TOTAL E&P PNG LIMITED

PAPUA LNG

Upstream Environmental Impact Statement

Volume 3: Technical Studies

Part 4

Marine Modeling for Impact Assessment

TOTAL

TOTAL E&P PNG LIMITED

Marine Modeling for Impact Assessment

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TECHNICAL REPORT SERIES

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1 Introduction

1.1 Project Overview

Total E&P PNG Limited (TEP PNG), a wholly-owned subsidiary of TOTAL S.A., is the leading joint venture partner for the Papua LNG Project (the Project). This Project involves the development of the Elk-Antelope gas field, which is located in Petroleum Retention License 15 (PRL-15) in Gulf Province, Papua New Guinea.

The Project includes two offshore export pipelines, running through the Gulf of Papua from Orokolo Bay in Gulf Province to Caution Bay in National Capital District. The pipelines will be buried along their nearshore reaches. This will require trenching (by dredger), pipeline placement and reburial.

Figure 1-1 shows the indicative marine pipeline corridor.

1.2 Assessment Context

In accordance with Papua New Guinea legislation, International Finance Corporation (IFC) Performance Standards, and TOTAL's corporate policies and standards, an environmental impact statement/environmental, social and health impact assessment (EIS/ESHIA) is being developed for the Project.

An important element of the EIS/ESHIA is quantifying the potential impact to the marine environment from the trenching activities. Dredging of the seabed and pipeline burial will cause seabed sediment to become suspended in the water column, causing changes in water quality with potential implications for sensitive marine biota. Modeling has therefore been undertaken to inform the assessment of the impacts of these activities.

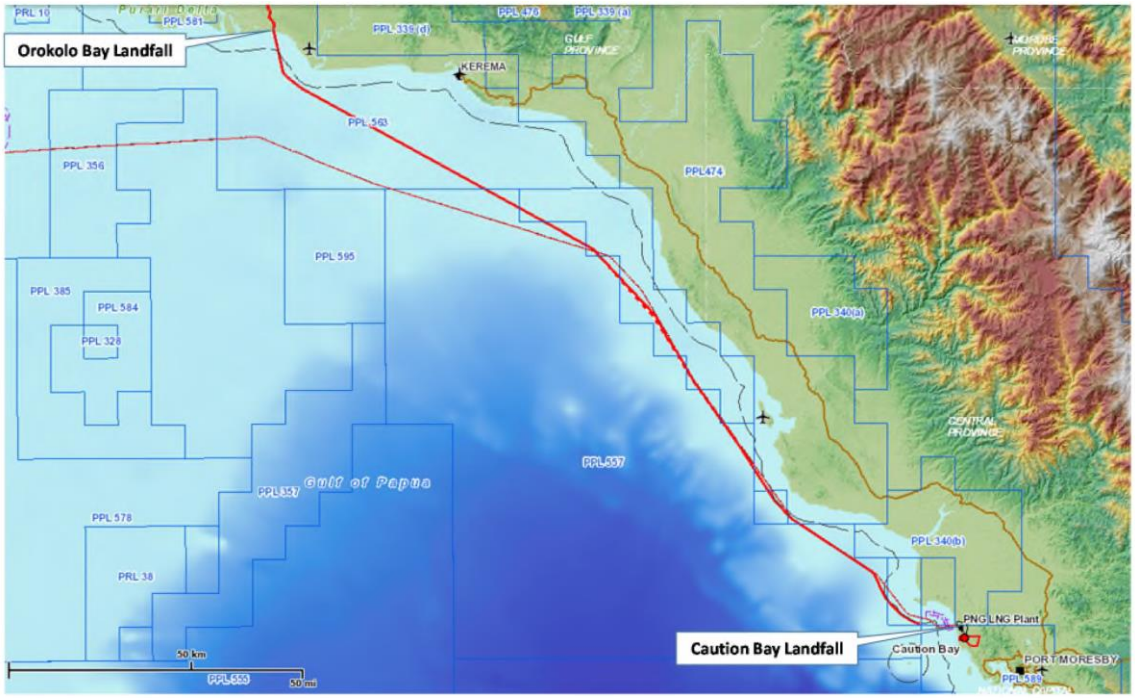


Figure 1-1 Offshore Export Pipeline Route

2 Project Description and Assumptions

2.1 Pipeline Alignment

The Project consists of separate gas and condensate export pipelines connecting an upstream central processing facility (CPF) in PRL-15 with a downstream liquefied natural gas (LNG) plant at Caution Bay. Both pipelines will follow the same route, including an offshore section of approximately 260 km through the Gulf of Papua. The gas export pipeline will be 40 inches (1 meter) in diameter while the condensate export pipeline will be 10 inches (0.25 meter) in diameter.

The proposed landfall location for the pipelines at Orokolo Bay is shown in Figure 2-1. As described in Part 9 of Volume 2, the proposed route through Orokolo Bay is not known to pass through any marine wetland environments or areas of reef, although it runs near to a rocky outcropping (near Site A in Figure 2-2).

From here the pipeline alignment runs to the southeast through the Gulf of Papua to Caution Bay, with a minimum distance of 5 km between the pipeline route and shore (Figure 1-1). This 5 km buffer necessitates a crossing of the PNG LNG Gas Pipeline approximately midway between Orokolo and Caution bays.

A final alignment has not been decided within Caution Bay; however, a pipeline corridor has been identified (Figure 2-3). Finalization of the pipeline alignment will be undertaken during the front-end engineering design (FEED) phase for the Project. TEP PNG has a preference that the pipelines do not cross the existing PNG LNG Gas Pipeline within this corridor, thereby necessitating a final landfall at Caution Bay that is to the south of the existing pipeline. For the purposes of the impact assessment modeling; however, TEP PNG has provided two indicative alignments at Caution Bay with one to the north and the other to south of the PNG LNG Gas Pipeline (Figure 2-4). These alignments are indicative only, and require further refinement following updated seabed mapping and engineering studies. Importantly, both alignments indicate the intention of TEP PNG for an approach through the center of Caution Bay that will pass between major barrier reef features.

2.2 Pipeline Construction Methodology

Pipeline installation will be undertaken by dedicated pipelaying vessel. This utilizes a continuous process of joining and lowering pipe sections from a lead pipelaying vessel, with resupply of new pipe sections from supporting pipe supply vessels.

In shallow areas, the pipeline will be laid in a trench and then buried to provide for stabilization and protection. The trench needs to be deep enough and wide enough to allow complete placement and burial of the pipelines. It is assumed, therefore, that the trench depth will be 2 m (allowing up to 1 m insurance for the condensate pipeline) and trench width will be 6 m. For the purpose of the modeling, it was also assumed that trenching will occur from the coast to the -15 m below LAT depth contour and would occur through both soft and hard sediment types. The method for trenching is not yet determined but, for the purposes of the impact assessment, it was assumed that it will be carried out by a cutter suction dredger (CSD). It is possible that a backhoe dredge may be used instead, but a CSD would likely involve a higher plume release rate and is therefore considered to provide a conservative scenario (in terms of plume dispersion outcomes).

Based on sediment classes identified during the ESBS studies (described in Part 9 of Volume 2), there are no stiff clays expected in the area to be trenched. Without more detailed geophysical data, it is therefore assumed that the only materials in these areas will be soft sediment, or reef in the case of Caution Bay.

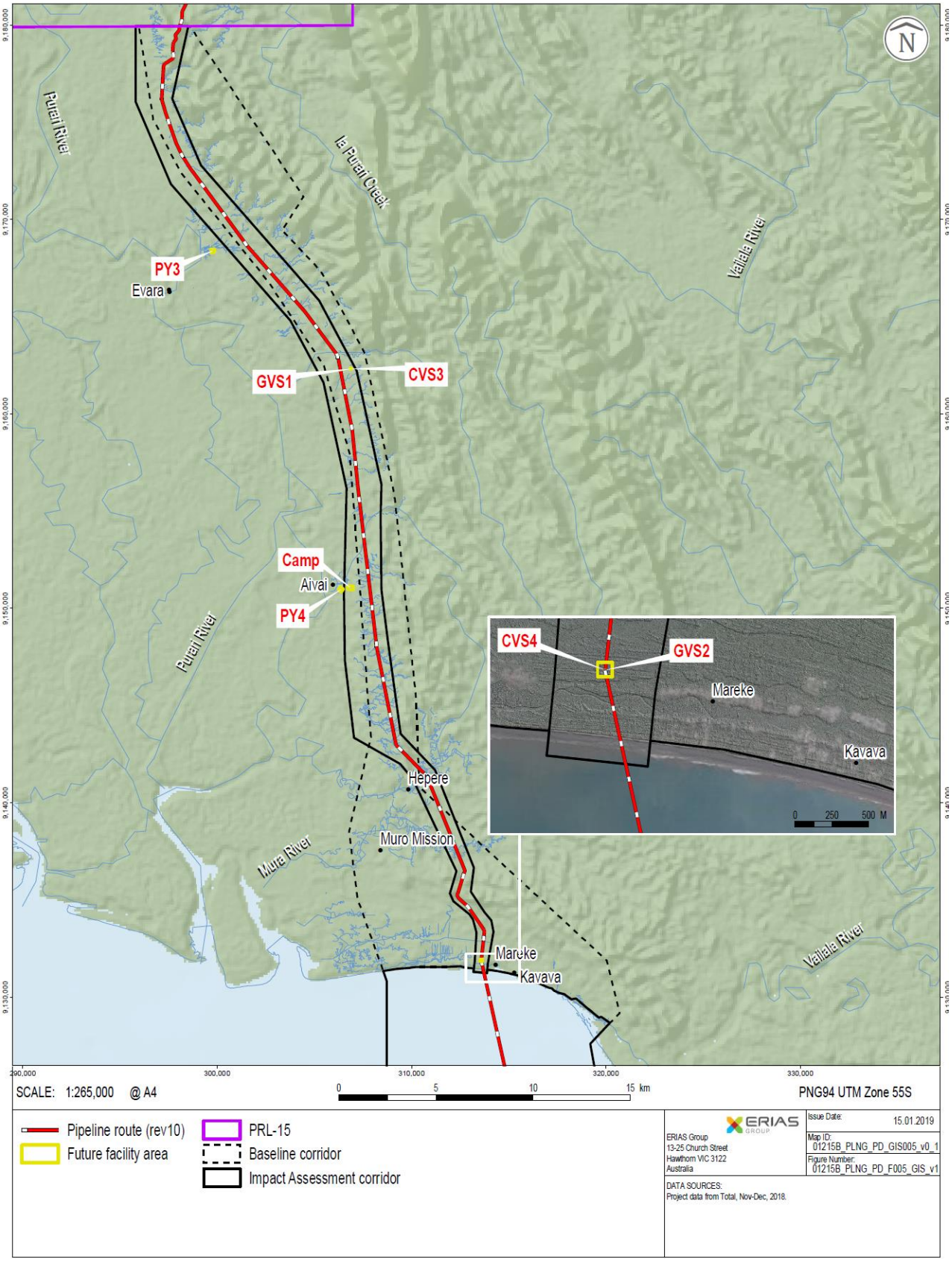
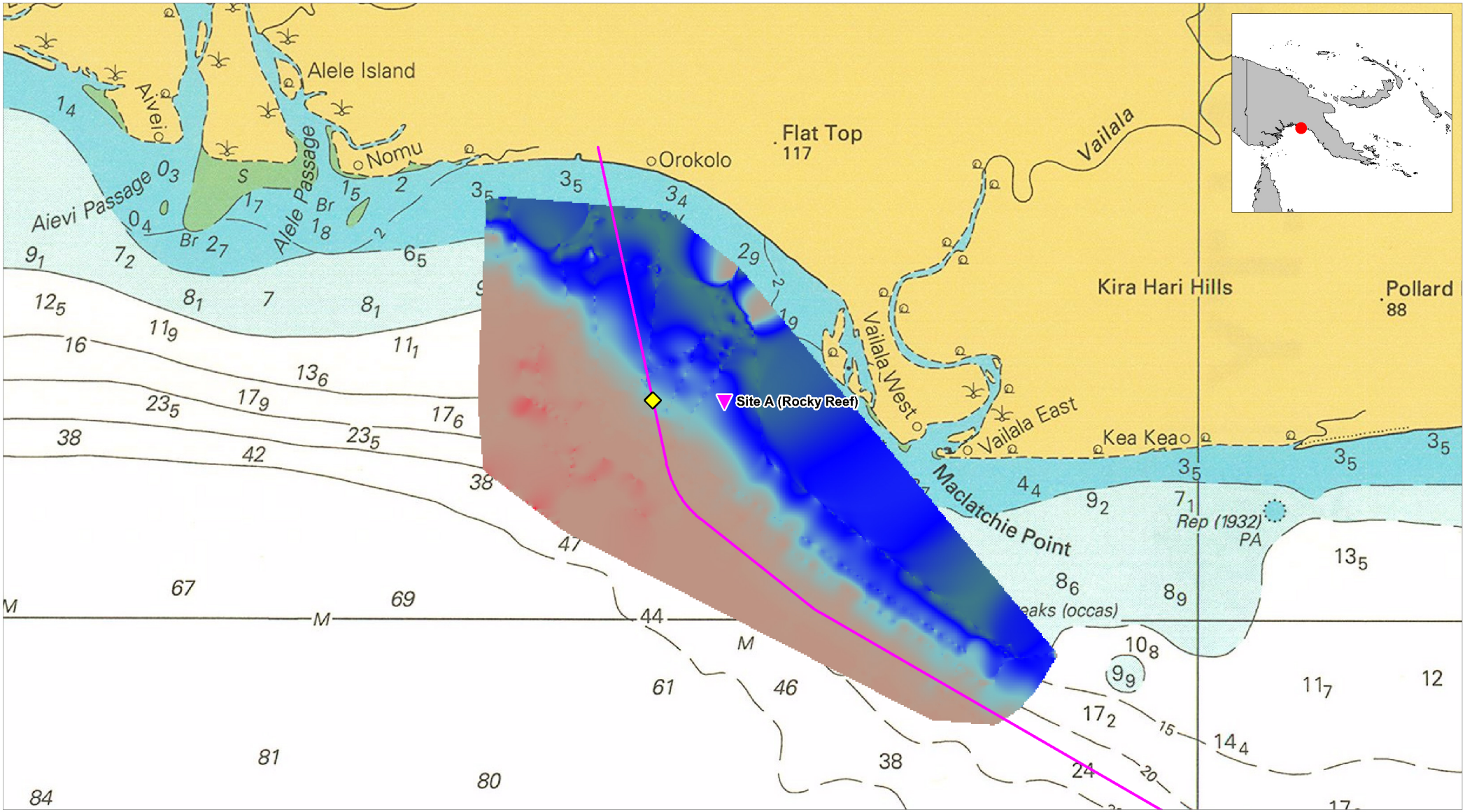


Figure 2-1 Onshore Pipeline Route and Orokolo Bay Landfall



LEGEND

- Potential Papua LNG Pipeline Routes
- Extent of Modelling
- Location of Rocky Reef

Benthic Habitat Classes

1. Silty substrate with debris
2. Textured silty mud with 25-30% clay
3. Uniform silty mud
4. Uniform silty clay
5. Higher relief bed structures

Title:

Orokolo Bay Pipeline Alignment Modeled for Impact Assessment

Figure: 2-2

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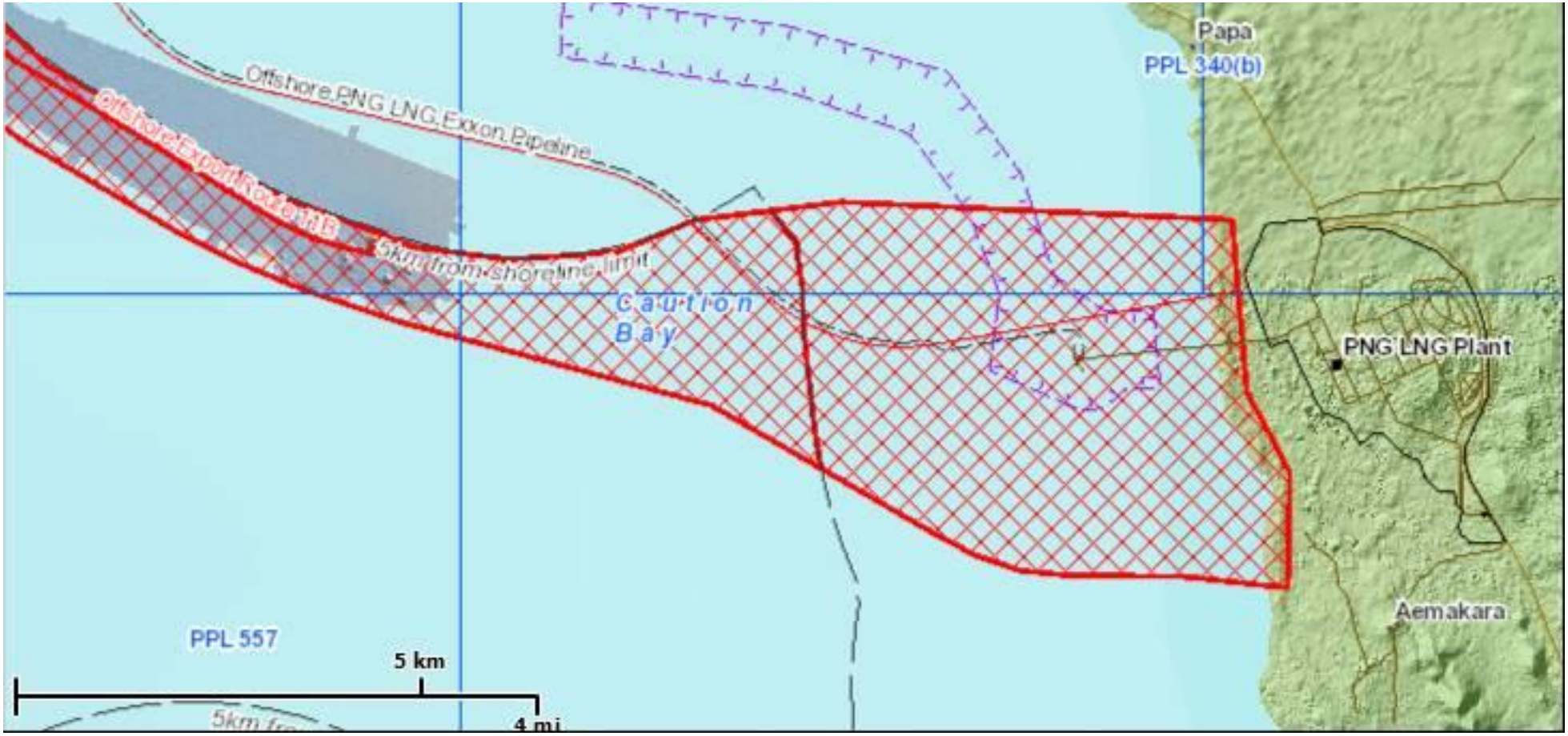
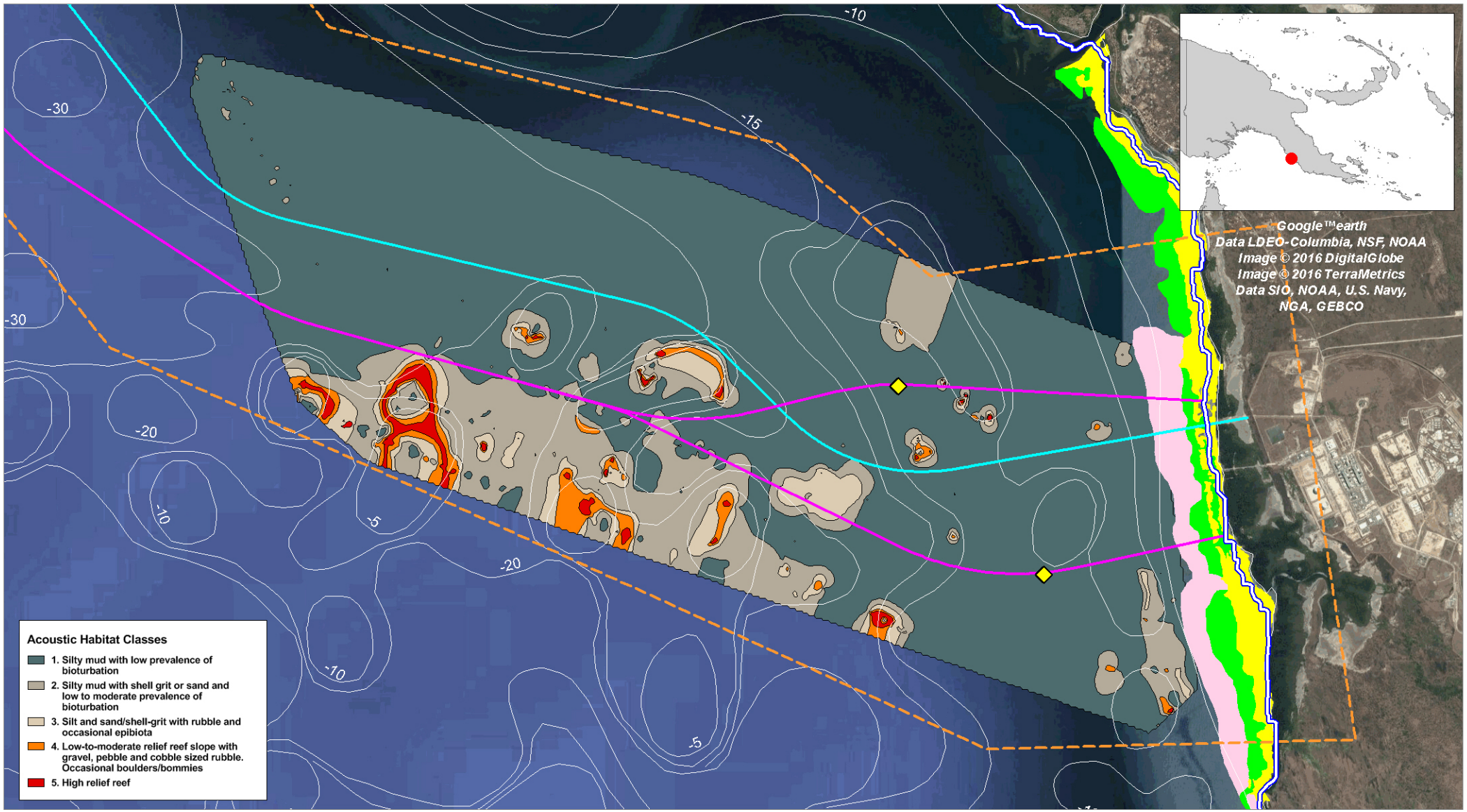


Figure 2-3 Export Pipeline Approach to Landfall at Caution Bay



LEGEND

- Pipeline Corridor
- PNG LNG Pipeline
- Potential Papua LNG Pipeline Routes
- Lowest Astronomical Tide
- Extent of Modelling

CNS (2009) Marine Habitat

- Coral Reef (Fringing Reef)
- Seagrass
- Submerged sand patches

Title:

Caution Bay Export Pipeline Alignments Modeled for Impact Assessment

Figure: 2-4

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3 Modeling Method

This section describes the modeling method used as part of this assessment. This method built on modeling already undertaken during the baseline phase of the EIS/ESHIA, therefore the methods set out below should be read in conjunction with the Marine Waters Modeling Report (Appendix A to Part 10 of Volume 2). Descriptions of the model development, calibration and validation results are presented in that report.

For the purpose of the impact assessment, updates to the model bathymetry were applied locally at both Caution Bay and Orokolo Bay by assimilating local survey depth data collected by BMT during the baseline surveys. These data were obtained from single beam sounding during the habitat mapping campaign in June to July 2016 (Orokolo Bay) and January 2017 (Caution Bay). Sounding data were quality assured, tide corrected, and datum adjusted. The data were then overlaid on previously available data and thus provided up-to-date bathymetry for the trenching impact modeling assessment.

3.1 Modeling Scenarios

Construction of the Project infrastructure will not cause permanent changes to the seabed profile in areas shallower than -15 m LAT, hence no long-term impacts to hydrodynamics or coastal processes are expected. Consequently, there was no need to undertake modeling to assess long-term alterations in hydrodynamic behavior and sediment transport in Orokolo Bay or Caution Bay.

The most relevant impact for assessment by modeling is water quality changes and sedimentation, i.e., sediment plume dispersion and settling, due to sediment mobilized by trenching and burial of pipelines. In relation to this, modeling was undertaken considering conservative scenarios to ensure the impacts presented in the impact assessment reflect what could happen during construction.

At Orokolo Bay, impacts on turbidity due to trenching and burial activities were modeled under conditions of both the southeast trade winds season and the northwest monsoon season, i.e., two scenarios, so that any seasonal differences are captured.

As described in Section 2.1, two alternative pipeline alignments are under consideration at Caution Bay with one to the north (northern alignment) and the other to south (southern alignment) of the PNG LNG Gas Pipeline. Modeling of each alignment was undertaken under both southeast trade winds season and northwest monsoon season conditions, providing four scenarios for Caution Bay. The indicative alignments for Caution Bay are based on information available at the time of the modeling investigation. If an alternative alignment is selected based on further considerations during FEED, the impact radius of the dredging-related plumes on either side of the new pipeline alignment would be expected to be very similar to the scenarios modeled.

Table 3-1 describes the six scenarios, agreed with TEP PNG, that were modeled. Simulations were undertaken for the duration of the entire trenching campaigns. This involved modeling of the hydrodynamics and wave and sediment transport processes for each scenario with the addition of the moving suspended (and seabed) sediment point source discharge at the assumed location of the trenching equipment at every model timestep.

Table 3-1 Modeling Scenarios for Marine Impact Assessment

No.	Description	Alignment	Assumptions
1	Orokolo Bay – southeast trade winds	As per Figure 2-2	• Trench from shore to -15 m LAT depth contour. • Trench width of 6 m and depth of 2 m. • Trenching of all sediment by cutter suction dredger with material discharged directly to surrounding environment. • Burial by ploughing or jetting. • Southeast trade winds season.
2	Orokolo Bay – northwest monsoon	As per Figure 2-2	• Trench from shore to -15 m LAT depth contour. • Trench width of 6 m and depth of 2 m. • Trenching of all sediment by cutter suction dredger with material discharged directly to surrounding environment. • Burial by ploughing or jetting. • Northwest monsoon season.
3	Caution Bay (northern alignment) – southeast trade winds	As per Figure 2-4	• Trench from shore to -15 m LAT depth contour. • Trench width of 6 m and depth of 2 m. • Trenching of soft sediment by cutter suction dredger with material discharged directly to surrounding environment. • Burial of soft sediment trench by ploughing or jetting. • Southeast trade winds season.
4	Caution Bay (northern alignment) – northwest monsoon	As per Figure 2-4	• Trench from shore to -15 m LAT depth contour. • Trench width of 6 m and depth of 2 m. • Trenching of soft sediment by cutter suction dredger with material discharged directly to surrounding environment. • Burial of soft sediment trench by ploughing or jetting. • Northwest monsoon season.
5	Caution Bay (southern alignment) – southeast trade winds	As per Figure 2-4	• Trench from shore to -15 m LAT depth contour. • Trench width of 6 m and depth of 2 m. • Trenching of soft sediment by cutter suction dredger with material discharged directly to surrounding environment. • Burial of soft sediment trench by ploughing or jetting. • Southeast trade winds season.
6	Caution Bay (southern alignment) – northwest monsoon	As per Figure 2-4	• Trench from shore to -15 m LAT depth contour. • Trench width of 6 m and depth of 2 m. • Trenching of soft sediment by cutter suction dredger with material discharged directly to surrounding environment. • Burial of soft sediment trench by ploughing or jetting. • Northwest monsoon season.

Modeling periods were chosen that had meteorological conditions that were representative of the long-term average conditions (March 2015 for the monsoon season and July 2015 for the southeast trade winds season).

For each scenario the model was run for one month; configured with one week of spin-off time prior to applying the trenching discharge (of one to five days duration depending on the scenario) followed by the remaining time to complete a full month simulation.

3.2 Dredging Source Rates

3.2.1 Orokolo Bay

Based on the proposed alignment and assumed dimensions of the trench to be excavated, the total volume of material to be dredged along the alignment within Orokolo Bay (to the -15 m LAT contour) is approximately 100,000 m^3. Assuming a cutter suction dredger achieves a production rate of 1,250 m^3/h, operating for 70% of the time (assumed 30% down time), the expected duration of the dredging campaign is 4.75 days. The assumed rate of loss of material to the water column (forming a suspended sediment plume) was 10%, which is a conservative assumption given the lack of knowledge of the operating specifications of the dredger to be used. The remaining 90% of material was added directly to the seabed adjacent to the trench in the numerical model. It was assumed that all the dredged material discharged either into the water column or deposited on the seabed is subject to water current and wave-induced resuspension processes, which were explicitly modeled to provide conservatism to the impact assessments.

The particle size distributions of sediment samples collected in Orokolo Bay during the baseline studies are presented in Part 9 of Volume 2. Analysis of the data indicates that an assumed split of 45% clay, 50% silt and 5% sand is a reasonable representation of the overall composition of the seabed within Orokolo Bay. A dry density of 1,800 kg/m^3 was assumed to convert the dredging volumes into mass of material.

3.2.2 Caution Bay

Based on the mapped alignment and assumed dimensions of the trench to be excavated, the total volume of material to be dredged along the two alternative alignments within Caution Bay (from the 0 m LAT to the -15 m LAT contour) is approximately 41,000 m^3 and 21,000 m^3 for the northern and southern alignment options, respectively. Assuming a cutter suction dredger achieves a production rate of 1,250 m^3/h, operating for 70% of the time, the expected duration of the dredging campaign is 2.0 days and 1.0 days for the northern and southern alignment, respectively. Based on similar assumptions adopted for Orokolo Bay, the assumed rate of loss of material to the water column was 10%, with the remaining 90% of material deposited on to the seabed but subject to resuspension by water current and wave-induced processes.

The particle size distributions of sediment samples collected in Caution Bay are presented in Part 9 of Volume 2. Analysis of the data indicates that an assumed split of 25% clay, 25% silt 45% sand and 5% gravel is a reasonable representation of the overall composition of the seabed within Caution Bay. A dry density of 1,800 kg/m^3 was assumed to convert the dredging volumes into mass of material.

4 Modeling Results

The modeled increases in suspended sediment levels due to trenching activities were statistically analyzed over the duration of each modeled trenching campaign. Spatial maps of the depth-averaged 50th and 95th percentiles of the increase in total suspended sediment (TSS) concentrations and the net dredging-related sediment deposition were produced and are presented herein. The 50th percentile (i.e., median) occurs 50% of the time and is therefore considered to represent typical conditions. The 95th percentile (i.e., concentration that is exceeded only 5% of the time) is considered to represent a short-term peak concentration, above background levels.

4.1 Orokolo Bay – Northwest Monsoon Season

The 50th and 95th percentiles of the increase in TSS concentrations during the 4.75 days of the dredging operation are shown in Figure 4-1.

The 50th percentile depth-averaged TSS concentration generated by trenching is up to approximately 5 mg/L. Within approximately 4 km to the east of the pipeline alignment, the median dredging-related TSS concentration reduces to less than 2 mg/L.

The 95th percentile depth-averaged TSS concentration generated by trenching is up to less than 100 mg/L in the immediate vicinity (within 500 m) of the dredging operation. Within approximately 5 km either side of the pipeline alignment, the short-term peak increase in TSS concentration is less than 2 mg/L.

The final net deposition of sediment due to the trenching activity during the northwest monsoon season is shown in Figure 4-3 (left panel). The sediment deposition impacts (above 200 mg/cm^2) are limited spatially to the immediate vicinity (within 500 m) of the dredging activity.

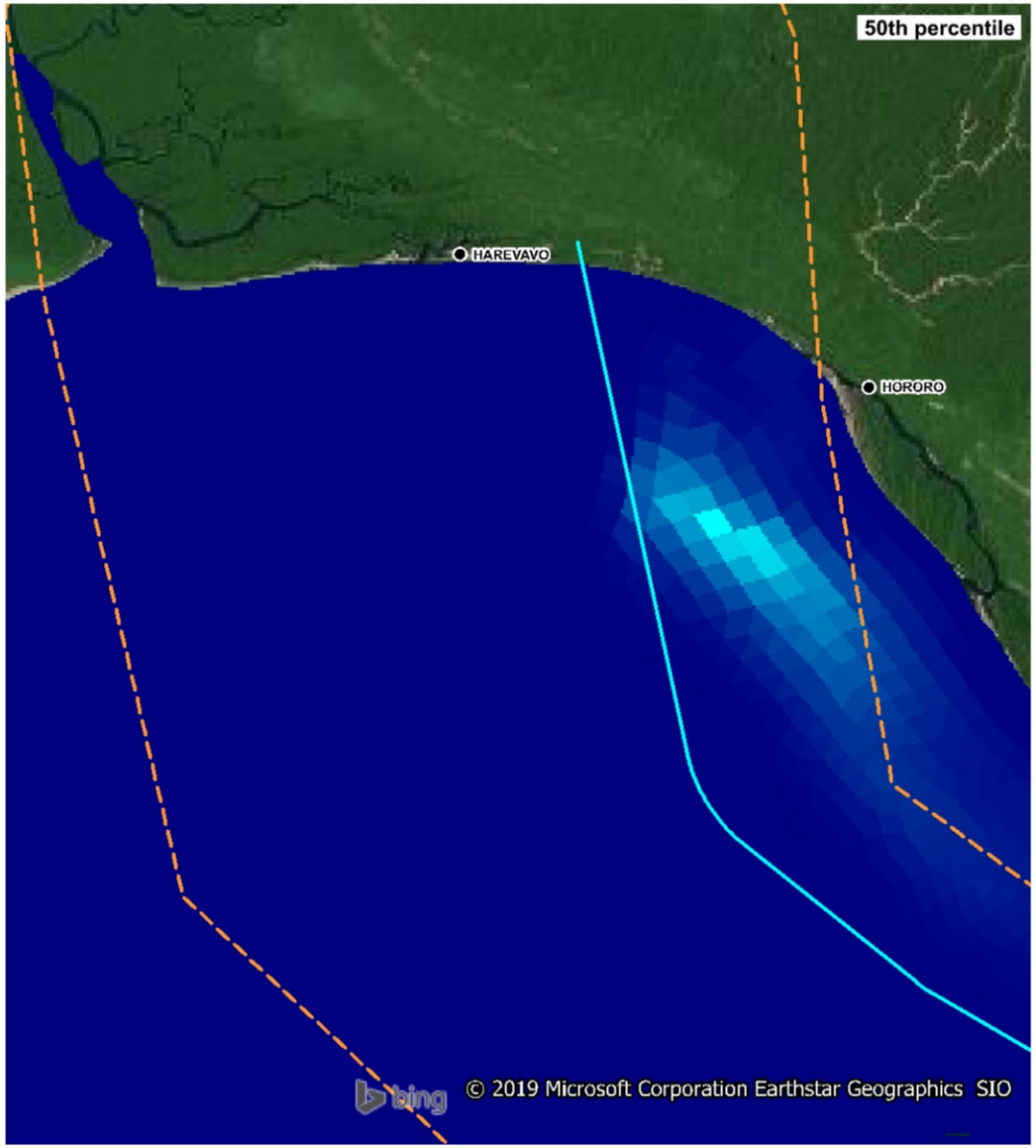
4.2 Orokolo Bay – Southeast Trade Winds Season

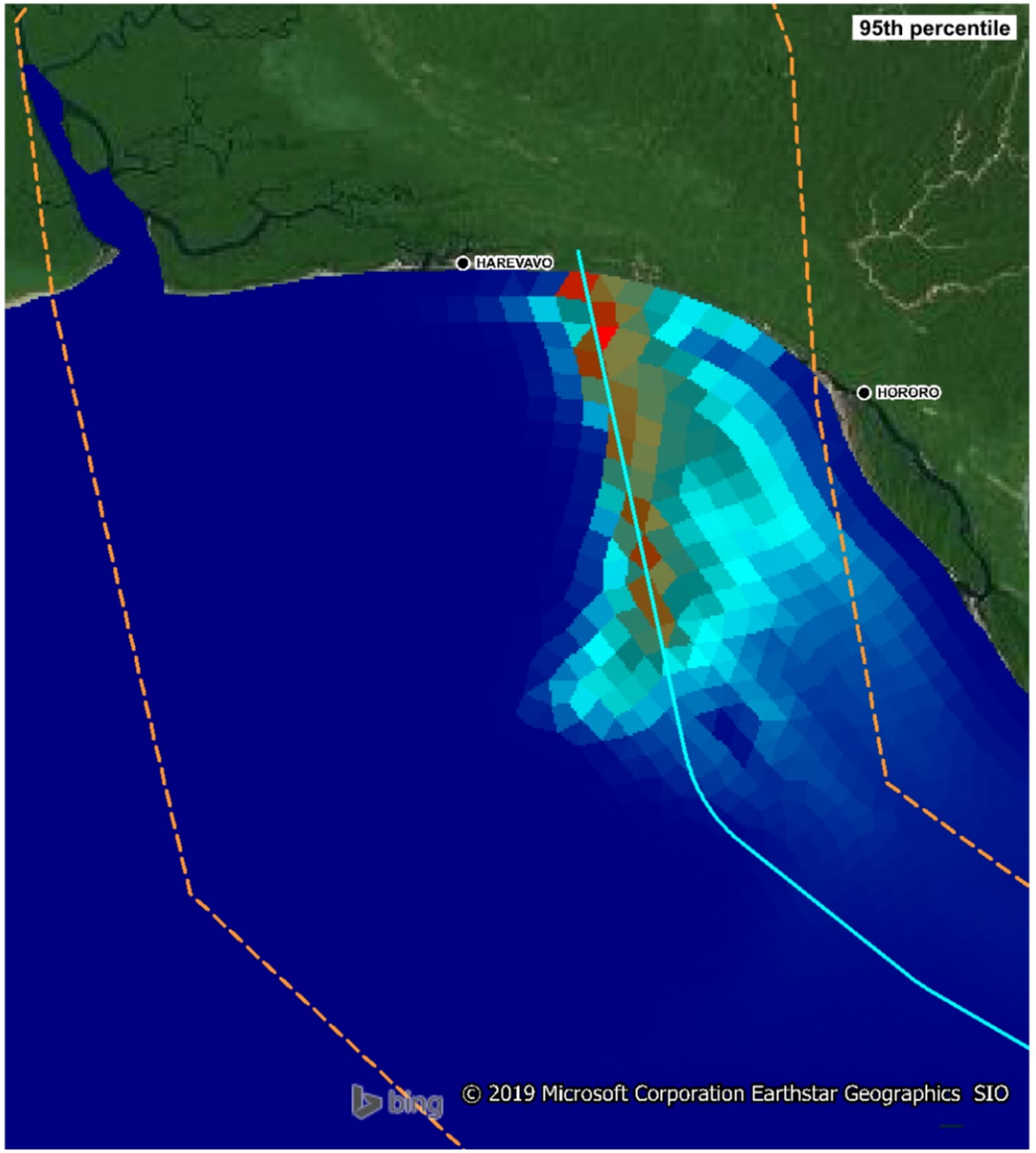
The 50th and 95th percentiles of the increase in TSS concentrations during the 4.75 days of the dredging operation are shown in Figure 4-2.

The 50th percentile depth-averaged TSS concentration generated by trenching is up to approximately 2 mg/L. The dredging-related TSS concentration increase up to 2 mg/L is limited to a distance of 10 km of the dredging operation, towards the west.

The 95th percentile depth-averaged TSS concentration generated by trenching is up to less than 100 mg/L in the immediate vicinity (within 500 m) of the dredging operation. Advection of the dredging-related plume is mostly in the westerly direction. Within approximately 6 km to the west of the pipeline alignment, the short-term peak increase in dredging-related TSS concentration is less than 2 mg/L.

The final net deposition of sediment due to the trenching activity during the southeast trade winds season is shown in Figure 4-3 (right panel). The sediment deposition impacts (above 200 mg/cm^2) are limited spatially to the immediate vicinity (within 500 m) of the dredging activity.





LEGEND

- Town/Village
- Papua LNG Pipeline Routes
- Pipeline Corridor

0 5 10 25 50 80

mg/L

Title:

Depth-averaged TSS Increases in Orokolo Bay During Northwest Monsoon Season

Figure: 4-1

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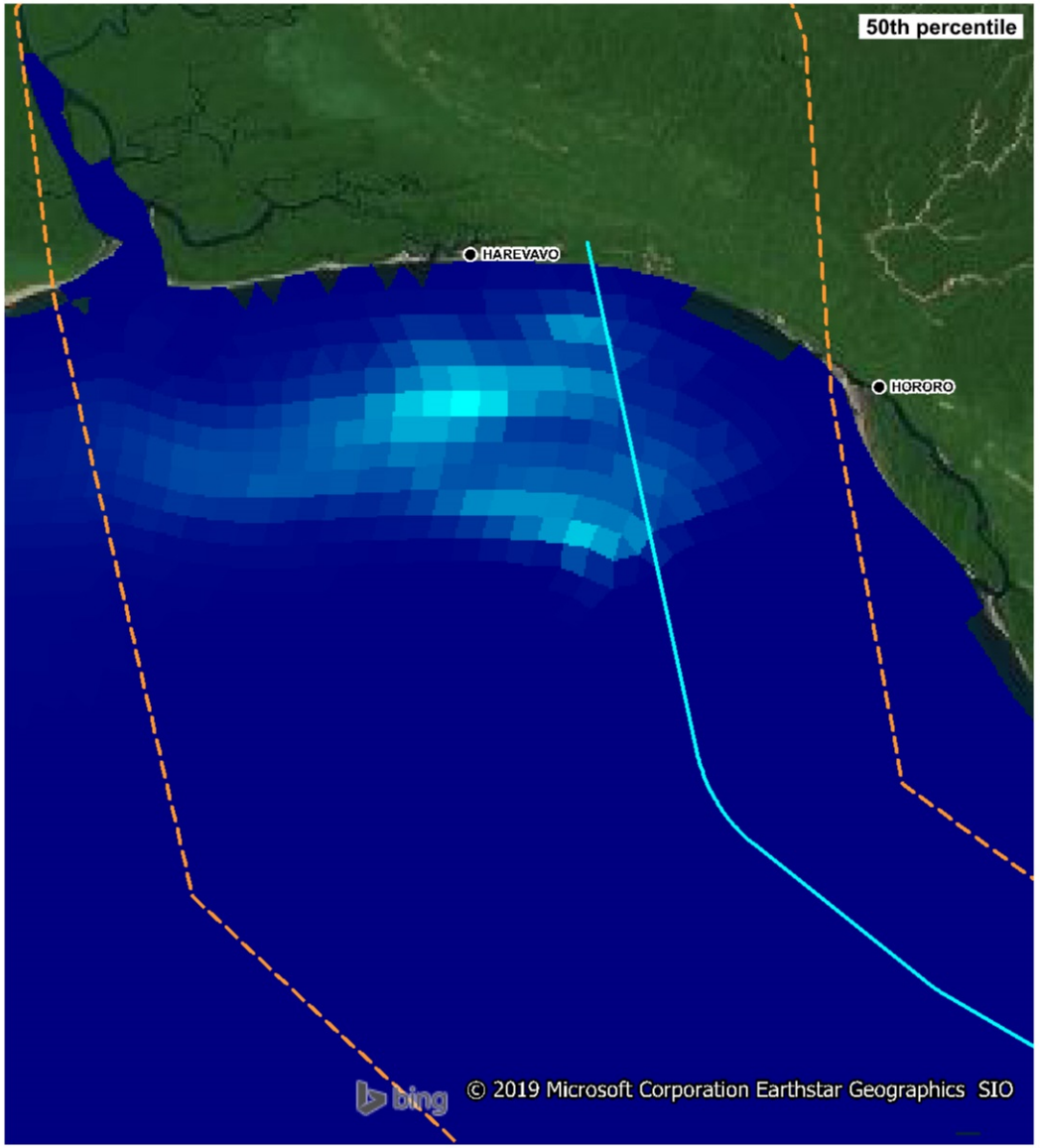

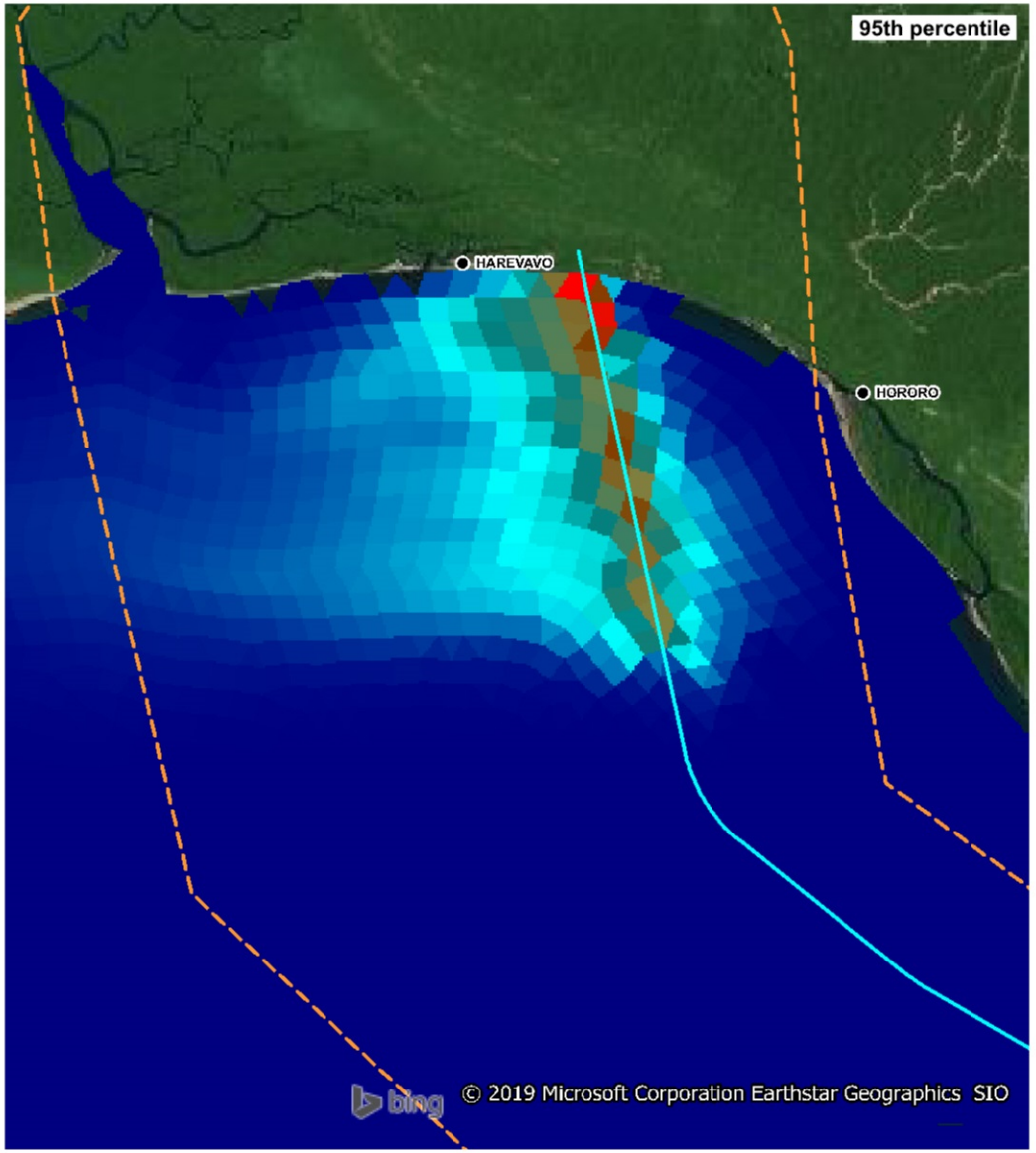

LEGEND

- Town/Village
- Papua LNG Pipeline Routes
- Pipeline Corridor

0 5 10 25 50 80

mg/L

Title:

Depth-averaged TSS Increase in Orokolo Bay During Southeast Trade Winds Season

Figure: **4-2**

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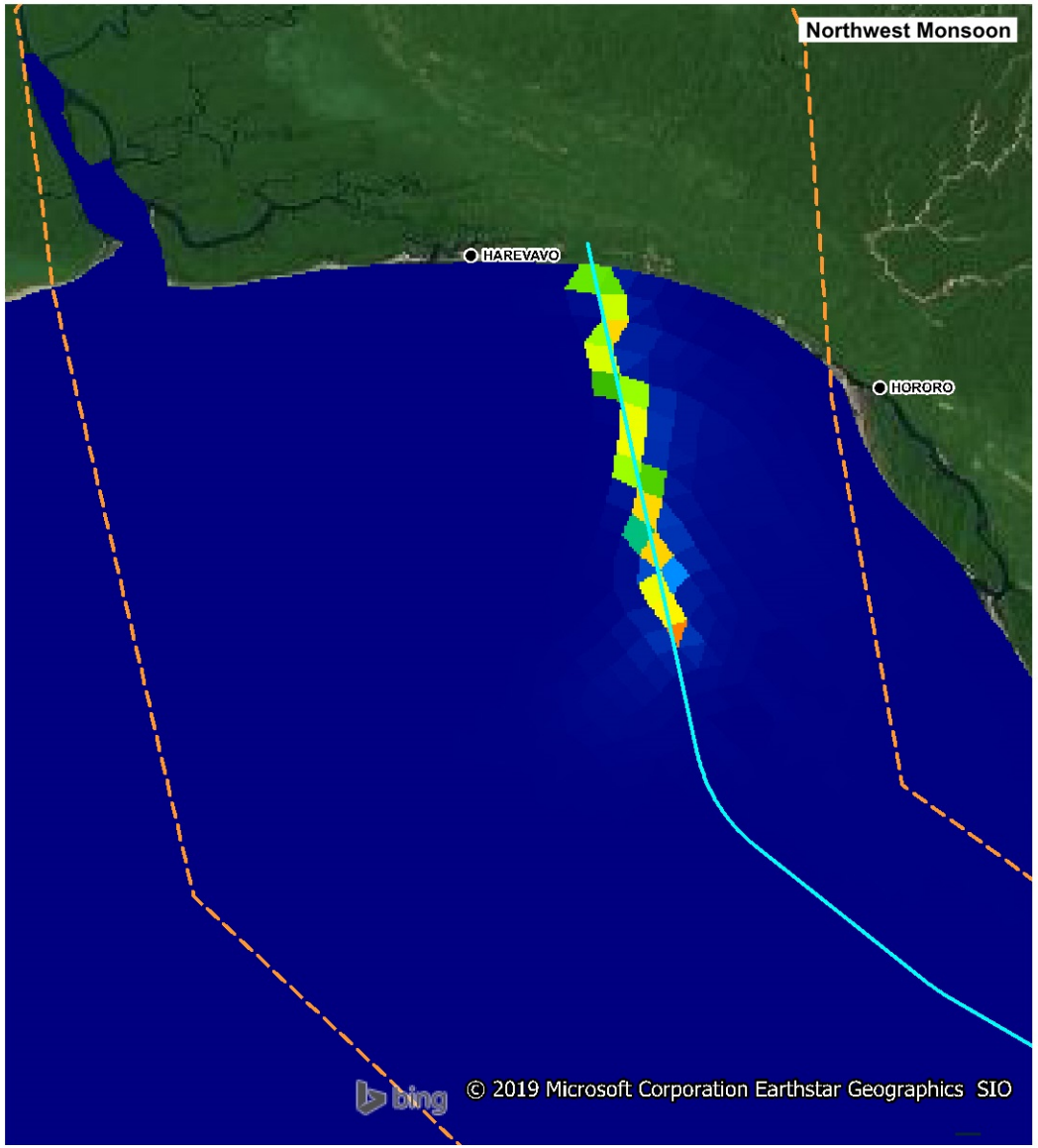

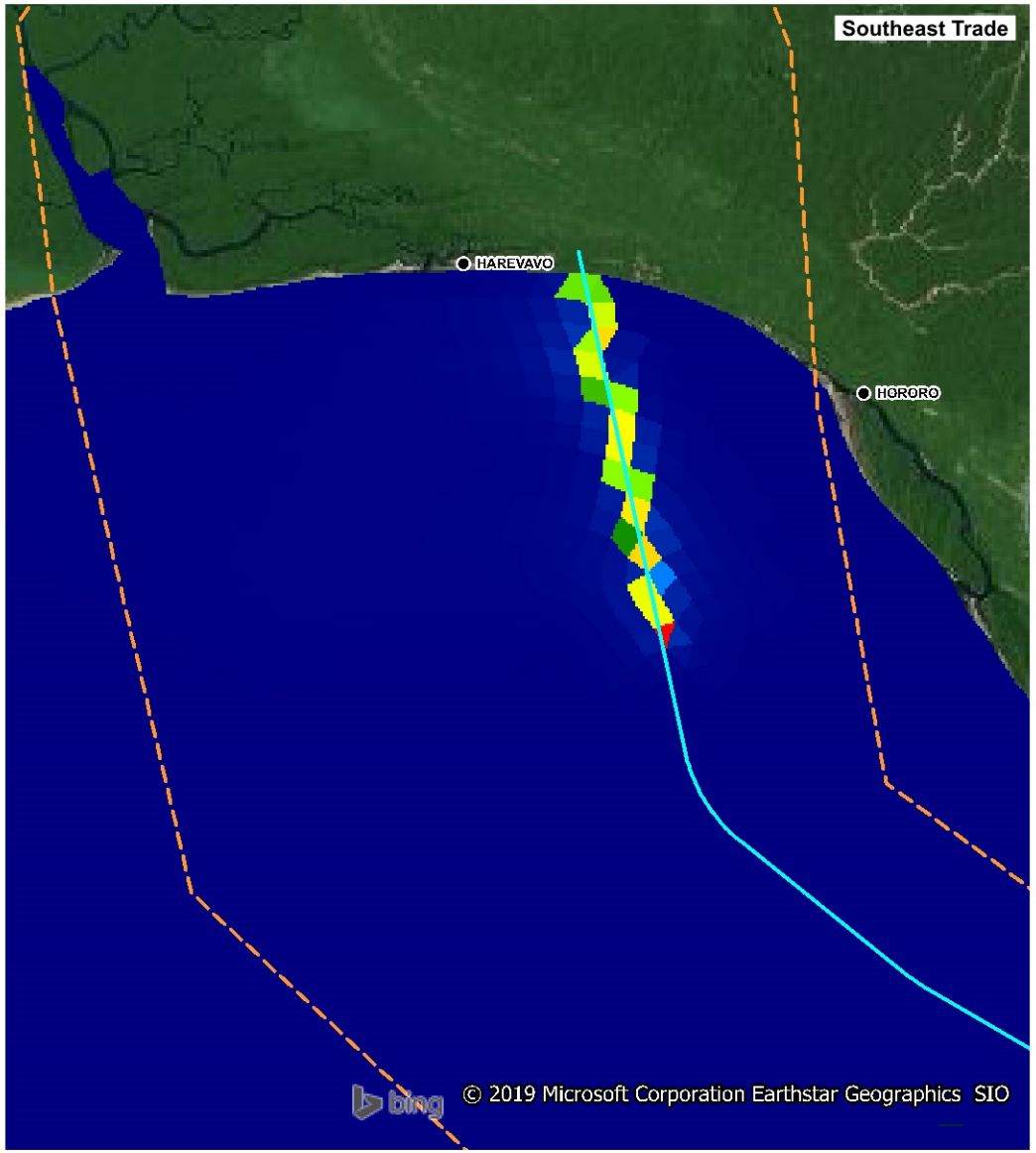

LEGEND

- Town/Village
- Papua LNG Pipeline Routes
- Pipeline Corridor

0 1,000 2,000 4,000 6,500 15,000 31,000

mg/cm2

Title:

Final Net Deposition of Sediment Mobilized from Trenching in Orokolo Bay

Figure: **4-3**

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4.3 Caution Bay (Northern Alignment) – Northwest Monsoon Season

The 50th and 95th percentiles of the increase in TSS concentrations during the 2.0 days of the dredging operation are shown in Figure 4-4.

The 50th percentile depth-averaged TSS concentration generated by trenching is up to approximately 5 mg/L. This low concentration plume extends south to Haidana Island due to the prevailing wind direction and resuspension associated with the hydrodynamic climate.

The 95th percentile depth-averaged TSS concentration generated by trenching is up to less than 100 mg/L in the immediate vicinity of the dredging operation. Advection of the dredging-related plume is mostly in the southeast direction. Within approximately 10 km either side of the pipeline alignment, the dredging-related increase of short-term peak TSS reduces to less than 2 mg/L.

The final net deposition of sediment due to the trenching activity is shown in Figure 4-6 (left panel). The sediment deposition impacts (above 200 mg/cm^2) are limited spatially to the immediate vicinity (within 500 m) of the dredging activity.

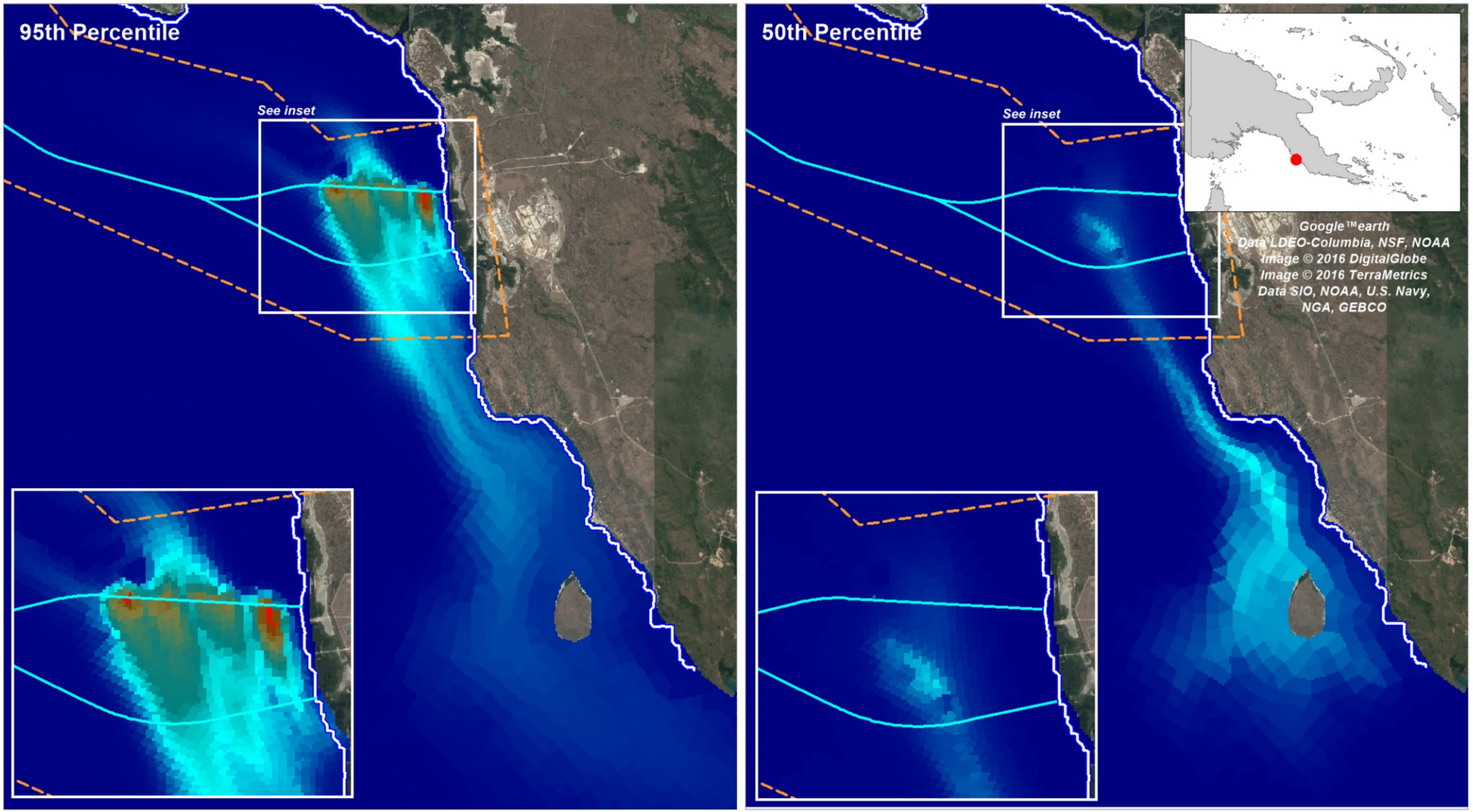
4.4 Caution Bay (Northern Alignment) – Southeast Trade Winds Season

The 50th and 95th percentiles of the increase in TSS concentrations during the 2.0 days of the dredging operation are shown in Figure 4-5.

The 50th percentile depth-averaged TSS concentration generated by trenching is up to approximately 5 mg/L. The dredging-related TSS increase up to 2 mg/L is limited to within 2 km of the dredging operation, on either side.

The 95th percentile depth-averaged TSS concentration generated by trenching is up to less than 100 mg/L in the immediate vicinity of the dredging operation. Advection of the dredging-related plume is mostly in the northerly direction. Within approximately 6 km to the north of the pipeline alignment, the dredging-related increase of short-term peak TSS reduces to less than 2 mg/L.

The final net deposition of sediment due to the trenching activity is shown in Figure 4-6 (right panel). The sediment deposition impacts (above 200 mg/cm^2) are limited spatially to the immediate vicinity (within 500 m) of the dredging activity.



LEGEND

- Lowest Astronomical Tide
- Papua LNG Pipeline Route
- Pipeline Corridor

0 5 10 25 50 80

mg/L

Title:

Depth-averaged TSS Increase in Caution Bay During Northwest Monsoon Season - Northern Alignment

Figure: **4-4**

Rev: **A**

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0 2.5 5km
Approx. Scale

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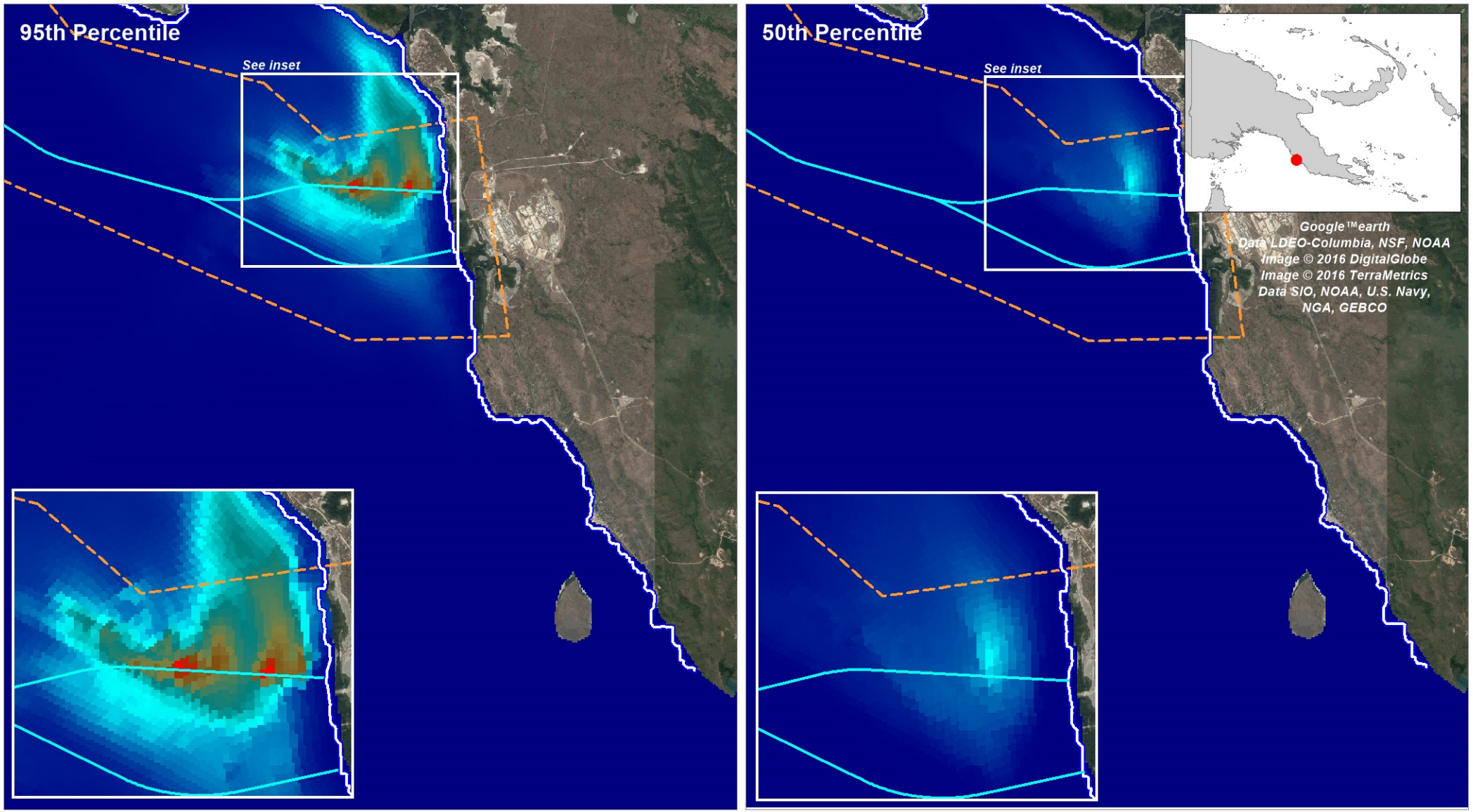

LEGEND

- Papua LNG Pipeline Route
- Lowest Atronomical Tide
- Pipeline Corridor

0 5 10 25 50 80

mg/L

Title:

Depth-averaged TSS Increase in Caution Bay During Southeast Trade Winds Season - Northern Alignment

Figure: **4-5**

Rev: **A**

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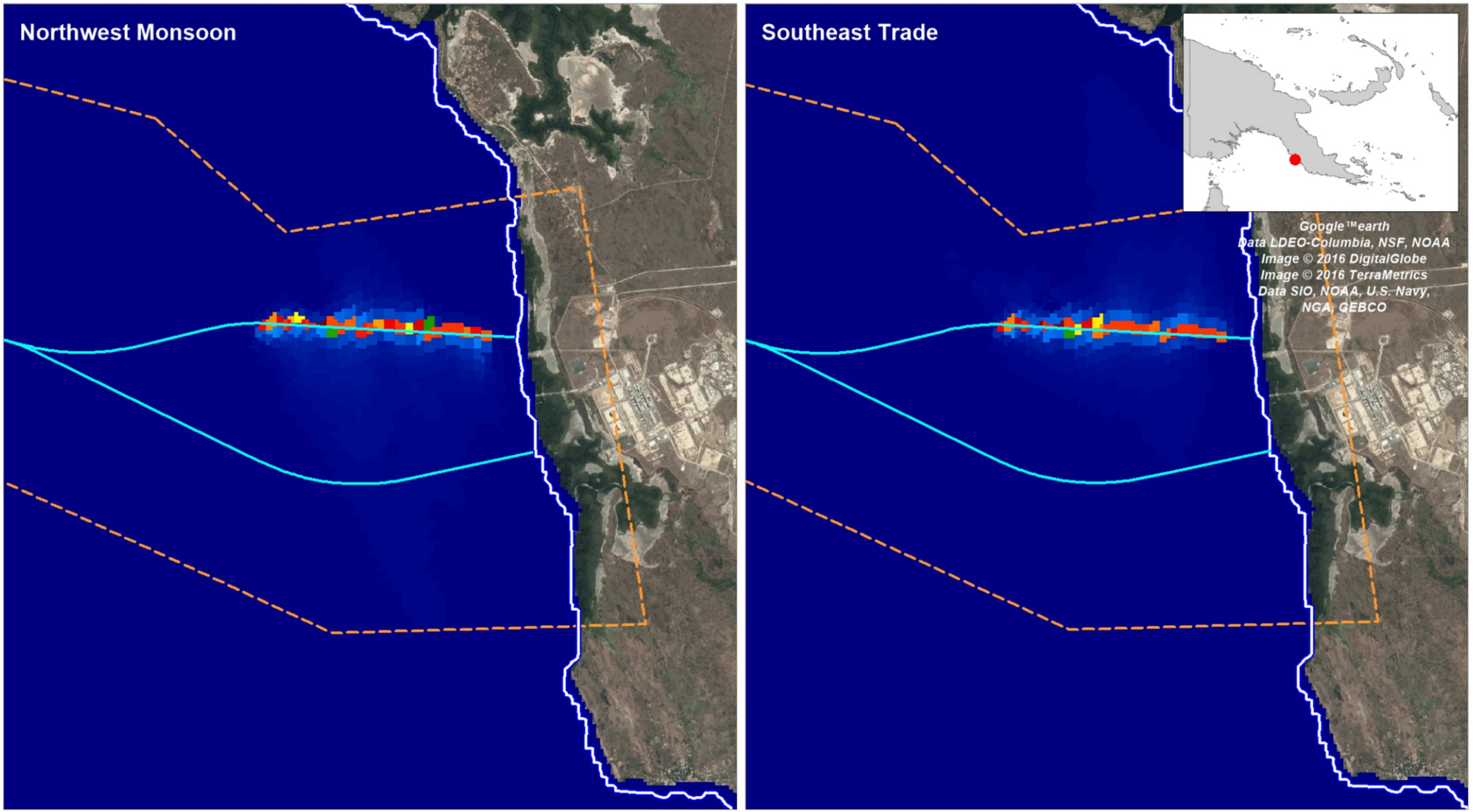

LEGEND

- Lowest Astronomical Tide
- Papua LNG Pipeline Route
- Pipeline Corridor

0 | 1,000 | 2,000 | 4,000 | 6,500 | 15,000 | 31,000

mg/cm2

Title:

Final Net Deposition of Sediment Mobilized from Trenching of Caution Bay - Northern Alignment

Figure: **4-6**

Rev: **A**

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Approx. Scale

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4.5 Caution Bay (Southern Alignment) – Northwest Monsoon Season

The 50th and 95th percentiles of the increase in TSS concentrations during the 1.0 days of the dredging operation are shown in Figure 4-7.

The 50th percentile depth-averaged TSS concentration generated by trenching is less than 5 mg/L.

The 95th percentile depth-averaged TSS concentration generated by trenching is up to less than 100 mg/L in the immediate vicinity of the dredging operation. Advection of the dredging-related plume is mostly in the southeast direction. Within approximately 10 km to the southeast of the pipeline alignment, the dredging-related increase of short-term peak TSS reduces to less than 2 mg/L.

The final net deposition of sediment due to the trenching activity is shown in Figure 4-9 (left panel). The sediment deposition impacts (above 200 mg/cm^2) are limited spatially to the immediate vicinity (within 0.5 km) of the dredging activity.

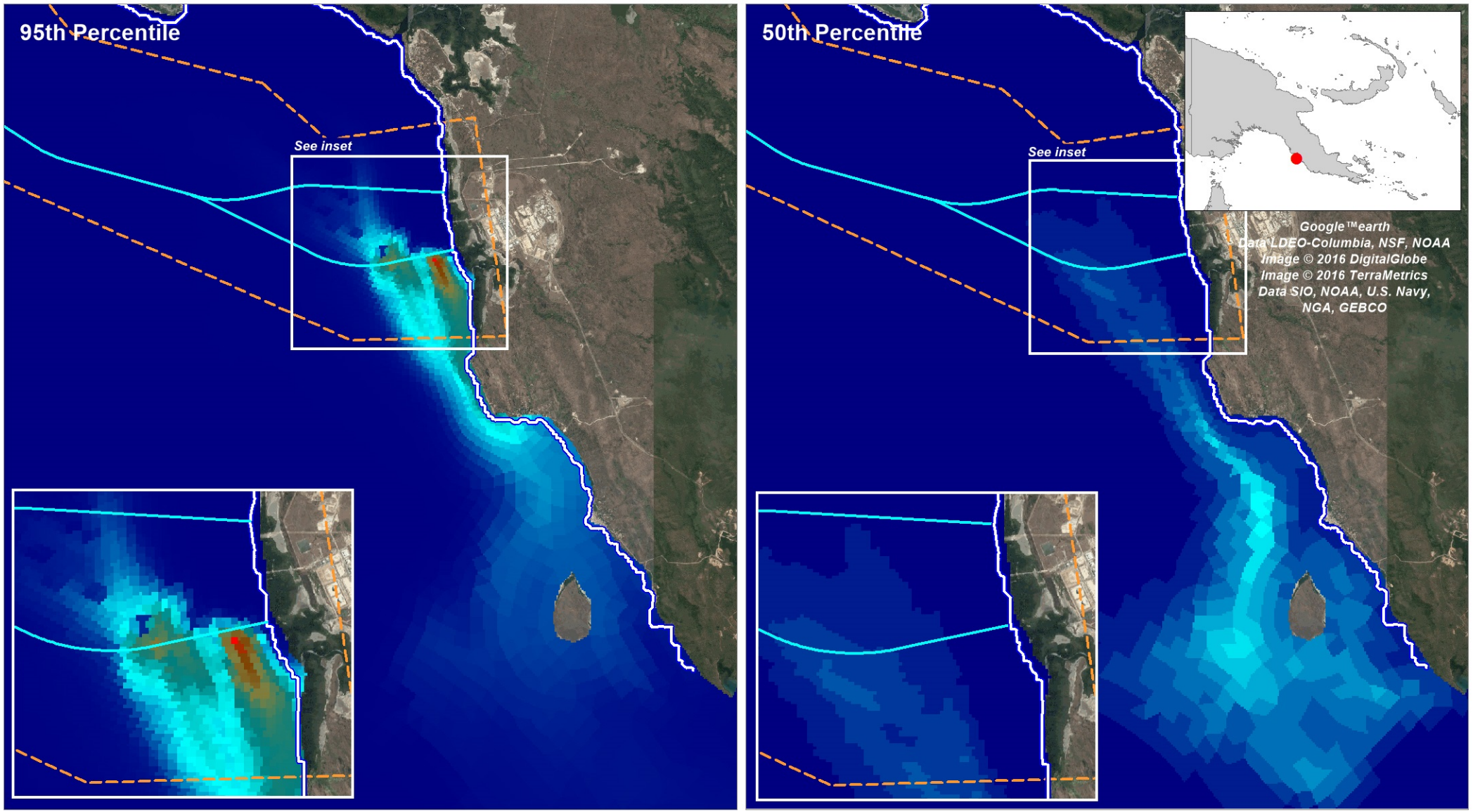
4.6 Caution Bay (Southern Alignment) – Southeast Trade Winds Season

The 50th and 95th percentiles of the increase in TSS concentrations during the 1.0 days of the dredging operation are shown in Figure 4-8.

The 50th percentile depth-averaged TSS concentration generated by trenching is less than 5 mg/L.

The 95th percentile depth-averaged TSS concentration generated by trenching is up to less than 100 mg/L in the immediate vicinity of the dredging operation. Advection of the dredging-related plume is mostly in the northerly direction. Within approximately 6 km to the north of the pipeline alignment, the dredging-related increase of short-term peak TSS reduces to less than 2 mg/L.

The final net deposition of sediment due to the trenching activity is shown in Figure 4-9 (right panel). The sediment deposition impacts (above 200 mg/cm^2) are limited spatially to the immediate vicinity (within 0.5 km) of the dredging activity.



LEGEND

- Papua LNG Pipeline Routes
- Lowest Astronomical Tide
- Pipeline Corridor

0 5 10 25 50 80

mg/L

Title:

Depth-averaged TSS Increase in Caution Bay During Northwest Monsoon Season - Southern Alignment

Figure: **4-7**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

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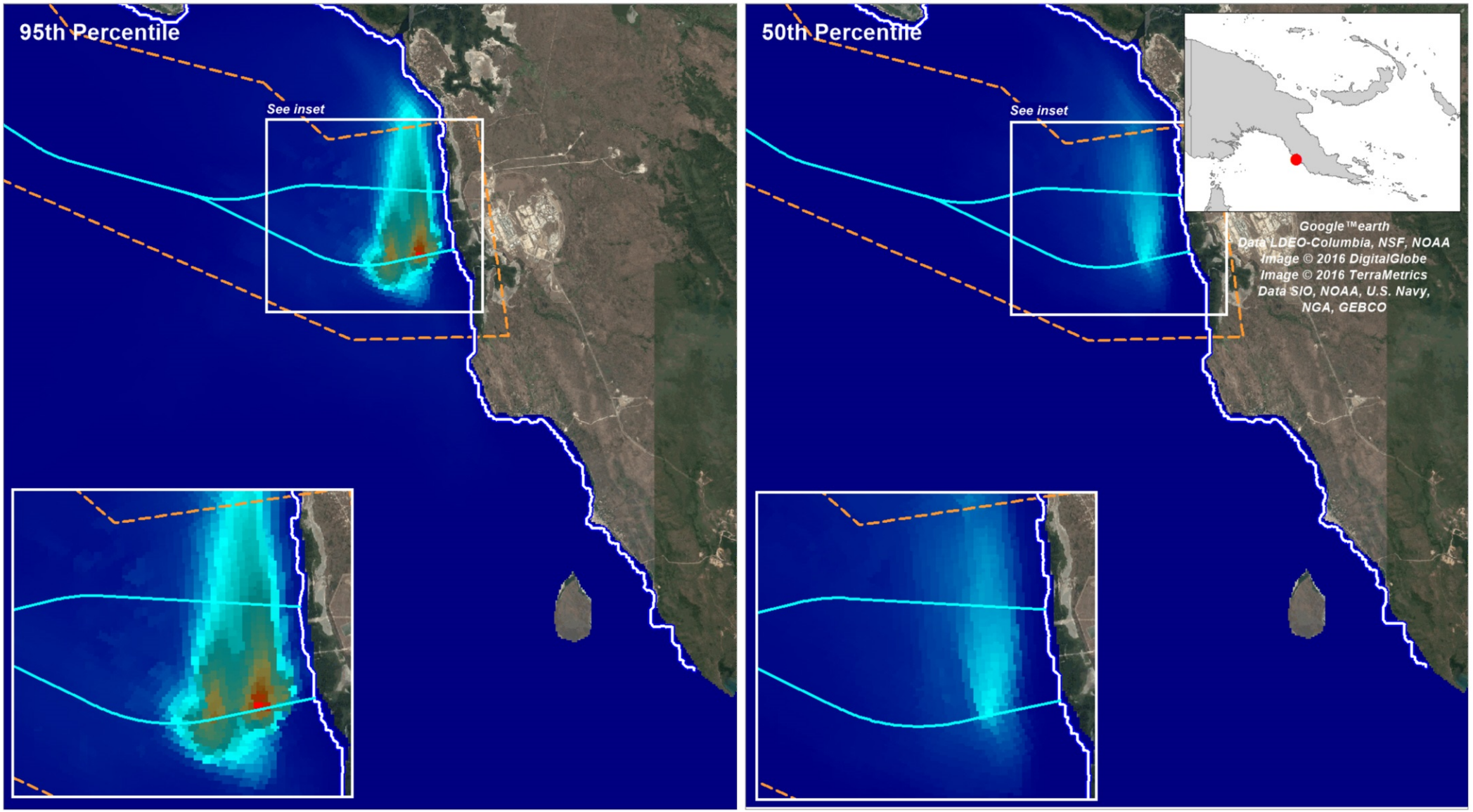

LEGEND

- Papua LGN Pipeline Route
- Lowest Astronomical Tide
- Pipeline Corridor

0 5 10 25 50 80

mg/L

Title:

Depth-averaged TSS Increase in Caution Bay During Southeast Trade Winds Season - Southern Alignment

Figure: **4-8**

Rev: **A**

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Approx. Scale

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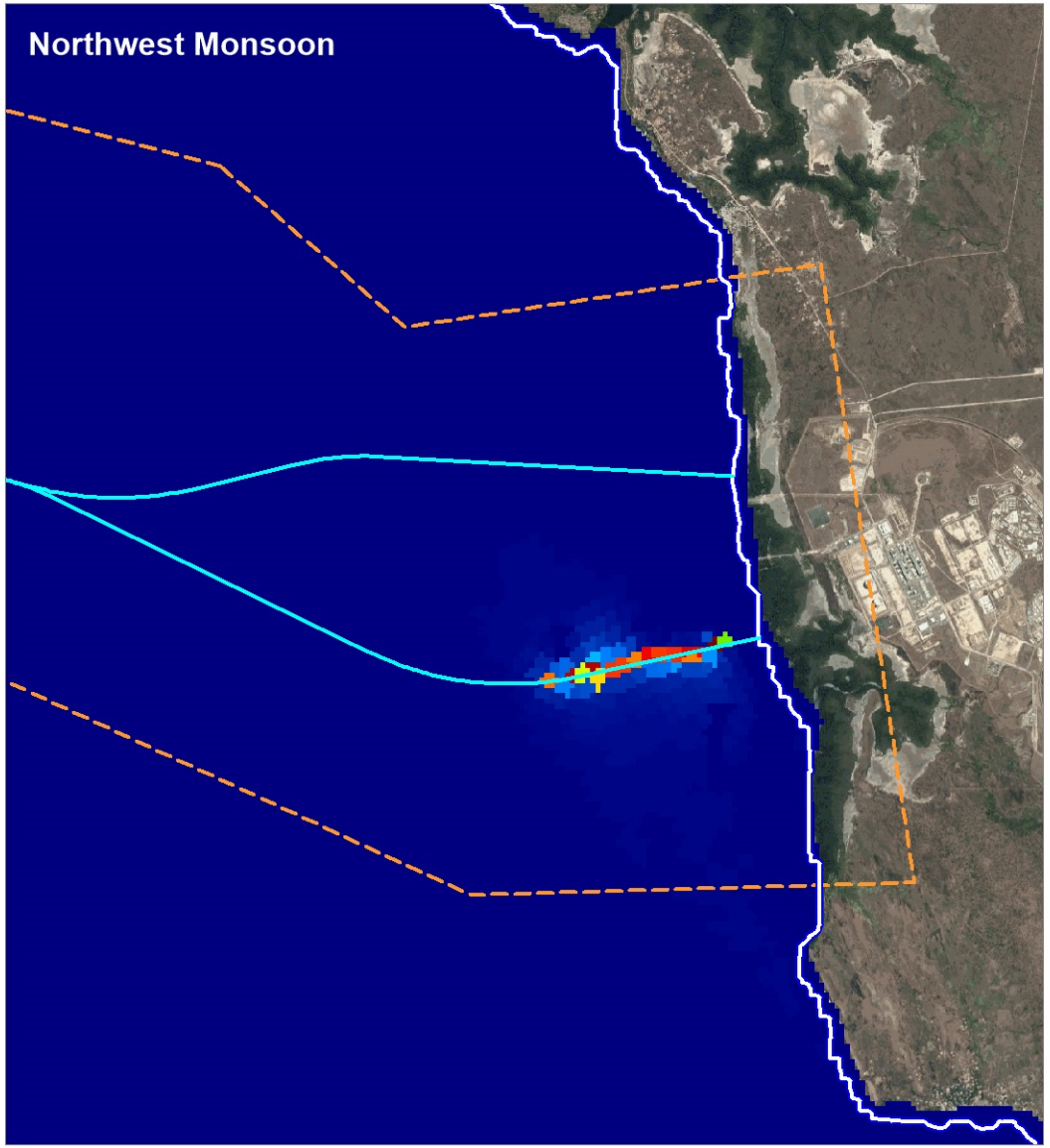

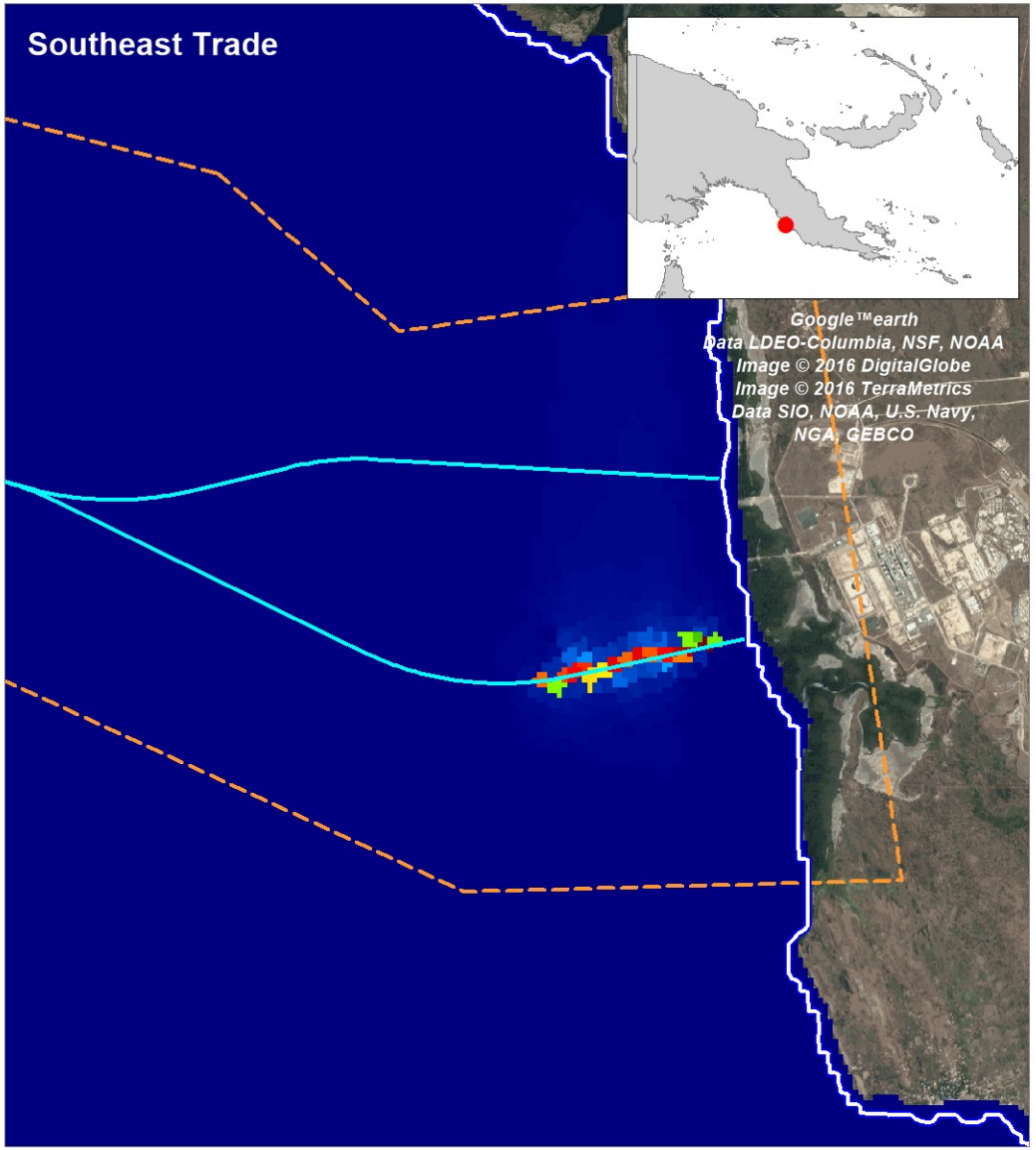

LEGEND

- Papua LNG Pipeline Routes
- Lowest Astronomical Tide
- Pipeline Corridor

0 | 1,000 | 2,000 | 4,000 | 6,500 | 15,000 | 31,000

mg/cm2

Title:

Final Net Deposition of Sediment Mobilized from Trenching of Caution Bay - Southern Alignment

Figure: **4-9**

Rev: **A**

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