Climate Change Adaptation Series: Document 5

RAPID ASSESSMENT OF SHORELINE CHARACTERISTICS AND DYNAMICS OF LAZY LAGOON AT MLINGOTINI VILLAGE, BAGAMOYO

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Cover photo caption: An area of Lazy Lagoon (Mbegani Bay), Bagamoyo
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1.0 INTRODUCTION

1.1 Background

The work presented in this report is based on a one week field study conducted in January/February, 2011 at Lazy Lagoon area, Bagamoyo for the purpose of making a rapid assessment of the shoreline characteristics and the dynamics of the Lagoon in response of the physical forcing agents (namely the oceanic and meteorological forcing factors). The study was a baseline study which will shed light on other planned scientific studies by the Tanzania Coastal Management Partnership (TCMP) which facilitates a participatory and a transparent process to unite government and the community, science and management, sectoral and public interests to wisely conserve and develop coastal ecosystems and resources.

1.2 Study area description

Lazy Lagoon located about 10 km south of Bagamoyo Town and about 60 km north of Dar es Salaam City (Fig. 1) is a northwesterly trending lagoon along the coast of Tanzania Mainland. The lagoon is roughly rectangular with an area of approximately 15 km^2 during high Spring tides. The landward side of the Lagoon extends for some 10 km between Mlingotini village located to the south and the Mbegani Fishery Station located to the north. The seaward side of the Lagoon is bounded by a narrow (<50m width) raised Pleistocene reef platform. Within the lagoon there are several other patchily distributed raised reef Pleistocene platforms. Mangrove forests occur as one of the most prominent features within the Lagoon. They are generally patchily distributed along the coastal section stretching from Mbegani to Mlingotini where they occur as mangrove fringes (Fig. 2) with relatively denser thickets at Mbegani and Mlingotini. Dense mangrove thickets are also common on most of the raised reef inside the Lagoon (Fig. 2) The Lagoon is connected to the Indian ocean through its northern end and a tidal creek located on the eastern side of the Lagoon proximal to Mlingotini.

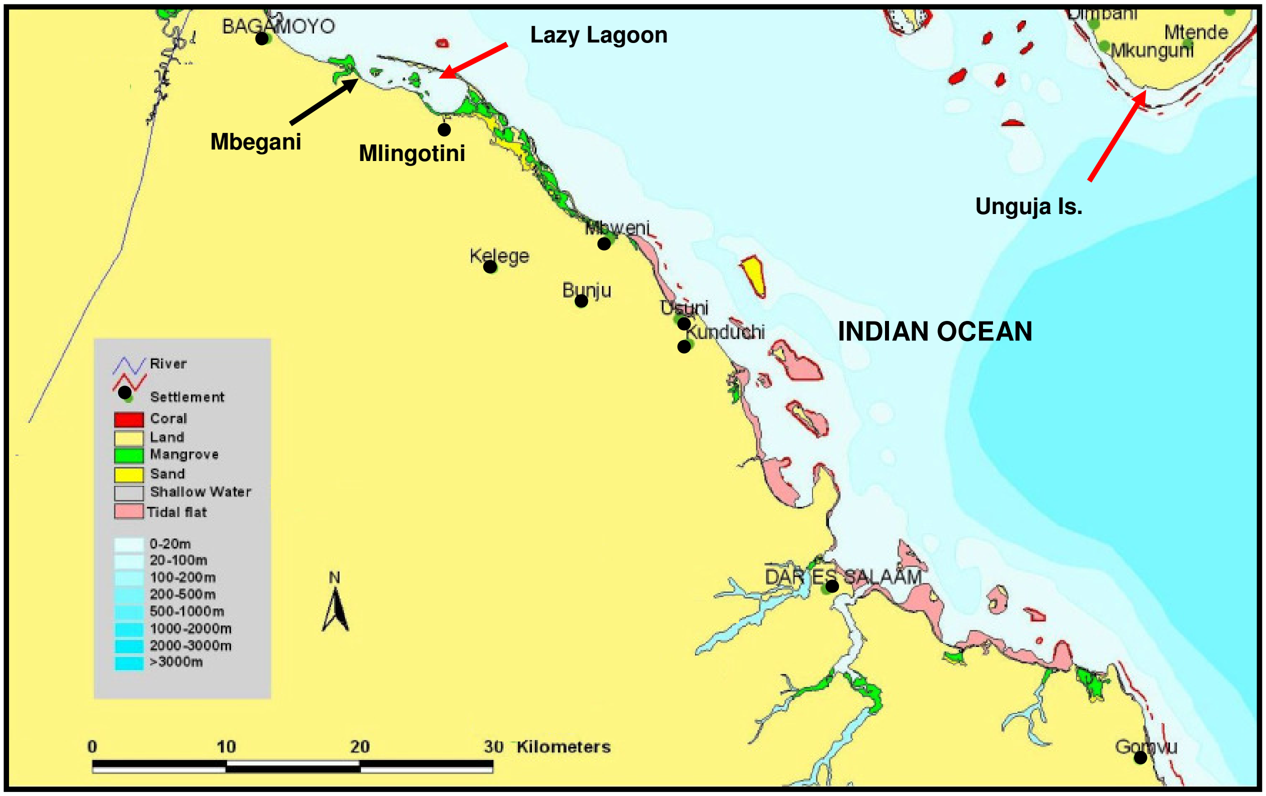

Fig. 1: Map showing the location of Lazy lagoon along the coast of Tanzania, north of Dar es Salaam City and south of Bagamoyo Town. Source: IMS GIS Unit.

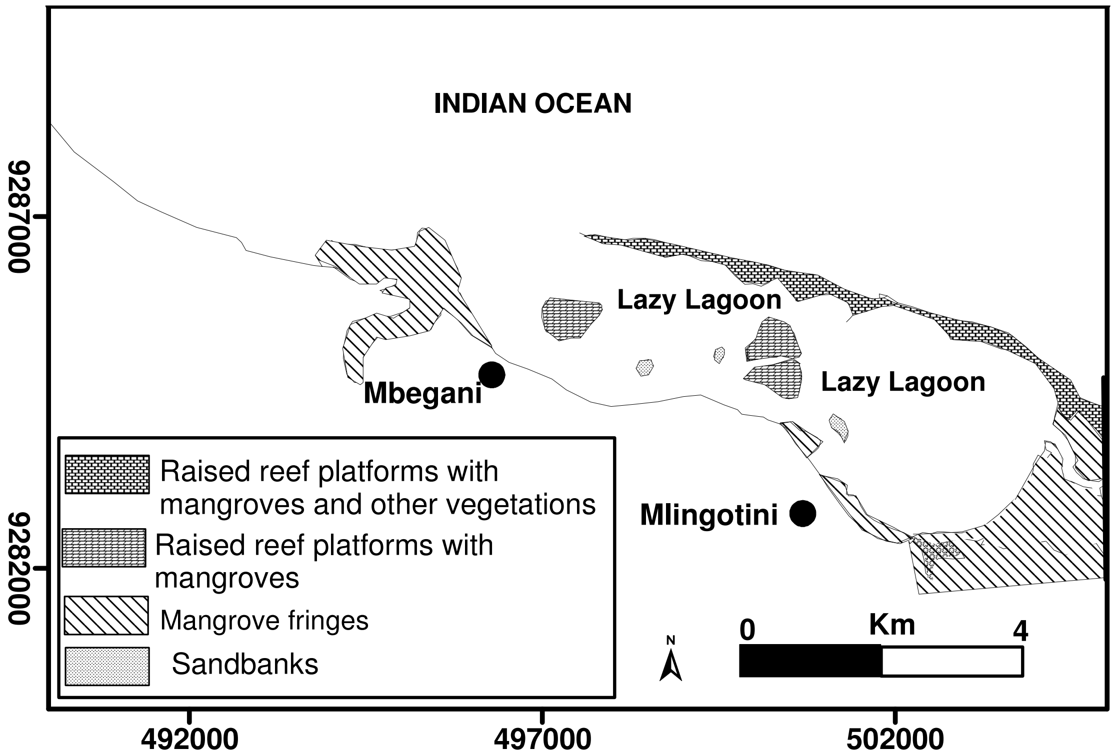

Fig.2. Map showing the main physiographic features of the Lazy Lagoon

An oceanographic and geological field work was conducted at Lazy Lagoon area in January/February 2011 for the purpose of making a rapid assessment of the shoreline characteristics and the dynamics of the Lagoon.

2.0 METHODS

The bulk of the field data used for the present study consisted of echo sounding data, sediment samples, tidal currents and tidal elevation measurements and field mapping of relevant physical features. The echo sounding data was collected along short cross-shore transects running from the landward side towards the raised reef platforms during high spring tides from 17-19th January 2011. The echo sounding measurements were conducted aboard a small fishing boat using a hand held echo sounder, with positioning (depth "fixes") taken using a hand held GPS. The depth, positions and time were simultaneously recorded in a Field logbook for further processing. During the survey a submersible tide recorder of the type RBR TWR-2050P was deployed for the purpose of recording tide level measurements. The equipment had two channels, namely the pressure channel which records the pressure (in decibar) of the water column above the sensor and the temperature channel, which records the temperature (in degrees celcius) of the sea water. Processing of the echo sounding data involved correction of the depth data for the tides. The tidal elevation data used for the correction of the depth data were obtained from the pressure measurements. An analysis of the echo sounding data was undertaken using surfer computer software. Surfer is a rectangular grid-based contouring program. Prior to contouring operation, the program require that grid files be created from the original X,Y, Z data points, where X, Y, and Z represents the geographic coordinates and depth respectively. The grid files were created using Kriging method (Keckler, 1995) with a linear variogram. The grid files were then contoured to investigate the pattern portrayed by the depth data points and the pattern portrayed was then edited using free hand drawn contours and the results were displayed on the basemap containing the investigated area.

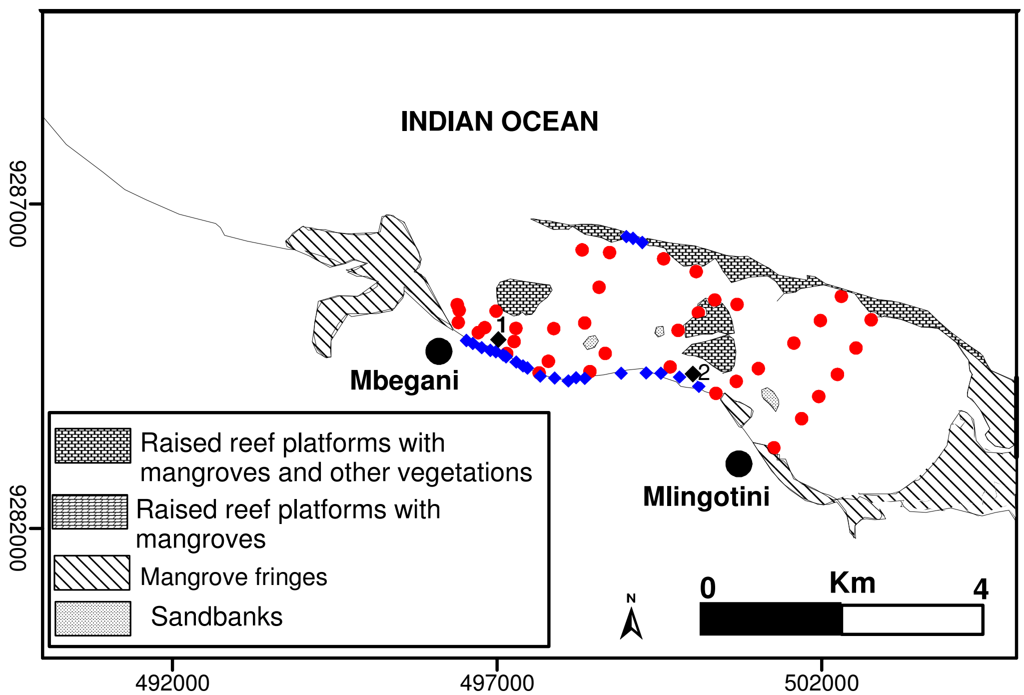

Fig. 3. Map showing the location of the sediment sampling sites and the current meter locations at Lazy Lagoon. Red dots = grab samples, blue diamond symbols = beach samples, black diamond symbols = Station 1 and 2 for the current meter.

Sea bottom sediment sampling was conducted using a light (approximately 10 kg) Van Veen Grab sampler where a total number of 37 samples were collected. Beach sediment samples were taken at the middle of the beach slope using a spoon size hand shovel, where a total number of 23.beach samples were collected. Thus, altogether, 60 sediment samples were collected for subsequent sedimentological analyses (Fig. 3), each sample consisting of at least half kg of sediments. All sediments were washed with fresh water to remove salts and wet sieved through a set of 12 sieves spaced between -2 phi (2mm) to 4 phi (63microns) and the grain size distribution was determined according to Folk and Ward (1957). During the beach sediment sampling, attempt was also made to document the major shore characteristic features as well as any observable shore erosion/accretion features.

3.0 RESULTS AND DISCUSSION

3.1 Echo sounding measurements and sea bottom topography

The spatial distribution of the depth data points is shown in Fig. 4-a, while the map of sea bottom topography of the Lazy Lagoon is shown on Fig. 4-b. The results indicate that the Lazy Lagoon is a shallow lagoon with a maximum depth of about 8 m with two main "deeps", one along the southern side of the lagoon (close to the shoreline), and the other along the northern side of the lagoon (proximal to the outer reef platform. The southern deep is relatively shallower (with maximum depth of about 4m) compared to the northern deep which has a maximum depth of about 8. The two deeps are the major conduits of the tidal currents in the Lagoon (See section 3.4).

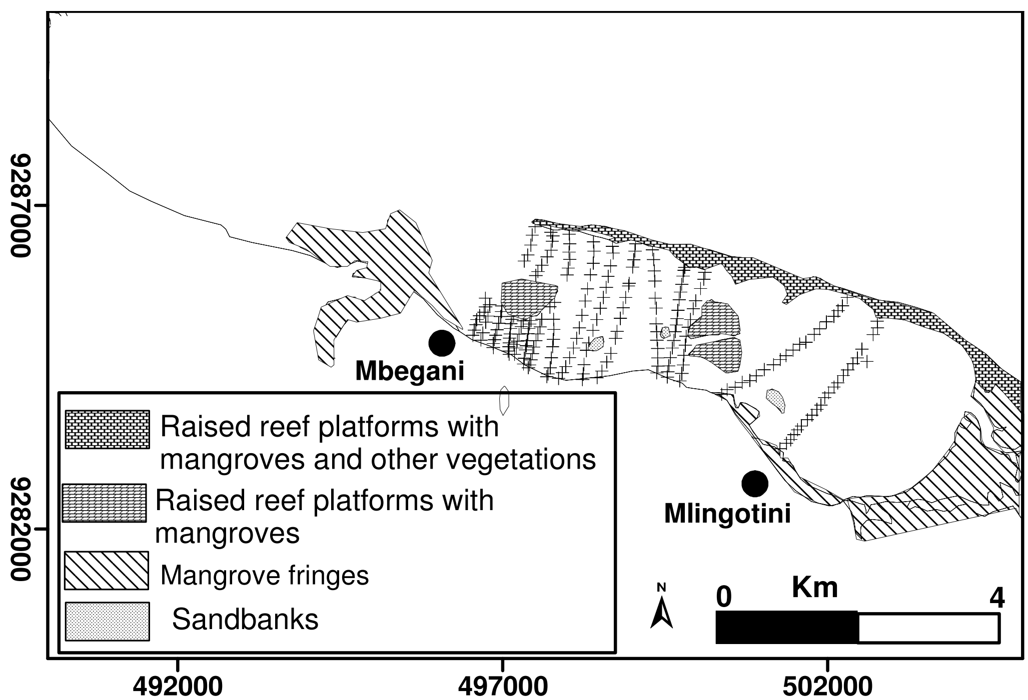

Fig 4-a: A map showing the echo sounding survey lines. The locations where depth soundings were taken are shown using cross symbols.

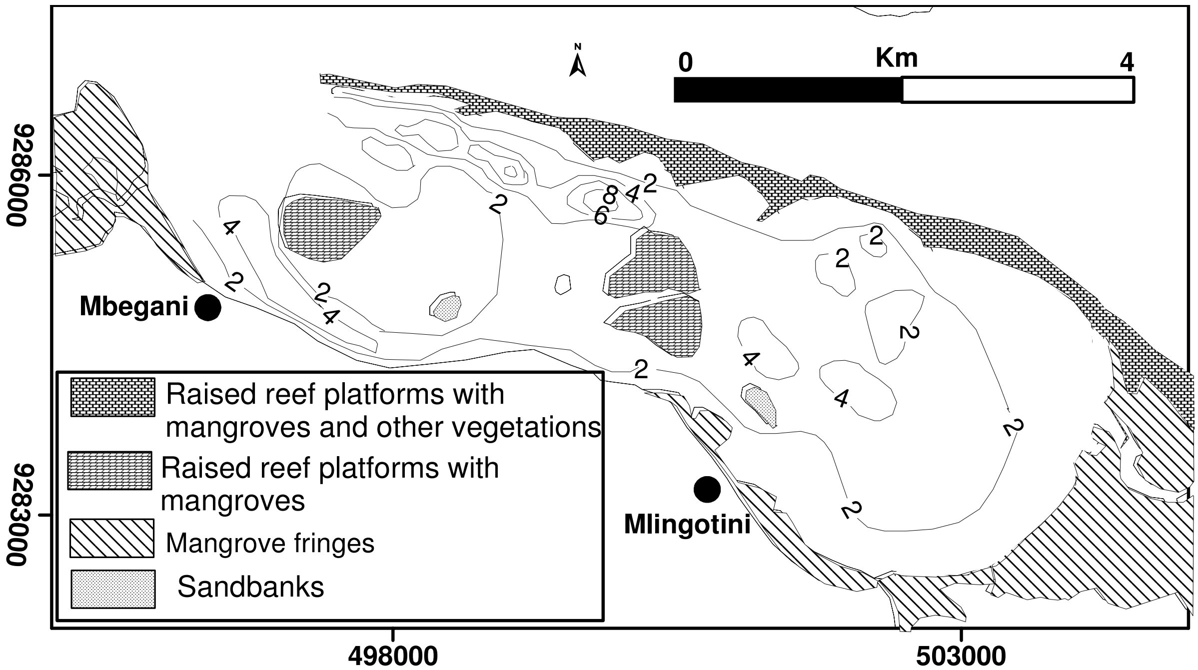

Fig 4-b: A map showing Lazy Lagoon the sea bottom topography. Note that the depth contours are in metres with contour interval = 2.

3.2 Sediment composition

The data on sediment composition revealed that the sea bottom sediment is dominated by siliciclastic (land derived) sediments, with very low proportions of biogenic components (Fig. 5). The analyses of $CaCO_3$ in the sediments revealed that the proportion of CaCO3 in the sediments varied between zero to 23% with an average value of about 5%. The highest carbonate content in the sediments were found in the sediments collected from the two "deeps" on the northwestern side and southwestern sides of the Lagoon respectively (Fig. 5). At the former "deep" the $CaCO_3$ content varied between 10 and 23% while at the latter "deep" the $CaCO_3$ content varied between 10 and 16%. Another site with relatively high values of $CaCO_3$ content was on the sediments on the sea bottom further upstream of the Lagoon where the $CaCO_3$ varied between 10 and 14%. Elsewhere the CaCO3 content on the sea bottom was below 10%.

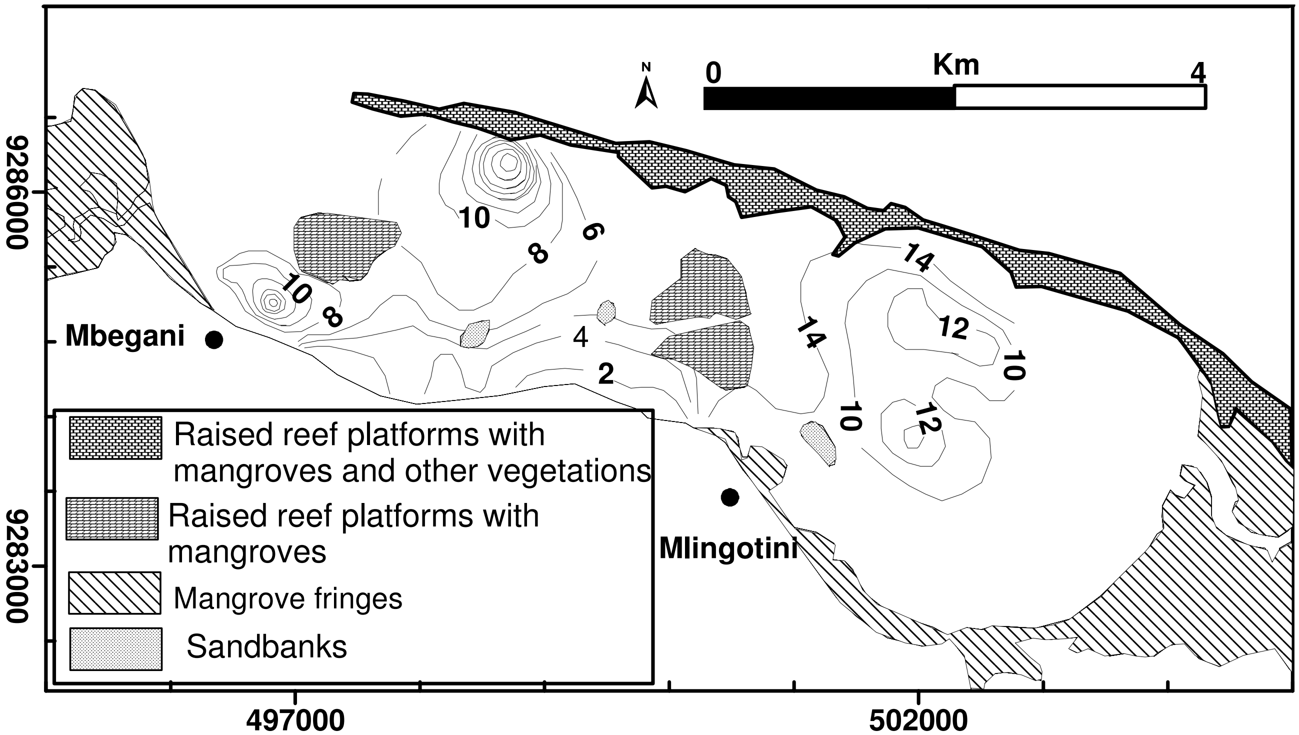

Fig. 5: Map showing the distribution of $CaCO_3$ in the sea bottom sediments.

3.3 Grain size distribution

3.3.1 Mean grain size

Mean grain size reflects the over all size of the grain particles as influenced by the source of supply and the depositional environment (Folk and Ward, 1957). The distribution of mean grain size along the beach and the sea bottom at Lazy Lagoon revealed that the mean grain size of the sediments varied between 0.183 phi (0.88 mm) and 2.598 phi (0.165 mm). On the Wentworth scale (Wentworth, 1922) these sediments varied between course through medium to fine classes. The majority (Fig. 6-a) of the sediment samples (>85%) were either within coarse size category (grain size between 0-1 phi) or medium size category (grain size between 1 to 2 phi) with only few samples belonging to fine sand class (grain size between 2 and 3 phi).

Furthermore, the mean grain size distribution of sediments at lazy Lagoon sea bottom (Fig. 6-b) revealed that the coarsest sediments were found on the sea bottom surrounding the western reef platform (the reef platform near the open end of the lagoon) as well as sediments on the southern side of the lagoon (from the mid part of the lagoon towards the shore) where the sediments were dominated by coarse sand size category. In contrast the sediments on the northern side of the lagoon were characterized by medium to fine sand categories. To a large extent, the mean grain size distribution at Lazy Lagoon seem to be controlled by depth, with coarser sediments on shallow areas and finer sediments in deeper parts of the sea bottom.

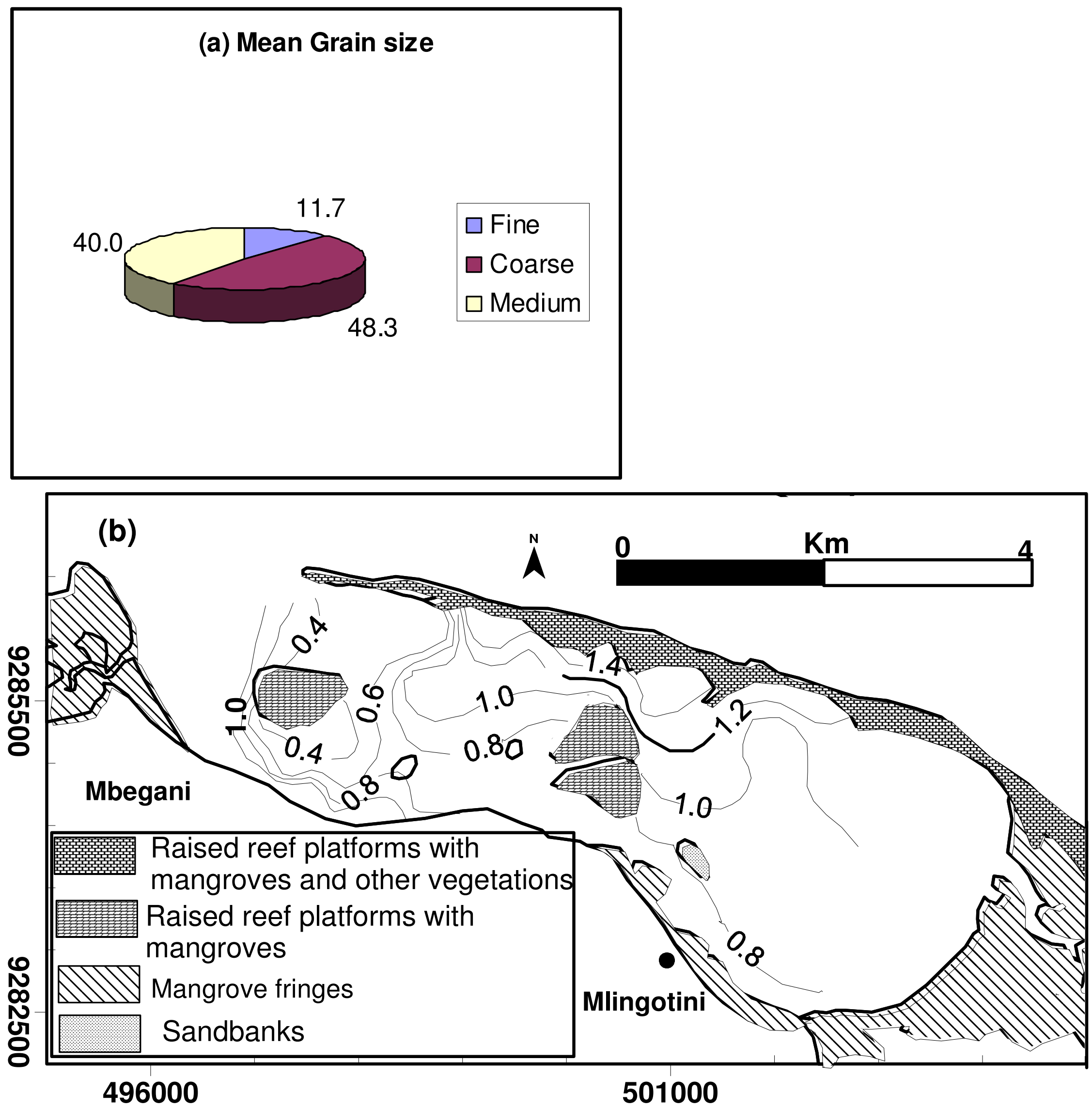

Fig. 6: Mean grain size distribution; (a) percentage of the sand size classes from the 60 sediment samples collected from Lazy lagoon and (b) the contour map for the mean grain size distribution of the Lazy Lagoon sediments. Note that the contour interval = 0.2 phi.

3.3.2 Sorting

Sorting of the sediments reflects the overall size variation of the particles as influenced by the variation of the energy of the depositing medium.Analyses of the sorting distribution of the sediments (Fig. 7-a) revealed that majority of the sediment samples (more than 85 %) were either poorly sorted (sorting range between 1 and 2 phi; Folk, 1966) or moderately sorted (sorting range between 0.7 phi and 1.0 phi; Folk, 1966), while 11.6 % of the sediments were either moderately well sorted (8.3%) or well sorted (3.3%), with sorting ranges between 0.5 and 0.7 phi and 0.35 and 0.5 respectively. Furthermore, the results revealed that the sediments surrounding the western reef platform (the reef platform off Mbegani) as well as the most of the sediments on and adjacent to the northern tidal channel were relatively better sorted than the rest of the Lazy Lagoon sediments, These sediments were characterized by sorting value less than 1.0 phi, while the remaining parts of the sea bottom was characterized by poorly sorted sediments (sorting value >1.0 phi).

3.3.3 Skewness

Skewness of the sediments is a measure of asymmetry of the sample distribution with respect to normal (Folk, 1966). Analyses of the skewness of the sediments revealed that 43.3% of the sediments samples analysed had symmetrical skewness, with skewness value in the range between -0,1 and +0.1, while 36.6% of the sample were either positively skewed(18.3%) or negatively skewed (18.3%), with skewness value in the ranges of +0.1 to +0.3 or -0.1 to -0.3 respectively. Very negatively skewed sediments (skewness value < -0.3) were also common with 15% of the 60 samples analysed but sediments with very positively skewness (skewness > 0.3) were relatively few.

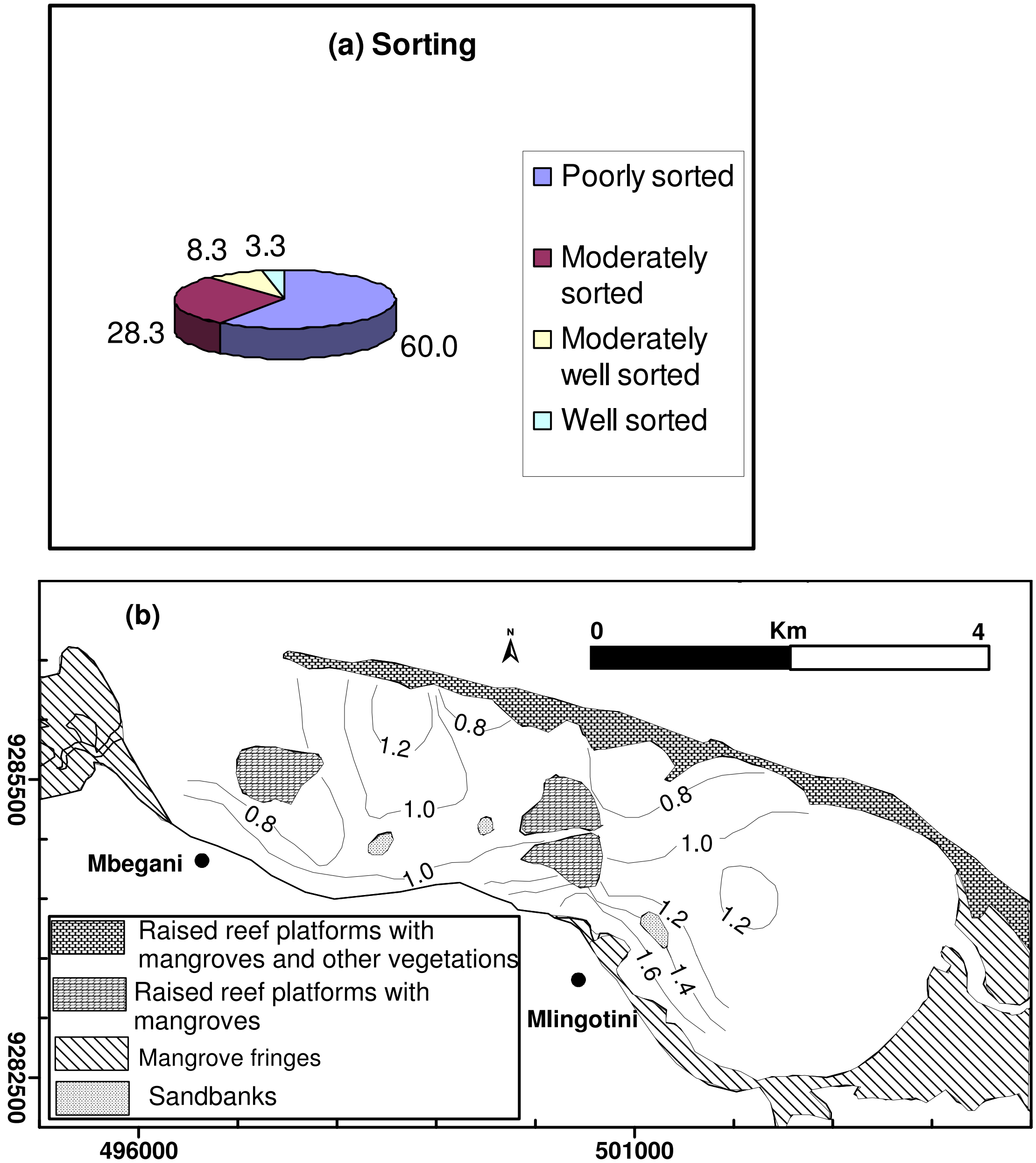

Fig. 7: Lazy Lagoon sediments sorting; (a) Percentage of sorting classes from the 60 sediment samples analysed from Lazy Lagoon and (b) the contour map showing the distribution of sorting at Lazy Lagoon.

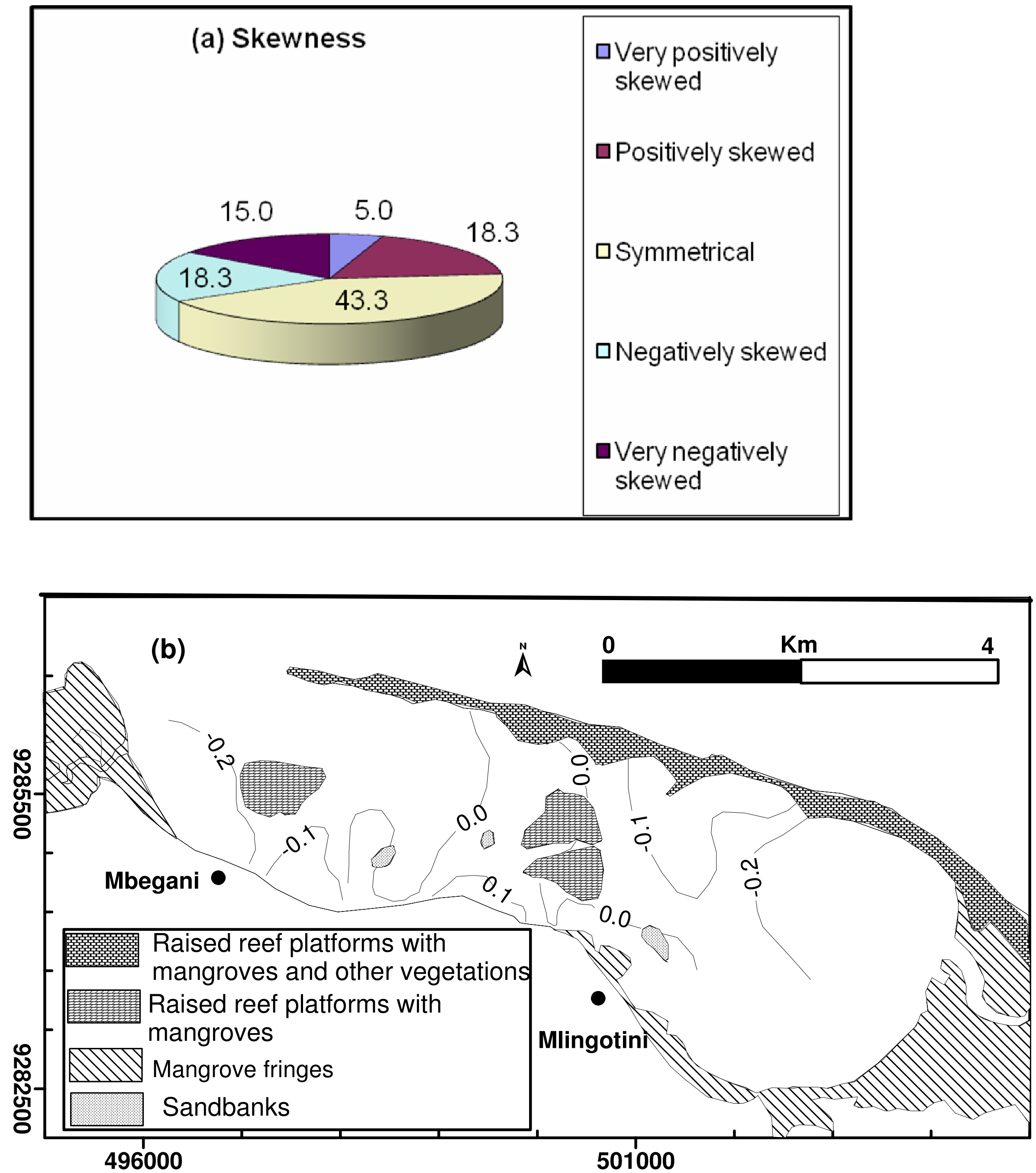

Fig. 8: Distribution of sediments skewness; (a) Percentage of skewness classes from the 60 sediment samples analysed at Lazy Lagoon and (b) the contour map showing the distribution of skewness at L:azy Lagoon.

3.4 Tidal currents

The field measurements of the tidal tides at Lazy Lagoon revealed that the tides are semi-diurnal types (two high waters and two low waters per day), with maximum amplitude of about 4 m (Fig. 9). The tides at Lazy Lagoon like the tides in many parts along the coast of Tanzania (Ngusaru, 2002) are meso-tides (i.e. tides with amplitude between 2-4 m). Maximum current speeds were slightly higher at station 1 (0.5 m/s) than at station 2 (0.42 m/s). However, at both stations the maximum current speeds occurred during the mid tide phase of the tide and the minimum current speeds were observed during the high and low water times where in both cases the current speeds were zero. Furthermore, at both stations, the maximum current speeds during flood and ebb were more or less comparable. The current roses of the Lazy Lagoon (Fig. 10) revealed that the tidal currents at both stations were consistently south-easterly during flood and north-westerly during ebb. During flood the tidal currents enter the Lagoon through the wider opening located on the western side of the Lagoon and then follows the paths through the two deeps described in section 3.3. Further upstream the two tidal streams as the sea bottom topography further upstream flattens (Fig. 11).

3.5 Status of coastal erosion and coastal vulnerability to erosion

Field signs of coastal erosion were abundant at several localities of the coastal stretch between Mbegani and Mlingotini, with highest abundance of the erosion signs on the western side (the coastal stretch towards Mbegani) as compared to the eastern side (Fig. 12). The field signs of coastal erosion included: Exposure of tree roots (particularly mangrove trees), uprooting of mangrove trees, the presence of beach scarps, and the presence of coastal protection structures.

The first coastal protective structure was encountered at the Old boat yard located 300 m west of Mbegani Fisheries Training Centre. The old jetty installed in front of the boatyard (Fig. 13) seem to have been functioning as a groyne (CIRIA, 1996; Shaghude et al., 2010), promoting accretion of sediments on one side of the jetty but accelerating erosion on the other side (the down drift side). Here it is evident that the quarried rock aprons were installed to protect the eroding seawall in front of the boatyard.

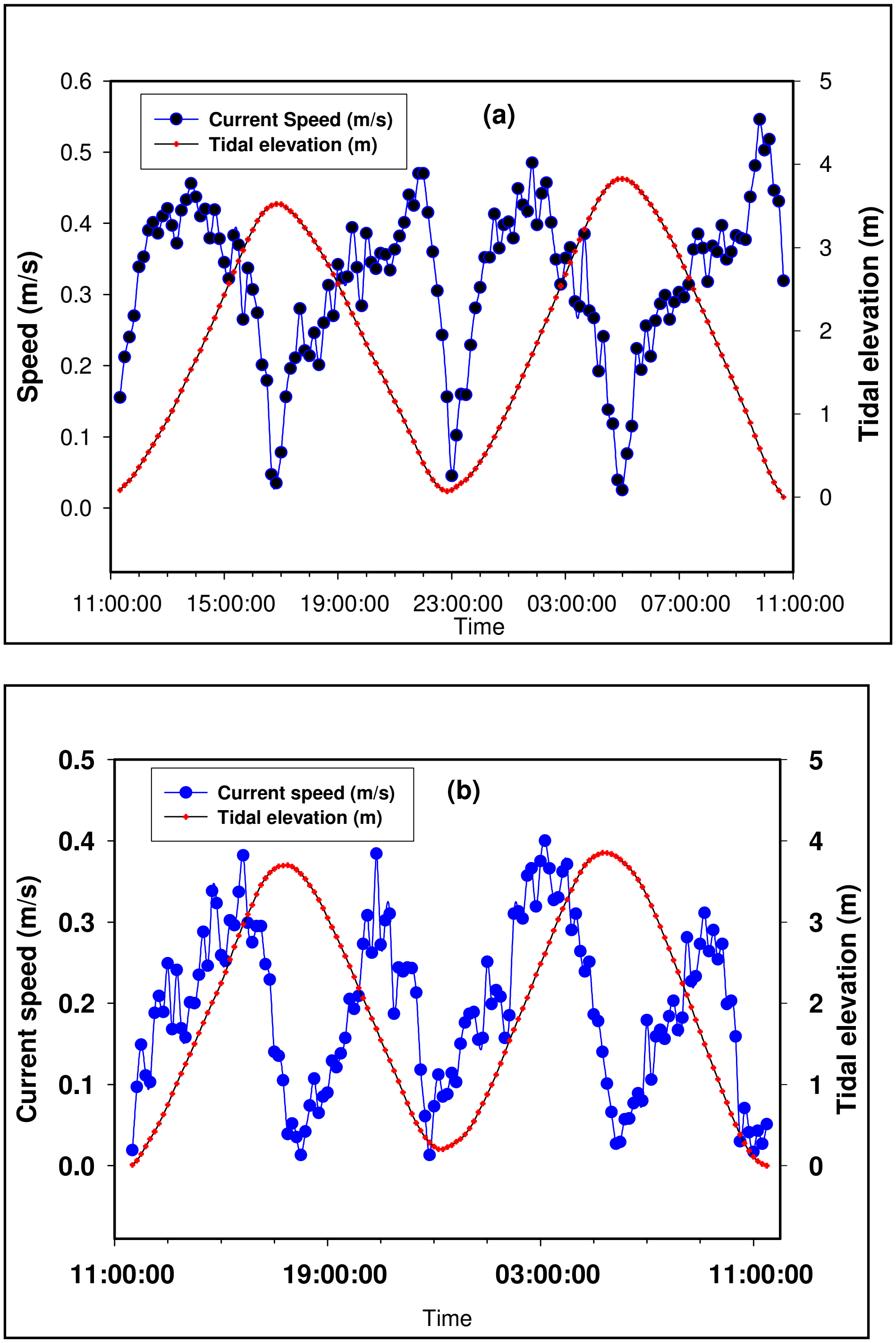

Fig. 9: Tidal current speeds and tidal elevations at Lazy Lagoon (a) Station 1 and (b) Station 2. The Station locations are shown in Fig. 3.

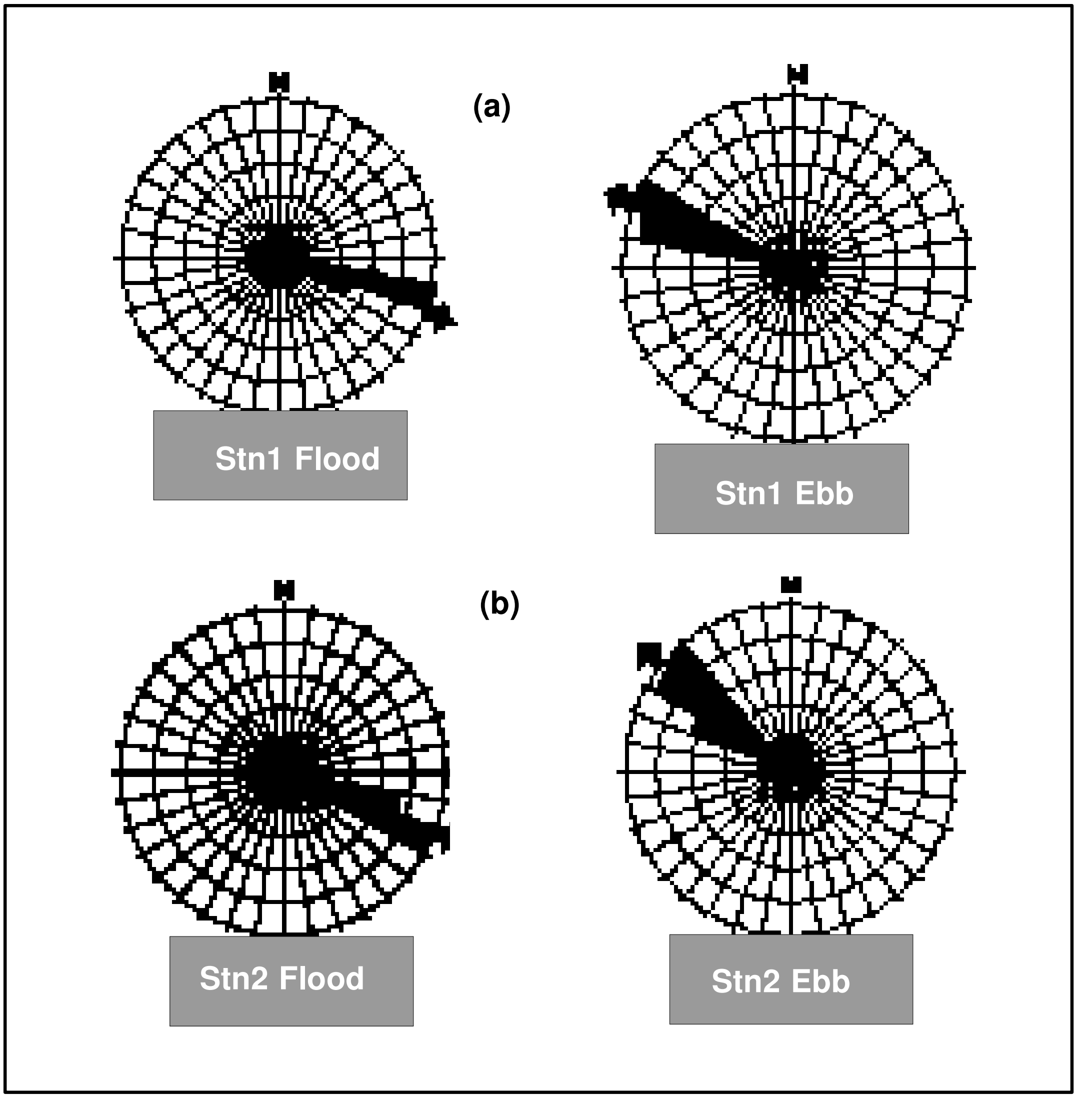

Fig. 10: Current roses at (a) Station 1 and (b) Station 2 of Lazy Lagoon, Bagamoyo. The current roses indicate the dominant current direction at two stations during Flood (**Left**) and Ebb **(Right)** tidal phases.

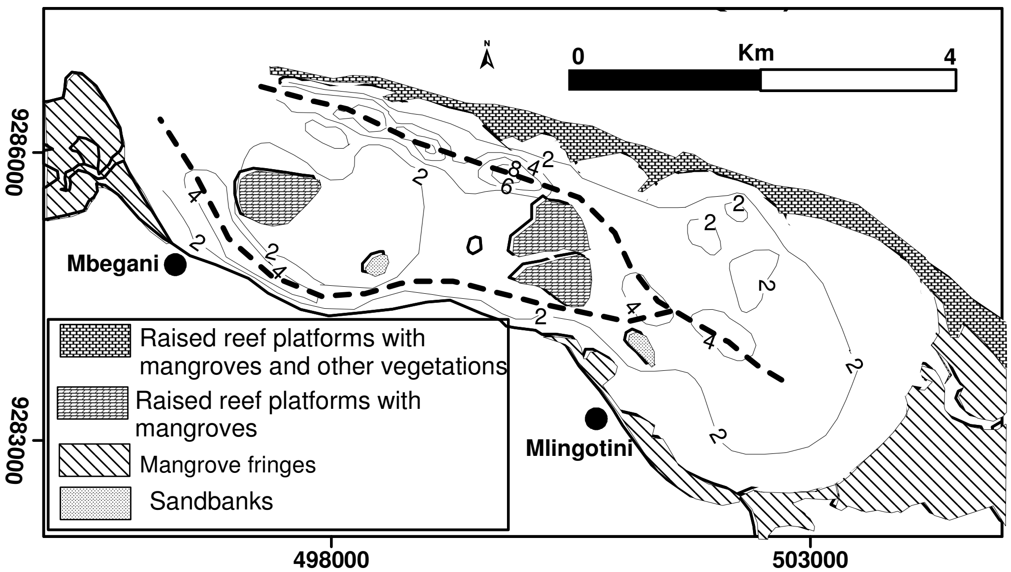

Fig. 11: Map showing the two major tidal current streams (dotted lines) in Lazy Lagoon, superimposed on the bathymetric contour map discussed in section 3.1.

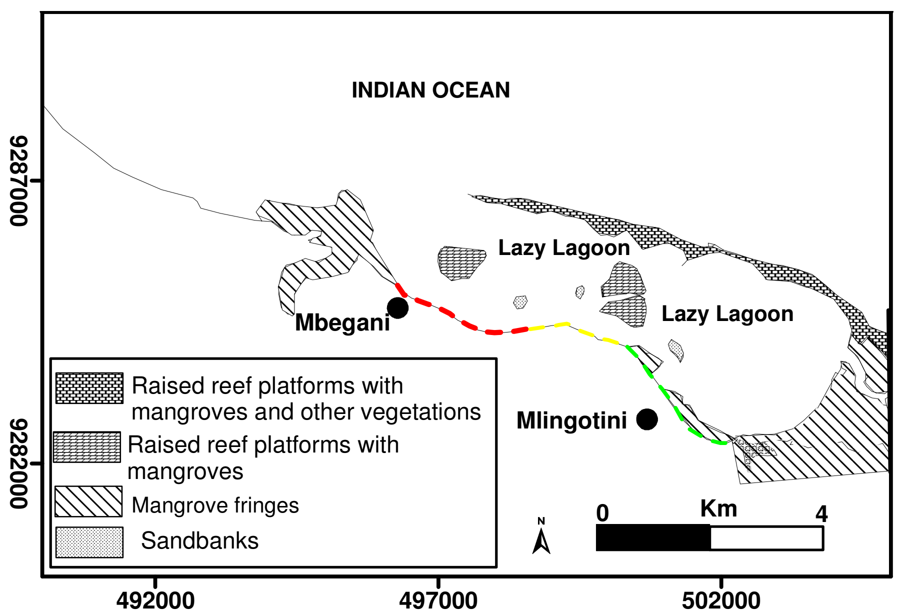

Fig.12: Map showing the status of coastal erosion along the coastal stretch between Mbegani and Mlingotini, Bagamoyo. The red dotted line (between 5-10 incidences of eroding coastal sites. encountered), Yellow dotted line (Less than 5 incidences of eroding coastal sites encountered), Green dotted line (No erosion observed).

Fig. 13. The jetty in front of the old boatyard at Mbegani, (**Top**) The eastern (upstream) side of the jetty with no evidence of erosion and (b) the western (downstream) side of the jetty, which was severely affected by coastal erosion

Fig. 13: Gabion seawalls used to protect an eroding Holocene beach ridge located about 2 km from Mbegani.

The other coastal protective structures encountered along the coastal stretch between Mbegani and Mlingtini were gabions Fig. 13. Gabions are vertical wall structures made of rectangular containers (baskets) of thick galvanized wire, which are normally filled with quarried rocks and stacked to each other, usually in tiers that step back with the slope rather than vertically (Fig. 13.

Exposure of tree roots (Fig. 14), incidences of uprooting of mangrove tress (Fig. 15) as well as actual collapse of cliffs (Fig. 16) were common features along a 2-3 km coastal stretch on the western side of the Lagoon (Fig. 12), but less common on the coastal stretch proximal to Mlingotini. The erosional features were generally absence along the coastal stretch fringed by dense mangrove thickets east of Mlingotini fish landing site.

Field investigations of the coastal stretch from Mbegani to Mlingotini revealed that mangrove vegetations formed one of the prominent features of the shoreline and to large extent the mangrove vegetations had played a significant role in shore stabilization and protection of the shore against wave erosion.

Other important features observed along the coastal stretch from Mbegani to Mlingotini were marine terraces and beach ridges. Marine terraces are relatively horizontal or inclined geomorphic surfaces with vertical steps of marine origin while beach ridges are wave-swept or wave-deposited ridges running parallel to the shoreline of marine origin. Both the marine terraces and beach ridges are considered to be distinctive backshore geomorphological features formed during the Late Pleistocene to Holocene sea level fluctuations, and are common backshore geomorphological features along the coast of Tanzania (Alexander, 1968, 1969, 1985; Muzuka *et al.* 2004).

In the present investigated coastal section between Mbegani and Mlingotini, beach ridges were particularly common on the 2 km western coastal stretch (Fig. 14-15). Further eastwards (the next 2 km) along the coastal stretch, the marine terraces (Fig. 16) were relatively more important distinctive backshore features than the beach ridges. Most of the marine terrace units observed along this central coastal stretch had vertical steps and in most cases the lowest terrace unit was eroding. The coastal stretch proximal to Mlingotini was characterized by superposition of beach ridges and marine terraces (Fig. 17).

The presented results indicates that the vulnerability to wave erosion of the coastal stretch between Mbegani to Mlingotini differs from west to east, with highest vulnerability on the western coastal stretch and lowest vulnerability on the eastern coastal stretch. The difference in vulnerability to wave erosion between the western side and the eastern side could be attributed to the discussed difference in the geomorphological setting. Alternatively the difference in the mangrove forest cover along the coastal stretch may also contribute to the observed difference in shoreline erosion along the coastal stretch. However further investigation of the backshore characteristics involving systematic field mapping of the backshore and auger drilling to explore the sub-surface 2m depth sediment composition could shed more light on the reasons for the observed magnitude of shoreline erosion between the western side and eastern side of the investigated coastal stretch.

Fig 14: Eroding shore at Mbegani as exemplified by exposure of tree roots. Such incidents were common along the entire 2km coastal stretch on the western side. Further on the backshore are the Holocene beach ridges with dense vegetations

Fig. 15: Eroding shore at Mbegani as exemplified by the uprooting of trees.

Further on the backshore are the Holocene beach rides with dense vegetations.

Fig. 16: Marine beach terrace units encountered along the investigated coastal stretch. Note that the lower terrace units are currently eroding.

Fig. 17: Beach ridges superposed on the marine terrace units proximal to Mlingotini fish landing site.

4. 0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

- The Lazy Lagoon, located between Mbegani and Mlingotini, Bagamoyo is a shallow lagoon with a maximum depth of 8 m, with two “deeps” one along the southern side of the lagoon (close to the shoreline), and the other along the northern side of the lagoon (proximal) to the outer reef platform. The northern “deep” with a maximum depth of 8 m was relatively deeper than the southern “deep”.

- The lagoon has two tidal channels, corresponding to the southern and northern “deep”, respectively. The two channels which merge on their upstream side are the major conduits of the tidal currents during flood and ebb.

- The sediments on the lagoon (including the beach sediments) are dominated by siliciclastic (land derived sediments) with the biogenic components in the sediments averaging to about 5%. The biogenic components was relatively higher (between 10-25%) on the northern and southern deeps as well as on the sea bottom proximal to Mlingotini, than in the remaining parts of the sea bottom including the beach sediment.

- The tides in the Lagoon were semi-diurnal (with two high waters and two low waters each day) with maximum tidal amplitude of about 4 m and maximum speeds of about 0.5 m/s. During the flood phase of the tides, the tidal currents were dominantly south-easterly and during ebb the tidal currents were dominantly north-westerly.

- Evidence of wave erosion along the coastal stretch between Mbegani and Mlingotini were abundant but the severity of wave erosion was relatively higher on the coastal stretch towards Mbegani than on the coastal stretch towards Mlingotini. The observed difference could either be attributed to the difference in the physiographic settings between the two sides or the difference in the mangrove coverage between the two.

4.2 Recommendations

- Future monitoring of the shoreline is recommended in order to provide an insight as to whether the observed erosion in the area is chronic or an acute problem which could recover after few years of observations. Furthermore investigation of the backshore characteristics (including systematic field mapping of the backshore and auger drilling to explore the sub-surface 2m depth sediment composition) is also recommended. The information from such study could provide more insights on why there are observed differences on the severity of wave erosion between the western side and eastern side of the investigated coastal stretch.

- Tidal currents measurements along the northern tidal channel were not measured during the present study. This would be another important data for the future studies as the data would provide further insights on the circulation pattern of the tides in the lagoon.

- It is important to note that the coastal stretch between Mbegani and Mlingotini still underdeveloped in terms of tourism infrastructures. However, with the increasing pace of Dar es Salaam City expansion, coastal encroachment of this coastal stretch is anticipated in the near future. Constructions of buildings close to the shoreline should be discouraged by the land planners so as to ensure that there is always a buffer zone between the beach and the backshore areas where developments are allowed.

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APPENDICES

Appendix 1: UTM Coordinates of the sediment sampling locations, grain size distribution parameters (Mean grain size, Sorting and Skewness) and % of calcium carbonate content in the sediment samples.

Appendix 2: The Mean grain size, sorting and skewness of the Lazy Lagoon sediments and their corresponding descriptive terms according to Folk (1966).

Appendix 3: The UTM coordinates of the sounding points and the corresponding depth in metres

Appendix 1: UTM Coordinates of the sediment sampling locations, grain size distribution parameters (Mean grain size, Sorting and Skewness) and % of calcium carbonate content in the sediment samples.

Sample	X	Y	Mean	Sorting	Skewness	Carbonate
BG1	497093	9284671	0.870	1.232	0.331	0.85
BG2	496979	9284723	1.800	1.672	-0.533	5.19
BG3	496892	9284742	1.517	1.794	-0.365	5.28
BG4	496761	9284785	0.802	1.332	0.357	0.67
BG5	496626	9284847	0.702	0.840	0.187	0.72
BG6	496528	9284896	1.140	0.788	0.175	1.70
BG7	496415	9285362	1.807	1.024	-0.463	12.53
BG8	496385	9285447	2.273	0.648	-0.200	4.25
BG9	496401	9285173	1.086	1.313	-0.075	2.85
BG10	496708	9285016	1.288	1.194	-0.064	10.86
BG11	496808	9285093	1.001	1.231	-0.164	17.89
BG12	496983	9285348	0.341	0.740	-0.082	7.58
BG13	497289	9285082	0.460	0.779	-0.085	8.77
BG14	497261	9284878	0.329	0.852	-0.023	6.51
BG15	497146	9284694	1.055	1.320	0.110	1.42
BG16	497646	9284395	0.932	1.469	0.177	2.87
BG17	497788	9284575	0.617	0.790	-0.145	4.62
BG18	497871	9285078	0.332	0.681	-0.115	4.89
BG19	498428	9284416	0.830	1.092	-0.115	4.58
BG20	498663	9284695	0.680	0.826	-0.101	4.08
BG21	498347	9285165	0.751	1.031	0.089	9.76
BG22	498569	9285716	1.332	1.152	-0.176	8.52
BG23	498731	9286251	0.204	1.678	-0.281	23.17
BG24	498308	9286290	0.183	1.107	0.124	10.24
BG25	498991	9286495	1.340	1.007	0.151	0.69
BG26	499092	9286469	2.388	0.305	-1.163	0.55
BG27	499236	9286404	2.464	0.425	0.014	0.66
BG28	499563	9286153	1.202	0.670	0.050	0.71
BG29	500065	9285956	1.545	1.044	0.004	6.45
BG30	500694	9285450	1.447	0.560	-0.075	7.01
BG31	500350	9285519	0.850	0.943	0.084	4.89
BG32	500098	9285321	0.755	0.870	0.078	4.80
BG33	499786	9285050	0.621	0.986	0.036	5.59
BG34	499663	9284486	0.916	1.051	0.020	3.08
BG35	500368	9284081	-0.629	3.191	-0.496	13.13
BG36	500682	9284265	0.927	1.235	-0.059	9.31
BG37	501022	9284462	0.956	1.110	-0.017	5.50
BG38	501569	9284854	1.134	1.035	-0.184	11.23
BG39	501977	9285201	0.664	0.923	-0.027	12.67
BG40	502300	9285575	1.556	0.800	-0.315	3.00
BG41	502760	9285212	1.052	0.967	0.026	1.88
BG42	502525	9284779	1.220	1.256	0.079	14.33

Sample	X	Y	Mean	Sorting	Skewness	Carbonate
BG43	502240	9284372	0.861	0.886	0.010	7.83
BG44	501952	9284032	0.784	1.017	-0.086	15.47
BG45	501688	9283690	1.036	1.151	-0.090	8.19
BG46	501262	9283240	1.135	1.675	0.018	7.11
BG47	497137	9284645	0.826	1.083	0.198	0.95
BG48	497293	9284563	2.317	1.278	-0.473	1.43
BG49	497395	9284502	2.135	1.417	-0.422	1.27
BG50	497464	9284470	2.342	1.192	-0.339	1.15
BG51	497662	9284346	1.512	1.444	-0.155	1.15
BG52	497884	9284315	2.598	1.562	-0.610	7.09
BG53	498096	9284272	1.399	1.087	0.171	0.76
BG54	498196	9284665	1.094	0.895	0.081	3.47
BG55	498350	9284310	1.610	1.353	0.063	3.14
BG56	498911	9284391	0.840	1.099	0.110	0.67
BG57	499295	9284394	0.807	1.099	0.183	0.58
BG58	499522	9284390	0.988	0.630	0.302	0.49
BG59	499807	9284330	1.156	0.851	0.127	0.36
BG60	500130	9284122	0.463	0.815	-0.001	0.48

Appendix 2: The Mean grain size, sorting and skewness of the Lazy Lagoon sediments and their corresponding descriptive terms according to Folk (1966)

Sample	Mean	Descriptive term	Sorting	Descriptive term	Skewness	Descriptive term
BG1	0.870	coarse	1.232	Poorly sorted	0.331	Very positively skewed
BG2	1.800	medium	1.672	Poorly sorted	-0.533	Very negatively skewed
BG3	1.517	medium	1.794	Poorly sorted	-0.365	Very negatively skewed
BG4	0.802	coarse	1.332	Poorly sorted	0.357	Very positively skewed
BG5	0.702	coarse	0.840	Moderately sorted	0.187	Positively skewed
BG6	1.140	medium	0.788	Moderately sorted	0.175	Positively skewed
BG7	1.807	medium	1.024	Poorly sorted	-0.463	Very negatively skewed
BG8	2.273	Fine	0.648	Moderately well sorted	-0.200	Negatively skewed
BG9	1.086	Medium	1.313	Poorly sorted	-0.075	Symmetrical
BG10	1.288	Medium	1.194	Poorly sorted	-0.064	Symmetrical
BG11	1.001	Medium	1.231	Poorly sorted	-0.164	Negatively skewed
BG12	0.341	Coarse	0.740	Moderately sorted	-0.082	Symmetrical
BG13	0.460	Coarse	0.779	Moderately sorted	-0.085	Symmetrical
BG14	0.329	Coarse	0.852	Moderately sorted	-0.023	Symmetrical
BG15	1.055	Medium	1.320	Poorly sorted	0.110	Positively skewed
BG16	0.932	Coarse	1.469	Poorly sorted	0.177	Positively skewed
BG17	0.617	Coarse	0.790	Moderately sorted	-0.145	Negatively skewed
BG18	0.332	Coarse	0.681	Moderately well sorted	-0.115	Negatively skewed
BG19	0.830	Coarse	1.092	Poorly sorted	-0.115	Negatively skewed
BG20	0.680	Coarse	0.826	Moderately sorted	-0.101	Negatively skewed
BG21	0.751	Coarse	1.031	Poorly sorted	0.089	Symmetrical
BG22	1.332	medium	1.152	Poorly sorted	-0.176	Negatively skewed
BG23	0.204	coarse	1.678	Poorly sorted	-0.281	Negatively skewed
BG24	0.183	coarse	1.107	Poorly sorted	0.124	Positively skewed

Sample	Mean	Descriptive term	Sorting	Descriptive term	Skewness	Descriptive term
BG25	1.340	medium	1.007	Poorly sorted	0.151	Positively skewed
BG26	2.388	Fine	0.305	Well sorted	-1.163	Negatively skewed
BG27	2.464	Fine	0.425	Well sorted	0.014	Symmetrical
BG28	1.202	medium	0.670	Moderately well sorted	0.050	Symmetrical
BG29	1.545	medium	1.044	Poorly sorted	0.004	Symmetrical
BG30	1.447	medium	0.560	Moderately well sorted	-0.075	Symmetrical
BG31	0.850	coarse	0.943	Moderately sorted	0.084	Symmetrical
BG32	0.755	coarse	0.870	Moderately sorted	0.078	Symmetrical
BG33	0.621	coarse	0.986	Moderately sorted	0.036	Symmetrical
BG34	0.916	coarse	1.051	Poorly sorted	0.020	Symmetrical
BG35	0.913	coarse	1.135	Poorly sorted	-0.496	Very negatively skewed
BG36	0.927	coarse	1.235	Poorly sorted	-0.059	Symmetrical
BG37	0.956	coarse	1.110	Poorly sorted	-0.017	Symmetrical
BG38	1.134	medium	1.035	Poorly sorted	-0.184	Negatively skewed
BG39	0.664	coarse	0.923	Moderately sorted	-0.027	Symmetrical
BG40	1.556	medium	0.800	Moderately sorted	-0.315	Very negatively skewed
BG41	1.052	medium	0.967	Moderately sorted	0.026	Symmetrical
BG42	1.220	medium	1.256	Poorly sorted	0.079	Symmetrical
BG43	0.861	coarse	0.886	Moderately sorted	0.010	Symmetrical
BG44	0.784	coarse	1.017	Poorly sorted	-0.086	Symmetrical
BG45	1.036	medium	1.151	Poorly sorted	-0.090	Symmetrical
BG46	1.135	medium	1.675	Poorly sorted	0.018	Symmetrical
BG47	0.826	coarse	1.083	Poorly sorted	0.198	Positively skewed
BG48	2.317	Fine	1.278	Poorly sorted	-0.473	Very negatively skewed
BG49	2.135	Fine	1.417	Poorly sorted	-0.422	Very negatively skewed
BG50	2.342	Fine	1.192	Poorly sorted	-0.339	Very negatively skewed
BG51	1.512	medium	1.444	Poorly sorted	-0.155	Negatively skewed
BG52	2.598	Fine	1.562	Poorly sorted	-0.610	Very negatively skewed

Sample	Mean	Descriptive term	Sorting	Descriptive term	Skewness	Descriptive term
BG53	1.399	medium	1.087	Poorly sorted	0.171	Positively skewed
BG54	1.094	medium	0.895	Moderately sorted	0.081	Symmetrical
BG55	1.610	medium	1.353	Poorly sorted	0.063	Symmetrical
BG56	0.840	coarse	1.099	Poorly sorted	0.110	Positively skewed
BG57	0.807	coarse	1.099	Poorly sorted	0.183	Positively skewed
BG58	0.988	coarse	0.630	Moderately well sorted	0.302	Very positively skewed
BG59	1.156	medium	0.851	Moderately sorted	0.127	Positively skewed
BG60	0.463	coarse	0.815	Moderately sorted	-0.001	Symmetrical

Appendix 3: The UTM coordinates of the sounding points and the corresponding depth in metres. Note that the positive are by convention below zero depth and negative values are above zero depth.(i.e. on land).

X	Y	Depth(m)		X	Y	Depth (m)
Line 1				Line 12		
497098	9284700	0.5		498549	9285578	-2
497084	9284751	5.2		498501	9285411	-1.7
497092	9284817	5.2		498447	9285237	-1.9
497097	9284876	5.4		498387	9285068	-2
497106	9284950	5.3		498322	9284876	-2.1
497116	9285015	3.3		498286	9284760	-2.7
497120	9285099	0.4		498251	9284542	-1
497128	9285172	-0.6		498239	9284395	1.6
497143	9285239	-1.4		498228	9284311	-1.9
497165	9285286	-2.3		Line 13		
Line 2				498450	9284339	-1.8
497314	9285215	-2.2		498525	9284443	3.4
497284	9285129	-1.3		498600	9284581	1
497250	9285011	-0.4		498663	9284713	-2.2
497227	9284904	3.9		498734	9284946	-2.1
497211	9284796	5		498760	9285052	-1.9
497183	9284700	6.8		498809	9285255	-1.3
497173	9284853	2		498853	9285418	-1.5
Line 3				498891	9285578	-1.9
497319	9284551	-1.4		498936	9285758	-1.6
497331	9284640	6.3		498945	9285796	-1.6
497349	9284766	3.8		498997	9286048	7.6
497361	9284833	2.4		499016	9286160	4.8
497376	9284910	-0.3		499035	9286295	-0.8
497388	9285018	-1.2		499042	9286407	-1.8
497400	9285100	-1.6		Line 14		
497414	9285167	-2.1		499303	9286314	-1.6
497436	9285223	-2.4		499321	9286164	-0.7
Line 4				499332	9285988	0.1
497600	9285240	-2.2		499340	9285831	3.8
497574	9285124	-1.9		499344	9285567	1.7
497542	9285014	-1.5		499363	9285412	-1
497511	9284913	-1.3		499359	9285169	-1.4
497478	9284812	0.6		499369	9285050	-1.3
497457	9284711	2.7		499373	9284919	-1.8

X	Y	Depth(m)		X	Y	Depth (m)
497435	9284612	5.4		499385	9284789	-1.2
497412	9284536	5.9		499384	9284644	-0.3
497394	9284493	-2.1		499388	9284519	1.8
Line 5				499370	9284413	0.6
496856	9284804	-0.8		Line 15		
496854	9284866	4		499533	9284349	1.3
496872	9284925	3.9		499537	9284429	-0.9
496889	9284993	4.4		499555	9284523	0.7
496912	9285079	5.67		499581	9284650	0
496939	9285179	4.4		499610	9284797	0.6
496967	9285284	1.5		499632	9284914	0.4
496981	9285360	-0.7		499655	9285049	-0.2
496986	9285446	-1.4		499669	9285155	0.2
Line 6				499683	9285250	-0.1
496799	9285466	5.3		499694	9285380	-1
496775	9285293	6.4		499714	9285544	0.1
496740	9285195	1.2		499734	9285663	2
496694	9285031	5.3		499755	9285780	10.8
496663	9284919	-0.5		499774	9285908	5.8
Line 7				499788	9285995	3.6
496540	9284993	-1.2		499800	9286042	-0.1
496562	9285075	0.9		Line 16		
496588	9285160	2.5		500110	9285966	-0.3
496603	9285236	1.3		500095	9285859	0.8
496642	9285297	-1.7		500042	9285716	7
496713	9285351	-1.5		499968	9285527	-0.3
496734	9285431	4.9		499933	9285405	-0.1
496734	9285568	6.2		499889	9285235	0.1
				499852	9285119	0.1
497497	9286671	5.1		499821	9284980	-0.6
497452	9286543	1.5		499809	9284840	-0.8
497432	9286385	1.6		499788	9284683	-0.7
497384	9286234	2.2		499778	9284535	-0.4
497331	9286143	-0.2		499756	9284404	-1.2
Line 9				499725	9284288	1.3
497509	9285916	-1.9		Line 17		
497543	9285977	-1.9		500368	9284081	-0.1
497603	9286078	3.6		500451	9284155	1.6
497683	9286203	0.2		500575	9284191	0.3

X	Y	Depth(m)		X	Y	Depth (m)
497745	9286310	-0.5		500682	9284265	-0.4
497763	9286448	0.4		500803	9284294	-1.1
497772	9286529	7.9		500903	9284365	-0.1
497740	9286583	8.3		501022	9284462	0.5
Line 10				501166	9284539	6.8
498022	9286557	0.8		501269	9284619	2.4
498030	9286405	6		501358	9284679	0.5
498020	9286278	-1		501468	9284764	0.3
498032	9286166	-1.3		501569	9284854	0.4
498009	9286033	0.7		501665	9284887	0
497990	9285926	2.2		501790	9285006	0.1
497798	9285501	-2.4		501877	9285095	-0.2
497726	9285432	-2.3		501977	9285201	-0.2
497782	9285240	-2.4		502094	9285288	1.6
497788	9285084	-1.9		502159	9285372	-0.9
497780	9284930	-1.6		502228	9285447	-0.2
497767	9284818	-1.6		502300	9285575	1.1
497748	9284646	-0.3		Line 18		
497731	9284491	5.5		502760	9285212	0.7
497696	9284398	2.1		502766	9285107	0.1
497677	9284354	-2.2		502700	9285004	0
Line 11				502605	9284588	0.9
497859	9284328	-1.5		502525	9284779	-0.1
497918	9284416	3.6		502455	9284642	-0.1
497969	9284511	3.1		502389	9284555	-0.4
498027	9284647	-1.9		502307	9284459	-0.2
498089	9284798	-1.2		502240	9284372	-0.2
498138	9284948	-1.6		502154	9284260	1.5
498179	9285108	-1.2		502097	9284195	6.1
498219	9285300	-1.9		502014	9284104	4.4
498269	9285525	-1.7		501952	9284032	1.2
498302	9285710	-1.2		501895	9283916	0.4
498350	9285927	-0.7		501834	9283848	0.9
498392	9286108	-1		501757	9283760	0.9
498404	9286293	6.2		501688	9283690	-0.6
498396	9286438	5.9		501595	9283591	-0.6
Line 12				501535	9283535	-0.6
498688	9286370	-1.8		501480	9283457	-0.6
498698	9286264	6.6		501429	9283383	-0.1

X	Y	Depth(m)		X	Y	Depth (m)
498657	9286065	-0.6		501366	9283325	-0.2
498621	9285902	-1		501262	9283240	-0.6
498592	9285734	-0.9				