COASTAL DYNAMICS AND HYDROLOGICAL STUDIES FAQ

Toco Port Project

What water resources could be affected by the development of the Port?

The construction of the Port may influence several natural coastal and inland processes. The Port's construction activities may influence the seabed or marine water quality. Similarly, the presence of the Port infrastructure and related operations may influence coastal dynamics, flooding, and water quality. To address all of these potential concerns, ERM conducted a "*coastal dynamics and hydrological study*" related to the potential changes in:

- Water quality and flushing due to the placement of port infrastructure (Chapter 2);
- Flooding potential during extreme weather conditions (Chapter 3);
- Natural sediment transport regime (Chapter 4);
- Wave regime due to the proposed port (Chapter 5);
- Natural coastal erosion due to the placement of the port infrastructure (Chapter 5);
- Water quality due to the dredging activities during port construction (Chapter 6); and
- Water quality in the event of accidental spills during port operations (Chapter 7)

The study is included as a standalone appendix to ERM's Environmental Impact Assessment (EIA) The chapter numbers reference the relevant sections within this appendix.

What does Environmental Management Authority (EMA) require?

To be responsive to T&T's regulatory requirements, the "*coastal dynamics and hydrological study*" was designed such that it addresses all the issues raised by EMA's Terms of Reference (TOR), as noted below:

- Predict changes in oceanographic conditions, and especially tidal flushing/inundation of rivers and harbor area
- The direct and indirect impacts of dredging and reclamation on adjacent shorelines
- Identify changes in coastal current patterns and estuarine flow dynamics
- Identification and prediction of any potential construction phase impacts such as elevations in background suspended sediment concentrations
- Quantification of effect on wave regime including from the wake of the movement of marine traffic
- The implications of the reclamation and presence of the breakwater with respect to changes in the wave climate, sediment transport, shoreline behavior and long-term coastal evolution

How are these potential effects studied?

The "*coastal dynamics and hydrological study*" develops a comprehensive understanding and estimate of the potential impacts to the coastal waters through detailed evaluation and reproduction of baseline conditions, and projection of 'during-construction' and 'post-construction' conditions. These estimates are made using highly complex computational models that are designed to reproduce the conditions observed, or expected to be observed in the natural environment with respect to flooding regime and freshwater flows in Grande l'Anse Bay, and coastal dynamics and water quality over a wider area of influence.

The approach includes developing a hydrodynamic model for the region of interest around the proposed port facility. The hydrodynamic modeling is combined with the wave model and set up for two different periods (wet season and dry season). These wet and dry season scenarios are then run for the existing pre-port conditions and future post-port conditions. Any change between the pre- and post-port conditions represent the impacts to the baseline conditions due to the construction of the port. A similar approach is used for other models such as sediment transport, wave and coastal erosion to similarly establish the baseline and assess the impacts due to the port.

A graphical representation of the models used, configurations considered and intended results are shown in Figure 1 below.

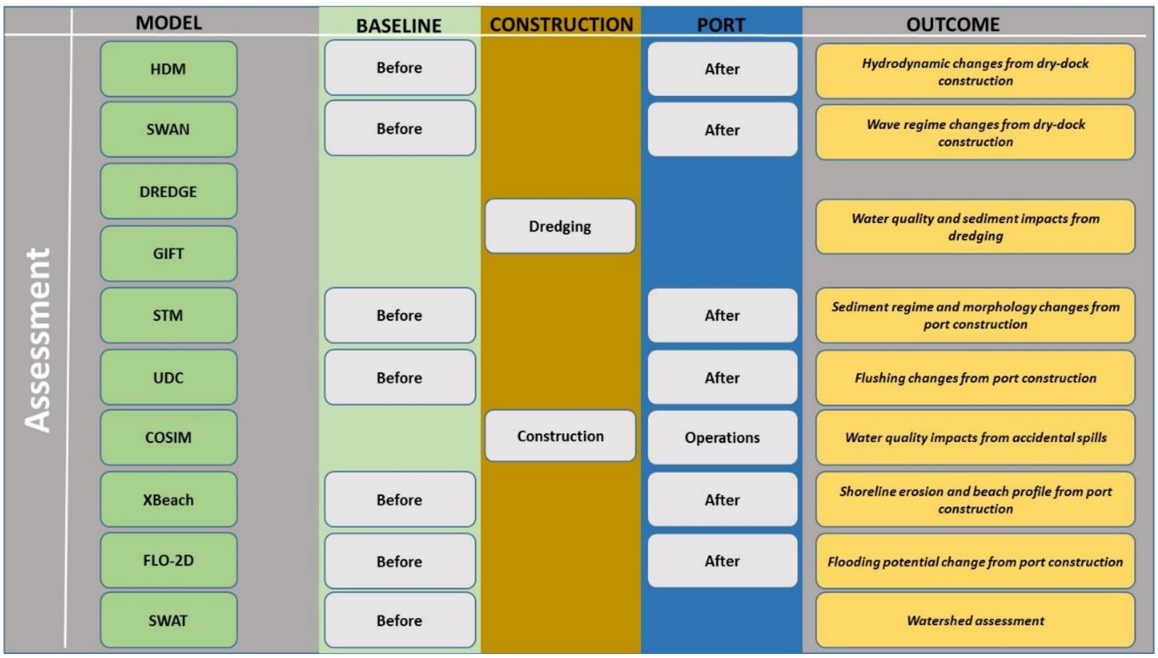

Figure 1 Coastal Dynamics and Hydrological Study Overview

What areas of the coast and upland are evaluated?

Because there are concerns related to beach erosion and the impacts that it may have on wildlife such as nesting leatherback turtles, ERM expanded the study area for coastal dynamics and hydrological studies to include the entire region along Grande l'Anse Bay from L'Anse Defour Bay on the west to Salybia Bay on the east. On the upland, the study area covered the entire watershed basin draining into the Grande l'Anse Bay with almost the same coastline extent and extending approximately 3.2 km inland. The study area including the marine (light blue) and upland watershed (black outline) is shown in Figure 2 below.

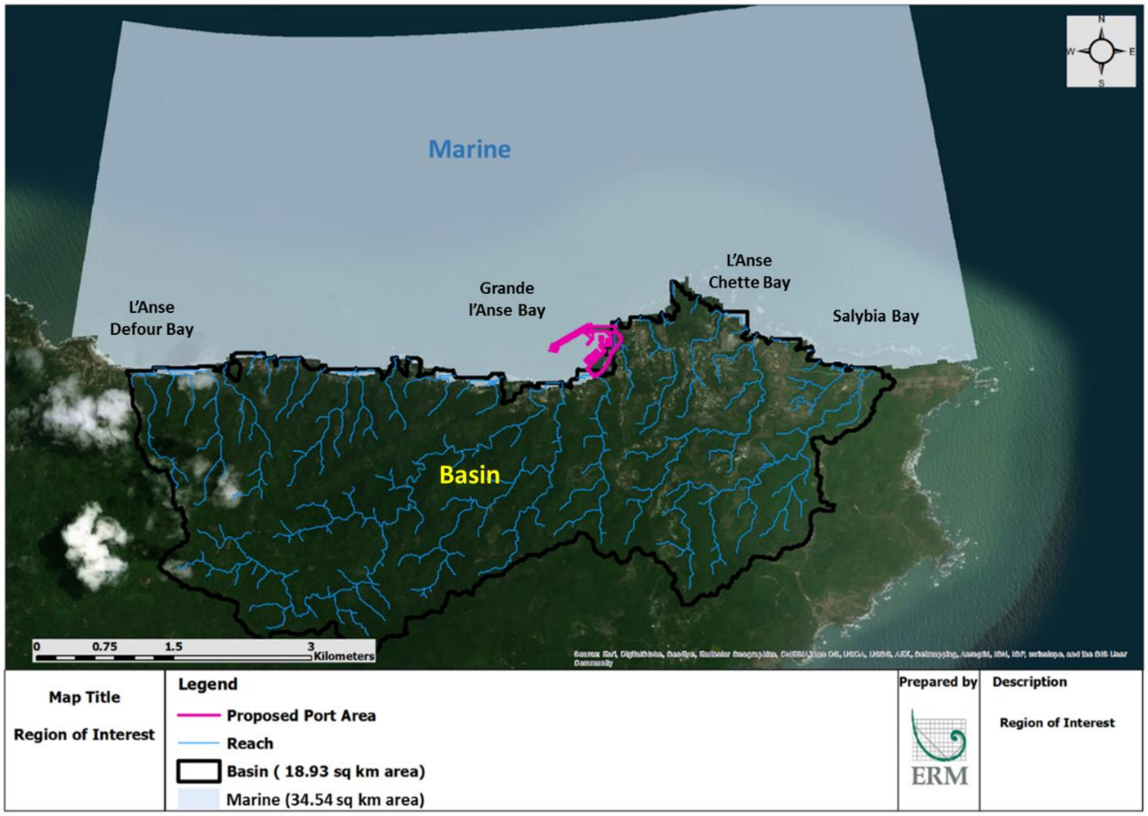

Figure 2 Coastal Dynamics and Hydrological Study Area

How are the hydrodynamics (coastal currents) in the region affected?

The model chosen to understand the hydrodynamic conditions of the waters between Trinidad and Tobago was based on GEMSS[1].The model simulations were set up such that an entire spring and neap tidal cycle was covered. Additionally, seasonality was considered due to the distinct freshwater flow characteristics defined by the wet and dry seasons.

Results from the model were compared to examine the impact of the Port on the velocity and circulation patterns. Current rose diagrams were produced to summarize the range of current speeds and frequency of times in which currents travel in a given direction. A series of locations were selected and grouped into regions labeled as the farfield, nearfield, and port area within the nearfield (see Figure 3 below).

[1] http://gemss.com/index.html

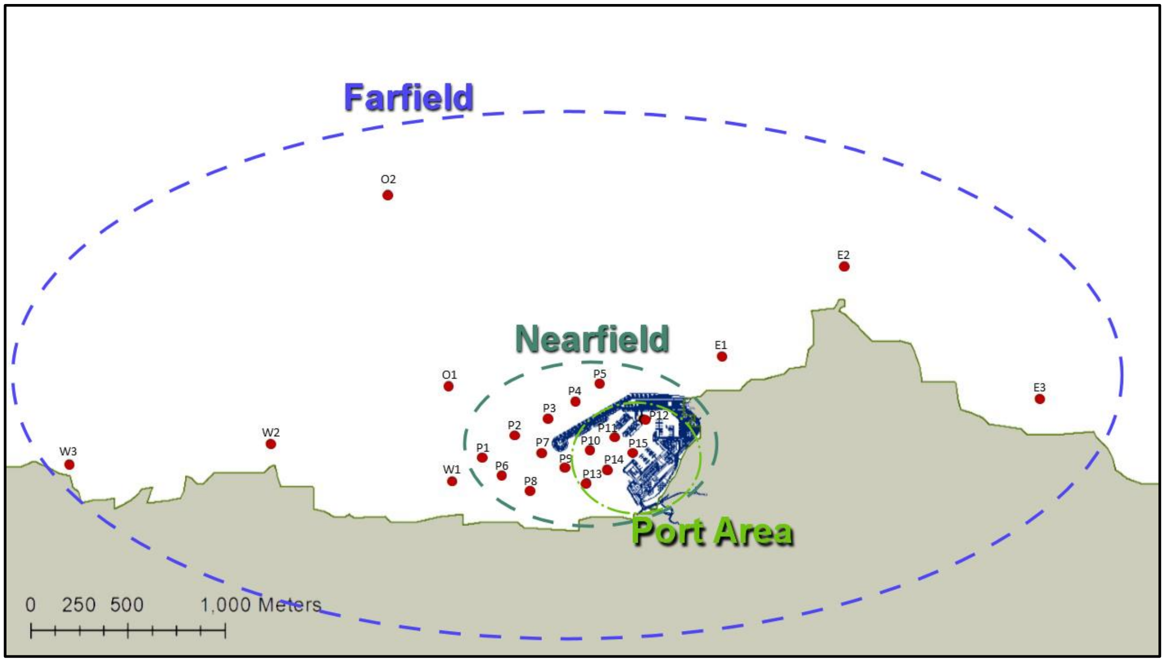

Figure 3 Comparative Current Rose Diagram Locations

The most observable alteration in current speeds and directions was observed within the port area. Effects diminished with distance from the port, such that negligible changes were seen in the farfield western locations (W1, W2, W3), eastern locations (E1, E2, and E3), and to the north away from the port (O1, and O2). An example of this is shown in Figure 4.

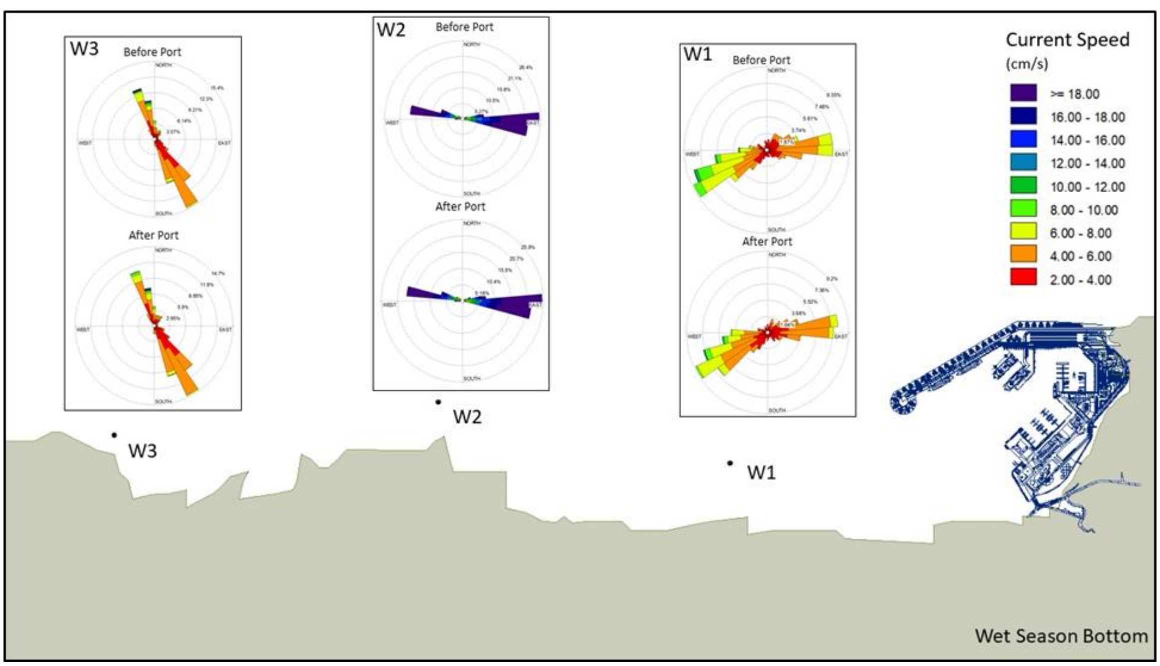

Figure 4 Comparative Current Rose Diagrams: Wet Season Bottom W1, W2, W3

Inside the port area (locations P10, P13, and P14), current speeds were approximately halved, reduced from a maximum around 16 cm/s to 8 cm/s. Seasonal differences were small, as the speeds and directions of the currents within the port area were fairly similar except directional changes exiting the port at P13 between dry season (flowing mostly northeast) and wet season (flowing mostly east). Further inside the port area (locations P11, P12, and P15), the pattern is similar with large speed reductions and directions indicative of currents circulating into and around the port instead of freely flowing approximately parallel to the coastline in pre-port conditions. An example of the changes in the currents inside the port is shown in Figure 5.

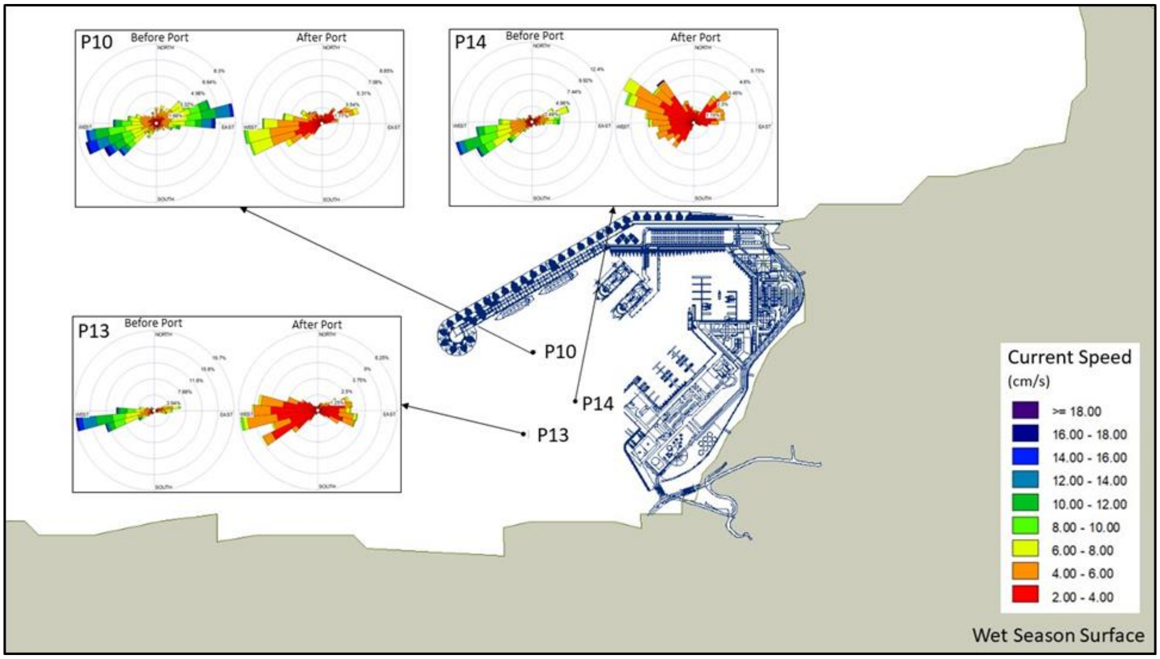

Figure 5 Comparative Current Rose Diagrams: Wet Season Surface P10, P13, P14

How are the wave dynamics in the region affected?

To develop a more comprehensive understanding of wave conditions in the Port region, and to project extreme wave conditions where notable sediment dynamics may occur, two separate models were used to simulate the nearshore wave conditions and the sediment transport regime: SWAN, utilized by ERM through the DELFT3D-WAVE interface, and XBEACH. The XBEACH model also includes calculations for coastal erosion, and was further used to simulate coastal erosion conditions under both baseline and Port conditions.

ERM's wave model for the port region considered various wind direction scenarios and various return periods for wind, water level (including added storm surge) and wave conditions. Scenarios included 50-, 100-, and 200-year return period conditions. Results for the various model simulations were extracted at points shown previously in Figure 3, and ERM analyzed these results to understand worst case results given by the maximum significant wave height resulting from a given wind direction. ERM compared significant wave heights, wave directions, and wave periods for various locations throughout the port region; each of the model scenarios were simulated with and without the port in order to understand the changes to the wave regime.

ERM found that within the port, significant wave heights are reduced by more than 4 meters as the port acts as a constructed breakwater. At other locations, differences are generally small (less than 1 m in wave height) except for the "W1" location which is moderately influenced by the port (approximately 1.5 m reduction in significant wave height with port addition for all return period cases). An example comparison with and without the Port is shown in Figure 6.

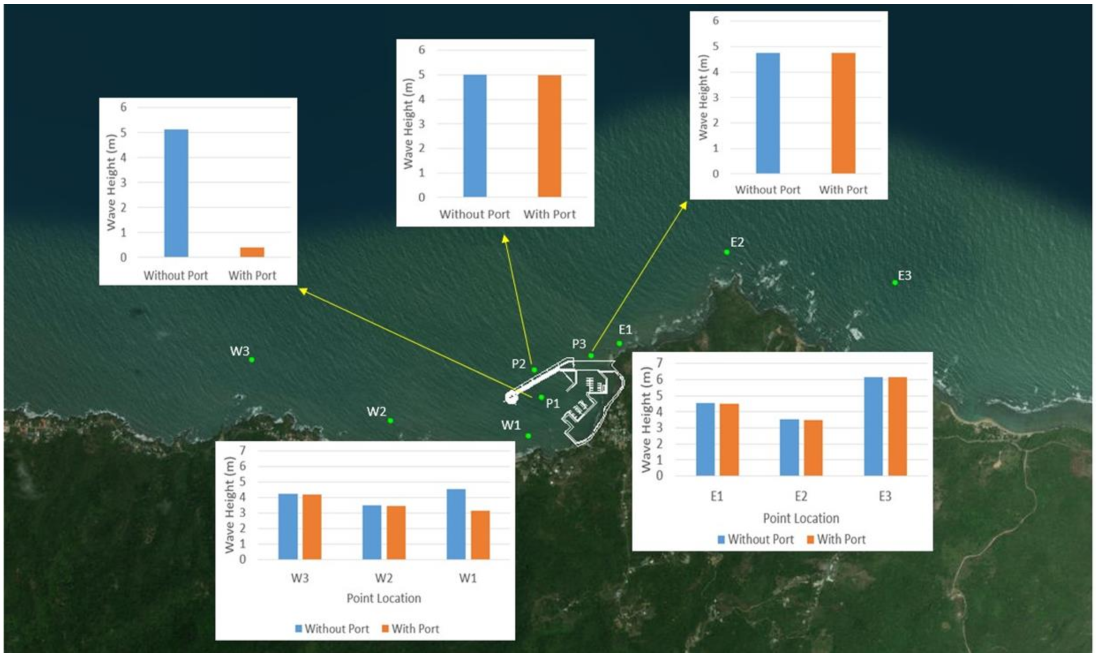

Figure 6 Map Showing Predicted Changes in Significant Wave Height at Various Locations for the 100-year Return Period

Will the marine traffic affect the wave dynamics in the region?

ERM's XBEACH model for the Port region also considered changes in hydrodynamics and coastal processes due to vessel traffic. ERM chose to model the impacts related to the largest anticipated vessel. The passenger ferry is anticipated to make multiple trips on a daily basis, and will potentially be the largest vessel entering the proposed port. Since the typical approach velocity for these ferries was not available, a constant value of 0.15 m/s (0.3 knots) was sourced from the World Association for Waterborne Transport Infrastructure (PIANC).

ERM found that as the ferry travels, it generates high frequency waves in all directions; waves generated outside of the Port are generally -0.1 m in size, and increase to 0.1 m when the ferry enters the port (see Figure 7). While ferry-generated waves do disrupt the hydrodynamics, the change is minimal and would result in insignificant amounts of deposition and erosion along the shoreline and within the Port.

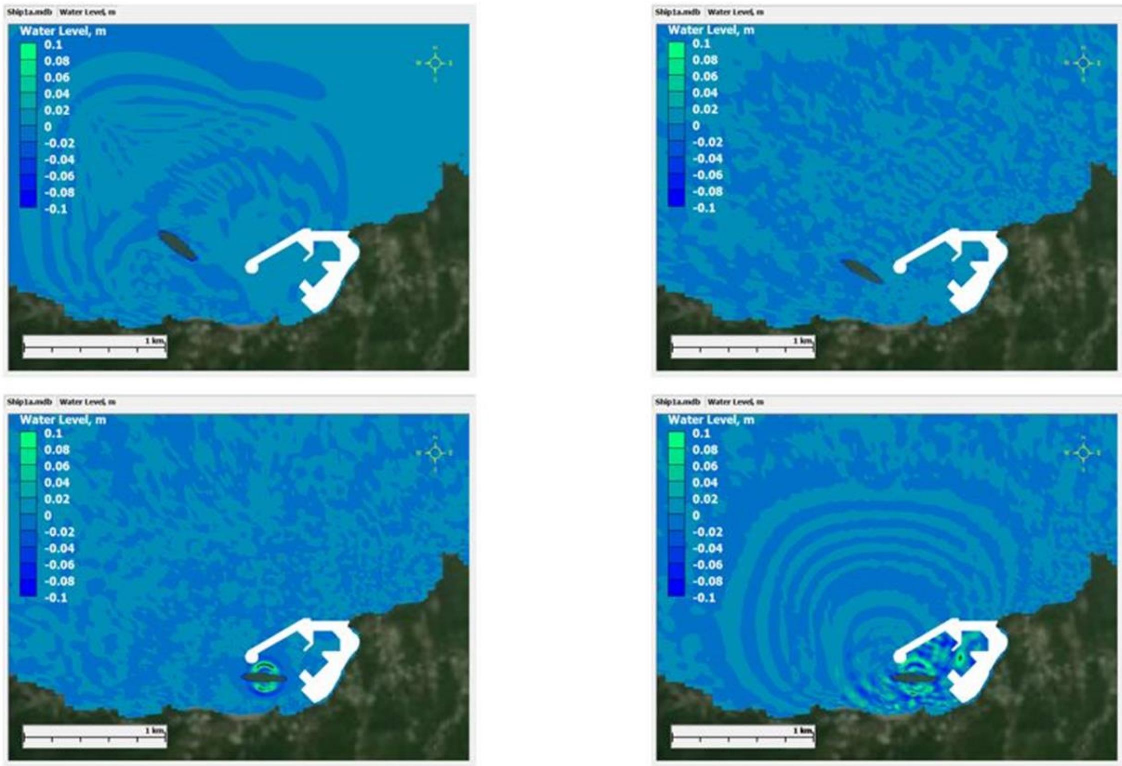

Figure 7 Ferry-Generated Waves Within the Port Region as it Approaches the Port

How are the freshwater runoff and floodplain affected?

To understand the freshwater flows into the Grande l'Anse Bay and to understand both existing and future increases in flooding risks, ERM conducted a detailed watershed and flood risk modeling assessment. The Soil & Watershed Assessment Tool (SWAT), a widely used watershed model developed by U.S. Department of Agriculture, was selected for the hydrological assessment. The hydraulic analysis was performed using the Flo-2D model. Two extreme scenarios were simulated as part of the hydraulic and flood inundation mapping to understand the surface runoffs to Toco Bay. These scenarios developed the flood map for a 1 in 100 year return period, with and without the Port.

ERM found that there was a slight increase in the areal extent of low and high flood hazard due to the Port as shown in Figure 8. These slight increases were in flow depths in the range of 1-40 cm at near shore regions. The flow depths on the proposed Port ranges between 0.4 – 1.1 m. It was found that none of the areas within the proposed Port except for the channel were classified as high hazard.

Hazard Level Flow Depths (m)	Area Inundated for Various Hazard Levels (ha) for Various Scenarios		
	Baseline (inland)	Post Development (Inland)	Post Development (includes reclaimed area)
Low	39.9	40.1	49.2
Medium	14.4	14.2	14.6
High	5.0	5.4	7.5

Figure 8 Area Inundated for Various Hazard Levels

What do we know about the natural coastal evolution for the region?

There have been several studies conducted by the Institute of Marine Affairs (IMA) assessing the characteristics and changes over time for the shoreline across Trinidad and Tobago. A study by Jehu and Ramsewak (2012) focused on coastline change detection across Trinidad and Tobago between 1994 and 2007. The study showed that the calculation of Net Shoreline Movement (NSM) using the Digital Shoreline Analysis System (developed by the United States Geological Survey) methodology did not identify the Toco region as hotspots for either accretion or erosion.

ERM further expanded these previously available studies with a quantitative assessment of historical satellite imagery using data for more recent years. The imagery-based analysis was performed using an open-source software named CoastSat, which allows detailed image processing and shoreline analysis (Vos et al., 2019). Tidal correction was computed based on observed water levels and approximate shoreline slopes extracted from the Google Earth terrain data to contextualize the results. ERM's own analysis confirmed that the shoreline from L'Anse Defour Bay to Salybia Bay are in dynamic equilibrium.

Are there any changes to the natural coastal evolution (erosion/accumulation) due to the Port?

ERM further evaluated changes to the coastline under extreme conditions and with the development of the Port. ERM's XBEACH model for the Toco Port region was used to understand changes to the coastline under different extreme conditions including storm surge. Scenarios included 50, 100, and 200-year return period conditions, and results for maximum erosion and sedimentation were analyzed for different wind directions.

ERM found that the northeast wind scenario resulted in the greatest magnitude and coverage of sedimentation and erosion in the region. Generally, for points closer to the port, sedimentation and erosion changes are more drastic and differences are less so for locations farther away from the Port location. The magnitude of sedimentation and erosion also generally increases with return period, as the 50-year return period has calmer wave activity than the more extreme, 200-year return period condition. Near the port, sedimentation increases immediately to the west as a result of the changes to the wave activity with the port acting as a structural breakwater. Waves are diverted to the west of the port and sediment can be deposited more frequently. At most, statistical maximum results considering extreme storm conditions showed a sedimentation increase of 15-20% with the presence of the port. Notably, erosion impacts for the various selected locations does not change significantly with the inclusion of the port in the model under these extreme conditions. In addition to this particular region of Trinidad being historically known to have limited shoreline erosion concerns relative to other regions, future changes in erosion are also predicted to be limited. An example comparison of erosion under extreme conditions between natural and with Port configuration are shown in Figure 9.

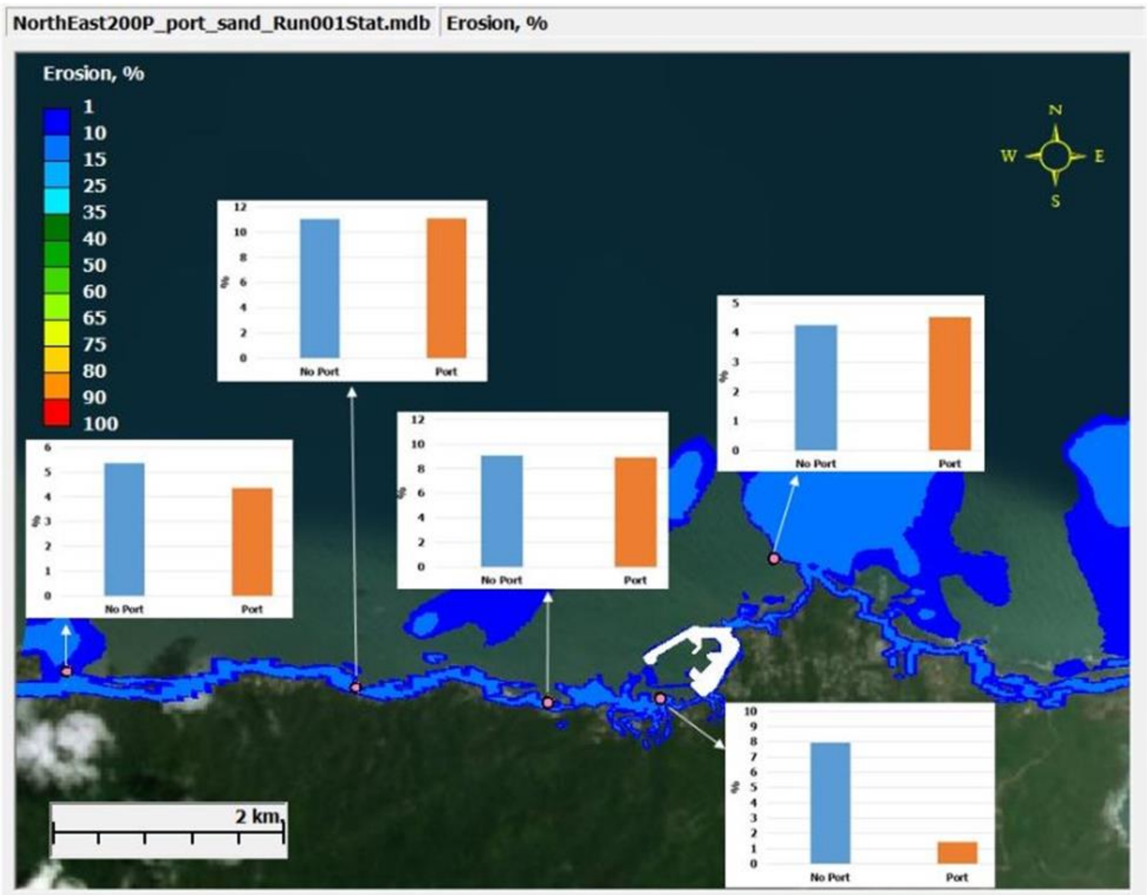

Figure 9 Map Showing Predicted Changes in Maximum Erosion at Various Locations for the 200-year Return Period

Will the Port affect water quality?

In addition to understanding the changes in currents due to the Port, ERM also evaluated changes in circulation and its resulting effect on water quality. Residence time is a parameter defined as the measurement of the length of time a parcel of water will remain at a given location. Natural water quality conditions within Toco Bay could be affected if the proposed port creates regions of poor circulation or zones of stagnation. Residence time, in this context, is a good surrogate for flushing (or circulation), and comparing the residence time can provide insights into whether regions or zones of poor water quality could be created after the port has been constructed.

ERM found that the port increases the residence times such that during the dry season, waters within certain regions of the port may take up to 36 times as long to flush out compared to present conditions (i.e. 36 hours to reach a 1/e dilution versus 1 hour without the port). In the wet season, the residence time in the port was improved, with some locations having a residence time of 36 hours compared to 4 hours without the port. Although relative stagnation occurs in regions within the port, a residence time of 36 hours isn't necessarily a sign of significant stagnation that would result in poor water quality. The regions that experience this increase in stagnation are typically shallow interior regions where dissolved oxygen re-aeration would assist with maintaining natural water quality throughout the water column. Most of the area does not experience any appreciable change in residence time suggesting that the water quality will not be affected.

Will the Port affect the natural sediment transport?

Changes in the currents could also result in changes to the natural sediment transport regime within the Port. Sediment transport is a complex phenomenon that consists of sediment deposition, erosion, mobilization, and transport (as bed load and suspended load). A good surrogate for the sediment transport and its effects on the sediment bed (seafloor) is the potential for erosion (mobilization) or deposition. Sediment particles continuously experience, under the influence of transient currents, mobilization and deposition, processes that either re-suspend particles into the water column or mobilize them to move along the sediment bed, or deposit on to the seafloor from suspension.

ERM found that the presence of the Port will block some of the faster currents, and redirect them to the north above the port. Above the port to the east is a deposition region where material may accumulate over time. This region is likely to be enhanced by the Port's presence. Figure 10 shows the change in erosion potential under high tide condition. ERM found that within the port area, either no change occurs, or an increased likelihood of deposition occurs.

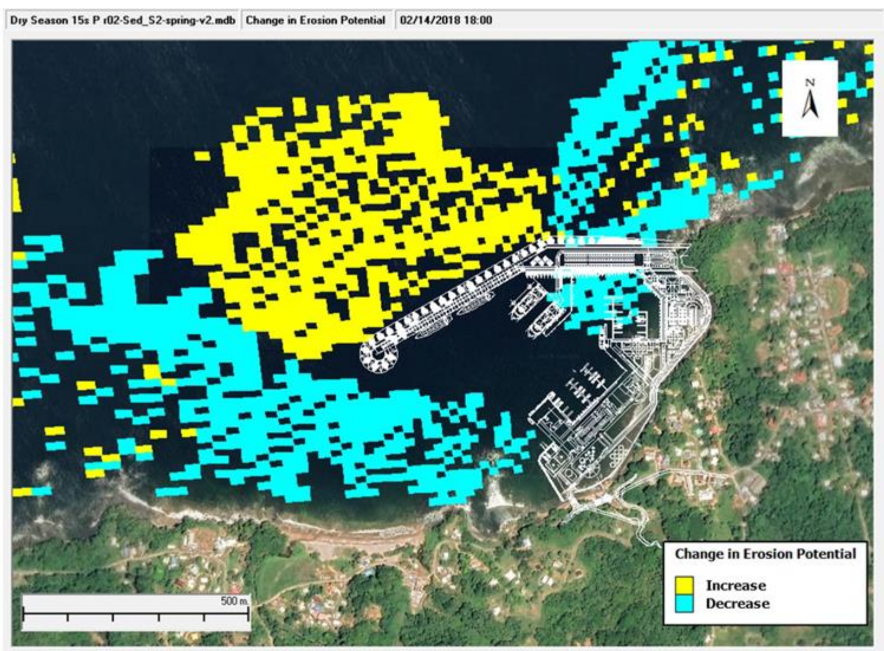

Figure 10 Coarse Sand Change in Erosion Probability: High Tide

What will happen during the dredging to support the Port construction?

The construction of the Port will require dredging for three areas throughout Grande l'Anse Bay. To evaluate the impacts associated with the proposed dredging activities, ERM developed a computational model based on the Generalized Integrated Fate and Transport (GIFT) model for the region to evaluate potential changes to the water quality (total suspended solids [TSS]) and sediment morphology (re-deposited sediments disturbed by dredging).

ERM found that although the area of TSS plume exceeding the threshold range of 35 mg/L from 641 m^2 to 10,190 m^2, these levels are not sustained for prolonged periods of time since the plumes dissipated to below 1 mg/L within 1 to 3 hours after the cessation of dredging on a given day. Similarly, the area of deposition exceeding 5 cm threshold ranged from 0.0254 to 0.329 km^2. However, most of that area was predicted to occur within the dredge area, a region that would go through multiple passes to reach the desired dredge depth. The only regions outside the dredge area that will received re-deposited sediments are in regions that will be reclaimed, leaving the region of actual re-deposited sediments mostly negligible as shown Figure 11.

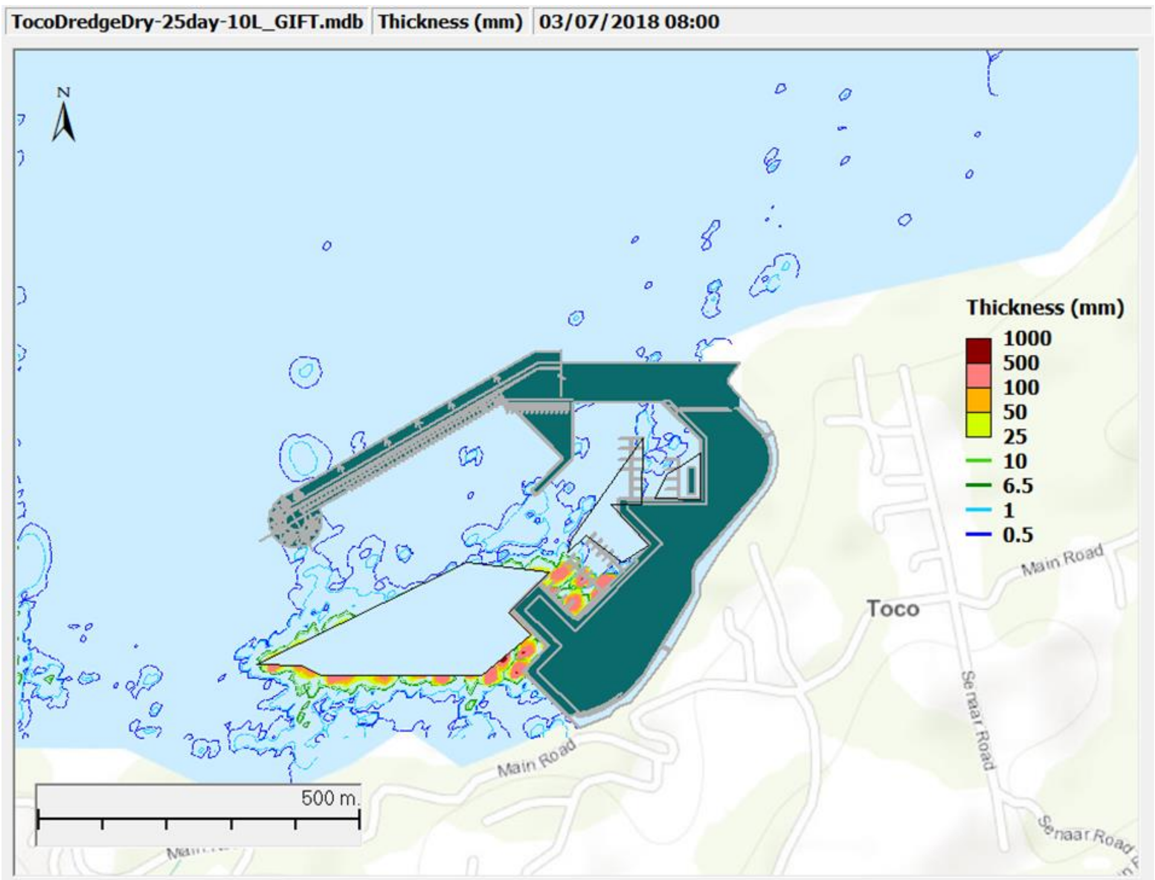

Figure 11 Dredging – 10% Loss Scenario Sediment Deposition Near Sea Floor Outside Dredging Area, Dry Season Currents

What will happen if there is an accidental oil or diesel spill at the proposed port?

The Port will be operational with an emergency response plan (ERP) in effect. The ERP is designed based on quantitative modeling of an actual spill, and its trajectory. In the event a spill occurs, the emergency response team would be prepared to respond to the spill and implement appropriate mitigation measures such as booming of the spill to contain it within the Port.

How will climate change impact the area after the proposed port facility is built?

ERM conducted a qualitative assessment of climate change impacts to the Port area. Climate change projections for the area indicate that for the intermediate-low emissions scenario (RCP 4.5 scenario), that the average annual temperature in the region is expected to rise by between 1.2 and 2.3 °C by the 2080s, and average annual rainfall is expected to decrease by anywhere between 1% and 10% (5% median value) by the 2080s

(IPCC 2014). Other climate change models are somewhat consistent with projected annual changes in temperature by the 2080s indicate increases between 1.0 ˚C and 3.7 ˚C.

Precipitation data for Trinidad and Tobago between 1960 and 2006 do not indicate any significant change during this period. However, the changes in seasonal precipitation simulated by the RCM vary considerably depending on the driving GCM. The RCM projections, driven by HadCM3 boundary conditions, indicate a large decrease in annual rainfall (-30%) when compared to simulations based on ECHAM4 (-22%).

Seal level rise in the northern part of Trinidad has been observed to be rising at a rate of about 1 mm per year. Sea levels in the region are predicted to rise by as little as 38 cm by the 2050s under a low emissions scenario (RCP 2.6) and by as much as 43 cm by the 2050s under the high emissions scenario (RCP 8.0). By the end of the century, sea level in the region is expected to rise by about 75 cm under the the RCP 2.6 scenario and by over a meter under the RCP 8.0 scenario.

Observed and projected increases in sea surface temperatures indicate the potential for continuing increases in hurricane activity. Model projections (although still relatively primitive) indicate that this may occur through increases in intensity of events (including increases in near storm rainfalls and peak winds), but not necessarily through increases in frequency.

The data summarized above suggest that, in the future, if projections materialize, coastal inundation, inland flooding, storm surge damage, and coastal erosion are likely to increase in the vicinity of the proposed Port, however, uncertainty remains high.