CAM de Smet

Volume 1

Site Investigation

Republic of Mozambique
Beira

Service Port

TU Delft
Technische Universiteit Delft

Faculteit der Civiele Techniek
Vakgroep Waterbouwkunde
Sectie Waterbouwkunde

Service Port for Beira Harbour, Mozambique

Volume 1

Site Investigation
(Appendix 1 to 10)

1991

This volume belongs to the main report with the title "Service Port, Beira".

INTRODUCTION

For the development of a new service port for Beira Harbour it was necessary to do a site investigation. For this reason there was a study-trip to Beira during a period of six weeks at the end of 1990.
During this stage it was the intention to collect all available data required to develop the new service port.
This purpose was achieved by:

- a literature study of the existing reports of earlier studies about Beira,
- meetings with authorities related to the project, and
- own investigation.

The results are shown in this volume. In particular, Appendix 1 to 7 show the results of the accumulated data in Beira. Appendix 8, 9 and 10 have been completed in The Netherlands, with the aid of Appendix 1 to 7.

TABLE OF CONTENTS - VOLUME 1
SERVICE PORT, BEIRA

page

LIST OF REFERENCES

V1.1. *Peoples Republic of Mozambique SADDC and Danish international development AGENCY*
Project identification and feasibility study for Port Traffic Control Centre
Beira Port, Mozambique.

V1.2. *Peoples Republic of Mozambique*
BCA
Beira Port Project - Dredging
Contract No. P - A - 1
Contract Documents - Volume 5
5.1. - Physical Information - Part B

V1.3. *Beira Port Projects*
Capital Dredging Works Contract P - A - 1
Memorandum No. 3
Pre - Dredging Survey
DHV Consultants March 1989

V1.4. *Beira Port Study*
Access Channel Study
Main Report
NEDECO

V1.5. *Beira Port Study*
Access Channel Study
Volume 3
NEDECO

V1.6. *Beira Port Study*
Masterplan Study
Volume 3
NEDECO

V1.7. *Beira Port Study*
Masterplan Study
Volume 4
NEDECO

V1.8. *Beira Port Study*
Masterplan Study
Volume 2
NEDECO

V1.9. *Inleiding Landmeetkunde*
Prof. Ir. J.E. Alberda

V1.10. *Mozambique - a tale of terror*
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V1.11. *Oefening Landmeetkunde practikum 1989/1990*
Ir. J. Garlisch
Ing. M.J.M. Kremers

LIST OF REFERENCES--Continued

V1.12. *Guidelines on port safety and environmental protection*
The International Association of Ports and Harbors

V1.13. *Havens*
Prof. Ir. H. Velsink/Ir. R. Groenveld e.a.

TABLES page

TABLES--Continued page

FIGURES

FIGURES--Continued page

ABBREVIATIONS

List of abbreviations:

B.C.A.	Beira Corridor Authority
BM	benchmark
C	Celsius
Calc.	Calculation
CD	Chart Datum
C.F.M	Caminhos de Ferro de Moçambique (Centro)
degr.	degrees
DHV Consultants	DHV Consultants
dir.	direction
Dis.	Distance
Dist.	Distance
d.s.	dry season
E	East
Emodraga	Empresa Mocambicana de Dragagem E.E. (Mozambican Dredging Company)
h	hour
hp	horse power
HW	High Water
HWL	High Water Level
Ing.	Ingenieur
Ir.	Ingenieur
Instr.	Instrument
Inv.	Inverse
K1,K2	(the two main tide components)
L	Length
LLWL	Lowest Low Water Level
LW	Low Water
m	meter
Max.	Maximum
MHWS	Mean High Water Spring
Min.	Minimum
MLW	Mean Low Water
mm	millimeter
Mr.	Mister
MSL	Mean Sea Level
N	North
Ndv	Nautical depth of the vessels

ABBREVIATIONS--Continued

NEDECO	Netherlands Engineering Consultants
No.	Number
Nr.	Number
O.	Orientating
P	penetration
P.A.	Port Administration
Pass.	Passengers
Prof.	Professor
PTCC	Port Traffic Control Centre
Ref.	Reference
S	South
s	second
SADDC	Southern African Development Coordination Conference
SE	South East
SEP	Secretariat for Fisheries
SMB	Sverdrup, Munk and Bretschneider
SPT	Standard Penetration Test
T.U.-Delft	Delft University of Technology
v.	vessel
VHF	Very High Frequency
W	West
w.s.	wet season

SYMBOLS AND DEFINITIONS

- Air temperature	[°C]
- amount of sediment, s_t	[kg/tide]
- Angle	[°]
- Atterberg limits:	
LL, Liquid Limit	[%]
PI, Plasticity Index	[%]
- average flow area, A_E	[m²]
- average sediment concentration during a tidal period, C	[mg/l]
- average water depth in the port, h	[m]
- α,tot, α,1, α,2	[°]
- blow count (15 cm)	[n]
blow count (30.5 cm)	[N]
- Buoy No.	[-]
- characteristic water velocity in front of the ports, U_c	[m/s]
- concentrations, C	[mg/L]
- Current velocity	[m/s]
- Dead weight	[ton]
- density variation during a tidal period in front of the ports, $\Phi_{\pm}$	[kg/m³]
- Depth	[CD + m]
- Direct shear strength	[KN/m²]
- Displacement, Δ	[ton]

SYMBOLS AND DEFINITIONS--Continued

- Distance	[m]
- Draft	[m]
- Draught	[m]
- Dry bulk density	[KN/m^3]
- Eastern (x)	[m]
- Exceedence	[%]
- Height Beacon	[m]
- Height CD + (z)	[m]
- Instr. Height	[m]
- Length	[m]
- length of vessel, L	[m]
- Level Instr.	[-]
- Low	[m]
- Middle	[m]
- Natural water	[%]
- Northern (y)	[m]
- Occurrence	[%]
- Pocket shearvane	[KN/m^2]
- Point No.	[-]
- Power, P	[hp]
- Rainfall	[mm]
- Relative humidity	[%]
- River discharges	[m^3/s]
- Specific gravity	[KN/m^3]
- Spt value	[blows/ft]
- Stopping Distance, S	[m]
- surface	[m^2]
- swell	[m]
- thickness, t	[m]
- tidal prism, P	[m^3]
- Tidal range	[m]
- Top	[m]
- volume of water filled voids, V_v	[-]
- Water-level	[CD + m]
- wave height	[m]
- wave period, T, T_p	[s]
- Width	[m]
- Width, B	[m]
- wind speed	[km/h, m/s]
- wind velocity	[Beaufort scale]

Republic of Mozambique   Beira

SERVICE PORT, BEIRA

Appendix 1

METEOROLOGICAL INFORMATION

1. METEOROLOGICAL INFORMATION

1.1 General climatological conditions

The climate is tropical, but also influenced by the sea. Inland is always cooler than the coast and the rainfall, too, is greater as the land rises. There are two seasons. From April to September the coast has a temperate climate, sunny and pleasantly warm and mainly dry. The hot, wet season lasts from October to March. Most of the rain falls between January and March but it is extremely variable from one year to the next, averaging 750 mm in the south, more in the north and rising inland to 900 mm and even 1,700 mm per year. Temperatures on the coast average about 27°C – 29°C, and humidity can be 80% when there is no wind from the direction of the sea.

The dry and calm season at Beira covers the period from May to September. The wet season which coincides with rougher conditions at sea lasts from December to April. In between both seasons transitory periods can be considered. From October to February there is a chance of strong winds from southerly, south-easterly and easterly directions. Tropical cyclones can occur from December to March.
Heavy seas from southerly directions can occur from September to April.

Some general climatological conditions at Beira are presented in the following table:

months	J	F	M	A	M	J	J	A	S	O	N	D
- dry season					—	—	—	—				
- wet season	—	—	—							- -	- -	—
- occurrence of strong winds from SE-quarter	—									—	—	—
- possible cyclones	—	—										—
- occurrence of heavy seas from S - SE	—	—	—						—	—	—	—
- more pleasant weather						—	—	—	—			

Table 1.1.1 Some general climatological conditions at Beira.

1.2 Winds and storms

Seasonal variation in wind direction is small. Most frequent wind directions are from the SE. Usually wind velocities are no stronger than Beaufort scale 4 to 5 but during tropical cyclones (sometimes occurring between December and March) high wind velocities are sometimes registered.

A general picture of the wind climate is listed below with the following general characteristics:
- Wind velocities are moderate. The mean wind speed is 13.2 km/h (3.7 m/s) (see Table 1.2.1).

period	Jan.	Febr.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	year
mean wind velocity (km/h)	13.3	13.0	13.2	11.8	11.2	11.4	11.3	13.1	14.8	16.3	15.4	13.6	13.2

Table 1.2.1 Mean wind speeds 1936-1965.

Table 1.2.2 presents the maximum mean hourly values for each month over 28 years. The mean maximum hourly wind speed is 35.5 km/h (9.9 m/s).

month	dir.	maximum hourly mean (km/h)	most frequent direction	mean maximum (km/h)	standard deviation (km/h)
Jan	N	60	SE, SSE, S	40	8
Feb	SSE, SE	48	SSE, SE, S	33	7
Mar	S	49	SSE, SE, S	35	6
Apr	S, W	50	SE, SSE, S	34	6
May	S	38	SSE, S, SSW	31	5
Jun	SSW	50	SSE, S, SE	33	6
Jul	SSW	41	S, SSE, SE	31	4
Aug	S	44	S, SSE, SE	35	5
Sep	SE	52	S, SE, E	36	6
Oct	SSE, S	52	S, SE, SSE	40	6
Nov	S	55	E, SE, S	40	6
Dec	NW	57	SE, SSE, S	38	7

Table 1.2.2 Maximum mean hourly winds 1941-1968.

- There is a seasonal variation throughout the year with a more frequent occurrence of slightly higher wind velocities from September to February.

- Wind direction is generally from the SE quadrant (see Table 1.2.3) and there is very little seasonal variation in the direction.

Direction	Occurrence (%)	Mean velocity (km/h)
N	2.3	9.7
NNE	3.2	9.6
NE	3.9	9.2
ENE	5.1	11.9
E	10.9	14.5
ESE	16.1	16.0
SE	12.4	16.7
SSE	7.4	17.8
S	5.2	18.2
SSW	5.4	17.1
SW	5.3	14.4
WSW	3.3	10.0
W	2.6	8.2
WNW	2.8	8.4
NW	2.7	8.8
NNW	2.4	7.9
CALM	8.2	0

Table 1.2.3 Wind directions, occurrence and mean hourly velocity 1936-1965.

- The higher wind velocity shows a preference of the SE quadrant (see Table 1.2.2 and 1.2.3).

- Tropical cyclones are liable to affect the Mozambique channel but hardly ever strike the mainland coast.

1.3 Rainfall

The rainfall varies with the season. Heavy rainfall occurs from December to March. The average annual rainfall in the Beira region amounts to 1,200-1,500 mm with strong local variations.
Average rainfall for January is 287 mm whilst the number of rainy days in that month averages 15 days.

1.4 Temperature

The air temperature in Beira (see Table 1.4.1) varies during the day and during the season. The maximum temperature occurs during the afternoon and on average is about 31°C in the months from December to February and about 25°C to 26°C in the months from June to August. During the night the temperature gradually drops. On average this drop amounts to about 8°C to 9°C. The mean monthly maximum temperature exceeds the main daily maximum by 2°C to 5°C. The absolute maximum temperature recorded at Beira Airport in the period 1970-1979 amounted to 40.6°C.
The absolute minimum temperature recorded in the above mentioned period was 9.4°C.

Month	Mean daily		Mean monthly		Extremes	
	max.	min.	max.	min.	max.	min.
Jan.	31.2	23.7	33.5	21.5	36.6	18.9
Febr.	30.9	23.4	33.2	21.2	34.2	19.9
March	30.3	22.7	32.2	20.6	33.9	18.8
April	28.9	20.9	32.3	17.7	36.8	16.9
May	27.6	18.0	29.8	14.0	31.9	12.5
June	25.5	16.2	29.8	12.6	31.9	9.4
July	25.0	15.3	28.9	12.1	31.7	11.0
Aug.	26.3	16.5	31.7	12.8	34.5	10.6
Sept.	27.2	18.2	31.1	13.5	32.8	10.9
Oct.	29.1	20.1	33.9	15.9	36.5	14.5
Nov.	30.2	21.8	34.8	18.1	40.6	15.7
Dec.	31.0	22.9	35.5	19.6	38.9	18.8

Table 1.4.1 Air temperature in °C at Beira Airport 1970-1979.

1.5 Humidity

The relative humidity varies only slightly during the season and more distinctly during the day. Relevant data is shown in Table 1.5.1 .

Month	9.00 h	15.00 h	21.00 h
Jan.	72	66	80
Febr.	77	68	80
March	79	67	80
April	77	66	81
May	78	63	83
June	79	64	83
July	81	63	85
Aug.	76	62	83
Sept.	70	66	81
Oct.	67	65	80
Nov.	69	67	80
Dec.	72	69	81

Table 1.5.1 Relative humidity in % at Beira Airport 1970-1979.

Republic of Mozambique Beira

SERVICE PORT, BEIRA

Appendix 2

TIDAL DATA

1. TIDAL DATA

1.1 Project reference level

In Beira an automatic tide gauge is installed in the existing harbour. There a Chart Datum is defined at a level of MSL-3.56 m. MSL is the Mean Sea Level measured over a long period.

All bathymetric Charts of Beira Harbour and its access channels have been reduced to the above Chart Datum. This Chart Datum (CD) will also be used in this report.

1.2 Vertical tide

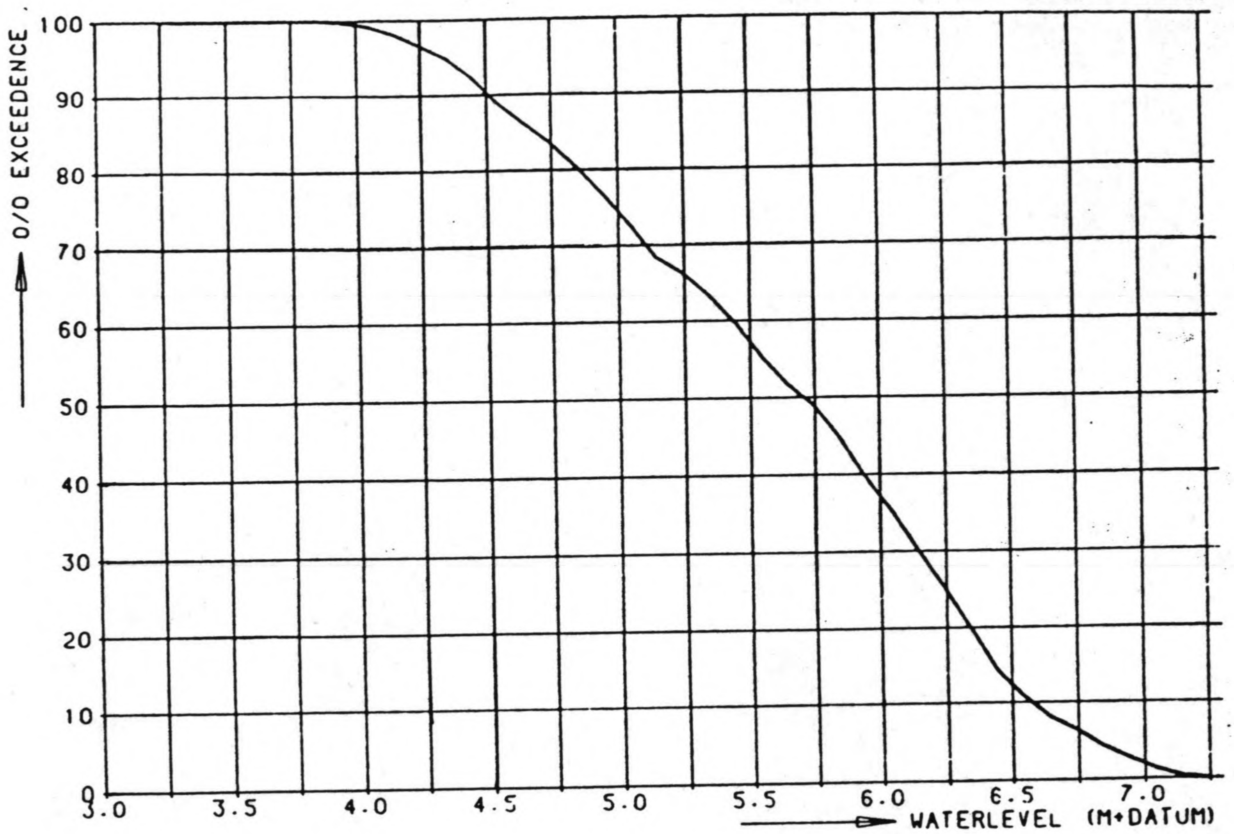
The large tidal range is a dominant factor in the area responsible for the high tidal currents and huge sediment transport. The tide penetrates deeply into the estuary. The tide is semi-diurnal with a daily difference of about 0.4 m in the tidal range. The tidal range at Beira is large; mean spring tidal range and mean neap tidal range amount to 5.7 m and 1.6 m respectively.

Tidal data of Beira Harbour has been processed statistically over a period of one year (from 8th January, 1981 to 8th January, 1982). As tide records were missing for some short periods, the one-year data base was completed by data generation based on the tide predictions for Beira Harbour and relations between these predictions and the observed tide in the relevant periods. The results of the statistical processing of the tidal range are shown in Table 1.2.1 whereas Figure 1.2.1 shows the results of the HW-levels at Beira Harbour. This data has been obtained as a result of the studies which have been carried out for the Masterplan study.

Interval in m	Frequency of occurrence in %			Frequency of exceedence in %		
	d.s.	w.s.	year	d.s.	w.s.	year
0.0-0.5	0.0	0.0	0.0	100.0	100.0	100.0
0.5-1.0	0.5	0.3	0.4	99.5	99.7	99.6
1.0-1.5	2.8	3.4	3.0	96.7	96.2	96.5
1.5-2.0	5.6	5.8	5.7	91.2	90.4	90.9
2.0-2.5	8.5	8.7	8.6	82.7	81.7	82.3
2.5-3.0	7.5	9.4	8.3	75.2	72.4	74.0
3.0-3.5	8.1	7.3	7.8	67.0	65.0	66.2
3.5-4.0	9.2	9.7	9.4	57.8	55.3	56.8
4.0-4.5	9.1	8.5	8.9	48.7	46.8	47.9
4.5-5.0	13.8	11.4	12.8	34.9	35.3	35.1
5.0-5.5	15.6	11.8	14.0	19.3	23.5	21.0
5.5-6.0	12.8	14.5	13.5	6.4	9.0	7.5
6.0-6.5	5.9	6.3	6.1	0.5	2.7	1.4
6.5-7.0	0.5	2.7	1.4	0.0	0.0	0.0
7.0-7.5	0.0	0.0	0.0	0.0	0.0	0.0
7.5-8.0	0.0	0.0	0.0	0.0	0.0	0.0

d.s. = dry season (May to December)
w.s. = wet season (December to April)

Table 1.2.1 Frequency distributions of the tidal range at Beira Harbour.



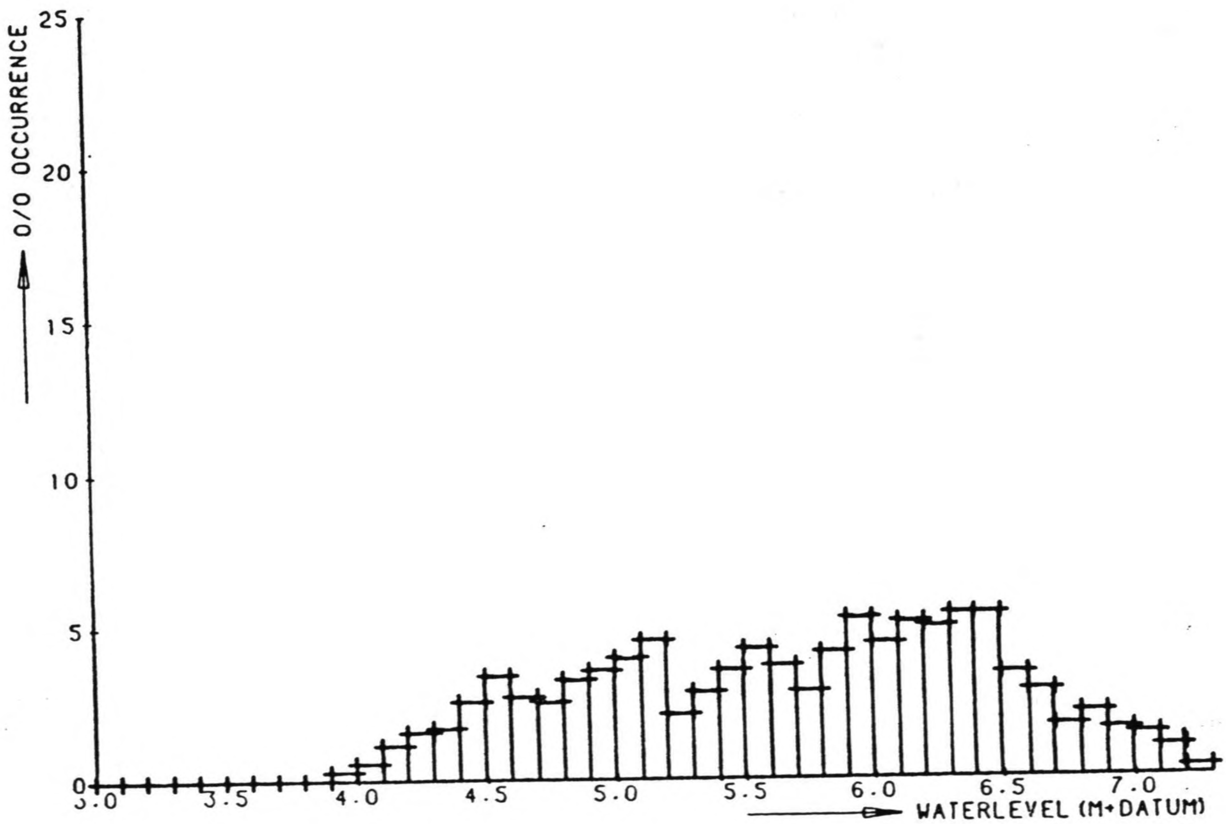


Figure 1.2.1 Tide levels.
Location: Beira Harbour,
High water +0 hour.

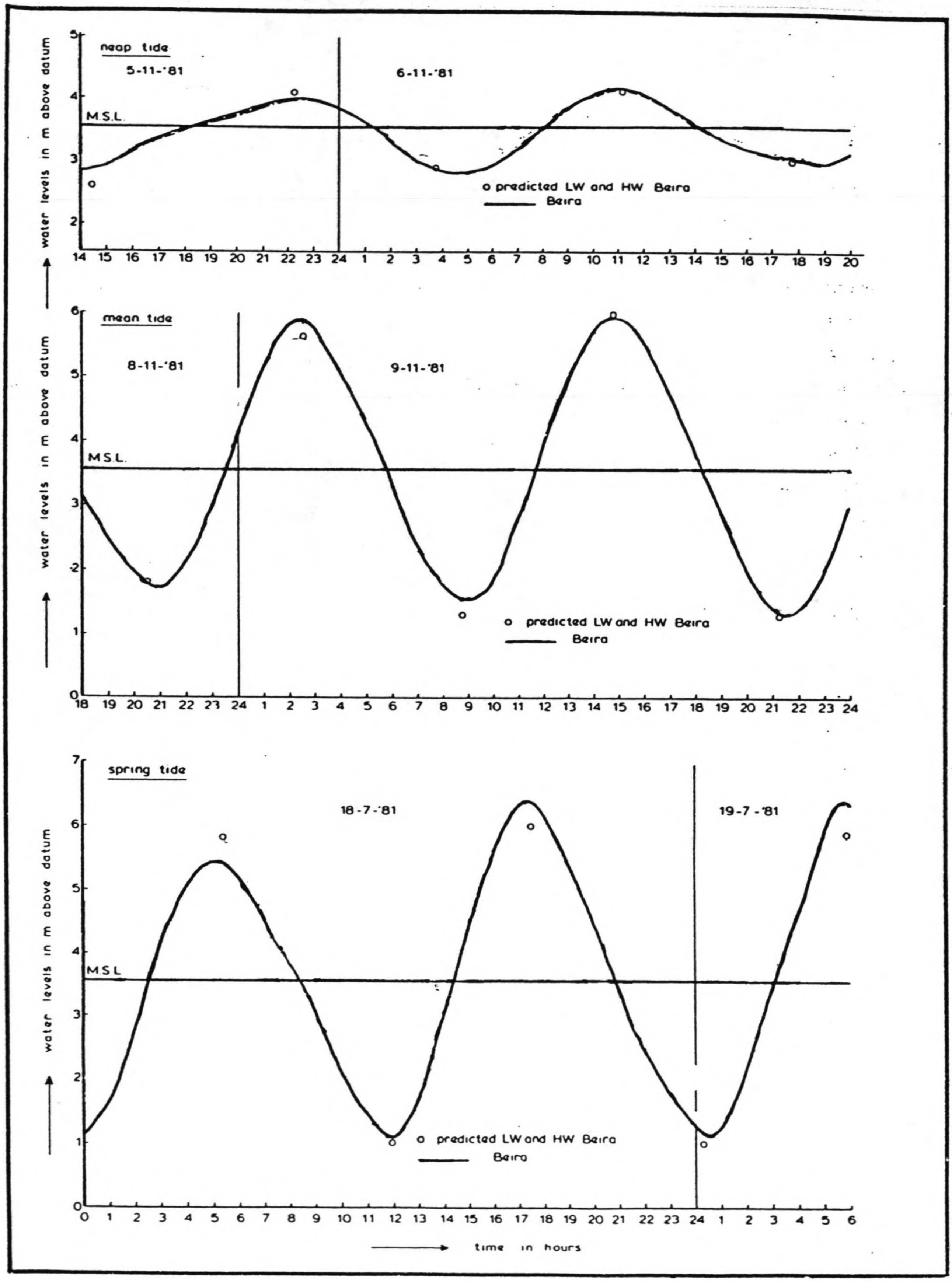


Figure 1.2.2 Tide at Beira Harbour (dry season).

As can be seen from Figure 1.2.2 there is a large difference in high water levels between spring tide and neap tide. The lowest high water is approximately 4 meters above datum, the highest high water is about 7 meters above datum.

1.3 Components of tidal variation

The tidal variations in Beira are governed by more than seven different components. The two main components (designated K1 and K2), which determine approximately 70 percent of all variations, cause the daily variation between high and low water and the monthly variation between spring tide and neap tide. The most important of the other components (with a combined total amplitude of approximately one meter) are seasonal variations.

1.4 Currents

The tide introduces strong incoming and outgoing tidal currents in the Pungué estuary. These currents are affected by the river discharges in particular during the wet season. Then, heavy rainfall in the catchment areas of the Pungué river and Buzi river causes considerable water discharges into the estuary generating a residual seaward flow and density currents due to the differences in salinity between the seawater and the river water.
Maximum river discharges into the Pungué and Buzi are about 600 m^3/s and 300 m^3/s respectively and most occur in December/ January. Average flow during the dry season is about 80 m^3/s and 50 m^3/s respectively. Ebb current velocities in front of the quays during spring tides in the wet season can well exceed 2 m/s.
In the dry season the current velocities have been monitored regularly over a full tidal cycle, both under neap and spring tide conditions. This has also been done during the wet season.
In general the flow velocities appear to be low during neap tides but can reach rather high values at the surface at the harbour site during spring tide.

	U_c	$\Phi_{\pm}$	C
Dry period			
spring tide	1.10	4.7	1,600
neap tide	0.20	3.2	44
Wet period			
spring tide	1.50	15.1	1,670
neap tide	0.80	9.0	82

U_c = characteristic water velocity in front of the ports (m/s)
$\Phi_{\pm}$ = density variation during a tidal period in front of the ports (kg/m^3)
C = average sediment concentration during a tidal period (mg/l)

Table 1.4.1 Characteristics data.

In an earlier study for the Masterplan, data has been collected about water velocity, density and sediment concentration. This has been done for the location Praia Nova. These characteristics data are listed on the previous page in Table 1.4.1 .

In Table 1.4.2 the maximum ebb and flood velocities (depth-averaged) and directions at the various locations have been collected.

Season	Location	Tidal range Beira Harbour		Maximum flow velocities			
				ebb		flood	
		ebb (m)	flood (m)	speed (m/s)	dir. (degr.)	speed (m/s)	dir. (degr.)
Dry	A	6.26	6.44	1.68	195	1.25	20
		1.59	1.60	0.45	210	0.15	20
Wet	B	5.73	5.70	2.09	190	0.90	20
		2.62	2.58	1.18	190	0.63	20

Table 1.4.2 Maximum depth- averaged tidal flow velocities.

For the locations A and B see Figure 1.4.1 .

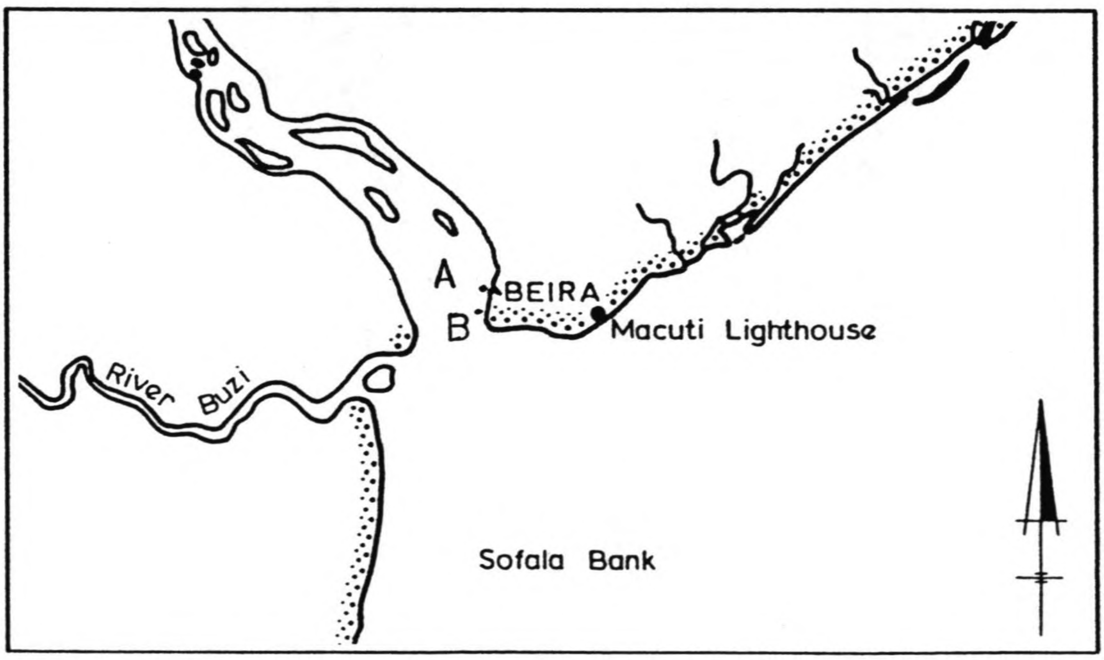


Figure 1.4.1 Location A and B.

Republic of Mozambique Beira

SERVICE PORT, BEIRA

Appendix 3

WAVE DATA

1. WAVE DATA

1.1 General wave conditions

Evaluation of the wave conditions in the harbour area is relevant for estimation of movements of moored vessels and for evaluation of fender systems and mooring arrangements. For smaller vessels both the short period, locally generated wind waves and the long period swells are of importance. For the larger vessels only swells will have significant influence on the ship movements and the forces in mooring lines.

The evaluation of wave conditions at the harbour area has been based on the characteristics of waves in deeper water outside the entrance to the access channel.
Visual observations indicate that the main wave direction varies between east and south.

In order to determine the frequency of occurrence of wave directions use has been made of the local wind observations data from Beira Airport. Local winds can generate waves with periods of up to 8 seconds. Waves with longer periods originate from distant wind fields. Visual observations indicate that these wave directions are mainly between ESE and SSE.

The SMB Prediction Method, described by Sverdrup Munk and Bretschneider has been used to compute locally generated waves (with wave periods of up to 8 seconds) from local wind observations. Bretschneider (1952) revised the semi-empirical wave forecasting relationships presented by Sverdrup and Munk (1947). The technique is thus called the Sverdrup-Munk-Bretschneider (SMB) method. The results of the calculations are summarized in Table 1.1.1 .

	Percentage of occurrence			
Wind velocity (km/h)	E	SE	S	Wave height (m)
0 - 20	14.40	17.90	9.10	0 - 0.85
20 - 40	5.60	0.60	6.30	0.85 - 2.0
40+	0.02	0.16	0.31	2.0+

Remarks: 1. Wind occurrence frequencies for the directions E, SE and S are obtained from observations at Beira airport for the period 1970-1979.
2. Calculations of wind waves according to the SMB method for wind field duration of approximately 12 hours.

Table 1.1.1 Local wind data and calculations of wind waves.

1.2 Wave conditions at "Praia Nova"

The extensive shoals south of the access channel to Beira Harbour provide some shelter against waves penetrating the channel. This particularly holds during low tide where these shoals partly emerge. During high tide, however, the considerable wave water depths on the shoals allow for a considerable wave energy flux into the channel. Hence, the rate of shelter provided by the shoals is strongly related to the tidal level.

By computations of the incoming wave height the maximum wave height just outside the breaker zone has been estimated.
The location along the coastline is shown in Figure 1.2.1 .

The results of the computations from location A can be used to design a service port at "Praia Nova".
For these results see Table 1.2.1 .

Condition	Incoming wave height (m)	Location along coastline: A wave height (m)
T=6 s	3.0	<0.9
	4.0	<1.2
S,T=6 s	3.0	1.2
	4.0	1.4
S,T=8 s	3.0	1.2
	4.0	1.4
S,T=10s	3.0	1.2
	4.0	1.4

Remark: Water level above CD is 7.0 m (±MHWS)

Table 1.2.1 Maximum wave height just outside breaker zone for the surroundings of "Praia Nova".

For the swell in the port area see Table 1.2.2 .

Wave type	SWELL (Tp > 9 s)		
Water level above CD (m)	1.5 (±MLW)	3.5 (±MSL)	5.5 (±HWL)
Wave height (m) at harbour area	0 0	0.03 0.05	0.05 0.1

Table 1.2.2 Swell in the harbour area.

Swell is an example of waves without wind. This is most often found along a coast bordering on the larger seas.

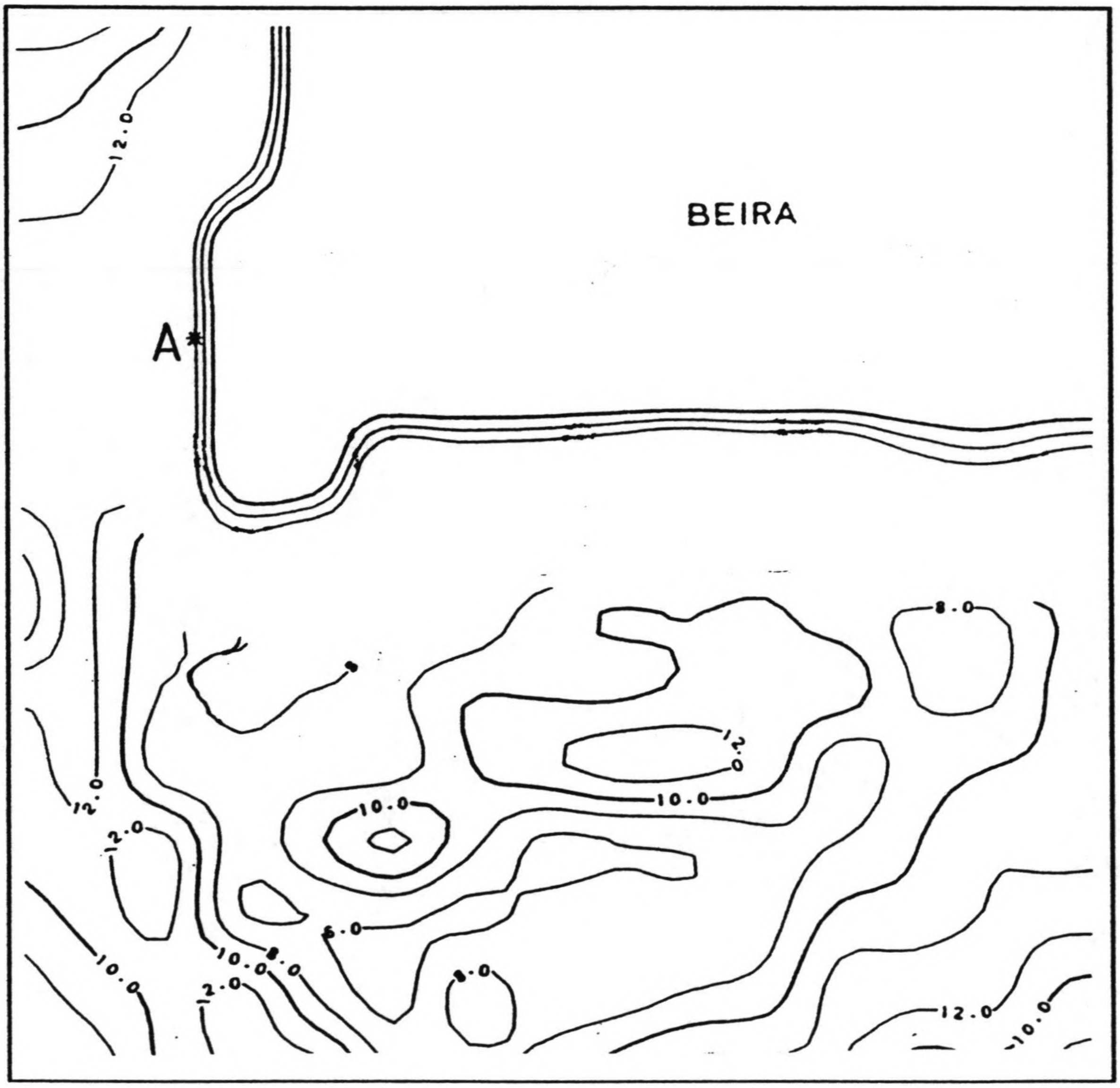


Figure 1.2.1 Location A.

Republic of Mozambique Beira

SERVICE PORT, BEIRA

Appendix 4

NATURE OF THE SOIL

1. NATURE OF THE SOIL

1.1 General geotechnical conditions

The knowledge of geotechnical conditions was considerably extended by a soil investigation program, which covered a total of 24 cased drillings and 70 vibrocorings, all executed in the access channel area of the harbour. The cased drillings were generally executed to a depth of −18 m CD, the vibrocorings were continued to a maximum penetration depth of 8 m. A summary of the soil characteristics of the various layers is given in the following table.

Layer	Atterberg limits LL* (%)	PI** (%)	Direct shear strength (KN/m2)	Dry bulk density (KN/m3)	Natural water (%)	Pocket shearvane (KN/m2)	Specific gravity (KN/m3)	Spt value (blows /ft)
A	Sand		-	-	-	-	26.3	20-25
B	70-90	45-60	-	-	75-100	0-25		
C	85-90	50-60	35-50	9.3-10.8	54-74	25-50		
D,E	Sand		-	-	-	-	26.5	15-23
F	23-41	11-27	45-55	13-13.7	30-34	50-100		
G	Sand		-	-	-	-	26.5	40-46
H	50-59	31-35	55-80	14-17.5	20-28	100-200		

Table 1.1.1 Summary of soil characteristics.

* = In this test the liquid limit, LL, is considered to be the water content at which two portions of soil will just flow together when lightly tapped 25 times in a standard apparatus.

** = The plasticity index, PI, is defined as the numerical difference between the liquid and plastic limit.

A schematic sub-bottom profile, including the various layers, is presented in Figure 1.1.1 .

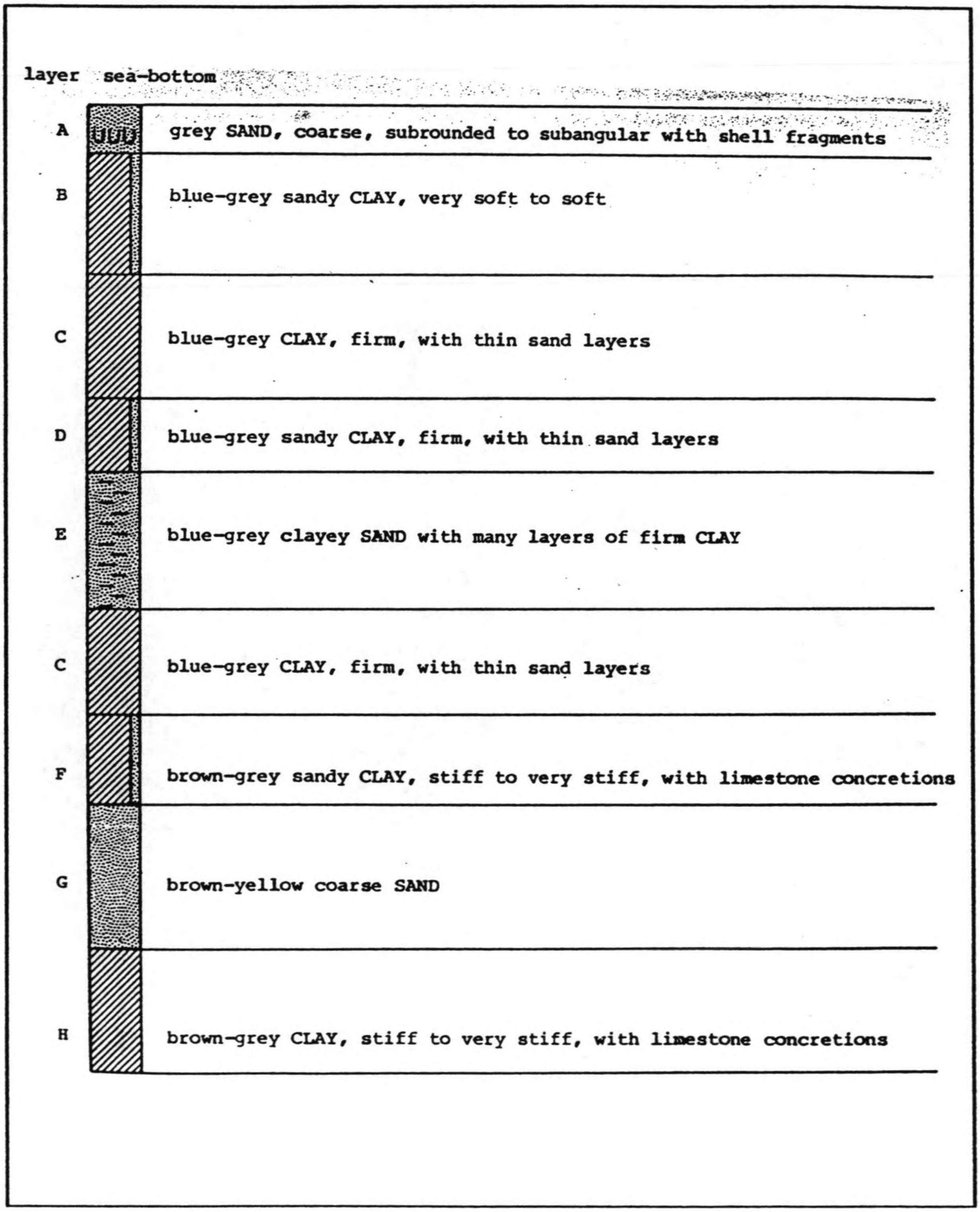


Figure 1.1.1 Schematic sub-bottom profile.

Remarks:
1. Not all layers are present in every part of the area, thickness of the layers varies considerably in the area.
2. The blue-grey layers A to E are recent marine sediments, while the brown-grey layers F to H are of a much older, probably continental origin.

1.2 A sieve analysis

In this area several samples were taken of the soil at the bottom. This was done to make a sieve analysis of the sand content. One of the sample locations was North of Praia Nova and this one can be used to tell us something about the soil. This is at location No. 1 in Figure 1.2.1 . (691700 E , 7807400 N)

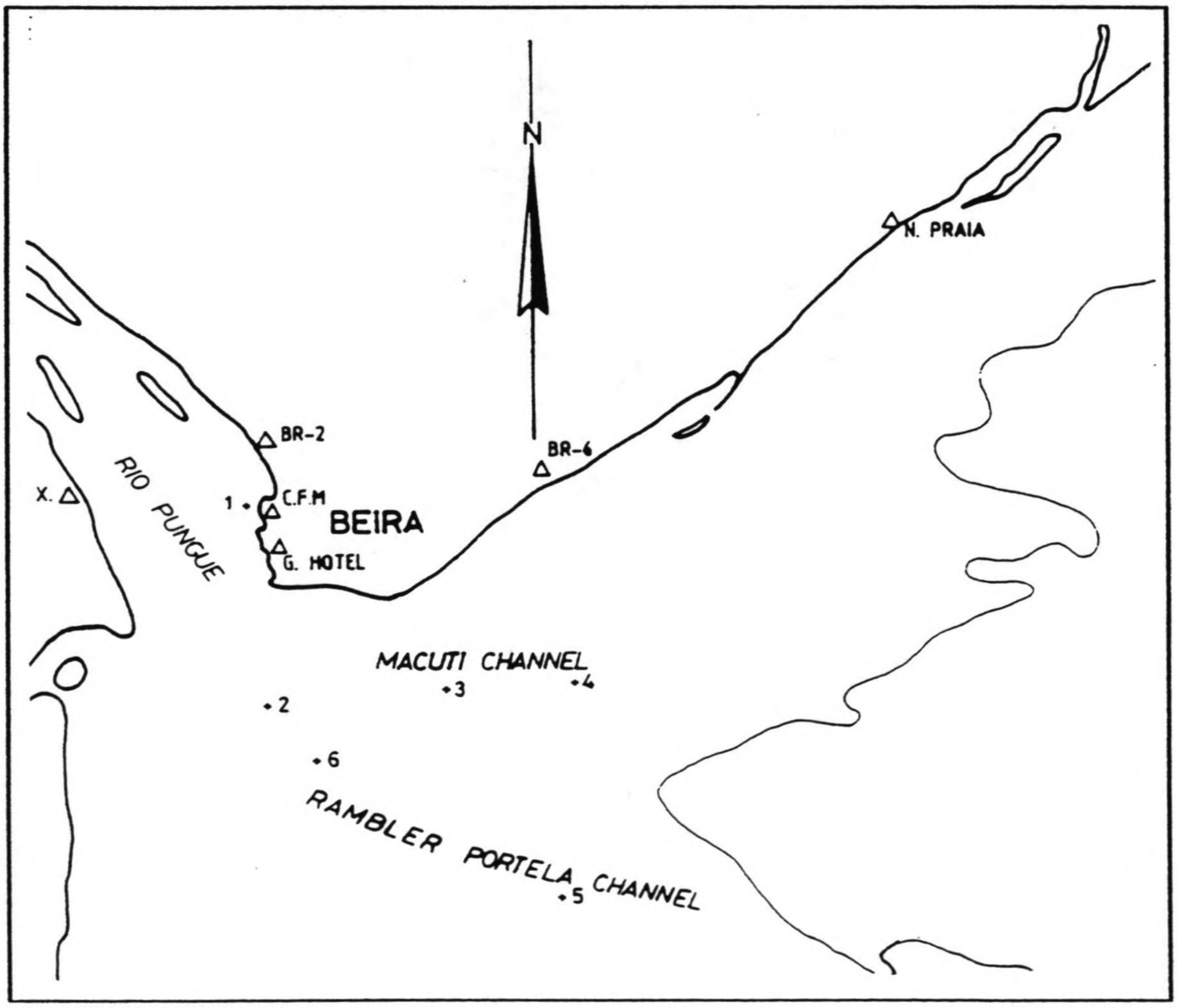
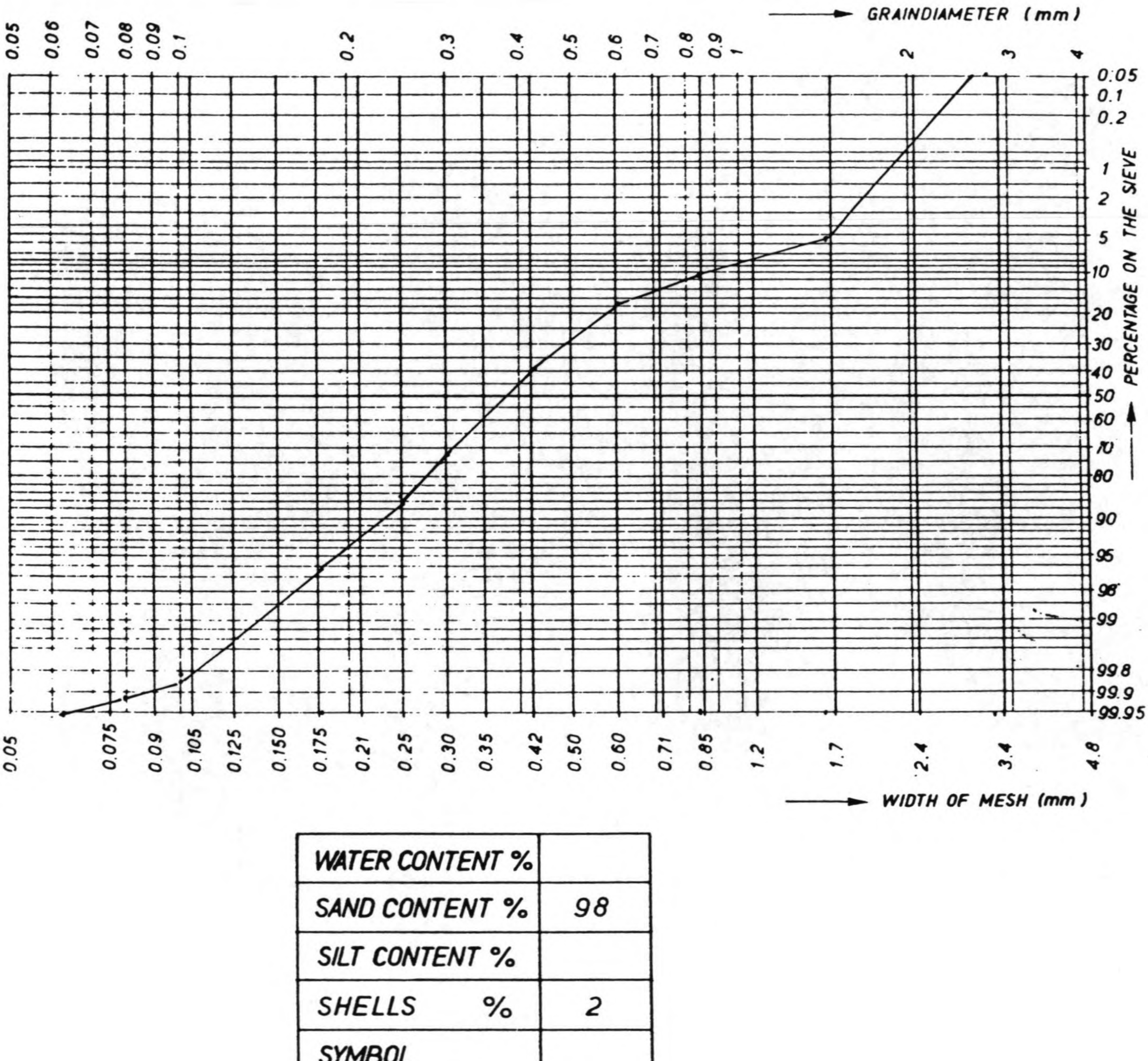


Figure 1.2.1 Location No.1.

For the sieve analysis sand content see Figure 1.2.2 .



WATER CONTENT %	
SAND CONTENT %	98
SILT CONTENT %	
SHELLS %	2
SYMBOL	
SAND d_{50} μm	380

Figure 1.2.2 Sieve analysis sand content.

1.3 The profiles of sounding at the three different locations

In an earlier site investigation, cone prenetation test were carried out by a Mozambican company. They made them on the three locations which are to be considered in this study. From this earlier site investigation some representative results will be listed below. For the numbers of the profile of sounding and their location see Table 1.3.1 .

Location	Number of the Profiles	Coordinates	
A	P-CE-2-101	-	-
B	P-CE-2-106	-	-
C	T.L. 11.	691827.8 E	7806470.2 N
	T.L. 12.	691855.9 E	7806380.0 N
	T.L. 14.	691861.0 E	7806092.2 N

Table 1.3.1 Listing of the profiles.

Use can be made of profile P-CE-2-101 to tell us something about the soil conditions at location A and profile P-CE-2-106 can be used for that purpose too but than for location B. See Figure 1.3.1 .

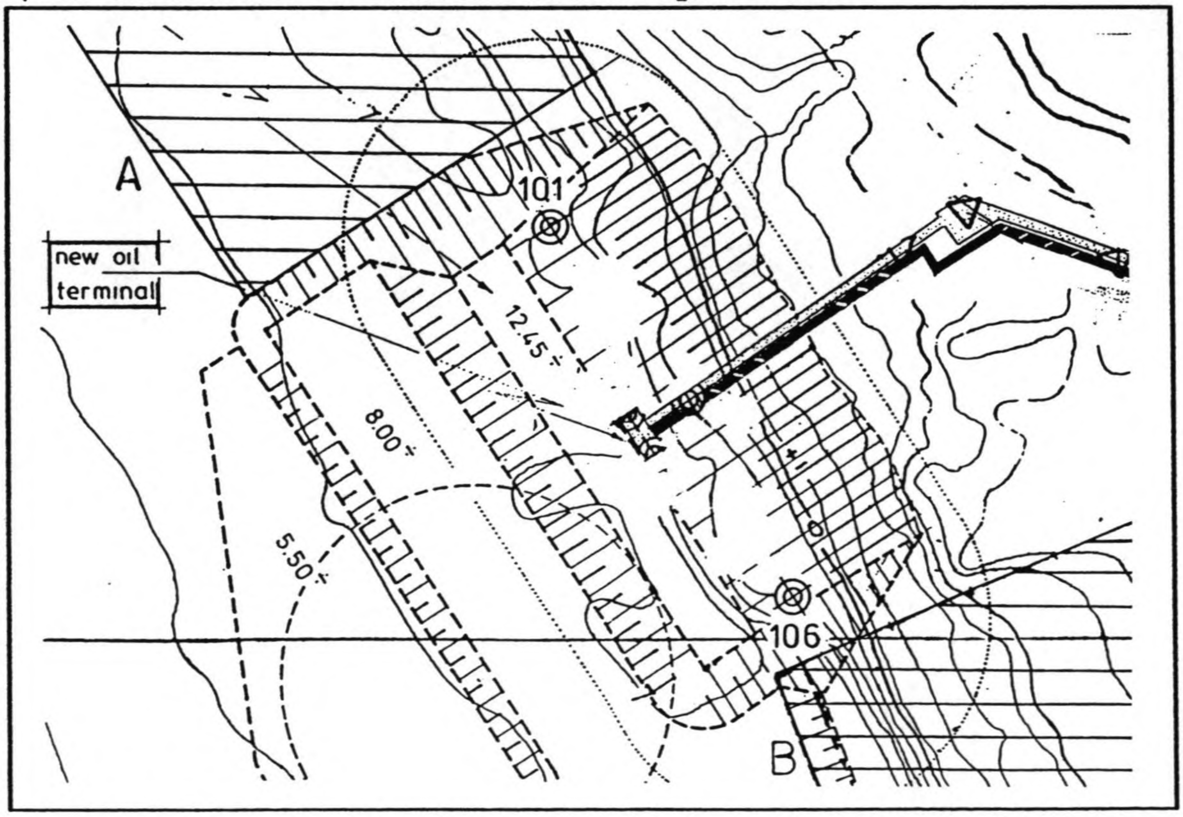


Figure 1.3.1 Situation of the profiles near location A and B.

For the profiles T.L. 11. ,T.L. 12. and T.L. 14. at location C see Figure 1.3.2 .

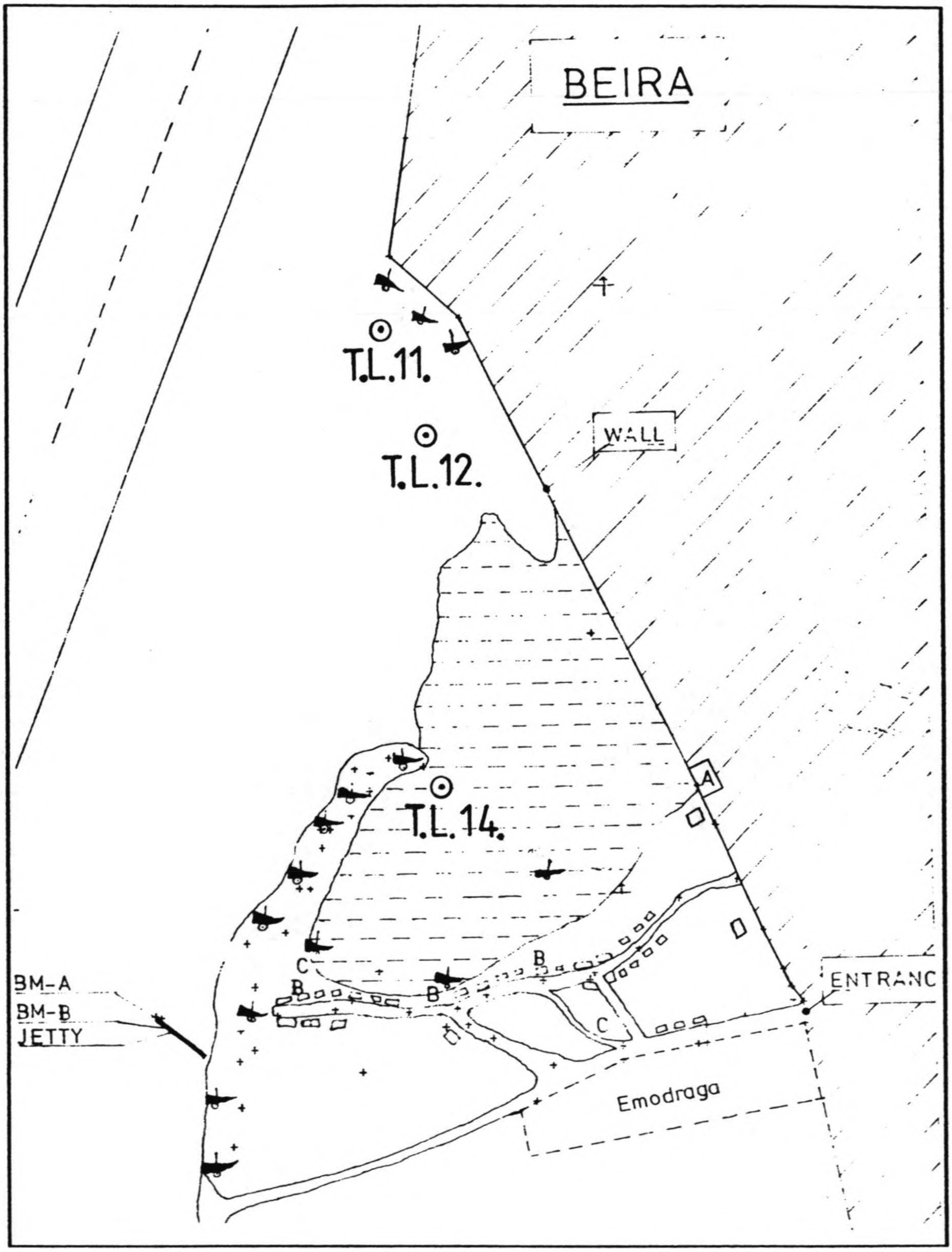


Figure 1.3.2 The profiles at location C.

For the profiles themselves see the next pages.

C.F.M.
GEOLOGICAL APPLICATION

Location	A
Sounding Nr.	P-CE-2-101
Level	CD-6.55 m
Equipment Nr.	-
Date of start	27-6-88
Date of conclusion	23-7-88
Penetration Max.	14 m
Working-days	-
Mean progress	-

Legend

- ◊ - sample unchanged
- ● - sample changed
- n - blow count (15 cm)
- N - blow count (30.5 cm)
- P - penetration

Scale 1:100

Bore-hole

Nr.	Sample	SPT -6.55 m
		Sand with nodules of mud
1	●	
2	●	Sandstone, limestone rock mixed with scouring-sand
		Sand
3	●	n = 15
		N = 62
4	●	Grey clay
		n = 4
		N = 8
5	●	Gravel with layers of clay
6	●	Idem
7	●	Idem but mixed with sandy sandstone
8	●	Idem
		End of bore-hole -20.55 m

C.F.M.
GEOLOGICAL APPLICATION

Location	B
Sounding Nr.	P-CE-2-106
Level	CD-4.50 m
Equipment Nr.	-
Date of start	20-6-88
Date of conclusion	26-6-88
Penetration Max.	13.5 m
Working-days	-
Mean progress	-

Legend
0 - sample unchanged
• - sample changed
n - blow count (15 cm)
N - blow count (30.5 cm)
P - penetration

Scale 1:100

Bore-hole

Nr.	Sample	SPT -4.50 m
1	•	Muddy sand with a residue of shells
2	•	Scouring-sand with dirty mud n = 1 N = 7
3	•	Compact sandy clay n = 5 N = 14
4	•	Sand mixed with limestone rock n = 2
5	•	Sandstone n = 9 N = 18
6	•	Gravel with shells of sandstone n = 4 N = 10 n = 13 N = 19
		End of bore-hole -18.00 m

C.F.M.
GEOLOGICAL APPLICATION

Location	C (Praia Nova)
Sounding Nr.	T.L. 11.
Level	CD+1.35 m
Equipment Nr.	2
Date of start	5-10-78
Date of conclusion	12-10-78
Penetration Max.	30.95 m
Working-days	7
Mean progress	4.42 m

Legend
0 – sample unchanged
● – sample changed
n – blow count (15 cm)
N – blow count (30.5 cm)
P – penetration

Scale 1:100

Bore-hole

Nr.	Sample	SPT	+1.35 m
1	●	Dirty weak mud	+0.75 m
	CD		
2	●	Coarse scouring-sand	
3	●	Idem but cleaner	
4	●	Idem	
5	●	Idem and dirty mud	
6	●	Idem	
7	●	Idem but cleaner and grey	
8	●	with shells	
9	●	without shells	
		n = 4 N = 11 Mud, shells and coarse pebble	−18.00 m
10	●	Mud which is very cohesive	−19.70 m −20.15 m

C.F.M.
GEOLOGICAL APPLICATION

Location	C (Praia Nova)
Sounding Nr.	T.L. 11.
Level	CD-20.15 m
Equipment Nr.	2
Date of start	5-10-78
Date of conclusion	12-10-78
Penetration Max.	30.95 m
Working-days	7
Mean progress	4.42 m

Legend
0 - sample unchanged
● - sample changed
n - blow count (15 cm)
N - blow count (30.5 cm)
P - penetration

Scale 1:100

Bore-hole

Nr.	Sample	SPT	Description	-20.15 m
11	●		Grey coarse scouring-sand	
12	●		Idem	-23.80 m
13	●	●	Sandy mud n = 3 N = 6	
14	●		Idem	-27.70 m
15	●		Muddy scouring-sand	-28.40 m
16	●		Sandy mud	
			End of bore-hole	-29.60 m

C.F.M.
GEOLOGICAL APPLICATION

Location	Tráfego Local
Sounding Nr.	T.L. 12.
Level	CD+3.90 m
Equipment Nr.	2
Date of start	14-5-79
Date of conclusion	22-5-79
Penetration Max.	24.70 m
Working-days	8
Mean progress	3.09 m

Legend
0 - sample unchanged
• - sample changed
n - blow count (15 cm)
N - blow count (30.5 cm)
P - penetration

Scale 1:100

Bore-hole

Nr.	Sample	SPT +3.90 m
1	•	Mud with little cohesion
2	•	Coarse sand
	CD	
3	•	
4	•	Idem but grey and with pieces of mud
5	•	Idem but cleaner and no mud
6	•	Idem
7	•	Idem
8	•	Idem
		-17.60 m

C.F.M. GEOLOGICAL APPLICATION	
Location	Tráfego Local
Sounding Nr.	T.L. 12.
Level	CD+3.90 m
Equipment Nr.	2
Date of start	14-5-79
Date of conclusion	22-5-79
Penetration Max.	24.70 m
Working-days	8
Mean progress	3.09 m

Legend

0 - sample unchanged
● - sample changed
n - blow count (15 cm)
N - blow count (30.5 cm)
P - penetration

Scale 1:100

Bore-hole

Nr.	Sample	SPT	-17.60 m
9	●		Idem
			End of bore-hole -20.80 m

C.F.M.
GEOLOGICAL APPLICATION

Location	Tráfego Local
Sounding Nr.	T.L. 14.
Level	CD+3.00 m
Equipment Nr.	2
Date of start	9-8-79
Date of conclusion	14-8-79
Penetration Max.	20.00
Working-days	3
Mean progress	6.67 m

Legend
0 - sample unchanged
● - sample changed
n - blow count (15 cm)
N - blow count (30.5 cm)
P - penetration

Scale 1:100

Bore-hole

Nr.	Sample	SPT	+3.00 m
			Grey cohesive mud
1	●		
2	●	CD	Sand and coarse pebble
3	●		Idem but fine sand and no coarse pebble
4	●		Idem
5	●		Idem but dirty and with pieces of mud
6	●		Idem
7	●		Idem
8	●		Idem
9	●		Idem
			End of bore-hole -17.00 m

Republic of Mozambique Beira

SERVICE PORT, BEIRA

Appendix 5

SURVEY

1. SURVEY

1.1 Introduction

In this appendix, the kind of surveying equipment used for this purpose and the method of calculations, will be discussed and listed. Finally the results of this are shown on the maps.

1.2 Equipment

In Chapter 6, Main Report section 6.3.1 the equipment used has already been listed. Now the equipment will be described.

- The levelling instrument

The levelling instrument used is a Wild Nak 1. In Figure 1.2.1 you can see a picture of a Wild Nak 1.

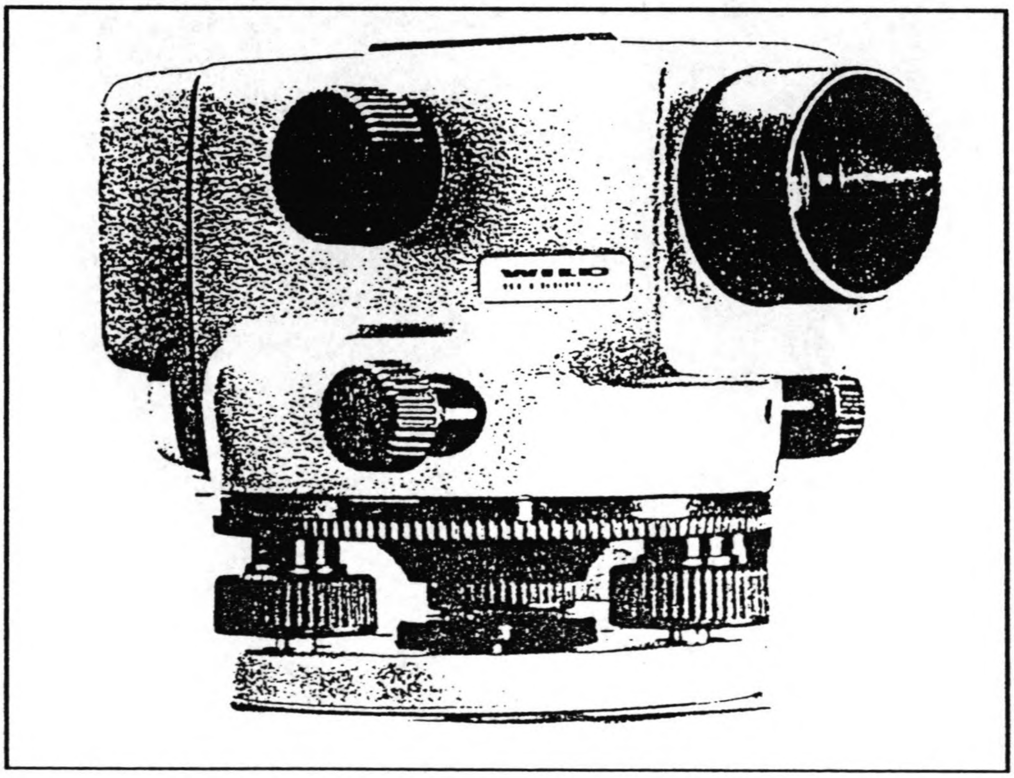


Figure 1.2.1 Picture of a Wild Nak 1.

For a detailed description of the levelling instrument see Figure 1.2.2 .

Wild Nak 1

1 central adjusting lens
2 sight
3 spyglass
4 push button
5 microscope to read the direction (grad)
6 foundation plate
7 circular spirit level
8 horizontal sensitive level
9 adjusting screw

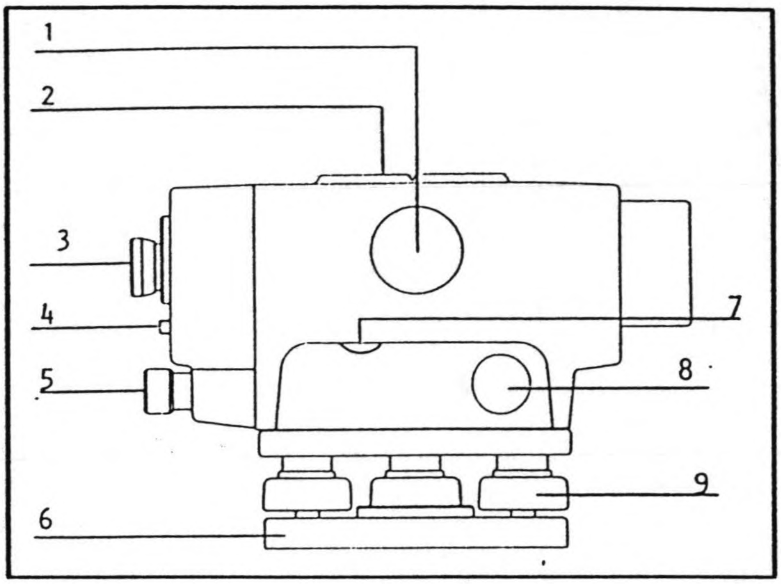


Figure 1.2.2 Description of the levelling instrument.

Explanation of the numbers (4,5,6,7) as indicated in Table 2.2.1 .

Looking through the spyglass, number (3) in Figure 1.2.2, one will see the same as shown in Figure 1.2.3 .

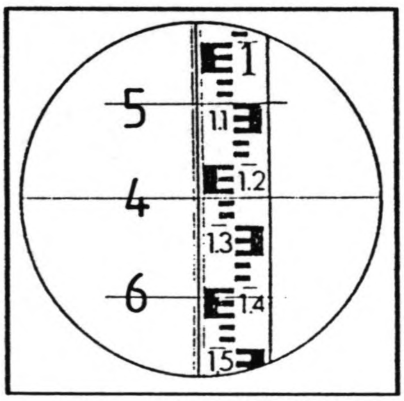


Figure 1.2.3 Looking through the spyglass of a levelling instrument.

One will see a beacon and three horizontal lines:

- The line in the middle is called the "middle". Number (4) are the readings of the middle.
- The line above the middle one is called the "top". Number (5) are the readings of the top.
- The line beneath the middle one is called the "low". Number (6) are the readings of the low.

Looking through the microscope, number (5) in Figure 1.2.2, one will see the same as shown in Figure 1.2.4 .

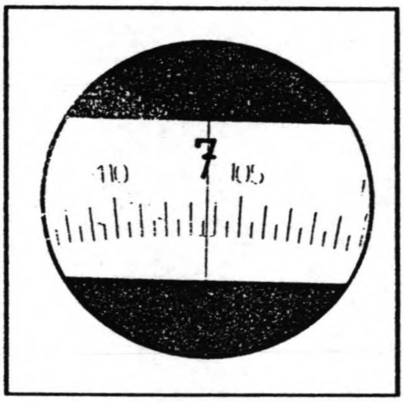
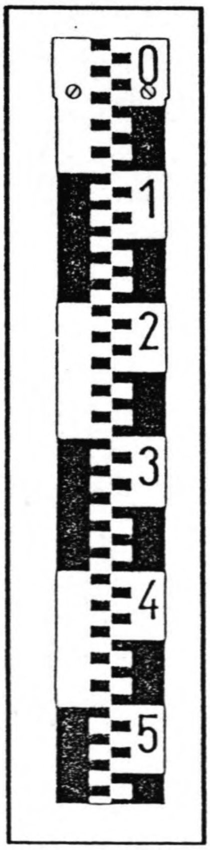


Figure 1.2.4 Looking through the microscope of a levelling instrument.

One can read the direction in which one is looking. Number (7) are the readings of the microscope.

- The beacon



In Figure 1.2.5 is an example of the beacon used. This vertical beacon has got a length of 4 m. It was provided with a circular spirit level so that it was easy to keep it in the right position. A metal shoe was used to put the beacon on.

Figure 1.2.5 The beacon.

The other equipment will not be described because it is easy to imagine how it works.

2. THE MEASUREMENTS AND RESULTS OF THE SURVEY AT PRAIA NOVA

2.1 The Areas

In Chapter 6 Main Report was explained that the terrain has been subdivided into four different parts (Area I to IV).
For a brief description of these areas see also Chapter 6.
Here only the measurements themselves, the calculations (prints of the spread sheets) and the results, like coordinates and height will be shown.

For Area I see section 2.2
For Area II and III see section 2.3
For Area IV see section 2.4

2.2 Praia Nova, Area I

			BACKSIDE				FORESIDE				
Level Instr. (1)	Point No. (2)	Point No. (3)	Middle (4)	Top (5)	Low (6)	Angle (7)	Middle	Top	Low	Angle	Instr. Height (8)
0	BM-A	1	1.774	2.140	1.412	397.0	2.812	2.942	2.682	313.2	-----
	BM-B	2	1.289	1.679	0.899	398.5	1.109	1.195	1.022	266.4	
3	1	4	2.772	2.888	2.660	345.9	1.310	1.501	1.120	142.8	1.420
	2	5	0.966	1.045	0.884	291.2	2.410	2.773	2.049	128.6	
6	4	7	1.339	1.590	1.086	172.7	1.918	2.130	1.701	375.5	1.480
	5	8	2.449	2.602	2.293	223.5	1.711	1.913	1.510	359.7	
9	7	10	1.400	1.567	1.232	325.1	2.720	2.804	2.635	126.7	1.380
	8	11	1.205	1.390	1.024	343.4	3.346	3.429	3.262	104.4	
12	10	13	2.517	2.618	2.415	106.2	1.141	1.272	1.009	277.5	1.460
	11	14	3.134	3.261	3.008	114.1	2.988	3.188	2.788	242.3	
15	13	16	1.314	1.389	1.241	32.8	2.043	2.141	1.950	260.9	1.350
	14	17	3.161	3.248	3.074	131.2	3.680	3.880	3.480	307.2	

(1) - The numbers of the locations of the levelling instrument
(2,3) - The numbers of the locations of the beacons
(4,5,6,7) - Readings of the levelling instrument, for an explanation see section 1.2 (equipment)
(8) - Height of the levelling instrument above ground level

Table 2.2.1 Data of measuring range.

Level Instr.	Eastern (x)	Northern (y)	Height CD+ (z)
0	691692.1	7805899.8	------
3	691689.3	7805897.5	7.480
6	691724.4	7805978.3	7.346
9	691756.8	7806047.0	6.938
12	691780.4	7806072.4	6.667
15	691800.4	7806107.7	6.941

Table 2.2.2 Coordinates levelling instrument.

Point No.	Eastern (x)	Northern (y)	Height CD+ (z)
BM-A	691620.0	7805910.0	7.166
BM-B	691615.1	7805912.5	7.651
1	691681.5	7805876.1	6.128
2	691697.9	7805883.5	7.831
4	691700.5	7805933.9	7.487
5	691694.7	7805969.7	6.387
7	691746.4	7806015.1	6.918
8	691735.9	7806016.9	7.125
10	691762.5	7806062.9	5.610
11	691756.6	7806063.7	4.984
13	691796.0	7806093.6	6.977
14	691783.6	7806112.2	5.130
16	691813.4	7806121.7	6.248
17	691840.2	7806111.6	4.611

Table 2.2.3 Coordinates beacons.

Buoy No.		
26	691199.5	7805718.5
27	691324.5	7805667.5
28	691763.1	7807100.0
29	691908.9	7807100.0

Table 2.2.4 Coordinates buoys.

From [Ref. V1.3.]

1	691836.2	7807099.3
2	690687.7	7804286.2

Table 2.2.5 Coordinates centre line entrance channel.

From [Ref. V1.3.]

Level Instr.	Point No.	Point No.	Calc. Dist. (1)		Height Instr. (2)	Height Beacon (3)
0	BM-A	1	72.8	26.0	-----	7.166
	BM-B	2	78.0	17.3		7.651
3	1	4	22.8	38.1	7.480	6.128
	2	5	16.1	72.4		7.831
6	4	7	50.4	42.9	7.346	7.487
	5	8	30.9	40.3		6.387
9	7	10	33.5	16.9	6.938	6.918
	8	11	36.6	16.7		7.125
12	10	13	20.3	26.3	6.667	5.610
	11	14	25.3	40.0		4.984
15	13	16	14.8	19.1	6.941	6.977
	14	17	17.4	40.0		5.130
	16					6.248
	17					4.611

(1) - Distances calculated with the aid of the readings. For example: the distance between levelling instrument at location 0 to the beacon at location 1 is 26.0 m.
(2) - Height of the ground level above CD at the location of a levelling instrument.
(3) - Height of the ground level above CD at the location of a beacon.

Table 2.2.6 Calculations distances/ height beacons.

Level Instr.	Point No.	Point No.	Dis. (1)	α,tot (2)	α,1 (3)	α,2 (4)	O.angle (5)	Angle (6)	Angle (7)	Inv.angle (8)	Inv.angle (9)
0	BM-A	1	16.426	95.244	45.341	49.903	108.931	308.931	226.631	108.931	426.631
	BM-B	2						310.431	178.331		
3	1	4	36.238	212.507	170.857	41.650		622.068	418.968	422.068	618.968
	2	5						291.200	404.768		204.768
6	4	7	10.616	185.868	76.472	109.396		1031.475	1234.275	831.475	1434.275
	5	8							1218.475		1018.475
9	7	10	5.858	247.290	86.709	160.581		1820.143	1621.743	1620.143	1821.743
	8	11						1032.606	1599.443	832.606	1399.443
12	10	13	22.387	179.084	122.473	56.611		2269.033	2440.333	2069.033	2640.333
	11	14						1352.153	2405.133	1152.153	2205.133
15	13	16						3019.418	3247.518	2819.418	3447.518
	14	17						2226.049	3293.818	2026.049	3493.818

(1) – Dis. is the distance between two beacons.
(2) – α,tot=α,1+α,2.
(3,4) – These are angles necessary for the calculations.
(5) – Orientation angle to turn the coordinates in the right direction.
(6,7) – Angles related to the Y-as of the connecting lines between beacons and levelling instrument.
(8,9) – The same kind of angles as (6,7) but seen from another point of view.

Table 2.2.7 Calculations distances/ angles.

2.3 Praia Nova, Area II + III

			BACKSIDE				FORESIDE				
Level Instr.	Point No.	Point No.	Middle	Top	Low	Angle	Middle	Top	Low	Angle	Instr. Height
0	BM-A	1	1.774	2.140	1.412	397.0	2.812	2.942	2.682	313.2	-----
	BM-B	2	1.289	1.679	0.899	398.5	1.109	1.195	1.022	266.4	
3	1	4	3.086	3.329	2.841	267.1	1.419	1.720	1.119	106.2	1.450
	2	5	1.265	1.428	1.102	257.7	0.860	1.101	0.620	112.4	
6	4	7	1.099	1.343	0.853	29.7	1.622	1.882	1.364	229.4	1.420
	5	8	0.540	0.837	0.243	19.8	1.458	1.780	1.132	205.8	
9	7	10	1.374	1.488	1.263	292.5	1.144	1.457	0.834	110.4	1.510
	8	11	1.212	1.388	1.036	342.0	1.463	1.729	1.199	77.8	
12	10	13	1.423	1.824	1.018	128.5	1.318	1.624	1.010	364.3	1.570
	11	14	1.740	2.032	1.440	148.8	1.768	2.121	1.415	350.0	
15	13	18	1.224	1.440	1.010	67.5	0.550	1.115	-0.015	200.9	1.520
	14	19	1.673	1.823	1.523	88.1	0.936	1.470	0.402	172.6	
20	18	21	1.080	1.570	0.590	387.7	1.561	1.771	1.350	197.1	1.590
	19	22	1.460	1.720	1.201	373.9	1.560	1.805	1.312	192.3	
23	21	24	1.466	1.674	1.258	148.4	2.098	2.466	1.725	346.4	1.550
	22	25	1.462	1.642	1.282	157.0	2.388	2.810	1.968	337.4	
26	24	27	0.504	0.972	0.036	113.2	1.250	1.752	0.748	329.3	1.610
	25	28	0.800	1.209	0.391	120.8	0.066	0.683	-0.551	314.5	
29	27	30	0.128	0.350	-0.094	104.9	1.496	1.529	1.463	326.4	-----
	28		1.206	1.301	1.110	110.1					
12	31		1.618	1.667	1.567	52.0					1.570
15	16		1.070	1.329	0.818	311.5					
	17		1.045	1.300	0.791	289.0					
33	34	16	1.497	1.508	1.488	101.1	1.622	1.709	1.538	356.2	-----
	35	32	0.624	0.698	0.549	109.7	1.840	2.262	1.418	29.1	
	36		0.630	0.808	0.458	119.3					
	37		0.644	0.990	0.296	122.2					

Table 2.3.1 Data of measuring range.

38	37	39	368.1	166.8
40	39	41	188.0	361.1
41	40	42	182.5	47.1

Table 2.3.2 The angles of the wall.

Level Instr.	Eastern (x)	Northern (y)	Height CD+ (z)
0	691693.1	7805896.8	-----
3	691717.0	7805907.6	7.764
6	691824.3	7805908.5	7.356
9	691893.1	7805884.9	7.018
12	691999.2	7805877.6	7.239
15	692097.5	7805899.1	7.193
20	692015.0	7805956.5	7.652
23	691936.6	7805929.0	7.591
26	691784.4	7805862.6	5.934
29	691658.2	7805801.4	6.428
33	692149.1	7805907.7	-----

Table 2.3.3 Coordinates levelling instrument.

Point No.	Eastern (x)	Northern (y)	Height CD+ (z)
BM-A	691621.0	7805907.0	7.166
BM-B	691616.1	7805909.5	7.651
1	691682.5	7805873.1	6.128
2	691698.9	7805880.5	7.831
4	691776.2	7805917.9	7.677
5	691765.0	7805911.2	8.236
7	691875.1	7805898.4	7.154
8	691888.1	7805919.8	7.318
10	691930.7	7805835.2	7.386
11	691941.7	7805863.7	7.067
13	692060.6	7805877.0	7.489
14	692068.2	7805892.7	7.039
18	692095.7	7806012.1	8.162
19	692050.0	7805994.8	7.776
21	691977.2	7805938.0	7.675
22	691972.5	7805931.6	7.676
24	691864.7	7805910.7	7.040
25	691858.7	7805896.9	6.750
27	691688.1	7805834.2	6.300
28	691677.3	7805801.4	7.484
30	691652.4	7805798.3	7.194
31	692001.1	7805867.7	7.191
16	692148.0	7805891.5	7.643
17	692147.4	7805909.4	7.668
32	692069.9	7805878.4	------

Table 2.3.4 Coordinates beacons (area II).

34	692147.7	7805909.1
35	692140.0	7805919.5
36	692132.1	7805938.3
37	692118.2	7805969.8
38	692080.8	7806054.4
39	692065.1	7806088.2
40	691884.2	7806476.1
41	691825.9	7806526.4
42	691841.4	7806625.1

Table 2.3.5 Coordinates wall (area III).

Level Instr.	Point No.	Point No.	Calc. Dist.		Height Instr.	Height Beacon
0	BM-A	1	72.8	26.0	-----	7.166
	BM-B	2	78.0	17.3		7.651
3	1	4	48.8	60.1	7.764	6.128
	2	5	32.6	48.1		7.831
6	4	7	49.0	51.8	7.356	7.677
	5	8	59.4	64.8		8.236
9	7	10	22.5	62.3	7.018	7.154
	8	11	35.2	53.0		7.318
12	10	13	80.6	61.4	7.239	7.386
	11	14	59.2	70.6		7.067
15	13	18	43.0	113.0	7.193	7.489
	14	19	30.0	106.8		7.039
20	18	21	98.0	42.1	7.652	8.162
	19	22	51.9	49.3		7.776
23	21	24	41.6	74.1	7.591	7.675
	22	25	36.0	84.2		7.676
26	24	27	93.6	100.4	5.934	7.040
	25	28	81.8	123.4		6.750
29	27	30	44.4	6.6	6.428	6.300
	28		19.1			7.484
	30					7.194
12	31		10.0			7.191
15	16		51.1			7.643
	17		50.9			7.668
13	32		9.4			
33	34	16	2.0	17.1		
	35	32	14.9	84.4		
	36		35.0			
	37		69.4			
	36	38	127.0			
	38	39	37.2	(2)		
	39	40	428.0			
	40	41	77.0			
	41	42	100.0 (1)			

(1) - In reality this distance is longer. Point 42 was calculated to make it possible to draw the direction of the wall on the map.
(2) - These distances have been measured with the use of a tape measure.

Table 2.3.6 Calculations distances/ height.

Level Instr.	Point No.	Point No.	Dis.	a,tot	a,1	a,2	O.angle	O.angle	Angle	Angle	Inv.angle	Inv.angle
0	BM-A	1	17.956	68.952	46.130	22.822	108.931		308.931	226.631	108.931	426.631
	BM-B	2							310.431	178.331		
3	1	4	13.092	207.631	170.543	37.088			649.939	489.039	449.939	689.039
	2	5								495.239		695.239
6	4	7	25.001	228.459	122.351	106.107				1312.470		1512.470
	5	8							1102.870	1288.870	902.870	1088.870
9	7	10	30.554	105.961	64.673	41.289			1940.929	1758.829	1740.929	1958.829
	8	11							1060.412	1726.229	860.412	1526.229
12	10	13	17.391	164.979	128.088	36.891			2264.790	2500.590	2064.790	2700.590
	11	14							1620.267	2486.290	1420.267	2286.290
15	13	18	48.829	93.267	77.945	15.321			3065.569	3198.969	2865.569	3398.969
	14	19							2321.311	3170.669	2121.311	3370.669
20	18	21	7.977	215.121	169.172	45.949			3661.593	3470.993	3461.593	3270.993
	19	22								3466.193		3266.193
23	21	24	15.050	181.536	142.192	39.344			3686.114	3884.114	3486.114	3684.114
	22	25							3681.314	3875.114	3481.314	3675.114
26	24	27	34.577	165.360	138.547	26.812			3665.650	3881.750	3865.650	3681.750
	25	28								3866.950	4047.110	3666.950
29	27	30							3647.110	3868.610	3847.110	
	28								4032.310	3922.210	3832.310	
	30											
12	31								2188.290			
15	16								3309.569			
	17								3287.069			
13	32		60.284	10.410	10.410	------			2490.180			
33	34	16	79.180	12.702	12.702	------			2749.478			
	35	32							2758.078	2677.478		2477.478
	36	38	34.473	194.156	194.156	------	2373.522	2173.522	2767.678			2567.678
	37								2770.578			
	38	39					1972.222					
	39	40					1972.222	1772.222				
	40	41					1945.322	1745.322				
	41	42					1609.922					

Table 2.3.7 Calculations distances/ angles.

2.4 Praia Nova, Area IV

Time	Reading (1)	Water-level (2)
9:45	5.6	1.7
10:00	-	1.9
10:15	-	2.1
10:30	4.75	2.4
10:45	4.53	2.6
11:00	-	2.8
11:15	4.25	2.9
11:30	-	3.2
11:45	3.70	3.5
12:00	-	3.7
12:15	-	3.9
12.30	-	4.3
12:45	2.65	4.5
13:00	-	4.7
13:15	2.23	4.9
13:30	-	5.2
13:45	1.80	5.4

(1) - Distance between water-level and upper side benchmark.
(2) - Water-level above CD [m].

Table 2.4.1 Water-level for depth-contours.

3. THE BENCHMARKS

At Praia Nova are two benchmarks. They are situated on the jetty. See the Map Topography on page 54. For a description of the two benchmarks see page 48.

In this report the benchmarks have been defined as follows:

- BM-A is Level with the Top of the Jetty.
- BM-B is Level with the Bolt on the Jetty.

On pages 49 and 50 one will find a report of the levelling survey from Pa2 to the Jetty.

These two benchmarks have been very useful for the measurements because they could be used as fixed points.

The coordinates of BM-A have been estimated with the use of a map where the benchmark was plotted. On this map the distances were measured to the lines 691500 E and 7806000 N. (scale 1:5000)

Calculation:

X-coordinate
691500 E + 2.42x5000/100 = 691621.0 E

Y-coordinate
7806000 N - 1.86x5000/100 = 7805907.0 N

Site Visit for levelling Survey Pa2-Top Jetty   Ref :SV05
Date:01/02/1999

Location: Beira, Tide gauge jetty , Praia Nova and the surroundings of the Capitania

Attendants: Engineer: Mr. W. Vader Survey Specialist
Mr. I. Blok Supervisor Dredging

Verification of level point on top of jetty where the v. Essen tide gauge is installed. This point will be used to level the tide pole and check and or correct the v. Essen tide gauge.

The levelling has been made in three parts :

Part I : Edge of footpath to Cadastral point Pa2.
Part II : Bolt on Jetty to temporary point on edge of footpath.
Part III: Top of Jetty to Bolt on Jetty and check on level of tide pole.

The results were :

Level Bolt on Jetty = CD + 7.675 m (Paint mark and bolt located on West end of Jetty.)
BM-B

Level Top of Jetty = CD + 7.166 m (Paint mark located on North side of Jetty approx. 5 meter East of shed.)
BM-A

Upper tide pole (CD +3.5 m upto CD +7.0 m) coincides with Benchmark Pa2 within 3 mm.

\RECORDS

RECORDS :

Levelling Survey from Pa2 to JETTY (PART I;Pa2-Footpath)

Date : 27/01/1989
Observers : I. Blok & W. Vader DHV Consulting Engineers
Used instrument : Wild NAK2 & E level staff

BACK middle mm	top	lower	FORE middle mm	top	lower	PH' mm	PH mm	Remarks
						8724		PA2
446	657	235	1574	1892	1257	7596	7596	
1559	1862	1254	1508	1788	1228	7647	7648	
1660	1976	1344	1467	1770	1164	7840	7841	
1423	1750	1097	1607	2044	1169	7656	7658	
1516	1804	1227	1665	1930	1399	7507	7509	
2086	2400	1773	1798	2086	1508	7795	7798	
1567	1814	1320	1587	1759	1415	7775	7778	EDGE FOOTPATH
1688	1952	1423	1669	1937	1400	7794	7797	
[illegible]	1922	[illegible]	1871	[illegible]	[illegible]	[illegible]	[illegible]	
1722	1938	1864	1710	1954	1425	7643	7647	
1803	2066	1540	1818	2086	1550	7628	7633	
1750	2029	1470	1724	2023	1424	7654	7659	
1685	1970	1400	1810	2092	1527	7529	7534	
1465	1736	1193	1495	1801	1188	7499	7505	
1652	1744	1561	433	489	377	8718	8724	PA2

dist. 781.6 dist. 821.2

After Closing: EDGE FOOTPATH = CD + 7.778 m
Closing error levelling 6 mm over total distanc 1603 m

Levelling Survey from Pa2 to JETTY(PARTII;Footpath-Jetty/bolt)

Date : 27/01/1989
Observers : I. Blok & W. Vader DHV Consulting Engineers
Used instrument : Wild NAK2 & E level staff

BACK middle mm	top	lower	FORE middle mm	top	lower	PH' mm	PH mm	Remarks
						7778		EDGE FOOTPATH
1072	1311	834	1447	1689	1204	7403	7403	
1539	1799	1279	1637	1902	1371	7305	7304	
1585	1869	1301	1458	1758	1158	7432	7431	
1940	2213	1666	1476	1746	1206	7896	7895	
811	1101	522	1031	1379	683	7676	7675	JETTY/bolt
1343	1681	1007	1087	1421	752	7932	7930	
1109	1439	780	1881	2173	1589	7160	7158	
1711	2044	1378	1509	1835	1183	7362	7359	
1611	1952	1271	1412	1710	1115	7561	7558	
1692	1909	1574	1472	1575	1268	7781	7778	EDGE FOOTPATH

dist. 560.6 dist. 555.9

After Closing: JETTY/bolt = CD + 7.675 m
Closing error levelling 3 mm over total distance 1117 m

Levelling Survey from Pa2 to JETTY (PART III;Jetty-Jetty/bolt)

Date : 31/01/1989
Observers : I. Blok & W. Vader DHV Consulting Engineers
Used instrument : Wild NAK2 & E level staff

BACK middle	BACK top	BACK lower	FORE middle	FORE top	FORE lower	PH'	PH	Remarks
mm			mm			mm	mm	
						7675		JETTY/bolt
1159	1339	979	1668	1762	1573	7166	7166	TOP JETTY
1587	1703	1471	1078	1236	919	7675	7675	JETTY/bolt

dist. 59.2 dist. 50.6

After Closing: TOP JETTY = CD + 7.166 m
Closing error leveling 0 mm over total distance 110 m.

Check on Position Tide pole :

Using a levelling instrument the tide pole has been read together
with a levelling staff hanging under the jetty with the top coinciding the paint mark TOP JETTY.
Reading on the tide pole was CD + 4.40 m.
Reading on the levelling staff was 0220, length of levelling staff was 2989 so level instrument was
7.166-2.989+.220= CD + 4.397 m.

----oOo-----

4. THE CALCULATIONS

4.1 The height

The height has been calculated as follows.

The formula: H,(A) = H,(B) + middle,(B) - middle,(A)

See Figure 4.1.1 .

- H,(A) is the height at point A
- H,(B) is the height at point B
- middle,(B) is the distance b
- middle,(A) is the distance a

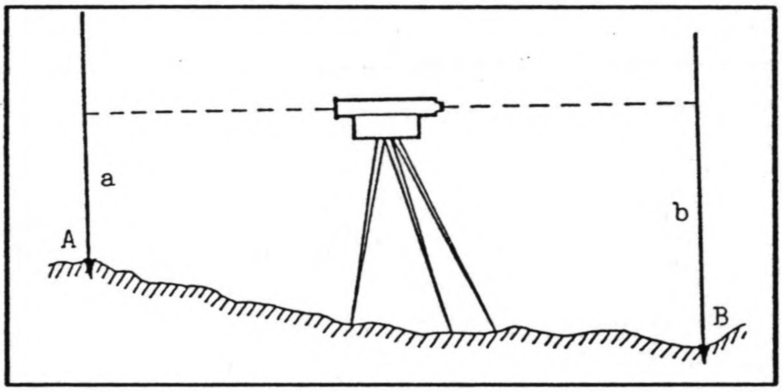


Figure 4.1.1 The height.

4.2 The distances

The distances have been calculated as follows.

The formula: D A,B = (I-II)x100

See Figure 4.2.1 .

D A,B is the distance between A and B
I is the top reading
II is the low reading
100 is a constant factor estimated by the mathematics and depending on the characteristics of the levelling instrument

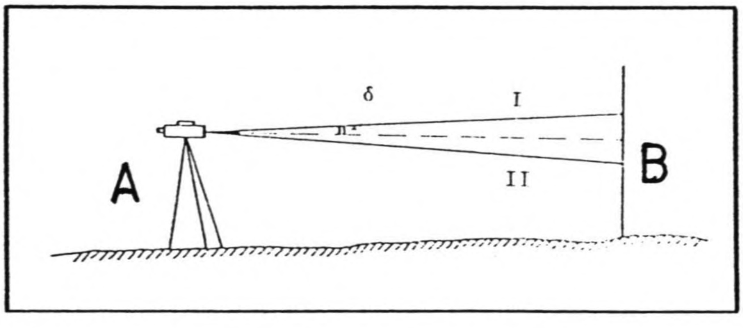


Figure 4.2.1 The distance.

4.3 The coordinates

In the geodesy we are working in a left-turning frame of reference.
The spread sheet to calculate the coordinates and the height of the measured points is based on this frame. Calculating in the geodesy is a matter of mathematics.

5. THE MAPS

On the next three pages one can find:
- the print of Freelance 2.0,
- Map Praia Nova Topography, and
- Map Praia Nova Contours.

The print of Freelance 2.0.

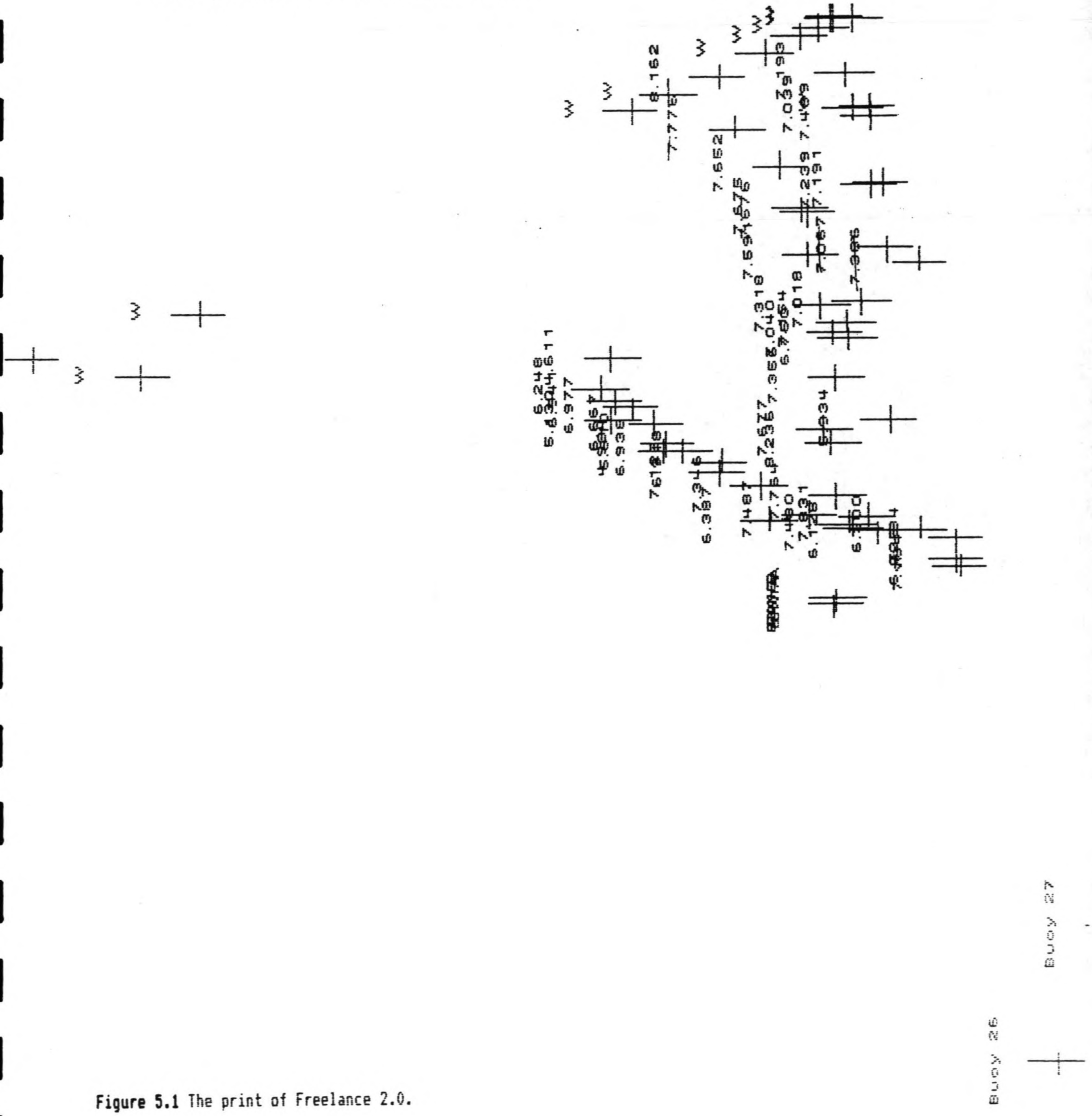
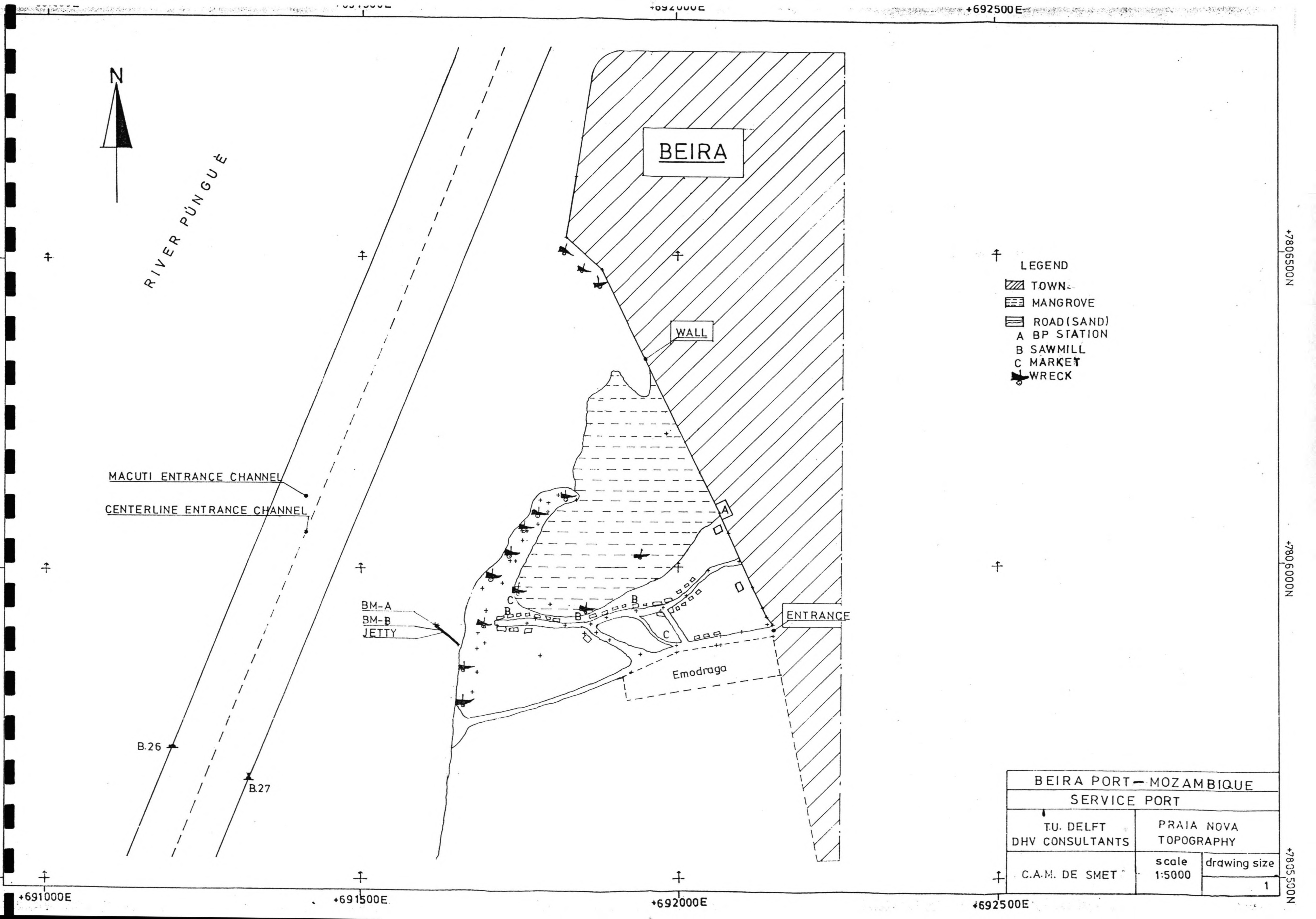
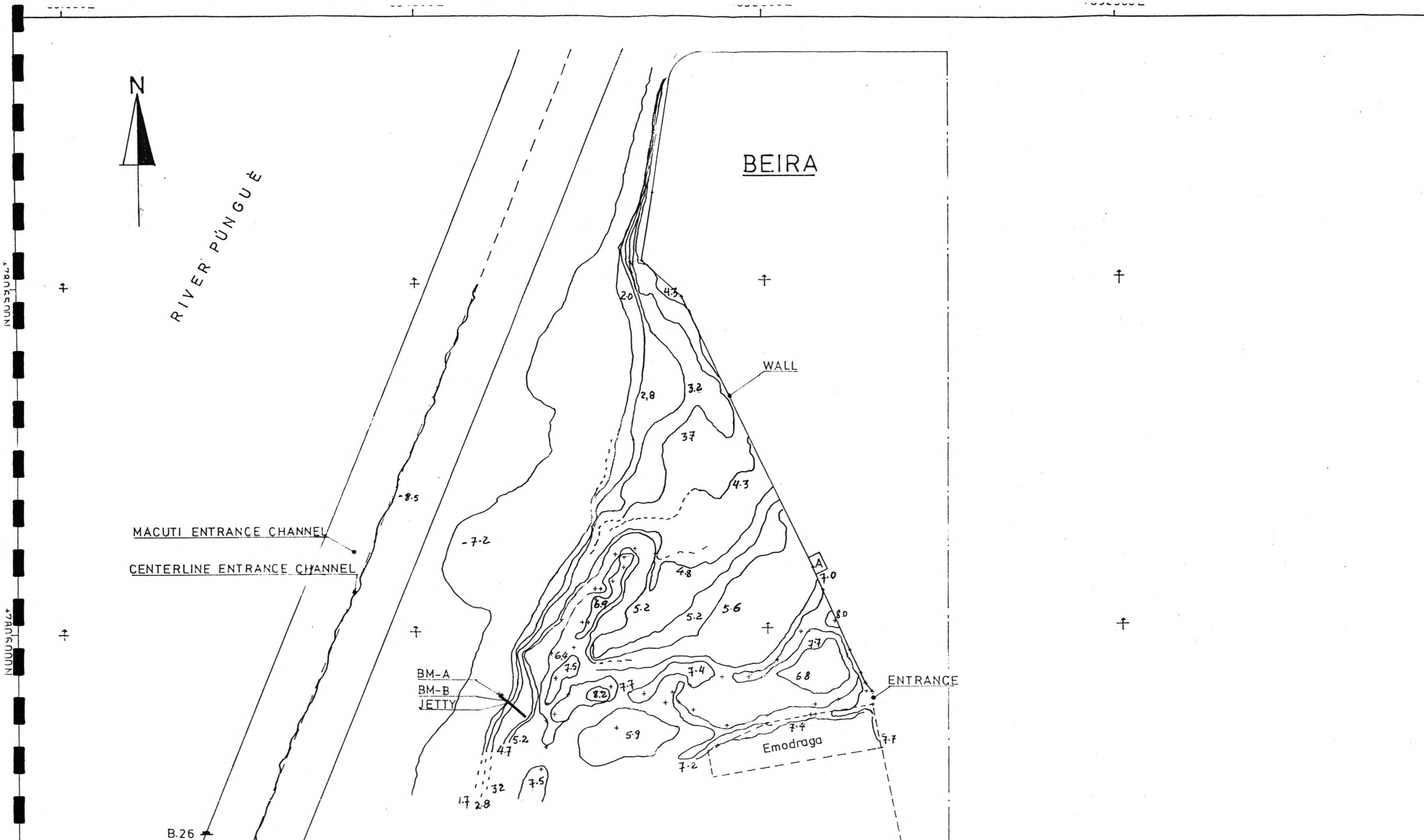


Figure 5.1 The print of Freelance 2.0.



+691000E
+691500E
+692000E
+692500E
+7806500N
+7806000N
+7805500N
N
RIVER PÚNGUÉ
BEIRA
LEGEND
TOWN
MANGROVE
ROAD (SAND)
A BP STATION
B SAWMILL
C MARKET
WRECK
WALL
MACUTI ENTRANCE CHANNEL
CENTERLINE ENTRANCE CHANNEL
BM-A
BM-B
JETTY
ENTRANCE
Emodraga
B.26
B.27
A
B
C
BEIRA PORT – MOZAMBIQUE
SERVICE PORT
T.U. DELFT
DHV CONSULTANTS
PRAIA NOVA
TOPOGRAPHY
C.A.M. DE SMET
scale
1:5000
drawing size
1



BEIRA PORT – MOZAMBIQUE		
SERVICE PORT		
T.U. DELFT DHV CONSULTANTS	PRAIA NOVA CONTOURS	
C.A.M. DE SMET	scale 1:5000	drowing size 1

Republic of Mozambique Beira

SERVICE PORT, BEIRA

Appendix 6

SHIPS/ EQUIPMENT DATA

To obtain the data for the study of a service port in Beira meetings were held with several authorities. See the list below for the authorities and the persons with whom the meetings had been arranged.
- The first meeting was to obtain the data.
- The second meeting was to control the data and to discuss the alternatives.

Authority	Name	Date
B.C.A. - Beira Corridor Authority Peoples Republic of Mozambique Ministry of Transport and Communications	Mr. Helge Guld Port Engineer	19-10-90 22-11-90
P.A. - Port Administration	Mr. J.S.J. Waterdrinker Harbourmaster for the Harbour of Beira	17-10-90 23-11-90
Mozambican Dredging Company EMODRAGA E.E.	Mr. Rassul Khan G. Mahomed General Manager	17-10-90 24-11-90
Administraçao Maritima da Beira	Mr. Abdul Magiole Director	18-10-90 (1)
Trans Maritima de Sofala Empresa de Transportes Maritimas e Fluviais E.E.	Mr. Xavier Director	18-10-90 (1)

(1) = There was not a final meeting with these authorities.

In this appendix is a report of all these discussions and a summary of the collected data.

1. PORT ADMINISTRATION

1.1 Service vessels

Service vessels operated by the Port Administration (P.A.) are tug-boats, pilot vessels and mooring vessels.

Characteristics of the vessels are shown in Table 1.1.1 .

Type	Name	Year build	Length (m)	Width (m)	Draft (m)	Draught (m)	Dead weight (ton)
Tug	Buzi	1989	26.00	8.40	4.50	3.75	187 (1)
Tug	Pungué	1989	26.00	8.40	4.50	3.75	187 (1)
Tug (2)	Messalo	1980	28.50	9.13	4.50	3.25	156.4
Pilot v.	Piloto 1	1988	12.41	4.88	1.20	?	25.9
Pilot v.	Piloto 2	1988	12.41	4.88	1.20	?	25.9
Mooring	-	1990	9.10	3.25	0.80	?	?
Mooring	-	1990	9.10	3.25	0.80	?	?
Mooring	Baia	1980	±6	±2	±0.6	?	±2.5

Remarks:
(1) = Gross Register Ton.
(2) = This tug-boat will be sent to Maputo before 1995.

Table 1.1.1 Service vessels.

The Port Administration does not foresee any changes of this fleet.

As can be derived from Table 1.1.1 the Port Administration has three tug-boats, two new ones and an old one which is used as standby.
The two new tugs are the same. They are called "Buzi and Pungué" like the two rivers entering the estuary of Beira. The old tug is the "Messalo".
The Port Administration has two pilot vessels which are the same.

The mooring vessels are used to assist during mooring of ocean ships, in particular for transporting the mooring lines.

1.2 Program of requirements

The program of requirements for the Port Administration is listed below:

- Create mooring facilities for the vessels listed in Table 1.1.1 .
- The tug "Messalo" needs a mooring.
- The other two tugs may be moored parallel to each other.
- The pilot vessels and the mooring vessels may also be moored parallel to each other.
  So not each vessel needs a mooring.
- It is important that all moorings are equipped with good fenders to protect the vessels so that damage is limited.
- The port entrance must be situated at right angles to the channel.
- The entrance has to be as wide as the longest vessel.
- Take into account the possibility of a marina in the future, but at present there are no definite plans.
- A class-room.
- A separate entrance for the passengers to the port area.
- Facility for Port Control, Port Administration and Storage.

1.3 The small pleasure crafts/ yachts

For the time being there are only two vessels of this kind. One is owned by the local aquatics club, "Club Nautico", but this club has his own slope near the club to store the speedboat.
The other boat is a motorboat but this boat has a mooring.
The conclusion which can be made is that a marina is not needed. Maybe in the future when the economy of Beira has grown, a marina could be a possibility. This should be taken into account.
A good location would be south of the fishery-port, because the sailing is good over there and the currents are less than north of the oil terminal.

1.4 Facilities

Facilities for the ships owned by the Port Administration.
There is a new plan to build an erection near the old fishery-port, a so called Port Traffic Control Centre (PTCC).
In this building will be housed:
- Port Control, Traffic Control and Coastal Radiostation.
- Port Administration.
- Storage facilities on the ground-floor to store materials and equipment for the activities of the Port Administration. The whole ground-floor is reserved for this purpose.

Discussion about the location.
- Praia Nova (New Beach) is the best location for a future marina. At present no marina is required.
- The service port can not be situated on the site of the oil terminal

because the surroundings are dangerous, too far away, bad connections and no infrastructure.

1.5 Present operations

The service vessels are presently all being berthed in the fishery port. The two new tug-boats are berthed side by side at the outermost part of the Chiveve Quay alongside an old wreck. The wreck is needed between the tug-boats and the quay in order to give sufficient water depth for the tug-boats and also to serve as a fender.
The water depth of 5 m in front of the quay is limited to 4 m due to the rubble foundation for the caisson quay.

The access to the tug-boats via the wreck and a ladder from the quay is quite dangerous with the wreck moving up to 7 m with the tides. Furthermore, it is very hard to take supplies of any kind on board the tug-boats.

The pilot vessels and the mooring vessels are likewise side by side in the inner part of the fishery-port alongside other old wrecks. The access conditions to these vessels are even worse than for the tug-boats, as two wrecks have to be crossed.

The main problem of berthing the service vessels in the fishery-port is space, as the Secretariat for Fisheries (SEP) expects the fishery-port to be fully utilized for fishing in the future.
Maintenance of service vessels is presently being carried out under the same bad conditions in the fishery port. All the maintenance is now taken over on a Danida financed contract by Danmarine, who also runs the tugs with a tug advisory team on contract for 3 years.

Operation of all service vessels is carried out from the Pilots Office via one VHF radio (or from the harbourmaster via a handheld VHF). The crews for the tug-boats and the pilot vessels sleep aboard the vessels, which at least the pilot vessels are not - and could not be - equipped for.

The Danish tug advisory team and the Russian pilots have an obligation to train their national crews in operation and maintenance of the vessels. This training is at the moment carried out on the vessels only. A small class-room is required.

For the storage and maintenance of the buoys they use the facilities of the Capitania. For this purpose there is a special boat, from Maputo moored near the Capitania when it is in Beira.

This information was obtained in a conversation with the harbourmaster Mr. J.S.J. Waterdrinker held on the 17-10-90.

2. EMODRAGA

2.1 Dredges

The dredges presently operated from the harbour (by Emodraga) are a backhoe dredge with two barges and a trailer hopper.
Emodraga expect to extend the fleet by one trailer hopper in the near future.

The characteristics of the dredge fleet are shown in Table 2.1.1 .

Type	Name	Year build	Length (m)	Width (m)	Draft (m)	Draught (m)	Dead weight (ton)
Trailer	Rovuma(1)	1962	77.75	13.40	5,50	4.50	1700
Backhoe	Sofala	1983	35.00	11.40	2.75	0.60	350
Barge(4)	Bob 1	1987	56.75	10.00	(3)3.50	?	?
Barge	Bob 2	1987	56.75	10.00	3.50	?	?
Tug	Chire	1987	18.75	5.75	2.75	2.00	?
Survey v	Tiky II	1977	9.90	3.35	?	0.92	?
Speedb.	Mugazine	1989(2)	5.00	2.05	?	0.50	?

Remarks:
(1) = At the moment this trailer hopper is operating in Maputo most of the time, but in the near future it will come to Beira.
(2) = Rebuild in this year.
(3) = This is in loaded condition, empty it is only 0.80 m.
(4) = These barges are split barges.

Table 2.1.1 Dredging vessels.

The new trailer hopper is expected in 1992.
The main data is:
- Length: 92.00 m
- Width: 16.80 m
- Depth (moulded): 7.40 m
- Draught (loaded): 6.65 m

2.2 Program of requirements

The program of requirements by Emodraga is listed below:

- Emodraga does not need maintenance facilities in the new service port because they have already a very well equipped area for this purpose. This facility is situated near the area which is the most logical location for the new service port (Praia Nova). So they would be very happy if the service port would come to this location. All they need is a mooring facility for the vessels in Table 2.1.1 .
- The dredging equipment may be moored parallel to each other.
- At the mooring will be a small facility for storage of water and fuel.
- For the maintenance they need a crane to lift components off the dredging vessels. For this reason they would like a crane with a lifting capacity of 40 tons on rails alongside the quay. The length of the quay needs to be as long as their largest vessel. So it should be a minimum of 100 m.
- When they get the new dredge, they would be very happy with a dry dock.
- A road to form a connection between the mooring and their maintenance area is also required. This is to transport the components of the vessels to the maintenance area.
- They would like sheltered mooring facilities.

2.3 Present operations

In the fishery-port are presently also berthed a backhoe dredge, two split barges and a survey vessel, all belonging to Emodraga. For the maintenance in the access channel no dredges are as yet available. In order to maintain the main entrance channel a new suction dredge will be required in the harbour permanently. However, this dredge would not require a permanent berth.

For the maintenance dredging along the quay-walls the backhoe dredge Sofala is available. The dredge is supported by two split barges with 600 m^3 hopper volume and a 720 hp tug-boat named "Chire".

For the support of the dredging in this harbour a hydrographic survey launch exists (the Tiky II), which has a fiberglass hull and 300 hp on the propellers.

The discussion with Rassul Khan G. Mahomed General Manager of Mozambican Dredging Company Emodraga E.E. was held on the 17-10-90.

3. ADMINISTRAÇAO MARITIMA DA BEIRA

3.1 Passenger vessels

The passenger vessels which use the fishery-port are listed in Table 3.1.1 .

Name	Pass. No.	Length (m)	Width (m)	Draft (m)
Jovo Tininha Mane Bom Sonho				
Rio Mondego	54	14.45	3.68	1.85
S. Pedro	106	15.40	4.00	1.70
Suzana	60	12.54	3.60	1.63
S. Joao Baptista	75	15.40	3.50	1.40
Patria	120	17.28	4.45	2.30
Machangane	50	15.20	3.55	1.40
Barada	75	10.60	2.80	1.22
Nacional	60	10.66	3.75	2.03
Chiloane	50	18.00	5.15	2.35
Divinhe	50	18.00	5.30	1.22
Li Berdade		10.66		2.02
Chiloane II		16.00		2.60
Marina		14.65		2.80

Table 3.1.1 Passenger vessels.

The total numbers of passengers per month which have been transported by the ships listed in Table 3.1.1 are listed in Table 3.1.2. These are the statistics for 1990.

Month	Number of passengers
January	4480
February	1856
March	7710
April	1474
May	55120 (1)
June	8380
July	1268
August	8380
September	9388
October	7200

Remark:
(1) = Possibly a mistake in the obtained data.

Table 3.1.2 Number of passengers 1990.

The data in Table 3.1.2 has been processed into a histogram. For this histogram see Figure 3.1.1 on the next page.

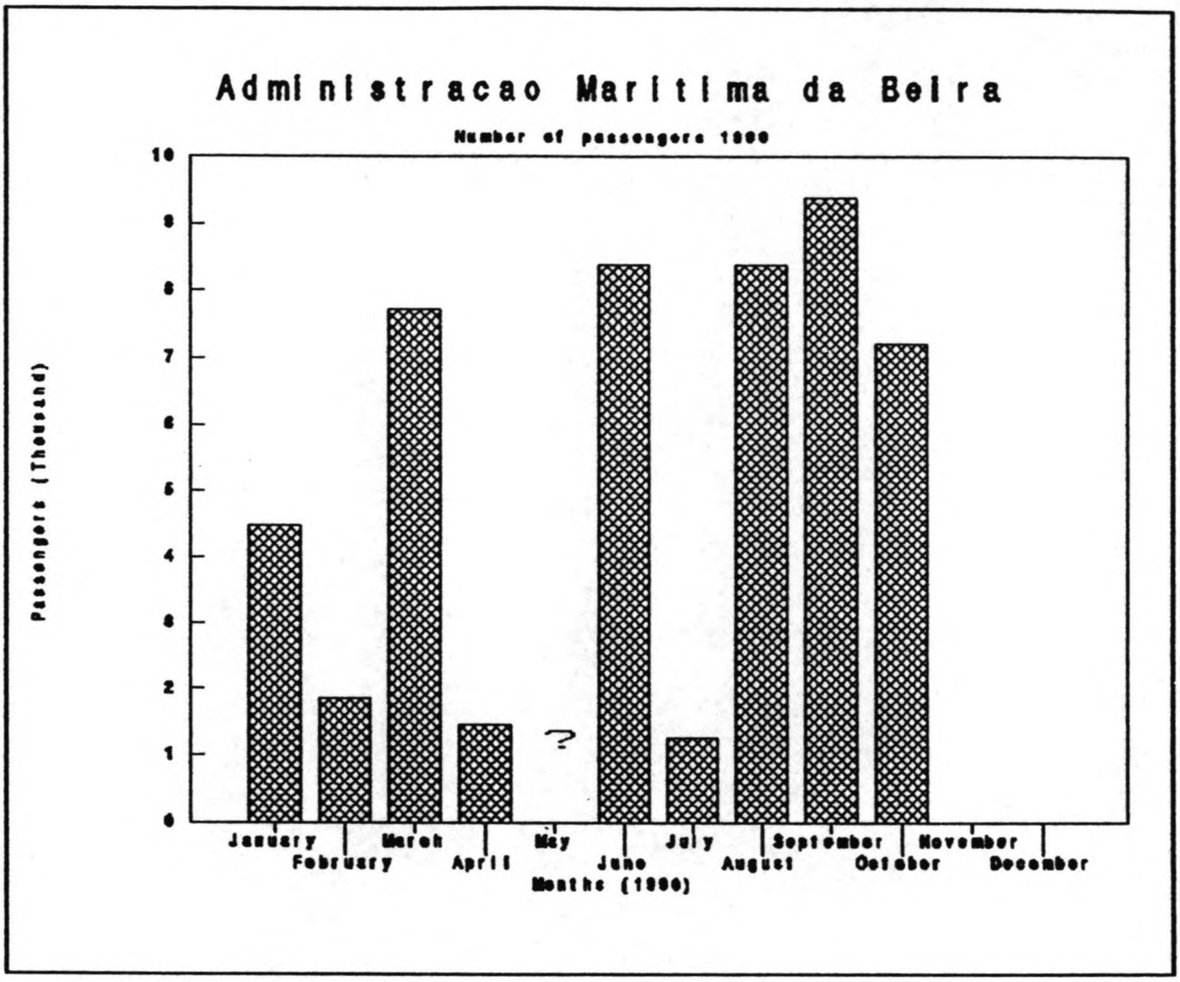


Figure 3.1.1 Histogram, number of passengers 1990.

3.2 Present operations

At present the south quay of the fishery-port (the Manate Quay) is being used for passenger vessels and small cargo vessels running along the river. The vessels berth alongside a staircase in the quay wall. When not in use, the vessels are berthed side by side. The Manate Quay is also being used by the shipyard as a repair and outfitting quay for trawlers. For the time being there are 4 to 5 ships in the harbour at the same time (Estimation by the harbourmaster).

This information has been obtained in a discussion with the director of the office Mr. Abdul Magiole on the 18th October.

4. TRANS MARITIMA DE SOFALA EMPRESA DE TRANSPORTES MARITIMAS E FLUVIAIS E.E.

4.1 Passenger vessels

This company has two ships:
- Lily Tamar
- Estrela do Mar

See Table 4.1.1 .

Name	Pass. No.	Length (m)	Width (m)	Draft (m)	Dead weight (ton)
Lily Tamar	400	86.00	14.70	4.39	1991(1)
Estrela do Mar	400	68.93	?	3.96	1991(1)

Remark:
(1) = Big uncertainty if this data is correct.

Table 4.1.1 Passenger vessels.

Sailing list of the Lily tamar:
- two days on the quay,
- one day and a half of sailing,
- two days on the quay,
- and so on.

(Obtained from the captain of the ship)

Height of entrance (deck-level) is 4.30 m above sea-level (Student's estimation).

Table 4.1.2 shows the number of passengers transported in 1989.

Month	Number of passengers	% (1)	Number of vessels (2)
January	1238	49.52	2
February	1020	40.8	2
March	1070	42.8	2
April	1664	46.64	2
May	1313	52.52	2
June	424	16.96	1
July	300	12	1
August	244	9.76	1
September	692	27.68	2
October	949	37.96	2
November	1173	41.96	2
December	1523	60.92	2

Remarks:
(1) = Transmaritima plans to transport 2500 passengers each month. The numbers which are shown, are the number of passengers which are transported in reality. The percentages have been calculated and listed.
(2) = Transmaritima has two passenger vessels, see Table 4.1.1, but it is not always possible to use both of them (maintenance, repairs).

Table 4.1.2 Number of passengers 1989.

Month	Number of passengers	Number of vessels	Number of trips (1)
January	112	1	2
February	1450	2	31
March	1474	2	33
April	664	2	17
May	439	2	9
June	1206	2	36
July	1268	2	29
August	1485	2	28
September	1178	2	28
October	(2)		

Remarks:
(1) = The total number of trips per month made to transport the passengers.
(2) = The data was collected in October, so there is no data for October, November and December.

Table 4.1.3 Number of passengers 1990.

On the next page is a histogram in which the data of Table 4.1.2 and Table 4.1.3 has been collected together. See Figure 4.1.1 .

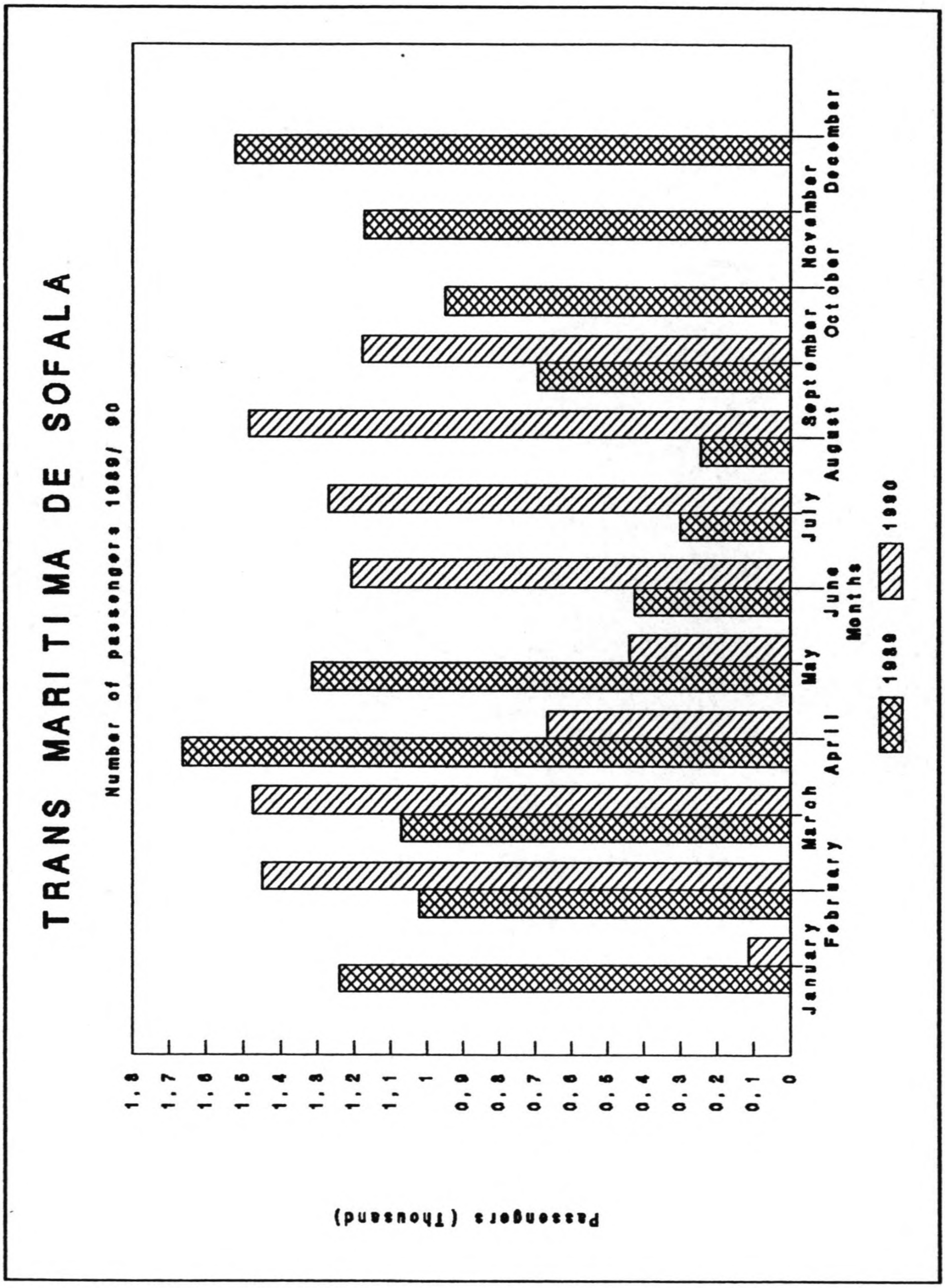


Figure 4.1.2 Histogram, number of passengers 1989/90.

5. BEIRA CORRIDOR AUTHORITY (BCA)

5.1 Program of requirements

In case the service port will be built, BCA will be the employer and for this reason I talked to Mr. H. Guld.

- The costs of the new service port are very important because one has to get the money for it from a donor. Keep the costs as low as possible.
- The cheapest solution is not always the best one. The way the maintenance is done and their costs in the future are important too.
  In this country the maintenance work has to be very simple (limited skill).
  The relation between costs and quality is very important.
- Try to design a service port which is maintenance free.
  (bad maintenance may give occasion to failure)
- Durability at least 40 years.
- Dredging company does not belong at service port really, but at the "Praia Nova" location it is possible.

Meeting with Mr. H. Guld at Beira Corridor Authority (BCA) Peoples Republic of Mozambique, Ministry of Transport and Communications, held on the 19th October, 1990.

Republic of Mozambique — Beira

SERVICE PORT, BEIRA

Appendix 7

THE WALL

1. THE WALL

1.1 Description

Between Praia Nova and the town is a wall. This wall is a partition wall. It is very important to know something about the wall in case one will build near it or do some excavation work for example. For this reason it was necessary to get some useful information. The municipal works of Beira promised to give this information before the end of the visit to Beira. Asking once again one week before leaving Beira, they promised the same but again without success. Thus, there is a lack of data about this wall. For a detailed study of constructions in the port close to the wall this data is required.

The only data of this wall has been obtained during the survey at Praia Nova. The situation of the wall is known exactly. For the situation of the wall see Map Praia Nova Topography in Appendix 5 in Volume 1.
During the survey photographs were taken of the wall.
For a photograph of this wall see Figure 1.1.1 .

Figure 1.1.1 Photograph of the wall.

Republic of Mozambique Beira

SERVICE PORT, BEIRA

Appendix 8

CALCULATIONS, PROGRAM FOR THE DIMENSIONS

1. LENGTH OF THE MOORING FACILITIES

1.1 Mooring length for the service vessels

	vessel	length
Tug-boats	Messalo (own mooring)	28.50 m.
	Pungué and Buzi (side by side)	26.00 m.
Pilot v.	Piloto 1+2 (side by side)	12.41 m.
Mooring v.	-,- (side by side)	9.10 m.
	Baia	6.00 m.
		+
		82.01 m.

82.01x1.1 = 90.21 ≈ 90 m.
(1)

(1) = factor for correction of the average length of the moorings so that the factor for the correction at the total port time is equal to 1. This means that the vessels do not need to queue (additional waits), (UNCTAD, "Port Development" 1978).

For the service vessels, operated by the Port Administration a total of ±90 m mooring length is needed.

1.2 Mooring length for the dredging vessels

	vessel	length
Barges	Bob 1+2 (side by side)	56.75 m.
Backhoe	Sofala	35.00 m.
Tug	Chire	
Survey v.	Tiky II (side by side)	18.75 m.
		+
		110.50 m.

110.5x1.1 = 121.55 ≈ 122 m.

For the dredging vessels, operated by the dredging company Emodraga a total of ±122 m mooring length is needed.

When the Rovuma and the new trailer hopper come to Beira they can use the same mooring facilities as for the vessels mentioned above. These two vessels will not use the service port very often, if correct. Most of the time they will operate during day and night.
For the channel- and port layout the large dimensions of the new trailer hopper have to be taken into account.

1.3 Mooring length for the passenger vessels administered by ADMINISTRAÇAO MARITIMA DA BEIRA.

The average length of the ships with a known length is: (14.45+15.40+12.54+15.40+17.28+15.20+10.60+10.66+18.00+18.00+10.66+16.00+14.65)/13 = 14.53 m.

According to the harbourmaster and our own observations, there are 4 to 5 passenger vessels in the port at the same time. Taking into account the four ships with an unknown length and the possible growth of the fleet, it is better to assume that there are 6 vessels in the port at the same time.

$14.53 \times 6 \times 1.1 = 95.89 \approx 96$ m.

For these passenger vessels a total of 96 m mooring length is needed.

1.4 Mooring length for the passenger vessels administered by TRANS MARITIMA DE SOFALA.

There are two ships and they need a special mooring. The largest vessel is the Lily Tamar with a length of 86 m. Looking at the schedule of sailing one mooring is sufficient with the possibility to moor side by side when the ships call at the port at the same time.

$86.00 \times 1.1 = 94.6 \approx 95$ m.

For these two vessels one mooring is needed with a length of 95 m.

2. DEPTH OF THE DIFFERENT PORT COMPONENTS

This subject can be subdivided into the access channel, the channel in the port and the inner part of the port.

2.1 The access channel

In this study the access channel is the channel from the estuary to the area in front of the port entrance. The Macuti Channel will of course form the main part of this channel.

Analysis of access channel depths.

The channel depth to be created is primarily dependant on the following factors:
- the nautical depth of the vessels who call at the port (Ndv = draught + tolerances),
- the tidal variations,
- the traffic pattern, and
- the cost of dredging.

Ndv = draught + tolerances

Tolerances are:
- water-level factors (waves),
- gross underkeel clearances (squat, margin for vertical motions and net clearance), and
- channel bottom factors.

The PIANC suggests by way of approximation that the gross underkeel clearance can be calculated as follows:
- channel exposed to strong and long swell, 15% of the draught.

The biggest draught have the trailer hopper Rovuma (4.50 m) and the new trailer hopper which is expected in 1992 (6.65 m loaded). The draught of this vessel in unloaded condition was not known during this study. The trailer hopper will not call at the port in loaded condition.
These vessels ought not to enter the port at just any time. They can enter the port at high water for example so that the depths of the channel can be kept to a minimum. Then only the tug-boats remain, with a draught of 3.75 m.
The draft of the tug-boats is bigger than the draft of the two large passenger vessels, the Lily Tamar and the Estrela do Mar. The draught of the large passenger vessels is not known so only the draft can be compared. The tug-boats are used to estimate the required access channel depth. They have to be able to enter the port at any time, this is very important.

squat = draft - draught = 4.50-3.75 = 0.75 m. (1)
underkeel clearance = 0.15x3.75 = 0.56 m.
gross underkeel clearance = 0.56+0.75 = 1.31 m.
waves: the maximum wave height is approximately 2 m this will cause vertical movements in the order of 1 m. (2)
channel bottom factors 0.30 m.

Remarks:
(1) = This is a high value and of course depends on the vessels velocity, but in the access channel it is possible that the tug-boats will sail their maximum speed.
(2) = The maximum wave height will only occur far from the coast where there is no reduction to this height by bottom friction. So closer to the entrance of the port the waves will not be as high.

The Ndv = 3.75+1.31+1+0.30 = 6.36 m.
The tidal variations: In the year 1985 the water-level was ten times lower than CD+0.5 m. Derived from TABLE DE MARES, 1985, Volume II. Instituto Hidrográfico, Lisboa. This will be used as LLWL, though it is not correct.

So the access channel depth can be estimated as follows:
Depth = LLWL - Ndv = CD+0.5-6.36 = CD-5.86 m.

2.2 The channel for the port entrance

This is the channel from the area in front of the port entrance to the service port.
squat = draft - draught = 4.50-3.75=0.75x0.5 = 0.38 m. (1)
underkeel clearance = 0.15x3.75 = 0.56 m.
gross underkeel clearance = 0.56+0.38 = 0.94 m.
waves: the maximum wave height at locations along the coastline is 1.4 m. this will cause vertical movements in the order of 0.7 m.
channel bottom factors 0.30 m.

Remark:
(1) = The speed is lower now and for this reason the squat can be reduced.

The Ndv = 3.75+0.94+0.7+0.3 = 5.69 m.
Depth = LLWL - Ndv
= CD+0.5-5.69 = CD-5.19 m.

2.3 Inner part of the port

The inner part of the port can be subdivided into three parts:
- the part for the service vessels,
- the part for the passenger vessels (Administraçao Maritima da Beira), and
- the part for the dredging fleet.

Data for the calculations of the inner part:
waves: the maximum wave height is approximately 0.5 m (They would like to design sheltered moorings), which will cause vertical movements in the order of 0.25 m.
bottom factors 0.30 m.
The PIANC suggests by way of approximation that the gross under keel clearance can be calculated as follows:
channel less exposed, 10% of the draught.

2.3.1 The part for the service vessels

Depth = LLWL - Ndv
= CD+0.5-(3.75+0.1x3.75+0.25+0.30) = CD-4.18 m.

2.3.2 The part for the small passenger vessels

Depth = LLWL- Ndv
= CD+0.5-(2.80+0.1x2.80+0.25+0.30) = CD-3.13 m.
(1)
(1) = The maximum draft of all small passenger vessels.

2.3.3 The part for the dredging fleet

Depth = LLWL - Ndv
= CD+0.5-(4.50+0.1x4.50+0.25+0.3) = CD-5.00 m.

3. LAYOUT

3.1 Access channel design

3.1.1 Turning manoeuvre

The turning diameter in deep water at service speed and a rudder angle of 35° varies considerably between types of ships and even between individual ships of the same category. Nevertheless there are clear tendencies.
The turning diameters are in the order of 2 to 2.5L (=Length) for a great number of conventional cargo and multipurpose vessels.

- For the large passenger vessels: 2.5L = 2.5x86 = 215 m.
- For the longest service vessel: 2L = 2x28.5 = 57 m.
- For the longest dredging vessel: 2.5L = 2.5x92 = 230 m.

Source: [Ref. V1.13]

3.1.2 Stopping distance

The stopping distance of vessels is obviously strongly influenced by the relation of astern power versus mass of the vessel. Also the astern power as a fraction of the installed power varies from one system to another and may be as low as 50% for a vessel with a steam turbine and fixed blade propeller to close to 100% for a vessel with diesel engine and controllable pitch propeller.

As a result the distance S travelled during an emergency stop varies considerably, even when expressed as a function of the vessel's length L.
For conventional general cargo ships and multi-purpose ships, S is in the order of 4 to 7L.

- For the large passenger vessels: 7L = 7x86 = 602 m.
- For the small passenger vessels: 6L = 6x18 = 108 m.
- For the longest dredging vessel: 5L = 5x92 = 460 m.

For the service vessels these general rules are not suitable because the power of these types of vessels related to their displacement is enormous. This will result in a short stopping distance. Figure 3.1.1 has been used for the calculation.

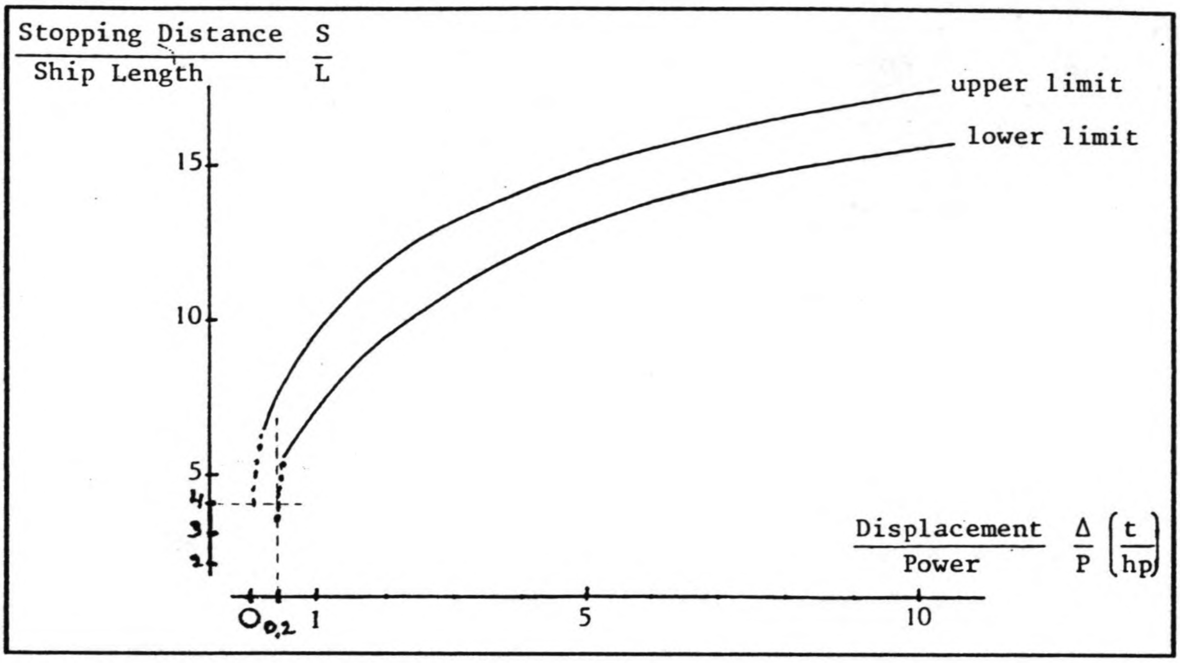


Figure 3.1.1 Stopping distances of ships.

Source: [Ref. V1.12.]

From other tug-boats it is known that the ratio between displacement and power is about 0.2. In this case this value will be used too. From Figure 3.1.1 can be derived that the average ratio between stopping distance and ship length is equal to 4.
4L = 4x28.5 = 114 m.

3.1.3 Channel width

A ship will generally not be able to navigate a channel in a position parallel to the channel axis or leading line. The forces acting on the ship by cross currents and wind necessitate the ship to steer under an angle – the leeway angle – in order to follow the leading line. Research and experience so far have shown that the required channel width depends particularly on environmental conditions like cross currents and cross current gradients, waves, swell, wind, visibility but also on the accuracy of information regarding the ship's position and the ease reading of this information to navigators.

An average value for the width of a one-way channel for average conditions would be 7 to 8B. B is the beam of the biggest vessel.

- Access channel for the two larger passenger vessels to their mooring outside the service port: 8B = 8x14.70 = 117.6 = ±120 m.
- Access channel to the actual service port: 8B = 8x9.13 = 73.44 = ±73 m.
- Access channel to the moorings of the small passenger vessel: 8B = 8x5.3 = 42.4 m.

Source: [Ref. V1.13.]

3.1.4 Channel layout

The access channel for the service port will be the same as for the main port. This is the Macuti Channel. There will still be a small access channel from the Macuti Channel to the service port. For this channel in so far as alternative layouts are possible, the following aspects should be duly considered in their evaluation.

- A channel should show as little curvature as possible. Curves should in particular be avoided near the port entrance.
- A single curve is better than a sequence of smaller curves.
- Curve radius should be > 10L.
  - service vessels: 10L = 10x28.5 = 285 m.
  - barges: 10L = 10x56.75 = 567.5 m.
  - small passenger vessels: 10L = 10x18 = 180 m.
- Cross currents should be avoided as much as possible.

3.2 Port design

The manoeuvring of small to medium size vessels generally poses no special problem in the sense that specific measures have to be taken in the dimensioning of the port infrastructure.
The required stopping lengths are limited and can generally be accommodated in traditionally sized inner channels and manoeuvring spaces. Manoeuvring capability of these vessels is generally good and upon entering port they will often manoeuvre and stop under their own power.
Main manoeuvring areas within the port.

3.2.1 Turning circle

The inner channel should have a turning circle at the end of the channel. The diameter of this turning basin should be ≥ 2L.
The longest vessels which will call at the service port frequently are the two barges. 2L = 2x56.75 = 113.5 = ±114 m.
Dependent on the design it can also be, 2L = 2x28.5 = 57 m. for the ships of the Port Administration or 2L = 2x18 = 36 m. for the small passenger vessels.

3.2.2 Width of the port entrance

This width is the same as the longest vessel that will call at the service port: 92 m.

4. BUILDINGS

4.1 PTCC building

A PTCC, Port Traffic Control Centre should be designed to provide combined facilities for the Harbour Master, the tug-boat service, the pilot service and possibly a coastal radio station and the Fishing Port Authorities. Space for the following functions should consequently be:

- Control room.
- Optional space for coastal radio operation.
- Equipment room.
- PTCC office.
- Harbour Master.
- Conference and classrooms.
- Pilot and Tug station including lounge, accommodation, toilet and bath.
- Workshop and Storage room for service vessels and maintenance area.
- Toilets.

4.2 Building for passengers

This building should contain:

- Offices.
- Waiting room.
- Toilets.
- Shop.

4.3 Building for general needs

This building should contain facilities for:

- customs,
- police, and
- medical needs.

5. THE REMAINING FACILITIES

- Mobile crane with a lifting capacity of 40 tons.

- Parking spaces for:
  5 lorries,
  20 cars, and
  3 busses.

- Facility for fuel and water.

- Height of the quay walls around the port.

The tidal variations: In the year 1985 the water-level was thirteen times as high as CD+6.5 m. Derived from TABLE DE MARES, 1985, Volume II. Instituto Hidrográfico, Lisboa. This level will be used as HHWL.

Height = HHWL + 1 m.
= CD+6.5+1 = CD+7.5 m.

The required surface area for the service port can be estimated and than it is possible to investigate if Praia Nova (location C) can accommodate such a service port.
The required surface area: approximately 80,000 m^2.
The surface area of Praia Nova: 212,500 m^2.
Conclusion: Praia Nova can accommodate the service port.

For the identified alternatives see the Appendix 9 in this Volume.

Republic of Mozambique Beira

SERVICE PORT, BEIRA

Appendix 9

THE ALTERNATIVES

1. DESCRIPTION OF THE ALTERNATIVES

1.1 Alternative 1

For a general outline of this alternative see Figure 1.1.1 (Alternative 1) on the next page. This alternative is situated in the southern part of Praia Nova also called location C in this study. This port will be constructed as a basin cut into the land along the river bank. The main advantage of such a basin would be the excellent shelter provided for the small passenger vessels. The main disadvantage is the heavy siltation that will occur in the basin. See Appendix 10 in this volume. The port-entrance will be situated where now the existing jetty is located. Behind the entrance is a basin, the actual service port. This basin has mooring facilities for the following types of vessels:

- ships owned by the Port Administration 92 m.
- the small passenger vessels 92 m.
- the fleet of Emodraga 122 m.

The moorings for the service vessels and the fleet of Emodraga are quays of concrete with ladders against the wall to get on and off. The moorings for the small passenger vessels are floating pontoons along piles, connected to the shore by a hinged access bridge. This makes getting on and off the vessels much safer and easier for the large numbers of people. The moorings for the small passenger vessels are situated as far as possible from the entrance, to provide in a sheltered mooring.

The port exists of two parts. The actual port as discussed above and then on the outside there is a mooring facility for the two larger passenger vessels. For these vessels proper mooring facilities could best be provided along the river bank, aligned with the direction of the currents. At present these two vessels are mooring in the same conditions. To provide a mooring like that the actual port surface area can be decreased. Another advantage is that it is easier to sail to their moorings. They can moor outside the port because they do not need sheltered moorings. For the other facilities like buildings for the passengers, the office for the Port Administration and parking spaces these will be provided on the northern side of the port.

In the basin a turning circle has been designed for the barges with a radius of 56.75 m, so the other vessels can also easily turn in this basin. Generally for all types of vessels the entrance or departure manoeuvres will be easy and safe but especially for the larger vessels of Emodraga it could be hazardous in view of the cross current and cross wind which will often be experienced. The entrance to the port is 150 m wide and this entrance is very close to the existing Macuti Channel.

The moorings for Emodraga are situated close to their maintenance area and will be connected by a road. The whole service port will be connected with the town by one big access road using the existing entrance to Praia Nova.
The entire surface area is about 63,100 m^2.

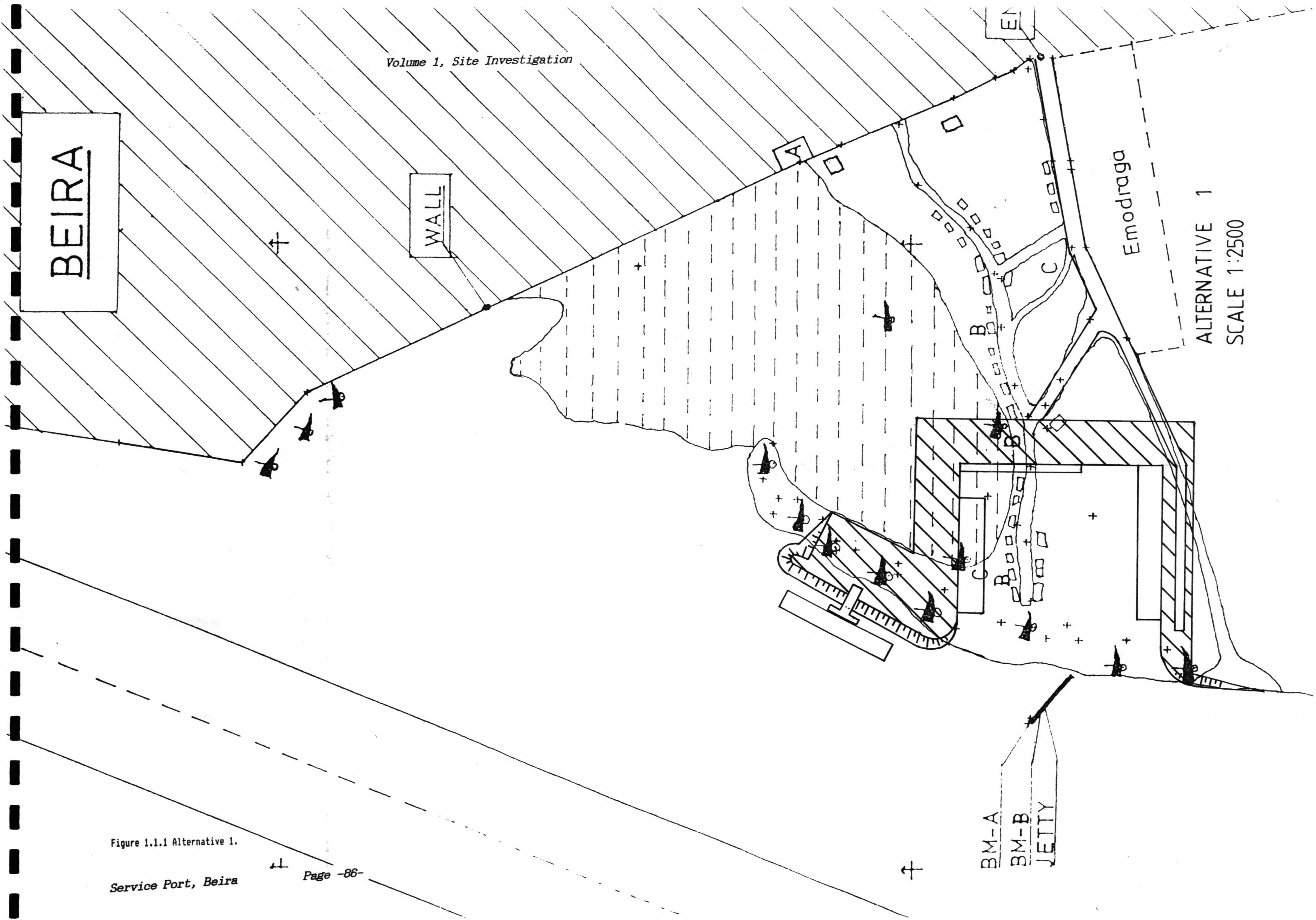


Figure 1.1.1 Alternative 1.

1.2 Alternative 2

For a general outline of this alternative see Figure 1.2.1 and Figure 1.2.2 (The proposed solution for the existing fishery-port and Alternative 2) on the next pages. This alternative is situated in the northern part of Praia Nova also called location C in this study. In this alternative the existing fishery port will be used. This port will be used to moor the ships owned by the Port Administration. They are using the port for this purpose at the moment. The Chiveve Quay is used to berth the vessels. These moorings have to be improved because at present they are not ideal. The facilities would consist of two pontoons and a row of dolphins on either side. Vessels would berth alongside the pontoon as well as along the dolphins. The dolphins would have steps and be connected to the pontoons by a catwalk. The pontoons would be connected to the shore by a hinged bridge which provides access for pedestrians only. The authorities are planning to build a new Port Traffic Control Centre (PTCC) at this location. For an outline of this plan see page 88. In that case the fishery port may also be used by the service vessels, otherwise the space-saving for the fishing-boats is not big enough. For the other vessels that are using the fishery port at the moment a new port will be built at Praia Nova. This port has mooring facilities for the following types of vessels:

- the small passenger vessels 107 m.
- the fleet of Emodraga 122 m.
- possibility for future extension 92 m.

There is also a mooring for the two larger passenger vessels outside the port. This facility is planned along side the wall. The mooring can be a floating pontoon to make getting on and off easier. This alternative envisages a port basin protected by two breakwaters located at right angles to the present river bank. The access between the breakwaters is 92 m wide. A turning circle of 56.75 m radius is planned within the port basin. Directly on the other side of the breakwater, are moorings planned for the small passenger vessels in order to combine the facilities required for the passengers. At present there is an open area which is suitable to build these facilities close to the centre of the town. The other breakwater floats and is made out of concrete. Both breakwaters will give a sheltered port. The floating breakwater gives the possibility to extend the port in an easy way. The vessels of Emodraga will moor alongside this floating breakwater and steps will be used to get on and off.

The entrance to the port is 92 m wide and this entrance is very close to the existing Macuti Channel and so it easy to call at this port.
In this alternative less surface area will be used and the port will be situated in the lower part of the area. The hindrance to the economic activities at the area is almost zero.
The entire surface area is about 54,700 m².

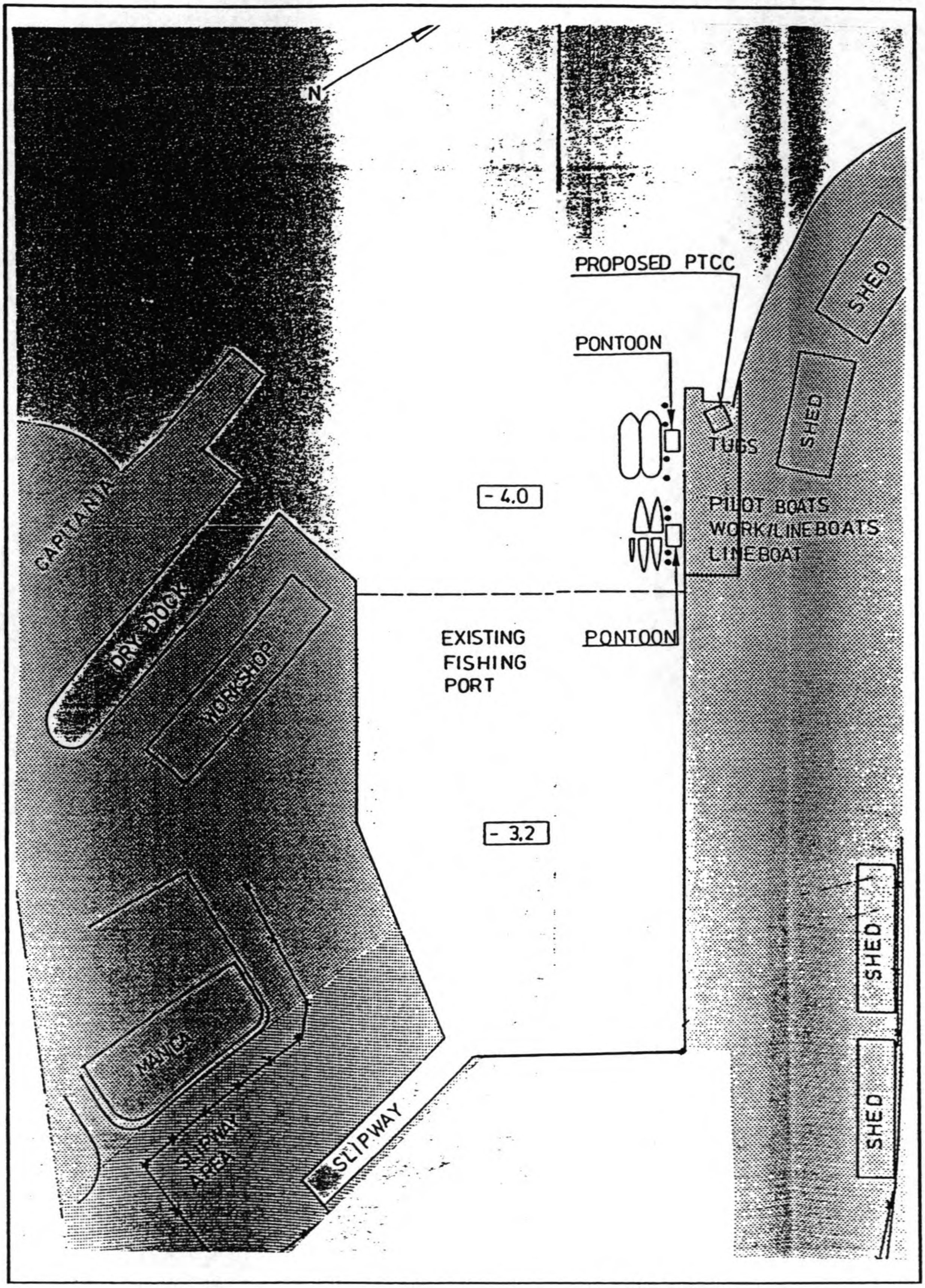


Figure 1.2.1 The proposed solution for the existing fishery-port.

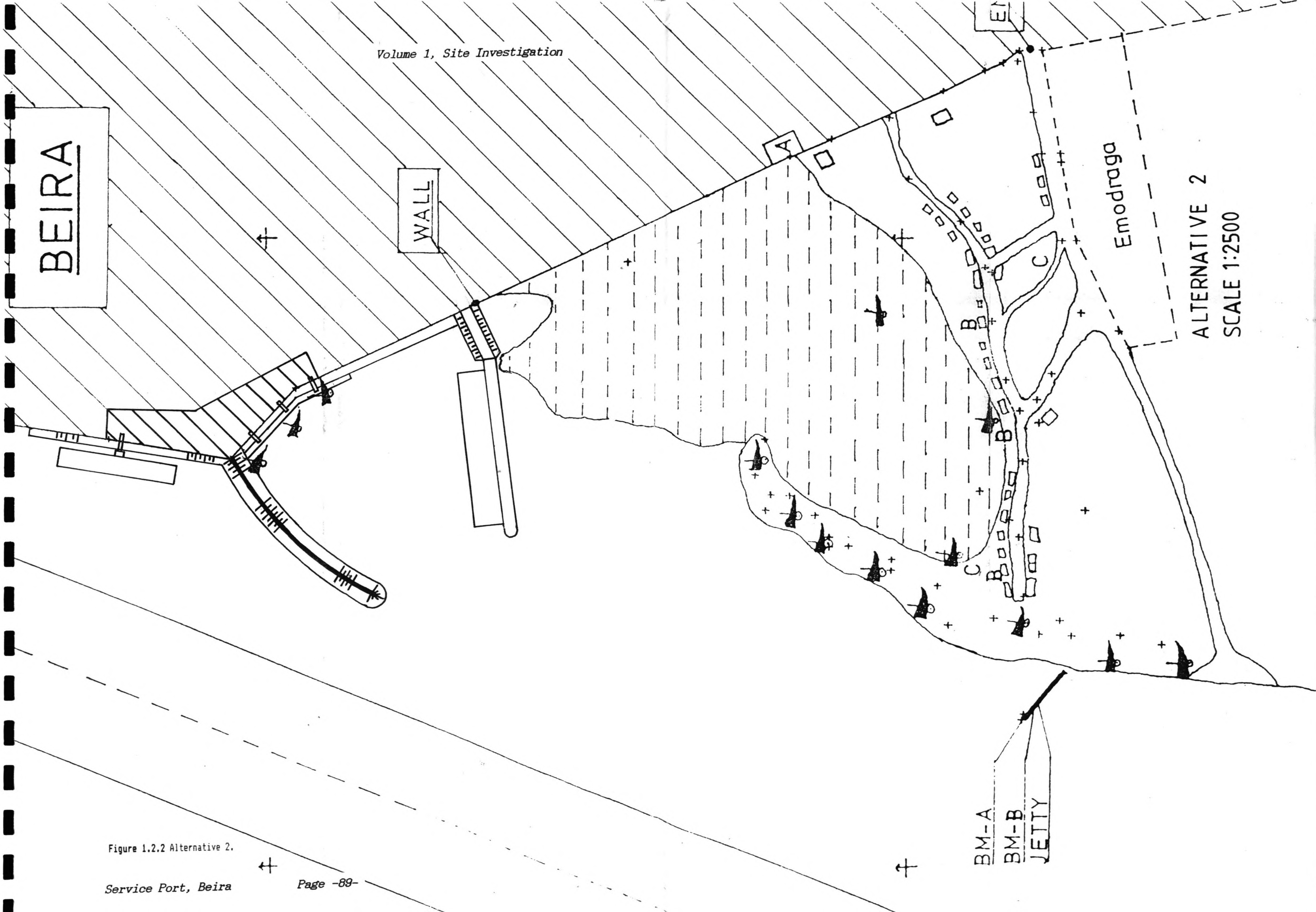


Figure 1.2.2 Alternative 2.

1.3 Alternative 3

For a general outline of this alternative see Figure 1.3.1 (Alternative 3) on the next page. This alternative is situated in the central part of Praia Nova. This is the lower part of the area which is covered by mangrove. This plan is composed of a totally new port, so the existing fishery port will not be used. The plan consists of a basin with a small breakwater near the west entrance and a dike on the opposite side, with future town extension possibilities behind it. This basin has mooring facilities for the following types of vessels:

- ships owned by the Port Administration 90 m.
- the small passenger vessels 95 m.
- the fleet of Emodraga 125 m.

A turning circle for the barges has been designed for the basin with a radius of 56.75 m, so all the other vessels can also easily turn in this basin. For the two larger passenger vessels there is a mooring outside the basin along the river bank. This solution is the same as in Alternative 1. Opposite the moorings for the large passenger vessels are the moorings for the small passenger vessels, so that all the facilities for these vessels can be located close to one another. Floating pontoon type berthing facilities are proposed where easy access for people to and from the vessels is required. Because the tidal range is about 5.70 m, a fixed berthing facility may cause dangerous conditions for embarkation. The pontoons would slide up and down with the tide along piles driven into the river bottom. The piles would keep the pontoons in their correct positions and absorb the pressure. For the passengers, the connection into town is not so good as in Alternative 2.

The entrance to the port is 88 m wide. The entrance to the port by land is the existing entrance to Praia Nova. On the east side of the port are the moorings for the service vessels planned and also the facilities for the Port Administration. The south quay in the port is reserved for Emodraga.

The surface area required for this port is quite large and the hindrance to the activities in this area is enormous. With the access channel there, almost the whole area will be used.
The entire surface area is about 82,500 m².

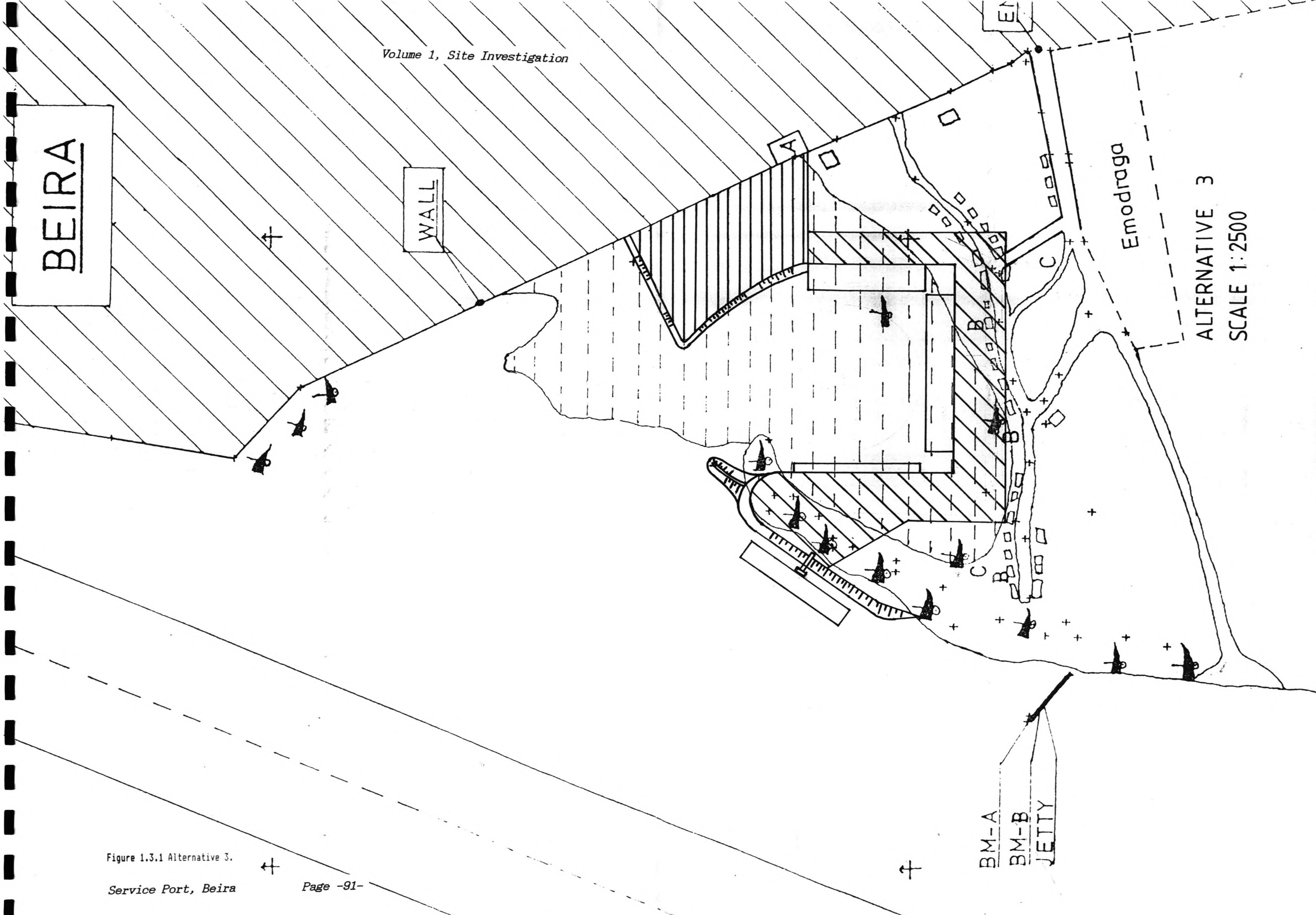


Figure 1.3.1 Alternative 3.

1.4 The improved Alternative 2

For a general outline of this alternative see Figure 1.4.1 and Figure 1.2.1 (The improved Alternative 2 and the proposed solution for the existing fishery port). This improved alternative is situated alongside the river bank of Praia Nova. Not the whole bank will be used in this design for the service port, in the middle there is a part reserved for eventual future extension. In this design the existing fishery port will be used.

This port will be used to moor the ships owned by the Port Administration. At present they are using the port for this purpose. The Chiveve Quay is used to berth the vessels. These moorings have to be improved because at present they are not ideal. The facilities would consist of two pontoons and a row of dolphins on either side. Vessels would berth alongside the pontoon as well as along the dolphins. The dolphins would have steps and be connected to the pontoons by a catwalk. The pontoons would be connected to the shore by a hinged bridge which provides access for pedestrians only.

There is a plan to build a new Port Traffic Control Centre (PTCC) at this location. For an outline of this plan see Figure 1.2.1 on page 88. The advantage is that the service vessels and their facilities are located in a central place in the port with good accessibility. In this case the fishery port may only be used by the service vessels, otherwise the space-saving for the fishing-boats is not big enough.

For the dredging vessels owned by Emodraga a mooring facility will be build as close as possible to their own maintenance facility near the entrance to the terrain of Praia Nova. A connecting road is planned from this maintenance facility to the mooring. This road has to be designed for a mobile crane with a lifting capacity of 40 tons. Near the mooring itself a parking-place with a capacity for 10 cars is projected. The surface area of this parking-place is about 1,000 m^2. The planned mooring is about 122 m long and 5 m wide and connected to the shore with a 95 m long and 5 m wide approach bridge, which provides access for vehicles (mobile crane). The mooring platform is protected by freestanding dolphins. It is assumed that two vessels can be moored side by side alongside the mooring.

The mooring is located near the depth contour of CD-7.2 m. This depth is sufficient and the main advantage is that no capital dredging is required. The result of this is that the approach bridge is a little bit longer. It is expected that the current will maintain the required depth. A bottom protection is projected around the mooring.

The small passenger vessels will be moored on a floating breakwater. This breakwater is a concrete construction with the following dimensions:
- length 45 m.
- width 12 m.
- height 3 m.

For the design of this floating breakwater see Volume 2.

This breakwater rises with the tide along a piles and will be connected to the shore by a hinged connecting bridge. The vessels are able to moor on both sides of this breakwater, depending on the direction of the current and the wave attack. The breakwater has to provide sheltered moorings on the leeward side of it.

This floating breakwater will be located perpendicular to a new seawall. This seawall is located closer to the entrance channel to provide moorings with a bigger current velocity to decrease or to prevent siltation. In fact a new river bank will be built. Another advantage is the depth of water at this location. The need for capital dredging is smaller because the water is not so shallow.

The advantage of this new seawall is also the area behind the wall. The surface of this area is estimated as approximately 25,000 m^2. This area may be used to locate all facilities for the large and small passenger vessels. The area is big enough for this purpose so no buildings or houses need to be demolished in the existing town around this area. By projecting the passenger moorings for both types of vessels together it is possible to decrease the number of buildings for facilities. The passengers who use the large and the small passenger vessels are able to share the same facilities.

For the two larger passenger vessels proper mooring facilities could best be provided along the existing river bank, aligned with the direction of the currents. This has already been suggested in Alternative 2. at the northern part of the terrain. At present these vessels are moored in the same conditions. An advantage is that they can easily sail to the moorings. They can moor outside the port without any problems, because they do not need sheltered moorings.

The mooring would consist of a floating pontoon along piles and a row of dolphins on either side. The vessels would berth alongside the pontoon as well as along the dolphins. The pontoon would be connected to the shore by a hinged bridge which provides easy and safe access for the pedestrians.

The dimensions of this floating pontoon are:
- length 10 m.
- width 5 m.

The length of the access bridge is about 18 m and the width is 5 m.

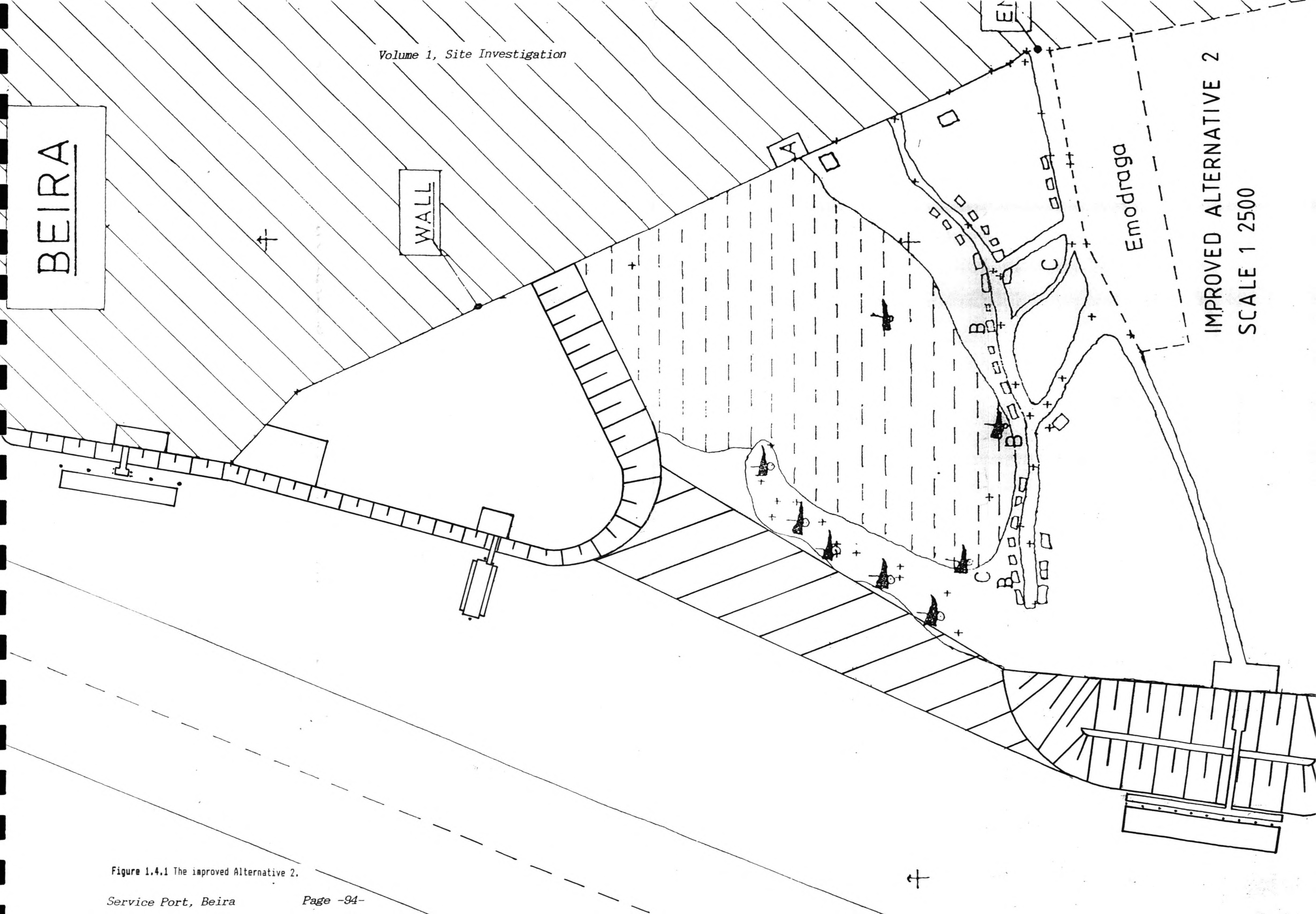


Figure 1.4.1 The improved Alternative 2.

Republic of Mozambique Beira

SERVICE PORT, BEIRA

Appendix 10

PORT SILTATION

1. PORT SILTATION

1.1 Introduction

Because of the high concentrations of sediment and the high tidal range it is necessary to investigate the siltation of all alternatives. Nowadays the siltation in the fishery port is a big problem which makes it clear, that it should not be underestimated. To obtain an impression of the siltation it will be calculated for one port only. Here the siltation for Alternative 3 will be calculated.

1.2 The calculations

The port siltation is computed by multiplying the volume of water exchanged in one tidal cycle in the basin by the difference in sediment concentration between the inflowing and outflowing water. These calculations are carried out by using a spreadsheet. To obtain a good impression of the siltation rate, the total siltation for one month has been calculated. This was done in December 1990, during the wet period when the concentration of sediment is highest. For the results of the calculations and the conclusion see the next two sections.

The port is 160 m long and has a prismatic cross section with vertical side slopes. The tidal range varies from 1.9 m to 5.6 m and the port depth at low water is 5.39 m. The bottom of the port has a width of 165 m.
The calculation will be described below:

The tidal range is calculated in column tide range as high water minus low water.

The average water depth in the port is:

$$\bar{h} = 5.39 + 1/2 \times \text{tide range}$$

The average flow area in the entrance is, then:

$$A_E = 160 \times \bar{h}$$

The tidal prism, P, of the port is the volume of water supplied per tide of incoming current.

$$P = 160 \times 165 \times \text{tide range}$$

Each liter of this water carries suspended sediment into the port. Probably not all of this sediment will settle in the limited retention time. Let us assume that the discharge water from the port carries an average of 10% dry silt. Thus 0.9C is retained in the port. In the wet period the concentration is 1670 mg/l during spring tide and 82 mg/l during neap tide. Between spring and neap tide the concentrations are interpolated.

The amount of sediment transported into the port by the incoming current is therefore:

$s_T = P \times C$

How much more shallow will the port become as a result of siltation? This can be answered if the density of the dry sediment particles and that of the situ sediment are known. Reasonable values for these are 2,650 kg/m^3 and 1,200 kg/m^3, respectively. Therefore, if V_v denotes the volume of water filling voids in 1 m^3 of sediment, then:

$$1{,}200 = 2{,}650(1-V_v) + 1{,}025(V_v)$$

of which $V_v = 0.89$.

Therefore, 1 m^3 of sediment contains $(1-0.89) \times 2{,}650 = 291.5$ kg of dry sediment particles.

The thickness can be calculated as follows:

$$t = S_T/(291.5 \times 160 \times 165)$$

The volume is spread over the port in a layer.

For all these calculated values see the spreadsheet and the graphic in the next section.

1.3 The spreadsheet

Below are listed the results of the spreadsheet.

Month: December Year: 1990

Day	Time	M	Tide Range [m]	$\bar{h}$[m]	A_E[m^2]	P[m^3]	C[mg/L]	Sf[kg/tide]	t[m]	Total[m]
1	0325	6.1								
	0951	1.0	5.1	7.94	1270.4	134640	1455	1.76E+05	0.022917	0.02
	1544	6.3								
	2218	1.3	5.0	7.89	1262.4	132000	1412	1.68E+05	0.021805	0.04
2	0410	6.4								
	1043	0.9	5.5	8.14	1302.4	145200	1627	2.13E+05	0.027629	0.07
	1627	6.4								
	2308	1.2	5.2	7.99	1278.4	137280	1498	1.85E+05	0.024055	0.10
3	0453	6.4								
	1132	0.8	5.6	8.19	1310.4	147840	1670	2.22E+05	0.028874	0.13
	1709	6.4								
	2353	1.1	5.3	8.04	1286.4	139920	1541	1.94E+05	0.025220	0.15
4	0535	6.4								
	1216	0.9	5.5	8.14	1302.4	145200	1627	2.13E+05	0.027629	0.18
	1750	6.3								

5	0033	1.2	5.1	7.94	1270.4	134640	1455	1.76E+05	0.022917	0.20
	0616	6.2								
	1255	1.0	5.2	7.99	1278.4	137280	1498	1.85E+05	0.024055	0.23
	1829	6.0								
6	0107	1.3	4.7	7.74	1238.4	124080	1284	1.43E+05	0.018628	0.24
	0657	5.9								
	1330	1.3	4.6	7.69	1230.4	121440	1241	1.36E+05	0.017622	0.26
	1909	5.7								
7	0138	1.6	4.1	7.44	1190.4	108240	1026	1.00E+05	0.012990	0.27
	0739	5.5								
	1403	1.7	3.8	7.29	1166.4	100320	897	8.10E+04	0.010529	0.28
	1950	5.4								
8	0208	1.9	3.5	7.14	1142.4	92400	769	6.39E+04	0.008306	0.29
	0828	5.2								
	1440	2.1	3.1	6.94	1110.4	81840	597	4.40E+04	0.005714	0.30
	2040	5.0								
9	0243	2.3	2.7	6.74	1078.4	71280	425	2.73E+04	0.003545	0.30
	0928	4.8								
	1530	2.5	2.3	6.54	1046.4	60720	254	1.39E+04	0.001801	0.30
	2143	4.7								
10	0346	2.6	2.1	6.44	1030.4	55440	168	8.37E+03	0.001088	0.31
	1043	4.6								
	1701	2.7	1.9	6.34	1014.4	50160	82	3.70E+03	0.000481	0.31
	2259	4.6								
11	0559	2.7	1.9	6.34	1014.4	50160	82	3.70E+03	0.000481	0.31
	1204	4.6								
	1839	2.6	2.0	6.39	1022.4	52800	125	5.94E+03	0.000771	0.31
12	0018	4.7								
	0725	2.4	2.3	6.54	1046.4	60720	254	1.39E+04	0.001801	0.31
	1317	4.8								
	1944	2.2	2.6	6.69	1070.4	68640	382	2.36E+04	0.003069	0.31
13	0128	5.0								
	0821	2.0	3.0	6.89	1102.4	79200	554	3.95E+04	0.005132	0.32
	1414	5.2								
	2036	1.9	3.3	7.04	1126.4	87120	683	5.35E+04	0.006957	0.32
14	0223	5.4								
	0908	1.7	3.7	7.24	1158.4	97680	855	7.51E+04	0.009761	0.33
	1500	5.5								
	2123	1.6	3.9	7.34	1174.4	102960	940	8.71E+04	0.011323	0.35
15	0309	5.7								
	0954	1.5	4.2	7.49	1198.4	110880	1069	1.07E+05	0.013863	0.36
	1541	5.8								
	2210	1.4	4.4	7.59	1214.4	116160	1155	1.21E+05	0.015690	0.37
16	0349	5.9								
	1038	1.4	4.5	7.64	1222.4	118800	1198	1.28E+05	0.016643	0.39
	1619	5.9								
	2254	1.3	4.6	7.69	1230.4	121440	1241	1.36E+05	0.017622	0.41
17	0427	6.0								
	1118	1.3	4.7	7.74	1238.4	124080	1284	1.43E+05	0.018628	0.43
	1654	6.0								
	2333	1.3	4.7	7.74	1238.4	124080	1284	1.43E+05	0.018628	0.45
18	0502	6.0								
	1153	1.3	4.7	7.74	1238.4	124080	1284	1.43E+05	0.018628	0.46
	1727	5.9								

19	0006	1.3	4.6	7.69	1230.4	121440	1241	1.36E+05	0.017622	0.48
	0534	6.0								
	1220	1.4	4.6	7.69	1230.4	121440	1241	1.36E+05	0.017622	0.50
	1758	5.9								
20	0034	1.3	4.6	7.69	1230.4	121440	1241	1.36E+05	0.017622	0.52
	0604	6.0								
	1241	1.4	4.6	7.69	1230.4	121440	1241	1.36E+05	0.017622	0.54
	1825	5.8								
21	0055	1.4	4.4	7.59	1214.4	116160	1155	1.21E+05	0.015690	0.55
	0633	6.0								
	1256	1.5	4.5	7.64	1222.4	118800	1198	1.28E+05	0.016643	0.57
	1851	5.7								
22	0114	1.4	4.3	7.54	1206.4	113520	1112	1.14E+05	0.014763	0.58
	0703	5.9								
	1312	1.5	4.4	7.59	1214.4	116160	1155	1.21E+05	0.015690	0.60
	1919	5.6								
23	0135	1.5	4.1	7.44	1190.4	108240	1026	1.00E+05	0.012990	0.61
	0737	5.7								
	1334	1.6	4.1	7.44	1190.4	108240	1026	1.00E+05	0.012990	0.62
	1953	5.4								
24	0204	1.7	3.7	7.24	1158.4	97680	855	7.51E+04	0.009761	0.63
	0821	5.4								
	1407	1.9	3.5	7.14	1142.4	92400	769	6.39E+04	0.008306	0.64
	2041	5.2								
25	0246	1.9	3.3	7.04	1126.4	87120	683	5.35E+04	0.006957	0.65
	0920	5.1								
	1454	2.2	2.9	6.84	1094.4	76560	511	3.52E+04	0.004577	0.65
	2153	4.9								
26	0354	2.2	2.7	6.74	1078.4	71280	425	2.73E+04	0.003545	0.66
	1039	4.9								
	1611	2.5	2.4	6.59	1054.4	63360	297	1.69E+04	0.002197	0.66
	2328	4.7								
27	0552	2.3	2.4	6.59	1054.4	63360	297	1.69E+04	0.002197	0.66
	1210	4.8								
	1832	2.6	2.2	6.49	1038.4	58080	211	1.10E+04	0.001431	0.66
28	0101	4.9								
	0730	2.1	2.8	6.79	1086.4	73920	468	3.12E+04	0.004048	0.67
	1334	5.1								
	2007	2.3	2.8	6.79	1086.4	73920	468	3.12E+04	0.004048	0.67
29	0216	5.3								
	0842	1.7	3.6	7.19	1150.4	95040	812	6.94E+04	0.009021	0.68
	1440	5.5								
	2117	1.9	3.6	7.19	1150.4	95040	812	6.94E+04	0.009021	0.69
30	0314	5.7								
	0945	1.4	4.3	7.54	1206.4	113520	1112	1.14E+05	0.014763	0.70
	1534	5.9								
	2217	1.6	4.3	7.54	1206.4	113520	1112	1.14E+05	0.014763	0.72
31	0403	6.1								
	1041	1.1	5.0	7.89	1262.4	132000	1412	1.68E+05	0.021805	0.74
	1621	6.1								
	2309	1.3	4.8	7.79	1246.4	126720	1327	1.51E+05	0.019660	0.76

0.76

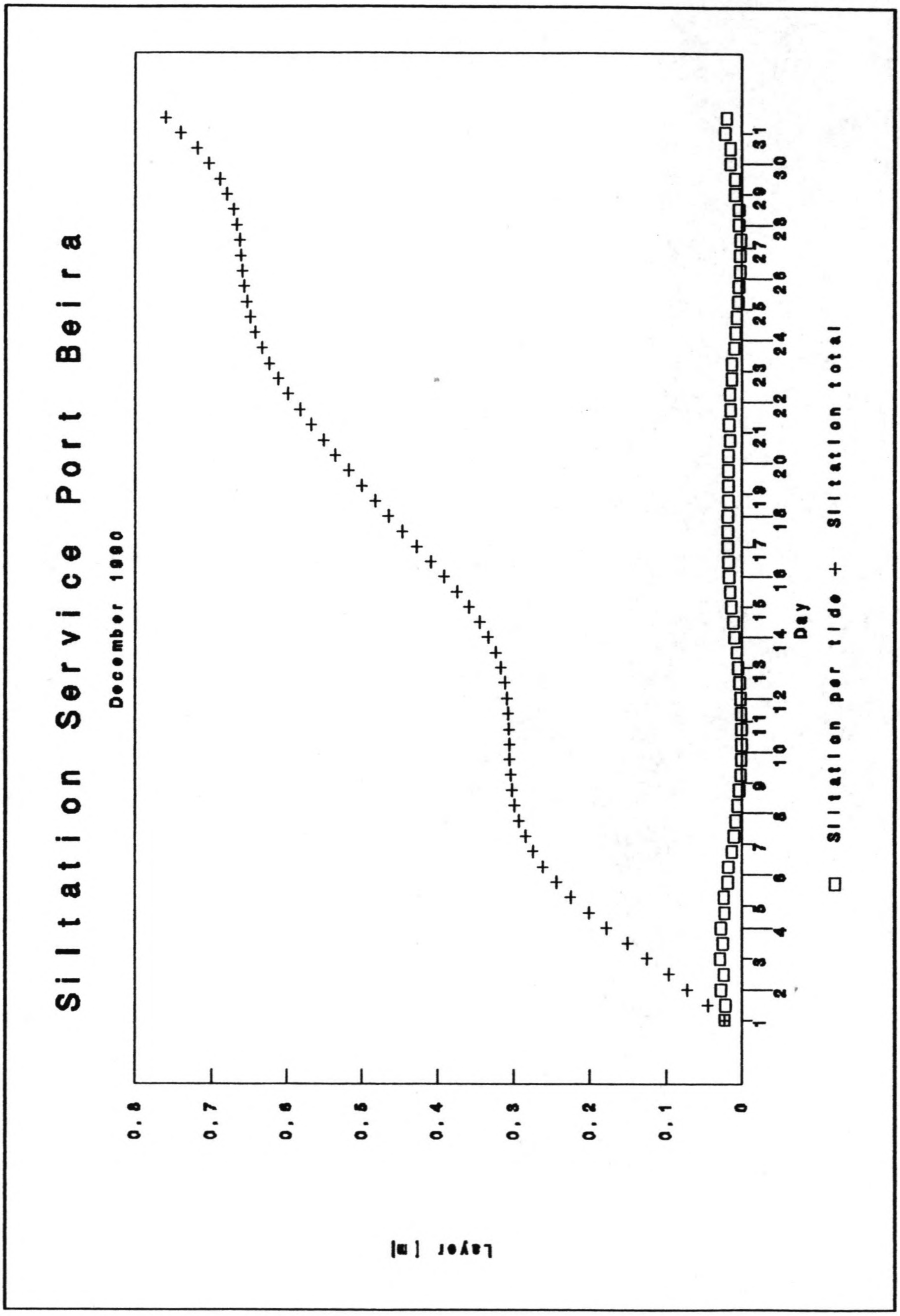


Figure 1.3.1 Siltation Service Port, Beira.

1.4 Conclusion

As one can see, the siltation in the wet period is almost 0.8 m per month. This is only the siltation caused by the incoming current. There is also sedimentation due to density currents. Thus, in reality the sedimentation will be more. This influence has not been calculated because the siltation caused by the incoming current alone is so enormous that one can say that it is not acceptable. By carrying out the calculations for the siltation in the wet period it is obvious that maximum siltation occurs then. In other months the siltation will be less. But even then the siltation rate is too high. The consequence of the high siltation rates is the need for dredging every two months. This will result in:
- high dredging cost for the maintenance of the port, and
- major inconvenience to the users of the port.

Measures have to be taken to decrease the siltation in the service port.