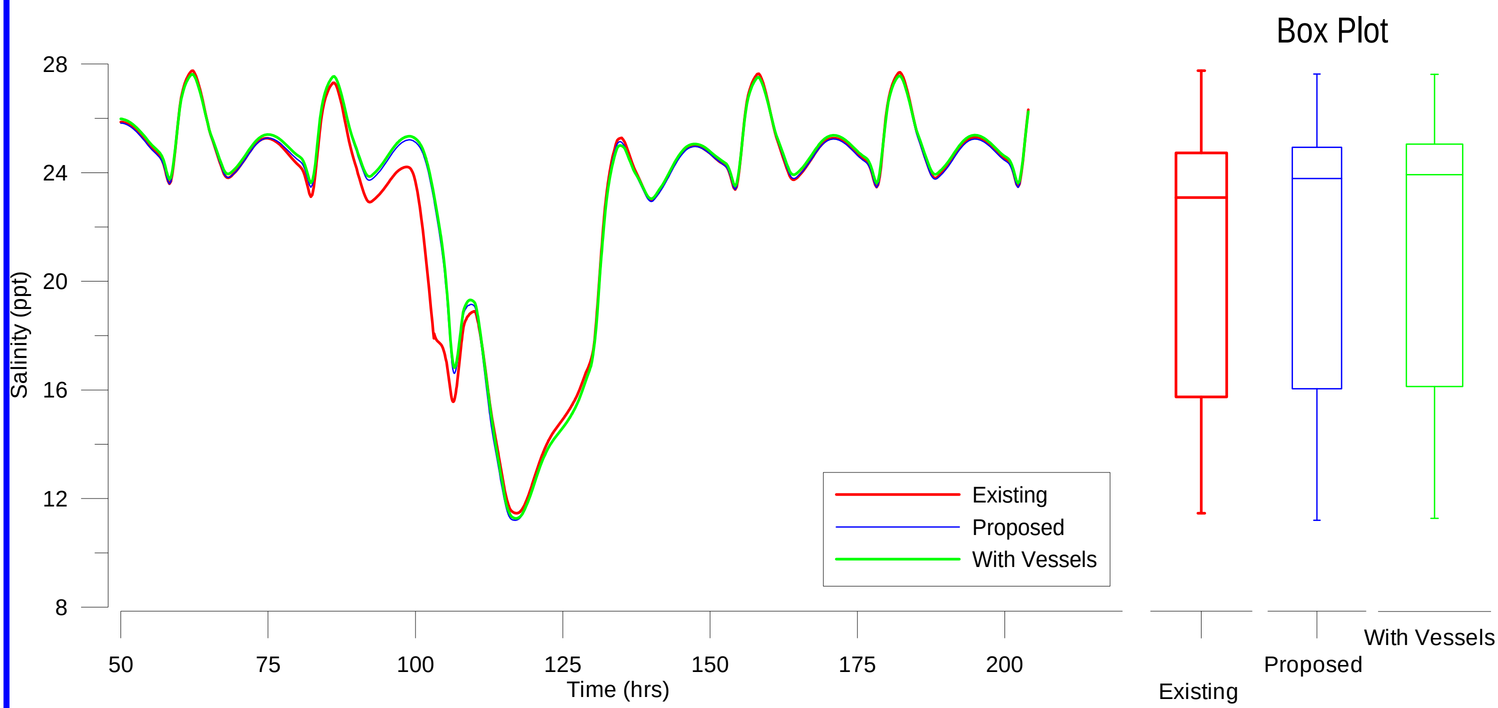


Figure 17 Salinity Comparison at the northern location of the inner bay near the surface.

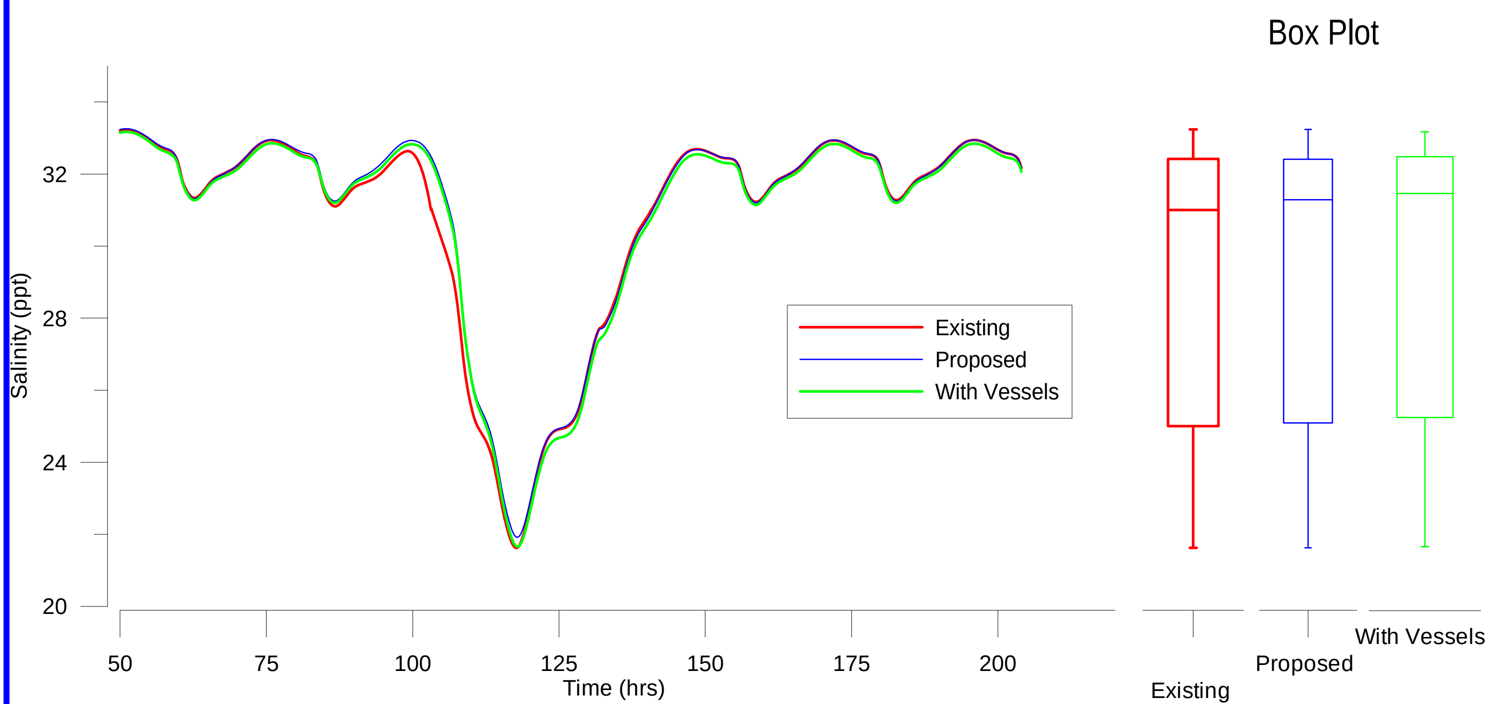


Figure 18 Salinity Comparison at the northern location of the inner bay near the sea floor.

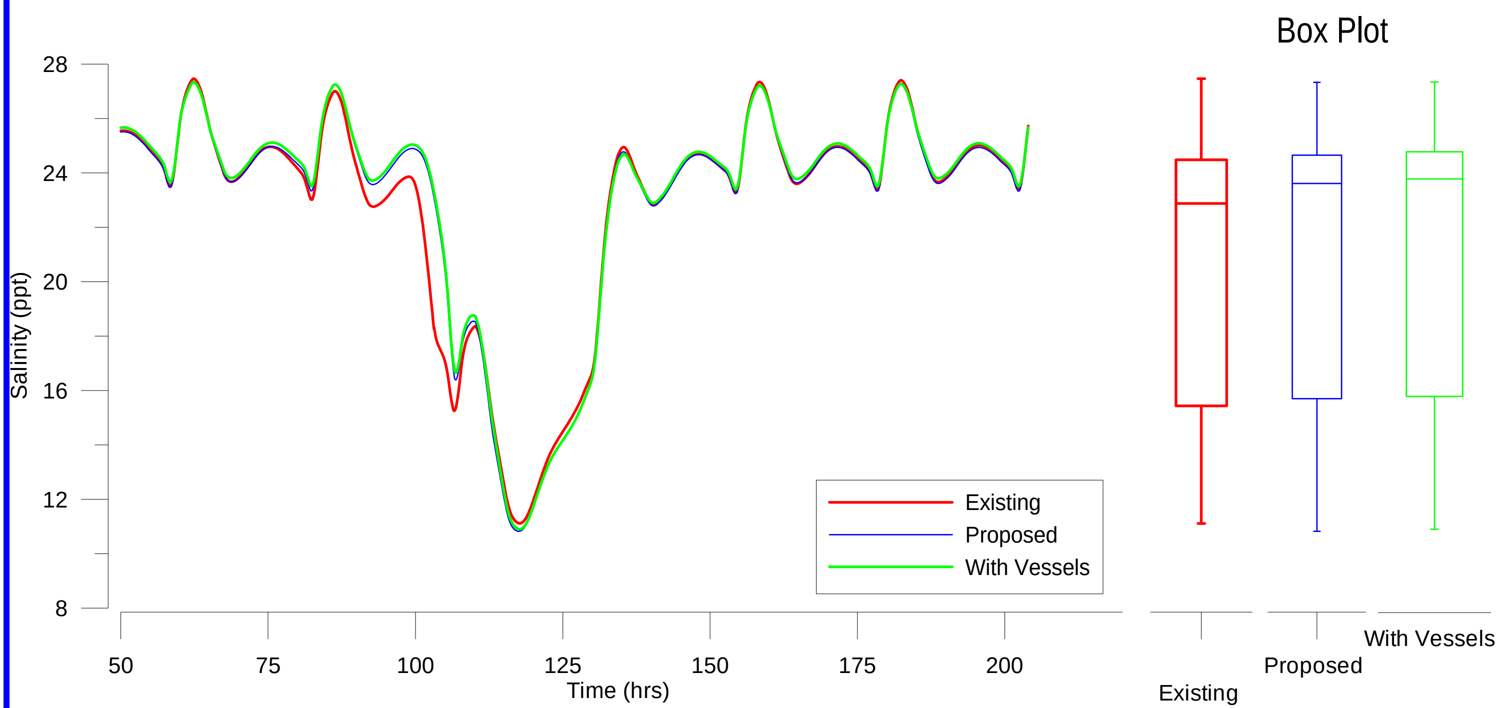


Figure 19 **Salinity Comparison at the eastern location of the inner bay near the surface.**

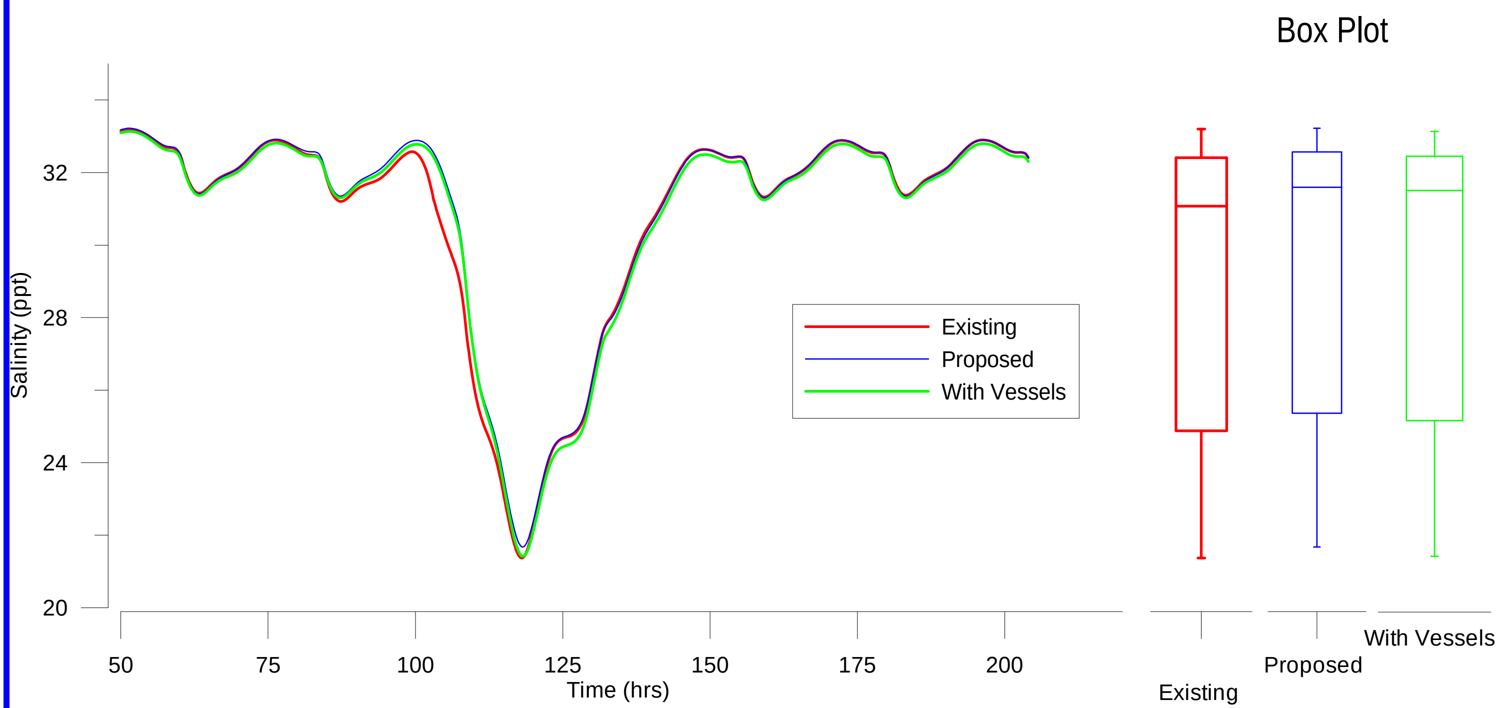


Figure 20 **Salinity Comparison at the eastern location of the inner bay near the sea floor.**

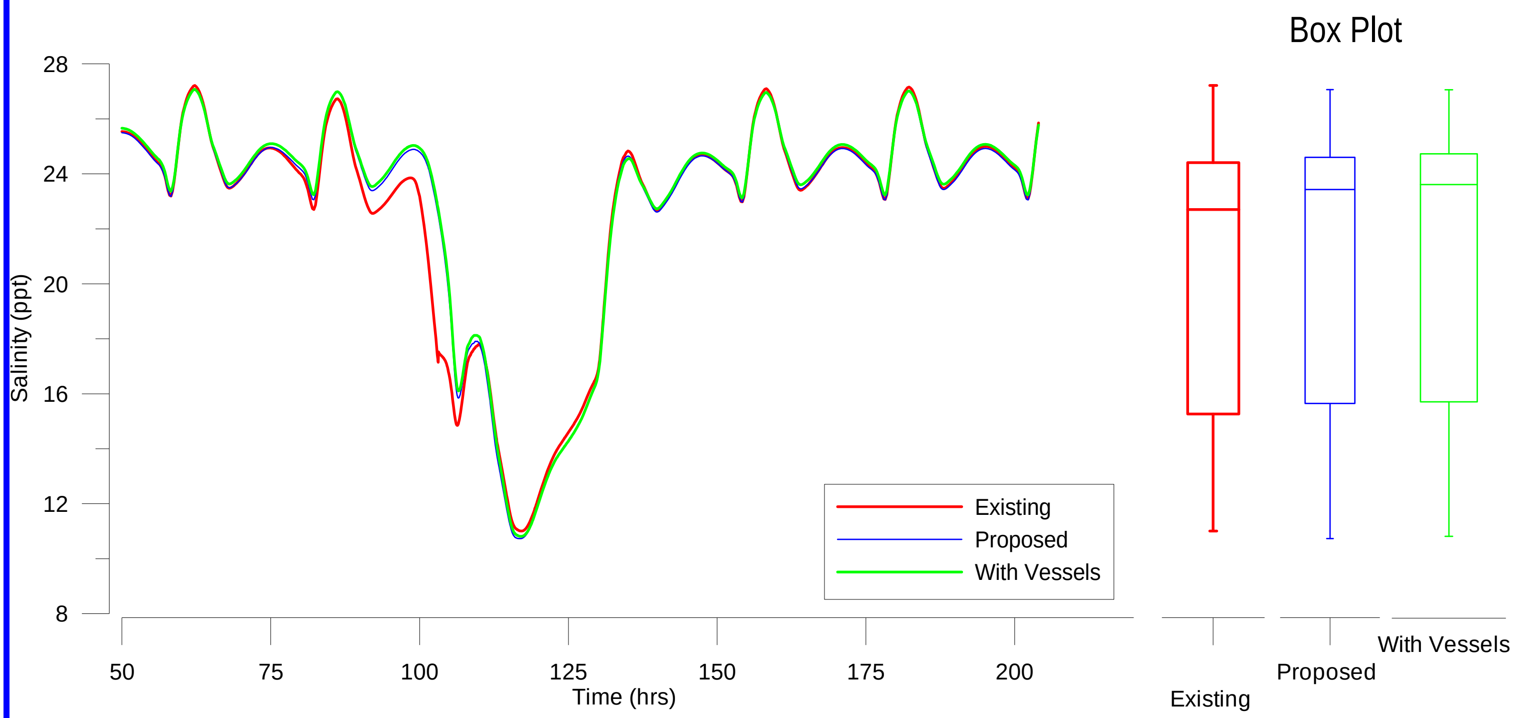


Figure 21 Salinity Comparison at the central location of the inner bay near the surface.

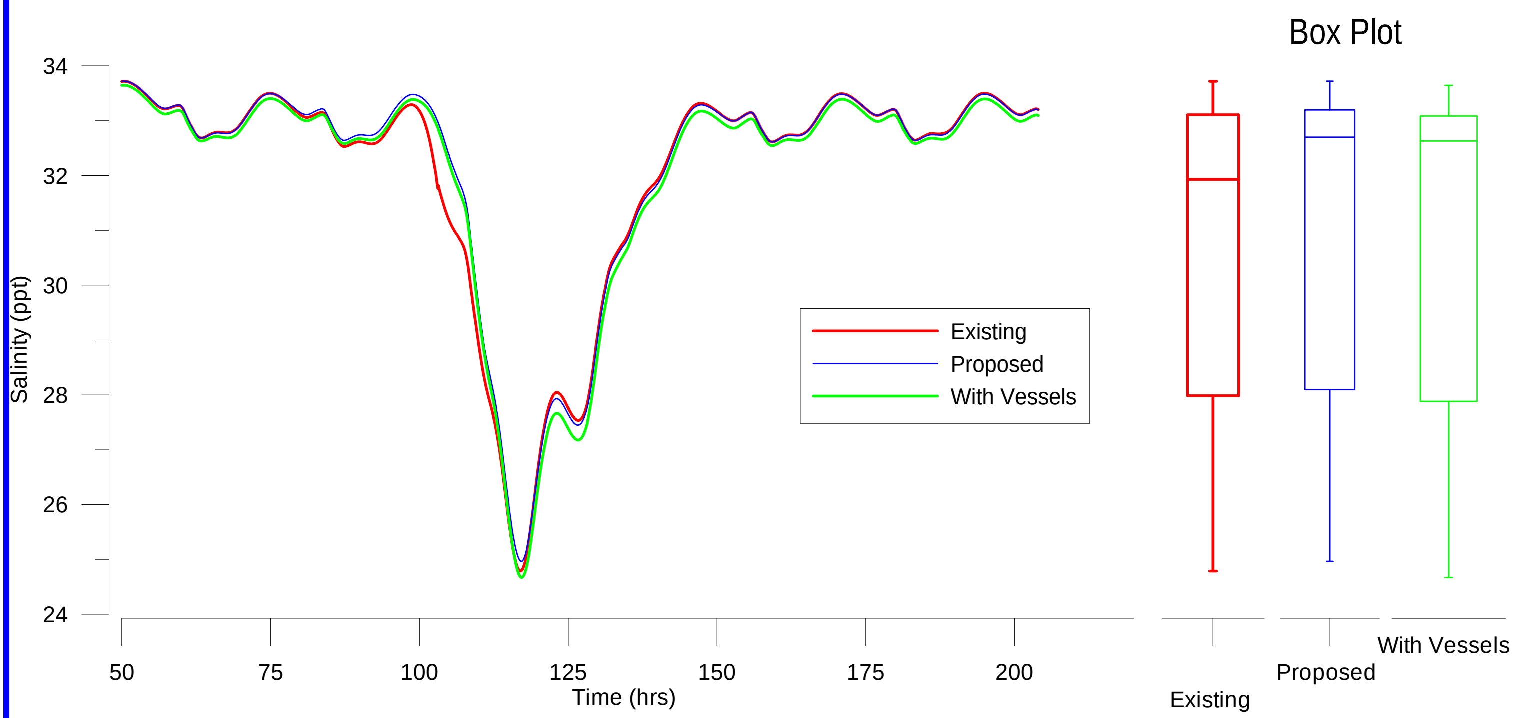


Figure 22 Salinity Comparison at the central location of the inner bay near the sea floor.

Flood Event and Time to Return to Normal Conditions (Suspended Sediment)

As part of the investigations, it was requested by NEPA that sedimentation levels be compared under normal conditions, followed by the application of a flood event, then back to normal conditions. The purpose of this investigation is to determine if the proposed structures and the proposed structures with vessels would have an adverse effect on the dinoflagellates in terms of suspended sediment concentrations. For this case, three locations were compared, the first being the eastern location of the inner bay, the northern location of the inner bay and the central location of the inner bay.

Figures 23 to 28 clearly show that under normal conditions there are negligible differences between the scenarios. During a flood event, the model shows that the existing conditions allow for more suspended sediment concentration than both the proposed and proposed with vessels scenarios. This difference could be due to the change in current speeds during the flood event. After the flood event, all scenarios return to normal conditions within 2 days.

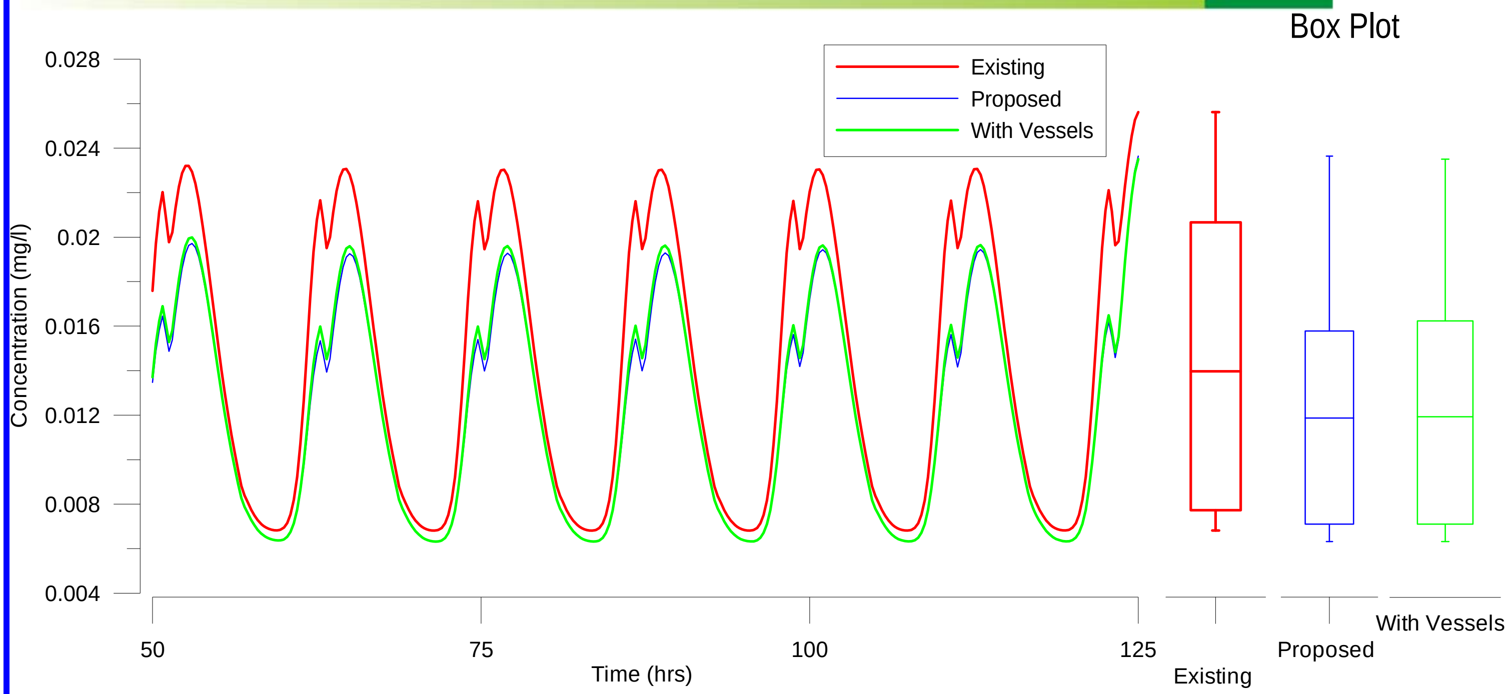


Figure 23 Time Series and Box Plot comparison of suspended sediment concentration at the eastern location under normal conditions

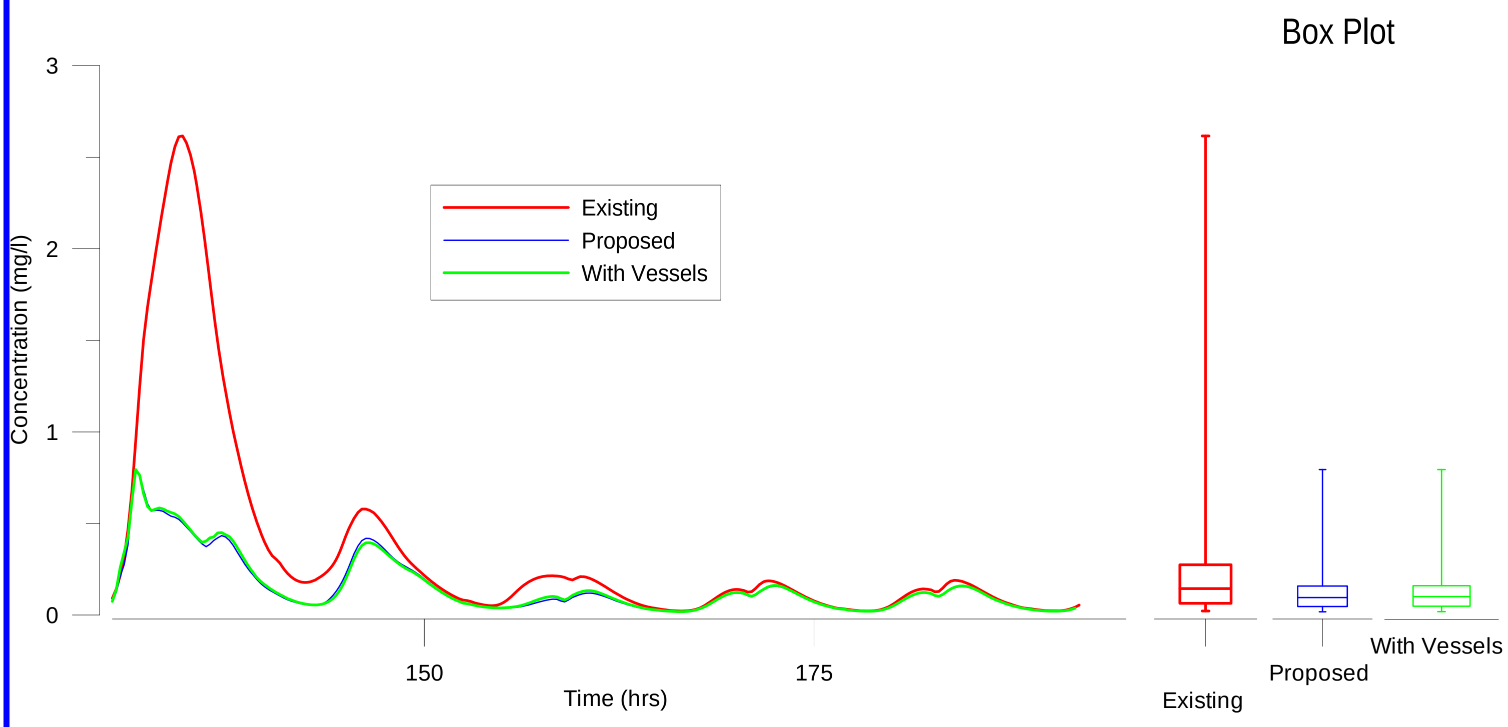


Figure 24 Time Series and Box Plot comparison of suspended sediment concentration at the eastern location under flood conditions

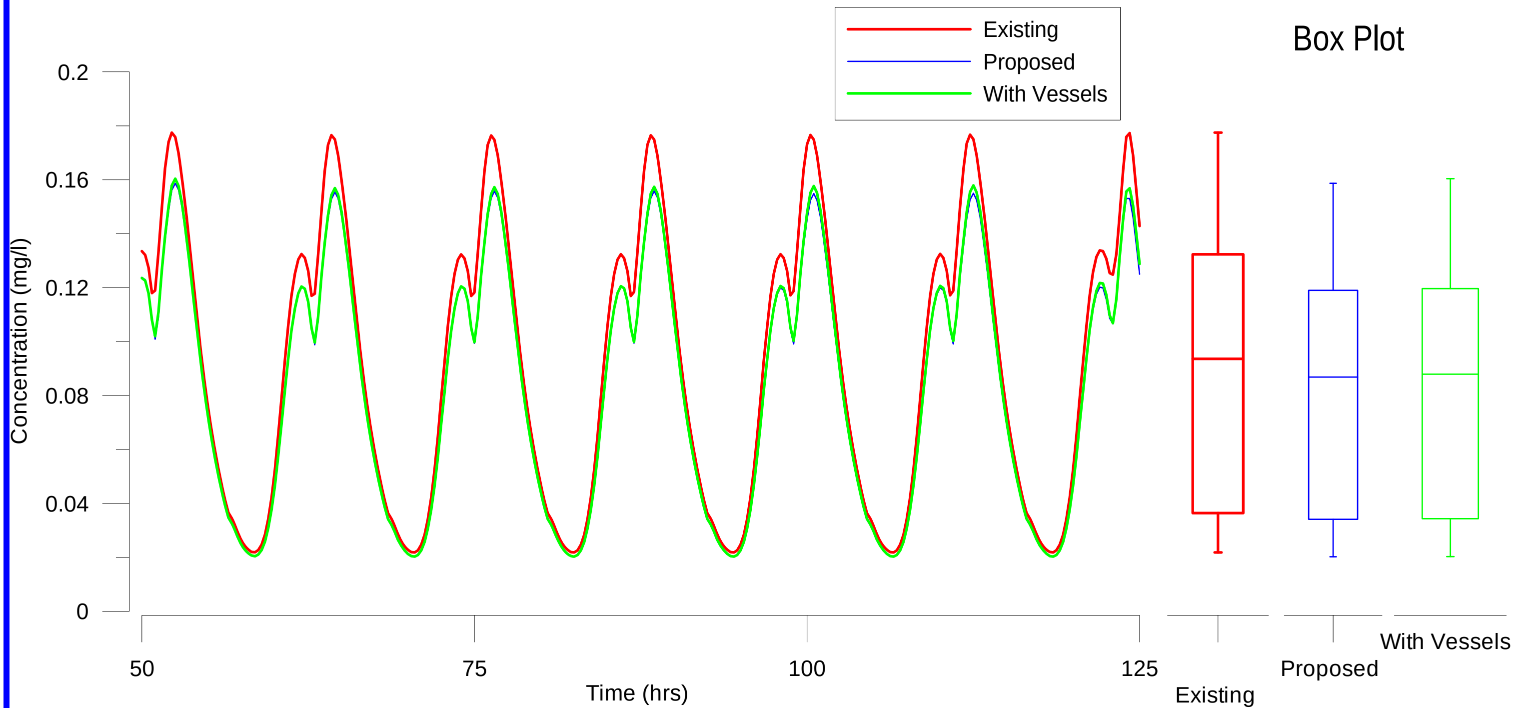


Figure 25 Time Series and Box Plot comparison of suspended sediment concentration at the northern location under normal conditions

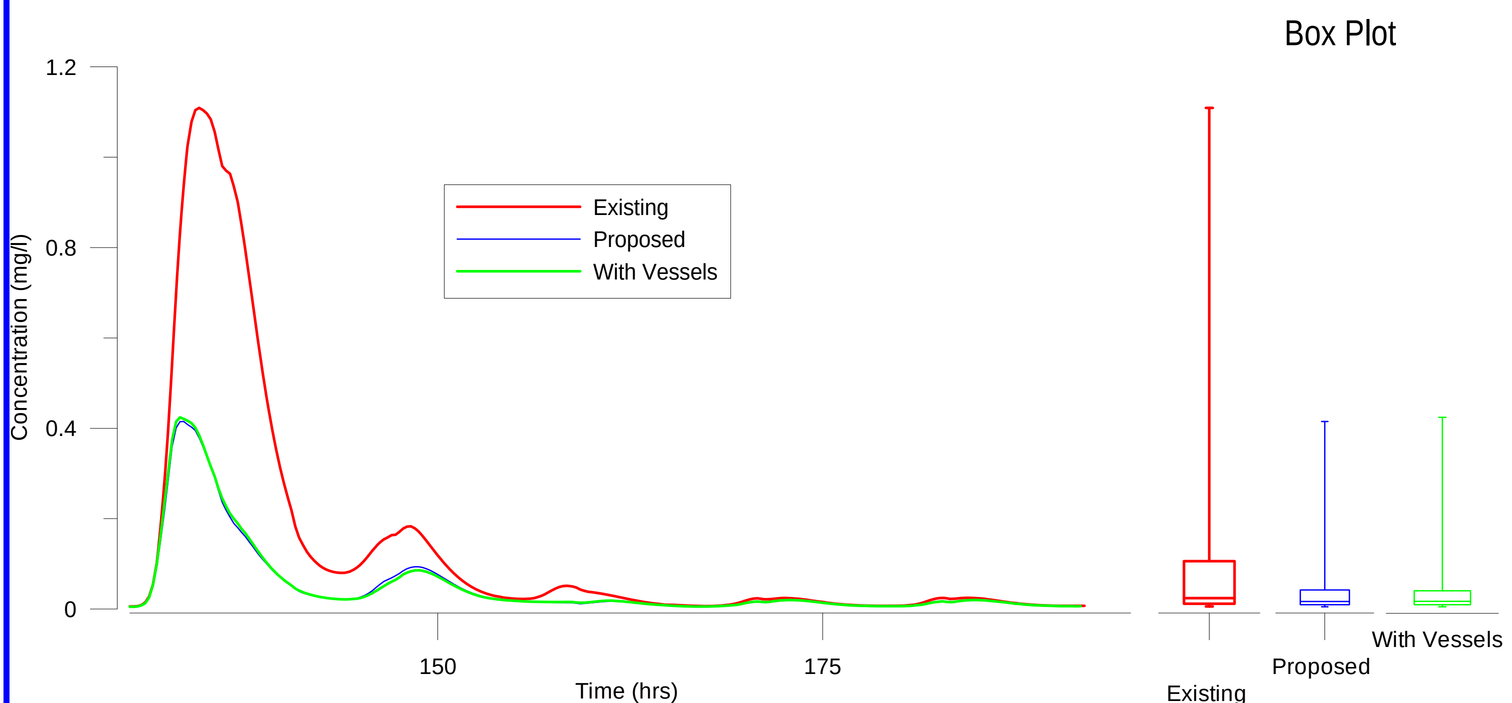


Figure 26 Time Series and Box Plot comparison of suspended sediment concentration at the northern location under flood conditions

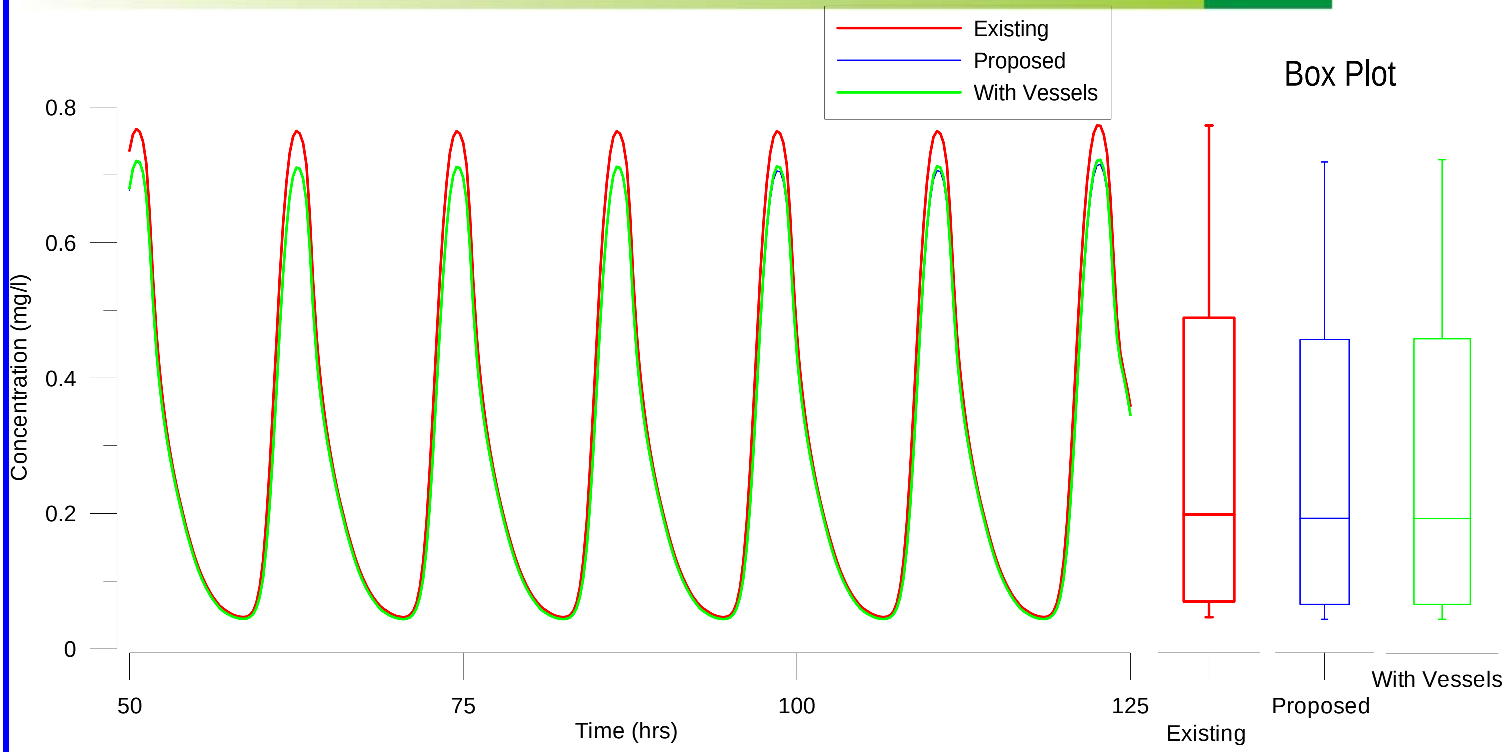


Figure 27 Time Series and Box Plot comparison of suspended sediment concentration at the central location under normal conditions

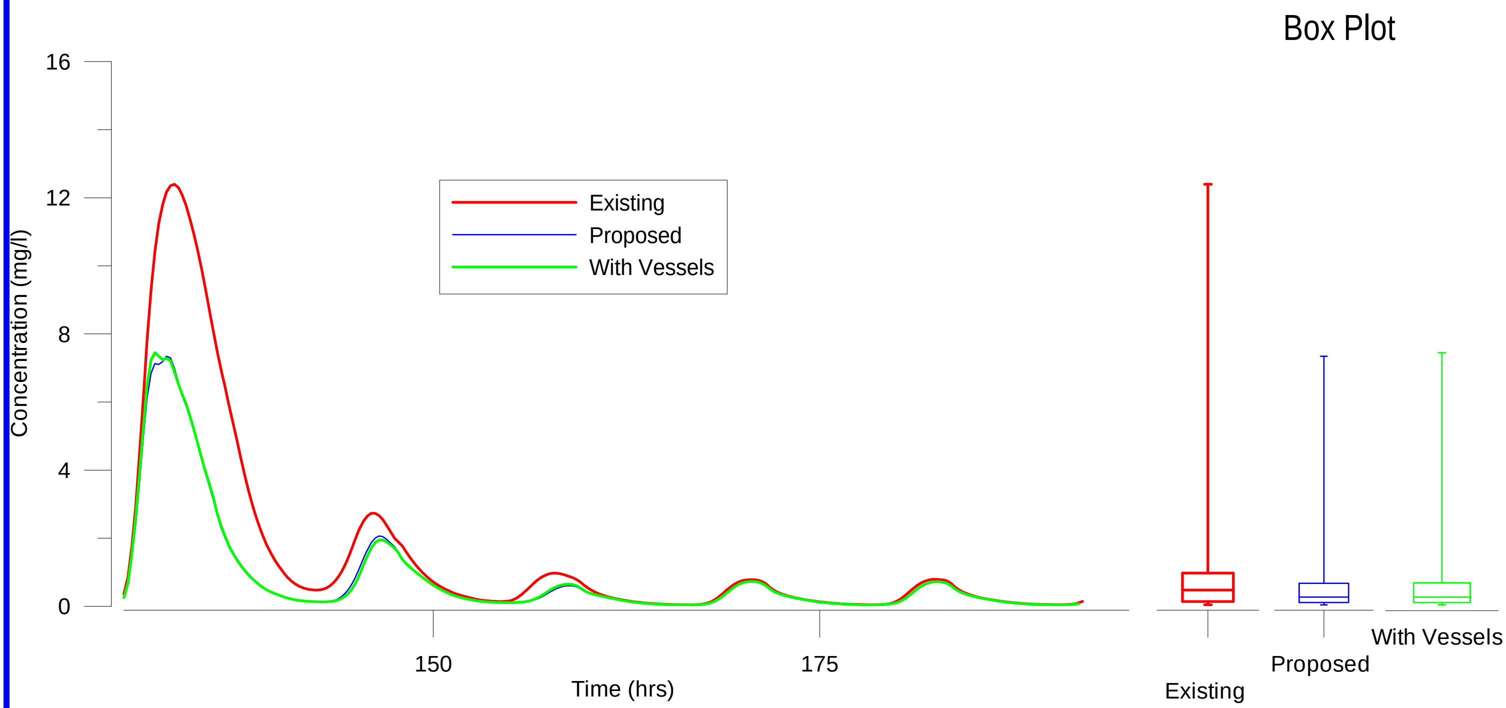


Figure 28 Time Series and Box Plot comparison of suspended sediment concentration at the central location under flood conditions

Conclusion

Based on the new study carried out, the model has been shown to be robust in its ability to accurately predict currents in both the outer harbour and the inner harbour.

The model demonstrates that it can predict typical drogue movements within the harbour.

The model results indicate that the proposed and proposed with vessels scenarios do not significantly change the salinity stratification in the area where the *dinoflagellates* reside.

The model shows that under normal conditions the suspended sediment concentrations of all the scenarios are very similar. Under a flood condition, the model shows higher suspended sediment concentration under existing conditions. The model also shows that conditions return to normal for all three scenarios within 48 hours after the flood event.