TECHNICAL REPORT

Potential Offshore Sand Sourcing for the Proposed Beach Nourishment Project, Memories White Sands, Coopers Pen, Trelawny

Report Version:	**Final**
Date:	**30 April 2012**
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Submitted to:	**MEMORIES WHITE SANDS**

PRELIMINARY TECHNICAL REPORT FOR THE POTENTIAL OFFSHORE SAND SOURCING FOR THE PROPOSED BEACH NOURISHMENT PROJECT, MEMORIES WHITE SANDS, COOPERS PEN, TRELAWNY

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APRIL 2013

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1.0 INTRODUCTION

Memories White Sands has begun renovation of their Trelawny property formerly known as Starfish Hotel. Part of the renovation project includes the expansion of the existing beach area. Sand to be used for beach nourishment will be sourced 400-500m north of the property. This technical report outlines the feasibility of the proposed project.

1.1 BACKGROUND

The study area is located on the north coast within the Mountain Spring Bay in Trelawny. The bay consists of approximately 6 km of shoreline (Figure 1-1).

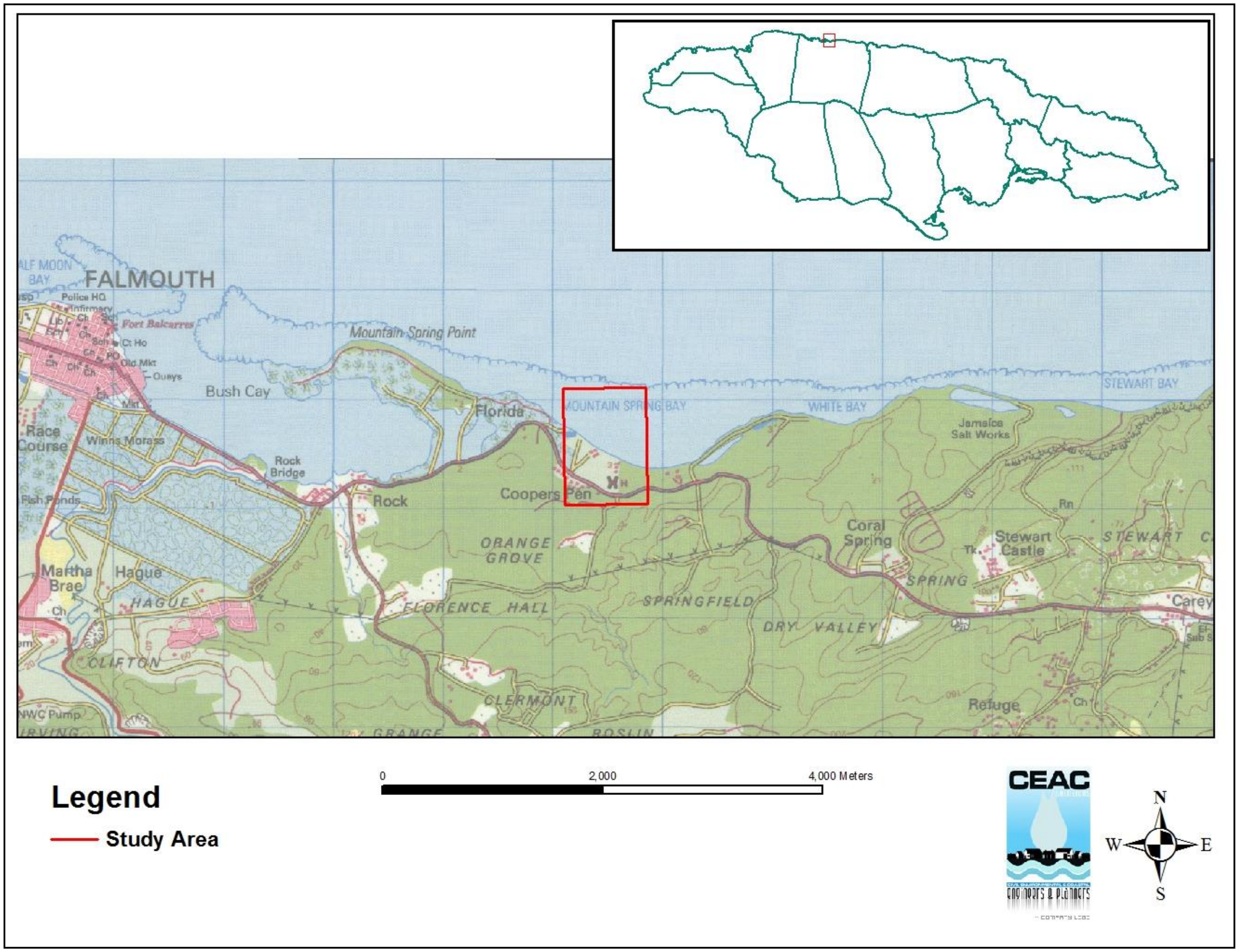


Figure 1-1 Location map of study area

There are concerns about the overall aesthetics of the existing beach as the property is now being renovated. The beach is approximately 4m wide from the high water mark to the back of the beach and has a fairly steep incline. The relatively short span of the beach and the steepness of the face can be seen in Plate 1-1 and Plate 1-2. The developers wish to extend the existing beach further inland to create a longer beach front which will add to the aesthetic appeal of their property. ***They will therefore not encroach on the seafloor in this area.***

A large enough area was identified approximately 500m to the northwest of the beach. This area is approximately 13,000 m2 with average depths of 4.5m below mean sea level. It is located in an area that is surrounded by reef and sparse sea grass patches. It was therefore necessary that this site be investigated to determine its suitability to provide sand to nourish the back of the existing beach.

Plate 1-1 Photograph of the western section of the beach

Plate 1-2 Photograph of the eastern section of the beach

1.2 METHODOLOGY

The methodology adopted is as follows:

- Collection of data describing the physical and biological attributes of the site
- Analysis of all relevant data to draw reasonable conclusions based upon the observations
- Recommend suitable action items for consideration and implementation

2.0 OCEANOGRAPHIC DATA COLLECTION

2.1 PHYSICAL

2.1.1 Bathymetric Survey and Topographic survey

Bathymetric surveys of the bay as well as a topographic survey of the shoreline were undertaken between May 20 and 21, 2013. The bathymetric surveys were done out to approximately 1km off shore whereas the topographic surveys were limited to +/-0.6m above and below the shoreline. See Figure 2-1 below.

This data was then supplemented with other deep water points from existing bathymetric chart which was then used to build a digital elevation model of the project area. This was then used to run the hydrodynamic and wave models.

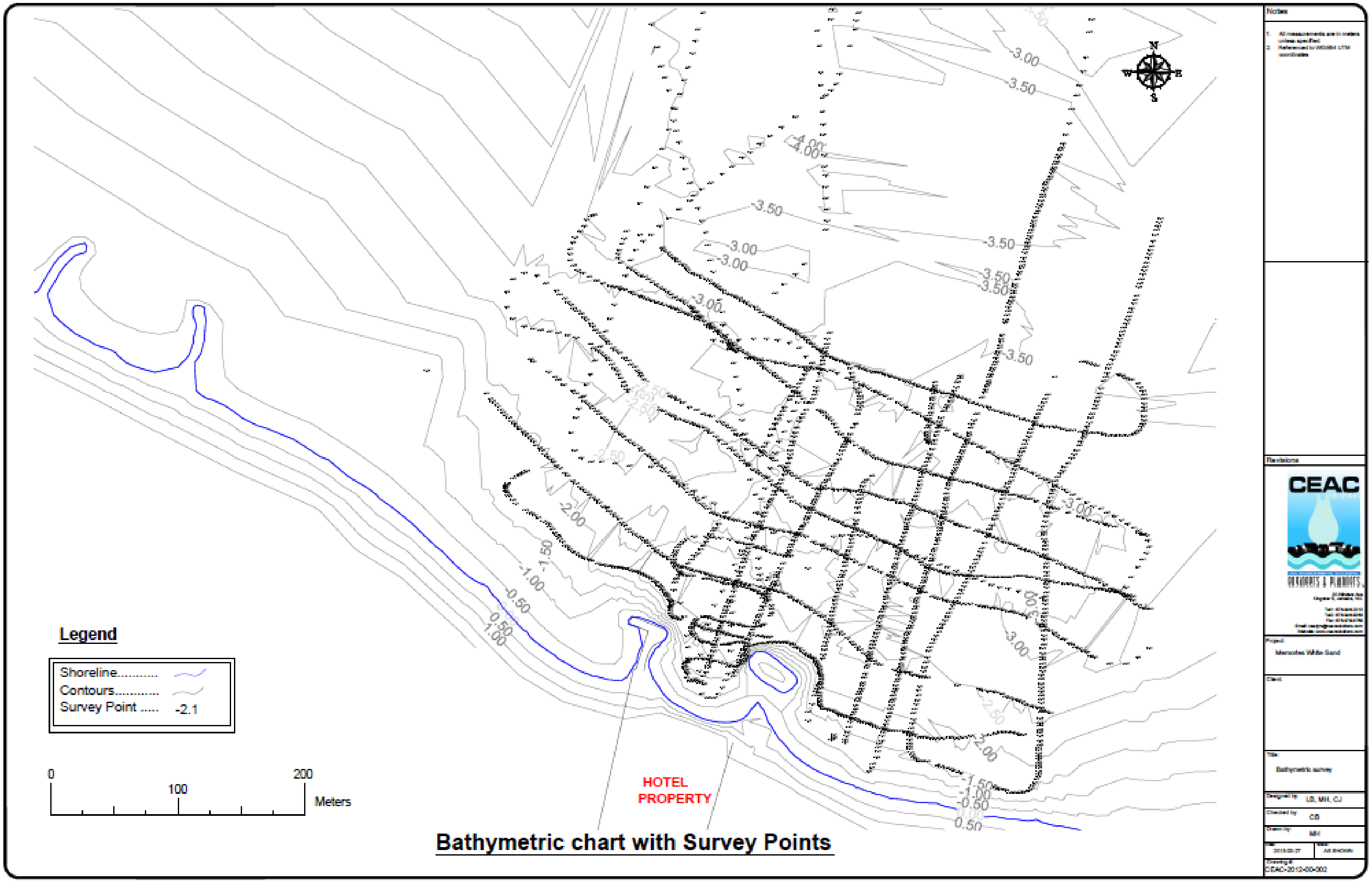


Figure 2-1 Overview of survey points collected in bathymetric survey

2.1.2 Wind Data

2.1.2.1 Long term wind data (NOAA)

Historical and current wind data for the project area was obtained from NOAA climate service floating stations (buoys). A node was chosen in front of the bay and the wind and wave data corresponding to that node obtained. The node used was:

- Zone: 18
- Easting: 226035.57
- Northing: 2046566.10

The data spanned the years of 1999 to 2007 recorded on a daily basis at three hour intervals. The data is shown in a wind rose. The data were analysed in terms of percentage occurrence of various wind speed and direction combinations in order to characterize the wind climate for the site.

The analysis revealed that the winds have a direction of E to ENE direction with wind speeds of 6 m/s or less approximately. North easterly and east south easterly winds were noted to occur. Overall the average wind speed and direction is between 4 to 6 m/s from the NE to ESE respectively. Figure 2-2 shows the wind rose plot of the for the NOAA data for the given point.

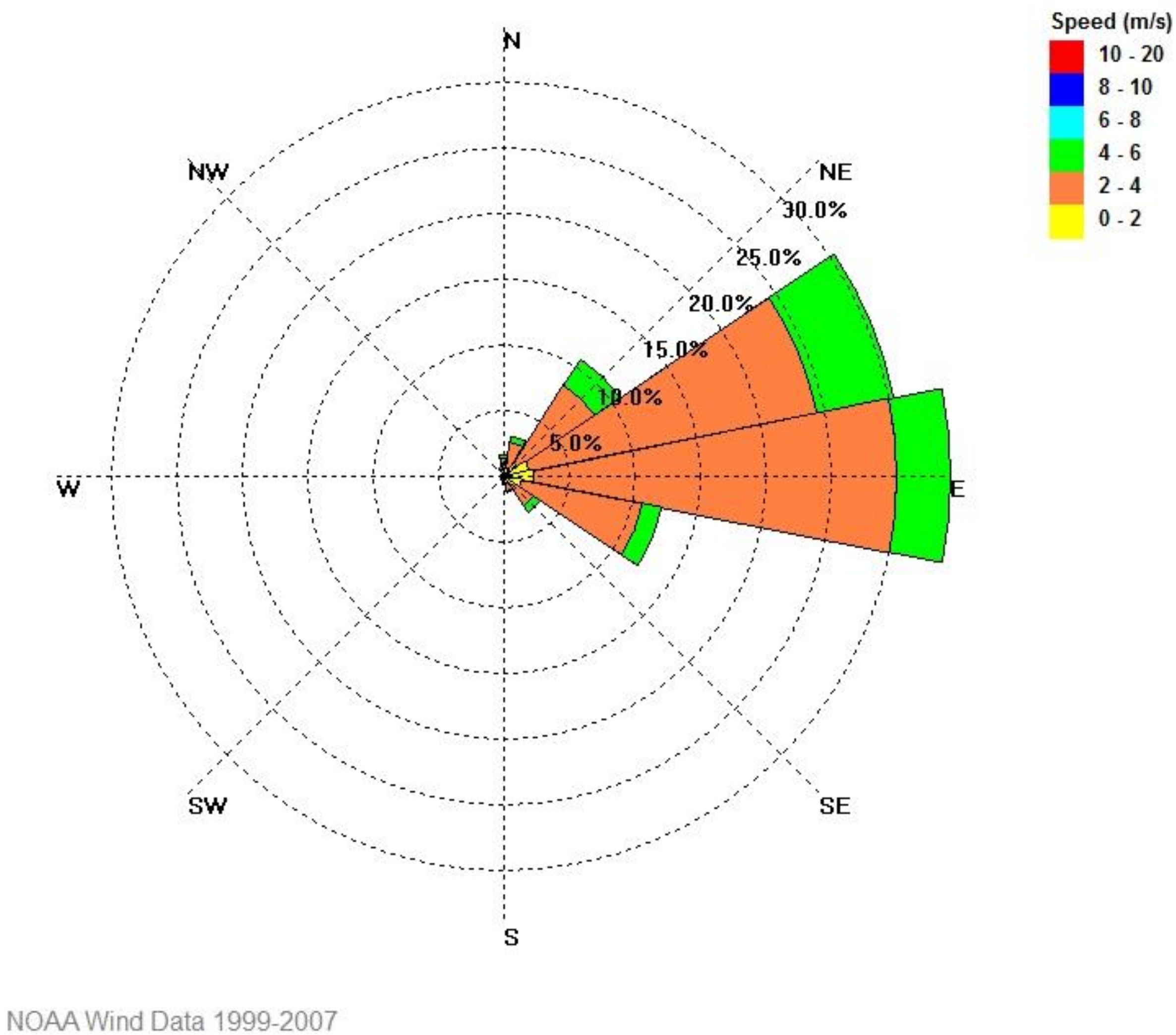


Figure 2-2 Wind Rose of NOAA Wind Data for 1999 – 2007

2.1.2.2 Short term wind data

Short term wind data was obtained from the Weather Underground website (www.weatherunderground.com). The data collected spanned two days from March 30th to March 31, 2013. The data contained hourly wind direction and speed. A graph plot of the data is shown in Figure 2-3.

Additional wind data was collected from the Sangster International airport weather station for the same period. The data showed the winds were predominantly from the eastern directions and were below 6 metres per second. This data corresponds to both the WU and NOAA data.

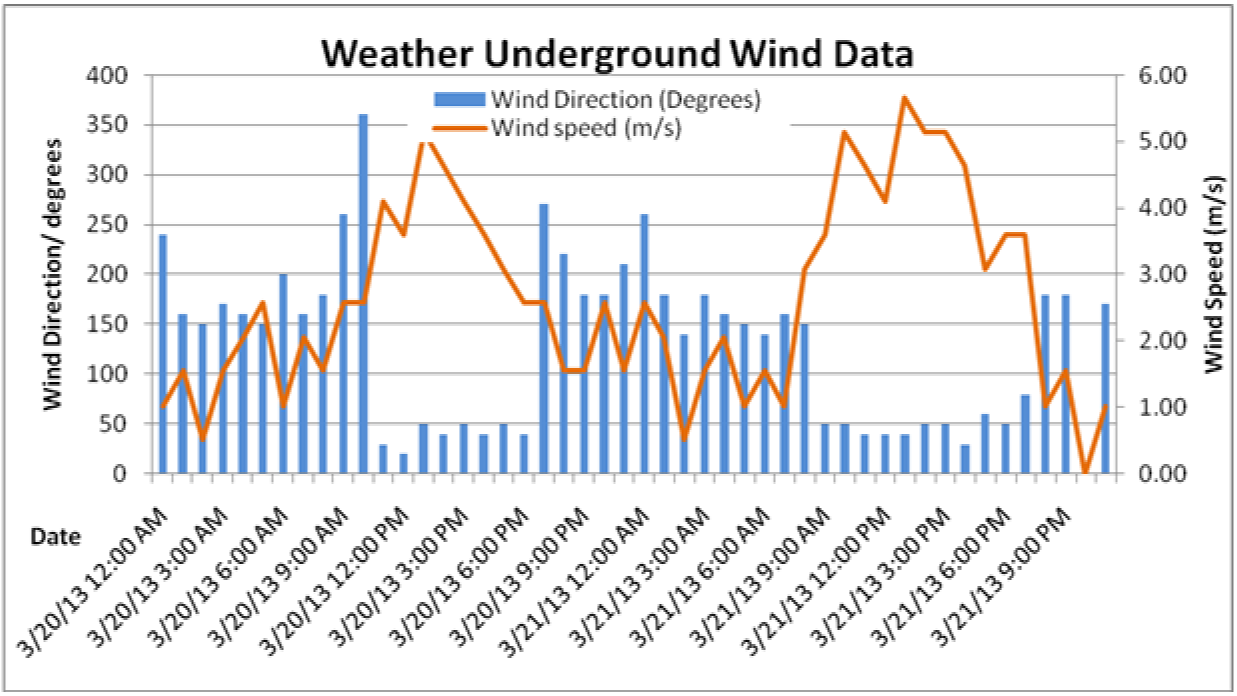


Figure 2-3 Graph showing summary of wind data for March 20 and March 21, 2013 (weather underground)

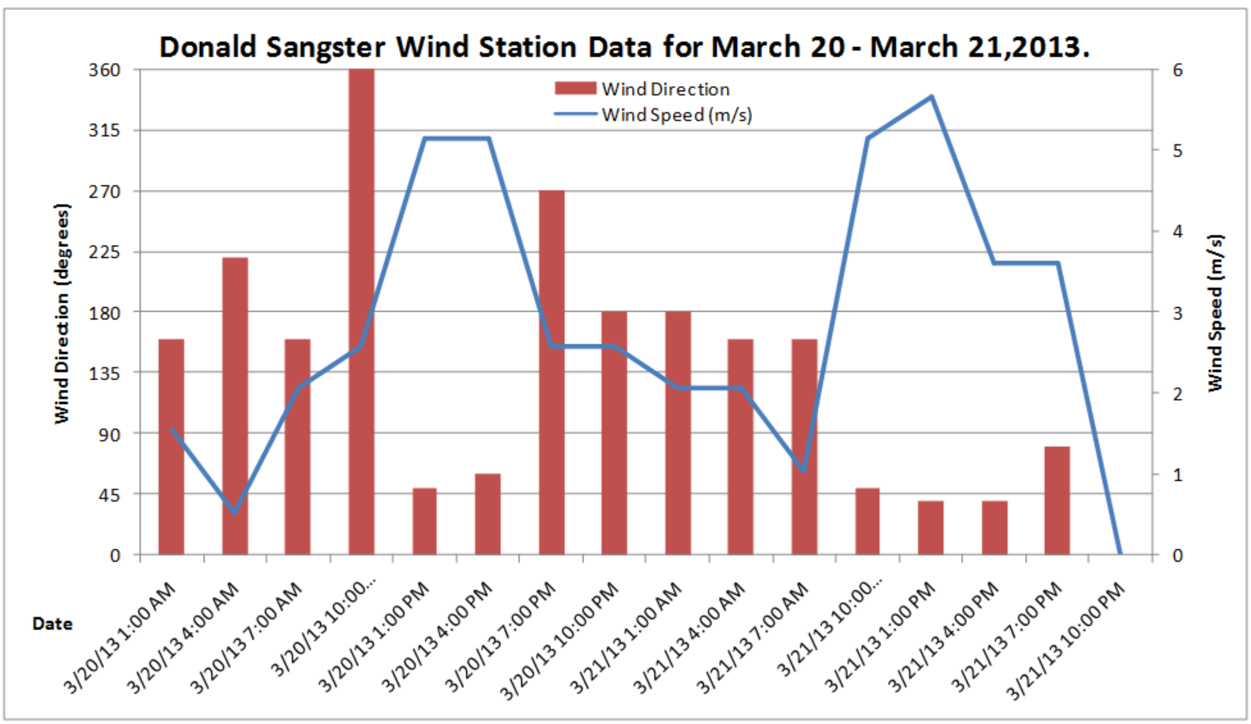
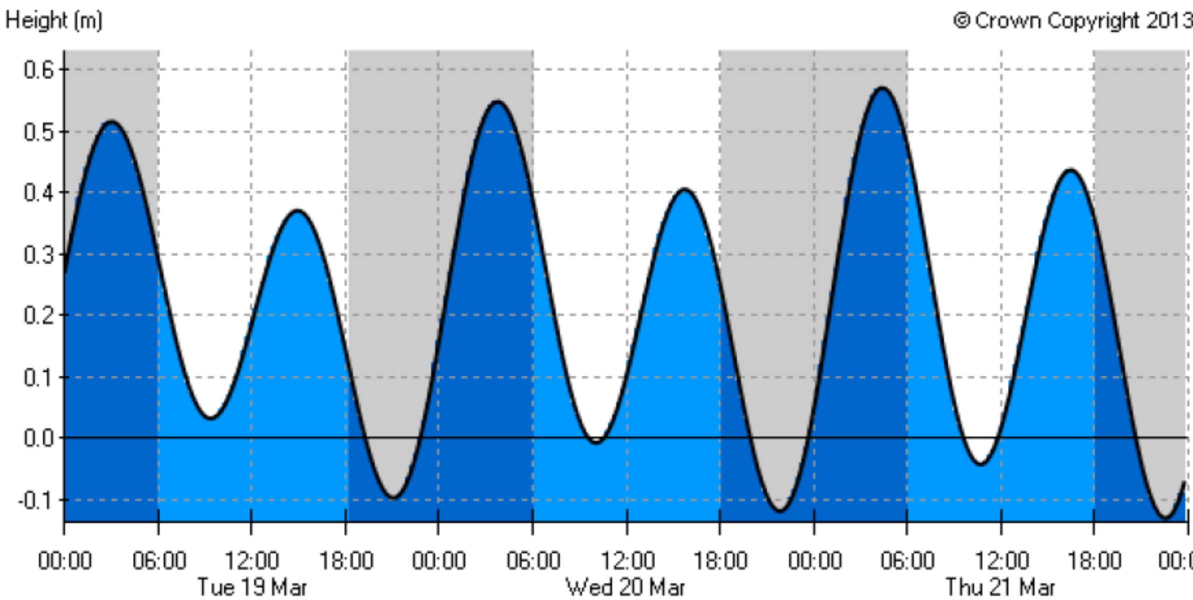


Figure 2-4 Graph showing summary of wind data for March 20th - March 21, 2013 (Sangster International airport weather station)

2.1.3 Tides

The tidal elevations for the 2-day drogue tracking missions were obtained from Admiralty Easy Tide website to identify the times during which rising and falling tides would occur over the period that drogue tracking (current measurements) was done. The tidal predictions for the nearest and more reliable station (Oracabessa, St Mary) were used and can be seen below in Figure 2-5.



Note: the date shown underneath 12:00 on any given day is applicable to the previous and next periods of 12 hours

Tue 19 Mar				Wed 20 Mar				Thu 21 Mar			
HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW
03:02	09:22	14:56	21:05	03:45	10:04	15:44	21:50	04:23	10:41	16:27	22:32
0.5 m	0.0 m	0.4 m	-0.1 m	0.5 m	0.0 m	0.4 m	-0.1 m	0.6 m	0.0 m	0.4 m	-0.1 m

Figure 2-5 Admirality Easy Tide predictions for Oracabessa between March 19 to 21, 2013

2.1.4 Currents

2.1.4.1 Drogue Tracking Missions

In order to facilitate the development of the hydrodynamic model for the area tides, winds and currents, current speed and direction information was required. This information was acquired by carrying out drogue tracking missions.

A two-day drogue tracking programme was executed on March 20th, 2013 and March 21st, 2013. Six (6) drogues were deployed; three (3) surface and three (3) sub-surface drogues (with depths ranging from 1.4 to 2 metres). The drogues were deployed at four (4) locations:

1) near shore in front the beach
2) approximately 250m off- shore
3) further offshore approximately 550m offshore
4) off shore towards the sand site and

The drogues were tracked during two separate sessions over the two days, one in the morning and the other in the evening, in order to determine the circulation patterns in the bay during the rising and falling tides on each day. The sessions tracked were the morning falling tide and the evening rising tide. Drogues were deployed to locations 1, 2 and 3 in monitoring sessions 1 and 2 while locations 1, 2 and 4 were used in monitoring session 3 and 4.

The GPS and drogue log sheet results from the drogue tracking missions were reduced and incorporated in a database. The data were then analysed in order to determine current speed and directions, and current speed vectors were produced for the rising and falling tides.

2.1.4.2 Winds during Drogue Tracking mission

The available wind data collected indicates average wind speeds during sessions varied from 2.06m/s to 4.97m/s while the and average directions were between SSE and NE. Table 2-1 below gives a summary of the winds encountered during each drogue tracking session.

Table 2-1 Showing wind data observed during drogue tracking missions (Weather Underground)

Session	Session type	Date	Average Wind Speed (m/s)	Average wind direction
Session 1	Falling Tide	20-Mar-13	2.06	SSE
Session 2	Rising Tide	20-Mar-13	4.63	NE
Session 3	Falling Tide	21-Mar-13	3.35	SSE
Session 4	Rising Tide	21-Mar-13	4.97	NE

2.1.4.3 Tracking Results – Falling Tide

Sessions 1 and 3 were conducted during falling tide conditions. The periods for falling tide conditions were as follows:

- Session 1 was observed from 7:37 am to 9:08 am on March 20th with average wind speeds of 7.4 km/h in a generally SSE direction.
- Session 3 was observed from 7:46 am to 8:30am on March 21st with average wind speeds of 12.05 km/h in a generally SSE direction.

Nearshore

The surface drogues in session 1 were observed moving at speeds of 1.17 cm/s in an easterly direction whereas those in session 3 were moving at an average speed of 1.73 cm/s north-westerly. The deeper sub-surface drogues (1.4m) deployed near shore also travelled in contrasting directions of south-easterly during session 1 of speeds of 0.93 cm/s and westerly during session 3 at speeds of 1.65 cm/s.

250m offshore

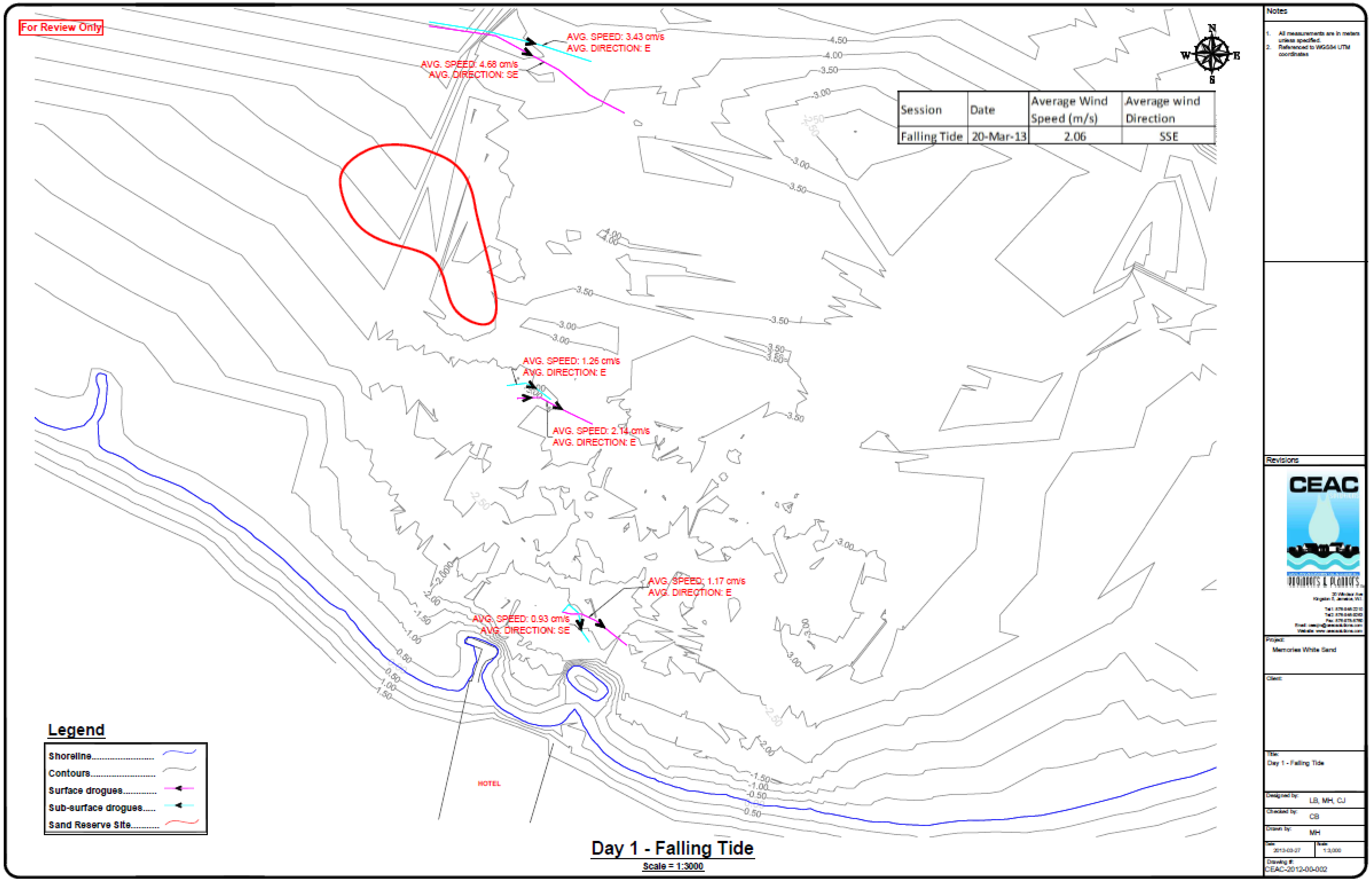
The surface drogues placed outside the near shore area were observed to move in an easterly direction at a speed of 2.15 cm/s for session 1. The sub-surface drogues (1.7m) were observed to be travelling easterly with average speeds of 1.26 cm/s. These currents seem to flow perpendicular to the wind by flowing into the beach during falling tides.

Deep Offshore

The surface drogues were tracked moving at average speeds of 4.68 cm/s and 1.59 cm/s in south easterly and south westerly directions respectively. The deeper sub-surface drogues (2m) travelled in directions of easterly and south westerly directions at average speeds between 3.43 cm/s and 1.14 cm/s respectively.

Near Proposed Donor Site

The surface drogue deployed near the sand reserve site was tracked moving at an average speed of 3.25 cm/s in a north westerly direction. The deeper sub-surface drogue (1.7m) travelled in a westerly direction at an average speed of 2.73 cm/s. This was demonstrative of the over-riding influence of the wind versus the tides. The strong tidal currents resulted in currents leading into the beach.



Session	Date	Average Wind Speed (m/s)	Average wind Direction
Falling Tide	20-Mar-13	2.06	SSE

Figure 2-6 Drogue movements during the falling tide on day 1.

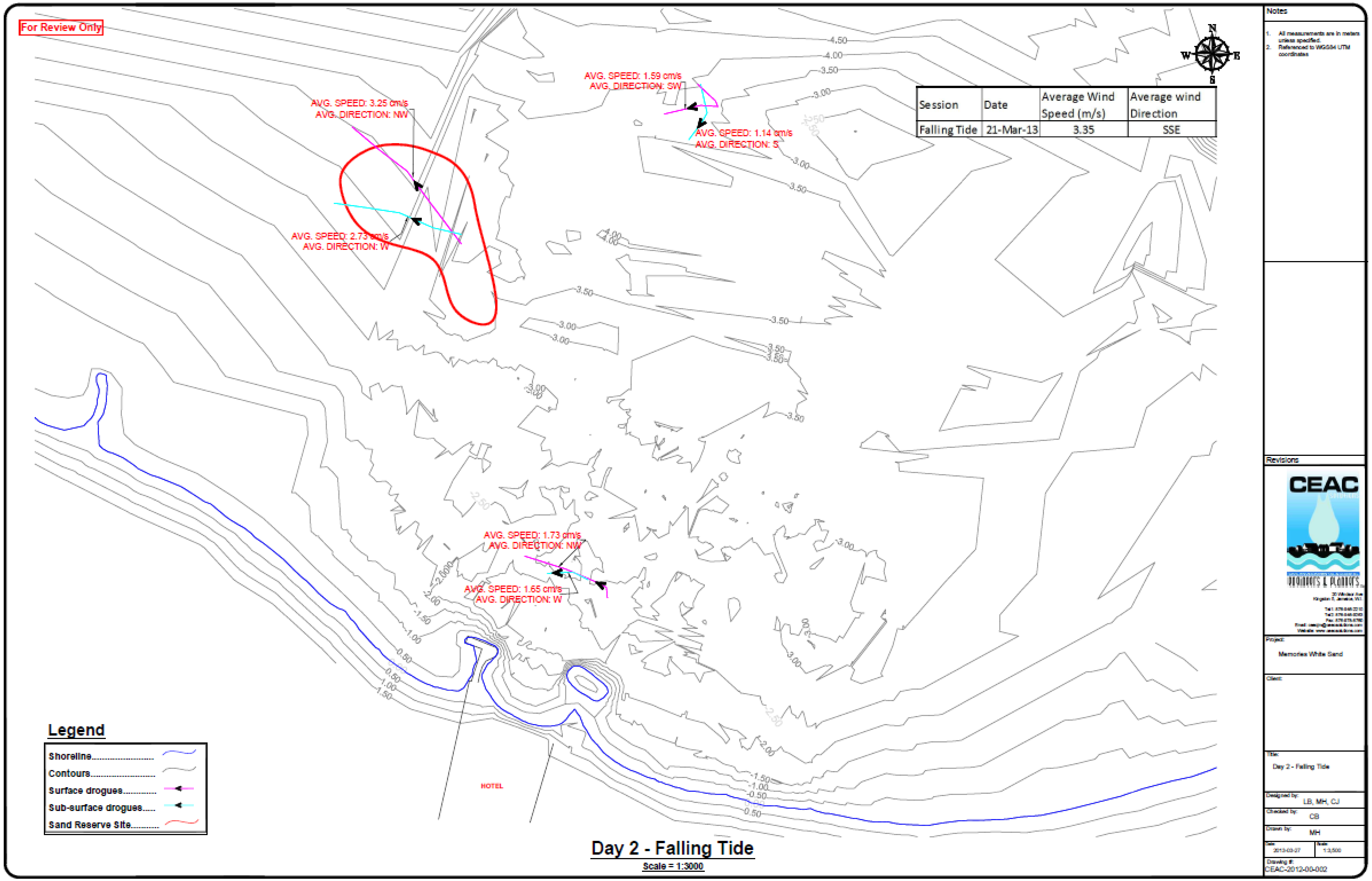


Figure 2-7 *Drogue movements during falling tide on day 2*

2.1.4.4 Tracking Results - Rising Tide

Sessions 2 and 4 were conducted during falling tide conditions. The periods for falling tide conditions were as follows:

- Session 2 was observed from 12:56 pm to 2:25 pm on March 20th with average wind speeds of 16.68 km/h in a generally NE direction.
- Session 4 was observed from 2:33 pm to 3:39 pm on March 21st with average wind speeds of 17.90 km/h in a generally NE direction.

Nearshore

During sessions 2 and 4, the surface drogues near shore were tracked moving in general south- westerly directions at speeds of 2.36 cm/s and 3.75 cm/s respectively. The deeper sub-surface drogues (1.4m) deployed near shore also travelled in a south westerly directions at average speeds of 1.40 cm/s and 2.33 cm/s for sessions 2 and 4 respectively. These currents seem to be dominated by the predominant wind.

250m Offshore

The surface drogue placed outside the near shore area was observed to move in a southerly westerly direction at a speed of 2.74 cm/s for session 1. The sub-surface drogues (1.7m) travelled southerly with average speeds of 1.52 cm/s. These currents also seem to be dominated by the wind and also flowing into the beach during rising tides.

Deep Offshore

The surface drogues were tracked moving at average speeds of 4.59 cm/s and 5.31 cm/s both in a westerly direction. The deeper sub-surface drogues (2m) also travelled in a westerly direction at speeds of 1.96 cm/s and 4.80 cm/s. These currents are also generated by the wind as the drogues are being carried by western currents.

Near Sand Site

The surface drogue deployed near the sand reserve site was tracked moving at an average speed of 6.96 cm/s in a westerly direction. The deeper sub-surface drogue (1.7m) travelled in a westerly direction at an average speed of 6.21 cm/s.

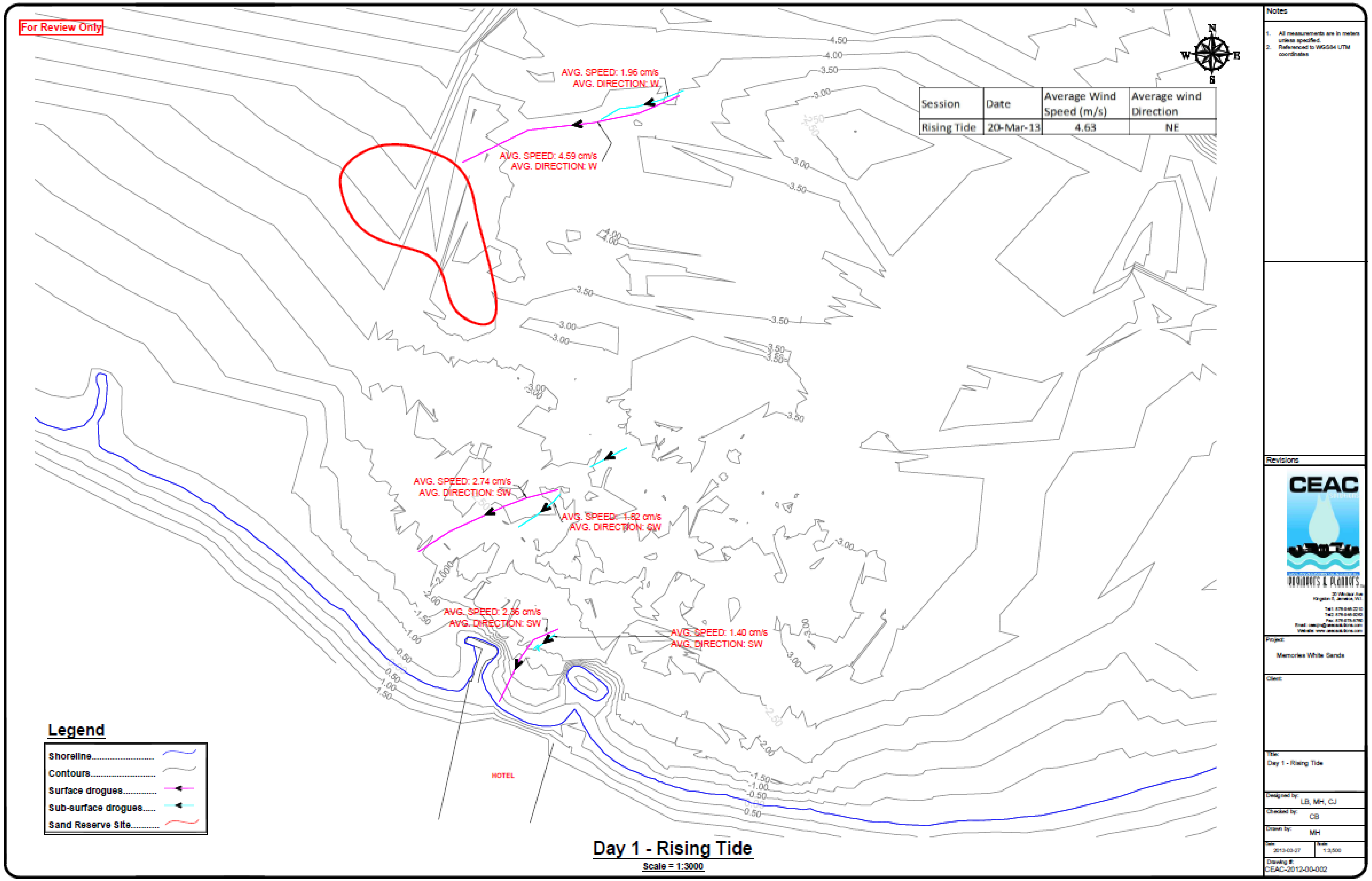


Figure 2-8 Drogue movements during falling tide on day 1.

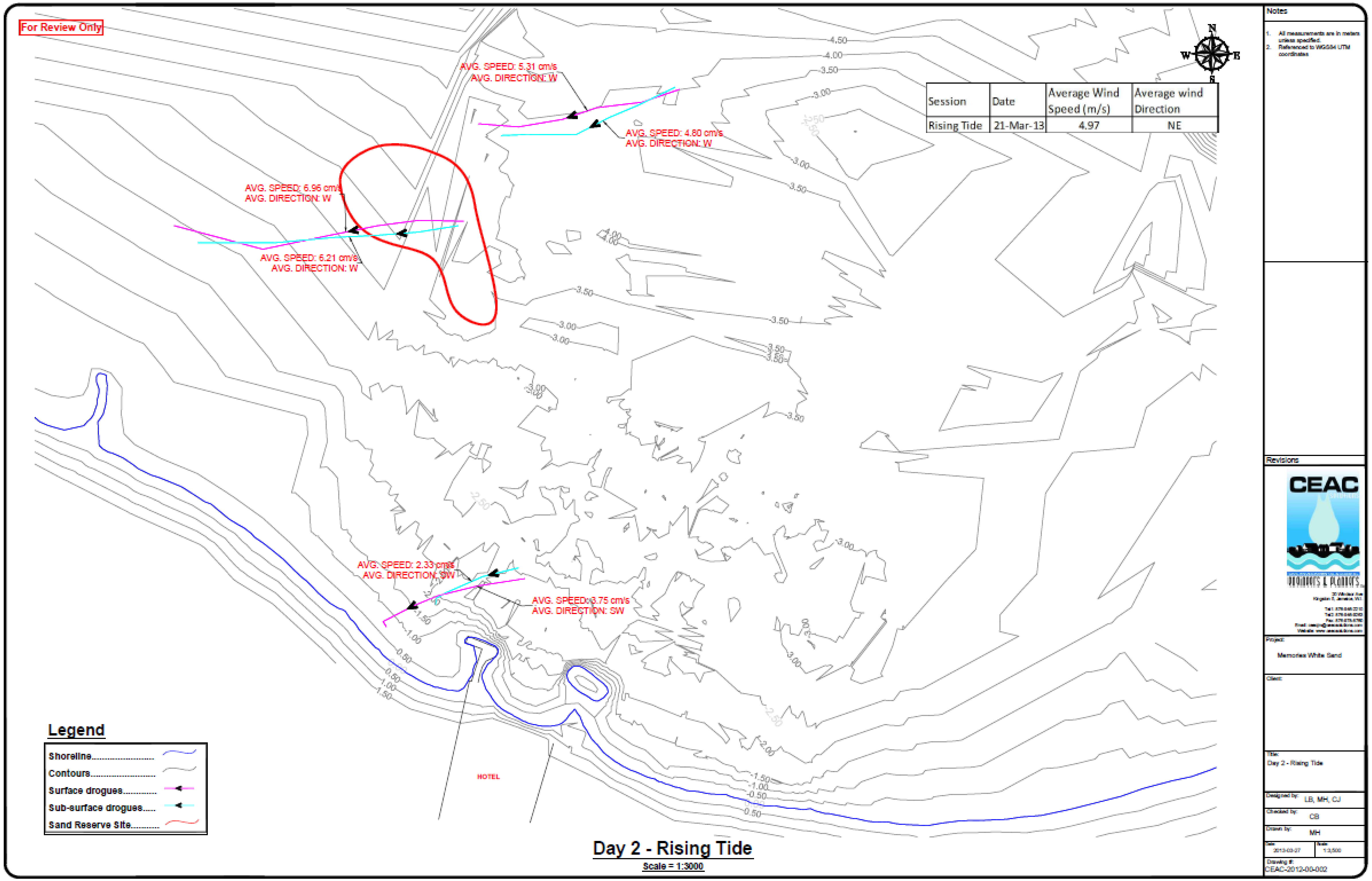


Figure 2-9 Drogue movements during Rising tide on day 2.

2.1.4.5 Summary

The two days of drogue tracking involved four sessions total; two falling and two rising tide sessions. The current speeds during falling varied from 1.2 cm/s to 4.68 cm/s and 0.93 cm/s to 3.43 cm/s for the surface and sub-surface drogues respectively. The speeds during the rising tide varied from 2.3 cm/s to 6.96 cm/s and 1.4 cm/s to 6.21 cm/s for the surface and sub-surface currents.

Knowledge of the prevailing wind conditions allowed for the determination of the effect of wind speed and direction. The current speeds are generally higher for the falling tides than for the rising tide session. It is also evident that when the wind speed is slow, the tides dominate the currents; however when the wind speeds increase to above 3 m/s then the effect of the tides appear to be negligible.

2.1.5 Water Quality

A marine water quality sampling exercise was conducted at seven (7) stations on April 25th, 2013. Their locations in JAD2001 are listed in Table 2-2and depicted in Figure 2-10

Temperature, conductivity, salinity, dissolved oxygen, turbidity, total dissolved solids, pH and Photosynthetically Active Radiation (PAR) were collected *in situ* using a Hydrolab DataSonde 5 water quality multi probe meter (Table 2-3).

Table 2-2 Table showing the coordinates of the Water Quality Stations

Station	COORDINATES (JAD 2001)	
	Northing (m)	Easting (m)
WQ1	704988.37	685671.05
WQ2	704378.32	685555.43
WQ3	704284.05	685407.50
WQ4	704239.60	685520.00
WQ5	704242.10	685635.39
WQ6	703898.76	685679.32
WQ7	703792.38	685676.53

The Hydrolab DS-5 calibration certificate can be seen in Appendix E.

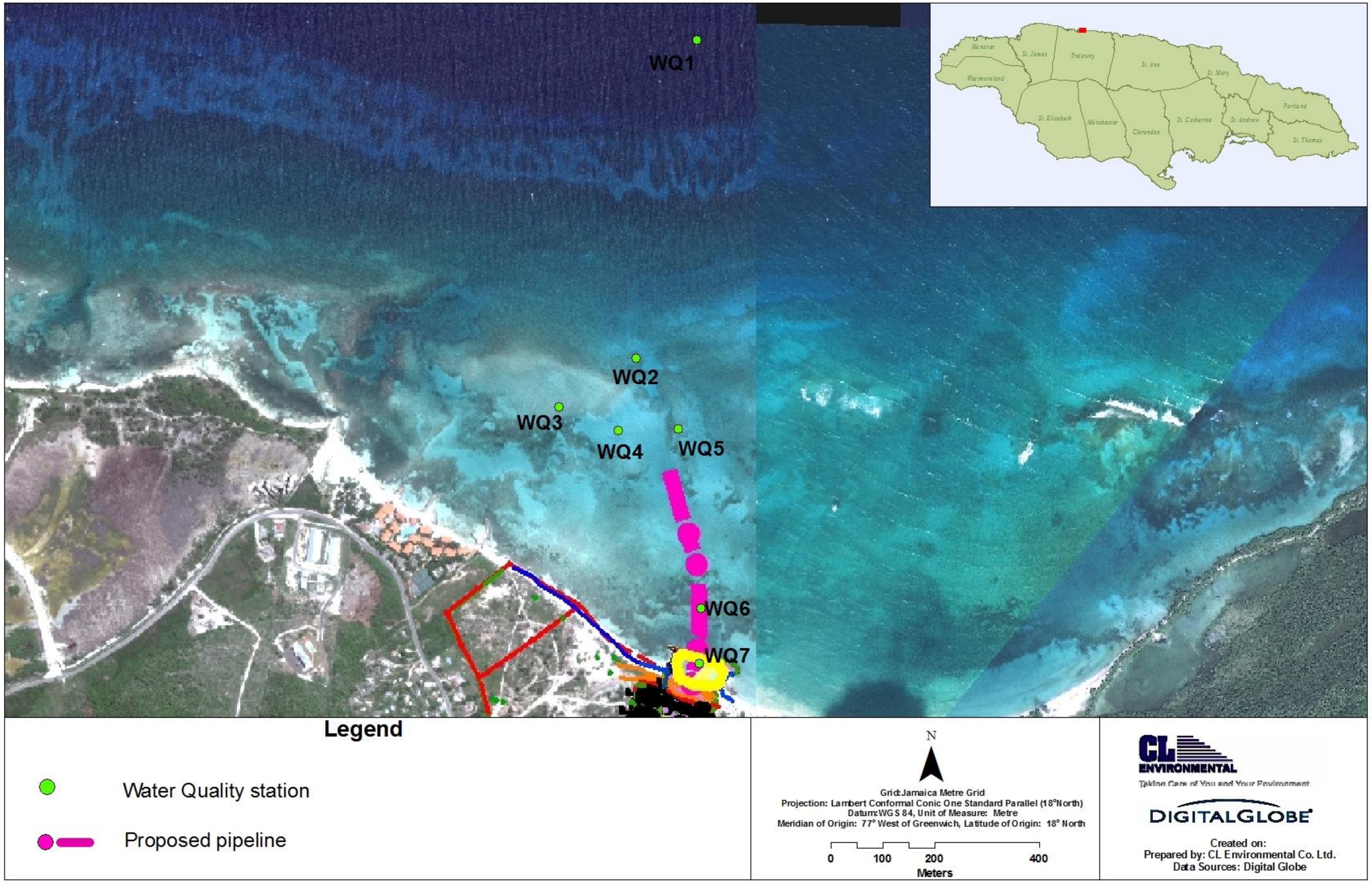


Figure 2-10 Map showing the Water Quality Stations

Table 2-3 Table showing the physicochemical values at each water quality station

Stations	Depth (m)	Temp. (°C)	SpC (mS/cm)	Sal (ppt)	pH	DO (mg/l)	TUR (NTU)	TDS (mg/l)	ORP	PAR (uE/m^2/s)
WQ1	0	27.83	54.33	36.01	8	6.56	0	34.76	410	1940
	1	27.83	54.31	36.02	8.02	6.53	0	34.74	399	2261
	2	27.84	54.31	36	8.04	6.52	0	34.75	393	1916
	3	27.83	54.28	36	8.04	6.57	0	34.75	388	1264
	4	27.83	54.3	36	8.05	6.56	0.1	34.75	384	1157
	5	27.83	54.32	36.01	8.06	6.52	0.2	34.75	381	1044
	6	27.83	54.31	36.01	8.06	6.52	0.2	34.75	378	1391
	7	27.83	54.29	35.99	8.07	6.56	0.3	34.75	375	1559
	8	27.83	54.3	36	8.07	6.56	0.5	34.75	373	934
	9	27.84	54.3	35.99	8.07	6.54	0.7	34.74	369	1034
	10	27.83	54.3	36	8.08	6.54	0.8	34.74	369	698
WQ2	0	27.9	54.37	36.64	8.03	5.98	0.5	34.79	391	2096
	1	27.89	54.33	36.04	8.04	6.02	1.1	34.78	387	1402
	2	27.89	54.34	36.02	8.05	6.14	0.6	34.77	380	1811
WQ3	0	28.09	54.37	36.06	8.05	6.14	1	34.8	374	2618
	1	28.12	54.37	36.03	8.05	6.13	1.1	34.79	371	2071
WQ4	0	27.99	54.37	36.05	8.06	5.96	1.3	34.78	365	2689
	1	28.04	54.35	36.03	8.06	6	1.3	34.78	363	1082
	2	27.99	54.35	36.02	8.05	5.94	1.6	34.77	368	1023
WQ5	0	27.93	54.37	36.05	8.06	6.07	2	34.79	371	2388
	1	27.94	54.36	36.05	8.06	6.1	2	34.79	368	2086
	2	27.95	54.35	36.03	8.06	6.12	2	34.79	365	2052
WQ6	0	28.63	54.29	35.98	7.98	6.35	1	34.72	382	2813
	1	28.64	54.28	35.99	8.01	6.34	5.8	34.74	355	2240
WQ7	0	28.87	54.43	36.09	7.96	6.35	41.7	34.81	397	1108
	1	28.88	54.38	36.05	7.97	6.23	33	34.8	384	1352

Table 2-4 Table showing the light extinction value at each station

Station	Extinction Coefficient
WQ1	0.060
WQ2	0.073
WQ3	0.234
WQ4	0.483
WQ5	0.076
WQ6	0.228
WQ7	-0.199

Temperature

The temperature values varied little across the stations ranging from 27.83 – 28.88C (Table 2-3). Station WQ1, located approximately 1.3km from the shore, had the lowest temperature whilst station WQ7 had the highest temperatures and was the closest to the shoreline (Figure 2-11). This elevated temperature could be due to the time of sampling and the shallow nature of the water. When compared to depth, temperature varied little at each station.

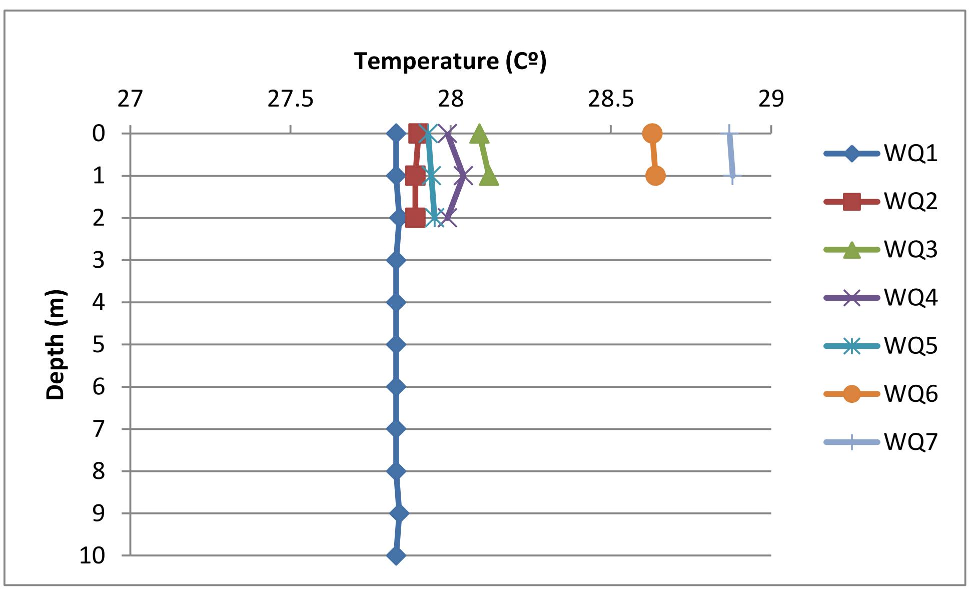


Figure 2-11 Temperature values at the various Water Quality Stations

Specific Conductivity

Specific conductivity varied little across the stations ranging from 54.20 - 54.43mS/cm (Table 2-3). Highest specific conductivity was observed at station WQ7 whereas lowest conductivity was observed at station WQ6 (Figure 2-12). At each station conductivity varied little when compared with depth. The homogeny of the values suggest there is mixing throughout the area.

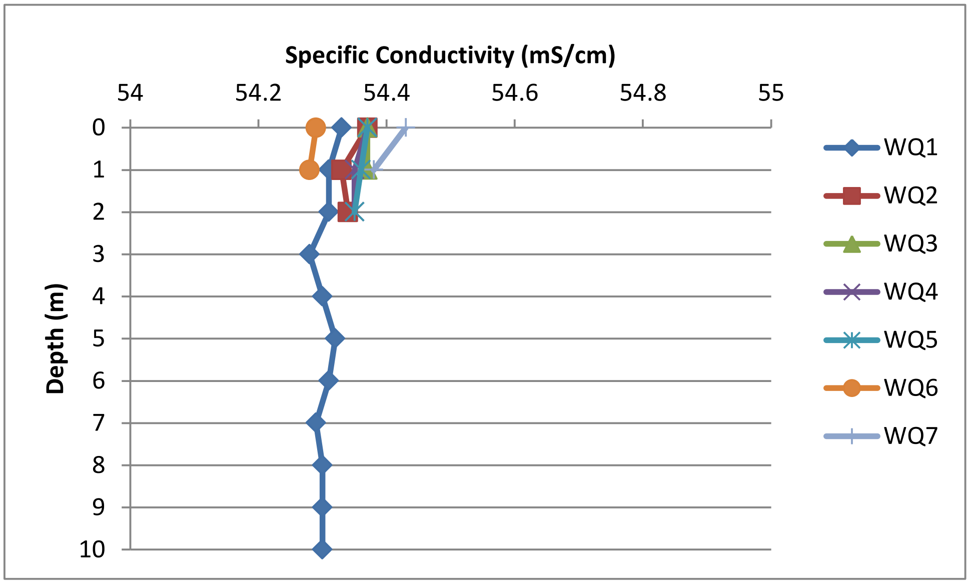


Figure 2-12 Specific Conductivity values at the various Water Quality Stations

Salinity

Salinity values for the stations varied little across stations ranging from 35.98 -36.64ppt (Table 2-3). Highest salinity was observed at station WQ2, whereas lowest salinity was observed at station WQ6 (Figure 2-13). When compared to depth, all stations showed little variation except for station WQ2. Station WQ2 showed a small decrease between the surface and 1m depth.

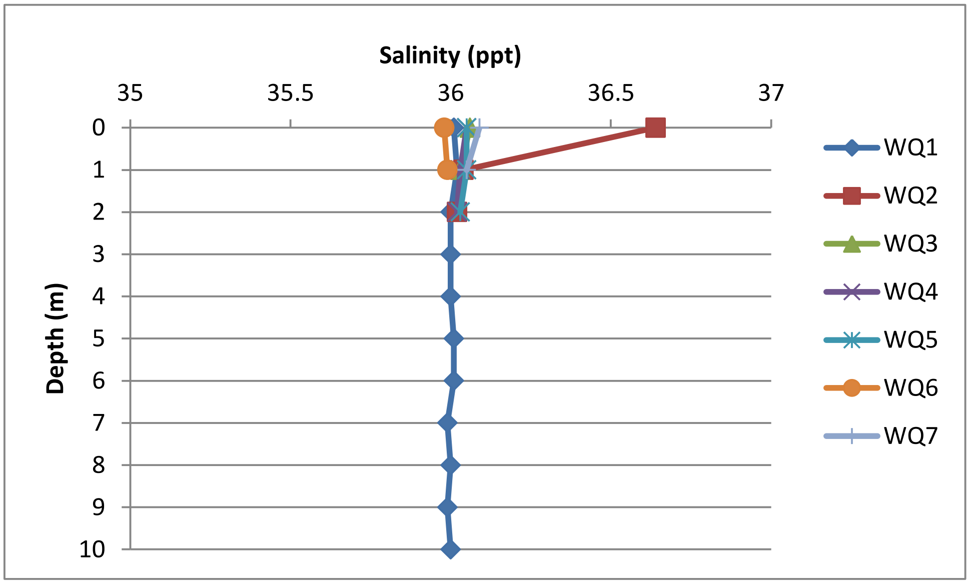


Figure 2-13 Salinity values at the various Water Quality Stations

pH

pH values varied little across the stations ranging from 7.96 – 8.08 (Table 2-3). Lowest pH value was observed at station WQ7 whereas station WQ1 had the highest value. When compared with depth at each station, there was a general increase in pH (Figure 2-14). Stations WQ6 and 7 were below the NEPA Standard for Marine Water of pH 8.

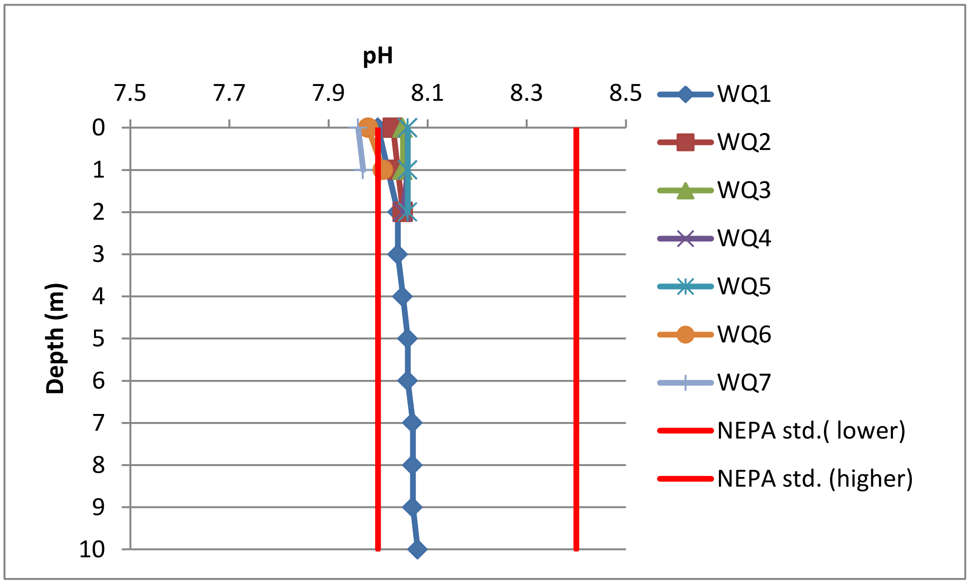


Figure 2-14 pH values at the various Water Quality Stations

Dissolved Oxygen (DO)

Dissolved oxygen varied slightly across the stations ranging from 5.96 -6.57mg/l (Table 2-3). Highest DO values were observed at station WQ1, whereas the lowest values were observed at station WQ4 (Figure 2-15). When compared with depth, DO values at each station showed little variation. However, station WQ7 showed a slight decrease in DO level.

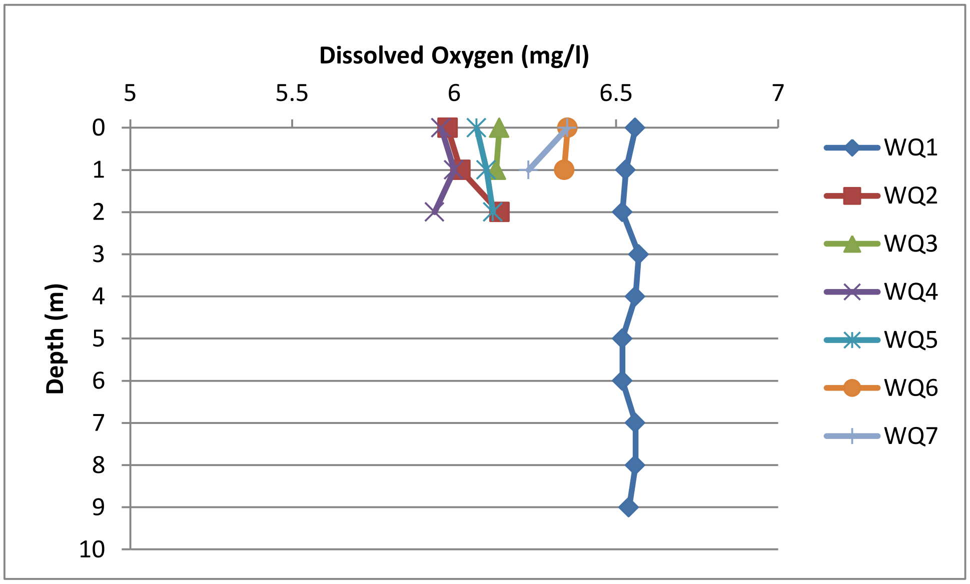


Figure 2-15 DO values at the various Water Quality Stations

Photosynthetically active radiation (PAR)

PAR is the amount of light available for photosynthesis and is affected by a number factors. When measuring PAR in the sea factors that affect PAR include cloud cover, time of day, depth, organic and inorganic material in the water column. PAR values varied greatly across stations ranging from 698 – 2813uE/m²/s (Table 2-3). Highest PAR value was recorded at station WQ6, whereas the lowest value was recorded at station WQ1. When compared to depth, there was a general decrease in PAR for most stations. However, station WQ7 and WQ2 showed a slight increase (Figure 2-16).

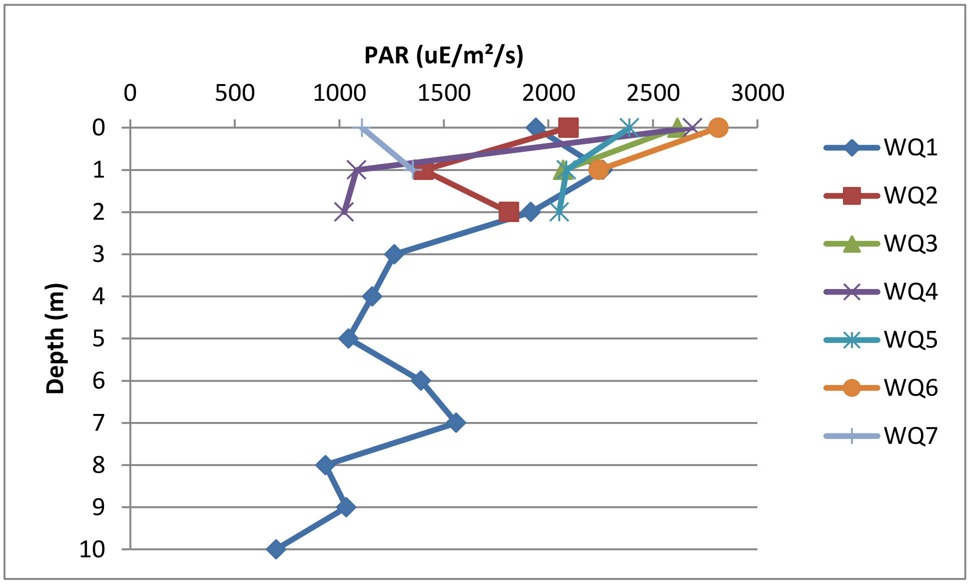


Figure 2-16 PAR values at the various Water Quality Stations

Extinction Coefficient (EC)

Extinction coefficient is the rate at which light is absorbed by seawater. The extinction coefficient values varied across stations ranging from -0.199 – 0.483 (Table 2-4). Low values of EC would indicate a high penetration of light which was noted at stations WQ1, 2 and 5. The EC value at station WQ7 was -0.199, this however could be due shadowing at a shallower depth.

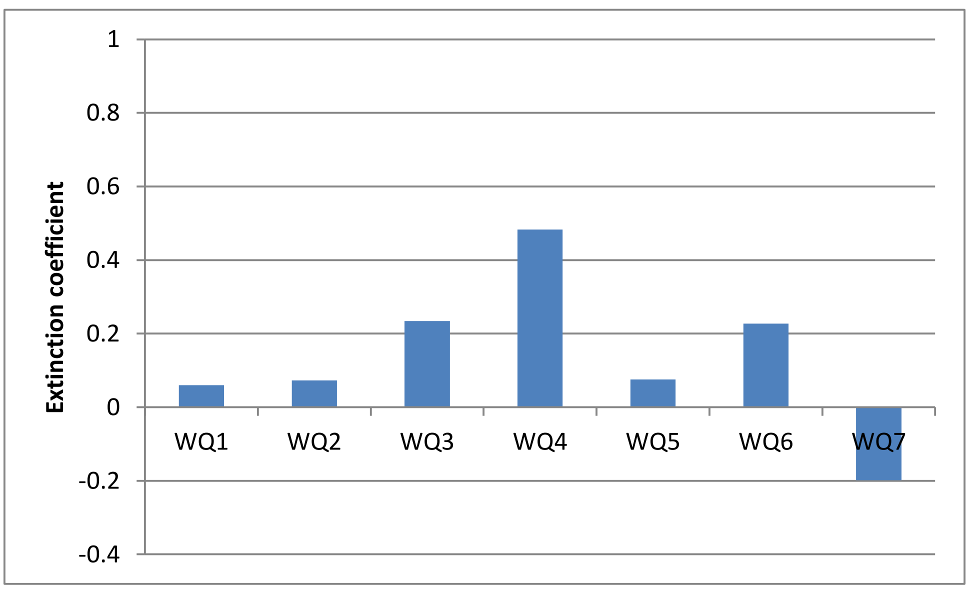


Figure 2-17 Extinction coefficient values at the various Water Quality Stations

Oxidative- reductive Potential (ORP)

ORP values varied across the stations ranging from 363 -410 (Table 2-3). Highest ORP value was observed at station WQ1, whereas the lowest value was observed at station WQ6 (Figure 2-18). There was a general decrease in ORP when compared with depth, with station WQ6 showing the most dramatic change. Station WQ1, located approximately 1km from shore, was expected to have the highest ORP values indicating the oligotrophic nature of this site.

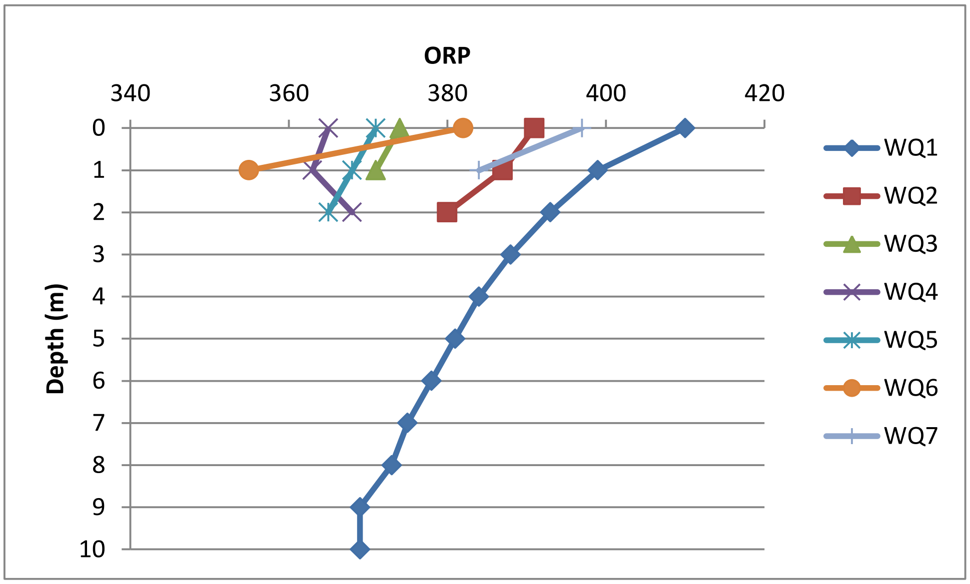


Figure 2-18 ORP values at the various Water Quality Stations

Turbidity

Turbidity values varied across stations ranging from 0 – 41.7NTU (Table 2-3). Lowest values were observed at station WQ1, whereas the highest value was observed at station WQ7 (Figure 2-19). Turbidity values varied little when compared to depth at each station; however station WQ6 showed a slight increase with depth. The elevated levels observed at station WQ7 may be due to the shallow nature of the water coupled with the sediment type and wave action in the area.

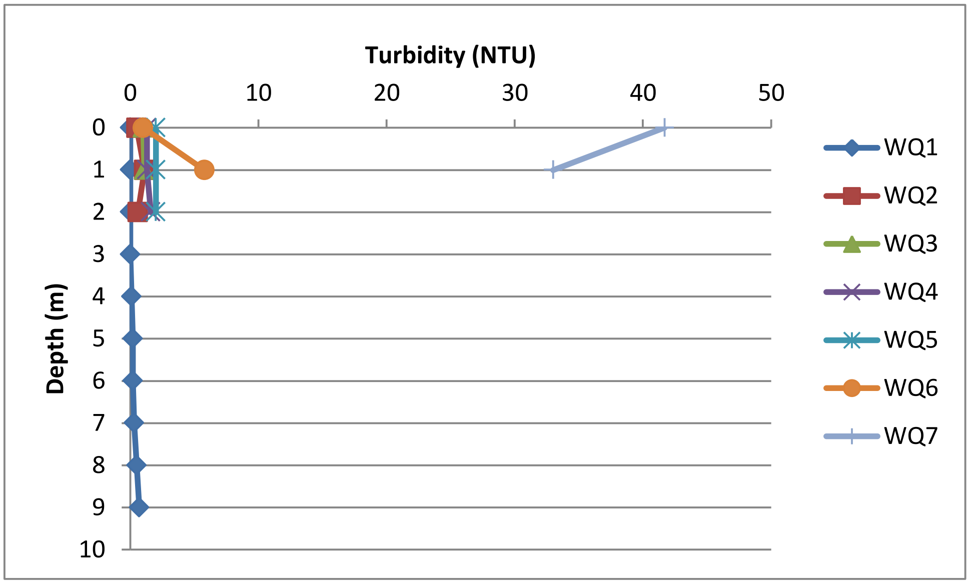


Figure 2-19 Turbidity values at the various Water Quality Stations

Total Dissolved Solids (TDS)

TDS values varied little across the stations ranging from 34.72 - 34.80mg/l (Table 2-3). When compared to depth, there was little variation observed at each station (Figure 2-20). The homogeny of the values suggests a similar quality to the background station, stationWQ1, which is located approximately 1 Km from shore.

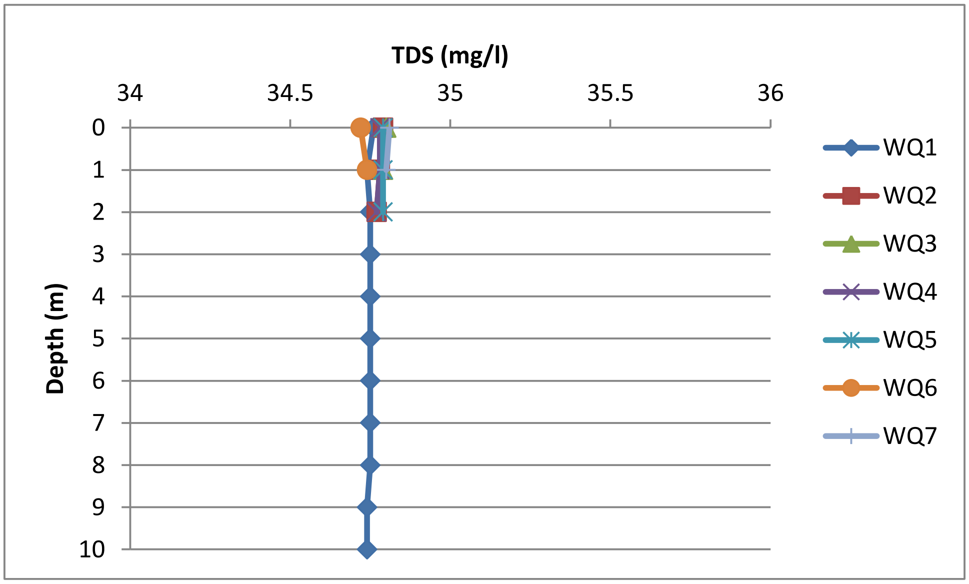


Figure 2-20 Total Dissolved Solids at the various Water Quality Stations

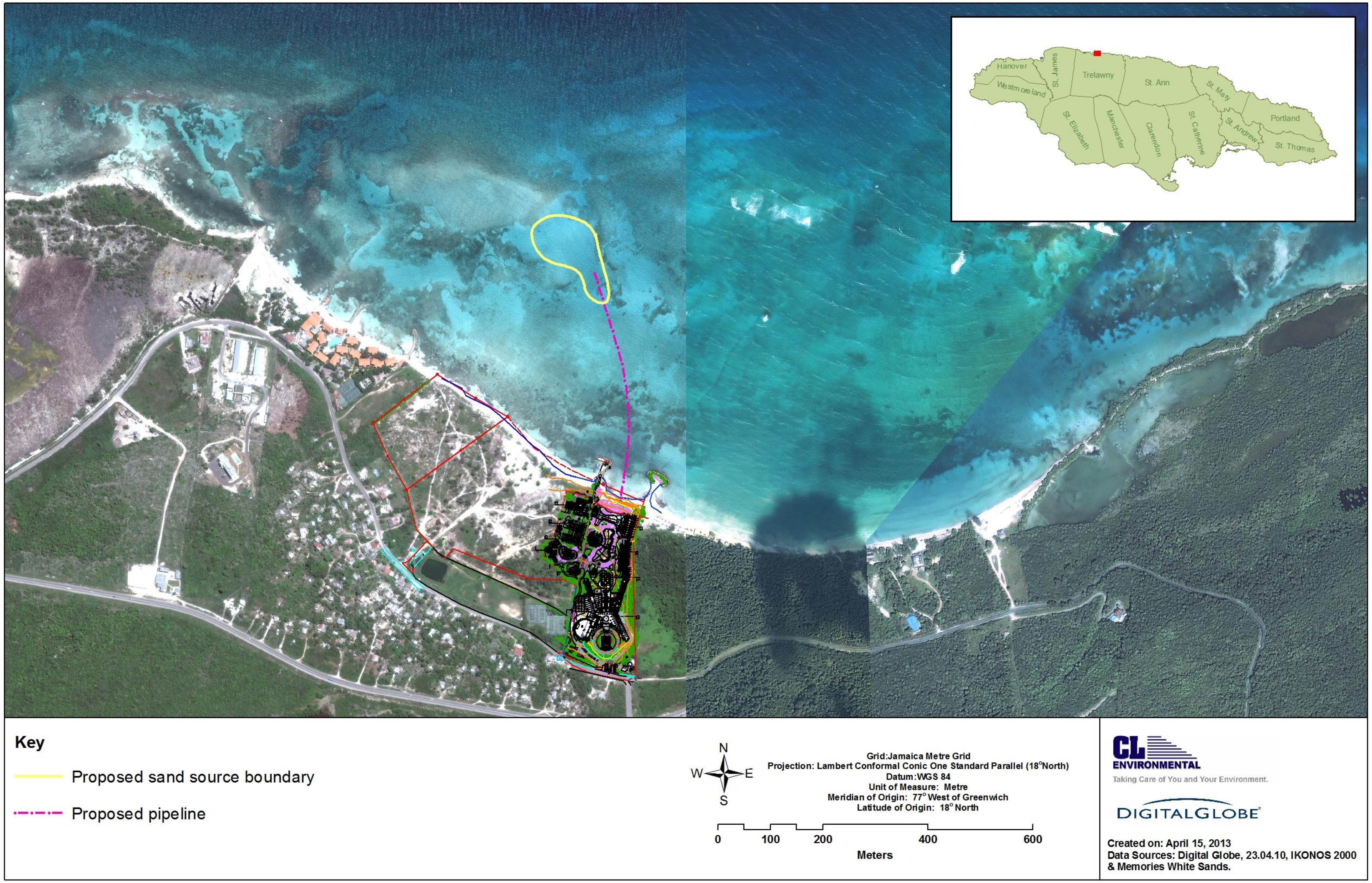


Figure 2-21 Map showing the proposed sand source area and pipeline route

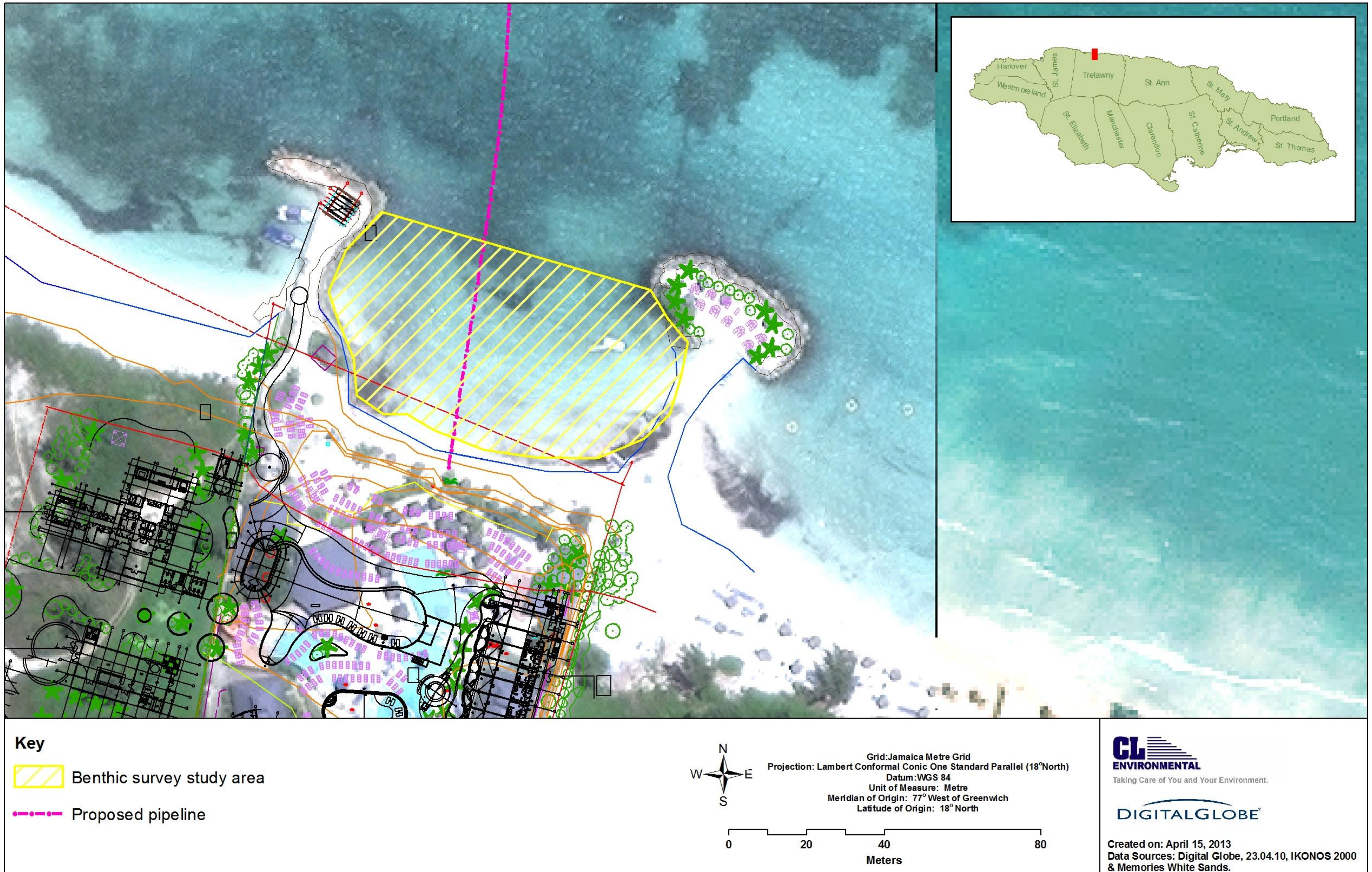


Figure 2-22 Map showing the shoreline survey area

2.1.6 Pipeline Route

The pipeline route (Figure 2-23) was assessed on 25 April, 2013 between 9:30 am and 11:30 am. The assessment was done by swimming along the pathway while guided by a Trimble Geo-XT GPS. Each distinct area was marked with the GPS. Each area or habitat type was then marked with a Trimble Geo-XT (Table 2-5). A photo inventory of features of each area was also taken. The assessment area included both the actual pipeline route and the immediate surrounding area. The distance from the pipeline surveyed depended on the visibility, which decreased moving towards the shoreline.

Table 2-5 Table showing pipeline survey coordinates

Survey Point	Coordinates	
	Northing (m)	Easting (m)
S1	685628.3	704158.7
S2	685633.5	704120.8
S3	658622	704117.6
S4	685639	704080.7
S5	685670.5	703965.2
S6	685675.5	703946.7
S7	685674.5	703940.2
S8	685674.5	703912.7
S9	685677.5	703888.1
S10	685671.5	703824.6

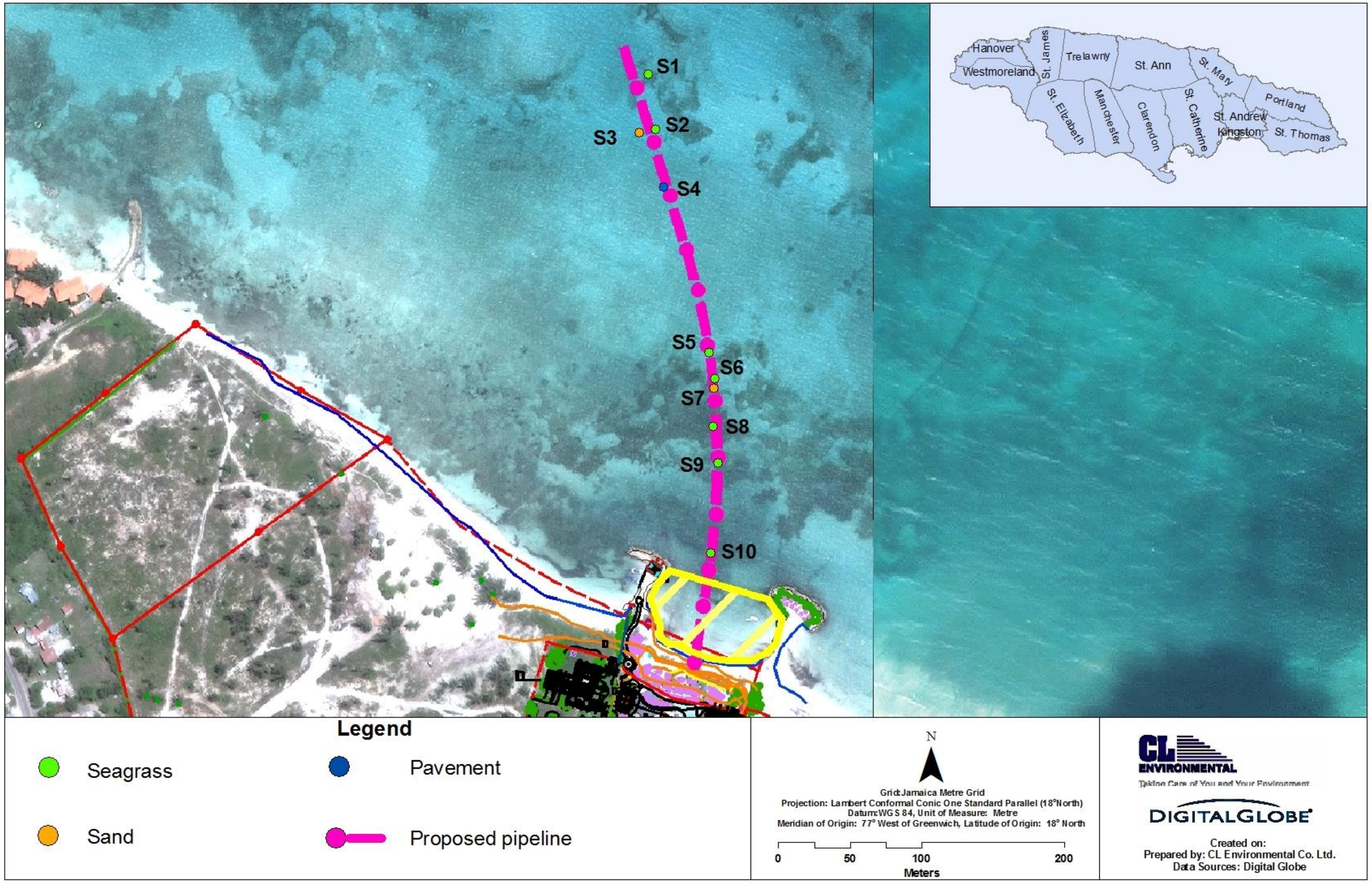


Figure 2-23 Map showing the survey points along the proposed pipeline route

2.2 RESULTS AND DISCUSSION

2.2.1 Sand Patch

The sand patch can be described as consisting of medium to coarse grain sand (Plate 2-1) with some rubble (Plate 2-2) and typical sand dwelling species such as *Cassiopeia sp.*, *Tripneustes sp.* and other invertebrates (listed in Table 2-6). A Southern Stingray (Plate 2-3) and three large Spotted Eagle rays were seen in the sand patch.

Table 2-6 Table showing the species observed in the sand patch

Fish	Coral	Invertebrate
3 Spotted Eagle Rays	-	*Lytechinus*
Goat fish	-	*Tripneustes*
1 Southern Caribbean Stingray	-	Heart Urchin
1 grunt	-	*Cassiopeia*
	-	Octopus
	-	Helmet Conch

Plate 2-1 Photo showing sand sample collection

Plate 2-2 Photo showing sand patch area

Plate 2-3 Photo showing southern stingray in sand pacth

2.2.2 Algal dominated zone

Interspersed between sections of seagrass beds and the sand patch, there were several large patches of rubble and sand with macro algae (Plate 2-4 and Plate 2-5). Transitional areas between sand, algae and seagrass were also seen (Plate 2-6).

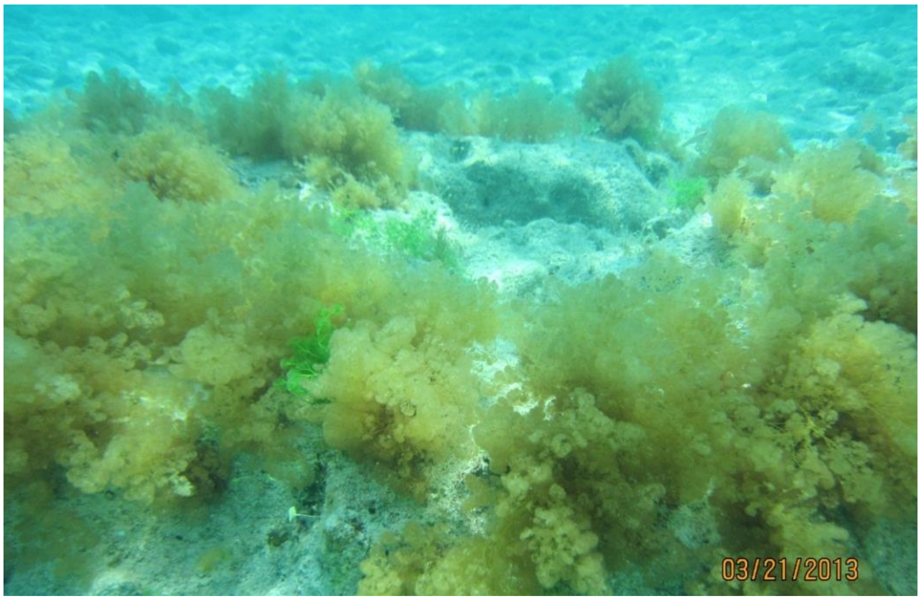


Plate 2-4 Photo showing algae growing on rubble on the edges of the sand patch

Plate 2-5 Photo showing algae growing on rubble with the sand patch

Plate 2-6 Photo showing the transition between algae and seagrass at the edge of the sand patch

2.2.3 Seagrass Beds

The seagrass bed habitat consisted of a mixed *Thalassia sp*. and *Syringodium sp*. (Plate 2-7and Plate 2-8) bed at the southern and western edges of the sand patch towards the western side of the patch, there was an extensive *Thalassia sp*. bed (Plate 2-9) with several dead areas (Plate 2-10). Several areas of rubble were also seen within the sand patch; a few small coral colonies were seen in some of these areas (Plate 2-11). Sections of the bed were dominated by *Syringodium sp*. (Plate 2-12). The bed has been affected by weather conditions in the area, clearly seen in the large blow outs and newly exposed root network (Plate 2-13-Plate 2-14). Table 2-7 gives the species found within the area.

Table 2-7 Table showing the species observed in the Sand patch

Fish	**Coral**	**Invertebrate**
Juvenile Parrot fish	*Porites divaricata*	*Tripneustes (numerous)*
Butterfly Fish	*Siderastrea siderea*	*Lytechinus*
Cocoa Damselfish		Starfish
Striped Parrot		Heart Urchins
Ocean sturgeon		*Cassiopeia*
Southern Stingray		

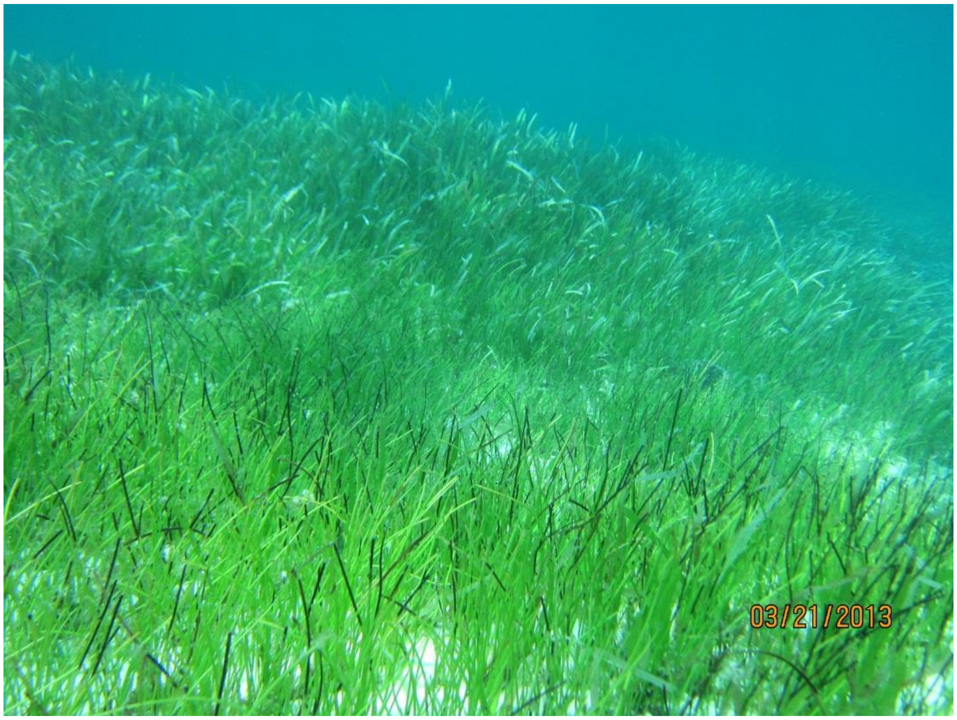


Plate 2-7 Photo showing part of the mixed seagrass bed

Plate 2-8 Photo showing a section of the mixed seagrass bed

Plate 2-9 Photo showing a section the Thalassia bed

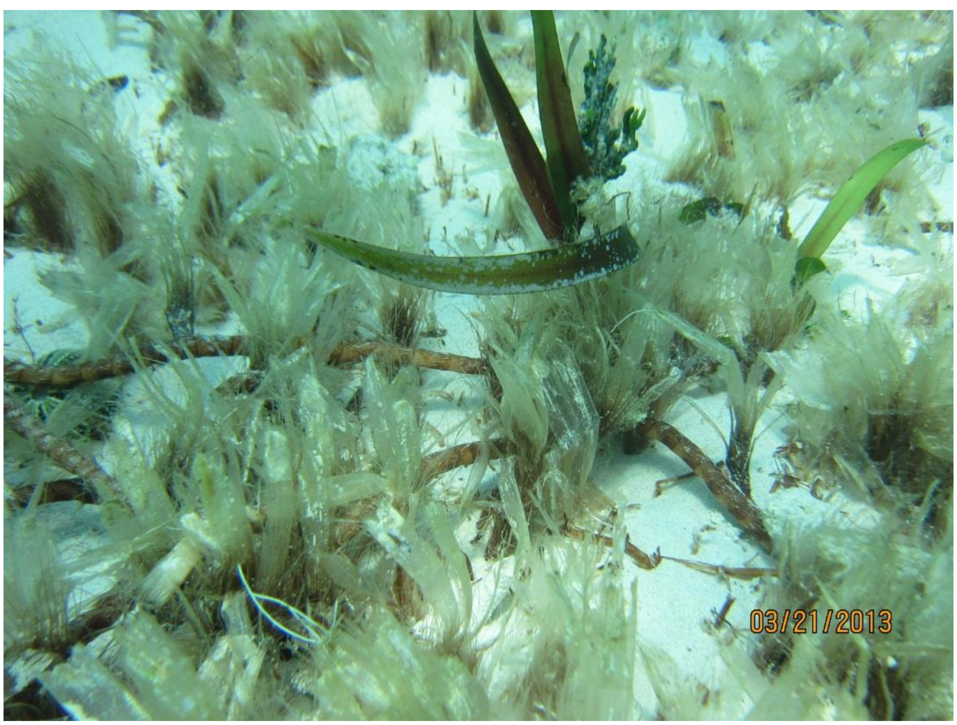


Plate 2-10 Photo showing a dead section the Thalassia bed

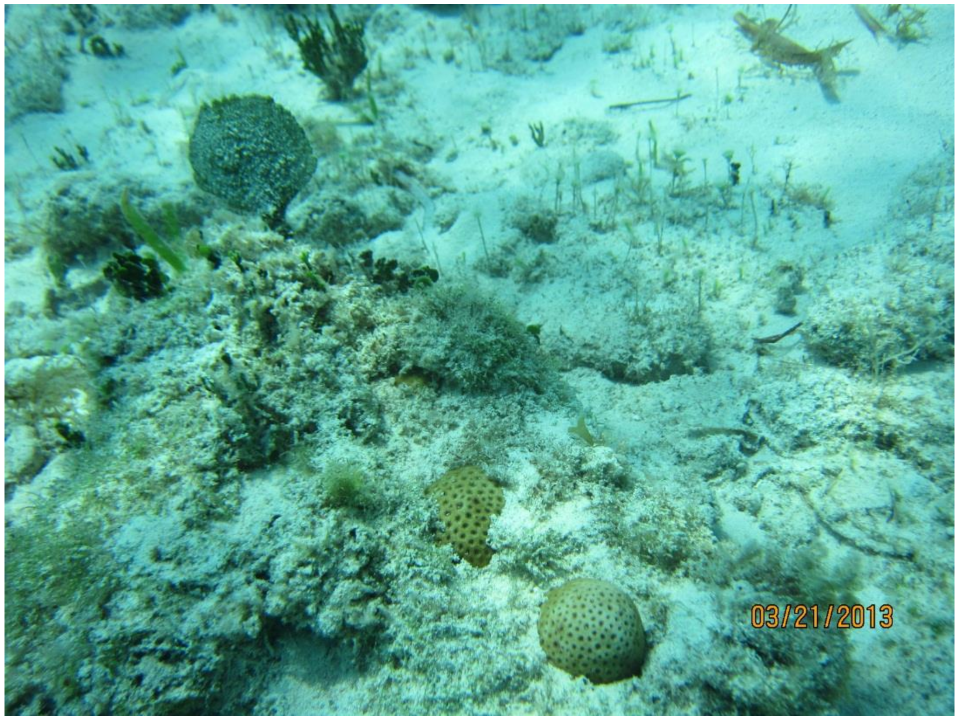


Plate 2-11 Photo showing rubble with coral in the sand patch area

Plate 2-12 Photo showing Syringodium bed

Plate 2-13 Photo showing eroded Thalassia bed with exposed rhizome network

Plate 2-14 Photo showing exposed rhizome network on the outside of the Syringodium bed

2.2.4 Backreef

The backreef area had little relief and was composed of rock, pavement and rubble. Several moderate to small coral colonies were observed (Plate 2-15) and are listed in Table 2-8. No large coral colonies were observed, nor were any endangered *Acroporid* species. Herbivory or scouring in the area appeared to be good, with large cleaned areas and limited macroalgae (Plate 2-16). Few biological nuisances were seen affecting the coral community; a few nuisance sponges (Plate 2-17), no bleaching or disease and some amount of bio erosion. It should be noted however that coral cover appeared to be low.

Table 2-8 Fish, corals, invertebrates and algae seen within the backreef area

Fish	Coral	Invertebrate
Wrasse	*Montastrea annularis*	*Chondrilla* (nuisance sponge)
Flounder	*Porites asteriodes*	Sponges
	Dichocoenia stokesi	Calcareous algae
	Siderastrea radians	Fleshy macroalgae
	Diploria strigosa	*Diadema*
	Diploria clivosa	
	Agaricia	
	Millepora	
	Gorgonians (Whips and Fans)	

Plate 2-15 Photo showing a moderately sized coral colony

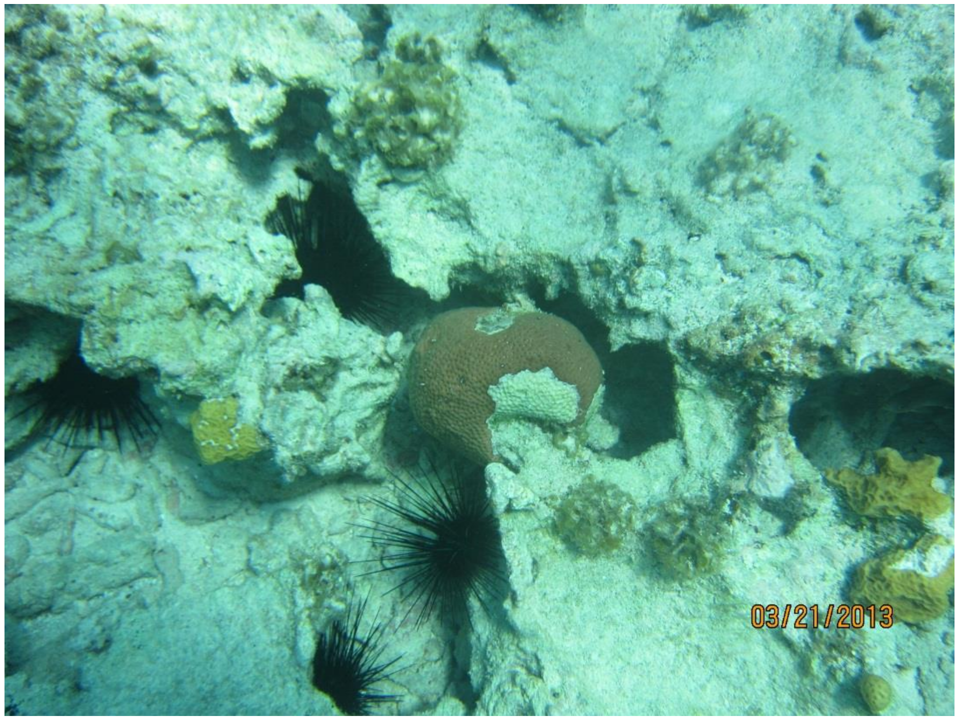


Plate 2-16 Photo showing a cleaned area with Diadema and several small coral colonies

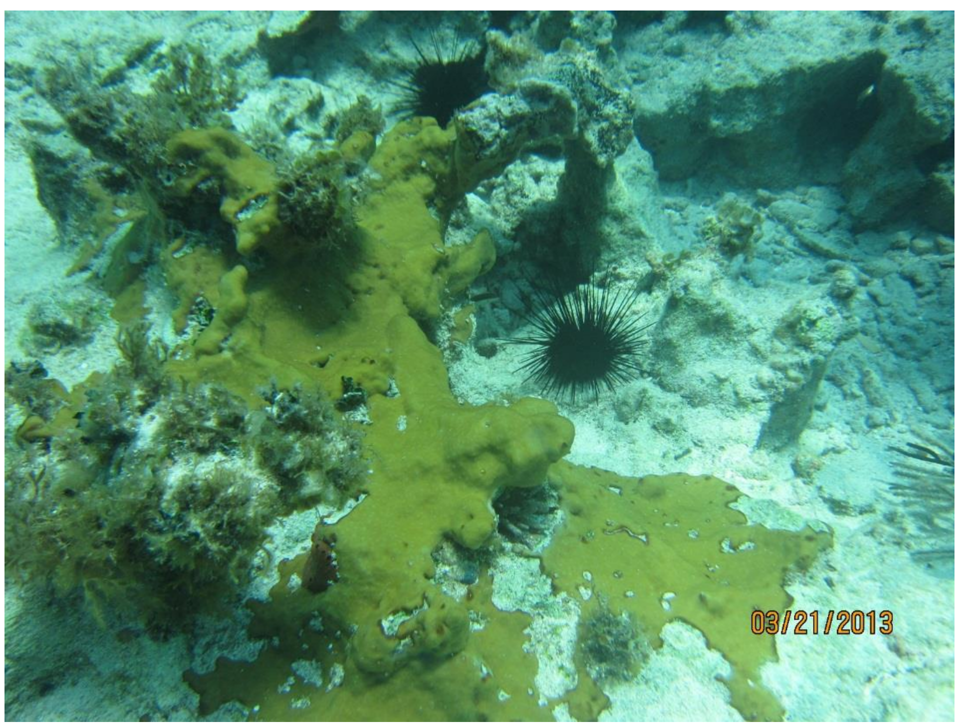


Plate 2-17 Photo showing Chondrilla (nuisance sponge)

2.2.5 Coastline and Inter-tidal Community

This community consisted of two artificial intertidal communities, the first being a rocky shore (western groyne) and the second one being a rocky and sandy island (eastern groyne). The visibility in the area was very poor and substrate consisted of silt mixed with sand. Macroalgae and seagrass was associated with rubble found around groynes and not in the bay itself.

Table 2-9 Species list found in the intertidal area

Fish	Coral	Invertebrate
Wrasse	*Montastrea sp*	Chiton
	Porites sp	
	Millepora sp	

Plate 2-18 Photo showing chitons on rocks

Plate 2-19 Vegetated sandy and rocky eastern groyne

Plate 2-20 Macroalgae growing on groyne

2.2.6 Pipeline Route

Several different habitat and substrate types were identified along the route of the pipeline (Table 2-10). Each habitat type was classified by noting the following categories of species; dominant; sensitive (corals), fish and invertebrates (Table 2-11).

Table 2-10 Table showing the various Habitat types observed along the proposed pipeline route

Substrate and Habitat description	Survey Point	Distance (m)
Sand Patch composed of coarse grain sand	start-s1	23
Thalassia dominated Seagrass bed with a sandy substrate	s1 to s2/s3	40
East of the pipeline - Thalassia seagrass bed	s2	
West of the pipeline with a sand substrate	s3	
Pavement	s2/s3-s5	160
Mixed Thalassia and Syringodium Seagrass bed	s5-s6	22
Sand Patch composed of coarse grain sand	s6-s7	7
Thalassia dominated Seagrass bed with a rocky substrate	s7-s9	52
Syringodium dominated Seagrass bed	s9-s10	65
Rubbly substrate with small seagrass patches	s10-beach line	20
Silty Sand	beach line- shoreline	52

Table 2-11 Table showing the various species observed with each habitat

Substrate and Habitat description	**Invertebrates**	**Corals**	**Fish**
Sand Patch composed of coarse grain sand	*Tripneustes, Echinometra*		
Thalassia dominated Seagrass bed with a sandy substrate			Caribbean Southern Stingray , Slippery Dick
Pavement	*Tripneustes, Echinometra, Diadema*	*Porites asteroides, Siderastrea radians*	French Angelfish, Spotted goatfish
Mixed *Thalassia* and *Syringodium* Seagrass bed			Spiny Puffer fish
Thalassia dominated Seagrass bed with a rocky substrate	*Tripneustes, Echinometra*	*Mancenia areolata*	

Sensitive species such as the small coral colonies and smaller seagrass patches can be easily avoided by shifting the pipeline to the east or west as needed. Pictures of various sections along the proposed pipeline (Plate 2-21-Plate 2-31)

Plate 2-21 *Photo showing the sand patch at the proposed start of the pipeline*

Plate 2-22 *Photo showing a sting ray on the edge of the donor sand patch*

Plate 2-23 Photo showing the edge of the donor sand patch and the seagrass bed with signs of erosion and exposed root network

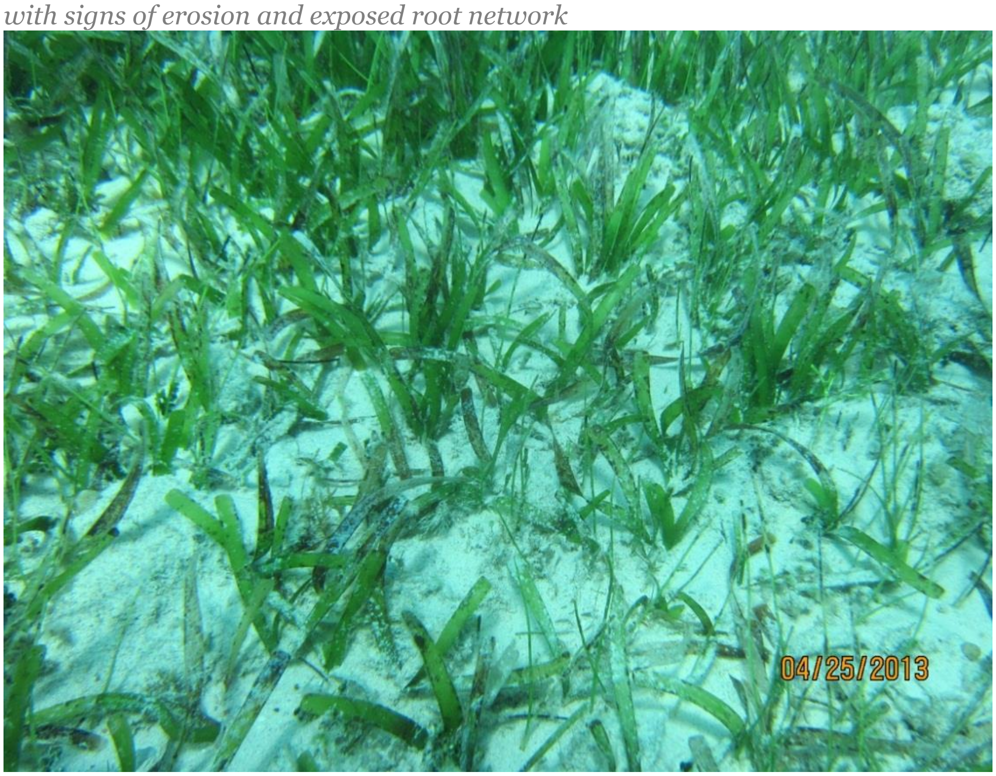


Plate 2-24 Photo showing a mixed bed, dominated by Thalassia on a rocky substrate

Plate 2-25 Photo showing a sand patch along the proposed pipeline route

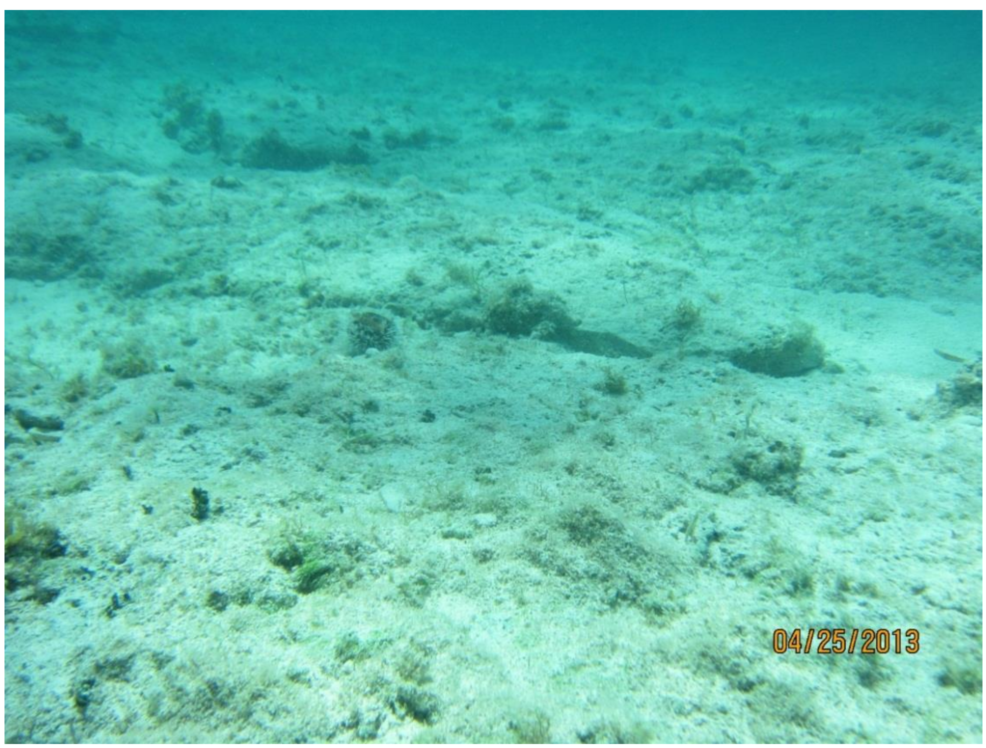


Plate 2-26 Photo showing a large area of pavement along the proposed pipeline route

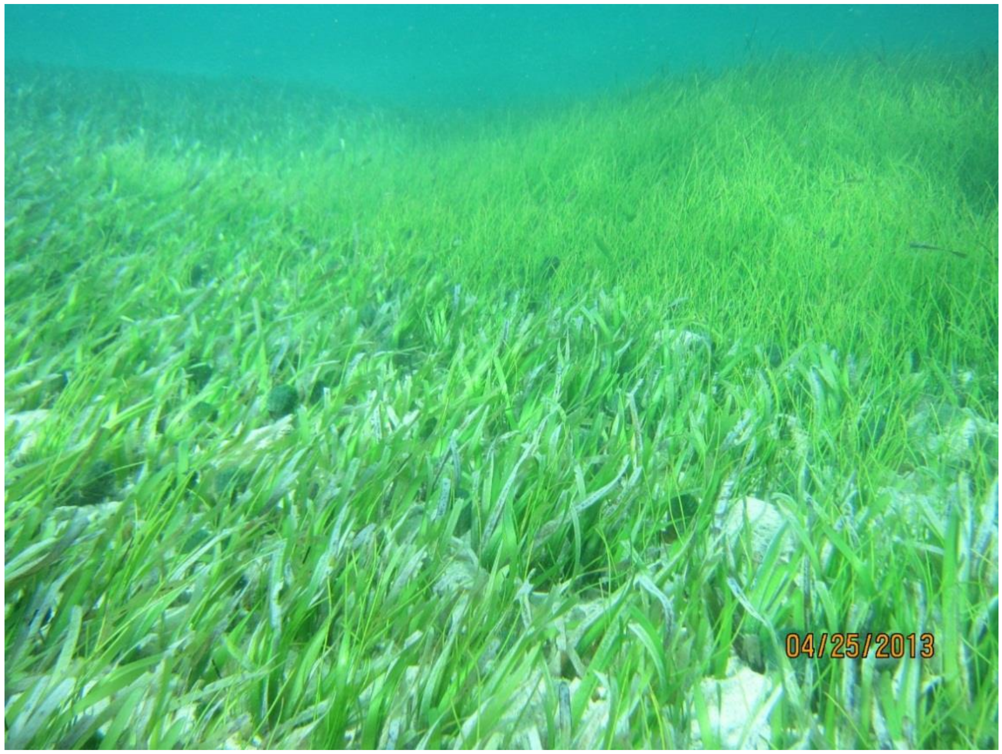


Plate 2-27 *Photo showing a 2disticnt sections of a mixed bed; the first dominated by Thalassia and the second dominated by Syringodium*

Plate 2-28 *Photo showing a small colony of Manicina areolata*

Plate 2-29 Photo showing large (deep and wide) broken sections of a seagrass bed along the proposed pipeline route

Plate 2-30 Photo showing a broken section of the seagrass bed

Plate 2-31 Photo showing small colonies of Siderastrea growing on sections of pavement along the proposed pipeline route

2.3 SEDIMENT ANALYSIS

2.3.1 Sampling Locations

Samples were collected for analysis from the beach face as well as at the sand donor site. Surface and subsurface samples were collected at different locations within the donor area. Test pits were also dug to determine the approximate depth of the sand and hence determine the available volume. See Figure 2-24 and Figure 2-25 as well as Table 2-12 for the location and description of the test pit dug and samples collected.

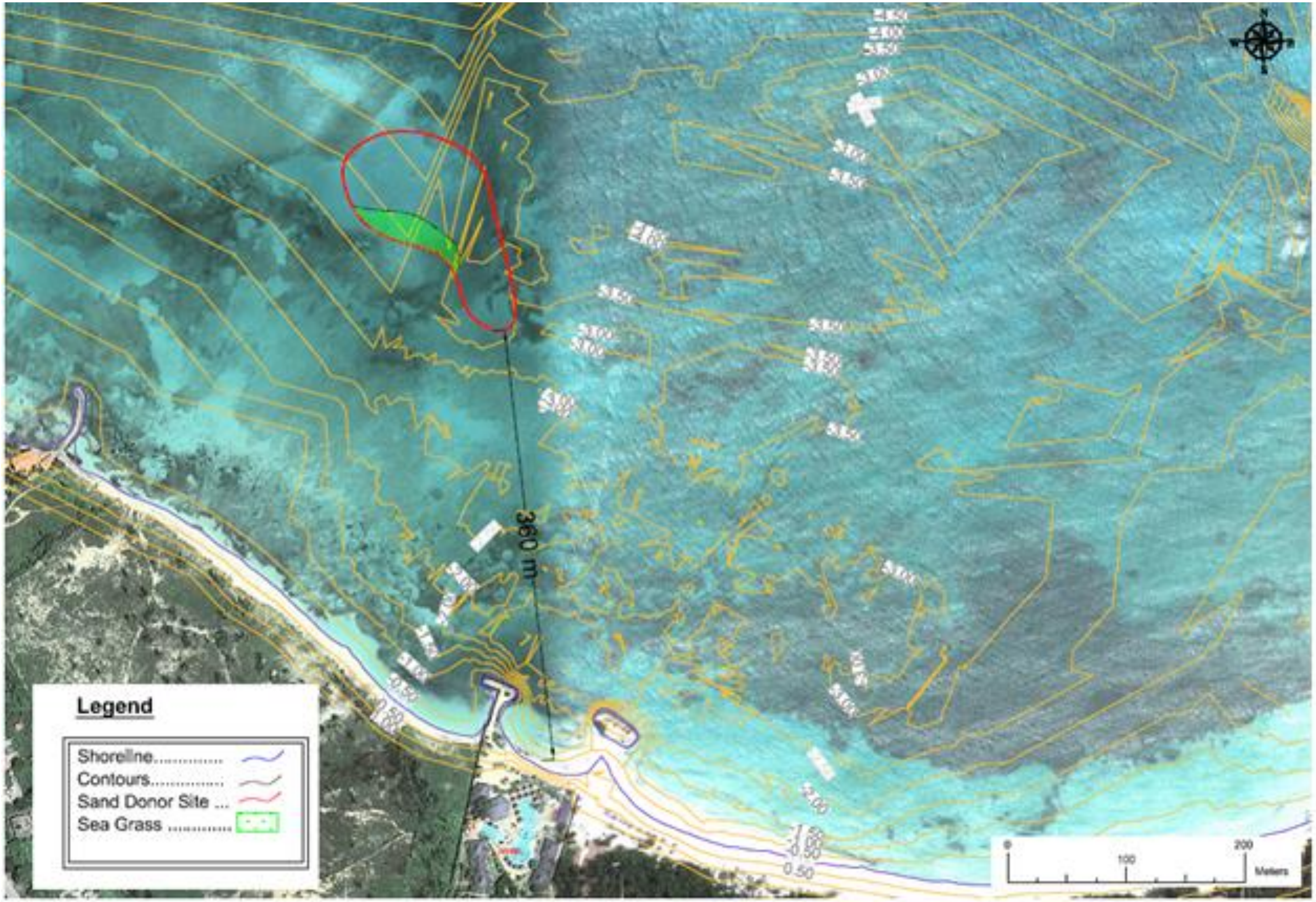


Figure 2-24 Location map of sand donor site in relation to the hotel property

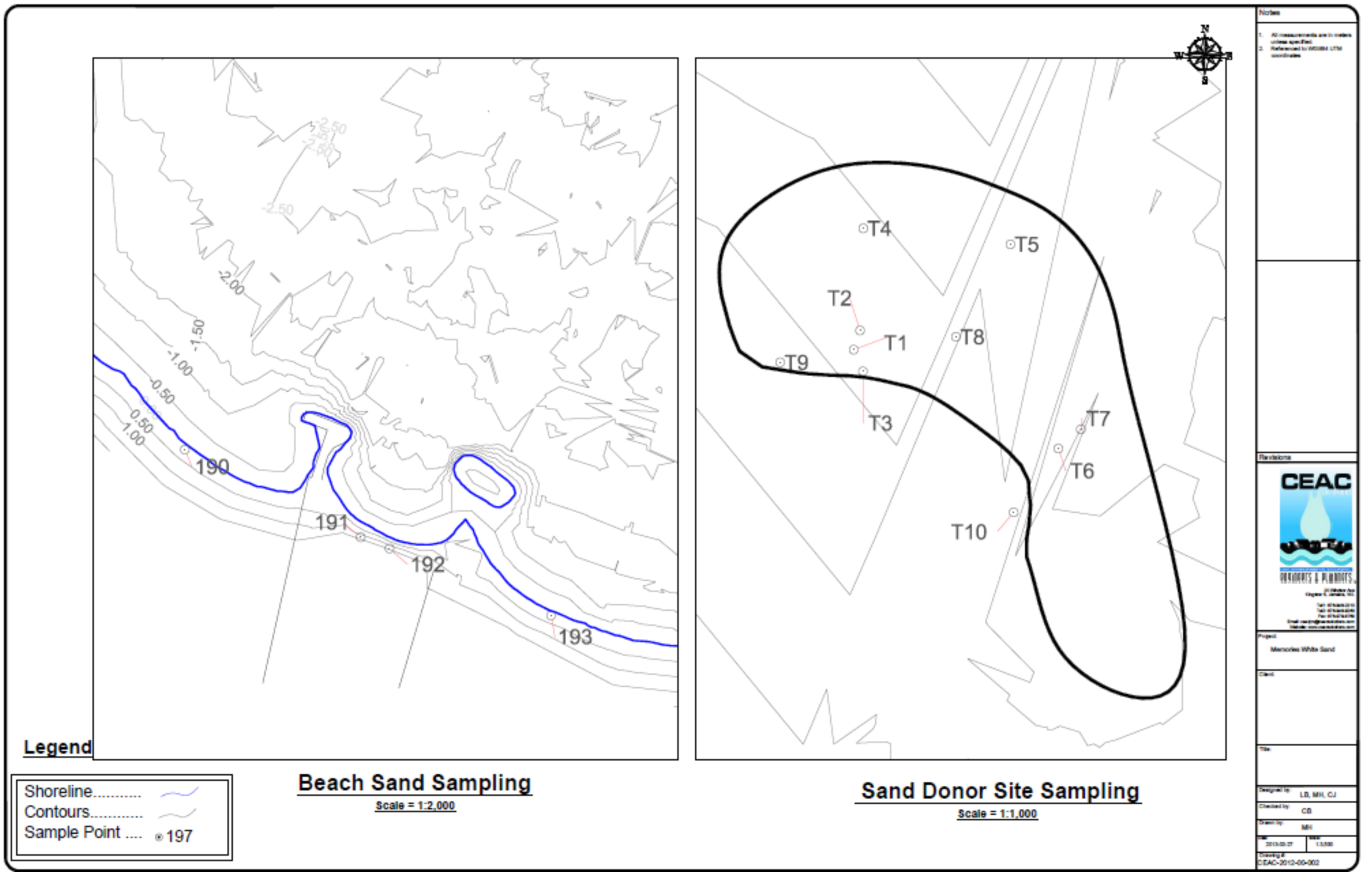


Figure 2-25 Location maps of sand sample locations

Table 2-12 Table of sand description at test site

Site ID	Description	Approximate Depth of sand
T1	Rocks visible within the sand	0.3 m
T3	Test pit collapses at approximately 0.5m, shells and coral beneath 0.5m of sand	0.5 m
T4	Very sandy area. Sand samples 1T and 1D collected	0.6 m
T5	Rocky towards sea grass. Sand sample 2D and 2T collected	0.6 m
T6	Patches of sea grass	-
T7	Sand sample 3D and 3T	0.6m
T8	Centre of sand patch	0.6 m
T9	Very rocky area	-
T10	Area dominated by rocks and grass.	-

Based on the sampling and test pits, the volume of sand that the site could yield was estimated to be 6,800 m^3 (see Table 2-13). The overall area was divided into two priority areas based on the description of the sea floor within the area. Priority area 1 was predominantly sand while priority area 2 had out crops of rocks.

Table 2-13 Table of estimated volume of available sand

	Approximate Area (m2)	Aproximate Volume (m3)
Priority Area 1	7,300	4,380
Priority Area 2	4,100	2,460
Total	11,400	6,840

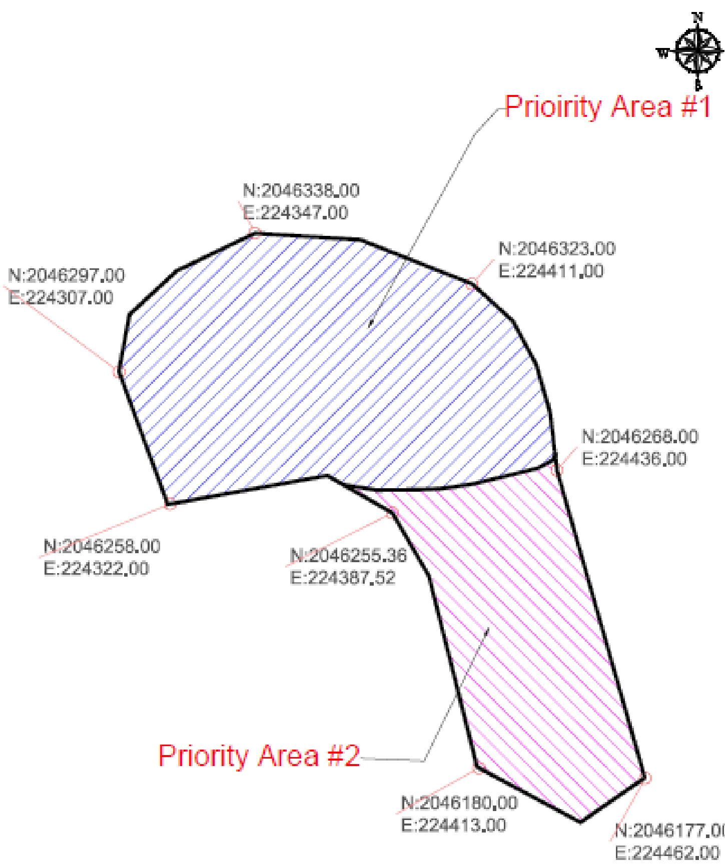


Figure 2-26 Diagram showing priority areas of donor site (coordinates in WGS84)

2.3.2 Grain Size Analysis

The samples were dried and sieved using ASTM standard sieves and the results analysed. The analysis includes coefficient of uniformity, standard deviation, skewness and kurtosis.

2.3.2.1 Existing shoreline

The grain size analysis was done using the unified classification which is widely used for classification of granular material. The sand sizes varied from medium sand to the west of the beach and coarse sand in front of the beach. The following is a summary:

- The sample collected to the west of the beach was medium sand, having a mean grain size of 0.336mm.
- The samples collected at the beach area were coarse sand with mean grain sizes between 0.651mm to 0.790 mm.
- The sample collected to the east of the beach was coarse sand, having a mean grain size of 0.722mm.

The lack of silt present in the sand samples are consistent what was observed on the beach.

Table 2-14 Summarized grain size analysis for the existing shoreline sand samples

Donor Site Samples	Beach Samples			
Sample ID	190	191	192	193
GRAIN SIZE ANALYSIS RESULTS				
Mean (mm)	0.336	0.790	0.651	0.722
Mean (phi)	1.574	0.340	0.618	0.469
Description	medium sand	coarse sand	coarse sand	coarse sand
Percentage silt	0.0%	0.0%	0.0%	0.0%
Percentage >0.06mm and <6.0 mm	100%	99%	100%	100%
Uniformity Coefficient	1.847	2.676	3.555	2.372
Standard Deviation	-0.222	0.947	0.940	0.710
	well sorted	moderately sorted	moderately sorted	moderately sorted
Skewness	50.837	0.440	1.076	1.003
	V. strongly positive skewed	strongly positive skewed	V. strongly positive skewed	V. strongly positive skewed
Kurtosis	2.351	1.415	0.991	2.198
	very leptokurtic	leptokurtic	mesokurtic	very leptokurtic

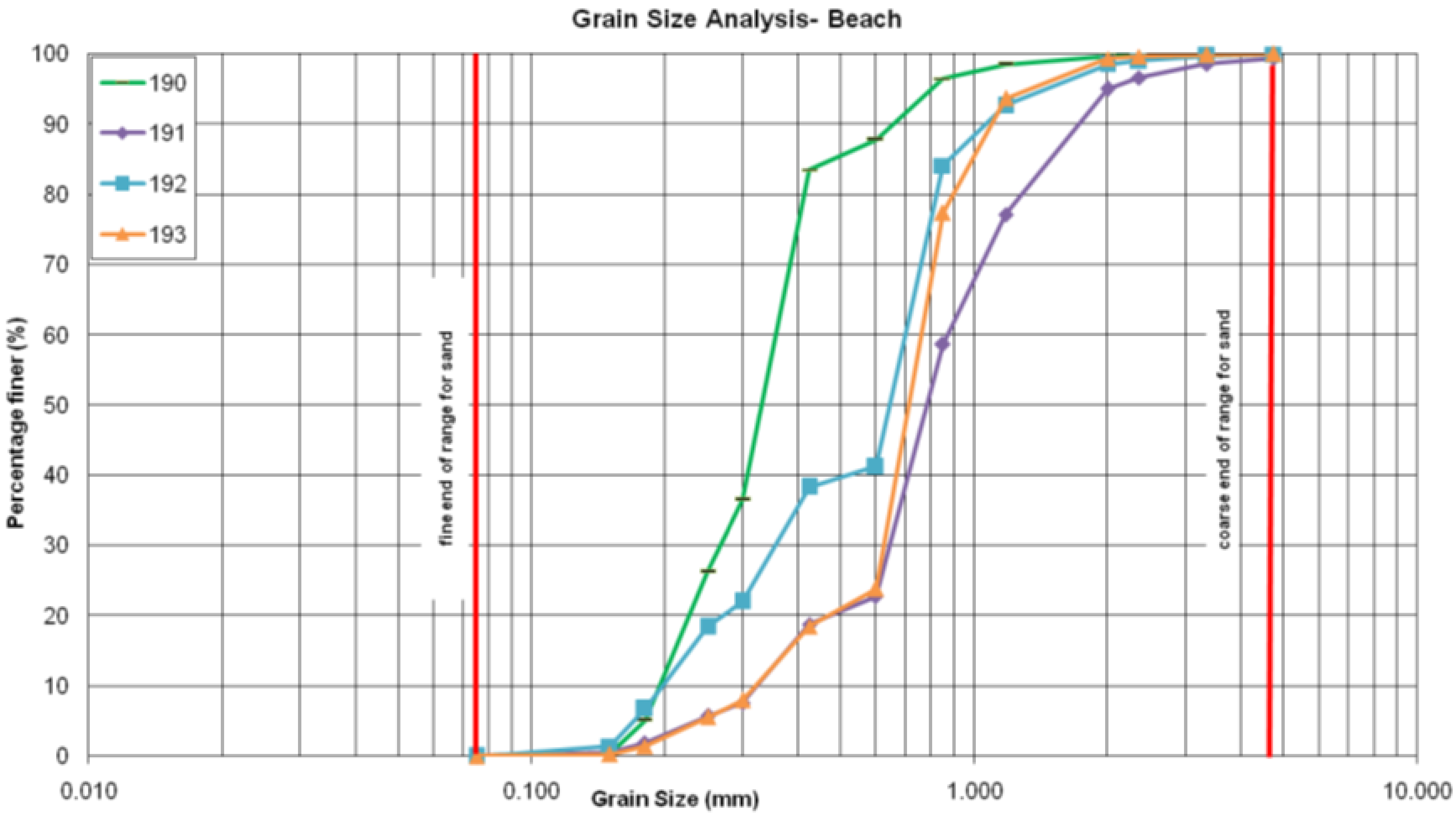


Figure 2-27 Graph showing grain size plot for existing shoreline sand samples

2.3.2.2 Donor Site

The grain size analysis was done using the unified classification which is widely used for classification of granular material. The analysis showed a rather consistent sand size throughout the sand reserve. The samples collected were all coarse sand, having a mean grain size range from 0.686mm to 0.867mm. The very low percentage of silt makes this sand well suited for beach application.

Table 2-15 Summarized grain size analysis of sand samples collected from the donor site.

	Donor Site Samples					
Sample ID	**T5-subsurface**	**T7-Subsurface**	**T4-Subsurface**	**T4-Surface**	**T5-Surface**	**T7-surface**
GRAIN SIZE ANALYSIS RESULTS						
Mean (mm)	0.686	0.699	0.867	0.800	0.686	0.703
Mean (phi)	0.543	0.517	0.207	0.322	0.543	0.509
Description	coarse sand	coarse sand	coarse sand	coarse sand	coarse sand	coarse sand
Percentage silt	0.03%	0.03%	0.0%	0.0%	0.0%	0.0%
Percentage >0.06mm and <6.0 mm	100%	100%	98%	100%	100%	100%
Uniformity Coefficient	2.125	2.012	2.740	2.226	2.059	1.823
Standard Deviation	-0.495	-0.456	-1.685	-1.140	-0.473	-0.409
	well sorted	well sorted	well sorted	well sorted	well sorted	well sorted
Skewness	13.018	14.129	2.669	4.290	13.319	14.831
	V. strongly positive skewed	V. strongly positive skewed	V. strongly positive skewed	V. strongly positive skewed	V. strongly positive skewed	V. strongly positive skewed
Kurtosis	1.118	1.126	0.982	0.876	1.061	0.987
	leptokurtic	leptokurtic	mesokurtic	platykurtic	mesokurtic	mesokurtic

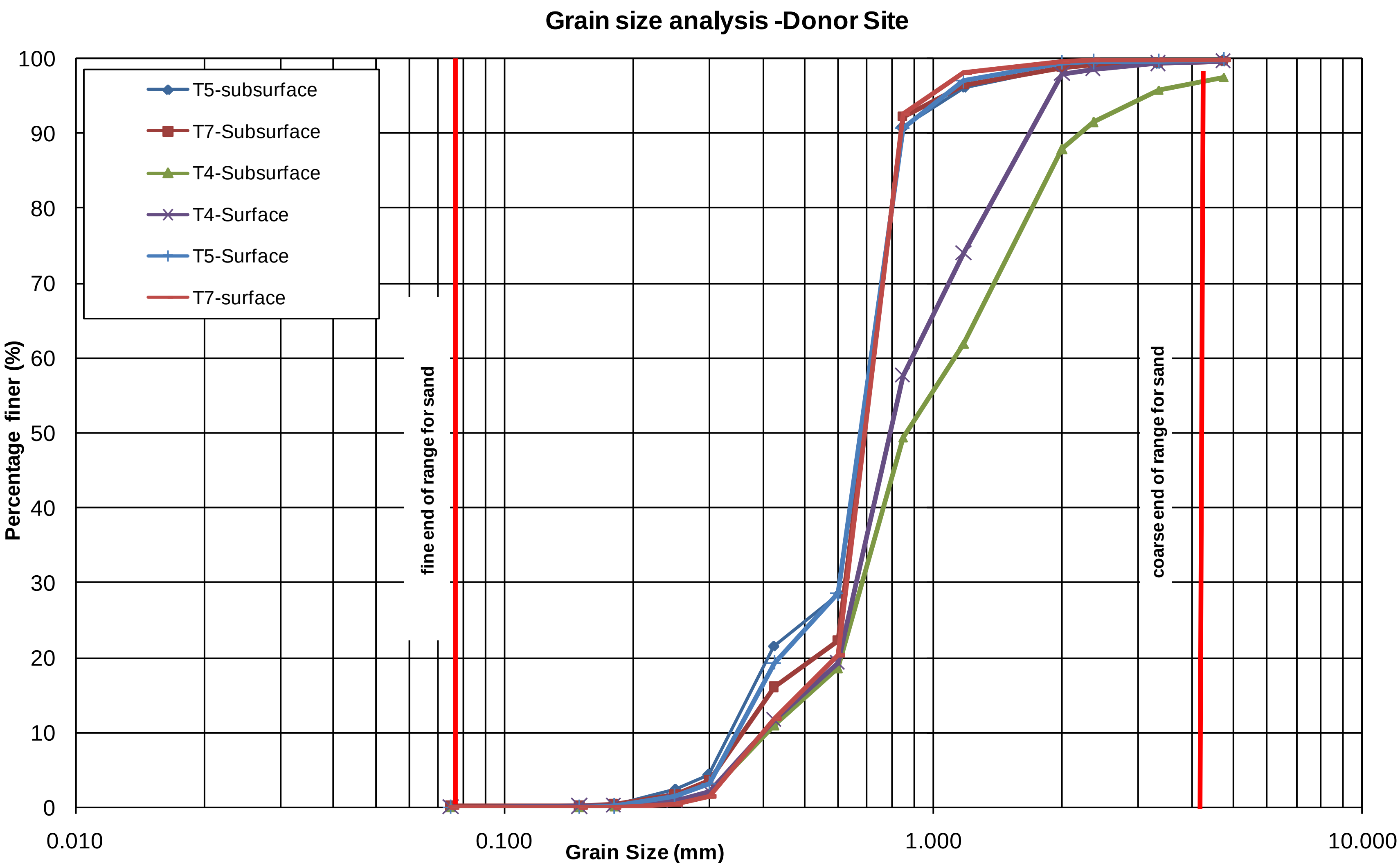


Figure 2-28 Graph showing plot of grain size for sand reserve sand samples

2.3.2.3 Uniformity coefficient

The uniformity coefficient is a measure of the variation in particle sizes. It is defined as the ratio of the size of particle that has 60 percent of the material finer than itself, to the size of the particle that has 10 percent finer than itself.

The uniformity coefficient is calculated as $Uc = D_{60}/D_{10}$

Where U_c – uniformity coefficient

D_{60} - The grain size, in mm, for which 60% by weight of a soil sample is finer

D_{10} - The grain size, in mm, for which 10% by weight of a soil sample is finer

Within the unified classification system, the sand is well graded if U_c is greater than or equal to 6.

Beach Shoreline

All the samples analysed had uniformity coefficient less than 6, ranging from 1.8 to 3.5 .

The soils can be classified as sorted. This is indicative of wave energy suspending finer particles and removing them offshore and depositing coarser particles on shore.

Donor Site

All the samples analysed had uniformity coefficient less than 6, ranging from 1.8 to 4.02 thus they can be classified as sorted.

2.3.2.4 Standard Deviation

The Standard deviation is a measure of the degree of sorting of the particles in the sample. A standard deviation of one or less defines a sample that is well sorted while values above one are poorly sorted.

The sand samples for the respective beaches are:

Beach Shoreline

- Eastern sample (190) - well sorted
- Other sample (191, 192, 193) - all samples were moderately sorted

This is indicative of relatively high wave energy at the shoreline which sorts the particles into their discrete sizes.

Donor Site

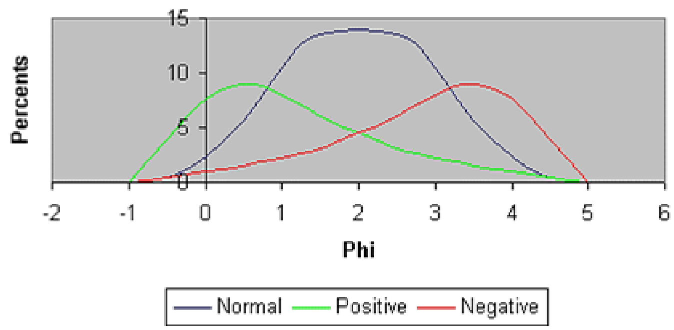
The sediment from the donor site showed well sort characteristics with standard deviation ranging from -409 to - 1.14.

2.3.2.5 Skewness

Skewness describes the shift in the distribution about the normal. The skewness is described by the equation:

$$S = \frac{\phi 84 + \phi 16 - 2(\phi 50)}{2(\phi 84 - \phi 16)} + \frac{\phi 95 + \phi 5 - 2(\phi 50)}{2(\phi 95 - \phi 5)}$$

This formula simply averages the skewness obtained using the 16 phi and 84 phi points with the skewness obtained by using the 5 phi and 95 phi points, both determined by exactly the same principle. This is the best skewness measure to use because it determines the skewness of the "tails" of the curve, not just the central portion, and the "tails" are just where the most critical differences between samples lie. Furthermore, it is geometrically independent of the sorting of the sample.



Symmetrical curves have skewness=0.00; those with excess fine material (a tail to the right) have positive skewness and those with excess coarse material (a tail to the left) have negative skewness. The more the skewness value departs from 0.00, the greater the degree of asymmetry. The following verbal limits on skewness are suggested: for values of skewness:

Values from	To	Mathematically:	Graphically Skewed to the:
+1.00	+0.30	Strongly positive skewed	Very Negative phi values, coarse
+0.30	+0.10	Positive skewed	Negative phi values
+0.10	- 0.10	Near symmetrical	Symmetrical
- 0.10	- 0.30	Negative skewed	Positive phi values
- 0.30	- 1.00	Strongly negative skewed	Very Positive phi values, fine

Beach Shoreline

The results for skewness for the stretch of shoreline showed high positive skewness ranging from 0.44 to 50.8 . This is indicative of a long coarse tail of particles and an aggressive wave climate that washes out the fines particles.

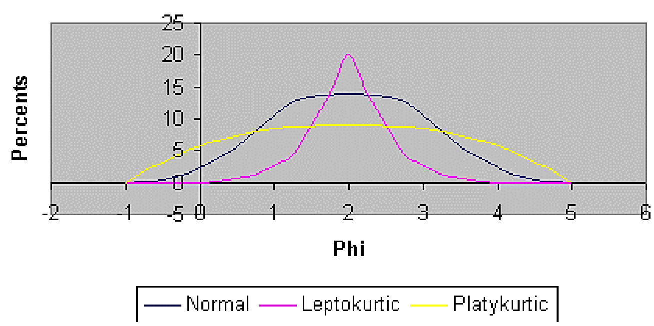
Donor Site

The skewnesss results for the samples inside the sand reserve also showed high positive skewness ranging from 2.69 to 14.83.

2.3.2.6 Kurtosis

Kurtosis describes the degree of peakedness or departure from the "normal" frequency or cumulative curve

In the normal probability curve, defined by the gaussian formula; the phi diameter interval between the 5 phi and 95 phi points should be exactly 2.44 times the phi diameter interval between the 25 phi and 75 phi points. If the sample curve plots as a straight line on probability paper (i.e., if it follows the normal curve), this ratio will be obeyed and we say it has normal kurtosis (1.00). Departure from a straight line will alter this ratio, and kurtosis is the quantitative measure used to describe this departure from normality. It measures the ratio between the sorting in the "tails" of the curve and the sorting in the central portion. If the central portion is better sorted than the tails, the curve is said to be excessively peaked or leptokurtic; if the tails are better sorted than the central portion, the curve is deficiently or flat-peaked and platykurtic.



Strongly platykurtic curves are often bimodal with subequal amounts of the two modes; these plot out as a two-peaked frequency curve, with the sag in the middle of the two peaks accounting for its platykurtic character. For normal curves, kurtosis equals 1.00. Leptokurtic curves have a kurtosis over 1.00 (for example a curve with kurtosis=2.00 has exactly twice as large a spread in the tails as it should have, hence it is less well sorted in the tails than in the central portion); and platykurtic have kurtosis under 1.00. Kurtosis involves a ratio of spreads; hence it is a pure number and should not be written with a phi attached. The following verbal limits are suggested for values of kurtosis:

Values from	To	Equal
0.41	**0.67**	very platykurtic
0.67	**0.90**	platykurtic
0.90	**1.11**	mesokurtic
1.10	**1.50**	leptokurtic
1.50	**3.00**	very leptokurtic
3.00	∞	extremely leptokurtic

Beach Shoreline

A similar trend was observed in the Kurtosis analysis as was observed in the skewness analysis. The following is a summary:

- The eastern and western beach sediment is very leptokurtic. This is indicative of aggressive coastal processes that sort out the particles into a discrete particle size.
- The central beach is leptokurtic to mesokurtic. This is indicative of mild to moderate sediment transport.

Donor Site

The samples collected within the sand reserve area showed characteristics ranging from platykurtic to mesokurtic to very lepokurtic.

2.3.2.7 Summary

Based on the grain size analysis done on the sand samples taken from the donor site, the sand is similar to that of the native sand on the existing beach. The average mean grain size of the existing beach is 0.72 mm while the average mean grain size of the donor site is 0.74 mm. This similarity in the mean grain size means that the sand is suitable for use on the beach.

3.0 WAVE CLIMATE ANALYSIS

3.1 DEEP WATER HURRICANE WAVE CLIMATE

3.1.1 Methodology

It was necessary to define the deepwater hurricane wave climate at the site as a part of defining the wave climate that the shoreline is subject to. Hurricane wave track data in the Caribbean Sea was available which enabled us to carry out a thorough statistical analysis to determine the hurricane wind and wave conditions at a deep-water location offshore the site.

A database of hurricanes, dating back to 1886, was searched for storms that passed within a 300km radius from the site. The following procedure was carried out.

1. **Extraction of storms and storm parameters from the historical database:** A historical database of storms was searched for all storms passing within a 300km radius of the site.
2. **Application of the JONSWAP wind-wave model.** A wave model was used to determine the wave conditions generated at the site due to the rotating hurricane wind field. This is a widely applied model and has been used for numerous engineering problems. The model computes the wave height from a parametric formulation of the hurricane wind field.
3. **Application of extremal statistics.** Here the predicted maximum wave height from each hurricane was arranged in descending order and each assigned an exceedance probability by Weibull's distribution.
4. A bathymetric profile from deepwater to the site was then defined and each hurricane wave transformed along the profile. The wave height at the nearshore end of the profile was then extracted from the model and stored in a database. All the returned nearshore values were then subjected to an Extremal Statistical analysis and assigned exceedance probabilities with a Weibull distribution.

3.1.1.1 Results

It was important to analyse the hurricane wave climate and its impact on the Mountain Spring Bay shoreline as Hurricanes which pass south of the bay generate waves which directly impact this shoreline. As mentioned previously, Hurricane track data were obtained for storms passing within 300 km offshore. This data was used in the storm surge model to generate the incident wave heights and periods expected from the different directions.

The results of the search clearly indicate that 93 hurricane systems came within 300 kilometres of the site between the start of records in 1852 until the year 2012. This relatively large number speaks to the site's overall vulnerability to such systems and the likelihood of events occurring relatively frequently.

Table 3-1 Name of storms that passed within 300 km of Memories since 1886.

Storm No.	Name	Date	Max. SS Category	
420	NOTNAMED	1909	3-	EXTENSIVE
426	NOTNAMED	1910	1-	WEAK
427	NOTNAMED	1910	3-	EXTENSIVE
433	NOTNAMED	1911	1-	WEAK
439	NOTNAMED	1912	4-	EXTREME
446	NOTNAMED	1915	4-	EXTREME
448	NOTNAMED	1915	2-	MODERATE
453	NOTNAMED	1916	3-	EXTENSIVE
466	NOTNAMED	1917	3-	EXTENSIVE
492	NOTNAMED	1923	1-	WEAK
503	NOTNAMED	1924	2-	MODERATE
522	NOTNAMED	1927	1-	WEAK
526	NOTNAMED	1928	1-	WEAK
540	NOTNAMED	1931	2-	MODERATE
550	NOTNAMED	1932	3-	EXTENSIVE
553	NOTNAMED	1932	4-	EXTREME
557	NOTNAMED	1933	1-	WEAK
560	NOTNAMED	1933	1-	WEAK
572	NOTNAMED	1933	4-	EXTREME
573	NOTNAMED	1933	2-	MODERATE
585	NOTNAMED	1934	1-	WEAK
590	NOTNAMED	1935	3-	EXTENSIVE
591	NOTNAMED	1935	1-	WEAK
630	NOTNAMED	1939	2-	MODERATE
653	NOTNAMED	1942	1-	WEAK
668	NOTNAMED	1944	3-	EXTENSIVE
686	NOTNAMED	1945	2-	MODERATE
698	NOTNAMED	1947	1-	WEAK
708	NOTNAMED	1948	3-	EXTENSIVE
721	NOTNAMED	1949	2-	MODERATE
734	KING	1950	3-	EXTENSIVE
739	CHARLIE	1951	4-	EXTREME
763	NOTNAMED	1953	1-	WEAK
786	HILDA	1955	3-	EXTENSIVE
811	ELLA	1958	3-	EXTENSIVE
813	GERDA	1958	1-	WEAK
842	GERDA	1961	1-	WEAK
857	FLORA	1963	4-	EXTREME
864	CLEO	1964	4-	EXTREME
886	INEZ	1966	4-	EXTREME
923	ALMA	1970	1-	WEAK
960	GILDA	1973	2-	MODERATE
974	CAROLINE	1975	3-	EXTENSIVE
976	ELOISE	1975	3-	EXTENSIVE
1011	CLAUDETTE	1979	1-	WEAK
1014	FREDERIC	1979	4-	EXTREME
1018	ALLEN	1980	5-	CATASTROPHIC
1029	ARLENE	1981	1-	WEAK
1095	GILBERT	1988	5-	CATASTROPHIC
1154	GORDON	1994	1-	WEAK
1224	DEBBY	2000	1-	WEAK
1228	HELENE	2000	1-	WEAK
1259	ISIDORE	2002	3-	EXTENSIVE
1262	LILI	2002	4-	EXTREME
1326	IVAN	2004	5-	CATASTROPHIC
1336	DENNIS	2005	4-	EXTREME
1366	ERNESTO	2006	1-	WEAK
1385	OLGA	2007	1-	WEAK
1400	FAY	2008	1-	WEAK
1401	GUSTAV	2008	4-	EXTREME
1410	PALOMA	2008	4-	EXTREME
1411	SANDY	2012	3-	EXTENSIVE
1095	GILBERT	1988	5-	CATASTROPHIC

Extremal analysis results are summarized for reference Table 3-2 and Table 3-4. The bi-variant table generated indicates the waves generated off the north coast originate most frequently from the NW to NE direction. It must be noted that waves were also being generated from the East and West but will have less of a direct impact on the site that those from the northeast to northwest.

Table 3-2 Bi-variant table showing incident wave heights and periods for the specific return periods and directions

Return Periods	Wave properties (m)																	
	All		SW		W		NW		N		NE		E		SE		S	
	Hs	Tp	Hs	Tp	Hs	Tp	Hs	Tp	Hs	Tp	Hs	Tp	Hs	Tp	Hs	Tp	Hs	Tp
1	2.0	7.2	0.0	0.0	1.0	5.1	1.0	5.1	1.0	5.1	1.0	5.1	1.0	5.1	0.0	0.0	0.0	0.0
2	3.7	9.6	0.0	0.0	3.7	9.6	3.6	9.5	3.4	9.3	3.6	9.6	4.5	10.6	0.0	0.0	0.0	0.0
5	4.8	11.0	0.0	0.0	4.6	10.8	4.6	10.7	4.4	10.5	4.4	10.5	5.5	11.7	0.0	0.0	0.0	0.0
10	5.5	11.7	0.0	0.0	5.1	11.3	5.1	11.3	4.9	11.0	4.9	11.0	6.1	12.3	0.0	0.0	0.0	0.0
20	6.2	12.4	0.0	0.0	5.5	11.7	5.6	11.8	5.3	11.5	5.2	11.4	6.5	12.7	0.0	0.0	0.0	0.0
25	6.4	12.5	0.0	0.0	5.7	11.8	5.7	11.9	5.4	11.6	5.3	11.5	6.6	12.8	0.0	0.0	0.0	0.0
50	6.9	13.1	0.0	0.0	6.0	12.2	6.1	12.3	5.7	11.9	5.6	11.8	7.0	13.1	0.0	0.0	0.0	0.0
75	7.2	13.3	0.0	0.0	6.2	12.4	6.3	12.5	5.9	12.1	5.7	11.9	7.1	13.3	0.0	0.0	0.0	0.0
100	7.4	13.5	0.0	0.0	6.3	12.5	6.4	12.6	6.1	12.2	5.8	12.0	7.3	13.4	0.0	0.0	0.0	0.0
150	7.7	13.8	0.0	0.0	6.5	12.6	6.6	12.8	6.2	12.4	5.9	12.1	7.4	13.5	0.0	0.0	0.0	0.0
200	7.9	14.0	0.0	0.0	6.6	12.7	6.7	12.9	6.3	12.5	6.0	12.2	7.5	13.6	0.0	0.0	0.0	0.0

The most intense hurricane waves have been noted to come from the eastern direction. The Extremal analysis results indicate that the 100-year return period event has a wave height of 7.3 m for eastern waves. Considering this, the directions to be modelled includes the north western, north, north east and east directions.

Overall, these are relatively large waves with potential for wreaking severe damage on the beach. Their potential resulting near shore climates were investigated using a wave refraction diffraction model as outlined in the section for nearshore wave climate below.

Table 3-3 Summary of the total setups for the offshore node selected

Return Period	Total setup (m)								
	All	SW	W	NW	N	NE	E	SE	S
1	NaN	0.00	NaN	NaN	NaN	0.10	0.10	0.00	0.00
2	0.16	0.00	0.10	NaN	NaN	0.44	0.68	0.00	0.00
5	0.50	0.00	0.16	0.16	0.26	0.69	1.00	0.00	0.00
10	0.84	0.00	0.23	0.22	0.40	0.85	1.18	0.00	0.00
20	1.23	0.00	0.31	0.29	0.53	0.99	1.34	0.00	0.00
25	1.37	0.00	0.33	0.31	0.57	1.04	1.39	0.00	0.00
50	1.81	0.00	0.43	0.38	0.69	1.17	1.52	0.00	0.00
75	2.08	0.00	0.49	0.43	0.76	1.24	1.60	0.00	0.00
100	2.28	0.00	0.53	0.46	0.82	1.29	1.65	0.00	0.00
150	2.58	0.00	0.59	0.51	0.89	1.36	1.72	0.00	0.00
200	2.79	0.00	0.64	0.55	0.94	1.40	1.77	0.00	0.00

The maximum storm surge that is estimated for this location is approximately 1.65 for the 100 year event. This is especially important for the setting of the floor levels on the site.

Table 3-4 Bi-variant table showing incident wave heights and periods for the directions.

Wind direction- NW

Tp(s)	Wave height(m)										Total
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6		16	1								17
8		26	10								36
10			10	2							12
12											
14											
16											
18											
20											
Total		42	21	2							65

Wind direction- N

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6		12									12
8		7	2								9
10			5								5
12											
14											
16											
18											
20											
Total		19	7								26

Wind direction- NE

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6		10									10
8		18	5								23
10			6								6
12											
14											
16											
18											
20											
Total		28	11								39

Wind direction- W

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6		13									13
8		31	14								45
10		1	15	1							17
12											
14											
16											
18											
20											
Total		45	29	1							75

All directions

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6		57	1								58
8		94	47								141
10		1	52	8							61
12											
14											
16											
18											
20											
Total		152	100	8							260

Wind direction- E

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6		4									4
8		11	16								27
10			14	5							19
12											
14											
16											
18											
20											
Total		15	30	5							50

Wind direction- SW

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6		1									1
8											
10											
12											
14											
16											
18											
20											
Total		1									1

Wind direction- S

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6											
8											
10											
12											
14											
16											
18											
20											
Total											

Wind direction- SE

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6		1									1
8		1									1
10			2								2
12											
14											
16											
18											
20											
Total		2	2								4

3.1.2 Operational and Swell Wave Data

Historical wave climate data were obtained from the NOAA weather service database for the period 1999 to 2007 at 3 hour intervals for an offshore node (Easting: 226035.57, Northing: 2046566.10). This data was used to generate bi-variant tables for the mean wave heights versus periods as well as the wave height versus direction.

The operational wave was then determined as the 50 percent wave occurring at the site whereas the swell were waves estimated by taking the highest 5 percent waves from the bi-variant table. Please see Table 3-6 and Table 3-7 which shows the bi-variant tables generated from the historical data and Table 3-5 which shows the incident operational and swell wave data deduced.

Table 3-5 Wave heights and periods used in the wave modelling process for Mountain Spring Bay

	Operational		Swell	
	Ts (s)	**Hs (m)**	**Ts (s)**	**Hs (m)**
NE	5.5	0.8	7.5	1.6
ENE	5.5	0.8	7.5	1.6
E	5.5	0.8	7.5	1.6

Table 3-6 Bi-variant table showing the occurrences of wave heights with respect to wave periods offshore Mountain Spring Bay

Count of Wave hieght Round	Wave hieght Round																									
Wave period Round	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	4.4	4.8	5.6	6.2	6.4	6.8	7.8	Grand Total
2.5		1	5																							6
3	4	46	172	41	4																					267
3.5	8	137	547	423	31																					1146
4	55	258	579	893	476	52	1																			2314
4.5	62	215	456	760	977	616	121	10	1		1															3219
5	45	154	392	583	602	651	437	181	31	3			1													3080
5.5	96	208	294	395	510	466	391	272	131	29	6															2798
6	105	409	303	256	306	298	289	189	136	68	30	12	3													2404
6.5	94	589	552	151	140	156	147	160	124	72	32	7		1												2225
7	34	265	749	368	119	58	60	77	111	72	37	26	7	1	2	1										1987
7.5	61	76	278	430	263	96	27	11	18	29	37	26	8	3		1	1	1								1366
8	25	29	68	136	146	50	15	9	5	1		2														486
8.5	21	29	18	25	43	25	6	5	5				1	1					1							180
9	30	26	18	21	22	10	2	6	1	3	1		2													142
9.5	11	16	10	17	3	3	2	3	6			1			1					1	1					75
10	10	23	6	9	12	4	4		5		1		2	1	1		1						1			80
10.5	3	2	4	5			3	2	2	1				1	2									1	1	27
11	2	12	14	1		1		2	2		1	1		2								1				39
11.5	1	6	4	1			1		5	1					1											20
12	1	3	5	1			1	1	2	1																15
12.5		1	4		1	1		1	2	1		1					1									13
13	3		4	2	1																					10
13.5			3	3																						6
14			3																							3
14.5			2	1																						3
15			1																							1
	4	7	6																							17
Grand Total	675	2512	4497	4522	3656	2487	1507	929	587	281	146	76	24	10	7	2	3	1	1	1	1	1	1	1	1	21929

Table 3-7 Bi-variant table showing the occurrences of wave heights with respect to direction offshore Mountain Spring Bay

Count of Wave hieght Round	Wave hieght Round																									
Wave direction round	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	4.4	4.8	5.6	6.2	6.4	6.8	7.8	Grand Total
11.25	4	10	17	34	20	32	20	15	12	4	1	1														170
22.5	2	16	31	40	37	30	28	25	19	10	5	1														244
33.75	4	16	38	77	78	51	53	33	12	6	7	2														377
45	4	13	51	78	64	100	72	51	34	5	11	4														487
56.25	11	34	93	140	119	109	59	54	24	10	4	1	1	1												660
67.5	39	97	241	211	159	173	109	68	33	27	16	5		1												1179
78.75	154	355	719	839	765	715	594	415	292	165	78	48	14	2	1											5156
90	136	426	1170	1526	1371	822	387	171	83	33	8	6	2		1	2				1				1	1	6147
101.25	175	1095	1745	1329	849	353	108	41	13	6	7	2	1	2			1	1	1		1	1	1			5732
112.5	103	278	230	84	63	8	4	1	1	1	1	2					1									777
123.75	3	1	8	6	4																					22
135	1	2	1	4	4	1	1		1																	15
146.25		3	3	3	1	1	1																			12
157.5		7	2	2	8																					19
168.75		4	1	7				1	1																	14
180	1	3	2	1				1			1															9
191.25		4	5	3									1		1		1									15
202.5	3	6	6	3	2																					20
213.75	4	8	3	4	1				1						1											22
225		10	2	7	8	3		1	4		1				1											37
236.25		13	5		7	4			1					1	1											32
247.5		10	9	5	13	4	4						1	1												47
258.75		6	7	1	5	5	4	5	11		1			1	1											47
270		1	6	2	12	4	7	6	6		1	2	3	1												51
281.25			2	8	1	3	6	1	1		1															23
292.5		5	7	8	3	1	3	1	5	4	1															38
303.75		7	1	4	8	12	5	3	1																	41
315	3	11	6	7	3	8	7	3	3																	51
326.25	5	11	14	8	15	6	3	5	1	4																72
337.5	4	15	15	21	10	12	6	13	10	2																108
348.75	10	13	20	24	7	13	10	7	12	2		1														119
360	2	10	12	16	10	5	4	5	2	1	1	1														69
	7	22	25	20	9	12	12	3	4	1	1		1													117
Grand Total	675	2512	4497	4522	3656	2487	1507	929	587	281	146	76	24	10	7	2	3	1	1	1	1	1	1	1	1	21929

3.2 NEARSHORE WAVE CLIMATE ANALYSIS

3.2.1 Objectives and Approach

It was necessary to estimate what the wave climate is like near shore in order to:

1) Allow for the estimation of wave forces on the existing shoreline to determine the stable grain size needed.
2) Determine the operational, swell and hurricane environments at the beach.

Deepwater water wave data forms the input for such analysis and by itself offers limited information on how waves reach the shoreline. The objective of this exercise is to derive a nearshore wave climate in order to better understand the environment and processes involved. The approach adopted in order to achieve these objectives was as follows:

1) Prepare a bathymetric database of the project domain for extremal analysis.
2) Determine the nearshore wave climate for the beach.

3.2.2 Wave Climate Model: REFDIF

The weakly nonlinear combined refraction and diffraction model described here denoted REFDIF simulates the behaviour of a random sea over irregular bottom bathymetry incorporating the effects of shoaling, refraction, energy dissipation and diffraction. Although the model is developed to simulate a random sea state it can also be used to model the behaviour of monochromatic waves. REFDIF was developed by Kirby and Dalrymple. The model REFDIF is constructed in parabolic form and thus there is a restriction of the model to cases where the propagation direction is within the assumed mean wave direction.

3.2.3 Modelling Approach and Summary of Incident Wave Conditions Modelled

The output from the storm surge model used for hurricane impact analysis provided us with the incident wave height and period as well as the water setup for the deepwater extremal analysis. These incident wave heights and periods were then used in the REFDIF model to generate the nearshore wave climate. The spatial patterns of wave breaking and shoaling were noted in relation to the proposed site. Should intense wave focusing be noted, then it would probably be advisable that this be considered in the design of adequate structural engineering provisions. See Table 3-8 for a summary of the incident wave conditions used for the analysis.

It must be noted that due to the limitations of the program, it was unable to run analysis for the eastern direction.

Table 3-8 Summary table of wave heights and periods used to model REFDIF

	OPERATIONAL		SWELL	
Direction	**Ts (s)**	**Hs (m)**	**Ts (s)**	**Hs (m)**
NE	5.5	0.8	7.5	1.6
ENE	5.5	0.8	7.5	1.6
E	5.5	0.8	7.5	1.6
HURRICANE				
Direction	**Return period**	**Ts (s)**	**Hs (m)**	
NE	50	11.8	5.6	
	100	12	5.8	
N	50	11.9	5.7	
	100	12.2	6.1	
NW	50	12.3	6.1	
	100	12.6	6.4	

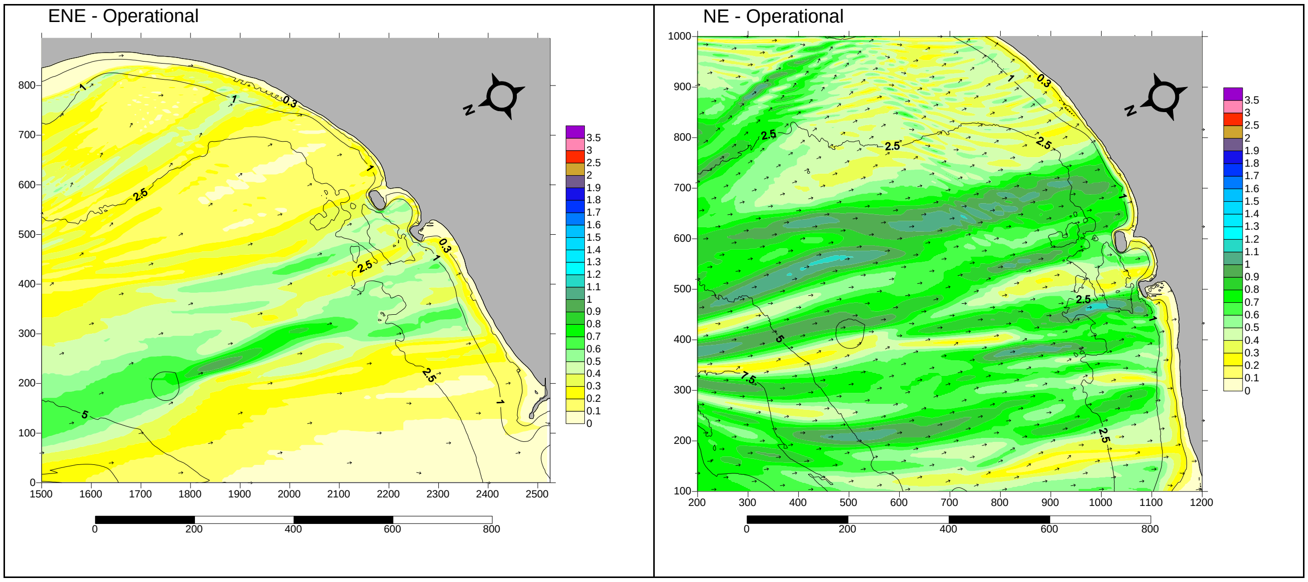
3.2.4 Operational Waves

The model was calibrated to run operational waves from the NE and ENE directions. The existing shoreline was modelled first to better understand the areas which are most vulnerable as well as to estimate based on the wave predictions, what wave heights are reaching the shoreline.

The model showed that the shoreline under operational conditions could possibly experience wave heights of 0.5 to 0.7m reaching up to the shoreline from the east north east and north easterly directions respectively. The east north easterly direction is however more frequent that that of north easterly at 30%.

Table 3-9 below shows the wave plots for operational conditions.

Table 3-9 RefDif plots of operational waves

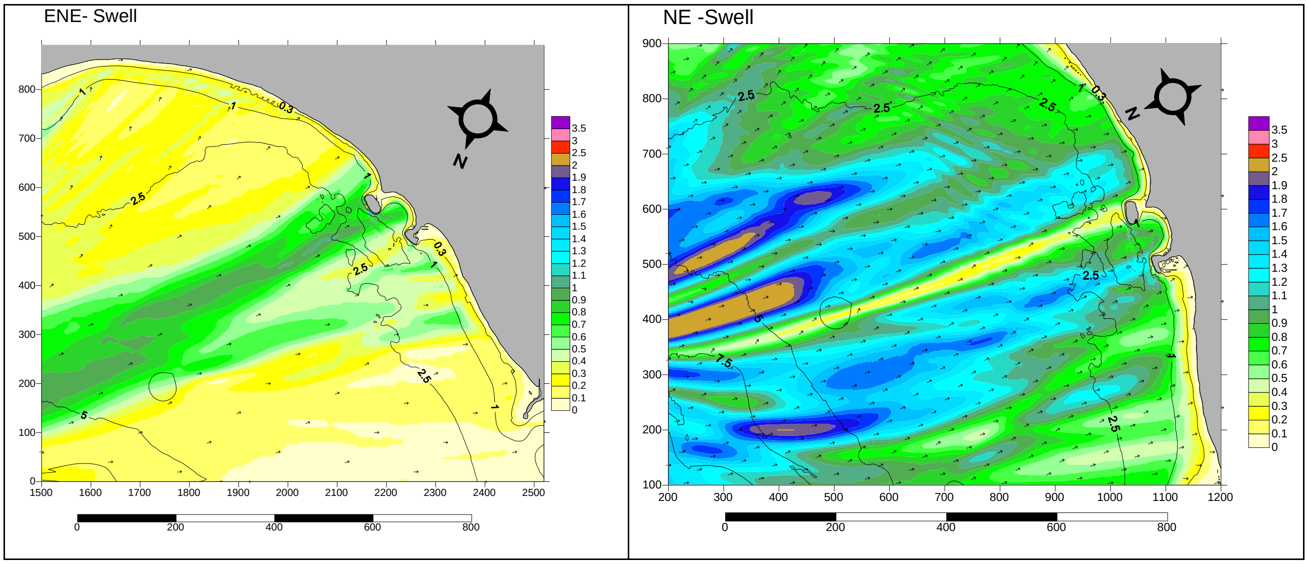


3.2.5 Swell Waves

It was also important to look at the swell wave climate so as to understand the impact on the existing shoreline and to design shoreline protective structures, if necessary, which would handle these scenarios. The model was manipulated to run swell waves from the NE and ENE directions.

The model showed that the shoreline under swell wave conditions could possibly experience wave heights of up to 0.8 m at the shoreline from the north eastern direction and 0.5m from the east north eastern direction. See Table 3-10 which shows these waves generated due to swells.

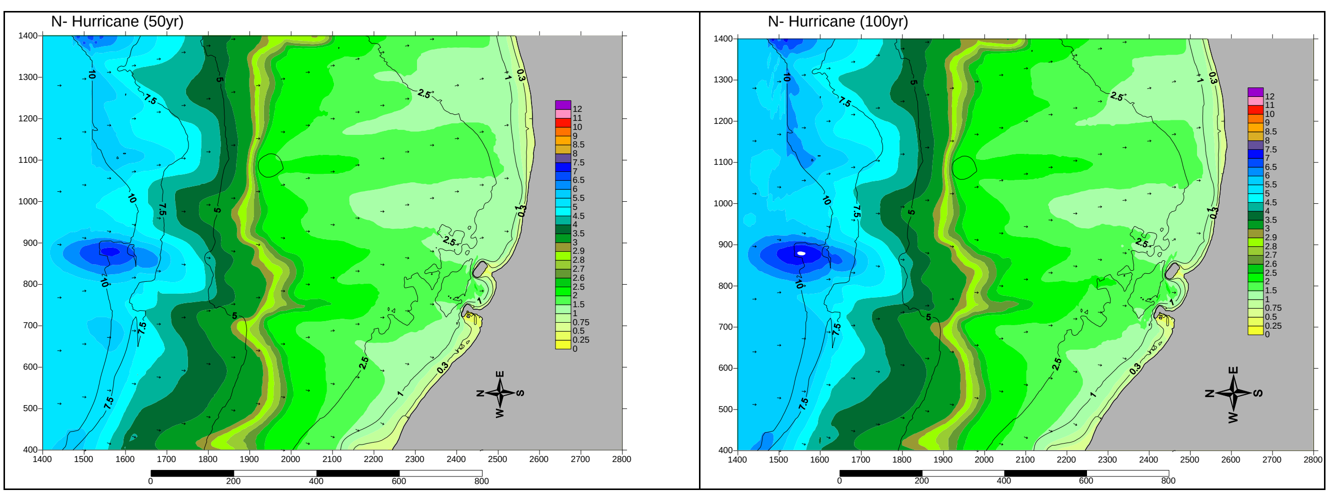
Table 3-10 RefDif plots of swell waves



3.2.6 Hurricane Waves

It is also important that we model hurricane wind generated waves which could form and affect the beach. The modelled directions were N, NW and NE for 50 and 100 years return periods. The wave plots generated from the model showed that during hurricane conditions, wave heights of up 2.3 m reaching the shoreline for 100 year return period. Table 3-11 shows the wave plots generated from the model for these scenarios.

Table 3-11 RefDif plots of hurricane waves



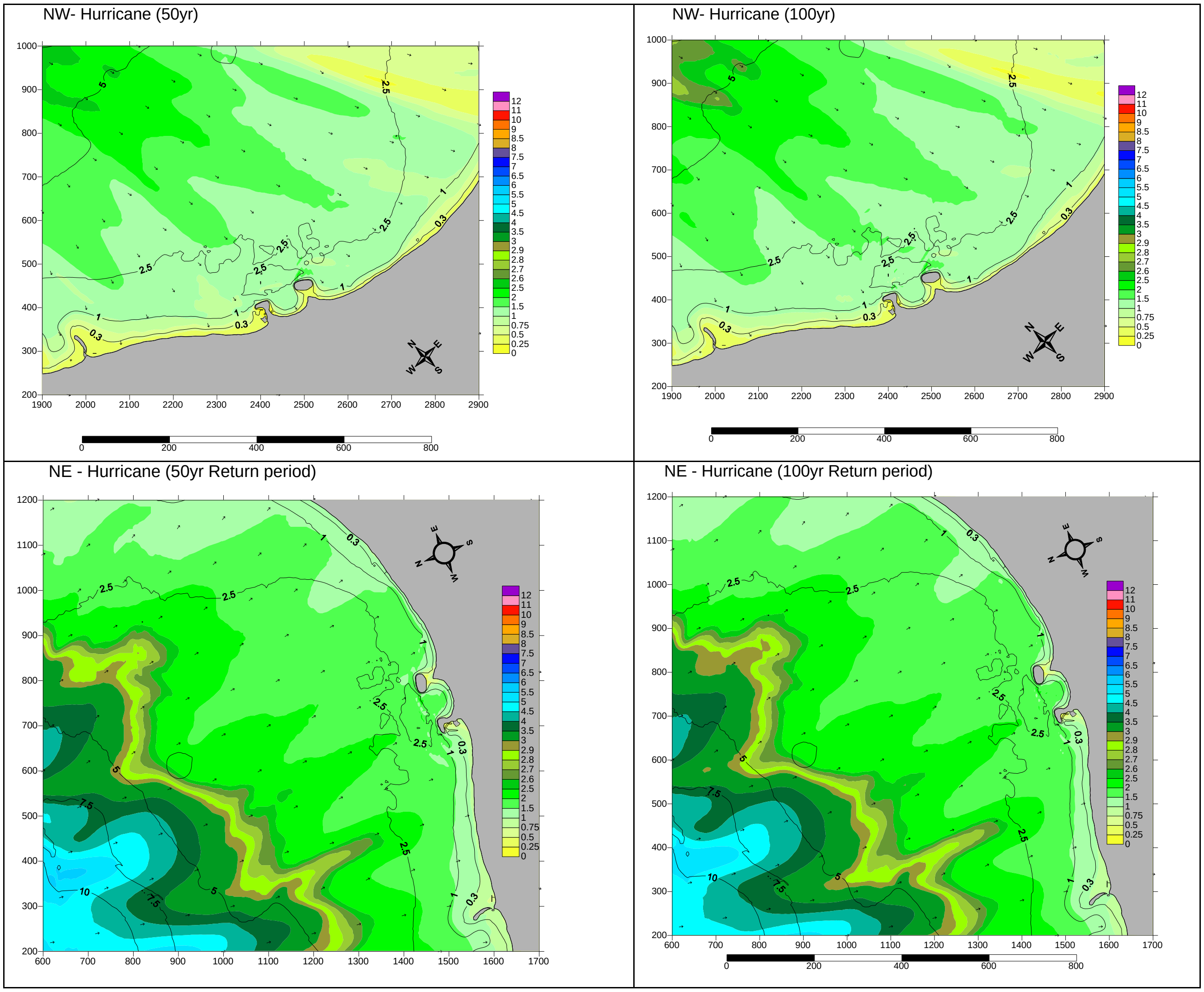


Table 3-12 Summary table of incident wave heights

Scenario	Direction	Hs (m)	
Operational	ENE	0.6	
	NE	0.8	
Swell	ENE	0.8	
	NE	1.0	
Hurricane	**Return period**	**50**	**100**
	NE	2.5	2.5
	N	1.8	2.5
	NW	2.0	2.5

The results of the modelling showed that waves of up to 2.5 m can reach the shoreline in the event of a storm. This has the potential to cause serious damage to structures located on the beach.

3.3 SHORELINE VULNERABILITY

3.3.1 Storm Surge

The storm surge modelling revealed the water surface elevation of up to 1.52 and 1.65m above msl could occur next to the shoreline. Wave run-up should also be factored in the overall water levels on the back of the beach. Wave run-up is an important process in causing and or promoting bluff erosion. Wave run-up may cause erosion by directly impacting the back of the beach, dislodging material, and redistributing it to the foreshore and near shore. The run-up estimated for this beach based on an average storm wave of 2m reaching the shoreline with a period of 12s is 1m. This estimated is based on the general formula outlined by Vandermeer and Stamm (1992)[1]. This would in effect cause the overall storm surge levels to become 2.25 and 2.62 respectively.

3.3.2 Erosion Hazard

It was considered necessary to assess the vulnerability of the shoreline to erosion hurricane waves, given the increased frequency of more intense storms as is shown in Table 3-1 above. The vulnerability of the shoreline to erosion by operational, swell and hurricane waves was investigate the cross shore sediment transport model.

Cross-shore transport is the seaward or landward movement of sediments due to wave breaking and the resulting cross shore currents which are set up. This results in changes in the beach profile due to accretion or erosion of sediments. Coarse suspended sediments settle faster and deposit on the back of beach whilst finer sediments are kept suspended and washed offshore. This process therefore implies that there is a relationship between the fall velocity of the sediment particles (W_f) and the wave climate that can be used to predict whether there will be accretion or erosion.

$$\frac{Ho}{w_f T} \cong 1$$

The fall velocity ratio;

Where H_o = deepwater wave height

w_f = fall velocity and

T = wave period

[1] VAN DER MEER J. W., J.W. and STAM, C.J.M. (1992), Wave run-up on smooth and rock slopes of coastal structures, ASCE, Journal of WPC&OE, Vol.118, No.5, 534-550.

If the ratio exceeds one (1), sediment moves offshore; if it is less than 1, sediment moves onshore. Table 3-13 outlines the results obtained for each of the samples collected. (note: 'T' Samples are surface samples and 'D' samples are subsurface samples). The grain sizes used for this analysis were the mean grain sizes for each sample. The fall velocity was estimated from the grain sizes after which the stable wave height was estimated from the period and the falling velocity.

Table 3-13 Summary table of cross-shore grain stability analysis

CROSS SHORE GRAIN SIZE STABILITY						
Sample ID	**T5-subsurface**	**T7-Subsurface**	**T4-Subsurface**	**T4-Surface**	**T5-Surface**	**T7-surface**
Water and sediment characteristics						
Mean (D50) mm	0.686	0.699	0.867	0.800	0.686	0.703
Specific density	2.65	2.65	2.65	2.65	2.65	2.65
Density of water	1.025	1.025	1.025	1.025	1.025	1.025
Gravity	9.82	9.82	9.82	9.82	9.82	9.82
Kinematic viscosity	8.01E-07	8.01E-07	8.01E-07	8.01E-07	8.01E-07	8.01E-07
Fall velocity (Wf/m/s)	0.21	0.21	0.27	0.24	0.21	0.21
Wave period (seconds)						
Operational	5.5	5.5	5.5	5.5	5.5	5.5
Swell	7.50	7.50	7.50	7.50	7.50	7.50
Hurricane						
10 yr	11	11	11	11	11	11
50yr	12.3	12.3	12.3	12.3	12.3	12.3
100yr	12.60	12.60	12.60	12.60	12.60	12.60
Stable Wave Height						
Operational	1.14	1.16	1.47	1.35	1.14	1.17
Swell	1.55	1.58	2.00	1.83	1.55	1.59
Hurricane						
10 yr	2.27	2.32	2.94	2.69	2.27	2.33
50yr	2.54	2.59	3.28	3.01	2.54	2.61
100yr	2.60	2.66	3.36	3.08	2.60	2.67

From this analysis, the stable wave height for each condition was determined. It gives an indication of the largest incident wave that will not remove the sediments from the shoreline.

These stable wave heights were compared to the wave heights incident at the shoreline given the various conditions (see Table 3-14). From this comparison it can be seen that the incident waves were of lower amplitude than the stable wave heights for all the donor site sand samples. This means that these sands are suitable for this beach nourishment project.

The stable wave height for the samples was checked against the wave heights expected to arrive at the shoreline, based on wave transformation modelling. The results indicate that the donor site sand is can withstand wave heights of up to 3.36 m. The sand on the existing beach has a stable wave height of about 2.46 m which is marginally less than the 2.5 predicted to reach the shoreline. This explains why the current beach is eroded based information garnered from interviews with persons working in the area for over 15 years. Table 3-14 below shows a summary of the wave height comparisons.

Table 3-14 Summary table comparing stable wave heights with the incident wave height

		Stable Wave height (m) for			
Wave Climate	**Incident wave height (m)**	**Current beach sand**	**Donor sand**		
			198	**200**	**197**
Operational	0.8	1.07	1.47	1.16	1.47
Swell	1.0	1.46	2.0	1.58	2.0
Hurricane					
50	2.50	2.40	2.54	2.59	3.28
100	2.50	2.46	2.60	2.66	3.36

The shoreline vulnerability was also assessed dynamically with SBEACH, an empirically based numerical model for estimating beach and dune erosion due to storm waves and water levels. The model relates the magnitude of cross-shore sand transport to wave energy dissipation per unit water volume in the main portion of the surf zone. The direction of transport is dependent on deep water wave steepness and sediment fall speed. SBEACH is a short-term storm processes model and is intended for the estimation of beach profile response to storm events. Typical simulation durations are limited to hours to days (1 week maximum).

The inputs into the model were wave heights and periods of storm events as well as the beach profile running from deep water to the back of the beach. The results indicate the existing shoreline could erode up to 30m inland. Most of the sediments would however be deposited inland as due to the relative coarseness of the sand. This still does require mitigation measures as the structures on or next to the beach could suffer damage. We recommend the use of a buried revetment to combat this issue. A revetment is a coastal defence structure that reduces the effect of erosion on the shoreline.

4.0 HYDRODYNAMIC MODELLING

4.1 MODEL DEVELOPMENT AND CALIBRATION

4.1.1.1 Description of RMA 10 model

RMA-10 is a three-dimensional finite element model for stratified flow by King (1993). The primary features of RMA-10 are:

- The solution of the Navier-Stokes equations in three-dimensions;
- The use of the shallow-water and hydrostatic assumptions;
- Coupling of advection and diffusion of temperature, salinity and sediment to the hydrodynamics;
- The inclusion of turbulence in Reynolds stress form;
- Horizontal components of the non-linear terms are included;
- A capacity to include one-dimensional, depth-averaged, laterally-averaged and three-dimensional elements within a single mesh as appropriate;
- No-, partial- and full-slip conditions can be applied at both lateral boundaries;
- Partial or no-slip conditions can be applied at the bed;
- Depth-averaged elements can be made wet and dry during a simulation; and
- Vertical turbulence quantities are estimated by either a quadratic parameterisation of turbulent exchange or a Mellor-Yamada Level 2 turbulence sub-model.

4.1.2 Finite Element Mesh Development

The process of mesh developments entails the following steps:

- Input of bathymetric data for the wider area and in detail for the project area
- Specifying of nodes in the mesh
- Element construction in the mesh
- Interpolation for depth at nodes
- Specifying of open boundaries

The mesh constructed for the calibration and existing configuration extended some 4 kilometres in a northerly direction. The outer deep water areas were gridded with large mesh which gradually decreases on approach to the project area. (See Figure 4-1).The eastern and western boundaries were used as the open boundaries on which tides were applied.

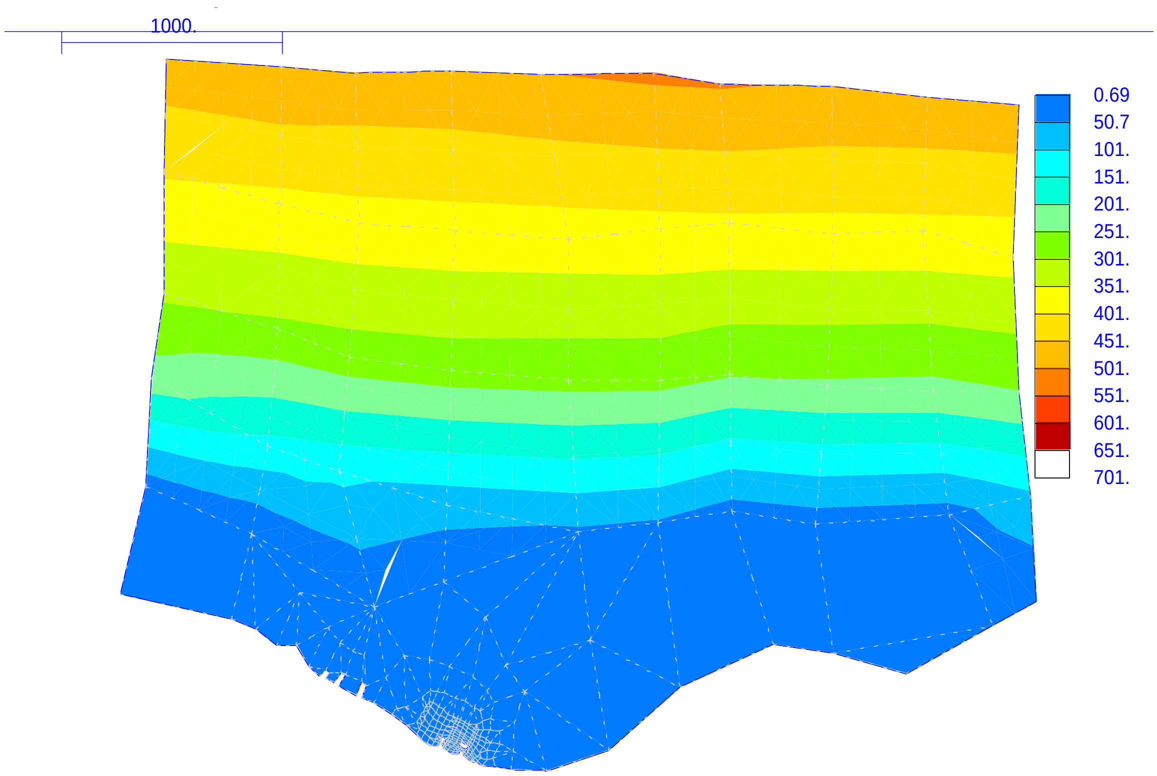


Figure 4-1 Entire Finite Element Mesh used for this project showing depth in metres

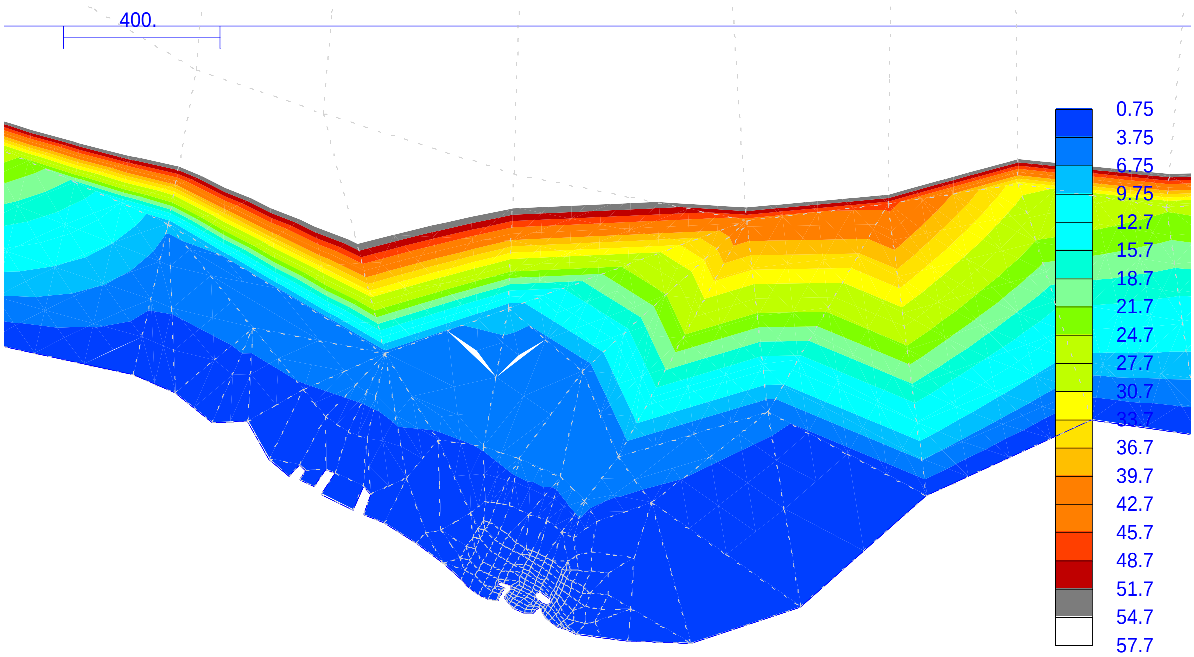


Figure 4-2 Part of Finite Element Mesh in the project area showing depths in metres

4.1.3 Calibration

The model was calibrated by adjusting the tide elevation signal on the model boundaries, turbulence and viscosity parameters, until there was reasonable agreement between the observed currents and model predictions. See Table 4-2, Table 4-3 and Table 4-4 for the predicted currents.

The predicted current speeds and directions, versus the data from the drogue tracking sessions are summarized in Table 4-1. The model predictions were within the data ranges for the observed occurrences in most instances. The calibration data essentially indicates that there is reasonable agreement between the model and the data.

Table 4-1 Calibration data for the existing bathymetric configuration based on drogue and wind data for the 2006/06/20

Day	Location	Observations		Model Predictions	
		Speed (cm/sec)	Direction	Speed(cm/sec)	Direction
1	Falling • Nearshore • Midway • Offshore	1.17 2.14 4.86	ESE E SE	0-1 2-3 4-5	SW W W
	Rising • Nearshore • Midway • Offshore	2.36 2.74 4.59	SW SW W	2 3 3	SW SW W
2	Falling • Nearshore • Midway • Offshore	1.73 3.25 1.59	NW NW SW	1-2 3-4 2	NW NW SW
	Rising • Nearshore • Midway • Offshore	3.75 6.96 5.31	SW W W	3 3-4 3-4	W-NW

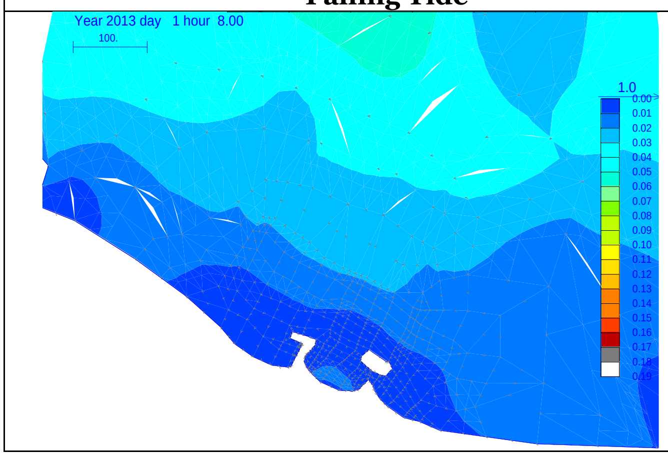
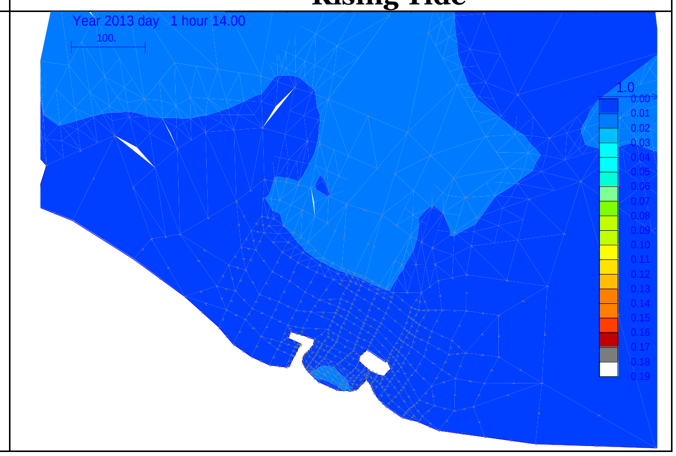
4.2 RESULTS

4.2.1 Currents

4.2.1.1 Slow Wind Conditions

Surface current predictions for the slow wind speed meteorological conditions for the existing shoreline configuration indicate that current velocities 1 cm/sec and below can be expected. The current directions are predominantly towards the west which indicates the surface currents are predominantly wind driven.

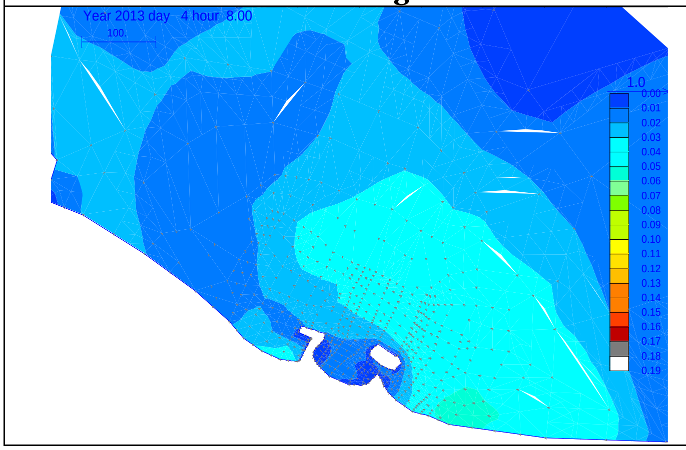
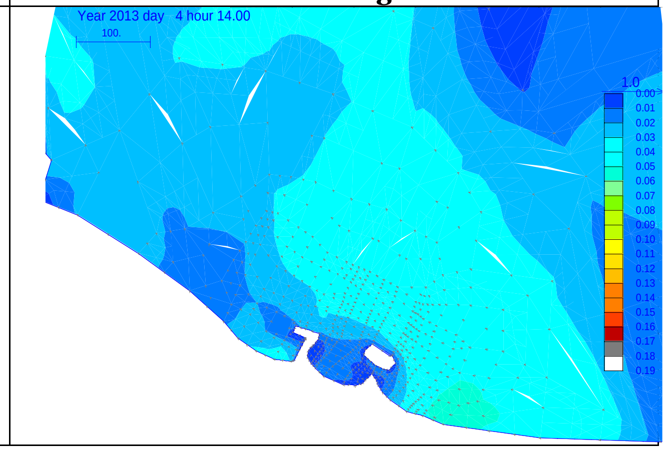
Table 4-2 Velocities (m/s) at surface from FEM of slow wind conditions during falling and rising tide

<table>
<tr><th>Falling Tide</th><th>Rising Tide</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

4.2.1.2 Average Wind Conditions

Surface current predictions for the average wind speed meteorological conditions for the existing shoreline configuration indicate that current velocities of 1 - 2 cm/sec for falling tides and rising tides can be expected in the near shore area. Current velocities of up to 5 cm/s can be experienced in the off shore area. The current directions are predominantly towards the west which indicates the surface currents are predominantly wind driven.

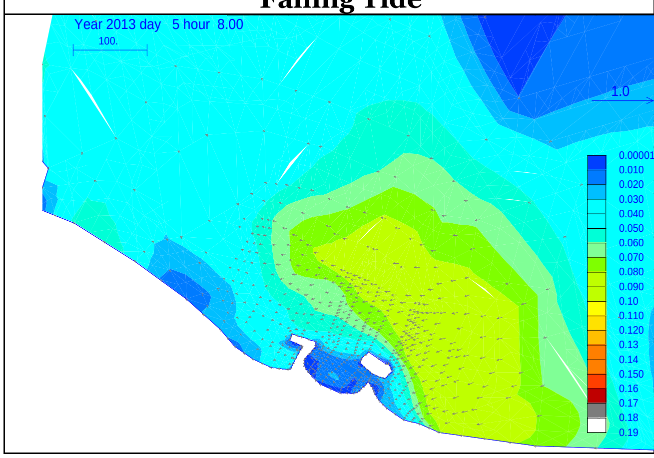
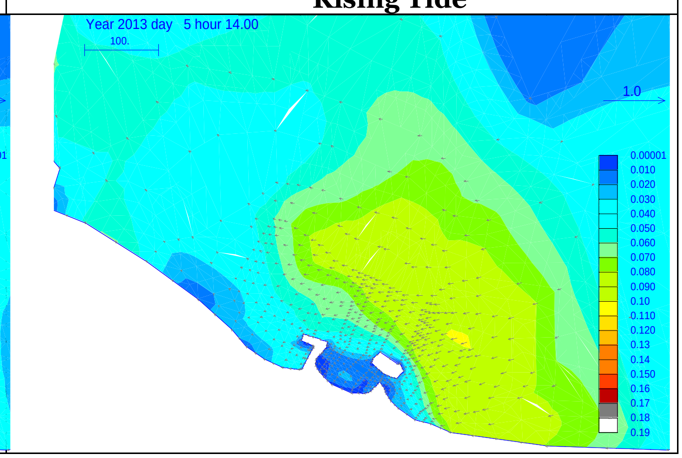
Table 4-3 Velocities (m/s) at surface from FEM of average wind conditions during falling and rising tide

Falling Tide	Rising Tide
	

4.2.1.3 Fast Wind Conditions

Surface current predictions for the average wind speed meteorological conditions for the existing shoreline configuration indicate that current velocities of 1 - 2 cm/sec for falling and rising tides can be expected in the near shore area. In the off shore area, currents speeds of up to 9 cm/s can be expected. The Currents are driven by the winds and tides.

Table 4-4 Velocities (m/s) at surface from FEM of fast wind conditions during falling and rising tide

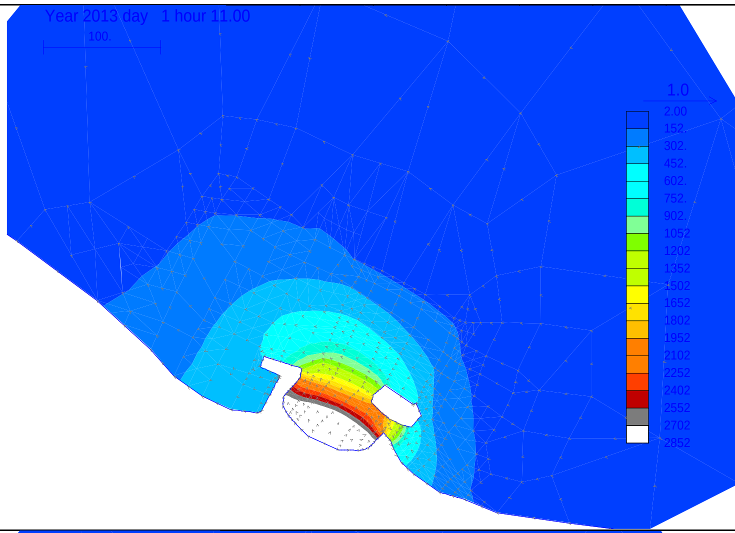
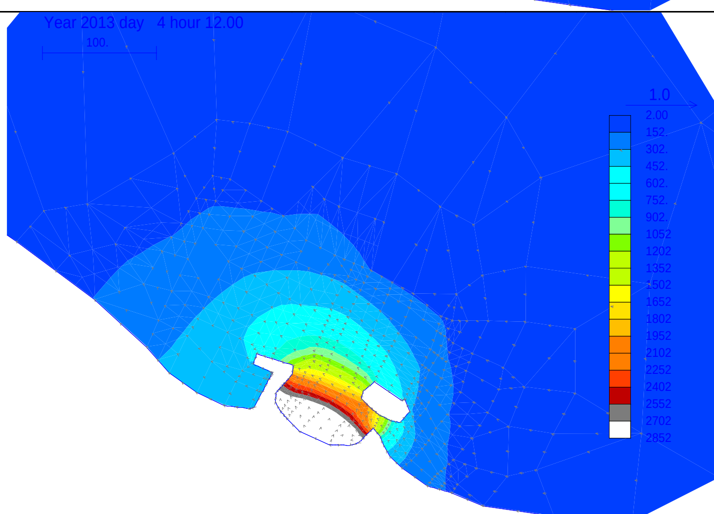
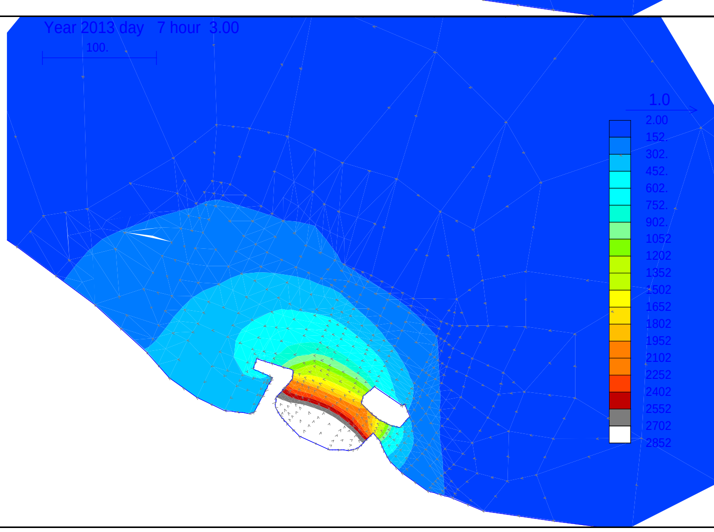
Falling Tide	Rising Tide
	

4.2.2 Sediment Transport

4.2.2.1 Near shore Sediment Plume

As the PSD pumps its dredged sediment on to the shoreline, the dredged material is expected to contain a lot of water which will run off into the sea. This activity is expected to produce a small sediment plume within the area of the North Beach. This plume would be expected to have a nominal length of 100 to 120 metres with a width of 100 to 200 metres. The first 25m to 50m of this plume is expected to have a sediment concentration ranging from 2400 - 1200 mg/l. From 50m to 75 m the sediment concentration is expected to range from 1200 – 600 mg/l. For a further 100 m from the core a concentration range of 100 mg/l – 2.0 mg/l is expected. The modelling result is shown in the Table 4-5 below.

Table 4-5 Concentration (mg/l) of sediment plume from FEM plots of sediment plumes at near shore

	**Slow wind conditions.** **Plume width: 110m – 180m**
	**Average wind conditions.** **Plume width: 110m – 200m**
	**Fast wind Conditions.** **Plume width:100m – 210m**

4.2.2.2 Burrow Area Sediment Plume

The hydro dynamic model reveal that any plumes generated in the general sand reserve is expected to stay with the sand reserve bands. The sand will fall out and settle quickly however it is recommended that turbidity barriers be deployed in the event finer and or slower settling sediments are encountered during the dredging exercise.

5.0 BEACH NOURISHMENT METHODOLOGY

The beach nourishment process will involve the following:

1. Sand Dredging,
2. Creation of a temporary settling basin,
3. Settling of the sand and overflow from settling basin,
4. Removal of sediment from settling basins

5.1 SAND DREDGING

The dredging can be conducted using a Plain Suction Dredger (PSD) that it is a stationary dredger, consisting of an anchored pontoon and with at least one sand pump, connected to a suction pipe. Sediment is deposited on the shoreline via the suction pipeline which will channel dredged. The suction tube is positioned in a well in the bows of the pontoon to which it is hinged. The other end of the suction pipe is suspended from a gantry or A-frame by the ladder hoist which can be lowered to a desired depth.

Excavation of material to dredge is by the erosion of a jet stream of water which break/breach the surface and the suction flow of the dredge pump. Depending on the pumping capacity, the discharge can be pumped over considerable distances. Suction dredgers are only used to extract non-cohesive sand and thus very suitable for the extraction of sand.

5.1.1.1 Benefits of PSD

There are benefits to using the PSD for this type of project, these include the following:

- Because there are no mechanical implements on the suction end of the pipe, thus sea floor disturbance is minimized.
- Depending on the size of the dredger used, the suction end can be manipulated by divers for greater accuracy.

5.1.2 Proposed Pipeline Route

The proposed Dredge route is shown below in Figure 5-1. The sand donor site will be dredged and pumped along a pipeline route approximately 440m long up to the shoreline.

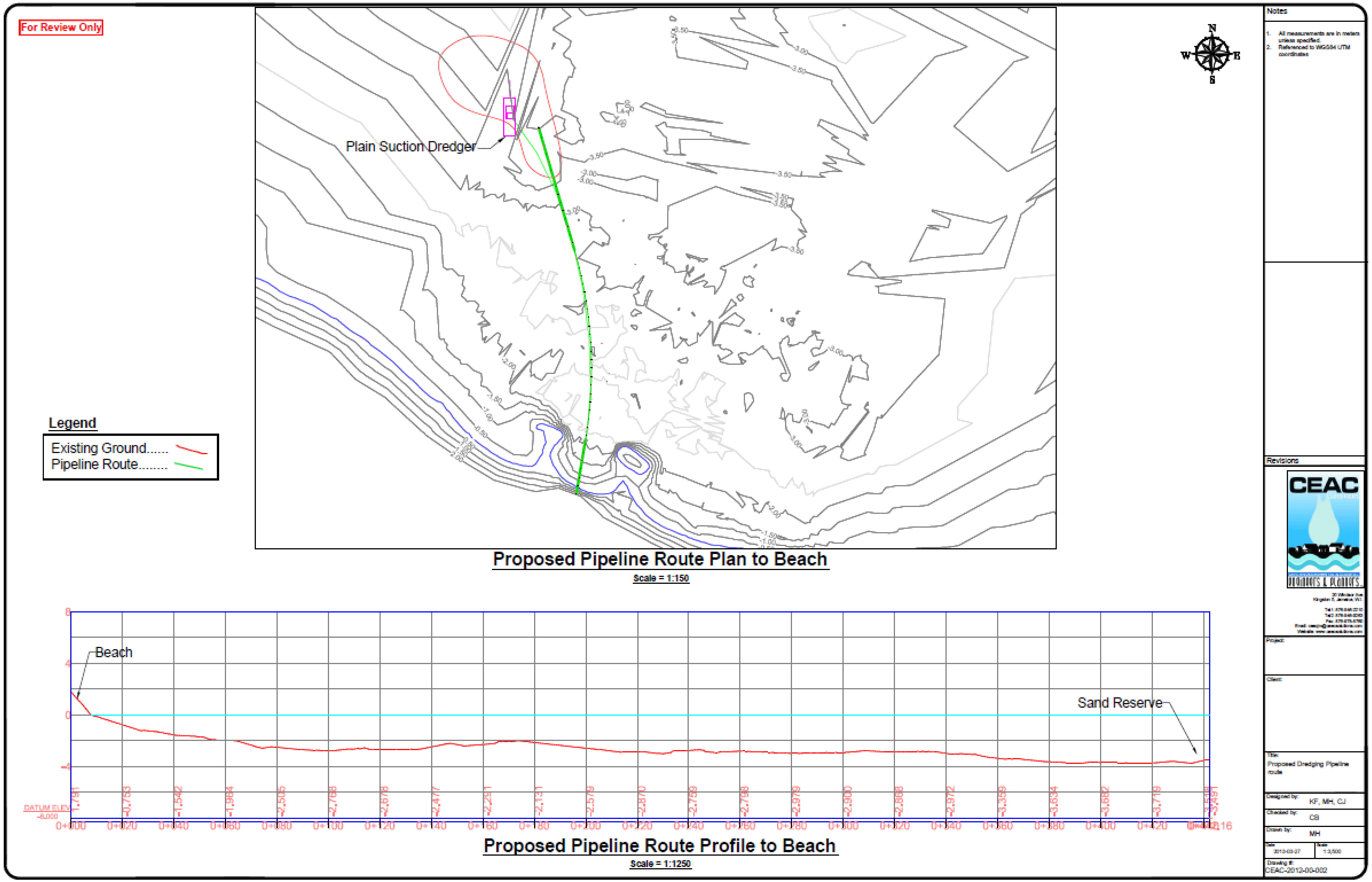


Figure 5-1 Proposed dredging route plan and profile

5.2 SAND NOURISHMENT SITE (THE BEACH)

The required beach is expected to extend 30m from the shoreline. This is a further 25m addition to the existing beach. The overall area of beach to be extended is approximately 3,700 m^2. The existing ground will have to be excavated before the filling is done. It must be noted that no excavation or beach nourishing occurs below the high water mark. Given the required beach area, the required fill volume is estimated to be 2,000 m^3 of sand.

Table 5-1 Summary of estimated quantities for proposed beach

Fill Area (m^2)	Average Depth of fill (m)	Fill Volume plus 20% (m^3)
3,300	0.5	2,000

5.2.1 Temporary Settling Basin

The dredged material is expected to reach onshore in the form of a sediment laden slurry. This slurry can have a sediment concentration in the range of 10% - 25% by volume. The slurry will require a sediment basin which will allow the sediment to separate from the water. The settled sediment will then be removed from the basin and place on the beach. Period removal of sediment should be carried out by a front end loader, giving the sediment time to settle out. The excess water will overflow from the basin and be returned to the sea.

5.2.1.1 Basin sizing

The settlement basin was sized based on the settlement velocity of the sand grains in water. The basin was sized to settle a grain size of 0.125 mm (the minimum size of fine sand), thus if a particle has a larger diameter then it will all settle out (The average grain size of the donor site is 0.74 mm). This is important as the more sediments that settle, the more efficient the basin and in turn, the less sediment wasted in the overflow.

The basin was sized for a sediment concentration of 15% by volume for a dredging period lasting approximately 6 weeks (see Table 5-2 below). The size of the basin design has a settlement velocity limit of 0.005 mm/s and the settlement velocity of fine sand is 2.0 mm/s thus over 90% of the sediment would have settle out. This level of settlement reduces the level of sediment in the over flow down to silt.

Table 5-2 Summary table of calculations for sizing sediment basin

sediment:water ratio	15%	15%	15%	Units
Mass of water	34666667	34666667	34666667	Kg
Estimated Time for dredging	5	6	7	weeks
	240	288	336	hours
Flow rate	634	528	453	USPM
	144	120	103	M3/Hr
Over flow				
Percolation	0.5	0.5	0.5	
Over flow	72.22	60.19	51.59	M3/Hr
Mass flux of dredged material	21667	18056	15476	Kg/hr
	8	7	6	m3/hr
Concentration	1.5	1.5	1.5	g/l
Basin cleaning interval	4	4	4	hours
Volume of sediment in cleaning interval	33.33	27.78	23.81	M3
Depth of sediment	0.077	0.077	0.077	M
Settling velocity-limit	0.005	0.005	0.005	MM/S
Prelim Basin Size				
Retention time	3	3	3	Hours
Volume	433	361	310	M3
Area	433	361	310	M2
Length	15	15	15	M
Width	29	24	21	M
Height	1	1	1	M

Figure 5-2 *Plan and profile of designed beach*

6.0 ENVIRONMENTAL IMPACT STATEMENT

6.1 OPERATION AND MAINTENANCE OF THE DREDGE

Dredging activities should not cause any disturbance to the surrounding environment The dredging contractor should ensure that every preventive/safety measure will be used in order to reduce the risk of spillages of fuel, lubricants and general reduced accident potential of all dredging operations. The dredge contractor should also ensure that all dredging activities are carried out correctly, including the placement and manoeuvring of the dredge and any auxiliary equipment both in the marine environment and on shore.

Personnel must be properly trained in both dredge and barge operations and all emergency response procedures. All activities must have the required contingency equipment. These emergency response procedures should be outlined in a detailed plan which includes an oil spill contingency plan.

Should there be any leaks on the dredge or any auxiliary equipment, whether in the form of greases/oils; or should any holes, or breakages occur in the suction pipeline resulting in the escape of, dredging activities must be immediately ceased until the problem is corrected. All equipment must then be checked and verified regularly to ensure its suitability for continue operations before any dredging activities are re-started.

In order to prevent leaks in the discharge line, the sediment suction pipe must be fully welded, with safety valves in the ends that allow sealing the pipes. Similarly, no water must filter from the pipe connections, for which purpose they will be secured with packing and bolted flanges or adjusted with other means.

Petroleum and oily wastes will be periodically taken on shore to the responsible agent for disposal. Solid wastes produced by activities carried out in vessels will be adequately collected and taken later to the plant for final disposal.

6.2 POTENTIAL ENVIRONMENTAL IMPACTS

The potential impacts of the dredging operations can be evaluated and predicted. Emergency Response Plans (ERP), Oil Spill Contingency Plan (OSCP) adequately trained staff, proper equipment maintenance and operation and sufficient safety and response equipment will ensure both a reduced accident potential and reduced damage to the marine environment in the event of an accident.

6.3 IMPACTS ON MARINE FLORA AND FAUNA

Dredging activities may result in impacts on marine flora and fauna. These impacts may include;

1. Increased Turbidity

   This may result in reduced light penetration and or PAR (Photosynthetically Active Radiation).

2. Increased Sedimentation

   This may also result in increased turbidity. Sedimentation may result in the smothering of sensitive habitats (coral reefs and seagrass beds) as well as the smothering of various organisms. Excessive or prolonged sedimentation can be lethal to both flora and fauna in the marine environment.

3. Shading

   Seagrass and corals maybe shaded by floating structures/equipment/barges placed over them for prolonged periods of time. This may result in reduced PAR. This may affect the functioning/photosynthesis of seagrass, corals and phytoplankton. Over extended periods of time this can have a severe impact on these communities.

4. Pipeline/Anchors/Equipment placed on the seafloor

   Sections of seagrass beds which cannot be avoided may be lost as a result of the placement of the pipeline, anchors and other equipment placed on the seafloor. The coral community in the project areas is very small and is highly unlikely to be affected by the placement of the pipeline and or other equipment (as they can be easily avoided).

Sensitive habitats may also be lost/damaged during general marine traffic activities in the area by vessels running aground, anchor damage etc.

5. Oil Spills and or Spill of Toxic Substances

   Spillages of oils/lubricants and other oily substances may act as a blanket on the surface of the water as well smother any marine life (seagrass, fish, mammals, corals, plankton etc.) it comes into contact with. Seabirds may also be affected by oil spills.

   Toxic substances/pollutants may have varying effects in the marine environment ranging from temporary and mild to lethal and prolonged.

6.4 IMPACTS ON TOPOGRAPHY AND BATHYMETRY

Dredging area

The bathymetry of the dredge area will change temporarily as seafloor depths will be lowered approximately 1 m during dredging activities. The natural movement of currents and sedimentation process will result in the maintenance of seafloor stability and a subsequent rise of the seafloor itself. The changes in bathymetry are not considered a negative or harmful impact as this is only a temporary change.

Dredged material deposit area

Unloading activities on the near shore seafloor will cause a change on the bathymetry, as seafloor elevations will rise approximately 0.8 m. The sediment will be distributed in a relatively large area, which will avoid the formation of sand banks etc.

6.5 IMPACTS ON WATER QUALITY

Water quality may be affected by any spillages and or leaks during dredging activities. Contaminants may be in the form of;

- Chemical or biological components and materials
- Surface contamination by greases, oils and debris.

Dredging activities must be stopped immediately under the following conditions

- Signs of any leaks or spills
- Malfunction of any dredging equipment (including auxiliary equipment such as silt screens)
- Unsuitable weather conditions (high waves, wind and rain)

In the event of an accident, all activities must be ceased, and every effort made to control/reduce and eliminate any further discharge and or dispersal of spill material/substances. These procedures should be clearly outlined in an emergency response and oil spill plan.

6.6 IMPACTS ON AESTHETIC

During the proposed project, ascetics within this area of coastline will be temporarily affected by the movement of barges and other dredging activity. Dredge operations have an estimated timeline of 2 months and as such no lasting effects on the aesthetics in the area are anticipated.

6.7 MITIGATION MEASURES

Mitigation measures for the potential negative impacts of dredging activities are outlined below.

No.	MITIGATION MEASURES
1	Ensure that all corals, sea grass associated with fauna, gorgonians, urchins and mussels beds are avoided where possible prior to and during the dredging activity
2	Marker buoys delineating the dredging area should be clearly visible at night and day to provide a clear visual reference for the point beyond which absolutely no activities are to occur.
3	No lying or placement of any and all pipelines associated with the dredging activity should be done without approval of the layout, location, anchoring methods and outfall locations for the said pipelines.
4	All pipelines and fixtures including anchors associated with the dredging exercise are removed from the foreshore, floor of the sea and water column upon the completion of the dredging exercises..
5	Ensure that there is no visible plume from the surface as a result of the discharge from the outfall pipe associated with the dredging activities.
6	Immediately report any spills of hazardous chemicals inclusive of all hydrocarbons to the relevant agencies and shall report on the clean-up activities as per MARPOL 73/78, annex1, regulations 26.
7	Erect and maintain continuous turbidity barriers (silt curtains) before any dredging activity. Ensure the barriers function correctly so as restrict and control the movement of and to prevent the escape of sediment generated by the dredging works into the adjacent marine environment.
8	Ensure that the turbidity outside the installed turbidity barriers does not exceed ambient values..
9	Ensure that the water quality surrounding the dredge activity is monitored.
10	Ensure that if the environmental conditions are unfavorable/unsuitable - all works re halted.
11	The turbidity barriers (silt curtain) deployed shall remain in place until suspended solids values within the work area fall below or equal to ambient conditions.
12	In the event that the turbidity barriers (silt curtains) are damaged, destroyed or otherwise rendered ineffective by waves, currents and /or other meteorological events, the works must be suspended until the disturbance has passed and the necessary repairs are carried out.
13	Prior to hurricane or other major meteorological events work should be halted and suspended solids values allowed to fall to ambient conditions. Turbidity barriers (silt screens) should then be removed and the work area adequately secured to prevent any undue runoff into the adjacent marine environment.

No.	MITIGATION MEASURES
14	Ensure the development of an Emergency Response Plan (ERP)
15	Ensure the development of an Oil Spill Contingency Plan (OSCP)

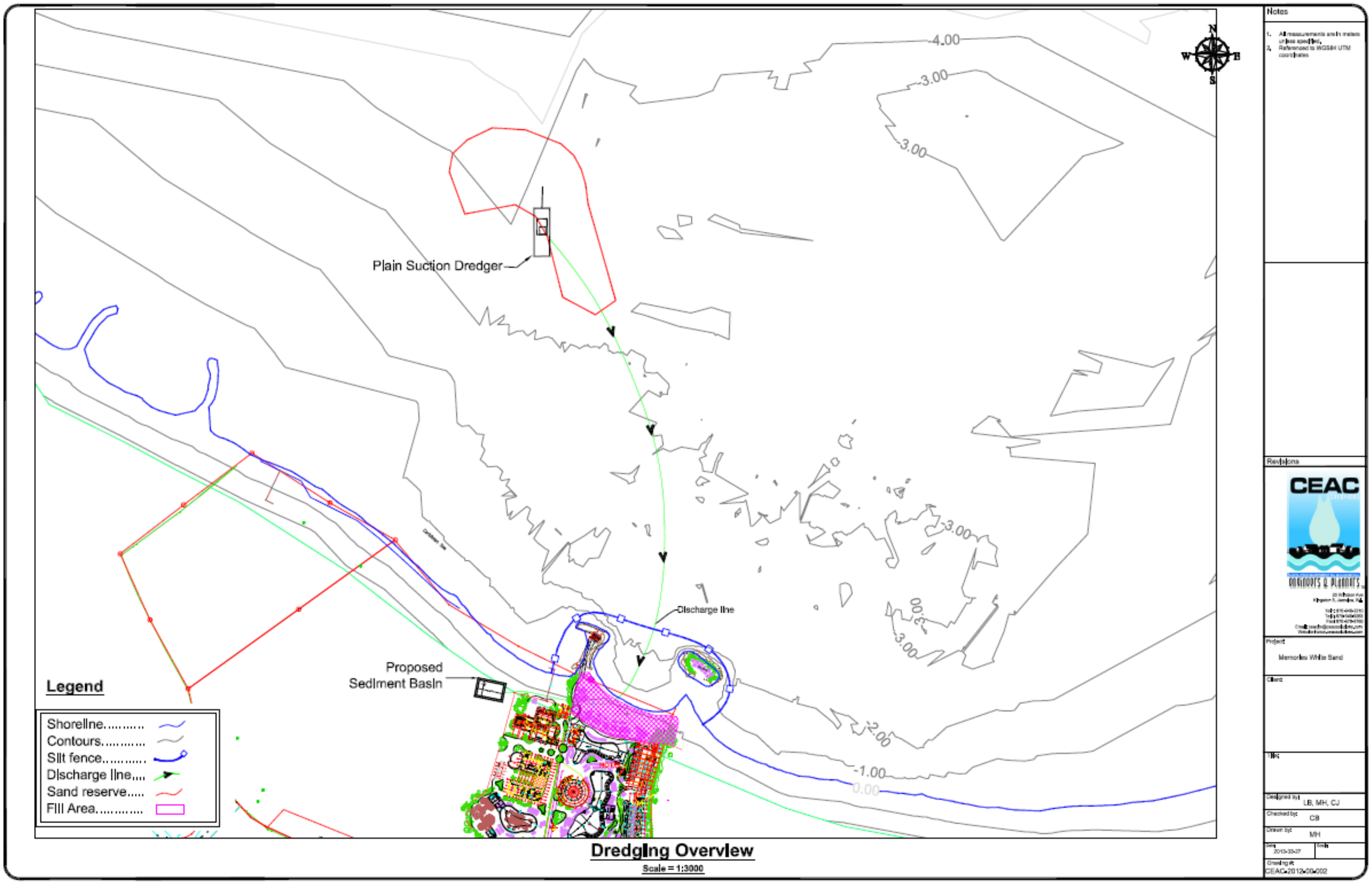


Figure 6-1 General overview of dredging activity and mitigation measure employed

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Based on the studies conducted to date, the following could be concluded:

1. The sand donor site is estimated to have more than the approximate fill volume required of 2000 cubic meters.
2. Sediment analysis has revealed the quality of the sand from the donor area is similar to that of the native beach and hence makes it suitable for use to extend the beach.
3. Wave transformation modelling and sediment stability analysis has revealed the sand on the beach is stable during the operational and swell wave conditions but is unstable during hurricane wave conditions. The sand from the donor site was however estimated to be marginally stable during hurricane conditions should it be placed on the beach.
4. A dynamic assessment of the shoreline stability using a cross shore model revealed however that the beach is overall vulnerable to erosion length of up to 30 metres from the shoreline.
5. Hydrodynamic modeling of the currents in the area has revealed that the currents (surface and subsurface) are move in a predominantly westerly direction at speeds ranging from 2 to 7cm/s. It has also revealed that sediments are expected to move up to 120 meters offshore
6. Storm Surge modeling has revealed that the maximum setup with wave's run-up expected at the site is 2.52m and 2.65 m above msl for the 50 and 100 year return storms respectively.

7.2 RECOMMENDATIONS

Based on the conclusions drawn, the following are our conclusions to date:

1. The owners should consider using the sand found at the donor site to nourish the back of the existing beach. A license will be required from NEPA dredge at the donor site but none is required at the beach area since no encroachment will occur on the sea floor.

2. A suction dredger on a barge should be used to dredge the donor are to ensure minimal disturbance to the ocean floor.
3. Turbidity barriers/screens are recommended during the dredging and discharging phases of construction to minimize the impact of sediment plumes on aquatic organisms, especially in the near shore area.
4. Minimum floor levels of 0.3 m above the 50 or 100 year storm surge is recommended for all buildings close to the shoreline.
5. A buried revetment should be considered to minimize the erosive effects of the hurricane waves on the shoreline in an effort to protect the infrastructures behind the beach.
6. The works should be monitored for compliance to engineering and environmental standards.

8.0 APPENDICES

Appendix A Summarized drogue tracking session #1 - Falling tide conducted on March 20, 2013

Falling Tide Drogue Session - Conducted March 20th, 2013										
Drogue #	Depth of Sail	Notes	Location	Distance Travelled (m)	Time (s)	Speed (cm/s)	Direction of Motion	Average Speed (cm/s)	Average Direction of Motion	
4	1.4 m	deploy	Near Shore	9.220	1454	0.634	40.601	0.925	121.809	South Easterly
4	1.4 m	measurement		12.042	1541	0.781	131.634			
4	1.4 m	measurement		17.263	1096	1.575	169.992			
4	1.4 m	measurement		12.207	1716	0.711	145.008			
4	1.4 m	remove								
6	Surface	deploy		8.246	1495	0.552	104.036	1.170	109.307	Easterly
6	Surface	measurement		10.000	1541	0.649	90.000			
6	Surface	measurement		14.318	1023	1.400	114.775			
6	Surface	measurement		37.014	1779	2.081	128.418			
6	Surface	remove								
7	surface	deploy	250m offshore	120.603	1508	7.998	344.120	2.148	107.383	Easterly
7	surface	deploy		21.024	1472	1.428	87.274			
7	surface	measurement		20.591	791	2.603	119.055			
7	surface	measurement		34.438	1427	2.413	115.821			
7	surface	remove								
6A	1.7 m	deploy		134.715	1278	10.541	341.834	1.261	109.141	Easterly
6A	1.7 m	deploy		17.117	1469	1.165	83.290			
6A	1.7 m	measurement		11.180	805	1.389	116.565			
6A	1.7 m	measurement		16.401	1336	1.228	127.569			
6A	1.7 m	remove								
3	surface	deploy	Deep Off Shore	62.650	1321	4.743	98.259	4.683	115.847	South Easterly
3	surface	measurement		67.119	1347	4.983	118.474			
3	surface	measurement		36.235	776	4.670	129.401			
3	surface	measurement		37.121	856	4.337	117.255			
3	surface	remove								
8A	2.0 m	deploy		55.731	1368	4.074	99.293	3.434	105.012	Easterly
8A	2.0 m	measurement		51.662	1252	4.126	104.574			
8A	2.0 m	measurement		22.136	789	2.806	108.435			
8A	2.0 m	measurement		26.249	962	2.729	107.745			
8A	2.0 m	remove								

Appendix B Summarized drogue tracking session #2 - Falling tide conducted on March 21, 2013

Falling Tide Drogue Session - Conducted March 21th, 2013										
Drogue #	Depth of Sail	Notes	Location	Distance Travelled (m)	Time (s)	Speed (cm/s)	Direction of Motion	Average Speed (cm/s)	Average Direction of Motion	
4	1.4 m	deploy	Near Shore	15.652	1237	1.265	296.565	1.653	282.090	Westerly
4	1.4 m	measurement		24.021	1177	2.041	267.614			
4	1.4 m	remove								
4	1.4 m	measurement								
4	1.4 m	remove								
6	Surface	deploy		10.050	1373	0.732	354.289	1.728	307.828	North Westerly
6	Surface	measurement		13.416	1657	0.810	296.565			
6	Surface	measurement		28.231	1309	2.157	292.932			
6	Surface	measurement		39.850	1240	3.214	287.526			
6	Surface	remove								
7	surface	deploy	Near Donor site	46.400	1276	3.636	322.883	3.253	315.945	North Westerly
7	surface	measurement		38.601	1154	3.345	323.427			
7	surface	measurement		31.401	1119	2.806	307.235			
7	surface	measurement		34.059	1056	3.225	310.236			
7	surface	remove								
6A	1.7 m	deploy		26.683	1224	2.180	282.995	2.736	283.339	Westerly
6A	1.7 m	measurement		34.928	1210	2.887	293.629			
6A	1.7 m	measurement		32.388	1064	3.044	278.881			
6A	1.7 m	measurement		29.275	1033	2.834	277.853			
6A	1.7 m	remove								
3	surface	deploy	Deep Off Shore	23.345	1492	1.565	133.264	1.595	205.450	South Westerly
3	surface	measurement		5.385	1535	0.351	158.199			
3	surface	measurement		16.031	989	1.621	273.576			
3	surface	measurement		34.928	1228	2.844	256.759			
3	surface	remove								
8A	2.0 m	deploy		11.180	1429	0.782	169.695	1.141	190.396	Southerly
8A	2.0 m	measurement		16.492	1553	1.062	165.964			
8A	2.0 m	measurement		10.296	982	1.048	209.055			
8A	2.0 m	measurement		20.000	1197	1.671	216.870			
8A	2.0 m	remove								

Appendix C Summarized drogue tracking session #2 - Rising tide conducted on March 20, 2013

Rising Tide Drogue Session - Conducted March 20th, 2012										
Drogue #	**Depth of Sail**	**Notes**	**Location**	**Distance Travelled** (m)	**Time** (s)	**Speed** (cm/s)	**Direction of Motion**	**Average Speed** (cm/s)	**Average Direction of Motion**	
4	1.4 m	deploy		21.401	853	2.509	232.595			
4	1.4 m	measurement		2.828	842	0.336	135.000			
4	1.4 m	measurement		5.099	2535	0.201	348.690	1.399	235.321	South Westerly
4	1.4 m	measurement		5.657	222	2.548	225.000			
4	1.4 m	remove	Near Shore							
6	Surface	deploy		25.080	943	2.660	246.501			
6	Surface	measurement		20.809	769	2.706	215.218	2.363	222.574	South Westerly
6	Surface	measurement		45.618	2649	1.722	206.003			
6	Surface	remove								
7	surface	deploy		31.048	879	3.532	255.069			
7	surface	measurement		22.472	805	2.792	249.146			
7	surface	measurement		55.036	2130	2.584	245.298	2.741	246.570	South Westerly
7	surface	measurement		34.670	1685	2.058	236.768			
7	surface	remove								
6A	1.7 m	deploy	250m offshore	10.630	848	1.254	221.186			
6A	1.7 m	measurement		19.209	800	2.401	231.340			
6A	1.7 m	measurement		20.248	2222	0.911	237.095	1.522	229.874	South Westerly
6A	1.7 m	remove								
6A	1.7 m	deploy		38.471	1649	2.333	242.103			
6A	1.7 m	remove								
3	surface	measurement		40.311	817	4.934	246.615			
3	surface	measurement		43.932	819	5.364	258.179	4.595	253.015	Westerly
3	surface	measurement		61.400	1349	4.552	263.454			
3	surface	measurement		67.978	1925	3.531	243.812			
3	surface	remove	Deep Off Shore							
8A	2.0 m	deploy		23.770	819	2.902	247.751			
8A	2.0 m	measurement		21.840	829	2.635	254.055	1.964	251.158	Westerly
8A	2.0 m	measurement		17.117	1255	1.364	263.290			
8A	2.0 m	measurement		19.723	2069	0.953	239.534			
8A	2.0 m	remove								

Appendix D Summarized drogue tracking session #4 - Rising tide conducted on March 21, 2013

Rising Tide Drogue Session - Conducted March 21th, 2013										
Drogue #	**Depth of Sail**	**Notes**	**Location**	**Distance Travelled** (m)	**Time** (s)	**Speed** (cm/s)	**Direction of Motion**	**Average Speed** (cm/s)	**Average Direction of Motion**	
4	1.4 m	deploy	Near Shore	33.956	733	4.632	256.373	2.329	235.814	South Westerly
4	1.4 m	measurement		27.313	675	4.046	246.251			
4	1.4 m	measurement		9.849	733	1.344	246.038			
4	1.4 m	measurement		10.296	880	1.170	240.945			
4	1.4 m	measurement		6.083	1338	0.455	189.462			
4	1.4 m	remove								
6	Surface	deploy		45.541	760	5.992	261.158	3.752	231.312	South Westerly
6	Surface	measurement		37.108	695	5.339	255.964			
6	Surface	measurement		23.770	676	3.516	247.751			
6	Surface	measurement		32.650	946	3.451	242.650			
6	Surface	measurement		5.831	1267	0.460	149.036			
6	Surface	remove								
7	surface	deploy	Near donor site	41.012	651	6.300	271.397	6.964	267.157	Westerly
7	surface	measurement		39.319	688	5.715	262.694			
7	surface	measurement		45.891	732	6.269	258.690			
7	surface	measurement		63.348	944	6.711	258.158			
7	surface	measurement		85.866	874	9.825	284.845			
7	surface	remove								
6A	1.7 m	deploy		37.483	598	6.268	260.789	6.207	265.688	Westerly
6A	1.7 m	measurement		39.115	687	5.694	265.601			
6A	1.7 m	measurement		39.051	737	5.299	267.064			
6A	1.7 m	measurement		57.219	926	6.179	264.987			
6A	1.7 m	measurement		71.000	935	7.594	270.000			
6A	1.7 m	remove								
3	surface	deploy	Deep Off Shore	37.000	634	5.836	251.075	5.315	260.053	Westerly
3	surface	measurement		42.297	666	6.351	263.211			
3	surface	measurement		33.838	760	4.452	251.030			
3	surface	measurement		41.593	939	4.430	260.311			
3	surface	measurement		37.121	674	5.508	274.635			
3	surface	remove								
8A	2.0 m	deploy		38.910	640	6.080	244.093	4.821	254.363	Westerly
8A	2.0 m	measurement		28.231	651	4.337	247.068			
8A	2.0 m	measurement		34.886	763	4.572	242.700			
8A	2.0 m	measurement		42.000	919	4.570	270.000			
8A	2.0 m	measurement		28.018	616	4.548	267.955			
8A	2.0 m	remove								

Appendix E Hydrolab DS-5 Calibration Certificate

Hydromet

Certificate of Instrument Performance

Agency Name: **CL Environmental**

Certification for Job# 1136954

Part/Model Number: **DS5**	Serial Number: **100100048757**

RECEIVED CONDITION: *(One must be checked)*

- [x] Within Tolerance
- [ ] Within Tolerance but Limited *(*see service report)*
- [ ] Out of Tolerance *(*see service report)*

RETURNED CONDITION: *(One must be checked)*

- [x] Within Tolerance
- [ ] Within Tolerance but Limited *(*see service report)*

Test Equipment Used, (ID#): N.I.S.T. - traceable glass thermometer (H-B Thermometer, Serial ***2Z9208)*** and a Cole-Parmer "*PolyStat*" Constant Temperature Circulator

Environmental Conditions:

Actual Temperature	Instrument Reading	Error
10.00 °C	10.03 °C	+***03*** °C
20.00 °C	20.01 °C	+***0.01*** °C
30.00 °C	29.97 °C	-***0.03*** °C

Hach Company does hereby certify that the above listed equipment meets or exceeds all Manufacturers' Service Specifications (unless limited conditions apply). Test equipment used for performance verification are calibrated using standards traceable to the National Institute of Standards and Technology (NIST). Where such standards do not exist, the basis for calibration is documented. The proper operation of the above instrument was established at the time of certificate issuance. To insure continued performance, user must adhere to all requirements listed in the instrument manual.

Certified by: J K Burton

Title: Instrument Service Technician

Certification Date: 3-14-13

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Doc# 1979?-01 Rev. 3