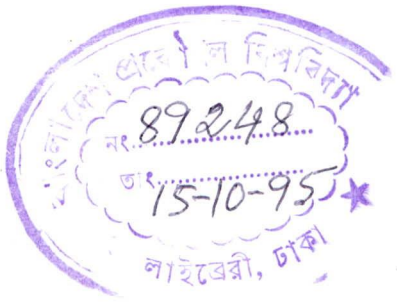
Sorting Characteristics of Beach Materials Along Cox's bazar - Teknaf Coast

Submitted By:

MD. ABDUL MATIN



In partial fulfillment of the requirements for Degree of
Master of Engineering (Water Resources)

DEPARTMENT OF WATER RESOURCES ENGINEERING
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

OCTOBER 1995

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF WATER RESOURCES ENGINEERING

We hereby recommend that the project report prepared by
MD. ABDUL MATIN
entitled SORTING CHARACTERISTICS OF BEACH MATERIALS ALONG COX'S BAZAR - TEKNAF COAST be accepted as fulfilling this part of the requirements for the degree of Master of Engineering (Water Resources).

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OCTOBER 1995

within the foreshore zone and progressively finer within the backshore zone.

Twelve water samples were also collected, six from the main stations, five from the bed of the khals and one from the secondary station where the beach is with boulders. Since its analysis was beyond the scope of the study, these have been kept in the Hydraulics and River Engineering Laboratory for future study.

A comparison of the result has been made with the earlier studies and with the Coast of U.S.A. It has been found from the comparison that the mean diameter of the beach materials of the South-eastern Coast of Bangladesh has the similarity with those of the Texas Coast of U.S.A.

Finally, recommendations have been made for further studies.

ABSTRACT

The beach between Cox's bazar and Teknaf lies between the latitude 20°44.7′N and 21°24.30′N and longitude 92°20.12′E and 91°57.88′E. The beach extends between the Bagkhali river at the north upto the Naf river at the south at Teknaf through Ukhia and Nhila and is oriented in 333° north-west in clock wise direction at Teknaf. This study is concerned with sand characteristics of the beach.

A reconnaissance survey was made and six main stations were selected for collecting beach materials samples from the surface, at 0.3m and 0.6m depth. The locations of the stations were fixed by a Nav 1000 Pro Global Position Survey (GPS) receiver. There are seven tidal khals crossing this 60.0 km. long beach between Cox's bazar and Teknaf. Bed materials were collected from these khals also except at Katabunia khal. A secondary station was also selected for collection of beach materials samples. Total sixty one samples, each 1 kg. in weight were collected by standard method and preserved in the plastic bags and carried to Hydraulics and River Engineering Laboratory in BUET for necessary analysis.

A team consisting of 5 members equipped with GPS receiver, levelling instrument and transport worked to do the necessary levelling works across the beach at different stations during winter 1995. The study reveals that the sea beach is more flatter at the north towards Cox's bazar compared to the south at Teknaf, the elevation of the sea beach with respect to mean sea level is increasing towards south.

The grain size distribution curve were plotted and the sorting characteristics of the sand were studied both along and across the beach. The beach sands are dominated by fine sand with a trace of medium sand and fine grained materials (silt and clay), the coarse sand is absent from the whole beach and snails are present in some cases. The beach soil sample tends to become progressively coarser in sizes from north to south

within the foreshore zone and progressively finer within the backshore zone.

Twelve water samples were also collected, six from the main stations, five from the bed of the khals and one from the secondary station where the beach is with boulders. Since its analysis was beyond the scope of the study, these have been kept in the Hydraulics and River Engineering Laboratory for future study.

A comparison of the result has been made with the earlier studies and with the Coast of U.S.A. It has been found from the comparison that the mean diameter of the beach materials of the South-eastern Coast of Bangladesh has the similarity with those of the Texas Coast of U.S.A.

Finally, recommendations have been made for further studies.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOGRAPHS

Chapter 1

INTRODUCTION

1.1 BACKGROUND AND IMPORTANCE OF THE STUDY

The coastline of Bangladesh (Figure no. 1.1) can be described under two major groups resulting from different geological processes. These two groups also conform to different physiographic descriptions. The first group having a near east-west orientation, extends from Haribanga channel along Indo-Bangladesh border in the west to the Sandwip channel in the east and covers a coastline of about 380 km (Barua 1991). The second group is the entire 275 km coastline of Chittagong and Cox's bazar which has a north-south orientation.

The coastal plain of Chittagong and Cox's bazar can further be sub-divided into two separate hydro-morphological units. The 230 km coastline from Naf river in the south to Karnaphuli river in the north can be described as a wave dominated sand coast and 45 km coast from Karnaphuli river in the south and Sandwip channel in the north can be described as an estuarine mud coast.

The 230 km coast line lies between the latitude 20°44.7′N and 22°16.0′N and longitude 92°20.12′E and 91°57.88′E and are characterized by the sandy beaches at Chittagong, Banskhali, Cox's Bazar, Ukhia and Teknaf and the Matamuhuri delta and Coastal Islands between Banskhali and Cox's Bazar (Figure no. 1.2). This coastline is interrupted by the four major rivers namely Karnaphuli, Sangu, Moheskhali channel, Bagkhali and the Naf river. Some small streams coming from the hills adjacent to the east of the coast are also present. The sandy beaches at Chittagong extends between Patenga at the north and upto Banskhali at the south. The sandy beaches at Cox's bazar extends between the Bagkhali river at the north and upto the Naf river at Teknaf through Ukhia and Nhila. A huge land has been accreted at Badarmokkam at the confluence of

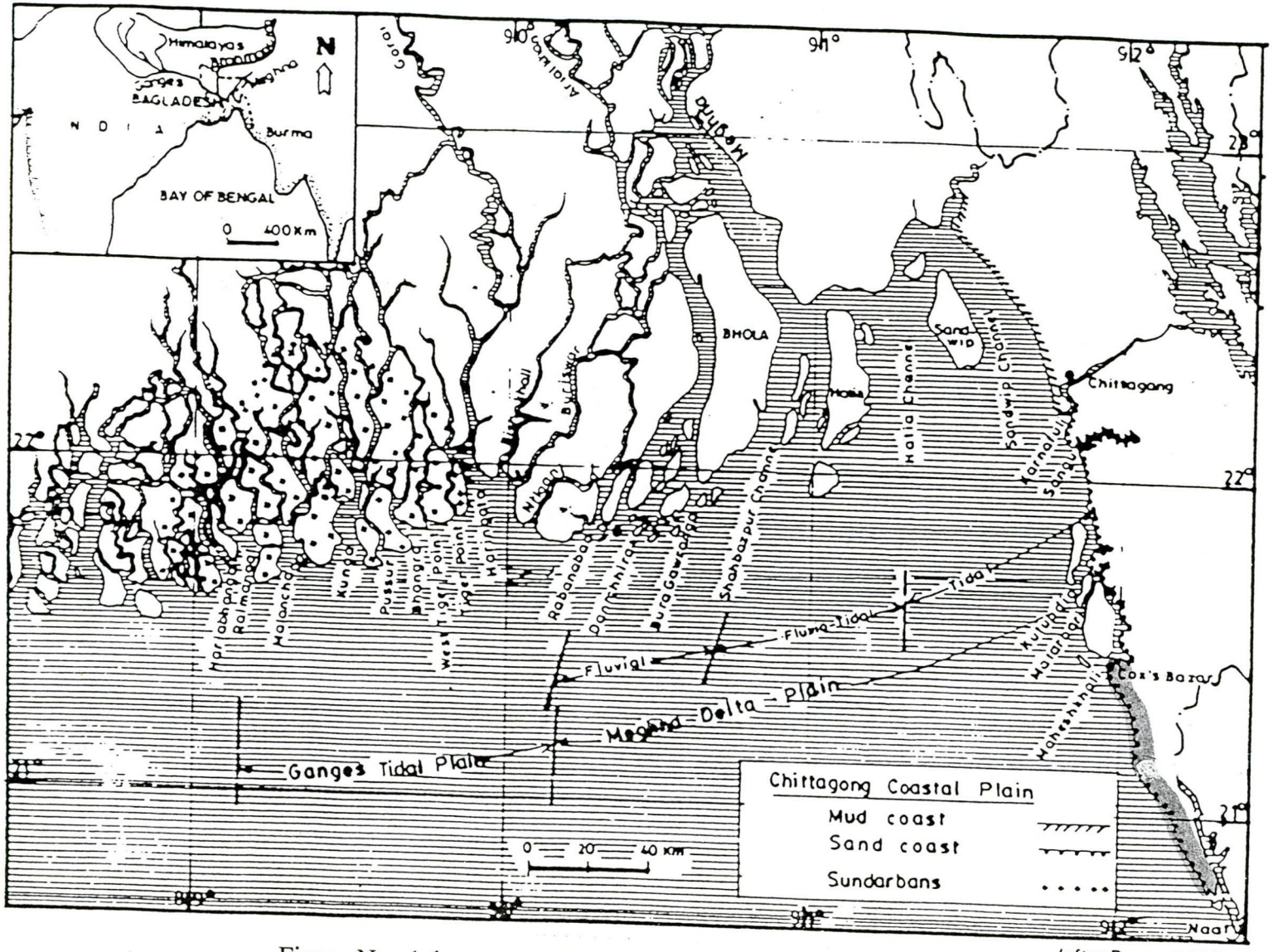


Figure No. 1.1 >>> Coastline of Bangladesh. (after Barua, 1991)

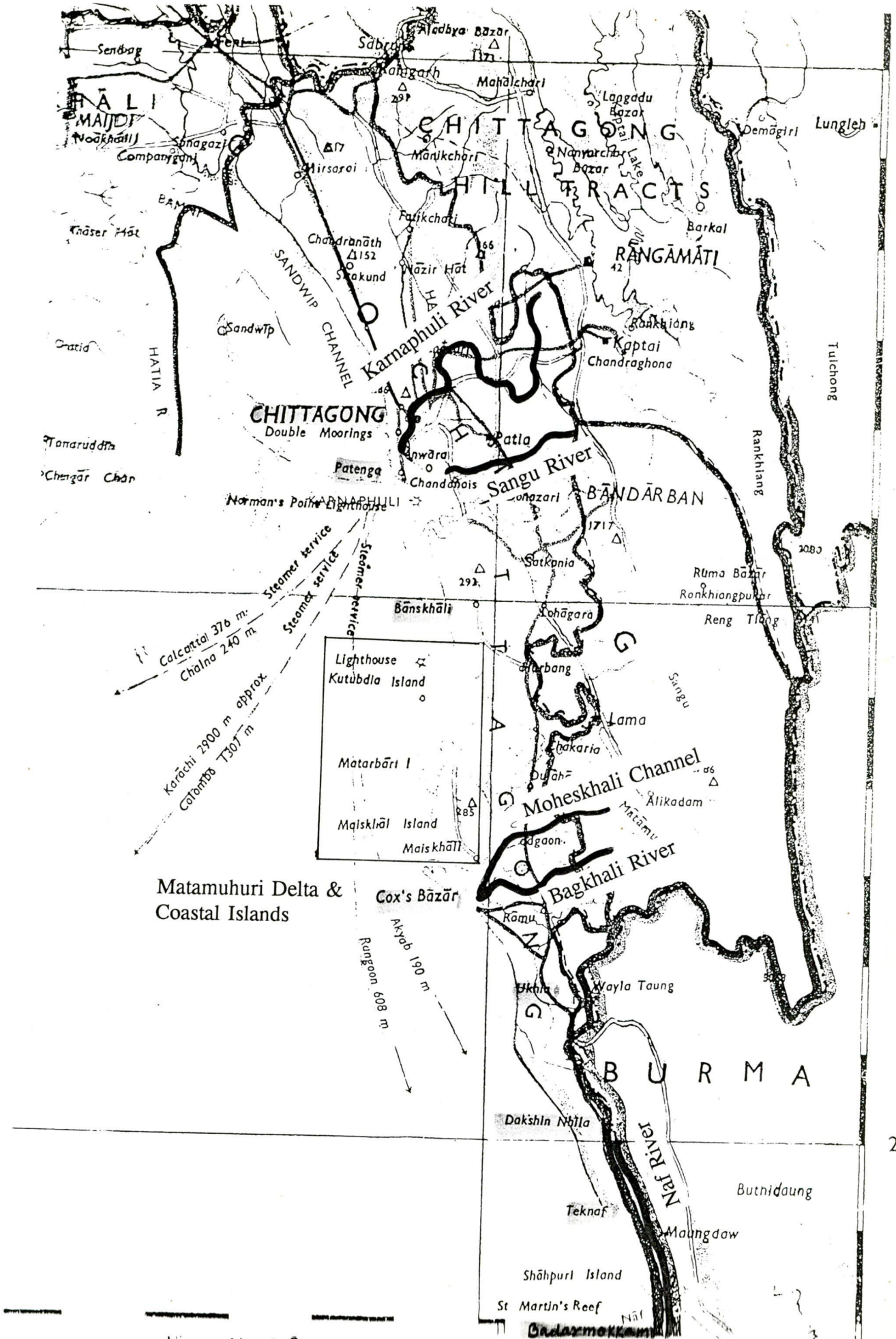


Figure No. 1.2 >>> South-eastern Coastline of Bangladesh.

the Naf river with the Bay of Bengal.

Beach sands containing valuable heavy minerals are common along the south eastern coast of Bangladesh. Valuable minerals like Jircon, Elmenite, Rutile, Garnet and Magnetite have been discovered in this coast between Cox's Bazar and Teknaf in 1975 by the Bangladesh Atomic Energy Commission (BAEC June 1991). It has revealed also that the concentrations of the heavy minerals within the beach sands are mostly dependent upon the grain size distribution of the beach sands. A number of small scale salt industries have also been grown up along this beach (Photograph 1) .

Photo 1: Salt Industry near the Beach at Cox's Bazar Coast.

Recently Government of Bangladesh have also taken steps to do the feasibility studies of extraction of the oil and natural gases within the nearshore zone of Cox's bazar sea beach. The study is undertaken by the "Holland Sea Research" of the Netherlands and "Keyan Energy" of Scotland. It has been opinioned by the specialists that there is an enormous possibility of oil and natural gases extraction within the nearshore zone of the Bay of Bengal (The Daily Inqilab, 29 December 1994).

It is, therefore, high time and important that the physical properties of the beach materials is investigated for better understanding of the coastal situation. Of greatest interest are those physical properties of beach materials that response to wind, wave and current action and in turn are important for the design of engineering works. A schematic diagram showing sea beach profile is shown in Figure no. 1.3.

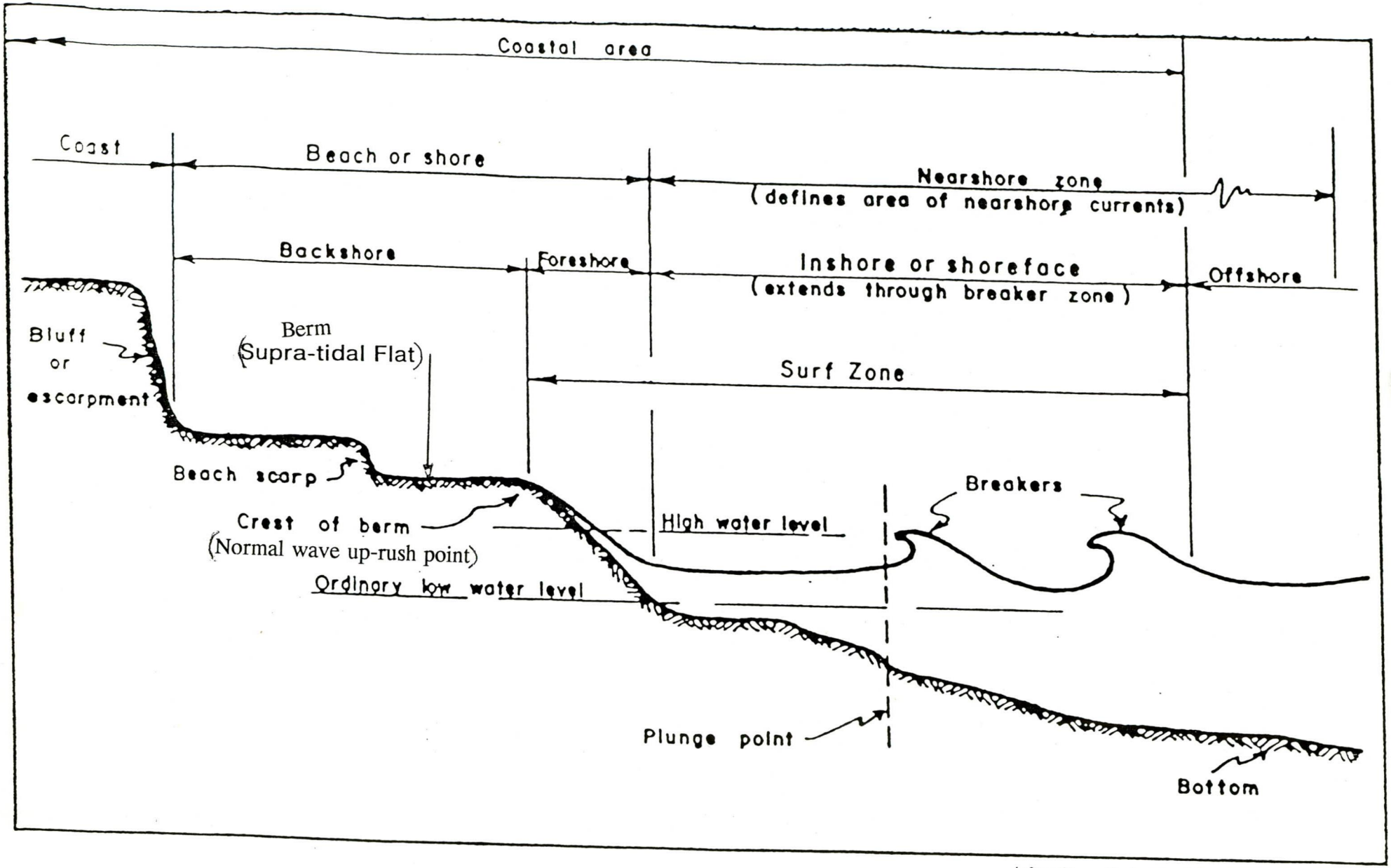
1.2 OBJECTIVES

The objectives of the study are:

(a) to determine the grain size distribution of the beach materials along the beach between Cox's Bazar and Teknaf; Figure no 1.4 shows the location of the study area;

(b) to have an idea about the cross profiles of the sea beach along the beach;

(c) to compare the variations of the grain size and distribution of the beach materials of the study area with some of the available data on beach materials of U.S coast.



(after Shore Protection Manual, Volume III, 1977)

Figure No. 1. 3 > > > Schematic Diagram Showing Sea Beach Profile.

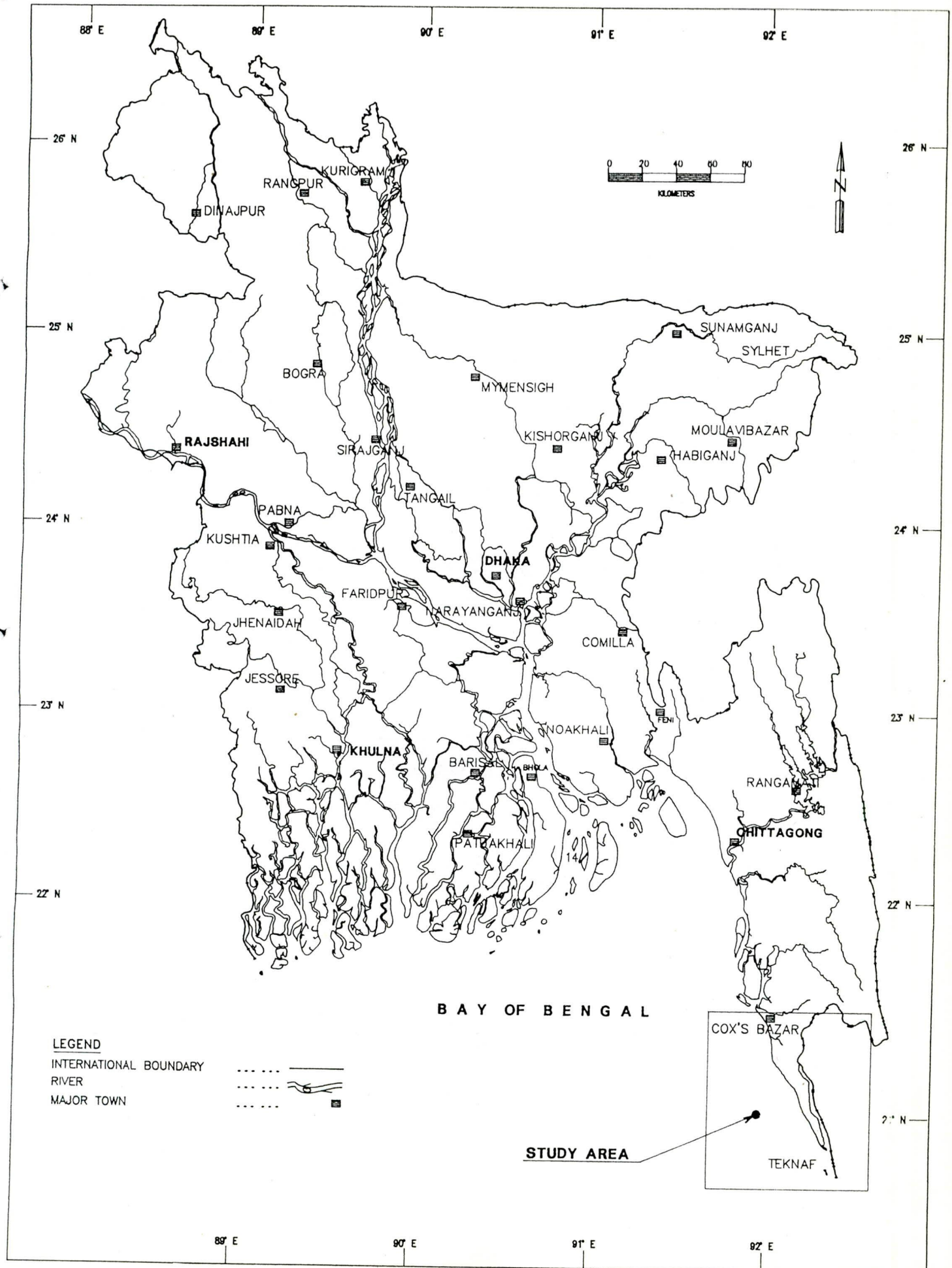


Figure No. 1.4 >>> Location of the Study Area.

Chapter 2

LITERATURE REVIEW

2.1 A BRIEF HISTORY OF COX'S BAZAR

The 60.0 km long shark free sandy beach between Cox's bazar and Teknaf within the latitude 20°44.7′N and 21°24.30′N and longitude 92°20.12′E and 91°57.88′E make Cox's bazar as one of the attractive tourist destinations and a perfect place for holiday-makers and sun-seekers. Cox's bazar was once controlled by Arakan, a former independent kingdom on the other side of the Naf river and now part of Myanmar (Burma). Although Muslims and Hindus have also settled here, the influence of Arakanese Buddhists still permeates the culture. For a time, Magh pirates and the Portuguese ravaged the Bay of Bengal and frequented the area. But in 1978, Captain Hiram Cox liberated the town from the Portuguese and was commissioned to settle the area Arakanese immigrants fleeing Burma. The Maghs are remained and today are engaged in handicrafts and cottage industries such as hand woven cloths and manufacture of cheroots (Degonto).

2.2 STUDIES BY BANGLADESH ATOMIC ENERGY COMMISSION

A survey of the available literature shows that systematic study on beach materials from Cox's bazar to Teknaf beach or coast is very sparse and rare. Only during 1960, Bangladesh Atomic Energy Commission took the pioneer study of this coast in search of heavy minerals with the assistance from the Australian Mineral Development Laboratory (AMDEL), an agency engaged by the Australian Government. Actual study began in 1968 and continued till 1985 (BAEC June 1991).

The main objectives of these studies were: i) to determine the area of high and low mineral content; ii) to delineate the economic margins of the deposits; and iii) to

establish the grades and estimate the ore reserves of the deposits. The study discovered heavy mineral deposits along the 550 km long coastal belt of Bangladesh. Of these, seven deposits are found along the main coast at Badarmokkam, Sabrang, Teknaf, Silkhali, Inany, Cox's bazar and Kuakata and ten deposits in the offshore islands of Moheshkhali (7 deposits), Matarbari (1 deposit), Kutubdia (1 deposit) and Nijhum Dwip (1 deposit). The summary of the reserve of economic heavy minerals in the beach sand of Bangladesh are shown in Table 2.1 as adopted from the report published by Bangladesh Atomic Energy Commission in June 1991.

2.2.1 Studies by Biswas

Biswas (1981) analyzed beach, dune and storm ridge sands as well as on sand stones from the coastal area of Cox's bazar. The study zone was about 10.0 km. long within the Cox's bazar sea beach.

Sand samples were taken on 4 stations as shown in Figure no. 2.1. For collection of samples, 10 holes to the depth of 3-4.5m were drilled on each profile with the help of hand auger. Two-three samples were collected from each hole. The length of the sample was 1.5m. In all 98 samples have been collected from beach sands, 12 from sand dunes, 2 from storm ridge sands and 12 from sandstones from adjacent hills.

Analysis of the samples show that the mean grain size of the beach sands varied from 0.075mm to 0.135mm (3.55 phi to 2.96 phi). For 70% cases mean grain size varied from 0.100mm to 0.12mm (3.30 phi to 3.10 phi) with an average value of 0.108mm (3.22 phi).

The results of the dune sands were similar to the beach sands. Mean grain size of the dune sands varies within a narrow range: from 0.091mm to 0.119mm (3.42 phi to 3.11 phi) with an average value of 0.112mm (3.18 phi). The storm ridge sands were free from fine silt and clay sized particles. Sands coarser than 0.315mm (1.75 phi) were

Table 2.1

SUMMARY OF THE RESERVE OF ECONOMIC HEAVY MINERALS IN THE BEACH SANDS OF BANGLADESH

(Source: Bangladesh Atomic Energy Commission, June, 1991)

(In Tons)

Deposit	Crude Sand	Heavy Minerals	Zircon	Rutile	ILmenite	Leucoxene	Magnetite	Monazite	Kyanite	Garnet
Badarmokkam	1765000	411000	4932	3288	94530	18002	10275	4932	*	*
Sabrang	347558	68582	4184	1372	19614	3470	1001	206	727	3018
Teknaf	1939580	442291	28306	13230	163170	20124	7209	3045	14728	22424
Silkhali	2756828	489714	33300	10774	173360	10970	3085	3918	4407	39422
Inani	729286	175476	10880	4036	53170	439	5545	965	1404	12810
Cox's Bazar	5119000	920000	23000	6440	161000	10488	33212	2024	*	50600
Moheskhali Island	4114230	784210	37122	24596	242963	20682	7604	2044	47496	35958
Matarbari Island	69030	15215	794	295	4962	374	575	20	*	*
Nijhum Dwip	379337	96348	2052	424	12978	77	4384	19.3	2592	*
Kutubdia Island	404646	120000	3900	1908	23796	2436	3384	96	2592	6300
Kuakata	2872486	831668	9647	3911	76015	9647	4325	83.2	16800	52229
Total	20496981	4354504	158117	70274	1025558	96709	80599	17352.5	90746	222761

* – Not estimated

also absent. The average value of mean grain size was 0.115mm (3.15 phi).

Analysis of 12 samples of sandstones showed that the grain size distribution curve was similar to that of beach and dune sediments. Mean grain size is 0.111mm (3.19 phi) with variation from 0.082 to 0.129mm (3.48 phi to 3.02 phi). This value does not significantly differ from that of beach (0.108mm, 3.22 phi) and dune (0.112mm, 3.18 phi) sediments. He also reported the mineralogical composition of the investigated samples.

The important findings of the study was that the concentration of heavy as well as useful minerals is in close relation with grain size characteristics of their enclosing sediments in the study area. Any change in the concentration of heavy minerals corresponds to the change in granulometric composition of the sediments, i.e, with the increase of coarse material, percentage of heavy minerals decrease within the study area.

Biswas (1988) also presented a paper on seasonal variations of the sand characteristics from upper foreshore of Cox's bazar beach. Between Bagkhali river in the north and Reju Khal in the south, 24 samples were collected in winter (mid January 1985) covering about 19km of shoreline and from approximately the same locations another 24 samples were obtained in summer (mid June 1985). At each collecting location, samples were collected from the upper foreshore which appeared to be the approximate high tide line. Lateral distance between the two samples was maintained at 0.8km. The samples were collected from the surface layer. Figure no. 2.2 shows the sample collecting locations.

Grain size analysis of both the winter and summer samples showed that the mean size of winter samples was 0.16 mm (2.72 phi), variation was from 0.28 mm to 0.11 mm (1.94 to 3.18 phi) and that of summer samples was 0.17 mm (2.58 phi), variation was from 0.264 mm to 0.119 mm (2.00 to 3.10 phi). This indicated that the summer sand was slightly coarser than the winter sand. However, the mean size of sands of both the

seasons were fine in general. In support of his findings, Duane in 1964 (after Biswas 1988) reported that the upper foreshore area of Cox's bazar beach has been in a state of erosion during winter and of deposition during summer.

Biswas (1990) showed the relationship between various textural parameters and heavy mineral concentration within the beach deposits at Sabrang (Katabunia), Teknaf, Silkhali and Inany as shown in Figure no. 2.3. Seven samples from Sabrang, forty six samples from Teknaf, fifty samples from Silkhali and thirty eight samples from Inany were collected during 1978 using hand auger. Beach sampling point was drilled up to the depth of 1.5m. Below this depth the content of heavy mineral in the sands was considered to be negligible.

The grain size distribution showed that the mean size of the soil samples at Sabrang was 0.16 mm (2.70 phi) varying between 0.18 mm to 0.14 mm (2.52 to 2.88 phi), at Teknaf it was 0.17 mm (2.57 phi) varying between 0.25 mm to 0.108 mm (2.07 to 3.22 phi), at Silkhali it was 0.18 mm (2.55 phi) varying between 0.234 mm to 0.13 mm (2.15 to 3.03 phi) and at Inany 0.198 mm (2.34 phi) varying between 0.284 mm to 0.16 mm (1.90 to 2.72 phi). The study showed that the sands at 1.5m below the beach surface were becoming progressively coarser in sizes from Sabrang in the south to Inany in the north. The percentage of the heavy minerals were found largely independent of sands mean grain size within the study area.

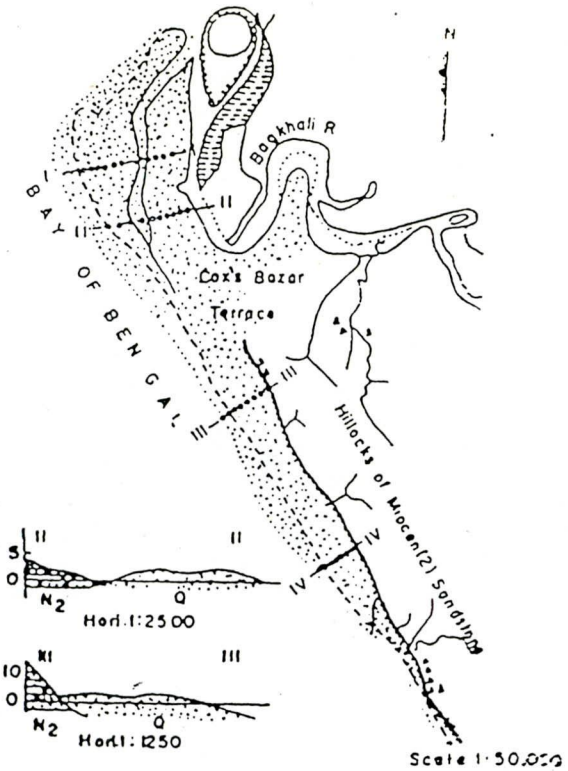


Figure No. 2.1 >>> Map of Study Area and Locations of Samples (Biswas 1981).

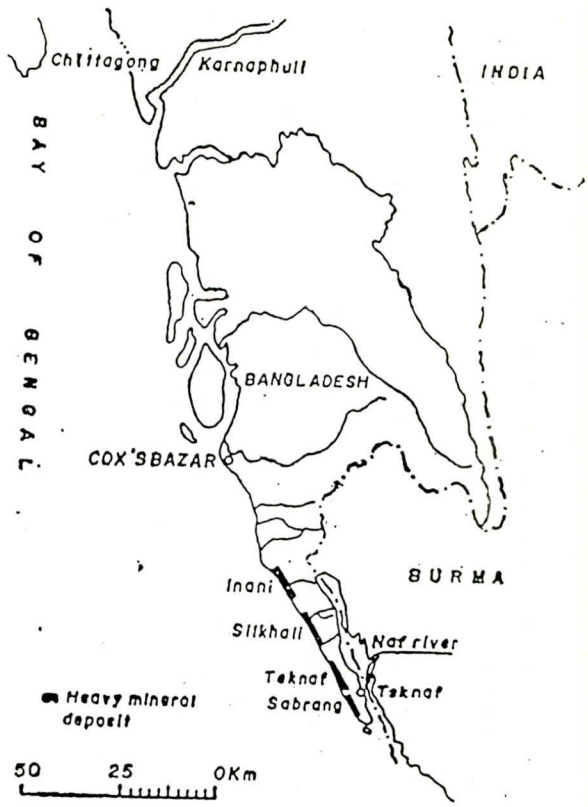


Figure No. 2.3 >>> Map Showing Locations of Heavy Mineral Deposits (Biswas 1990).

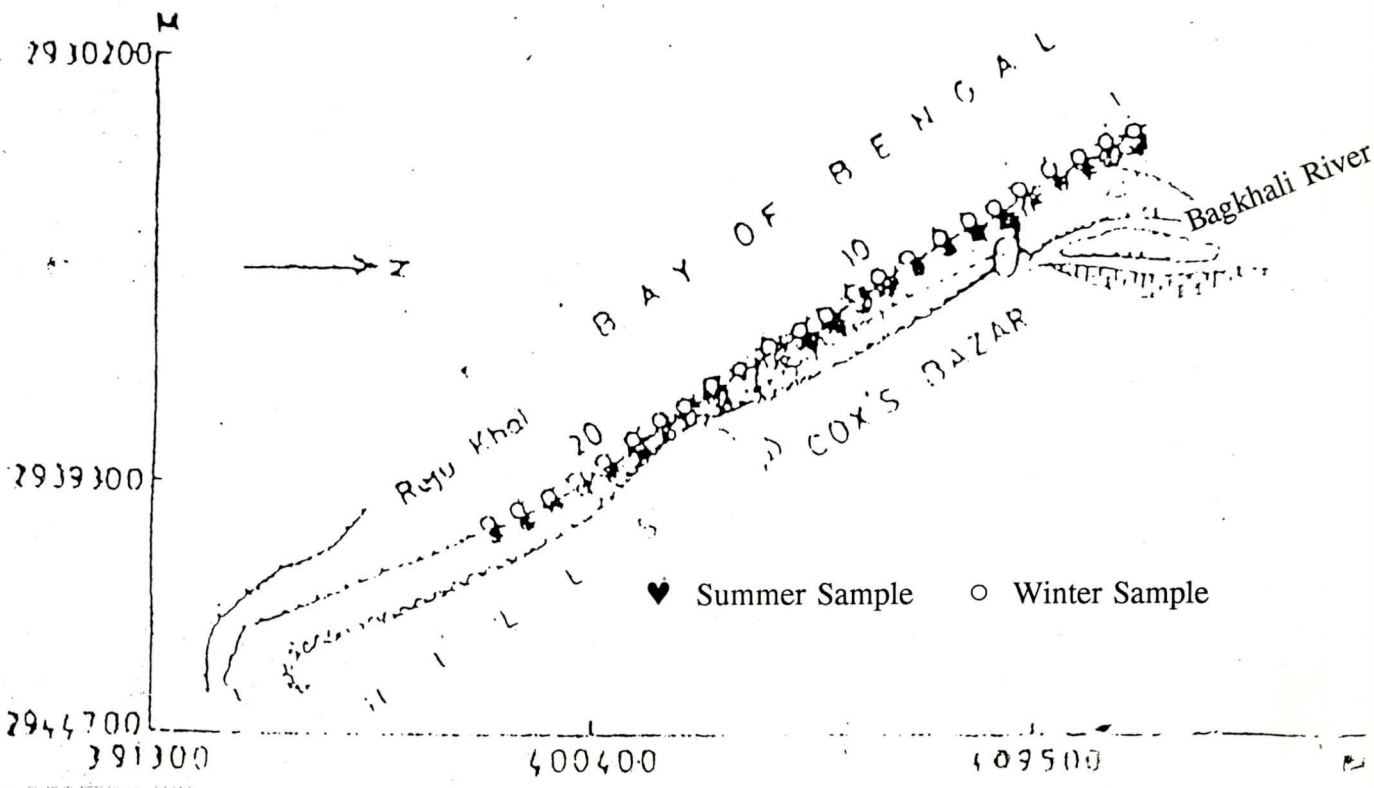


Figure No. 2.2 >>> Locations of Sample Collections (Biswas 1988).

Chapter 3

DATA COLLECTION AND LABORATORY TESTING

3.1 INTRODUCTION

The field work of this project started on 21st January 1995 and continued till 26th January 1995.A team of five members, consisting of surveyors, technicians was engaged for the work.

Before the start of the actual data collection, a full reconnaissance of the beach from Cox's bazar to Badarmokkam (south of Teknaf) was necessary for the tentative selection of the stations. The work took about 12 hours from morning till evening on 21st January 1995.

3.1.1 Communication

The study area was not fully accessible by the usual vehicle. The main interruptions are due to 75m wide Reju Khal and 50m wide Katabunia Khal. The bed level of the Reju Khal and Katabunia khal are 0.70m PWD and 0.62m PWD and the dunes near the Reju khal has made the vehicular passage inaccessible along the beach. The beach is accessible by vehicle between Cox's bazar and Himchari and then between Inany and Katabunia.

The present entry points to the beach are at:

a) Cox's bazar, the most important place with respect to tourism;
b) Inany through a Herring Bone Bond (HBB) road from Court bazar on Cox's bazar-Teknaf highway;
c) Howaikong through a HBB road from Nhila upon Cox's bazar-Teknaf road and;
d) at Teknaf through a HBB road.

However, a road network is being developed by the Roads and Highways Department along the sea beach through the foot of the eastern hills from Cox's bazar to Teknaf.

Photo 2: Vehicles for Field Investigation

3.1.2 Physical descriptions of the study area

The physical system of the 60.0 km long Sea Beach between Cox's bazar and Teknaf Coast makes an orientation of 333° north west in clock wise direction at Teknaf point. The global position of the beach is shown in Figure no. 3.1.

Tides in the investigated area are semi-diurnal and vary from approximately 3 to 5m in height. During summer (May-October) the wind blows over the investigated area from south-east and sometimes from south-west with an average velocity of 13.3km/hour. During winter (November-April) the wind blows from north-east. Sometimes from north-west with an average velocity of 9.7km/hour. Average annual rain fall over the area is 2160mm, temperature 25°C and humidity of the air vary from 50 to 90% (Biswas 1981).

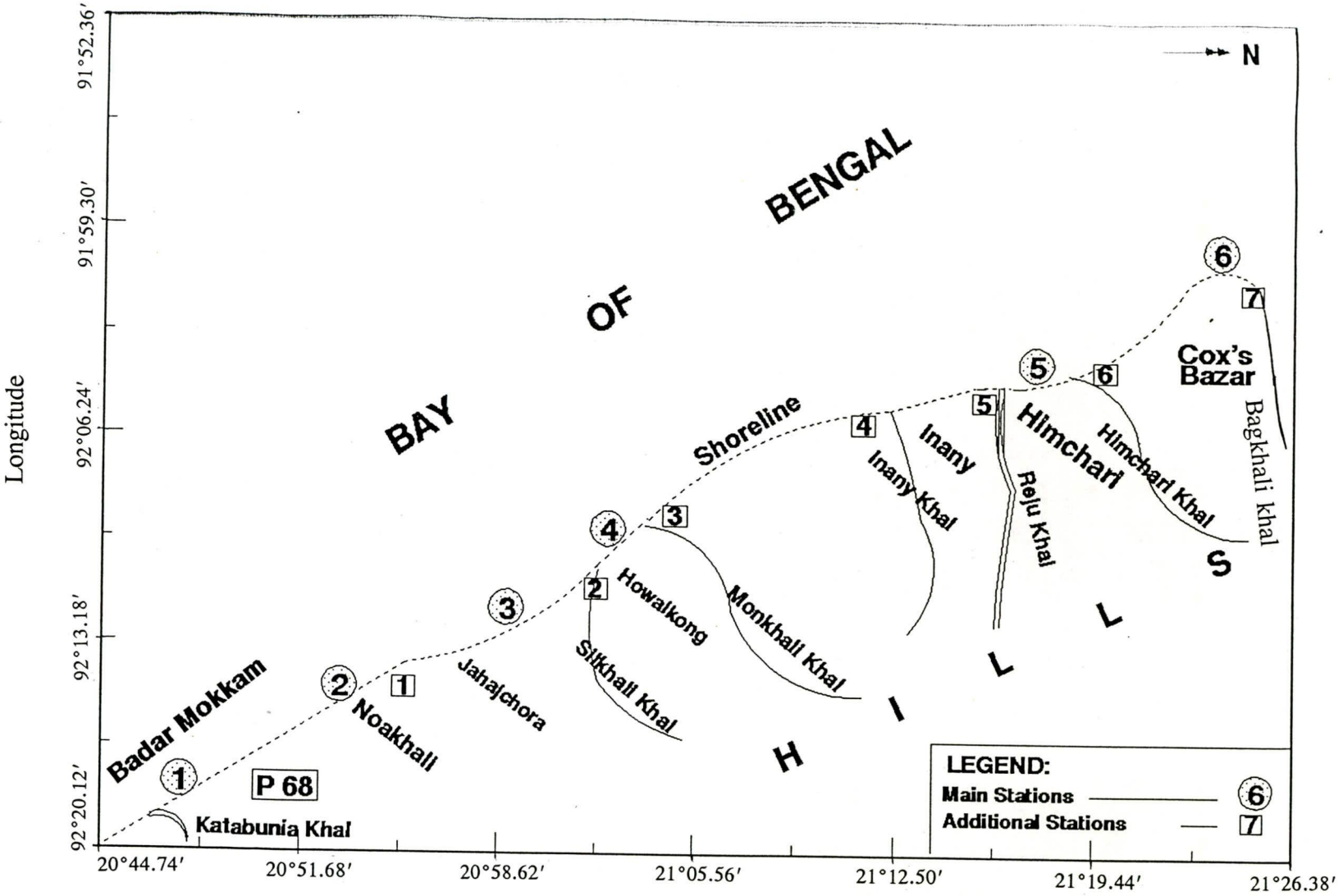


Figure No. 3.1 >>> Global Position of the Sea Beach

Along the beach, a flat land surface is observed, one or two meter higher than the high tide level (Photograph 3). The width of the flat land varies and is extended from the foot of the cliff upto the dune towards the beach. This flat area has been named as supra-tidal flat (NOAMI, June 1994). Tidal channels, streams cross this supra-tidal flat.

Photo 3: Supra-tidal Flat at Teknaf Coast.

The local name of these tidal streams are: Himchari Khal, Reju Khal, Inany Khal, Monkhali Khal, Silkhali Khal and Katabunia Khal. Of these inlets, Himchari Khal, Reju Khal, Monkhali Khal (Photograph 4) and Shilkhali Khal (Photograph 5) are the hilly streams originate from the adjacent hills and meets with the sea. The Katabunia Khal is a tidal creek originate from the sea and flows toward landward side. Enquiry from local people revealed that the supra-tidal flat is occasionally flooded, only during the storm periods, add some increments of marine sediments. Supra-tidal flat is quite absent at Himchari coast where the waves directly hit the Cliff (Photograph 6). Boulders are seen within the foreshore at Jahajchora and Inany beach (Photograph 7 and 8).

Photo 4: Monkhali Khal meets with the Sea.

Photo 5: Shilkhali Khal meets with the Sea.

Photo 6: Cliff at Himchari Coast.

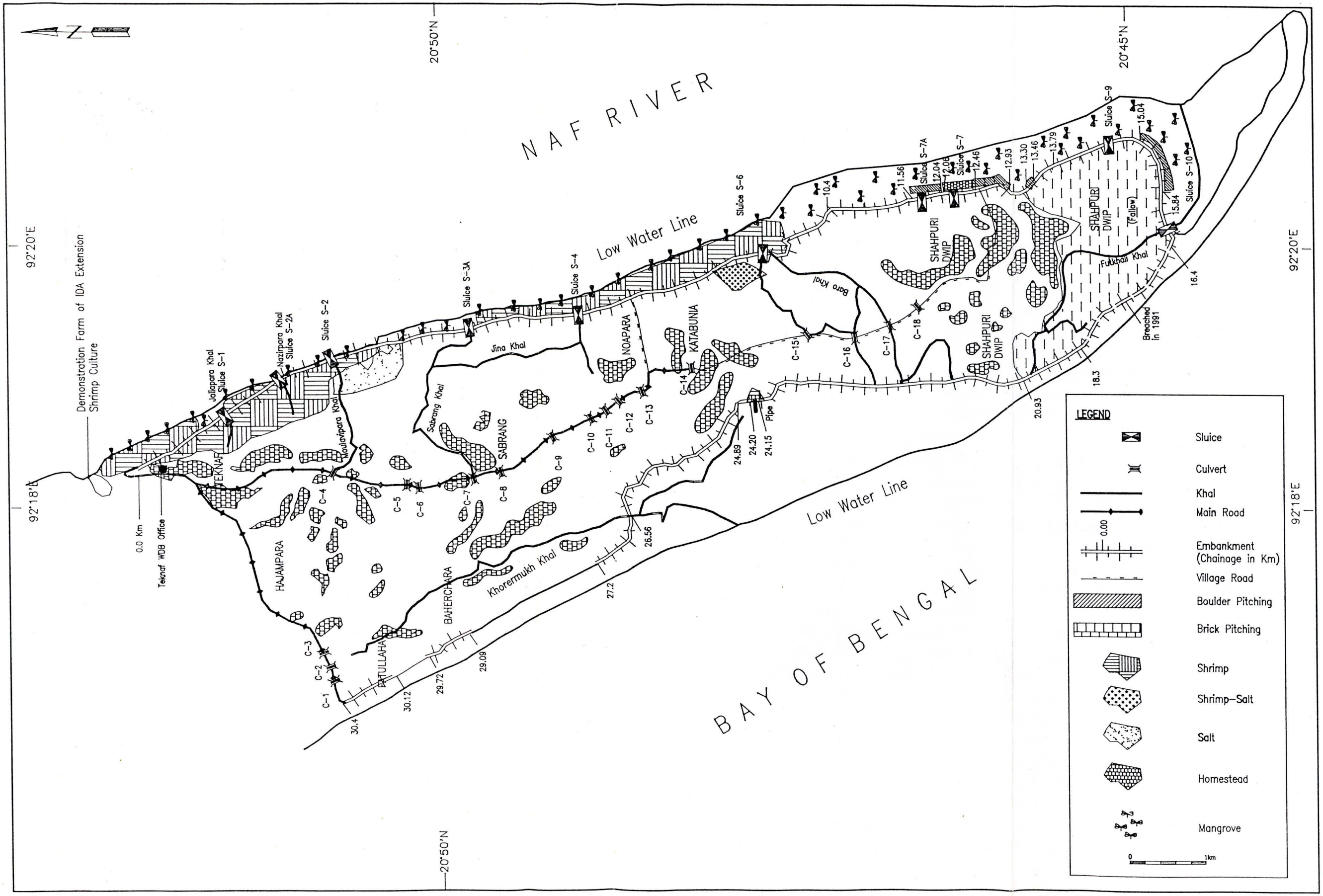
The flat land in between Badarmokkam at the south (which has been taken as the reference station for the present study) and Teknaf at the north extends up to the Naf river at the east. Like as the other coastal areas of the country, this flat land was reclaimed against the intrusion of saline water from the Naf river at the east and from the Bay of Bengal at the south and the west under the Coastal Embankment Project (CEP) in between 1967 and 1971. The Dutch term "Polder" has been adopted to designate these reclaimed bodies of land in the coastal areas (Nishat 1988). The

Photo 7: Beach with Boulders at Jahajchora.

Photo 8: Beach with Boulders at Inany.

empoldered flat land was designated as Polder 68 (Figure no. 3.2). Subsequently the southern part of the area enclosed had been being used for shrimp culture and salt production.

Natural protective dunes (Photograph 9) with an approximate width of 3.0m and 1.5m high along the beach within the backshore zone is seen throughout the whole beach except at Himchari. Grass and bushes on the dunes is seen at Katabunia. These dunes provide a natural protection to the supra-tidal flat. A cross wise small dunes with an approximate width of 2.0m and 0.5m high has also been formed at Jahajchora in between Station no. 2 and Station no. 3 within the foreshore zone. In some of the places, temporary storage of water within the dunes was also seen within the foreshore zone during the field works (Photograph 10).



(after BWDB Systems Rehabilitation Project, 1993)

Figure No. 3.2 >>> Polder No. 68.

Photo 9: Dunes near Reju khal.

Photo 10: Temporary Storage of Water within the Dunes at Cox's Bazar Coast.

3.2 STATION SELECTIONS

Six main stations was planned for the collection of basic data and was marked in the map shown in Figure no. 3.1. The main stations were selected on the basis of (i) accessibility, (ii) in conformity with the earlier information of Biswas and (iii) uniformity in space distribution. During the field survey the location of these main stations were determined by the Global Position Survey (GPS) receiver. The latitudes and longitudes of these main stations are shown in Table 3.1 and 3.2. A brief description of the stations are as follows:

1. Station no. 1 at Katabunia is in between Teknaf and Badarmokkam, the station is just at immediate north of the confluence of the Katabunia khal with the Bay of Bengal. The CEP polder 68 is at the east of the station. The Latitude and Longitude of the station is 20°47.75′N and 92°17.96′E respectively.

2. Station no. 2 at Noakhali is at just opposite to Teknaf. The hills of the Teknaf reserve forest is at the east of the station with some supra-tidal flat between the hills and the beach. The Latitude and Longitude of the station is 20°54.29′N and 92°14.06′E respectively.

3. Station no. 3 at Jahajchora is at just opposite of Nhila. Supra-tidal flat exists here between the hills and the beach. The Latitude and Longitude of the station is 21°00.89′N and 92°11.27′E respectively.

4. Station no. 4 at Howaikong is in between Ukhia and Nhila. East of the beach are the hills with supra-tidal flat. The Latitude and Longitude of the station is 21°04.68′N and 92°08.02′E respectively.

5. Station no. 5 at Himchari is in between Cox's bazar and Ukhia. East of the beach are the hills. The supra-tidal flat is absent at Himchari. The Latitude and

Table 3.1

WAYPOINT LOG (Sheet-1)

PROJECT TITLE: SORTING CHARACTERISTICS OF BEACH MATERIALS ALONG COX'S BAZAR - TEKNAF COAST.

Waypoint Name	SL 1	Date	01/23/95	S =	16.7	Satellite No / SQ				
Latitude	20° 47.75′ N	Time (UT)	03:53:27	No of Fixes	005	01	15	23	25
Longitude	92° 17.96′ E	Datum	WGS 84	xPDOP	2.8	9	9	9	9
Altitude	– m	Waypoint Description	Station 1, adjacent to Katabonia Khal						

Waypoint Name	SL 2	Date	01/23/95	S =	10.1	Satellite No / SQ				
Latitude	20° 54.29′ N	Time (UT)	05:24:25	No of Fixes	005	14	20	22	25
Longitude	92° 14.06′ E	Datum	WGS 84	xPDOP	2.6	9	9	9	9
Altitude	– m	Waypoint Description	Station 2, Noakhali (Teknaf)						

Waypoint Name	SL 3	Date	01/23/95	S =	5.7	Satellite No / SQ				
Latitude	20° 56.17′ N	Time (UT)	06:28:27	No of Fixes	005	01	14	15	22
Longitude	92° 13.03′ E	Datum	WGS 84	xPDOP	2.7	9	9	9	9
Altitude	– m	Waypoint Description	Khoechopya, Beach with Boulders (AS-1)						

Waypoint Name	SL 4	Date	01/23/95	S =	10.3	Satellite No / SQ				
Latitude	21° 00.89′ N	Time (UT)	08:14:18	No of Fixes	005	18	22	25	14
Longitude	92° 11.27′ E	Datum	WGS 84	xPDOP	2.9	8	9	9	9
Altitude	m	Waypoint Description	Station 3, Jahajchora (Nila)						

Waypoint Name	SL 5	Date	01/23/95	S =	8.7	Satellite No / SQ				
Latitude	21° 03.65′ N	Time (UT)	09:16:50	No of Fixes	005	14	19	22	29
Longitude	92° 08.97′ E	Datum	WGS 84	xPDOP	2.6	9	9	9	9
Altitude	– m	Waypoint Description	Shilkhali Khal meets with the Sea (AS-2)						

Waypoint Name	SL 6	Date	01/23/95	S =	6.9	Satellite No / SQ				
Latitude	21° 04.68′ N	Time (UT)	09:28:48	No of Fixes	005	14	19	22	29
Longitude	92° 08.02′ E	Datum	WGS 84	xPDOP	2.4	9	9	9	9
Altitude	– m	Waypoint Description	Station 4, Howaikong (Between Ukhia and Nila)						

Waypoint Name	SL 7	Date	01/23/95	S =	8.2	Satellite No / SQ				
Latitude	21° 05.49′ N	Time (UT)	10:04:50	No of Fixes	005	14	19	28	29
Longitude	92° 07.38′ E	Datum	WGS 84	xPDOP	2.7	9	9	9	9
Altitude	– m	Waypoint Description	Monkhali Khal Meets with the Sea (AS-3)						

Waypoint Name	SL 8	Date	01/23/95	S =	8.9	Satellite No / SQ				
Latitude	21° 14.48′ N	Time (UT)	11:13:50	No of Fixes	005	18	28	02	15
Longitude	92° 02.94′ E	Datum	WGS 84	xPDOP	2.7	9	6	2	9
Altitude	m	Waypoint Description	Inany Khal meets with the Sea (AS-4)						

Waypoint Name	SL 9	Date	01/25/95	S =	9.9	Satellite No / SQ				
Latitude	21° 18.38′ N	Time (UT)	07:31:28	No of Fixes	005	22	25	28	29
Longitude	92° 02.48′ E	Datum	WGS 84	xPDOP	3.1	9	9	8	9
Altitude	– m	Waypoint Description	Reju Khal meets with the Sea. (AS-5)						

Waypoint Name	SL A	Date	01/25/99	S =	6.5	Satellite No / SQ				
Latitude	21° 21.25′ N	Time (UT)	07:18:20	No of Fixes	005	22	25	28	29
Longitude	92° 01.53′ E	Datum	WGS 84	xPDOP	2.8	9	9	7	9
Altitude	– m	Waypoint Description	Himchari Khal meets with the Sea (AS-6)						

Waypoint Name	SL B	Date	01/25/99	S =	9.0	Satellite No / SQ				
Latitude	21° 22.00′ N	Time (UT)	07:12:21	No of Fixes	005	22	25	28	29
Longitude	92° 01.15′ E	Datum	WGS 84	xPDOP	2.7	9	9	7	9
Altitude	– m	Waypoint Description	Station 5, Himchari						

Table 3.2

WAYPOINT LOG (Sheet-2)

PROJECT TITLE: SORTING CHARACTERISTICS OF BEACH MATERIALS ALONG COX'S BAZAR - TEKNAF COAST.

Waypoint Name	SL C		Date	01/25/99	S =	4.2	Satellite No / SQ			
Latitude	21° 25.46'	N	Time (UT)	07:59:59	No of Fixes	005	18	22	25	28
Longitude	91° 58.50'	E	Datum	WGS 84	xPDOP	2.9	7	9	9	9
Altitude	—	m	Waypoint Description	Entrance of Cox's Bazar Beach						

Waypoint Name	SL D		Date	01/25/95	S =	9.5	Satellite No / SQ			
Latitude	21° 26.41'	N	Time (UT)	06:55:16	No of Fixes	005	22	25	28	29
Longitude	91° 57.56'	E	Datum	WGS 84	xPDOP	2.5	9	9	7	9
Altitude	—	m	Waypoint Description	Station 6, Cox's Bazar						

Waypoint Name	SL E		Date	01/25/95	S =	4.8	Satellite No / SQ			
Latitude	21° 24.30'	N	Time (UT)	06:39:51	No of Fixes	005	01	15	22	29
Longitude	91° 57.88'	E	Datum	WGS 84	xPDOP	2.3	5	9	9	9
Altitude	—	m	Waypoint Description	Bagkhali river meets with the sea (AS-7)						

Waypoint Name	SL F		Date	10/05/92	S =	13.7	Satellite No / SQ			
Latitude	20° 44.74'	N	Time (UT)	05:35:22	No of Fixes	30	16	20	24	26
Longitude	92° 20.12'	E	Datum	WGS 84	xPDOP	3.2	9	9	9	8
Altitude	—	m	Waypoint Description	Badar Mokkam (Reference point)						

Waypoint Name			Date		S =		Satellite No / SQ			
Latitude		N	Time		No of Fixes					
Longitude		E	Datum		xPDOP					
Altitude		m	Waypoint Description							

Waypoint Name			Date		S =		Satellite No / SQ			
Latitude		N	Time		No of Fixes					
Longitude		E	Datum		xPDOP					
Altitude		m	Waypoint Description							

Waypoint Name			Date		S =		Satellite No / SQ			
Latitude		N	Time		No of Fixes					
Longitude		E	Datum		xPDOP					
Altitude		m	Waypoint Description							

Waypoint Name			Date		S =		Satellite No / SQ			
Latitude		N	Time		No of Fixes					
Longitude		E	Datum		xPDOP					
Altitude		m	Waypoint Description							

Waypoint Name			Date		S =		Satellite No / SQ			
Latitude		N	Time		No of Fixes					
Longitude		E	Datum		xPDOP					
Altitude		m	Waypoint Description							

Waypoint Name			Date		S =		Satellite No / SQ			
Latitude		N	Time		No of Fixes					
Longitude		E	Datum		xPDOP					
Altitude		m	Waypoint Description							

Waypoint Name			Date		S =		Satellite No / SQ			
Latitude		N	Time		No of Fixes					
Longitude		E	Datum		xPDOP					
Altitude		m	Waypoint Description							

Longitude of the station is 21°22.00′N and 92°01.15′E respectively.

6. Station no. 6 at Cox's bazar is at the south of the confluence of the Bagkhali river. The Latitude and Longitude of the station is 21°26.41′N and 91°57.56′E respectively.

In addition to these six main stations, seven additional stations were selected and marked in the map shown in Figure no. 3.1 to collect the soil sample from the surface and also to collect the water sample from the nearshore zone. These stations have been selected where the tidal streams have met the sea and where there are the boulders within the foreshore zone. During the field survey the location of these additional stations were determined by the Global Position Survey (GPS) receiver. The stations were designated as AS-1, AS-2, AS-3 etc. and the latitudes and longitudes of these additional stations are shown in Table 3.1 and 3.2. A brief description of the additional stations are as follows:

i. AS-1 in between Jahajchora and Noakhali, where the beach is with boulders, the latitude and longitude of the station is 20°56.17′N and 92°13.03′E respectively;

ii. AS-2 in between Howaikong and Jahajchora, where Silkhali Khal meets with the sea, the latitude and longitude of the station is 21°03.65′N and 92°08.97′E respectively;

iii. AS-3 in between Howaikong and Inany, where Monkhali Khal meets with the sea, the latitude and longitude of the station is 21°05.49′N and 92°07.38′E respectively;

iv. AS-4 at Inany, where Inany khal meets with the sea and the beach is with the boulders, the latitude and longitude of the station is 21°14.48′N and 92°02.94′E respectively;

v. AS-5 in between Himchari and Inany, where the Reju Khal meets with the sea, the latitude and longitude of the station is 21°18.38′N and 92°02.48′E respectively;

vi. AS-6 at Himchari, where the Himchari Khal meets with the sea, the latitude and longitude of the station is 21°21.25′N and 92°01.53′E respectively; and;

vii. AS-7 at the north of the confluence of the Bagkhali Khal with the sea, the latitude and longitude of the station is 21°24.30′N and 91°57.88′E respectively.

3.3 DATA COLLECTION

The actual data collection was done between 23 and 25 January 1995. As mentioned earlier the usual transport was found not useful during the survey work . Locally available four wheel drive jeeps were necessary for data collection along the stations (Photograph 2).

3.3.1 Types of data

The data collected from the six main stations included:

a) cross-sectional survey of the sea beach at each stations;
b) collection of soil sample at each station from the surface, from 0.3m depth and from 0.6m depth within the backshore and foreshore zone; and;
c) collection of water sample from the nearshore zone at each station.

The data collected include from the seven additional stations are:
a) spot level of the stations;
b) collection of soil sample at each station from the surface; and;
c) collection of water sample from the nearshore zone at each station.

3.3.2 Instruments used

The instruments used to conduct the field works were:

a) a Nav 1000 Pro Global Position Survey (GPS) receiver,

b) level and staff,

c) tape,

d) spade,

e) steel plate,

f) iron grid (specially fabricated for the purpose),

g) 6" dia. open box,

h) polythene bags, water pot, stapler etc.

Possible Instrumental Error:

The Nav 1000 Pro Global Position Survey (GPS) receiver has a possible error of (+/-)30m and the staff has a possible error of (+/-)10%.

3.3.3 Cross-sectional survey of the stations

The cross-sectional survey of each station was done by direct levelling. The readings were taken with the help of a staff and the distances were measured with the tape (Photograph 11). It was not possible to continue the survey work throughout the day because of high tides and waves. The survey readings were recorded in a level book and the reduced levels were calculated with respect to water level elevation with respect to PWD at Cox's bazar. The calculated reduced levels are presented in Table 3.3 and 3.4. The bed level of the khals were also surveyed and are shown with the Table 3.4.

3.3.4 Collection of soil samples

Three locations were selected from each station as shown in Figure no.3.3. These locations were: one within the foreshore zone adjacent to the existing water level; one

Table 3.3

Cross Sectional Survey of the Sea Beach (Sheet – 1)

Station no: 1

Name : Katabunia
Location : Longitude: 92 deg 17.96 min
Latitude : 20 deg 47.75 min
W.L : 0.71 m PWD
Time : 09 – 40 AM
Tide : High
Date : 23–01–95
HWL : 2.07 m PWD
LWL : 0.55 m PWD

Dist.(m)	RL(mPWD)	Remarks
0.00	3.04	
5.00	3.32	
10.00	3.43	
15.00	3.32	
20.00	3.22	
30.00	3.00	3rd Sample Location
40.00	2.75	
50.00	2.52	
60.00	2.29	
70.00	2.07	
80.00	1.97	
90.00	1.95	2nd Sample Location
100.00	1.94	
110.00	1.80	
120.00	1.65	
130.00	1.51	
140.00	1.41	
150.00	1.27	
160.00	1.01	1st Sample Location
170.00	0.71	Water Level
180.00	0.65	
190.00	0.60	
195.00	0.55	
200.00	0.50	

Station no: 2

Name : Noakhali
Location : Longitude: 92 deg 14.06 min
Latitude : 20 deg 54.29 min
W.L : 1.42 m PWD
Time : 11 – 59 AM
Tide : High
Date : 23–01–95
HWL : 2.07 m PWD
LWL : 0.55 m PWD

Dist.(m)	RL(mPWD)	Remarks
0.00	2.54	
3.00	2.77	
5.00	2.93	
8.00	3.16	
10.00	3.18	
11.00	3.00	
11.50	2.85	
13.00	2.67	
14.00	2.40	
24.00	2.43	
33.00	2.43	
36.00	2.76	
40.00	2.80	
50.00	2.85	3rd Sample Location
60.00	2.95	
70.00	2.93	
80.00	3.04	
90.00	3.08	
100.00	3.01	
110.00	2.66	
118.00	2.47	2nd Sample location
130.00	2.29	
135.00	2.27	
140.00	2.59	
150.00	2.84	
160.00	2.89	
164.00	2.86	
170.00	2.53	
179.00	2.01	1st Sample location
187.00	1.42	Water Level
200.00	1.35	
230.00	1.22	

Station no: 3

Name : Jahajchora
Location : Longitude: 92 deg 11.27 min
Latitude : 21 deg 00.89 min
W.L : 1.85 m PWD
Time : 02 – 57 PM
Tide : Low
Date : 23–01–95
HWL : 2.07 m PWD
LWL : 0.55 m PWD

Dist.(m)	RL(mPWD)	Remarks
0.00	3.04	
1.00	3.30	
3.00	3.48	
5.00	3.70	
6.00	3.67	
7.00	3.27	
8.00	3.01	
15.00	2.90	
25.00	2.94	
31.00	3.32	
35.00	3.70	
39.00	3.82	
45.00	3.63	
55.00	3.61	
65.00	3.70	
75.00	3.75	
85.00	3.83	
90.00	3.79	
95.00	3.75	
101.00	4.12	
105.00	4.11	
110.00	3.89	
115.00	3.66	
122.00	3.36	3rd Sample Location
132.00	3.14	
142.00	2.99	
160.00	2.82	2nd Sample Location
162.00	2.79	
172.00	2.73	
182.00	2.69	
192.00	2.39	
202.00	2.23	
205.00	2.03	1st Sample Location
215.00	1.92	
223.00	1.85	
225.00	1.85	Water Level
235.00	1.70	
240.00	1.65	

Table 3.4

Cross Sectional Survey of the Sea Beach (Sheet – 2)

Station no: 4

Name : Howaikong
Location : Longitude: 92 deg 08.02 min
Latitude : 21 deg 04.68 min
W.L : 1.65 m PWD
Time : 03 – 43 PM
Tide : Low
Date : 23–01–95
HWL : 2.07 m PWD
LWL : 0.55 m PWD

Dist.(m)	RL(mPWD)	Remarks
0.00	4.31	
10.00	4.16	
15.00	3.87	
20.00	3.88	
25.00	3.89	
30.00	3.92	
40.00	3.96	
45.00	3.99	
50.00	4.02	
55.00	3.90	
60.00	3.78	
70.00	3.62	
80.00	3.24	3rd Sample location
90.00	3.01	
100.00	2.83	
110.00	2.63	
120.00	2.41	2nd Sample location
130.00	2.23	
140.00	2.08	
150.00	1.96	
160.00	1.86	1st Sample location
170.00	1.71	
177.00	1.65	Water Level
180.00	1.63	
185.00	1.62	

Station no: 5

Name : Himchari
Location : Longitude: 92 deg 01.15 min
Latitude : 21 deg 22.00 min
W.L : 0.73 m PWD
Time : 09 – 44 AM
Tide : Low
Date : 25–01–95
HWL : 1.75 m PWD
LWL : 0.59 m PWD

Dist.(m)	RL(mPWD)	Remarks
0.00	4.54	
10.00	4.03	
20.00	3.96	
30.00	3.82	
40.00	3.66	
50.00	3.53	
60.00	3.51	
70.00	3.69	
80.00	3.86	
86.00	3.82	
92.00	3.67	3rd Sample location
100.00	3.38	
105.00	3.48	
110.00	3.50	
113.00	3.60	
115.00	3.70	
120.00	3.66	
124.00	3.19	
130.00	2.72	
138.00	2.27	2nd Sample location
150.00	1.89	
160.00	1.81	
170.00	1.54	
174.00	1.33	
180.00	1.24	
190.00	1.29	
200.00	1.31	
210.00	1.31	
220.00	1.30	
230.00	1.29	
240.00	1.23	
250.00	1.16	
260.00	1.08	
270.00	1.01	1st sample location
280.00	0.99	
290.00	0.93	
300.00	0.81	
305.00	0.73	Water Level
308.00	0.70	
310.00	0.69	
325.00	0.59	
340.00	0.50	

Station no: 6

Name : Cox's bazar
Location : Longitude: 91 deg 57.56 min
Latitude : 21 deg 26.41 min
W.L : 0.59 m PWD
Time : 11 – 11 AM
Tide : Low
Date : 25–01–95
HWL : 1.75 m PWD
LWL : 0.59 m PWD

Dist.(m)	RL(mPWD)	Remarks
0.00	4.28	
6.00	4.14	
10.00	3.92	
15.00	3.65	
24.00	3.57	
30.00	3.78	
40.00	3.86	
50.00	3.68	
56.00	3.22	
62.00	2.59	3rd Sample Location
70.00	2.17	
80.00	1.97	
90.00	1.83	
100.00	1.70	
110.00	1.58	
120.00	1.46	
130.00	1.36	
140.00	1.27	
150.00	1.22	
160.00	1.21	
164.00	1.18	2nd Sample lOcation
170.00	1.14	
180.00	1.07	
193.00	0.89	1st Sample location
200.00	0.62	
206.00	0.59	Water Level
210.00	0.58	
215.00	0.57	
225.00	0.55	
240.00	0.50	

Bed Level of the Khals

Name of the Khals	Elevation (m PWD)
Himchari khal	0.75
Reju khal	0.50
Inany khal	0.65
Monkhali khal	1.10
Silkhali khal	1.00
Katabunia khal	0.70

at the backshore zone near the limit of normal wave uprush (approximately selected by enquiry from the local people) and one approximately at the middle of the two. The distance between the locations were measured with the tape. At every locations, three samples were collected; one from the surface; one at 0.3m depth below the surface; and one at 0.6m depth below the surface. Thus nine soil samples were collected from the three locations at each station and all together total fifty four nos. of soil samples were collected from the main six stations. In addition to these fifty four samples from the six main stations, seven more surface samples were collected from the additional seven stations within the foreshore zone along the beach and thus altogether sixty one soil samples have been collected.

Photo 11: Distance Measurement across Station no. 4 at Howaikong.

The samples from the surface were collected by hand scrapping and the samples at 0.3m depth and 0.6m depth were excavated by the spade in a test pit and were collected by the hand (Photograph 12). The soil samples from the additional seven stations were collected from the bed of the streams and from the surface. No additional

sample was collected from the bed of the Katabunia khal as it close to the Station no. 1. The depth of these streams varied between 0.3m to 0.5m and the soil samples were collected by hand scrapping.

Approximately 1 kilogram of soil was stored in the plastic bag for each sample. These were properly marked stating the Station no., Location no. and the Sample no. as explained in Figure no. 3.3. For example, Sample no. 3-3-1 means surface soil sample from Station no. 3 and at location no. 3, Sample no. 3-3-2 means soil sample at 0.3m depth from Station no. 3 and at location no. 3 and Sample no. 3-3-3 means soil sample at 0.6m depth from Station no. 3 and at location no. 3 (Figure no. 3.3). The samples from the additional seven stations were leveled as ISS-1, ISS-2, etc., where ISS stands for Intermediate Soil Sample and the numeric value stands for the additional Station no. as shown in Figure no. 3.1. Details of the samples are presented in Table 3.5.

3.3.5 Collection of the water samples

As field survey works are costly, it was thought that though it is beyond the scope of the present study, a few water samples should be collected for salinity and sediment studies in future. These were collected; six from the main sampling stations and seven from the additional stations. Water samples were collected from the nearshore zone after the wave breaking. Approximately 500 ml volume of water were stored in the plastic bottle (Photograph 13).

Water samples from six main stations were levelled as Stn-1, Stn-2 etc and the samples from the additional stations have been levelled as IWS-1, IWS-2 etc, where "Stn" stands for the station and "IWS" stands for Intermediate water sample and the numeric value stands for the Station no. as presented in Table 3.5. All the soil samples and water samples have been carried to Dhaka in wooden boxes for laboratory testing.

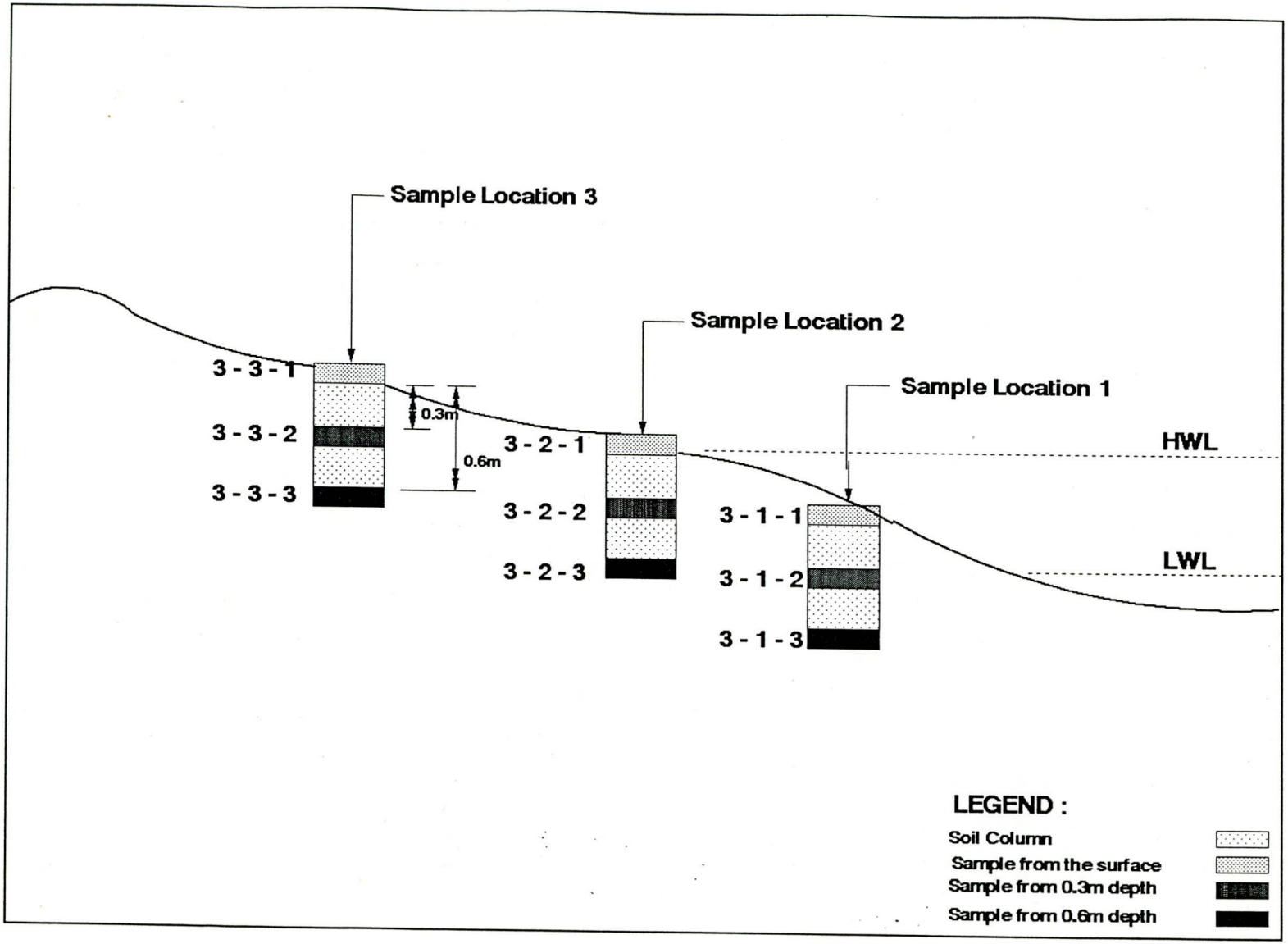


Figure No. 3.3 >>> Locations of Soil Samples across the Beach at a Station

Table 3.5

DETAILS OF SAMPLES

A. SOIL SAMPLE

Date	Station no.	Sample no.	Time
23–01–95	1	1–1–1	10 – 05
		1–1–2	10 – 05
		1–1–3	10 – 05
		1–2–1	10 – 10
		1–2–2	10 – 10
		1–2–3	10 – 10
		1–3–1	10 – 15
		1–3–2	10 – 15
		1–3–3	10 – 15
23–01–95	2	2–1–1	11 – 25
		2–1–2	11 – 25
		2–1–3	11 – 25
		2–2–1	11 – 30
		2–2–2	11 – 30
		2–2–3	11 – 30
		2–3–1	11 – 30
		2–3–2	11 – 30
		2–3–3	11 – 30
23–01–95	3	3–1–1	14 – 45
		3–1–2	14 – 45
		3–1–3	14 – 45
		3–2–1	14 – 25
		3–2–2	14 – 25
		3–2–3	14 – 25
		3–3–1	14 – 35
		3–3–2	14 – 35
		3–3–3	14 – 35
23–01–95	INTERMEDIATE SOIL SAMPLE	I.S.S – 1	12 – 30
23–01–95		I.S.S – 2	15 – 15
23–01–95		I.S.S – 3	16 – 00
23–01–95		I.S.S – 4	17 – 15
25–01–95		I.S.S – 5	08 – 20
25–01–95		I.S.S – 6	08 – 40
25–01–95		I.S.S – 7	12 – 35

Date	Station no.	Sample no.	Time
23–01–95	4	4–1–1	15 – 50
		4–1–2	15 – 50
		4–1–3	15 – 50
		4–2–1	15 – 30
		4–2–2	15 – 30
		4–2–3	15 – 30
		4–3–1	15 – 45
		4–3–2	15 – 45
		4–3–3	15 – 45
25–01–95	5	5–1–1	09 – 10
		5–1–2	09 – 10
		5–1–3	09 – 10
		5–2–1	09 – 10
		5–2–2	09 – 10
		5–2–3	09 – 10
		5–3–1	09 – 10
		5–3–2	09 – 10
		5–3–3	09 – 10
25–01–95	6	6–1–1	11 – 15
		6–1–2	11 – 15
		6–1–3	11 – 15
		6–2–1	11 – 15
		6–2–2	11 – 15
		6–2–3	11 – 15
		6–3–1	11 – 15
		6–3–2	11 – 15
		6–3–3	11 – 15

B. WATER SAMPLE

Date	Sample no.	Time	Remarks
23–01–95	I.W.S – 1	12 – 28	Beach at Jahajchora
23–01–95	I.W.S – 2	15 – 16	Outfall of Silkhali khal
23–01–95	I.W.S – 3	16 – 04	Outfall of Monkhali khal
23–01–95	I.W.S – 4	15 – 14	Outfall of Inany khal
25–01–95	I.W.S – 5	13 – 31	Outfall of Reju khal
25–01–95	I.W.S – 6	13 – 18	Outfall of Himchari khal
23–01–95	STN – 1	09 – 40	Station No. 1
23–01–95	STN – 2	11 – 59	Station No. 2
23–01–95	STN – 3	14 – 57	Station No. 3
23–01–95	STN – 4	15 – 43	Station No. 4
25–01–95	STN – 5	09 – 44	Station No. 5
25–01–95	STN – 6	11 – 11	Station No. 6

I.W.S ---- Intermediate Water Sample

3.4 SECONDARY DATA COLLECTION

In addition to collection of the basic data from the field survey, secondary data like water level variation with time at Cox's bazar and general information on meteorological conditions of the study area was collected as described below.

Water level data

The water level data of the BIWTA gauge station at Cox's Bazar for 23rd and 25th of January was collected from the BIWTA office at Cox's bazar. The water level data consisted of readings normally at 3 hours interval. The supplied data were in Chart Datum unit and have been converted to PWD datum for the calculation purposes as presented in Table 3.6.

Meteorological data

The meteorological data includes temperature, humidity,wind speed and direction on the day of sample collection. The data has been collected from the Defendable Meteorological Office at Cox's Bazar and is shown in Table 3.7.

Photo 12: Collection of Soil Sample from the Pit at Station no. 1 at Katabunia.

Table 3.6

WATER LEVEL AT COX'S BAZAR

(Source: BIWTA Gauge Reader at Cox's Bazar, the Gauge is at Kasturighat upon Bagkhali River and the value supplied are in mCD)

Date	Time	WL(mCD)	WL(mpwd)	Remarks
23-01-95	0	2.03	1.58	* starts from 12.00 midnight
	0.5	2.19	1.71	**
	1	2.34	1.83	**
	1.5	2.5	1.95	**
	2	2.65	2.07	*
	2.33	2.65	2.07	* High Water Level
	2.5	2.6	2.03	*
	3	2.45	1.91	*
	3.5	2.25	1.76	**
	4	2.04	1.59	**
	4.5	1.84	1.44	**
	5	1.64	1.28	**
	5.5	1.43	1.12	**
	6	1.23	0.96	*
	6.5	1.14	0.89	**
	7	1.06	0.83	**
	7.5	0.97	0.76	**
	8	0.88	0.69	**
	8.5	0.8	0.62	**
	9	0.71	0.55	* Low Water Level
	9.5	0.85	0.66	*
	10	1.05	0.82	**
	10.5	1.24	0.97	**
	11	1.44	1.12	**
	11.5	1.63	1.27	**
	12	1.83	1.43	*
	12.5	2.01	1.57	**
	13	2.19	1.71	**
	13.5	2.37	1.85	**
	14	2.55	1.99	*
	14.5	2.55	1.99	* High Water Level
	15	2.35	1.83	*
	15.5	2.18	1.70	**
	16	2.01	1.57	**
	16.5	1.84	1.44	**
	17	1.67	1.30	**
	17.5	1.5	1.17	**
	18	1.33	1.04	*
	18.5	1.22	0.95	**
	19	1.11	0.87	**
	19.5	1	0.78	**
	20	0.9	0.70	**
	20.5	0.79	0.62	**
	21	0.68	0.53	*
	21.25	0.68	0.53	* Low Water Level
	21.5	0.75	0.59	*
	22	0.88	0.69	*
	22.5	1.12	0.87	**
	23	1.36	1.06	**
	23.5	1.59	1.24	**
	24	1.83	1.43	* Ends at 12.00 midnight

Date	Time	WL(mCD)	WL(mpwd)	Remarks
25-01-95	0	1.33	1.04	*
	0.5	1.47	1.15	**
	1	1.61	1.26	**
	1.5	1.76	1.37	**
	2	1.9	1.48	**
	2.5	2.04	1.59	**
	3	2.18	1.70	*
	3.5	2.22	1.73	**
	4	2.25	1.76	*
	4.5	2.25	1.76	* High Water Level
	5	2.15	1.68	*
	5.5	2.02	1.58	**
	6	1.88	1.47	*
	6.5	1.74	1.36	**
	7	1.6	1.25	**
	7.5	1.46	1.14	**
	8	1.31	1.02	**
	8.5	1.17	0.91	**
	9	1.03	0.80	*
	9.5	0.96	0.75	**
	10	0.89	0.69	**
	10.5	0.82	0.64	**
	11	0.75	0.59	*
	11.5	0.75	0.59	* Low Water Level
	12	0.83	0.65	*
	12.5	0.99	0.77	**
	13	1.15	0.90	**
	13.5	1.31	1.02	**
	14	1.46	1.14	**
	14.5	1.62	1.26	**
	15	1.78	1.39	*
	15.5	1.91	1.49	**
	16	2.04	1.59	**
	16.5	2.17	1.69	**
	17	2.3	1.79	*
	17.25	2.3	1.79	* High Water Level
	17.5	2.25	1.76	*
	18	2.18	1.70	*

* – Water levels taken from the BIWTA office at Cox's bazar

** – Interpolated Water levels

– Zero value of the upper gauge is (+)1.68 mpWD

– Zero value of the lower gauge is (+) 0.34 mPWD

– CD stands for Chart datum

Table 3.7

Meteorological Data of Cox's Bazar

(Source: Defendable Meteorological Office, Cox's Bazar)

A. Temperature, Wind Speed and Direction:

Date	Time (BST)	Direction (Deg)	Speed (Knots)	Speed (km/hr)	Avg. Temp (celcius)
23–01–95	10.00	360	10	16	
	11.00	40	8	12.8	
	12.00	360	8	12.8	
	13.00	360	14	22.4	18
	14.00	360	15	24	
	15.00	360	13	20.8	
	16.00	360	14	22.4	
	17.00	360	10	16	
	18.00	360	6	9.6	
25–01–95	07.00	30	4	6.4	
	08.00	25	5	8	
	09.00	30	6	9.6	22
	10.00	40	8	12.8	
	11.00	40	10	16	
	12.00	10	6	9.6	
	13.00	330	8	12.8	
	14.00	300	10	16	
	15.00	330	11	0	

B. Humidity (%)

Date	Morning	Noon	Afternoon
23–01–95	70	30	78
25–01–95	67	26	–

Photo 13: Collection of Water Sample from Surf Zone at Himchari.

3.5 LABORATORY TESTING OF SOIL SAMPLES

Laboratory testing of the soil samples was done in the Hydraulics and River Engineering Laboratory of the Bangladesh University of Engineering and Technology, Dhaka. The test was done by using the U.S standard sieve number 16, 30, 50, 100 and 200 (sieve opening 1.18mm, 0.60mm, 0.30mm, 0.15mm and 0.075mm) and by the British Standard (BST) method. The hydrometer analysis of the samples were not required as the presence of fine grained materials were very less (maximum 5%).

The procedure for laboratory testing is described as below:

a. the samples were dried by the oven for 20 hrs;

b. the dried samples were weighted and 500 gms. samples were separated for laboratory testing, the electronic digital balance were used for weighing and an

instrumental error of (+/-)0.1% was allowed for the purposes;

c. the sieves and the pan were also weighted by the electronic digital balance;

d. the sieves were then arranged vertically one upon another, the pan was placed at the bottom and then sieve no. 200, 100, 50, 30 and 16 were placed above the pan one upon another;

e. the sample was then placed upon sieve no. 16 at the top and covered and then placed with the mechanical vibrator for sieving for 20 minutes;

f. individual sieve and the pan was then weighted including the sample retained, the result was then deducted by the weight of the sieve and the pan to get the weight of sample retained in each sieve and the pan;

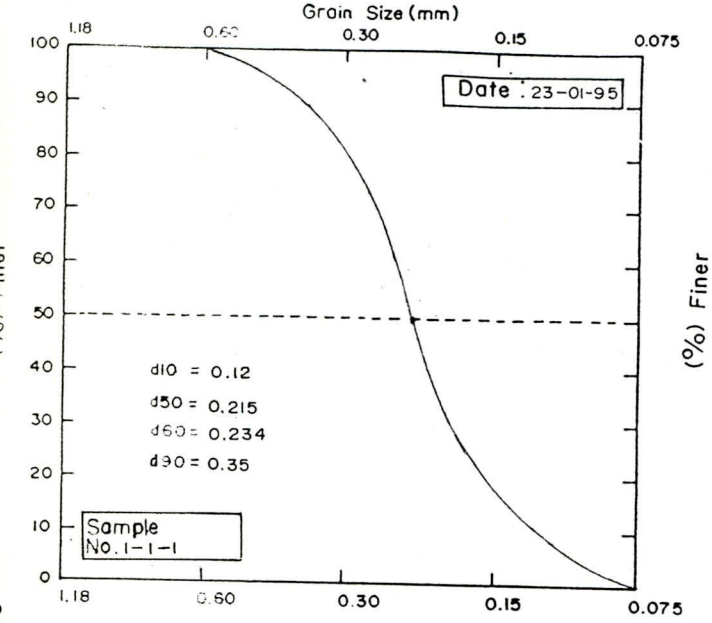
g. the percent retained and cumulative percent retained in each sieve was then calculated;

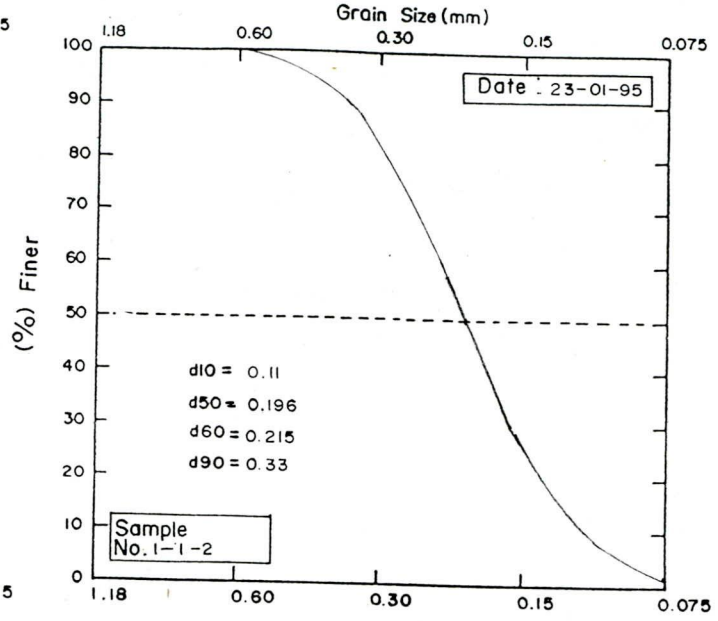
h. the cumulative percent retained was then deducted from 100 to get percent finer through that sieve;

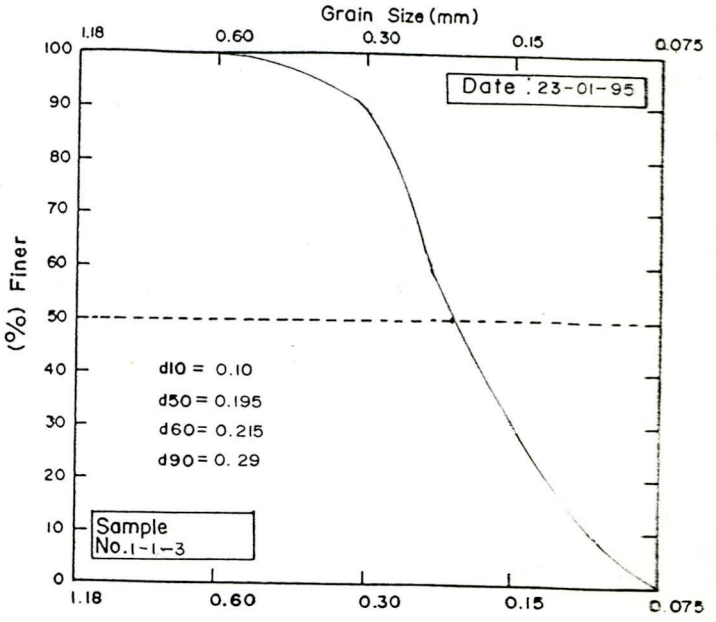
i. the results were plotted in a semi-logarithmic graph paper. The percentage finer was plotted as the ordinate to a natural scale, and the corresponding particle diameter (sieve opening) was plotted as the abscissa to a logarithmic scale. The curve thus plotted was the gradation curve as shown in the figures between Figure no. 3.4 through 3.14 and;

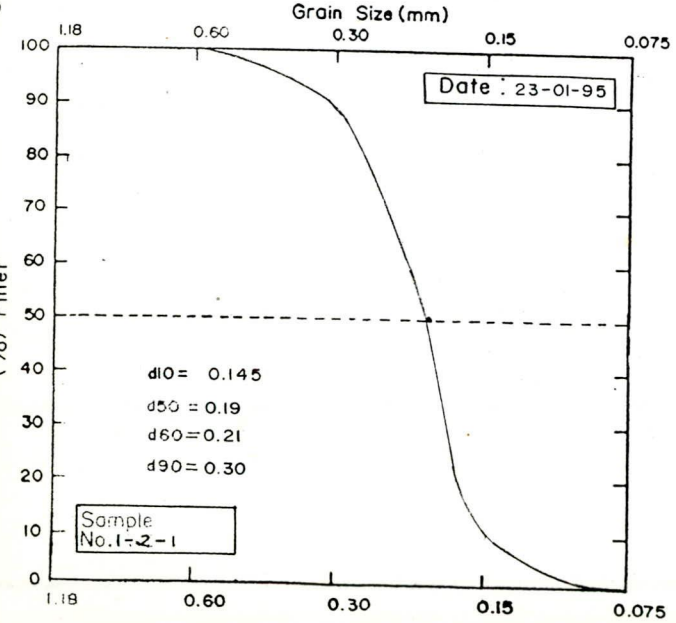
j. where there were the snails with the sample, the snails first were separated by mechanical sieving of 500 gms. sample for 20 minutes by sieve no. 16, the sieve no. 16 was then weighted including the snails retained, the weight was then deducted by the weight of the sieve and the result was the weight of snails in that sample, the percentage of snails was then calculated; the rest portion of the sample excluding the snails were used for sieve analysis by following the steps from c to j;

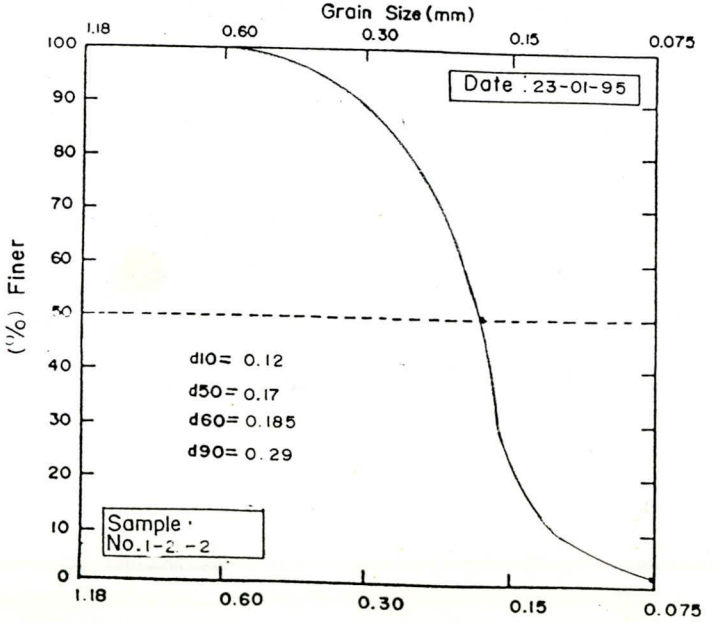
No laboratory test was carried out for the water samples which was considered beyond the scope of the present study as mentioned earlier.











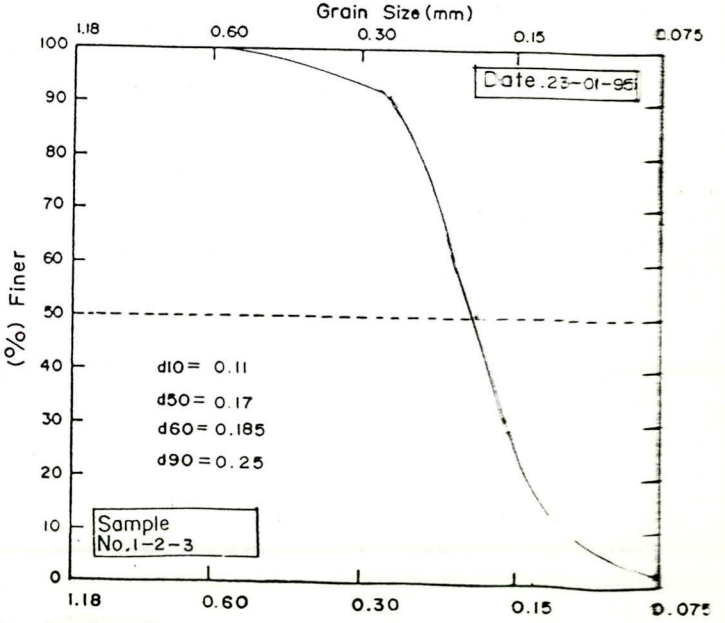


Figure No. 3.4 >>> Grain Size Distribution Curve for Station 1

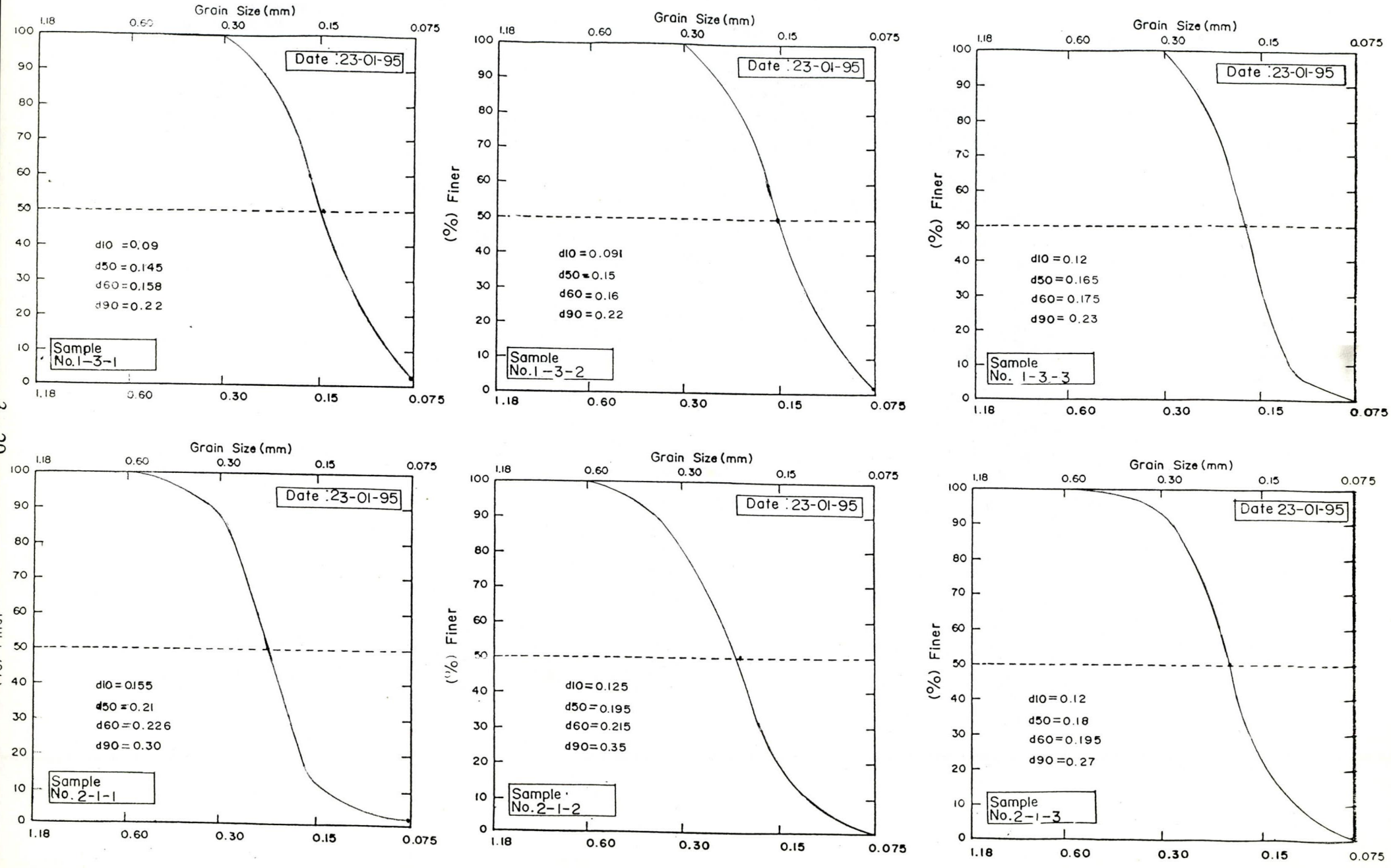
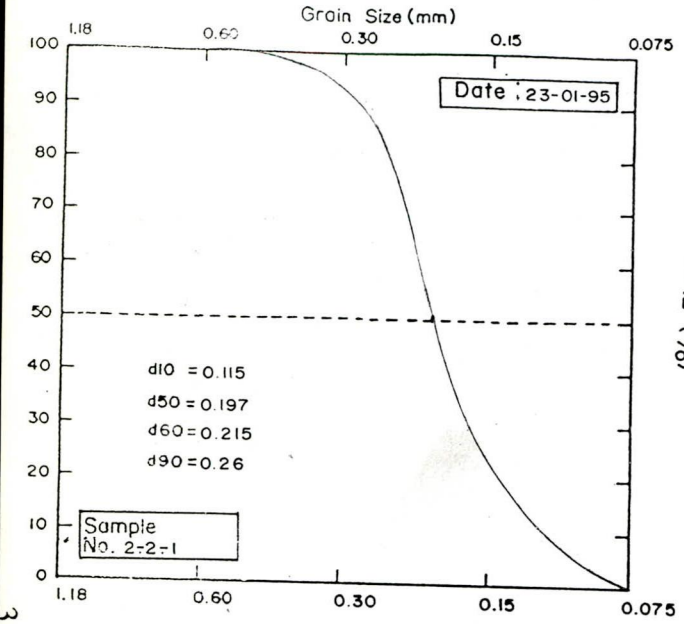
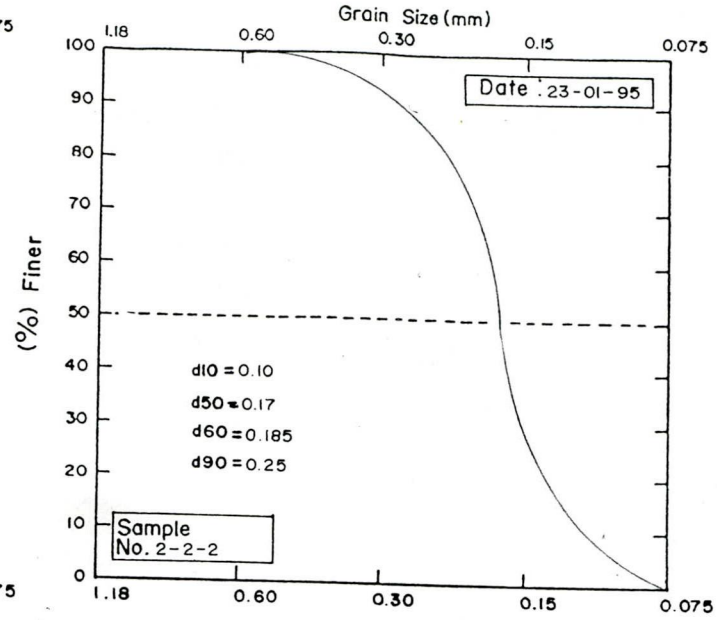
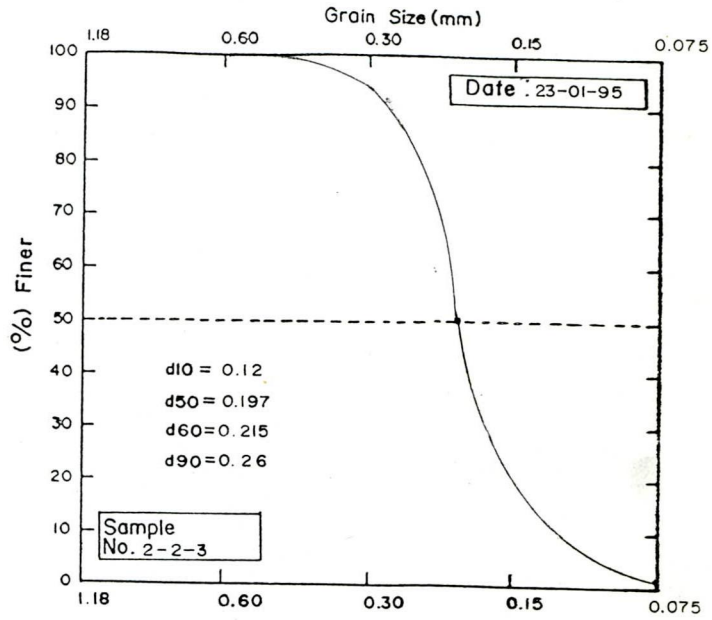
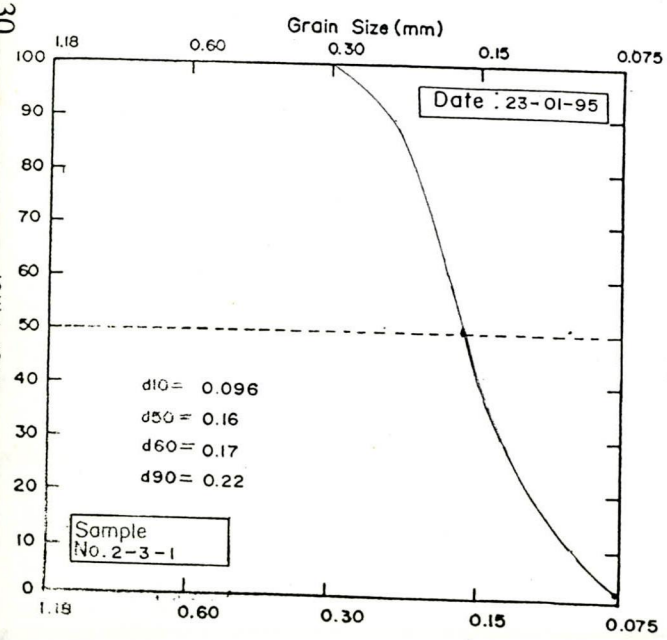


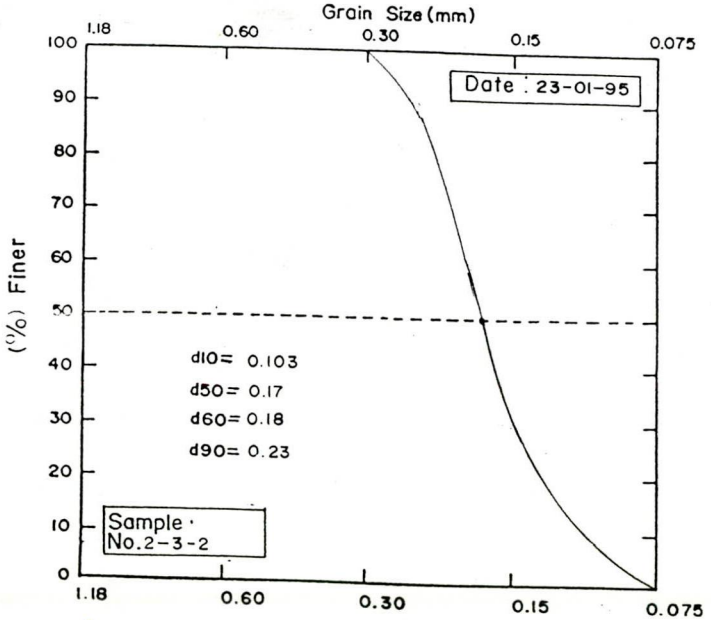
Figure No. 3.5 >>> Grain Size Distribution Curve for Station 1 & 2











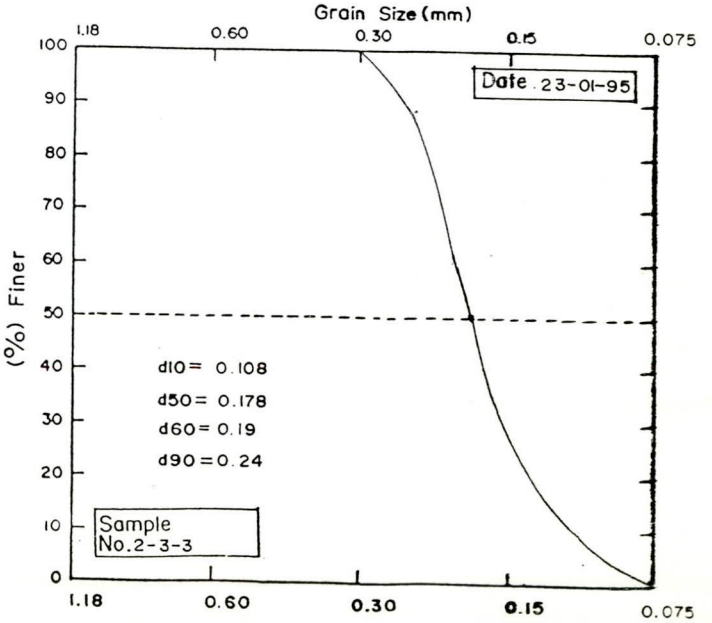


Figure No. 3.6 >>> Grain Size Distribution Curve for Station 2

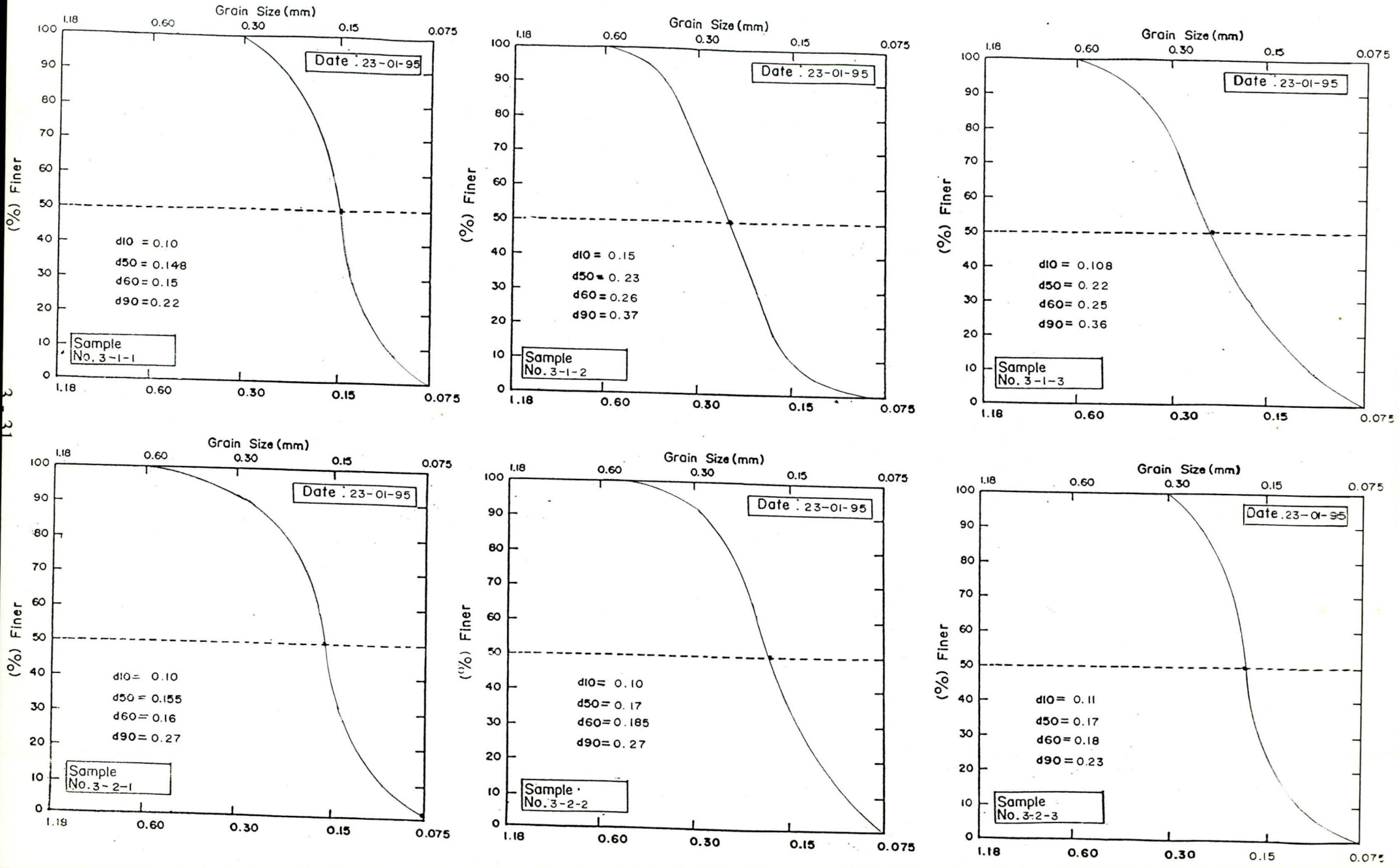


Figure No. 3.7 >>> Grain Size Distribution Curve for Station 3

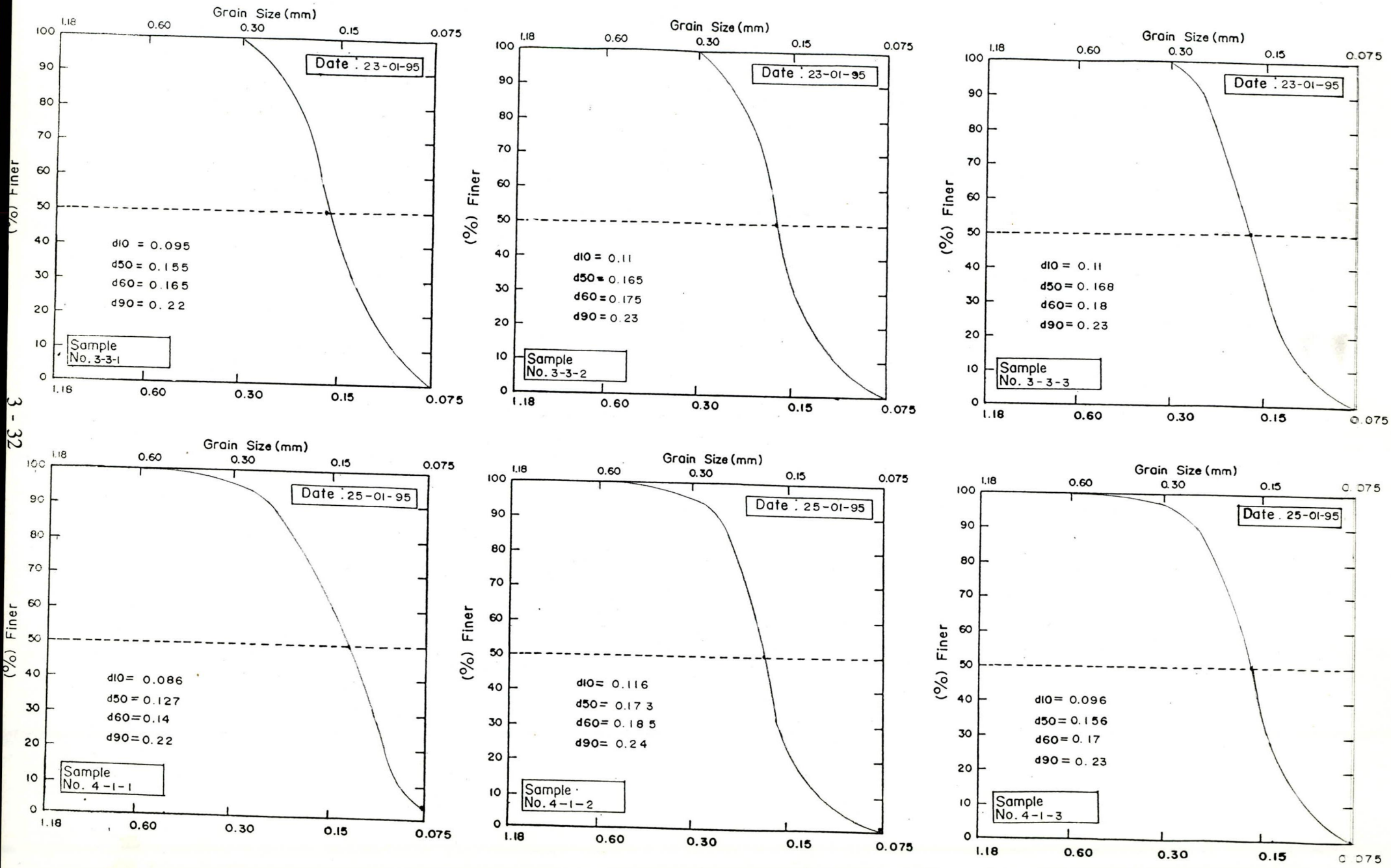


Figure No. 3.8 >>> Grain Size Distribution Curve for Station 3 & 4

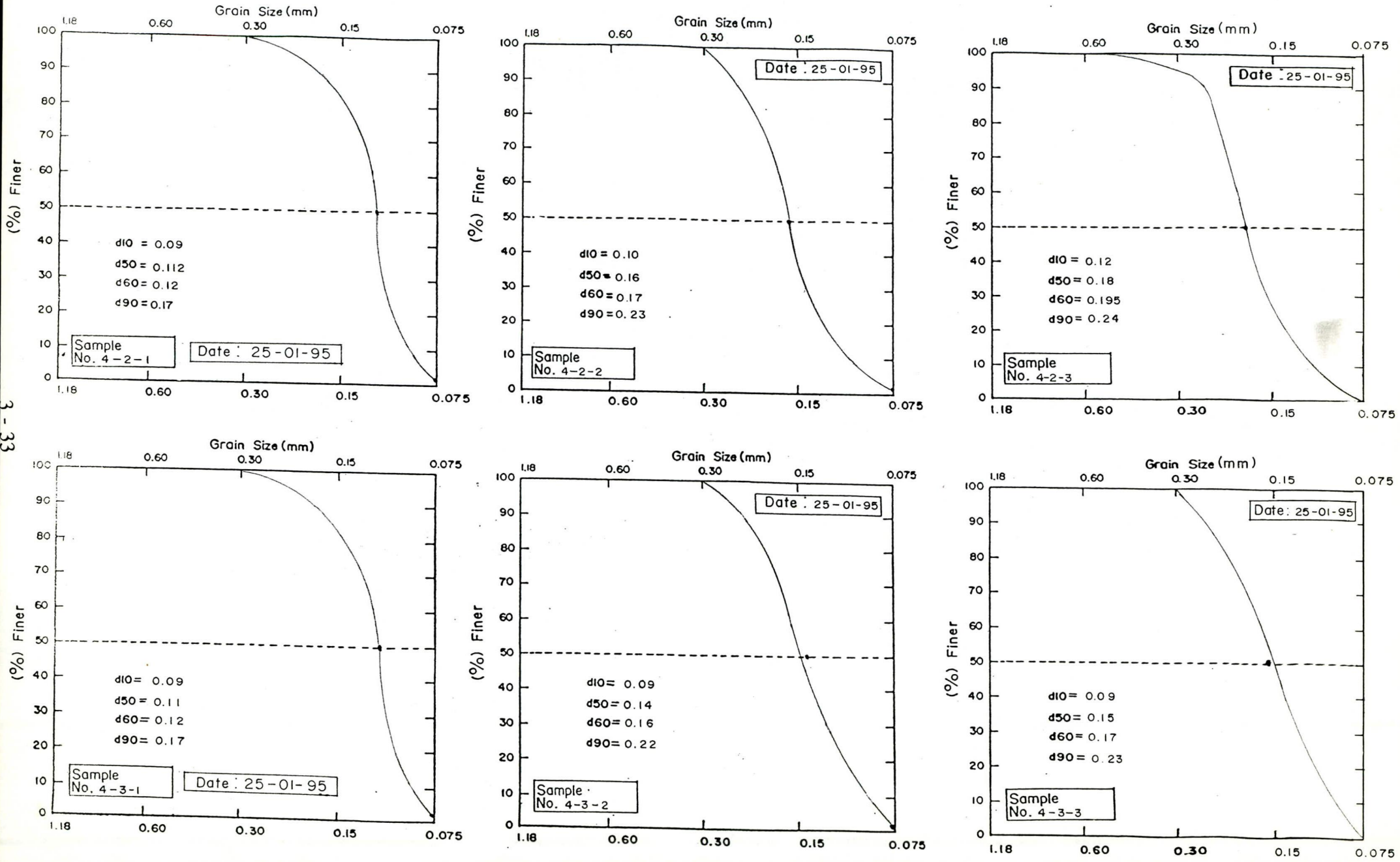


Figure No. 3.9 .> > > Grain Size Distribution Curve for Station 4

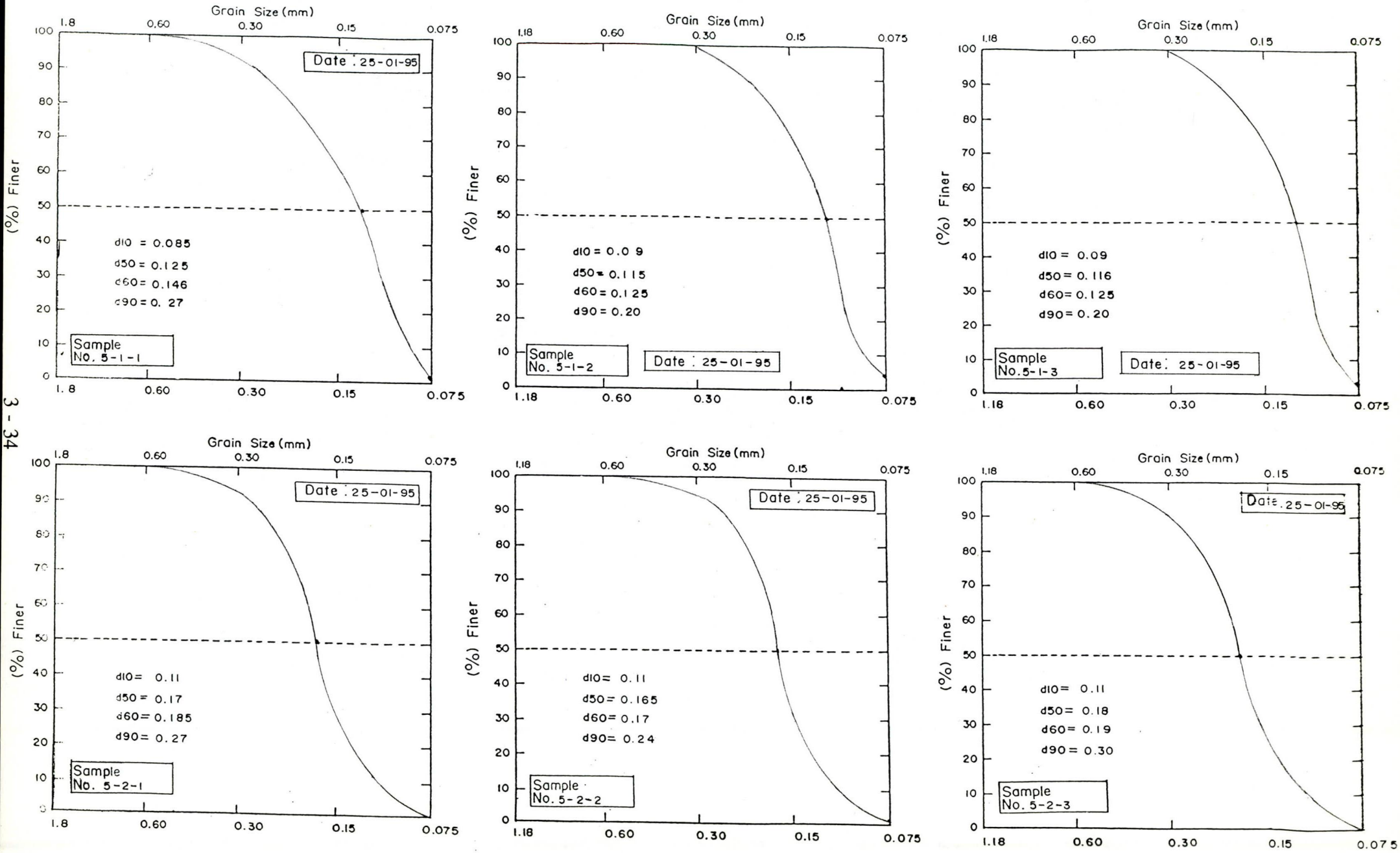


Figure No. 3.10 >>> Grain Size Distribution Curve for Station 5

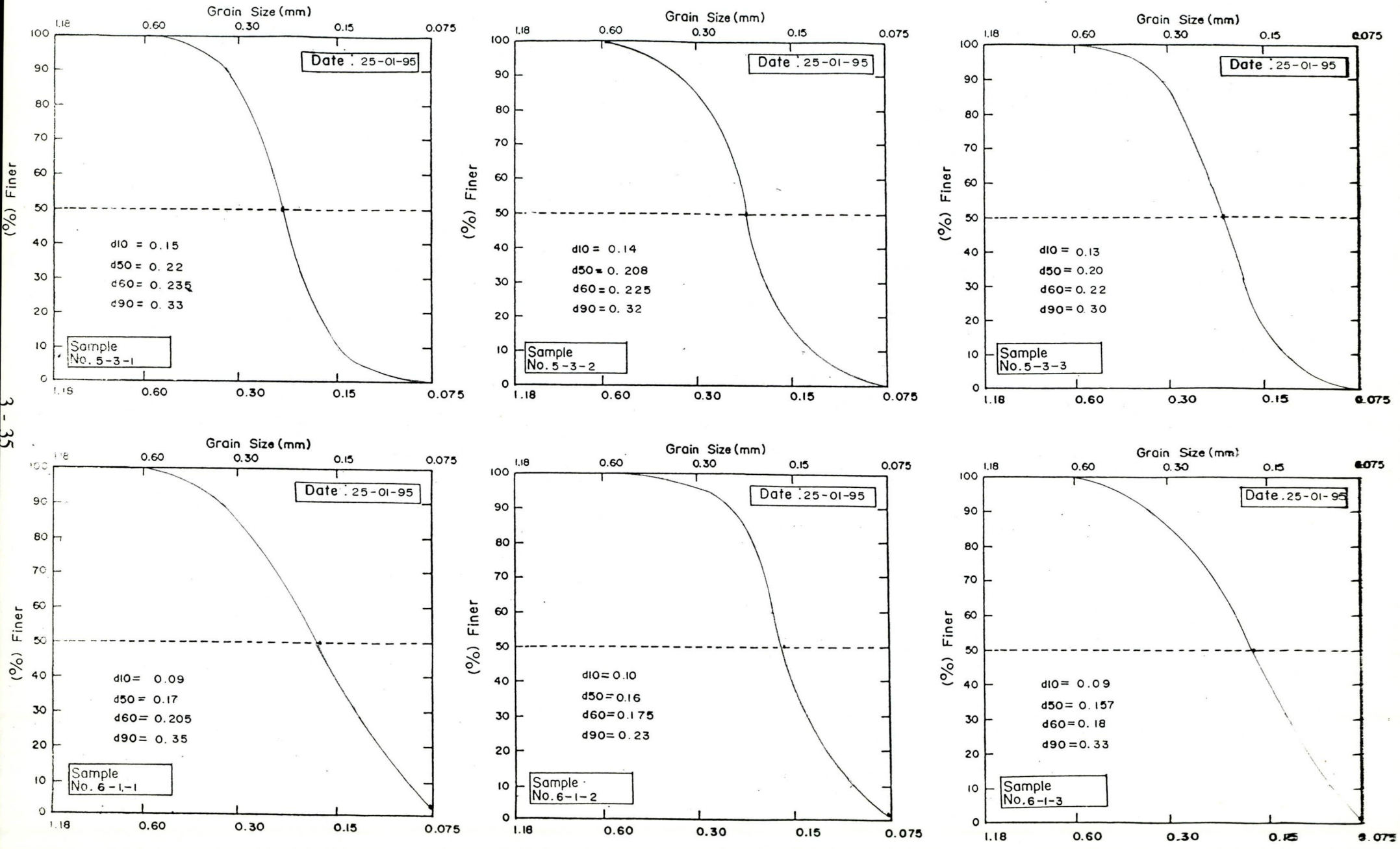


Figure No. 3.1.1 >>> Grain Size Distribution Curve for Station 5 & 6

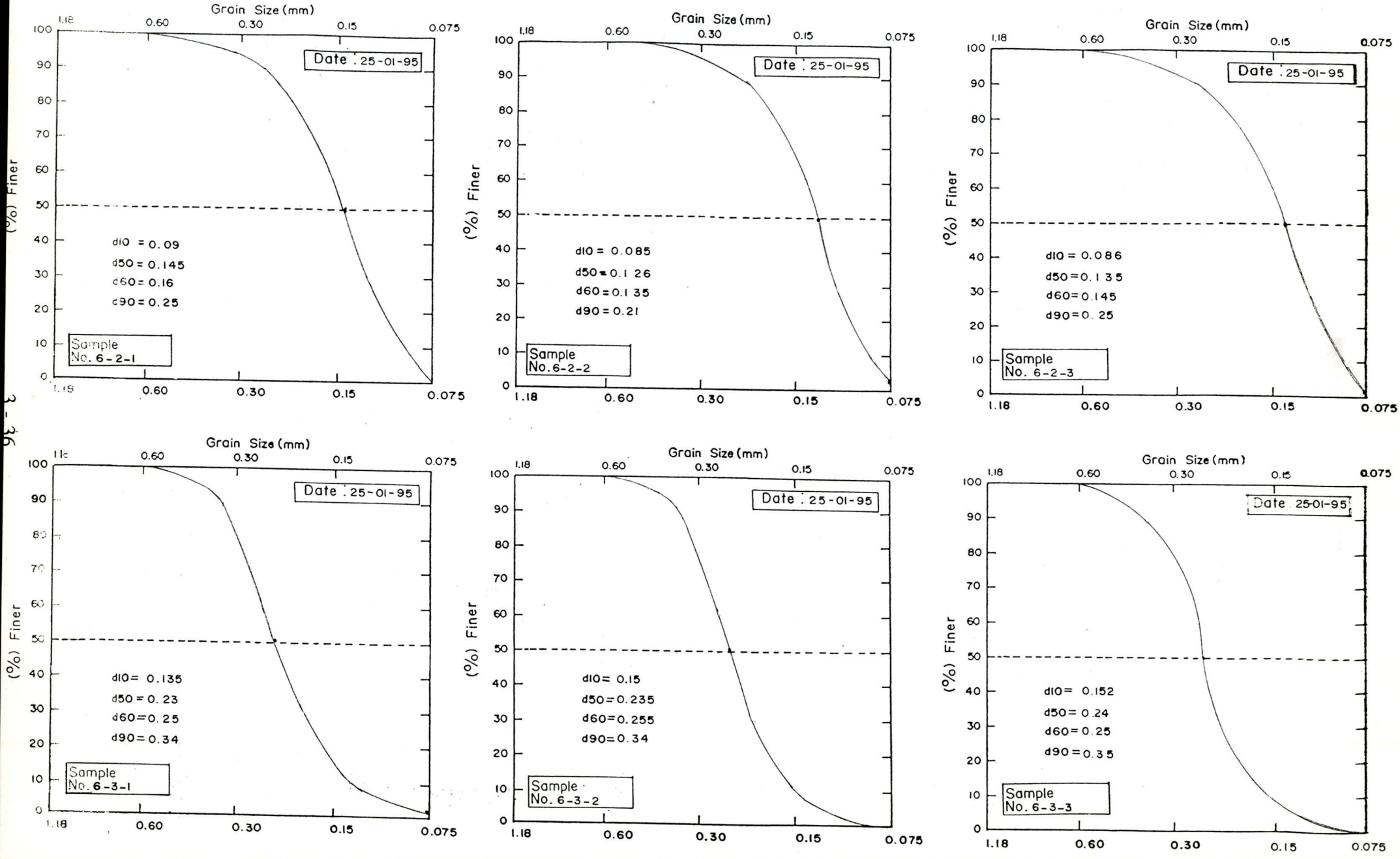


Figure No. 3.12 >>> Grain Size Distribution Curve for Station 6

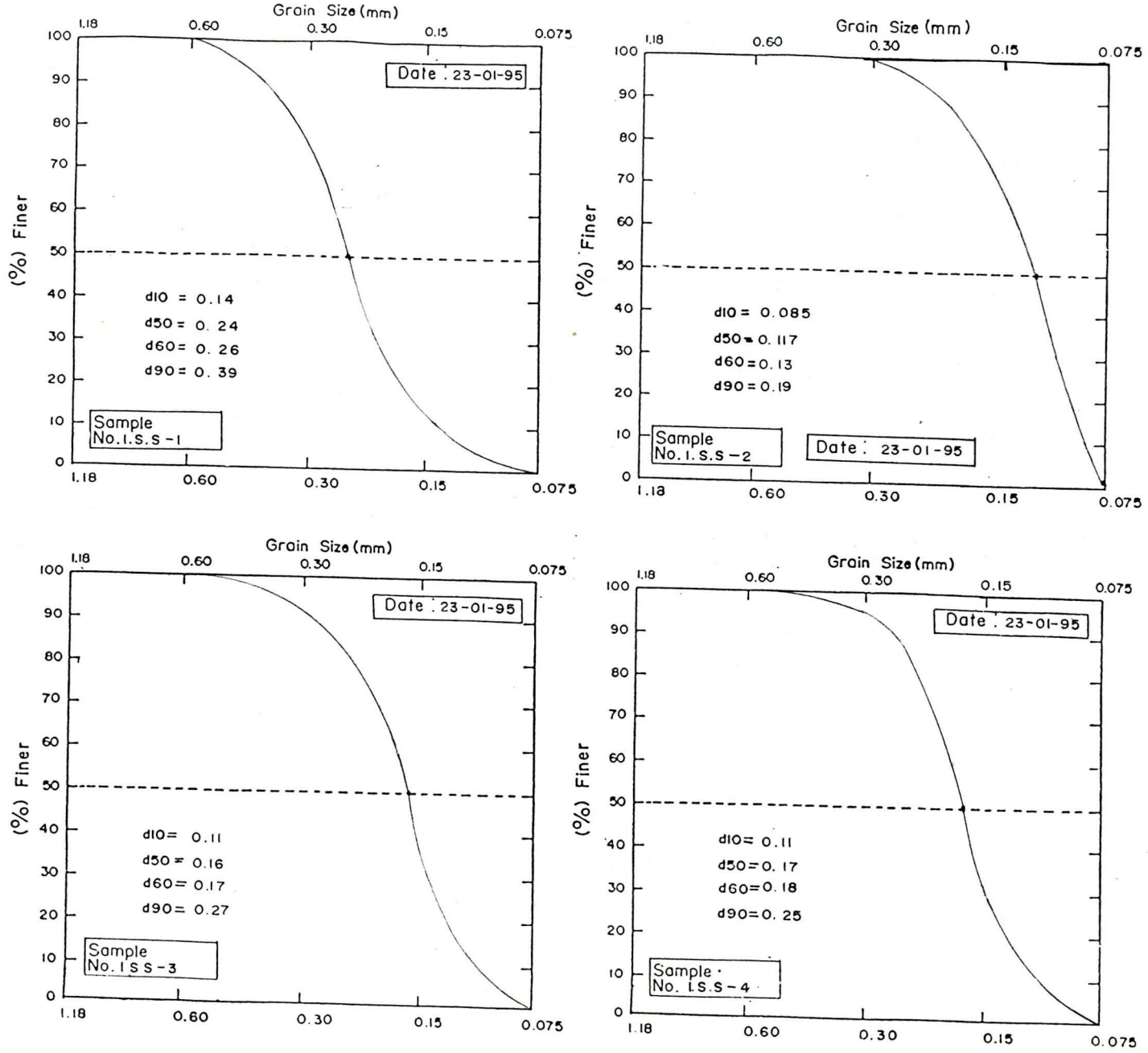
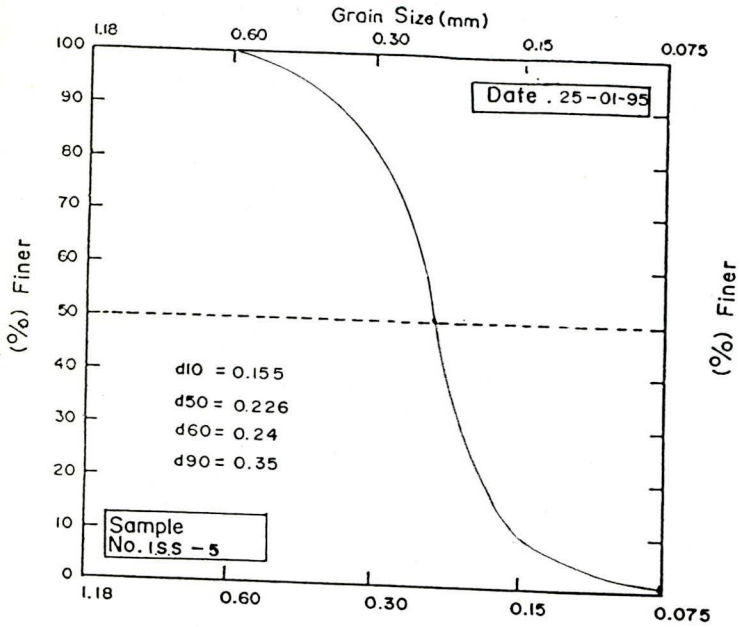
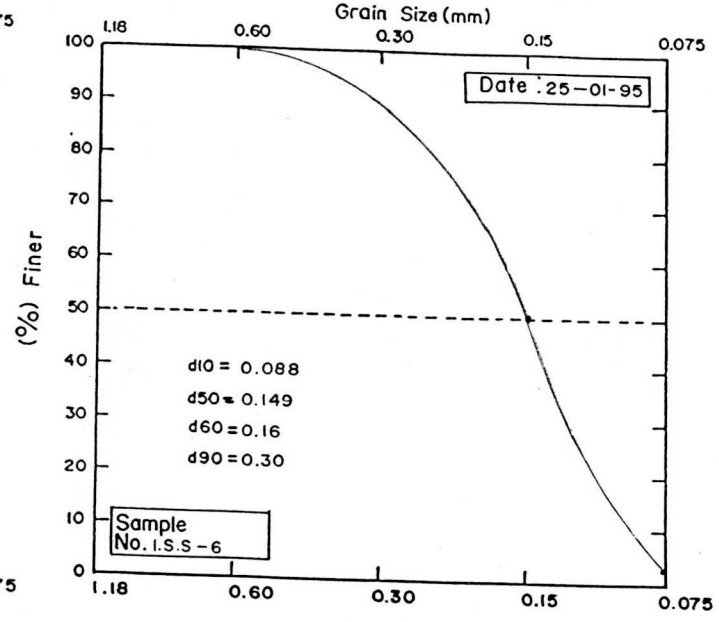


Figure No. 3.13 .> > > Grain Size Distribution Curve for addi. stations





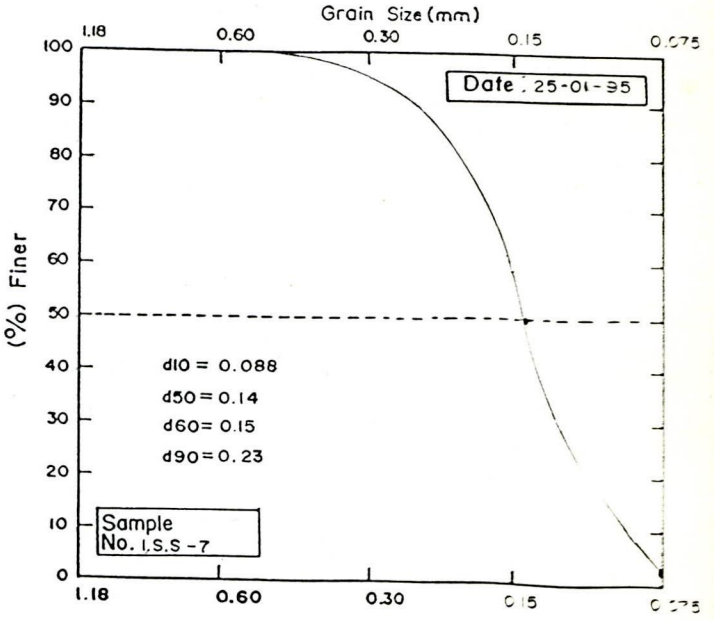


Figure No. 3.14 >>> Grain Size Distribution Curve for addi. stations

CHAPTER 4

DATA ANALYSIS, RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

It has been mentioned in the previous chapter (Chapter 3) that the field data collected consisted of spot level readings along the beach and collection of fifty four soil samples from the six main stations and seven from seven additional stations. For comparing beach profile elevation along the beach a reference level either with Mean Sea Level (MSL) or Public Works Department (PWD) was necessary. Since there was no bench mark record in the study area either by Survey of Bangladesh or any other recognized institution/organization, the water level elevation at Cox's bazar during the survey period was taken as reference datum as presently practiced by the engineering organisation. This level was considered same from Cox's bazar to Teknaf and all the elevations have been calculated with respect to this reference level. The supplied water level data by BIWTA office at Cox's bazar was at 3 hrs. interval and interpolation of the water level with time was done to calculate the spot levels of different stations at different times. The field survey of the work started from Badarmokkam which has been taken as reference station for horizontal distance measurement. The global position (Latitude and Longitude) of this place is 20°44.74′N and 92°20.12′E respectively. The horizontal distance between the stations were calculated from the GPS readings of the stations considering that approximately 24 m. distance is traversed with 1"(second) traverse in latitude or longitude. To have an idea of the width of the beach (foreshore and backshore portion), no fixed reference line was considered and the distances measured by tape were plotted with reference to last the landward sand dune bordered to the supra-tidal flat.

The cross-sectional profiles of the beach at various stations thus drawn (Figure no. 4.1 through 4.6) show the backshore zone (partially) and the foreshore zone. It was,

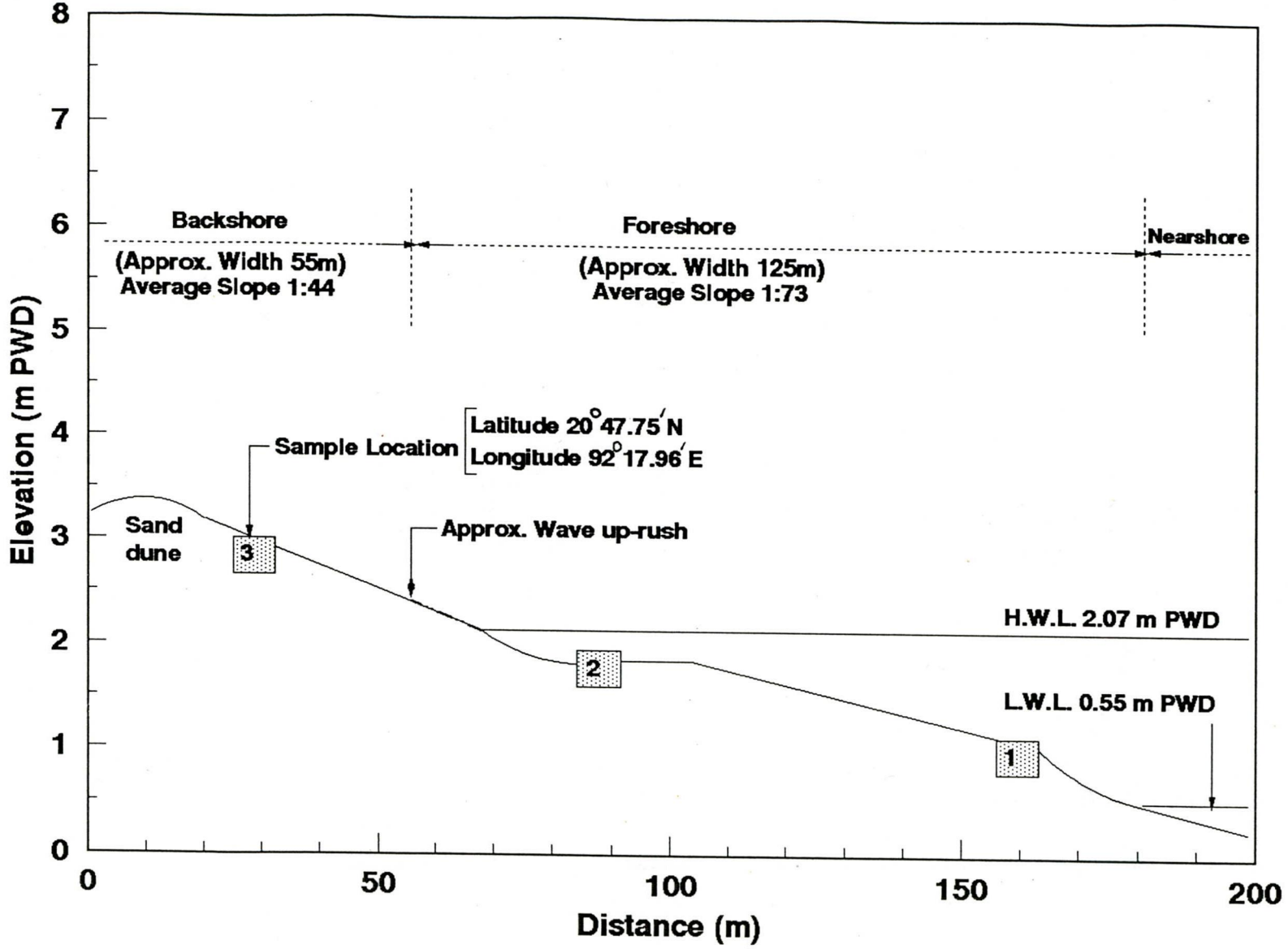


Figure No. 4.1 >>> Cross-sectional Profile of Station No. 1

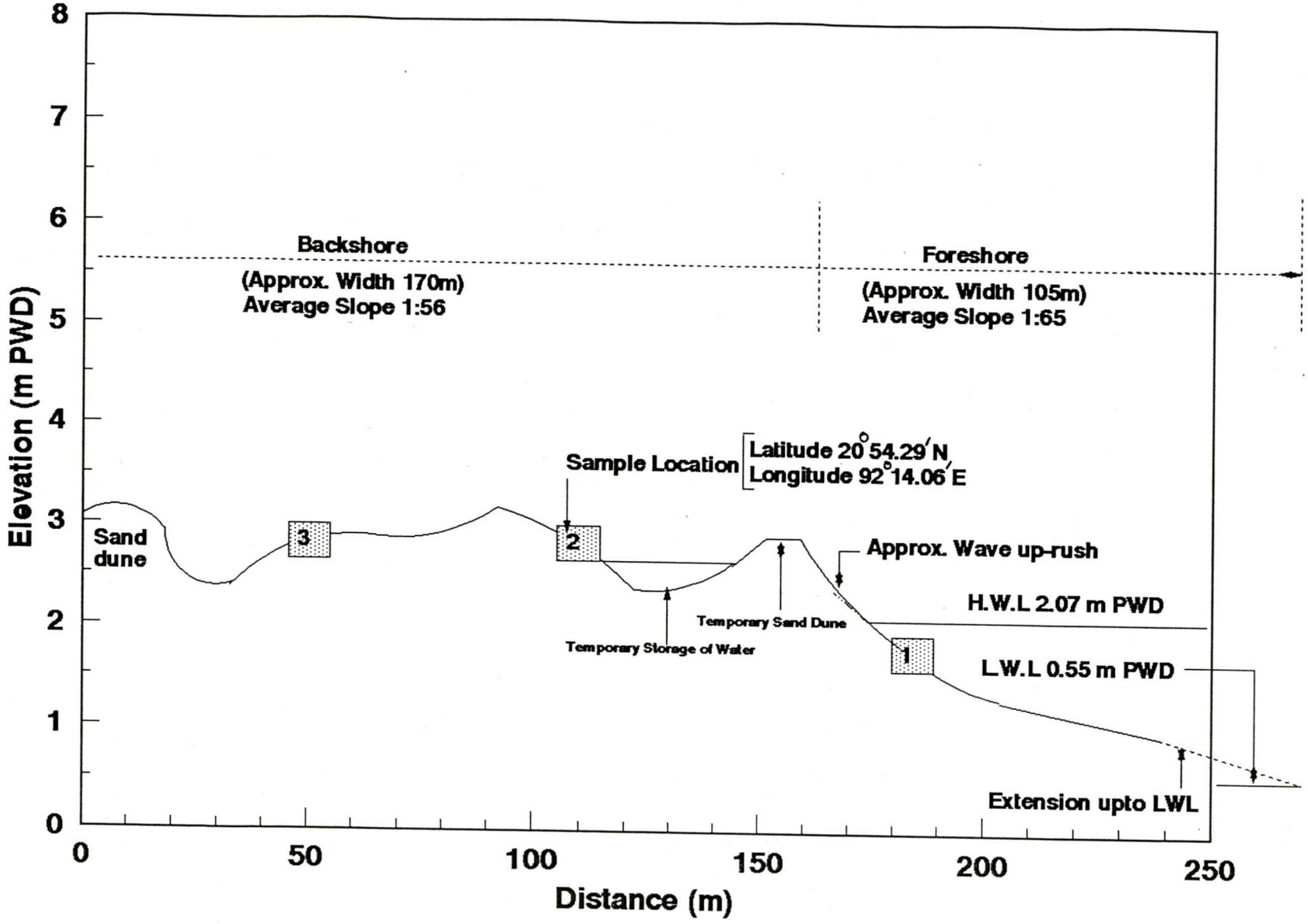


Figure No. 4.2 >>> Cross-sectional Profile of Station 2

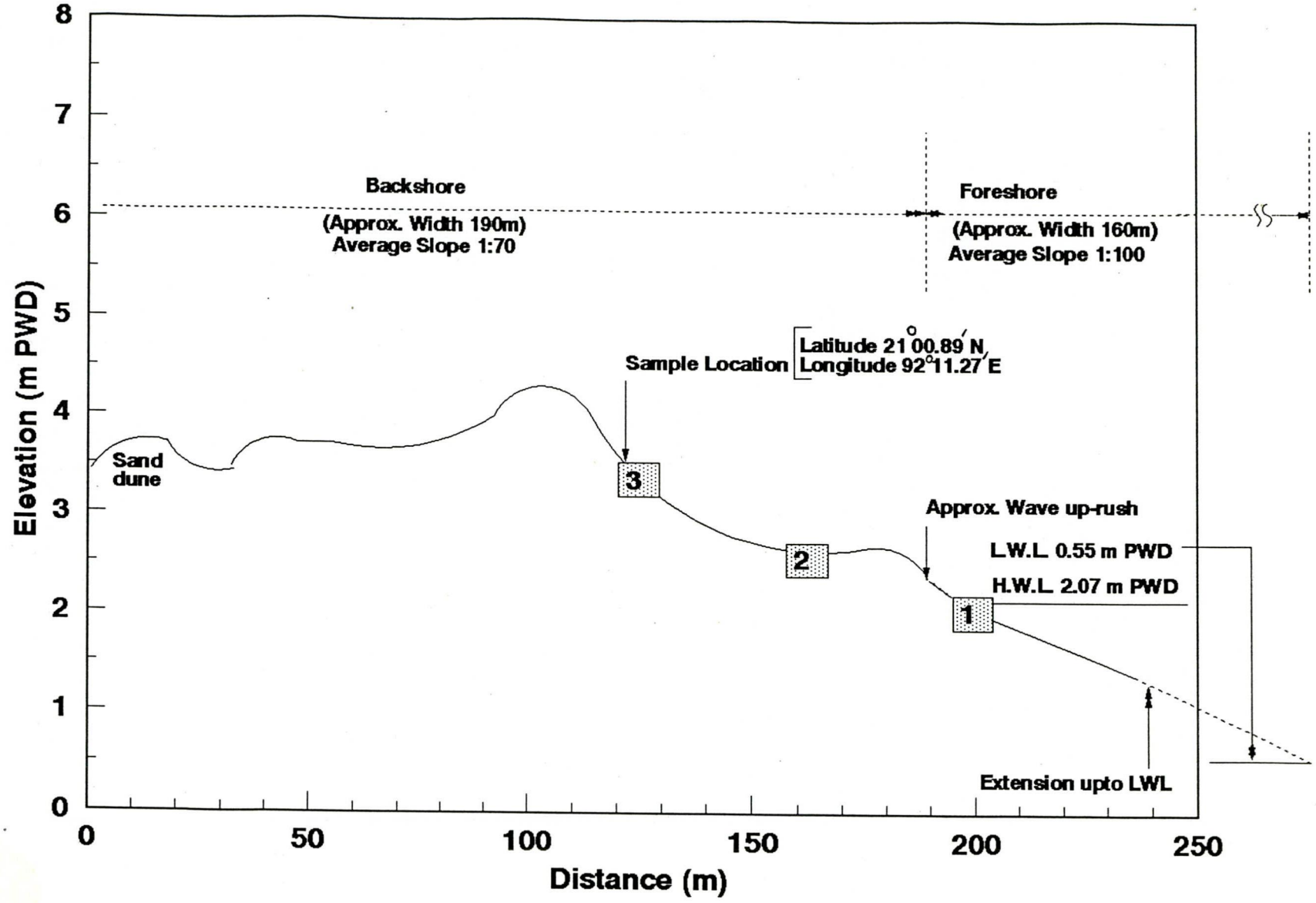


Figure No. 4.3 >>> Cross-sectional Profile of Station 3

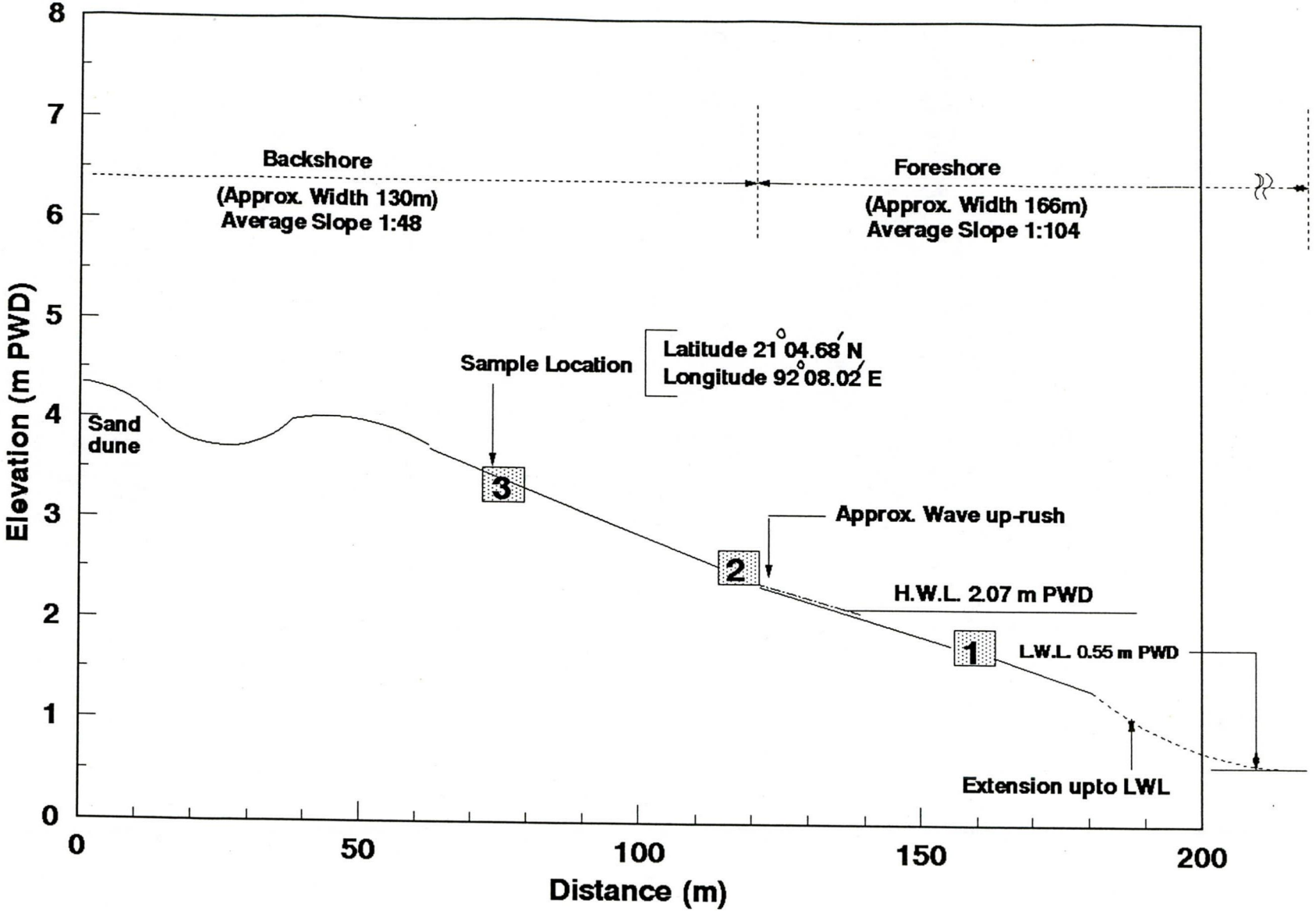


Figure No. 4.4 >>> Cross-sectional Profile of Station 4

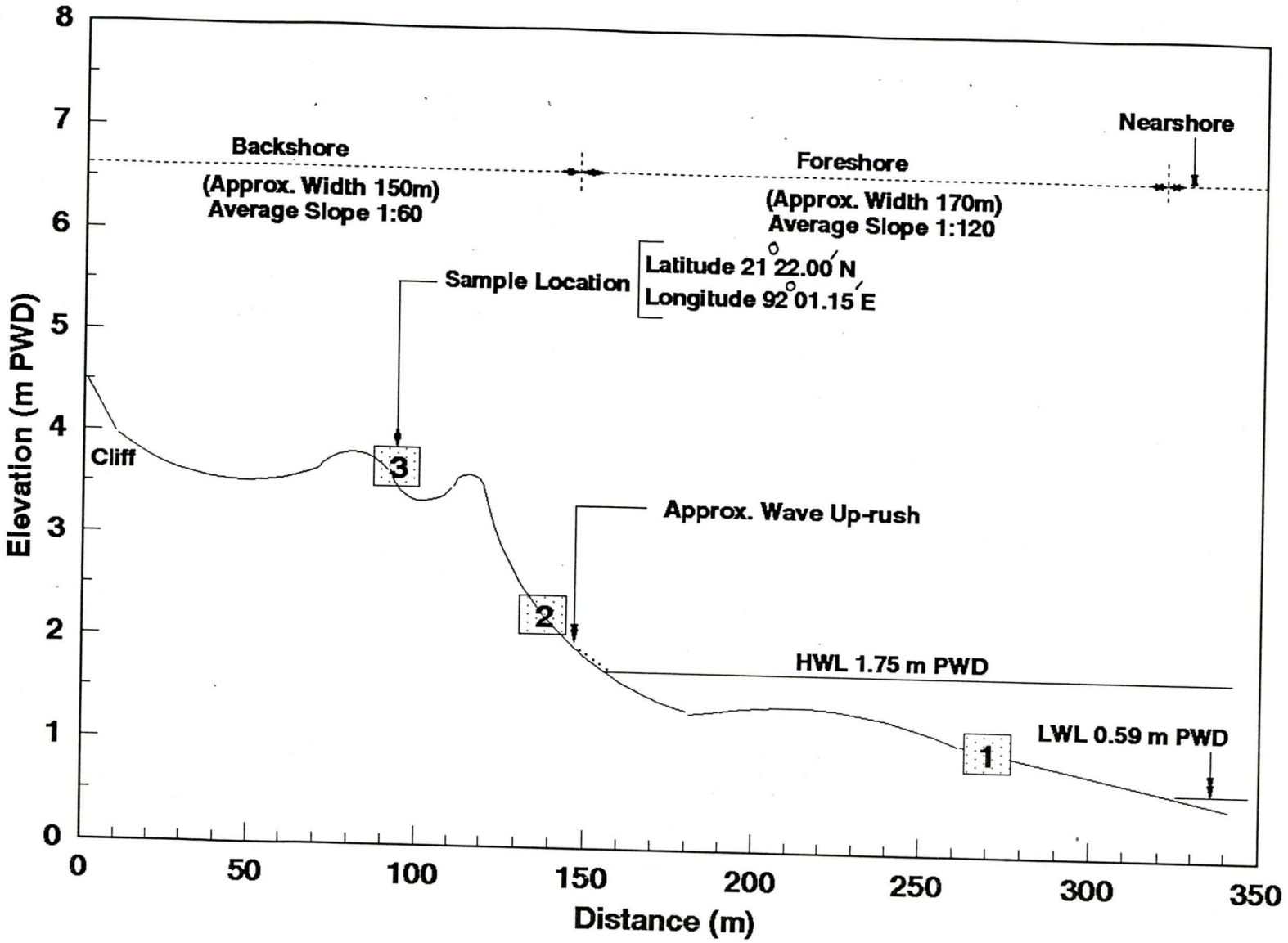


Figure No. 4.5 >>> Cross-sectional Profile of Station 5

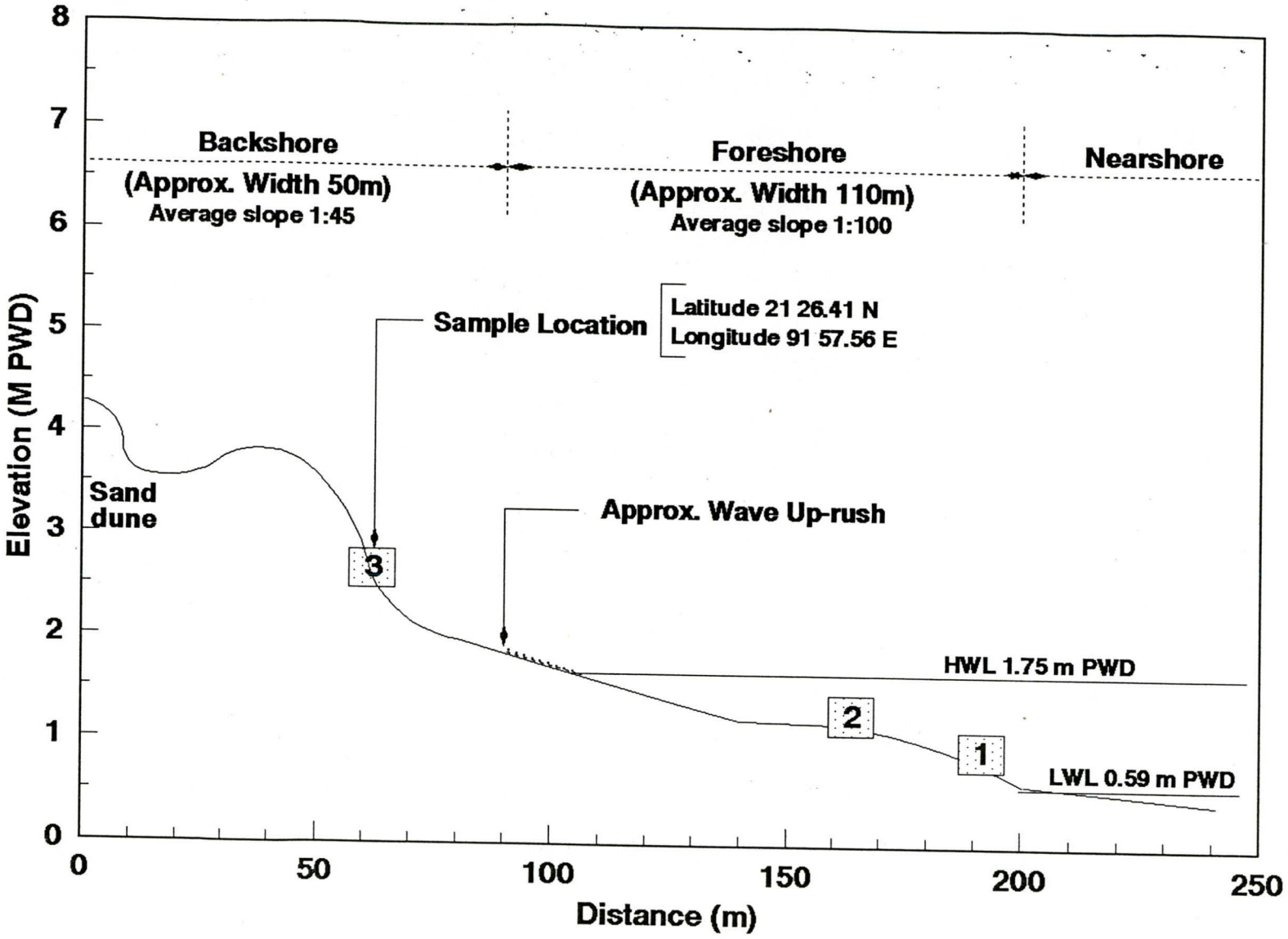


Figure No. 4.6 >>> Cross-sectional Profile of Station 6

however, not possible to show the foreshore zone at Station nos. 2, 3 and 4 in full, because of discontinuation of the survey work due to high tides and waves. The actual width of the supra-tidal flat was also not surveyed as it was beyond the scope of the study.

4.2 LONGITUDINAL PROFILE FROM COX'S BAZAR TO TEKNAF

The variation of elevation along the foreshore zone is shown in Figure no. 4.7. In drawing the plot the average of the spot levels of a station within the foreshore zone has been considered. The bed levels of the khals between Cox's bazar and Teknaf were not considered while calculating the average elevation.

Looking Figure no. 4.7, it can be said that the beach is hump shaped (concave downward) in longitudinal profile. From Cox's bazar the elevation of the foreshore zone of the beach increases towards Teknaf upto a distance of 40 km. The average rate of increase of beach elevation is approximately 1:64,000 upto a distance of 35 km. The slope is then almost flat in the region between Station no. 4 and Station no. 3. After Station no. 3, the beach slopes downwards at an average rate of 1:67,000 towards the sea near Badarmokkam. In between Himchari (Station no 5) and Cox's bazar (Station no. 6) the beach elevation is almost same.

The bed levels of the khals to a great extent also confirms this observation (Figure 4.8). The banks of the khals are quite stiff and vertical and approximately 1.0 m below the average foreshore level except the Himchari khal. The bed level of the Himchari khal is approximately 0.3m below the average foreshore level.

4.3 CROSS-SECTIONAL PROFILE OF THE BEACH

The cross-sectional profiles of the beach at various stations are shown in Figures 4.1 through 4.6. The profiles are normally characterized by Supra-tidal flat in the

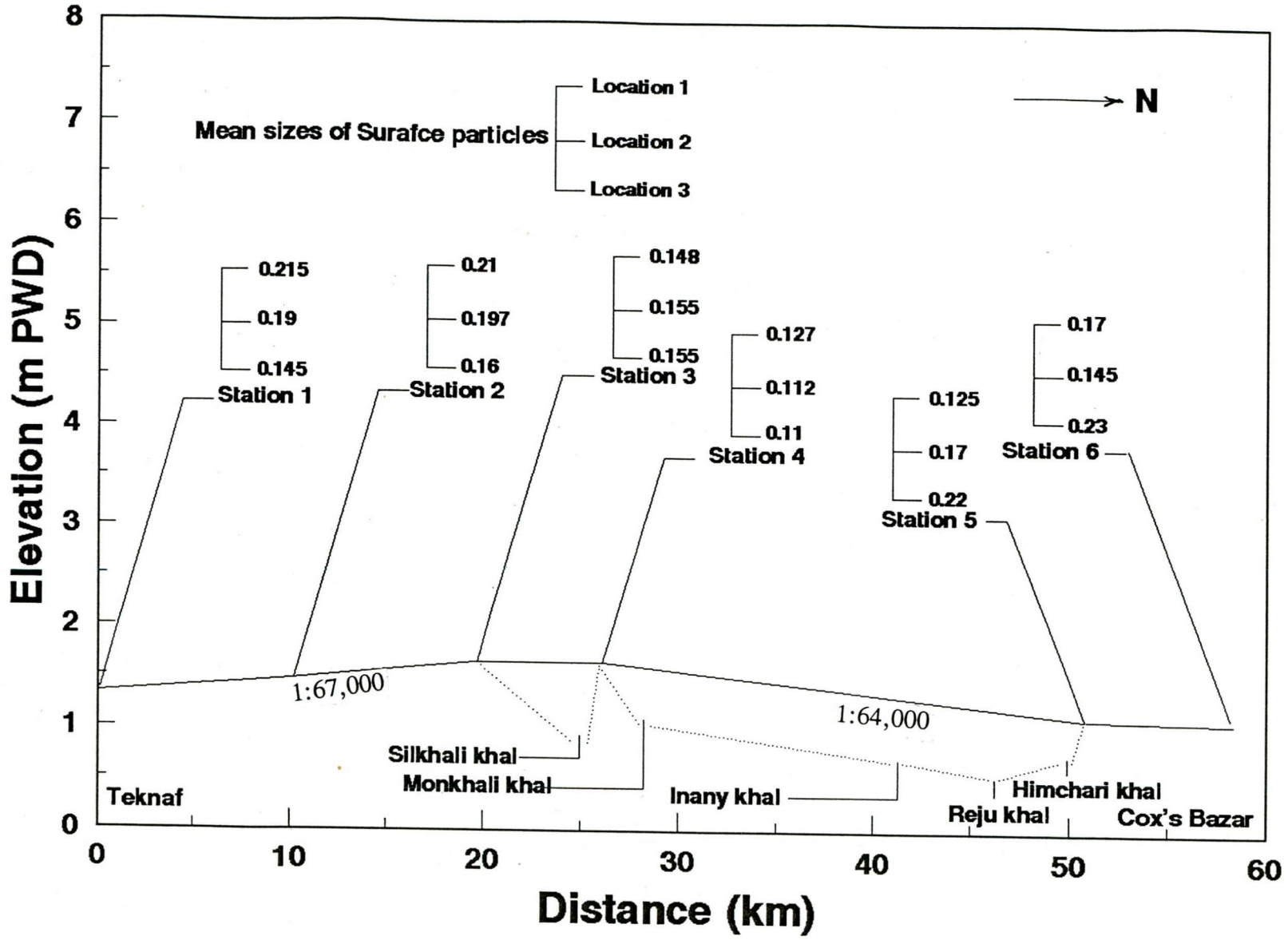


Figure 4.7 >>> Variation of beach elevation along the Foreshore zone

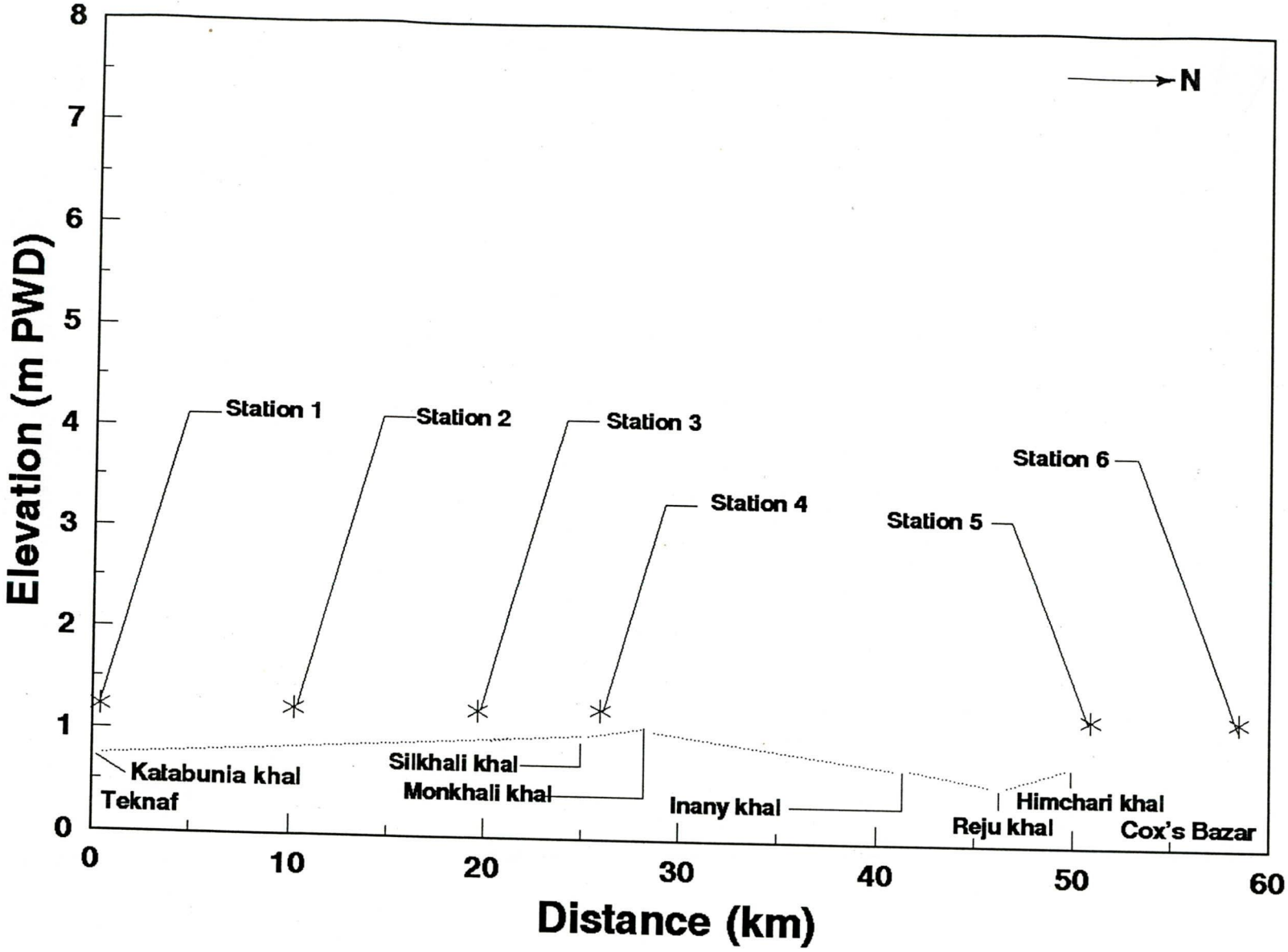


Figure 4.8 >>> Variation of bed elevation of the khals along the beach

backshore zone (land between the wave up-rush point and terrain or stiff cliff), a flat sandy terrain in the foreshore zone (distance between the low water level and the wave up-rush point) and in some cases part of the Surf zone or nearshore zone (lands toward sea from the low water level). It should be mentioned here that the approximate wave up-rush point has been defined from the local people interview. However, supra-tidal flat does not exist at Himchari (Station no. 5) where stiff cliff stands immediately after the foreshore zone. As during levelling at Station nos. 2, 3 and 4, spot levels upto low water level could not be taken because of high tide, while plotting the cross-sections of these stations, the foreshore zone has been extended by dotted line to get the width of the foreshore zone. The actual width of the supra-tidal flat was not surveyed because it was beyond the scope of the study. The width of the backshore zone shown in the figures, therefore, donot represent the full width.

Examining Figures 4.1 through 4.6 , it is seen that at every stations there exists two distinct slopes, a steeper slope in the backshore zone and a relatively flatter slope in the foreshore zone (Table 4.1). The backshore slopes ranges between 1:44 and 1:70, where the foreshore slopes vary between 1:65 and 1:120. The important observation is that the foreshore slopes are flatter towards north (Station nos. 3, 4, 5 and 6) and relatively steeper at the south towards Teknaf (Station nos. 1 and 2). Comparative study (Figure 4.9) shows that the foreshore slope has minimum value at Himchari (Station no. 5, 1:120) where the beach is the flattest and maximum value at Noakhali (Station no. 2, 1:65). The foreshore slopes at Cox's bazar (Station no. 6), Jahajchora (Station no. 3), Howaikong (Station no. 4) are more or less same (Table 4.1). The only difference is in the longitudinal elevation. Also the foreshore slopes at Katabunia (Station no. 1) and Noakhali (Station no. 2) are more or less same.

Figures 4.1 through 4.6 and Table 4.1 also reveals that the width of the foreshore zone varies between 110 m and 170 m and the width of the backshore zone varies between 50 m and 190 m. The exception at Himchari is that the beach here extends upto the cliff and no supra-tidal flat exists.

Table 4.1

Summary of the Cross Profiles

Station No.	Station Name	Lat / Long	Cross Slope		Width (m)	
			Foreshore	Backshore	Foreshore	Backshore
1	Katabunia	20 47.75E/ 92 17.96N	1 : 73	1 : 44	125	55
2	Noakhali	20 54.29E/ 92 14.06N	1 : 65	1 : 56	105	170
3	Jahajchora	21 00.89E/ 92 11.27N	1 : 100	1 : 70	160	190
4	Howaikong	21 04.68E/ 92 08.02N	1 : 104	1 : 48	166	130
5	Himchari	21 22.00E/ 92 01.15N	1 : 120	1 : 60	170	150
6	Cox's bazar	21 26.41E/ 91 57.56N	1 : 100	1 : 45	110	50

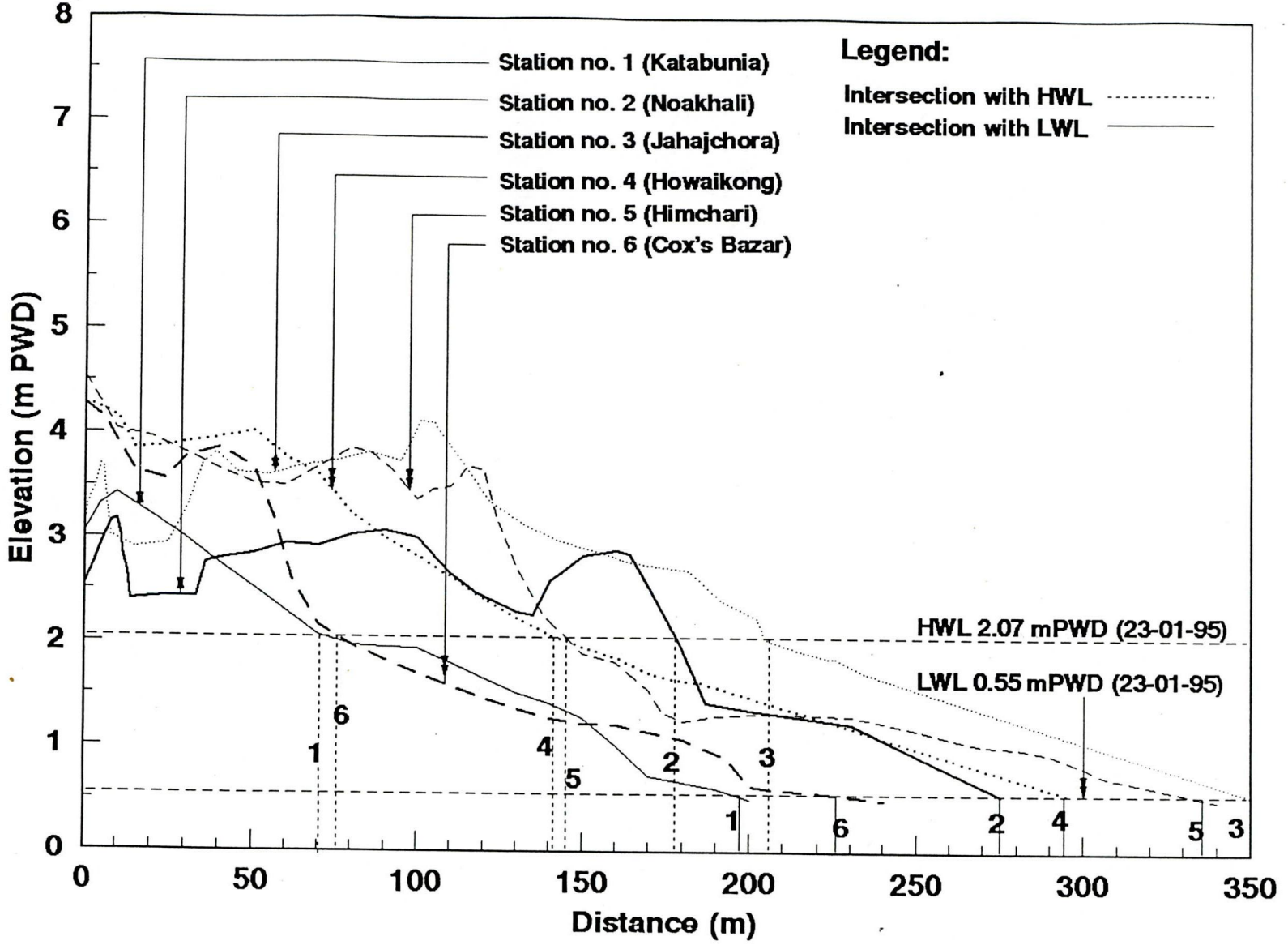


Figure No. 4. 9 >>> Combined diagram of the sampling stations

As found in the analysis of Longitudinal profile in Figure no. 4.7, the elevation of the beach is the highest at Jahajchora (Station no. 3), whereas the beach is at the lowest elevation at Cox's bazar. Himchari (Station no. 5) has the second lowest elevation.

4.4 PARTICLE SIZE DISTRIBUTION: OVERALL VARIATION

Figures no. 3.4 through 3.14 presented in Chapter 3, show the gradation curves (particle size distribution) of the collected soil samples. Table 4.2 and 4.3 have been prepared from those curves to show d_{10}, d_{30}, d_{50}, d_{60} and d_{90} (% finer) sizes of the samples. From Table 4.2 it can be seen that the mean particle sizes (d_{50}) of the beach sand at the surface varies between 0.11 mm and 0.23 mm (3.18 phi and 2.12 phi[1]), at 0.3m depth varies between 0.126 mm and 0.235 mm (3.00 phi and 2.09 phi) and at 0.6m depth between 0.135 mm and 0.24 mm (2.89 phi and 2.06 phi). The particle diameters at 10% finer varies between 0.085 mm and 0.155 mm, at 30% finer between 0.095 mm and 0.20 mm, at 60% finer between 0.12 mm and 0.26 mm and at 90% finer between 0.17 mm and 0.39 mm as shown in Table 4.3. Table 4.3 also presents the uniformity co-efficient of the soil samples which varies between 1.33 and 2.28 for the surface samples, between 1.39 and 1.95 for the samples at 0.3m depth and between 1.39 and 2.31 for the samples at 0.6m depth. The beach sands, therefore, are poorly graded with uniformity co-efficient (d_{60}/d_{10}) varying between 1.33 and 2.31.

Table 4.4 shows the percentage of silt, clay, fine sand, medium sand, coarse sand and snails at different stations. From this table it is seen that the percentage of medium sand (0.425 mm to 2.00 mm) varies between 0.5 and 5.0 percent through the whole study area. Medium sands are almost absent at Howaikong (Station no. 4). Fine sands (0.075 mm to 0.425 mm) are mostly abundant in the study area and varies between 94%

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1 phi units $= -\text{Log}_2 d(\text{mm})$
$= -\text{Log}_2 e \times \text{Log}_e d$
$= -1/(\text{Log}_e 2) \times \text{Log}_e d$

Table 4.2

PARTICLE SIZE DIAMETER OF DIFFERENT SAMPLES

Station no.	Dist.(m)	Mean Particle Size, Diameter in mm and phi units									Remarks
		Surface Sample			0.3m below Surface			0.6m below Surface			
		d_{50}	Dia (phi)	Sam no.	d_{50}	Dia (phi)	Sam no.	d_{50}	Dia (phi)	Sam no.	
1	0	0.145	2.79	1–3–1	0.15	2.74	1–3–2	0.165	2.6	1–3–3	Location 3
	60	0.19	2.4	1–2–1	0.17	2.56	1–2–2	0.17	2.56	1–2–3	Location 2
	130	0.215	2.22	1–1–1	0.196	2.35	1–1–2	0.195	2.36	1–1–3	Location 1
2	0	0.16	2.64	2–3–1	0.17	2.56	2–3–2	0.178	2.49	2–3–3	Location 3
	68	0.197	2.34	2–2–1	0.17	2.56	2–2–2	0.197	2.34	2–2–3	Location 2
	129	0.21	2.25	2–1–1	0.195	2.36	2–1–2	0.18	2.47	2–1–3	Location 1
3	0	0.155	2.69	3–3–1	0.165	2.6	3–3–2	0.168	2.57	3–3–3	Location 3
	38	0.155	2.69	3–2–1	0.17	2.56	3–2–2	0.17	2.56	3–2–3	Location 2
	83	0.148	2.76	3–1–1	0.23	2.12	3–1–2	0.22	2.18	3–1–3	Location 1
4	0	0.11	3.18	4–3–1	0.14	2.84	4–3–2	0.15	2.74	4–3–3	Location 3
	40	0.112	3.16	4–2–1	0.16	2.64	4–2–2	0.18	2.47	4–2–3	Location 2
	80	0.127	2.98	4–1–1	0.173	2.53	4–1–2	0.156	2.68	4–1–3	Location 1
5	0	0.22	2.18	5–3–1	0.208	2.27	5–3–2	0.2	2.32	5–3–3	Location 3
	46	0.17	2.56	5–2–1	0.165	2.6	5–2–2	0.18	2.47	5–2–3	Location 2
	178	0.125	3	5–1–1	0.115	3.12	5–1–2	0.116	3.11	5–1–3	Location 1
6	0	0.23	2.12	6–3–1	0.235	2.09	6–3–2	0.24	2.06	6–3–3	Location 3
	102	0.145	2.79	6–2–1	0.126	3	6–2–2	0.135	2.89	6–2–3	Location 2
	131	0.17	2.56	6–1–1	0.16	2.64	6–1–2	0.157	2.67	6–1–3	Location 1

INTERMEDIATE SOIL SAMPLES

Sample no.	Mean dia (phi units)	Mean dia (mm)	Remarks
I.S.S–1	2.06	0.24	Beach with Boulders at Jahajchora
I.S.S–2	3.1	0.117	Outfall of Silkhali khal
I.S.S–3	2.64	0.16	Outfall of Monkhali khal
I.S.S–4	2.56	0.17	Outafall of Inany khal
I.S.S–5	2.15	0.226	Outfall of Reju khal
I.S.S–6	2.75	0.149	Outafall of Himchari khal
I.S.S–7	2.84	0.14	South of Bagkhali river

Table 4.3

GRADING PARAMETERS

Sample Location	Station No.	Sample No	D10	D30	D50	D60	D90	Cu	Station No.	Sample No	D10	D30	D50	D60	D90	Cu
Surface Sample	1	1-1-1	0.12	0.18	0.215	0.234	0.35	1.95	4	4-1-1	0.086	0.106	0.127	0.14	0.22	1.63
		1-2-1	0.145	0.17	0.19	0.21	0.3	1.45		4-2-1	0.09	0.095	0.112	0.12	0.17	1.33
		1-3-1	0.09	0.12	0.145	0.158	0.22	1.76		4-3-1	0.09	0.096	0.11	0.12	0.17	1.33
	2	2-1-1	0.155	0.18	0.21	0.226	0.3	1.46	5	5-1-1	0.085	0.11	0.125	0.146	0.27	1.72
		2-2-1	0.115	0.165	0.197	0.215	0.26	1.87		5-2-1	0.11	0.16	0.17	0.185	0.27	1.68
		2-3-1	0.096	0.135	0.16	0.17	0.22	1.77		5-3-1	0.15	0.19	0.22	0.235	0.33	1.57
	3	3-1-1	0.1	0.135	0.148	0.15	0.22	1.50	6	6-1-1	0.09	0.13	0.17	0.205	0.35	2.28
		3-2-1	0.1	0.14	0.155	0.16	0.27	1.60		6-2-1	0.09	0.12	0.145	0.16	0.25	1.78
		3-3-1	0.095	0.13	0.155	0.165	0.22	1.74		6-3-1	0.135	0.19	0.23	0.25	0.34	1.85
Sample at 0.3m Depth	1	1-1-2	0.11	0.155	0.196	0.215	0.33	1.95	4	4-1-2	0.116	0.16	0.173	0.185	0.24	1.59
		1-2-2	0.12	0.155	0.17	0.185	0.29	1.54		4-2-2	0.1	0.14	0.16	0.17	0.23	1.70
		1-3-2	0.091	0.125	0.15	0.16	0.22	1.76		4-3-2	0.09	0.12	0.14	0.16	0.22	1.78
	2	2-1-2	0.125	0.17	0.195	0.215	0.35	1.72	5	5-1-2	0.09	0.095	0.115	0.125	0.2	1.39
		2-2-2	0.1	0.155	0.17	0.185	0.25	1.85		5-2-2	0.11	0.15	0.165	0.17	0.24	1.55
		2-3-2	0.103	0.15	0.17	0.18	0.23	1.75		5-3-2	0.14	0.18	0.208	0.225	0.32	1.61
	3	3-1-2	0.15	0.19	0.23	0.26	0.37	1.73	6	6-1-2	0.1	0.14	0.16	0.175	0.23	1.75
		3-2-2	0.1	0.118	0.17	0.185	0.27	1.85		6-2-2	0.085	0.11	0.126	0.135	0.21	1.59
		3-3-2	0.11	0.14	0.165	0.175	0.23	1.59		6-3-2	0.15	0.2	0.235	0.255	0.34	1.70
Sample at 0.6m Depth	1	1-1-3	0.1	0.15	0.195	0.215	0.29	2.15	4	4-1-3	0.096	0.14	0.156	0.17	0.23	1.77
		1-2-3	0.11	0.15	0.17	0.185	0.25	1.68		4-2-3	0.12	0.16	0.18	0.195	0.24	1.63
		1-3-3	0.12	0.15	0.165	0.175	0.23	1.46		4-3-3	0.09	0.12	0.15	0.17	0.23	1.89
	2	2-1-3	0.12	0.16	0.18	0.195	0.27	1.63	5	5-1-3	0.09	0.095	0.116	0.125	0.2	1.39
		2-2-3	0.12	0.17	0.197	0.215	0.26	1.79		5-2-3	0.11	0.16	0.18	0.19	0.3	1.73
		2-3-3	0.108	0.155	0.178	0.19	0.24	1.76		5-3-3	0.13	0.17	0.2	0.22	0.3	1.69
	3	3-1-3	0.108	0.17	0.22	0.25	0.36	2.31	6	6-1-3	0.09	0.125	0.157	0.18	0.33	2.00
		3-2-3	0.11	0.145	0.17	0.18	0.23	1.64		6-2-3	0.086	0.115	0.135	0.145	0.25	1.69
		3-3-3	0.11	0.145	0.168	0.18	0.23	1.64		6-3-3	0.152	0.195	0.24	0.25	0.35	1.64
Intermediate Soil Sample		I.S.S - 1	0.14	0.2	0.24	0.26	0.39	1.86								
		I.S.S - 2	0.085	0.1	0.117	0.13	0.19	1.53								
		I.S.S - 3	0.11	0.14	0.16	0.17	0.27	1.55								
		I.S.S - 4	0.11	0.15	0.17	0.18	0.25	1.64								
		I.S.S - 5	0.155	0.195	0.226	0.24	0.35	1.55								
		I.S.S - 6	0.088	0.12	0.149	0.16	0.3	1.82								
		I.S.S - 7	0.088	0.12	0.14	0.15	0.23	1.70								

D10 – Particle diameter at 10% Finer
D30 – Particle diameter at 30% Finer
D50 – Particle diameter at 50% Finer
D60 – Particle diameter at 60% Finer
D90 – Particle diameter at 90% Finer
Cu = Uniformity Co-efficient = D60/D10

Table 4.4

ASTM CLASSIFICATION OF SOIL

Sieve no.	>> 4	10	40	200	200 <<
Dia. in mm	>> 4.75	2	0.425	0.075	0.075 <<
Classification	Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines (Silt & Clay)

Station no.	Sample no	% Coarse Sand	% Medium sand	% Fine Sand	% Fines (Silt & Clay)	% Snails
1	1-1-1	0	5	94.4	0.6	4.4
	1-1-2	0	4	94.6	1.4	1.2
	1-1-3	0	3.5	96.3	0.2	0.8
Katabunia	1-2-1	0	2.5	96.7	0.8	0
	1-2-2	0	2	96.8	1.2	0
	1-2-3	0	1.5	97.3	1.2	0
	1-3-1	0	0	98.4	1.6	0
	1-3-2	0	0	98.8	1.2	0
	1-3-3	0	0	99.6	0.4	0
2	2-1-1	0	2.5	96.1	1.4	0.8
	2-1-2	0	3.5	96.09	0.41	3.2
	2-1-3	0	1	98.2	0.8	0.8
	2-2-1	0	1	98.2	0.8	0
Noakhali	2-2-2	0	1.5	98.1	0.4	0
	2-2-3	0	0.5	98.5	1	0
	2-3-1	0	0	97.2	2.8	0
	2-3-2	0	0	99.2	0.8	0
	2-3-3	0	0	99.6	0.4	0
3	3-1-1	0	0	99.4	0.6	0
	3-1-2	0	4.5	95.3	0.2	1.2
	3-1-3	0	3.5	94.5	2	0
	3-2-1	0	2	97	1	0
Jahajchora	3-2-2	0	1	98.4	0.6	0
	3-2-3	0	0	99.6	0.4	0
	3-3-1	0	0	99.2	0.8	0
	3-3-2	0	0	99.4	0.6	0
	3-3-3	0	0	99.2	0.8	0
4	4-1-1	0	1	95.2	3.8	0
	4-1-2	0	1.5	97.1	1.4	0
	4-1-3	0	1	98.2	0.8	0
	4-2-1	0	0	98.2	1.8	0
	4-2-2	0	0	99.2	0.8	0
Howaikong	4-2-3	0	1	98.4	0.6	0
	4-3-1	0	0	98.8	1.2	0
	4-3-2	0	0	98.6	1.4	0
	4-3-3	0	0	99.2	0.8	0
5	5-1-1	0	1.5	97.5	1	0.6
	5-1-2	0	0	96.8	3.2	0.8
	5-1-3	0	0	96.98	3.02	0.6
	5-2-1	0	1.5	98.1	0.4	0
Himchari	5-2-2	0	1	98	1	0
	5-2-3	0	2	97.2	0.8	0
	5-3-1	0	2	97.6	0.4	0
	5-3-2	0	3.5	96.1	0.4	0
	5-3-3	0	2	97.8	0.2	0
6	6-1-1	0	3	94.8	2.2	0
	6-1-2	0	1	97.8	1.2	0
	6-1-3	0	3.5	94.9	1.6	0
	6-2-1	0	1.5	98.1	0.4	0.6
Cox's bazar	6-2-2	0	0.5	96.9	2.6	0.4
	6-2-3	0	1	98.2	0.8	1.2
	6-3-1	0	3	95.6	1.4	0
	6-3-2	0	2.5	96.9	0.6	0
	6-3-3	0	5	94.4	0.6	0
	I.S.S-1	0	4.5	94.89	0.61	2.2
	I.S.S-2	0	0	99	1	0
Intermediate	I.S.S-3	0	1.5	98.3	0.2	0.8
Soil	I.S.S-4	0	0.5	98.9	0.6	0
Sample	I.S.S-5	0	4.5	94.5	1	0
	I.S.S-6	0	2.5	95.1	2.4	0
	I.S.S-7	0	0.5	97.1	2.4	0

Ref: Ralph B. Peck, Walter E. Hanson, Thomas H. Thornburn, 1973, "Foundation Engineering , 2nd Edition, Table 1.1"

to 99%. A small percentage of silt and clay (<0.075 mm), varying between 0.2 to 3.8 percent are present in the soil samples of the beach. No shingles and gravels are found throughout the beach. Scattered boulders (sizes between 0.3m to 0.6m) are found in the foreshore zone at Inany and Jahajchora.

The variation of particle mean diameter at the surface, at 0.3m depth and at 0.6m depth across the stations has been plotted by using Freelance Graphics (a computer software) with distance as the abscissa and the mean diameter as the ordinates as shown in Figures 4.10 through 4.15. The distance shown in the graphs represent the distances between the sample locations only.

4.4.1 Particle size distribution at the bed of the khals

The particle mean diameter of the soil samples at the outfall of the khals is within 0.117 mm to 0.17 mm (3.10 phi to 2.56 phi), only an exception is at the outfall of the Reju khal (ISS-5) where the particle mean diameter is 0.226 mm (2.15 phi).

4.5 PARTICLE SIZE DISTRIBUTION ALONG THE FORESHORE

4.5.1 Surface particle size distribution

From Figure 4.16 it is seen that the surface particle mean diameter between Cox's bazar (Station no. 6) and Himchari (Station no. 5) decreases from 0.17 mm to 0.125 mm . From Himchari (Station no. 5) to Howaikong (Station no. 4), the mean diameter is almost same (0.125 mm and 0.127). From Howaikong (Station no. 4) to Katabunia (Teknaf) (Station no. 1), the particle mean diameter increases from 0.127 mm to 0.215 mm.

It means from all of the above findings that, within the foreshore zone the surface particles are progressively finer from Cox's bazar to Himchari and progressively coarser

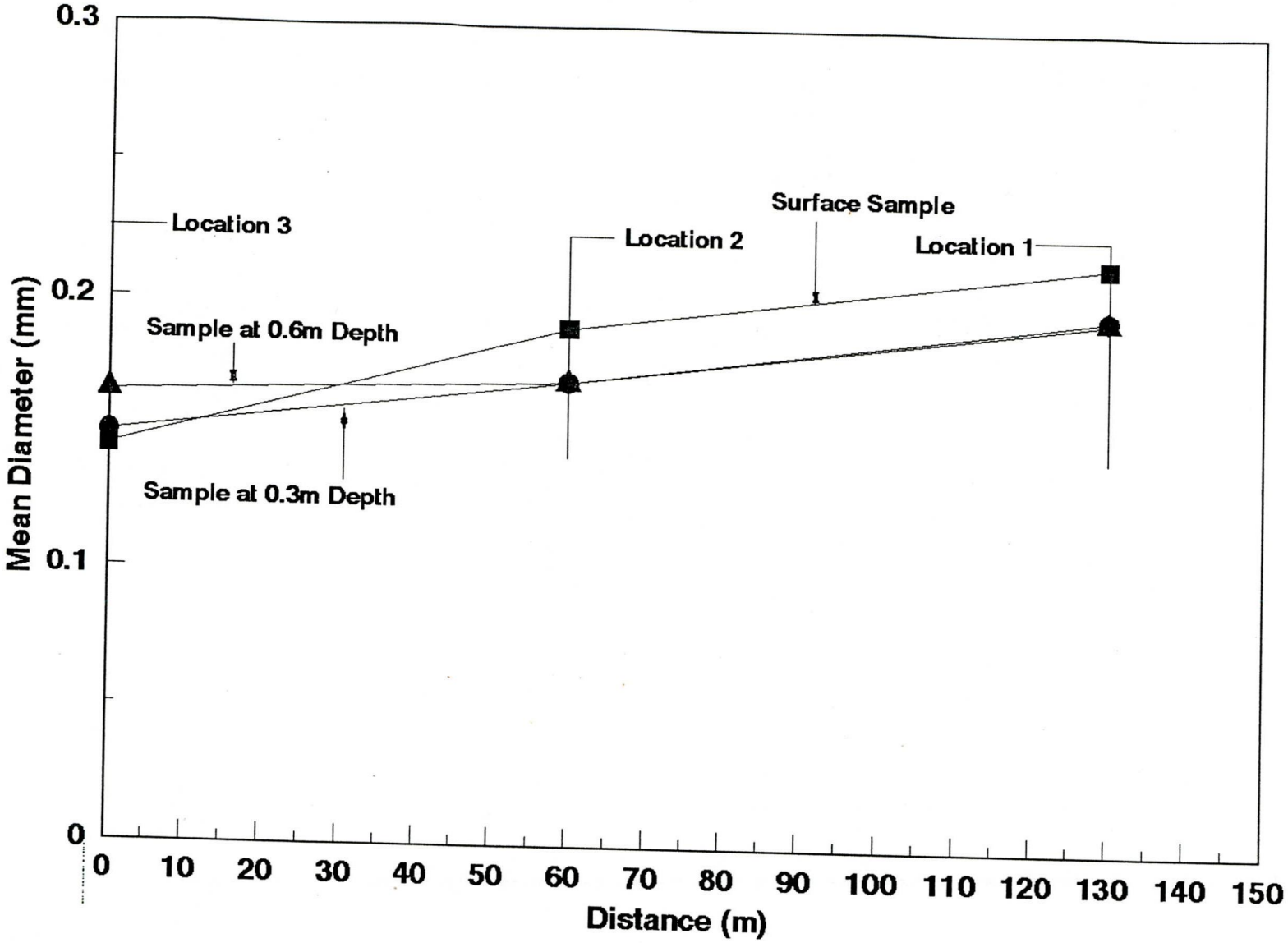

Figure No. 4.10 > > > Variation of Mean Diameter across Station No. 1

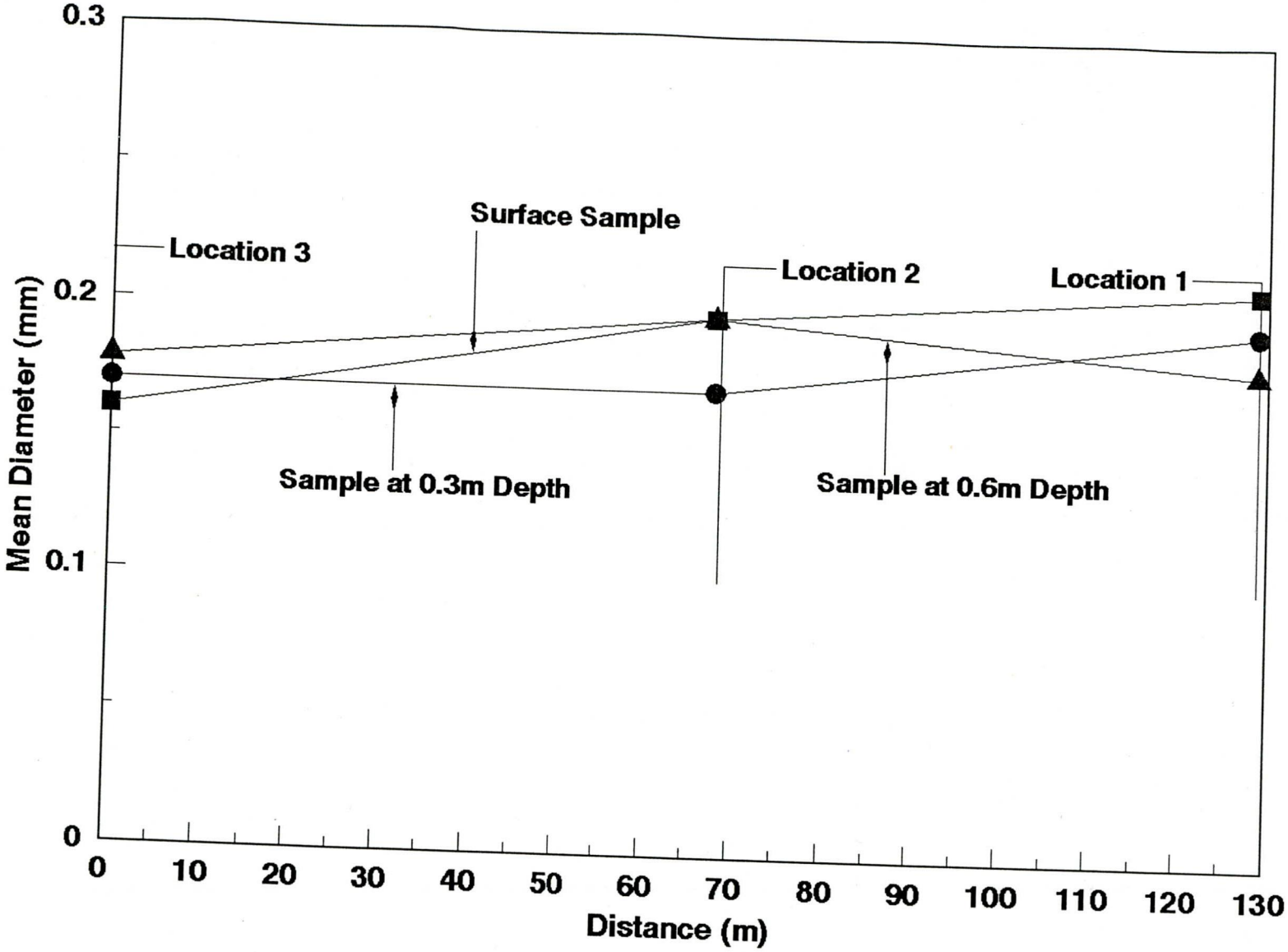

Figure No. 4.11 >>> Variation of Mean Diameter across Station No. 2

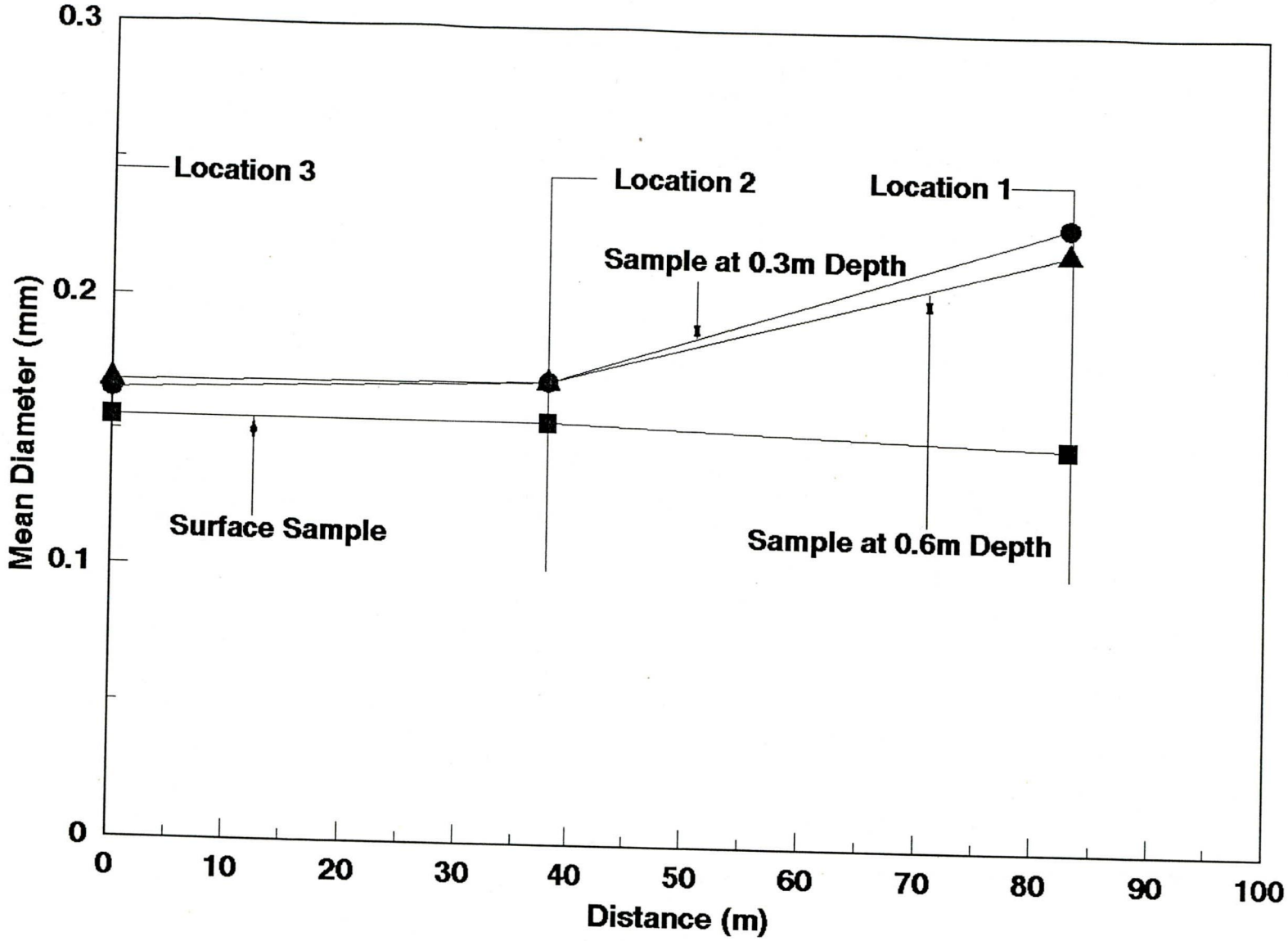

Figure No. 4.1 2 > > > Variation of Mean Diameter across Station No. 3

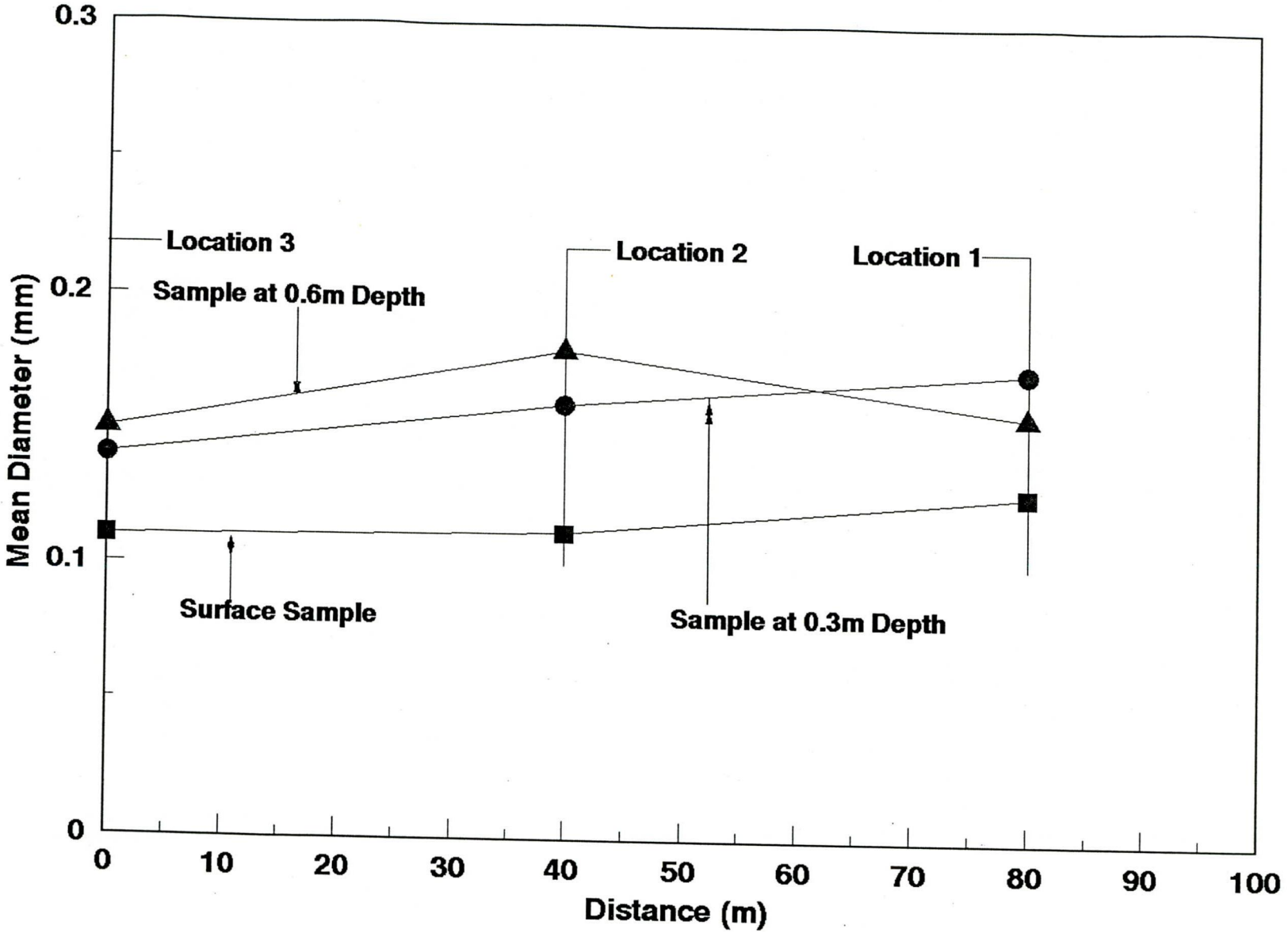

Figure No. 4.13 >>> Variation of Mean Diameter across Station No. 4

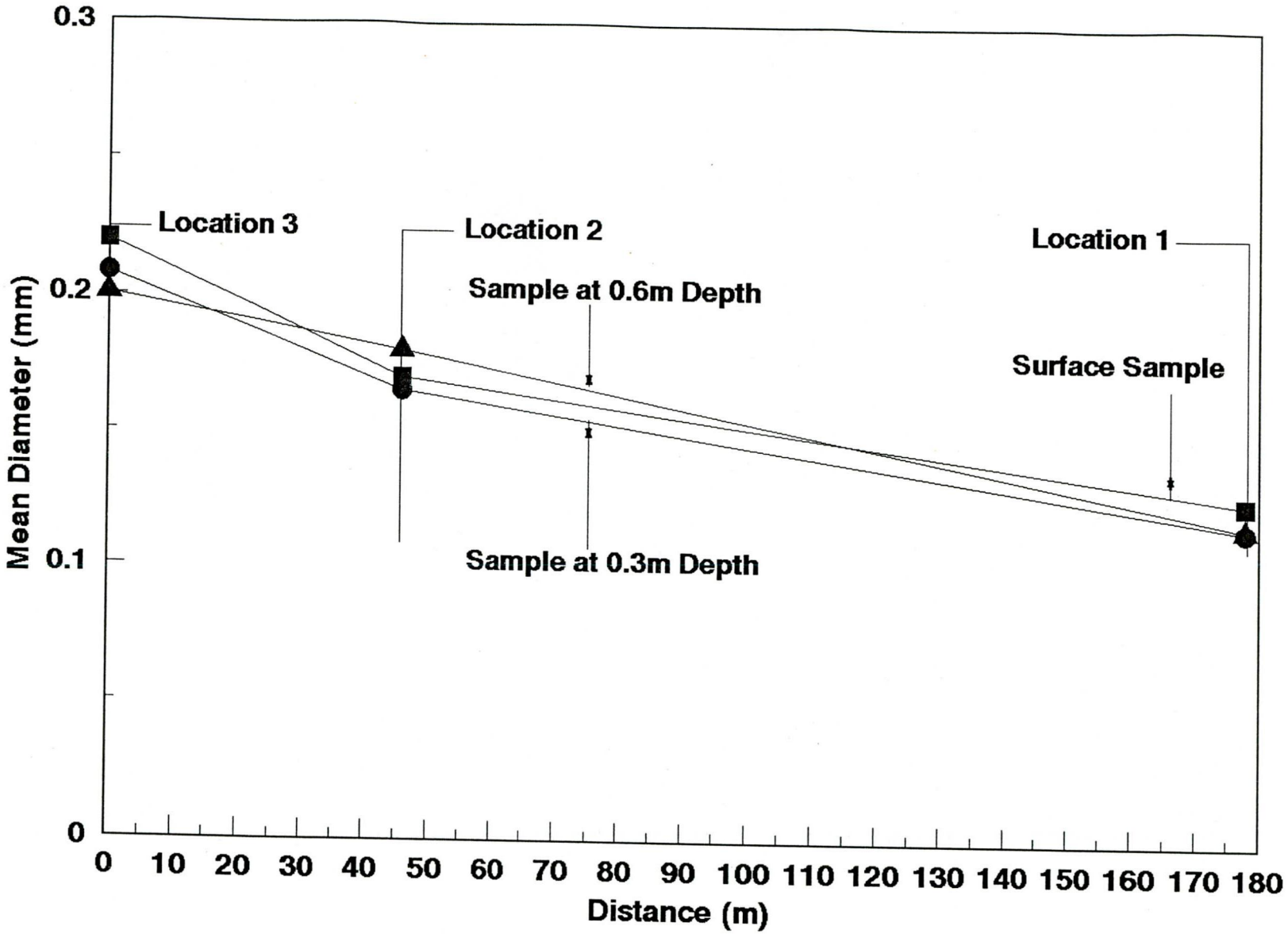

Figure No. 4.14 >>> Variation of Mean Diameter across Station No. 5

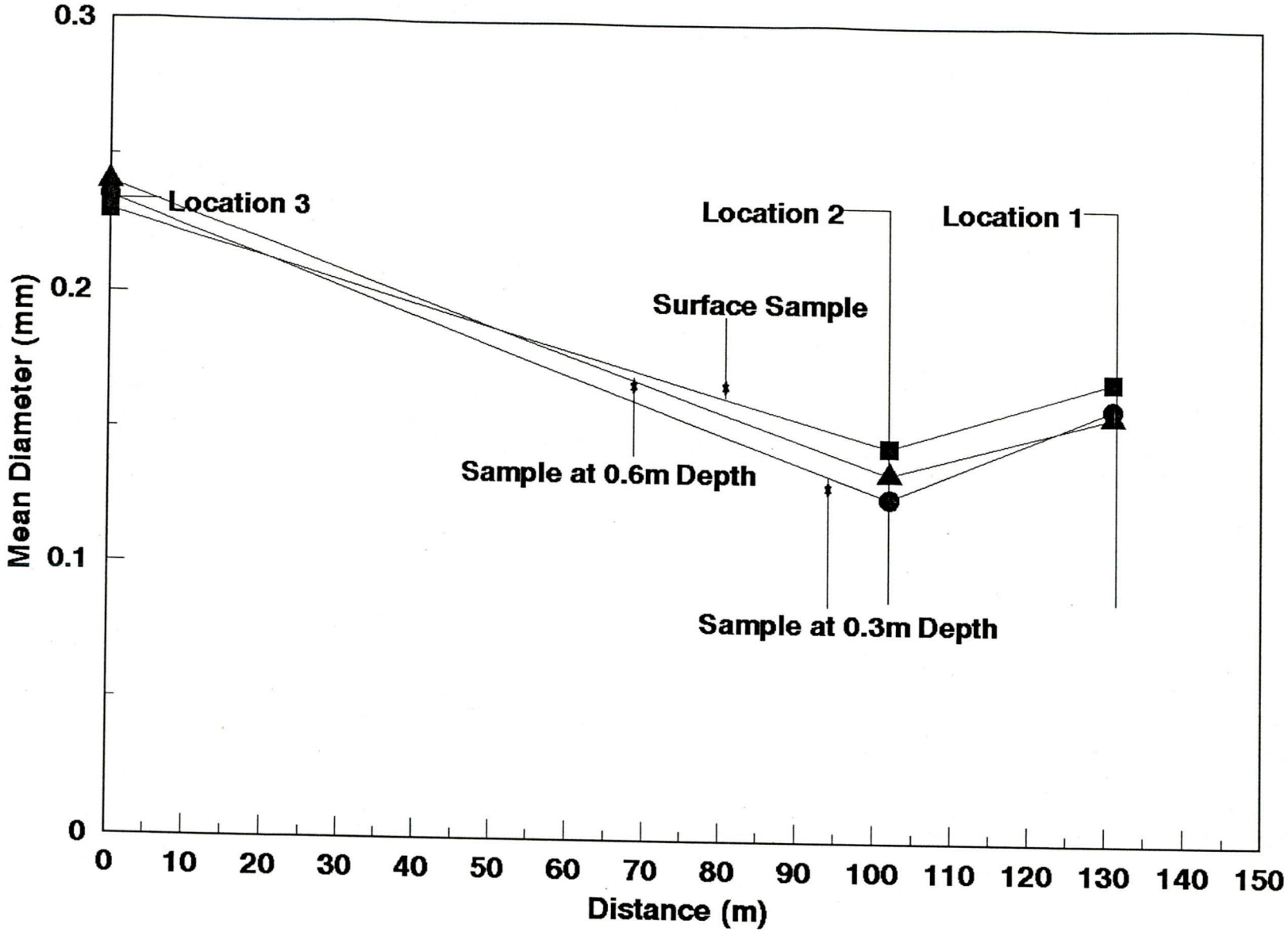

Figure No. 4.15 >>> Variation of Mean Diameter across Station No. 6

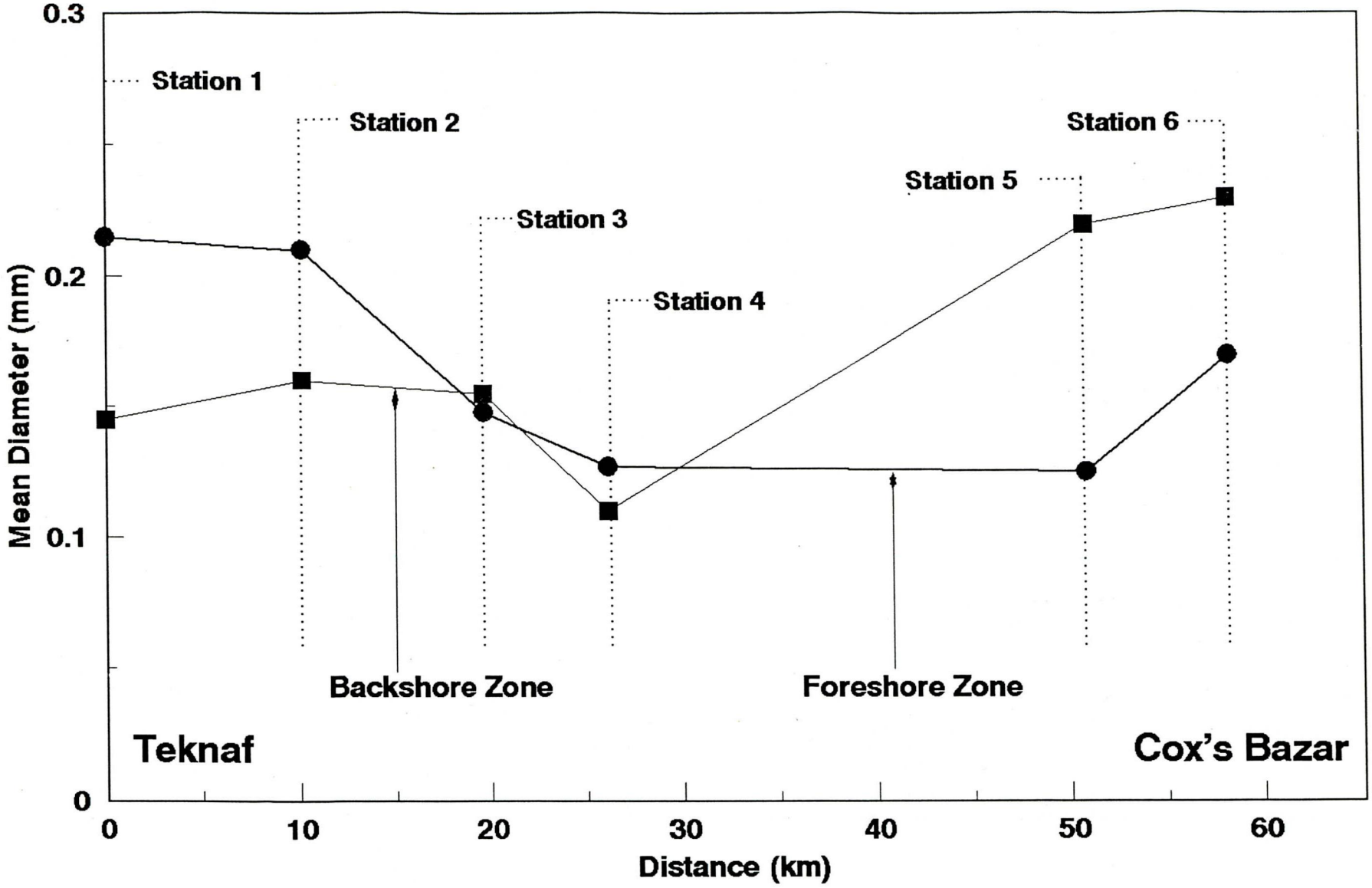

Figure No. 4.16 >>> Variation of Particle Mean Diameter along the Beach at the Surface

from Howaikong to Katabunia. In between Himchari and Howaikong, the particle mean diameter of the surface soil samples within the foreshore zone remain almost same.

4.5.2 Particle size distribution at 0.3m depth

Figure no. 4.17 shows the variation of the particle mean diameter at 0.3m depth in the foreshore zone along the beach. The figure shows that the particle mean diameter decreases from Cox's bazar (Station no. 6) to Himchari (Station no. 5) from 0.16 mm to 0.115 mm. From Himchari (Station no. 5) to Jahajchora (Nhila, Station no. 3), the mean diameter is increasing (0.115 mm to 0.23 mm). From Jahajchora (Station no. 3) to Noakhali (Teknaf, Station no. 2), the particle mean diameter decreases again from 0.23 mm to 0.195 mm. From Noakhali (Station no. 2) to Katabunia (Station no. 1), the mean diameter is almost same (0.195 mm at Noakhali and 0.196 at Katabunia).

The variation of the soil particles at 0.3m depth along the foreshore zone has almost the same trend as that of the variation of soil particles at the surface.

4.5.3 Particle size distribution at 0.6m depth

Figure 4.18 shows the variation of the particle mean diameter at 0.6m depth in the foreshore zone along the beach. It reveals from the figure that the particle mean diameter decreases from Cox's bazar (0.157mm, Station no. 6) to Himchari (0.116mm, Station no. 5). From Himchari (Station no. 5) to Jahajchora (Nhila, Station no. 3), the mean diameter is increasing (0.116 mm to 0.22 mm). Again from Jahajchora (Station no. 3) to Noakhali (Teknaf, Station no. 2), the particle mean diameter decreases from 0.22 mm to 0.18 mm. From Noakhali (Station no. 2) to Katabunia (Station no. 1), the mean diameter is almost same (0.18 mm at Noakhali and 0.195 at Katabunia).

Within the foreshore zone the variation of soil particles at 0.6m depth are, therefore, follow the same trend of that of its upper layer.

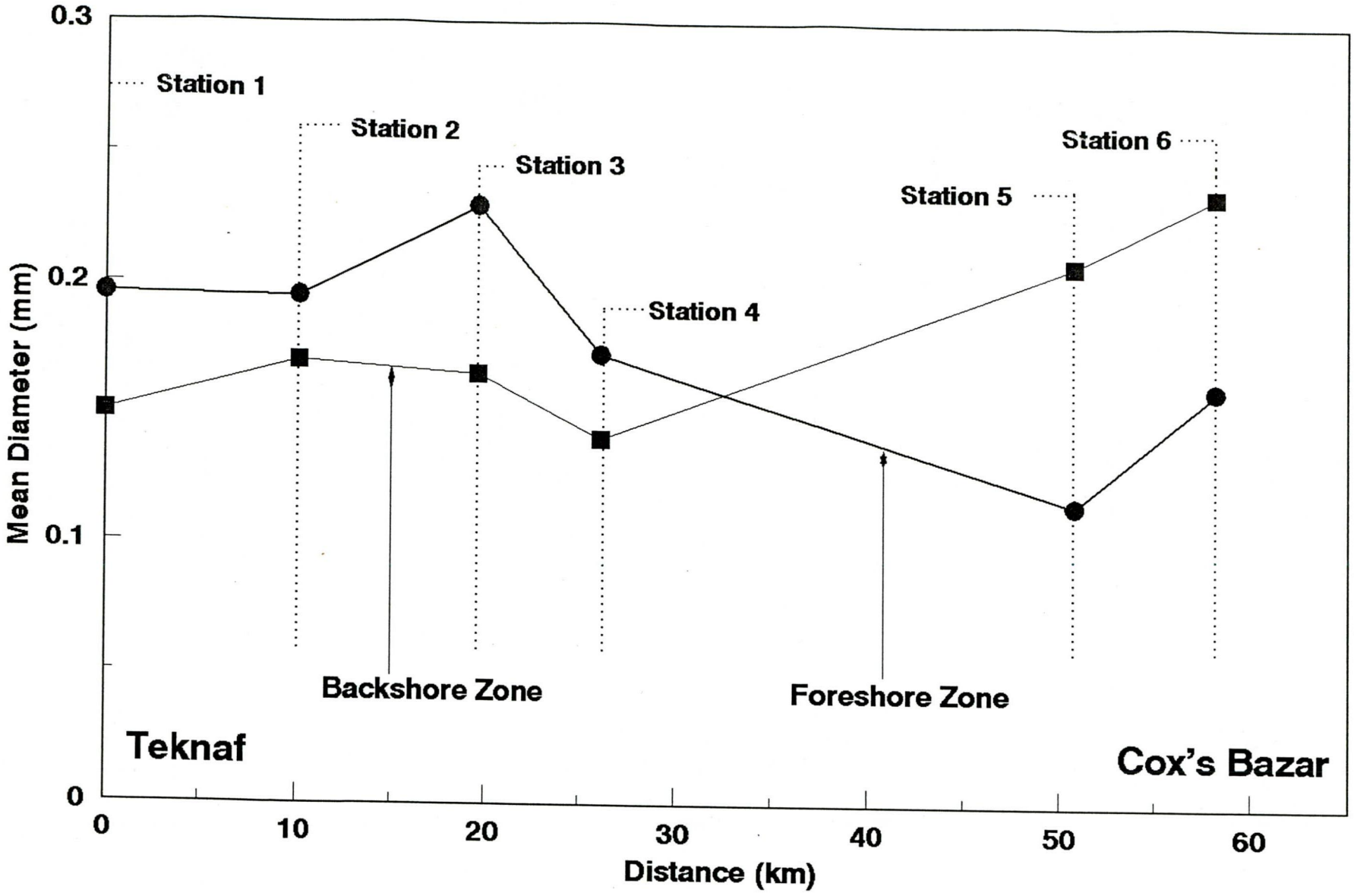

Figure No. 4.17 >>> Variation of Particle Mean Diameter along the Beach at 0.3m Depth

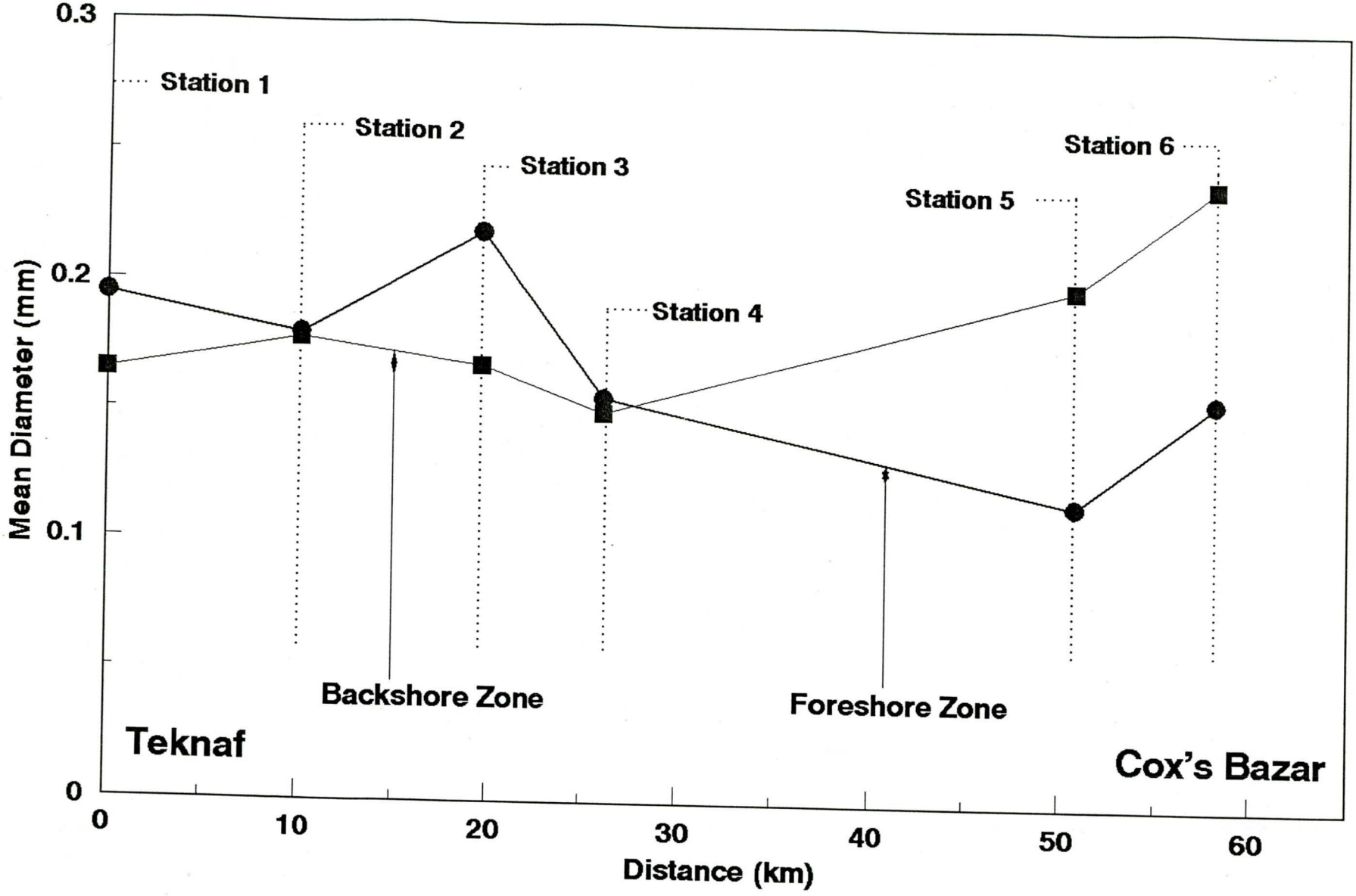

Figure No.4.18 > > > Variation of Particle Mean Diameter along the Beach at 0.6m Depth

4.6 PARTICLE SIZE DISTRIBUTION ALONG THE BEACH IN THE BACKSHORE

4.6.1 Surface particle size distribution

The mean diameter of the surface particle from Cox's bazar (Station no. 6) to Himchari (Station no. 5) are more or less same (Figure 4.16, 0.23 mm at Cox's bazar and 0.22 mm at Himchari). From Himchari (Station no. 5) to Howaikong (Station no. 4), the mean diameter decreases (0.22 mm to 0.11 mm). From Howaikong (Station no. 4) to Noakhali (Station no. 2), the mean diameter increases from 0.11 mm to 0.16 mm and from Noakhali (Station no. 2) to Katabunia (Teknaf, Station no. 1), the particle mean diameter again decreases from 0.16 mm to 0.145 mm.

Within the backshore zone the surface particles are, therefore, becoming progressively finer from Himchari to Howaikong and Noakhali to Katabunia and progressively coarser from Howaikong to Noakhali. In between Cox's bazar and Himchari, the particle mean diameter of the surface soil samples within the backshore zone remain same.

4.6.2 Particle size distribution at 0.3m depth

The particle mean diameter at 0.3m depth (Figure 4.17) decreases from Cox's bazar (Station no. 6) to Howaikong (Station no. 4) from 0.235 mm to 0.14 mm. From Howaikong (Station no. 4) to Noakhali (Station no. 2), the mean diameter increases (0.14 mm to 0.17 mm) and from Noakhali to Katabunia (Station no. 1), the mean diameter decreases (0.17 mm to 0.15 mm).

The variation of the soil particles at 0.3m depth along the backshore zone has almost the same trend as that of the variation of soil particles at the surface.

4.6.3 Particle size distribution at 0.6m depth

Figure no. 4.18 shows the variation of the particle mean diameter at 0.6m depth in the backshore zone along the beach. The particle mean diameter at 0.6m depth decreases from Cox's bazar (Station no. 6) to Howaikong (Station no. 4) from 0.24 mm to 0.15 mm and from Howaikong to Noakhali (Station no. 2), the mean diameter increases (0.15 mm to 0.178 mm). From Noakhali to Katabunia (Station no. 1), the mean diameter decreases (0.178 mm to 0.165 mm).

The trend of variation is therefore as same as those of the upper layers.

4.7 PARTICLE SIZE DISTRIBUTION ACROSS THE BEACH

Close look to Tables 4.2 and 4.3 and Figures 4.10 through 4.15 show that the diameter of the particles normally decreases from the sea side towards landward side, i.e, from Foreshore zone to backshore zone. When the variation along the depth is concerned, the diameter of the particle decreases with depth in the foreshore zone, and increases with depth in the backshore zone.

4.8 WAVE BREAKING PHENOMENON AT THE SHORE LINE

Field observations reveal that waves begin breaking at a relatively great distance from shore and break very gradually as they approach still shallow water. Foams develop at the crest during breaking and leaves a thin layer of foam over a considerable distance. Mostly the wave energy are dissipated within the foreshore and a very little reflection of momentum back toward the sea (Photograph 14).

The significant deep water wave periods is between 11 to 13 sec (FAP -7,Appendix C, 1992). When the waves travel a long distance over shallow water, the

wave breaking cause a lowering of the significant wave period to 7 to 9 sec. (FAP-7, Appendix C, 1992). Considering the still water height above the average level of the sea bed (d) where the wave breaks as 6.0m (19.58 ft.) (the highest value given by FAP-7), the corresponding value of nearshore significant wave height (H_s) is 3.6m (11.81 ft.) (FAP-7, Appendix C, 1992, Table 7.7).

Based on the above information, the wave breaking phenomenon have been analyzed by the method suggested by Battjes (1974) and W W Massie (1986) and are shown in the Appendix. The analysis shows that the wave breaking phenomenon in the coast is of Spilling Type. Figure 4.19 shows the general character of Spilling Breakers.

Photo 14: Wave Breaking in the Bay of Bengal at Cox's bazar.

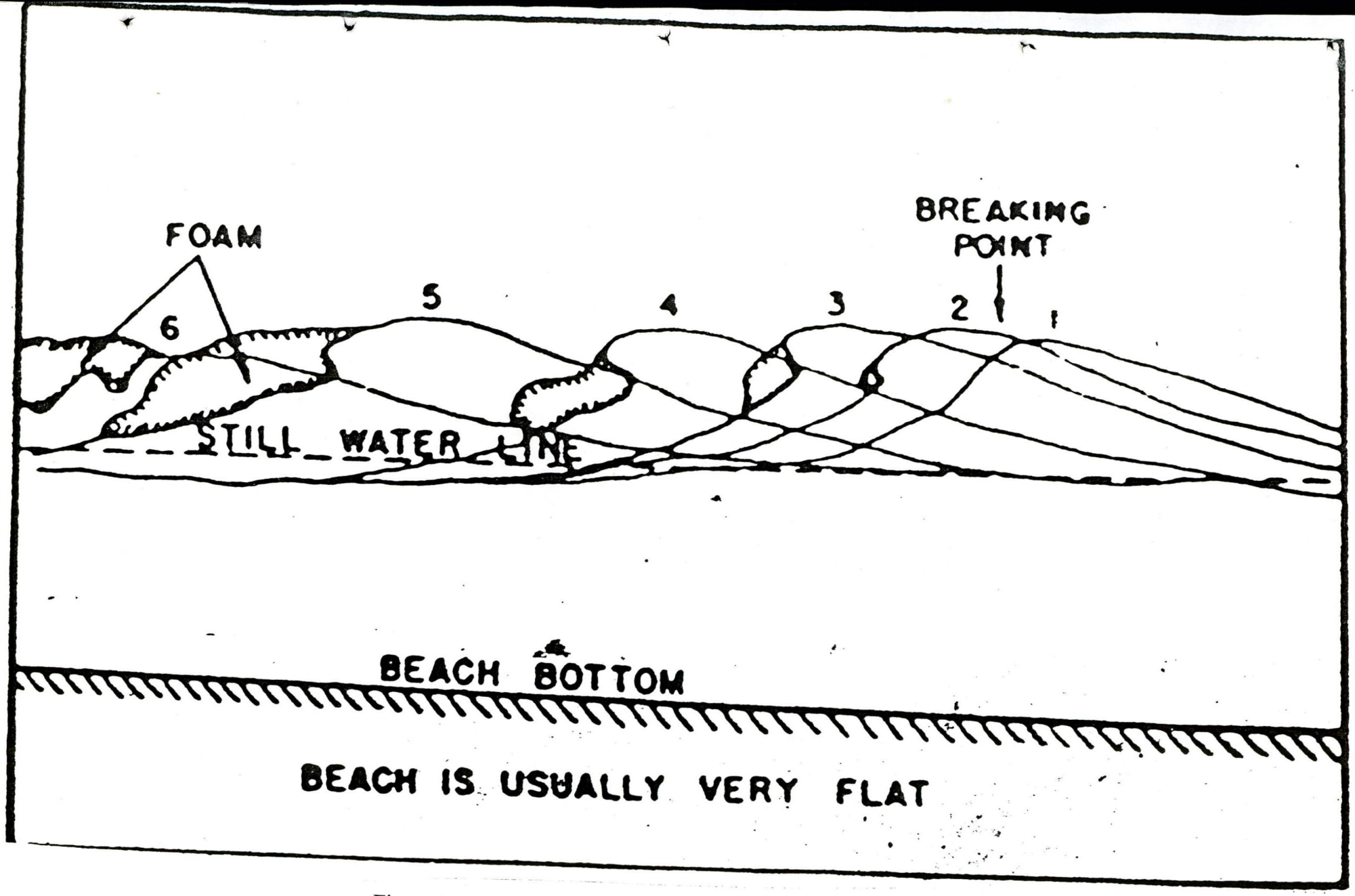

Figure No. 4.19 >>> General Character of Spilling Breakers. (after Wiegel, 1953)

4.9 COAST OF THE WORLD AND COX'S BAZAR - TEKNAF COAST

The Cox's bazar - Teknaf Coast lies between the latitude 21°30′N and 20°50′N. Comparison of the beach material characteristics of the sea coasts and beaches between these latitudes all over the world would have been worthwhile. The Coasts within these latitudes are Atlantic Coast on the eastern side of Mexico, Gulf of Mexico Coast on the eastern side of Mexico, Texas Coast on the eastern side of Mexico, Pacific Coast on the western side of Mexico, Mauretania Coast in north-western Africa, Eastern Coast of Oman, Western Coast of India above Bombay, Eastern Coast of India below Calcutta, Easter Coast of China (Hongkong) etc. But information about these are not readily available.

A survey of the U.S. Coasts was, therefore, made which shows that all the important U.S. Coasts, like Atlantic Coast, Gulf Coast, Pacific Coast, Texas Coast are above the Tropic of Cancer (23.5^0N) (Figure no. 4.20). However, sparse data about the grain size distribution characteristics of some of the U.S. Coasts were available from Shore Protection Manual (SPM, 1984) for comparison. The survey shows that the littoral materials in the Texas Coasts are predominantly fine sand with median diameters between 0.1 and 0.2 mm (3.3 and 2.32 phi) and has the similarity with the south-eastern coast of Bangladesh. It is important to note that from the geographic point of view, the Texas Coast is within the same longitude of South-eastern Coast of Bangladesh in opposite direction. That is, the Bangladesh Coast is in the east longitude of the greenwich and Texas Coast is in the west longitude of greenwich.

4.10 DISCUSSIONS

The sorting pattern, i.e, the sand particle distribution along the beach (foreshore zone) shows that the southern part of the beach (Teknaf - Katabunia area) is characterized by coarser portions of the fine sand group (0.075 mm to 0.425 mm), and towards north the particle diameter becomes progressively finer upto Cox's bazar.

As particle size is controlled by wave energy and by the nature of available material adjacent to the area, it can be said that the Teknaf - Katabunia area and the outfall of the Naf river may the source of supply of the beach sand in the study area. The Teknaf Coast is exposed to the sea both at the south and the west. The Cox's bazar Coast is exposed to the sea at the west. The waves move from south to the north and as it move northward, the relatively coarser particles are gradually deposited in the beach as the dissipation of the wave energy make the wave weaker and weaker. It can be mentioned here that a huge land has been accreted at Badarmokkam at the confluence of the Naf river with the Bay of Bengal. Field observation confirms that the accreted land is full of sand deposition and hence probably the sand deposited within the accreted land at Badarmokkam is greatly influencing the distribution pattern of the beach sand.

The samples within the backshore is influenced by the upstream sheet flow due to rains and floods towards the beach. The particle mean diameter has an overall decreasing trend from Cox's bazar at the north to Teknaf at the south along the backshore.

Considering the cross-wise surface particle distribution at the stations, the fact is that, the wave after breaking deposits the coarser particles within the foreshore zone and as it proceeds towards landward as wave rush, it deposits the finer particles. This phenomenon is clear at Station nos. 1 through 4 (Katabunia to Howaikong). After Howaikong, the situation seems to be reverse. Possibly the sand deposition at this location (adjacent to Cox's bazar) is more influenced by the upland discharge and sediment flow, specially from Moheskhali and Bagkhali rivers. The trend of the surface particle deposition (Figure 4.7) also suggest this.

Analyzing the variation of the particles along the depth at a station in the foreshore zone, the finer particles are lying over the coarser particles as per normal phenomenon at Station nos. 3 and 4. However, the deposition pattern at Station nos. 1, 2, 5 and 6, where coarser particles are lying above finer particles is not still fully

understood. It may happen that the storm surges during cyclones have influenced the pattern.

This study under field investigation could not find any trend of beach erosion or loss of beach materials. The width of the beach appears to be of reasonable dimension, not being too short, nor too long, and convenient to pleasure maker and sight-seeing lovers.

Figure No. 4.20 > > > The Coasts of U.S.A.

CHAPTER 5

CONCLUSIONS AND SUGGESTIONS FOR FUTURE STUDY

5.1 CONCLUSIONS

From the present study the following can be concluded:

i) The overall shape of the beach (foreshore zone) from Cox's bazar to Teknaf is concave downward (hump shaped). The beach surface elevation increases from Cox's bazar to Jahajchora and then the elevation decreases towards the sea;

ii) The widths of the beach (foreshore zone) varies between 110m to 170m;

iii) The beach has got very flat slope and lies between 1:65 and 1:120 (vertical to horizontal). The beach is relatively flatter at the north (Cox's bazar side) than at the south (Teknaf-Katabunia side);

iv) The beach is more or less stable even though it has been subjected to storm surges over the historical periods and the stability is more at the north compared to the south. The flatter slope at the north compared to the south may be the state of more stability.

v) The waves in the beach approaches from the south and the wave breaking phenomenon is of spilling type;

vi) The particle mean diameter of the surface samples vary between 0.125 mm and 0.215 mm (3.00 phi and 2.22 phi) within the foreshore zone and between 0.11 mm and 0.23 mm (3.18 phi and 2.12 phi) within the backshore zone. The surface particle mean diameter along the beach found from this study conforms to that of the findings by

Biswas (1988) in which it was shown that the particle mean diameter varied between 0.11 mm to 0.28 mm (3.18 phi to 1.94 phi) in the upper foreshore zone (close to backshore zone) during winter;

vii) The particle mean diameter within the foreshore zone shows that particle sizes at the surface, at 0.3m depth and at 0.6m depth are becoming finer from Cox's bazar to Howaikong and progressively coarser from Howaikong to Katabunia. In between Himchari and Howaikong, the particle mean diameter of the surface soil samples within the foreshore zone remain almost same;

viii) The particle mean diameter decreases from the sea side towards landward across the beach. Also the particle mean diameter increases down in the foreshore zone and decreases down in the backshore zone;

ix) The particle mean diameter within the backshore zone are becoming progressively finer from Cox's bazar to Howaikong and Noakhali to Katabunia and progressively coarser from Howaikong to Noakhali;

x) The particle mean diameter is the highest at Jahajchora where the beach is covered with boulders. The particle mean diameter at the outfall of the Reju khal is about 0.226mm and is the coarsest among the khals. No co-relation could be found between the bed materials of the khals (which varies between 0.117mm and 0.226mm) and the surrounding beach materials;

xi) The beach materials of Cox's bazar - Teknaf Coast (0.11mm - 0.24mm) can be considered similar to the grain size characteristics of the Texas Coast (Gulf Coast of USA). An interesting similarity can also be mentioned in its global physical position, i.e, the Texas Coast is within the same longitude of South-eastern Coast of Bangladesh in opposite direction.

5.2 SUGGESTIONS FOR FUTURE STUDY

i) This study was done during winter (January 1995). It is about 4 years after severe storm surges in April 1991. Since the coast is subjected to frequent attack by the storm surges, investigations immediately after any storm surges in the future will be worthwhile for useful comparison.

ii) It was found by the earlier investigator that beach materials are slightly coarser in summer season compared to winter season. An investigation in summer, when wind and wave characteristics are opposite to the winter situation will, therefore, be useful in understanding season to season variation of beach materials. Moreover, quantitative studies on waves phenomenon and longshore transport will also be worthwhile.

iii) A Bench Mark Station at Teknaf will be useful for conducting topographic, hydrographic survey etc. in the area.

APPENDIX

A. BATTJES 1974, Breaking Types as a function of

Battjes described the following criteria for breaking phenomenon:

$= \tan a / (H_s/L_0)^{1/2}$

when > 5 wave breaking will be Surging type,

when $3.3 < < 5$ wave breaking will be Collapsing type,

when $0.5 < < 3.3$ wave breaking will be Plunging type,

when < 0.5 wave breaking will be Spilling type.

where $\tan a$ = Beach cross slope at foreshore,

H_s = Significant Shallow Water Wave Height

L_0 = Deep Water Wave Length = $5.22\ T^2$, where T is deep water wave period in sec.

Now, in our case, $\tan a$ = 1:65 to 1:120 (Table 4.1)

H_s = 11.81 ft

T = 11 sec. (considered)

$L_0 = 5.22\ T^2 = 5.22 \times 11^2 = 631.32$ ft.

Case 1, considering the slope as the steepest, i.e, $\tan a$ = 1:65 = 0.015

$= 0.015 / (11.81/631.32)^{1/2} = 0.11$

Case 2, considering the slope as the flattest, i.e, $\tan a$ = 1:120 = 0.008

$= 0.008 / (11.81/631.32)^{1/2} = 0.06$

So, it is seen that in both the cases the value of is less than 0.5 and as such the wave breaking phenomenon is of Spilling type.

B. W W MASSIE 1986, Breaking Type as a function of $H_0 / (L_0m^2)$

Massie described the following wave breaking phenomenon:

when $0.0 > H_0 / (L_0m^2) < 0.09$ wave breaking will be surging type,
when $0.09 > H_0 / (L_0m^2) < 4.8$ wave breaking will be plunging type
when $4.8 > H_0 / (L_0m^2) <$ wave breaking will be spilling type

where H_0 = Deep water wave height
L_0 = Deep water wave length
m = Beach cross slope at Foreshore

Now, in our case, L_0 = 631.32 ft (as before)
m = 1:65 to 1:120 (Table 4.1)
d = 19.58 ft
H_s = 11.81

Now, using Table C-I of the Shore Protection Manual (Vol. III):
$d/L_0 = 19.58/631.32 = 0.031$, corresponding value of $H_s/H_0 = 1.118$
So, $H_0 = H_s/1.118 = 10.56$ ft.

Case 1, considering the slope as the steepest, i.e, m = 1:65 = 0.015
$H_0 / (L_0m^2) = 10.56/(631.32 \times 0.015^2) = 74.34$

Case 2, considering the slope as the flattest, i.e, m = 1:120 = 0.008
$H_0 / (L_0m^2) = 10.56/(631.32 \times 0.008^2) = 139.39$

So, it is seen that the value is within the range of $4.8 > H_0 / (L_0m^2) <$ in both the cases and as such the wave breaking will be spilling type.

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