Chapter 3 Natural Conditions in and around Ghana Sea Ports

3.1 Climatic Conditions

3.1.1 General

The study area falls within the tropical zone, in which each year has rainy and dry seasons. The study area lies within the dry Equatorial climatic region of Ghana.

Tema area, which is part of the Accra Plains, is one of the driest parts of the country. It experiences two rainfall maxima in the months of May/June and September/October. During these periods, the region is affected by the warm moist South West (SW) monsoon winds. The dry season (Harmattan) occurs in the months of December/January with minimum rainfall. During this period, the region is occasionally affected by the dry North East (NE) Trade winds.

Takoradi area is one of the moderate rainfall parts of the country. The main rainy season is in May and June, followed by a late minor rainy season lasting from October to November. The dry season lasts from around December to around March.

Details of data on Temperature, Relative Humidity, Rainfall and Wind are presented in the following sections.

3.1.2 Temperature

The hottest periods of the year in Tema and Takoradi are in the months of February and March with daytime temperatures reaching up to 35℃. This is the period preceding the onset of the minor rains. The mean monthly temperature during this time is about 29℃. July and August are relatively cooler months with mean temperatures of 26℃.

Table 3.1.1 The Monthly Average Temperatures – Tema

(Unit:℃)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av
93-97	27.5	28.5	28.2	28.4	28.1	26.7	25.2	25.1	25.8	27.0	28.0	28.0	27.2
1998	28.2	29.3	30.0	29.7	28.2	27.1	25.8	25.0	26.0	27.4	28.7	28.4	27.8
1999	27.9	28.4	28.4	28.5	28.3	27.4	26.0	25.0	25.3	26.5	28.0	28.3	27.3
2000	27.8	28.4	29.4	28.7	28.1	27.0	25.1	24.8	25.8	26.7	27.7	28.0	27.3

Source: Meteorological Services Department, Tema

Table 3.1.2 The Monthly Average Temperatures – Takoradi

(Unit:℃)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av
61-97	26.6	27.7	27.7	27.7	27.3	26.4	25.2	24.9	25.3	26.0	26.8	26.8	26.5
1998	27.6	28.9	29.5	29.3	28.0	26.9	25.7	25.0	25.8	26.7	28.0	27.8	27.4
1999	27.5	27.5	28.0	27.9	27.6	26.9	25.8	24.8	25.2	25.8	27.0	27.7	26.8
2000	27.0	27.5	28.3	27.6	27.4	26.3	24.9	24.6	25.2	26.3	27.4	27.1	26.6

Source: Meteorological Services Department, Takoradi

3.1.3 Relative Humidity

The variation in Relative Humidity at Project area is minimal and sometimes erratic due to the daily influence of the sea and the land breezes. The values range between 80% during the night to about 60% at daytime, and falls to less than 30% during the dry season (Dec-Jan), when the dry North- East Trade winds reach the coastline. The highest humidity is experienced around August after the rainy season and the lowest in December. Table 3.1.3 and Table 3.1.4 give the monthly average Relative Humidity at Tema and Takoradi.

Table 3.1.3 Relative Humidity Data for Tema

(Unit: %)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av.
73-97	72.8	74.4	74.5	75.5	77.5	80.3	82.2	81.8	79.8	70.8	66.8	65.3	75.1
1998	65.0	77.0	78.0	76.0	81.0	83.0	82.0	80.0	82.0	79.0	76.0	75.0	77.8
1999	83.0	74.0	79.0	79.0	81.0	84.0	87.0	85.0	83.0	78.0	74.0	70.0	79.8
2000	75.0	62.0	71.0	75.0	76.0	81.0	82.0	82.0	79.0	76.0	75.0	74.0	75.7

Source : Meteorological Services Department, Tema

Table 3.1.4 Relative Humidity Data for Takoradi

(Unit: %)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av.
61-97	70.7	73.5	73.6	74.5	77.5	81.7	82.0	83.0	82.5	79.4	75.2	73.8	77.5
1998	68.0	72.0	71.0	73.0	78.0	79.0	81.0	79.0	79.0	78.0	72.0	72.0	75.1
1999	76.0	69.0	74.0	75.0	75.0	79.0	81.0	81.0	82.0	79.0	74.0	71.0	76.3
2000	75.0	62.0	72.0	75.0	77.0	81.0	81.0	82.0	82.0	77.0	71.0	73.0	75.7

Source : Meteorological Services Department, Takoradi

3.1.4 Rainfall

The minor rainy season begins around March and reaches its peak of about 200 mm at Tema, 300 mm at Takoradi in the month of June, when the region comes under the influence of the moisture-laden South-West winds. Rainfall declines after June to August after which it starts rising again and reaches to about 60 mm at Tema, and about 100 mm at Takoradi in October.

The monthly average rainfalls for the past 25 and 31 years and for the last 3 years recorded at the Tema Meteorological station and at the Takoradi Meteorological station are shown in the Table 3.1.5 and Table 3.1.6.

Table 3.1.5 Monthly Rainfall – Tema

(Unit: mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot.
73-97	8.3	25.5	48.9	88.0	129.1	203.3	63.9	25.7	45.9	56.5	25.3	12.8	734
1998	0.0	12.6	N.A	12.0	135.4	60.9	4.7	2.4	6.9	82.7	5.6	11.7	334
1999	29.2	83.2	13.4	55.7	48.8	169.3	41.7	5.2	28.5	29.7	7.0	3.5	515
2000	N.A	0.0	30.0	39.0	146.8	67.7	44.7	4.2	3.4	39.9	25.7	15.3	417

Source : Meteorological Services Department, Tema

Table 3.1.6 Monthly Rainfall – Takoradi

(Unit: mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot.
61-97	20.2	32.0	62.7	110.4	190.4	312.2	107.8	61.1	85.0	111.1	69.8	22.1	1185
1998	12.5	7.6	22.7	134.6	101.5	107.7	34.5	10.0	5.5	324.4	23.4	41.8	826
1999	55.4	25.5	58.2	218.1	112.4	192.0	195.1	103.1	15.4	58.7	89.4	20.5	1144
2000	27.2	0.0	68.0	145.1	194.9	296.3	24.7	34.1	33.3	42.1	30.2	155.2	1051

Source : Meteorological Services Department, Takoradi

3.1.5 Wind

Wind data compiled by Meteorological Services Department, reveal that the mean wind speed is about 6 knots. Mean wind speed of 4 knot could be regarded as periods of relative calmness. The North-East Trade and the South-West Monsoon are the major winds which influence the project area. In addition to this is the daily changes in the wind direction, resulting from the differential heating and cooling of the land and sea, During the day, the local breeze is therefore from off-shore and the reverse occurs in the night. The prevailing wind influencing the area is from south to south-west.

Table3.1.7 and Table3.1.8 below give the monthly average wind velocity for the past 10 years and latest 1 year at Tema, and for the past 26 years ,and latest 1 year recoded at Takoradi.

Table 3.1.7 Monthly Average Wind Speed and Direction.(1990 - 99) - Tema

(Unit: knot)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av.
Dir.	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
Vel.	5.0	6.1	6.0	5.5	5.1	5.1	5.5	5.9	6.5	6.3	5.2	4.7	5.6
Dir.(2000)	SW	SW	SW	SW	SW	-	SW	SW	SW	SW	NW	SW	SW
Vel.(2000)	4.6	4.7	4.7	4.1	3.8	4.9	5.1	5.2	5.4	5.3	4.3	4.3	4.7

Source : Meteorological Services Department, Tema

Table 3.1.8 Monthly Average Wind Speed and Direction.(1973 - 99) - Takoradi

(Unit: knot)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av.
Dir.	S	S	SW	SW	S	S	SW	SW	SW	SW	S	S	SW
Vel.	2.8	3.8	4.1	3.7	3.1	3.7	3.8	4.0	4.5	4.2	3.0	2.3	3.6
Dir.(2000)	SW	SW	SSW	SSW	SSW	SW	SW	SW	SW	SW	SW	SSW	SW
Vel.(2000)	4.0	3.0	4.0	3.0	4.0	3.0	3.0	4.0	5.0	4.0	4.0	2.0	3.6

Source : Meteorological Services Department, Takoradi

3.2 Marine Conditions

3.2.1 General

The seashore in Ghana is faced on the Guinea Gulf of the Atlantic Ocean.

The marine conditions of the Ghana's coast is directly influenced on the conditions of Atlantic Ocean and Monsoon wind.

3.2.2 Tide Level

The tide in Ghana is semidiurnal pattern which has generally two high and low tide levels each day. There is no time difference between Tema and Takoradi Ports. The tide levels of Ports in Ghana are correlated to standard port of Takoradi.

Annual tidal predictions are computed and published by GPHA. However, tide level observation have been discontinued from last year (2000) in Tema Port, and since 1998 in Takoradi Port.

The tide level observation was carried out in Tema and Takoradi ports by Study Team from mid-January to mid-February, 2001. The observation result were similar to GPHA published tidal data.

The tide levels of Tema and Takoradi Ports are shown in the Table 3.2.1 and Table 3.2.2.

Table 3.2.1 Tide Level of Tema Port

(Unit: m)

	MHMS	MHWN	MLWN	MLWS
GPHA	1.6	1.3	0.7	0.3

Tema Port: 5 ° 52 ′ N. 0 ° 00 ′

Source: Tide Tables 2,001 (GPHA)

Table 3.2.2 Tide Level of Takoradi Port

(Unit: m)

	MHMS	MHWN	MLWN	MLWS
GPHA	1.5	1.2	0.6	0.2

Takoradi Port: 4 ° 53 ′ N. 1 ° 45 ′ W

Source: Tide Tables 2,001 (GPHA)

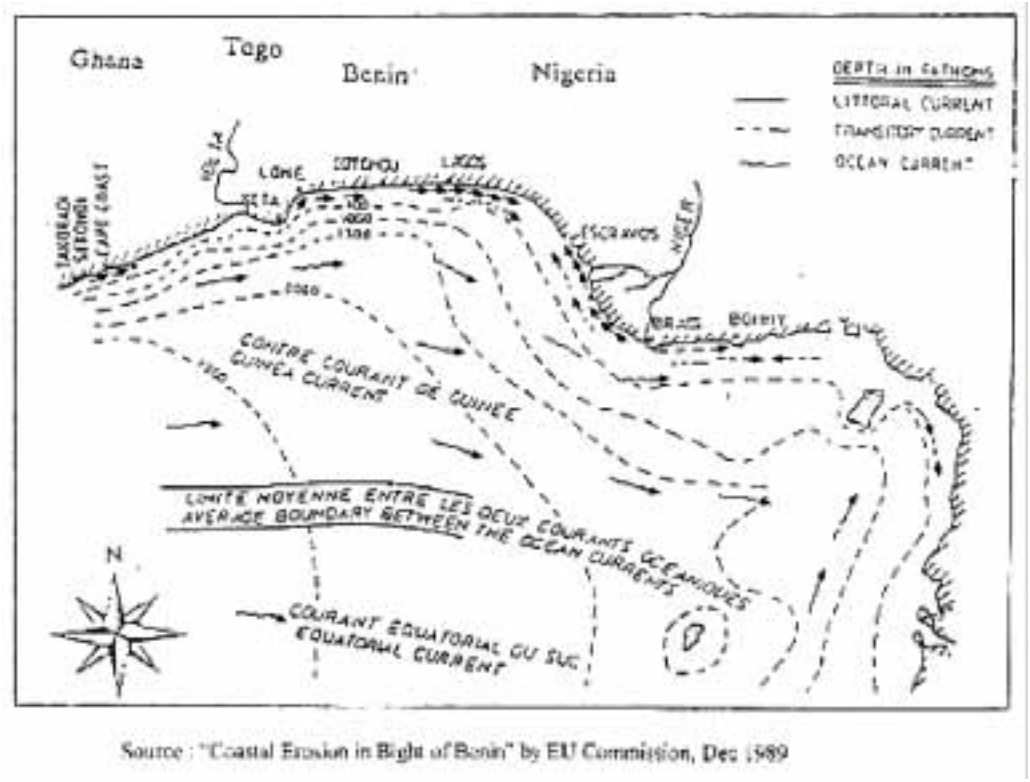
3.2.3 Tidal Current

Figure 3.2.1 shows the pattern of surface currents along the West African coast.

The direction of tidal current around the coast in Ghana is mostly North or North-East.

The velocity of the tidal current is generally less than 0.1 m/sec. The maximum velocity of tidal current observed in a day of strong winds is about 0.5 m/sec.

At a part of the ports, it is said that tidal current velocity sometimes exceeds 0.5 m/sec, however, there is no striking tidal current to influence vessel operation.



Source : "Coastal Erosion in Bight of Benin" by EU Commission, Dec 1989

Figure 3.2.1 Pattern of Surface Currents along West African Coast

3.2.4 Wave Condition

There is no wave observation data available locally for Tema and Takoradi Ports.

The wave characteristics for this study are derived during latest 40 years from The Global Wave Statistics published by British Maritime Technology.

It is found that the predominant waves flow in the South to South-West direction (about 60 % of the time). Most of the waves are between 1and 2 meters in height. Wave heights during the rainy season (June-September) when the Monsoon winds predominate, may exceed 2 meters more frequently.

The frequency distribution of the concluded wave （1960－2000）is shown in Table 3.2.3.

Table 3.2.3 The Frequency Distribution of Wave at offshore of Ghana (1960-20000)

(Unit: %)

HIGHT	N	NE	E	SE	S	SW	W	NW	TOTAL
0.0-1.0	2.45	2.00	1.84	4.38	10.55	10.30	7.48	3.98	42.97
1.0-2.0	1.69	0.84	0.92	5.04	19.85	7.82	2.98	2.84	41.98
2.0-3.0	0.24	0.17	0.19	1.36	6.93	2.15	0.60	0.62	12.44
3.0-4.0	0.07	0.02	0.03	0.22	1.36	0.41	0.08	0.09	2.28
4.0-5.0	0.00	0.00	0.00	0.02	0.19	0.04	0.01	0.01	0.29
5.0-6.0	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04
TOTAL	4.63	3.04	2.99	11.03	38.92	20.72	11.15	7.54	100.00

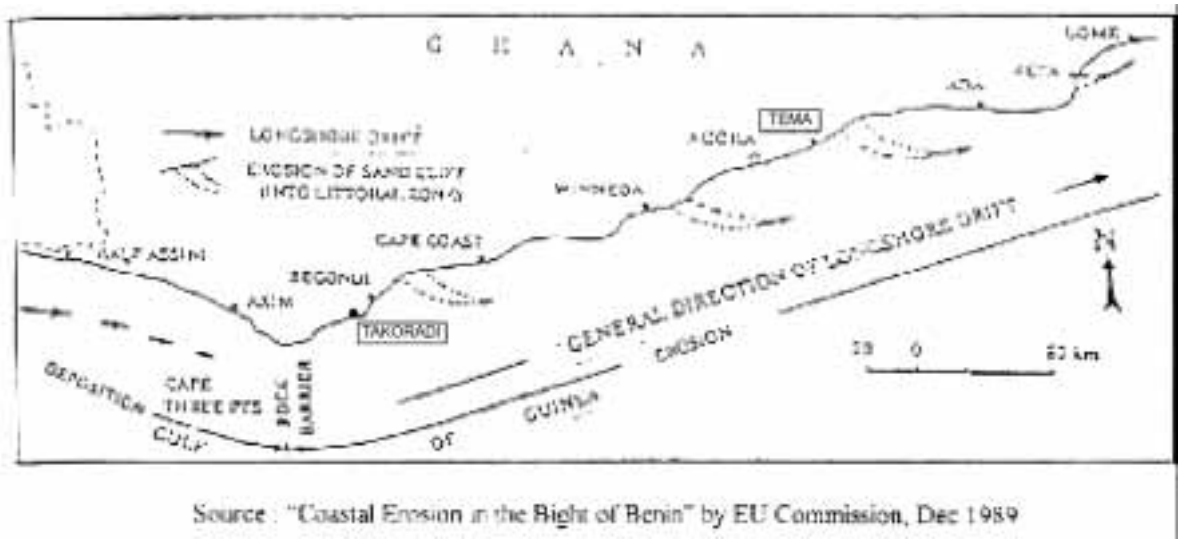
Number of Observations: 267,326

Source: “The Global Wave Statistics” published by British Maritime Technology

3.2.5 Sand Drift

The West African coast extending from Cape Palmas to The Niger Delta generally has an accretion tendency in the eastern section near Cape Three Points in Ghana and an erosion tendency in the West around the Niger Delta. Figure3.2.2 shows the direction of Sand Drift along Ghana’s coast.

Shoreline recession has been recorded at various locations along the East Coast of Ghana. The worst hit areas are the shores of Atorkor and Ada. The shoreline was found to have receded about 10 m in some areas, and erosion of another area was about 7 m in Ada.



Source : “Coastal Erosion in the Bight of Benin” by EU Commission, Dec 1989

Figure 3.2.2 Littoral Transport along Ghana coast

3.3 Topography

3.3.1 General

Tema

The shoreline direction of Tema port area is pointed from South-West to North-East. The both side coast of Tema port is sandy beach. The slope of sea bottom is about 1 % (The depth of the point distant 1 km from shoreline is about 10m deep).

There is a main breakwater at Tema Port on the western side of the port. The direction of the breakwater is forward South-East being extended about 1 km to offshore, then is turned to North-East direction from that point with the length about 1.5 km.

The sub breakwater is located on the eastern side of the port. Direction of the sub breakwater is South-South-East and extended about 1 km long to offshore. The sub breakwater forks into two sides at that point to South-West and to North-East.

The Tema Fishing Port is located at the eastern side of the sub breakwater.

The western hinterland of Tema port is about 500 m deep and 1.5km wide. A hill of about 15 m high is located in the back of the western hinterland.

The eastern hinterland of Tema port is about 800 m deep and 3Km wide. The eastern hinterland is almost flat and about 5 to 10 m above sea level.

Takoradi

The Takoradi port is located at a cape. The western coast of Takoradi port is formed with rock or reef while the northern coast is sandy beach.

The slope of sea bottom is about 1 % judging from about 10 m fall in 0.9 km distance from the shoreline.

The main breakwater is located on southern side of Takoradi port. Direction of the main breakwater is toward East being extended about 1.5 km to offshore, then is turned to North-North-East from that point with the length about 700 m.

The sub breakwater is located on the northern side of the port. Direction of the sub breakwater is toward East, and extended about 700 m to offshore and its width is about 100 m.

The reclaimed land area, about 500 m deep and 700 m wide is located at the foot of the sub breakwater.

The hinterland of Takoradi port is about 200 m deep and 2 km wide. A bluff about 10 m high is located behind the hinterland of Takoradi port. Takoradi port has narrow and small hinterland.

3.3.2 Topographic Map

The latest topographic maps with a scale at 1 to 50,000 along the shoreline of Ghana have been collected from National Survey Department which have been made based on Air photographs taken from 1972 to 1975, and in 1996.

Some of the topographic map's with a scale at 1 to 1,250 around Tema and Takoradi ports were collected. However the maps do not cover whole study areas.

Figure 3.3.1 and Figure 3.3.2 are the base maps for Tema and Takoradi ports.

3.3.3 Bathymetric Condition

A Bathymetric Survey covering the outer areas of breakwaters in Tema and Takoradi Ports were carried out in the Study. The Bathymetric Charts showing the results at Tema and Takoradi ports are shown in Figure 3.3.3 and Figure 3.3.4 respectively.

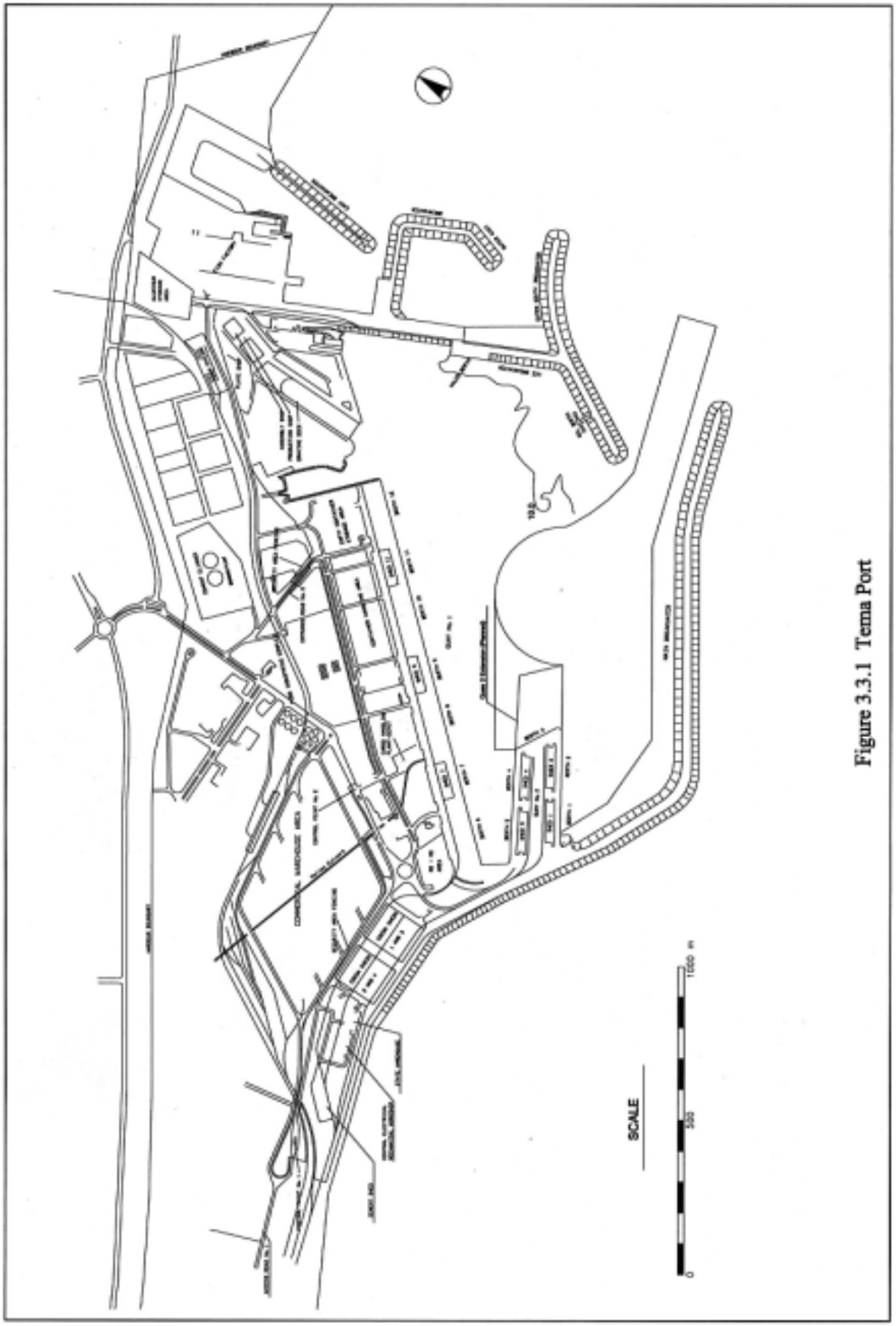


Figure 3.3.1 Tema Port

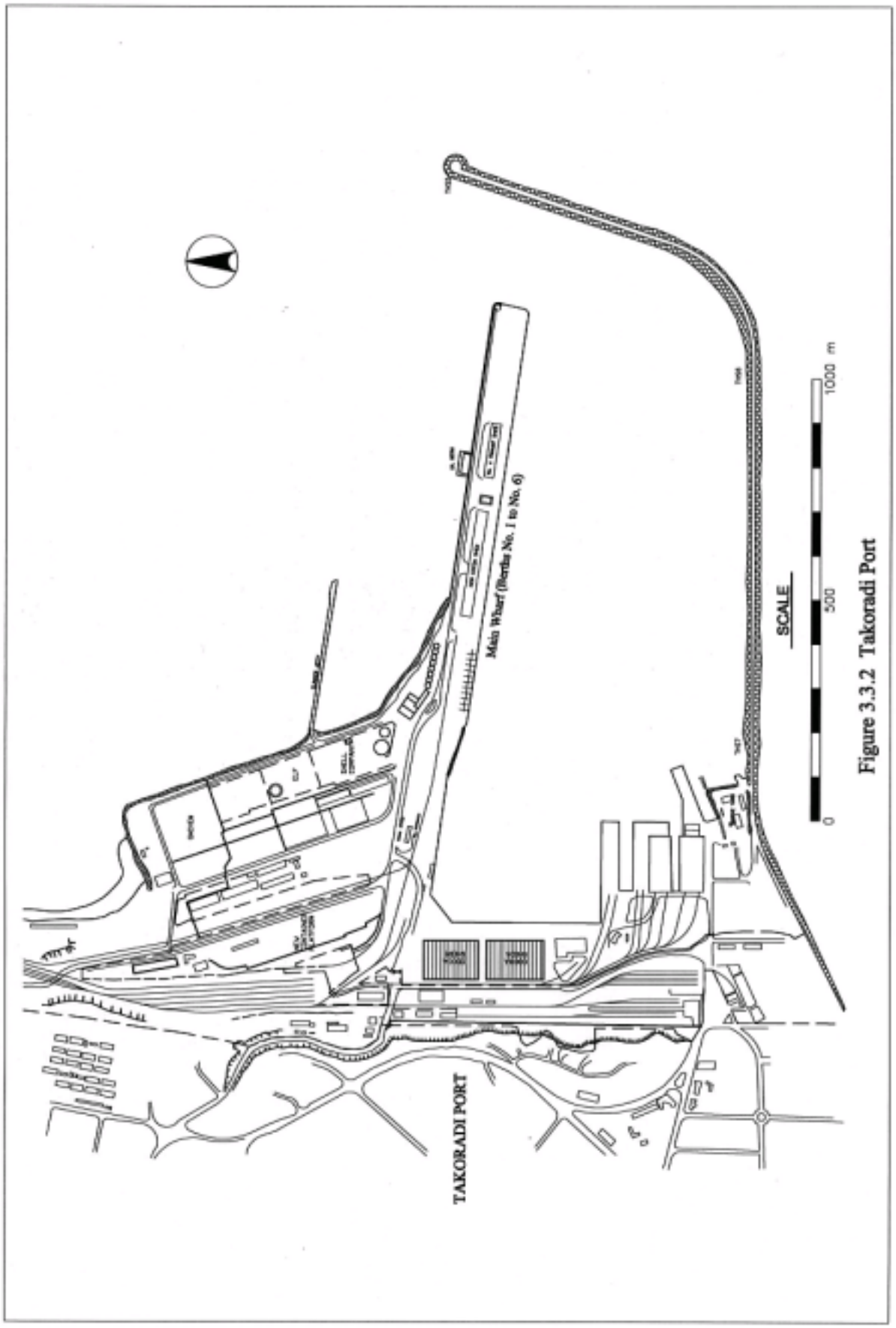


Figure 3.3.2 Takoradi Port

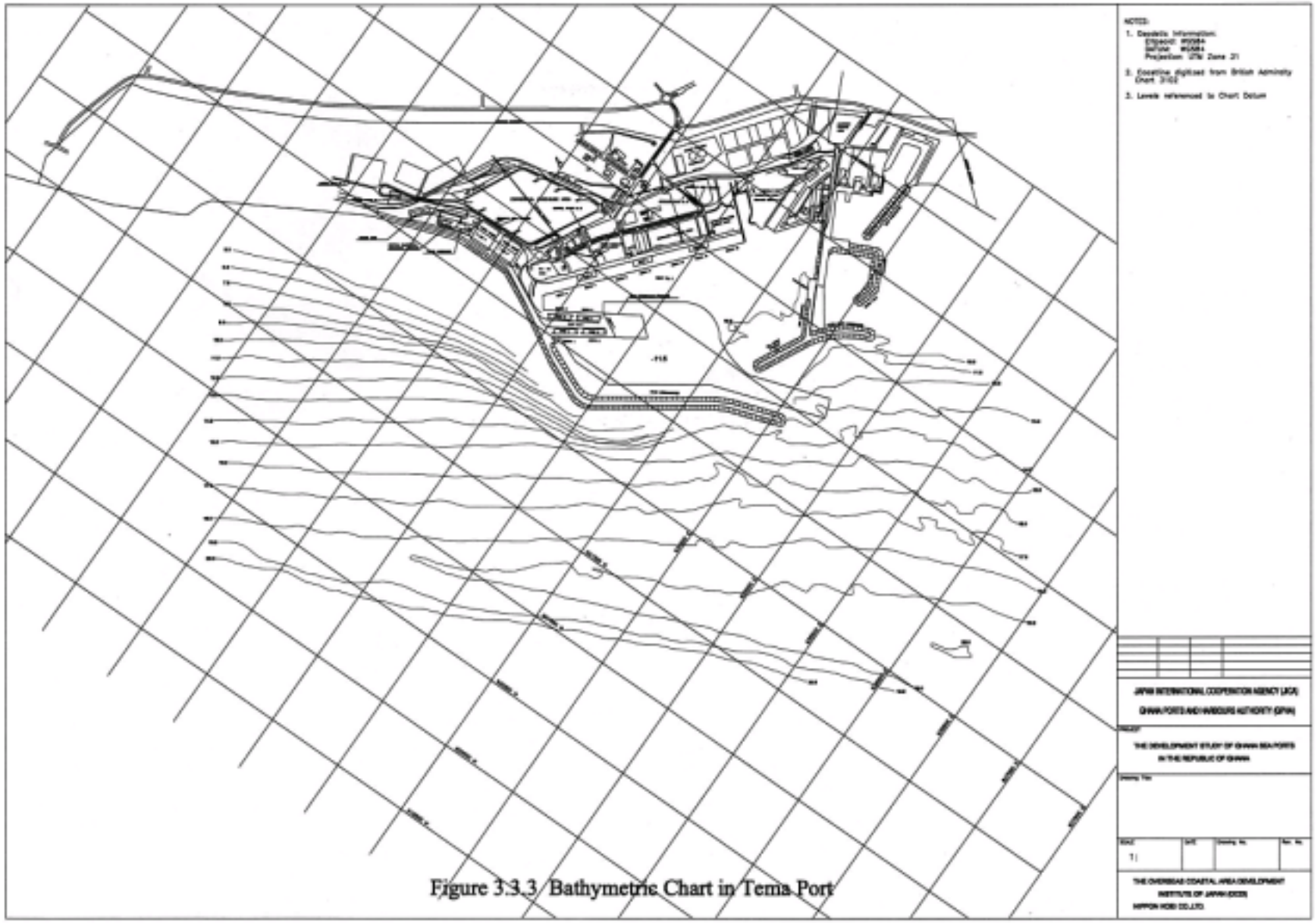


Figure 3.3.3 Bathymetric Chart in Tema Port

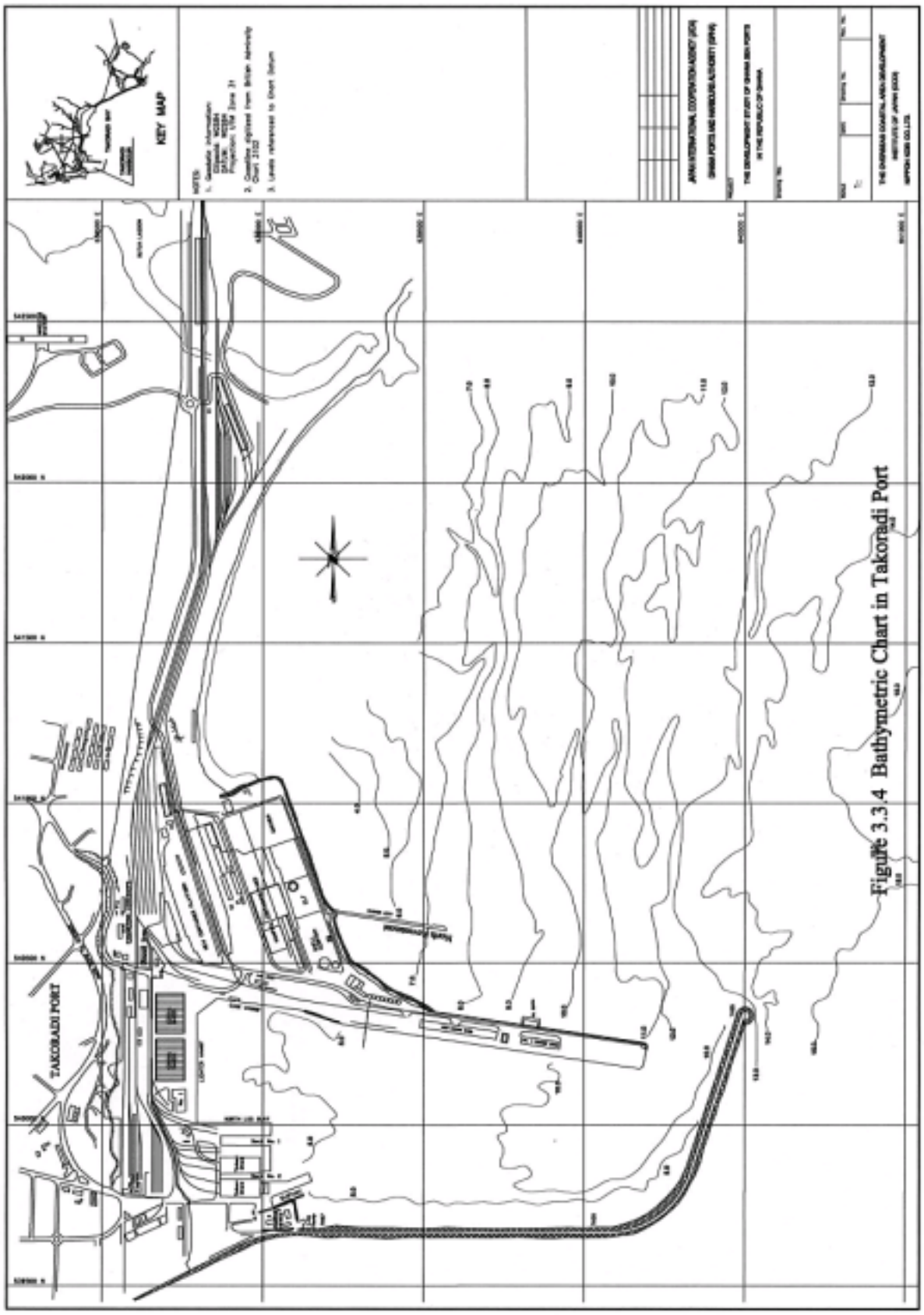


Figure 3.3.4 Bathymetric Chart in Takoradi Port

3.4 Geological Condition

3.4.1 General

The geological data of Tema and Takoradi Ports have been collected from GPHA, which is derived from a geotechnical site investigation conducted at Tema and Takoradi Ports in 1992. A total of 25 bore-holes with approximately 4 m of penetration in solid rock, were drilled in Tema and Takoradi ports. 17 bore-holes were carried out in Tema and 8 bore-holes in Takoradi.

An estimated occurrence of the rock types at Tema and Takoradi Ports were drawn as shown in Figure 3.4.1.

(1) Tema

The hard ground in the Port of Tema consists mainly of gneiss. The gneiss can be subdivided into 3 main groups. The characteristics of each rock type are drawn as follows;

- Rock type A1:

Micaseous quartz gneiss occurs in the inner part of the port. It has a very platy character, causing fault development in the mica, often weathered to chlorite, rich zones. The weathering index is generally 4, but varies form place to place. To evaluate the weathering distribution more drill-holes in a regular grid are necessary.

- Volumetric weight : 2,500 kg/m^3
- Mean compressive strength : 38.2 MPa
- Max. compressive strength : 58.9 MPa

- Rock type A2:

Leucocratic granitic gneiss occurs probably in a narrow NNE-SSW trending zone (lee-breakwater and in the port entrance). Foliation is not well developed in this rock type. Fracturing is intense and increases in NNE direction. Larger unfractured zones occur. The weathering index is generally 3.

- Volumetric weight : 2,650 kg/m^3
- Mean compressive strength : 253 MPa
- Max. compressive strength : 253 MPa

- Rock type A3:

Felsic quartz gneiss. The high content of felsic minerals results in a high volumetric weight. The hardest parts to resemble rock type A1. This rock type occurs in the east part of the port. Weathering index varies in the different bore-holes from 2 to 6.

- Volumetric weight : 3,050 kg/m^3
- Mean compressive strength : 152 MPa
- Max. compressive strength : 152 MPa

- Rock type B1:

Only near the port entrance, BH13 and 15 a 1.5 to 2m thick porous bioclastic limestone, containing lithic breccia elements was encountered on top of the gneissic basement.

(2) Takoradi

Two distinct rock types are present in the Port of Takoradi. Their field relationship is unknown. A deeper drill-hole in the central part of the port might reveal the relationship.

- Rock type A:

Strongly lithified arkosic sand (rock type A1) and silt-stones (rock type A2) . These rocks occur in the south (A1) and west (A2) part of the port. Fracturing and weathering is not very severe. BH6 is however completely broken and weathered. BH1 has zones with a larger clay content, in which shear-zones have been developed. These zones strongly affect the strength.

		A1	A2
- Volumetric weight	:	2,460 kg/m^3	2,465 kg/m^3
- Mean compressive strength	:	80.3 MPa	43.6 MPa
- Max. compressive strength	:	86.4 MPa	46.7 MPa

- Rock type B:

A carbonate cemented quartz sandstone, grading into sandy clay. These rocks occur in the north part of the port. Fracturing is not very severe. UCS samples could only be taken from the sandstone part.

- Volumetric weight : 2,110 kg/m^3
- Mean compressive strength : 17.1 MPa
- Max. compressive strength : 35.8 MPa

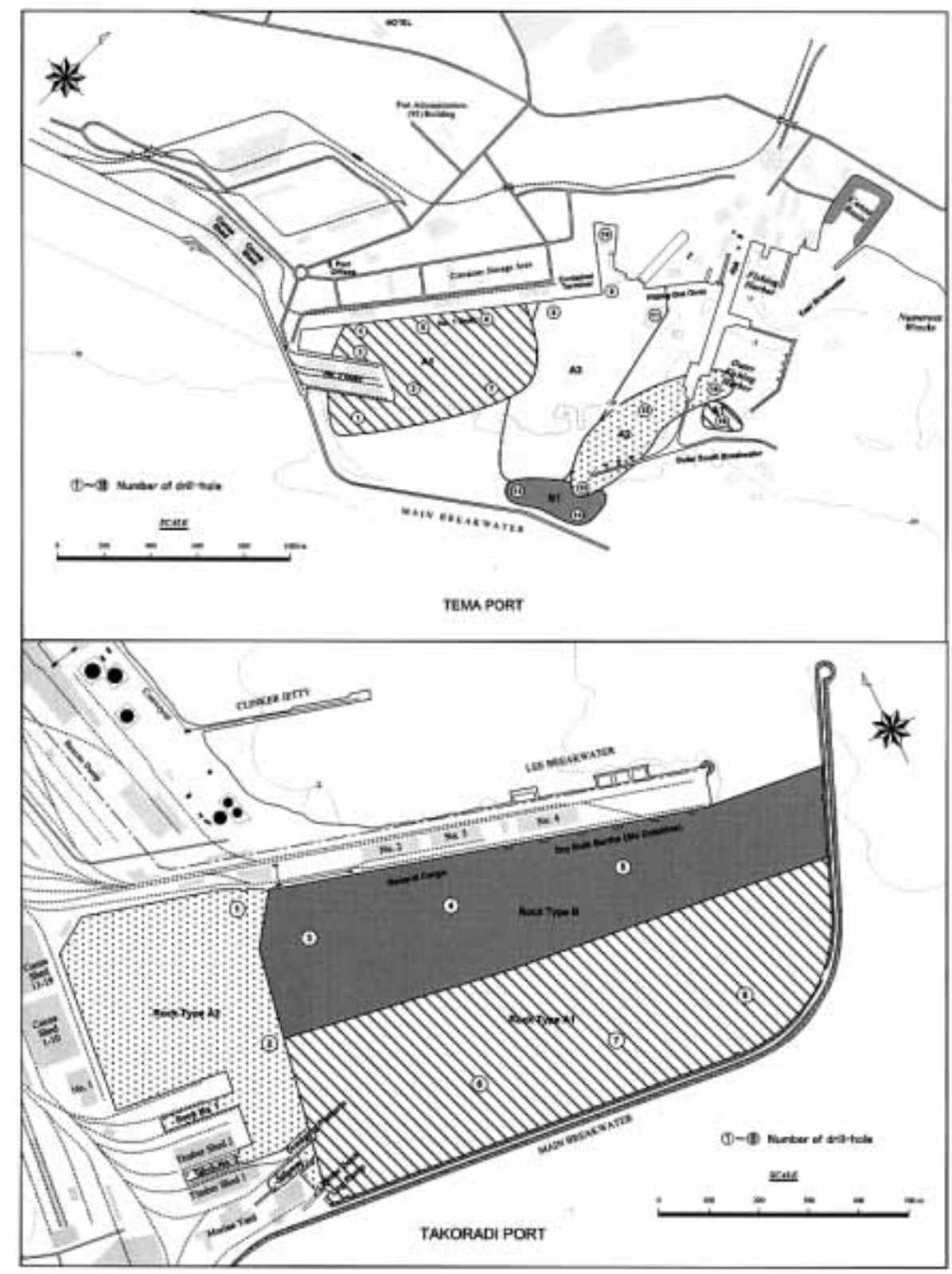


Figure 3.4.1 Estimated Rock Types Occurrence (Geotechnical Investigation in 1992)

3.4.2 Geological Survey

The Study Team has carried out the seismic profiling and the geotechnical investigation by rock boring at Tema and Takoradi Ports to examine the geological conditions for the future development areas.

The survey areas of the seismic profailing are about 3 km x 4.5 km at Tema port and 2 km x 2 km at Takoradi port, covering the same area of the bathymetric survey. (refer to Figure 3.3.1 and Figure 3.3.2)

The estimated rockhead levels at Tema and Takoradi ports are shown in Figure 3.4.2. and 3.4.3. As well as the boring locations respectively.

2 bore-holes with approximately 5 m of penetration into rock formation were drilled from the existing berth decks to examine the soil conditions of future development area at Takoradi Port.

At Tema Port, a total of 4 bore-holes with more than 6 m each of penetration into rock layers were drilled. Two of them were conducted along the main breakwater inside basin of the Port under off –shore drilling using a steel platform, whilst the other two were conducted by on-shore drilling.

The results of the geotechnical investigation by rock borings are indicated in Table 3.4.1 and Table 3.4.2.

Table 3.4.1 Geotechnical Investigation Result (Tema Port)

Bore Hole No.	Ground Elv. End of Drill (C.D.)	Rockhead Level	Specific Gravity	Compressive Strength (MPa)	Rock Type Description
No. 1	-4.50 -13.80	-12.90	(No core sample recovered)		Completely to highly weathered Gneiss
No. 2	-5.50 -14.00	-9.50	(No core sample recovered)		Completely to highly weathered Gneiss
No. 3	+4.00 -6.20	-	2.72	4.4~13.8	Granitic Gneiss boulder - bouldery
No. 4	-2.50 -1.30	+1.70	2.67~2.73	2.9~32.4	Completely to highly weathered Gneiss

Source : Study Team

Table 3.4.2 Geotechnical Investigation Result (Takoradi Port)

Bore Hole No.	Ground Elv. End of Drill (C.D.)	Rockhead Level	Unit Weight (KN/m^3)	Compressive Strength (MPa)	Rock Type Description
TK-1	-7.40 -13.80	-9.10	23.0~25.0	13.2~22.7	Highly to moderately weathered Fine-graded SAND STONE, Moderately weak to moderately strong
TK-2	-7.30 -14.00	-8.90	23.0~26.0	11.9~30.3	Ditto

Source : Study Team

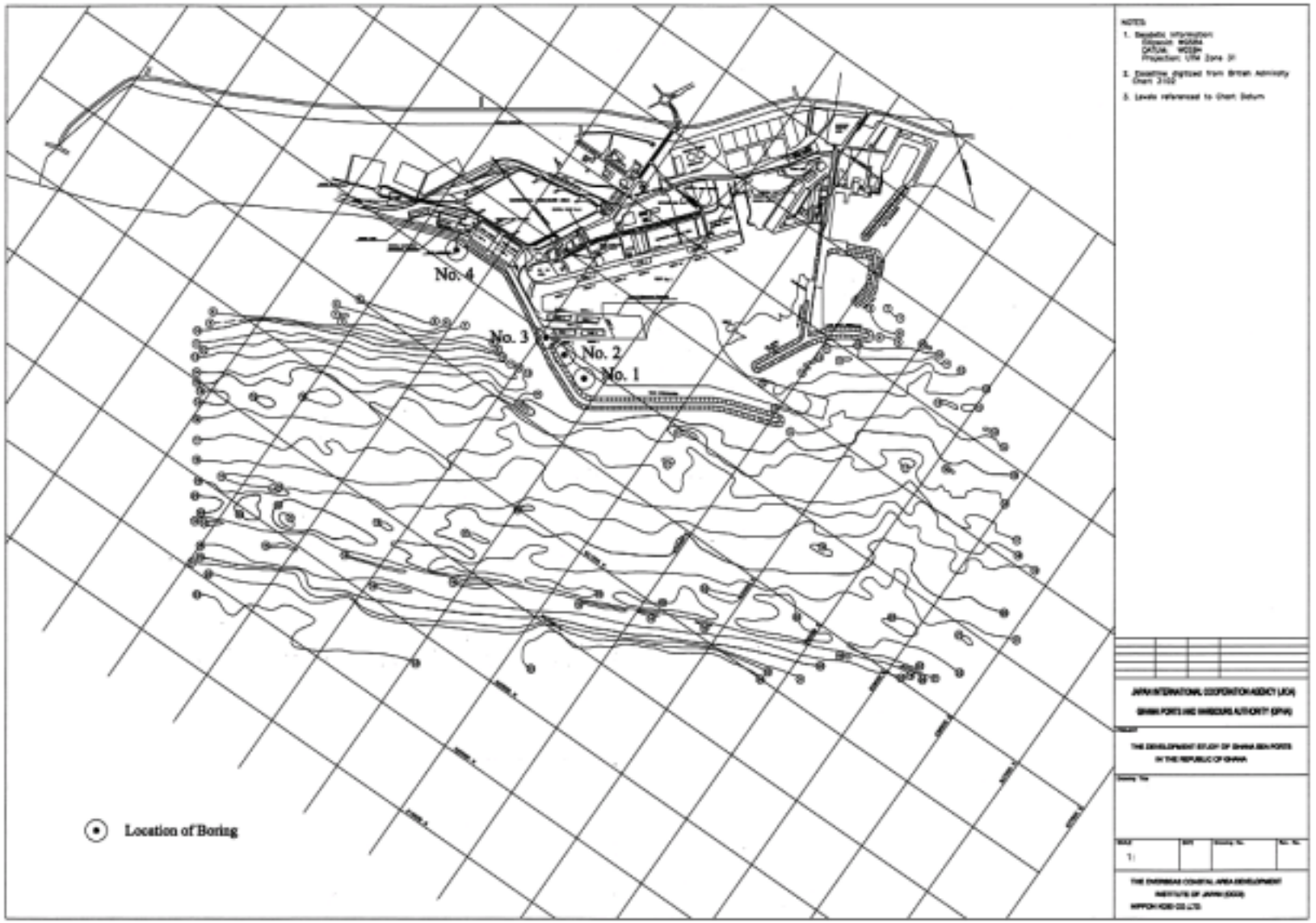


Figure 3.4.2 Rockhead Levels at Tema Port

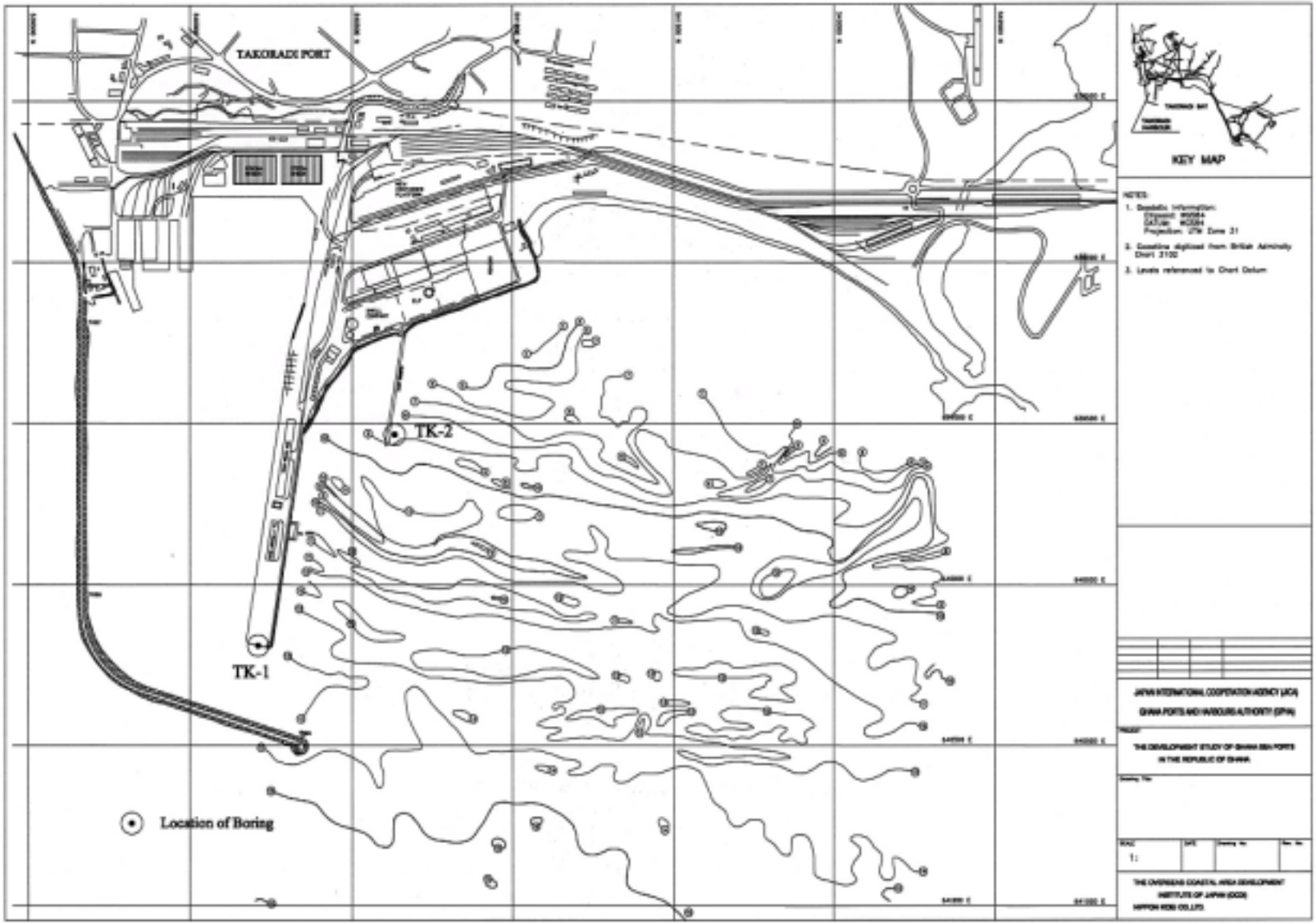


Figure 3.4.3 Rockhead Levels at Takoradi Port

3.5 Seismic Condition

3.5.1 General

Ghana is not located close to any of the world's well-known seismic zones. However, significant earthquake activities have been reported in some areas of southern Ghana.

The historical seismic data in Gahna has been recoded from the 17th Century.

As shown in Figure 3.5.1, seismic activity in southern Ghana is believed to be caused by movement along two active fault systems, namely the Akwapim Fault Zone along the Akwapim mountain range which trends approximately NE-SW and is located about 20 km to the west of Accra and the Coastal Boundary Fault which lies some 3 km offshore and runs almost parallel to the coastline in the vicinity of the Tema port. This fault is confirmed by the seismic profiling. The fact that these two fault systems intersect close to the village of Nyanyanu to the west of Accra is believed to be responsible for the seismic activity experienced in Tema port and Takoradi areas.

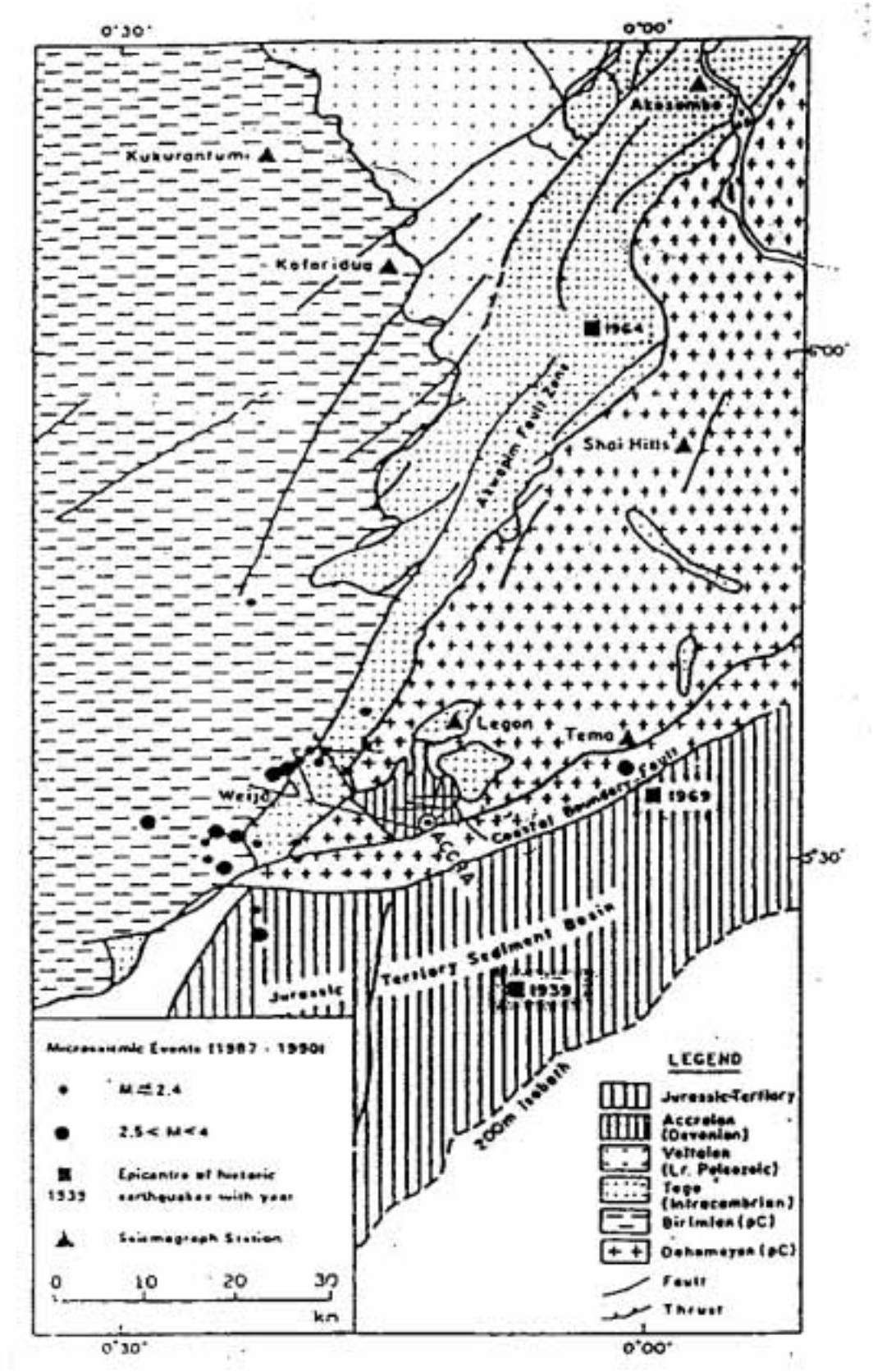
3.5.2 Earthquakes

Major earthquakes which destroyed a part of the city of Accra were observed in 1862, 1906, 1939, 1964, 1969, and 1982.

The records of the major earthquakes in Ghana are shown in Table 3.5.1.

Table 3.5.1 Major Earthquakes in Ghana.

Time	Hypocenter		Magnitude	Note
1862	—	—	—	Ghana Mining Journal ,Vol.2, No1.
1906	—	—	—	Ghana Mining Journal ,Vol.2, No1.
1939/6/22	5 ° 20 ′ N	0 ° 10 ′ W	6.8	National Earthquake Information Center
1964	6 ° 05 ′ N	0 ° 05 ′ W	—	Ghana Mining Journal ,Vol.2, No1.
1969	5 ° 35 ′ N	0 ° 00 ′	—	Ghana Mining Journal ,Vol.2, No1.
1982	—	—	4.0	S/W Mission Report
1987/12/03	—	—	3.1	National Earthquake Information Center
1988/02/27	—	—	3.4	National Earthquake Information Center
1988/03/29	—	—	3.5	National Earthquake Information Center
1990/04/14	—	—	3.1	National Earthquake Information Center
1997/03/06	—	—	4.4	National Earthquake Information Center



Source: "Ghana Mining Journal, vol. 2, No. 1"

Figure 3.5.1 Geology of the region around Accra – Tema and the hysterical seismic and recent micro-seismic