1-2-6 Ports

Three Ports handle Sri Lanka's international marine transport namely, Colombo, Trincomalee and Galle. They are all planned, managed and operated by the Sri Lanka Ports Authority (SLPA) which was established as a government owned corporation in 1979. Key performance indicators of the three ports for 1986 and 1987 are summarized in Table 1-11.

TABLE 1-11 Selected Performance Indicators (1986 and 1987)
Ports of Colombo, Trincomalee and Galle

	Colombo		Trincomalee		Galle		Total	
	1986	1987	1986	1987	1986	1987	1986	1987
No. of ship calls	2,505	2,335	220	296	59	83	2,784	2,714
Total GRT of ships serviced ('000s)	24,257	22,330	1,287	1,475	129	224	25,673	24,029
Total tonnage of dry cargo handled ('000)	6,334	7,470	1,180	1,014	169	226	7,663	8,595
Total tonnage of liquid cargo handled ('000s)	2,184	1,327	-	-	-	-	2,187	1,327
Containers handled ('000 TEUs)	341.4 (220.4)	429.3 (300.2)	- -	- -	- -	- -	341.4 (220.4)	429.3 (300.2)

* Figures in brackets are transshipment. Source: SLPA Yearbook 1987

Since the Port of Colombo is described in detail in Chapter 2, the port of Trincomalee and the Port of Galle are described below.

(1) The Port of Trincomalee

The Port of Trincomalee, located on the east coast of Sri Lanka facing the Bay of Bengal, is situated at lat. 8°31'N. long. 81°15'E. The Port of Trincomalee is a good natural harbour located in the innermost part of Trincomalee Bay. The Port of Trincomalee has a land area of 2,036 ha. and a water area of

5,261 ha. The major facilities are positioned in Cod Bay, China Bay, Clappenburg Bay and Malay Cove. The volume of cargo handled during 1987 was 1,013,000 tons and about 60% of the volume was imported wheat. Cargo throughput at Trincomalee accounted for 12% of the total port cargo throughput of the country. A map of Trincomalee Port is attached as Appendix 1-15.

(2) The Port of Galle

The Port of Galle is located in southwestern Sri Lanka at lat. 6°1'N. long. 80°13' E. and Galle was the main Sri Lankan Port before the Port of Colombo was established. The Port of Galle is located about 120 km south of Colombo and is connected with the capital by both roads and railway.

As shown in Appendix 1-3, the Port of Galle is located in the inner eastern part of the bay, and is sheltered from the ocean by stone masonry breakwaters.

For their location, please refer to Appendix 1-16.
The port facilities are located in the narrow port area between the quay and the breakwater of Gibbet Island. A fishery port, a yacht harbour, a slipway and a factory are located around the bay.

The development of Galle port is one of Sri Lanka's highest priority projects under the present government policy. The port, similar to Colombo, is located on the main shipping routes and has the potential to develop into a container transshipment port and complementing Colombo. Though the port of Galle presently handles a certain amount of cargo, a substantial amount investment for breakwaters, channels and basis, which will not yield direct financial benefits, is pre-requisite for large-scale development.

CHAPTER 2 PORT OF COLOMBO

2-1 History and Characteristics of the Port

The Port of Colombo, Sri Lanka's main Port, is on the west coast of the island at latitude 6° 57' North and longitude 79° 51' East, washed by the waves of the Indian Ocean. The Port lies on the traditional sea trade route to Australia, the Far East and South Asia, and links Sri Lanka with Africa, the Gulf, Europe, Canada and the U.S.

Colombo, with its favourable natural conditions, had been a popular trading station of sea-faring Arab merchants and Indian traders. The construction of Colombo as a modern port started in the late 19th century.

The construction of the South west breakwater undertaken in 1875 transformed the roadstead port of call into a port with a safe anchorage. Following the construction of the Southwest breakwater, construction of the Northeast breakwater and the North west breakwater started in 1898 and the port became a world famous bunkering and transshipment port. The extension of the arm to the Southwest breakwater was carried out in 1912.

The Port of Colombo, with approximately 260 hectares of sheltered water area, acted mainly as a lighterage port until 1950.

The first major port development and expansion scheme including construction of modern deepwater wharves was started in 1950.

The completion of the various capital works under the scheme in 1956 resulted in the commissioning of 3,200 meters of deepwater (9 - 11 meters) quays--Queen Elizabeth Quay, Delft Quay (now Bandaranaike Quay), Prince Vijaya Quay and Oil Dock which provided 15 berths and coaster berths at 7.5 meter depth together with 55,800 M^2 of pillarless type transit sheds complete with road and rail access. Other ancillary facilities for ship repair service were also provided.

These improvements in infrastructure together with the favourable location of the harbour on the traditional East-West sea routes, minimal tide variation (a mere 0.95m range) that ensured availability of maximum water depth in the harbour basin and the approaches at all times, served to enhance the reputation of Colombo as a popular port in the Indian region handling conventional cargoes.

In the early 1970s, there was a plan to extend the Queen Elizabeth Quay by 1000 ft. to be utilised for bulk handling of cargo such as fertilizer. But, by the time work was taken in hand, the pattern of international shipping was undergoing rapid changes due to the introduction of containers; and, by 1973, Colombo itself experienced a steady increase in this mode of traffic. It was then decided to complete and fit out the proposed extension for the handling of containers.

With the formation of the Sri Lanka Ports Authority in August 1979, entrusted with the "... Promotion of the use, improvement and development of the specific Ports..." this project received the highest priority and work was expedited on a policy directive from the government the aim of which was to exploit the strategic location of the port and transform it into a modern container handling port attracting transshipment traffic in the region.

The project featured a tied-back concrete cylinder quay wall 1,000' (300m) *400' with a back-up area of 10 acres of newly reclaimed land. The entire project from concept to execution was by the Port's own engineering and technical personnel without foreign funding and foreign consultancy services or contractors. The completed terminal was inaugurated by the President of Sri Lanka on 1st August, 1980.

Parallel action was taken on a priority basis to equip the new terminal with basic specialised equipment such as shifters for the movement and stacking of containers, 40-ton and 25-ton forklift trucks for container handling work and smaller forklifts for stuffing and de-stuffing operations. Later, to enable the terminal to handle "gearless" vessels, a quay-side gantry crane (Tango 80) was obtained on a hire basis and installed on site after shifting QEQ No.4 Transit Shed. Gearless vessels commenced calling at Colombo in October 1982. As Colombo was fast becoming a transshipment point for ports in the Gulf, the Indian sub-continent and East Africa, with more and more gearless vessels calling at the Port, two sets of new Leiberr Gantry Cranes were also installed at the Q.E.Q. Terminal in September 1983 to provide additional cranage (quay-side) to give speedy turn-round to such vessels.

As the Q.E.Q. Container Terminal was hard-pressed to cope with the mounting inflow containers, it was decided to accept one of the proposals made in the Master Plan drawn up by the Japan International Cooperation Agency (JICA) in 1980 to provide additional container berths by constructing a deep-water quay at the site of the Old Coaling Jetties in the northern sector of the Port. Construction work on Stage I of the Port of Colombo Expansion Project began in March 1983 to provide one fully equipped container berth to cater to Third Generation vessels.

In order to cope with the forecast strong traffic demand, work on Stage II to provide a second berth as a southward extension of the first berth was undertaken parallel with work on Stage I, in May 1984. As some shipping lines proposed to deploy Fourth Generation Container Ships (lifting 4,000 TEUs or more) on round-the-world services calling at selected base ports, design changes were effected in respect of Stage II, anticipating future needs. Gantry cranes upgraded for height and reach were installed for Stage I and the equipment for Stage II was upgraded along the same lines. Berth No.I (Stage I) was opened on 2nd August, 1985 and Berth No.II (Stage II) was commissioned on 18th March, 1987. This fully equipped multi-berth terminal and complex designated as the Jaye Container Terminal has enabled Colombo to gear itself to service the fast-growing demands of container traffic and function as a pivotal port handling transshipment in the region.

2-2 Organization and Management

History and Present Organization of SLPA

Since 1918, the Port was administered by the Colombo Port Commission, a governmental department which was made responsible for the supply and maintenance of cargo-handling equipment and other infrastructure, pilotage services, and docking and slipping. The government funded all its activities. Stevedoring and shore handling activities were in the hands of several private wharfage companies. In 1958, the Port (Cargo) Corporation was set up to take over these activities performed by a multiplicity of operators. The Port Tally and Protective Services Corporation was formed in 1967 in order to perform onboard tallying and security services on behalf of agents.

The Sri Lanka Ports Authority (SLPA) was constituted under the provisions of the Sri Lanka Ports Authority Act No.51 of 1979 on 1st August, 1979, having effected the merger of the Colombo Port Commission Department and the two existing statutory corporations. This resulted in a unified organization with a streamlined structure and a cadre of about 22,000. The Ports Authority does not receive financial allocations from the government but operates on its own revenues and resources.

The present organization chart of SLPA is shown in Figure 2-2-1.

The total number of employees as of end of 1988 was 20,407, and the details of the division/section breakdown are attached as Appendix 2-2-1.

SLPA has nine Directors headed by the Chairman. The other eight directors are nominated by the ministers concerned, according to the Ports Authority Act, and represent the various organizations closely related to the Port of Colombo. There is one exception that the Director General of the Customs is always assigned as one of the Directors as stipulated in the Ports Authority act. The functions and organization of the members of the Board of Directors are summarized hereunder.

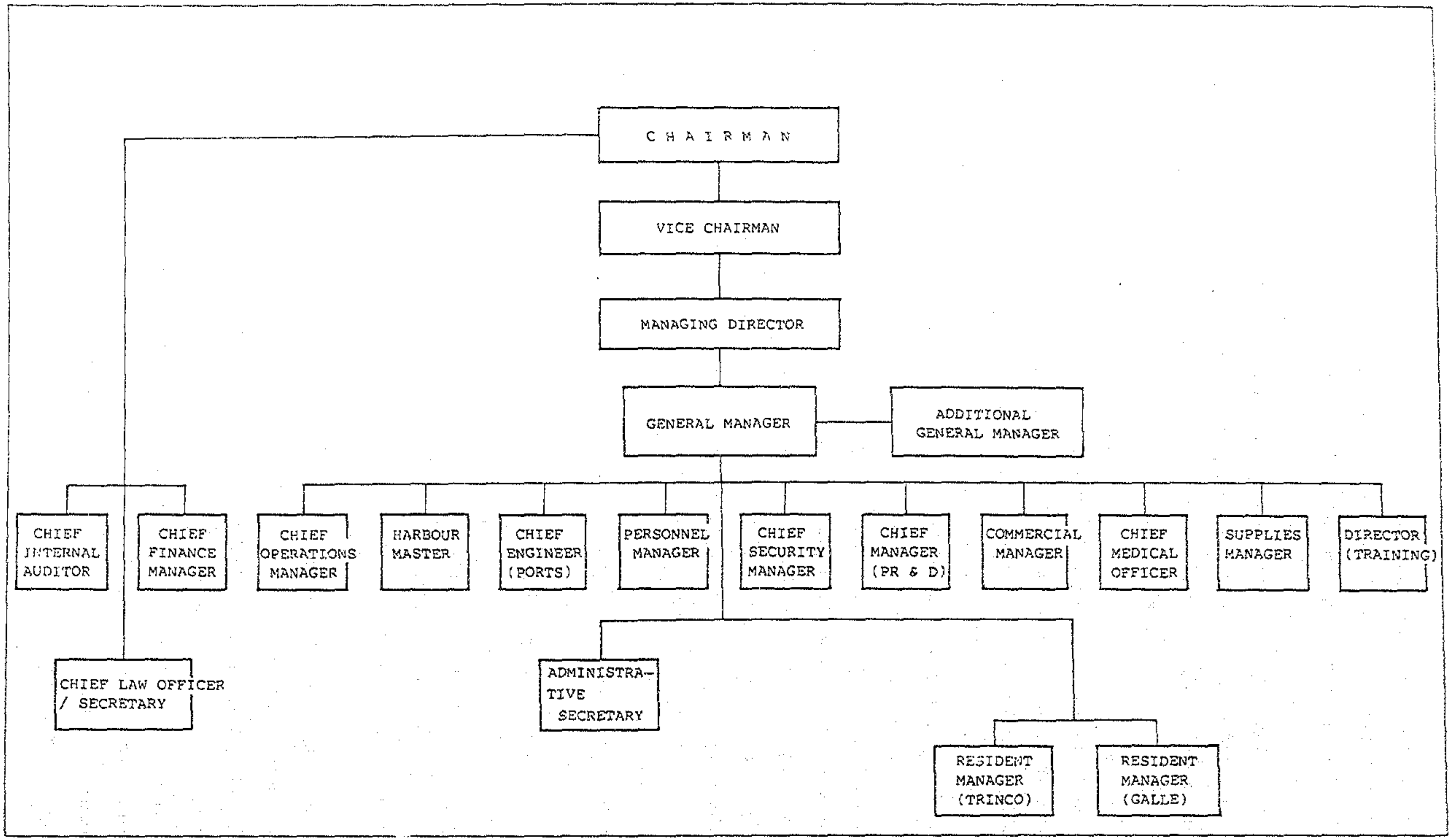


Fig. 2-2-1 Organizational Structure of SLPA

- Chairman
- Vice Chairman (appointed by Minister of Trade and Shipping)
- Director (Full Time)
- Director
- Director
- Managing Director
- Director (Customs)
- Director (Treasury)
- Director (Fisheries)

SLPA is under the jurisdiction of the Ministry of Trade and Shipping.

The main objects and duties of SLPA are as follows.

i) to provide port services such as cargo handling, pilotage, towing, bunkering, water supply, tallying and protective works:

ii) to regulate and control navigation in the ports:

iii) to develop and maintain the ports
(The ports, at present, consist of 4 ports namely, Colombo, Galle, Trincomalle and Kankasenture.)

Ship repair services are available at Colombo Dockyard Ltd. which is located within the Port of Colombo. Other governmental services related to the port provided by the concerned ministries are; i) Customs under the Ministry of Finance ii) Security by Superintendent of the Harbour Police; and Immigration and Emigration Officer under the Ministry of Defence, iii) Quarantine by the Port Health Officer under the Ministry of Health and Women's Affairs, iv) Animal and Plant Quarantine by the Agricultural Officer and Grain and Fruit Fumigation by the Fumigation Unit under the Ministry of Agriculture Food and Co-operative. An organization chart summarizing these relations, is attached as Appendix 2-2-2.

2-3 Facilities and Throughput

2-3-1 Port Facilities

(1) General

The existing layout and facilities of Colombo are shown in Fig. 2-2.

1) The harbour basin is sheltered by three breakwaters, Southwest breakwater, Northwest breakwater (Island breakwater), and Northeast breakwater.

2) There are two entrance channels, a channel (227m in width and 13.0m in depth) between the SW breakwater and the Island breakwater and a channel (154m in width and 10.0m in depth) between the Island breakwater and the NE breakwater.

3) The water area of the Port extends over 224 ha. (at L.W.L.) and has a minimum depth of 11m and a maximum depth of 14m around the center of inner harbour. The sea bed is generally sandy silt, but there are many exposed hard base rocks.

4) Such being the case, vessels up to about 30,000 DWT can enter the port fully loaded. Vessels greater than 30,000 DWT must enter the port partially loaded.

5) Berthing facilities include the Queen Elizabeth Quay (QEQ) along the SW breakwater, the Jaye Container Terminals (JCT #1, #2), the Bandaranaike Quays (BQ), and the North Pier (NP) for a total of 17 deepwater berths with a draft of 9m or over and 19 small berths with a draft of 5.0m or less.

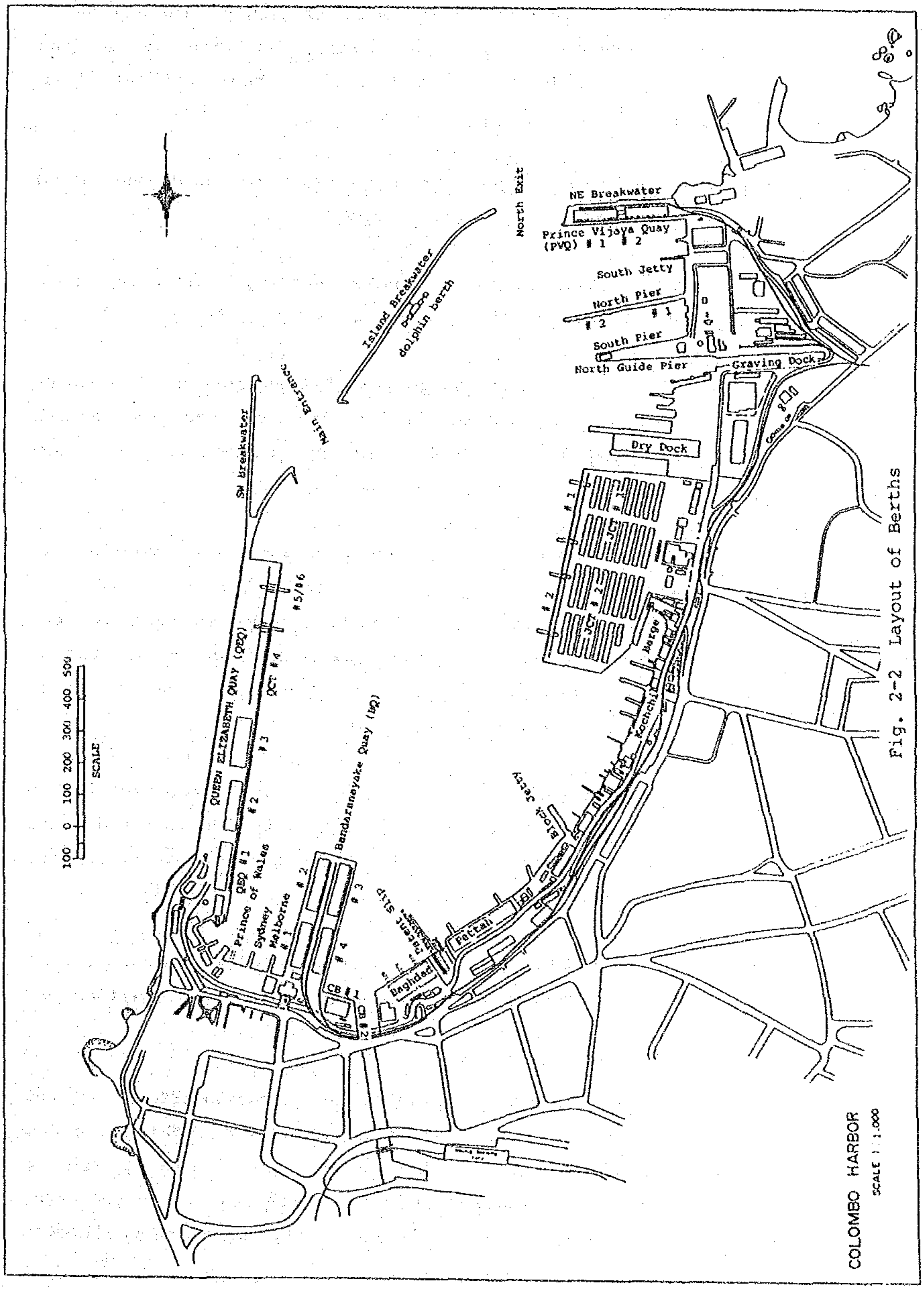


Fig. 2-2 Layout of Berths

6) Of these berths, three berths of QEQ and two berths of JCT are used as container berths, and North Pier and the North Guide Pier (NGP) handle crude oil/petroleum products.

A large oil berth is under construction inside the Island break-water at the middle section.

7) In addition to these regular berthing facilities, there are 18 buoy berths. (A list is shown in Annex 2-3-2)

8) The land portion of the port has a total area of about 102 ha. and includes the Fort Area, Bagdhad Area, Pettah Area and Kochchikade Area, extending from the base of QEQ towards the northeast breakwater.

A road network extends along the waterfront covering the entire port area. Originally, the port road was only two lanes along its entire length, but was expanded to four lanes in the section from the south side of JCT to the base of QEQ. The section from the north side of JCT to PVQ still remain as two lanes.

9) The Port Railway is laid along the port road from the BQ to the north side of JCT, with a portion intruding into the road area and limiting the road width available for traffic.

10) The Fort district accommodates a passenger terminal, buoy berth supply base, barge cargo unloading facilities and water supply barge base.

11) Warehouses are concentrated in the backup area of QEQ and along the waterfront of the Fort ～ Kochchikade area. There are only two other warehouses in the backup area of the Prince Vijaya Quay at the north end of the port area and sheds leased to the Food Public Corporation located

the base of P.V.Q.
(See Annex 2-3-1)

12) In the Pettah-Kochchikade area, shipyards and repair shops for small vessels, a buoy repair shop and a carpenter shop are located here and there. Some of these facilities are extremely old and superannuated. Dangerous cargo storage and the Port fire station are in this area.

13) On the north side of the Kochchikade area is Navy General Headquarters, and there is a barge repair basin to the north adjacent to the Navy Headquarters.

14) Along the road in the container yard of JCT#1 is a kitchen which prepares all meals for port workers. This kitchen building cuts off part of the container stacking areas of JCT#1, and #2.

15) On the north side of JCT is a dry dock (263m x 44.0m x 8.9m) for vessels of the 90,000 D.W.T. class, completed in 1986. On the north adjacent to the dry dock is a group of dry docks including the New Dock for vessels of the 6,000 D.W.T. class, the Graving Dock (213m x 26.0m x 9.7m) for vessels of the 30,000 D.W.T. class and the Inner Dock for vessels of the 6,000 DWT class.

16) On the north side of the dry dock area, the land behind the South Jetty is used as a petroleum shipping base.

17) Six gates connect the Port road system to the city road network, among these the Main Gate at the base of QEQ, the Layden Bastian Gate, and the Baghdad Gate at the base of Bandaranaike Pier are well utilized.

2-3-2 Quays

A list of existing alongside berths is shown in Table 2-1.

Table 2-1 List of Existing Alongside Berths

Quays, Piers & Berths	Length in Meters		Depth in Meters	Max. vessel (DWT)	Type of cargo handled
	Water front	Berth			
QEQ	1,150 (1,125)	1,080 (875)			
1		210 (150)	11.0 (9.0)	20,000 (15,000)	General cargo
2		210 (150)	11.0 (10.3)	20,000 (22,000)	
3		210 (150)	11.0 (10.3)	20,000 (22,000)	
4		210 (150)	11.0 (11.0)	20,000 (22,000)	Container
5 & 6		240 (275)	12.0 (12.0)	30,000 (40,000)	
BQ	940 (920)	805			
1		165 (135)	9.0 (8.5)	10,000	General cargo
2		165 (150)	9.0 (9.5)	10,000	
2A		105 (85)	6.0 (10.0)	3,000	
3		185 (150)	10.0 (9.0)	15,000	
4		185 (150)	10.0 (8.5)	15,000	
CB	200 (185)	140 (185)			
1		70 (100)	5.0 (5.5)	1,000	General cargo
2		70 (85)	5.0 (5.5)	1,000	
JCT	632 (632)	632 (632)			
1		300 (300)	12.0	Full Container Vessel	Container
2		332 (332)	13.0		
PVQ	370 (330)	330 (285)			
1		165 (135)	9.0 (8.0)	10,000	Bulk/General cargo
2		165 (150)	9.0 (9.5)	10,000	
NP	370 (390)	225 (200)			
1		225 (200)	11.0 (10.5)	30,000	Oil cargo
SP	280 (270)	185 (175)			
1		185 (175)	10.0 (9.5)	15,000	General/Oil cargo
NGP	360 (330)	330 (300)			
1		165 (150)	9.0 (9.5)	10,000	General cargo
2		165 (150)	9.0 (7.9)	10,000	
Dry Cargo Berth Total	3,932 (3,792)				
Oil Berth Total	370 (390)				
Alongside Total	4,302 (4,182)				

Remarks: Numerals in ( ) quoted from "PORT OF COLOMBO HANDBOOK".

1) Queen Elizabeth Quay, 1,125 meters in length, has 6 alongside berths to accommodate large vessels. The draught alongside ranges from 9 to 12 meters. An extent of 500 meters of this berth has been developed as the Container Terminal where containers are handled using gantry cranes.

2) Jaye Container Terminal which is 632 meters in length has 2 alongside berths to accommodate fourth generation container vessels. The draught alongside of the first is 12 meters and that of the second berth is 13 meters.

3) Bandaranaike Quay has 4 berths to accommodate large vessels with draught ranging from 6.7 meters to 9.46 meters. In addition, there are 2 other Coastal berths with a draught of 5.5 meters.

4) Prince Vijaya Quay has two alongside berths with draughts ranging from 7.5 to 9.5 meters.

5) Guide Pier has two alongside berths at the entrance to the Graving Dock with draughts ranging from 7.5 to 9.5 meters. Across this berth is one alongside berth Called South Pier which can accommodate a large vessel with a maximum draught of 9.5 meters.

6) North pier has a draught of 10.3 meters.

7) SPMB, owned by Petroleum Cooperation, for crude oil, has a draft of -29 meters.

2-3-3 Berth Utilization

Dry cargo is handled at most of the quays while wet cargo is handled at North Pier (oil), South Pier (coconut oil), a part of midstream buoy berths, or SPMB which locates outside port.

Among the dry cargo, the majority are containers. But, there is considerable dry bulk cargo and break bulk cargo.

Containers are handled at most of the quays while Q.C.T. #6, #5, #4, J.C.T. #1 and #2 are the exclusive berths for containers.

Major non-containerized dry cargo are handled mainly at the following berths;

Cement	Bulk/bag	P.V.Q. B.Q. Q.E.Q.
Fertilizer	Bag (no bulk handled)	B.Q. S.P. P.V.Q. Q.E.Q. Castal Berth
Sugar	Bag (no bulk handled)	B.Q. P.V.Q. S.P.
Wheat	Bulk	P.V.Q.
Flour	Bag (no bulk handled)	B.Q. C.B.
Rice	Bag	B.Q. Q.E.Q. #1 Q.E.Q. #2 S.P.

2-3-4 Berth Production

Table 2-2 indicates tonnage handled by berth in 1987.

Table 2-2 Tonnage Handled by Berth in 1987 ('000 tons)

Name of berth	Loaded	Discharged	Total
QEQ	1,111	1,299	2,410
BQ	211	756	967
CB	34	154	188
GP	23	114	137
SP	30	173	203
PVQ	62	556	618
JCT	1,328	1,391	2,719
OJ	4	3	7
PETTAH	2	16	18
EJ	1	2	3
ADM	5	7	12
MT	2	1	3
STREAM	88	103	191
TOTAL	2,901	4,575	7,476

Fig. 2.4 shows the average value of "Cargo volume/Berthing hour" during March - May '88.

It is remarkable that J.C.T. handles 350 tons/berthing hour which is 7 times the productivity of other quays.

Q.E.Q. has two types of productivity (see Fig. 2-5). One is a conventional value which is the same value as of B.Q. (0-75 tons/hr.) and the other is the semi-containerized value (150-200 tons/hr.), while the average value for productivity at J.C.T. is 350 tons/hr.

Oil handling; Crude oil is the major cargo among the liquid cargo handled in the port.

Crude oil import to Sri Lanka has been carried out by Lanka Tankers Ltd. through single point mooring buoy, 10 km off Colombo by 125,000 D/W thankers and through north pier inside port by 30,000 D/W tankers.

Concerning the production ratio at SPMB, under normal operating condition, it will take 2 to 3 days to discharge because the pipe line can transport 3,000 tons of oil per hour with ship pump. But during SW monsoon season, discharging operation is said to be suspended occasionaly due to the sea condition. Presently adopted criteria for interruption of discharging operation (and tanker to be off the buoy) are; $H_{1/3}$ 10 to 15 feet, or wind speed 10 to 12 knots per hour. For the positioning of tanker, one 7,500 HP ocean tug is being used.

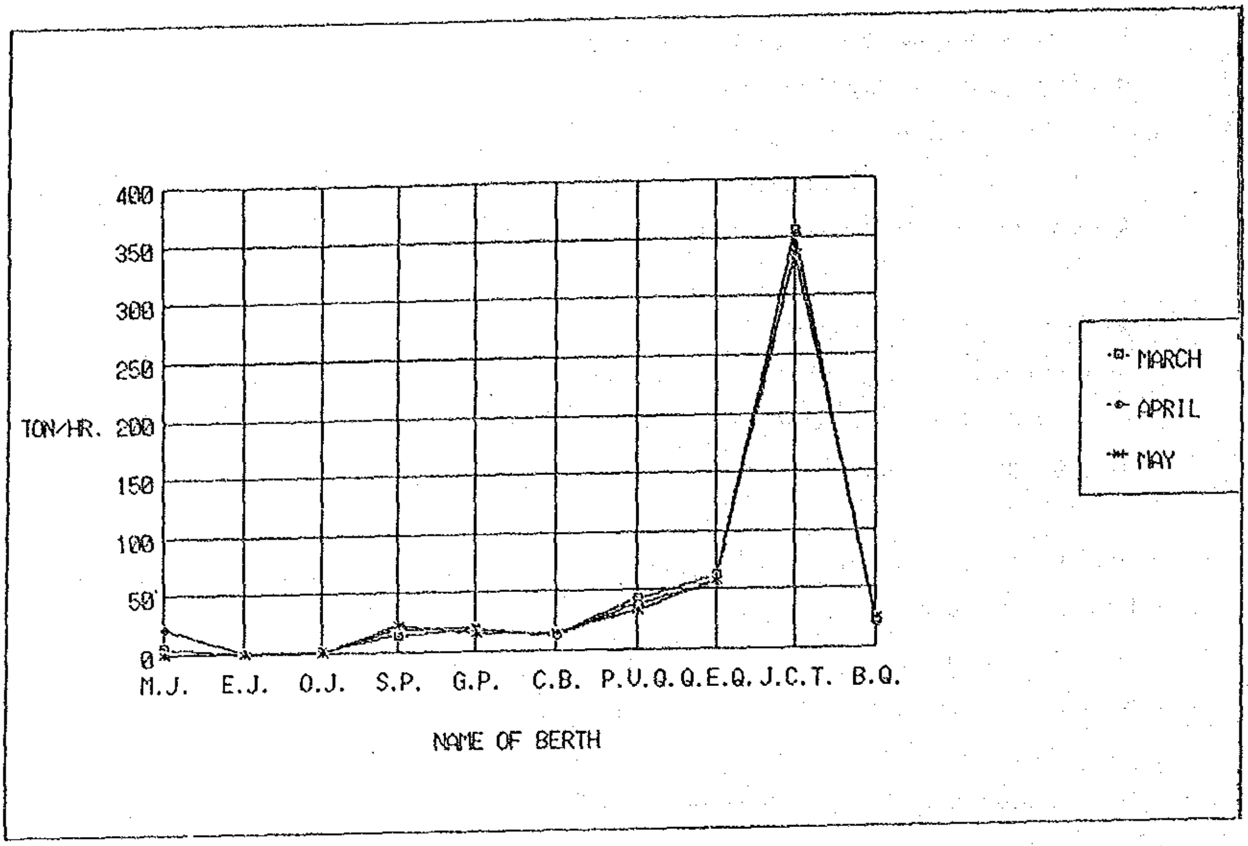


Fig. 2-4 Average Value of 'Cargo Volume/Berthing Hour' in March - May '88

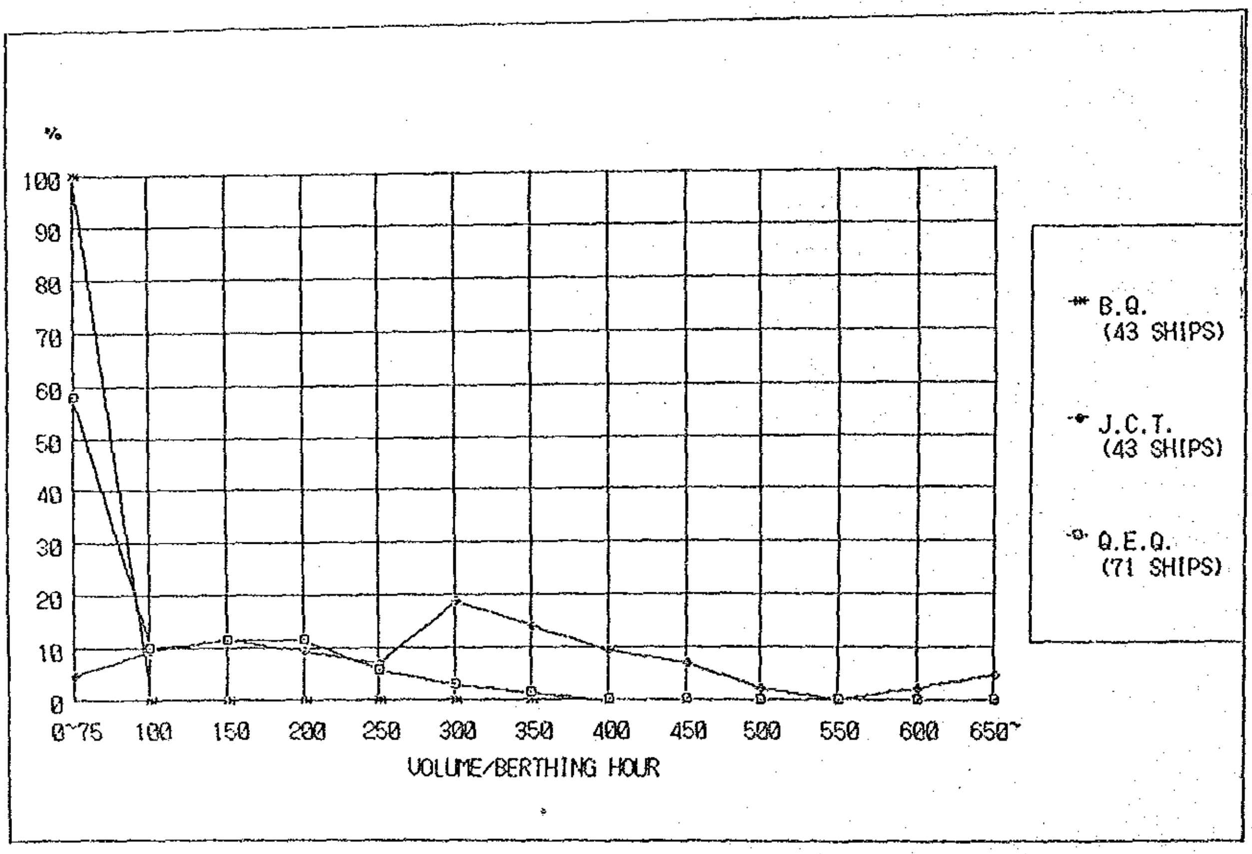


Fig. 2-5 Distribution of 'Cargo Volume/Berthing Hour/Ship' in March '88

(2) Present Capacity of Container Terminals

1) JCT

Facilities presently in use at JCT are indicated in Table 2-3.

The number of containers handled at the two berths of J.C.T. during the recent 6 months (from 01 Jan. 30 June 1988) was 211,194 TUE's, and the average berth occupancy was 64% - 93%.

There is a small decrease in the number of containers handled while the berth occupancy becomes great in the later part of the observed period.

This means that 211,000 TEUs is the maximum value presently attained for one berth per year at J.C.T. (422,000 TEUs per year at two berths).

2) QEQ

Facilities presently in use at QCT are indicated in Table 2-4.

It is observed that the traffic at Q.E.Q. is not smooth owing to the narrowness of the yards, the many corners and the uneven grounds.

At present, Q.C.T. has two gantries and is handling 17,000 TEUs per month as a whole. This is equivalent to 204,000 TEUs per year. We understand the value is the maximum value at this moment.

Table 2-3 Container Handling Facilities at the JCT

Item		#1	#2
Berth	Berth Length	300 m	332 m
	Depth (below LWOST)	-12.0 m	-13.0 m
	Type of Structure	Concrete Caisson	Concrete Caisson
Container Yard	Total Area	10.8 ha.	9.9 ha.
	Marshaling Yard	8.6 ha.	8.4 ha.
	Total No. of Dry Slots	1,680 TEU	1,752 TEU
	Total No. of Reefer Slots	72 TEU	72 TEU
Gantry Crane	Number (Model	2 units (Mitsui Paceco)	2 units (Mitsui Paceco)
	Max. load under spreader	35.5 tonns	35.5 tonns
	Rail Span	16.0 m	16.0 m
	Outreach	38.1 m	38.1 m
	Backreach	16.0 m	16.0 m
	Clear lift above dock	29.3 m	29.3 m
Transfer Crane	Number	5 units	5 units
	Capacity	35.5 tonns	35.5 tonns
	Span	22.7 m	22.7 m
	Lifting height above ground	12.5 m	12.5 m
	Stacking Row	5 Rows and 1 Chassie Lane	5 Rows and 1 Chassie Lane
Other Main Equipment	Prime Mover	12 units	12 units
	Trailer 20'	18 units	12 units
	40'	22 units	21 units
	Weighbridge (50 tonns)	2 units	2 units

Table 2-4 Container Handling Facilities at the QEQ

	Item	QEQ4	QEQ5,# QEQ 6	Total
Berth	Berth length	150 m	275 m	425 m
	Depth (below LWOST)	-11.0 m	-12.0 m	
	Type of Structure	Concrete block	Concrete cylinder	
Container Yard	Storage Area	13,600 m^2	26,580 m^2	40,180 m^2
	Total No. of Dry slots	1,741 TEU		
	Total No. of Reefer slots	36 TEU		
Gantry Crane	Number of unit (Model)	1 unit *	2 units (Liebherr P115L)	3 units
	Max. load under spreader		35.5 tonns	
	Rail span		27.0 m	
	Outreach		35.1 m	
	Backreach		10.7 m	
	Clear lift above dock		24.4 m	
Transfer Crane	Number	-	4 units	4 units
	Capacity	-	35 tonns	
	Span	-	13.6 m	
	Lifting height above ground	-	9.0 m	
	Stacking row	-	3 Rows and 1 chassie lane	
Other Main Equipment	Mobile Crane	2 units - 135 tonns & 80 tonns		
	Forklift Trucks	12 unit - 40 tonns		

* To be installed until Dec '89

2-3-5 Calling Vessels

1) Table 2-5 indicates the number of ship arrivals in 1986-1987 and the distribution of their Gross Registered Tonnage.

Table 2-5 No. of Ships Arrived

And Thier Percentage Distribution by G.R.T. Group

	No. of ships	% (1986)	No. of ships	% (1987)
Below - 2000	482	20.6	453	18.1
2000 - 3999	242	10.4	273	10.9
4000 - 5999	188	8.0	146	5.8
6000 - 7999	187	8.0	230	9.2
8000 - 9999	343	14.7	366	14.6
10000 - 11999	177	7.6	279	11.1
12000 - 13999	178	7.6	179	7.1
14000 - 15999	121	5.2	127	5.1
16000 - 17999	93	4.0	157	6.3
18000 - and over	324	13.9	295	11.8
TOTAL SHIPS	2,335	100.0	2,505	100.0
TOTAL G.R.T. ('000)	22,330		24,257	
AVERAGE G.R.T. PER SHIP ('000)	9.6		9.7	

2) Fig.2-6 shows that there are two groups of vessels; One group of ships carry 100 - 2000 tons per ship per call, while the ships of the second group carry 4,000 - 15,000 tons per call per ship.

3) Fig.2-7 implies that vessel calls at J.C.T. are not random calls but scheduled calls actually. Annex 2-3-3 shows the periodic call of all ships from 01 Dec. 1987 to 30 Nov. 1988 at J.C.T.

4) Occupancy of midstream berths is indicated in Fig.2-8.

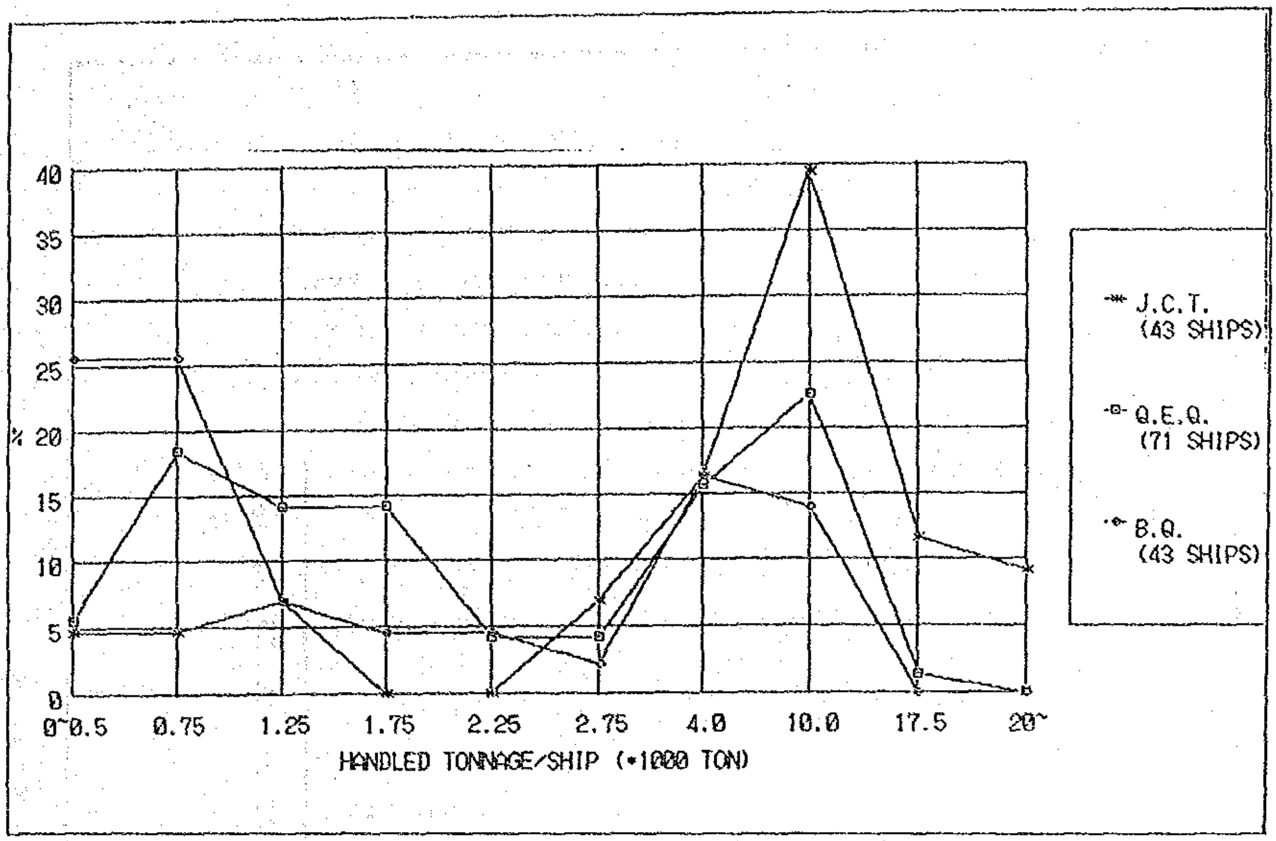


Fig. 2-6 Handled Tonnage per Ship in March '88

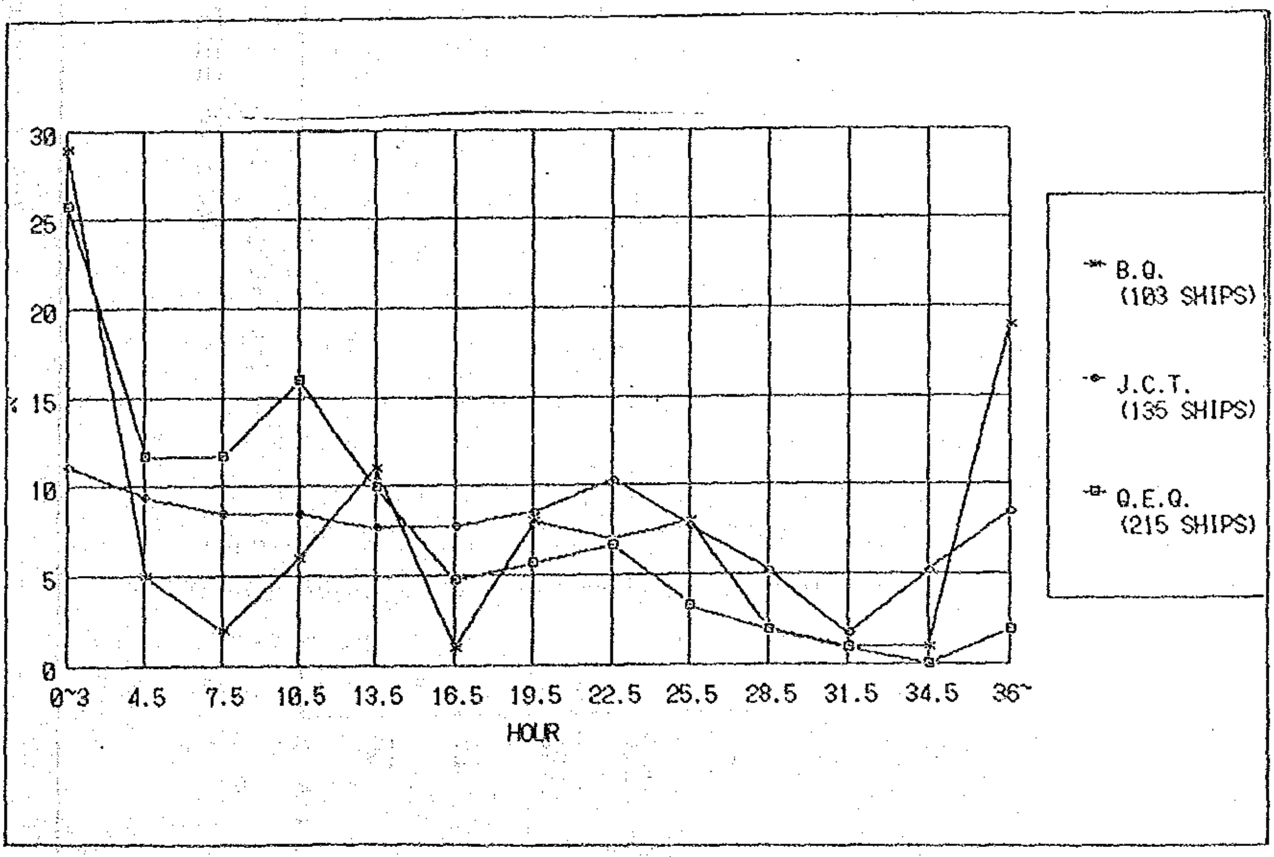


Fig. 2-7 Ship to Ship Intervals (March - May '88)

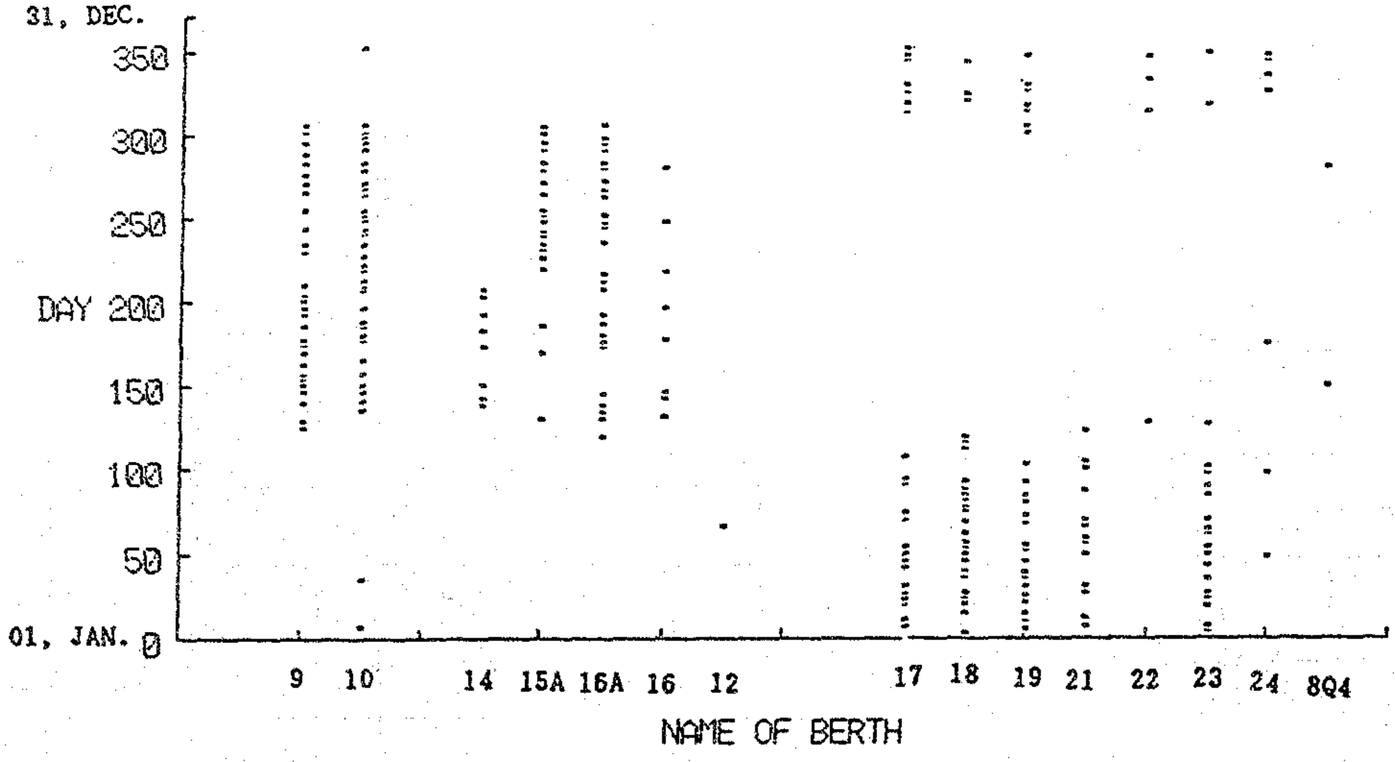


Fig. 2-8 Midstream Berth Occupation

2-4 Port Operations

(1) Outline of the Port Operations

The Port of Colombo operates around the clock. Vessels can enter and leave the port at any time. Berthing and cargo handling operations, when necessary, are also carried out 24 hours a day. Pilotage is compulsory and the use of tugboats under the pilot's discretion. Port pilots board incoming vessels at an anchorage area one mile from the port entrance. Berth assignment is made on the principle of public use, but for JCT berths and part of the QCT berths an implicit preferential use system is applied. Since JCT berths accept only scheduled callers, the berth assignment is made one month in advance. Other berths are assigned based on applications made 7 days prior to the vessel's arrival to the port. In any case, final confirmation is made 24 hours prior to the vessel's arrival.

All of the cargo handling operations are executed by SLPA's own workers, and the operations consist of two shifts. The normal working hours are; the first shift from 7.30 hrs. to 16.30 hrs. and the second shift from 16.30 hrs. to 24.00 hrs. When necessary, the 2nd shift can be extended till 4.00 hrs. on an overtime basis, and a further extension to 6.30 hrs. is possible at SLPA's discretion. There are four non-working port holidays a year namely, Sinhala & Tamil New Years Day, May Day, Wesak Fullmoon Poya Day and Christmas day.

Transportation of export/import cargo between the port and its hinterland is mostly done by truck, and the share of rail is reported to be less than 5%. For the vanning and de-vanning of containers, SLPA has been encouraging the participation of the private sector. As a result, SLPA's share of this service remains low; about 25% for import and less than 1% for export. Details of the privately owned inland container depots (ICD) are summarized and attached as Appendix 2-4-1 (Table and Figure).

One of the most important changes among the various aspects of port operations is the drastic decrease of midstream cargo operations which had been the mainstay of the Port. Trends in loading and unloading at midstream from 1975 to 1988 are summarized in Figure 2-4-1. From this it may be concluded that the present usage of midstream berths is mainly for the handling of dangerous cargo, bunkering and water supply and waiting for berthing.

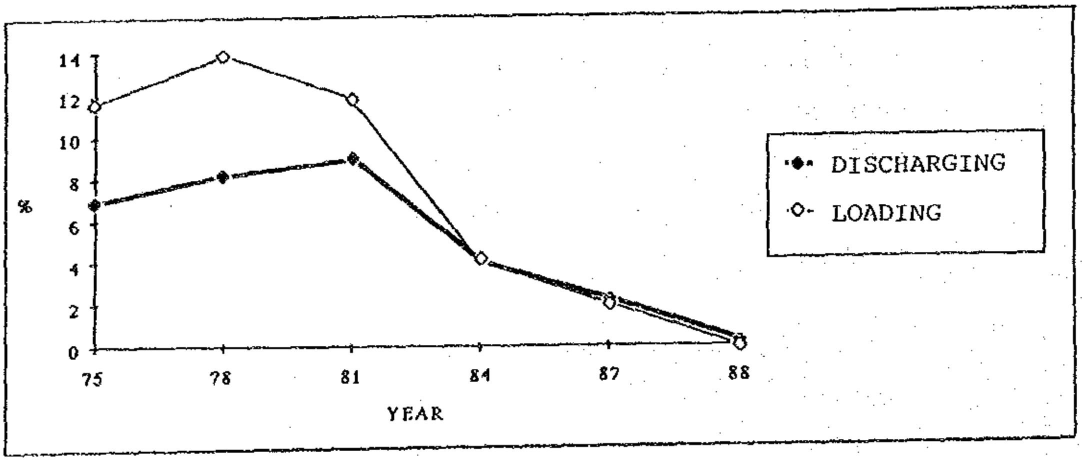


Fig. 2-4-1 Trends of Midstream Cargo Operation

(2) Details of the Port Operations

1) Management of entry and departure of vessels

The Harbour Master of SLPA regulates and directs the movement of vessels within the port and the approaches to the port. The port records approximately 200 ship calls per month in 1988. There is no time restriction for entry and departure. Berthing/deberthing is carried out on a 24-hour basis. However, tankers should be brought into the berth during daylight but can sail anytime. The daily pattern of vessel arrival by ship type is shown in Fig. 2-4-2.

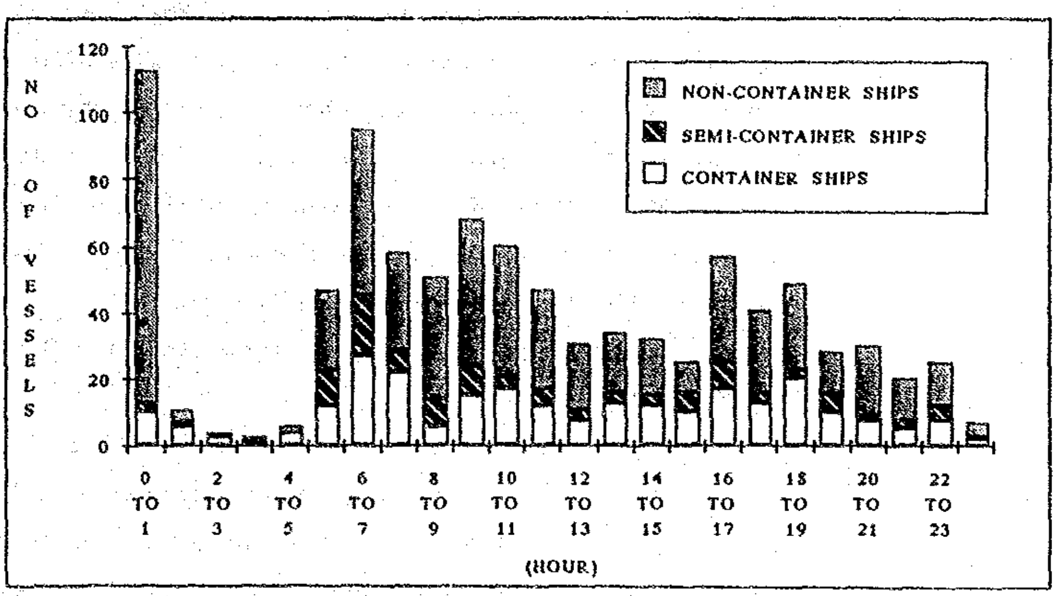


Fig. 2-4-2 Vessel Arrivals by Time and Ship Type (Dec. 88 to Mar. 89)

There are twelve points and five towing tugs with 300 hp, and nine berthing tugs with over 2000 hp, four of which, however, are over 20 years of age*. At this port, pilotage is compulsory except for small vessels. The number of tug boats employed is left entirely to the discretion of the pilots. The standard number is two. The Harbour Master coordinates with the Central Control Room of the Operations Division of SLPA in assignments of pilots, tugs, etc. The Pilot Station exchanges its messages with ships within and nearby the port through the port VHF system.

* According to information from the pilot station, there are only four tugs with over 2,000 hp, and these are utilized on a rotating basis, two tugs per ship.

2) Management of berthing facilities

i) Trends of lighter operation

As mentioned above, one of the main changes regarding the utilization of berthing facilities is the drastic decrease of midstream cargo operations. Less than one percent of dry cargo is transported by barges. Certain types of dangerous cargoes have to be handled solely by lighters or barges. There are three principal lighter landing berths in the port, viz. UNIT 2 (Fort), UNIT 4/6 (Pettah) and UNIT 7/10 (Kochchikade). The present lighter fleet is as follows; 60 steel barges of 80 DWT each

8 deck barges ranging from 100 to 250 DWT

ii) Berth allocation

Berth allocation in the port is made on a public use principle, that is, "first come, first served," but for JCT and a part of the QCT berths, an implicit preferential use system is applied. Especially, JCT accepts only "scheduled callers." If any vessel doesn't call on the scheduled date, she loses her berth and has to wait for a vacancy. If however there is a long queue at JCT and there is a vacant berth at QCT, the vessel may be diverted to QCT.

In order to minimize unnecessary shifting of cargoes with in the port area, from one warehouse/open storage to other berth in a remote area, shipping lines are allowed to make advance requests for specific berths where their cargoes are stored nearly.

As regards vessels calling at QCT and/or other conventional berths in the port, the arrival information is submitted to the Central Control Room of the Operations Division by shipping agents at least seven days before vessel arrival to ensure proper planning.

In the case of container vessels calling at JCT, the arrival schedules are prepared by the JCT office on a monthly basis.

In either case, final confirmation of the ETA of the vessels is made at least twenty-four hours before the arrival of the vessels. Shipping agents pay the charges of stevedoring and navigation in advance and submit a service form. Failure to comply with the above requirements means that the vessels will not be assigned a berth (For details, please refer to Appendix 2-4-2 and Appendix 2-4-11).

3) Management of freight handling facilities and delivery/receiving of cargo

i) Cargo delivery/receiving

Dry cargo flow in the port of Colombo is shown in table 2-4-1.

Table 2-4-1 Dry Cargo Flow (Including Containers)

Unit: ton

	YEAR	LOADING		DISCHARGING		TOTAL	
DIRECT	87	338,886	11%	1,417,689	32%	1,756,575	24%
	88	208,874	6%	1,634,841	30%	1,843,715	21%
FROM/TO OPERATIONAL AREA	87	131,290	4%	414,215	9%	545,505	7%
	88	25,694	1%	339,002	6%	364,696	4%
FROM/TO WAREHOUSES	87	170,342	6%	243,938	5%	414,280	6%
	88	114,801	3%	187,204	3%	302,005	3%
FROM/TO YARDS	87	2,363,571	79%	2,391,431	54%	4,755,002	64%
	88	3,137,097	90%	3,284,419	60%	6,421,516	72%
TOTAL	87	3,004,089	100%	4,467,273	100%	7,471,362	100%
	88	3,486,466	100%	5,445,466	100%	8,931,932	100%

* 88(JAN.~NOV.)

Container cargo flow is shown in Fig. 2-4-3. At JCT, all containers are transported via the container stacking yard. No containers are delivered or received directly to/from consignees or shippers.

At QCT, all of the loaded containers are transported via the stacking yard, but a small portion of the empty containers can be transported directly to/from consignees or shippers.

The delivery/receiving of cargo is carried out from 0730hr. to 1630hr. on all weekdays, including Saturdays, as normal working hours in both terminals, and from 1630hr. to 0730hr. of the following day on an overtime basis. For Sundays and Holidays, except port Holidays, all delivery/recieving is made on an overtime basis. Besides, delivery at QCT may be carried out at any time by special request. On the port holidays throughout the year, neither delivery nor receiving is made at JCT or QCT.

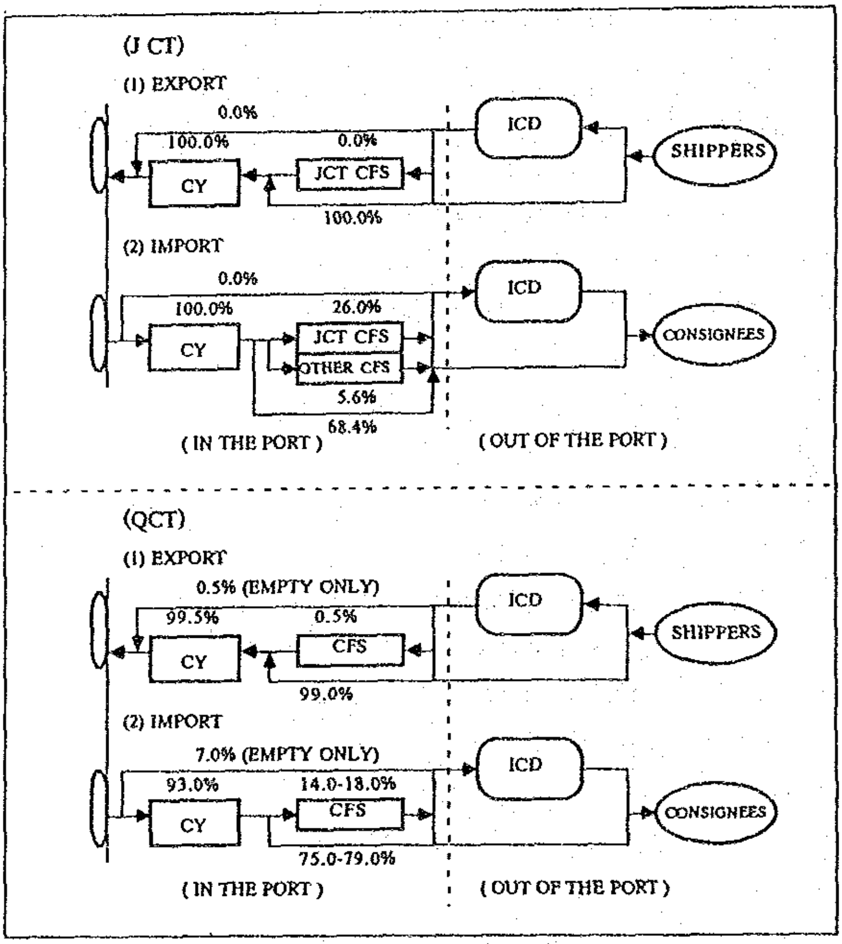


Fig. 2-4-3 Container Cargo Flow in the Port of Colombo

The closing time for receiving export cargo is 24hrs. prior to the vessel's ETA in the case of FCL cargo and 8hrs. before the commencement of loading in the case of LCL cargo, but the latter case is very limited (only at QCT).

The stacking plan for export containers is prepared one day before the first container is received based on the booking lists submitted from agents. The plan for delivery of import containers is prepared one day before based on the notice from consignees. Containers are stacked as per the ports of destination and weight after being sorted out by shipping line and by transshipment/local.

At QCT, all plannings (yard stacking plans, loading plans, etc.) are taken care of by two planners. At JCT, yard stacking plans are prepared by two planners with the aid of computers. The control room and the gates at JCT are connected via an air tube instead of an on-line computer system.

ii) Stuffing/Unstuffing

Cargo stuffed/unstuffed at CFS or ICDs out of the port occupies a large share in container transport and cargo stuffed/unstuffed at CFS in the port is very limited as shown in Fig. 2-4-3. No export cargo is stuffed at CFS in JCT. This is the reason why SLPA doesn't have facilities where they stuff/unstuff cargo to/from containers. As a result, almost all the export and most of import cargoes are stuffed/unstuffed in CFS/ICDs outside of the port or within the shippers/consignee's premises.

iii) Storage of container cargo

Free storage periods for various types of container cargoes are set in the following manner;

Loaded export; seven clear days (exclusive of Sat., Sun. and holidays)

Loaded import and empty; three clear days (exclusive of Sat., Sun. and holidays)

Transshipment: twenty-eight normal days (inclusive of Sat., Sun. and holidays)

Three clear days are given to the consignees after LCL cargo is stripped out and ready for delivery.

If the storage period exceeds the free storage period, storage rent and penalty fees are charged (Appendix 7-6-1). And all imported cargoes except containers not cleared within seven clear days from the data of landing are removed to a repository transit shed. Further the Port Authority may, when goods which have been placed in sheds are not removed from such sheds within a period of twenty-one days from the time when such goods were placed in such sheds, at the expiration of such periods, sell by public action any or all of such goods.

The average dwelling time of containers at present, is as follows.

QCT	export	10 to 12 days
	import	9 days
	transshipment	14 days
JCT	total	6 days

At JCT, approximately 90% of both transshipment and local containers are carried out within 10 days as shown in Figure 2-4-4 and Appendix 2-4-3.

Empty containers are driven out of the port as quickly as possible.

The change of the number of containers stacked at JCT is shown in appendix 2-4-4. The number varies between 3,000s TEU and 6,000s TEUs. THe average height of stacked containers is two to three.

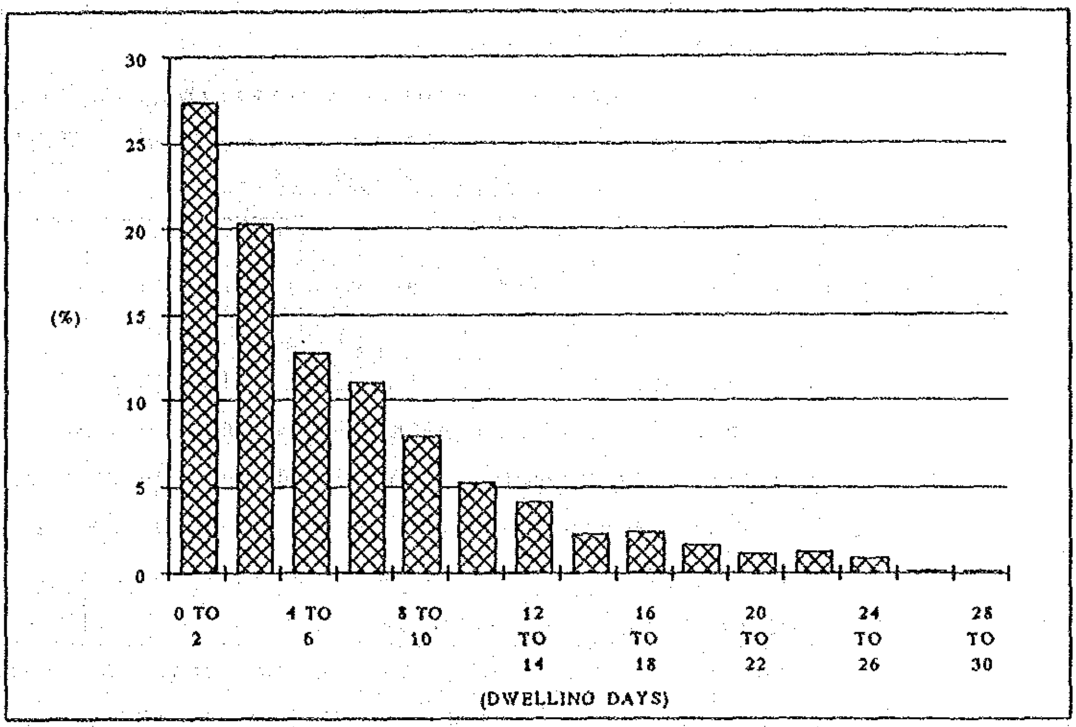


Fig. 2-4-4 Dwelling time of Transshipment Containers at JCT ('88 Yearly)

iv) Labour force and equipment

The labour force and equipment for cargo delivery/receiving are shown in Table 2-4-2 and Appendix 2-4-5. Two of ten transfer cranes are assigned for delivery/receiving of containers at JCT.

Table 2-4-2 Formation of Gangs for Delivery/Receiving

		FCL		LCL		
		RECEIVING	DELIVERY	RECEIVING	DELIVERY	DESTUFFING
RECEIVING/ DELIVERY	KANGANY(LEADER)	0	1	1	1	1
	LABOURERS	0	12	8	12	12
	TOTAL	0	13	9	13	
		2 GANGS PER SHIFT		2 GANGS PER DAY SHIFT		2 GANGS PER NIGHT SHIFT

FORMATION OF GANGS AT CFS IN JCT

CFS GANG	DESTUFF	25 (BESIDES 15 FOR SUPPORTING JOBS)

v) Procedures

The procedures concerning delivering and receiving containers (FCL) at JCT are summarized and shown in Appendix 2-4-6 and Appendix 2-4-7.

4) Loading and discharging of cargo

i) Working days and hours

The port of Colombo operates on two shifts; day and night. The day shift operates from 0730 hrs. to 1630 hrs. with a break for meals from 1200 hrs. to 1300 hrs. The night shift operates from 1630 hrs. to 2400 hrs. with a break for from 2100 hrs. to 2200 hrs. The night shift is extended when necessary up to 0400 hrs. on an extended shift (overtime) and up to 0630 hrs. at the discretion of SLPA. The rotations between day and night shift are changed on weekly basis.

The port normally works round the clock throughout the year except on the four "non-working" holidays.

ii) Labour force

The labour gangs for discharging/loading at QCT are shown in Table 2-4-3. At JCT a labour gang system is used only for CFS labourers and there is no gang work in the other fields of operation at JCT. The allocation of labour for discharging/loading is done by the Central Control Room of the Operations Division before the commencement of the shift.

There are also non-labour staff and labourers whose jobs are subject to shift work as per shifts. Gantry crane operators are changed every four hours but no such rotation system is introduced for transfer crane operators or prime mover drivers.

The number of employees at QCT and JCT by different job group is shown in Appendix 2-4-8.

Table 2-4-3 Formation of Gangs and Drivers for Discharging and Loading at QCT

		By Ship Gear		By Gantry Crane
		Discharging	Loading	Discharging & Loading
Stevedoring Gang	Foreman	1	1	1
	Tindal (Leader)	1	1	1
	Winchman	4	4	
	Crane Operator			1
	Labourers	12	16	12
	Total	18	22	15
		5 Gangs per Shift		

		Discharging	Loading
Wharf Gang	Kangany (Leader)	1	1
	Labourers	5	0
	Total	6	1
		8 Gangs per Shift	

The formation of gangs for discharging and loading break-bulk cargo is the same as that for container handling at QCT, however, double gangs are allowed for handling of refrigerated, dusty and irritable cargos. SLPA doesn't operate stevedoring of bulk cargos, such as cement and petroleum.

iii) Equipment

The equipment for discharging/loading at QCT and JCT are shown in Appendix 2-4-5. At JCT five prime movers and two transfer cranes are assigned to each gantry crane. The maintenance of equipment is carried out by SLPA's Engineering Division. A daily check including greasing, etc. and a monthly check for over haul are the back bone of the maintenance system.

iv) Planning

At QCT two planners take care of loading and discharging plans before commencement of discharging/loading, however in the case of Cylone Shipping Corporation (CSC), CSC themselves prepare loading bay plans and loading sequences.

At JCT nine planners prepare plans for discharging/loading, stowage, etc. using computers before the commencement of discharging/loading.

v) Procedures

The procedures which shipping lines (or their agents) follow for discharging and loading cargos are shown in Appendix 2-4-9, Appendix 2-4-10 and Appendix 2-4-11.

vi) Weather conditions

Except for the port holidays, the port does not stop working but there are cases in the SW monsoon season when ship work stops for a few hours due to poor visibility in the heavy rainfall. Strong winds of 15 meters per second or over also stop ship cargo operations for a few minutes.

2-5 Computer System

(1) The Existing Computer System

SLPA presently has two IBM 4361 mainframe computers and a number of terminals as shown in Table 2-5-1. Computerization at SLPA first started in 1985 with the purchase of an IBM 4361 mainframe computer. It has a main memory of 4 megabytes and an on-line disk capacity of 1500 megabytes. Subsequently, another IBM 4361 mainframe was purchased. It has a main memory of 12 megabytes and an on-line disk capacity of 2500 megabytes.

The first system that was run on the computer was the Jaye Container Terminal Operation System. SLPA purchased the Container Terminal Operating Package from Japan. This system consists of an on-line processing series, and covers delivery and receiving of containers, stacking planning, stowage planning, etc.

The flow of these planning works are shown in Appendix 2-4-6, 2-4-7, 2-4-9, and 2-4-10.

Table 2-5-1 Number of Computer Terminals of Computer System by Office In the Port of Colombo

Office or Section	JCT Operation System	Central Billing System	Payroll System *	Stock Control System *	Management Information System *	Total
JCT Office	10	8				18
JCT CFS	1					1
Export Office		2	4			6
Stevedoring Section		4	2			6
Navigation Section		1	4			5
Flagstaff (Pilot Station)		1				1
P.V.Q.			2			2
All heads of divisions					21	21
Supplies Division						
Office				4		4
Stores				4		4
Total	11	16	12	8	21	68

* Under Development

The next system computerized was the Billing System for port users. A subsidiary of the Port of Singapore Authority developed this system. This system was operational at Colombo from the beginning of 1988. This system consists of both online and batch processing series. The purposes of the system are;

1 to provide an online system to print bills for the services rendered to agents,
2 to capture revenue from consignees and shippers, and
3 to produce revenue analysis reports and vessel statistics reports.

The two systems are only introduced at SLPA and are not yet connected with the port users' computer system.

(2) Development Plans (Fig. 2-5-1)

It was decided that at the beginning of 1989, SLPA would increase the disk capacity of the machines by 1500 megabytes each.

In 1989, SLPA plans to start using the Payroll System, Account System, Stock Control System and Management Information System developed at the port. They have purchased an Electronic Mailing and Office Automation System from IBM. Micro computers will be connected to the mainframe computer. The management information system will process information from all the other systems.

Further, they plan to computerize QCT operations. The same packages which were purchased from Japan will be used to computerize QCT terminals as well.

They plan to introduce at a future stage an on-line network connecting with customs, shipping agents, etc.

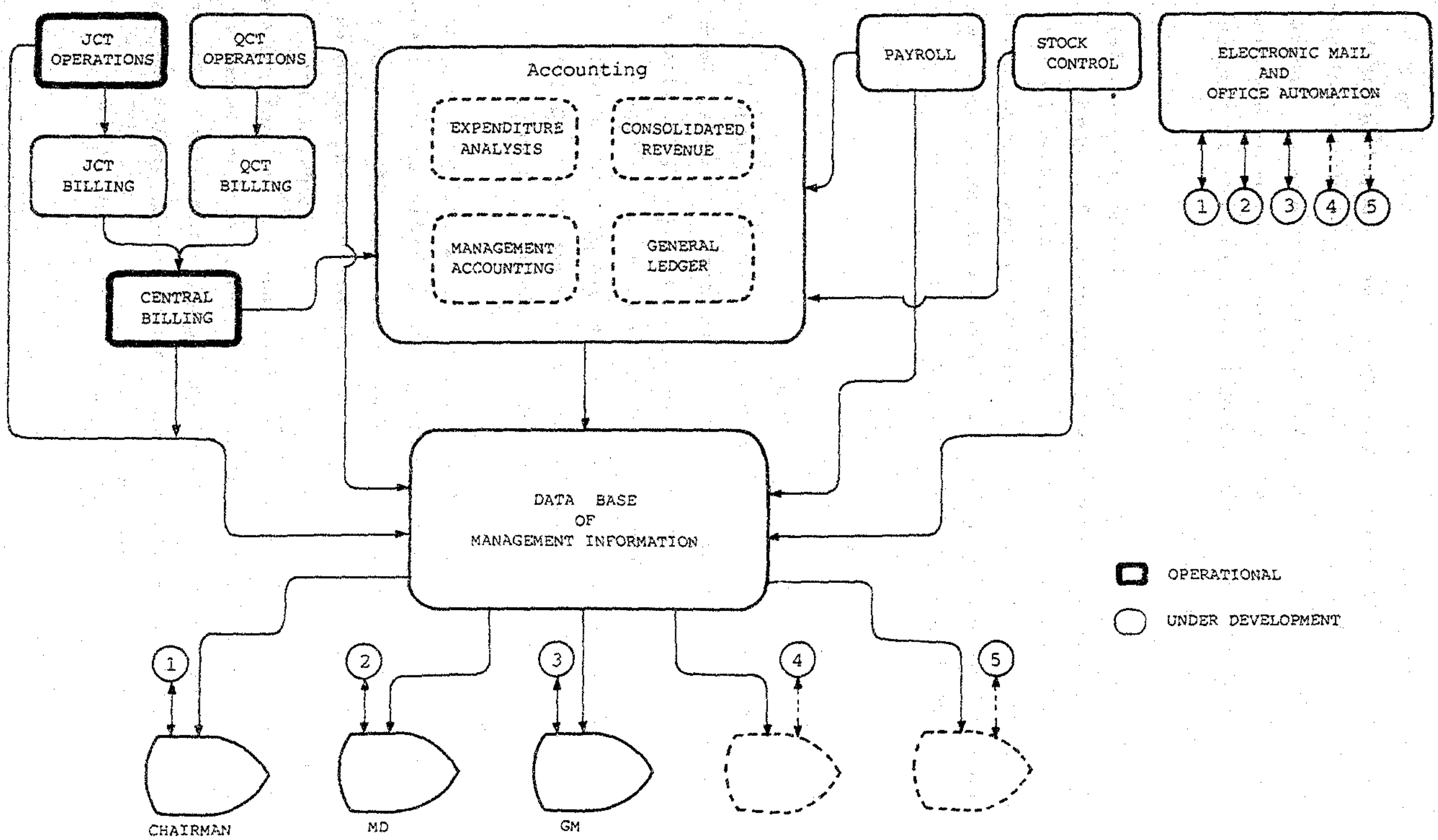


Fig. 2-5-1 Computerization Development Plan

2-6 Training System

SLPA has a fully equipped training center to identify the training needs in the context of the rapid introduction of new technologies and the need to provide qualified manpower to perform specialized port activities. This training center, completed and fully equipped with the aid of UNDP was declared open on 21st January, 1987, as the "Mahapola Training Institute".

The training course of the Institute is divided into 3 categories, that is operations, management and technical. The operations course is subdivided into 5 categories: cargo handling equipment operations, container operations, conventional cargo operations, maritime & seamanship, and safety. Over 700 trainees study through both lectures and practical work in this center every year.

2-7 Welfare and Labour Relations

Many welfare schemes for port workers have been provided in SLPA, including a housing scheme, medical care, loans and meals. The working conditions include items yet to be improved. However, the efforts made by SLPA management have to be recognized. One of the typical examples is its unique meal service which is supplied by a huge kitchen with a capacity of 20,000 meals per day. By this service, every port worker is entitled to have free meals at all times he is on duty.

In labour relations, SLPA has long adopted a policy of ensuring job security to its employees. This policy is backed up with its well-equipped training centre which was established with assistance from UNDP. Thus with mechanization and computerisation the employees made redundant are re-trained to fit into new fields of activities. Encouragement is also given to those who wish to seek employment abroad to do so on the basis of unpaid leave, which has helped greatly to overcome the problems of excess labour, although as a side effect the better calibre employees tend to seek foreign employment leaving behind the less skilled staff.

Based on the above situation, SLPA has established good labour relations. Stoppages of port operations caused by labour problems have not been experienced during the last 8 years. In 1988, port operations virtually stopped twice, in November and December, but these were induced by the nationwide political conflict and this is considered beyond the direct control of SLPA's management.

2-8 Environmental Aspects

(1) General

In the Port of Colombo, where storm water from the urban area behind has been draining into the harbor basin, the rapid growth of the city has brought about the discharge of domestic waste water into the existing storm water drainage. Moreover, a series of port development projects undertaken in recent years tends to make the harbor area increasingly narrow, giving rise to greater possibility of water contamination in the basin.

In August 1985, when the Jaye Container Terminal No. 2 Project was under construction, the Sri Lanka Ports Authority carried out an investigation at several selected points in the harbor basin to determine the water quality. The investigations disclosed that the water in the vicinity of the existing quays was gradually beginning to be contaminated due to the deposition over a long period of harmful substances contained in the domestic effluent, and that the contamination was spreading to the central part of the basin.

The JICA Team has carried out an analysis of the water quality in the Port of Colombo and compared the investigation results with the data from the SLPA investigation referred to above in order to define the trends in water contamination in the harbor area of the port and to use the analytical data for the purpose of water pollution control in the future.

(2) Investigation

1) Locations of Sampling

Water samples were obtained at six points indicated in Fig. 2-8-1 for laboratory testing. The selected points are as listed below.

(a) Barge Repair Basin;

(b) Canal;

(c) Outfall of city drainage;

(d) Central part of harbour basin;

(e) Entrance channel; and

(f) North Pier

2) Number and Dates of Sampling

Water samples were obtained from two depth layers (-0.5 m and -2.0 m) at the same points. Twelve of the samples from the six points named in 1) above were taken at high tide on May 25, 1989 and another set of 12 samples were taken at low tide on the morning of May 26.

3) Laboratory Analysis

Analysis of pollutants was undertaken by a local firm, Messrs. Bamber & Bruce, in respect of the following items:

(a) Hydrogen ion exponent (PH);

(b) Chemical oxygen demand (COD);

(c) Oil content (OC);

(d) Dissolved oxygen (DO);

(e) Sulphide content (S); and

(f) Coliform group (CG)

(3) Results of Analysis

Details of the results and method of analysis are described in a report of Bamber & Bruce which is given in Appendix 2-8-1.

Table 2-8-1 presents a summary of the analytical results together with the relevant Japanese standards.

The normal PH value of seawater is 8.3 to 8.4. However, samples taken in the innermost part of the harbour showed a PH value of 7.1 to 7.5 --- values close to that of pure water. The PH value of samples from the central part and the harbor entrance ranged from 7.5 to 7.8. These results indicate that the seawater of the harbour basin has a high content of fresh water from the urban area.

With respect to coliform groups, samples obtained in the innermost part of the harbour showed values larger than the Japanese standard, while smaller values were obtained from samples taken in the central part and at the harbour entrance. These results suggest that drain water from the urban area contains not only storm water, but also pollutants.

All samples obtained in the harbour basin exhibited slightly larger COD and DO values than the corresponding Japanese standards. This points to the need for appropriate measures to control water pollution of the harbour from municipal drain water.

With reference to Table 2-8-1, a comparison of the oil content and dissolved oxygen values obtained in investigations conducted in 1985 and 1989 reveals increasing pollution levels.

It is highly desirable that periodic water quality investigations be undertaken in the Port of Colombo in coming years with a view to obtaining necessary data for the implementation of measures for improving the water quality of the harbour.

Table 2-8-1 Results of Water Quality Tests in 1985 and 1989

Sampling Point			① Barge Repain Basin		② Canal		③ Melbourne Jetty		④ Center of Harbor		⑤ Entrance Channel		⑥ North Pier		Japanese
Test Parameter		Carried out	−0.5m	−2.0m	−0.5m	−2.0m	−0.5m	−2.0m	−0.5m	−2.0m	−0.5m	−2.0m	−0.5m	−2.0m	Standard
I	Hydrogen Ion Exponent [PH ppm]	1985	7.2. 7.2. 7.5	7.2. 7.4. 7.6	7.2	−	−	−	7.5	7.3	−	−	−	−	7.8~8.3
		1989	7.2. 7.1	7.1. 7.5	7.5. 7.4	7.4. 7.4	7.6. 7.5	7.7. 7.4	7.8. 7.6	7.8. 7.6	7.6. 7.6	7.7. 7.6	7.5. 7.6	7.2. 7.6	
II	Chemical Oxygen Demand [COD ppm]	1985	8. 16. 44	40, 40, 32	12	−	−	−	24	8	−	−	−	−	Less than 8
		1989	Nil	Nil	Nil	10. 10	Nil	210. 10	Nil	Nil. 10	10. 10	Nil	Nil. 70	Nil. 10	
III	Oil Content [OC ppm]	1985	11. 6. 8	12. 20. 14	191	−	−	−	3	14	−	−	−	−	−
		1989	4. 264	115. 120	43. 294	13. 149	130. 83	109. 185	198. 158	72. 260	112. 260	32. 391	86. 148	123. 180	
IV	Dissolved Oxygen [DO ppm]	1985	3. 3.5. 6.3	6.7. 4.3. 3.9	4.2	−	−	−	5.5	5.4	−	−	−	−	More than 2
		1989	1.08. 1.24	1.24. 1.48	1.00. 1.40	1.12. 0.96	0.64. 1.44	1.10. 1.60	0.68. 1.32	0.82. 1.56	1.60. 1.56	1.60. 1.50	1.12. 1.38	0.82. 1.28	
V	Suplhide Content [S ppm]	1985	−	−	−	−	−	−	−	−	−	−	−	−	−
		1989	0.32. 1.36	0.44. 0.72	0.88. 0.88	0.32. 1.36	0.24. 1.68	0.4. 1.20	0.72. 1.68	0.48. 1.80	0.22. 1.80	0.26. 0.88	1.04. 0.64	0.64. 1.60	
VI	Coliform Group [CG $\frac{MPN}{100m\ell}$]	1985	More than 1,600	More than 1,600	81	−	−	−	More than 1,600	More than 1,600	−	−	−	−	Less than 1,000
		1989	More than 1,600	More than 1,600	920. 430	920. 44	More than 1,600	11. 280	21. 6.1	13. 7.8	32. 7.8	130. 8.3	39. 8.3	12. 1.8	

Note : Japanese Standard denotes the limits expressed in numerical terms within which people will not feel discomfort while walking along, say, a seaside promenade.

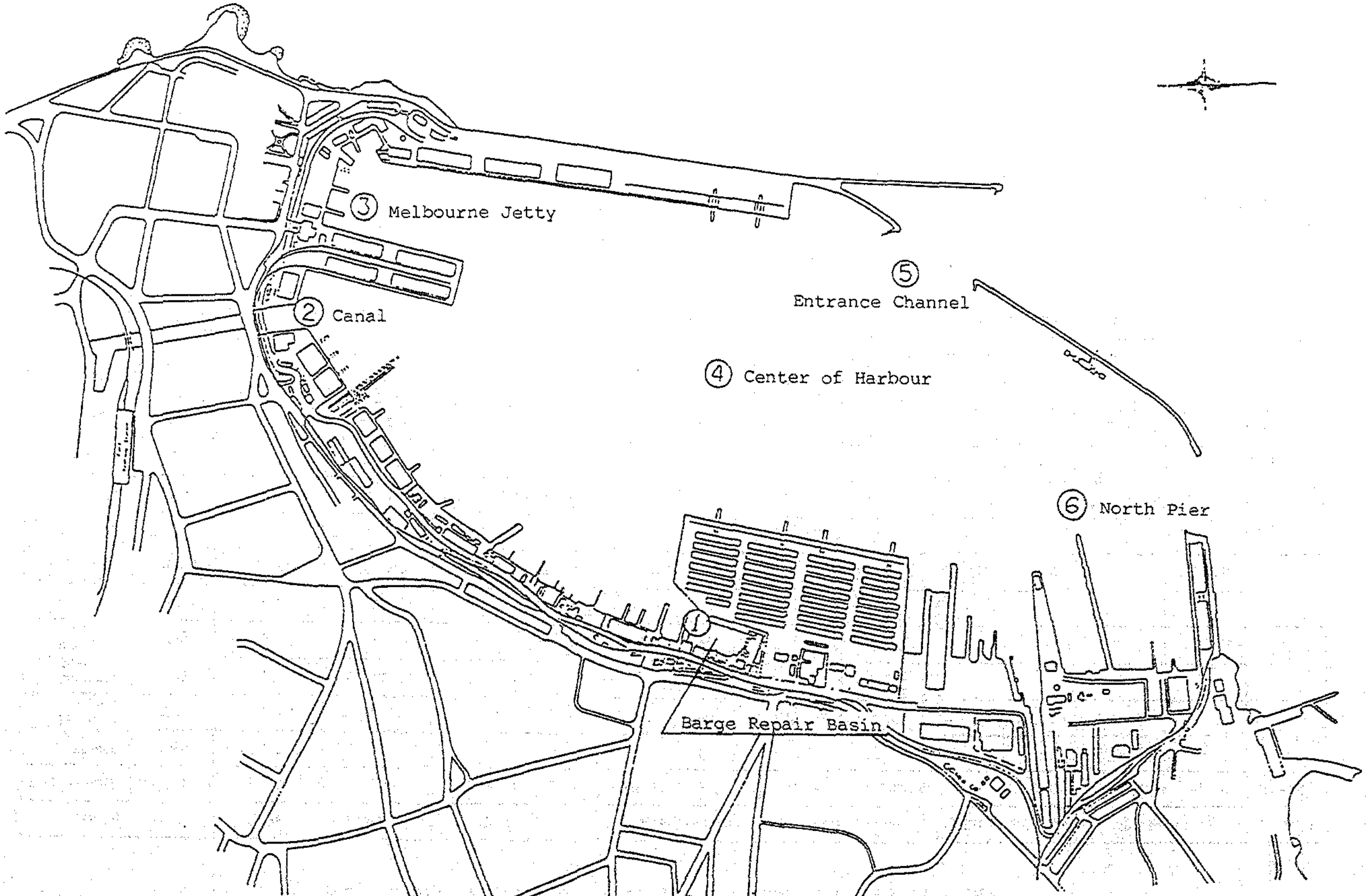


Fig. 2-8-1 Water Sampling Points for Water Quality Investigation

CHAPTER 3 NATURAL CONDITIONS

3-1 General Description

A general description of the natural conditions is omitted here. For a general description, refer to Chapter 1.

3-2 Wind

(1) Observations Records

Since the wind characteristics will directly affect vessels, the design of structures and the basic data for estimating wave heights and directions, the necessary data have been collected at the following locations:

1) Colombo Port:

Location of observations	:	Pilot station, Southwest Breakwater in the Port of Colombo
Equipment	:	Electric anemograph
Equipment height	:	53.5 ft above sea level
Period of observation	:	From April 1979 to March 1980 and From December 1982 to November 1984

The wind records after 1985 are partly illegible with the lines indicating the wind velocity and the wind direction overlapping.

Although full wind records for a 10-year period were not available, it was necessary to obtain wind data covering a minimum period of three years for analyzing annual wind characteristics.

2) Department of Meteorology

Location of observations: Lat.6 deg. 54'N, Long.79 deg. 52'E

Equipment	: 3 cup types (made by Casella)
Equipment height	: 6.1 meters above the ground level
Period of observations	: From 1978 to 1987

Mean wind velocity for a duration of three minutes for the eight prevailing directions are recorded manually by the observatory personnel every three hours.

Wind date obtained for the Port of Colombo cover only a three-years period. For this reason, attempts were made to compensate for the shortage of wind data.

Firstly, attempts were made to extract some data on abnormal weather conditions from the long-range observation records of the Observatory and then to compare the field wind data for the Port with the Observatory records in order to establish a correlation between the two sets of data.

Secondly, attempts were made to use this correlation to convert the wind observation records at the Observatory to the wind directions and velocities at the Port of Colombo for estimating waves during abnormal weather as part of the procedure for determination of the design wave.

However, the wind velocities observed at the Observatory were of the order of 5 knots and did not show very wide variations. This relatively low wind velocity presumably is attributable to (1) the location of the Observatory which is about 2.5km inland from the coast and (2) the limited height where the anemograph is installed (6.1 m). Therefore, any correlation between the wind data for the Port and the Observatory records could not be established.

(2) Results of Analysis

The results of the wind data analysis for the Port of Colombo spanning a three-year period are presented below.

1) Frequency of Wind Occurrence by Direction and Velocity

Tables 3-2-1(1) to 3-2-1(5) present the annual and seasonal wind occurrence in the Port of Colombo and Figs.3-2-1(1) to 3-2-1(5) are the wind roses for the port.

As can be seen from the tables and figures, the prevailing wind direction all the year round is WSW (15.9%) and the directions W-SSW account for nearly 50% of the total winds observed in the port. The prevailing directions of winds with a velocity of 15 knots or more show similar trends. This is largely due to the southwest monsoon which is of the longest duration and characterized by higher-speed winds.

In the NE monsoon season lasting from December to February, the prevailing wind directions are NNE (15.3%) and NE (12.3%), but the N to NW winds account for nearly 9%. In Colombo, NE monsoon winds blow from the shore direction with a reduced speed and when sweeping through the Palk Straight they tend to veer toward the NW.

In the southwest monsoon season lasting from May to September, monsoon winds blow at a substantially high speed. The prevailing wind directions are WSW (26.7%) to SW (23.7%) and the W to SSW winds account for no less than 81.3% of the total winds observed in the Port of Colombo. Thus the southwest monsoon season has a greater concentration of specific wind directions than the other seasons. Winds of 15 knots or more with prevailing directions show similar trends and occur with the highest frequency during this season in the Port of Colombo.

The months of March and April represent the transition from the NE monsoon to the SW monsoon season. During the two months, east and west winds prevail, but the wind velocity is the lowest of all the seasons.

During the October-November period which represents the transition from the southwest to the northeast monsoon season, westerly winds are somewhat prevalent, but the prevailing directions are not so conspicuous as in the other seasons. The wind velocity during the October-November period is the second lowest after that of the March-April period.

2) Strong Wind

All the year round, strong winds of 20 knots or more occur with a 0.8% frequency during the southwest monsoon season and with a frequency of about 0.2% during the northeast monsoon season. Strong winds during the southwest monsoon blow primarily from the WSW direction and those during the northeast monsoon season blow largely from the NW direction. Their maximum speed does not vary widely, but levels off at the order of 25 knots. This is primarily attributable to the fact that the Port of Colombo lies off the course of cyclones and does not undergo drastic changes in weather.

TABLE 3-2-1(1) Frequency of Wind Occurrence (%)

ANNUAL

DIRECTION / VELOCITY (KNOT)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-4	0.7 (3.5)	0.5 (4.5)	1.0 (3.8)	1.8 (3.2)	3.7 (8.1)	2.8 (8.3)	1.4 (3.5)	0.9 (2.5)	1.0 (3.7)	0.7 (11.3)	0.8 (13.0)	0.7 (15.9)	0.9 (9.9)	0.5 (4.6)	0.7 (4.1)	0.8 (4.1)	18.8
5-9	1.0 (2.8)	1.8 (4.0)	1.9 (2.8)	1.1 (1.4)	2.2 (2.4)	3.4 (3.5)	1.8 (2.1)	1.5 (1.8)	2.1 (2.7)	6.4 (10.6)	8.1 (12.2)	6.2 (15.2)	3.5 (9.0)	1.7 (4.1)	1.6 (3.4)	1.4 (3.5)	43.4
10-14	1.4 (1.7)	1.7 (2.2)	0.9 (0.9)	0.2 (0.3)	0.2 (0.2)	0.1 (0.1)	0.1 (0.2)	0.1 (0.1)	0.5 (0.6)	3.9 (4.2)	5.4 (6.1)	7.8 (9.0)	4.8 (5.5)	1.8 (2.4)	1.3 (1.8)	1.5 (2.1)	31.8
15-19	0.3 (0.3)	0.5 (0.5)	0.1 (0.1)	0.1 (0.1)		0.0			0.0 (0.1)	0.3 (0.3)	0.7 (0.7)	0.9 (1.2)	0.6 (0.7)	0.5 (0.6)	0.5 (0.5)	0.7 (0.6)	5.2
20-	0.0										0.1	0.2	0.2	0.2	0.1	0.0	1.0
TOTAL	3.5	4.5	3.8	3.2	8.1	8.3	3.5	2.5	3.7	11.3	13.0	15.9	9.9	4.6	4.1	4.1	100.0

note: percentage exceedence in brackets

TABLE 3-2-1(2) Frequency of Wind Occurrence (%)

Dec-Feb

DIRECTION / VELOCITY (KNOT)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-4	1.3 (8.9)	1.1 (15.3)	2.3 (12.3)	2.5 (5.9)	4.8 (7.5)	4.0 (6.2)	1.8 (2.9)	0.7 (1.2)	0.7 (1.6)	0.3 (1.2)	0.4 (1.6)	0.8 (3.5)	0.9 (6.5)	0.9 (7.2)	1.0 (9.5)	1.3 (8.8)	24.5
5-9	2.5 (7.6)	5.8 (14.2)	6.1 (10.0)	2.4 (3.4)	2.8 (2.9)	2.0 (2.2)	0.9 (1.1)	0.6 (0.5)	0.8 (0.9)	0.7 (0.9)	0.9 (1.2)	1.8 (3.0)	3.2 (5.6)	2.9 (6.3)	3.1 (8.5)	2.8 (7.5)	39.1
10-14	3.6 (5.1)	6.4 (6.4)	3.4 (3.9)	0.8 (1.0)	0.2 (0.1)	0.1 (0.2)	0.2 (0.2)		0.1 (0.1)	0.1 (0.2)	0.2 (0.3)	1.0 (1.2)	1.9 (2.4)	2.5 (3.4)	3.2 (5.4)	3.5 (4.7)	27.3
15-19	1.2 (1.3)	2.0 (2.0)	0.4 (0.5)	0.2 (0.2)		0.1 (0.1)			0.1 (0.0)	0.1 (0.1)	0.2 (0.1)	0.1 (0.2)	0.4 (0.5)	0.8 (0.9)	1.7 (2.2)	1.3 (1.2)	8.4
20-													0.1	0.2	0.4		.7
TOTAL	8.9	15.3	12.3	5.9	7.5	6.2	2.9	1.2	1.6	1.2	1.6	3.5	6.5	7.2	9.5	8.8	100.0

note: percentage exceedence in brackets

TABLE 3-2-1(3) Frequency of Wind Occurrence (%)

Mar-Apr

DIRECTION / VELOCITY (KNOT)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-4	0.9 (1.9)	0.3 (1.2)	1.1 (1.1)	5.1 (7.0)	7.9 (12.0)	4.3 (11.0)	2.2 (6.4)	1.3 (4.0)	2.0 (5.4)	1.0 (6.8)	1.5 (7.3)	1.1 (12.9)	2.0 (13.8)	1.1 (4.8)	0.9 (1.8)	0.7 (3.2)	32.9
5-9	0.2 (1.0)	0.5 (0.9)		1.8 (1.9)	3.5 (4.1)	6.5 (6.7)	4.2 (4.2)	2.8 (2.7)	3.1 (3.4)	4.1 (5.8)	4.0 (5.8)	7.1 (11.8)	4.8 (11.9)	1.7 (3.7)	0.4 (0.9)	1.0 (2.5)	45.4
10-14	0.7 (0.8)	0.4 (0.4)		0.1 (0.1)	0.6 (0.6)	0.3 (0.3)			0.3 (0.3)	1.7 (1.8)	1.8 (1.8)	4.6 (4.7)	7.0 (7.1)	2.1 (2.1)	0.5 (0.5)	1.3 (1.5)	21.0
15-19	0.1 (0.1)									0.1 (0.1)	0.1 (0.1)	0.1 (0.2)	0.2 (0.1)			0.3 (0.3)	.8
20-																	
TOTAL	1.9	1.2	1.1	7.0	12.0	11.0	6.4	4.0	5.4	6.8	7.3	12.9	13.8	4.8	1.8	3.2	100.0

note: percentage exceedence in brackets

TABLE 3-2-1(4) Frequency of Wind Occurrence (%)

May-Sep

DIRECTION / VELOCITY (KNOT)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-4	0.0 (0.2)	(0.0)		0.4 (0.6)	1.2 (2.1)	0.9 (3.4)	0.5 (2.4)	0.7 (2.0)	1.0 (4.2)	0.9 (19.4)	0.7 (23.7)	0.6 (26.7)	0.3 (11.5)	0.0 (2.9)	0.1 (0.7)	0.1 (0.4)	7.4
5-9	0.1 (0.2)	0.0 (0.0)		0.1 (0.2)	0.8 (0.9)	2.4 (2.5)	1.8 (1.9)	1.2 (1.3)	2.4 (3.2)	11.4 (16.5)	10.4 (23.0)	9.3 (26.1)	3.4 (11.2)	0.6 (2.9)	0.3 (0.6)	0.1 (0.3)	44.1
10-14	0.1 (0.1)			0.0 (0.1)	0.0 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.7 (0.8)	6.5 (7.1)	11.1 (12.6)	14.5 (16.8)	6.1 (7.8)	1.2 (2.3)	0.2 (0.3)	0.1 (0.2)	40.6
15-19									0.0 (0.1)	0.5 (0.6)	1.3 (1.5)	2.0 (2.3)	1.1 (1.7)	0.7 (1.1)	0.1 (0.1)	0.1 (0.1)	5.8
20-							0.0			0.2	0.2	0.4	0.5	0.4	0.0	0.0	1.8
TOTAL	0.2	0.0		0.6	2.1	3.4	2.4	2.0	4.2	19.4	23.7	26.7	11.5	2.9	0.7	0.4	100.0

note: percentage exceedence in brackets

TABLE 3-2-1(5) Frequency of Wind Occurrence (%)

Oct-Nov

DIRECTION / VELOCITY (KNOT)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-4	1.3 (5.2)	1.3 (3.0)	1.3 (3.6)	1.1 (1.8)	4.2 (8.1)	4.2 (9.3)	2.4 (4.2)	1.1 (4.0)	0.6 (3.8)	0.8 (10.9)	0.8 (9.3)	0.8 (10.5)	1.2 (7.4)	0.4 (4.8)	1.6 (7.2)	0.9 (7.3)	23.7
5-9	1.8 (3.9)	1.3 (1.7)	2.1 (2.3)	0.7 (0.7)	3.5 (3.9)	4.9 (5.1)	1.5 (1.8)	2.5 (2.9)	2.5 (3.2)	4.5 (10.1)	5.3 (8.5)	4.5 (9.7)	2.8 (6.3)	2.5 (4.4)	3.6 (5.6)	2.8 (6.4)	46.3
10-14	2.0 (2.1)	0.4 (0.4)	0.3 (0.3)		0.5 (0.5)	0.1 (0.2)	0.3 (0.3)	0.5 (0.5)	0.7 (0.7)	5.1 (5.7)	2.7 (3.2)	4.7 (5.2)	3.5 (3.5)	1.9 (1.9)	2.1 (2.1)	2.3 (3.6)	27.0
15-19	0.1 (0.1)					0.1 (0.1)				0.6 (0.6)	0.5 (0.5)	0.5 (0.6)				1.4 (1.4)	3.0
20-											0.1	0.1					.2
TOTAL	5.2	3.0	3.6	1.8	8.1	9.3	4.2	4.0	3.8	10.9	9.3	10.5	7.4	4.8	7.2	7.3	100.0

note: percentage exceedence in brackets

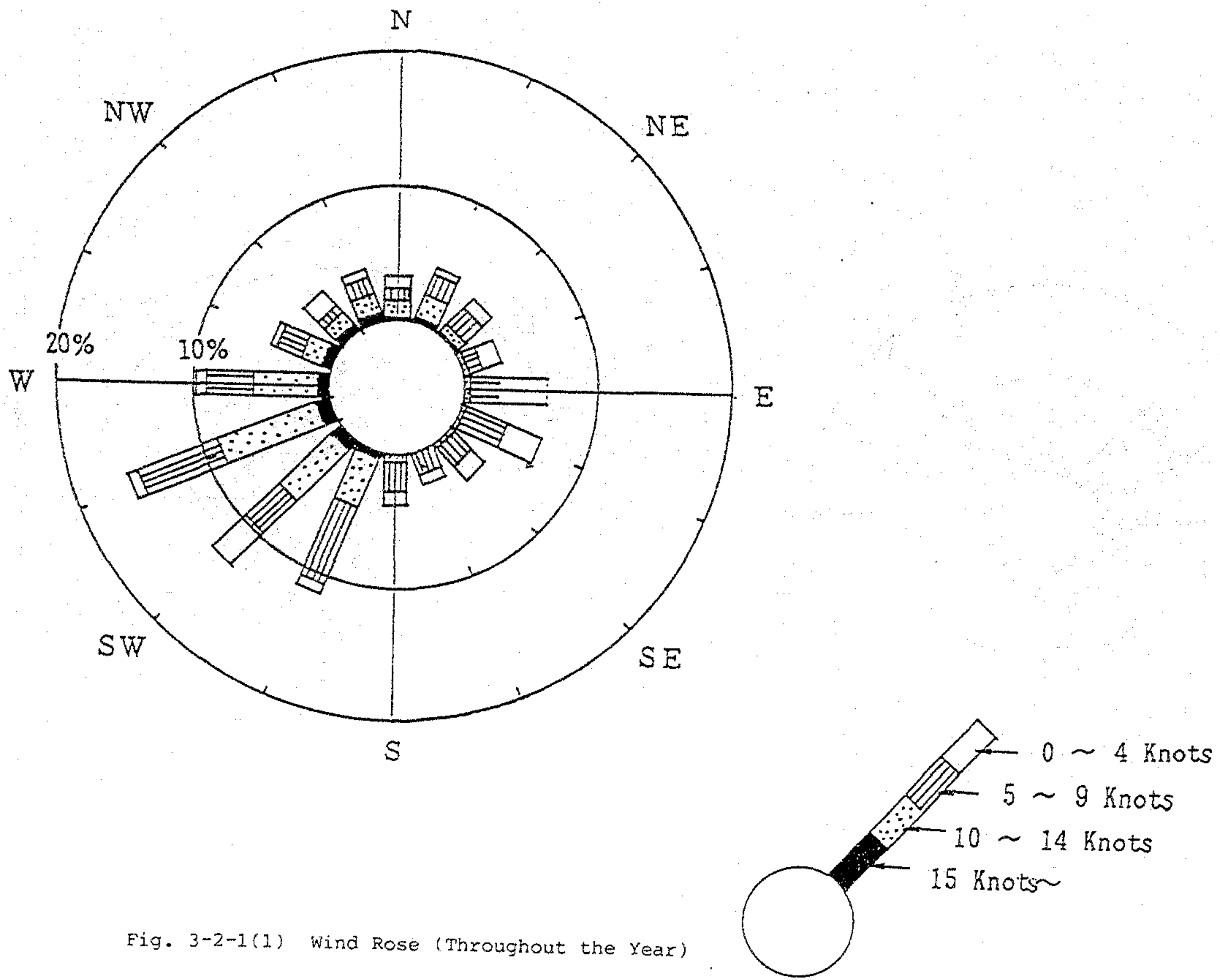


Fig. 3-2-1(1) Wind Rose (Throughout the Year)

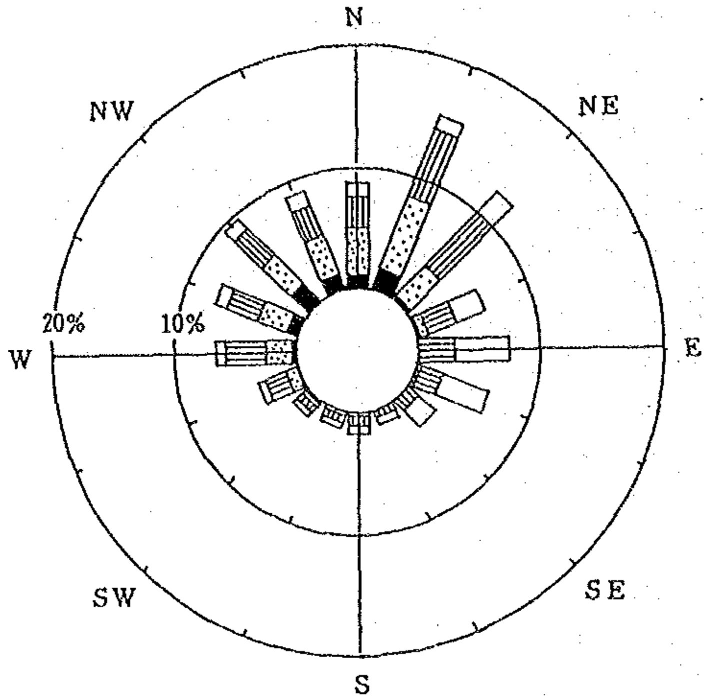


Fig. 3-2-1(2) Wind Rose (Dec., Jan. and Feb.)

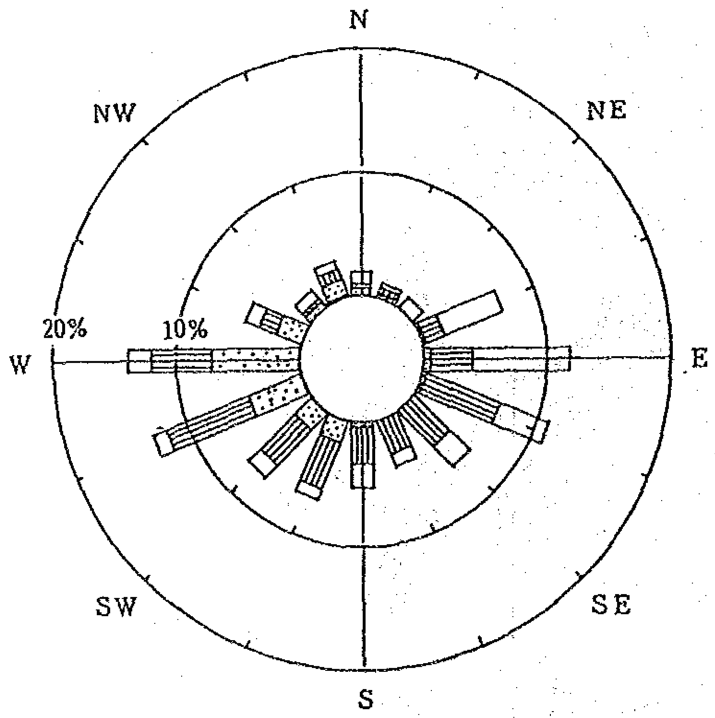


Fig. 3-2-1(3) Wind Rose (Mar. and Apr.)

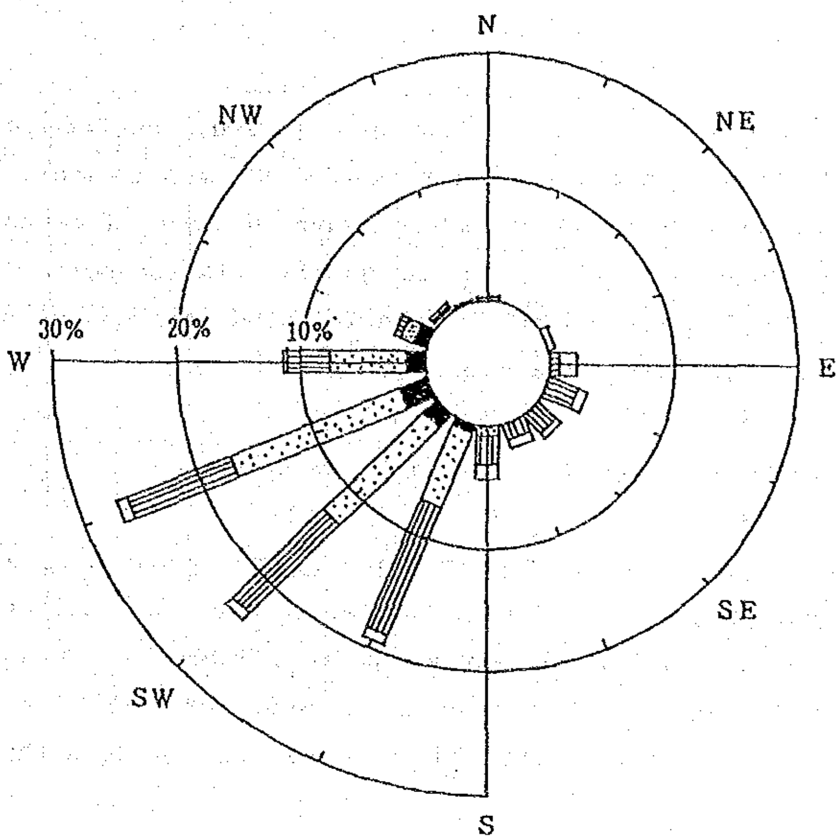


Fig. 3-2-1(4) Wind Rose (May to Sept.)

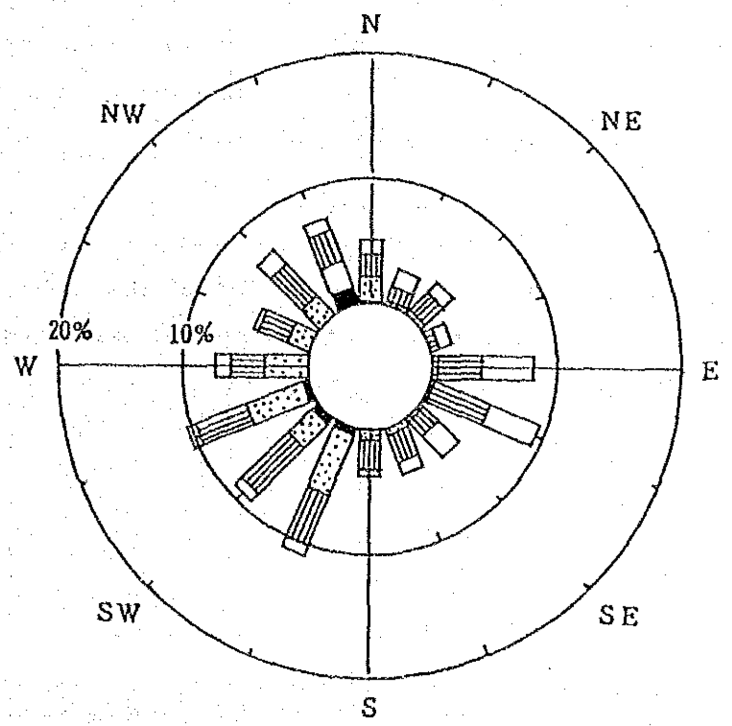


Fig. 3-2-1(5) Wind Rose (Oct. and Nov.)

3-3 Waves

The annual wave characteristics (height, period, and frequency of occurrence in each direction) and the characteristics (height, period, direction and return period) of extreme waves analyzed from the long-term observation are essential for design criteria for port planning. When observation records are not available, wind data can be utilized for estimating wave characteristics.

(1) Wave observation records in the Port of Colombo

Wave observation in the Port of Colombo have been carried out by the Coastal Engineering Centre and Lank Hydraulic Institute since 1980 primarily in the SW Monsoon period. Tables 3-3-1 and 3-3-2 present the observation results. SLPA is considering the continuation of wave height and direction observations throughout 1989.

As can be seen from Table 3-3-2, during the SW monsoon season, the frequency of wave heights of over 1.3m is 50% and that of heights greater than 1.8m is 10%. Although wave directions are not provided in this record, wave directions are presumed to range from W to SW on the basis of the prevailing wind direction and wave refraction by the contour lines of the seabed.

According to the observation records for the NE monsoon months of January and February 1988, the number of days when waves of over 1.0m occur in a day was 20 and the maximum significant wave height was 1.4m.

TABLE 3-3-1 Wave Observations at Port of Colombo (*)

Year	NE		INT		SW					INT	NE		Recording Interval	Type of Recording
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec		
1981				—	—	—	—	—					6 Hourly	Analog
1982						—	—	—	- - -	- - -			12 Hourly	Analog
1983						—	—	—	- - -	- - -			3 Hourly	Analog & Digital
1984					—			—	—	—			3 Hourly	Analog & Digital
1985									- - -	- - -		—	3 Hourly	Analog & Digital
1986	—	—	—	—									3 Hourly	Analog & Digital
1987							—	—	— - -	- - -		- - -	3 Hourly	Analog & Digital
1988	—	—	—	—	—	—	—	—	—	—	—	—	3 Hourly	Analog & Digital

TABLE 3-3-2 Wave Height Statistics for SW Monsoon (*)

Wave Height	% of Occurrence	% of Excedence
2.8 ∿ 3.0		
2.6 ∿ 2.8	0.07	0.07
2.4 ∿ 2.6	0.06	0.13
2.2 ∿ 2.4	0.17	0.3
2.0 ∿ 2.2	2.8	3.1
1.8 ∿ 2.0	6.0	9.1
1.6 ∿ 1.8	11.0	20.1
1.4 ∿ 1.6	18.5	38.6
1.2 ∿ 1.4	22.4	61.0
1.0 ∿ 1.2	18.4	79.4
0.8 ∿ 1.0	12.8	92.2
0.6 ∿ 0.8	7.3	99.5
0.4 ∿ 0.6	0.5	100.0
0.2 ∿ 0.4		
0. ∿ 0.2		

(*) Analysis of Wave Measurements 1980 - 1987
Interim Report 1, Jan. 1988/8803, Colombo Wave Measurements - 1988, Lanka Hydraulic Institute Ltd.

(2) Estimation of Wave Characteristics

Wave observations have been carried out since 1980 as stated above. However, the data obtained were not sufficient to allow a sound grasp of the annual wave characteristics for the following reasons.

1) Wave directions were not observed.

2) Observations were made primarily during the SW monsoon and did not cover the NE monsoon.

3) Most of the observation records do not cover the whole of the SW monsoon season of each year.

Therefore, the wave height calculated by the SMB method on the basis of the wind data for the Port of Colombo was corroborated by actual measurements. The next step was the correction of wind speed data obtained in the port to make the calculated wave height value as close to the actual measurements as possible.

This was followed by the estimation of waves in the port at an interval of three hours over a three-year period. The wave estimation results are presented in Table 3-3-3(1) to 3-3-3(5) and Fig.3-3-1(1) to 3-3-1(5).

1) Frequency of Wave Occurrence by Direction and Height
A comparison of the wind characteristics of Figs.3-2-1(1) to 3-2-1(5) and the wave characteristics of Figs.3-3-1(1) to 3-3-1(5) shows that except for Fig.3-2-1(1) for the whole year and Fig.3-2-1(2) for the December - February period and for the corresponding Fig.3-3-1(1) and Fig.3-3-1(2), all the wind roses and corresponding wave diagrams show more or less similar distributions of directions. During the northeast monsoon season, NNW waves are generated by NNE to N winds and this wave direction prevails. As is evident from the

distribution of wave directions in Fig.3-3-1(2), NNW waves occur with a relatively high frequency during the northeast monsoon, though they are limited in height.

Throughout the year the prevailing wave direction is WSW with a frequency of 28%, followed by SW with 19.1% and W with 15.2% for a total of 62.3%. On the other hand, NNW to WNW waves account for only 23.8% and their height is generally limited and seldom attains 2m or more. Waves higher than 2m come from the W to SSW directions, accounting for no more than 2.3%.

During the southwest monsoon season, WSW waves comprise 36.3% and SW waves 31.6% for a total of 67.9%. As for wave heights of 2m or more, WSW waves account for 2.3% and SSW to WNW waves 5.2%.

During the NE monsoon season, waves are influenced by the seabed configuration and the NNW waves account for 37.6%, but nearly two-thirds of them are less than 1.0m in height. Waves 2m or more in height occur with a 0.6% frequency and come from the W and NW directions.

2) High Waves

Waves of 3.0m or more in height occur with a frequency of 0.4% all the year round and they come from the SW to W directions. These higher waves occur during the southwest monsoon season only. The maximum estimated wave height during the period under consideration is 3.5m for May 1979.

(3) Consideration of Extreme Waves with Specific Return Period

During the field study, an attempt was made to determine extreme waves with a given return period from the long-range wind observation records. For the reasons explained above, however, the attempt had to be abandoned. Thus the available wind and wave data are discussed below in some detail.

(a) JICA Feasibility Study, March 1980 (*)

For wave estimation purposes, the maximum annual instantaneous wind velocity was converted to an equivalent mean wind velocity at sea and wind velocity changes over time were modeled. Using this model, wave estimation was made by the SMB method and the result was the maximum wave with a 25-year return period has a height of 6.1m, a period of 9.1 sec and a WSW direction.

For the purpose of our study, waves with a three-year return period were estimated from the above results. The estimated three-year waves have a height of 3.5m, the same value as the estimated maximum height noted in 2) of (2) above.

Estimations of wave height greater than 5m indicate that the wave heights tend to increase considerably with a longer return period.

(b) U.S. Navy Marine Climatic Atlas (**)

This atlas provides a compilation of visual wave observation reports received mainly from vessels in different parts of the world since 1940. The atlas gives the following wave information pertaining to the sea area surrounding Sri Lanka:

Direction	Height	Period
SW ～ W	6 to 7 m	8 to 9 sec
NW ～ N	3 to 4	6 to 7

(*) Report on the Development Project of the Port of Colombo, March 1980, Japan International Cooperation Agency.

(**) U.S. Navy Marine Climatic Atlas of the World, Vol.III, March 1976

The height of the western waves appears to be reduced slightly under the influence of the topographic features of the southernmost part of the Indian subcontinent. Northern waves are also under the same topographic influence and their height presumably is lower than 3 to 4m.

(4) Waves with a Certain Return Period Estimated for the Port of Colombo

(a) SW to WSW Waves

From the wave height of 6.1m and the wave period of 9.1 sec given in the JICA Report, the return period may be considered to be nearly 50 years.

(b) NNW to NW Waves

Estimation by the SMB method based on a fetch of 250km (the fetch in the NW direction at Colombo), a wind velocity of 25 knots and a duration of 20 hours gives a height of 3.0m and a period of 7 sec for the NNW to NW waves. Taking into account the velocity and duration of monsoon winds, it may safely be assumed that these waves have a return period of 50 years.

Obviously, there is considerable time before the implementation program for the breakwater construction can take shape. It is recommended that prior to the breakwater construction, arrangements should be made by SLPA to procure anemographs for undertaking long-term wind observations, and that continuous wind observations be carried out to permit the appropriate estimation of waves with a certain return period for the purpose of the breakwater construction.

TABLE 3-3-3(1) Frequency of Wave Occurrence (%)

[ANNUAL]

DIRECTION / WAVE HEIGHT (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0.00-0.49	2.6 (4.0)	2.2 (10.1)	3.5 (19.1)	5.4 (28.0)	4.9 (15.2)	1.6 (5.1)	2.0 (5.6)	4.4 (13.1)	26.6
0.50-0.99	1.2 (1.4)	5.3 (7.9)	8.5 (15.6)	13.7 (22.6)	6.1 (10.3)	2.6 (3.5)	2.4 (3.6)	5.7 (8.7)	45.5
1.00-1.49	0.2 (0.2)	1.7 (2.6)	5.4 (7.1)	6.4 (8.9)	2.9 (4.2)	0.6 (0.9)	0.8 (1.2)	2.6 (3.0)	20.6
1.50-1.99		0.7 (0.9)	1.1 (1.7)	1.4 (2.5)	0.9 (1.3)	0.3 (0.3)	0.4 (0.4)	0.4 (0.4)	5.2
2.00-2.49		0.1 (0.2)	0.3 (0.6)	0.6 (1.1)	0.2 (0.4)				1.2
2.50-2.99		0.1 (0.1)	0.2 (0.3)	0.3 (0.5)	0.1 (0.2)				0.7
3.00-			0.1	0.2	0.1				0.4
TOTAL	4.0	10.1	19.1	28.0	15.2	5.1	5.6	13.1	100.2

note: percentage exceedence in brackets

TABLE 3-3-3(2) Frequency of Wave Occurrence (%)

Dec.-Feb.

DIRECTION / WAVE HEIGHT (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0.00-0.49	3.1 (3.4)	1.2 (1.4)	2.0 (3.3)	6.2 (14.3)	7.7 (16.9)	3.3 (9.7)	5.1 (13.8)	11.8 (37.6)	40.4
0.50-0.99	0.3 (0.3)	0.2 (0.2)	1.2 (1.3)	7.6 (8.1)	6.6 (9.2)	4.3 (6.4)	4.3 (8.7)	16.6 (25.8)	41.1
1.00-1.49			0.1 (0.1)	0.4 (0.5)	2.1 (2.6)	1.9 (2.1)	2.7 (4.4)	7.6 (9.2)	14.8
1.50-1.99				0.1 (0.1)	0.3 (0.5)	0.2 (0.2)	1.3 (1.7)	1.6 (1.6)	3.5
2.00-2.49					0.2 (0.2)		0.2 (0.4)		0.4
2.50-2.99							0.2 (0.2)		0.2
3.00-									0.0
TOTAL	3.4	1.4	3.3	14.3	16.9	9.7	13.8	37.6	100.4

note: percentage exceedence in brackets

TABLE 3-3-3(3) Frequency of Wave Occurrence (%)

Mar., Apr.

DIRECTION / WAVE HEIGHT (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0.00-0.49	4.1 (4.9)	2.6 (6.5)	6.7 (13.8)	11.7 (35.8)	9.7 (24.5)	2.1 (5.7)	1.4 (4.3)	1.8 (4.4)	40.0
0.50-0.99	0.8 (0.8)	3.6 (3.9)	4.7 (7.1)	22.0 (24.2)	12.6 (14.8)	3.6 (3.6)	2.9 (2.9)	2.3 (2.6)	52.4
1.00-1.49		0.2 (0.3)	2.3 (2.5)	2.2 (2.2)	2.1 (2.2)			0.3 (0.3)	7.0
1.50-1.99		0.1 (0.1)	0.2 (0.2)		0.2 (0.2)				0.4
2.00-2.49									0.0
2.50-2.99									0.0
3.00-									0.0
TOTAL	4.9	6.5	13.8	35.8	24.5	5.7	4.3	4.4	99.8

note: precentage exceedence in brackets

TABLE 3-3-3(4) Frequency of Wave Occurrence (%)

May - Sept.

DIRECTION / WAVE HEIGHT (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0.00-0.49	1.0 (2.4)	2.3 (16.4)	2.3 (31.6)	2.6 (36.3)	0.4 (11.4)	0.1 (1.3)	0.0 (0.1)	0.0 (0.2)	8.7
0.50-0.99	1.1 (1.4)	9.8 (14.1)	15.3 (29.3)	16.1 (33.7)	3.7 (11.0)	0.2 (1.2)	0.1 (0.1)	0.1 (0.2)	46.4
1.00-1.49	0.3 (0.3)	2.6 (4.3)	10.6 (14.0)	12.2 (17.6)	4.7 (7.3)	0.3 (1.0)		0.1 (0.1)	30.8
1.50-1.99		1.2 (1.7)	2.3 (3.4)	3.1 (5.4)	1.7 (2.6)	0.4 (0.7)			8.7
2.00-2.49		0.2 (0.5)	0.5 (1.1)	1.3 (2.3)	0.5 (0.9)	0.2 (0.3)			2.7
2.50-2.99		0.2 (0.3)	0.4 (0.6)	0.6 (1.0)	0.1 (0.4)	0.1 (0.1)			1.4
3.00-		0.1	0.3	0.4	0.3				1.1
TOTAL	2.4	16.4	31.7	36.3	11.4	1.3	0.1	0.2	99.8

note: percentage exceedence in brackets

TABLE 3-3-3(5) Frequency of Wave Occurrence (%)

Oct., Nov.

DIRECTION / WAVE HEIGHT (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0.00-0.49	4.2 (8.1)	3.3 (10.9)	5.5 (16.4)	5.3 (19.6)	6.9 (12.9)	2.1 (6.8)	3.1 (8.1)	6.8 (17.5)	37.0
0.50-0.99	3.2 (3.9)	3.6 (7.6)	6.4 (10.9)	8.9 (14.3)	4.8 (6.0)	4.7 (4.7)	4.5 (5.1)	6.9 (10.7)	42.9
1.00-1.49	0.8 (0.8)	3.4 (4.0)	3.3 (4.5)	4.9 (5.4)	1.2 (1.2)		0.5 (0.2)	3.4 (3.8)	17.2
1.50-1.99		0.7 (0.7)	0.2 (1.3)	0.4 (0.6)			0.2	0.4	1.8
2.00-2.49			0.7 (1.1)	0.1 (0.2)					0.8
2.50-2.99			0.4 (0.4)	0.1 (0.1)					0.5
3.00-									0.0
TOTAL	8.1	10.9	16.4	19.6	12.9	6.8	8.1	17.5	100.1

note: percentage exceedence in brackets

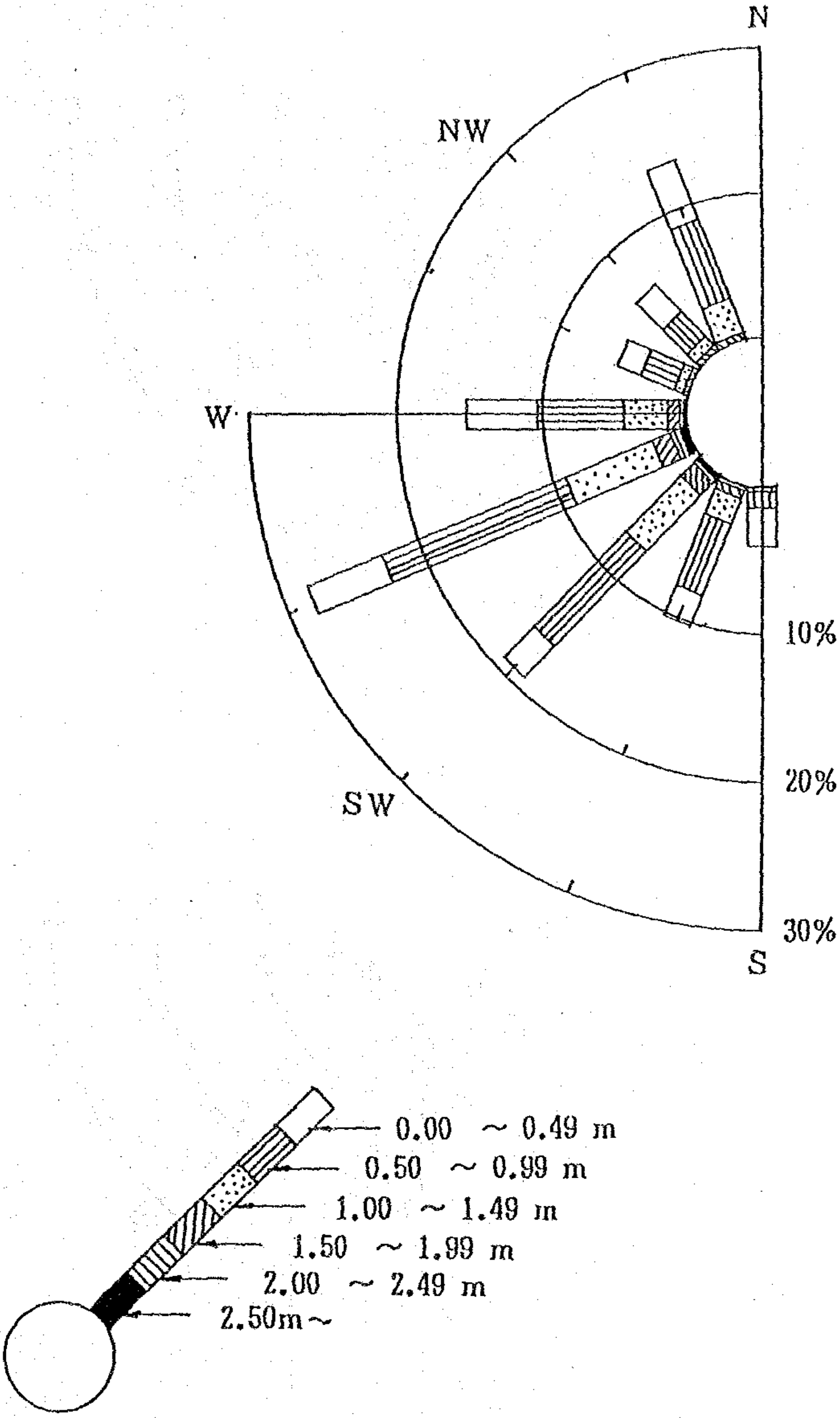


Fig. 3-3-1(1) Wave Occurrence (Throughout the Year)

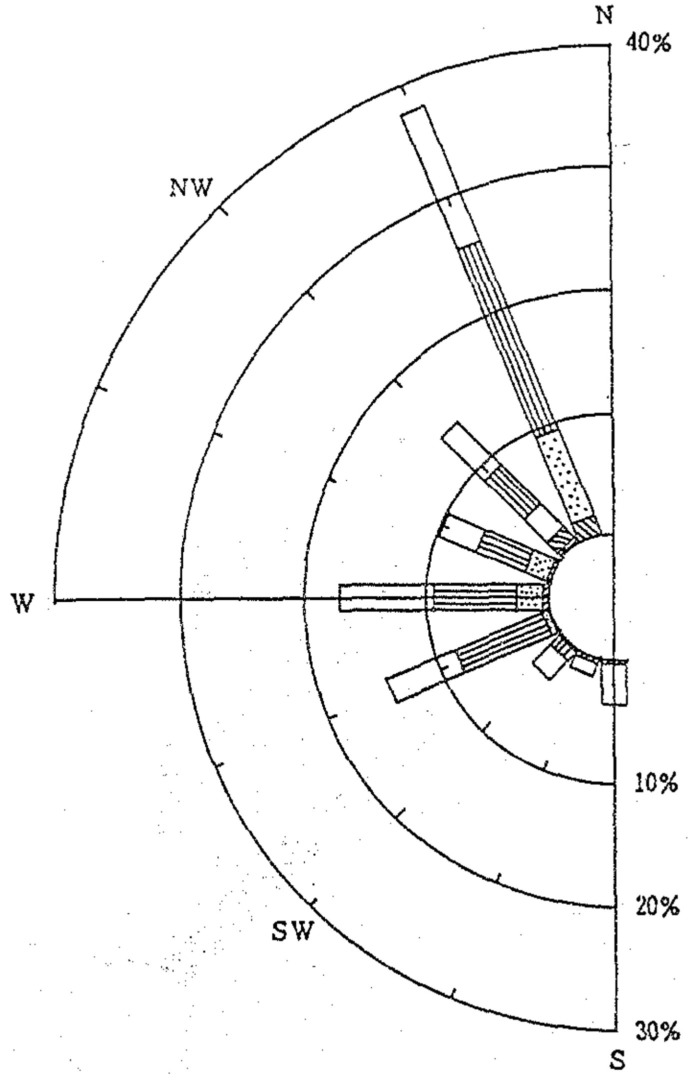


Fig. 3-3-1(2) Wave Occurrence (Dec., Jan. and Feb.)

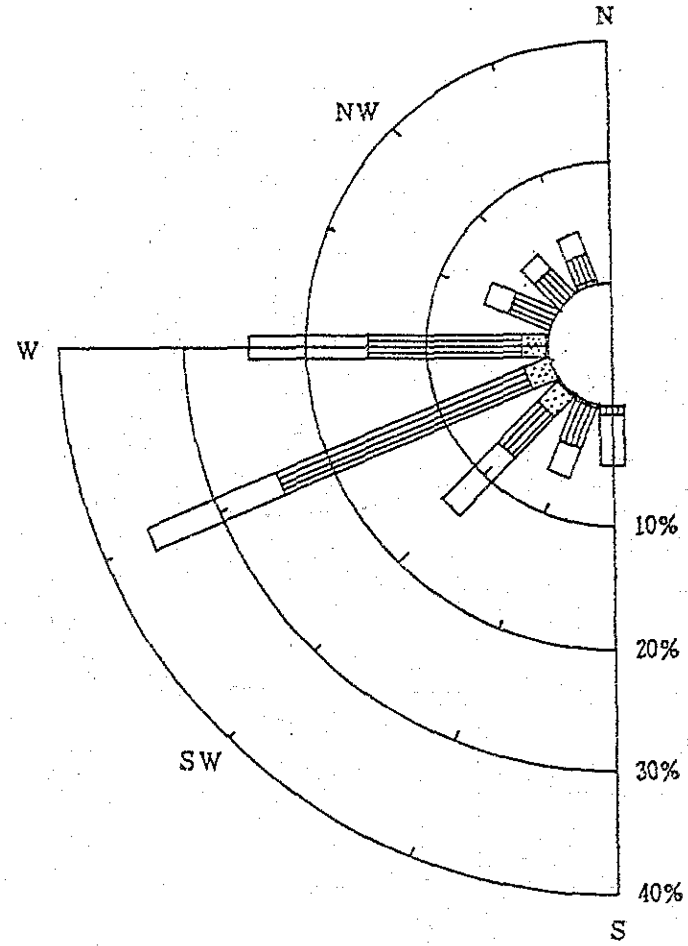


Fig. 3-3-1(3) Wave Occurrence (Mar. and Apr.)

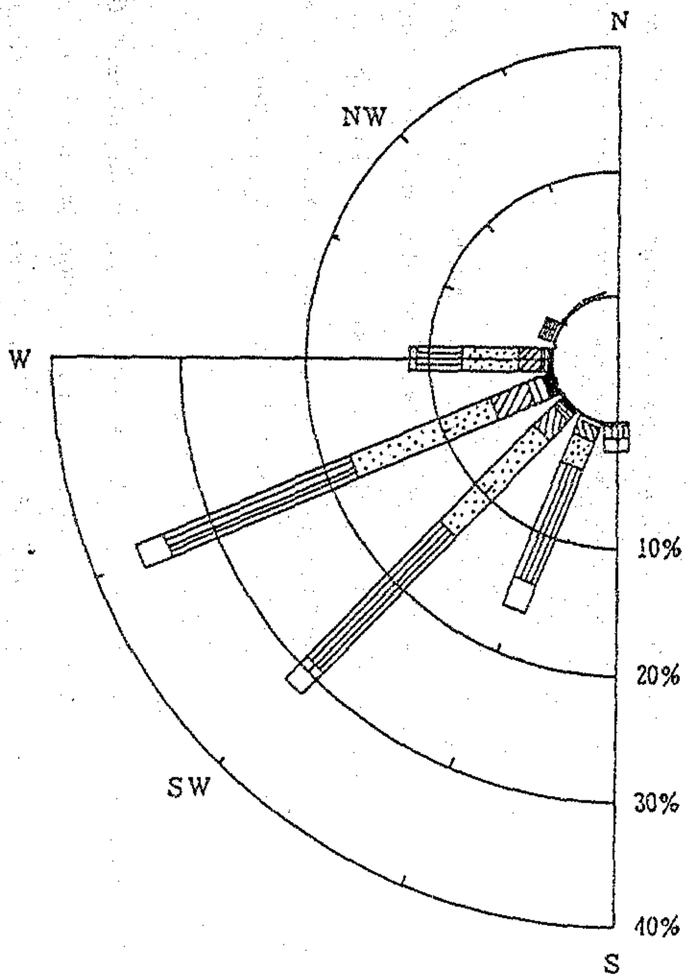


Fig. 3-3-1(4) Wave Occurrence (May to Sept.)

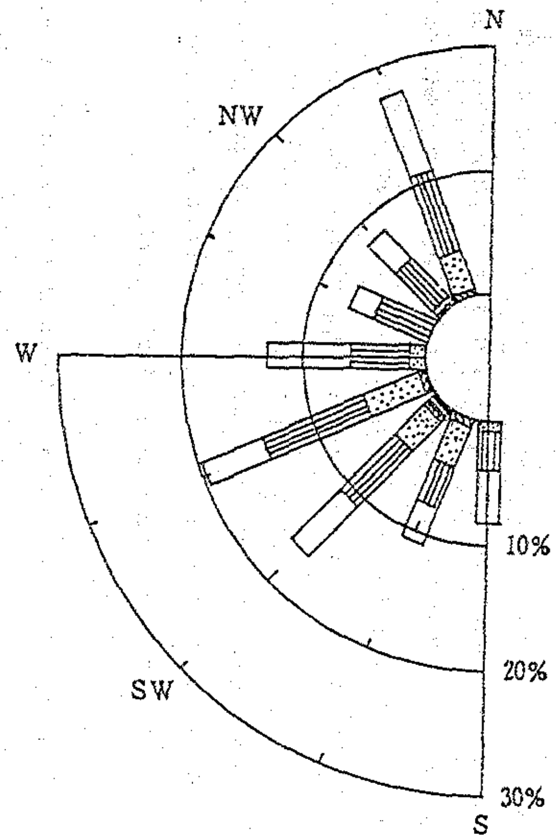


Fig. 3-3-1(5) Wave Occurrence (Oct. and Nov.)

3-4 Soil Conditions

3-4-1 General Description of Geology

The geology of the Port of Colombo and its vicinity in both inland and offshore areas consists primarily of gneiss formations as the bedrock overlain by laterite layers which are, in turn, overlain by earth sediments which constitute the superficial layer.

Fig.3-4-1 shows the geological map of the port and its vicinity, Fig.3-4-2 the soil profile of the port and Fort areas and Fig.3-4-3 the soil profile of Crown Land behind the port.

Table 3-4-1 indicates the availability of essential soil data obtained during the JICA feasibility Study Team in early 1989 and previous studies at different points in and around the Port of Colombo. The locations of soil borings conducted during these studies are shown in Figs. 3-4-4 and 3-4-5 and the soil profiles based on the outcome of the studies in Figs.3-4-6(a) to 3-4-6(d).

In addition, a geophysical survey using a subbottom profiles was carried out in waters outside the harbor entrance and in the northern part of the harbor basin to determine the depth of hard soil layers of the bottom. The results of this survey are given in Figs.3-4-7(a) to 3-4-7(c).

The soil investigation results referred to above indicate that the gneiss and laterite layers in the Port of Colombo are generally formed at depths ranging from -15 to -20m and provide the bearing strata for harbor structures, while they are likely to obstruct dredging operations in the harbor basin or access channels for deepening.

The bedrock is overlain largely by a sand layer which showed SPT N-values of 10 to 20. In the harbor basin, sludge deposits are formed on the bottom in a thickness of 2 to 3m. These deposits should be taken into account in planning reclamation works and quay construction.

Crown Land is a marshland consisting primarily of a layer of organic humus with a thickness of 5 to 7m.

In this area, the bedrock is found at a depth of -10m and there are intervening soft silt layers between the bedrock and humus layers. Adequate precautions should, therefore, be taken against consolidation settlement in implementing a development project in the Crown Land area.

3-4-2 Soil Properties

This section summarizes the soil properties of the Port of Colombo and Crown Land as defined on the basis of the available soil data.

(1) Harbor Area

Detailed results of laboratory tests on soil samples from QEQ Berth No.4 and the North Pier area are available, and permit a sound grasp of the properties of the representative soil of the harbor area. The plasticity chart, triangular classification and grain size distribution curves obtained through soil tests for QEQ Berth No.4 and offshore boring behind QEQ are given in Figs.3-4-8, 3-4-9 and 3-4-10, respectively, and the comparable data covering the North Pier area and JCT No.4 quay line in Figs.3-4-11, 3-4-12 and 3-4-13.

These figures indicate that the bedrock is mostly overlain by sandy soils with a local distribution of cohesive soils. For these cohesive soils, Fig. 3-4-14 gives the relationship between moisture content and clay content and Fig.3-4-15 the relationship between wet density and clay content. As indications of the consolidation characteristics of the cohesive solid, the relationships between void ratio and consolidation pressure, between the coefficient of volume compressibility and the average consolidation pressure and between the coefficient of consolidation and the average consolidation pressure are given in Figs.3-4-16, 3-4-17 and 3-4-18, respectively.

In respect of the strength characteristics of the cohesive soils, the cohesion value is determined as below from the relationship between the depth of undisturbed sampling and unconfined compressive strength.

$qu = 0.0907Z + 0.400\ (kg/cm^2)$

Since $qu/2 = C\ (kg/cm^2)$, cohesion, Cu, is

$Cu = 0.0454Z + 0.200\ (kg/cm^2)$

For sandy silt layers, the following cohesion value has been obtained.

$$Cu = 0.0454Z + 0.495 \ (kg/cm^2) \ (Z = 0m; \ EL\text{-}17.50m)$$

(2) Crown Land

The results of the laboratory tests performed during the JICA study are given in the Supplement. The Crown Land area consists of very soft cohesive soils. Figs.3-4-19, 3-4-20 and 3-4-21 give the plasticity chart, triangular classification and grain size distribution curves, respectively, for the representative soil samples obtained from this area.

The laboratory test results show the following properties for the very soft cohesive soil layers.

Organic content	13.1 - 34.4%
Specific gravity of soil particles	2.428 - 2.560
Moisture content	149.3 - 196.3%
Liquid limit	114.5 - 227.5%
Plastic limit	53.1 - 93.5%
Wet density of soils	1.236 - 1.341 g/cm^3
Void ratio	2.80 - 5.08

As indications of the consolidation characteristics of the cohesive soils, the relationships between the void ratio and consolidation pressure (e - log P), between the coefficient of volume compressibility and the average consolidation pressure (P-Mv) and between the coefficient of consolidation and the average consolidation pressure (P-Cv) are given in Figs.3-4-22, 3-4-23 and 3-4-24, respectively.

As an indication of the strength characteristics of the cohesive soils, Fig.3-4-25 illustrates the relationship between the depth of undisturbed sampling and unconfined compressive strength. From this relationship are derived the following equations:

$$qu = 0.048Z - 0.025 \ (kg/cm^2)$$

$$c = qu/2 = 0.024Z + 0.013 \ (kg/cm^2)$$

C/P = 0.87 ... coefficient of incremental consolidation strength

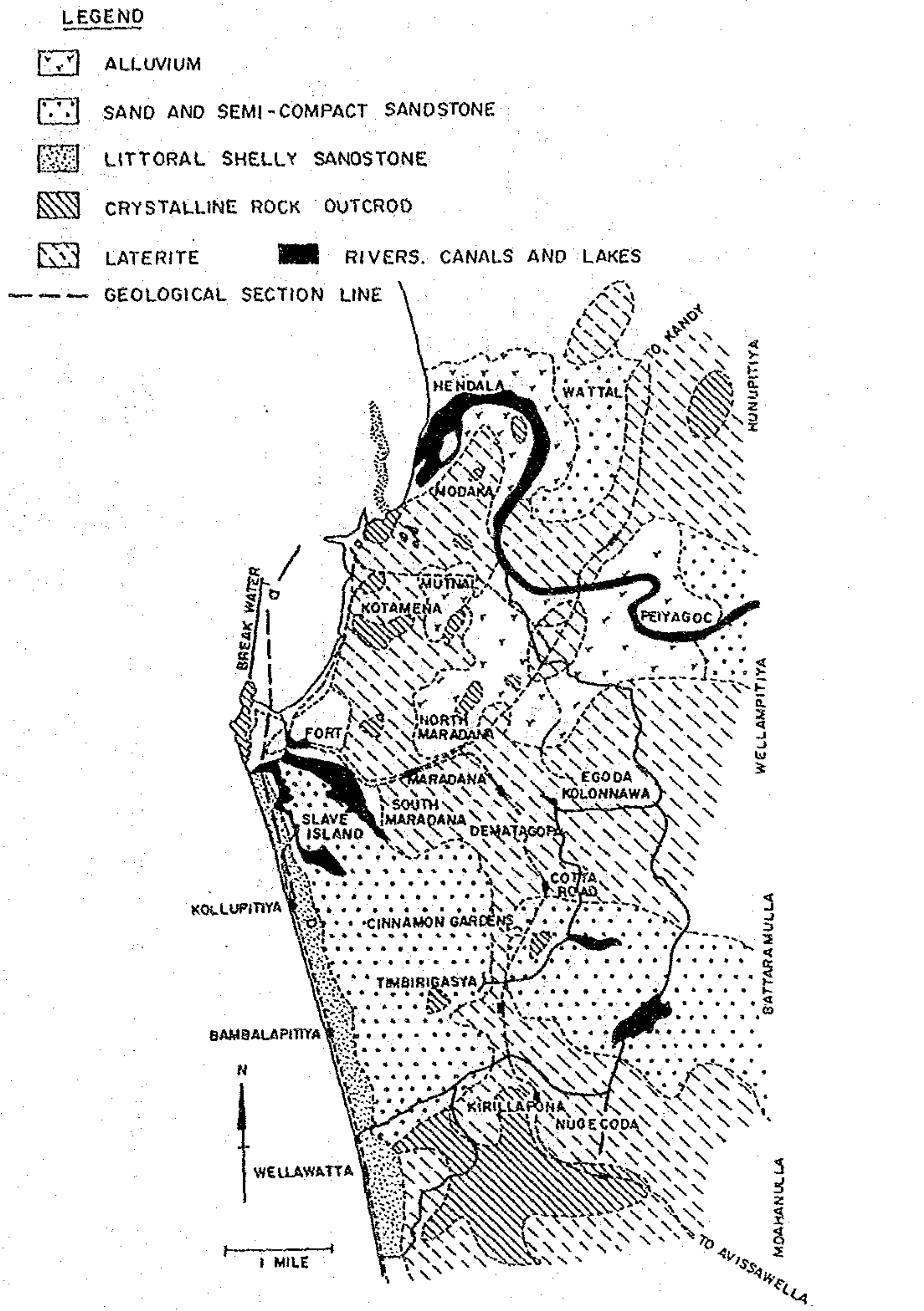
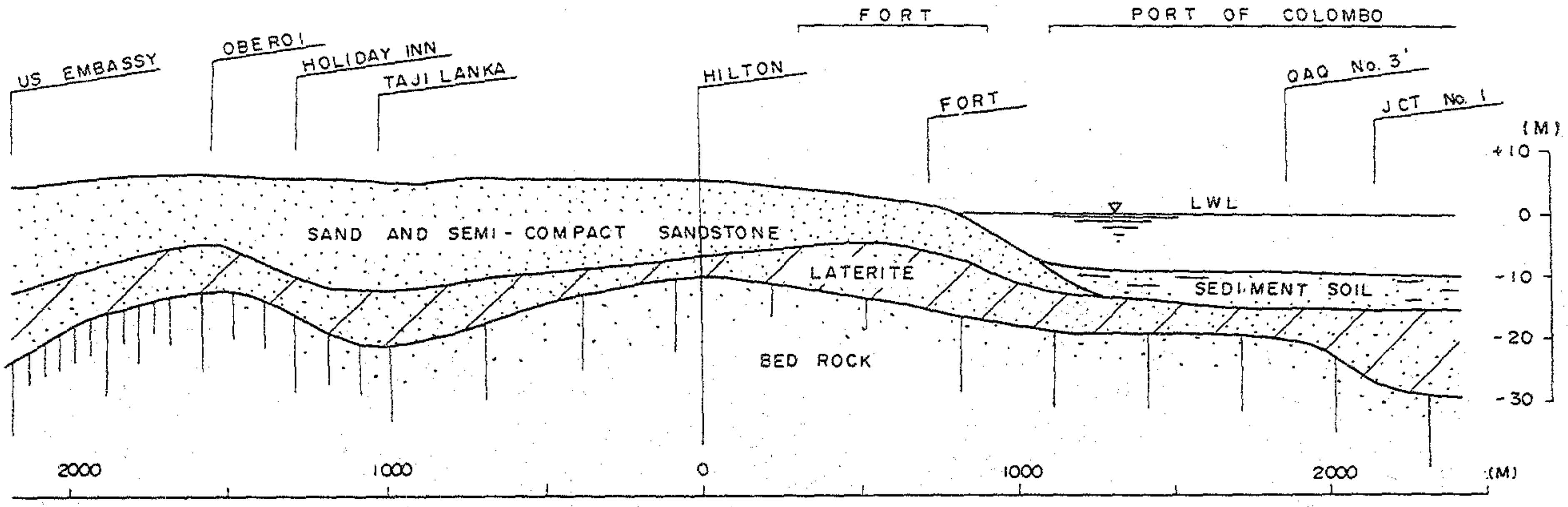


Fig. 3-4-1 Geological map of the Colombo District
Ref. Cooray (1967)

Source: Geotechnical mapping for structural building purposes with an example from the city of Colombo by Prof.B.L.Tennekoon, K.A.S.Kumarge, K.A.M.K. Ranasinghe and D.S.Wimalaratne.



a — a' SECTION

Fig. 3-4-2 Soil Profile of the Strata for Colombo Port Area

Scale H=1/2000, V=1/1000

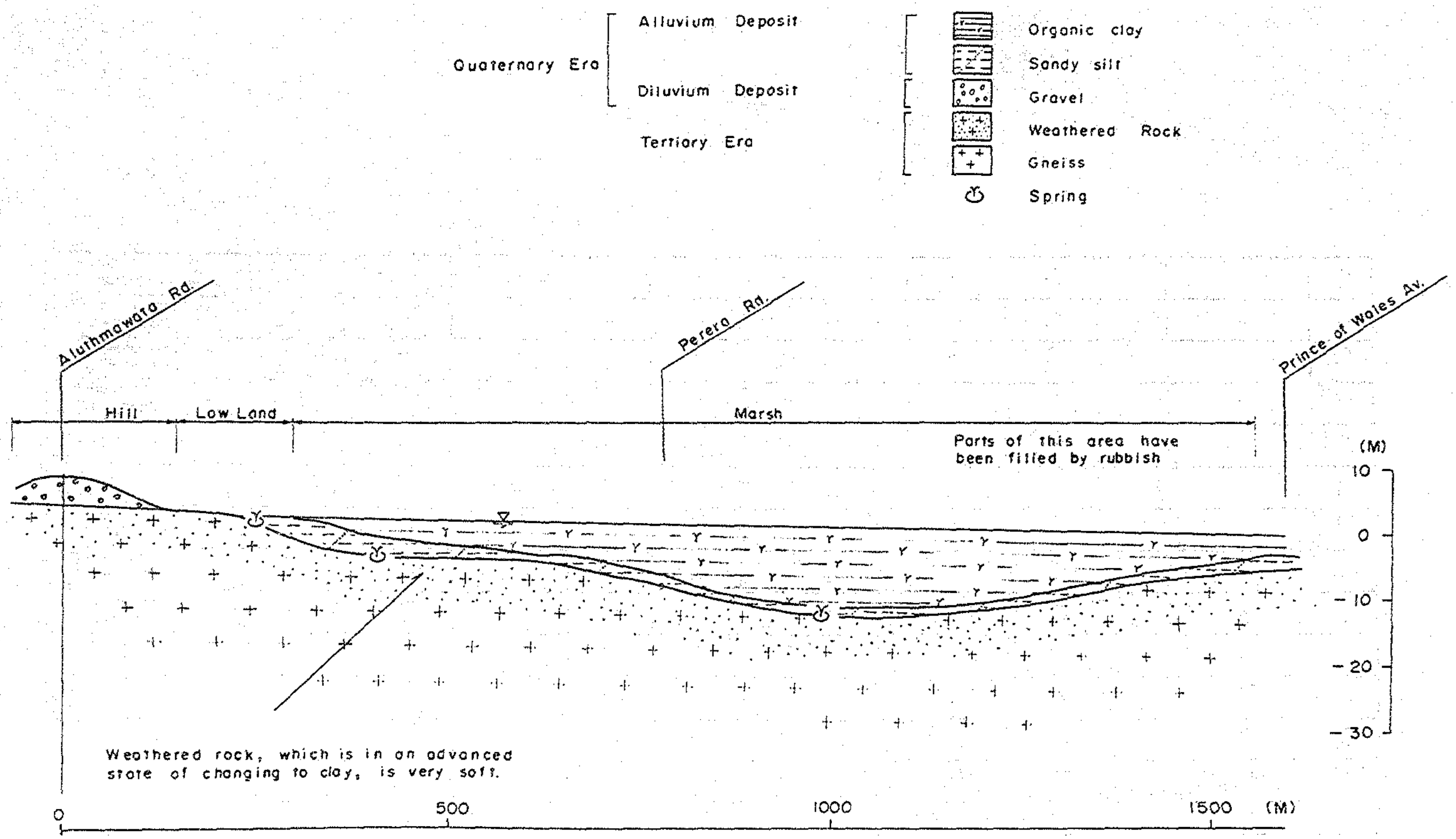


Fig. 3-4-3 Soil Profile of the Strata for Access Road

TABLE 3-4-1 Soil Data Availability for Different Points in and around the Port of Colombo

		JICA Study (1989)			Previous Investigations								
		JCT No. 4	SW Breakwater	Crown Land	JCT No. 1	JCT No. 2	JCT No. 3	Turning Area	QEQ Nos. 2/3	QEQ Nos. 4/5	North Pier	NW Breakwater & North Channel	Crown Land
In Situ Studies	Soil boring	○	○	○	○	○	○	○	○	○	○	○	○
	SPT	○	○	○	○	○	○	○	○	○	○	○	○
	Undisturbed sampling	-	-	-	-	-	○	-	-	○	-	-	○
Laboratory Soil Test	Specific gravity	○	○	○	○	○	-	-	-	○	○	-	○
	Moisture content	○	○	○	○	○	-	-	-	○	○	-	○
	Mechanical analysis	○	○	○	○	○	-	-	-	○	○	-	○
	Liquid limit	-	-	-	-	-	-	-	-	○	-	-	○
	Plastic limit	-	-	-	-	-	-	-	-	○	-	-	○
	Organic content	-	-	-	-	-	-	-	-	-	-	-	○
	Unconfined compression test	-	-	-	-	-	-	-	-	○	-	-	○
	Triaxial compression test	-	-	-	-	-	-	-	-	○	-	-	-
	Consolidation test	-	-	-	-	-	-	-	-	○	-	-	○

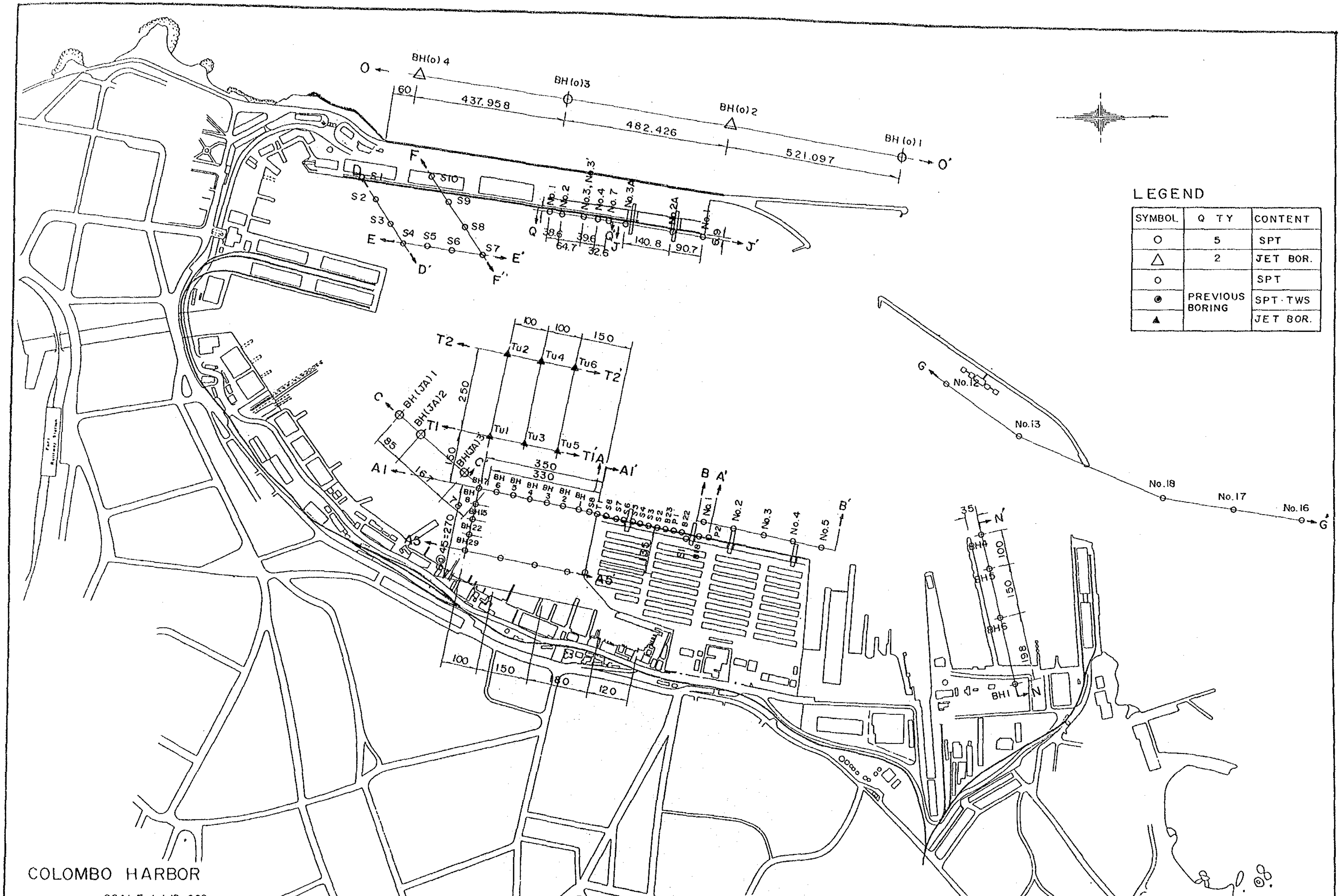


Fig. 3-4-4 Location of Boring Points

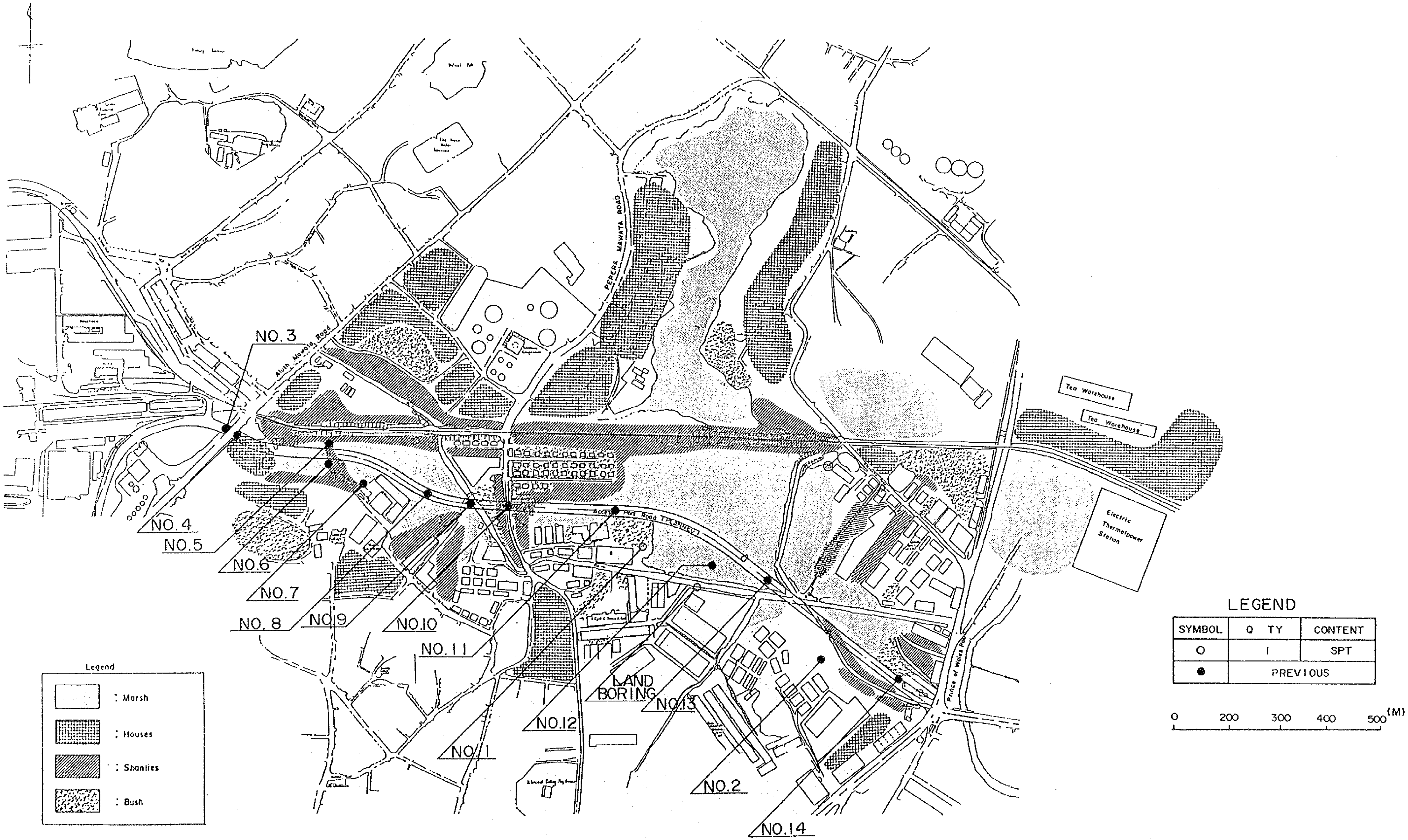
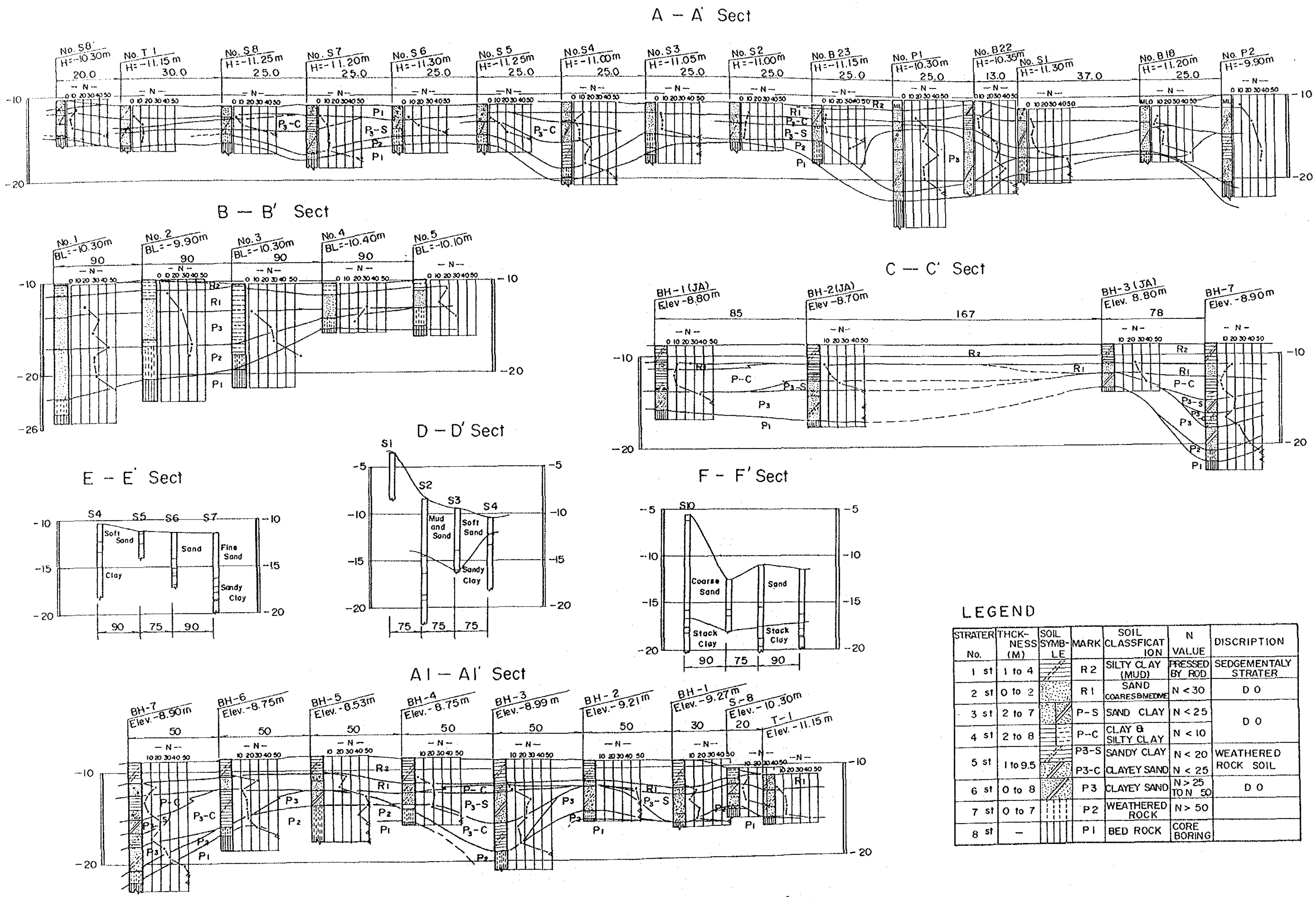


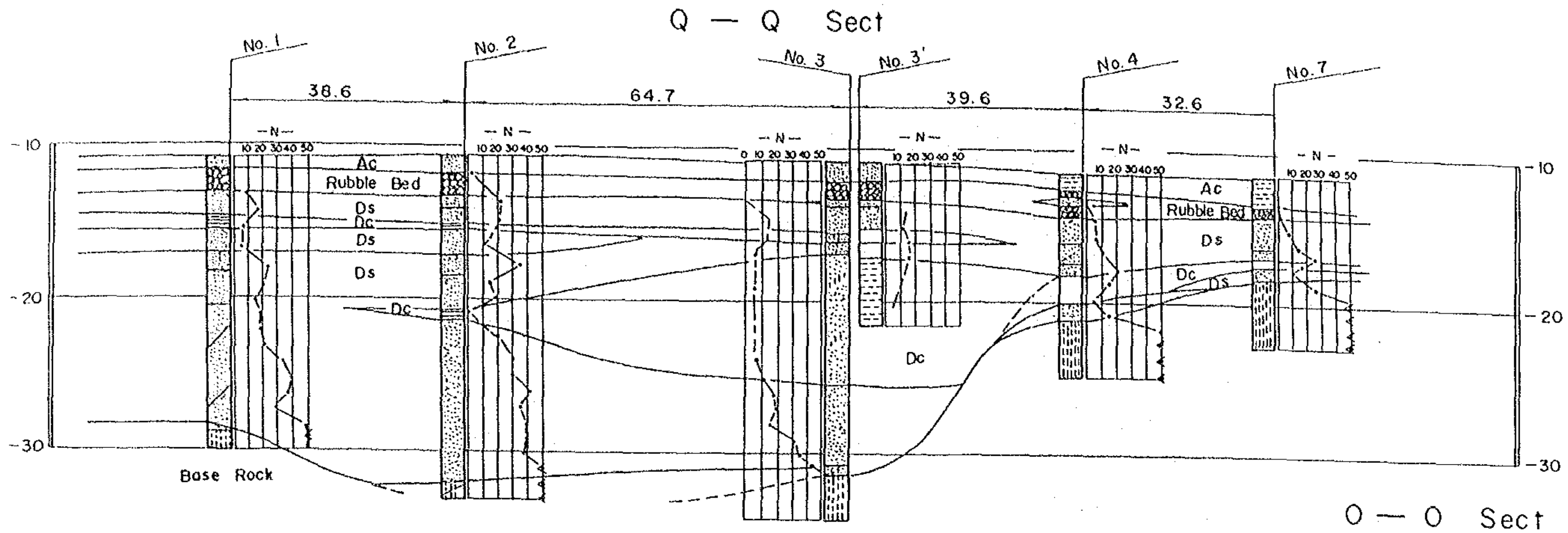
Fig. 3-4-5 Location of Boring Points



LEGEND

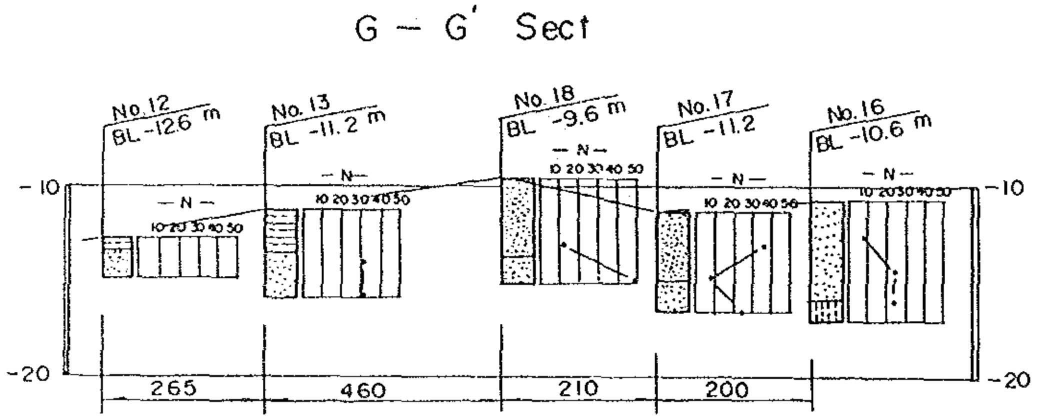
STRATER No.	THCKNESS (M)	SOIL SYMBLE	MARK	SOIL CLASSIFICATION	N VALUE	DISCRIPTION
1 st	1 to 4		R2	SILTY CLAY (MUD)	PRESSED BY ROD	SEDGEMENTALY STRATER
2 st	0 to 2		R1	SAND COARES&MEDME	N < 30	D O
3 st	2 to 7		P-S	SAND CLAY	N < 25	D O
4 st	2 to 8		P-C	CLAY & SILTY CLAY	N < 10	
5 st	1 to 9.5		P3-S P3-C	SANDY CLAY CLAYEY SAND	N < 20 N < 25	WEATHERED ROCK SOIL
6 st	0 to 8		P3	CLAYEY SAND	N > 25 TO N 50	D O
7 st	0 to 7		P2	WEATHERED ROCK	N > 50	
8 st	—		P1	BED ROCK	CORE BORING	

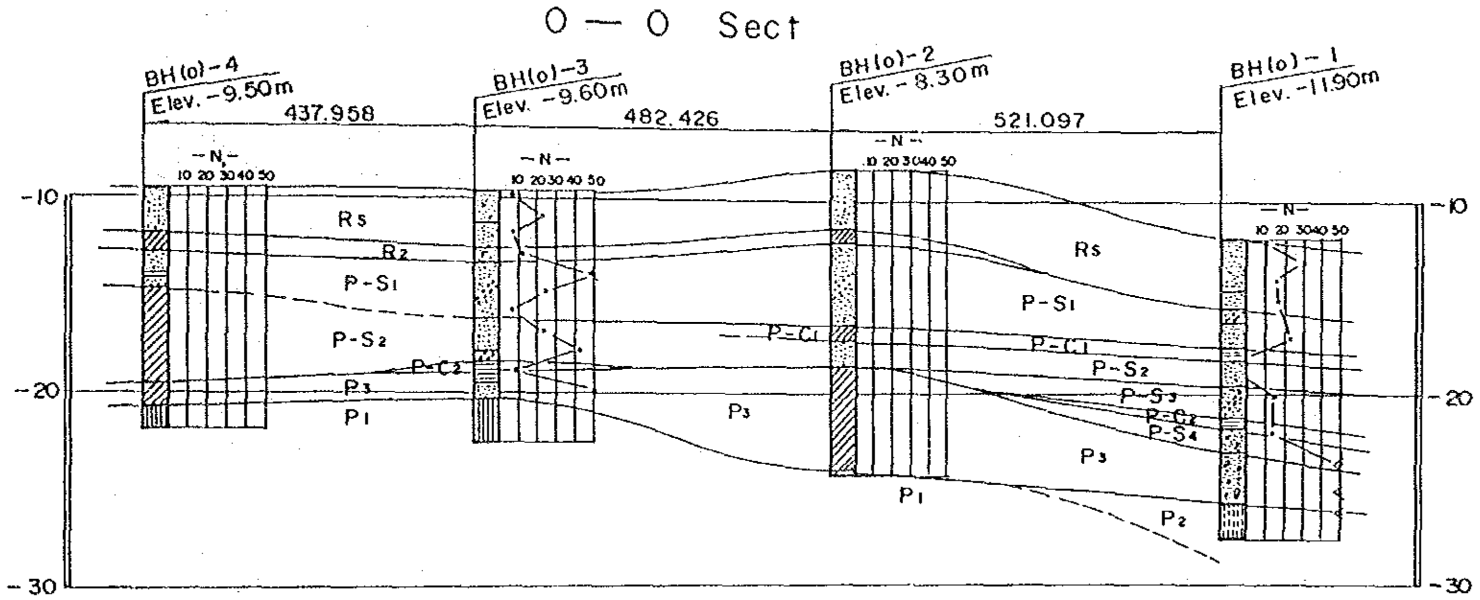
Fig. 3-4-6(a) Soil Profile of Port Area

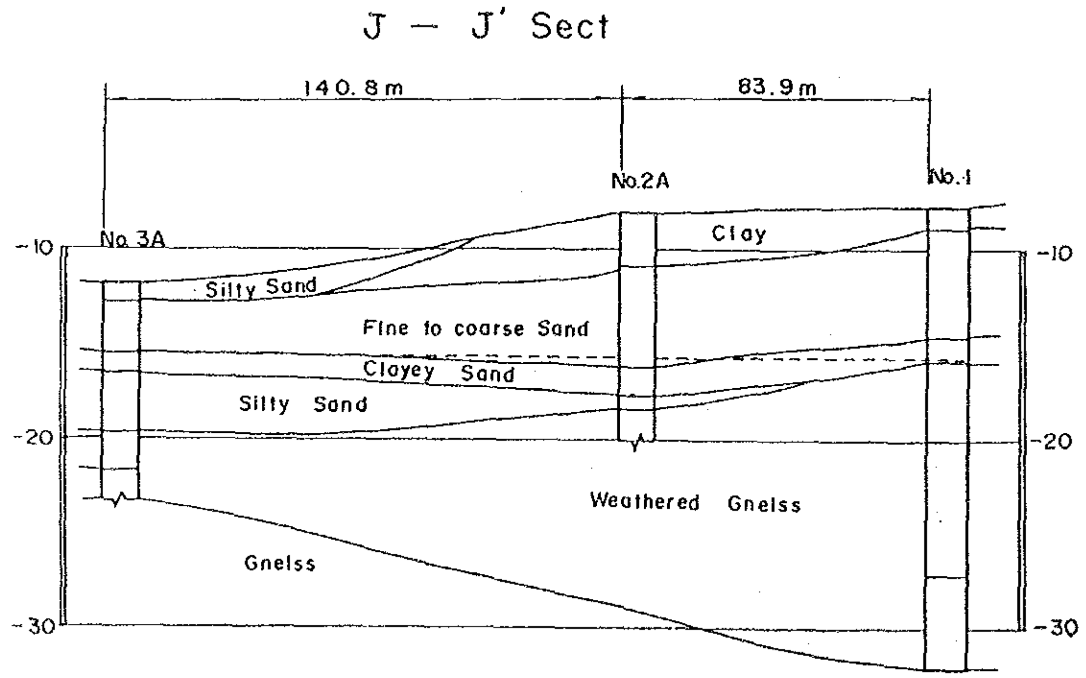


LEGEND

STRATER No.	THCK-NESS (M)	SOIL SYMB-LE	MARK	SOIL CLASSFICATION	N VALUE	DISCRIPTION
1 st	1 to 4		R 2	SILTY CLAY (MUD)	PRESSED BY ROD	SEDGEMENTALY STRATER
2 st	0 to 2		R 1	SAND COARES&MEDME	N < 30	D O
3 st	2 to 7		P-S	SAND CLAY	N < 25	D O
4 st	2 to 8		P-C	CLAY & SILTY CLAY	N < 10	
5 st	1 to 9.5		P3-S	SANDY CLAY	N < 20	WEATHERED ROCK SOIL
			P3-C	CLAYEY SAND	N < 25	
6 st	0 to 8		P 3	CLAYEY SAND	N > 25 TO N > 50	D O
7 st	0 to 7		P 2	WEATHERED ROCK	N > 50	
8 st	—		P 1	BED ROCK	CORE BORING	







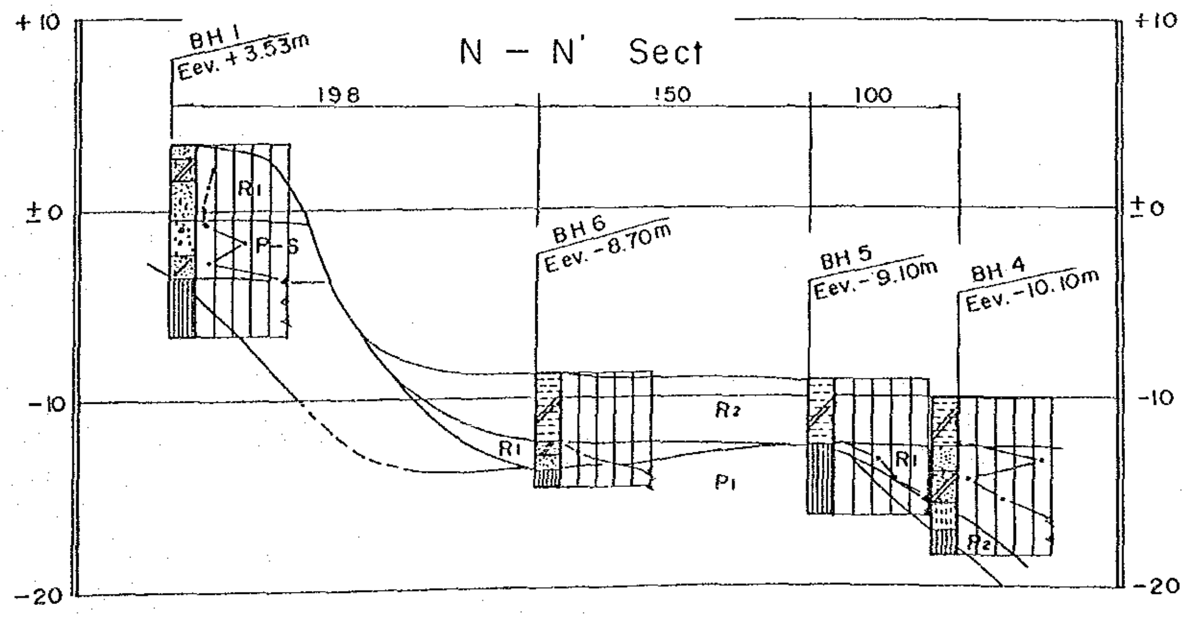
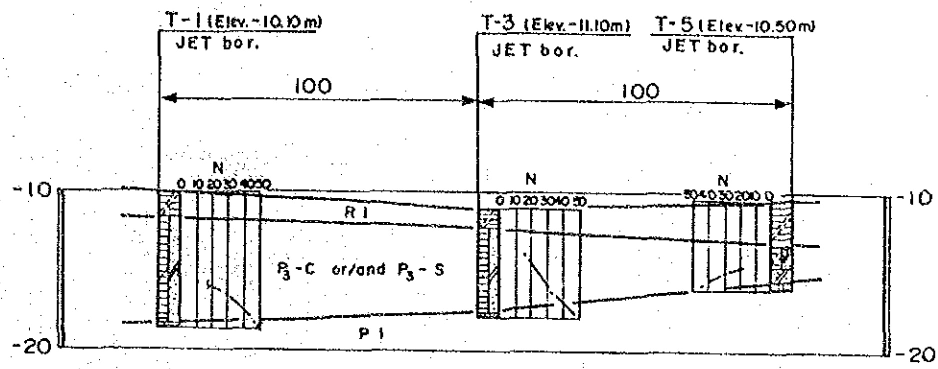


Fig. 3-4-6(b) Soil Profile of Port Area

T1 - T1' Sect



T2 - T2' Sect

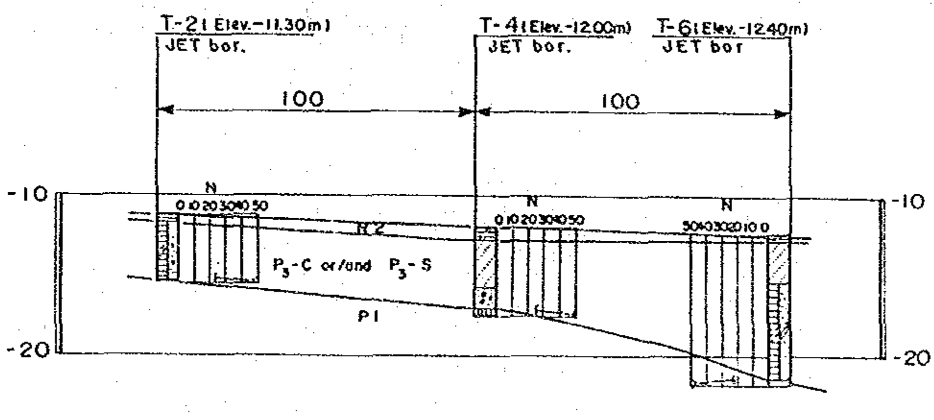
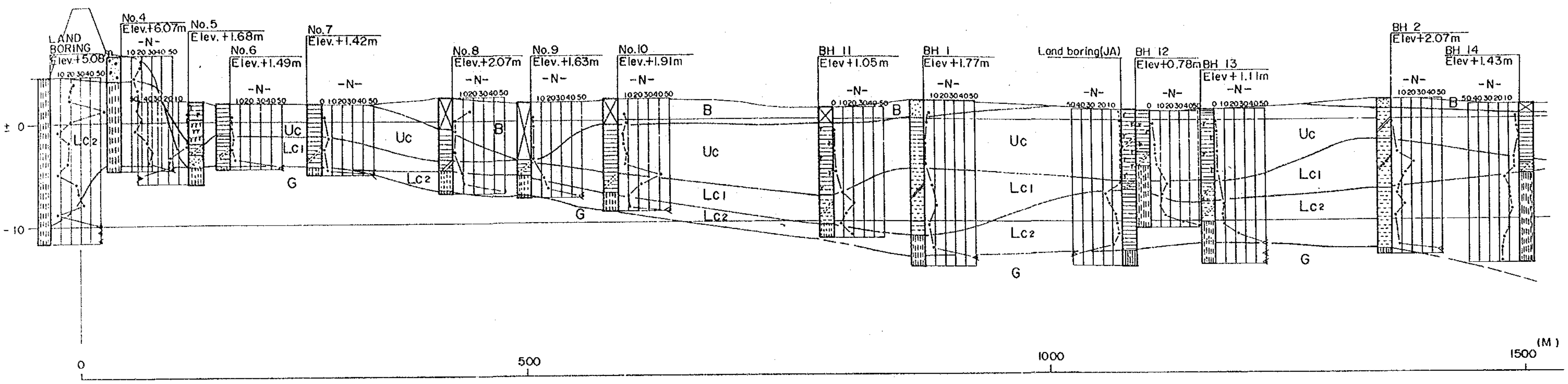


Fig. 3-4-6(C) SOIL PROFILE OF PORT AREA



LEGEND

B	Bank
Uc	Clay : Very soft
Lc1	Silt : Medium
Lc2	Clay : Medium
G	Base Rock

Fig. 3-4-6(d) Soil Profile of Access Road

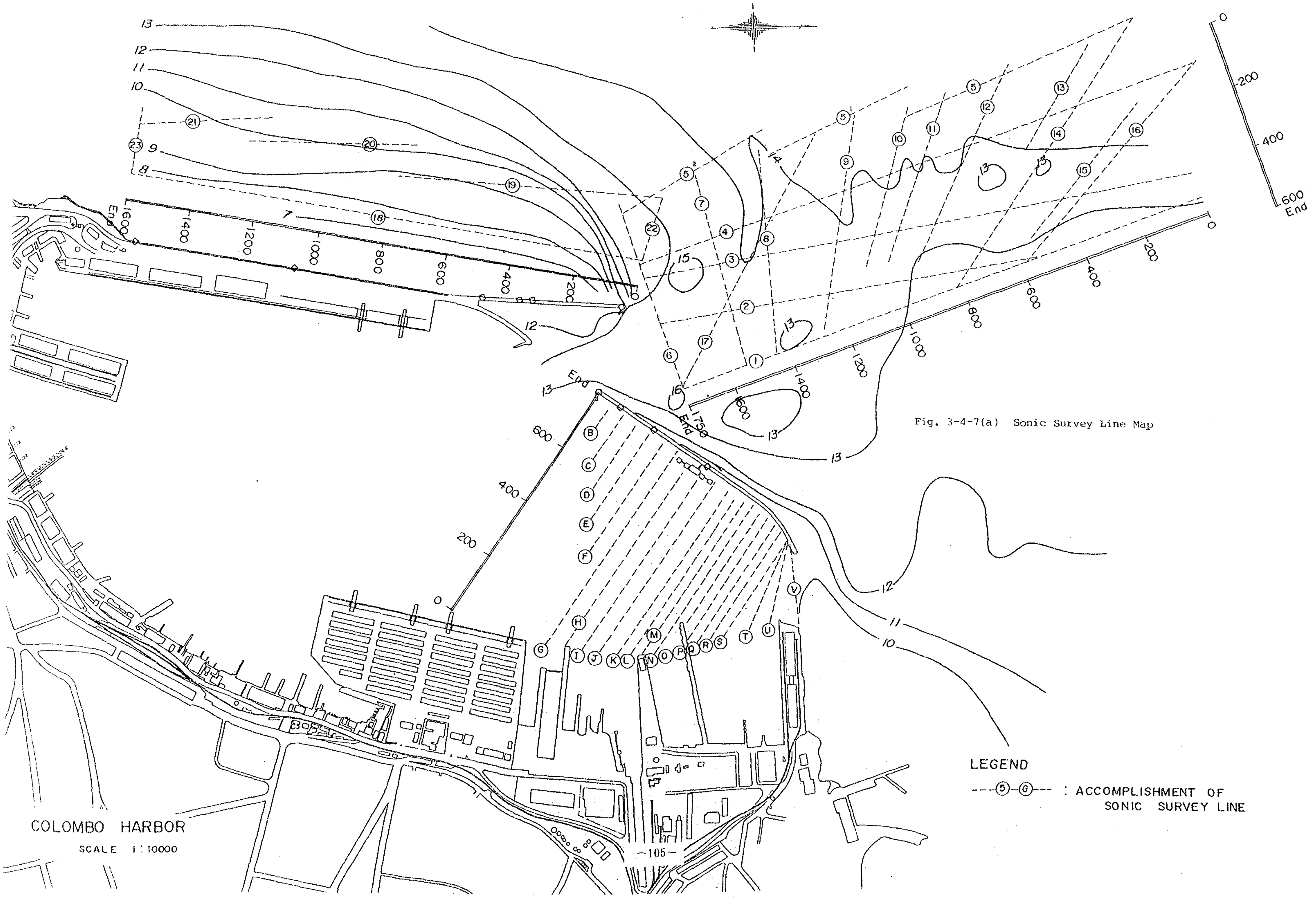


Fig. 3-4-7(a) Sonic Survey Line Map

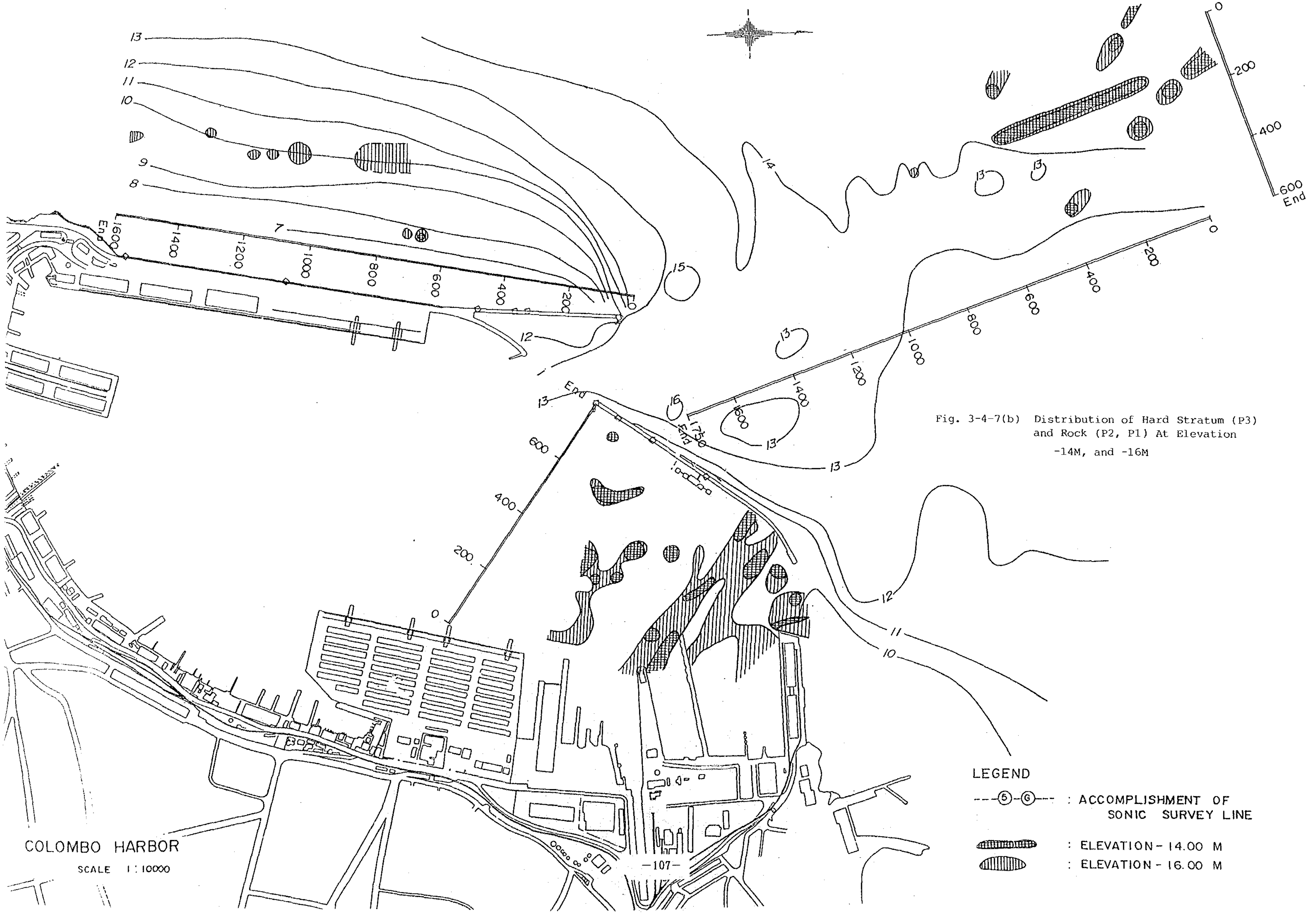


Fig. 3-4-7(b) Distribution of Hard Stratum (P3) and Rock (P2, P1) At Elevation -14M, and -16M

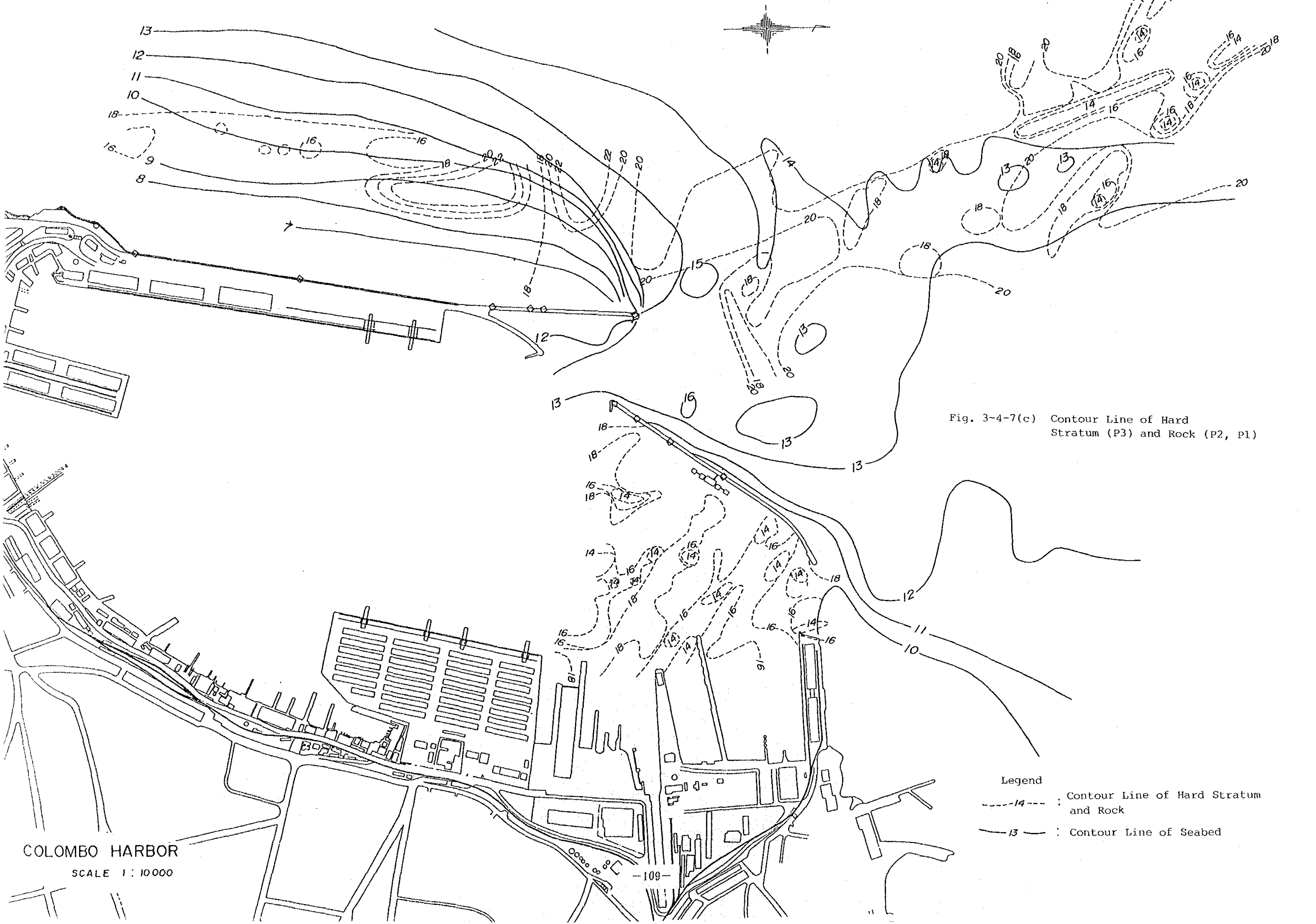


Fig. 3-4-7(c) Contour Line of Hard Stratum (P3) and Rock (P2, P1)

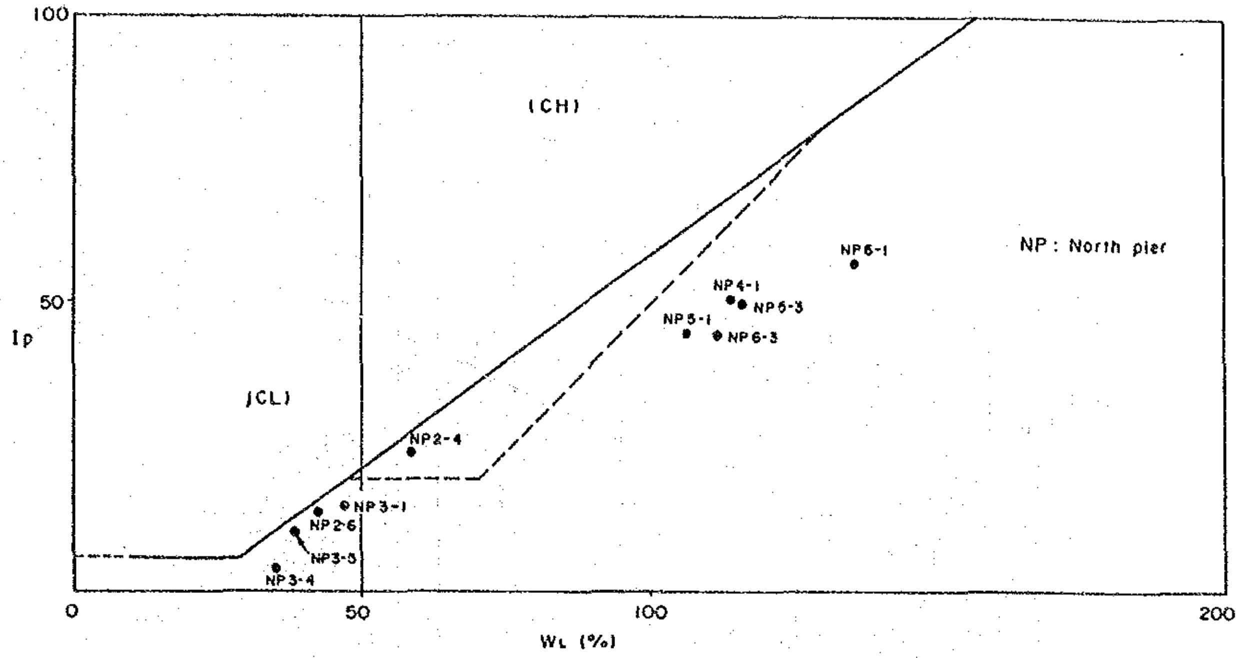


Fig. 3-4-8 Plasticity Chart of QEQ

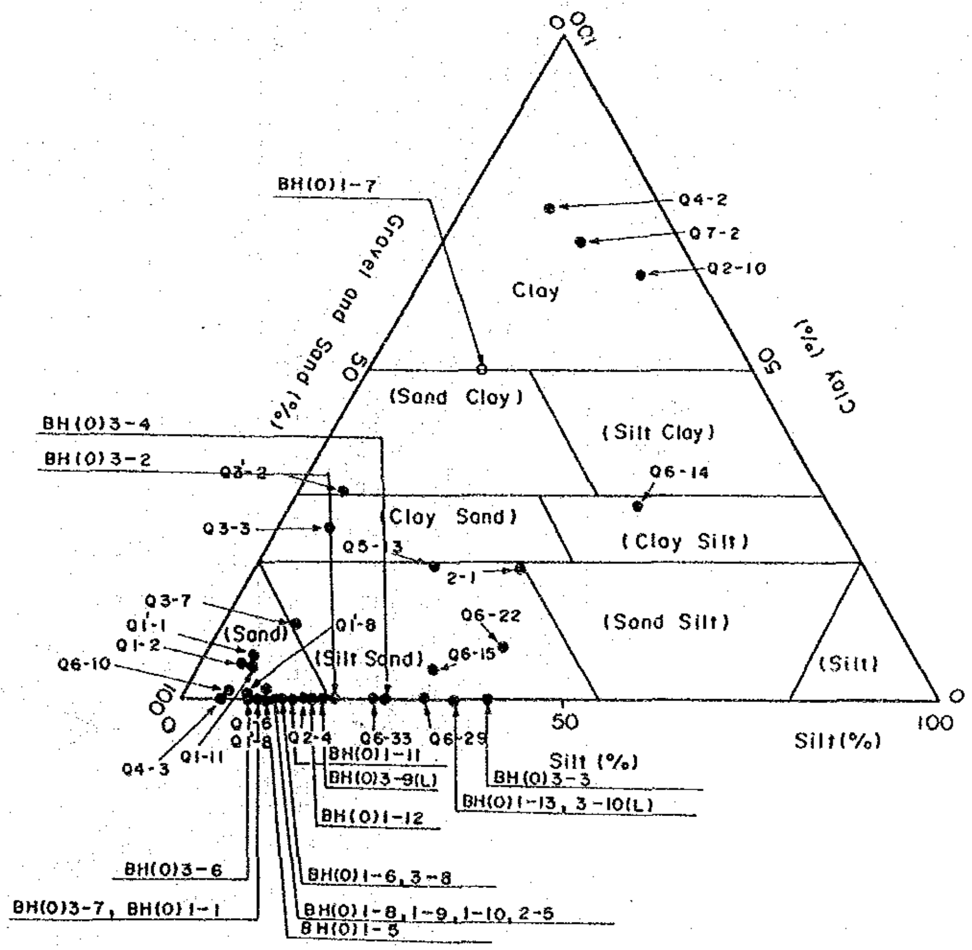


Fig. 3-4-9 Triangular Classification of QEQ

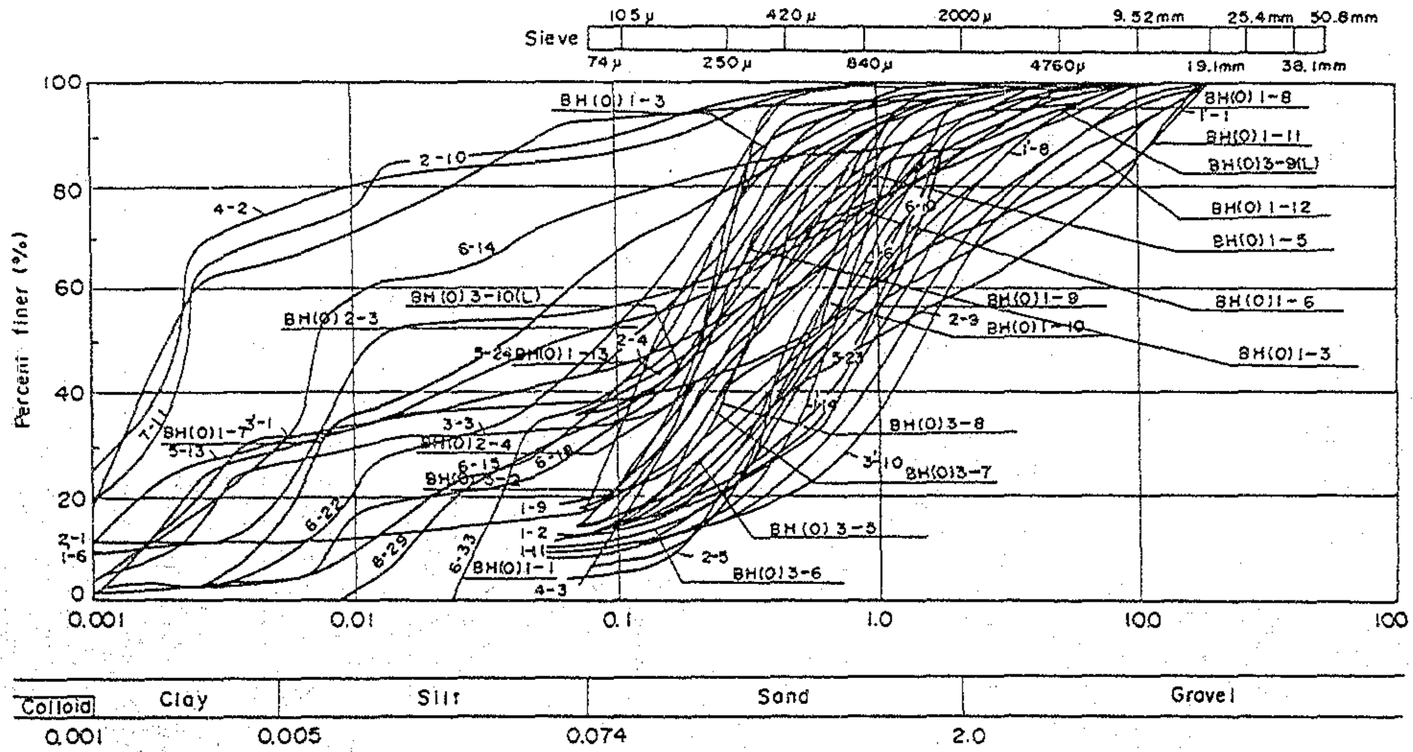


Fig. 3-4-10 Grain Size Distribution Curves of QEQ

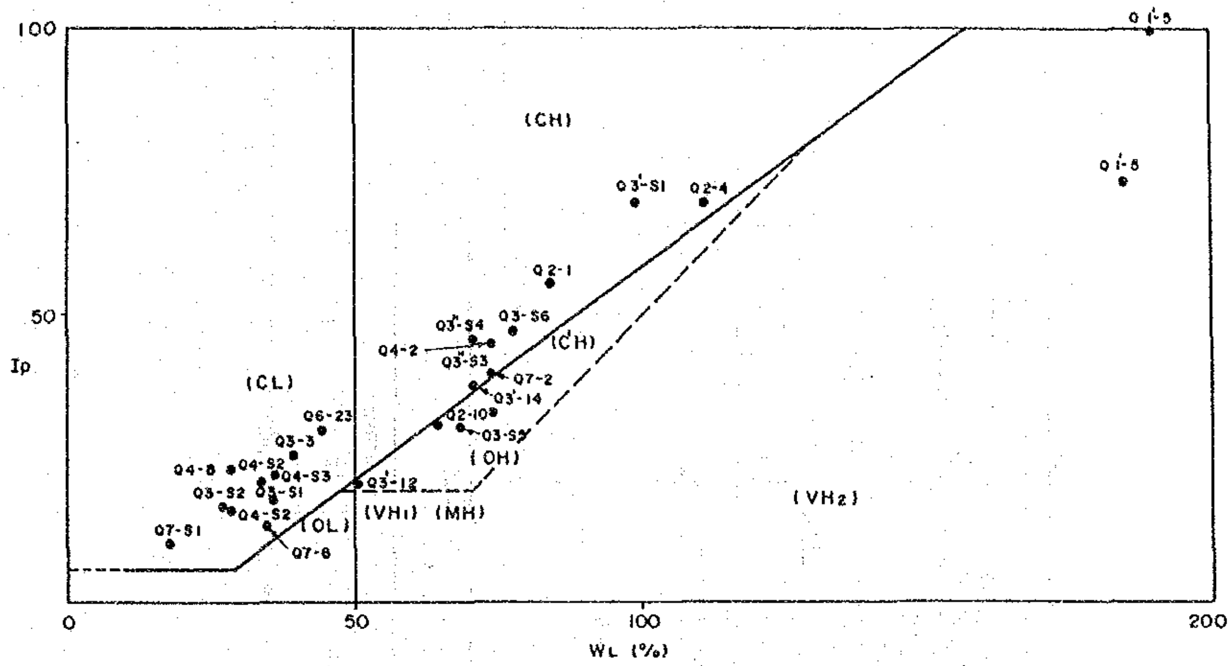


Fig. 3-4-11 Plasticity Chart of North Pier and JCT4

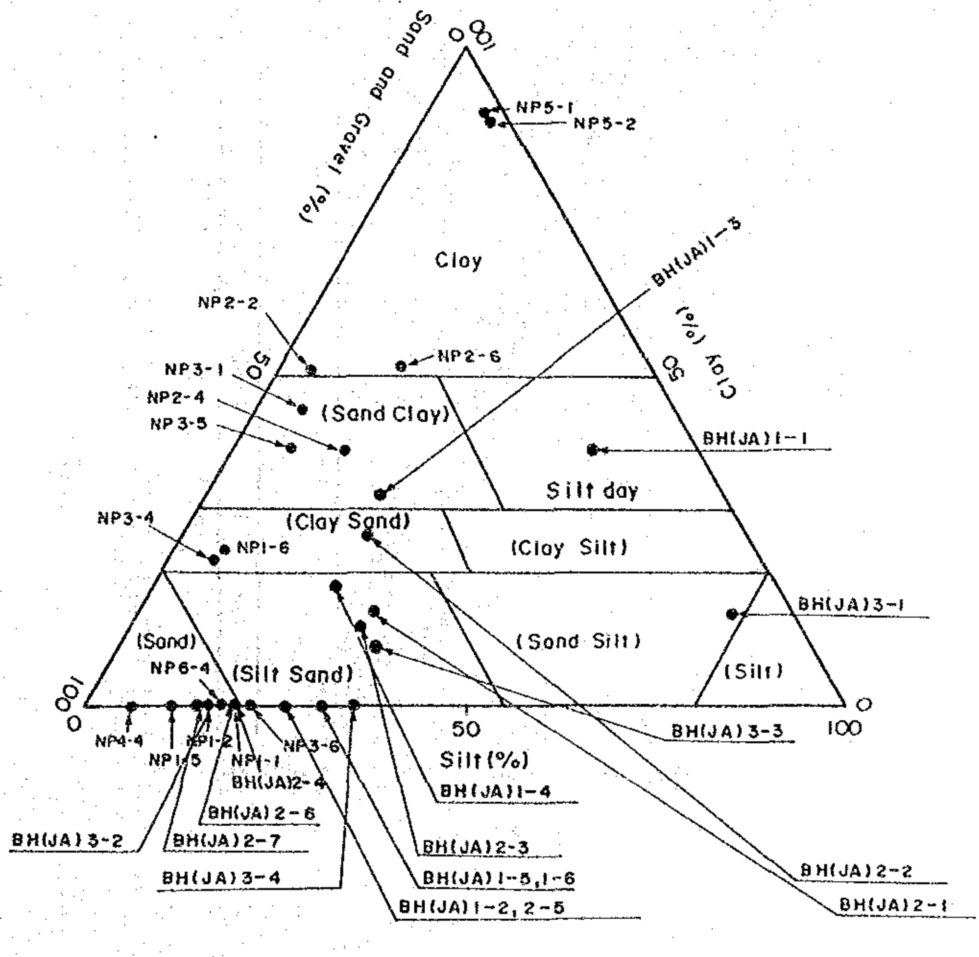


Fig. 3-4-12 Triangular Classification of North Pier and JCT4

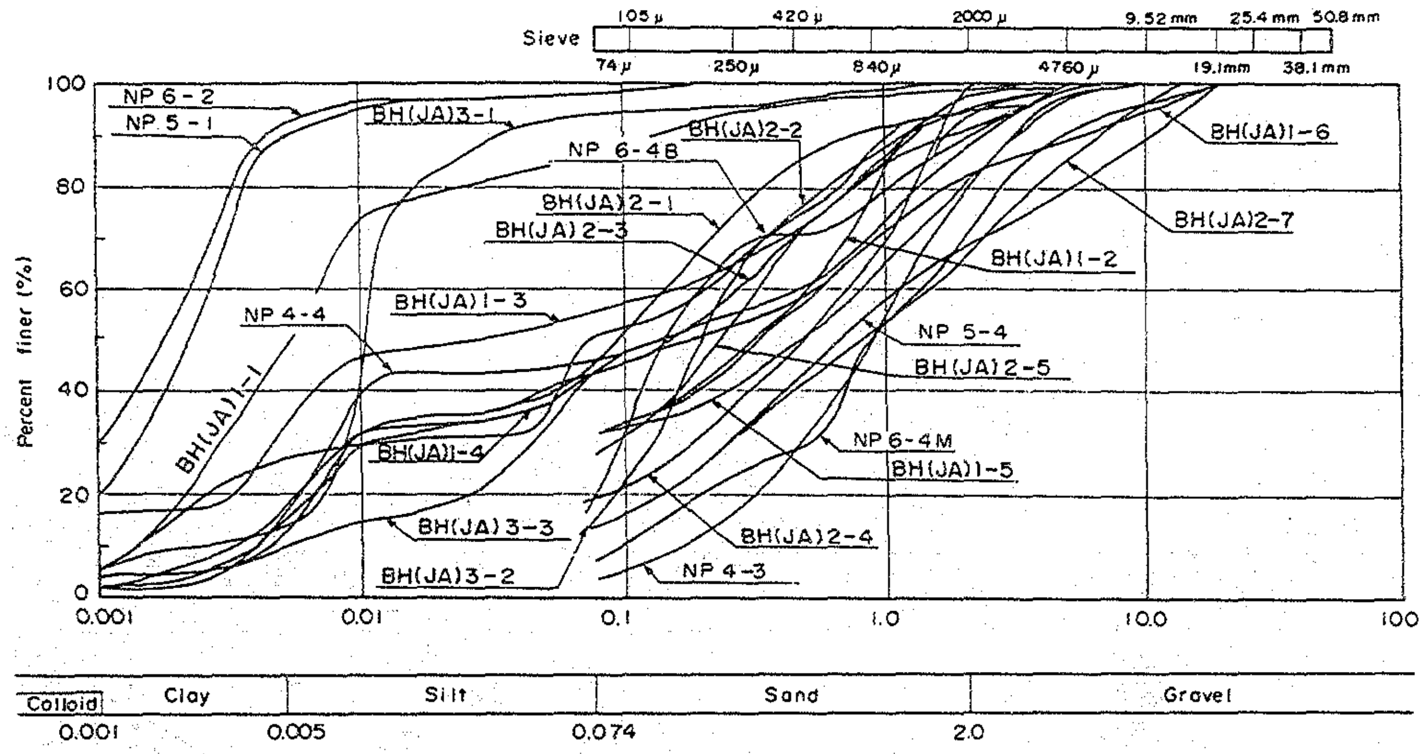


Fig. 3-4-13 Grain Size Distribution Curves of North Pier and JCT 4

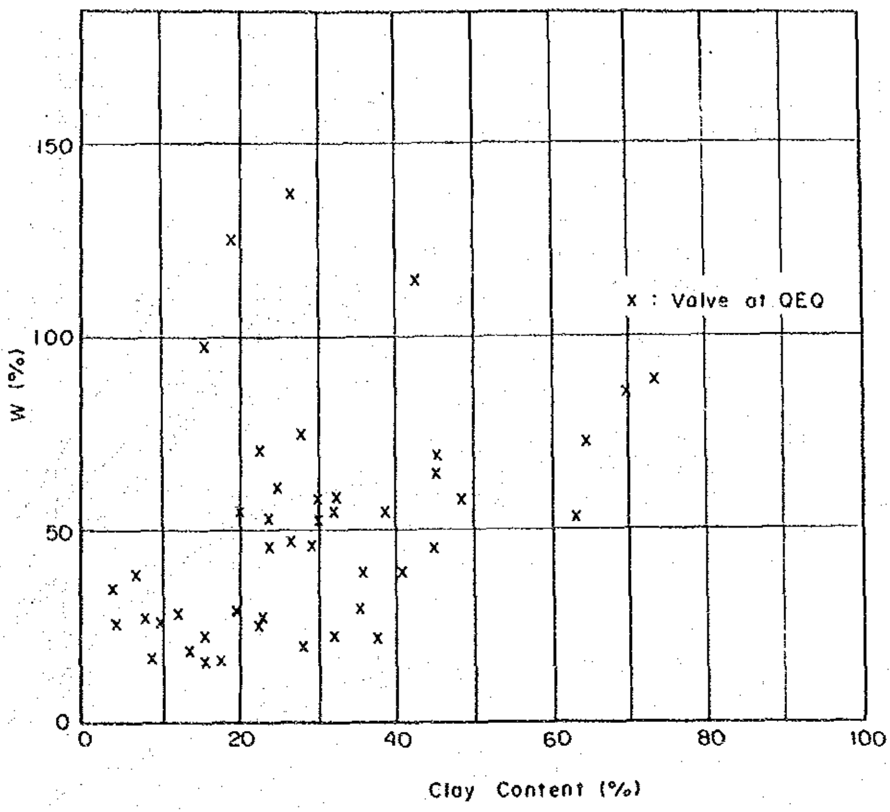


Fig. 3-4-14 Relationship between Moisture Content and Clay Cont of QEQ

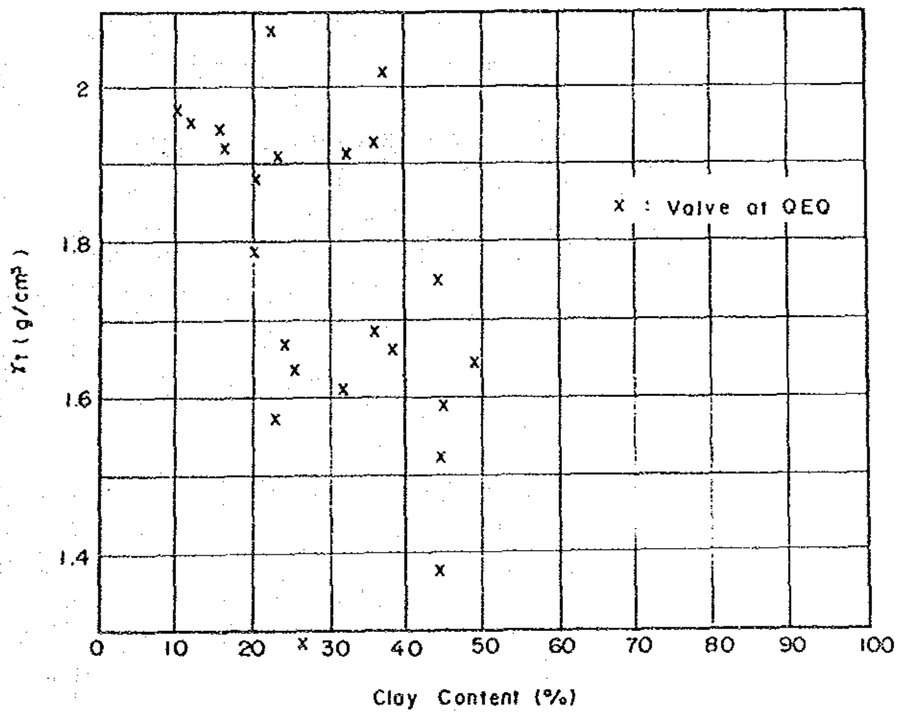


Fig. 3-4-15 Relationship between Wet Density and Clay Content of QEQ

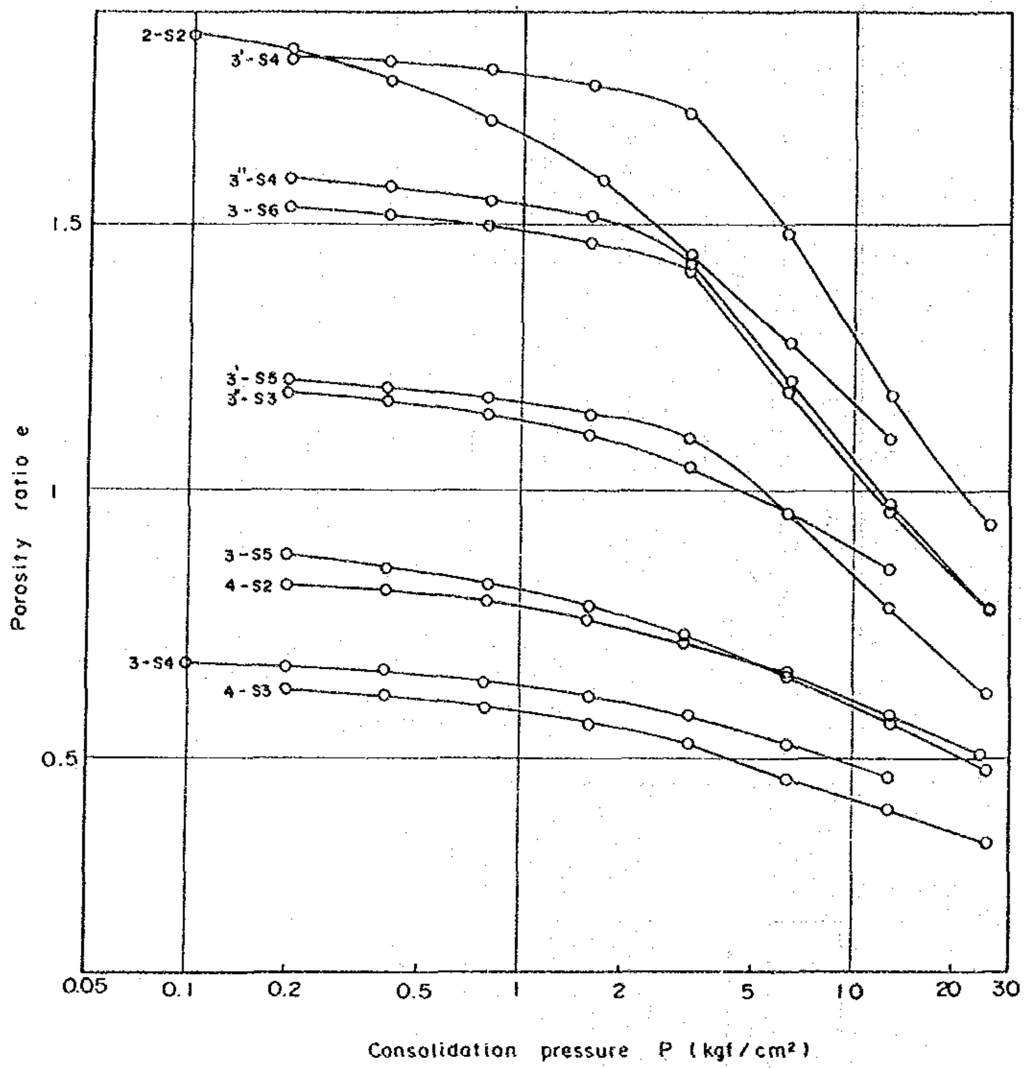


Fig. 3-4-16 Relationship between Void Ratio and Consolidation Pressure (e - log P) of QEQ

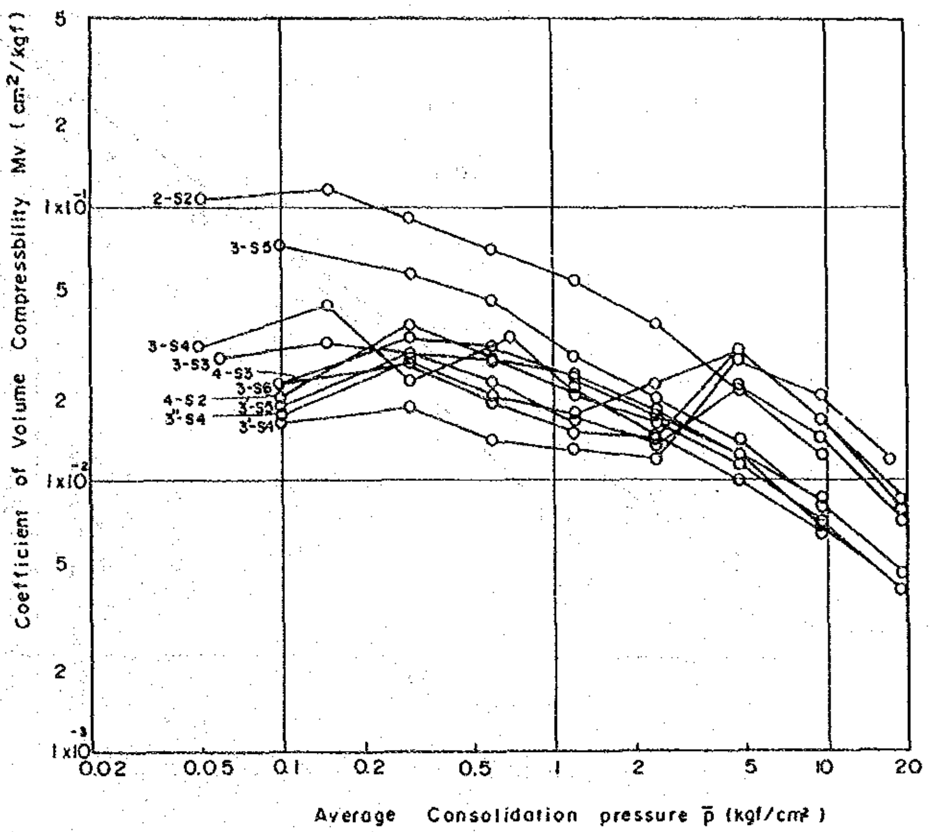


Fig. 3-4-17 Relationship between Coefficient of Volume Compressibility and Average Consolidation Pressure (log Mv - log $\overline{P}$) of QEQ

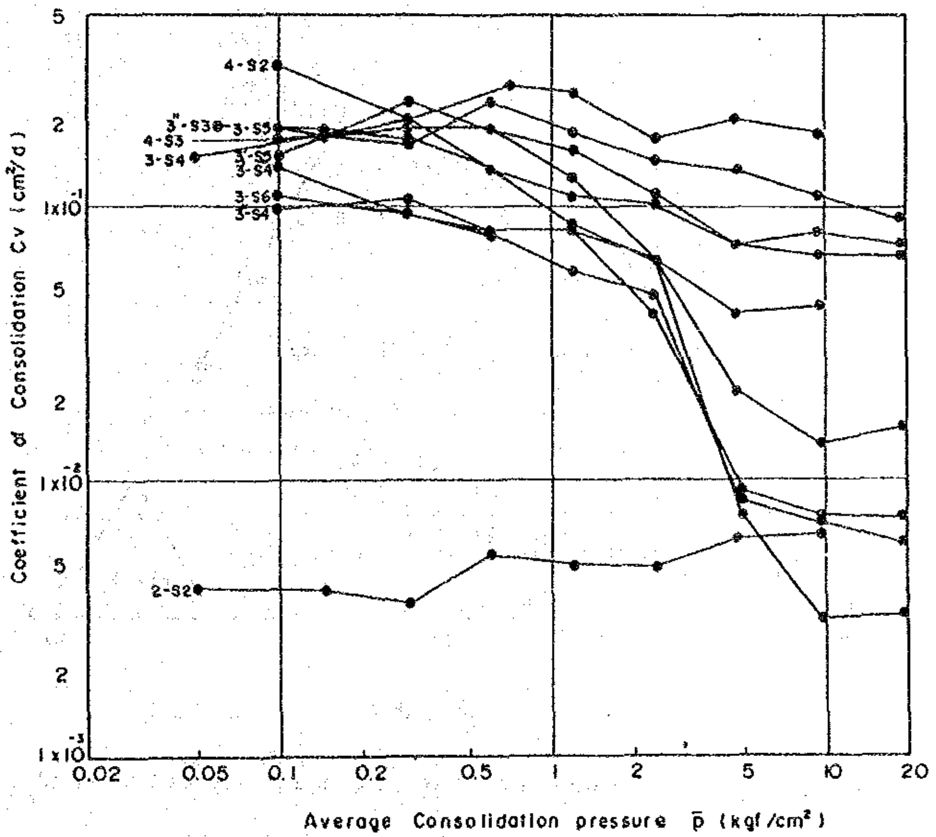


Fig. 3-4-18 Relationship between Coefficient of Consolidation and Average Consolidation Pressure (log Cv - log $\overline{P}$) of QEQ log Cv - log $\overline{P}$

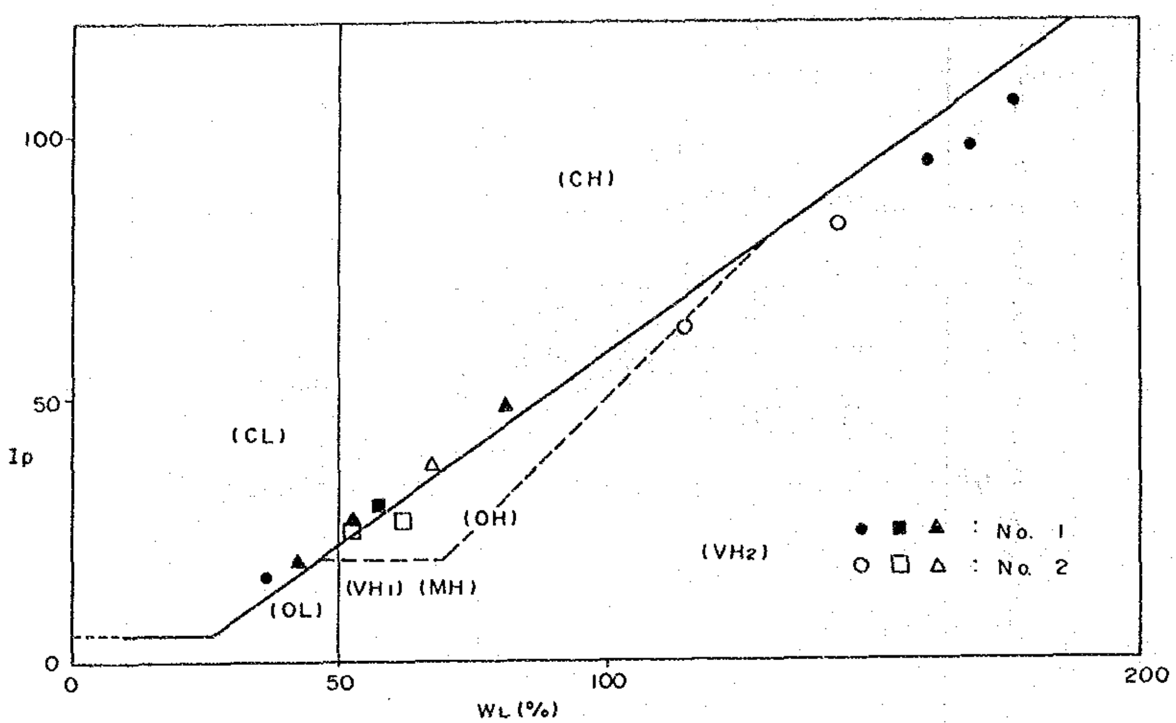


Fig. 3-4-19 Plasticity Chart of Crown Land

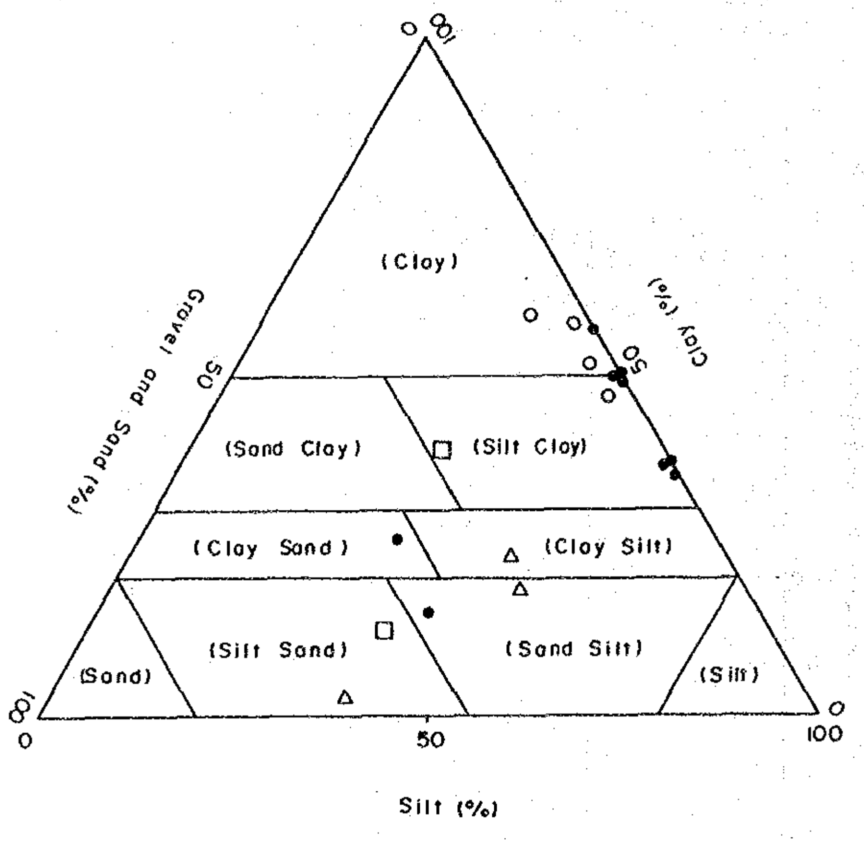


Fig. 3-4-20 Triangular Classification of Crown Land

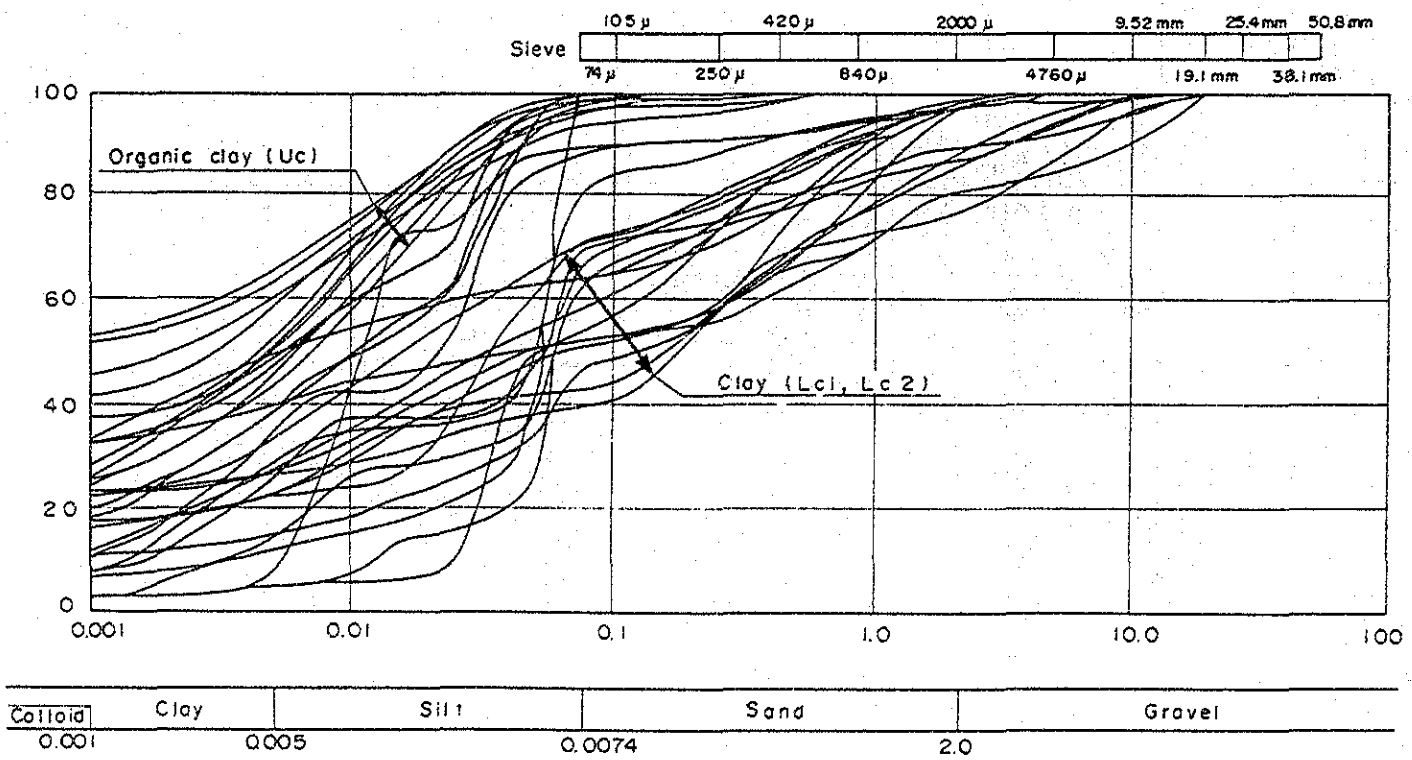


Fig. 3-4-21 Grain Size Distribution Curves of Crown Land

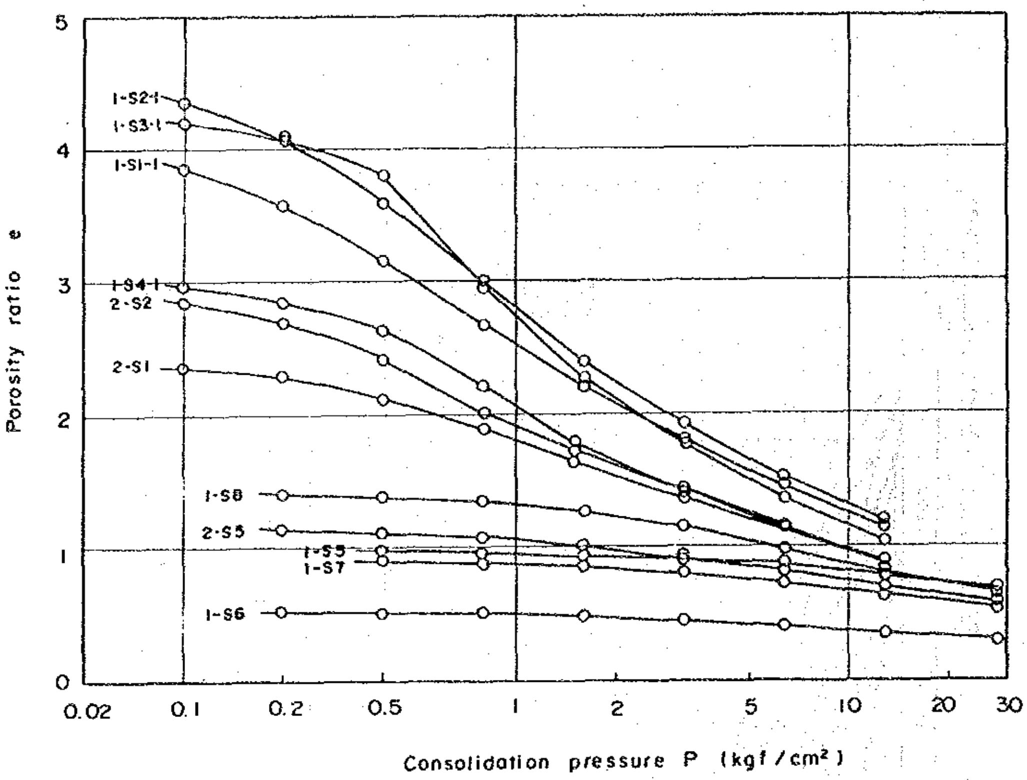


Fig. 3-4-22 Relationship between Void Ratio and Consolidation Pressure (e - log P) of Crown Land

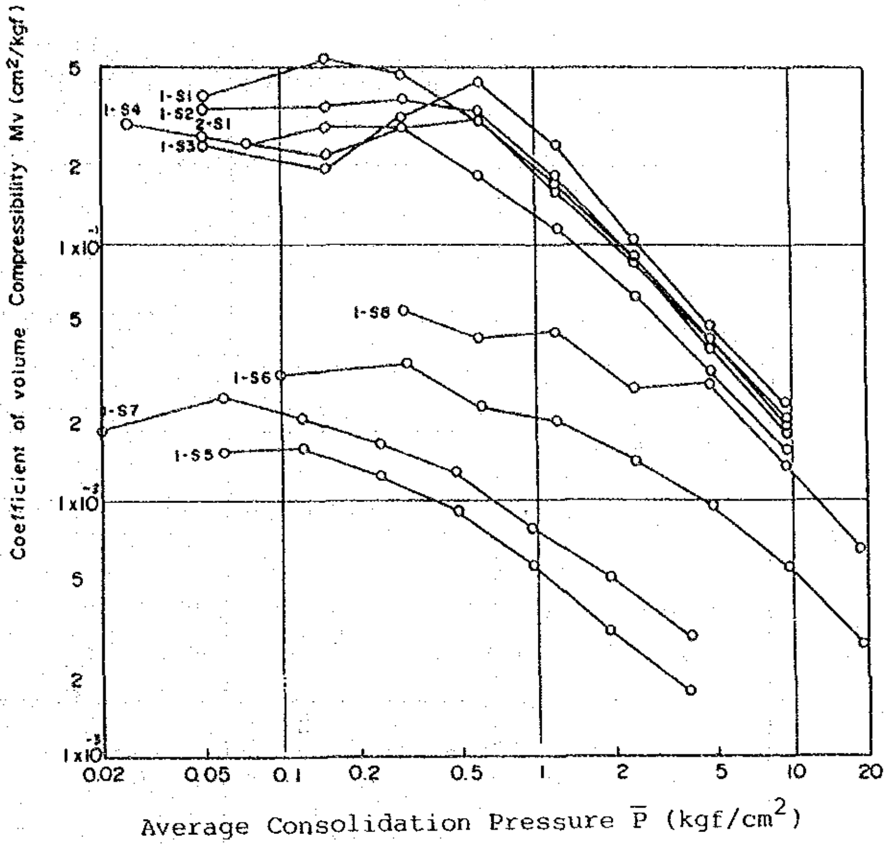


Fig. 3-4-23 Relationship between Coefficient of Volume Compressiblity and Average Consolidation Pressure (log Mv - Log P̄) of Crown Land

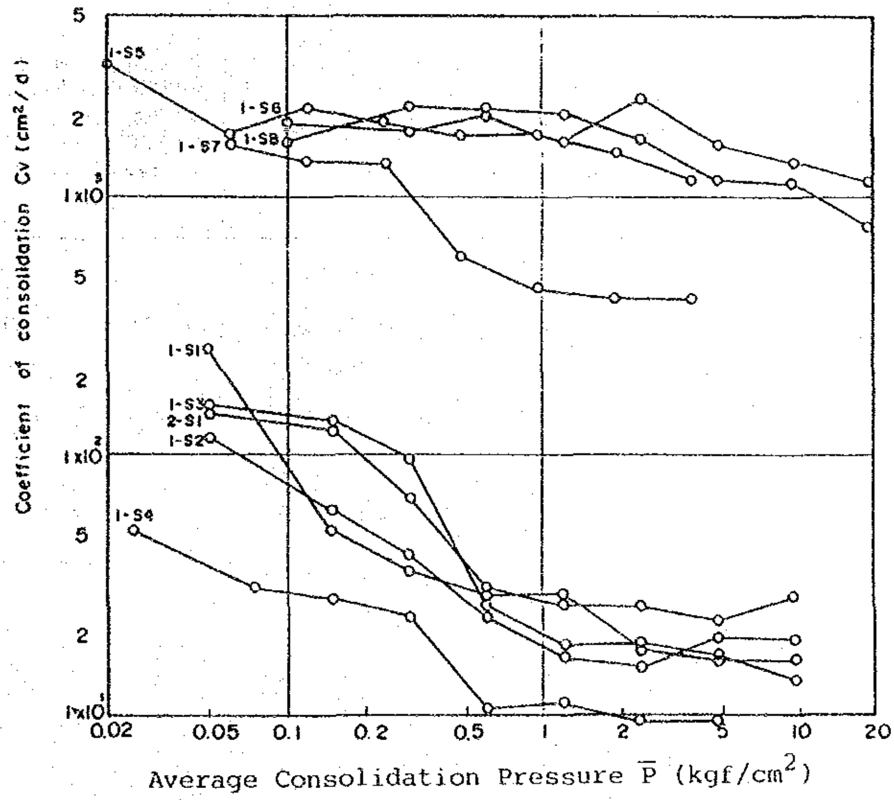


Fig. 3-4-24 Relationship between Coefficient of Consolidation and Average Consolidation Pressure (log. Cv - log. P̄) of Crown Land

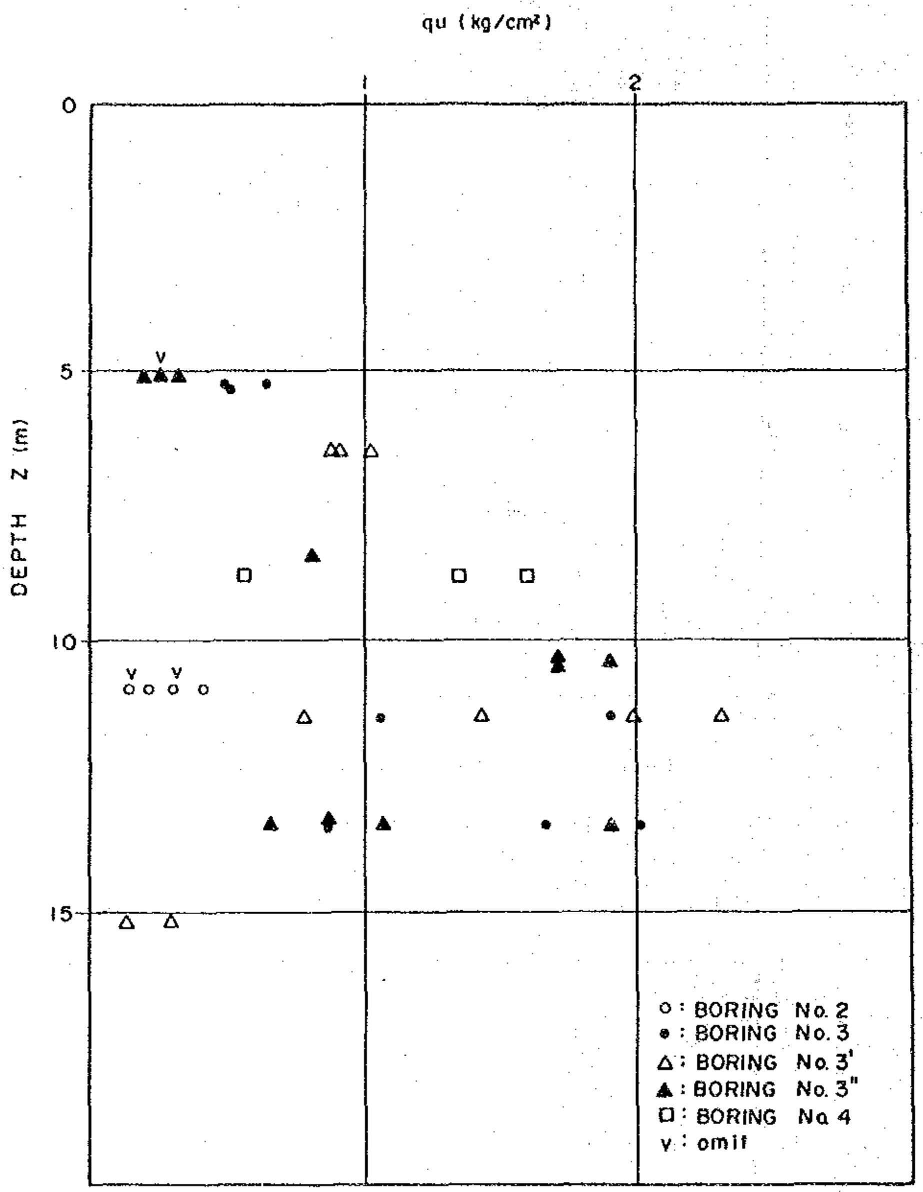


Fig. 3-4-25 Relationship between Depth and qu-Values of Crown Land