CHAPTER 4 PRESENT SITUATION AT THE PORT OF SAN PEDRO DE MACORIS

1. General

The port of San Pedro de Macoris is located 64 km east of the capital city, Santo Domingo, and faces the Caribbean Sea.

The Port is connected by a highway with Santo Domingo, and also has good road connections with Hato Mayor and La Romana, local commercial centers in the eastern region.

The Port is located on the east bank of the Higuamo River and the city of San Pedro de Macoris is expanding toward the north and the east supported by the Port.

All the existing port facilities were constructed in 1945-46, about 40 years ago, and since then the port has played a very important role in the economic development of the east region of the Dominican Republic. However, the port facilities have deteriorated due to their long service period and inadequate maintenance work to the extent that the major repair or total reconstruction is urgently required for efficient and safe port operation.

The local commercial and industrial activities including those in the free zone of San Pedro de Macoris have been developing smoothly in accordance with the policy stipulated in the regional development plan. Further, the tourism sector has been rapidly developing in recent years, and with these promising economic aspects the Port shall be of increasingly greater importance in the national economy.

2. Natural Conditions

2.1 Topographical and Geological Features

The existing wharfs of the port of San Pedro de Macoris were developed along the east bank and near the mouth of the Higuamo River. The existing wharfs are protected from ocean waves by the breakwater, Punta Sur and La Isleta. This situation provides calmness for the port and enables smooth cargo handling (See Fig. I.4.1).

The Higuamo River flows into the ocean between Punta Macoris and Punta Pescadero where the water depth is about 10 m. The water depth 10 km away from the river mouth is about 180 m and the average slope of the sea bed is around 1 to 50 (See Fig. I.4.2).

A topographical survey was carried out during the field work. The results of this survey have been arranged on maps with scales of 1/500, 1/2,000, and 1/7,500. In making maps, the latest city planning maps constituted the primary reference and the latest aerial photos were used supplementarily.

The geology around the Port is dominated by quaternary pleistocene reef except for the area along the Higuamo River which is comprised of quaternary holocene fluvial deposits (See Fig. I.4.3).

2.2 Meteorological Conditions

The climate of the country is sub-tropical and oceanic and has distinct rainy and dry seasons. The rainy seasons are from May to June and from September to November as mentioned in Chapter 2.

The meteorological data by month at San Pedro de Macoris, Santo Domingo, La Romana, Cabo Engano, Las Americas Airport, Barahona, Puerto Plata and Sabana de la Mar are shown in Tables I.4.1 - I.4.8. The location map is shown in Fig. I.4.4.

Yearly average temperature, annual total rainfall and rainy days are shown in Fig. I.4.5, I.4.6 and I.4.7, respectively.

(1) Temperature

The average temperature at San Pedro de Macoris varies from 24.2°C to 27.4°C and the maximum temperature varies from 28.9°C to 31.9°C while the minimum varies from 19.0°C to 22.0°C. The difference between the maximum and the minimum temperatures is 9 to 10°C and is almost constant throughout the year.

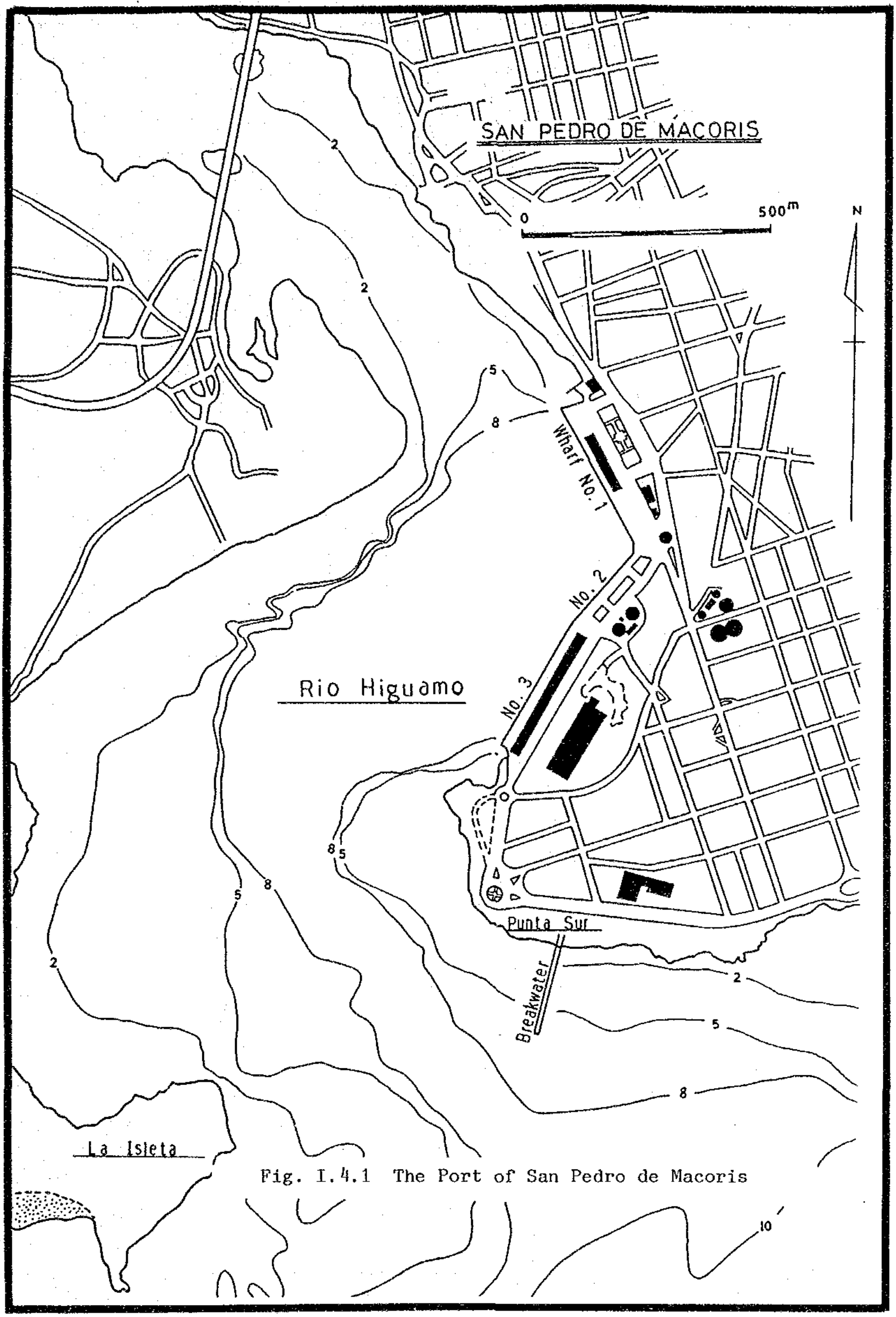


Fig. I.4.1 The Port of San Pedro de Macoris

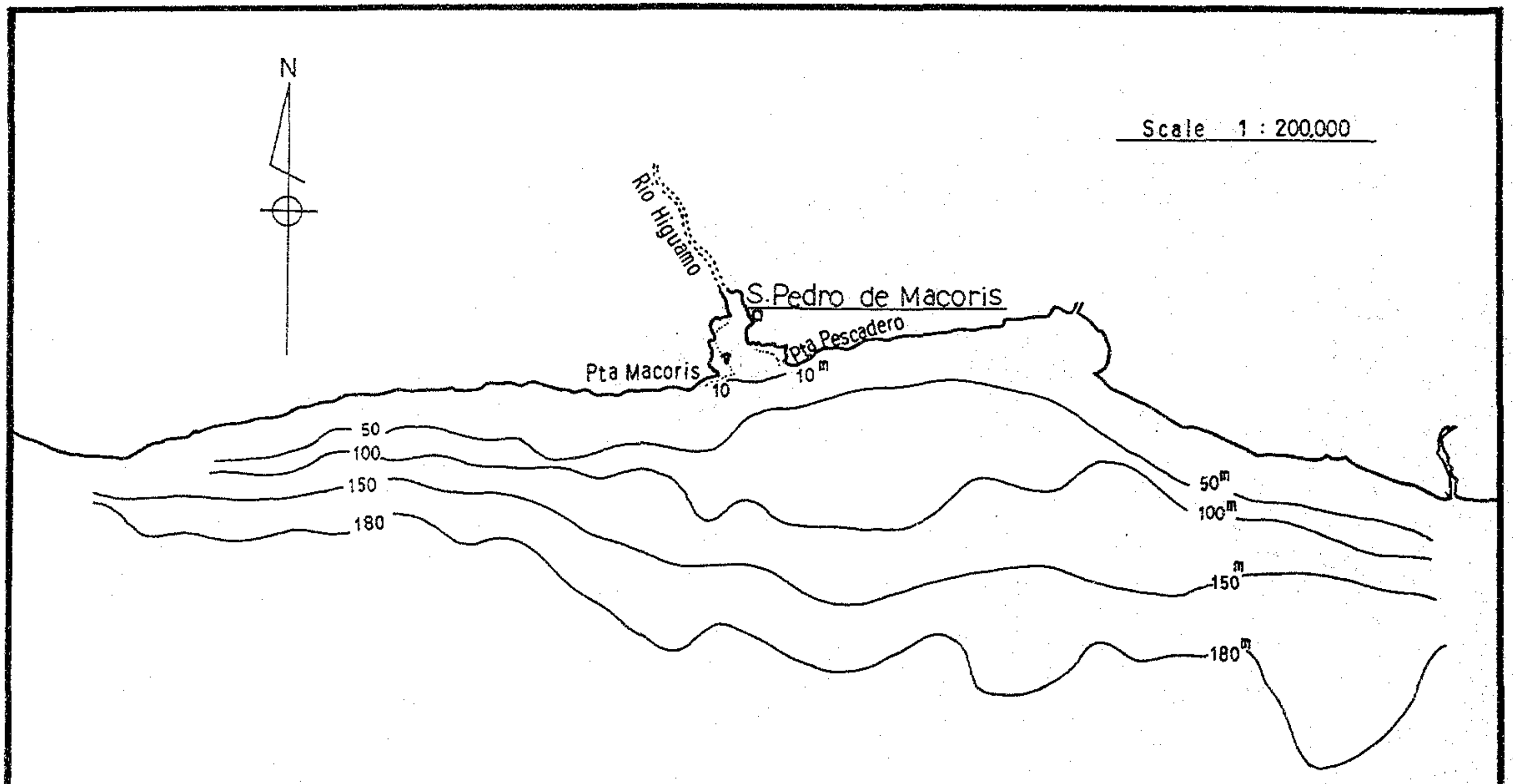


Fig. I.4.2 Bathymetric Chart

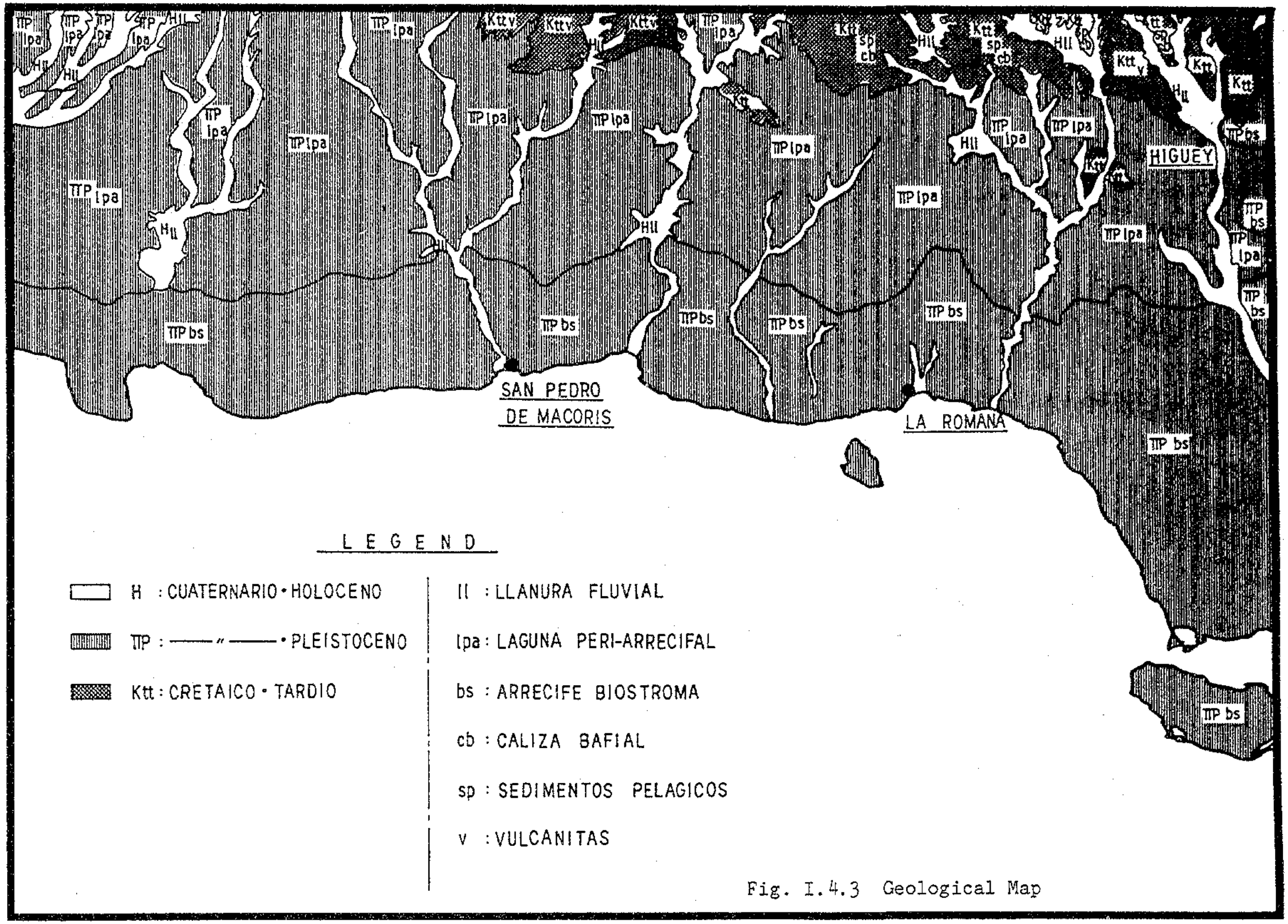


Fig. I.4.3 Geological Map

Table I.4.1 Meteorological Data (San Pedro de Macoris)

Item / Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Temperature (°C)													
Average	24.2	24.3	25.0	25.8	26.4	27.1	27.3	27.4	27.2	26.7	25.8	24.7	-
Maximum	28.9	29.3	30.3	30.7	30.9	31.4	31.8	31.9	31.7	31.3	30.6	29.6	-
Minimum	19.0	19.2	19.8	20.8	22.0	22.7	22.8	22.9	22.6	22.4	21.1	19.2	-
Precipitation													
No. of rainy days	5.8	4.7	4.3	5.3	9.1	8.9	9.2	9.5	11.0	11.3	8.9	7.2	95.2
Rainfall (mm)	27.6	28.8	24.9	54.7	126.0	98.9	105.9	113.8	146.4	145.2	99.0	41.4	1,012.6

Source : Statistics of Meteorological Data for 1931 - 1980, National Meteorological Office

Table I.4.2 Meteorological Data (Santo Domingo)

Item / Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Temperature (°C)													
Average	24.0	24.1	24.7	25.4	26.1	26.7	27.0	27.1	26.9	26.6	25.8	24.8	-
Maximum	29.0	29.0	29.4	29.9	30.1	30.8	31.3	31.5	31.3	31.0	30.4	29.5	-
Minimum	19.3	19.2	19.9	20.8	22.1	22.7	22.7	22.6	22.6	22.2	21.0	19.9	-
Precipitation													
No. of rainy days	9.2	7.6	7.3	9.1	14.3	13.8	14.6	14.0	14.4	14.5	12.1	11.5	142.4
Rainfall (mm)	50.9	43.8	44.5	67.6	187.2	151.8	178.6	156.7	165.3	169.7	96.4	69.9	1,382.4
Humidity (%)	82.8	81.0	79.6	79.9	83.5	85.4	85.1	88.5	86.7	87.0	85.4	84.7	-
Wind													
Avg.velocity (m/sec)	3.3	3.4	3.3	3.3	2.9	2.8	2.9	2.9	2.7	2.6	3.0	3.2	-
Predominant direction	N	SE-N	SE-N	SE-N	SE-N	N	N	N	N	N	N	N	-
Max.velocity (m/sec) and direction	20.0 NE	18.0 N	19.2 NNE	27.8 N	18.1 NE	18.1 SSE	23.1 ENE	61.7 SE	22.2 SE	18.6 SE	20.6 NE	18.1 SE	- -

Source : Statistics of Meteorological Data for 1931 - 1980, National Meteorological Office

Table I.4.3 Meteorological Data (La Romana)

Item Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Temperature (°C)													
Average	24.3	24.6	25.2	25.9	26.8	27.5	27.8	27.9	27.5	27.1	26.2	25.0	-
Maximum	28.9	29.3	30.1	30.5	30.9	31.6	31.9	32.3	31.9	31.5	30.6	29.3	-
Minimum	19.5	19.6	20.1	21.2	22.5	23.3	23.4	23.5	23.2	22.8	21.8	20.5	-
Precipitation													
No. of rainy days	10.2	7.7	7.1	8.0	12.3	11.6	11.6	12.0	14.5	13.8	12.9	11.4	133.1
Rainfall (mm)	37.0	34.1	28.8	53.6	140.5	95.2	82.6	109.7	151.9	149.2	108.2	49.2	1,040.0

Source : Statistics of Meteorological Data for 1931 - 1980, National Meteorological Office

Table I.4.4 Meteorological Data (Cabo Engano)

Item Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Temperature (°C)													
Average	24.7	24.7	25.3	25.7	26.6	27.1	27.6	27.7	27.7	27.2	26.4	25.4	-
Maximum	27.4	27.5	28.2	28.5	29.6	30.2	30.3	30.6	30.8	30.4	29.6	27.9	-
Minimum	22.1	21.9	22.3	22.9	23.6	24.3	24.9	25.0	24.7	24.0	23.6	22.8	-
Precipitation													
No. of rainy days	11.4	8.6	8.5	8.2	12.5	11.2	11.5	12.3	11.0	12.1	12.9	13.1	133.3
Rainfall (mm)	62.3	46.3	51.6	58.2	107.9	108.7	78.4	97.3	88.2	135.0	116.8	79.0	1,029.7
Humidity (%)	84.0	82.0	82.3	83.3	83.9	82.8	82.5	83.0	82.6	82.8	82.5	83.7	-
Wind													
Avg.velocity (m/sec)	4.1	4.2	4.0	4.0	3.5	3.5	4.2	3.9	3.4	3.3	4.1	4.4	-
Predominant direction	E	E	E	E	E	E	E	E	E-SE	SE	E	E	-
Max.velocity (m/sec) and direction	16.7 E	15.3 NE	15.6 NE	17.2 ESE	18.0 E	13.3 NE	16.1 ESE	29.4 NE	26.1 SE	21.3 E	20.6 NE	15.6 NE	- -

Source : Statistics of Meteorological Data for 1931 - 1980, National Meteorological Office

Table I.4.5 Meteorological Data (Las Americas Airport)

Item Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Temperature (°C)													
Average	24.2	24.3	24.7	25.4	26.2	26.9	27.1	27.2	27.0	26.0	25.9	24.6	-
Maximum	29.5	29.6	30.3	30.5	30.7	31.3	31.7	31.8	31.6	31.2	30.3	29.5	-
Minimum	18.8	18.8	19.4	20.3	21.7	22.5	22.5	22.5	22.4	22.2	21.1	19.6	-
Precipitation													
No. of rainy days	8.3	6.6	7.3	7.6	11.7	11.0	11.2	11.9	12.3	13.5	12.1	10.3	123.8
Rainfall (mm)	33.3	31.4	34.4	68.0	118.1	115.6	96.7	152.3	149.6	162.5	87.8	66.3	1,116.0
Humidity (%)	82.7	80.6	79.4	79.0	81.5	82.2	82.1	82.6	84.3	85.0	84.4	84.1	-
Wind													
Avg.velocity (m/sec)	3.7	4.0	4.1	4.0	4.0	4.0	3.8	3.6	3.4	3.3	3.4	3.6	-
Predominant direction	N	N-SE	N-NE	N-SE	SE	N	N	N	N	N-NE	N	N	-
Max.velocity (m/sec) and direction	19.4 N	15.0 N	13.9 NE	16.7 NE	13.9 NE	19.4 N	19.4 ESE	-	25.0 ENE	19.4 SSE	17.8 SE	16.7 NE	- -

Source : Statistics of Meteorological Data for 1931 - 1980, National Meteorological Office

Table I.4.6 Meteorological Data (Barahona)

Item Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Temperature (°C)													
Average	24.5	24.2	25.3	25.9	26.6	26.9	27.7	27.6	27.3	26.5	25.9	24.9	-
Maximum	28.9	29.0	29.4	29.8	30.4	30.5	31.4	31.6	31.2	30.4	30.0	29.2	-
Minimum	20.0	20.5	21.2	22.1	22.2	23.5	23.9	23.6	23.3	22.6	21.8	20.7	-
Precipitation													
No. of rainy days	3.8	4.2	4.2	6.6	11.8	8.9	4.2	6.6	9.6	11.5	5.8	3.6	80.8
Rainfall (mm)	28.4	33.2	29.3	60.4	189.0	159.6	38.5	81.8	139.9	191.6	63.7	31.7	1,047.1
Humidity (%)	72.9	73.6	71.6	71.4	74.8	75.8	72.0	73.8	76.6	79.5	76.1	68.7	-
Wind													
Avg.velocity (m/sec)	3.2	3.4	3.8	3.6	3.6	3.4	4.6	3.6	3.2	2.9	2.8	2.9	-
Predominant direction	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	-
Max.velocity (m/sec) and direction	10.3 SE	12.8 SE	16.7 ESE	10.3 SE	8.3 SE	10.3 SE	13.9 SE	16.7 SE	20.6 E	11.1 SE	10.3 SE	11.7 S	- -

Source : Statistics of Meteorological Data for 1931 - 1980, National Meteorological Office

Table I.4.7 Meteorological Data (Puerto Plata)

Item Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Temperature (°C)													
Average	22.8	22.9	23.0	24.3	25.4	26.4	26.7	26.9	26.9	26.4	25.0	23.6	-
Maximum	27.1	27.2	27.9	28.6	29.5	30.7	30.8	31.2	31.5	31.0	29.3	27.8	-
Minimum	18.7	18.5	19.1	20.1	21.1	22.1	22.6	22.6	22.3	21.8	20.7	19.3	-
Precipitation													
No. of rainy days	14.1	10.0	8.9	9.2	11.4	6.7	8.3	8.5	8.9	10.9	14.5	15.9	127.3
Rainfall (mm)	191.1	154.5	123.0	151.2	131.0	60.7	71.9	85.3	92.2	131.7	293.5	273.6	1,759.7
Humidity (%)	83.9	83.1	82.2	82.3	81.8	79.9	78.8	78.9	78.9	79.6	82.7	84.2	-
Wind													
Avg.velocity (m/sec)	2.2	2.3	2.5	2.6	2.5	2.9	3.1	2.9	2.5	2.1	2.0	2.1	-
Predominant direction	ESE	ESE	SE-E	SE-E	SE-E	SE-E	SE-E	SE-E	SE-E	SE-E	SE-E	SE-E	-
Max.velocity (m/sec) and direction	12.5 E	12.5 S	19.4 SE	16.7 ENE	15.3 SE	27.8 SE	18.1 SSE	13.9 E,ESE	16.7 W	15.3 SSW	14.4 NE	25.2 E	- -

Source : Statistics of Meteorological Data for 1931 - 1980, National Meteorological Office

Table I.4.8 Meteorological Data (Sabana de la Mar)

Item Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Temperature (°C)													
Average	23.6	23.6	24.1	24.7	25.5	26.1	26.4	26.6	26.4	26.2	25.3	24.3	-
Maximum	27.9	27.9	28.6	29.1	29.7	30.4	30.5	30.8	30.9	30.8	29.8	28.6	-
Minimum	19.2	19.3	19.6	20.3	21.3	21.8	22.2	22.4	21.8	21.5	20.8	19.9	-
Precipitation													
No. of rainy days	14.7	11.3	10.8	10.6	16.0	15.9	18.5	18.1	16.7	16.3	16.9	16.0	181.8
Rainfall (mm)	111.2	108.3	107.3	159.4	237.9	187.8	201.6	218.8	175.8	197.6	239.8	177.0	2,122.5
Humidity (%)	83.2	81.9	80.7	80.7	83.1	84.0	83.6	84.3	85.1	85.4	81.2	80.7	-
Wind													
Avg.velocity (m/sec)	2.6	2.8	3.0	3.1	2.6	2.7	3.0	2.8	2.2	1.9	2.2	2.5	-
Predominant direction	E-NE	E-NE	E-S	E-NE	NE	S-E	E	NE	NE	S	NE	NE	-
Max.velocity (m/sec) and direction	11.1 N,E	13.9 E	15.3 N	11.7 NE	20.8 NW	14.7 E	18.9 NE	34.2 E	16.7 E	14.4 E	15.0 NE	20.0 ESE	- -

Source : Statistics of Meteorological Data for 1931 - 1980, National Meteorological Office

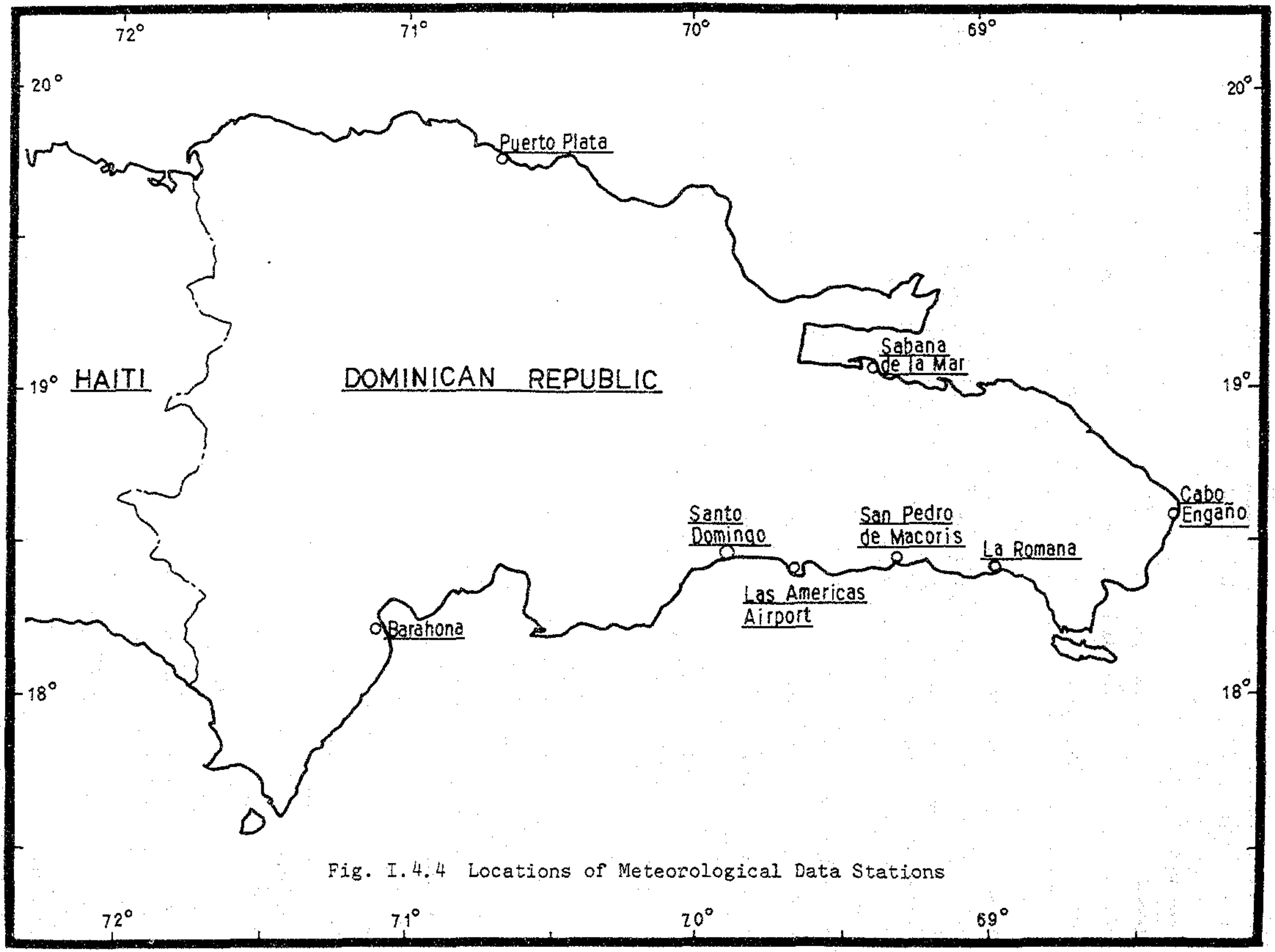


Fig. I.4.4 Locations of Meteorological Data Stations

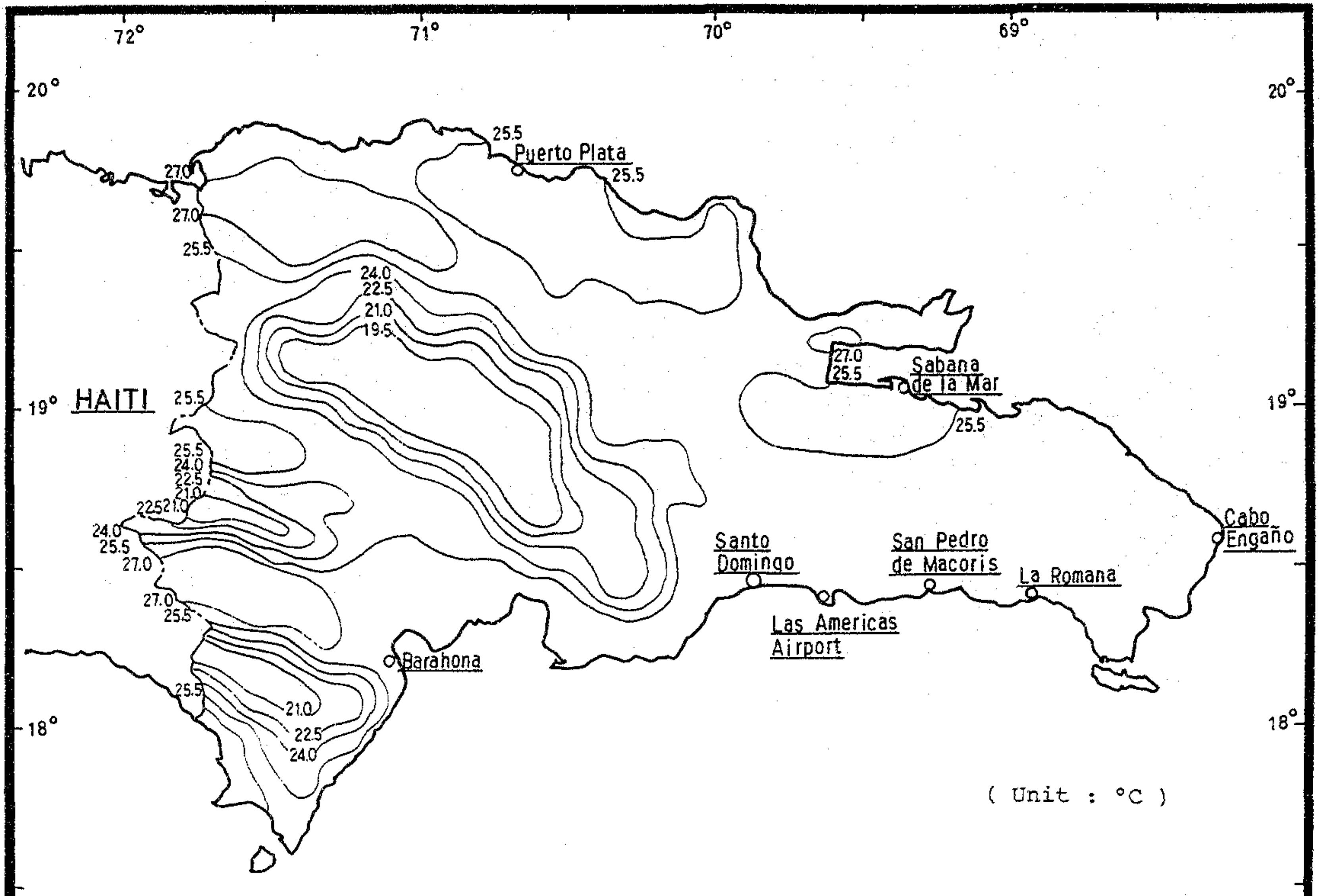


Fig. I.4.5 Distribution of Yearly Average Temperature

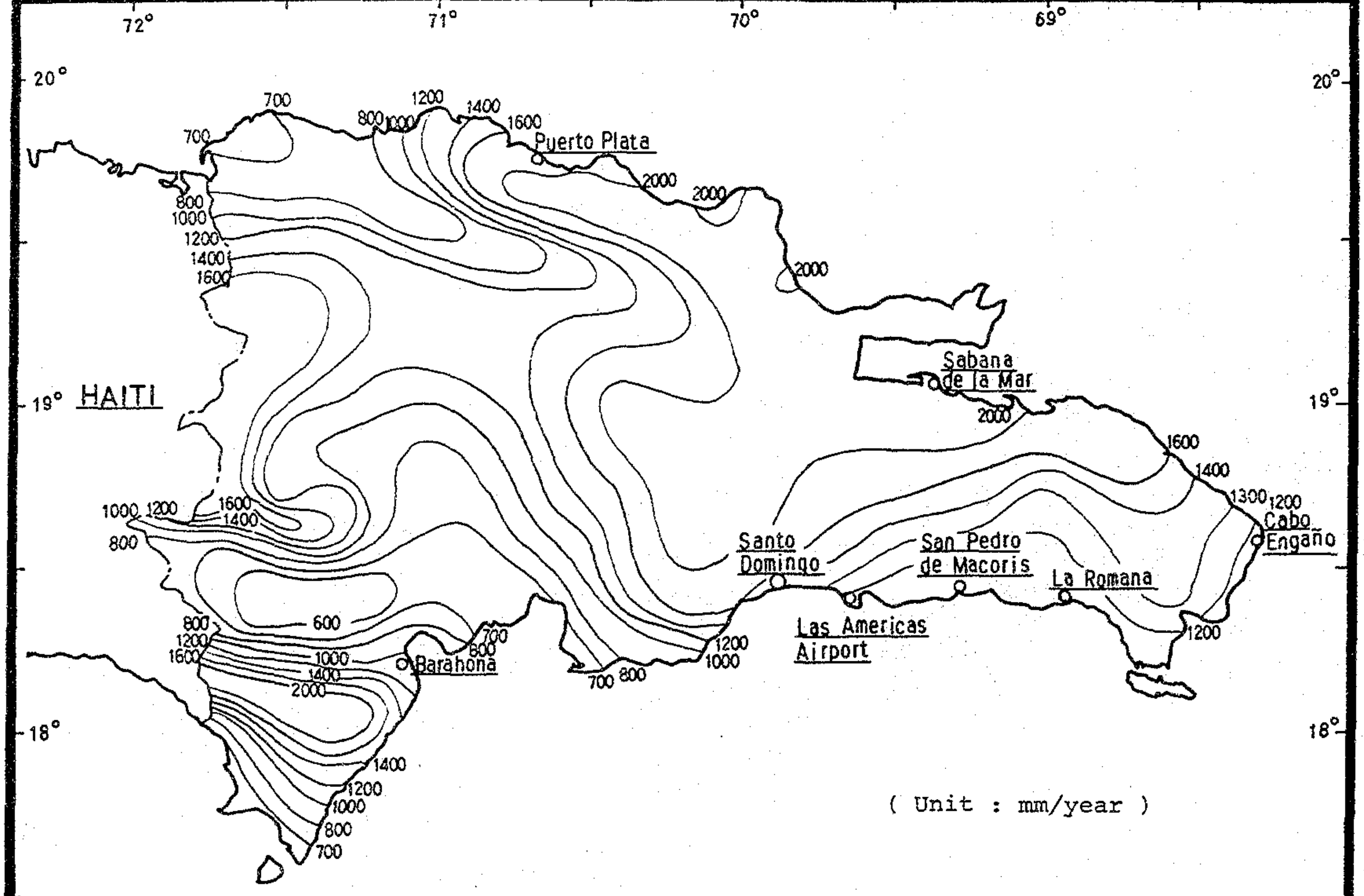


Fig. I.4.6 Distribution of Annual Total Rainfall

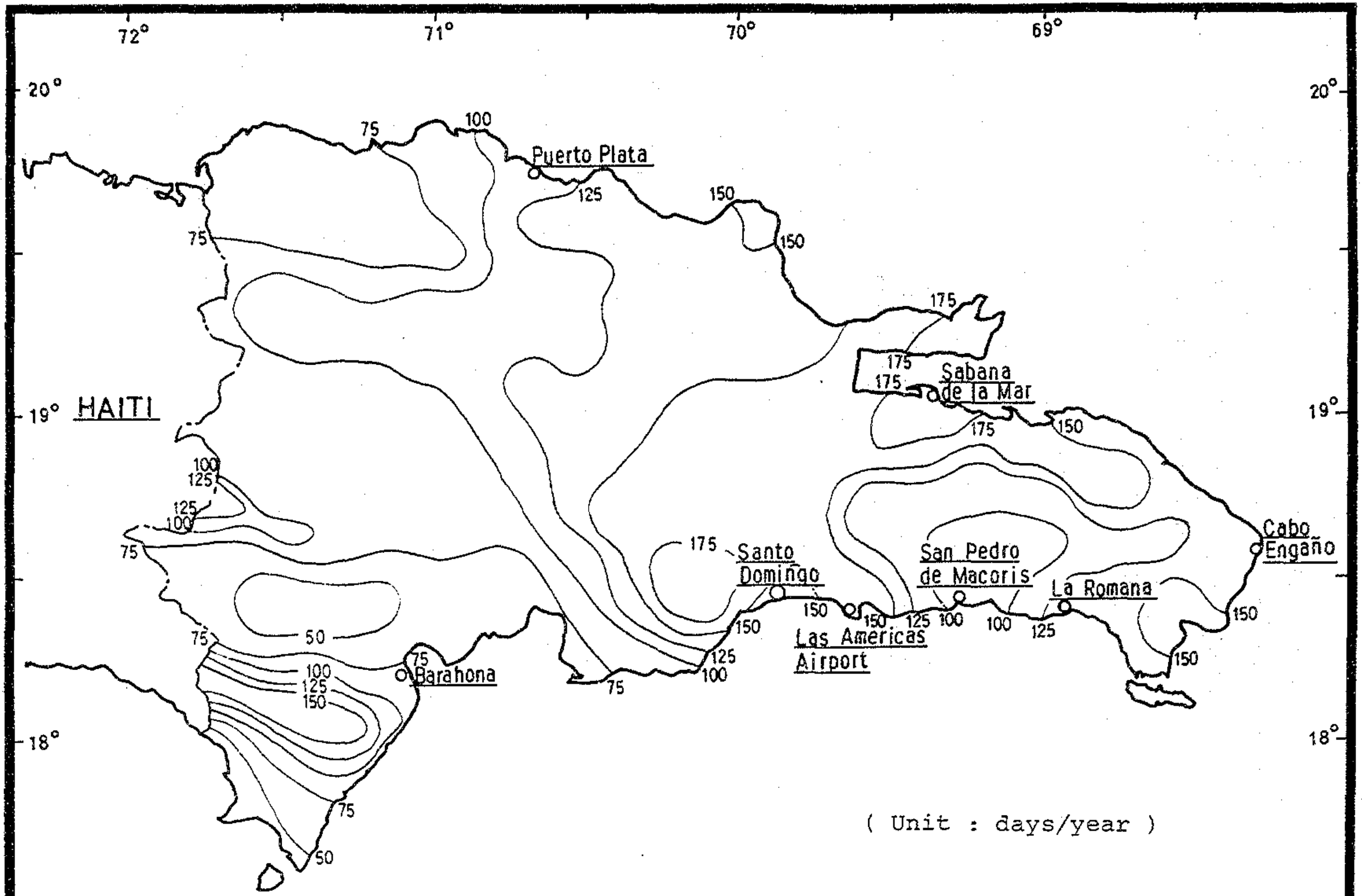


Fig. I.4.7 Distribution of Annual Total Rainy Days

(2) Precipitation

The yearly total rainfall at San Pedro de Macoris is 1,012.6 mm which is somewhat less than at the other stations mentioned above. It seems that the south coast has less rainfall than the north coast. The monthly rainfall of San Pedro de Macoris varies from 27.6 mm in January to 146.4 mm in September. The number of rainy days varies from 4.3 days in March to 11.3 days in October.

(3) Wind

No wind data have been recorded at San Pedro de Macoris and the nearest station having a wind record is Las Americas Airport located about 35 km west of San Pedro de Macoris. The average wind velocity at Las Americas Airport is 3 to 4 m/sec which is almost constant throughout the year and the predominant wind direction is mostly N-NE, but it is SE in May. The maximum wind velocity at Las Americas Airport varies from 13.9 to 25.0 m/sec.

The record of the wind data collected every three hours at Las Americas Airport for the three years from 1983 to 1985 was also obtained. Fig. I.4.8 shows the wind rose based on this data. The most frequent wind direction and velocity during the above period were NE followed by SE and S and 2-4 m/sec respectively. These characterisics are almost constant throughout the year.

These wind data are used to hindcast the ordinary wind waves in order to estimate the calmness of the port basin.

(4) Hurricanes

The Country has experienced numerous hurricanes and tropical depressions. 142 hurricanes and tropical depressions affected the Country during the 100 years from 1885 to 1984. The number of such major storms by month is as follows.

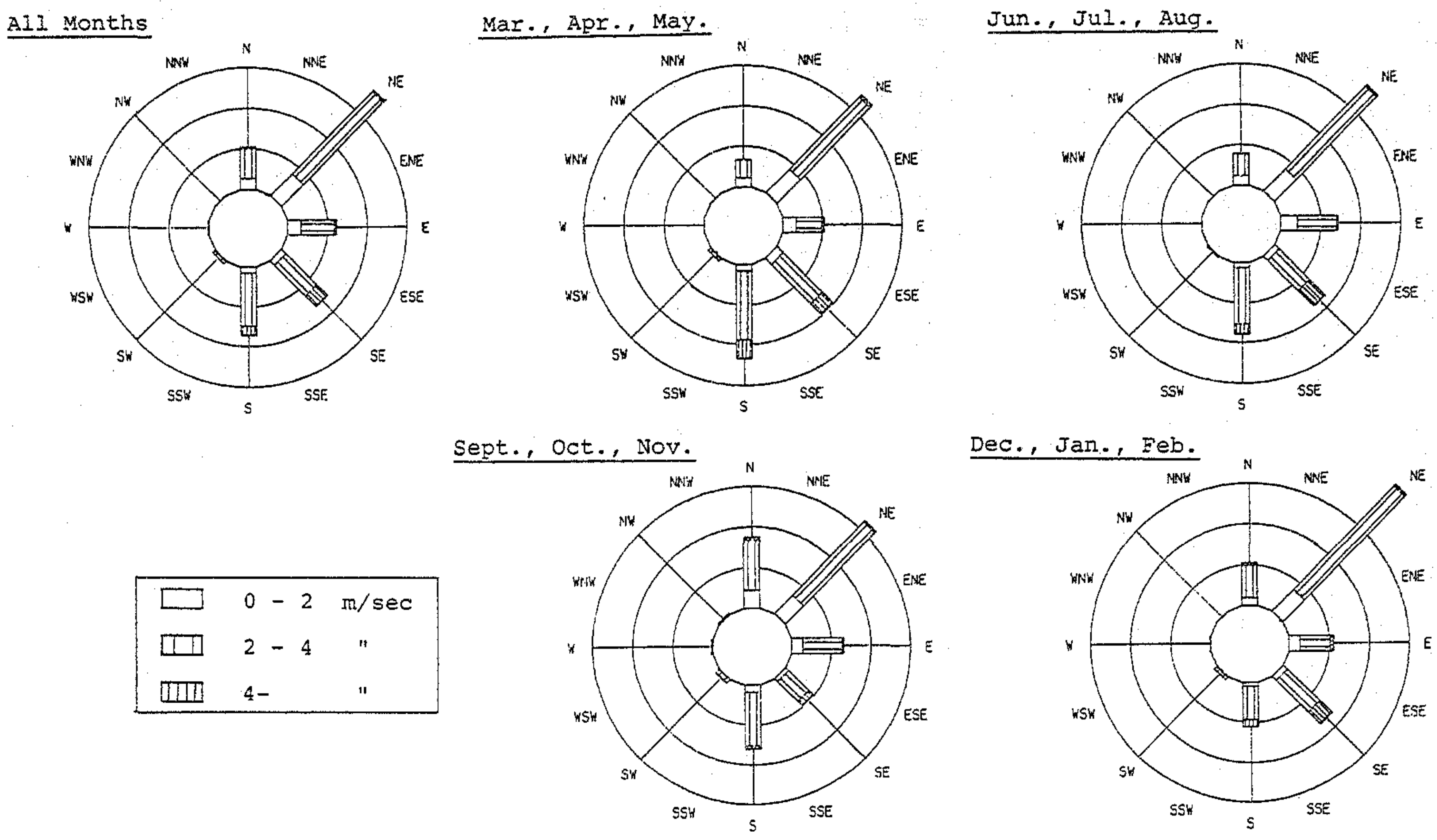


Fig. I.4.8 Wind Rose of Las Americas Airport

Month	Number	Percentage (%)
May	2	1.4
June	1	0.7
July	10	7.0
August	46	32.4
September	55	38.8
October	21	14.8
November	5	3.5
December	2	1.4
Total	142	100.0

According to the above table, 70 % of the major storms occurred in August and September.

During the 30 years from 1955 to 1984 the Country experienced 5 big hurricanes with a maximum velocity of more than 40 m/sec, namely Flora (1963), Inez (1966), Beulah (1967), David (1979) and Allen (1980). Among those hurricanes, David is considered to have caused the worst damage to the Country. Fig. I.4.9 shows the trajectories of these 5 hurricanes.

The heights of extraordinary waves caused by hurricanes are calculated to determine the design wave height of the port facilities.

2.3 Oceanographic Conditions

(1) Tides

No tidal data have been recorded at the Port. However, the ports of Boca Chica about 35 km west of the Port and La Romana about 35 km east of the Port have tide tables as follows.

	Boca Chica	La Romana
	(m)	(m)
Highest tide observed	+ 0.40	+ 0.21
Mean high water	+ 0.12	+ 0.13
Mean sea level	± 0.00	± 0.00
Mean low water	- 0.10	- 0.11
Lowest tide observed	- 0.30	- 0.18

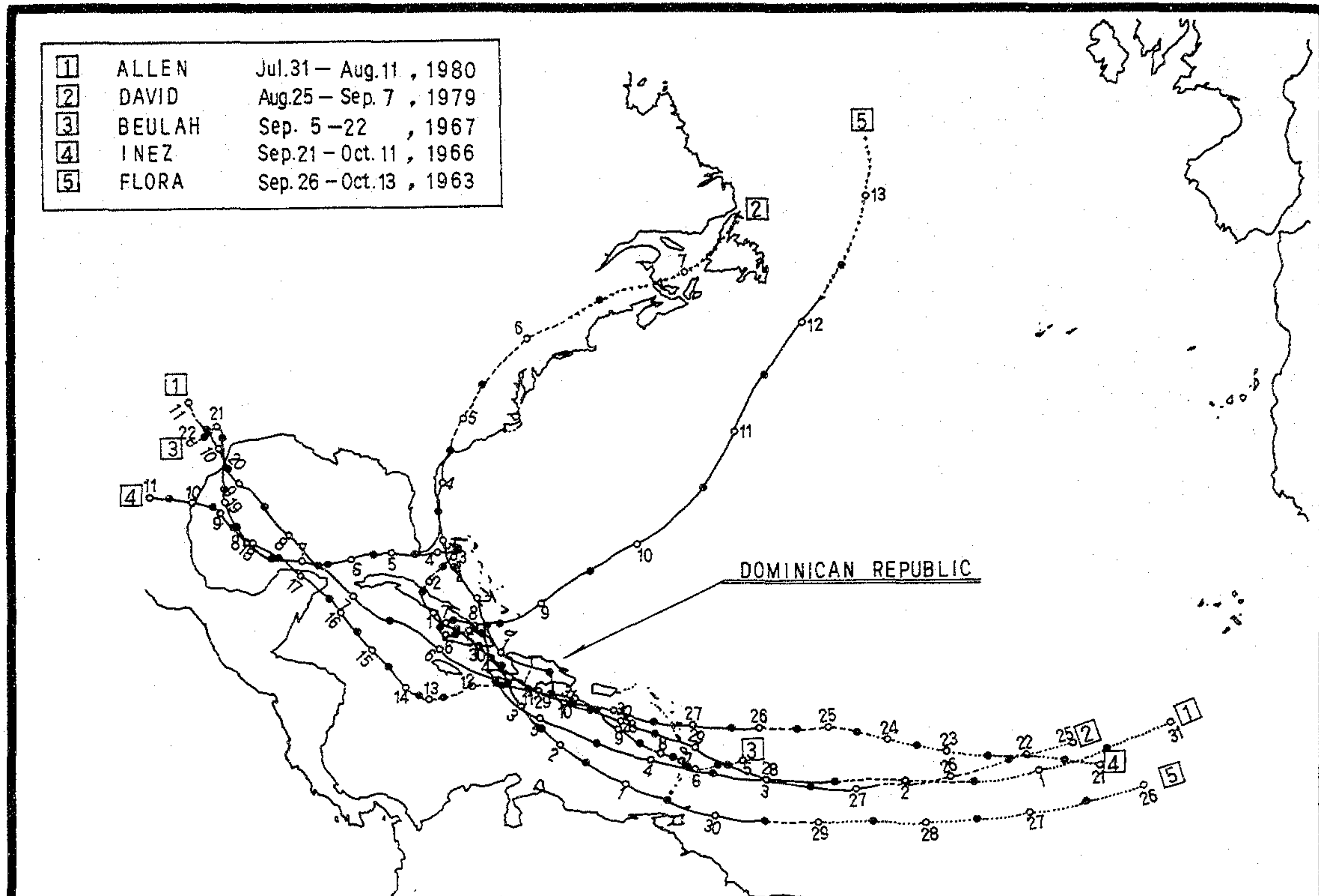


Fig. I.4.9 Trajectories of Major Hurricanes

There are three stations recording actual tidal data in the Dominican Republic, namely Barahona, Puerto Plata and Boca Chica, and they are under the jurisdiction of the Navy. A tide survey was carried out at the north end of Wharf No.1 using a tentative tidal gauge. Fig. I.4.10 shows samples of the results of the survey. The tide of the Port can be considered chiefly diurnal and the tidal range during the survey period was 23 to 25cm. If the tide was recorded at Boca Chica at the same time as the survey, the tide table of the Port might be established by comparison between the data of the ports of San Pedro de Macoris and Boca Chica. However, the Study Team was not allowed to collect data at Boca Chica.

However, since the ports of Boca Chica and La Romana are located at almost the same distance from the Port, the tide table of the Port can be estimated by averaging the values of these two ports. The result is as follows.

Tide Table of the Port of San Pedro de Macoris

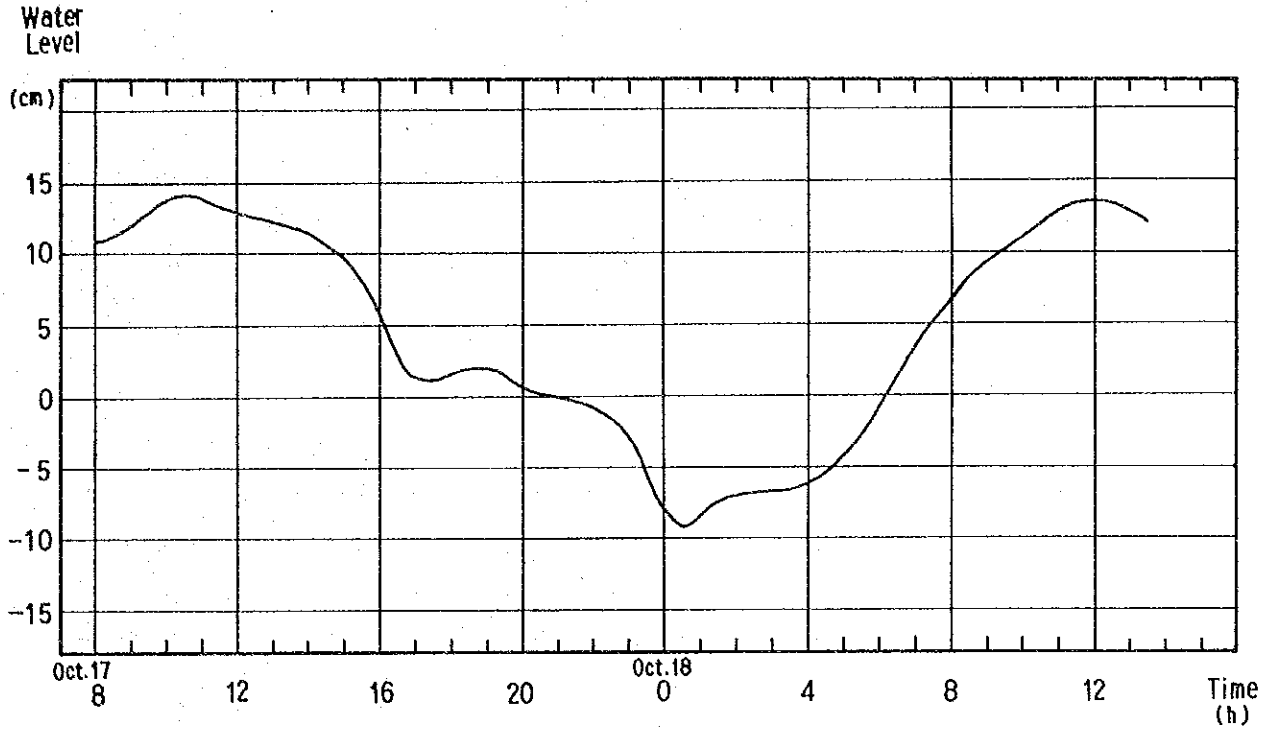
	(m)
Highest high water	+ 0.30
Mean high water	+ 0.12
Mean sea level	± 0.00
Mean low water	- 0.10
Lowest low water	- 0.24

The tidal range of 23 to 25cm noted during the survey period approximates the range between the mean high water and the mean low water of the tide table above.

(2) Waves

There is no data station in the Dominican Republic with a wave recording gauge. However, the National Meteorological Office has statistics of waves in the Caribbean Sea based on reports from ocean-going vessels covering the 5 year period from 1965 to 1969.

According to these statistics, the most frequent wave height, period and direction in the Caribbean Sea are 1 to 1.5m, less than 5 sec and ENE. Since ships tend to avoid stormy weather, the above statistics can be considered as a description of the characteristics of ordinary waves.



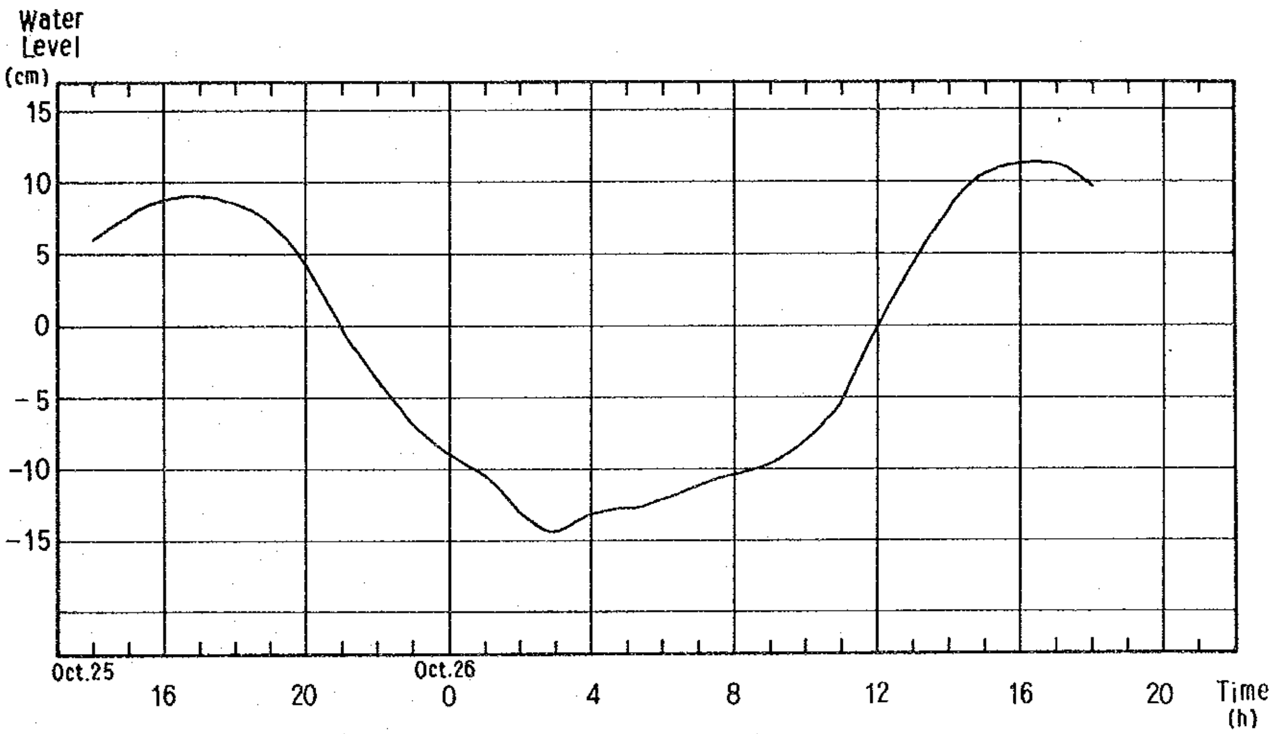


Fig. I.4.10 Sample Tide Records

However, from the engineering viewpoint, it is indispensable to calculate the dimensions of the waves reaching a particular port in order to estimate the workable days and the design wave height of the port facilities. As for the workable days, normal wave conditions are analysed based on normal meteorological conditions while for the design wave height abnormal wave conditions are analysed by considering hurricanes and tropical storms.

1) Normal Waves

Normal wave conditions can be calculated by the SMB method using the wind record of 1983 - 1985 of Las Americas Airport which is the nearest wind data station to the Port as mentioned previously.

The frequency of offshore wave occurrence by direction and wave height and by wave period and wave height are shown in Table I.4.9 and I.4.10 respectively. Fig. I.4.11 and I.4.12 show the probability of nonexceedance of offshore wave height for all directions and for each direction, respectively.

Table I.4.9 Offshore Wave Occurrence by Direction and Height

Direction / Height(m)	SE	S	SW	Total
0 - 0.49	2,961 (35.8)	3,187 (38.5)	202 (2.4)	6,350 (76.7)
0.50 - 0.99	609 (7.4)	701 (8.5)	16 (0.2)	1,326 (16.1)
1.00 - 1.49	241 (2.9)	219 (2.6)	2 (0)	462 (5.6)
1.50 - 1.99	77 (0.9)	39 (0.5)	0 (0)	116 (1.4)
2.00 - 2.49	16 (0.2)	2 (0)	1 (0)	19 (0.2)
2.50 - 2.99	2 (0)	1 (0)	0 (0)	3 (0)
3.00 -	0 (0)	1 (0)	3 (0)	4 (0)
Total	3,906 (47.2)	4,150 (50.3)	224 (2.7)	8,280 (100.0)

Note: Figures in parentheses denote percentages

Table I.4.10 Offshore Wave Occurrence by Period and Height

Period(sec) / Height (m)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-	Total
0 - 0.49	5,398	109	749	94	0	0	0	0	6,350
	(65.2)	(1.3)	(9.0)	(1.1)	(0)	(0)	(0)	(0)	(76.7)
0.50 - 0.99	0	0	350	895	81	0	0	0	1,326
	(0)	(0)	(4.2)	(10.8)	(1.0)	(0)	(0)	(0)	(16.1)
1.00 - 1.49	0	0	0	107	341	14	0	0	462
	(0)	(0)	(0)	(1.3)	(4.1)	(0.2)	(0)	(0)	(5.6)
1.50 - 1.99	0	0	0	0	68	48	0	0	116
	(0)	(0)	(0)	(0)	(0.8)	(0.6)	(0)	(0)	(1.4)
2.00 - 2.49	0	0	0	0	0	18	1	0	19
	(0)	(0)	(0)	(0)	(0)	(0.2)	(0)	(0)	(0.2)
2.50 - 2.99	0	0	0	0	0	2	1	0	3
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
3.00 -	0	0	0	0	0	0	2	2	4
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Total	5,398	109	1,099	1,099	490	82	4	2	8,280
	(65.2)	(1.3)	(13.3)	(13.3)	(5.9)	(1.0)	(0)	(0)	(100.0)

Note: Figures in parentheses denote percentages

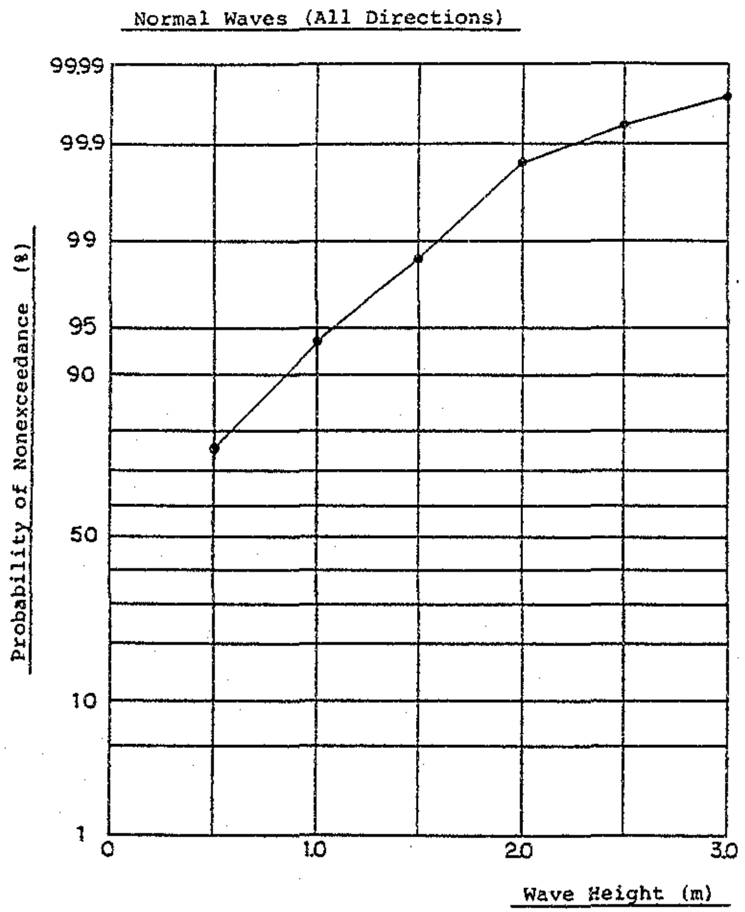


Fig. I.4.11 Probability of Nonexceedance for All Directions

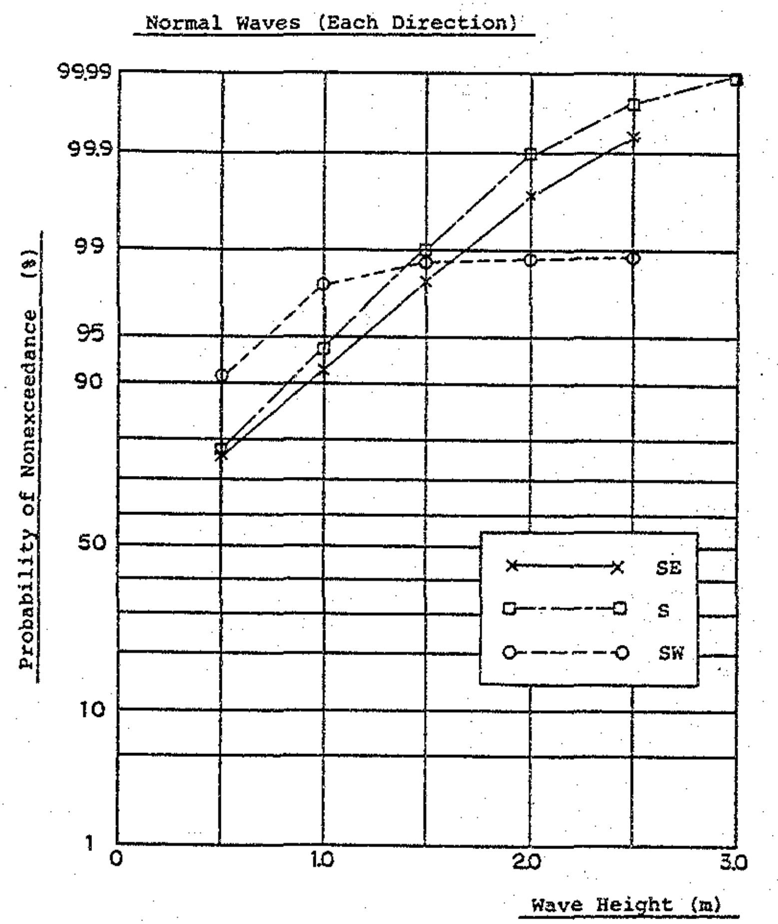


Fig. I.4.12 Probability of Nonexceedance for Each Direction

2) Abnormal Waves

Abnormal offshore waves can be calculated by Wilson's method using the weather maps. The 5 hurricanes mentioned before were selected for the weather conditions used to calculate the abnormal offshore waves. The results of the calculation are summarized in the table below.

Table I.4.11 Abnormal Offshore Waves by Hurricanes

Hurricane	Allen	David	Beulah	Inez	Flora
	(1980)	(1979)	(1967)	(1966)	(1963)
Height(m)	4.47	6.55	5.14	3.75	2.08
Period(sec)	8.28	10.02	8.47	7.24	6.05
Direction	SE	SE	SSE	ESE	SSE

Fig. I.4.13 shows the return period of abnormal wave height. The historical biggest wave height caused by David (1979) is equivalent to the wave height with a return period of about 50 years. In Japan it is common to apply the wave with a 50 year return period as the design wave for port facilities. According to the Japanese standard above and by taking the accuracy of the calculation into account, a wave of 7.0 m height, 10.0 sec period and SE direction can be considered as the design offshore wave.

(3) Water Depth

No sounding survey had been carried out at the Port since 1976. A new sounding survey was implemented from the beginning of October 1986 to the beginning of November 1986. Fig. I.4.14 shows the survey area. The actual survey work was carried out by a survey team of SEOPC with one echo sounder and two theodolites. The Study Team supported and advised the survey team, especially on how to operate the echo sounder.

Fig. I.4.15 shows the annual siltation rate by area calculated by comparing the sounding charts of 1976 and 1986. The siltation rates of areas in front of Wharfs No.1, No.2 and No.3 are 17-19, 16-17 and 13-17 cm/year respectively. The siltation rate decreases downstream reaching the value of 1.0 cm/year near the channel entrance. The total siltation volume

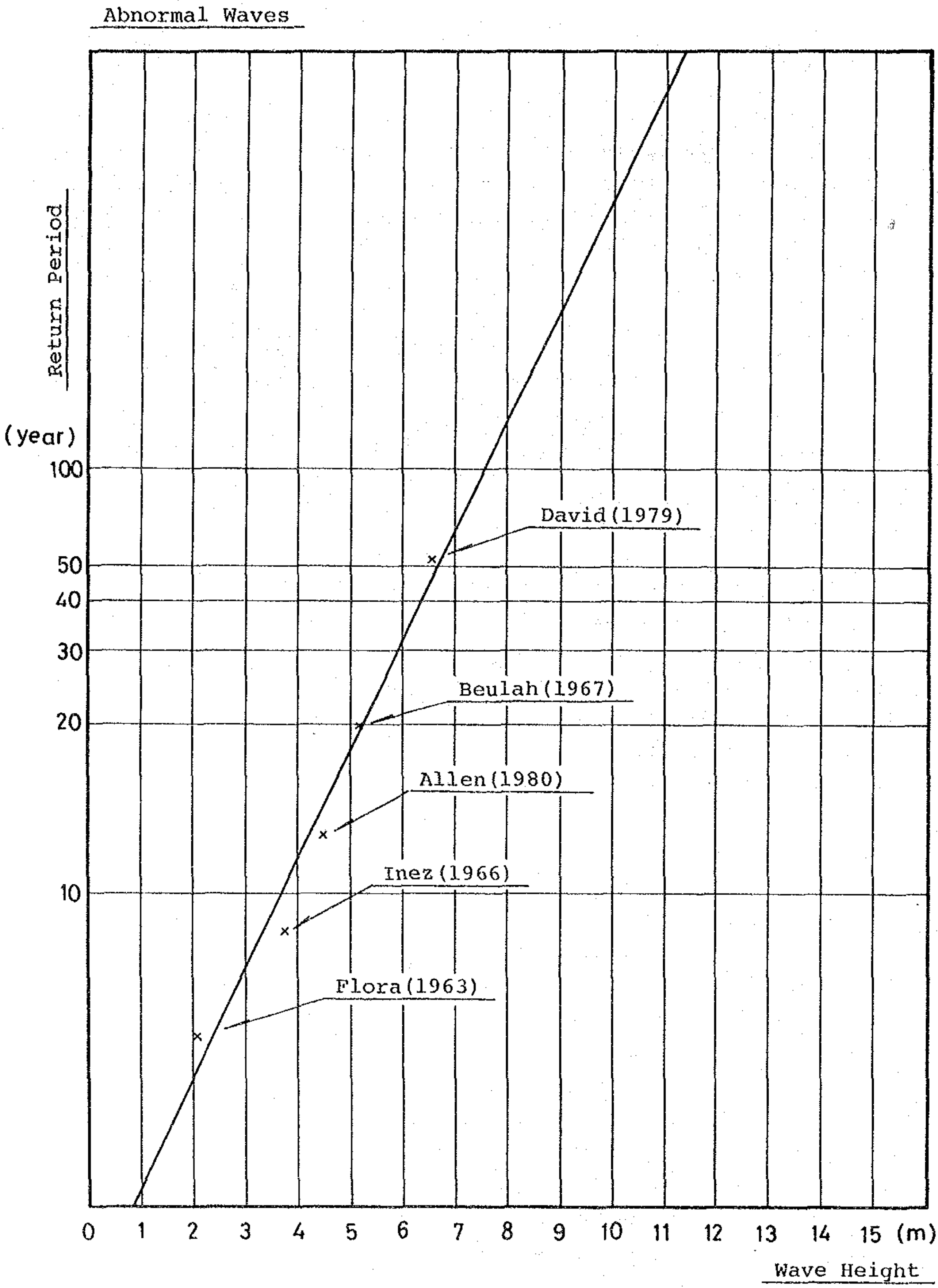


Fig. I.4.13 Return Period of Abnormal Offshore Wave Height

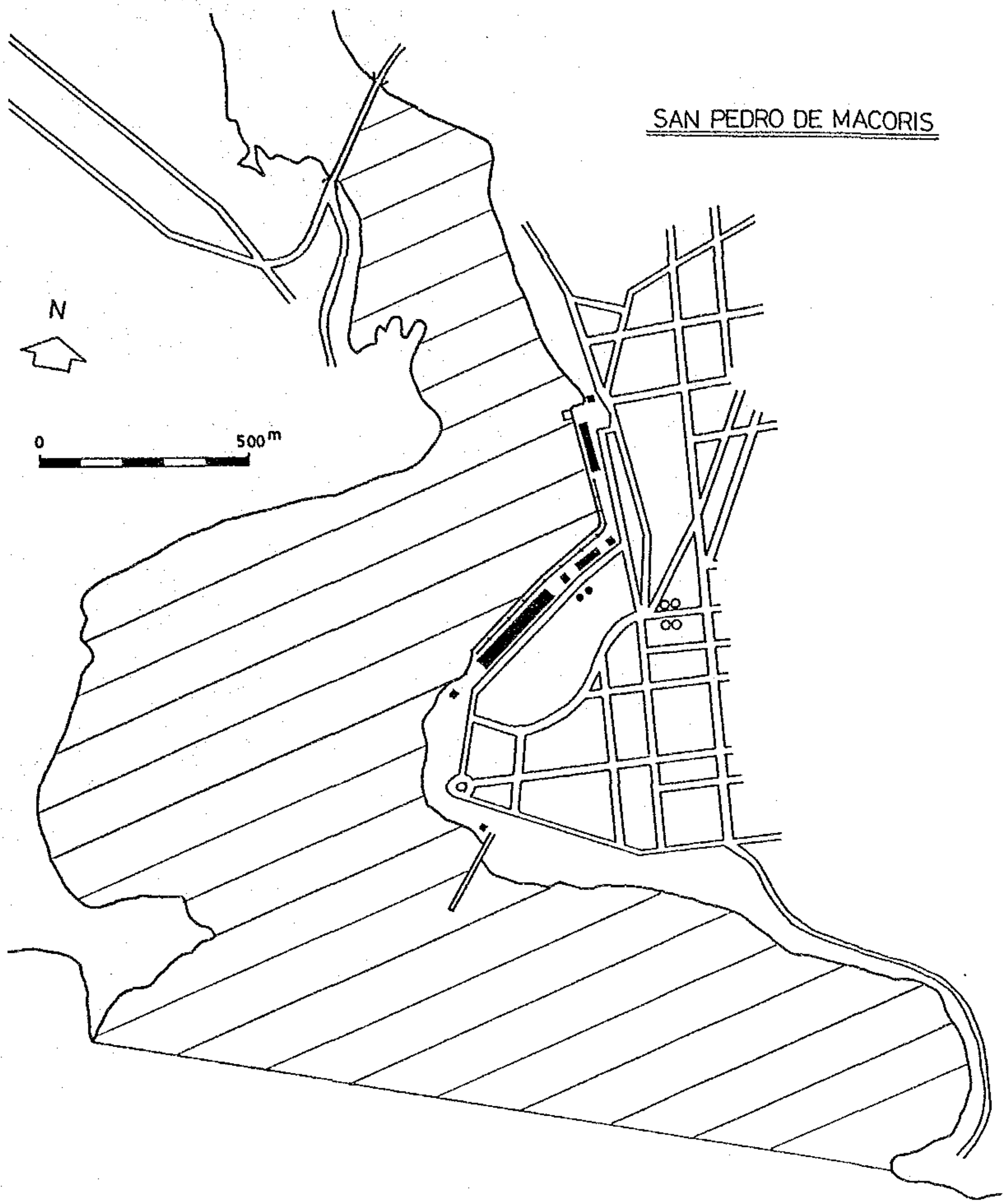


Fig. I.4.14 Area of Sounding Survey

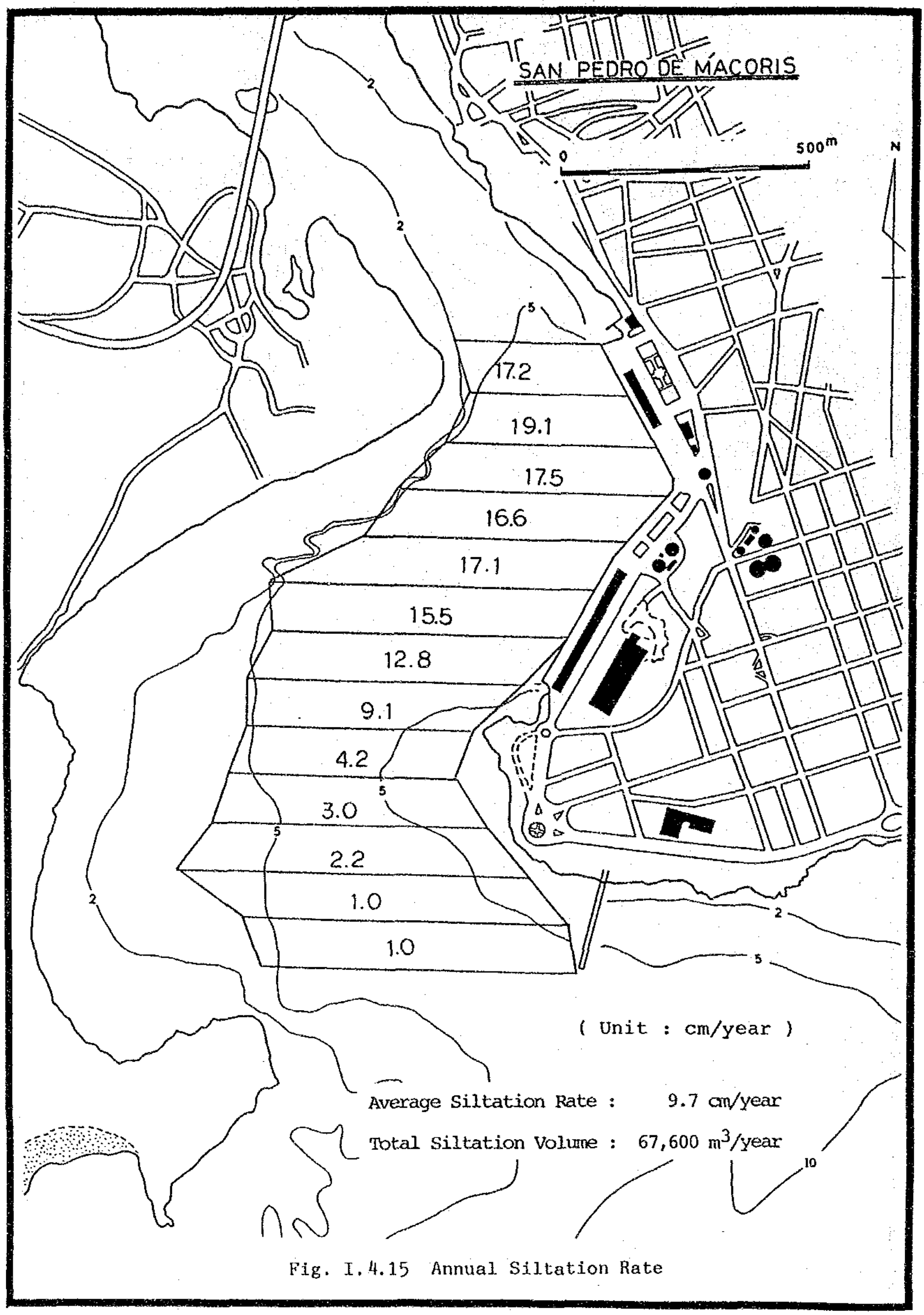


Fig. I.4.15 Annual Siltation Rate

of the whole area shown in Fig. I.4.15 is about 67,000 m^3/year and the average siltation rate is about 10 cm/year.

Fig. I.4.16 shows the change of the -5 m contour and the collapsed parts of the breakwater. This collapse is reported to have occurred when the hurricane David attacked the Country in 1979. The change of the contour shows the erosion clearly and it is considered to have been caused by the movement of sand from east to west through the collapsed parts.

According to interviews and to an old marine chart, there was previously a beach at the east of the breakwater which was a good swimming spot. If the breakwater is repaired, the sand will be trapped by it and the beach will be reformed.

(4) Current

According to the Stanley Report (1970), during ordinary flood flows, velocities may reach about 1.5 m/sec and during hurricanes they may reach at most 2.5 m/sec. However, the current usually does not disturb the navigation of ships.

A simple current survey was carried out using floats. Fig. I.4.17 shows the results of the survey. The vectors indicate the velocity, and the continuous vectors coupled with the broken lines indicate the trajectory of each float. The intensity of the current is 5 to 10 m/sec in front of the existing wharfs and 10 to 20 cm/sec at the lower channel.

According to the Stanley Report, the results presented above and the observations during the field work, it seems that the current does not disturb the navigation of vessels.

(5) Bed Material

A bed material sampling was carried out at 8 points within the port area and 1 point about 2 km upstream of the Bridge Macoris. Fig. I.4.18 shows the sampling points and the values of D50 for each point. The bed materials for point No.1 to 5 consist of silt and the materials at point No.7 consist of silt mixed with sand. The bed at points No.6, 8 and 9 consists of sand. The sediment accumulated in front of the existing wharfs is considered to have come from upstream of the Port, and the sediment near the channel entrance around sampling point No.7 is considered to be a mixture of the silt from upstream and the sand from the east of the breakwater.

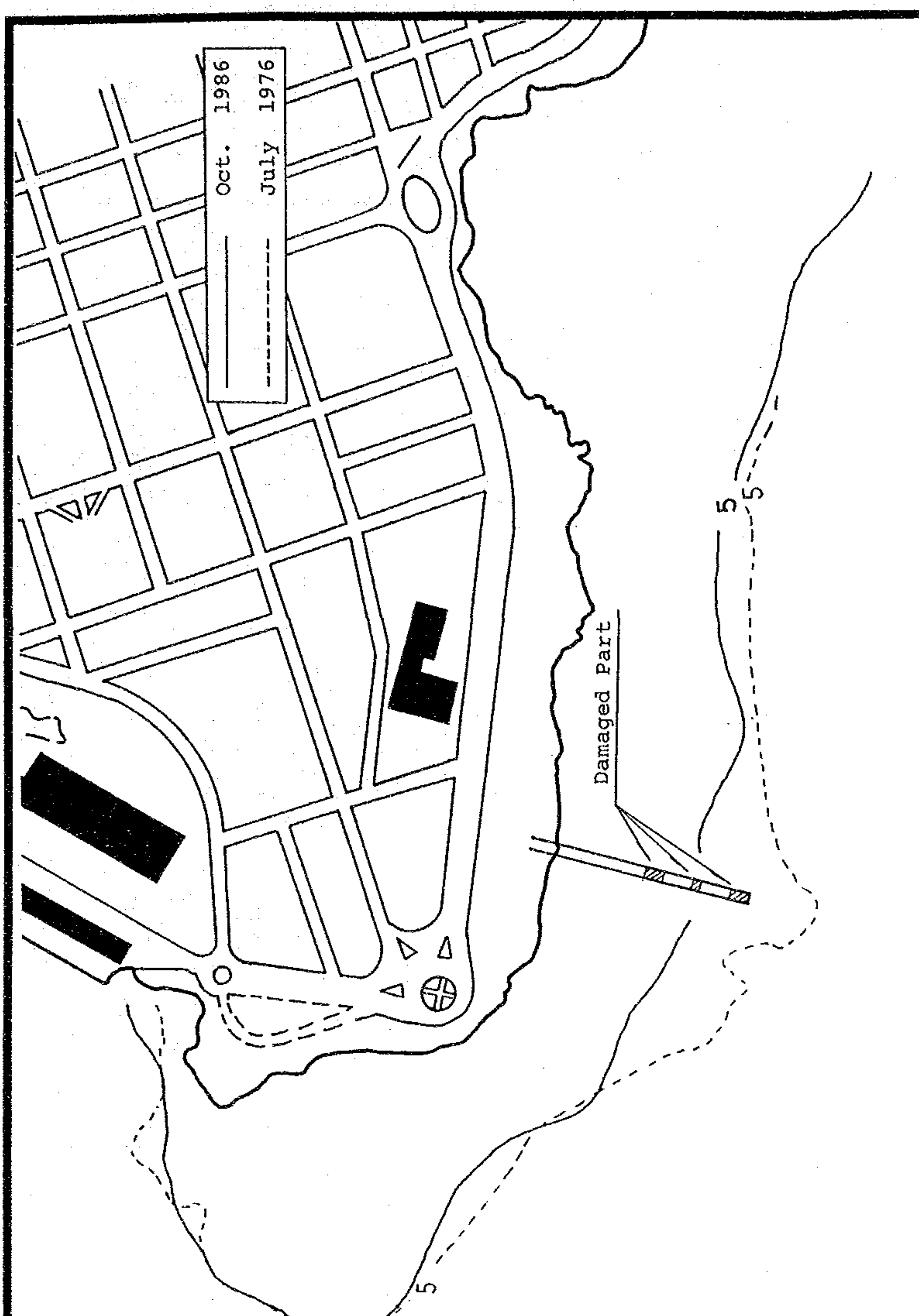


Fig. I.4.16 Change of the -5m Contour

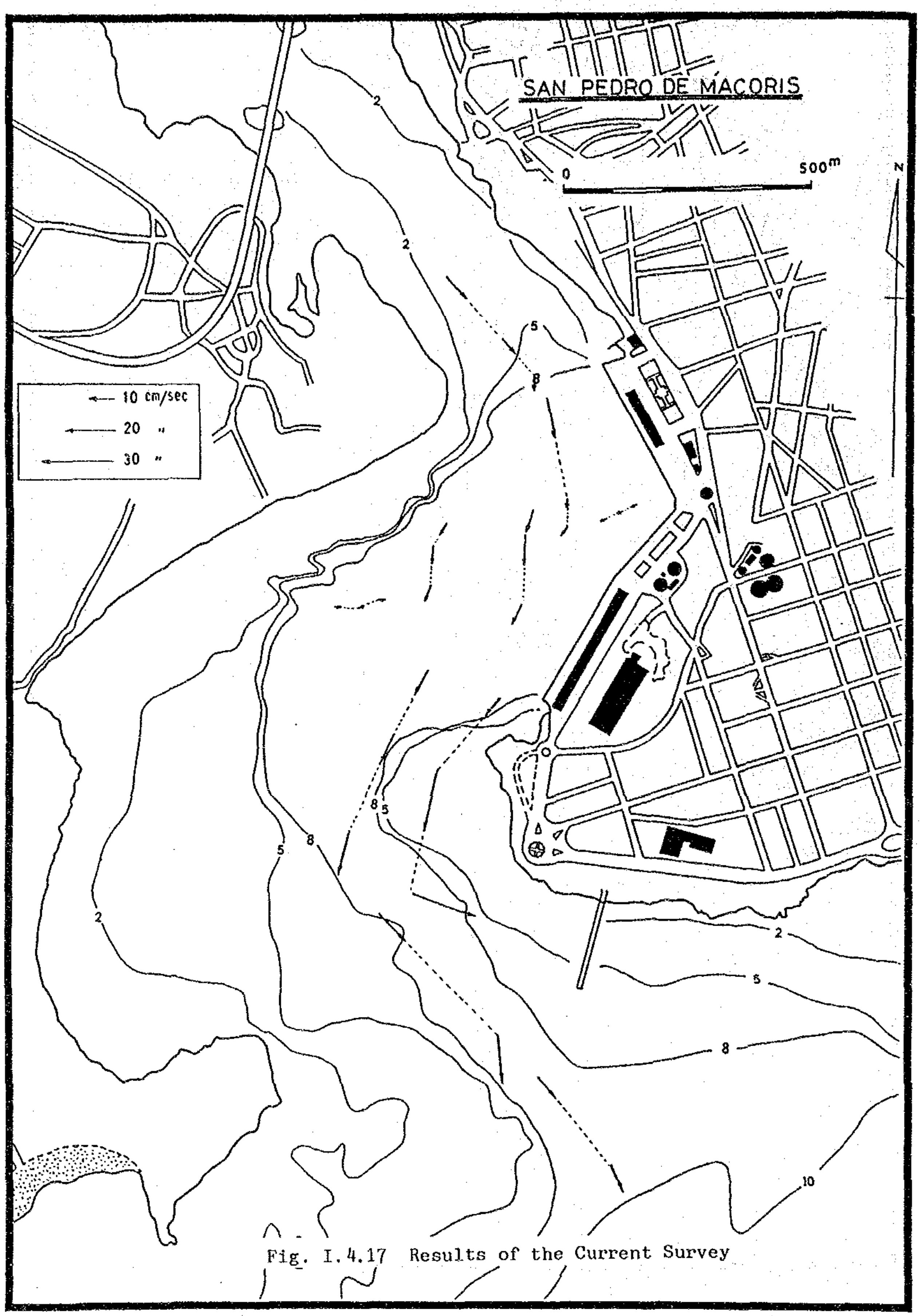


Fig. I.4.17 Results of the Current Survey

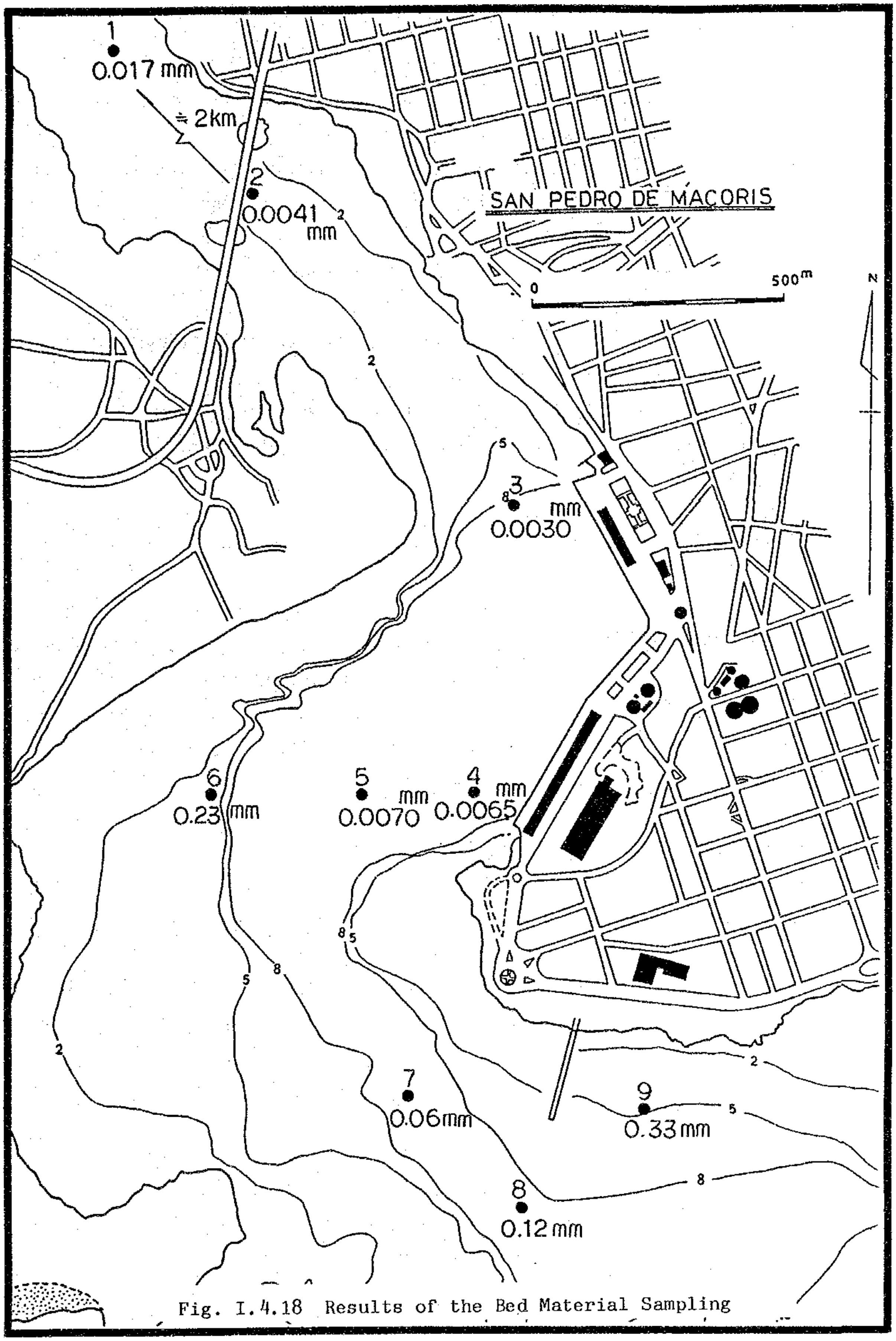


Fig. I.4.18 Results of the Bed Material Sampling

2.4 Soil Conditions

A soil investigation was carried out at six bore holes in the port area including drilling, sampling and in-situ tests.

The objective of the investigation was to provide fundamental data on soil conditions to be used for basic design and the improvement of the structures of the port facilities.

The soil investigation was carried out in order to confirm:

(i) the bearing stratum up to the bed rock or hard stratum with an N-value of more than 50, and

(ii) the phsical and mechanical properties of the soil determined by laboratory tests, including undisturbed sampling and standard penetration tests.

A soil investigation was also carried out at the opposite side of the Higuamo River for possible future development.

The soil investigation was commenced at the beginning of October 1986 and the field work of the boring was completed at the beginning of November 1986. The laboratory tests were finished at the end of November 1986.

The locations of the six bore holes are shown in Fig. I.4.19. Bore holes No.1, 3, 4 and 6 are located along the faceline of the existing wharfs, bore hole No.2 is located behind the transit shed at Wharf No.1, and bore hole No.5 is located on the opposite side of the Higuamo River across from the existing wharfs.

The soil profile and the characteristics such as N-value and grain size distribution along the existing wharfs and the transverse line of the Higuamo River are shown in Fig. I.4.20 and Fig. I.4.21, respectively.

The bearing stratum of each bore hole consists of caliche[1] with an N-value of more than 50 as shown in the soil profiles Fig. I.4.20 and Fig. I.4.21.

The penetration depth and the elevation of the caliche of each bore hole are shown in the following table.

Note:(1)Caliche is a silt or sand of the semiarid areas of the southwestern United States cemented with calcium carbonate.
The calcium carbonate is deposited by the evaporation of ground water brought to the ground surface by capillary action.

Table I.4.12 Elevation of Bearing Stratum

Bore hole No.	Penetration Depth (m)	Elevation of Caliche (m)
1	16.0	- 17.8
2	11.2	- 7.8
3	16.5	- 17.3
4	57.1	- 58.2
5	16.4	- 14.6
6	46.1	- 50.0

The soil characteristics along the existing wharfs shown in Fig. I.4.20 are summarized as follows.

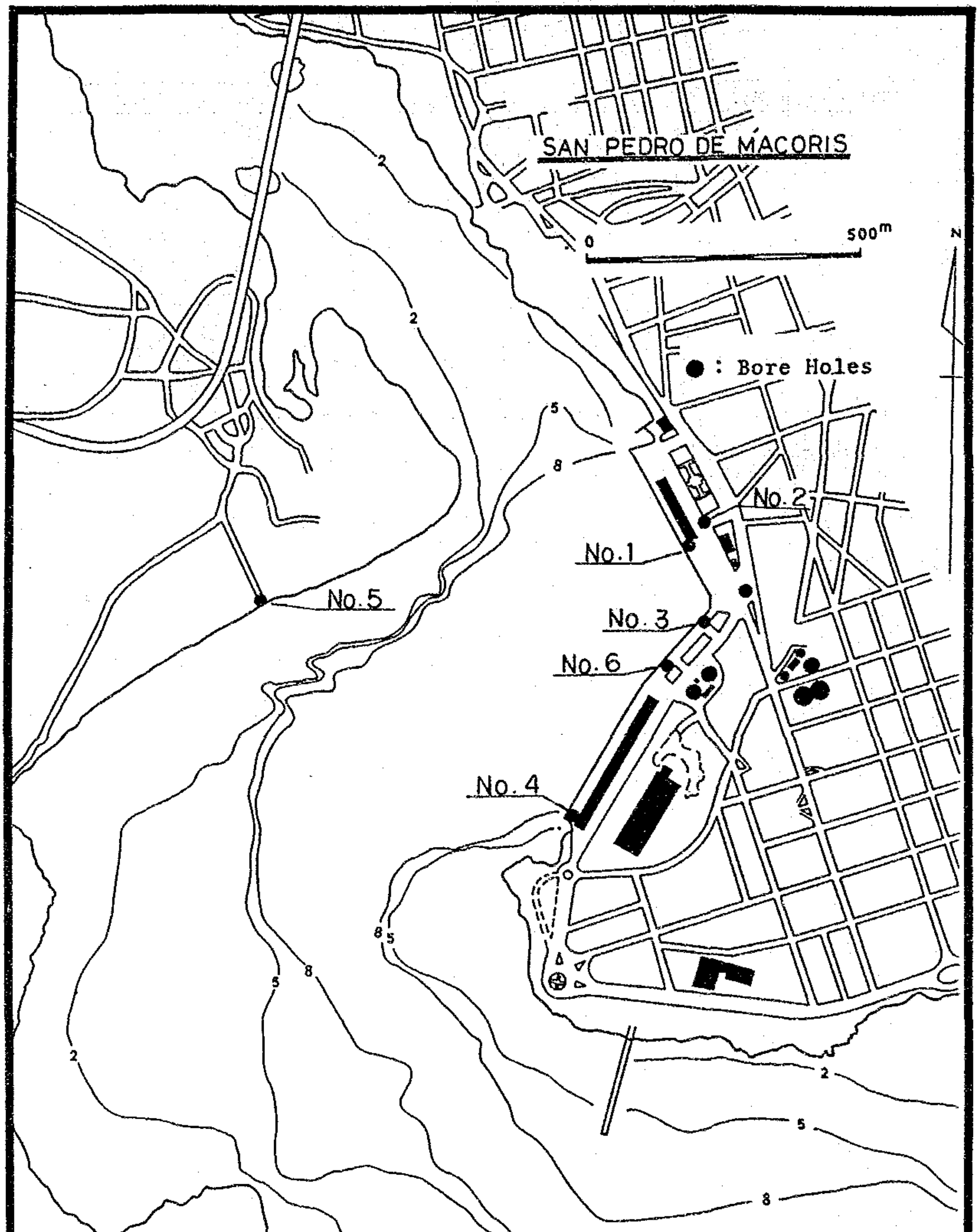


Fig. I.4.19 Locations of the Bore Holes

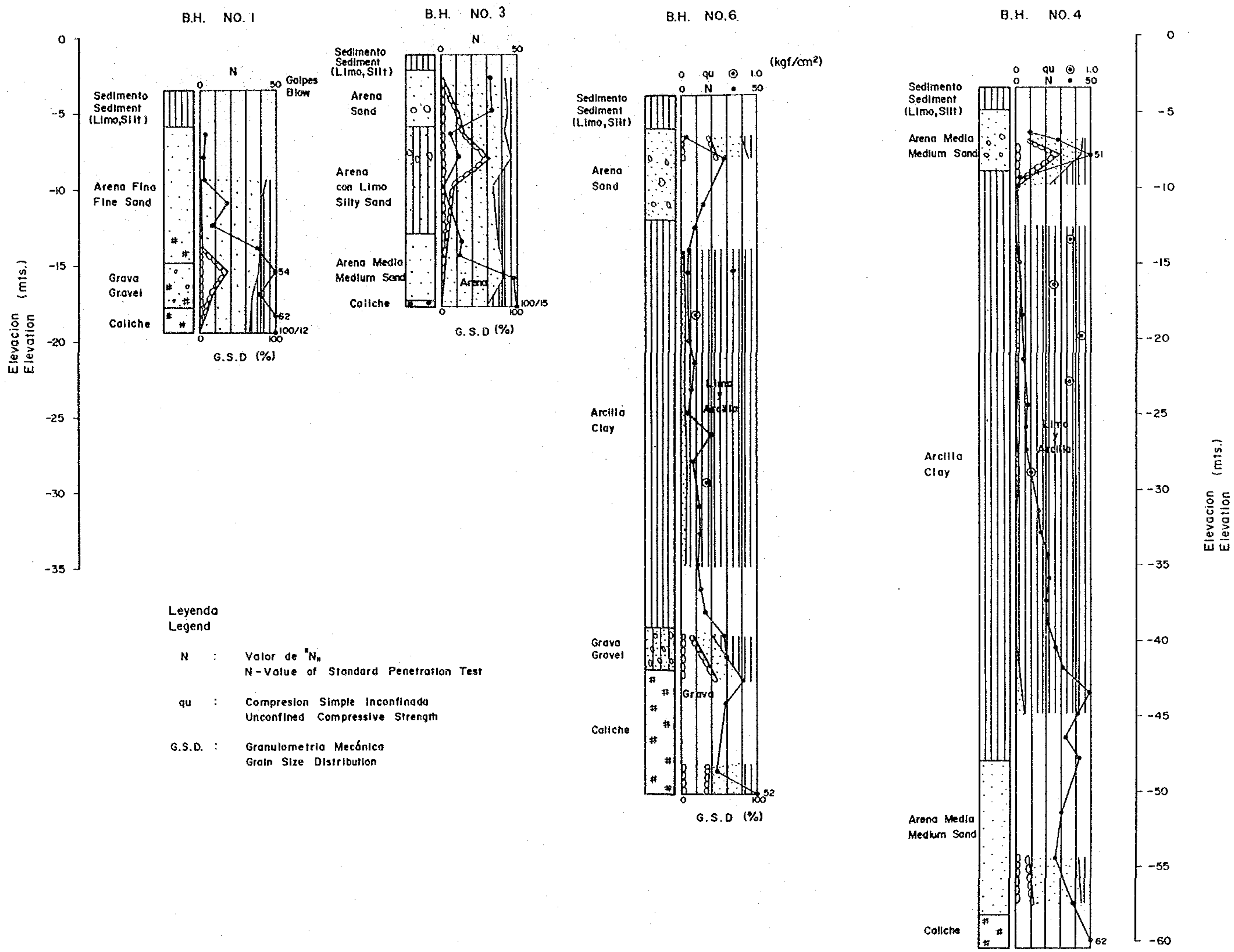
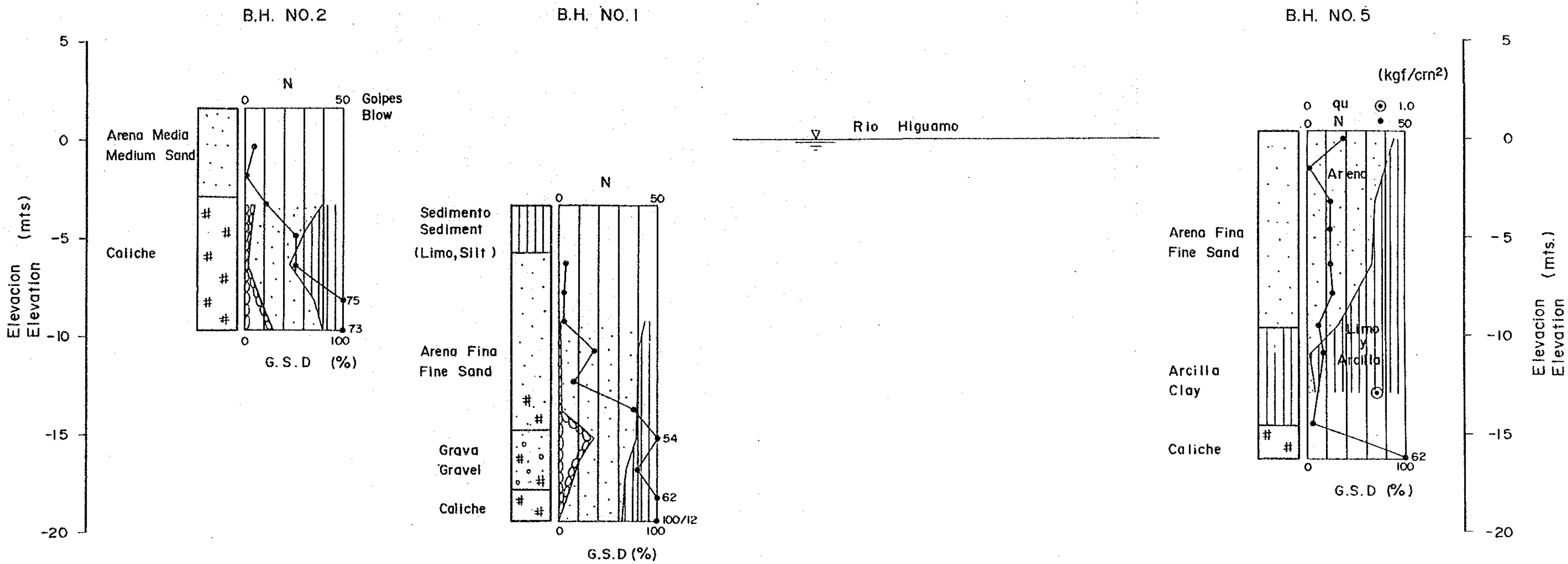


Fig. I.4.20 Soil Profiles (1)



Leyenda
Legend

N	:	Valor de "N" N-Value of Standard Penetration Test
qu	:	Compresion Simple Inconfinada Unconfined Compressive Strength
G.S.D	:	Granulometria Mecánica Grain Size Distribution

Fig. I.4.21 Soil Profiles (2)

The top layer is organic mud consisting of very soft sediment. This layer is considered to have accumulated after the construction of the existing port facilities and to have been mixed with stone blocks or concrete fragments which fell into the layer during or after the construction of the existing wharfs.

The top layer of bore hole No.1 at Wharf No.1 and bore hole No.3 near the ferry ramp consists of fine to medium sand. The second layer is gravel. The caliche of the bearing stratum is relatively shallow about -18 m under the second layer.

However, a very thick third clay layer lies about 30-40 m under the sediment and sand layers at wharfs No.2 and No.3 as shown in Fig. I.4.20.

The elevation of the bearing stratum, therefore, is located at a very deep level of -50 to -60 m at these holes in marked contrast to the soil conditions at Wharf No.1.

Fig. I.4.21 shows a transverse section including Wharf No.1 and the opposite side of the Higuamo River. The inclination between bore hole No.2 behind the warehouse and bore hole No.1 at wharf No.1 is about 1:6 toward the wharf side. Data from bore hole No.2 will be helpful for the future development of land facilities.

The upper layer of bore hole No.5 at the opposite side of the river is -15 m in depth to reach the caliche and consists of fine sand and clay.

Tests were carried out for the five physical properties of grain size distribution, moisture content, consistency (LL-PL), specific gravity and unit weight. The results of the tests are shown in Fig. I.4.22 and summarized in the Table I.4.13.

Table I.4.13 Summary of Physical Properties

Property	Range	Mean value
Moisture Content	55 - 80 %	60 %
Liquid Limit	60 - 75 %	70 %
Plastic Limit	20 - 35 %	30 %
Specific Gravity	2.6 - 2.9 tf/m^3	2.70 tf/m^3
Unit Weight	1.5 - 1.8 tf/m^3	1.65 tf/m^3

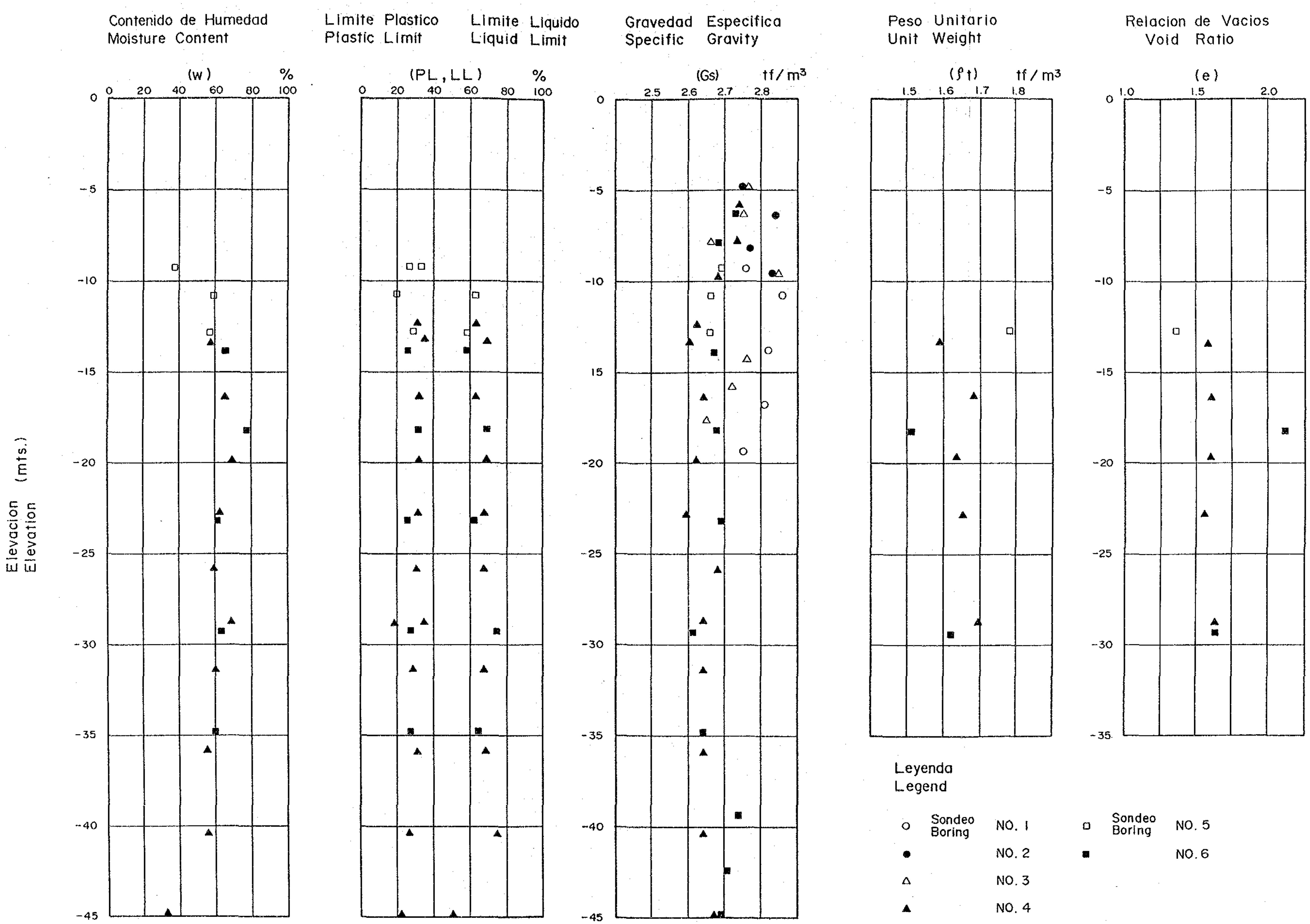


Fig. I.4.22 Soil Properties

The results of the unconfined compressive strength test are shown in Fig. I.4.23. The maximum compressive strength was measured at 0.9 kgf/cm^2. The structures of the proposed port facilities are designed based on both the cohesion and the N-values observed.

A consolidation test was made on three samples at bore holes No.4 #2, No.4 #4 and No.5 #1. Fig I.4.24 (1) shows the coefficient of consolidation (Cv) and Fig. I.4.24 (2) shows the coefficient of volume compressibility (Mv).

Fig. I.4.25 shows the results of the boring survey carried out along the approach channel by SEOPC. As shown in the figure, the hard layer of caliche is encountered at a relatively shallow level of about -5 m near the coast off Punta Sur while at bore holes No.1 - No.3 at the other bore holes No.4 - No.9 the caliche is located deeper than -14 m.

2.5 Earthquakes

In the 20th century the Dominican Republic experienced over 10 significant earthquakes. The earthquake in 1946 was the biggest with a magnitude of 8.1. The epicenter was located at 19 50'N 69 50'W.

As for the seismic factor for the design work of the port structures, the preceding design reports were reviewed and interviews with SEOPC were also held. According to these reviews and the interviews, seismic factors of 0.05 for the live load and 0.10 for the dead load are considered reasonable.

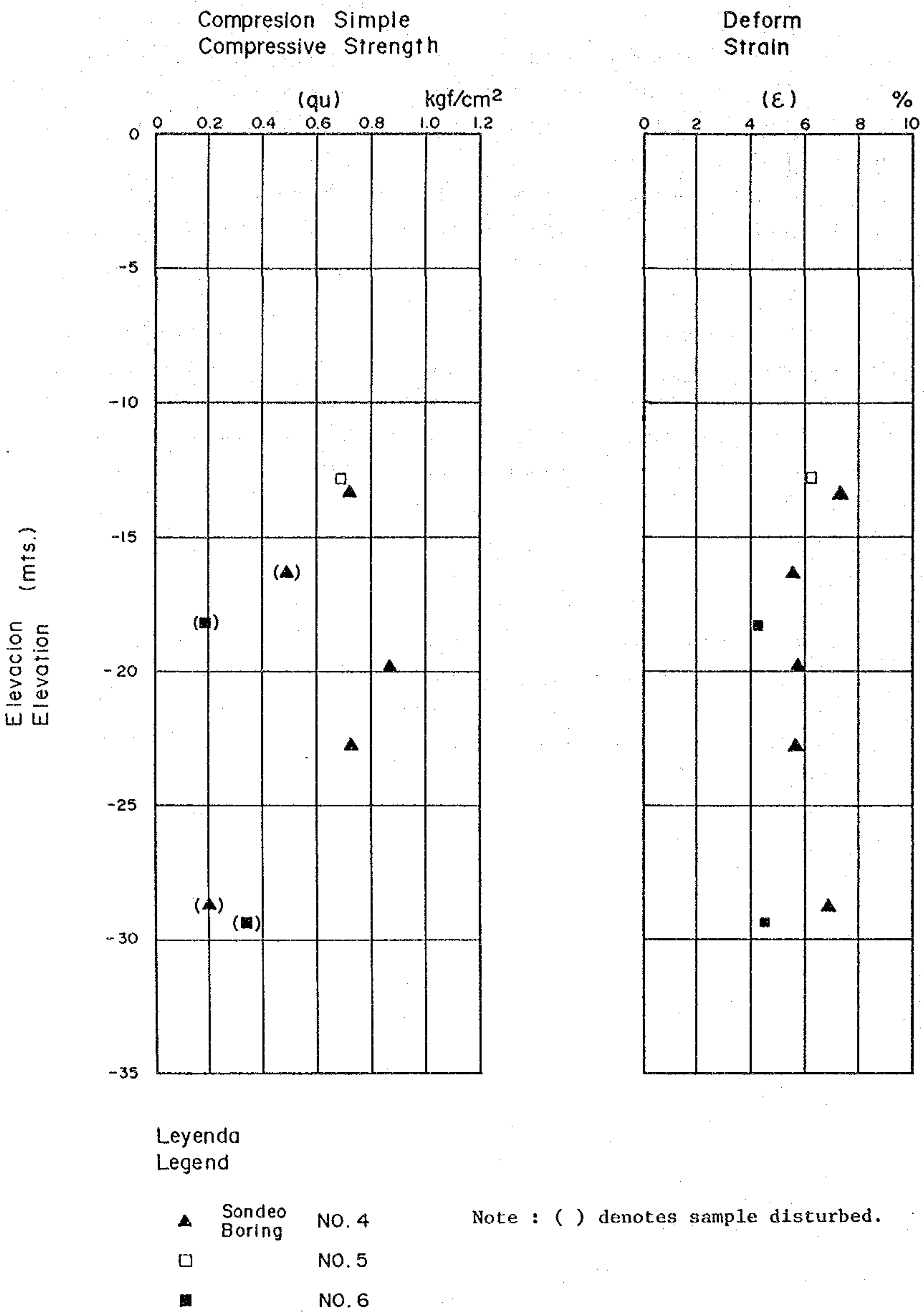


Fig. I.4.23 Unconfined Compressive Strength

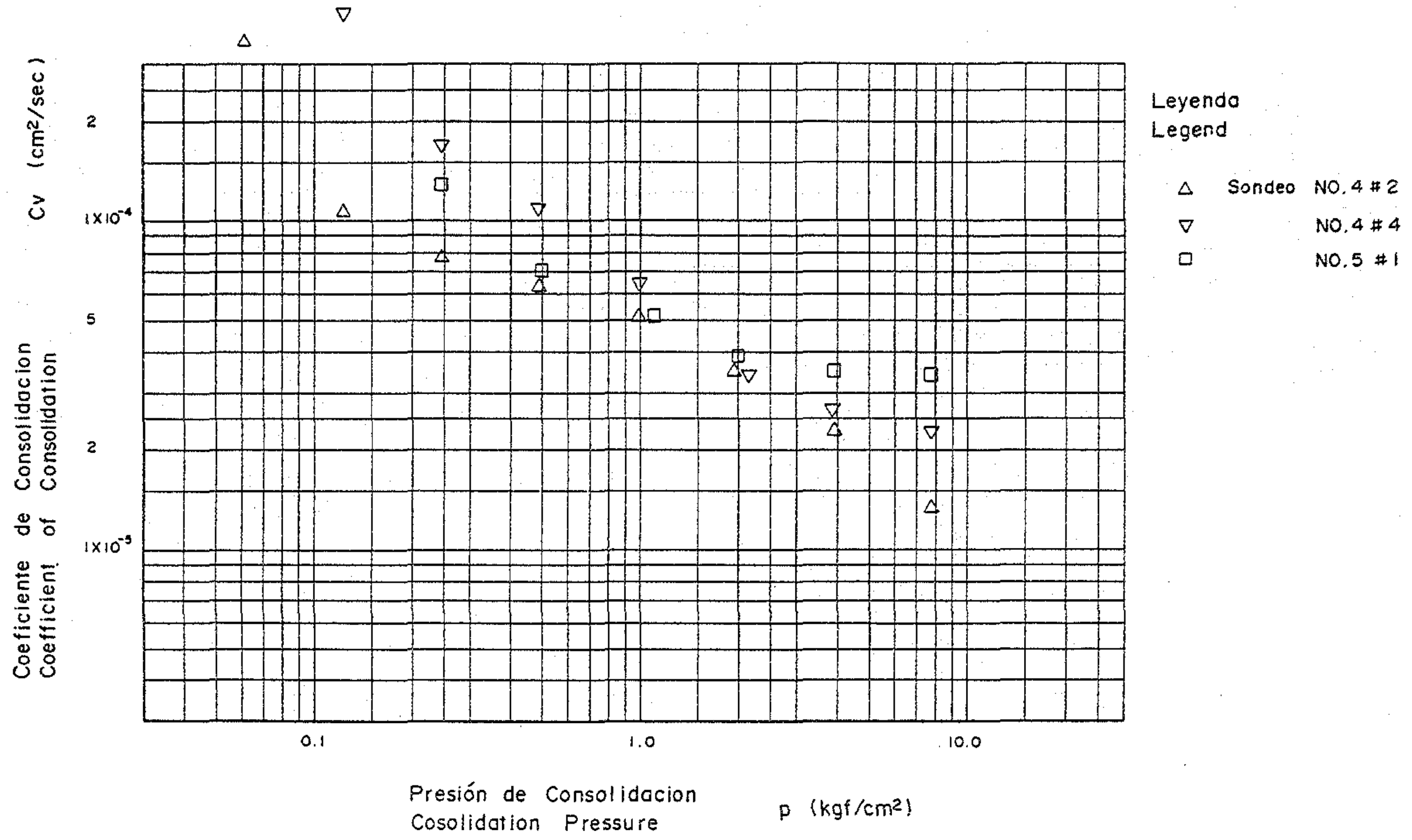


Fig. I.4.24 (1) Consolidation Test (1)

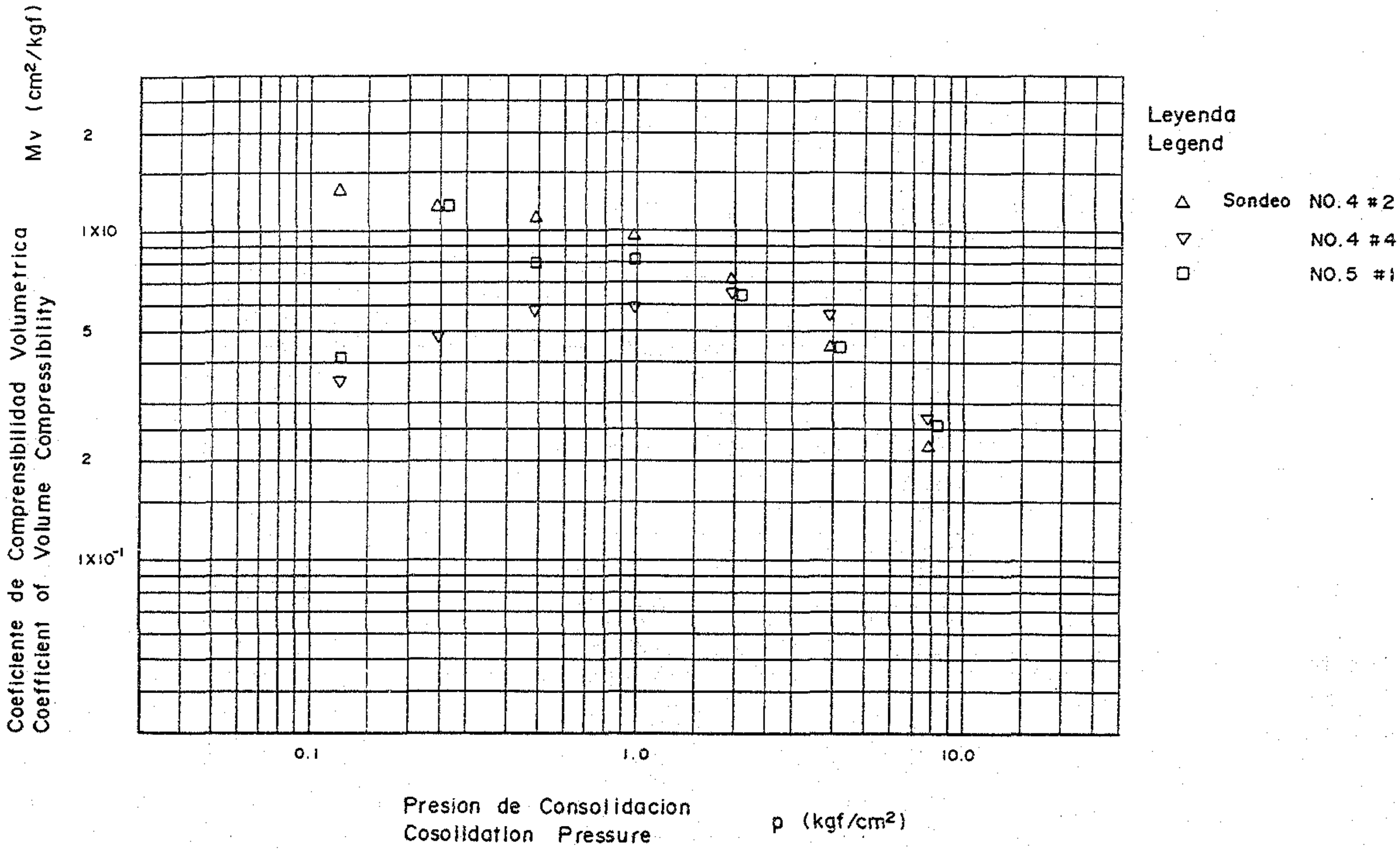


Fig. I.4.24 (2) Consolidation Test (2)

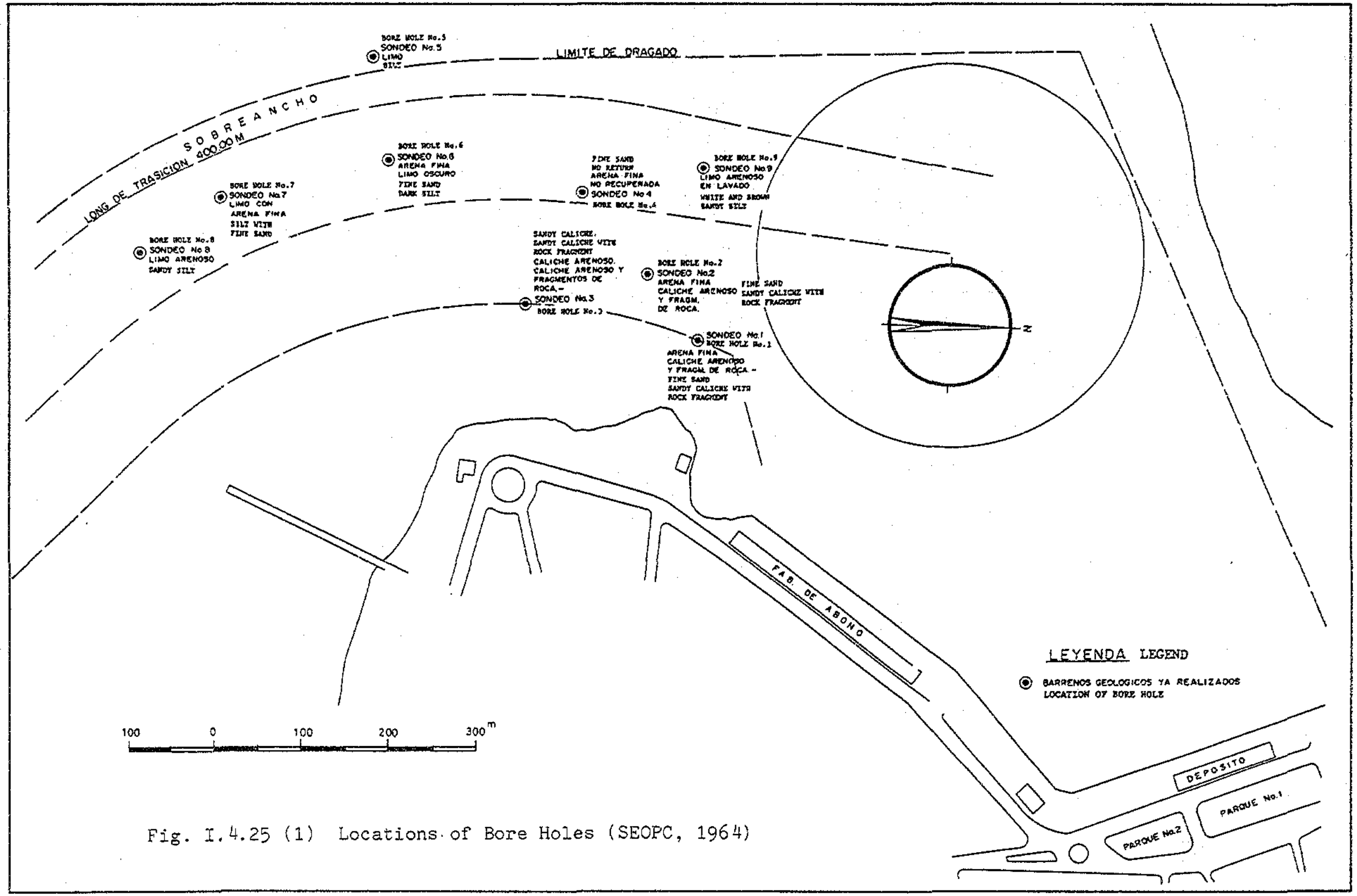


Fig. I.4.25 (1) Locations of Bore Holes (SEOPC, 1964)

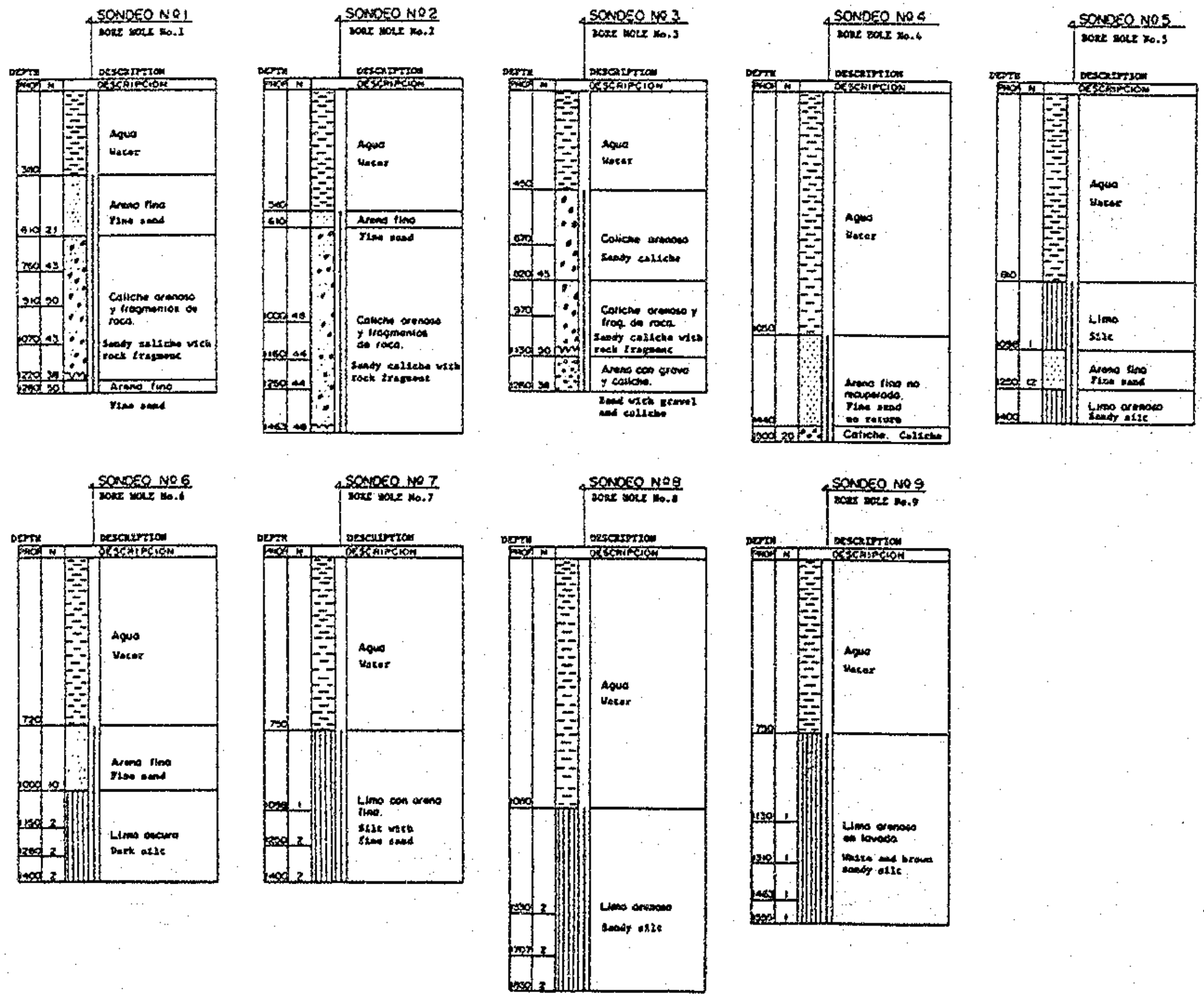


Fig. I.4.25 (2) Soil Profiles (SEOPC, 1964)

3. Port Layout and Facilities

The port layout is shown in Fig. I.4.26 and the port facilities are detailed in Table I.4.14.

3.1 Approach Channel and Turning Basin

The apporach channel to the port is aligned straight at N 130 E and connected to the turning basin via a sharp and narrow bend off the projected tip of the east river bank. The straight reach of the approach channel is about 1 km long and about 80 m wide at its narrowest curved section. The water depth along the channel is 10 m at the entrance and about 8 m in its inner reach.

At the bend a hard rocky layer known as "Caliche" exists and dredging work was once attempted to straighten and widen the channel but was abandoned due to the difficulty of dredging hard Caliche.

The area of the turning basin is about 400,000 m^2, and the water depth is about 9 m in its southern half and about 8.5 m in its northern half.

The water depth along the immediate frontage of the wharfs is 4.5 m for Wharf No.1, 4.2 m for the Wharf No.2 and 4.0 m for Wharf No.3.

The channel and the turning basin are marked with seven navigation buoys and the structures of these buoys are shown in Fig. I.4.27. The approach channel is marked with a piller type entrance buoy and two spar buoys, and the turning basin is marked with two conical buoys and two spar buoys. The buoys are colored green for port and red for starboard and are maintained by the Departamento de Bolizamiento y Ayuda a La navegacion of the Dominican Navy. The light house is located in Punta Pesca, about 3 km east of the port.

3.2 Breakwater

The breakwater is located on the east bank of the mouth of the Higuamo River at N 193 E. It is about 200 m long and the water depth at the seaward end is about 5.5 m. Its structure is a rubble mound armoured with concrete blocks and an in-situ concrete slab on top as shown in Fig. I.4.28. A parapet with a height of about 1.5 m is erected along the east edge of the concrete slab. The breakwater shelters the water area in the

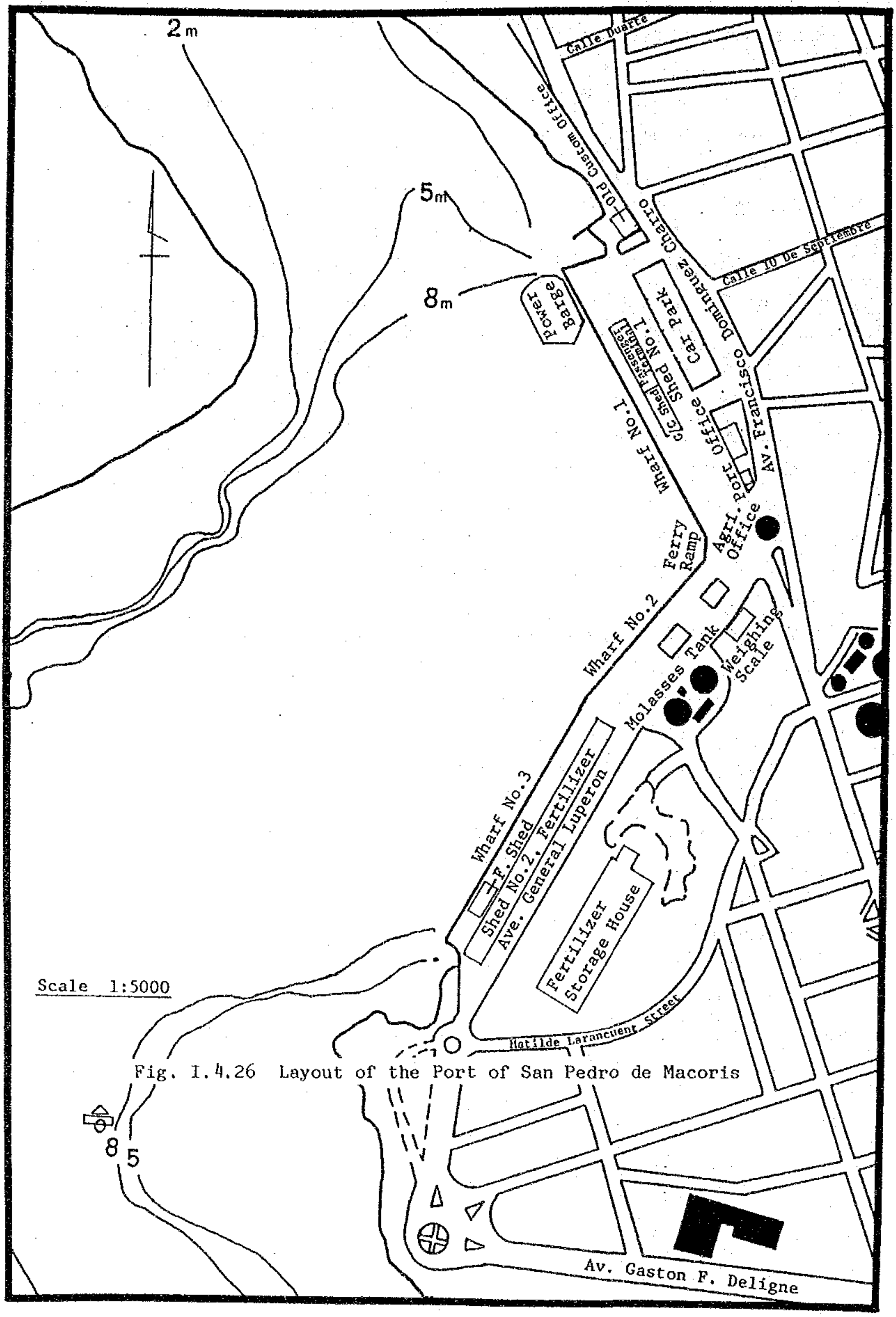


Fig. I.4.26 Layout of the Port of San Pedro de Macoris

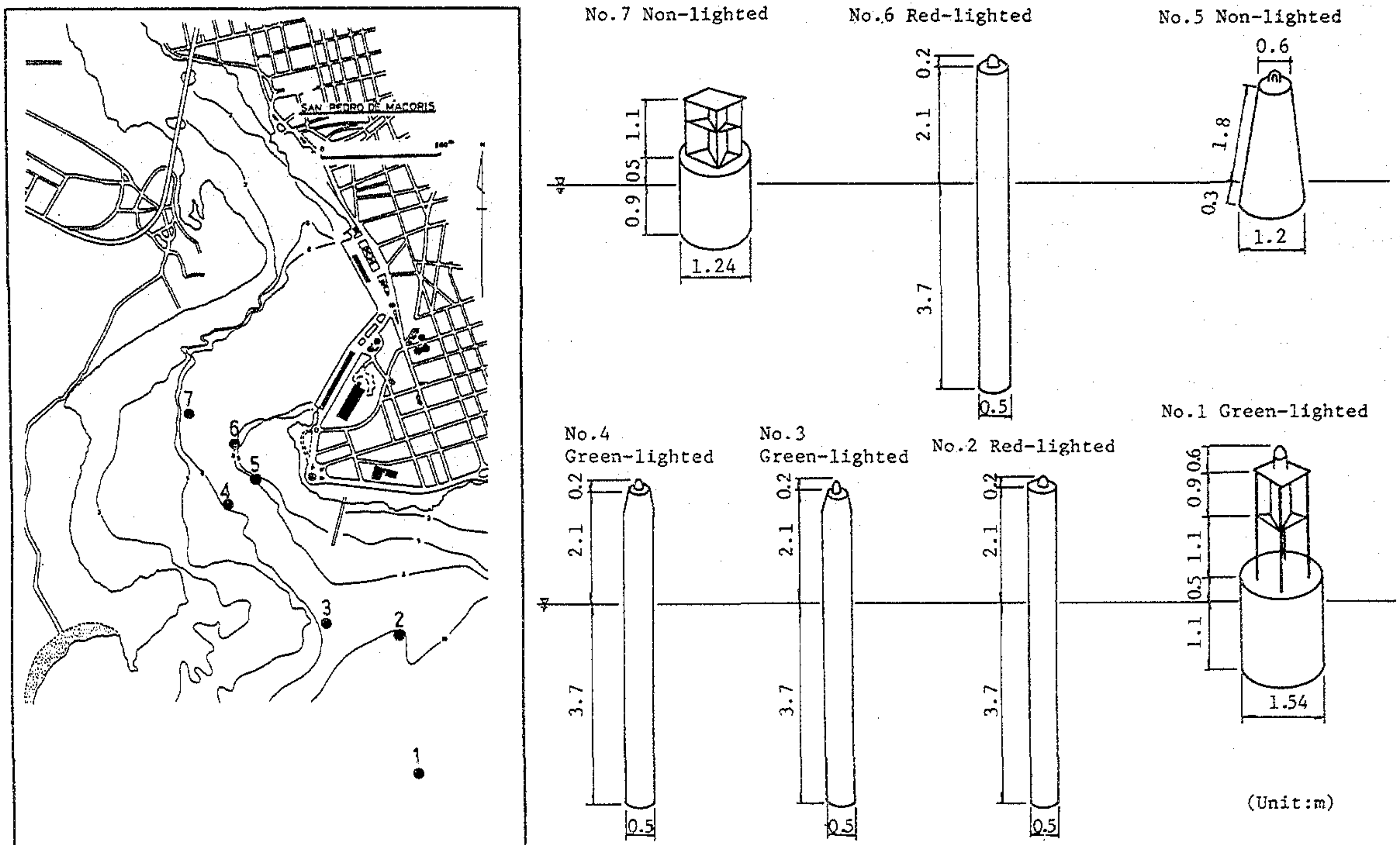


Fig. I.4.27 Location and Structures of Existing Navigation Buoys

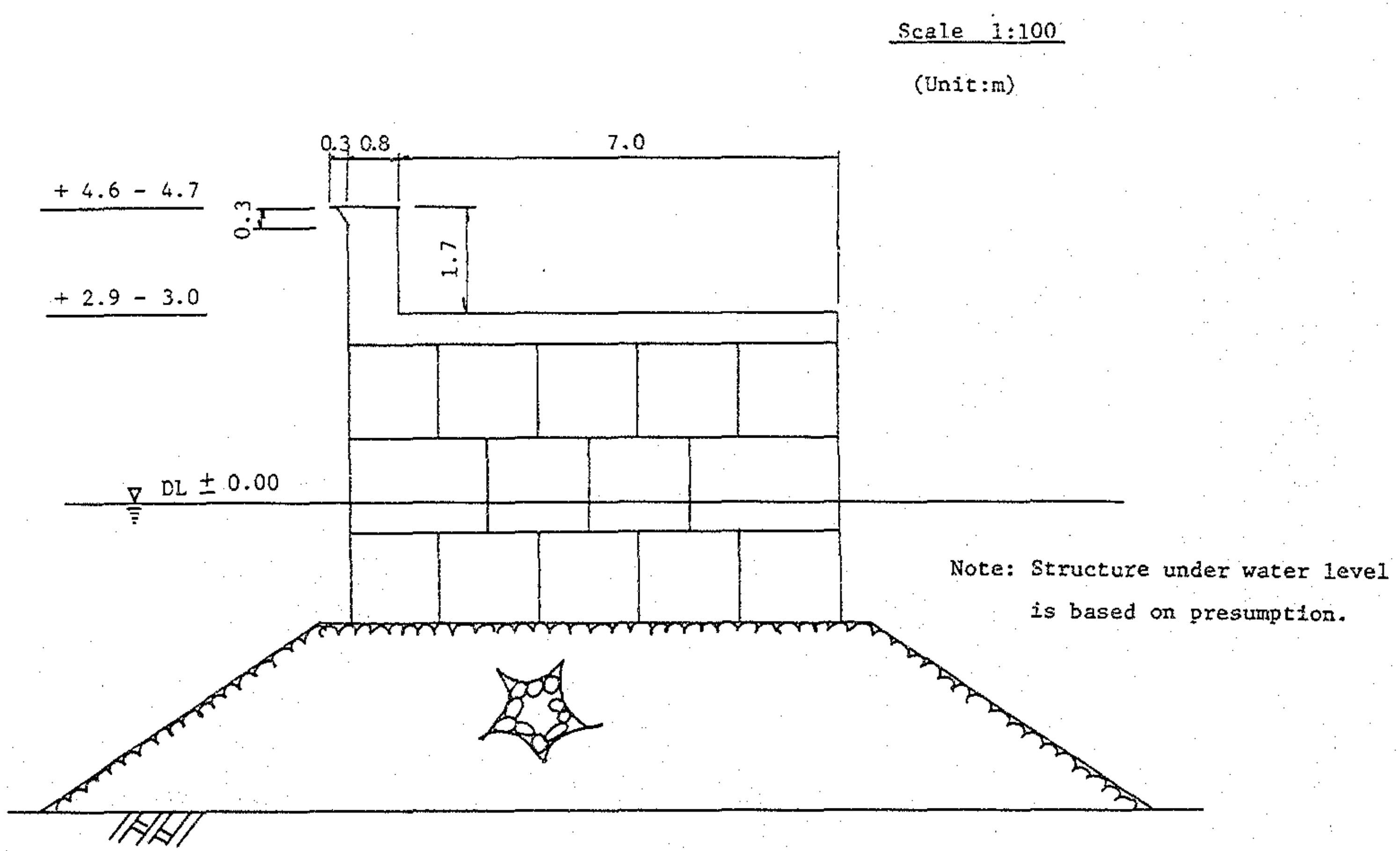


Fig. I.4.28 Cross Section of Breakwater

port from SE waves and also prevents littoral sand from penetrating into the approach channel and turning basin.

Table I.4.14 Facilities of the Port of San Pedro de Macoris

No.	Assets	Dimensions	Remarks
Governmental Assets			
1	Wharf No.1	325 m	
2	Apron	4,004 m^2	
3	Wharf No.2	195 m	include ferry ramp
4	Apron	3,410 m^2	
5	Wharf No.3	288 m	
6	Apron	5,184 m^2	
7	Shed No.1	999 m^2	on Wharf No.1
8	Passenger Terminal	1,240 m^2	adjoining to the above
9	Shed No.2	6,831 m^2	on Wharf No.3
10	Small Fert. Shed	375 m^2	on Wharf No.3
11	Open Storage Area	10,372 m^2	
12	In-port Road	17,190 m^2	Av. General Luperon
13	Parking Area	6,264 m^2	behind Shed No.1 under planning
14	Power Barge Area	3,498 m^2	
15	Old Custom Area	2,570 m^2	abandoned on Wharf No.1
16	Port Office Area	2,151 m^2	
17	Agri. Office Area	875 m^2	on Wharf No.2
18	Breakwater	205 m^2	51 m damaged
19	Approach Channel	60,000 m^2	approx.
20	Channel Buoy	7 Nos	
21	Turning Basin	400,000 m^2	approx.
22	Pilot Boat	1 No	wooden with outboard engine
23	Office Car	1 No	
Private Assets			
24	Storage Tank Area	3,651 m^2	behind Wharf No.2
25	Storage Shed	5,585 m^2	air domed for fertilizer
26	Weighing Scale Area	990 m^2	
27	Open Area	53,510 m^2	
28	Mobile Crane	1 No	
29	Conveyor Belt	3 Nos	for fertilizer

The breakwater was badly damaged by the hurricane "David" in 1979. Its head section of about 28 m and trunk section of about 23 m were badly damaged with concrete armour blocks dislodged, and the concrete slab sank underwater as shown in Fig. I.4.29. This damage has brought about a change in sand movement and the beach which formerly existed east of the breakwater has been eroded with sand moving into the port area through the damaged section of the breakwater. A considerable number of armour blocks formerly set on the rubble mound are observed to have widely scattered especially in the area near the seaward end of the breakwater.

3.3 Wharfs

The exisiting wharfs have a total length of 763 m. From north to south, there are 3 wharfs: No.1, No.2 and No.3.

Wharf No.1 is 325 m long and 4.5 m deep. Its southern half is mainly used for loading bagged sugar and molasses while the northern half is used for mooring the power generating barge and navy ship. The southern end of the wharf is used as a mooring area for the pilot boat and the tug boat. Wharf No.2 is 195 m long and 4.2 m deep with an open pile type ferry ramp at the northern end. It is almost exclusively used by the private ferry company which provides service between San Pedro de Macoris and Mayagüez, Puerto Rico. Wharf No.3 is 288 m long and 4.0 m deep. It is used for handling fertilizer, sugar, coal, etc. The local fertilizer company "FERQUIDO" uses the storage and processing facilities located along almost the entire length of the apron and handles raw and processed materials via this wharf. As shown in Fig. I.4.26 a small storage shed is located close to the wharf front near the southern end of the wharf and prevents efficient use of that part of the wharf.

The existing wharfs were constructed about 40 years ago, and neither structural drawings nor design information are available for any part of the wharfs. A survey on their structures was conducted to obtain the most important technical information for formulating the rehabilitation plan.

Based on the survey results, the cross section of each wharf is drawn as shown in Fig. I.4.30, and as shown all the wharfs are of the same structural type, open type concrete pile with concrete deck, which is widely adopted in most of the ports in the Country. The dimensions are different for each wharf, e.g. the width of the deck is 6 m at Wharf No.1,

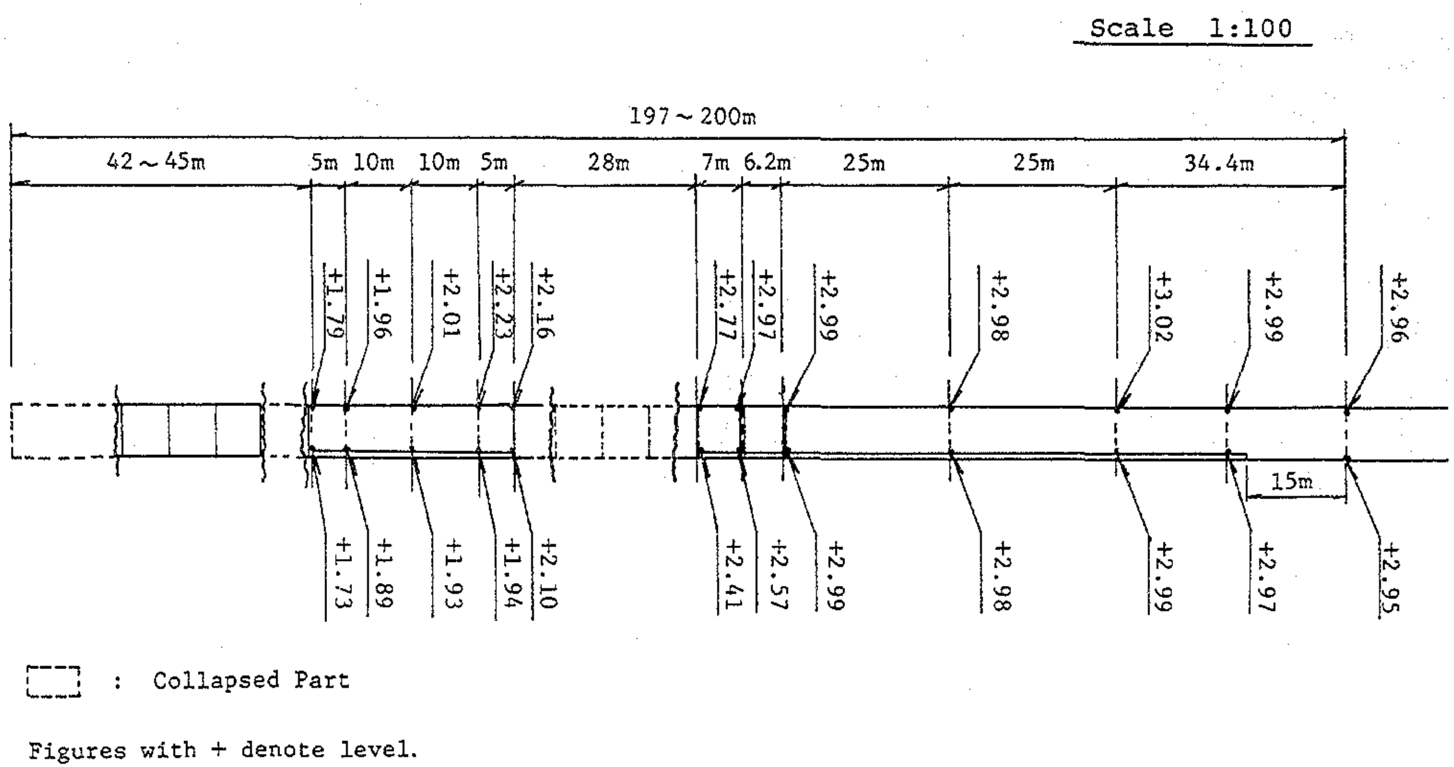


Fig. I.4.29 Damage to Breakwater

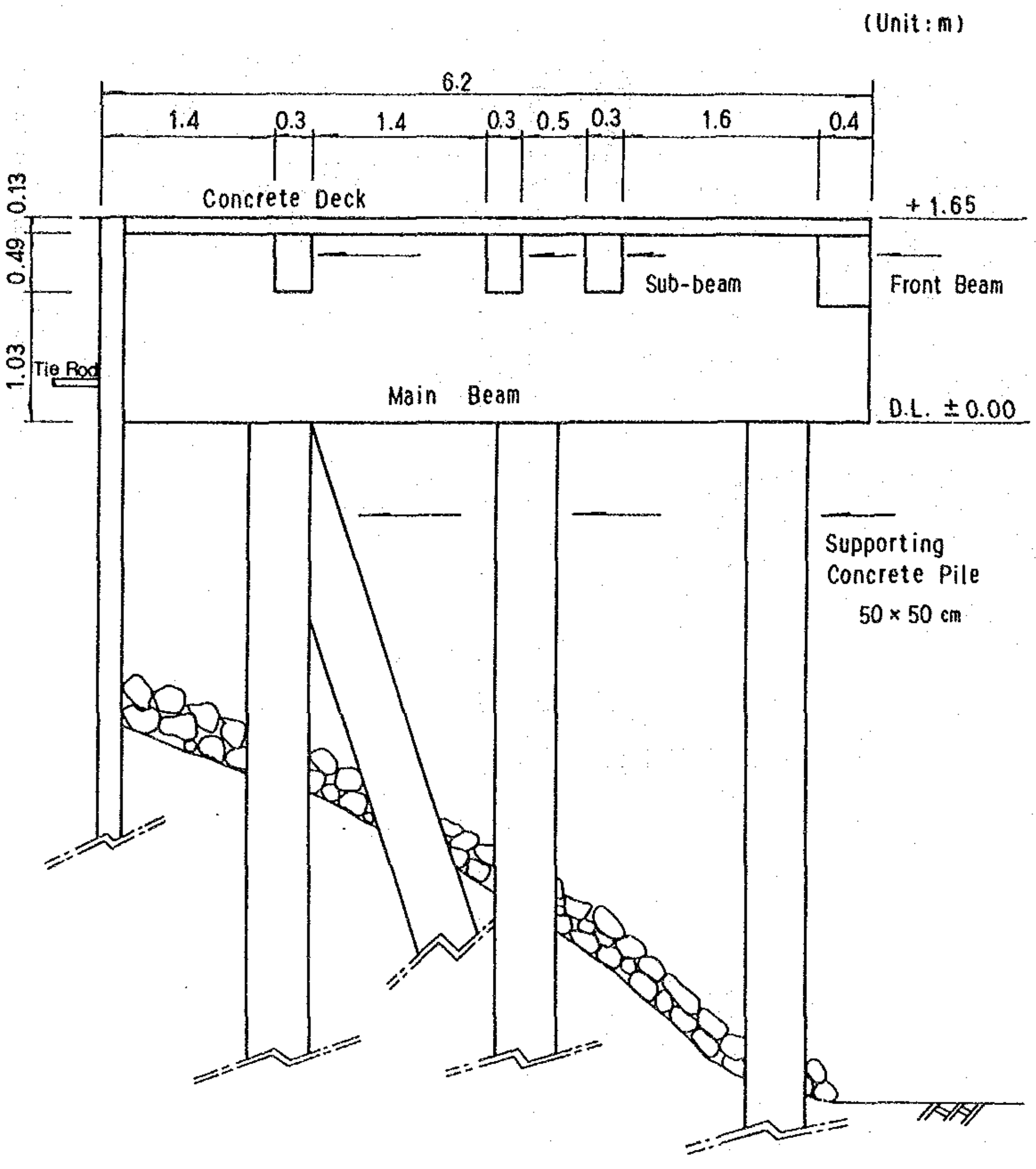


Fig. I.4.30 (1) Structure of Existing Wharf No.1

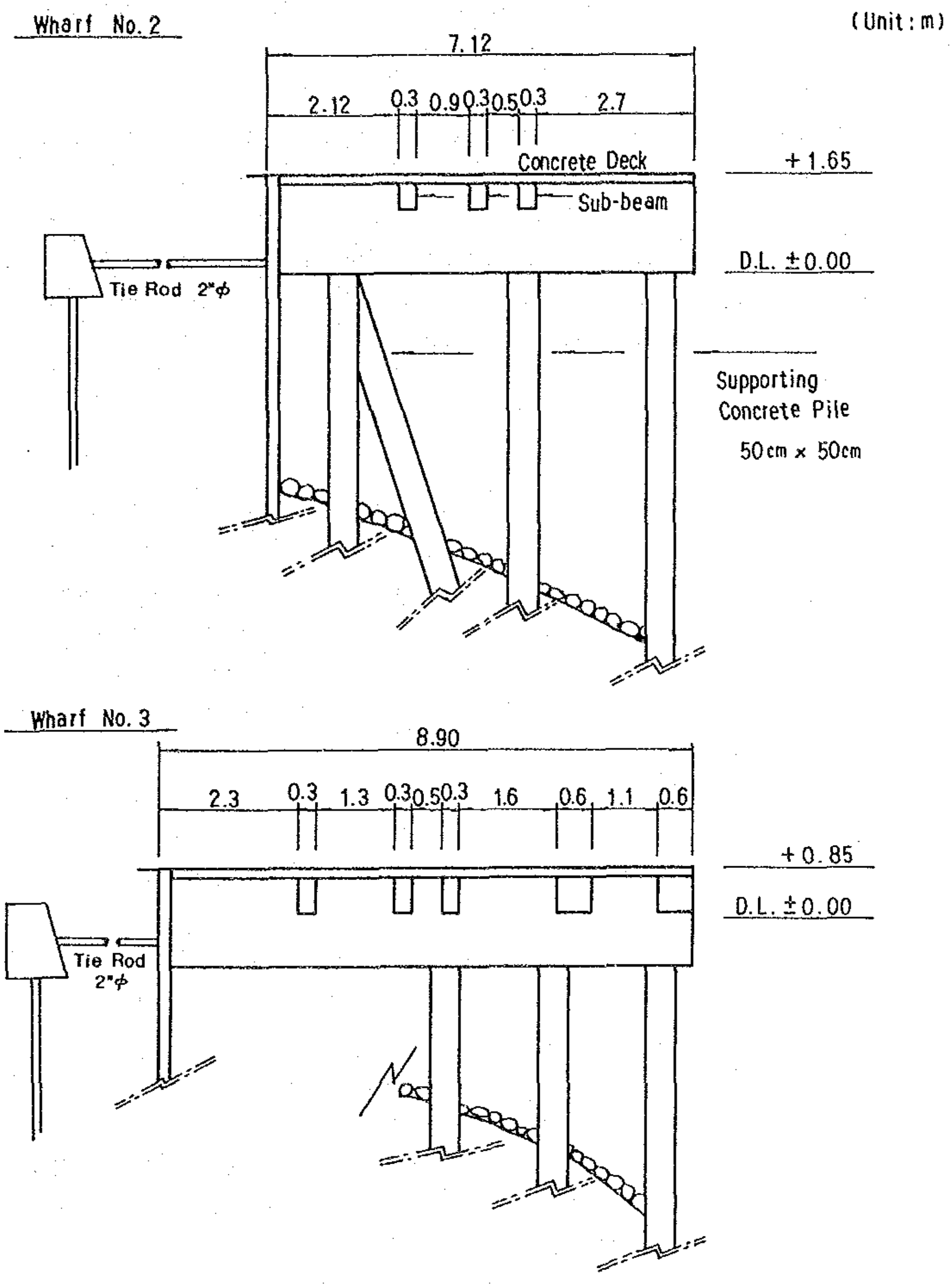


Fig. I.4.30 (2) Structure of Existing Wharfs No.2 and No.3

7 m at Wharf No.2 and 9 m at Wharf No.3. The dimensions of the main beams are almost the same for all the wharfs with cross-sections of about 120 cm x 160 cm while the sub-beams are rather small with cross-sections of about 30 cm x 50 cm. The concrete decks are about 13 cm thick: considerably small when compared with the thickness usually used in current port design for similar load conditions.

The concrete deck is seriously damaged as detailed in the following section. The damage is concentrated on the decks and sub-beams.

Steel sheet cellular piles with superstructures of concrete filled steel pipes are installed in front of the wharfs for the purpose of keeping ships away from the shallow areas immediately in front of the wharfs and absorbing ships' berthing energy, functioning as fenders.

3.4 Cargo Storage Facilities

Two covered cargo storage facilities are provided in the port area, one at Wharf No.1 and the other at Wharf No.3. The southern half of Shed No.1 is used for storing general cargos and Shed No.2 is used for storing and processing raw materials by the private fertilizer company FERQUIDO.

The two sheds are of the same structure with concrete block walls and sheeted roofs. The total floor area of Shed No.1 is about 2,240 m^2 of which about 1,000 m^2 is used as a cargo storage area and the remainder of about 1,240 m^2 is remodeled as a terminal for ferry passengers. Shed No.2 has recently been extended by about 35 m and its floor area is measured at about 6,800 m^2. The central part of this shed is used for processing raw materials and both sides are used for storage.

In addition to these facilities, a small storage shed with an area of about 380 m^2 is provided near the southern end of Wharf No.3, and behind Shed No.2, across Ave. General Luperon, there is an air domed storage house with an area of about 6,570 m^2. An overhead conveyor belt is provided between this shed and the one on the wharf.

Besides the above storage facilities, tanks for storing molasses are installed in the area behind the port and they are connected to outlet valves on Wharfs No.1 and No.2 through an underground pipeline.

As shown in Fig. I.4.26, since Ave. General Luperon runs closely behind the wharfs, the total land area of the port is very limited at about 47,500 m^2 broken down as follows:

wharf apron	12,700 m^2
storage shed	7,830 m^2
passenger terminal	1,240 m^2
parking area	6,264 m^2
open area	10,400 m^2
power barge area	3,500 m^2
old customs area	2,600 m^2
office & other area	3,000 m^2
Total	47,500 m^2

Of the above, the parking area is for ferry traffic planned behind Shed No.1. The open area on Wharf No.1 is mainly used for handling ferry cargos, while the areas on Wharfs No.2 and No.3 are used for handling coal and sugar. The northernmost area at the Wharf No.1 is used as a back-up land area for the power generating barge. The area behind it used to be a customs area and the office located there is no longer used.

3.5 Cargo Handling Equipment

All the cargo handling equipment used in the port is owned and operated by the private sector. The major cargo handling equipment presently in use is listed below.

Cargo Handling Equipment	Cargo Handled
- mobile cranes	sugar, fertilizer
- shovel loaders	coal
- tractors, chassis	container
- conveyor belts, hoppers, buckets	fertilizer
- trucks	all cargos

3.6 Offices and Buildings

The navy office responsible for port administration is located at the entrance gate behind Wharf No.1 and houses an administration section, a port-ship telecommunications system, etc.

The agricultural office is located on Wharf No.2 near the ferry ramp and the car check gate is located next to this office.

The floor area of the navy office is about 380 m^2 and about 30 officials work there. The customs office is located outside of the port area near the city center.

3.7 Harbor Craft

The harbor craft presently available for port service are one pilot boat and one tug boat. The former is operated by the navy office while the latter is run by a private company.

Their capacities are shown below:

Pilot Boat	2 m x 6 m	wooden with outboard engine
Tug Boat	175 x 2 = 350 HP	LOA 14 m

3.8 Access Roads

As shown in Fig. I.4.26, the port is located on the populated western boundary of San Pedro de Macoris City and can be accessed through the major city roads, Ave. Francisco Dominguez Charro from the north, Ave. Gaston F. Deligne from the south and Calle 10 de Septiembre, etc. from the east.

As the port is located close to the city's commercial center, there are no access road exclusively used by port traffic. This gives rise to mixed city/port traffic on the roads near the port. A considerable amount of the port cargos are destined and originated to and from the area east of the port, and hence the port traffic concentrates on Ave. Francisco Dominguez Charro. The northern continuation of this road up to the bridge Puente Higuamo is rather narrow with only two lanes, and the road is sometimes congested. This is especially true when the road is used by large size trucks carrying bulky port cargos such as coal, sugar, etc.

In planning future city roads, due consideration should be given to widening the above section of the road to accommodate the increasing city and port traffic.

The ferry service generates a considerable volume of cargo traffic, and since there is no sufficiently large parking area in the port area, the road immediately behind the port, Ave. General Luperon, is partly used as a parking area at present. A car park area for ferry traffic in the area behind Shed No.1 is being planned as mentioned previously.

3.9 Others

The other port facilities are outlined below.

Water supply	The pipeline for water supply is aligned along the front edge of the wharf.
Truck scale	The truck scale is installed adjacent to the molasses tank area behind Wharf No.2 in the covered shed walled and roofed with corrugated tin plate.
Security fence	The port area is fenced in around Wharf No.1 and Wharf No.2, but Wharf No.3 is not fenced in.
Bunkering service	Not available.

4. Present Situation of the Existing Port Facilities

4.1 Existing Port Facilities

The existing layout and facilities of the port of San Pedro de Macoris are discussed in the previous section, and in this section the condition of the existing wharfs is discussed.

The existing port was constructed in 1946, and all the wharfs have become badly deteriorated through their long service period of over 40 years. The adverse effects of the deteriorated wharfs on efficient and safe cargo handling operations have long been recognized, but no major rehabilitation work has taken place.

A detailed survey was carried out on the present deterioration of all three wharfs including investigations both above and below the water. The results of the survey give a basic direction on how to improve the Port and therefore should be duly considered in formulating the future port improvement and development plan.

The chief engineer who was in charge of the construction work of the existing port was interviewed, and the information obtained from him includes very useful technical data for the present study and is summarized below.

Before construction of the existing port facilities, there were two small wooden wharfs at the existing Wharfs No.1 and No.2, mainly for exporting sugar. The former coastline ran along Ave. Francisco Domingues Charro with the back of the existing Wharfs No.2 and No.3 meeting the coast line at the southern end of Wharf No.3. The land area immediately behind the existing Wharfs No.2 and No.3 was reclaimed by sand dredged from the existing approach channel and turning basin.

All the construction works including three wharfs, two sheds, dredging of the approach channel and the turning basin, etc. started in 1944 and were completed in 1948-1949, 2-3 years after the scheduled completion date of 1946.

The supporting concrete piles are 40-50 feet long for Wharf No.1, about 60 feet for No.2 and about 75 feet for No.3, and were driven from both land and sea by 1 ton class steam hammers.

Export sugar was carried to the Port by either steam locomotives or 10-20t trucks.

Concrete was poured for the main beams and sub-beams at the same time, and the concrete deck was rigidly connected to them by reinforcing steel bars.

The main beams were connected to the supporting piles in the same way.

During the construction period, a strong earthquake took place in 1946 and a considerable number of supporting piles subsided by as much as 2 feet.

Steel sheet cellular pile was installed in front of the wharfs as a fender and for the purpose of keeping ships away from the area immediately in front of the wharfs where the water depth is not sufficient to berth a large ship.

4.2 Method of Investigations

The preliminary visual inspection of the wharfs leads to the survey including the following items necessary to assess the present conditions of the wharfs.

- damage of wharf decks
- subsidence of wharf decks
- deviation of wharf facelines
- damage of sub-beams
- damage of main beams
- damage of supporting piles
- displacement/inclination and corrosion of steel pipe piles
- present strength of concrete/steel members

The methods of the surveys of each of these items are presented below.

(1) Damage of Wharf Decks

The survey included an overall visual inspection and measurement of the size of holes on the decks and a visual inspection of the concrete spalling and exposure of the reinforcing steel bars on the under deck surface over the entire reach of all the wharfs. Since the clearance between the decks and the sea surface is not large enough to allow even a small boat to get underneath, the survey was conducted by visual inspection and using photographs of all the spans of the wharfs taken by divers. Wharf No.3 has subsided considerably and the clearance between the deck and the rubble mound underneath is not large enough for divers to check the condition of the innermost part of the wharf.

(2) Subsidence of the Wharfs

This survey was aimed at clarifying the extent of the non-uniform subsidence of the wharfs. A remarkable difference of apron elevation caused by non-uniform subsidence was observed at Wharf No.2 near the ferry ramp. A levelling survey was carried out at intervals of 4 m along the wharf faceline and 2 m normal to it.

(3) Deviation of Wharf Facelines

The deviation of wharf facelines was measured at intervals of 4 m along the front surface of the wharfs.

(4) Damage of Sub-beams

The preliminary survey revealed that most of the sub-beams are badly damaged with wide and long cracks stretching over their entire spans. The survey was conducted in the same way as the survey of the under surface of the wharf decks mentioned above.

(5) Damage of Main Beams

The survey was also conducted in the same way as explained above, and in addition an underwater survey by divers was conducted for the lower part of the main beams which are underwater for most of the time.

(6) Supporting Piles

The main beams are supported by concrete piles which are completely underwater. The survey included preparation work of scraping off a thick layer of seashells covering the concrete surface and thereafter a visual check of the damage to the piles.

(7) Steel Sheet Cellular Piles

Nine steel sheet cellular piles are installed immediately in front of the wharfs and are damaged by the berthing impact of ships. The survey included measurement of the displacement/inclination of the piles as well as of the damage to the wharf's frontage caused by the berthing impact transferred through the pile movement. The present thickness of the steel piles was measured using an ultrasonic thickness gauge to evaluate the corrosion, especially in the splash zone.

(8) Present Strength of Concrete/Steel Members

The deterioration of concrete and steel strength is one of the major factors to evaluate the overall structural strength of wharfs. The strength of the concrete was tested by means of a compression test of core samples taken from each structural member of the wharfs and at the same time measurement of concrete strength using a Schmidt Hammer was conducted at the same sampling points and these two values were compared. For parts of the wharfs from which it was difficult to take core samples, the concrete strength was measured by using a Schmidt Hammer only and the values measured were adjusted based on the relationship between the two measuring methods. The present strength of reinforcing steel bars was measured by a laboratory tensile test on samples taken from the damaged parts of the wharfs where the steel bars are exposed and do not contribute to the structural strength of the wharf. This laboratory test was conducted in Japan.

4.3 Results of the Investigations

In this section, the results of the above surveys are presented. The deterioration of the existing wharfs is relatively simple in nature and is characterized by concentrated damage on the decks and sub-beams.

The underwater visibility was extremely poor which hampered the divers from carrying out an accurate investigation. The visibility at the site ranged from only 1 cm due to the muddy river water frequently encountered in the rainy seasons to about 1 m during the period of clearest water. Despite this unfavourable visibility, it is believed that the investigations were carried out satisfactorily providing almost all the data necessary for this particular study.

(1) Damage to Wharf Decks (see Fig. I.4.31 and Table I.4.15)

As mentioned previously, the damage to the wharfs is concentrated on the decks and the sub-beams. The deterioration of the decks is not so remarkable from its appearance on the upper surface, but the damages appear much more serious when seen from underneath the decks. The concrete surface layer of about 5 cm covering the reinforcing steel bars has widely spalled off and the bars are exposed and corroded over most of the under surfaces. In many cases except for repaired sections, the damages cover from one-third to the entire area of the under surface of individual decks as detailed in Table I.4.13.

It is reported that a truck fully loaded with cargo fell into the sea, breaking a deck. Other similar accidents have also been reported.

According to the visual survey on the under surface of the decks carried out this time, many of the deck spans have been repaired. In some cases, steel rails are used as reinforcing steel bars as well as an under shuttering plate by placing them closely between the main beams. In this case, the strength of the repaired decks may be sufficient even if the concrete work is not adequate.

In most cases, the repair work was done using steel reinforcing bars and a plywood shuttering plate, and the concrete work is inadequate in both quality and design. During the period of the field survey, repair work was being carried out on Wharf No.3 and at the same time the other parts of the concrete deck were damaged on Wharf No.2 necessitating continual repair

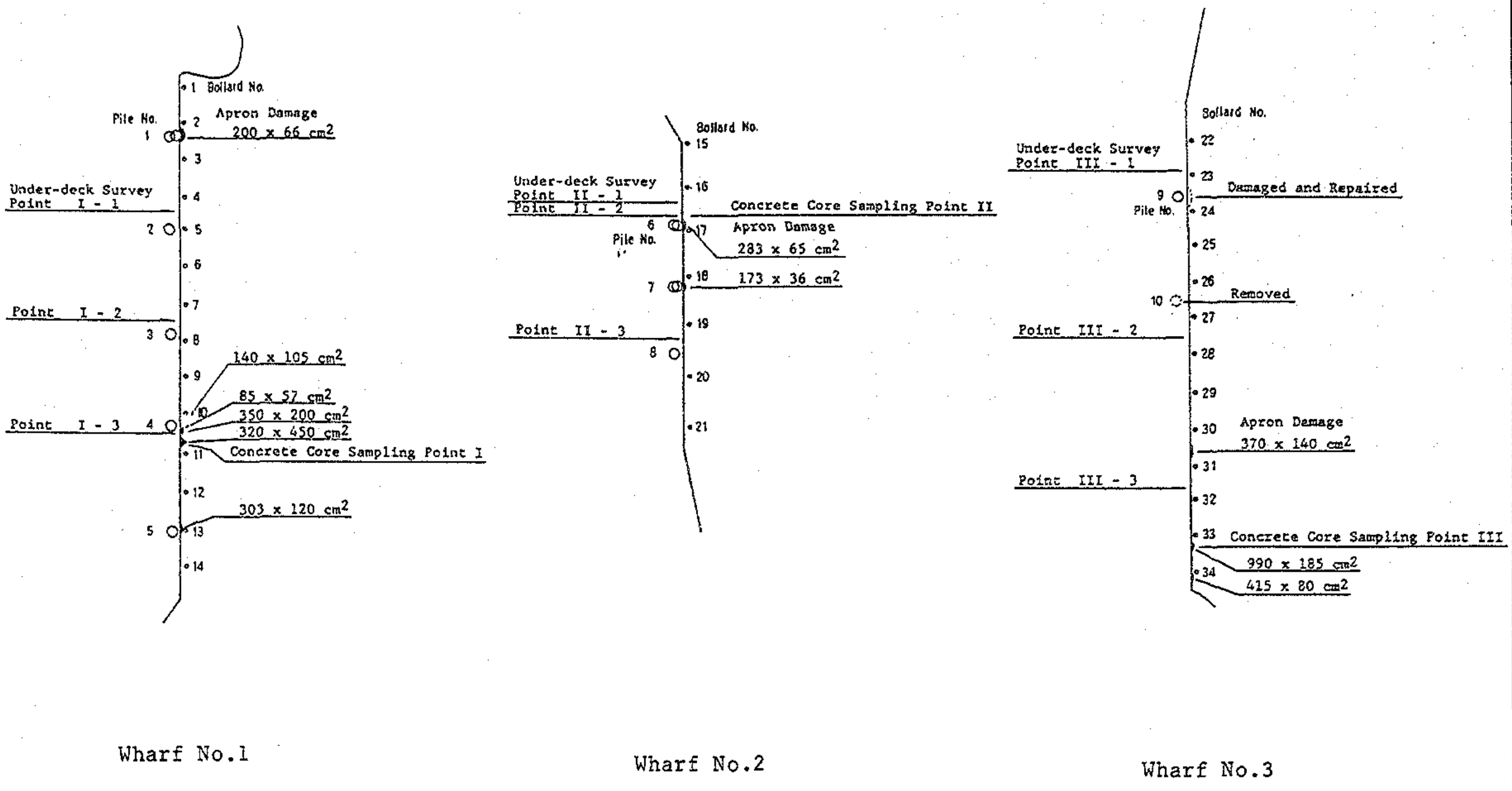


Fig. I.4.31 Deterioration Survey

Table I.4.15 (1) Deterioration of Concrete Deck and Beam, Wharf No.1

Span No.	Deck	Sub-beam	Main Beam
1.	Rep.x2,Re Bar Exp.x1 1/2	Rep.x1,Re Bar Exp.x1 3m	
2.	Rep.x1,	Re Bar Exp.x2 3m	
3.	Rep.x1,	Re Bar Exp.x1 3m	
4.	Re Bar Exp.x3 1/1		
5.	Not Observed		
6.	Re Bar Exp.x3 1/2	Re Bar Exp.x2 3m	
7.	Rep.x1,Re Bar Exp.x1 1/1		
8.	Rep.x1,	Re Bar Exp.x2 1m	
9.	Rep.x2,	Re Bar Exp.x1 2m	
10.	Rep.x1,	Re Bar Exp.x3 2m	
11.	Rep.x1,	Re Bar Exp.x1 3m	
12.	Rep.x1,Re Bar Exp.x3 1/1	Rep.x1	
13.	Rep.x1,Re Bar Exp.x1 1/3	Re Bar Exp.x2 4m	
14.	Rep.x1,Re Bar Exp.x1 1/3	Rep.x2,	
15.	Re Bar Exp.x1 1/4	Rep.x2,	
16.	Re Bar Exp.x3 1/4	Crack 4m	
17.	Re Bar Exp.x1 1/5	Crack	
18.	Re Bar Exp.x3 1/3	Re Bar Exp.x2 2m	
19.	Re Bar Exp.x2 1/5		
20.	Re Bar Exp.x2 1/5	Rep.x1,Re Bar Exp.x1 3m	
21.	Re Bar Exp.x2 1/3	Re Bar Exp.x2 2m	
22.	Rep.x1,	Re Bar Exp.x2 3m	
23.	Rep.x2,Re Bar Exp.x1 1/2	Re Bar Exp.x2 4m	
24.	Rep.x1,	Re Bar Exp.x2 3m	
25.		F. Beam spalling	
26.	Rep.x2,	Crack	
27.	Rep.x1,	F. Beam spalling	
28.	Not Observed		
29.	Not Observed		
30.	Not Observed		
31.	Rep.x1,	Re Bar Exp.x2 3m	
32.	Rep.x3,	Rep.x1,Re Bar Exp.x1 4m	

Table I.4.15 (1) Deterioration of Concrete Deck and Beam, Wharf No.1 (Cont'd)

Span No.	Deck	Sub-beam	Main Beam
33.	Rep.x1,Re Bar Exp.x1 1/2	Re Bar Exp.x1 3m	
34.	Rep.x1,Hole	Re Bar Exp.x1 3m	
35.	Rep.x1,	Rep.x1,Re Bar Exp.x1 3m	
36.	Rep.x1,	Re Bar Exp.x3 3m	
37.	Rep.x1,Re Bar Exp.x2 1/1	Re Bar Exp.x1 1m	
38.	Rep.x2,	Re Bar Exp.x2 2m	
39.	Rep.x1,	Rep.x2,Re Bar Exp.x1 2m	
40.		Re Bar Exp.x3 3m	
41.	Re Bar Exp.x1 1/4	Rep.x1	
42.	Re Bar Exp.x1 1/3	Rep.x1, Re Bar Exp.x2 2m	
43.		Re Bar Exp.x1	
44.	Rep.x1,	Re Bar Exp.x3 3m	
45.		Re Bar Exp.x2 4m	
46.		Rep.x1,Re Bar Exp.x3 4m	
47.		Re Bar Exp.x3 4m	
48.	Re Bar Exp.x2 1/3	Re Bar Exp.x2 4m	
49.		Re Bar Exp.x3 4m	
50.		Re Bar Exp.x1 3m	
51.		Rep.x1,Re Bar Exp.x2 4m	
52.	Re Bar Exp.x1 1/5		
53.		Rep.x3,Re Bar Exp.x1 3m	
54.	Re Bar Exp.x1 1/2	Re Bar Exp.x2 3m	
55.		Rep.x1,Re Bar Exp.x2 3m	

Note: Rep. x 2 denotes 2 deck sections have been repaired.
Re Bar Exp. x 1 1/2 (2m) denotes the reinforcing bars are exposed on 50% (2m) of deck (beam) of one deck section (beam).
F. beam denotes a front beam
The span is numbered from the end of the power barge moorage.

Table I.4.15 (2) Deterioration of Concrete Deck and Beam, Wharf No.2

Span No.	Deck	Sub-beam	Main Beam
1.		Rep.x3,Re Bar Exp.x1 3m	
2.		Re Bar Exp.x1 3m	Crack
3.	Re Bar Exp.x1 1/1	Rep.x2, Re Bar Exp.x1 2m	Re Bar Exp. 4m
4.	Rep.x2,	Rep,x2, Re Bar Exp.x1 4m	Spalling
5.	Re Bar Exp.x1 1/1	Rep.x3,	Crack
6.	Rep.x1,		Re Bar Exp. 5m
7.	Rep.x1,	Re Bar Exp.x3 2m	Re Bar Exp. 1m
8.	Rep.x1,	Re Bar Exp.x3 4m	Re Bar Exp. 3m
9.	Rep.x1,	Re Bar Exp.x3 4m	Crack
10.	Rep.x1,	Rep.x1, Re Bar Exp.x3 4m	Re Bar Exp. 4m
11.	Re Bar Exp.x1 1/1	Rep.x1, Re Bar Exp.x1 4m	Re Bar Exp. 3m
12.	Rep.x1,	Re Bar Exp.x2 4m	Re Bar Exp. 2m
13.	Rep.x1,	Re Bar Exp.x3 4m	
14.	Rep.x1,	Rep.x1, Re Bar Exp.x2 4m	
15.	Not Observed		
16.	Rep.x1,	Re Bar Exp.x3 4m	
17.	Rep.x1,	Re Bar Exp.x2 3m	
18.	Rep.x1,	Rep.x1,	
19.		Rep.x2, Re Bar Exp.x1 4m	
20.	Rep.x1	Rep.x1, Re Bar Exp.x1 4m	
21.	Rep.x1,	Rep.x1, Re Bar Exp.x2	
22.	Rep.x1,	Re Bar Exp.x1 4m	
23.	Rep.x1,	Re Bar Exp.x2 3m	Re Bar Exp. 1m
24.	Rep.x1,	Re Bar Exp.x1 4m	Re Bar Exp. 2m
25.	Rep.x1,	Rep.x3,	
26.	Rep.x1,	Rep.x1, Re Bar Exp.x2 4m	
27.		Re Bar Exp.x2 4m	
28.	Re Bar Exp.x1 1/1		
29.	Rep.x1,	Re Bar Exp.x3 3m	
30.		Re Bar Exp.x2 4m	
31.	Rep.x1,	Be Bar Exp.x2 4m	
32.	Rep.x1,	Re Bar Exp.x1 4m	

Table I.4.15 (2) Deterioration of Concrete Deck and Beam, Wharf No.2 (Cont'd)

Span No.	Deck	Sub-beam	Main Beam
33.		Re Bar Exp.x3 4m	
34.	Rep.x1	Re Bar Exp.x3 4m	
35.	Re Bar Exp.x1 1/4	Re Bar Exp.x1 2m	
36.	Re Bar Exp.x1 1/2	Re Bar Exp.x3 4m	Re Bar Exp. 3m
37.	Re Bar Exp.x1 1/4	Re Bar Exp.x3 3m	
38.		Rep.x1, Re Bar Exp.x3 3m	Re Bar Exp. 1m
39.		Re Bar Exp.x3 4m	
40.		Re Bar Exp.x3 4m	
41.		Re Bar Exp.x3 4m	Re Bar Exp. 3m
42.	Rep.x1,	Rep.x1, Re Bar Exp.x3 3m	Spalling
43.		Rep.x1,	
44.	Rep.x1,	Re Bar Exp.x3 4m	
45.	Rep.x1,Re Bar Exp.x1 1/1	Re Bar Exp.x2 4m	
46.	Rep.x1,	Re Bar Exp.x2 4m	

Note. Rep. x 2 denotes 2 deck sections have been repaired.
Re Bar Exp. x 1 1/2 (2m) denotes the reinforcing bars are exposed on 50% (2m) of deck (beam) of one deck section (beam).
F. beam denotes a front beam.

Table I.4.15 (3) Deterioration of Concrete Deck and Beam, Wharf No.3

Span No.	Deck	Sub-beam	Main Beam
1.		Re Bar Exp.x1	
2.		Re Bar Exp.x3	
3.	Not Observed		
4.	Crack		
5.	Rep.x1,	Re Bar Exp.x2 4m	
6.	Re Bar Exp.x1 1/5	Re Bar Exp.x1 2m	
7.	Rep.x1,	Re Bar Exp.x1 4m	
8.	Rep.x1,	Re Bar Exp.x3 3m	
9.	Re Bar Exp.x1 1/1	Re Bar Exp.x1 4m	
10.	Rep.x1,	Re Bar Exp.x3 4m	
11.		Re Bar Exp.x3 4m	
12.	Not Observed		
13.	Not Observed		
14.	Not Observed		
15.		Re Bar Exp.x1	
16.		Re Bar Exp.x3 4m	
17.	Rep.x1,	Re Bar Exp.x1 4m	
18.	Rep.x2,	Re Bar Exp.x1	
19.		Re Bar Exp.x3 4m	
20.	Rep.x1	Re Bar Exp.x2 2m	
21.		Re Bar Exp.x1	
22.		Crack	
23.	Rep.x1,	Re Bar Exp.x1 4m	
24.		Re Bar Exp.x1 4m	
25.	Rep.x1, Crack		
26.		Re Bar Exp.x1 3m	
27.	Rep.x1,	Re Bar Exp.x1	
28.	Not Observed		
29.	Rep.x1,	Re Bar Exp.x1 3m	
30.		Re Bar Exp.x1 4m	
31.	Rep.x1,	Re Bar Exp.x1 4m	
32.	Crack		

Table I.4.15 (3) Deterioration of Concrete Deck and Beam, Wharf No.3 (Cont'd)

Span No.	Deck	Sub-beam	Main Beam
33.		Re Bar Exp. x1	
34.	Crack		
35.		Re Bar Exp.x1 4m	
36.	Rep.x1	Re Bar Exp.x1 4m	
37.		Re Bar Exp.x1 3m	
38.		Re Bar Exp.x1 3m	
39.		Re Bar Exp.x1 3m	
40.	Rep.x1	Re Bar Exp.x1 3m	
41.	Not Observed		
42.	Not Observed		
43.	Not Observed		
44.	Not Observed		
45.	Re Bar Exp.x1 1/1		
46.		Re Bar Exp.x1	
47.		Re Bar Exp.x2 4m	
48.	Re Bar Exp.x1 1/1	Re Bar Exp.x1 4m	
49.		Re Bar Exp.x2 4m	
50.	Re Bar Exp.x2 1/1		
51.	Not Observed		
52.	Re Bar Exp.x1 1/2	Re Bar Exp.x1 4m	
53.		Re Bar Exp.x1 4m	
54.	Not Observed		
55.		Re Bar Exp.x2 4m	
56.		Re Bar Exp.x2 4m	

Note: Rep. x 2 denotes 2 deck sections have been repaired.
Re Bar Exp. x 1 1/2 (2m) denotes the reinforcing bars are exposed on 50% (2m) of deck (beam) of one deck section (beam).
F. beam denotes a front beam.
Several spans were not investigated between span No.50 and No.51 due to the moorage of a ship for a long period.

work.

The following are the major reasons for these serious damages:

i) surcharge larger than the original design load
ii) insufficient cross-section of the decks and sub-beams
iii) poor quality of maintenance work
iv) deterioration of concrete/steel members

Of the above, item i) is obviously the major factor. At the time the present wharfs were designed about 40 years ago, the design live load would have been on the order of about 10 tons, while at present in extreme cases the live load exceeds 30 tons according to the weighing records of trucks carrying sugar for export on Wharf No.3. This excessive load generates a bending moment much larger than the design strength of the deck and thereby causes a spalling of the concrete layer on the under surface covering the reinforcing steel bars. Then the reinforcing steel bars are exposed and corroded resulting in reduced resisting moment and further damage.

The exisitng wharfs must have been designed with an appropriate safety factor. However, the present increased loading conditions are considered to have brought them into the critical region of structural failure. A detailed analysis on structural strength is presented in the following section.

Frequent repair work to the decks has been carried out. However, the method and quality are not necessarily adequate, necessitating repetitive minor repairs to damaged sections. During the field survey repair works were carried out on several damaged sections and according to the observations the following shortcomings are noted:

i) In some cases repair work is limited to a small area holed on the deck only. This work is not adequate from the viewpoint that when even minor damage of a small area occurs it means that the total area of the deck span between two beams is so deteriorated that it may readily collapse at any time when loaded with heavy trucks and therefore requires overall major repair to the entire area of one span rather than to the limited small area where the damage is clearly visible. As mentioned previously, most of the main beams are in a good condition. It is thus recommended that a new concrete deck with sufficient thickness be placed by taking supporting ends on the main beams. The present 13 cm thickness of the concrete slab is not sufficient to carry the increased live load. An improved concrete deck should have the thickness of about 25 cm or more with which decks with similar loading conditions are usually designed.

ii) The quality of concrete used for the repair work is observed to be very poor with considerable mud in both the sand and the aggregate. To produce high quality concrete, pre-cleaning of the materials is recommended. One of the damaged areas on Wharf No.2 which was recently repaired is believed to have collapsed due solely to the poor quality of the concrete.

The major damages observed during the field survey are summarized as follows:

- Wharf No.1

The front beam and deck are damaged for an area of about 1.0 m x 0.7 m by collision of the steel sheet cellular piles near the northern end where the power generating barge is moored. Near the southern end, the wharf has collapsed for an area of 3.0 m x 3.0 m by collision of the steel sheet cellular pile, 3.2 m x 4.5 m by ship collision, 3.5 m x 2.0 m by a loaded truck and two other areas of 0.9 m x 0.6 m and 1.5 m x 1.0 m due to insufficient strength.

- Wharf No.2

At the northern end, the wharf has collapsed over two areas of about 2.8 m x 0.7 m and 1.7 m x 0.4 m by collision of the steel sheet piles and about 0.5 m x 0.5 m of a repaired area due to the poor quality of the concrete.

- Wharf No.3

Three areas of 3.7 m x 1.4 m, 9.9 m x 1.9 m and 4.2 m x 0.8 m have collapsed on the front side of the wharf probably by ship's collision. Many other damages must have occurred to the deck but they have already been repaired.

(2) Subsidence of the Wharfs (see I.4.32)

Since the original design drawings of the existing wharfs are not available, the absolute value of subsidence can not be derived for any part of the three wharfs. However a clear non-uniform subsidence is observed near the ferry ramp on Wharf No.2. The difference of the elevation there is measured at about 20 cm. According to the results of soil investigations carried out this time, this non-uniform subsidence is judged to have been caused by a remarkable difference of sub-soil profiles. A hard bearing layer is encountered at a depth of about 20 m below sea level at the bore hole on Wharf No.1 while this layer is about 60 m below sea level at Wharf No.3. The detailed results of the soil investigation are presented in Fig. I.4.20.

(3) Deviation of Wharf Faceline

The results of the survey are shown in Fig. I.4.32. No significant deviation of the wharf faceline is observed.

(4) Damage to Sub-beams

Most of the sub-beams are badly damaged with clear structural cracks of 1-3 cm in width and from 1 m to the entire span in length. For most of the damaged beams, the concrete cover layer has spalled off the under beam surface and the reinforcing steel bars are exposed and badly corroded.

Three sub-beams support the concrete deck and of them two beams are aligned under the rails of 90 cm gauge which used to carry trains for sugar export. It is judged that the cross section of about 30 cm x 50 cm is not large enough to carry the surcharge loaded on the decks at present.

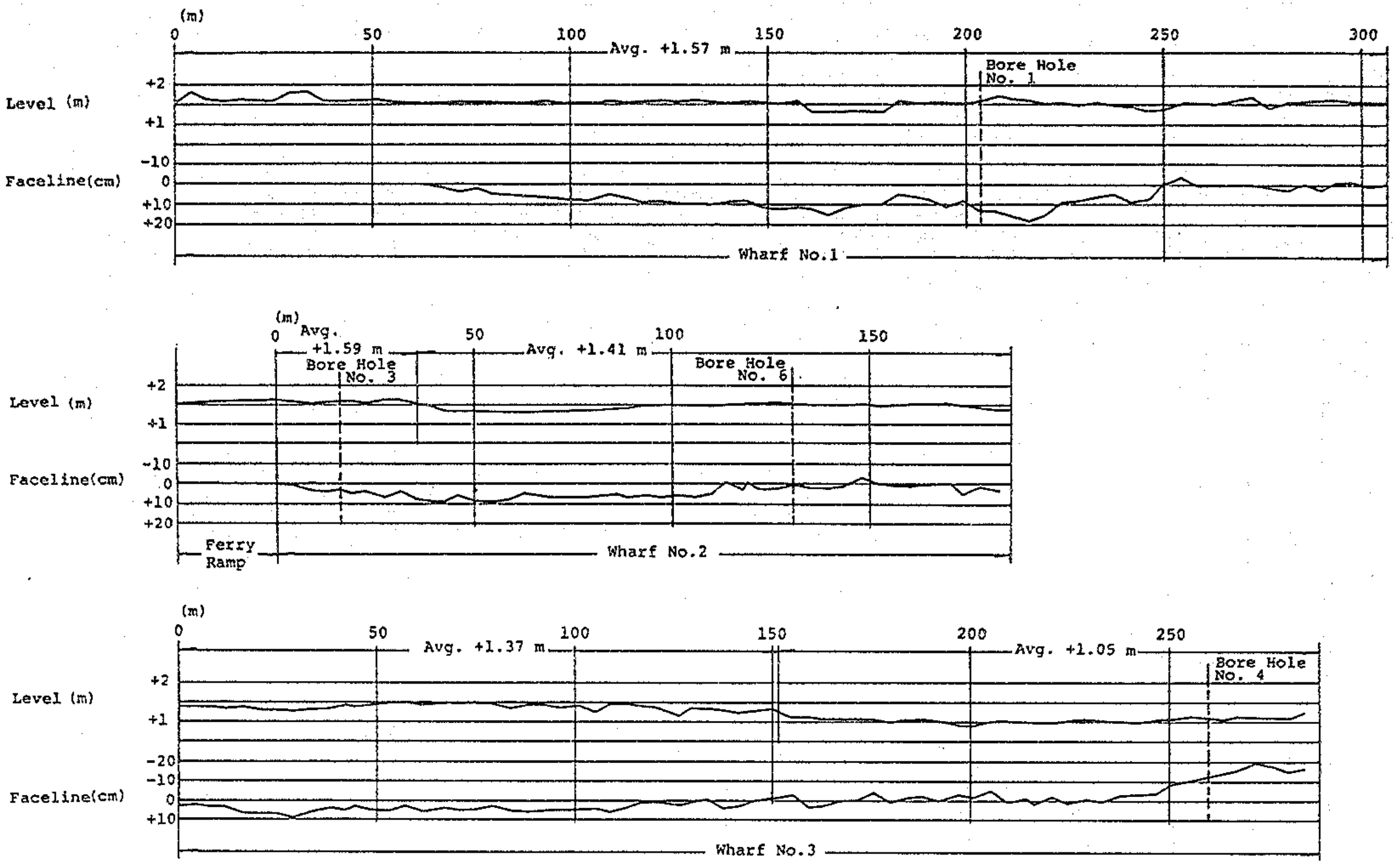


Fig. I.4.32 Subsidence and Faceline Deviation of Existing Wharfs

(5) Damage to Main Beams (see Table I.4.15)

The under surface of the main beams is at the level of the low water and most of this surface is above sea level and clearly visible. A visual inspection by divers was conducted for all the main beams of the three wharfs. Since as mentioned previously the cross sections of the main beams are designed large enough to carry the present live load, no significant damage is observed except for several parts of Wharf No.2 which have been damaged by ship collisions or at the time of repair work to the decks.

(6) Supporting Piles

The supporting piles are under water for their entire section necessitating survey by divers. The survey was done for the section from the pile top to about 4 m below the water level. The concrete surface was cleaned before inspection by scraping seashells off. The inspection revealed that though the concrete surface is, in some cases, deteriorated with a very thin surface layer spalling off, no cracks or buckling were observed.

(7) Steel Sheet Cellular Piles (see Table I.4.16)

The damage to steel sheet cellular piles is summarized in Table I.3.16. The piles driven in front of the wharfs ae steel sheet cellular pile for the underwater sub-structure and welded steel pipe pile filled with concrete for the super-structure.

The survey on the piles included measurement of displacement, inclination and the thickness of the steel plates. Since the piles are not adequately equipped with fenders and receive large berthing forces of ships, several piles are tilted and displaced. To make matters worse, the piles break the frontage of the wharfs when moved by berthing ships and some piles were observed to have moved into the concrete decks. Some inclined piles were observed to be disconnected between their super and sub-structures. The thickness of the steel plate on the super structures was measured by an ultrasonic thickness gauge and a corroded thickness of about 3 mm was measured in the splash zone where the corrosion is most advanced.

During the field survey, a 7,000 ton class sugar carrier berthed at Wharf No.3 where only one pile is provided. There are no rubber fenders in front of or behind the pile. The ship contacts the pile directly and the entire berthing force is transferred through the pile to the wharf front. It should be noted that the berthing force acts as a point load on the wharf front through the circular pile in the above process. This damages both the wharf and the ship. A simple rubber tyre fender would be the cheapest solution to this situation, and such a tyre should be provided both in front of the pile and between the pile and wharf.

(8) Present Strength of Concrete/steel Members (see Table I.4.17 - I.4.19)

As mentioned above, the quality of the concrete used for the repair work to the decks is not high as it includes a considerable volume of mud. Three core samples were taken from each berth and sent for laboratory test. At the construction stage, the adequate control of the quality of construction materials is imperative and is highly recommended.

Also samples of reinforcing steel bars were taken from the damaged parts of the wharfs. All the results of the analyses are presented in Table I.4.17 - I.4.19. According to the results, the grade of the reinforcing steel bars used for the wharfs is considered to be very close to SD30B JIS 3112-1985 except for the remarkable difference in the chemical content of phosphorus and sulphur.

Table I.4.16 Damage to Steel Sheet Cellular Pile

Pile No.	Displacement (cm)	Inclination ( )
1	64	-
2	7	-
3	9	-
4	36	-
5	62	12
6	78	6
7	55	5
8	33	-
9	34	4

Table I.4.17(1) Compressive Strength of Concrete Core

Sample No.	Load (kg)	Area (cm^2)	C. Strength (kg/cm^2)	Unit weight (kg/cm^2)	
1 - 1	3,350-	26.42	126	2.040	Wharf
1 - 2	4,125-	"	156	2.032	No.1
1 - 3	3,500-	"	132	1.998	
2 - 1	3,400-	"	128	2.055	Wharf
2 - 2	2,850-	"	107	2.117	No.2
2 - 3	3,600-	"	136	2.189	
3 - 1	3,100-	"	117	2.018	Wharf
3 - 2	3,900-	"	147	2.089	No.3
3 - 3	2,600-	"	98	2.045	
4 - 1	3,600-	"	136	2.059	Breakwater
4 - 2	3,800-	"	144	2.113	
4 - 3	5,200-	"	196	2.122	

Table I.4.17(2) Compressive Strength of Concrete by Schmidt Hammer

	Wharf No.1		Wharf No.2		Wharf No.3	
	F. Beam	M. Beam	F. Beam	M. Beam	F. Beam	M. Beam
1	95	153	53	138	153	130
2	90	175	40	118	90	103
3	65	130	138	70	48	153

Note: The values measured by Schmidt Hammer which are calibrated by the results of laboratory compression test, include an error of $\pm$40% at 100kg/cm^2 and $\pm$20.7 at 300kg/cm^2.

F. Beam and M. Beam denote front beam and main beam, respectively.

Table I.4.18 Tensile Strength Test of Reinforcing Steel Bar

Sample No.	Breaking Strength (kgf/mm^2)	Yield Strength (kgf/mm^2)	Strain (%)
No. 1-1	75.1	-	29.5
1-2	43.4	-	42.5
1-3	51.9	37.7	37.0
No. 2-1	44.8	-	8.0
2-2	47.5	39.1	42.0
2-3	42.8	36.9	25.0
No. 3-1	89.8	-	18.0
3-2	-	-	-
3-3	90.3	-	19.5

Chemical Content C : 0.13%, Si : 0.01%, Mn : 0.8%,
P : 0.137%, S : 0.31% for sample No.3-2

JIS G3112-1985

SD 30B	Breaking Strength (kgf/mm^2)	30 - 40
	Yield Strength (kgf/mm^2)	245
Chemical	C 0.27%, Si 0.55%, Mn 1.50%	
Content	P 0.04%, S 0.04%	

Table I.4.19 Estimation of Proportion of Hardened Concrete

Sample No.	3-3		
Unit weight of sample concrete	a	Weight under water	0.27 kg
	b	Weight under saturated surface-dry	0.53 kg
	c	Weight under oven-dry	0.51 kg
	d	Unit weight (under oven-dry)	1,960 kg/m^3
	e	Unit weight (under staturated surface-dry)	2,040 kg/m^3
Chemical compound of concrete	f	CaO content in concrete	34.4 %
	g	Insoluble content in concrete	59.2 %
Chemical compound of materials	h	CaO content in aggregate	30.5 %
	i	Insoluble content in aggregate	69.5 %
Mix proportion	j	Quantity of aggregate	85.2 %
	k	Quantity of cement	14.8 %
Quantity of material per unit volume of concrete	l	Weight of aggregate per unit volume of concrete	1,670 kg/m^3
	l'	Average weight of absorption per unit volume of concrete	1,690 kg/m^3
	m	Cement content per unit volume of concrete	290 kg/m^3
	n	Specific gravity of cement	3.16
	o	Average specific gravity of coarse and fine aggregate	2.91
	p	Air content	4 %
	q	Water content per unit volume of concrete	287 kg/m^3

As shown in the tables, the present compressive strength of the concrete is in the range of 98 - 196 kg/cm^2 and the strength of the reinforcing steel bar is 43 - 90 kg/mm^2 for the breaking point and 37 - 39 kg/mm^2 for the yield point.

4.4 Structural Analysis of Existing Wharfs

In this section, the existing wharfs are evaluated from the viewpoint of structural strength based on the results of the investigation presented in the previous section.

(1) Concrete Decks

The structural strength of the concrete decks of the existing wharfs is checked based on the results of the investigation. The strength of the concrete and the reinforcing steel bars is set based on the laboratory test results. The strength of the concrete and the reinforcing steel bar varies considerably depending on the sampling points as shown in Table I.4.17 and I.4.18.

The reinforcing steel bars are 12 mm in diameter and are placed at 20 cm intervals, and the thickness of the concrete slabs is 13 cm. Whether or not the concrete deck span is stable against a certain load condition is determined by the weakest part of its entire area. In the investigation carried out this time, the test samples were taken from several selected points only, and the strength of the concrete and reinforcing steel bars is set at the minimum of the measured values.

The structural strength of the existing concrete decks is considered to vary depending on the extent of corrosion of reinforcing steel bars and differences of deterioration of concrete quality. The strength of the reinforcing steel bars decreases through reduction of sectional area due to corrosion at an annual rate of about 0.1 mm/year.

According to the results of the calculation, the original strength of the deck is assessed to have been stable with a safety factor of 2.0 against an axle load of about 10 t. According to the field survey on trucks carrying the port cargos, the present maximum axle load of trucks is about 30 t. The existing concrete decks are being used in a critical condition just under the failure point with an absolute minimum safety factor. Further, the strength of the repaired sections is, even if restored to the original design, not high enough to carry the present truck load with an acceptable safety factor of 2.0 or more. To carry the present load with a safety factor of 2.0, the concrete decks should be designed with a thickness of 30 cm and with reinforcing steel bars of 25 mm dia. placed at 20 cm intervals.

(2) Supporting Concrete Piles

The supporting piles have a cross sectional area of 50 x 50 cm^2 and are 40 - 50 feet long at Wharf No.1, about 60 feet long at Wharf No.2 and about 75 feet at Wharf No.3. The horizontal force acting on the wharfs is designed to be resisted by a retaining wall and a batter pile and during the underwater investigation no perceivable damage caused by horizontal forces was observed. On the other hand, vertical forces have caused a considerable subsidence of the wharfs. The bearing capacity of the supporting piles is examined below.

The bearing capacity of supporting piles is calculated by the following equations:

Bc = 40 x Ne x Ap + Na x As/5 .... for sandy strata
Bc = 8 x Ce x Ap + Ad x As .... for silty strata

Where;

Bc ...	Bearing capacity	t/pile
Ne ...	N value at the pile end	
Ap ...	Cross sectional area of the pile end	m^2
Na ...	N value on vertical pile surface	
As ...	Area of vertical pile surface	m^2
Ce ...	Cohesion at the pile end	t/m^2
Ad ...	Adhesion on vertical pile surface	t/m^2

The bearing capacity of the supporting piles is calculated based on the soil boring data at about 90 t/pile for Wharf No.1 and about 70 t/pile for Wharfs No.2 and No.3.

With a live load of 3.0 t/m^2, the total vertical load is calculated as about 45 t/pile for Wharf No.1, 55 t/pile for Wharf No.2 and 45 t/pile for

Wharf No.3. The safety factor of the bearing capacity for each wharf is 2.0, 1.3 and 1.6 for Wharfs No.1, No.2 and No.3 respectively.

Supporting piles are usually designed with a safety factor of 2.0 - 2.5 and based on the above figures only Wharf No.1 meets this requirement.

The soil conditions at each wharf are shown in Fig. I.4.20 and the bearing stratum of Caliche at Wharf No.1 is located at a depth of about -18 m, -42 m at Wharf No.2 and -58 m at Wharf No.3. The intermediate layer to the bearing stratum is sandy for Wharf No.1 and silty for Wharfs No.2 and No.3. Wharf No.2 is used almost exclusively for the ferry service and does not carry any heavy load on its deck and therefore its subsidence is measured at only about 20 cm. However, if Wharf No.2 is required to handle part of the increasing future port cargos with a heavier load on the deck, it should be improved to attain an adequate safety factor. The safety factors for Wharfs No.1 and No.3 are considered to be acceptable assuming that the present vertical load will not be increased.

In planning the future port development plan, the following deteriorated structural condition of the existing wharfs should be given a thorough consideration;

- economic service life of concrete structures (50 years) and structural difficulty of expanding it
- insufficient cross section of the wharf decks and sub-beams
- subsidence of the wharfs
- upgraded and regular maintenance work
- limitation of truck load
- future increase of ship size
- insufficient water depth of the wharfs and water area
- adequate fendering system
- instability of the supporting piles for increasing the wharf depth
- future increase of surcharge to the wharf
- poor sub-soil conditions and insufficient bearing capacity of the piles

5. Cargo and Vessel Movement

5.1 Cargo Volume

Sugar (raw and refined), molasses, blended fertilizer, cement and clinker are this port's major export commodities, and raw materials for fertilizer, coal for cement production and fuel oil are the major import commodities.

A wide range of general cargo is also transported bgy ferry boat to and from Puerto Rico, but the cargo volume is still small.

The historical cargo volume is presented above in Chapter 3, Fig. I.3.2, and Fig. I.3.4.

In 1970, the recorded cargo volume was extraordinarily large. There is a possibility that this data may be incorrect.

Foreign trade is dominent at the port. The percentage of domestic trade varies from 0 percent to 50.5 percent, but in 7 recent years, this percentage remained smaller than 5 percent, and some of the exported cargo i.e., sugar, may have been counted as domestic cargo because it was transported by ships which called at other Dominican ports next to SPM before leaving the Dominican Republic.

It is difficult to analyze how much domestic cargo volume was actually for foreign trade using the existing shipping records.

So in this study only the cargo recorded as foreign trade cargo is considered.

Additional traffic information besides that mentioned in Chapter 3 was obtained from the Customs office and the Port Commander's office at San Pedro de Macoris.

The monthly cargo volume by commodity over a recent two years and nine months (Jan. 1984 to Sept. 1986) is shown in Tables I.4.20 to I.4.22. These tables are prepared using Form 50, Direction General de Aduanas.

The annual change of cargo volume by major commodity is shown in Table I.4.23 and Fig. I.4.33.

5.2 Ship Calls

A summary of the ship calls published by ONE is shown in Table I.4.24.

Table I.4.20 Monthly Port Traffic by Commodity

YEAR: 1984
NAME OF PORT: SAN PEDRO DE MACORIS

(UNIT: TONS)

	MONTH	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
EXPORT	SUGAR (RAW)	18,092	7,125	12,000	19,240	26,294	25,024	1,252		601	18,501	819	401	129,349
	SUGAR (REFINED)							108	6,096			5,249		11,453
	MOLASSES	4,251				8,017				7,229	3,386	11,592		34,475
	CEMENT		2,367	2,585	4,174	2,461	597	2,622	4,622	5,623				
	CLINKER		2,786	9,050	6,350	4,253				5,767				28,206
	FERTILIZER		1,209			502	1,261		1,063	201	570	74	12,438	17,318
	FRUIT & VEGETABLE			10	6	10	3	6	3	10				48
	FOODS			21			40		39				22	122
	COFFEE										3			3
	GRAVEL										300			300
	OTHERS			53	19		6	2	14		31	11	86	222
	SUB-TOTAL	22,343	13,487	23,719	29,789	41,537	26,931	3,990	11,837	19,431	28,313	22,587	20,768	264,732
IMPORT	FERTILIZER(RAW MATERIAL)			6,178	6,659		2,345		5,979	5,943	3,149	2,855	15,430	48,538
	FUEL-OIL		7,131	6,946			3,206	3,859	4,039		7,857	7,687		40,725
	PETROLEUM COKE			5,850				5,786			24,525			36,161
	OTHERS	8	23	3	7	3	11	13	8	7	14	49	37	182
	SUB-TOTAL	6	7,154	18,977	6,666	3	5,562	9,658	10,027	5,950	35,545	10,591	15,467	125,606
	TOTAL	22,349	20,641	42,696	36,455	41,540	32,493	13,648	20,864	25,381	63,858	33,178	36,235	390,338

SOURCE: FORM 50 REF., DIRECCION GENERAL DE ADUANA

Table I.4.21 Monthly Port Traffic by Commodity

YEAR: 1985
NAME OF PORT: SAN PEDRO DE MACORIS

(UNIT: TONS)

	MONTH	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
	SUGAR (RAW)		454	351	1,002	13,218	14,471		1,030		501	601	4,699	36,327
E	SUGAR (REFINED)	5,283		11,322	3,610	100	13,929	364	990	594	100	301	150	36,743
X	MOLASSES		5,674		11,391				5,510	5,508				28,083
P	CEMENT	5,667	8,012	9,166	6,766	5.294	5,625	1,111	1,965	1,687	2,390	4,195	984	52,862
O	FERTILIZER	314	732	753		2,562	2,509		974			120		7,964
R	FRUIT & VEGETABLE	6	49				1						248	304
T	FOOD	5	8				1	132						146
	COFFEE													
	OTHERS		7		1		2		146		118	2	124	400
	SUB-TOTAL	11,275	14,936	21,592	22,770	33,624	36,538	1,607	10,615	7,789	3,109	5,219	6,205	175,279
I	FERTILIZER (RAW	7,377	1,535	2,539	4,002	9,000	5,786	5,777		2,235	6,027		2,984	47,262
M	MATERIAL)													
P	FUEL-OIL			4,061				4,050		3,976	4,007			16,094
O	COAL	11,511				11,532			11,598			14,995		49,636
R	VEHICLE	1										182		183
T	SUGAR (REFINED)												4,841	4,841
	OTHERS	4	13	8	10	6	11	14	8	22	32	76	212	461
	SUB-TOTAL	18,893	1,548	6,608	4,012	20,538	5,797	9,841	11,606	6,233	10,066	15,253	8,037	118,432
	TOTAL	30,168	16,484	28,200	26,782	54,162	42,335	11,448	22,221	14,022	13,175	20,472	14,242	293,711

Source: FORM 50 REF., DIRECCION GENERAL DE ADUANA

Table I.4.22 Monthly Port Traffic by Commodity

YEAR: 1986
NAME OF PORT: SAN PEDRO DE MACORIS

(UNIT: TONS)

	MONTH	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
E	SUGAR (RAW)		3,598	8,321	1,118	501	301		3,656	902				
X	SUGAR (REFINED)		332											
P	MOLASSES				13,327	11,271	7,856			4,086				
O														
R	OTHERS	1,433	463	2,095	759	2,409	1,163		1,216	789				
T														
	SUB-TOTAL	1,433	4,393	10,416	15,204	14,181	9,320	20,095	4,872	5,777				
	FERTILIZER (RAW	3,425	10,926		9,772	3,230	4,475	5,500	3,547	8,369				
I	MATERIAL)													
M	FUEL-OIL			6,567										
P	COAL		25,155		15,302			15,974						
O	VEHICLE													
R														
T	OTHERS	114	56	345	422	286	1,111	1,216	7,455	1,952				
	SUB-TOTAL	3,539	36,137	6,912	25,496	3,516	5,586	22,690	11,002	10,321				
	TOTAL	4,972	40,530	17,328	40,700	17,697	14,906	42,785	15,874	16,098				

Source: FORM 50 REF., DIRECCION GENERAL DE ADUANA

Table I.4.23 Cargo Throughput at the Port of San Pedro de Macoris

	Comodity	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
E	Raw Sugar	215,383	195,320	148,957	188,042	164,574	191,069	176,355	131,163	133,612	184,730	129,412	36,977
	Refined Sugar				321							11,454	38,744
X	Molasses	79,802	122,059	93,702	70,057	84,862	74,509	46,031	19,803	93,321	38,746	34,475	28,082
	Fertilizer	10,883			1,808		16,782	22,543	22,053	10,624	3,250	17,201	7,598
P	Cement						7,961	29,905	54,222	52,995	12,190	46,087	52,392
	Clinker							444	8,550			25,420	12,452
O	Agriproduct, Foods				37	57	100	16	22	17	68	246	607
	Feed						211	410	454	130	71		
R	Chemical Products				502		5	5	2,811			132	33
	Printed Matter	381											3
T	Machinery		486				4	51					27
	Bricks, Ceramics				2			77	117	700	13	4	39
	Others	0	2	1,083	2	5,031	40	3	9,949	22	8	313	1
	Sub Total	306,449	317,867	243,742	260,771	254,524	290,681	275,840	249,144	291,421	239,076	264,744	176,955
I	Fertilizer(Raw Material)	46,369	23,522		81,886	50,733	73,906	119,033	46,714	70,288	74,720	23,745	47,262
	Coal												49,636
M	Coke								1,700	8,474	200	11,675	
	Diesel, Fuel oil				3						7,014	83,734	16,094
P	Chemical Products				3			15	3		7		
	Textiles	2,673	67		3,136	91	3,546	108	28	1,154	9		4,841
O	Machinery	344	211		1,019			103	185	2		7	183
	Metal	847	1,784					1	10				
R	Agriproducts, Foods				169						8	1	
	Others	74	22		12	98	109	242	1	33	7	47	416
T	Sub Total	50,307	25,606		86,228	50,922	77,561	119,502	48,641	79,951	81,965	119,209	118,432
	Total	356,756	343,473		346,999	305,446	368,242	395,342	297,785	371,372	321,041	383,953	295,387

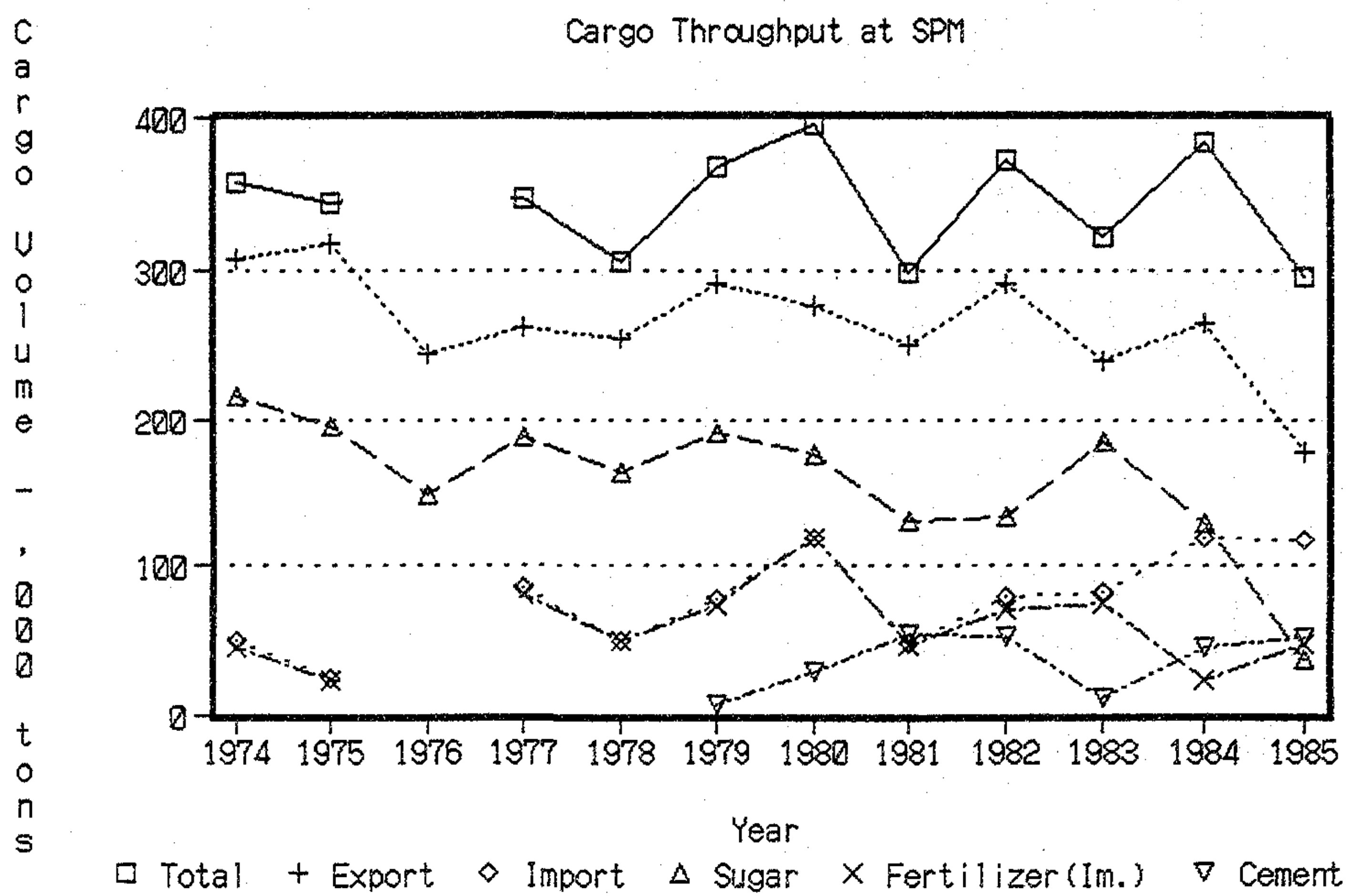


Fig. I.4.33 cargo Throughput at SPM Port

Table I.4.24 Number of Ship Calls (Loaded Ships)
Port of San Pdero de Macoris

Year	Entered			Departed			
	Number of Ships	GRT	NET Tonnage	Number of Ships	GRT	NET Tonnage	Total GRT
1970	19	541,126	127,400	42	453,935	198,866	995,061
1971	15	55,537	30,032	65	251,849	143,836	307,386
1972	28	90,822	51,340	68	251,784	153,841	342,606
1973	28	90,822	51,340	68	251,784	193,755	428,125
1974	28	92,081	54,429	52	131,785	69,635	223,866
1975	19	63,196	36,033	44	354,815	160,154	418,011
1976	17	55,038	31,306	56	286,254	169,397	341,292
1977	22	97,338	61,599	67	242,412	152,244	339,250
1978	13	40,491	25,689	66	232,293	138,642	272,784
1979	20	81,966	50,141	94	279,790	167,842	361,756
1980	28	85,732	54,547	131	273,193	136,922	358,525
1981	21	62,813	39,158	144	237,229	149,309	300,042
1982	25	73,463	45,804	96	263,624	173,922	337,287
1983	20	66,752	42,452	79	225,116	138,961	291,668

As there are no published records which present both cargo and ship information, shipping information is determined by combining ship information from the commander's office and cargo volume information from the customs office.

The commander's office presents ship information from Jan. '84 to Sept. '86, so shipping information is provided for this period as follows:

(1) Export

1) Sugar

The shipping record of sugar export is shown in APP Table I.4.1. The numbers of ships calling in 1984 was 35, and 28 ships called in 1985.

Additional information concerning sugar export in 1985 was obtained from CEA and VICINI independently as shown in Table I.4.25. According to this information, the number of ships calling in 1985 was 28 while according to commander's data, 22 ships called in that year.

(i) Ship size distribution

The ship size distribution in GT based on commander's information is shown in Fig. I.4.34. The average ship size is 2,800 GT.

Table I.4.25 Sugar Export in 1985

	NAME OF SHIP	GROSS TONNAGE	NUMBER OF HATCH	WORKING DAYS START	WORKING DAYS FINISH	ACTUAL WORKING DAYS	ACTUAL WORKING HOURS	DRAFT AT DEPARTURE BOW	DRAFT AT DEPARTURE STERN	CARGO WEIGHT TOTAL	Lbs. IN BAG	IN BULK	DESTINATION
CEA	PROMETHEUS V	3865	4	108	117	10	394	2600	2300	11,648,000		11,648,000	U.S.A.
	AURORA	4599	4	211	305	19	552	2302.3	2309.8	17,024,000		17,024,000	U.S.A.
	NORBRIT HOPE	1597	2	212	216	5	92	1220	99	2,204,600	2,204,600		SURINAM
	PROMETHEUS V	3865	4	301	316	14	434	2407	2601	12,345,760		12,345,760	TRINIDAD
	ALBATROS	293	2	314	316	3	30			771,610	771,610		GRENADA
	CORANTIJN	2738	3	328	404	8	130	1306	1506	2,204,600	2,204,600		SURINAM
										1,780,000	1,780,000		SURINAM
	CARIB DAWN	1399	3	415	424	10	229	1408	1906	6,172,880		6,172,880	U.S.A.
	GOLDEN MED METALLURG	5350	5	419	510	18	599	2603	2603	16,226,560		16,226,560	U.S.A.
	ANOSOV	11205	6	425	503	7	281	1106	2003	11,200,005		11,200,005	U.S.S.R.
	PROMETHEUS V	3658	4	429	517	15	479			12,676,494		12,676,494	TRINIDAD
	NEGOMBO	442	2	502	503					330,690	330,690		GRENADA
	KLIN	8540						1909	2202	11,199,999		11,199,999	U.S.S.R.
	COESEWIJNE	921	1	513	524	9	63	1002	1010	1,799,993	1,799,993		SURINAM
	PRIPIATLES	4520	4	520	528	8	211	1903	2103	9,171,136		9,171,136	U.S.S.R.
	NEGOMBO	442	2	610	612	3	48			1,322,760	1,322,760		GRENADA
										220,460	220,460		GRENADA
	ELPIDA	9985	6	617	626		295	2306	2400	22,400,000		22,400,000	U.S.A.
	SURINAME	1078	2-3	713	715	2	27	900	1100	800,000	800,000		SURINAM
	NEGOMBO	442	2	729	801			1004	1200	1,102,300	1,102,300		GRENADA
										440,920	440,920		GRENADA
	RIVER ARC	499	2	729	805	7	43	702	1202	1,102,300	1,102,300		ST. LUCIA
										220,460	220,460		ST. LUCIA
	SURINAME	1078	2-3	809	813	4	61	1201	1205	1,515,041		1,515,041	SURINAM
	EXPENSA	499								62,500	62,500		SAINT MARTEEN
	CORANTIJN	2738	3	917	919	3	51	1003	1306	1,304,976	1,304,976		SURINAM
	ALEJANDRA	1699	2	1002	1004	4	50	806	1200	1,102,300	1,102,300		GRENADA
										220,460	220,460		GRENADA
	RIO YUNA	499	2	1031	1106	6	74	1204	1500	1,322,760	1,322,760		ST. VINCENT
										661,380	661,380		ST. VINCENT
	ALBATROS	297	2							661,380	661,380		GRENADA
	ALEJANDRA	1699	2							1,102,300	1,102,300		GRENADA
	SUB TOTAL									152,318,624 (69,090 TONS	20,738,749 (13.6%)	131,579,875 (86.4%)	
VICINI	VELIKIE LUCKY									5,417,797		5,417,797	U.S.A.
	MACORIX									6,272,000		6,272,000	U.S.A.
	SUB TOTAL									11,689,797		11,689,797	
	GRAND TOTAL									164,008,421	20,738,749	143,269,672	

Source: CEA, VICINI

(ii) Mooring time

Mooring time is calculated in days, becuase the raw data presents only date and not time data.

Excluding ship data which do not have dates, mooring days and ship size are shown in Fig. I.4.35.

Large size ships have many hatches, so many gangs can work at the same time and productivity increases.

The mooring days distribution is shown in Fig. I.4.36. The average mooring days of sugar export vessels is 10.8 days.

2) Fertilizer

The shipping record of fertilizer is shown in APP. Table I.4.2. Blended fertilizer is exported in bags at Wharf No.3 by ships which are smaller than the import ships.

The cargo loading system onto ships is very similar to the system used for sugar export: essentially, the cargo is loaded by hand.

(i) Ship size distribution

The ship size distribution is shown in Fig. I.4.37. The average ship size is 3,510 GT.

(ii) Mooring time

The mooring days and the ship size relation are shown in Fig. I.4.38.

The mooring time varies between 1 and 33 days. The mooring days distribution is shown in Fig. I.4.39. The majority of ships moor between 2.5 and 7.5 days, and the average mooring time is 7.6 days.

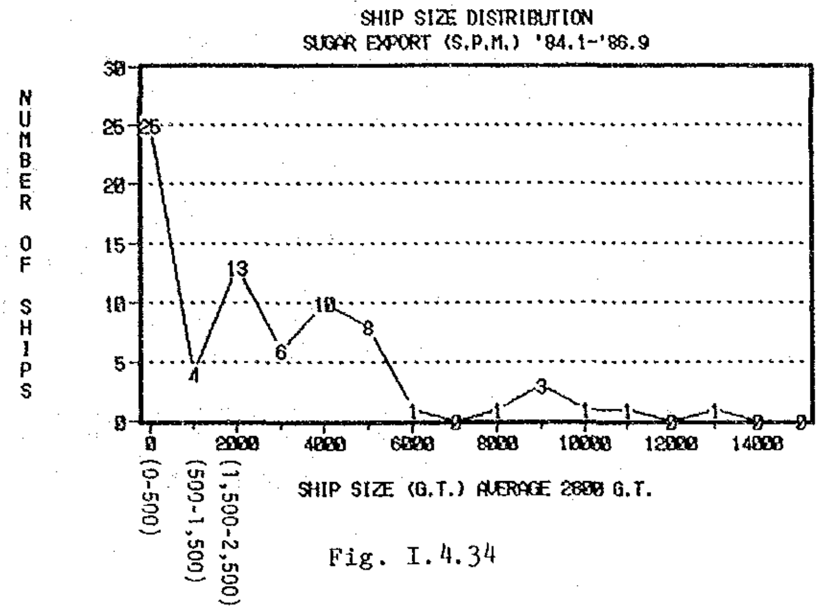
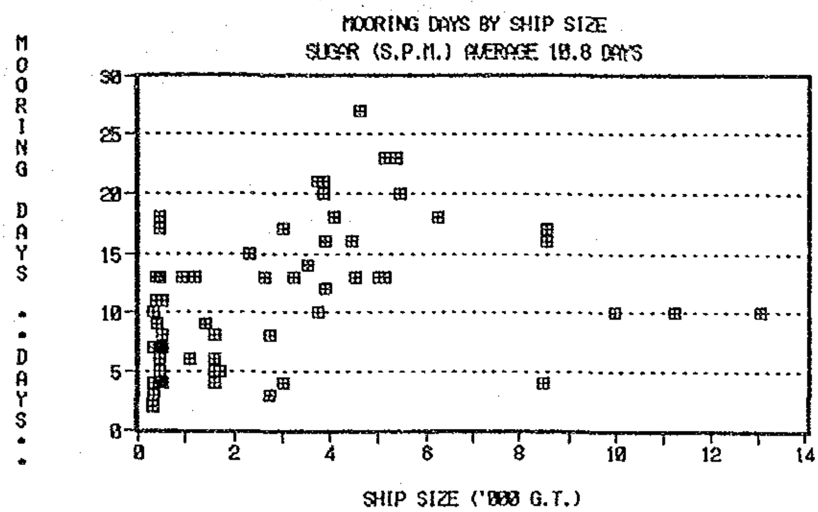


Fig. I.4.34



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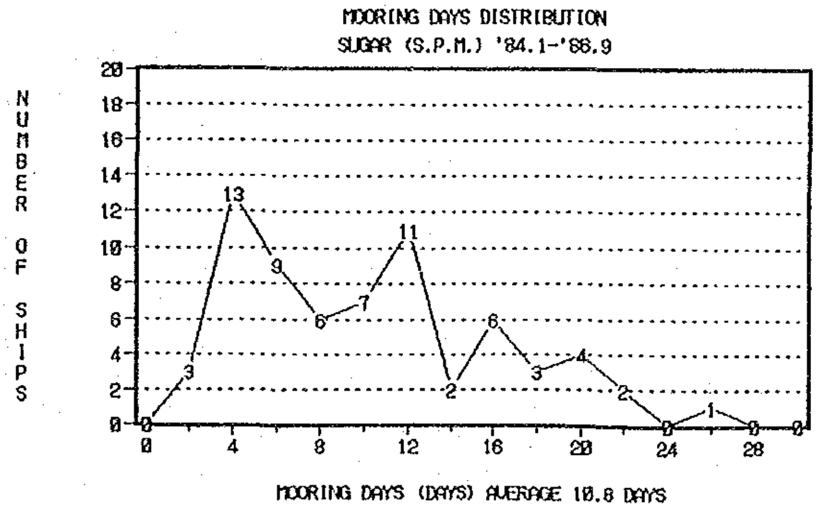

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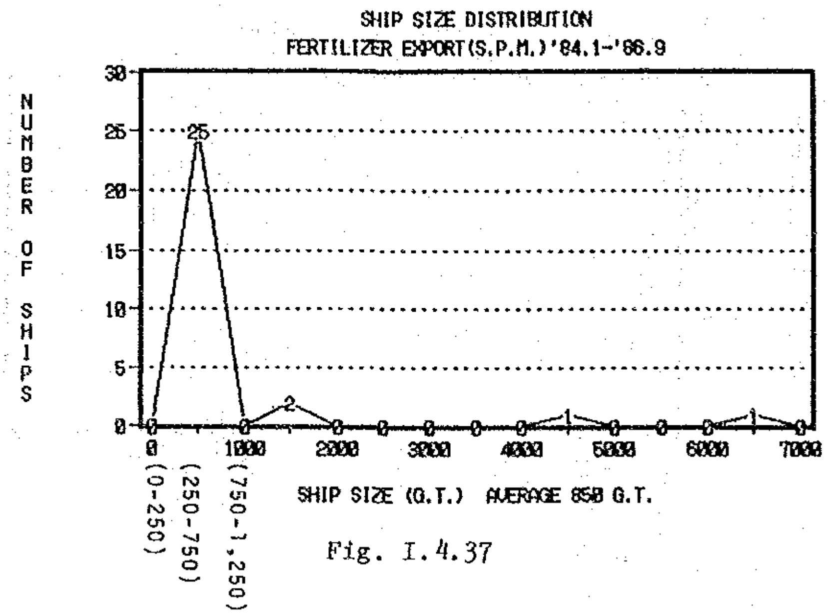

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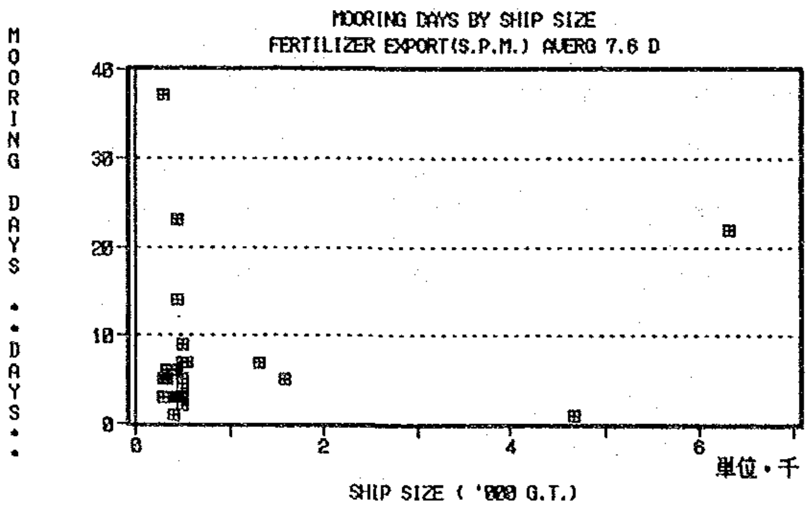

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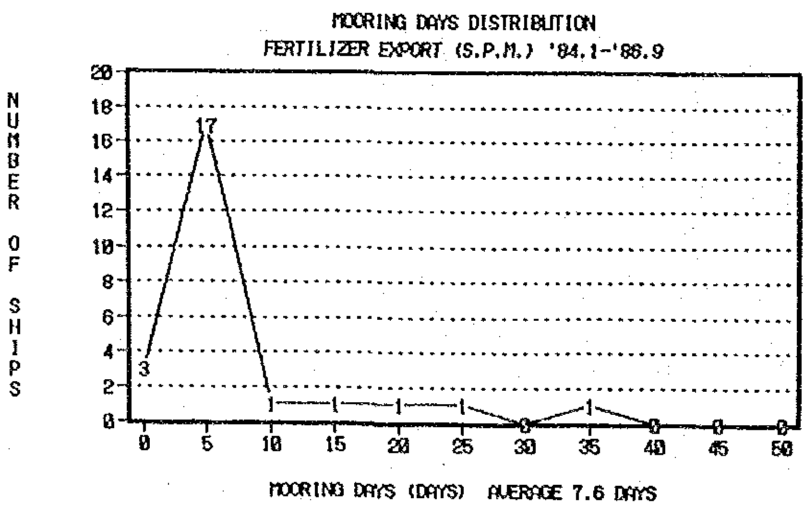


Fig. I.4.39

3) Cement

The shipping record of cement export is shown in APP. Table I.4.3. Cement export mainly takes place at a private wharf located upstream on the Higuamo river. The port of San Pedro de Macoris is used by large size ships.

(i) Ship size distribution

As shown in Fig. I.4.40, ship size is divided into two groups. Small size vessels use a private wharf and large size vessels use SPM.

Average ship size is 560 GT.

(ii) Mooring time

The mooring days and ship size relation are shown in Fig. I.4.41. The mooring time varies between 1 and 40 days. The mooring days distribution is shown in Fig. I.4.42.

The majority of ships moor between 1 and 10 days, and the average mooring time is 6.3 days.

4) Clinker

The shipping record of clinker export is shown in APP. Table I.4.4. The volume of export changes greatly from year to year.

(i) Ship size distribution

The ship size distribution is shown in Fig. I.4.43. The average ship size is 3,510 GT.

£ii) Mooring time

The mooring days and the ship size relation are shown in Fig. I.4.44.

The mooring days varies between 2 and 3 days. The mooring days distribution is shown in Fig. I.4.45.

The majority of ships moor 3 days, and the average mooring time is 2.75 days.

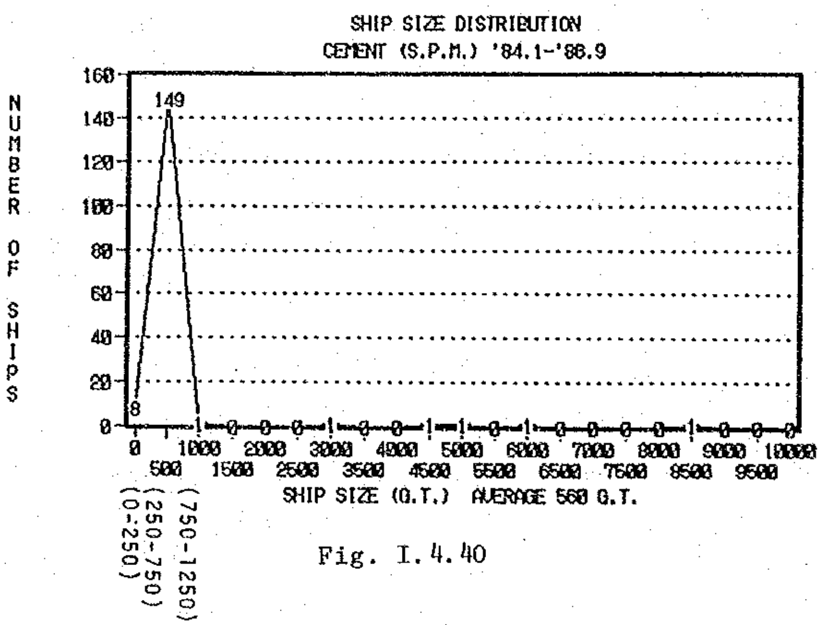


Fig. I.4.40

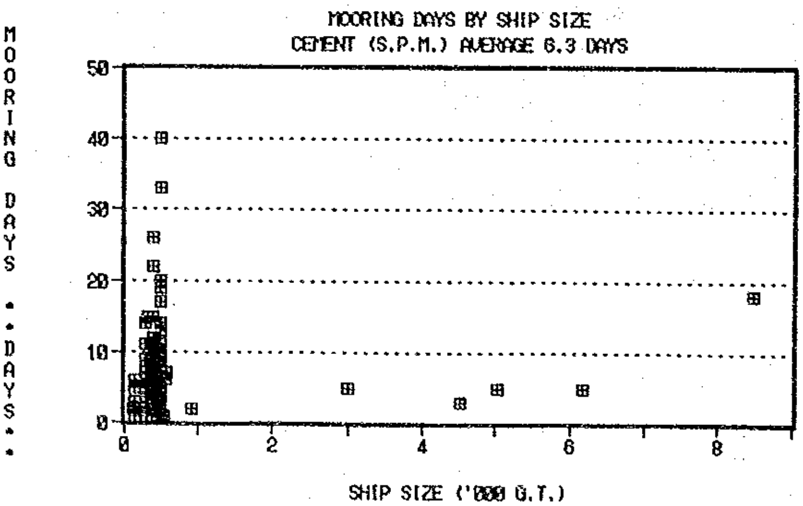
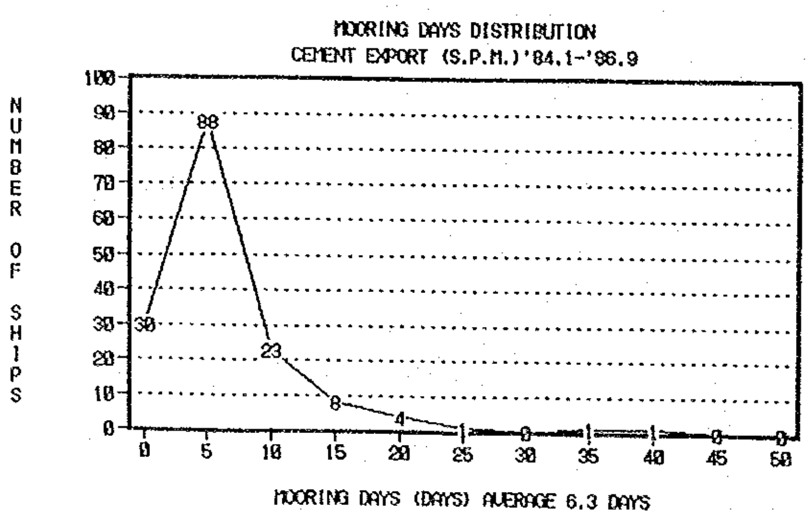


Fig. I.4.41



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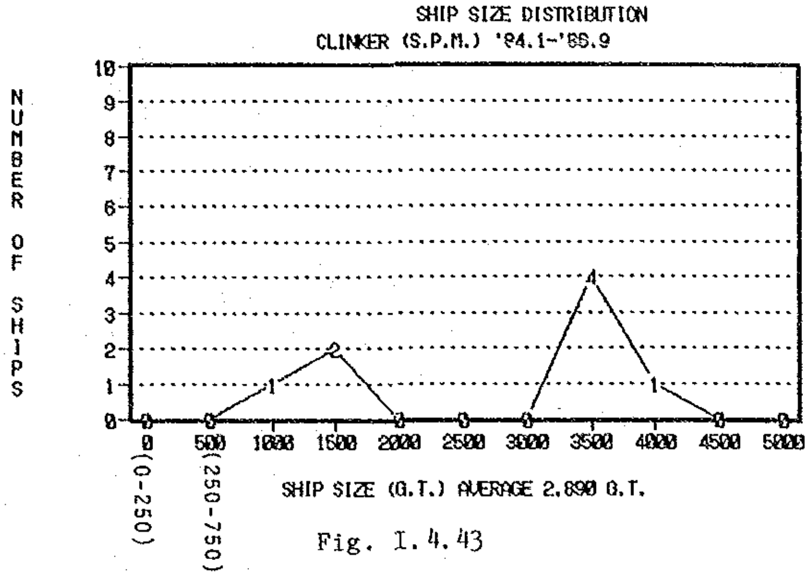

Fig. I.4.43

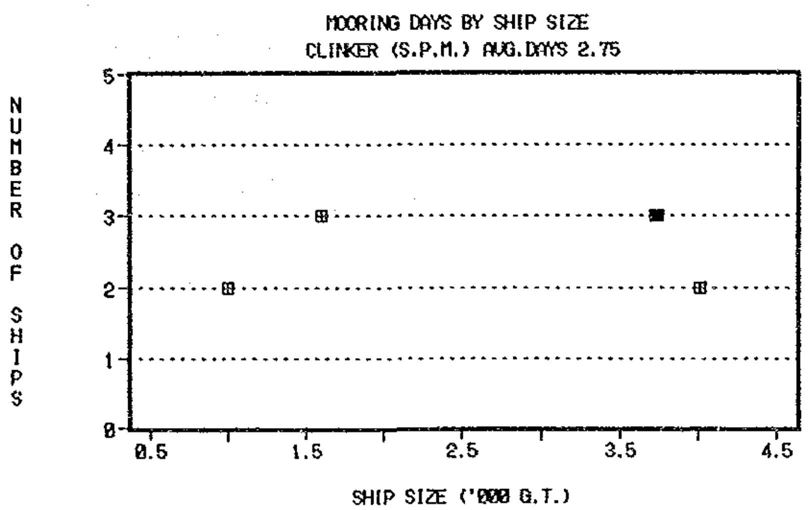

Fig. I.4.44

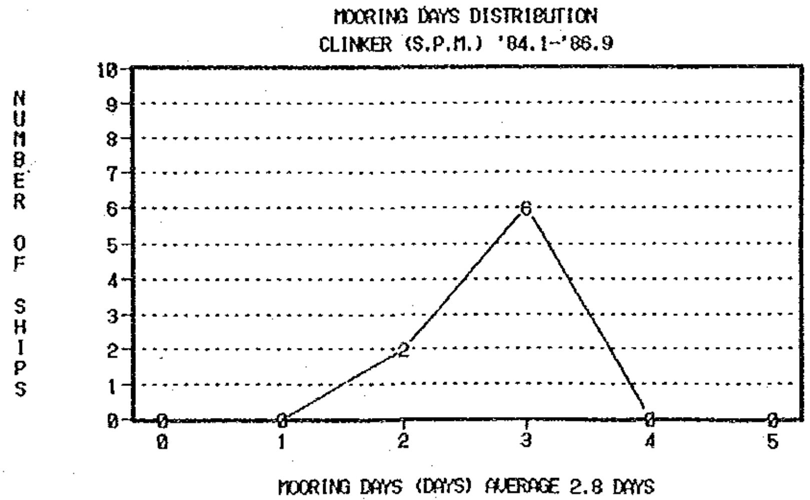

Fig. I.4.45

(2) Import

1) Raw Materials for Fertilizer

Raw materials for fertilizer are imported in bulk and unloaded using ship gear with FERQUIDO's grab attachment at Wharf No.3.

Raw material is unloaded directly on the belt conveyer of FERQUIDO and transported to its warehouse or factory.

The shipping record of fertilizer import is shown in APP. Table I.4.5.

(i) Ship size distribution

Ship size distribution is shown in Fig. I.4.46. The average ship size is 3,510 GT.

(ii) Mooring time

Mooring days and ship size relation are shown in Fig. I.4.47.

The mooring time varies between 1 and 7 days. The mooring days distribution is shown in Fig. I.4.48.

The majority of ships moor between 1 and 5 days, and the average mooring time is 3.5 days.

Imported cargo is handled by a mechanized system so compared with the export of fertilizer the productivity is high and the mooring time is rather short.

2) Coal

The cement company imports coal from Colombia in bulk. The shipping record of coal is shown in APP. Table I.4.6. The import of coal was started in Jan. 1985 and vessels call about once in three months.

Coal is unloaded between Wharf No.2 and Wharf No.3 by ship gear directly to dump trucks waiting on the apron. When there are no trucks waiting, the coal is unloaded onto the apron and moved to the area behind the apron using shovel loaders.

(i) Ship size distribution

Ship size distribution is shown in Fig. I.4.49. The average ship size is 12,700 GT.

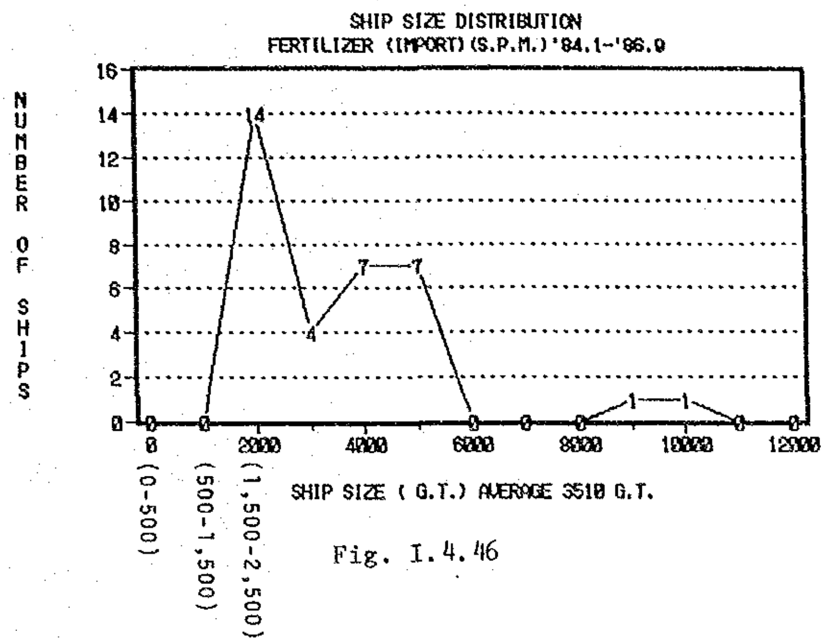

Fig. I.4.46

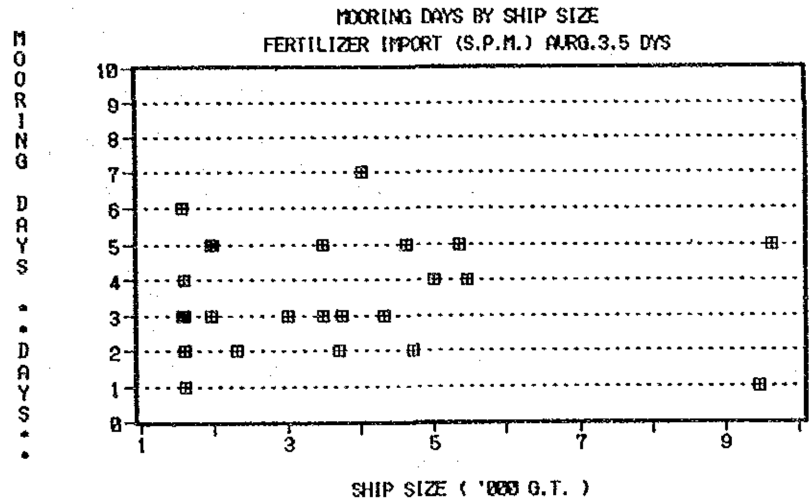

Fig. I.4.47

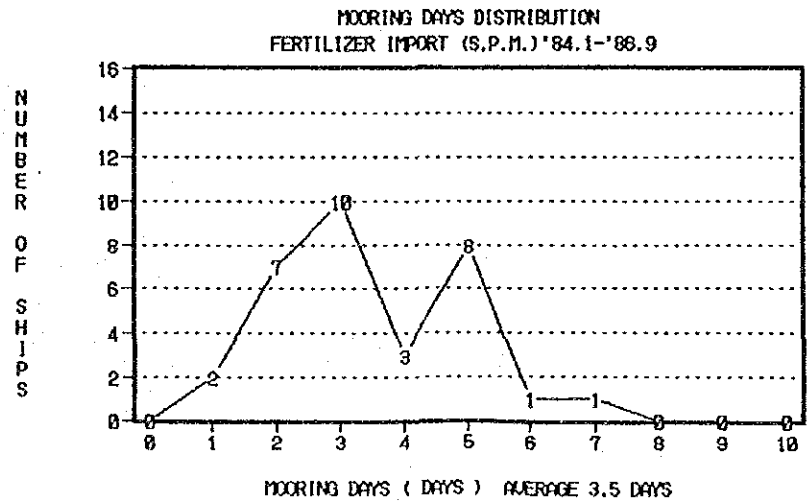

Fig. I.4.48

(ii) Mooring time

Mooring days and ship size relation are shown in Fig. I.4.50. The mooring time varies between 2 and 6 days. The mooring days distribution is shown in Fig. I.4.51.

The majority of ships moor for about 3 days, and the average mooring time is 3.4 days.

3) Fuel oil

The shipping record of fuel oil import is shown in APP. Table I.4.7. In 1984, fuel oil was imported mainly by tankers, but recently the oil is mainly imported using barges. In 1986, fuel oil was unloaded at Wharf No.1.

(i) Ship size distribution

As shown in Fig. I.4.52, ship size is divided into two groups. One is from 1,000 to 5,000 GT and the other is about 200,000 GT. The small group represents barges and the large group tankers. The average ship size is 11,200 GT.

(ii) Mooring time

The mooring days and ship size relation are shown in Fig. I.4.53. The mooring time varies between 1 and 4 days. The mooring days distribution is shown in Fig. I.4.54.

The majority of ships moor for 1 day, and the average mooring time is 1.3 days.

A summary of the analysis of shipping is shown in Table I.4.26.

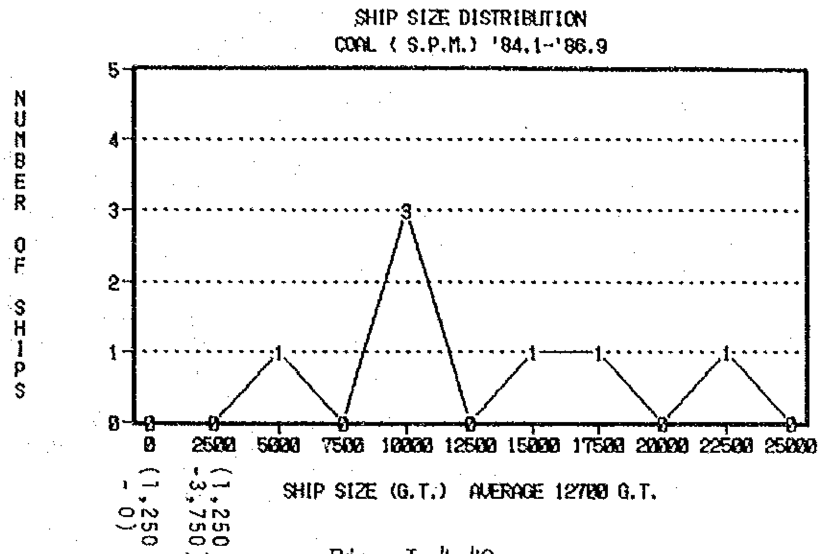

Fig. I.4.49

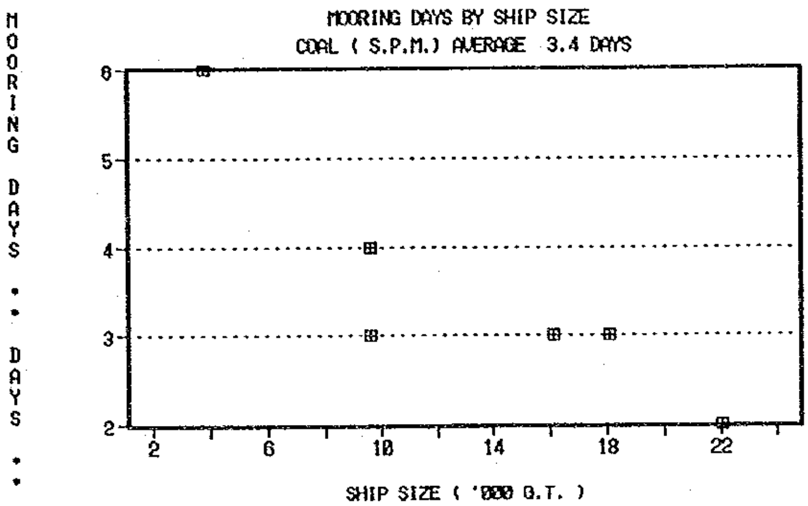

Fig. I.4.50

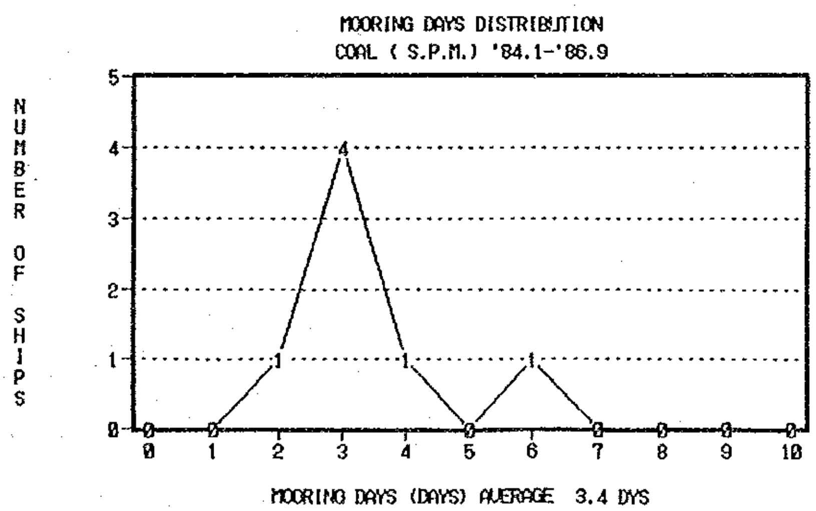

Fig. I.4.51

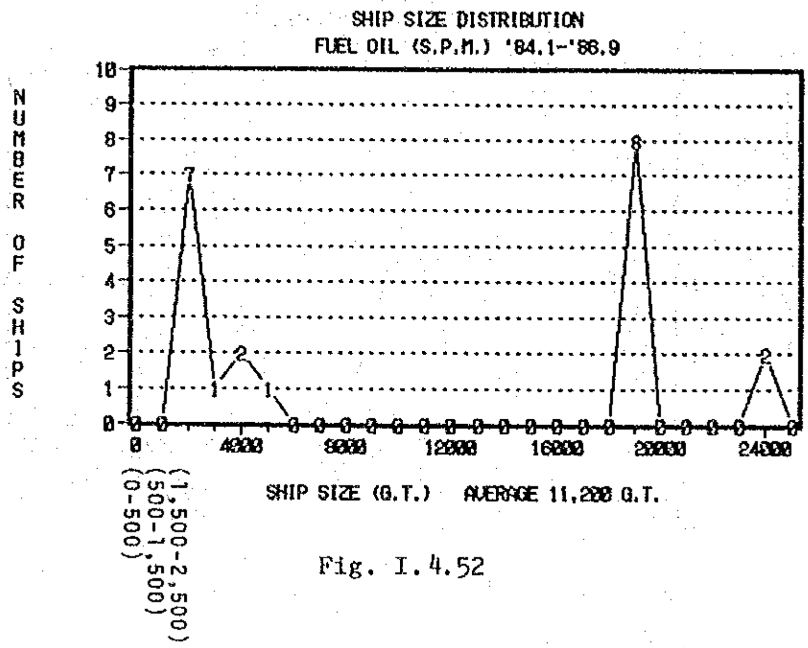

Fig. I.4.52

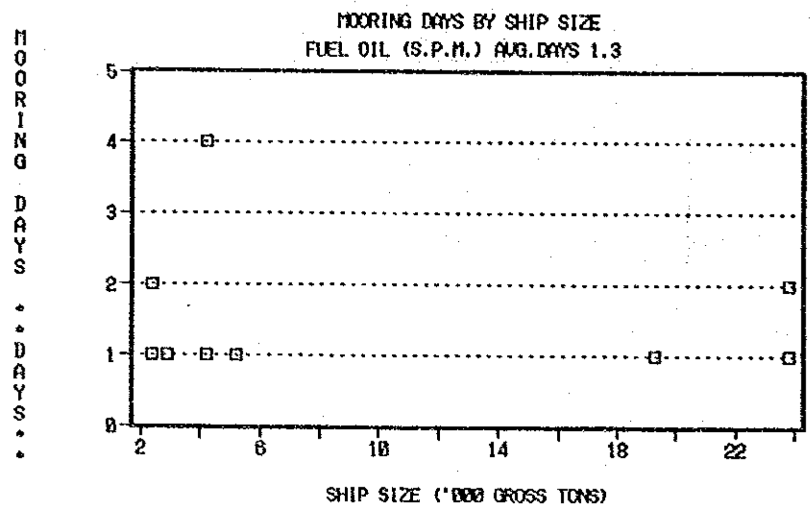

Fig. I.4.53

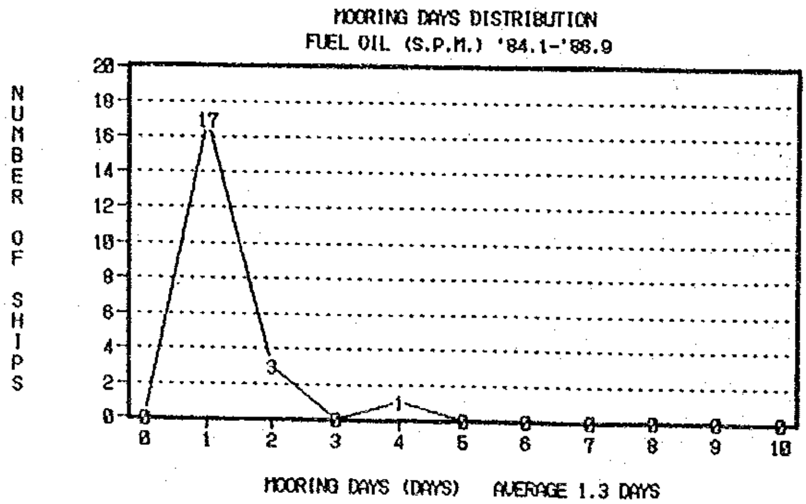

Fig. I.4.54

Table I.4.26 Summary of Present Shipping at SPM in 1985

		Number of Ship Calls	Share (%)	Average Ship Size (GRT)	Cargo Volume (tons/yr)	Avg. Cargo Volume per Ship (tons)	Average Mooring days
Export	Sugar	28	19.10	2,800	75,715	3,493	10.8(1)
	Fertilizer	8	5.40	850		686	4.8(2)
	Cement	88	59.90	560			6.3(3)
	Clinker	2	1.40	2,890			2.8(3)
Import	Fertilizer	14	9.50	3,510		3,640	3.1(2)
	Coal	3	2.00	12,700		13,100	3.4(3)
	Fuel Oil	4	2.70	11,200		3,928	1.3(3)
Total		147	100.00				

Notes:(1) Average from Jan. 1984 to Sep. 1986, excluding extremely long mooring data.
This data is used in the simulation.
(2) Average mooring time in 1985 based on the cargo volume data.
(3) Overall average of the data from Jan. 1984 to Sep. 1986.

6. Cargo Handling

6.1 Cargo Handling System

(1) Port Cargo Operations

The major import cargoes handled at the port of San Pedro de Macoris are coal, raw materials for fertilizer and general cargo carried by ferries. On the other hand, the major export cargoes handled at the Port are sugar, molasses, and fertilizer.

At SPM Port, there is a syndicate consisting of about 380 workers. Stevedoring works are carried out by the syndicate. The syndicate does not possess any handling equipment but uses the handling equipment of shipping agents and of the fertilizer factory as well as ship gear.

Regular working hours are from 8:00 a.m. to 12:00 a.m. and from 2:00 p.m. to 6:00 p.m. However, if necessary, the laborers work overtime.

(2) Sugar Handling

Sugar produced in sugar mills around San Pedro de Macoris is sacked in the factories and transported to the Port by trucks. There are two sizes of sacks, i.e. 125 pounds and 260 pounds. At the wharf, the sacks are loaded using ship cranes. In almost all cases (about 85%), the sacks are opened on board.

Each gang is comprised of 15 workers, as follows:

	Position	Number
On Board	Indicator	1
	Crane	2
	Hold	8
On Shore	Apron	4
	Total	15

The number of gangs per ship depends on the number of ship cranes on board. Besides these gang workers, persons who supply the workers with water and who mend sacks or collect open sacks are added as needed.

(3) Fertilizer Handling

There is a fertilizer factory "Fertilizantes Químicos Dominicanos, C. por A.", located just behind Wharf No.3. The company imports raw materials and exports fertilizer at this wharf.

1) Unloading

12 kinds of raw materials are unloaded, and 4 of these are handled in large volumes.

The number of gangs per ship varies from one to three depending on the number of ship cranes on board. The gangs work only on board, and the unloaded cargo is carried into the factory directly by belt conveyors.

The cargo handling equipment owned by the factory is as follows:

Equipment	Capacity	Number
Shovel/Loader*	1,200 lbs. (544 tons)	1
Belt Conveyor		1
Bucket**	1 1/2 $Yard^3$ (1.5 m^3)	6
Bucket**	3/4 $Yard^3$ (0.57 m^3)	4
Hopper		4

* Used in hold

** Used attached to cranes on board

Each gang is comprised of the following workers.

Position	Number
Indicator	1
Crane	2
Hold	7
Total	10

2) Loading

Fertilizer to be loaded is sacked in the factory and carried to the apron by trucks.

The number of gangs per ship varies depending on the number of hatches on the vessels.

Cargo handling is carried out using ship cranes.

Each gang is comprised of the following workers.

Position		Number
On Board	Indicator	1
	Crane	2
	Hold	11
On Shore	Apron	8
	Total	22

The maximum volume handled per day is about 200 tons per gang.

(4) Cement Handling

Cement is exported to Caribbean countries by 500 GT class ships. Cement to be loaded is sacked in the factory 8km apart from the Port and carried to the apron by trucks.

Cargo handling is carried out using ship cranes. The number of workers in each gang is not specified, but the loading conditions seem similar to the loading conditions of fertilizer.

6.2 Cargo Handling Productivity

(1) Productivity

With respect to the cargo handling, there are two sets of data to serve as a basis for estimating the productivity.

One source document is the "Entrance/Clearance Notice" from the Dominican General de Aduanas and the other is "Shipping Information 1985" by CEA.

Based on these documents, the productivity by commodity can be estimated as shown in Table I.4.27.

It can be said that these figures show the average productivity eliminating the monthly fluctuations.

(2) Cargo Handling Productivity of Sugar

1) Rated and Effective Productivity

The mooring days termed service time consist of actual handling days, holidays, and days necessary for related works before and after handling.

The rated productivity is defined as the number of tons handled per actual handling day.

The actual performance is reduced to what may be termed the effective productivity due to idle time, i.e. holidays and days necessary for related works before and after handling.

The rated and the effective productivity of sugar handling are obtained by analyzing the CEA data (1985), as follows:

		in Bulk	in Bags
average ship size	(GT)	5,000	600
average cargo volume per ship	(tons/ship)	5,465	775
average mooring days per ship	(days/ship)	15.8	7.2
actual handling days	(days/ship)	11.4	5.0
holidays	(days/ship)	1.9	0.7
standby/lost time before handling	(days/ship)	1.8	1.1
standby/lost time after handling	(days/ship)	0.7	0.4
tons/gang/hour	(tons)	15.5	12.7

		in Bulk	in Bags
average number of gangs (average number of hatches)	(gangs/ship)	4.2	2.1
rated productivity	(tons/day)	480 $\left(\frac{5,465}{11.4}\right)$	155 $\left(\frac{775}{5.0}\right)$
effective productivity	(tons/day)	346 $\left(\frac{5,465}{15.8}\right)$	108 $\left(\frac{775}{7.2}\right)$

The working intensity of gangs is examined based on the shift records of CEA, as follows:

		in Bulk	in Bags
average working days per week	(days/week)	5.5	5.5
average working hours per day	(hrs/day)	9.4	7.4
overall fraction of time worked		0.31 $\left(\frac{9.4 \times 5.5}{24 \times 7}\right)$	0.24 $\left(\frac{7.4 \times 5.5}{24 \times 7}\right)$

Therefore, the rated productivity can be also estimated by the following formula.

rated productivity:

in Bulk $\quad 15.5 \times \frac{9.4 \times 5.5}{24 \times 7} \times 24 \times 4.2 = 480$ tons/day

in Bags $\quad 12.7 \times \frac{7.4 \times 5.5}{24 \times 7} \times 24 \times 2.1 = 155$ tons/day

2) Stevedoring and Productivity

Sugar is shipped in two different forms:

in bulk - large quantity (around 5,000 tons)

in bags - small quantity (around 600 tons)

The packing method is selected based on the situation at the unloading port. It seems that in general sugar in bulk is transported to the U.S.A. and sugar in bags is transported to Carribean countries.

In the case of shipping sugar in bulk, additional work is involved as the sugar must be removed from the bags in the hold.

Table I.4.27 Cargo Handling at SPM Port

Commodity	Export /Import	Packaging Type	*** Average Cargo Volume/Ship (tons/ship)	*** Average Mooring Days (days/ship)	Effective Productivity (tons/day)
* Sugar (in Bulk)	Export	Bulk	5,465	15.8	346
* Sugar (in Bags)	Export	Break-Bulk	775	7.2	108
** Fertilizer (Products)	Export	Break-Bulk	686	4.8	143
** Fertilizer (Raw Materials)	Import	Bulk	3,640	3.1	1,174
** Cement	Export	Break-Bulk	554	6.3	88
** Clinker	Export	Bulk	6,225	2.8	2,223
** Coal	Import	Bulk	13,100	3.4	3,853
** Fuel Oil	Import	Liquid-Bulk	3,928	1.3	3,022

Sources: * "Shipping Information 1985" by CEA.
** "Entrance/Clearance Notice" from the Dominican General de Aduanas. (1984-1986)
*** These data are selected to estimate the productivity.

Fig I.4.30 shows the relation between the cargo volume handled per ship and the number of tons handled per gang-hour.

The number of tons handled per gang-hour does not change with the packing form.

It is almost constant at 15.0 tons per gang-hour.

This means that the productivity is affected by the work on the apron more than the stevedoring.

3) Ship Size and Productivity

The ship size for sugar export varies widely from 300 GT to over 10,000 GT, and the average ship size is 3,100 GT.

It can be observed that the productivity is proportionate to the ship size (Fig. I.4.31).

In handling sugar, one gang works at each hatch. When the ship size is large, many gangs are engaged on the ship and the productivity becomes higher.

4) Existing Operational Problems

In the port of San Pedro de Macoris, some sugar is handled as break-bulk.

The long-run performance, that is the overall productivity of 270 tons per day seems low compared with the average productivity at other ports.

And a widely scattered distribution of the productivity figures for the same size ship is observed (see Fig. I.4.56).

At present, the major operational problems in handling sugar at the port of San Pedro de Macoris can be summarized as follows:

(i) Handling activities are confused due to the narrowness and the poor condition of the apron.

(ii) The flow of cargo through the port is not smooth.

shippers (sugar-mill) ——► port area ——► ship

(iii) The loading is carried out using ship crane, and the productivity is consequentially limited by the capacity of each ship's gear.

The handling equipment on board ships sometimes malfunctions and loading is interrupted.

(iv) Cargo handling depends mostly on hard manual labor.

(v) There are some problems concerning safety.

(3) Cargo Handling Productivity of Fertilizer

1) Unloading (raw materials)

The ship sizes range from 500 GT to 5,500 GT. The average ship size is 3,300 GT (Fig. I.4.33) and the average cargo volume per ship is about 3,600 tons.

It takes one and a half minutes for one crane operation cycle.

The maximum volume handled per day is about 2,000 tons.

The average productivity is 1,162 tons per day, but the productivity varies widely irrespective of ship size.

Probably, this is mainly due to varied conditions at the factory.

The average number of mooring days is 3.1 days per ship.

2) Loading (product)

The ship sizes range from 300 GT to 540 GT, but most vessels are about 500 GT (Fig. I.4.35).

The average cargo volume per ship is only 700 tons, but the average mooring time is 4.8 days per ship.

Therefore, the productivity is only 146 tons per day.

Perhaps the low productivity is related to conditions at the factory.

(4) Cargo Handling Productivity of Cement

The average ship size is 520 GT and the average cargo volume per ship is about 550 tons (Fig. I.4.62).

Almost all the ships are under 500 GT but large ships over 6,000 GT turn round occasionally and load a large volume of cement.

The average productivity is only 86 tons per day. So, the average mooring period is too long -- up to 6.4 days -- in spite of the small size of the vessels.

The maximum productivity is about 600 tons per day.

Perhaps the low productivity is related to conditions at the storage area (factory), onward transport and the cargo handling system.

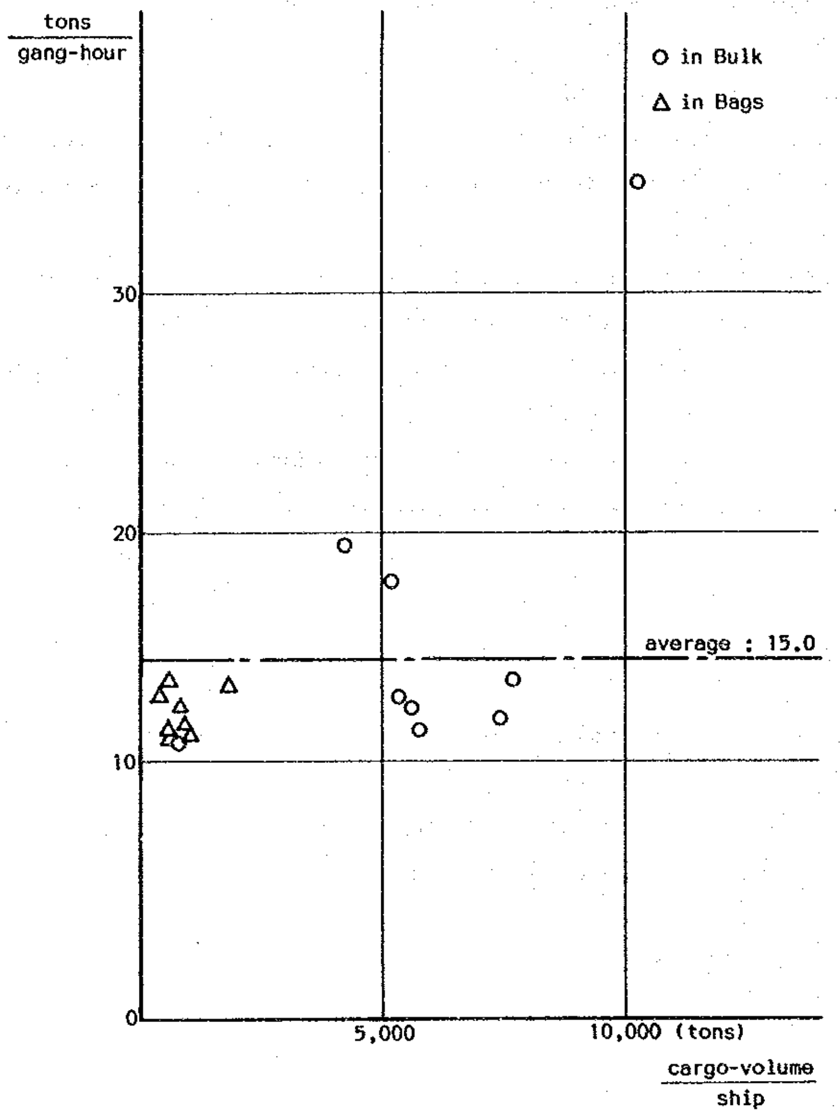

Fig. I.4.55 Relation Between Cargo Volume per Ship and Cargo Volume Handled per Gang-Hour

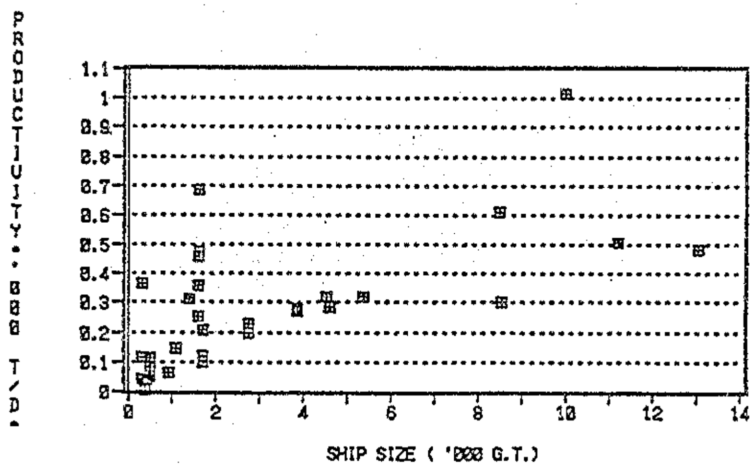

Fig. I.4.56 Productivity Distribution
Sugar (SPM)

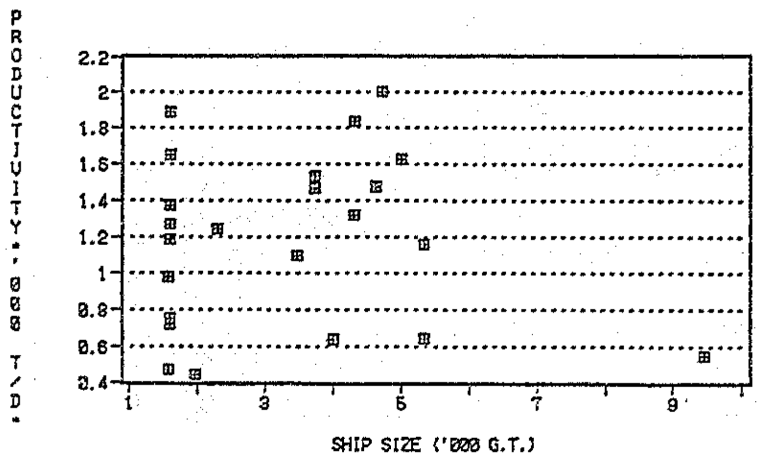

Fig. I.4.58 Productivity Distribution
Fertilizer Imports (SPM)

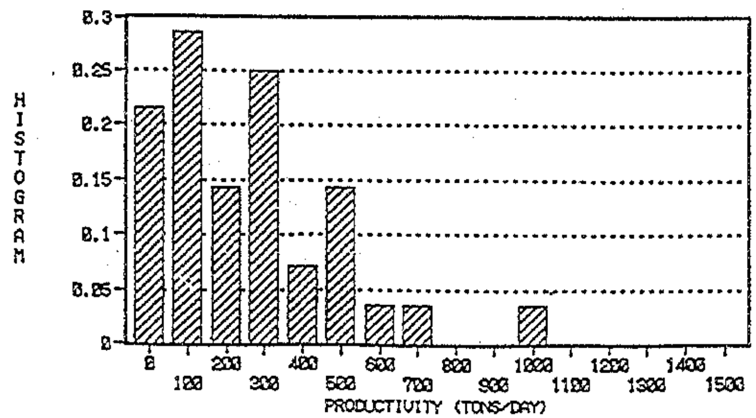

Fig. I.4.57 Productivity Distribution
Sugar (SPM)

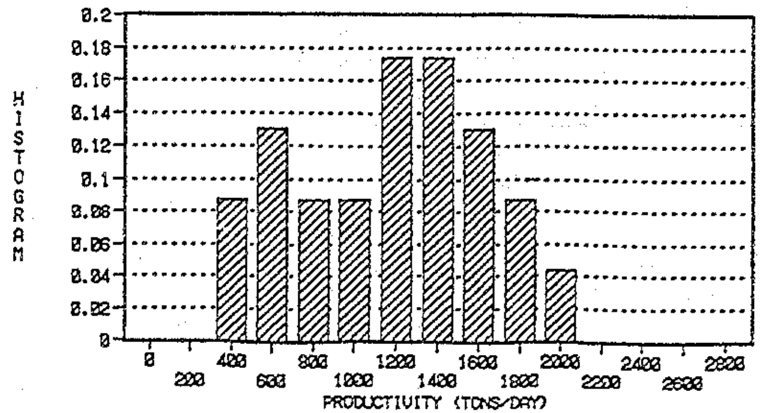

Fig. I.4.59 Productivity Distribution
Fertilizer Imports (SPM)

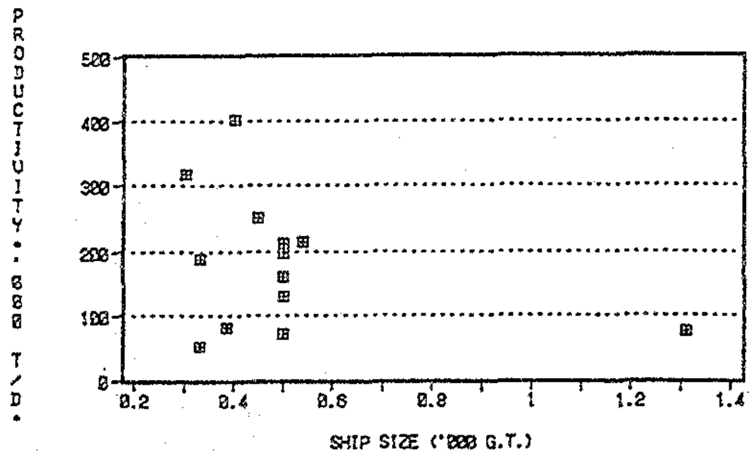

Fig. I.4.60 Productivity Distribution
Fertilizer Exports (SPM)

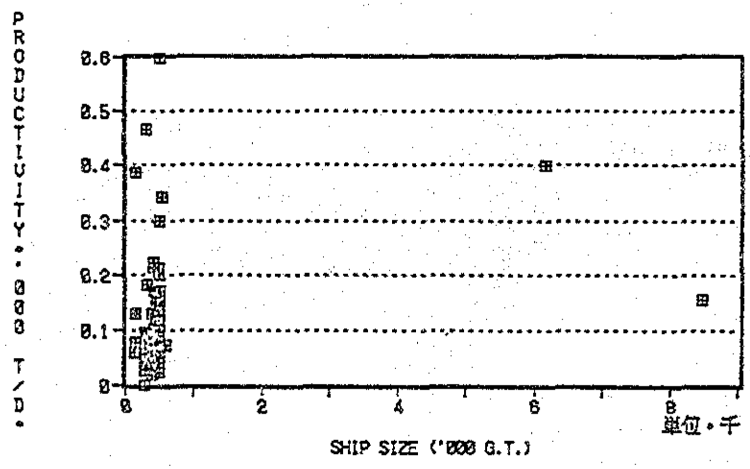

Fig. I.4.62 Productivity Distribution
Cement (SPM)

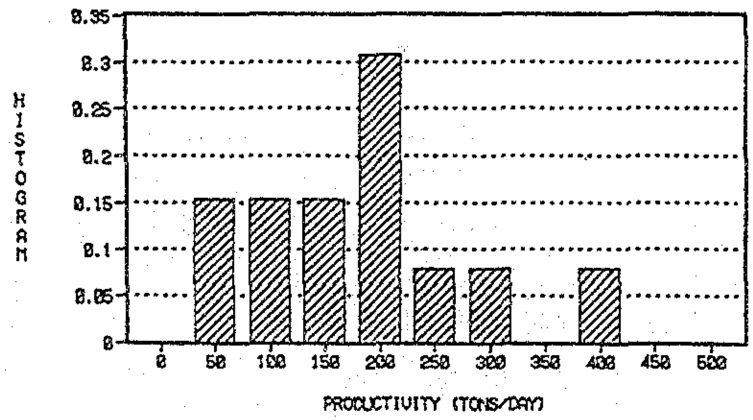

Fig. I.4.61 Productivity Distribution
Fertilizer Exports (SPM)

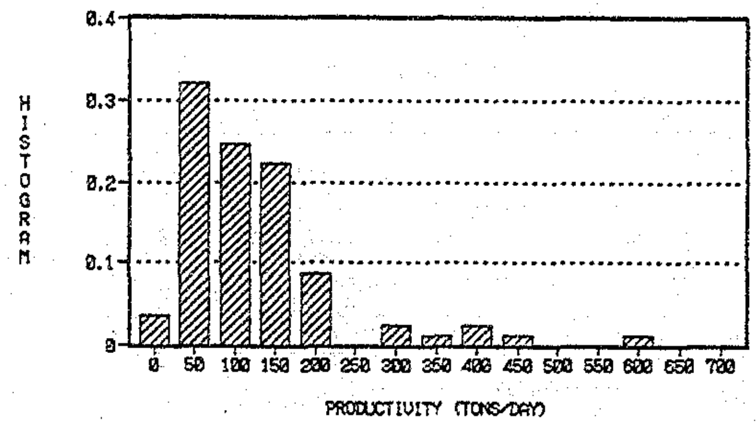

Fig. I.4.63 Productivity Distribution
Cement (SPM)

7. Port Administration and Management

The actual conditions of port administration and management at the ports of Haina, Santo Domingo, Boca Chica and San Pedro de Macoris are explained in Chapter 3.

In this section, the actual functions of SEOPC, the Port Commander and the Customs Office at the port of San pedro de Macoris are summarized.

7.1 The Functions of SEOPC

1) Construction of port facilities
2) Control and technical investigation of construction works
3) Maintenance works of the port facilities

However, as a matter of fact, no construction works or maintenance works have been carried out for almost 40 years. Small repairs of port facilities are executed by users without any supervision by SEOPC.

7.2 The Functions of the Port Commander

1) Administration of port facilities
2) Permission for use of port facilities
3) Acceptance of entrance and clearance notices and permission for clearance
4) Assignment of berths
5) Pilotage
6) Mooring aids
7) Control of ship traffic in the port
8) Port police and security guards

7.3 The Functions of Customs Office

1) Acceptance of manifests
2) Collection of charges for use of wharfs
3) Observation of cargo handling

PART II MASTER PLAN

CHAPTER 1 BASIC CONCEPTS AND DEVELOPMENT SCENARIO

1. Basic Concepts

The goal of the Project is to promote the development of the regional and national economy and ultimately to improve the standard of living of the Dominican people. The Port plays a major role in promoting foreign and domestic maritime trade which supports commercial and industrial development.

Successful port development projects in the past have proven that carefully planned port development can and does promote regional and national economic growth.

The Master Plan shall be formulated from the viewpoint of long-term development policy in accordance with national development plans and regional development principles.

The purposes of the Master Plan are:

- To set the right course for the development, clarifying the functions of the Port.
- To determine the appropriate scale and type of facilities required in the target year in accordance with the demand forecast.
- To draw up the land and water use plans.
- To formulate the layout of the breakwaters and entrance channel, and to define the limits of the land and water areas, and
- To establish a major access road between the port and its adjoining area.

The target year of the Master Plan for the port of San Pedro de Macoris is set as 2005. The size of the port area and the requirements of the facilities for the Master Plan are estimated based on the traffic forecast for 2005. However, the scope of the Master Plan is not limited only to the period prior to 2005, and it is important to have a longer-term development conception for the Port in order to formulate the correct course of the Master Plan.

The location of the present SPM port is excellent in terms of natural conditions.

The Port is blessed with a sufficiently large water area in the estuary of the Higuamo river sheltered by capes. The sedimentation and river flow are not very strong in this estuary .

The port water area is from below the first bridge of the Higuamo river up to the river month including the estuary and the adjacent land area.

The land area comprises the east bank side utilized at present and part of the west bank side including an area reserved for future development.

The relation between the Port and Haina Port is also considered. The capacity of Haina Port is estimated in order to examine whether SPM Port should be used to handle overflow cargo from Haina Port.

2. Development Scenario for the Master Plan

The present physical condition of SPM Port is miserable. Port facilities are extremely superannuated and the appropriate maintenance works have not been carried out. In consequence, port operations are unsafe and the Port cannot handle all the cargoes to and from the five eastern provinces of the country. For example, container cargo to and from the San Pedro de Macoris industrial free zone must be shipped via the ports of Haina, Santo Domingo and Boca Chica. Almost all the general cargo for the five eastern provinces is handled at Haina Port.

In view of the high land transport costs, many of the cargoes presently shipped via other ports could be handled more economically at SPM Port. If the Port had the proper facilities to handle these cargoes, transport costs could be greatly reduced. In order to make the Port attractive, the superannuated facilities must be reconstructed to facilitate mechanized cargo handling, efficient container handling and other improved cargo handling system.

The first target of the port development is to ensure that the Port has sufficient facilities to handle all the cargoes for the eastern provinces. Containers, general cargo and industrial cargoes to and from this region will be handled at the Port.

For this purpose, it will be necessary to construct a ro/ro wharf and to provide new physically stable wharfs with sufficient water depth and appropriate mechanized handling systems.

The second target of the port development is to encourage the development of regional industry and promote the location of industries at inland, port and coastal areas. Agro-industrial development will be accelerated because of reduced transport costs due to the improved infrastructure.

The target year of the Master Plan, 2005, is set for the initial stage of the second phase. In this stage the expanded free zone will start full operation and CDE's new floating power plants will begin full production with an total output of 60,000 kw.

Sugar will mostly be shipped in bulk, but sugar shipped to the Antilles Islands will be shipped in bags. The bulk sugar will be handled using an improved mechanized system.

Cement and clinker will continue to be exported, and the fertilizer factory will be operating at capacity. The recently proposed shipyard will be completed and will begin operations.

Ferry boats between San Pedro de Macoris and Mayaguez will continue their five day a week service. In addition, Caribbean cruise passenger boats will call frequently, say once a week, and tourism will also be developed.

Further growth can be expected. For example, a large-scale coal powered electric power plant and tourism development combined with coastal and residential development projects like Puerto Plata and La Romana. However, at this moment it is not possible to estimate the type, size and timing of the location of such industries.

Thus, it is strongly recommended that portions of the west side of the Higuamo estuary be reserved for the future development. The action required to reserve this area should start immediately, if possible.

In 2005, according to the land use plan, the east side of the Higuamo estuary will be considered as a clean cargo area for the handling of containers and general cargo. On this side the residential area is very close to the port area. Coal and clinker shall be handled on the west side of the river where there are very few residents.

It is also recommended that dry and liquid bulk cargoes be handled on the west side of the river, but the raw materials for fertilizer can be handled on the east side as the fertilizer factory (FERQUIDO) is expected to remain at its present location. It would be ideal for FERQUIDO to move to the west side of the river in the future and to use the site of the current FERQUIDO facilities for a container terminal, but this may not be practical prior to 2005.

CHAPTER 2 DEMAND FORECAST

1. Actual Cargo Traffic at the Port of San Pedro de Macoris

Table II.2.1 shows the historical volume of foreign trade by commodity at the Port of San Pedro de Macoris.

The data was taken from the statistics of ONE and from the statistics of the General Bureau of Customs and the CEDOPEX supplement. The import data for 1976 was lost in a hurricane.

The main export commodities are sugar (raw, refined), molasses, fertilizer, cement and clinker, and these commodities amount to almost 100% of the total export volume. The main import commodities are the raw materials for fertilizer, coal, coke and fuel oil, and these commodities amount to almost 100% of the total import volume.

There have been regular ferry services five times a week between Mayagüez in Puerto Rico and SPM Port since December 1985.

Table II.2.2 shows the actual ferry traffic until October 1986.

Table II.2.1 Historical Volume of Foreign Trade by Commodity at the Port of San Pedro de Macoris

(Unit: tons)

	Commodity	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Export	Crude Sugar	215,383	195,320	148,957	188,042	164,574	191,069	176,355	131,163	133,612	184,730	129,412	36,977
	Refined Sugar				321							11,454	38.744
	Molasses	79,802	122,059	93,702	70,057	84,862	74,509	46,031	19,803	93,321	38,746	34,475	28,082
	Fertilizer	10,883			1,808		16,782	22,543	22,053	10,624	3,250	17,201	7,598
	Cement						7,961	29,905	54,222	52,995	12,190	46,087	52,392
	Clinker							444	17,625			25.420	12,452
	Agriproducts, Foods				37	57	100	16	22	17	68	246	607
	Feed						211	410	454	130	71		
	Chemical Products				502		5	5	2,811			132	33
	Printed Matter	381											3
	Machinery		486				4	51					27
	Bricks, Ceramics				2			77	117	700	13	4	39
	Others	0	2	1,083	2	5,031	40	3	9,949	22	8	313	1
	Total	306,449	317,867	243,742	260,771	254,524	290,681	275,840	249,144	291,421	239,076	264,744	176,955
Import	Fertilizer(Raw Materials)	46,369	23,522		81,886	50,733	73,906	119,033	46,714	70,288	74,720	23,745	47,262
	Coal												49,636
	Coke								1,700	8,474	200	11,675	
	Diesel, Fuel Oil				3						7,014	83,734	16,094
	Chemical Products				3			15	3		7		
	Textiles	2,673	67		3,136	91	3,546	108	28	1,154	9		4,841
	Machinery	344	211		1,019			103	185	2		7	183
	Metal	847	1,784					1	10				
	Agriproducts, Foods				169						8	1	
	Others	74	22		12	98	109	242	1	33	7	47	416
	Total	50,307	25,606		86,228	50,922	77,561	119,502	48,641	79,951	81,965	119,209	118,432
Total		356,756	343,473		346,999	305,446	368,242	395,342	297,785	371,372	321,041	383,953	295,387

Table II.2.2 Actual Ferry Traffic at the Port of San Pedro de Macoris

(Unit: meters)

	Maz ⟶ S.P.M.	S.P.M. ⟶ Maz
1985 December	407	252
1986 January	573	617
February	520	435
March	661	508
April	780	695
May	521	324
June	1,236	609
July	2,117	945
August	3,100	717
September	816	817
October	1,223	1,189
Total	11,954	7,108
	19,062	

2. Future Socioeconomic Framework

2.1 Population

Table II.2.3 shows the future population of the Dominican Republic from 1985 to 2000 as forecast by ONE-CELADE in 1985.

Table II.2.3 Future Population of the Dominican Republic

(Unit: persons)

Year	1985	1986	1987	1988	1989	1990	1995	2000
Population	6,416,289	6,560,381	6,707,710	6,858,347	7,012,367	7,169,846	7,915,317	8,620,870

Source: República Dominicana en Cifras 1986, ONE

According to the same forecast, the increase of the population during the five years from 2000 to 2005 is estimated as 661,666 persons. Thus, the population of the Dominican Republic in 2005 is estimated as 9,282,536 persons.

Table II.2.4 shows the estimated population of each subregion from 1985 to 1990.

Table II.2.4 Estimated Population of Each Subregion

(Unit: persons)

Year	1985	1986	1987	1988	1989	1990
Subregion Cibao Central	1,433,957	1,456,015	1,478,132	1,500,291	1,522,474	1,544,662
Subregion Cibao Oriental	681,990	688,258	694,287	700,057	705,544	710,726
Subregion Cibao Occidental	316,506	319,414	322,211	324,890	327,436	329,841
Subregion Enriquillo	289,554	292,216	294,777	297,226	299,554	301,754
Subregion del Valle	494,196	502,235	510,310	518,416	526,549	534,699
Subregion de Valdesia	2,611,717	2,701,309	2,794,240	2,890,645	2,990,658	3,094,425
Subregion del Yuma	588,369	600,934	613,753	626,822	640,152	653,739
Total	6,416,289	6,560,381	6,707,710	6,858,347	7,012,367	7,169,846

Source: República Dominicana en Cifras 1986, ONE

2.2 Gross Domestic Product

Table II.2.5 shows the GDP of the Dominican Republic from 1975 to 1985, and Table II.2.6 shows the sectoral GDP from 1975 to 1981.

Table II.2.5 GDP and Annual Growth Rate

(Unit: Million Pesos, %)

Year	GDP at Constant 1970 Prices	Annual Growth Rate
1975	2,288.9	5.2
1976	2,442.9	6.7
1977	2,564.6	5.0
1978	2,619.5	2.1
1979	2,738.2	4.5
1980	2,903.9	6.1
1981	3,021.9	4.1
1982	3,072.5	1.7
1983	3,193.7	3.9
1984	3,205.5	0.4
1985	3,174.2	-1.0

Source: Cuentas Nacionales Banco Central
República Dominicana en Cifras 1986, ONE

Table II.2.6 Sectoral GDP of the Dominican Republic at constant 1970 Prices

(Unit: Million Pesos)

Sector \ Year	1975	1976	1977	1978	1979	1980	1981
Agriculture	399.9	429.2	436.8	456.8	461.8	484.2	510.8
Mining	121.7	146.7	143.0	114.3	146.5	124.6	135.6
Manufacturing	428.5	457.4	483.4	482.6	504.8	530.2	544.5
Construction	152.6	153.2	168.7	174.5	183.6	197.5	196.4
Commerce	385.9	414.0	429.8	438.8	451.5	473.6	494.9
Transport & Communications	182.6	190.8	211.8	218.9	224.3	230.5	242.7
Electricity	30.0	30.9	39.3	42.9	43.7	49.0	53.4
Finance	48.7	58.2	63.4	66.4	67.9	70.4	73.3
Government	183.1	189.9	191.1	200.4	233.6	280.3	300.1
Other services	355.9	372.6	397.2	423.9	420.5	463.6	470.2
Total	2,288.9	2,442.9	2,564.5	2,619.5	2,738.2	2,903.9	3,021.9

Source: "Cuentas Nacionales" Producto Nacional Bruto, Banco Central

It is quite difficult to estimate the future economic growth of the Dominican Republic. Since 1984, the economic situation has been sluggish. The new government established in August 1986 is going to specify a high growth target in an effort to recover from the current economic difficulties.

On the other hand, the annual growth rate of GDP of Latin American Countries from 1985 to 2010 is estimated at 3% by two think tanks, one in Japan and the other in America.

In this study, it is assumed that the annual rate of real economic growth of the Dominican Republic will be 5% from 1986 to 1990 and 3% from 1991 to 2005. Table II.2.7 shows the future GDP estimated under this assumption.

Table II.2.7 Estimated Future GDP of the Dominican Republic

(Unit: Million Pesos)

	1985 (Actual Value)	1995	2005
GDP at Constant 1970 Prices	3,174.2	4,696.4	6,311.6

2.3 Production and Foreign Trade of Agricultural Products

Table II.2.8 shows the estimated agricultural production in 1990 by subregion. Table II.2.9 shows the forecast import and export volumes of the main agricultural products from 1986 to 1995.

Table II.2.8 Forecast Agricultural Production in 1990 by Subregion

(Unit: 1,000 tons)

Product \ Subregion	Subregion Cibao Central	Subregion Cibao Oriental	Subregion Cibao Occidental	Subregion Enriquillo	Subregion del Valle	Subregion Valdesia	Subregion del Yuma	Total
Grain								
Rice	90.5	141.1	130.0	2.8	69.6	13.5	16.7	464.2
Corn	46.9	20.6	10.1	7.7	51.0	11.5	9.6	157.4
Wheat	-	-	257.2	16.3	205.5	-	-	479
Roots								
Potatoes	16.9	0	-	-	1.3	12.4	4.1	34.7
Yuca	106.8	69.5	41.8	6.3	51.6	50.2	24.9	351.1
Yautia	1.1	35.6	0.1	1.0	0.4	18.8	18.8	75.8
Name	1.1	14.5	0.3	0.9	0.5	8.3	20.3	45.9
Sweet potatoes	58.9	25.6	4.2	3.7	22.7	6.5	1.6	123.2
Fruits								
Bananas	38.9	17.4	7.6	13.6	5.0	14.2	2.6	99.3
Legumes								
Habichuelas	30.3	6.2	8.8	12.0	47.2	15.1	11.1	130.7
Guandul	2.3	0.5	3.1	4.6	14.9	26.8	1.1	53.3
Meat								
Chicken	31.1	5.2	2.6	1.0	1.0	6.2	0.5	47.6
Beef	21.4	11.1	5.8	2.8	4.8	12.0	23.3	81.2
Fish	0	-	-	-	0	0	0	17.4
Pork	62.4	37.9	12.5	6.3	23.3	29.7	23.5	195.6
Oil								
Peanut	5.1	6.8	21.3	1.7	35.7	6.0	8.5	85.1
Vegetables								
Onions	4.0	0	1.7	0.4	1.4	14.1	0.1	21.7
Tomatoes	3.6	0	0.3	7.7	2.2	12.3	-	26.1
Pumpkins	4.7	0.1	2.1	2.3	5.0	3.3	-	17.5
Milk	146.4	82.3	50.3	16.0	16.0	91.5	54.9	457.4
Eggs	8.5	0.1	-	0.1	0.1	5.4	-	14.2
Sugar cane	434.0	-	229.7	944.5	-	4,454.6	6,701.0	12,763.8
Coffee	52.3	29.9	10.3	26.2	13.0	25.9	3.2	160.8
Cacao	9.2	35.2	-	-	-	5.7	9.5	59.6
Tobacco	583.0	4.1	11.0	0.8	2.3	3.4	1.3	605.9

Source: SEA

Table II.2.9 Forecast Import and Export Volume of Main Agricultural Products (From 1986 to 1995)

(Unit: 1,000 tons)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
EXPORT										
Sweet Potatoes	9.3	9.8	10.4	10.8	11.3	11.8	12.4	12.9	13.4	13.9
Ñame	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6
Yautia	20.7	21.7	22.7	23.7	24.7	25.7	26.7	27.6	28.7	29.6
Yuca	5.9	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8
Guandul	9.9	10.2	10.5	10.8	11.1	11.4	11.7	12.0	12.3	12.6
Pumpkins	4.3	4.5	4.7	4.9	5.0	5.2	5.4	5.6	5.8	5.9
Beef	3.3	3.3	3.3	3.3	3.4	3.4	3.4	3.4	3.5	3.5
Cacao	34.0	34.9	35.8	36.7	37.6	38.5	39.4	40.3	41.2	42.0
IMPORT										
Corn	213.1	226.9	240.8	254.7	268.5	282.4	296.3	310.2	324.0	337.9
Wheat	202.0	211.0	219.9	228.8	237.7	246.7	255.6	264.5	273.5	282.4

Source: Depto. Control Evaluatión, SEA

3. Hinterland of the Port of San Pedro de Macoris

Fig. II.2.1 shows the administrative division and the location of the international ports of the Dominican Republic.

San Pedro de Macoris is located in the Subregion del Yuma, in the southeast part of the country, 64 kilometers east from Santo Domingo, the capital. There are two international ports in this subregion: San Pedro de Macoris and La Romana. In the case of San Pedro de Macoris, all the port facilities are public. Several commodities such as sugar, cement and fertilizer are handled and there is also a regular ferry service.

On the other hand, almost all of the port facilities of La Romana belong to the Central Romana Corporation and these are used mainly to export sugar and molasses by this private company.

There is no port with large facilities on the north coast (Samana Bay side) of this subregion.

San Pedro de Macoris is well connected with the principal cities of this subregion such as Hato Mayor, Higuey and La Romana by road.

The Subregion de Valdesia located to the west of the Subregion del Yuma is the center of the economic activity and consumption of the Dominican Republic, and 40% of the national population concentrates in this subregion. There are three international ports, Haina, Santo Domingo and Boca Chica, in this subregion and 70% of the national marine cargo is handled at these three ports.

The port of Santo Domingo is the oldest port in the Dominican Republic and most marine cargo to and from the metropolitan area used to be handled at this port. Recently, a large passenger terminal was constructed at the Sans Souci area, opposite to the old terminal area. The port of Haina was opened in 1972. It is located 15km west from the port of Santo Domingo and has modern, large-scale port facilities. A considerable volume of cargo has been transferred from Santo Domingo to Haina. The port of Boca Chica is located 30km east from the port of Santo Domingo and it also functions as a port for the metropolitan area. Thus, these three ports can be regarded as the metropolitan port complex. Currently, APD administers only these three ports.

Currently, the Dominican government and APD are expanding the port of Haina including the construction of a new container terminal. On the other hand, they are planning to convert the ports of Santo Domingo and Boca

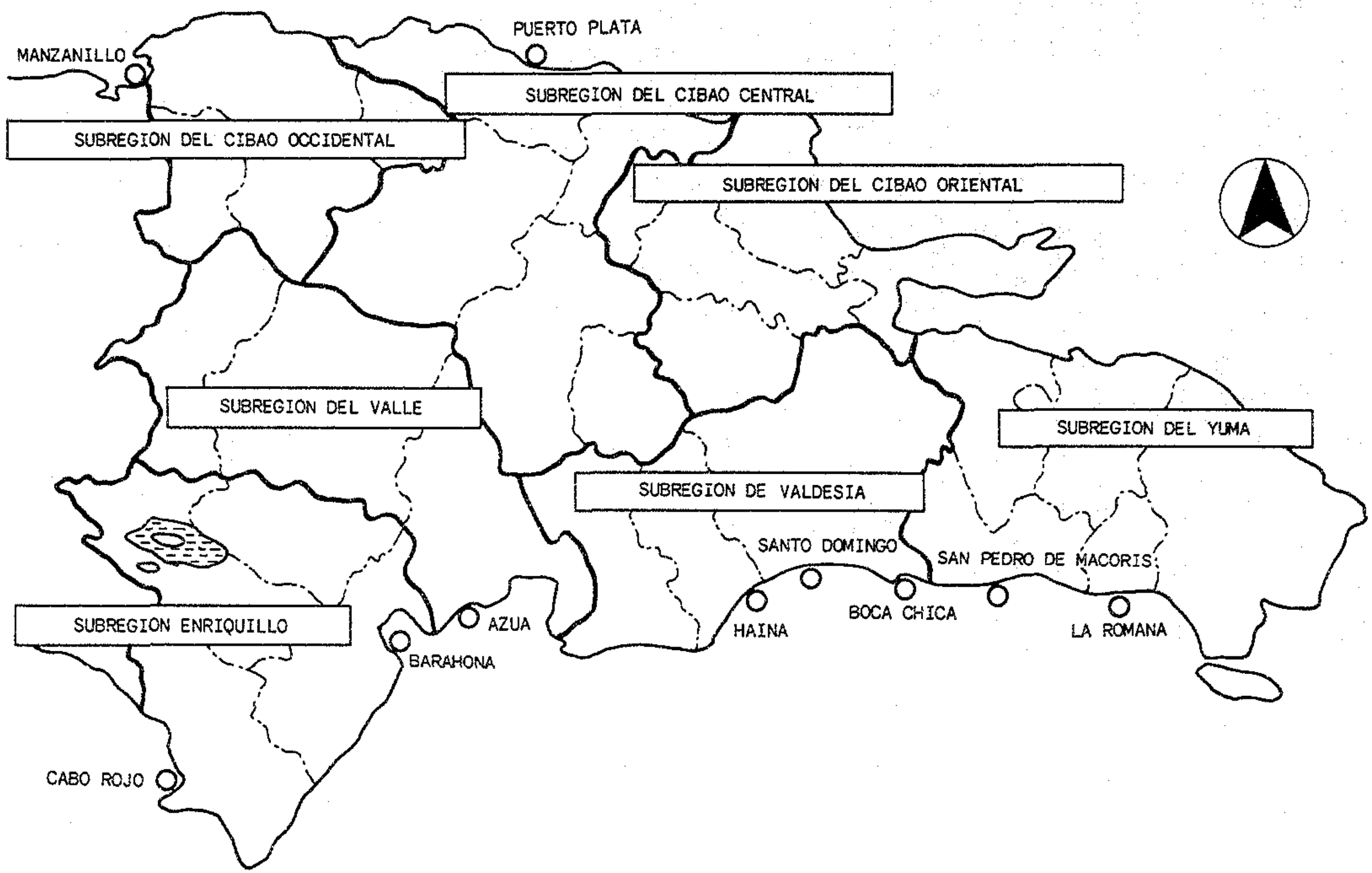

Fig. II.2.1 Administrative Division and the Location of the International Ports of the Dominican Republic

Chica into tourist ports in the future. As a result, the cargo presently handled at these two ports will mostly be handled at the port of Haina.

As mentioned in Chapter 1, the capacity of SPM Port is insufficient on account of the superannuation of facilities and the insufficient water depth. In consequence, almost all of the container cargo to and from the industrial free zone in San Pedro de Macoris and miscellaneous general cargo for the Subregion del Yuma must be handled at the metropolitan port complex and then transported to the Subregion overland. From the economic point of view, this is inefficient because the land transport cost is very high. If the facilities of SPM Port were improved, these cargoes could be handled at SPM Port, and significantly less land transport would be necessary.

According to a brief analysis of the capacity of the port of Haina carried out in APP.II.3, it is thought that there will be no overflow cargo from the port of Haina. Therefore, overflow cargo is not included in the estimated future cargo volume of the Port of San Pedro de Macoris in this study.

Considering this situation, the entire area of the Subregion del Yuma is considered as the hinterland of the Port of San Pedro de Macoris. The Subregion del Yuma consists of five provinces: El Seibo, Hato Mayor, La Altagracia, La Romana and San Pedro de Macoris.

4. Cargo Traffic Forecast of the Port of San Pedro de Macoris

4.1 General

Very little domestic cargo has been handled at the Port of San Pedro de Macoris except for gypsum unloaded at the private berth of the cement factory located upstream on the Higuamo River. It is presumed that this situation will not change in the future. Thus, mostly foreign trade cargo and ferry service are considered in the future cargo traffic estimate. In addition, Caribbean cruise passenger boats are also considered.

Generally, two methods are used for forecasting port cargo traffic. One is a macro forecast which is a method to estimate the total cargo volume as a group including many commodities, regardless of the volume of each commodity. The other is a micro forecast, which is a method to estimate the cargo volume of each commodity individually.

Table II.2.10 shows the major commodities which will be handled at SPM Port in the future.

Table II.2.10 Future Commodities at the Port of San Pedro de Macoris

EXPORT	Sugar Molasses Fertilizer Cement Clinker Products from industrial free zones Agricultural products Miscellaneous general cargo
IMPORT	Raw materials for fertilizer Coal and coke Fuel oil Materials for industrial free zones Agricultural products Miscellaneous general cargo