The steps of the forecast for transshipment container cargo volume in Sri Lanka are described below:

- Estimate the volume of containerizable cargo in each feeder area for the planning period;
- Estimate the grade of the ratio of containerization over the planning period by applying a logistic curve;
- Estimate container throughput in each feeder area for the planning period by multiplying the volume of containerizable cargo by the ratio of containerization.
- Estimate transshipment container cargo volume in Sri Lanka by considering Sri Lanka's share.

3-3 Demand Forecast for Import/Export Cargo

3-3-1 Hinterland of the Port of Galle

In general, the hinterland of the Port of Galle seems to be limited in the Southern Province: Galle, Matara and Hambantota districts. However, it is necessary to examine its reliability.

Appendix II-3-1 shows the comparison of the road distance from Colombo, Trincomalee and Galle to principal cities in Sri Lanka. Only Matara and Hambantota districts are closer to Galle than Colombo and Trincomalee. A part of Kalutara, Ratnapura and Monaragara districts are also closer to Galle than Colombo. However, it is necessary to take the present economic balance of Colombo and Galle into consideration. Consequently, Galle, Matara and Hambantota districts are to be defined as the hinterland of the Port of Galle at present.

3-3-2 Import Cargoes

(1) Paddy (Rice)

The total import volume of rice is estimated by the difference between consumption and production in Sri Lanka. Appendix II-3-2 shows some statistics on paddy sector from 1980 to 1989.

1) Future Production in Sri Lanka

The yield of rice per hectare increased by 15% from 1980 to 1989, and it will increase more in consideration of the increase of fertilizer issue per hectare in future (215 kg/ha in 1989). The future production of rice in Sri Lanka is calculated by correlation with the projected value added from the non-plantation agricultural sector in Sri Lanka, which is shown in Table 3-1-6 of this Chapter.

$$Y = 0.07909X + 55.47 \qquad (r = 0.811)$$

where, X: Value added Non-plantation agricultural sector in Sri Lanka (Rs. million)

Y: Production of rice in Sri Lanka ('000 M.T.)

An annual growth rate of about 3% seems to be reasonable, even though the correlation coefficient is rather low. A three year-time lag is to be adopted in the above equation because of the decrease of rice cultivation area due to the civil disturbances, that is:

Y = 1,995 '000 M.T. (1997)

Y = 2,548 '000 M.T. (2005)

2) Future Consumption in Sri Lanka

The average annual per capita consumption of rice in Sri Lanka from 1979 to 1981 was 95.3 kg and that in 1987 was 94.4 kg according to Food Balance Sheets (FAO). However, consumption has a tendency to increase during a good harvest year. Therefore, future consumption of rice in Sri Lanka is calculated based on the assumption that per capita consumption in Sri Lanka will increase by 10% up to 105 kg/year, as follows: (The projected population in Sri Lanka is shown in Table 3-1-1 of this Chapter)

2,167	'000 M.T.	(1997)
2,437	'000 M.T.	(2005)

3) Estimation of Import Volume

172	'000 M.T.	(1997)
0	M.T.	(2005)

4) Volume Handled at the Port of Galle

The Southern Province has gradually increased its share of rice production in Sri Lanka since 1985 and as of 1989 had a 14.3% share. In future, the province's share of total production will increase to 15%, whereby the province's production will surpass its local consumption. Therefore, rice will not be handled at the Port of Galle in future.

(2) Wheat & Flour

Since Sri Lanka has no domestic production of wheat/flour, all flour consumed in the country is imported.

The volume handled at the Port of Galle is to be decided after studying the trade and coastal transportation roles of three ports; Colombo, Trincomalee and Galle. Appendix II-3-3 shows volumes of wheat and flour handled at three ports from 1980 to 1989.

1) Future Consumption in Sri Lanka

The average annual per capita consumption of flour in Sri Lanka from 1979 to 1981 was 44.1 kg according to Food Balance Sheets (FAO). The future consumption of flour in Sri Lanka is calculated based on the assumption that per capita consumption in Sri Lanka will increase by 10% up to 48.5 kg/year as well as rice, as follows:

910	'000 M.T.	(1997)
1,011	'000 M.T.	(2005)

Consumption figures are directly tied to import volumes, as we mentioned above. Some 700,000 tons will be imported at the Port of Trincomalee according to the capacity of the port's flour mill. Flour of 700,000 tons is made from wheat of 1,077,000 tons.

2) Future Consumption in the Southern Province

Future consumption of flour in the Southern Province is calculated on the same basis as that for Sri Lanka, as follows:

113	'000 M.T.	(1997)
125	'000 M.T.	(2005)

3) Volume Handled at the Port of Galle

As mentioned in Chapter 2 of this Part, a new flour mill, to import wheat and export flour with no domestic distribution, will be located in the Galle port area. Production capacity of flour will be 65,000 tons in 1997 and 455,000 tons in 2005.

Therefore, total volumes handled at the Port of Galle consist of the wheat imported, the flour exported and the flour transported from Trincomalee.

The summary is shown in Table 3-3-1:

Table 3-3-1 Volume of Wheat/Flour Handled at the Port of Galle

(000 tons)

	Wheat(Import)	Flour (Export)	Flour (Coastal)
1997	100	65	113
2005	700	455	125

(3) Sugar

Total import volumes of sugar are estimated by the difference between consumption and production in Sri Lanka.

Appendix II-3-4 shows some statistics on sugar sector from 1980 to 1989.

1) Future Production in Sri Lanka

Sugar production is expected to increase steadily as sugar is one of the most important crops which the Government devote its energy to production.

The production of sugar changed irregularly and does not correlate with any socioeconomic indices as well as with time series. However, production has risen steadily in recent years and in 1989 was double the 1980 level (see Appendix II-3-4).

In estimating future production of sugar in Sri Lanka, we have assumed an average annual growth rate of 7.0%.

The result is as follows:

93	'000 M.T.	(1997)
159	'000 M.T.	(2005)

2) Future Consumption in Sri Lanka

The annual per capita consumption of sugar in Sri Lanka has gradually increased from 16.6 kg in 1980 to 24.4 kg in 1987 according to Appendix II-3-4. Future consumption of sugar in Sri Lanka is calculated on the assumption that the per capita consumption in Sri Lanka will increase by 1% per annum, reaching a ceiling of 30 kg/year, as follows:

507	'000 M.T.	(1997)
608	'000 M.T.	(2005)

3) Estimation of Import Volume

414	'000 M.T.	(1997)
449	'000 M.T.	(2005)

4) Volume Handled at the Port of Galle

Since there is no production of sugar in the Southern Province, all sugar consumed in the province is imported. The import volume at the Port of Galle is calculated by using the ratio of the population of the Southern Province to the national population. However, as only a small volume of sugar is handled at the Port of Galle at present, the percentage of the province's sugar imports handled at the port will increase by 10% per annum from 50% to 100% during from 1994 to 1999. Projected import volume at the Port of Galle is as follows:

41	'000 M.T.	(1997)
56	'000 M.T.	(2005)

(4) Fertilizer

Due to the high cost of manufacturing, domestic production of urea fertilizer has been abandoned. Thus, Sri Lanka has no production of fertilizer at present except for small quantity of local rock phosphate at Eppawala (around 25,000 tons per annum) and dolomite. All fertilizer consumed in the country are assumed to be imported for the calculation purpose.

1) Future Consumption in Sri Lanka

Fertilizer issues for rice, tea, rubber, coconuts and other crops are shown in Appendix II-3-5.

As these issues changed irregularly, they do not correlate with any socioeconomic indices. Therefore, future consumption of fertilizer is calculated by using the average issue of fertilizer per production volumes from 1980 to 1989 for rice, tea, rubber and coconuts, and is calculated by using a time series analysis for other crops, where production data are not available.

Future production of rice is refered to "3-3-2 (1)" and those of tea, rubber and coconuts are refered to "3-3-3 (1), (2) and (3)", respectively.

Average fertilizer issues per production (ton) are as follows:

121.7 kg/M.T.	for rice
608.4 kg/M.T.	for tea
168.3 kg/M.T.	for rubber
46.2 kg/M.T.	for coconuts

The correlation equation by time series analysis is as follows:

$$Y = 4.404X - 8,664 \quad (r = 0.968)$$

where, X: Year

Y: Fertilizer issues for other crops ('000 tons)

The summary of future consumption of fertilizer is shown in Table 3-3-2.

Table 3-3-2 Future Consumption of Fertilizer in Sri Lanka

('000 tons)

Year	Paddy	Tea	Rubber	Coconuts	Others	Total
1997	242.8	137.5	20.9	49.3	130.4	581
2005	310.1	160.0	24.4	56.4	165.6	717

The import volume of fertilizer is the same as the consumption in Sri Lanka, as mentioned above.

2) Volume Handled at the Port of Galle

Statistics of fertilizer issues in the Southern Province are available only in 1986 and 1987 (see Appendix II-3-6). They show that the ratios of fertilizer issues in the Southern Province to those in Sri Lanka were 16.5% and 16.1%, respectively.

The Study Team adopted the ratio of 18.0% in consideration of the future development of the Southern Province.

The import volume at the Port of Galle should be the same as the consumption in the Southern Province. However, as fertilizer is not handled at the Port of Galle at present, the percentage of the province's fertilizer imports handled at the port will increase by 10% per annum from 50% to 100% during from 1994 to 1999. Consequently, the projected import volume at the Port of Galle is as follows:

84	'000 M.T.	(1997)
129	'000 M.T.	(2005)

All fertilizer handled at the Port of Galle will be in bulk.

(5) Cement

There are six cement factories in Sri Lanka, of which four are public factories. However, some factories have been shut down because of the civil disturbances, while almost all factories require modernization of production. In recent years, therefore, cement production in Sri Lanka was around 600,000 tons, compared with 1,000,000 tons of the demand.

The total import volume of cement is estimated by the difference between consumption and production in Sri Lanka. Appendix II-3-7 shows some statistics on cement sector from 1983 to 1989.

1) Future Production in Sri Lanka

Total production capacity of cement factories in Sri Lanka currently is about 1.3§1.5 million tons per annum.

Future production of cement in Sri Lanka is based on the assumption that the factories will produce cement at full capacity in 1997, and that their total capacity will increase by 50% by the year 2001, owing to modernization of their facilities. Thereafter, it will increase by 5.5% per annum, in line with growth in GDP. Projected cement production is as follows:

1,400	'000 M.T.	(1997)
2,745	'000 M.T.	(2005)

2) Future Consumption in Sri Lanka

Future consumption of cement in Sri Lanka is calculated based on the assumption that the per capita consumption will increase by 5 kg per annum after 1989 and that it will increase by 10 kg per annum after reaching 100 kg/year, in consideration of worldwide trend of per capita consumption of cement (refer to Appendix II-3-8). Projected cement consumption is as follows:

1,877	'000 M.T.	(1997)
3,751	'000 M.T.	(2005)

3) Estimation of Import Volume

477	'000 M.T.	(1997)
1,006	'000 M.T.	(2005)

4) Future Consumption in the Southern Province

Future consumption of cement in the Southern Province is calculated by multiplying the national consumption by the ratio of GDP of the Southern Province to the national GDP, as follows: (Projected GDP figures for the Southern Province and for Sri Lanka are shown in Table 3-1-5 and 3-1-8, respectively.)

203	'000 M.T.	(1997)
455	'000 M.T.	(2005)

5) Volume Handled at the Port of Galle

There is a public cement factory in the Galle District. The factory currently has the capacity of 200,000 tons, which will rise to 300,000 tons in 2005 as mentioned in Chapter 2 of this Part. This capacity reflects cement production in the Southern Province. Cement volume of difference between production and consumption and clinker for cement factory will be handled at the Port of Galle as follows:

Cement		Clinker		
0	M.T.	194	'000 M.T.	(1997)
155	'000 M.T.	291	'000 M.T.	(2005)

All cement and clinker handled at the Port of Galle will be in bulk.

(6) Other Break Bulk Cargo

The other import break bulk cargoes comprise all break bulk cargoes other than rice, wheat/flour, sugar, fertilizer and cement.

1) Estimation of Import Volume

Import volumes of break bulk cargoes do not correlate with GDP in Sri Lanka. Therefore, in this Study, the future import volume of other break bulk cargoes is calculated by using an elastic value which is calculated based on the difference between the growth rate of the cargo volume and the GDP from 1980 to 1989. The volume of other break bulk cargo from 1980 to 1989, the GDP in Sri Lanka from 1980 to 1989 and the future GDP in Sri Lanka are shown in Appendix II-3-9, I-2-3 and Table 3-1-5, respectively. The projected import volume in Sri Lanka is as follows:

1,870	'000 M.T.	(1997)
2,869	'000 M.T.	(2005)

2) Volume Handled at the Port of Galle

The import volume of other break bulk cargo at the Port of Galle is calculated by using the ratio of the GDP of the Southern Province to that of Sri Lanka. However, as only a small volume of other break bulk cargo is handled at the Port of Galle at present, the percentage of its export handled at the port will increase by 10% per annum from 50% to 100% during from 1994 to 1999. The projected import volume at the Port of Galle is as follows:

162	'000 M.T.	(1997)
348	'000 M.T.	(2005)

(7) Liquid Bulk Cargo

It is not necessary to forecast volumes of liquid bulk cargo, because the Port of Galle will only bunker oil during the planning period.

3-3-3 Export Cargoes

(1) Tea

Total export volumes of tea are estimated by measuring the difference between production and consumption in Sri Lanka. Appendix II-3-10 shows some statistics on tea sector from 1980 to 1989.

1) Future Production in Sri Lanka

The yield per hectare of tea in Sri Lanka is currently rather low at about 1,000 kg, compared with 2,000 kg in India. However, tea is one of the most important crops in generating foreign currencies. As such government has an investment plan to improve the efficiency of tea production, in particular for small holders.

Effects of this investment should be visible from 1995. Future production of tea in Sri Lanka is calculated based on the assumption that production will increase by 1% per annum up to 1995 and that it will increase by 10% per every five (5) years from 1996, as follows:

226	'000 M.T.	(1997)
263	'000 M.T.	(2005)

2) Future Consumption in Sri Lanka

As tea has been a traditional product in Sri Lanka, the per capita consumption is unlikely to drastically change in future. Future consumption of tea in Sri Lanka is calculated by using the average per capita consumption from 1980 to 1989, as follows:

26	'000 M.T.	(1997)
28	'000 M.T.	(2005)

3) Estimation of Export Volume

The export volume of tea in Sri Lanka is calculated by multiplying the difference between production and consumption by the elastic value, which is calculated mainly based on the difference between the port's statistics and customs' statistics. Projected export volume in Sri Lanka is as follows:

488	'000 M.T.	(1997)
574	'000 M.T.	(2005)

4) Future Production in the Southern Province

Cultivation of low grown tea is prosperous in the Southern Province, in particular Galle and Matara districts. The area under tea cultivation in the province has increased steadily despite a general decline in Sri Lanka. The province's share of the total area in Sri Lanka under tea cultivation in 1988 was 15.0%, compared with 12.9% in 1982 (see Appendix II-3-11). Further, the province's share of total fertilizer issues in Sri Lanka is more than 25% (refer to Appendix II-3-6); then, the tea yield per hectare in the Southern Province is more than 1,200 kg/ha, compared with 1,000 kg/ha in Sri Lanka.

The future production of tea in the Southern Province is calculated based on the assumption that the province's share of the total area in Sri Lanka under tea cultivation will increase by 0.1% per annum, and that the yield per hectare in the province will remain 1.2 times that in Sri Lanka. Projected production in the province is as follows:

42	'000 M.T.	(1997)
51	'000 M.T.	(2005)

5) Future Consumption in the Southern Province

The method is the same as "Future Consumption in Sri Lanka". Projected consumption in the Southern Province is as follows:

3	'000 M.T.	(1997)
4	'000 M.T.	(2005)

6) Volume Handled at the Port of Galle

The export volume of tea at the Port of Galle is calculated by multiplying the difference between the production and consumption by the elastic value, which is based on the difference between the port's statistics and customs' statistics. However, as only a small volume of tea is handled at the Port of Galle at present, the percentage of tea exports handled at the port will increase by 10% per annum from 50% to 100% from 1994 to 1999. The projected export volume at the port is as follows:

75	'000 M.T.	(1997)
114	'000 M.T.	(2005)

(2) Rubber

The total export volume of rubber is estimated by measuring the difference between production and consumption in Sri Lanka. Appendix II-3-12 shows some statistics on rubber sector from 1980 to 1989.

1) Future Production in Sri Lanka

The yield per hectare of rubber in Sri Lanka currently is rather low at about 800 kg, compared with 1,400 kg in Malaysia. However, rubber is another important crop in terms of generating foreign currencies. The government has an investment plan to improve the efficiency of rubber production, in particular for small holders.

Effects of this investment should be visible from 1995. The future production of rubber is calculated based on the following assumption:

a) The production of rubber is calculated by multiplying the yield per hectare by area under tapping.
b) The yield per hectare in 1990 is the average value for the last decade. It will increase by 1% per annum up to 1995, and increase by 2% per annum from 1996.
c) Area under tapping in 1990 is calculated by using the average rate of decline from 1980 to 1989 and the area will remain after 1991.

124	'000 M.T.	(1997)
145	'000 M.T.	(2005)

2) Future Consumption in Sri Lanka

As the consumption of rubber in Sri Lanka does not correlate with any socioeconomic indices, it is calculated by using the average growth rate of 3.80% from 1980 to 1989 as follows:

28	'000 M.T.	(1997)
38	'000 M.T.	(2005)

3) Estimation of Export Volume

The export volume of rubber in Sri Lanka is calculated by multiplying the difference between production and consumption by the elastic value, which is calculated based on the difference between the port's statistics and customs' statistics. Projected export volume in Sri Lanka is as follows:

105	'000 M.T.	(1997)
118	'000 M.T.	(2005)

4) Future Production in the Southern Province

Rubber is cultivated mainly in the Galle and Matara districts. Both production and the area under tapping of rubber in the province have slowly decreased as have those in Sri Lanka. Both the province's shares of the total production and the total area under tapping of rubber in Sri Lanka from 1982 to 1986 have shown similar downtrends (see Appendix II-3-13 and II-3-14). It is the main reason that rubber raw materials have been in short supply in the province, despite that the replanting of rubber of 3% per annum is required.

The short supply of raw materials is to be recovered to the average level, to some extent, in Sri Lanka till 1995. Future production of rubber in the province is calculated based on the assumption that the province's share of the total rubber production in Sri Lanka will slip by 0.1% per annum to 1995 and that the share will remain from 1996, as follows:

16	'000 M.T.	(1997)
18	'000 M.T.	(2005)

5) Future Consumption in the Southern Province

Consumption of rubber in the Southern Province has been estimated at about 1% of production in the province, due to the lack of development of rubber industries, based on the Marga Institute's report: "Strategy for the Accelerated Development of the Southern Province of Sri Lanka". The ratio will remain during the planning period; then, increase in future consumption will be negligible.

6) Volume Handled at the Port of Galle

The export volume of rubber at the Port of Galle is calculated by multiplying production by the elastic value, which is calculated based on the difference between the port's statistics and customs' statistics. However, as only a small volume of rubber is handled at the port at present, the percentage of province's rubber exports handled at the port will increase by 10% per annum from 50% to 100% during from 1994 to 1999. Projected export volume at the port is as follows:

14	'000 M.T.	(1997)
20	'000 M.T.	(2005)

(3) Coconuts & Coconut Products

The total export volume of coconuts & coconut products is estimated by measuring the difference between production and consumption in Sri Lanka. Appendix II-3-15 shows some statistics on the coconut sector from 1980 to 1989 and Appendix II-3-16 shows the relation among the export, production and consumption of coconuts and the conversion factor between "tons" and "nuts".

1) Future Production in Sri Lanka

Production of coconuts & coconut products does not correlate with the sectoral GDP of plantation agriculture. Sri Lanka's yield per hectare of coconuts is relatively low, compared with the Far East countries. However, coconuts are important foreign exchange crops, and production of coconuts has a tendency to increase.

It is calculated based on the assumption that production in 1990 will be the average value from 1985 to 1989, that it will increase by 2% per annum up to 2000 and that it will increase by 1.5% per annum from 2001. Projected production in Sri Lanka is as follows:

1,067	'000 M.T.	(1997)
1,220	'000 M.T.	(2005)

2) Future Consumption in Sri Lanka

As the per capita consumption of coconuts & coconut products changed very little in Sri Lanka for the last decade, it is also not expected to change in future. Future consumption of coconuts in Sri Lanka is calculated by using the average per capita consumption from 1980 to 1989, as follows:

786	'000 M.T.	(1997)
873	'000 M.T.	(2005)

3) Estimation of Export Volume

The figures for production and consumption of coconuts & coconut products include coconut oil. The average share of the coconut oil exports to total exports of coconuts & coconut products, which can be calculated based on Appendix II-3-16, is about 12%. The future export volume of coconuts & coconut products excluding coconut oil is calculated by using the above share and shown in Table 3-3-3.

Table 3-3-3 Future Export Volume of Coconuts & Coconut Products

(Unit: 000 tons)

Year	Coconuts & Coconut Products	Coconut Oil	Total
1997	247	34	281
2005	305	42	347

4) Future Production in the Southern Province

The province's share of total area in Sri Lanka under coconut cultivation was 12.5% according to "Census of Agriculture 1982". As there is no available data concerning production in the province, future production of coconuts in the province is calculated by using the above share, as follows:

133	'000 M.T.	(1997)
153	'000 M.T.	(2005)

5) Future Consumption in the Southern Province

The method is the same as "Future Consumption in Sri Lanka". Projected consumption in the Southern Province is as follows:

97	'000 M.T.	(1997)
108	'000 M.T.	(2005)

6) Volume Handled at the Port of Galle

The export volume of coconuts & coconut products excluding coconut oil at the Port of Galle should be 88% of the volume estimated by the difference between production and consumption in the Southern Province. However, as only a small volume of coconuts is handled at the port at present, the percentage of the province's coconut exports handled at the port will increase by 10% per annum from 50% to 100% from 1994 to 1999. All coconut oil will be exported at the Port of Colombo. Projected export volume at the port is as follows:

25	'000 M.T.	(1997)
40	'000 M.T.	(2005)

(4) Other Break Bulk Cargoes

The other export break bulk cargoes are comprised of all break bulk cargoes other than tea, rubber and coconuts and coconut products.

1) Estimation of Export Volume

Export volumes of break bulk cargoes do not correlate with GDP in Sri Lanka. Therefore, in this Study, the future export volumes of other break bulk cargoes are calculated by using an elastic value, which is calculated based on the difference between the growth rate of the cargo volume and the GDP of mining, manufacturing and construction sectors from 1982 to 1989. The sectoral GDP in Sri Lanka from 1980 to 1989 and the future sectoral GDP in Sri Lanka are shown in Appendix I-2-3 and Table 3-1-6, respectively. Projected export volume in Sri Lanka is as follows:

819	'000 M.T.	(1997)
1,562	'000 M.T.	(2005)

2) Volume Handled at the Port of Galle

The export volumes of other break bulk cargoes at the Port of Galle are calculated by using the ratio of the GDP of the Southern Province to that of Sri Lanka. However, as only a small volume of other break bulk cargoes are handled at the Port of Galle at present, as shown in Chapter 5 of Part I, the percentage of exports handled at the port will increase by 10% per annum from 50% to 100% from 1994 to 1999.

71	'000 M.T.	(1997)
189	'000 M.T.	(2005)

(5) Liquid Bulk Cargoes

Forecasting volumes of liquid bulk cargoes is not necessary, because the Port of Galle will only bunker oil during the planning period.

3-3-4 Container Cargo Volume

The volume of container cargo and the number of containers are forecast by using the following procedure:

-Selection of containerizable cargo

-Estimation of the ratio of container cargo to containerizable cargo

-Estimation of the volume of container cargo and the number of containers

(1) Containerizable Cargo in Sri Lanka

Containerizable import cargoes in Sri Lanka are composed of rice, flour, sugar, bagged fertilizer, bagged cement and other break bulk cargoes. In regards to export cargoes, all cargoes, excepting liquid bulk cargo, are considered containerizable cargoes. The volume of containerizable cargo is calculated as the sum of these commodities.

Appendix II-3-17 and II-3-18 show the volumes of containerizable import/export cargoes from 1980 to 1989 and in future.

(2) Ratio of Containerization in Sri Lanka

Appendix II-3-17 and II-3-18 also show the volumes of containerized import/export cargoes from 1980 to 1989. The ratio of container cargo volume to containerizable cargo volume in future is calculated by making a logistic curve based on the data in Appendix II-3-17 and II-3-18.

1) For Import Cargo

The maximum limit of the ratio of containerization for import cargo is assumed to be 85% after estimating the containerized ratio of each commodity.

The ratio of containerization during the planning period is shown by the following equation:

$$Y = \frac{85}{1 + e^{(323.110 - 0.1621X)}}$$

where, X: Year

Y: Ratio of containerization (%)

2) For Export Cargo

The maximum limit of the ratio of containerization for export cargo is assumed to be 95% after estimating the containerized ratio of each commodity.

The ratio of containerization during the planning period is shown by the following equation:

$$Y = \frac{95}{1 + e^{(496.663 - 0.2503X)}}$$

where, X: Year

Y: Ratio of containerization (%)

3) Summary

Table 3-3-4 shows the past trend of the ratio of containerization from 1980 to 1989 and the result of the calculations.

Table 3-3-4 Ratio of Containerization

	Year	Raito of Containerization (%)	
		Import	Export
Past Trend	1980	4.44	17.63
	1981	12.69	33.49
	1982	18.81	35.26
	1983	18.00	37.24
	1984	17.75	45.45
	1985	18.44	48.74
	1986	20.83	53.95
	1987	22.91	62.61
	1988	23.22	66.09
	1989	27.62	70.94
Estimate	1997	56.05	90.92
	2005	74.49	94.43

(3) Container Cargo Volume and Number of Containers in Sri Lanka

The cargo volumes of containers for import and export are calculated by multiplying the containerizable cargo volume mentioned in (1) by the ratio of containerization estimated in (2).

The cargo volumes in TEUs are then estimated by dividing the above container cargo volume by 13.4 tons per TEU for imports and 12.5 tons for exports. However, these figures do not reflect the effect of empty containers. The total volumes of TEUs are obtained by calculating in TEUs of empty containers; the ratios here are assumed to be 33.9% for import containers and 19.6% for exports. The tonnage per TEU and the ratio of empty containers for imports and exports are calculated in Appendix II-3-19 as average values from 1980 to 1989.

Table 3-3-5 shows the container cargo volume and the number of containers for import and export in Sri Lanka during the planning period of this project.

Table 3-3-5 Container Cargo Volume and Number of Containers for Import and Export in Sri Lank

Year	Container Cargo Volume		Number of Containers	
	Import (000 tons)	Export (000 tons)	Import (000 TEUs)	Export (000 TEUs)
1997	1,854	1,508	211	151
2005	3,067	2,416	349	242

(4) Containers Handled at the Port of Galle

The container cargo volume handled at the Port of Galle is calculated by using the ratio of containerization estimated in (2). However, the following assumptions are to be considered:

-All wheat, fertilizer, cement and clinker for import are in bulk;
-All flour coming from Tricomalee is in break bulk;
-All flour for export is containerized.

The number of containers handled at the port is based on Appendix II-3-19.

The results are shown in Table 3-3-6.

Table 3-3-6 Container Cargo Volume and Number of Containers handled at the Port of Galle

Year	Container Cargo Volume		Number of Containers	
	Import (000 tons)	Export (000 tons)	Import (000 TEUs)	Export (000 TEUs)
1997	114	233	13	23
2005	301	798	34	80

3-3-5 Summary

The cargo volume, handled at the Port of Galle, by commodity is shown in Table 3-3-7. The cargo volume by handling mode is shown in Table 3-3-8.

Table 3-3-7 Cargo Volume at the Port of Galle by Commodity

(Unit: '000 tons)

	1997	2005
(Import)		
Bulk Wheat	100	700
Bulk Fertilizer	84	129
Bulk Cement	0	155
Bulk Clinker	194	291
Flour (Coastal)	113	125
Sugar	41	56
General Cargo	162	348
Total	694	1,804
(Export)		
Containerized Flour	65	455
Tea	75	114
Rubber	14	20
Coconuts & Coconut Products	25	40
General Cargo	71	189
Total	250	818

Table 3-3-8 Cargo Volume at the Port of Galle by Handling Mode

	1997	2005
(Import)		
Bulk('000 tons)	378	1,275
Break Bulk ('000 tons)	202	228
Container ('000 tons)	114	301
Loaded ('000 TEUs)	8.5	22.5
Empty ('000 TEUs)	4.4	11.7
Total ('000 TEUs)	12.9	34.2
(Export)		
Bulk('000 tons)	0	0
Break Bulk ('000 tons)	17	20
Container ('000 tons)	233	798
Loaded ('000 TEUs)	18.7	63.8
Empty ('000 TEUs)	4.7	16.0
Total ('000 TEUs)	23.3	79.8
(Total)		
Bulk('000 tons)	378	1,275
Break Bulk ('000 tons)	219	248
Container ('000 tons)	347	1,099
Loaded ('000 TEUs)	27.1	86.3
Empty ('000 TEUs)	9.1	27.7
Total ('000 TEUs)	36.2	114.0

3-4 Transshipment Cargoes

3-4-1 Container Cargo Volume Handled in Each Feeder Area

(1) Bangladesh

Data from Chittagong port are to be used, because virtually all containers have been handled at this port in Bangladesh.

1) Future Containerizable Cargo Throughput in Bangladesh

The volume of containerizable cargo in Bangladesh does not correlate with GDP figures for Bangladesh, which we have sourced from "the Overseas Economic Cooperation Handbook", issued by the Overseas Economic Cooperation Fund of Japan (OECF). Therefore, the future volume of containerizable cargo is to be adopted from the report of "Feasibility Study on Development Project of Container Terminal at Dhaka-Narayanganj Port in the People's Republic of Bangladesh", issued by JICA (refer to Appendix II-3-20).

2) Ratio of Containerization

Appendix II-3-21 shows the container cargo volume by TEU and by tonnage in Bangladesh from 1983 to 1988. The ratio of container cargo volume to containerizable cargo volume in future is calculated by making a logistic curve based on the data mentioned above.

The maximum limit of the ratio of containerization is assumed to be 90%.

The ratio of containerization during the planning period is shown by the following equation:

$$Y = \frac{90}{1 + e^{(615.483 - 0.3091X)}}$$

where, X: Year

Y: Ratio of containerization (%)

3) Container Cargo Volume Handled in Bangladesh

Future container cargo volume is calculated by multiplying the volume of containerizable cargo by the ratio of containerization, as follows:

2,582	'000 M.T.	(1997)
4,533	'000 M.T.	(2005)

(2) India

The major ports handling containers on the east coast of India are Calcutta, Haldia, Madras and Vishakhapatnam while those on the west coast are Bombay, Cochin, Kandla and Tuticorin. Although Tuticorin is on the east coast, this port is defined as a westcoast port in this Study because of its geographical location relative to Sri Lanka.

The data from these ports are to be used for the forecast of cargo volume in India.

1) Future Break Bulk Cargo Throughput in India

The volume of break bulk cargo in India does not correlate with GDP figures for India, which we have sourced from "the Overseas Economic Cooperation Handbook", issued by the OECF of Japan. The future growth rate of GDP in India is projected at 5% in "the Seventh 5-Year Plan in India". Therefore, the future volume of break bulk cargo is assumed to increase by 4% per annum in consideration of the difference between growth rates of the GDP and the break bulk cargo volume, which was obtained from "MOST in India", issued by the Ports Reforms Committee. Projected volume of break bulk cargo is as follows:

35,520	'000 M.T.	(1997)
48,610	'000 M.T.	(2005)

2) Ratio of Containerization

Appendix II-3-22 shows the container cargo volume and the number of containers in India from 1980 to 1986. They were calculated based on Appendix II-3-23 and II-3-24, which were obtained from "Containerization International Year Book".

The ratio of container cargo volume to break bulk cargo volume in future is calculated by making a logistic curve based on the data mentioned above. The maximum limit of the ratio of containerization is assumed to be 90%.

The ratio of containerization during the planning period is shown by the following equation:

$$Y = \frac{90}{1 + e^{(351.467 - 0.1762X)}}$$

where, X: Year

Y: Ratio of containerization (%)

3) Container Cargo Volume Handled in India

Container cargo volume is calculated by multiplying the volume of break bulk cargo by the ratio of containerization, as follows:

19,821	'000 M.T.	(1997)
38,055	'000 M.T.	(2005)

(3) Pakistan

Data from Karachi port are to be used, because virtually all containers have been handled at this port in Pakistan.

1) Future Total Cargo Throughput in Pakistan

The future cargo volume in Pakistan is calculated by correlation with the projected GDP of Pakistan, which is calculated by using a time series analysis. Figures for GDP and the total cargo volume from 1980 to 1985 were taken respectively from "the Overseas Economic Cooperation Handbook", issued by the OECF of Japan, and from "For the Development Study on the Port of Colombo in the Democratic Socialist Republic of Sri Lanka", by JICA.

The correlation equation between the total cargo volume and the GDP is as follows:

$$Y = 52.21X + 804.9 \qquad (r = 0.963)$$

where, X: GDP of Pakistan (Rs. '000 million)

Y: Total cargo volume in Pakistan ('000 tons)

Y = 30,207	'000 M.T.	(1997)
Y = 37,285	'000 M.T.	(2005)

2) Ratio of Containerization

Appendix II-3-25, which was obtained from "Containerization International Year Book", shows the container cargo volume and the number of containers in Pakistan.

The ratio of container cargo volume to total cargo volume in future is calculated by making a logistic curve based on the data mentioned above. The maximum limit of the ratio of containerization is assumed to be 60%.

The ratio of containerization during the planning period is shown by the following equation:

$$Y = \frac{60}{1 + e^{(554.565 - 0.2787X)}}$$

where, X: Year

Y: Ratio of containerization (%)

3) Container Cargo Volume Handled in Pakistan

Container cargo volume is calculated by multiplying the total cargo volume by the ratio of containerization, as follows:

15,770	'000 M.T.	(1997)
22,017	'000 M.T.	(2005)

(4) The Gulf & Red Sea

The following ports handling containers in the Gulf and Red Sea area are selected in consideration of the past records of SLPA.

1.	Mina Sulman	(Bahrain)	6. Dammam	(Saudi Arabia)
2.	Aqaba	(Jordan)	7. Jeddah	(Saudi Arabia)
3.	Shuwaikh	(Kuwait)	8. Port Rashid	(UAE, Dubai)
4.	Shuaiba	(Kuwait)	9. Fujairah	(UAE, Fujairah)
5.	Mina Qaboos	(Oman)	10. Khor Fakkan	(UAE, Sharjah)

Data from these ports are to be used to forecast the cargo volume in the Gulf and Red Sea.

The calculation of the ratio of containerization may be not required because that of the Gulf and Red Sea is assumed to have already reached its limit.

Appendix II-3-26 shows the container cargo volume and the number of containers in the Gulf and Red Sea from 1977 to 1988. They were calculated based on Appendix II-3-27, which was obtained from "Containerization International Year Book".

The future container cargo volume is calculated by using a time series analysis.

$$Y = 1{,}439X - 2{,}840{,}000 \quad (r = 0.976)$$

where, X: Year

Y: Container cargo volume in Gulf and Red Sea ('000 tons)

Y = 33,977 '000 M.T. (1997)

Y = 45,491 '000 M.T. (2005)

3-4-2 Sri Lanka's Share of Container Throughput in Each Feeder Area

(1) Bangladesh

Sri Lanka's share, tonnage per TEU and the ratio of empty containers are calculated based on statistics collected by SLPA.

Sri Lanka's share:	43.1 %
Tonnage per TEU:	13.6 M.T.
Ratio of empty containers:	5.1 %

It is assumed that Sri Lanka's share will decrease by 2% per annum from 43.1% to 38.8% from 2000 to 2005 in consideration of future development of facilities related to containers in other countries, and that tonnage per TEU and the ratio of empty cargo will remain at the same level. Projected container volume in Sri Lanka is as follows:

1,113	'000 M.T.,	86	'000 TEUs	(1997)
1,758	'000 M.T.,	136	'000 TEUs	(2005)

(2) India

Some 35% of total container volume is to be handled in East India, with 65% of the total is to be handled in West India, based on the past trend in Appendix II-3-23 and II-3-24.

Sri Lanka's share, tonnage per TEU and the ratio of empty containers are calculated based on statistics collected by SLPA.

	East India	West India
Sri Lanka's share:	31.5 %	25.0%
Tonnage per TEU:	13.0 M.T.	11.6 M.T.
Ratio of empty containers:	12.1 %	12.2%

It is assumed that Sri Lanka's share will decrease by 2% and 6% per annum from 31.5% to 28.4% and from 25.0% to 17.5% from 2000 to 2005, respectively, as same as (1), and that tonnage per TEU and the ratio of empty cargo will remain at the same level. Projected container volume in Sri Lanka is as follows:

(East India)				
2,185	'000 M.T.,	191	'000 TEUs	(1997)
3,776	'000 M.T.,	330	'000 TEUs	(2005)
(West India)				
3,221	'000 M.T.,	316	'000 TEUs	(1997)
4,329	'000 M.T.,	425	'000 TEUs	(2005)

(3) Pakistan

Sri Lanka's share, tonnage per TEU and the ratio of empty containers are calculated based on statistics collected by SLPA.

Sri Lanka's share:	7.1 %
Tonnage per TEU:	12.1 M.T.
Ratio of empty containers:	20.1 %

It is assumed that Sri Lanka's share will decrease by 2% per annum from 7.1% to 6.4% from 2000 to 2005 as same as (1), and that tonnage per TEU and the ratio of empty cargo will remain at the same level. Projected container volume in Sri Lanka is as follows:

1,105	'000 M.T.,	116	'000 TEUs	(1997)
1,407	'000 M.T.,	146	'000 TEUs	(2005)

(4) The Gulf & Red Sea

Sri Lanka's share, tonnage per TEU and the ratio of empty containers are calculated based on statistics collected by SLPA.

Sri Lanka's share:	2.9 %
Tonnage per TEU:	12.2 M.T.
Ratio of empty containers:	21.7 %

It is assumed that Sri Lanka's share will decrease by 4% per annum from 2.9% to 1.7% from 1995 to 2005 as same as (1), and that tonnage per TEU and the ratio of empty cargo will remain at the same level. Projected container volume in Sri Lanka is as follows:

907	'000 M.T.,	95	'000 TEUs	(1997)
792	'000 M.T.,	83	'000 TEUs	(2005)

3-4-3 Some Considerations about Container Throughput in Sri Lanka

(1) Effect of the Development of Madras Container Terminal

Madras Container Terminal is to be developed to cater to the requirements of the fourth-generation container ships up to the year 2000. The total container cargo volume handled in 2000 will be 420,000 TEUs, which is projected in the report of "Madras Port Master Plan Study", issued by Indian Ports Association. Some 30% (126,000 TEUs) will be handled by the fourth-generation ships and 70% (294,000 TEUs) by first and second-generation ships. The container cargo volume transferred from Sri Lanka is calculated based on the following assumptions:

- The fourth-generation ships are regarded as mother vessels;
- 40% of the container cargo handled by fourth-generation ships is local cargo (from and to Madras Port) based on the past trend;
- The other 60% is to be transshipment cargo for Chittagong, Calcutta, Haldia and Vishakhapatnam.

Madras local cargo:	31,500	TEUs
Transshipment cargo:	47,250	TEUs

(31,500 + 47,250 x 2 = 126,000)

Therefore, the number of containers transferred from Sri Lanka are about 80,000 TEUs. It is assumed that the number of transshipment containers will decrease by 8,000 TEUs per annum from 1991 to 2000 and that it will remain constant from 2001. The reducing factors ("Factor 1") are calculated as follows:

0.847 (1997)

0.781 (2005)

(2) Effect of Shipping Lines' Movements

As mentioned in Chapter 2 of Part I, American President Lines (APL) stopped using Colombo as a pivotal port for its feeder service to Karachi and Bombay (this function is now carried out by Fujairah) and to Calcutta and Chittagong (this function is now carried out by Singapore) in November 1988, because of the civil disturbances. Appendix II-3-28 and II-3-29 show that the average cargo volume per month previously handled by APL at Colombo was 22,850 TEUs, compared with 12,810 TEUs following its decision. It means that APL's cargo decreased by about 10,000 TEUs per month, or 120,000 TEUs per year. These cargoes are to be redistributed to each feeder area, except for the Gulf & Red Sea, according to the total volume handled at each feeder area.

However, instead of APL, Greenlanka Shipping (Evergreen) started the transshipment service (Colombo-Cochin-Bombay-Colombo) to take up the room resulting from APL's withdrawal. The cargo volume handled by Evergreen is about 40,000 TEUs per year based on an interview with Evergreen. This effects cargo volumes only to and from West India.

The ratio of the cargo volume decreased (by APL) and increased (by Evergreen) to the total cargo volume in Sri Lanka for each feeder area in 1988 can be calculated. "Factor 2" for each feeder area is calculated on the assumption that its ratio will remain in future.

0.739	(Bangladesh)
0.865	(East India)
0.926	(West India)
0.767	(Pakistan)
1.0	(Gulf & Red Sea)

(3) Effect of Transshipment between the Feeder Areas

It is necessary to reduce transshipment cargoes from one feeder area to another feeder area because of double accounting. It is calculated by using both origin/destination data of transshipment containers and their discharged/loaded data. The result of calculation shows that about 25,000 TEUs counted twice.

It is very difficult to distinguish which feeder area's cargo is doubly counted. Therefore, the volume calculated above is to be redistributed 15,000 TEUs to West India, where the largest volume of cargo is handled, and 10,000 TEUs to the Gulf & Red Sea, where almost all cargo is biased to Fujairah, in 1990.

The ratio of the cargo volume decreased to the total cargo volume in Sri Lanka for two feeder areas in 1988 can be calculated. "Factor 3" for two feeder areas is calculated on the assumption that its ratio will remain in future.

0.880	(West India)
0.863	(Gulf & Red Sea)

(4) Summary of Transshipment Container Throughput in Sri Lanka

The summary of transshipment container throughput in Sri Lanka is shown in Table 3-4-1.

Table 3-4-1 Transshipment Containers in Sri Lanka

(Unit: '000 TEUs)

		1997	2005
From/to the feeder ports	Bangladesh	54	78
	East India	140	223
	West India	257	346
	Pakistan	89	112
	Gulf & Red Sea	82	72
	Sub Total	622	831
From/to the Mother's ports		622	831
Total		1,244	1,662

3-4-4 Transshipment Container Volume Handled at the Port of Galle

(1) Examination of the Capacity of the Port of Colombo

Handling capacity for containers at the Port of Colombo was examined for the formulation of the Masterplan of the Port of Colombo two years ago. Consequently, containers of 300,000 TEUs per berth at Jaye Container Terminals (JCT) and 340,000 TEUs per three berths at Queen Elizabeth Quays (QEQ) were assumed.

Containers of 225,000 TEUs per berth at JCT and 178,000 TEUs at QEQ were handled in 1988, respectively. Based on the existing facilities, these handling capacities were judged to be the maximum. To attain target capacities, some improvement will be required as mentioned below:

1) JCT

Because of a lack of feeding container capacity, better connections between quays and container yards at the backsite are required. For instance, using transfer cranes, etc.

2) QEQ

The introduction of another gantry crane, securement of further stacking yards and introduction of computer operation system are required.

The attainment of these target capacities is not impossible, but there are many difficulties. Especially, in case of JCT, the situation changed considerably after the last examination of the capacity. Container handling pattern changed drastically due to the withdrawal of APL in Nov. 1988. Container volume handled at the port decreased from 450,826 TEUs in 1988 to 403,584 TEUs in 1989 despite an increase in the number of container ships visiting the port increased to 923 from 491 during the same period. It means that loading/unloading volume per ship rapidly decreased to less than half of the previous year. The composition of the size of containers also changed. The proportion of 40-foot containers in total dropped to 27% from 36% during the same period, despite an upward trend prior to APL's withdrawal.

These changes will reduce handling capacity; the original premise for capacity of 300,000 TEUs called for a 50% weighting in 40-foot containers. The actual handling capacity for containers is calculated based on the assumption that the proportion will be 30§40% in 1997 and that it will recover up to 50% in 2005. Moreover, after consideration of the change of the average ship size, which affects the handling productivity, the handling capacity is decided. They are 260,000 TEUs per berth in 1997 and 300,000 TEUs in 2005, respectively.

The total handling capacity for containers at the Port of Colombo is as follows:

1,380,000 TEUs (1997)
(260,000 x 4 + 340,000)

1,540,000 TEUs (2005)
(300,000 x 4 + 340,000)

(2) Transshipment Containers at the Port of Galle

All excess transshipment containers from the Port of Colombo will be handled at the Port of Galle. The results are shown in "3-5 Summary of the Cargo Forecast".

3-5 Summary of the Cargo Forecast

Table 3-5-1 and 3-5-2 show the total container throughput in Sri Lanka and at the Port of Colombo, respectively. Table 3-5-3 shows the total cargo throughput at the Port of Galle.

Table 3-5-1 Total Container Throughput in Sri Lanka

		1997	2005
Discharged	Container('000 TEUs)	211	349
Loaded	Container('000 TEUs)	151	242
Sub Total	Container('000 TEUs)	362	591
Transshipment	Container('000 TEUs)	1,244	1,662
Total	Container('000 TEUs)	1,606	2,253

Table 3-5-2 Total Container Throughput at the Port of Colombo

		1997	2005
Discharged	Container('000 TEUs)	198	315
Loaded	Container('000 TEUs)	128	162
Sub Total	Container('000 TEUs)	326	477
Transshipment	Container('000 TEUs)	1,054	1,063
Total	Container('000 TEUs)	1,380	1,540

Table 3-5-3 Total Cargo Throughput at the Port of Galle

		1997	2005
Discharged	Bulk ('000 Tons)	378	1,275
	Break Bulk ('000 Tons)	202	228
	Container ('000 TEUs)	13	34
Loaded	Break Bulk ('000 Tons)	17	20
	Container ('000 TEUs)	23	80
Sub Total	Bulk ('000 Tons)	378	1,275
	Break Bulk ('000 Tons)	219	248
	Container ('000 TEUs)	36	114
Transshipment	Container ('000 TEUs)	190	599
Total	Conventional ('000 Tons)	597	1,523
	Container ('000 TEUs)	226	713

4 MASTER PLAN

4-1 Port Development Policy

Through the analysis of port functions, the capacity of Galle Bay and so on, the following conclusions are reached:

(1) Promoting the development of the port for container transshipment cargo, making use of its advantageous location on international shipping routes.

(2) Enhancing the potential of a bulk cargo distribution base, exploiting locational advantage

(3) Contributing to regional development

1) Supporting the development of the EPZ by providing necessary port facilities such as a container terminal

2) Providing necessary facilities for industries directly related to the port

3) Providing necessary facilities for the transportation of commodities in the hinterland of the port

(4) Supporting other activities conducted within the Bay area

1) Maintaining the condition of the present fishery port facilities, to insure their full utilization

2) Securing some spaces for yacht anchoring now being conducted within the basin

(5) While there are some problems to be solved, the entire Bay area is designated as space for future development

(6) Securing safe navigation in the harbour taking into consideration natural conditions such as high waves, rocks scattered on the sea bed and so on.

(7) Connecting the port to land transportation facilities while avoiding traffic congestion

(8) Consideration of environmental preservation

4-2 Vessel Size and Berth Dimensions

(1) Container Cargo

The table below made by using the service schedule table of shipping lines in the Port of Colombo shows the distribution by size (TEU) of container vessels.

Table 4-2-1 Container Ship Size distribution (Port of Colombe)

Unit: %

TEU	<100	100 ~ 300	300 ~ 600	600 ~ 1000	1000 ~ 1500	1500 ~ 2000	2000 ~ 2500	2500 ~ 3000	3000 ~ 3500	>3500
Share	1.8	25.3	25.2	16.0	4.5	8.8	0.6	5.6	9.2	3.0

From this table following is understood:

a) More than 50% of container vessels belong to the category of 100～600 TEUs.

b) Fourth-generation container vessels (more than 3000 TEUs) occupy a share of 12.2%.

According to the report published by NYK (Nippon Yusen Kabushiki gaisha), eleven vessels with more than 3000 TEU capacity were newly introduced on main routes in 1989 (See Appendix II-4-1).

Many vessels with large capacity were introduced on the Far East, Japan/Europe route in 1989. There is a large possibility that this will make influence on the situation of the Port of Sri Lanka.

The main large vessels which already took part in main shipping route services are as follows:

Route: Far East and North America, American President Line
President Adams: 61,926GRT, 4,340TEU, 24.2 Knots
(L, B, Dr = 275.2m, 39.4m, 12.0m)
Route: Far East and Europe, NYK
Kaga: 51,047GRT, 3,618TEU, 23.0 knots

(L, B, Dr = 289.5m, 32.2m, 13.0m)

Route: Europe and North America, Sea-Land
Sea-Land Atlantic: 58,943GRT, 3,400 TEU, 18.0 Knots
(L, B, Dr = 289.5m, 32.2m, 12.6m)

Route: Around the World, Maersk
Maersk Tokyo: 52,191GRT, 4,000 TEU
(L, B, Dr = 294.3m, 32.2m, 13.5m)

In 1988, the number of over 3000-TEU-Type full container vessels in the world was 55 and their distribution was as follows;

3000~3500 TEU	3500~4000 TEU	Over 4000 TEU
45 (82%)	3 (5%)	7 (13%)

The length distribution was as follows:

240~260m	260~280m	280~300m
17 (31%)	21 (38%)	16 (29%)

According to new building order of container vessel, seventeen vessels with capacities of more than 3000 TEU were ordered by main shipping lines in 1989, and it can be said that the trend toward larger vessels is continuing (See Appendix II-4-2).

The Port of Galle will play a role as one of the hub ports on world shipping routes, taking over some of the functions being exercised by the Port of Colombo. Accordingly, it must be furnished with a sufficient capacity to accommodate the largest vessels that have been introduced in the East-West route.

In the case of Colombo, a berth with a length and depth of 330~350 m and 14m, respectively, was planned. This is the result of considering the trend of vessel size in the world and the physical limits of the port.

The planned berth will be the first container berth in the Port of Galle, and is also important factor for deciding the future development of the port. Therefore, the size of the berth should be at least the same as that of Colombo.

Based on these considerations, the criteria shown below shall be adopted as an objective container vessel:

50,000 GRT, 3,500 TEU type

Accordingly the berth dimension shall be as follows:

Length = 330§350m: Depth = -14m

In formulating the master plan, a length of 350 m is adopted.

(2) General cargo

It is not appropriate to use the data of ships that have previously called at the port of Galle for determining vessel size in formulating the future plan. It is first necessary to evaluate the ship size distribution in the port of Colombo.

The figure below shows the distribution of conventional ships which called at the port of Colombo in 1989. In this figure, there are some ships which are double-counted due to shifting from one berth to another during one arrival at the port.

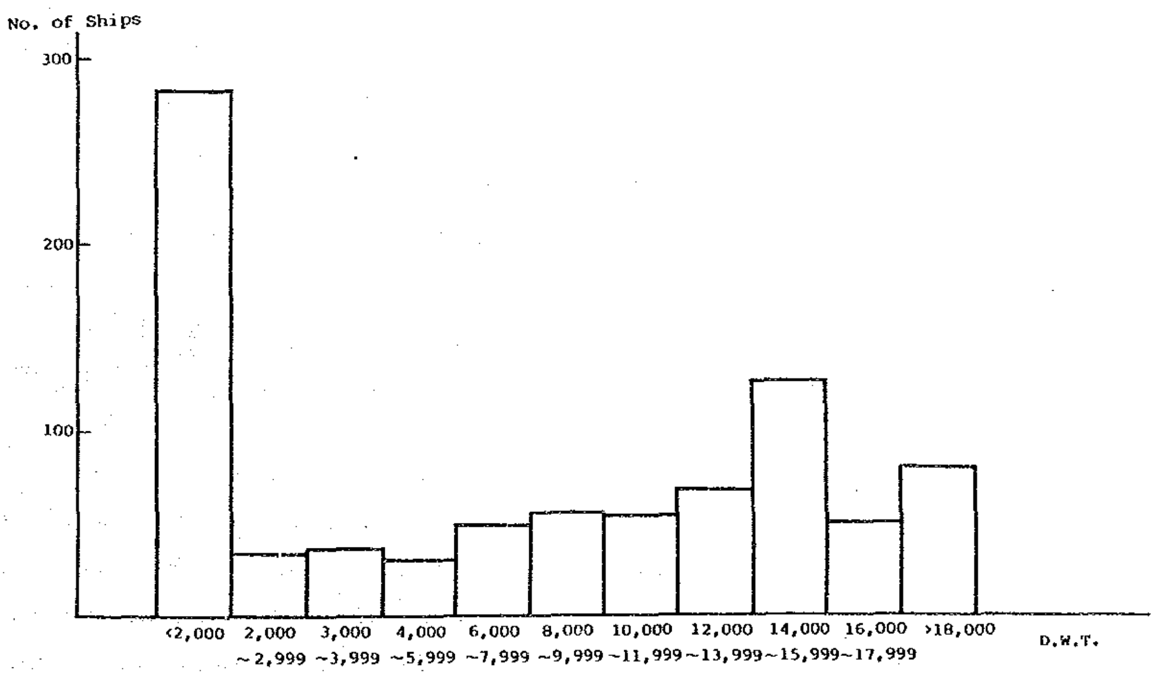


Fig. 4-2-1 Distribution of General Cargo Vessels by D.W.T. in the Port of Colombo

Of 876 vessels,the number of vessels whose capacities were less than 2000 DWT was 383(43.7%). Average vessel size was 7,354GRT and the maximum was 41,600 DWT. The maximum length was 197m.

Figure 4-2-2 shows the distribution of vessel size in use in the world. It is known that the average size of general cargo vessels around the world has not changed during the past 10 years.

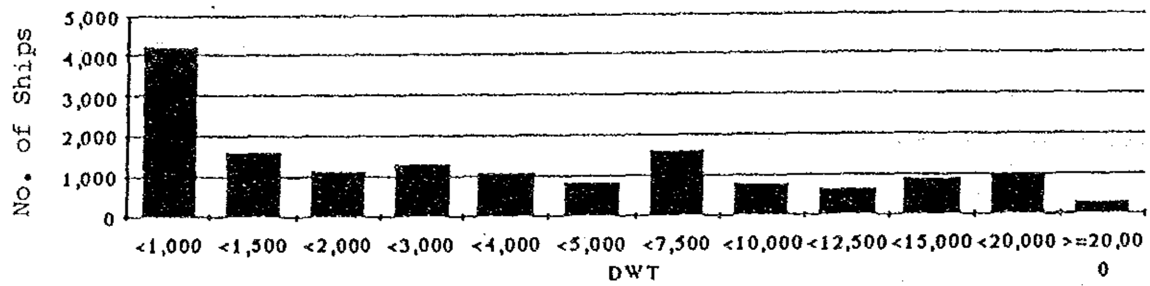


Fig. 4-2-2 Distribution of General Cargo Vessel Size in the World

It was found that larger vessels visited more at the port of Colombo by comparing Fig. 4-2-1 with Fig. 4-2-2. Most quay walls are less than 11 m maximum depth in the Port of Colombo. However, it cannot be said that there are any special problems in accommodating general cargo vessels to the port.

Judging from the above, it would be sufficient to have facilities of 11 m depth.

(3) Bulk cargo

It is anticipated that wheat, fertilizer, clinker and cement will be handled as the main bulk cargoes at the port of Galle in the future. Of these cargoes, the vessel size for wheat is assumed as the biggest.

In case of handling wheat, the port of Trincomalee is the main port in Sri Lanka. The number of vessels which conveyed wheat in the period from January to August in 1990 to the port of Trincomalee is 21. It is understood that the proportion of vessels weighing more than 50,000 DWT to the total is around 30%. The average vessel size was 34,890 DWT and the maximum was 66,900 DWT. Maximum overall length was 223m and the maximum draft was 12.2m. The total cargo volume of bulk wheat handled at the port of Trincomalee was 734,922 tons in 1989.

Fertilizer, at present, is transported in bags and general cargo vessels are used for conveying it. The cargo volume of fertilizer to be handled at the Port of Galle will be rather small, but there is some possibility that introduction of large vessels will be implemented.

The number of vessels which conveyed clinker to the port of Galle in 1989 was 18 and the average vessel size was 10,290 DWT. Their maximum size was 15,385 DWT, but such vessels are assumed to have entered the port after unloading some of their cargoes at the port of Colombo. The cement factory has an intention of introducing vessels of 20,000 - 30,000 DWT for carrying clinker after improvement of the port in order to save transportation costs. Ordinary vessel size of cement is around 10,000 DWT.

On the other hand, Fig. 4-2-3 shows distribution of ship size of bulk carriers in the world. It shows that there are two peaks in which one is 25,000 - 30,000 DWT and the other is 50,000 - 75,000 DWT. Fig. 4-2-4 shows the size distribution of bulk grain carriers. It is understood that the proportion of vessels of more than 80,000 DWT is very small.

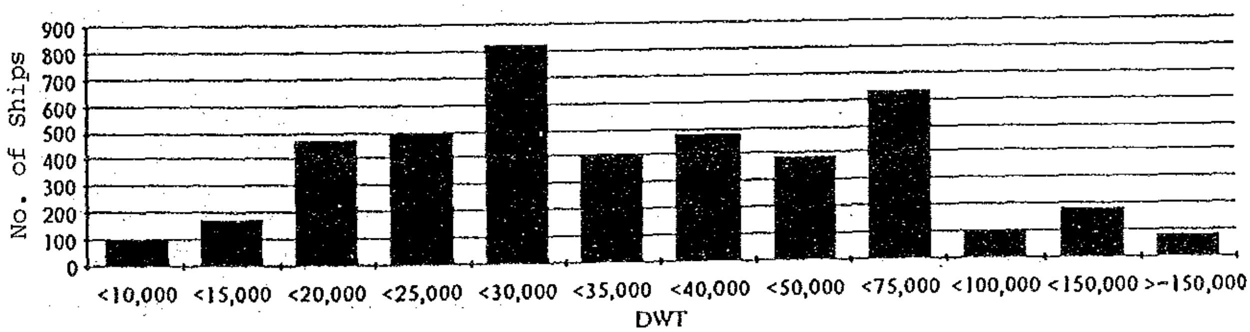


Fig. 4-2-3 Distribution of Bulk Carrier Size

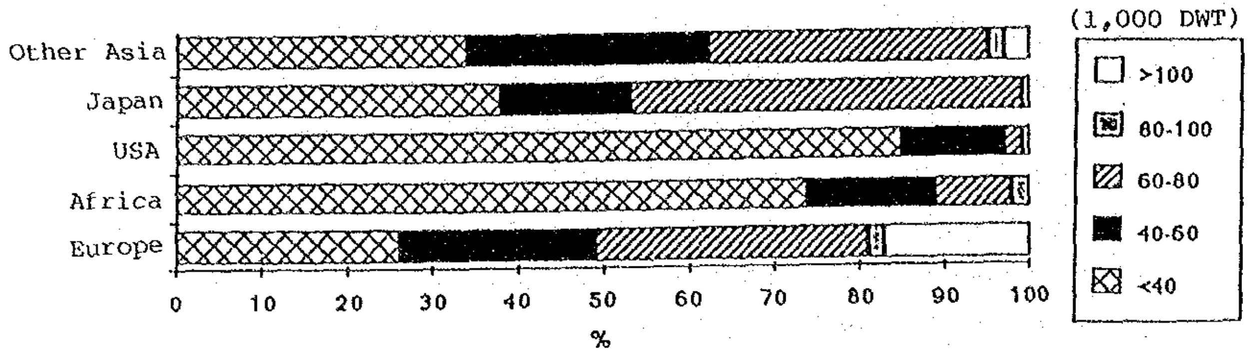


Fig. 4-2-4 Distribution of Grain Bulk Carrier Size by Importing Region

Considering the situations described above, the following are adopted as maximum and objective vessel for bulk cargo respectively:

65,000 DWT, 30,000 DWT

Accordingly the dimensions are as follows, respectively:

Berth length = 270m, Depth = -14m

Berth length = 240m, Depth = -12m

(4) Others

Tankers enter into the Port of Galle, except for bulk or conventional carriers, at present. The number of tankers calling at the port was 25 in 1989. The average ship size was 2,145 DWT and the maximum DWT was 2,995 DWT. All these ships are operated exclusively by the Ceylon Petrochemical Corporation.

Although there are no bunkering facilities in the port of Galle at present, it is indispensable to furnish such facilities for accommodating many varieties of ships.

According to a high ranking official of the Ceylon Petrochemical Corporation, they have a intention that 5,000 DWT tankers be introduced to convey several kinds of oil products from the port of Colombo to the port of Galle. There is a plan to construct a distribution center with the capacity of 18,150 tons including LPG somewhere near the port.

Considering the above, the below will be adopted as the objective vessel for liquid bulk.

5,000 DWT, LOA = 104m, Dr = 6.5m

Accordingly, the dimensions of the berth are as follows:

Berth length = 120m, Depth = -7.5m

4-3 Required Number of Berth

According to UNCTAD, it is recommended that berth occupancies for conventional general cargo operations should be set so as not to exceed figures described below:

Number of Berths	Recommended Maximum Berth Occupancy
1	40
2	50
3	55
4	60

In this examination these figures are used for judging.

4-3-1 Container Berth

The container berth to be constructed in the port of Galle is not a remodeled one using the existing wharf but a new one, and many conditions are assumed to be similar to those of the Jaye Terminal in the port of Colombo. Therefore, in this examination, statistical data of Jaye Terminal are used as parameters for calculation of the required scale of container terminal at Galle.

Handling cargo volume per container vessel at Jaye Terminal was 918 TEUs in 1988 but dropped to 437 TEUs in 1989. This difference was due to the removal of some functions of one shipping company to other port in a neighboring country. In this calculation, 1,000 is assumed expecting somewhat increasing of handling cargo volume per vessel in 2005. Average cargo handling productivity per crane is set as 25 pieces per hour, considering present efficiency.

Other parameters are assumed as follows;

i) Cargo handling hours per day

Cargo handling begins at 7:30 in the morning and continues to 6:30 next morning, including overtime work, in the case of the port of Colombo. These handling hours include rest time, non-working time for shift changes and so on. Although port operation at the port of Galle is carried out in a single-shift system, it is anticipated that a two shift system similar to that in the port of Colombo will be introduced as cargo volume increases. Considering these factors, the number of cargo-handling hours is assumed to be 20 in the case of container handling.

ii) Annual number of workable days

The number of days available for using the berth is set at 356 days. The berth cannot be used on the remaining nine days because of national holidays, or unfavorable wave conditions.

iii) 20/40 feet container ratio

In 1989, 20-foot containers occupied 72.5% of the total number of containers. In 1988, however, it was around 64%. As the proportion of 40-foot containers is expected to increase in future, the 20/40 foot container ratio is estimated at 50:50 in 2005.

The volume of container cargoes handled at the Port of Galle is expected to be 713,000 TEUs in 2005. Using the average cargo handling volume per vessle, the number of calling container vessels is assumed to be 713 vessels annually. Necessary days for berthing per vessel will be calculated as 0.767 day, including non-handling time of 0.1 day at berth. Accordingly, the berth occupancy rate is calculated as follows:

Number of berths = 3, Berth occupancy rate = 51.2%

Number of berths = 4, Berth occupancy rate = 38.4%

The number of container berths required will be 3.

4-3-2 General/Bulk Cargo Berths

Some dry bulk cargoes will be handled at the Port of Galle in 2005. However, the volume of these cargoes is not large enough to plan a separate berth for these commodities. Instead, general/bulk cargo berths are planned for accommodating vessels that convey break bulk, fertilizer, clinker, cement and wheat.

Cargoes to be handled at the existing berths are assumed to be mainly break bulk as suggested by the size of the vessel.

For break bulk cargo, assumptions will be made on stevedoring productitity. As described in chapter 5 of Part I, the present productivity rate is 11 tons/hour per gang in the case of the Port of Galle. This rate has improved each year year, but the speed of improvement has been very slow. The method of cargo handling for conventional vessels will not change drastically in the future and therefore it is possible to anticipate a slight increase in productivity. In this calculation, a rate of 13 tons/hour per gang is assumed.

From these assumptions the capacity of existing berths is calculated at around 250,000 tons for break bulk. Accordingly, it is possible to assume that cargo volumes to be handled at the new general/bulk cargo berths are 155,000 tons for cement, 129,000 tons for fertilizer, 291,000 tons for clinker and 700,000 tons for wheat.

In the case of bulk cargo, the handling capacity per hour depends on the capacity of the handling equipment. For this calculation, it is assumed that ship gears will be used for handling fertilizer and clinker. For handling wheat and cement, the unloader installed at the quay and the pump of vessel are used respectively.

Cargo handling hours per day for these cargoes is assumed as 18, considering the two-shift system of stevedoring.

Even if general/bulk cargo berths are planned, it is reasonable to assume that special cargoes such as wheat will be handled at a designated berth with the required handling equipment. Therefore, it is appropriate to designate one berth mainly for wheat, and another berths for fertilizer, clinker and cement separately. Assuming that the cargo volumes per vessel for cement, fertilizer, clinker and wheat are 10,000 tons, 15,000 tons, 20,000 tons and 35,000 tons respectively, the number of calling vessels are 15.5, 8.6, 14.55 and 20 respectively. On the other hand, the service times per vessel for these cargoes are assumed to be 1.984, 4.166, 5.555 3.47 day/vessel respectively.

The berth occupancy rate can be calculated as follows:

Berth mainly for wheat:	20.6%
Berth for others :	43.2%

Based on these calculations, required number of berths will be 2.

4-3-3 Other berth

One oil products berth is planned for accommodating a 5,000 DWT tanker and bunkering inside the existing breakwater.

4-3-4 Summary

Through the calculations described above, the following facilities are planned:

Berth	Objective vessel	Length	Depth	Number	Main cargo
Container Berth	50,000 GRT	1,050	-14	3	Container
General/Bulk Cargo Berth	65,000 DWT	270	-14	1	Wheat
	30,000 DWT	240	-12	1	Fertilizer, Others
Oil Berth	5,000 DWT	120	-7.5	1	Oil

4-4 Required Scale of Facilities/Equipment

4-4-1 Container Berth

(1) Handling system

A lift-on, lift-off system on the quay wall and a transfer crane system at the terminal will be used in the port of Galle since these systems have been used at the port of Colombo and a comparatively small area of the container yard is prepared through reclamation.

(2) Container yard

The required storage number of containers is calculated by the following formula:

$$M_l = (M_y/D_y \times D_w + M_i) \times P$$

where M_l: Required storage number of containers

M_y: Annual container traffic

D_w: Dwelling time at terminal

D_y: Operating days

M_i: Half of the average number of containers handled per vessel

P : Peak ratio

In the case of the Jaye Terminal, where most containers are transshipped, dwelling time is comparatively short, at around 6 days. Assuming that the stacking height of container is based on the present condition (1.73), the required number of ground slots is calculated as around 2200.

(3) Container freight station

The required area for the CFS is calculated as for the warehouse using the formula below:

$A = (M_C \times D_W \times P) / (\omega \times r \times D_Y)$

where A : Required floor area of CFS

M_C: Annual container volume of containerized cargo through CFS

ω : Volume of cargoes per unit area

r : Utilization rate of CFS floor

In the case of the Jaye Terminal, the proportion of cargo passing through the CFS is around 30% in imports, around 0% in exports. Assuming the same conditions at the container terminal of the port of Galle, 100,000 tons of cargo will pass through the CFS.

$A = (100{,}000 \times 6 \times 1.3) / (1.3 \times 356 \times 0.5) = 3{,}370$ m2

The dimension of the C.F.S is 45m in width and 80m of frontage.

(4) Cargo handling equipment

1) Container crane

2 container cranes are required per berth. Required number of crane is 6.

2) Transfer crane

The required number of transfer cranes at a berth is calculated by the following equation:

NTR = 2N + 1 or 2

where NTR: Required number of transfer cranes

N: Number of container crane

The number of transfer cranes required will be 14.

3) Tractor-trailers at the yard

The required number of tractor-trailer for transport between container cranes and transfer cranes are determined using the following formula:

NTT = 6N

where NTT: Required number of tractor-trailers at the yard

Therefore, the required number of tractor-trailers is 36.

4) Tractor-trailors at the CFS

The required number of tractors and trailers at the CFS is calculated using the following formula:

NT = 1/(8~10) x n

NR = (1.2 ~1.5) x n

where NT: Required number of tractors at the CFS

NR: Required number of trailers at the CFS

n: Number of berths of the CFS

As the number of bays of the CFS is planned as 25, NT and NR are calculated as 3 and 35.

Other than tractor-trailer, it is necessary to prepare 6 fork lifts (2 tons) at the CFS.

(5) Others

Other facilities to be installed at the container terminal for each berth are described as follows:

* Administration office: 800 m^2
* Maintenance shop: 1,000 m^2
* Others (Water supply facility, Cleaning facility, etc.)

It is necessary to secure an open yard for storing containers other than the container yards, considering the fact that there are many inland depots in the hinterland of the port of Colombo. There are 13 inland depots with a total area of 216,661m^2 for the local container cargo volume of 158,980 TEUs in 1989. Considering the local container cargo volume of Galle, it is necessary to secure around 50,000 m^2 even if the space is secured for a third of the local container cargo volume.

4-4-2 General/Bulk Cargo Berth

(1) Handling system

As described, unloading of fertilizer and clinker will be carried out by ship gear while the unloader and pump will be used for handling wheat and cement. Unloading general cargo conveyed by conventional vessels will be carried out by ship gear, and cargo handling between apron and shed will be done by fork-lifts.

(2) Scale of shed

In the case of the port of Colombo, 30 §50 % of volume of cargo transported by conventional vessels is directly delivered to the outside of the port and 10 % of it is stored at the open yard in the port.

The required storage facilities area is calculated using the following formula:

$$A = (N \times C) / (R \times \alpha \times \omega)$$

where A: Required storage facilities area
N: Annual handling volume of cargo
C: Peak ratio (1.5)
R: Turnover rate
α: Utilization rate (0.7)
ω: Volume of cargoes per unit area (1.2 t/m2)

On the basis of the formula, A for shed is assumed as 9,425 m^2. As there are two warehouses whose area is 6,474 m^2 in total, it is necessary to secure around 3,000 m^2 additionally. However, if this facility is prepared at the separate place from existing facilities, the required area will increase. Then, 6,000 m^2 is planned considering lot size of fertilizer.

Open yard required is assumed as 1,265 m2.

(3) Cargo handling equipment

As described in (1), cargo handling will be carried out mainly by ship gear. For cement, wheat and fertilizer, handling equipment need to be installed. They are:

* Cement

Hopper	1 unit
Belt conveyer	1 unit
Silo	20,000 ton

* Wheat

Unloader(400t/h)	2 units
Belt conveyer(400t/h)	2 units
silo	100,000 ton

* Fertilizer

The cargo volume of fertilizer is not so great. Although some parts of fertilizer will be directly delivered outside in bulk, the rest of it (around 70 %) will be bagged and stored in the warehouse.

For handling break bulk and fertilizer, 20 units of fork lift (3 tons) will be necessary. There are already 3 fork lifts and 17 more units will be prepared.

4-5 Other Facilities

4-5-1 Breakwater Alignment

The following points represent the fundamental conditions needed for determining the alignment of the breakwater:

i) Waves

There are two kinds of waves: one consists of swells which come mainly from the south all year round, while the other consists of SW sea waves caused mainly by south west monsoon for around 7 months. To ensure a calm water space, the construction of breakwaters against both types of waves is a fundamental necessity.

ii) Water area

As a result of the forecasted demand, it is necessary to prepare about 1,500 m length of quay wall for accommodating vessels visiting the port. The study carried out in the former chapter, suggests that almost all of the bay area should be considered for future development.

Taking these two matters into consideration, it is necessary to align the breakwater.

iii) Construction cost and ship maneuvering

It is easy to construct the breakwater on the sea bed rocks while dredging the rocks can be expensive. Basement rocks crop out here and there at the bottom of the sea in the bay. Therefore, the alignment of the breakwater has much influence on the construction cost. At the same time, the breakwater must not obstruct the maneuvering ability of the ships.

Under these conditions, the alignment of the breakwater will be determined in one way; namely, a combination of two breakwaters. One will be constructed from the Fort towards the southeast to combat the W to SW sea waves caused mainly by southwest monsoons. Rocks crop out from the front of the Fort, and it is useful to develop this area as the edge of the breakwater. The other breakwater will be constructed from Rumassala towards the west to combat swells mainly from the south. Since the port mouth will be established towards the south to the south-east for easy maneuvering of ships, the main breakwater is the former one. To secure a sufficient water area, it will be necessary to construct breakwaters of approximately 1,500 m in length.

The length depends on the calmness of the basin and the alignment of the channel.

4-5-2 Channel

Fundamental conditions of the channel are as follows:

i) Width of channel

The maximum length of the objective vessel is assumed to be 295 m. Thus 300 m is adopted as the width of the channel.

ii) Width of the mouth of the port

The structure of the breakwater will be rubble mound. In this case the gradient of slope is 1:1.5. Considering the depth of the construction site and the height of the breakwater, it is necessary to secure at least 35 m as an allowance from the edge of channel to the centerline of the breakwater. Therefore, the width of the mouth of the port is 370 m.

iii) Stopping distance

It is said that 5L(L=length of ship) is necessary to maneuver ships for stopping safely in ports. However, it is a fact that there are many ports in the world where this is not the case. In this study, 5L will be taken into consideration in formulating the master plan.

There are two ways of entering the port; one is from the southeast, the other is from the south. The mouth of the port will be established at the eastern part of the bay taking wave and sea bed conditions into account.

There is a Eastern Channel which is not used now in Galle Bay. This channel runs along places where it is deep and there are less rocks. In the case that the mouth is established toward the southeast, it is very useful to expand this existing channel as the future channel.

Alignment of the channel shall be decided by considering the alignment of the wharves.

4-5-3 Land Transportation Facilities

(1) Road

A road is planned to connect the reclaimed area to the existing road running along the coast. This road is set behind the storage area of the port.

The traffic volume which will be generated by port activities is forecast as follows:

$$\text{Volume} = N \times \alpha/W \times \beta/12 \times \gamma/30 \times (1+\delta)/\varepsilon \times \sigma$$

where: N = Cargo volume per annum

α = Modal split ratio by truck

β = Variation ratio per month

γ = Variation ratio per day

W = Actual carrying capacity by truck

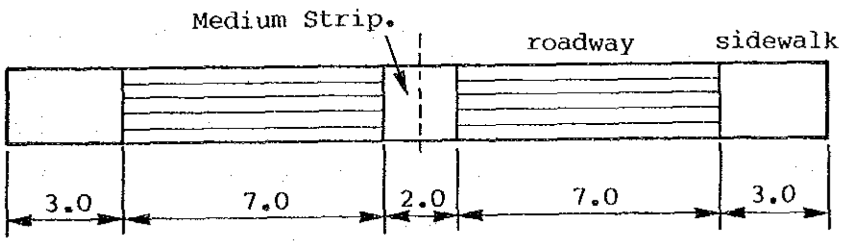
δ = Cargo related vehicle ratio

ε = Actual vehicle ratio

σ = Variation ratio per hour

Traffic volume per hour will be 679, and it is thus necessary to plan a 4-lanes road. The standard cross section is shown below:

Unit: m



(2) Railway

Since a railway and a CFS are planned for the site of koggala EPZ, the railway should be constructed in the port area.

The alignment of the railway shall be decided through consideration of smooth connection.

4-5-4 Navigational Aids

The following navigational aids shall be planned according to the channel and breakwater plan.

* Two tug boats: 2500 HP
* Light beacons on the breakwater 4
* Light buoys along the channel 12
* Light guide post 1

4-5-5 Others

Apart from what has been written above, it is necessary to prepare a water-supply facility, an electric power supply facility and an administrative facility.

4-6 Alternatives of Master Plan Layout

4-6-1 Selection of the Site to be Developed for the Port

Galle Bay is designated as a zone for port development and industrial development through consideration of future development trend for the overall coastal area in the vicinity of the Bay.

Although Galle Bay is not a large bay, many conditions such as land use, natural conditions and so on differ in the western and eastern parts of the Bay. They have been described in detail before.

Concerning port development, there are two ways to construct port facilities: reclamation and excavation. Almost all the land areas of Galle Bay are used for various functions, and it is thus impossible to excavate some parts of it. Therefore, reclamation is the only way to construct port facilities in this area.

Judging from present conditions, especially water area use, there are three sites that be nominated for the development of the port in Galle Bay.

They are listed as follows, and are also shown in Figure 4-6-1.

Site 1. West side of the Bay, very close to the centre of Galle city.

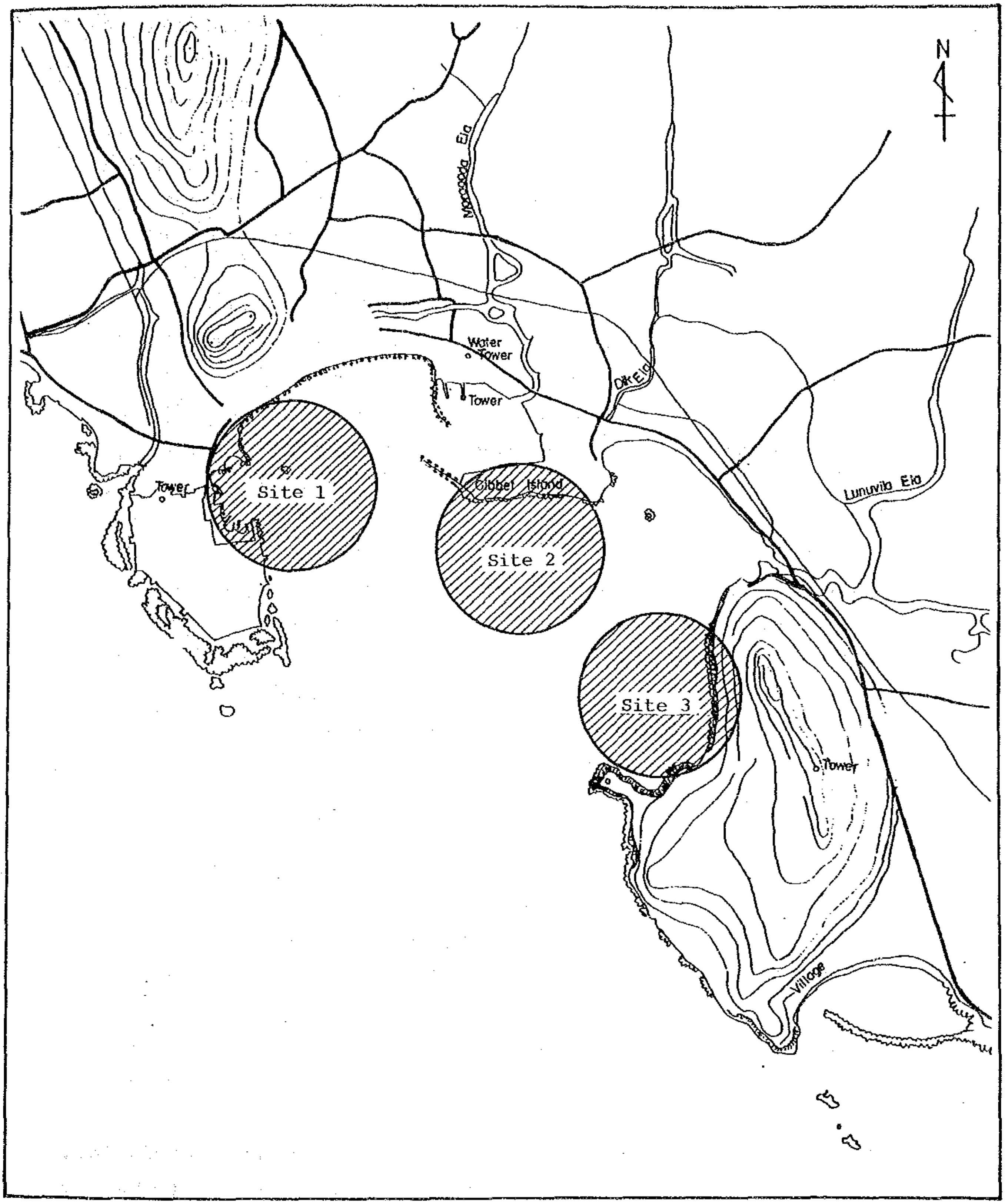


Fig. 4-6-1 Nominated Sites for Port Development

Site 2. Centre of the Bay off-shore from the existing port.

Site 3. East side of the Bay next to the hill of Rumassala.

The features of each site are as follows:

Site 1

1) Close to the Fort
2) Close to the centre of Galle City
3) Marine road just behind
4) Old port to be demolished
5) Anchoring yard of some fishing boats to be demolished
6) Least influence from SW Waves

Site 2

1) Extension of existing port in a sense
2) Easy to connect the functions of the new port to those of the existing Port.
3) Necessary to remove many rocks in revetments
4) Least influence on city life in Galle City
5) Necessity of longest revetments
6) Somewhat deep

Site 3

1) Some distance from main road
2) Preferable not to touch Hill Rumassala
3) Comparatively low population density
4) Most influence from SW Waves
5) Existence of river mouth
6) Some less-utilized area behind

The features described above are not all conducive to port development. However, there are no fundamental features excluding any of these sites as candidates for port development, and it is considered that all three of them are possible candidates.

4-6-2 Formulation of Alternatives

The configuration of the wharves in each site will be considered as follows:

(1) First of all, there would be some objections against the reclamation itself in the case of site 1. Even if it is decided to undertake reclamation there, only an area corresponding to the minimum required area could be reclaimed. Therefore, only one alignment of the wharf would be planned in order to secure the necessary space for the container terminal.

(2) Although it is possible to secure a large reclaimed area in which several piers are included at site 2, it is obvious that this would cost more compared with the reclamation of the same area at other sites and that it is difficult to reserve sufficient water area on both sides of reclaimed area. Therefore, if this site is selected as the main development area for the container terminal, one pier type with sufficient width would be better.

(3) There are two alternatives concerning the configuration of the wharves in the case of site 3. One is a parallel alignment to the coastline and the other is an alingment composed of several piers perpendicular to the coastline.

There are five alternatives in the master plan layout with a combination of sites or configuration of wharves. They are:

Alternative-1: To develop site 1 as the first container terminal, and continue to develop site 2 for the next stage.

Site 1 is the best equipped to protect the quay wall from southwestern sea waves. However, there are some restrictions. One is caused by the existence of the Fort. Secondly, dredging the many rocks on the sea bed is an expensive procedure.

Alternative-2: To develop site 2 for the long term

If site 1 is to be preserved for environmental reasons, then, the next best site for protection against SW waves is the western side of site 2. This site not only offers protection from SW waves, but it is also easy to connect with existing facilities.

Alternative-3: To develop site 3 as a pier-type berth

In this plan , the calmness and area size of the turning basin are considered most preferable. However, it is necessary to dredge an extensive rocky area.

Alternative-4: To develop simultaneously site 3 as a parallel berth and perpendicular berth to the coast while continuing to extend both berths as the next step.

If wharves are constructed in the western part of the bay, it will cost a lot to dredge the sea bed of many rocks. In this alternative plan, since allocation of the channel and basin are planned mainly considering sea bed conditions, the dredging cost would be the least.

Alternative-5: To develop site 2 in the cheapest way and develop site 3 as the next step

The costs involved in constructing port facilities such as a breakwater and a basin are high. This alternative plan attempts to increase cost savings in the short term plan. However, the depth of basin is limited to -12m.

They are shown in the next Figures.

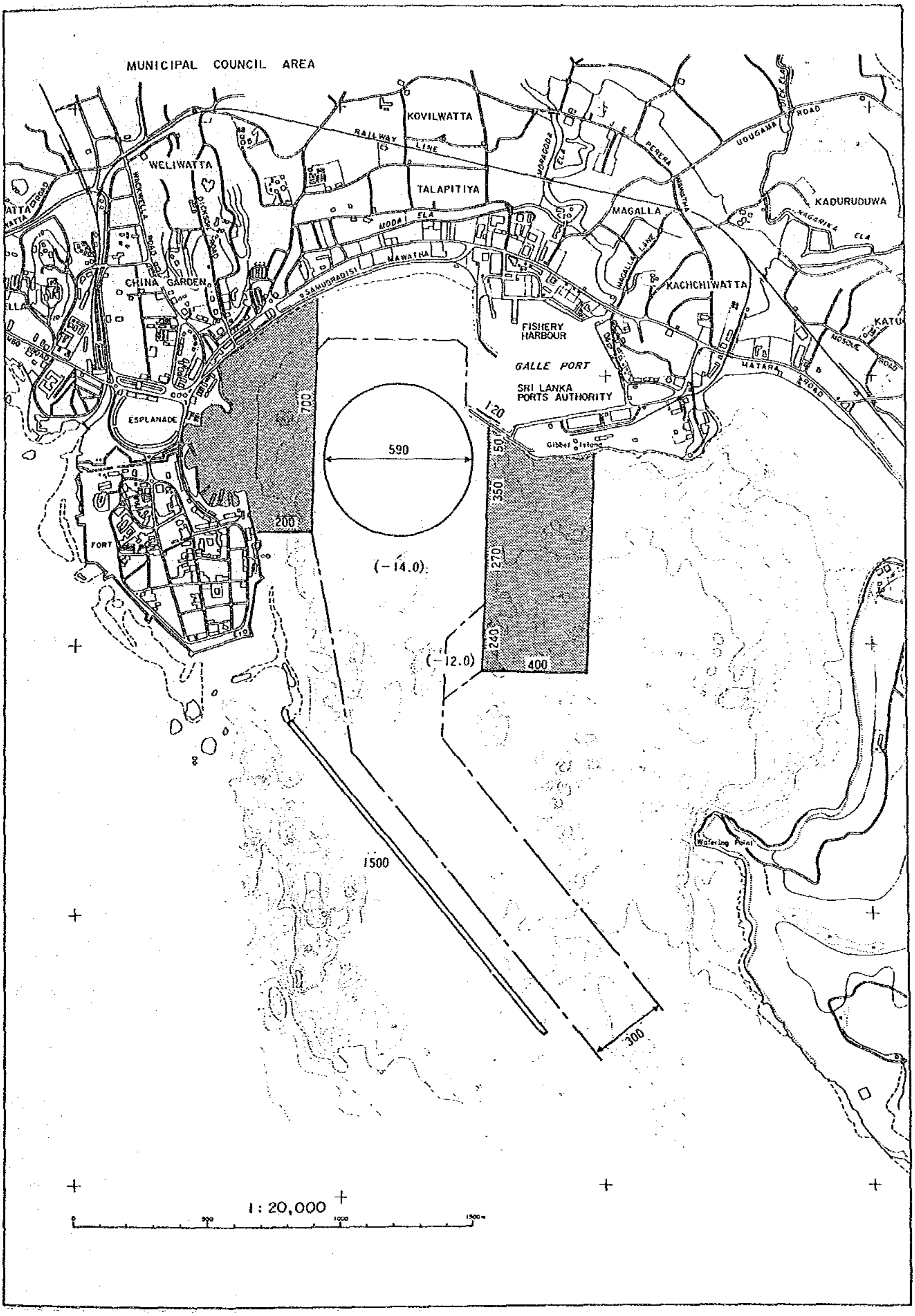


Fig. 4-6-2 Alternative 1

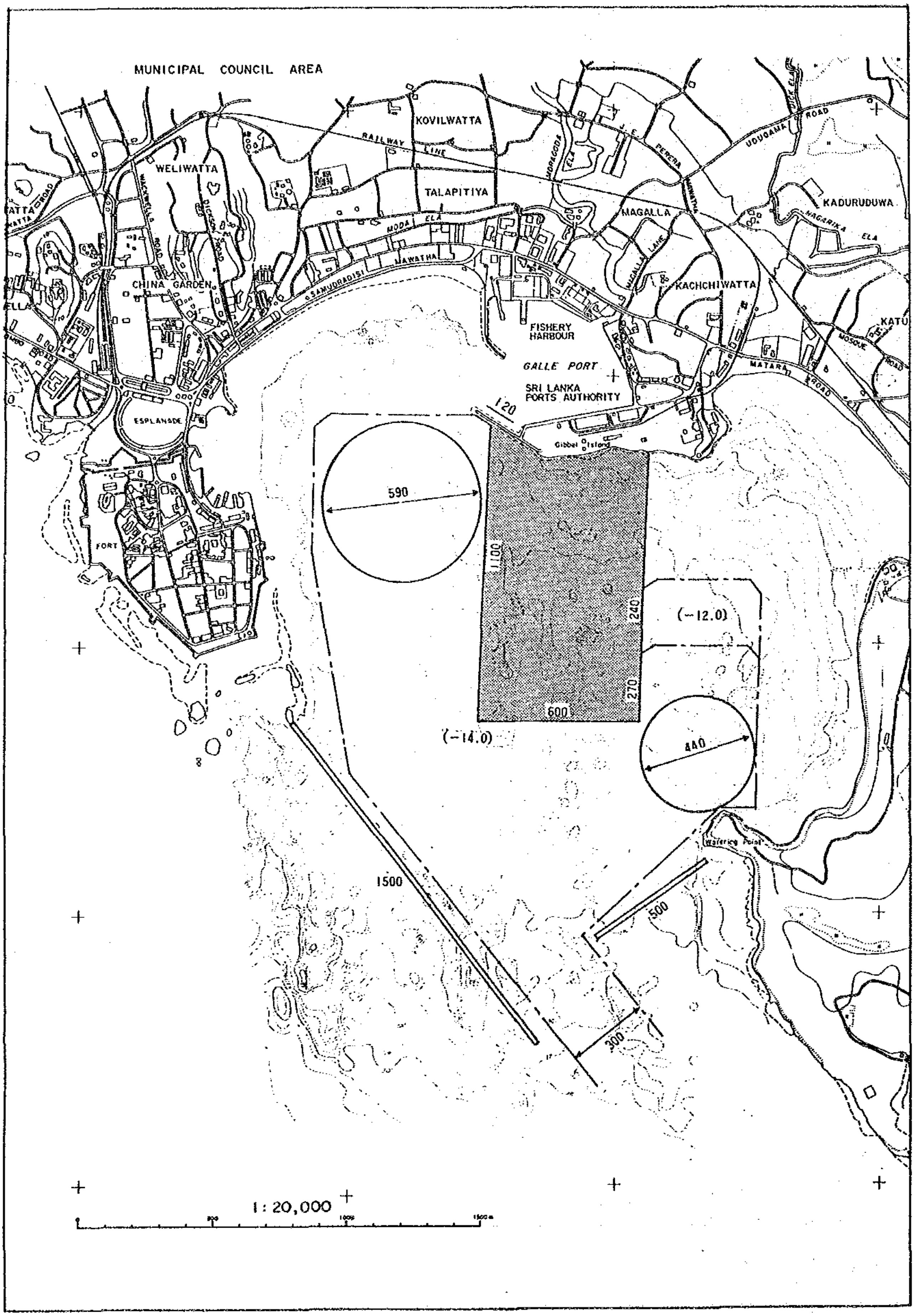


Fig. 4-6-3 Alternative 2

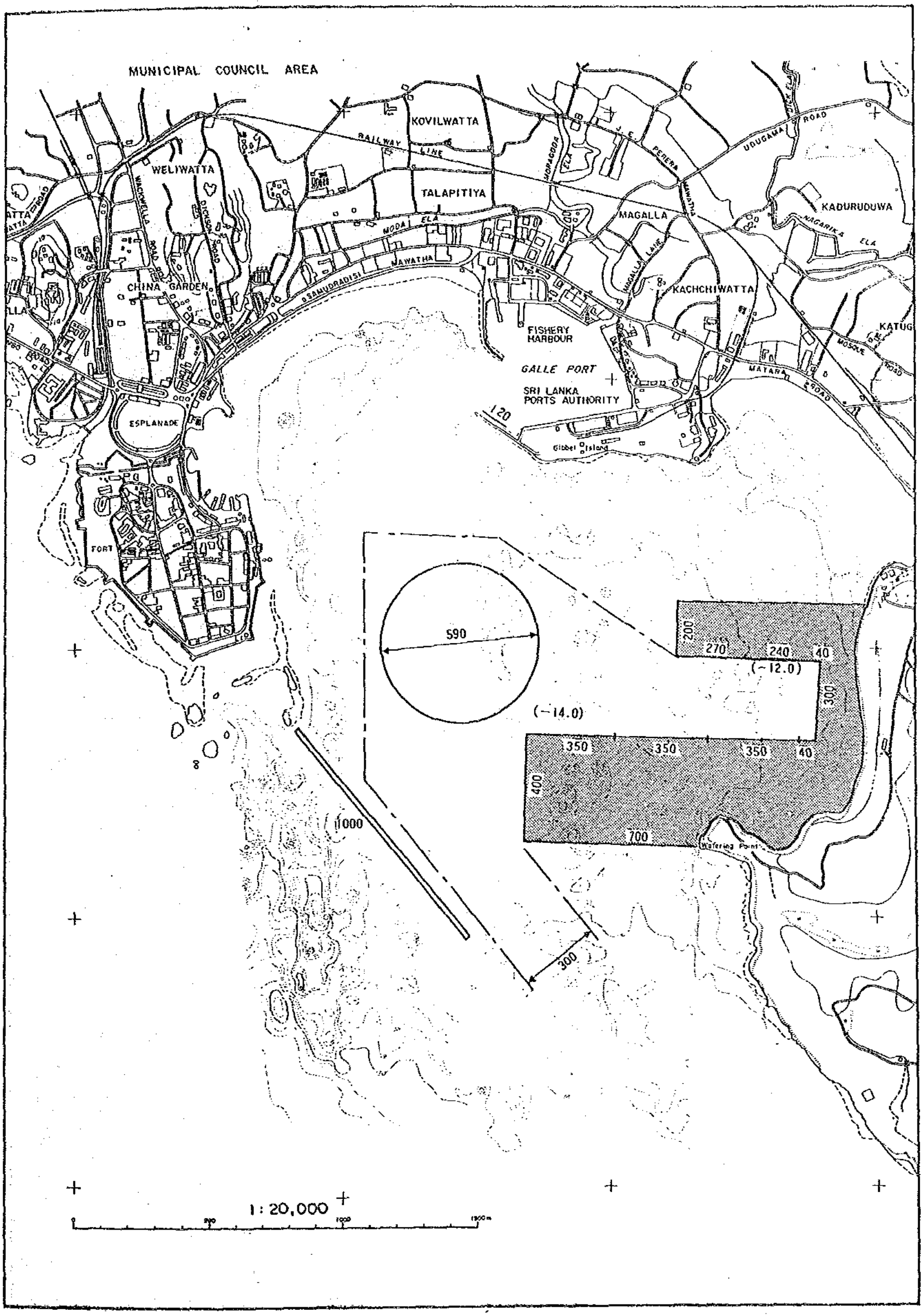


Fig. 4-6-4 Alternative 3

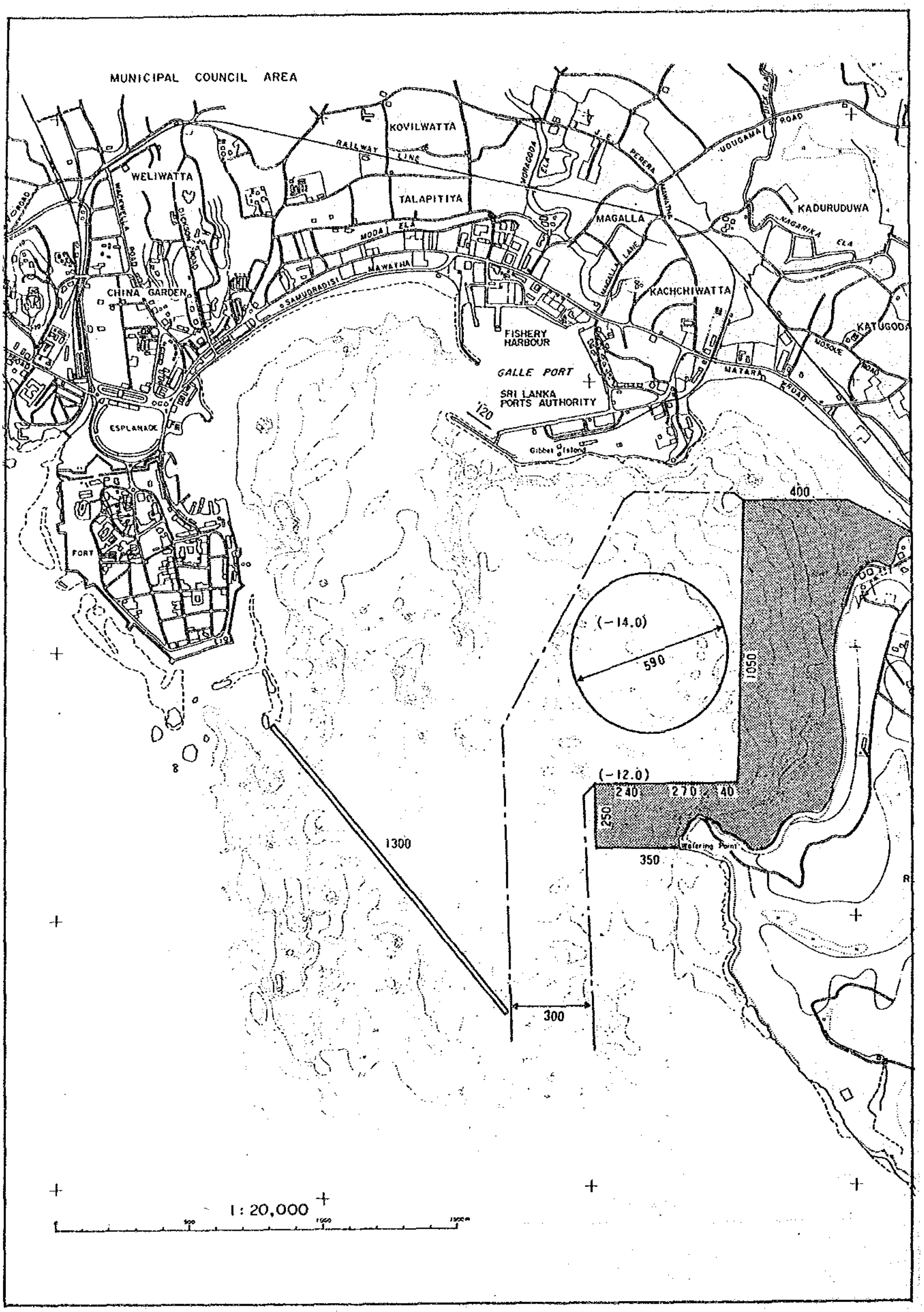


Fig. 4-6-5 Alternative 4

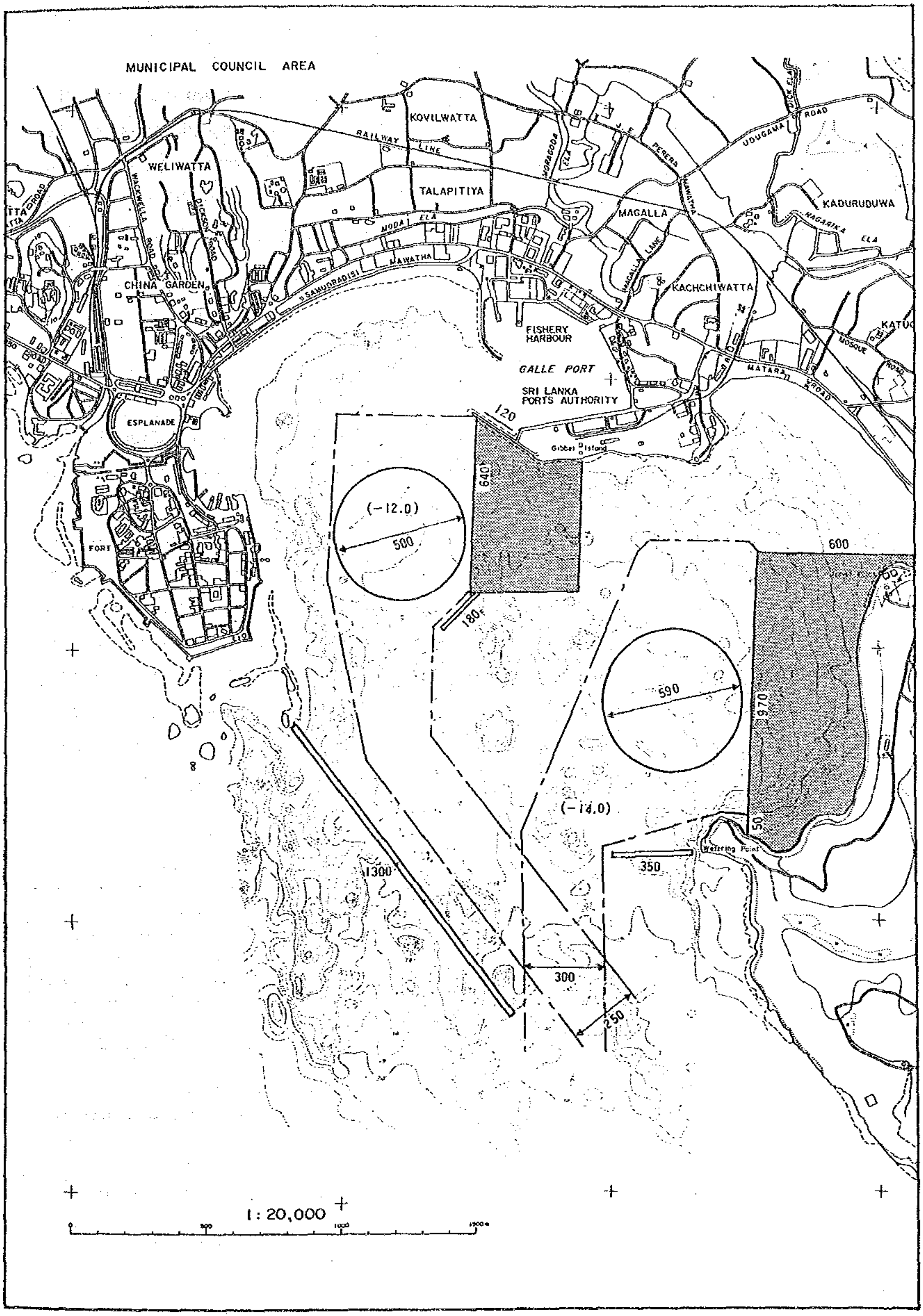


Fig. 4-6-6 Alternative 5

4-6-3 Study of Calmness

A computer-aided simulation analysis has been undertaken to determine the effects on the calmness of the inner harbour with respect to the five master plan layout being alternatives considered for Galle Port, including the proposed breakwater, reclamation works, container berth, and other necessary harbour works.

(1) Conditions of Computation

1) Incident Wave at Harbour Entrance

Appendix I-4-10 and Appendix I-4-12 present the frequencies of wave height occurrence for swells and wind waves in an area 68 m of water off Galle Port.

These waves vary in height under the influence of depth, refraction, bottom friction and other effects before they reach the harbour entrance which is 15 m of water. Variations in the direction of swells and wind waves due to refraction in the vicinity of the harbour entrance are illustrated in Appendix II-4-3(1) to II-4-3(10). Coefficients of refraction are shown in Appendix II-4-4(1) to II-4-4(10). Table 4-6-1 gives a spectrum of deformations of deep water waves at the harbour entrance obtained from the foregoing figures.

Table 4-6-1 Wave Deformation

	Swell	Wind Wave								
Wave Direction (Deep Water)	S6°W	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW
Wave Direction (Harbour Entrance)	189.7°	155.5°	161.1°	162.2°	180.6°	199.3°	220.6°	231.6°	254.3°	262.4°
Coefficient of Wave Height	1.00	0.50	0.59	0.70	0.92	0.96	0.95	0.92	0.78	0.64

Note 1). Wave directions are angles measured clockwise from north.

2). The coefficients of wave height are the ratio of deep water wave height.

As the swells and wind waves attack the harbour entrance simultaneously, they are subjected to deformations on the basis of the deformation data of Table 4-6-1. Table 4-6-2 presents the direction-wise frequencies of wind wave height occurrence according to the ranks of swell wave height at the harbour entrance. In the table, the swell wave direction is taken as S 9.7° W from Appendix I-4-10 and Fig. 4-3-1 of Part I.

Table 4-6-2 Frequency of Wind Wave Height Occurrence According to Swell Scale

Swell $H_{1/3}$ = 0.00~0.49

$H_{1/3}$ (m) \ Direction	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	OTHER	TOTAL
0.00-0.49	0.00	0.00	0.35	0.03	0.00	0.00	0.00	0.00	0.00	0.05	0.45
0.50-0.99	0.00	0.00	0.49	0.27	0.06	0.00	0.00	0.00	0.00	0.00	0.83
1.00-1.49	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.08
1.50-1.99	0.00	0.00	0.00	0.00	0.00	0.05	0.03	0.00	0.00	0.00	0.08
2.00-2.49	0.00	0.00	0.00	0.00	0.02	0.09	0.01	0.00	0.00	0.00	0.12
2.50-2.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00-3.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.50-3.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	0.84	0.30	0.09	0.15	0.10	0.00	0.00	0.05	1.56

Swell $H_{1/3}$ = 0.50~0.99

$H_{1/3}$ (m) \ Direction	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	OTHER	TOTAL
0.00-0.49	0.00	0.00	12.52	0.75	0.77	1.68	1.53	2.02	0.00	5.53	24.80
0.50-0.99	0.00	0.00	5.94	1.27	0.61	1.74	1.85	0.70	0.00	0.00	12.10
1.00-1.49	0.00	0.00	0.17	0.06	0.08	1.11	0.94	0.13	0.00	0.00	2.49
1.50-1.99	0.00	0.00	0.00	0.00	0.08	1.20	0.97	0.05	0.00	0.00	2.29
2.00-2.49	0.00	0.00	0.00	0.00	0.00	0.46	0.26	0.03	0.00	0.00	0.75
2.50-2.99	0.00	0.00	0.00	0.00	0.00	0.15	0.09	0.01	0.00	0.00	0.25
3.00-3.49	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.00	0.00	0.00	0.11
3.50-3.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	18.62	2.08	1.54	6.35	5.74	2.95	0.00	5.53	42.80

Swell $H_{1/3}$ = 1.00~1.49

$H_{1/3}$ (m) \ Direction	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	OTHER	TOTAL
0.00-0.49	0.00	0.00	0.73	0.13	0.51	0.89	1.45	0.35	0.00	1.24	5.30
0.50-0.99	0.00	0.00	0.31	0.55	0.37	4.71	5.86	0.65	0.00	0.00	12.45
1.00-1.49	0.00	0.00	0.15	0.03	0.26	4.31	5.31	0.20	0.00	0.00	10.26
1.50-1.99	0.00	0.00	0.00	0.00	0.15	1.85	2.41	0.03	0.00	0.00	4.45
2.00-2.49	0.00	0.00	0.00	0.00	0.02	0.58	0.42	0.00	0.00	0.00	1.03
2.50-2.99	0.00	0.00	0.00	0.00	0.01	0.20	0.15	0.00	0.00	0.00	0.35
3.00-3.49	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.04
3.50-3.99	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
TOTAL	0.00	0.00	1.19	0.72	1.31	12.58	15.62	1.25	0.00	1.24	33.89

Table 4-6-2 Frequency of Wind Wave Height Occurrence According to Swell Scale (Continued)

Swell $H_{1/3}$ = 1.50~1.99

$H_{1/3}$ (m) \ Direction	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	OTHER	TOTAL
0.00-0.49	0.00	0.00	0.09	0.01	0.01	0.21	0.26	0.12	0.00	0.31	1.01
0.50-0.99	0.00	0.00	0.00	0.00	0.11	2.21	2.20	0.26	0.00	0.00	4.79
1.00-1.49	0.00	0.00	0.00	0.01	0.27	3.61	3.78	0.18	0.00	0.00	7.84
1.50-1.99	0.00	0.00	0.00	0.00	0.03	1.52	1.84	0.02	0.00	0.00	3.42
2.00-2.49	0.00	0.00	0.00	0.00	0.01	0.37	0.63	0.00	0.00	0.00	1.01
2.50-2.99	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.02
3.00-3.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.50-3.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	0.09	0.01	0.43	7.93	8.74	0.58	0.00	0.31	18.10

Swell $H_{1/3}$ = 2.00~2.49

$H_{1/3}$ (m) \ Direction	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	OTHER	TOTAL
0.00-0.49	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.08	0.19
0.50-0.99	0.00	0.00	0.00	0.00	0.03	0.42	0.44	0.00	0.00	0.00	0.89
1.00-1.49	0.00	0.00	0.00	0.00	0.03	0.71	0.81	0.00	0.00	0.00	1.55
1.50-1.99	0.00	0.00	0.00	0.00	0.01	0.26	0.20	0.00	0.00	0.00	0.47
2.00-2.49	0.00	0.00	0.00	0.00	0.00	0.04	0.05	0.00	0.00	0.00	0.09
2.50-2.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00-3.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.50-3.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	0.00	0.00	0.07	1.47	1.55	0.00	0.00	0.08	3.18

Swell $H_{1/3}$ = 2.50~2.99

$H_{1/3}$ (m) \ Direction	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	OTHER	TOTAL
0.00-0.49	0.00	0.00	0.00	0.00	0.00	0.06	0.02	0.00	0.00	0.00	0.08
0.50-0.99	0.00	0.00	0.00	0.00	0.00	0.04	0.12	0.04	0.00	0.00	0.20
1.00-1.49	0.00	0.00	0.00	0.00	0.01	0.08	0.10	0.00	0.00	0.00	0.18
1.50-1.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00-2.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.50-2.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00-3.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.50-3.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	0.00	0.00	0.01	0.17	0.25	0.04	0.00	0.00	0.47

2) Reflection Coefficients for Structures

The following values are normally taken as the reflection coefficients for existing and proposed harbour structures:

Vertical wall	0.7 to 1.0
Rubble slopes	0.3 to 0.6
Wave breaking blocks	0.3 to 0.5
Natural beaches	0.05 to 0.2

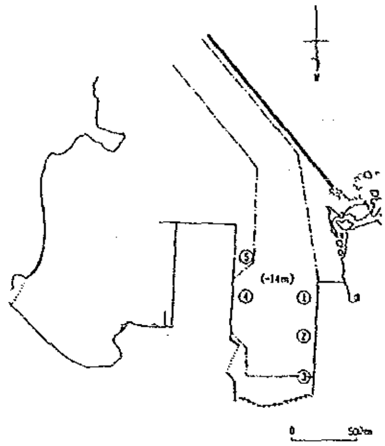
(2) Wave Height Distribution in Inner Harbour

In respect of the five alternative layout plans discussed earlier, height distributions in the inner harbour of incident waves coming from harbour entrance were obtained by a computer-aided numerical simulation analysis. The calculation results are compiled in Appendix II-4-5 to II-4-9. Tables 4-6-3 shows the diffraction coefficients determined for the different points.

Table 4-6-3 Coefficient of Diffraction for Wind Wave and Swell

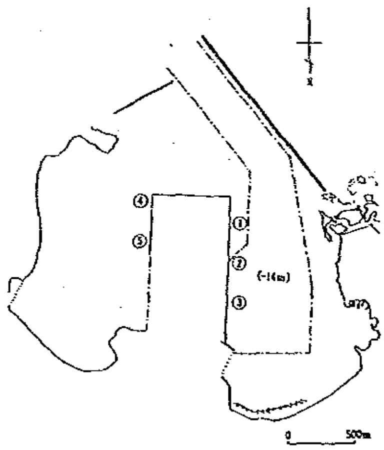
Alternative 1

Direction / Point	SE	SSE	S	SSW	SW	WSW	W	S 9.7°W (Swell)
1	0.67	0.65	0.44	0.25	0.14	0.06	0.03	0.24
2	0.72	0.73	0.52	0.28	0.14	0.05	0.02	0.28
3	0.55	0.66	0.54	0.30	0.16	0.07	0.02	0.33
4	0.15	0.17	0.14	0.08	0.04	0.02	0.01	0.12
5	0.32	0.36	0.29	0.17	0.09	0.04	0.02	0.20



Alternative 2

Direction / Point	SE	SSE	S	SSW	SW	WSW	W	S 9.7°W (Swell)
1	0.22	0.28	0.24	0.14	0.07	0.04	0.02	0.18
2	0.09	0.12	0.10	0.06	0.03	0.02	0.01	0.09
3	0.07	0.09	0.07	0.04	0.02	0.01	0.01	0.07
4	0.08	0.13	0.19	0.20	0.15	0.09	0.05	0.23
5	0.09	0.14	0.21	0.22	0.16	0.09	0.05	0.24



Alternative 3

Direction / Point	SE	SSE	S	SSW	SW	WSW	W	S 9.7°W (Swell)
1	0.04	0.05	0.04	0.04	0.02	0.01	0.01	0.08
2	0.03	0.04	0.03	0.02	0.01	0.01	0.00	0.05
3	0.03	0.03	0.03	0.02	0.01	0.00	0.00	0.04
4	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.04

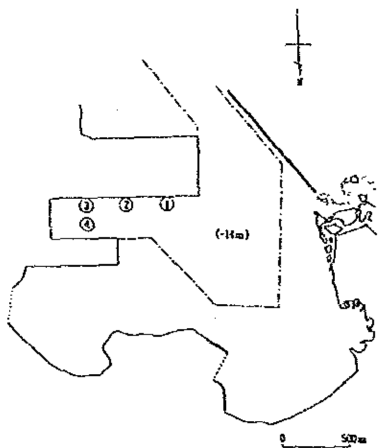
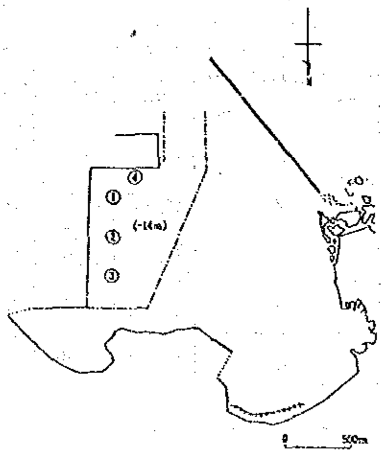


Table 4-6-3 Coefficient of Diffraction
for Wind Wave and Swell (Continued)

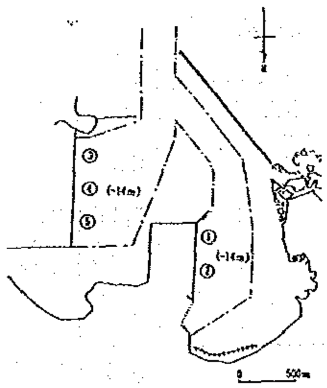
Alternative 4

Direction / Point	SE	SSE	S	SSW	SW	WSW	W	S 9.7°W (Swell)
1	0.10	0.16	0.20	0.16	0.09	0.04	0.01	0.20
2	0.08	0.12	0.14	0.11	0.07	0.03	0.01	0.18
3	0.08	0.12	0.17	0.18	0.12	0.07	0.01	0.23
4	0.11	0.17	0.21	0.17	0.11	0.05	0.01	0.21



Alternative 5

Direction / Point	SE	SSE	S	SSW	SW	WSW	W	S 9.7°W (Swell)
1	0.20	0.22	0.17	0.09	0.05	0.02	0.01	0.12
2	0.22	0.19	0.12	0.07	0.03	0.01	0.00	0.09
3	0.13	0.17	0.19	0.17	0.11	0.07	0.02	0.22
4	0.10	0.14	0.17	0.18	0.15	0.08	0.04	0.23
5	0.09	0.13	0.20	0.23	0.19	0.11	0.06	0.26



1) Alternative 1

At Point 1, 2 and 3 the effects of sheltering by the proposed reclamation area in front of Gibbet Island are considered to be limited. These points will be reached by diffracted waves coming around the tip of the 1,500 m Southwest Breakwater.

A higher degree of calmness will be provided in the water area embracing Points 4 and 5, since this area is exposed to secondary diffracted waves from the southern tip of the reclamation area.

Wave directions affecting the degree of calmness in the inner harbour are SE to SSW. W to SW wind waves with a high frequency will be blocked by the Southwest Breakwater.

2) Alternative 2

The proposed 1,500 m Southwest Breakwater and the 500 m East Breakwater would make the harbour entrance narrower and provide a high degree of calmness for the entire inner harbour area. Diffracted waves from the harbour entrance will be further diffracted at the southwestern tip of the proposed reclamation area in front of Gibbet Island, creating a well-sheltered area for Points 1, 2 and 3. For Points 2 and 3 the diffraction coefficient would be less than 0.1 with respect to all wave directions.

Diffracted waves passing Points 4 and 5 would reach the inner harbour without undergoing any energy reduction due primarily to the limited sheltering effects produced by the southeastern tip of the proposed reclamation area. However, the maximum diffraction coefficient would still be as small as 0.2 to 0.25 for southerly wind waves and swells.

3) Alternative 3

Under this alternative, the Southwest Breakwater will be reduced to 1,000 m in length as compared with Alternative 1. However, the reclamation area fronting the White Tower would be extended westward with a resulting decrease in the harbour entrance width. In consequence, a very calm inner harbour would be created as under

Alternative 2.

The proposed quay structure would be well sheltered by the reclamation area fronting the White Tower. The diffraction coefficient for all the points of calmness estimation will be less than 0.1 with respect to waves from all directions.

4) Alternative 4

The reclamation area in front of the White Tower would perform much the same function as the East Breakwater. Diffracted waves coming from the Southwest Breakwater would be further diffracted at its tip, creating a very calm area which will embrace all the points of calmness estimation. The maximum diffraction coefficient will be about 0.2 for southerly wind waves and swells.

For the northwestern part of the Bay (north of Fort Area) the diffraction coefficient will be slightly smaller than that under Alternative 1. This is ascribable to the effect of a reduction in the harbour entrance width resulting from the proposed reclamation works in front of the White Tower, although under Alternative 4 the Southwest Breakwater will be 200 m shorter than under Alternative 1.

5) Alternative 5

The position and length of the Southwest Breakwater and the East Breakwater remain the same as under Alternative 4. Under Alternative 5, however, the diffraction coefficients for Point 3, 4 and 5 show slightly larger values than under Alternative 4. The reason is that Alternative 5 does not involve the reclamation of the area inside of the East Breakwater.

The area embracing Points 1 and 2 will be very calm since it will be well sheltered by a small breakwater planned for the southwestern end of the reclaimed area in front of Gibbet Island.

(3) Degree of Clamness in the Port

1) Critical Wave Height

Quayside cargo handling efficiency is affected by the motions of moored ships. The magnitude of ship motions varies widely depending on various factors including, among others, (1) the height, direction and period of waves, (2) direction and speed of winds, (3) type and size of ships moored, (4) method of taking mooring lines, and (5) stiffness of fenders.

The wave height in front of the proposed quay structure is the key factor affecting cargo handling efficiency. Generally, wave heights up to 0.5 to 0.7 m are known to produce no adverse impact on the efficiency in loading and unloading an oceangoing vessel moored alongside a quay.

For the purpose of this study, the overall wave height of swells and wind waves combined in front of the proposed quay structure can be obtained by the following equation:

$$H_c > H = \sqrt{(K_s \cdot H_s)^2 + (K_w \cdot H_w)^2}$$

where

H_c: Critical wave height (0.5 to 0.7 m)

H : Overall wave height of swell and wind wave combined in front of quay

H_s: Swell wave height at harbour entrance

H_w: Wind wave height at harbour entrance

K_s: Diffraction coefficient of swell wave in front of quay

K_w: Diffraction coefficient of wind wave in front of quay

2) Degree of Calmness in Harbour Basin

Using the diffraction coefficients, attempts were made to determine from Table 4-6-2 the frequency of occurrence of the overall wave height, H, which is below the critical wave height, H_c of 0.5 m. In the case of a container wharf, in particular, a high degree of calmness is required. Thus the critical wave height of 0.5 m has been taken for the purpose of this study. The calculation results are as given in Table 4-6-4.

Generally, the utilization rate of a conventional cargo berth must be 95% or more. In the case of a container berth, it is preferable to attain a utilization rate of 100% except in times of exposure to unusually high waves.

Under Alternative 1, the berth utilization would be lowest with resulting impediment to quayside cargo handling operations. For improved berth utilization, therefore, the solution would be an extension of the proposed Southwest Breakwater or the construction of the East Breakwater as envisaged in Alternative 2.

Under Alternative 2 to 4, the degree of calmness will be over 95% for all points of calmness estimations earlier noted and the value will attain 100% under Alterative 3. Therefore, the Southwest Breakwater length could be reduced further than 1,000 m without impairing the adequate degree of calmness required for the harbour basin. However, this alternative expects the reclamation of the area immediately in front of the White Tower to provide most of the calmness required for the basin. Thus, insofar as Alternative Plan 3 is concerned, the question will arise in the implementation of the Short Term Development Plan that if the Southwest Breakwater is to be reduced further than 1,000 m, then the reclamation will be required instead of the breakwater. The breakwater length of nearly 1,000 m would be required to secure the necessary degree of calmness for the turning basin.

Under Alternative 5, the degree of calmness for the area encompassing Point 5 is 89%, a lower value than the other points of calmness estimation.

To improve this lower degree of calmness, it is conceivable that the area north of the East Breakwater will be reclaimed to be used as berthing facilities as in the case of Alternative 4. Although this will add to the total project cost, it may be a solution, since the Southwest Breakwater and the East Breakwater cannot be extended because their extension will go across the south approach channel.

Table 4-6-4 Degree of Calmness

(Critical Wave Height 0.5 m)

Plan / Point	1	2	3	4	5
1	90.9 (%)	100.0 (%)	100.0 (%)	99.5 (%)	100.0 (%)
2	82.8	100.0	100.0	99.5	100.0
3	70.5	100.0	100.0	96.3	97.1
4	100.0	95.8	100.0	99.3	95.8
5	99.3	94.7	....	....	89.0

4-6-4 Rough Cost Estimate

Comparative cost estimation is carried out to the major port facilities of the five Alternative Proposals contained in the Master Plan. The common cost items of Building Works and Cargo Handling Equipment are excluded from the cost calculation.

The Table No. 4-6-5 and 4-6-6 show the results of the calculation.

The most influential factor to the cost differential in the five Proposals lies with the layout of the Quaywall.

Because each layout in the Proposals possesses different factors both in maintaining magnitude of port calmness which is prone to fluctuate due to differing direction of incoming waves at the quaywall frontage and in the distribution of rock layer, the length of breakwater and the volume of dredging are obliged to diversify from one alternative proposal to the other. Such factors have contributed to the creation of big difference in costs among the Poposals.

Of the five Alternative Proposals, the No. 4 and No. 5 Proposals have a design concept to utilize the back site of the cape in the East as quaywall that is succeeded in huge reduction of the length of the breakwater.

Locations of navigation channel and anchorage position in the No. 4 and No. 5 Proposals are so selected as to minimize the dredging volume of anchorage and rock layer, under which design concept relatively economical port facilities are obtained compared with the other three.

Table 4-6-5 Rough Cost Estimates of Master Plan (Alternative 1~5)

(UNIT ; Million US$)

Facility	Plan-1	Plan-2	Plan-3	Plan-4	Plan-5
Dredging					
Rock Material	96.18	111.99	100.73	42.67	36.73
Other Material	18.52	21.10	16.59	12.31	16.57
Breakwater					
Southwest Breakwater	96.90	96.00	64.77	83.98	95.61
East Breakwater	-	42.80	-	-	29.96
Quays					
-14.0M Wharf	109.58	109.33	88.12	98.41	78.76
-12.0M Wharf	17.20	11.35	21.09	16.81	38.14
Oil Berth	4.43	4.43	4.43	4.43	4.43
Revetment	51.77	66.45	83.20	46.42	39.86
Reclamation	63.35	74.43	87.30	59.78	65.08
Pavement	46.96	43.00	54.35	43.07	48.10
Grand Total	504.89	580.88	520.58	407.88	453.24

Table 4-6-6 Major Works in Five Alternatives

Facility	Unit	Plan-1	Plan-2	Plan-3	Plan-4	Plan-5
Dredging						
Rock Material	m3	1,375,000	1,601,000	1,440,000	610,000	525,000
Other Material	m3	3,265,000	3,719,000	2,924,000	2,170,000	2,920,000
Breakwater						
Southwest Breakwater	m	1,500	1,500	1,000	1,300	1,480
East Breakwater	m	-	500	-	-	350
Quays						
Container	m	*1,100	*1,100	*1,140	*1,090	*1,150
Grain	m	270	270	270	270	270
General/Bulk Cargo	m	240	240	240	240	240
Oil	Sum	1	1	1	1	1
Revetment	m	2,000	1,815	2,300	1,770	1,520
Reclamation	m3	5,850,000	6,940,000	8,160,000	5,470,000	5,955,000
Pavement	m2	616,000	564,000	713,000	565,000	631,000

* : Including the transitional part

4-6-5 Evaluation of Alternatives

An evaluation of the 5 alternatives by item are shown in the table below.

Table 4-6-7 Evaluation of Alternatives

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Construction cost	C	C	C	A	B
Breakwater	B	C	A	A	C
Dredging	C	C	C	A	A
Development potential	A	A	C	B	C
Maneuvering of ships	A	B	A	A	A
Calmness of basin	B	A	A	A	A
Functional connection	B	A	A	A	B
Relation to land transportation	B	A	A	A	A
Total evaluation	C	C	C	A	B

Note: A:preferable, B:normal, C:Not preferable

(1) Construction cost

As described in the previous section, construction costs are highest for Alternative-2 and lowest for Alternative-4.

(2) Development potential

This factor will be judged from the total length of the berth and area to be secured in the long-term plan. The following table shows a very rough estimation of the length of the reserved quay walls considering unutilized water area. The figure for length of the quay walls (in parentheses) excludes those portions of the wall which will be prepared on the east side of the Fort. In the case of Alternative-1, the area next to the Fort is originally included as a reclaimed area. Judging from this table, Alternative-1 and Alternative-2 have the biggest potential for future development. However, with the exception of Alternative-3, the difference in length among the quay walls is fractional.

	Reserved length of quay wall
Alternative 1	2,200
Alternative 2	2,200 (1,500)
Alternative 3	1,700 (1,000)
Alternative 4	2,000 (1,300)
Alternative 5	2,000 (1,300)

In the case of alternative 5, the depth of some quay walls and basin is restricted to -12 m.

(3) Maneuvering ability of ships

All of the alternatives include a few places at which the vessels must turn as they approach the inner channel. Especially, in the case of Alternative-2, vessels must turn near the entrance of the harbor in order to approach the eastern side berth.

(4) Calmness of the basin

With the exception of Alternative-1, the difference in calmness at the berth side among the alternatives is small. Alternative-1 is affected by swells which enter the innermost parts of the quay wall.

(5) Functional connection

In the case of Alternative-1 and Alternative-5, reclaimed areas are apart from each other. In the case of Alternative-1, since it is difficult to get a large reclaimed area near the Fort, container berths are constructed separately. This reduces efficiency as traffic between the two wharves arises.

(6) Connection to land transportation

In the case of Alternative-1, in which the front of the city center is reclaimed, the connecting point between the access road and the main road is established near the city center, causing traffic problems. The extention of the railway is also a major problem.

(7) Environmental aspect

The Fort is a living monument and it is believed on the Sri

Lankan side that it should be preserved. From this point of view Alternative-1 is judged to be not preferable.

(8) Relationship with short-term development plan

Galle Bay has very strict natural conditions such as waves and a rocky sea bed. Even if it is decided that a quay wall should be constructed in the western part of the bay which is covered by the Fort to some extent, it is necessary to construct a long breakwater in order to offer protection from swells. Although the depth of the bay is comparatively deep in Galle Bay, it is necessary to dredge the rocky sea bed in order to accommodate large vessels.

According to a very rough estimation of the initial cost for the short term development plan, Alternative-5 is the cheapest, followed by Alternative-4. However, Alternative-5 has a very big defect because, with a shallow depth of -12m, it is impossible to accommodate the large container vessels which frequently run along the main shipping route.

(9) Comprehensive evaluation

Based on these evalnations, it is judged that alternative 4 is the best. However, alternative 5 is cost effective for the short term development plan.

4-6-6 The layout Plan

The following items are considered before determining the land use of the reclaimed area.

* Necessary facilities including offices related to the port are located at the reclaimed area so as not to influence the environmental condition of Rumassala Hill.
* Storing areas for containers and general cargoes other than container yards and shed are secured within the port territory.

The layout of the master plan is shown in the next Figure.

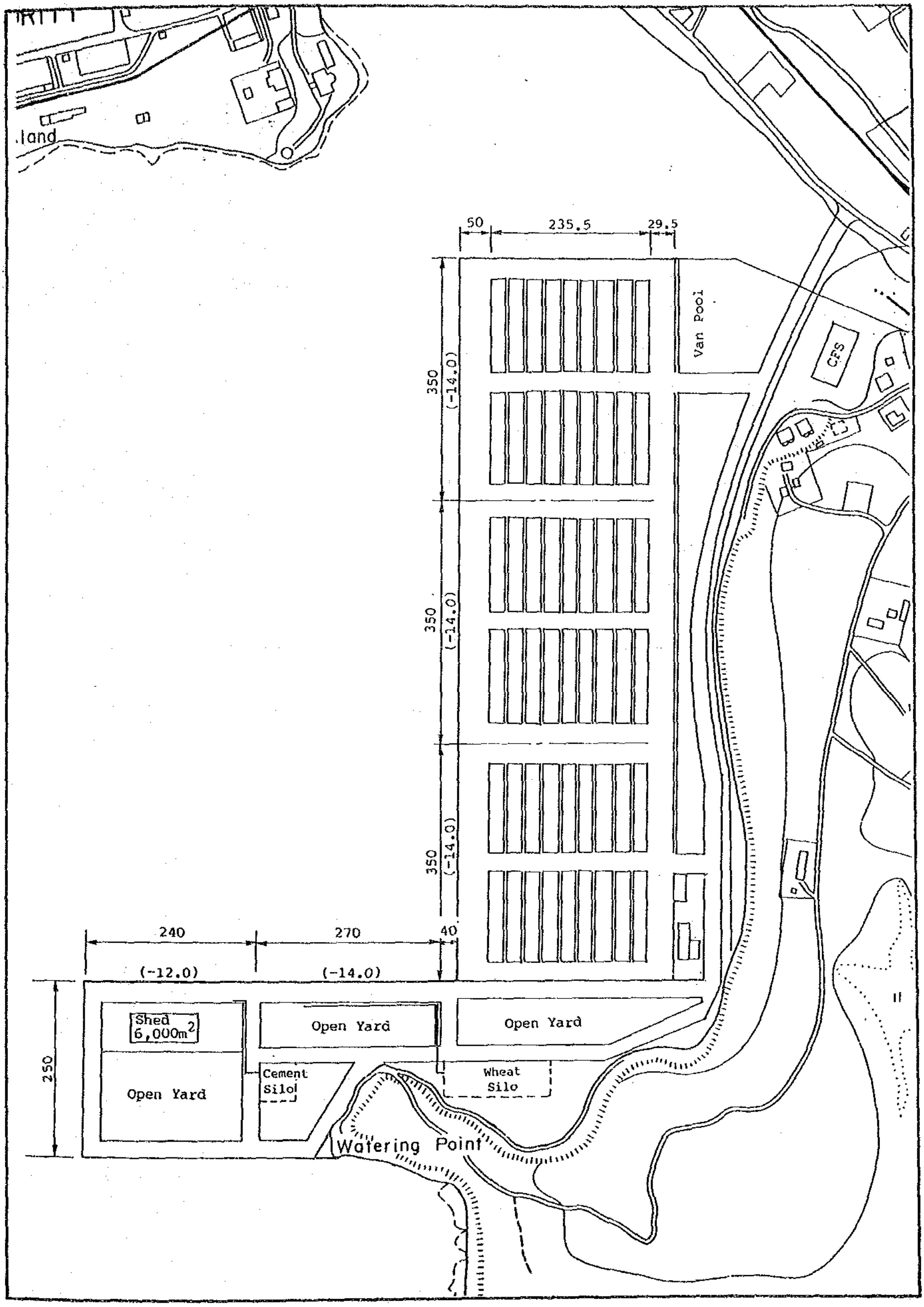


Fig. 4-6-7 Layout of Master Plan

4-6-7 Conceptual Development Plan for the Long Term

In this section, we want to present a conceptual understanding of the bay's future from the viewpoint of port development. Our aim here is not to formulate a long-term plan but to clarify the development potential beyond the year 2005.

Therefore, in this section, we will not examine a host of port trends. For instance, we do not document trends on demand, vessel type and size, etc.

Three sites in the bay already have been selected as candidates for port development. After the completion of Alternative-4, site 1 and 2 will be developed. The development of these sites will likely follow patterns established in Alternatives 1, 2 and 5. In considering alignment of break-waters, it is possible to draw a conceptual picture for the future by combining Alternatives 1 and 5. This concept is shown in Fig. 4-6-8. Broken lines indicate the alignment of the quay wall and revetment.

To transform these dotted lines into real ones, the following key items must be examined:

1) Environment aspects of reclamation on the east side of the Fort
2) The desired depth of the basin and waterways while considering the economic implication of bedrock bottoms
3) The degree of calmness in the basin facing the eastern side of the central wharf

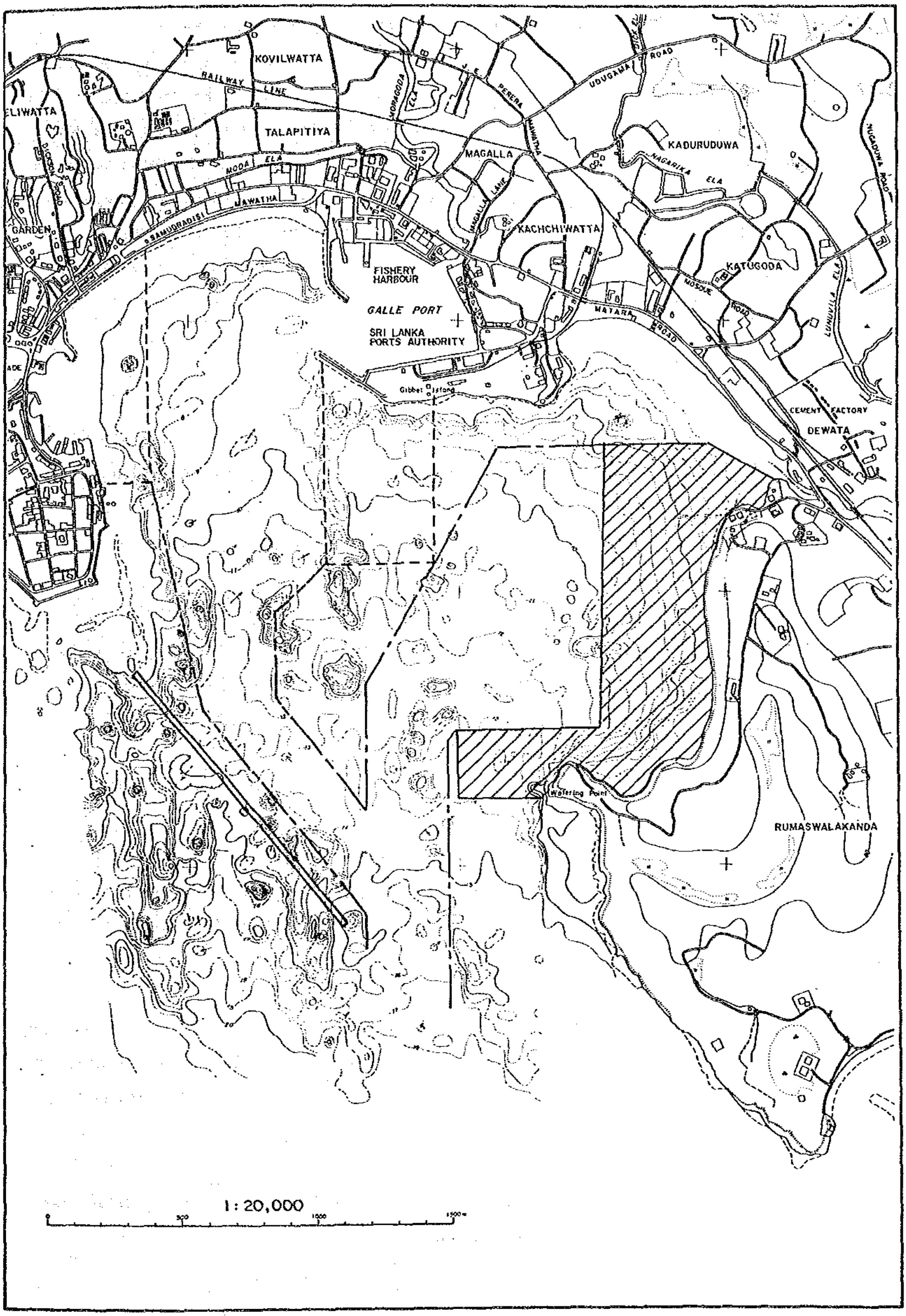


Fig. 4-6-8 Conceptual Full Scale Development Plan

4-7 Design, Rough Cost Estimation and Implementation Program

As mentioned in Section 4-6-4, the No. 4 and No.5 Proposals of the five Alternative Proposals were selected for further study, and the No. 4 Proposal was finally selected as the best-suited plan. Accordingly, the studies on the design, rough cost estimation and implementation program of the No. 4 Proposal were presented in this Section, while those on cost estimation and implementation program of the No. 5 Proposal were given in the Appendix II-4-10 ~ 11.

4-7-1 Design

(1) Main Port Facilities;

The port facilities to be constructed under the Master Plan Scheme comprise

1) Breakwater

2) Quay Structures

   a) Container Berth (planned depth -12.0 and -14.0 m)

   b) Grain Berth (planned depth -14.0 m)

   c) General/Bulk Cargo Wharf (planned depth -12.0 m)

   d) Oil Berth (planned depth -7.5 m)

3) Revetment

   a) Sea Wall

   b) Revetment

(2) Selection of the Type of Structure and Typical Cross Section;

The Port of Galle has, at its whole area, rock layer in the seabed with soft soil layer at certain places.

If the design depth of -14.0 m are adopted to the port basin, dredging of rocks is therefore required at the majority of the area. Under the above condition, available numbers of quaywall structures for selection in the design has become less.

Consequently, the gravity type Caisson and Rubble Mound have been chosen as the types of structures.

Typical cross sections for those Port Facilities are basically the same as those shown in the Part III Short Term Plan referring to the Fig. 3-2-1 -- 3-2-8.

Attention is, however, drawn to the fact that design is so made as to enable the laying of rail on the Grain Berth to install a crane thereon.

4-7-2 Rough Cost Estimation

(1) Of the Alternative Plans presented in the preceding article of 4-6, the Alternative Proposals of No. 4 is selected as the optimum Master Plan and the cost estimation is performed thereto.

The Table No. 4-7-1 and 4-7-2 account for the results of the calculation.

(2) The total cost in US$.
(US$ 1.00=Rs. 41.00=¥138.85;
Quotation of Third Site Survey in May 1991)
- Alternative No. 4 : US$ 592 Million

4-7-3 Implementation Program

The target years set up in the Implementation Program are 1997 and 2005 for the Short Term and the Master Plan respectively.

The time schedule for the major items of works are explained in the Table 4-7-3.

Table 4-7-1 Rough Cost Estimates of Master Plan Project (2005)
(Alternative No. 4)

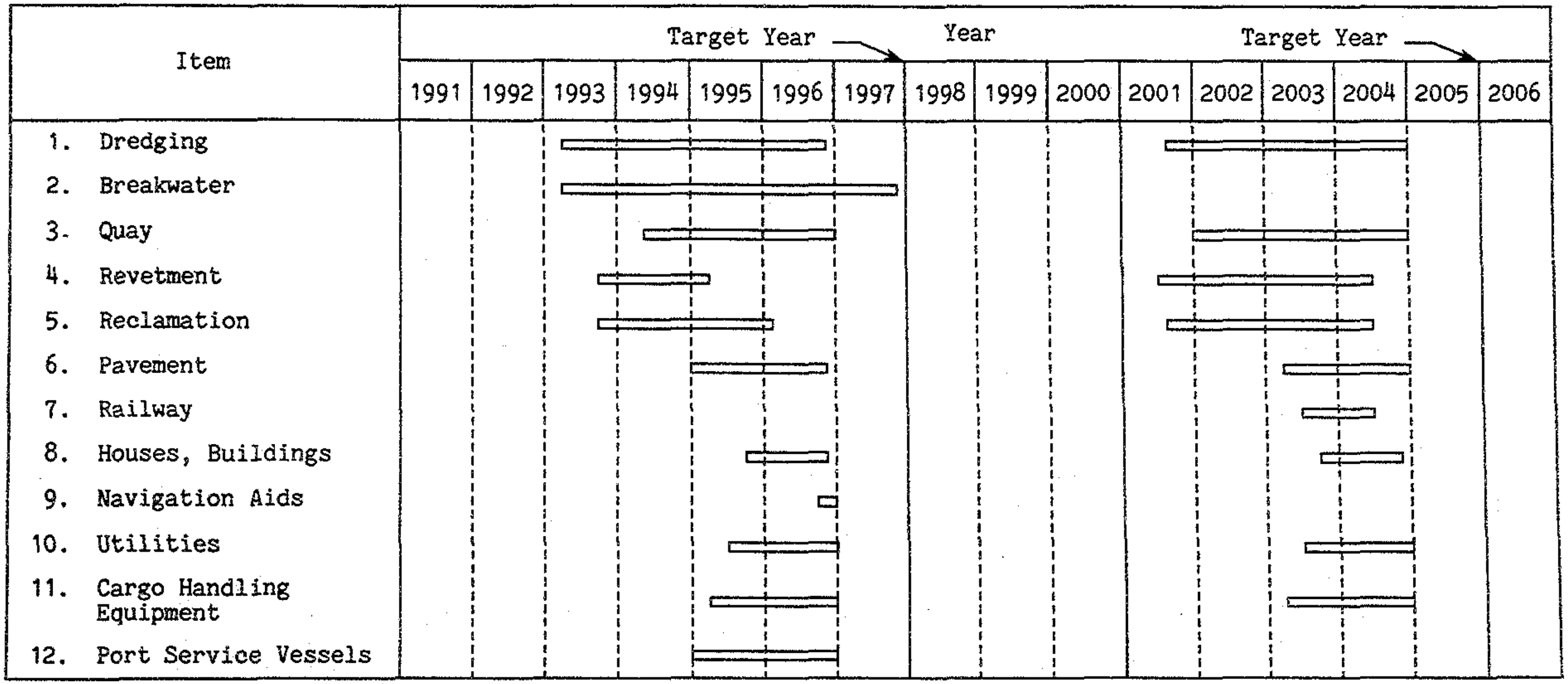
Facility	Quantity		Cost (Million US$)
1. Dredging			
Rock Material	610,000	m3	42.67
Other Material	2,170,000	m3	12.31
2. Breakwater			
Southwest Breakwater	1,300	m	83.98
3. Quays			
Container (-14.0m)	1,090	m	80.63
Grain (Wheat)	270	m	17.78
General/Bulk Cargo	240	m	16.81
Bunker Oil	1	Sum	4.43
4. Revetment	1,770	m	46.42
5. Reclamation (Filling)	5,470,000	m3	59.78
6. Pavement	565,000	m^2	43.07
7. Rail Way	1,000	m	1.08
8. Houses Buildings	1	Sum	11.76
9. Navigation Aids	1	Sum	0.70
10. Utilities (Water and Electric)	1	Sum	25.00
11. Cargo Handling Equipment			
Container	1	Sum	69.35
Grain	1	Sum	25.71
Fertilizer	1	Sum	7.56
Cement	1	Sum	1.50
Bunker Oil (Loading arm)	1	Sum	1.30
12. Port Service Vessels	2	Nos	6.48
13. Contingency (6%)			33.50
Grand Total (1~12)			592.00

Table 4-7-2 Rough Cost Estimates of Master Plan Project (2005)
(Alternative No. 5)

Facility	Quantity		Cost (Million US$)
1. Dredging			
Rock Material	525,000	m^3	36.73
Other Material	2,920,000	m^3	16.57
2. Breakwater			
Southwest Breakwater	1,480	m	95.61
East Breakwater	350	m	29.96
3. Quays			
Container	1,150	m	74.76
Grain (Wheat)	270	m	24.77
General/Bulk Cargo	240	m	17.37
Bunker Oil	1	Sum	4.43
4. Revetment	1,520	m	39.86
5. Reclamation (Filling)	5,955,000	m^3	65.08
6. Pavement	631,000	m^2	48.10
7. Rail Way	1,000	m	1.08
8. Houses Buildings	1	Sum	11.76
9. Navigation Aids	1	Sum	0.70
10. Utilities (Water and Electric)	1	Sum	25.00
11. Cargo Handling Equipment			
Container	1	Sum	69.35
Grain	1	Sum	25.71
Fertilizer	1	Sum	7.56
Cement	1	Sum	1.50
Bunker Oil (Loading arm)	1	Sum	1.30
12. Port Service Vessels	2	Nos	6.48
13. Contingency (6%)			36.32
Grand Total (1~12)			640.00

Table 4-7-3 Implementing Steps for the Master Plan

(Alternative No. 4)



4-8 Consideration of Environmental Aspects

4-8-1 Rough Evaluation of Environmental Conditions In Galle Bay

Not only surveyed data concerning water quality, such as COD, BOD, coliform, etc., but also other data related to environmental conditions such as air pollution, vibration and animals and plants do not exist in Galle Bay. Hence, there is no quantification of pollution level at the Bay. The available criteria applies to discharge limit from point-sources into the environment. There are no ambient environmental quality standards at present, but they are defined in the Terms of Reference for Environment Impact Assessment Study.

The following points are considered significant.

(1) Sewage

Drainage from houses flows directly into the public water without any treatment but is obliged to proceed through a simple treatment process in the case of feces. And each house has a septic tank, according to municipal regulations.

The National Environmental (Protection and Quality) Regulation No. 1 of 1990 regulates the discharge of pollution from any source. Any industries have to operate on a license issued by the Authority. Discharge limits have been laid down in this Regulation.

Also, industries have to conform to the UDA Planning and Building Regulations.

(2) Garbage Disposal Yard

There are two areas for Garbage disposal in the Galle area, which are located in the North-Eastern part, and their capacities for disposal will remain sufficient for more than ten years. And this does not have any influence on the water pollution of the sea.

(3) Cultural Protection

The area within the Fort is famous for many old structures built mainly by the Dutch more than 300 years ago. Demolition or rebuilding of these structures are forbidden in principal by the regulations of the Archaeological Department, and also any development activity within 400 yards from the boundary of the Fort has to get approval from the same department.

Blasting of seabed rock is prohibited within four chains (88 yds.) from the Fort based on the agreement between the SLPA and the Archaeological Department.

(4) Maintenance of Hill Environment

The Hill of Rumassala, which is located on the eastern side of Galle Bay, has some restrictions against development. They have some relationship to religious beliefs. Some of the plants found on this hill has special medicinal values as well. It is necessary to consider these values.

(5) Species to be Protected

It is stipulated by the regulations of the Ministry of Fisheries that turtles be protected in the Galle Region as marine species. Also, coral reef are to be protected accordingly. It is reported that there are no specific species to be protected in the Bay.

4-8-2 Picking-up of Environmental Components to be Affected by the Port Development

Environmental characteristics of the port plan are as follows:

i) The main contents of the plan are to construct wharves for handling containers. These facilities themselves don't affect environmental conditions.

ii) However, the construction of the breakwater for protecting port facilities from big waves will result in the closed water area in which it is not easy to exchange water with the outer sea.

iii) It is possibile to assume that environmental conditions in Galle Bay area are generally in good. Also, it is possibile to assume that the environment in this area has some residual capacity to absorb or cope with a slight increased pollution.

iv) On the contrary, some attention should be paid to preservation of the landscape.

Considering these characteristics, components of the environment to be affected by the port development are selected as follows:

* The air condition

This is a factor which has a strong relationship with the usage of automobile. In port, exhausted gases from ships and automobiles in the port area are main resources of air pollution. Generally speaking, however, the volume of gas produced by them is comparatively less than that resulting from automobile in the area surrounding the port.

* Water quality

This is a factor which is mostly affected by the construction of port facilities such as breakwater and quay walls.

* Vibrations

The deepening of existing channel was carried out by blasting, and this caused some vibrations near the construction work area.

* Oceanography, topography

Construction work will have some impact on topography and in particular oceanography will be affected by port construction work.

* Animals, plants

When some water areas are reclaimed, marine species will suffer to a certain extent.

* Landscape

When environmental conditions are to be well maintained at the construction site, consideration of the landscape and of animals and plants will be more necessary.

* Others

The relationship with activities such as fisheries shall be taken into consideration.

4-8-3 Environmental Impact and Countermeasures against it

Development projects in coastal areas can cause many changes in surrounding environment. Accordingly, it is necessary to examine and exchange views about assessment of environmental influence beforehand.

The following are brief comments regarding environmental impact and countermeasures against such impact:

(1) Oceanography, topography

Construction of a breakwater will cause a big change in waves and currents in Gall Bay and its vicinity. As the objective of construction of the breakwater is to protect the bay area from high waves, these are normal and inevitable. However, it should be noted that the narrower bay mouth will become an obstacle for exchanging water with the outer sea. It is necessary to conduct some survey of environmental conditions in the process of construction of the breakwater.

As described in 4-3-4 of Part I it is not assumed that erosion or accumulation of sand outside of the breakwater will be brought about by the construction of the breakwater.

In Galle Bay the mouth of the Lunuvila river is usually blocked with the sand drift by waves dashing against the shores. Judging from the basin area of the river, the annual total volume of material discharged from the river is not considered very significant.

When the breakwater proposed in the Master Plan is built, the waters adjacent to the river mouth will become very calm and the material discharged from the river is likely to be deposited in the relatively narrow sea area in the vicinity of the mouth. Under Alternative 4, reclamation is planned for the area extending to a point close to the river mouth and it may be necessary to undertake monitoring of possible depth changes in the neighborhood of the river mouth as a result of the construction of facilities such as breakwater and quay walls.

(2) Water quality

As describe in (1), the bay mouth will become narrower with the construction of the breakwater and it will become difficult for contaminants to be diluted and dissolved by exchanging with the outer sea. The volume of contaminants flowing into the Bay will increase with activation of many activities and reach a level such that the capacity of the Bay cannot accept them. Besides applying stricter criteria regarding discharge limits, construction of sewage disposal plants and discharging some parts of sewage into outer sea directly should also be considered.

There is a closed water area in the port of Colombo and its water quality of it is in bad situation. The authorities concerned should take necessary countermeasures in case of the port of Galle, making use of the experience of Colombo.

(3) Animals, plants

Although it is difficult to clearly determine the impact on species living in the sea and coastal area because of lack of data concerning living creatures, it is reported that there are no species that need to be protected in these area.

Generally speaking, species living in the coastal area to be reclaimed will be affected, but there will be relatively little impact on plant and animal life in the vicinity.

(4) Others

1) Fishery activity

There are some beaches now being used for berthing fishing boats as well as some water areas being used for fishery activities in the Bay. Some of them will vanish, or their use will be restricted to some extent as a result of reclamation and port activities. It is necessary to promote offshore fishery and to make appropriate compensation for fishermen using these areas.

2) Influence of construction activities

a) Muddiness

Rubble stones will be used as a material for breakwater. Muddiness will occur owing to soil articles attaching themselves to rubble stones in the course of construction. This muddiness will be rapidly diluted by waves coming continuously and will not stay for a long time in the water.

Some of the soil dredged for construction of the channel and basin will be abandoned near by in the outer sea area. Dredged soils originally composed of sea ground and minute articles that cause muddiness will already have been washed out. Therefore, it is anticipated that there will be little muddiness caused by abandoning dredged soils in the outer sea area.

b) Vibrations

There are many rocks and boulders on the seabed of Galle Bay and it is necessary to remove these materials in order to construct the channel. The method used to dredge these areas is to blast rocks and boulders first and gather materials blasted by the grab next. As this method has already been applied in dredging the existing channel, it is assumed that it will not result in many problems regarding environmental conditions.

It is possible to reduce the impact of blasting by reducing blasting charges.

3) Traffic congestion

Port activities will result in more traffic burdens on the present road system. And yet, there are some parts of the road system around Galle Bay where smooth traffic conditions do not exists. Thus is necessary to improve road conditions such as alignment and width.

4) Landscape design

The port spaces so far have been constructed in order to provide transportation and production functions without full consideration of their environmental aspects and there are many examples in which well-balanced spaces have not been created, thus affecting the hinterland environment. At the same time, there are many beautiful ports in the world where we can enjoy recreational and educational activities.

The Fort has been identified as a historic monument, and we can enjoy the very beautiful scenery from the hill located near by. The main items to be considered for the creation of a good landscape can be listed as follows:

* Creation of landscape by making full use of characteristics of the port

There are old warehouses and wharves at the gate of the Fort. These facilities should be preserved considering harmonious measures with the historical values possessed by the Fort. By doing so, some historical atmosphere will be generated.

Rumassala is a small hill and people can enjoy beautiful scenery from there. Providing places where it is possible to have a good view is very important.

There is a monument at the gate of the port of Colombo. People can gain a special impression of the port by that landmark. Accordingly, preservation or creation of any landmark is useful.

* Harmonizing of many functions in the port space

There are people who live near the port. It is necessary to give a great deal of consideration to the way the port is developed in order that its transportation and production functions do not negatively affect these people's daily lives.

5) Disposition for the Waste Oil

a) Types of the Waste Oil

The types of waste oil appearing during ordinary operations of ships are mainly bilge, ballast water and tank cleaning water.

Bilge means waste oil accumulated in the bottom of a ship. It is composed of fuel and lubricating oil leaking from the engine mixed with water which is used to wash out these fuels and oils.

Ballast water means water loaded in the cargo hold or fuel tank to balance the ship. It is sea water, including oil remaining in the bottom of the tank, adhesive oil on the wall of the tank and so on.

In the case of a tanker, tank cleaning water appears when the slop tank is cleaned up after the slop is discharged, the tank is cleaned up before the clean ballast water is loaded or the tank is cleaned up before the ship enters the dock for repairs.

b) International Conventions Relating to Marine Pollution

The prevention of marine pollution was early acknowledged as a subject to be promoted through international cooperation. It has been gradually accorded higher priority by international conventions. The Oilpol convention of 1954 (1962, 1969 amendments) and the Marpol 73/78 convention are well-known.

The Oilpol convention's main object is to restrict discharging crude oil and heavy oil into sea. Sri Lanka has ratified this

Oilpol convention.

The Marpol 73/78 convention consists of the basic text and five annexes. Text and annex I widely restrict discharging all kinds of oil, including light oil, into the sea. Annex V prohibits throwing away all kind of plastics into all sea areas and domestic waste, i.e., food waste and empty cans generated by the crew during ordinary living, into the sea area within an area three miles from a country's territorial waters. And more international conventions for the prevention of marine pollution have been adopted by many countries. Though some of marine pollution prevention measures are not in force yet, most people all over the world are very interested in the problem of marine pollution. Sri Lanka has not ratified this Marpol convention.

c) Disposal Facilities for Waste Oil

The landing disposal volume of bilge has no connections with the dimensions or functions of ships. This depends on the intentions of the operating company, and the structures or facilities of ships.

As there are many indefinite factors, it is considered that the dimensions of disposal facilities for waste oil depend on actual results and data.

The dimensions of disposal facilities are mainly decided based on the following two elements. One is the capacity volume of receiving tanks, which are for ballast and cleaning water and for bilge. Another is the capacity of separation facilities for waste oil. These separation facilities are rather expensive. Therefore, it is important to decide on an adequate capacity. It is considered that the capacity volume of tanks for bilge is 10 m^3 at most, because most data concerning the volume of bilge landed from ships gives figures of less than 10 m^3. As well, discharging, collection of oil and fire-fighting facilities have to be planned.

About 3,000 m^2 will be required for the site, including these facilities, based on actual data.

4-9 Socioeconomic Impact

The implementation of the Master Plan will bring socioeconomic impacts on the Southern Province. For example,

- It will provide direct access to overseas markets from the Southern Province: Galle, Matara and Hambantota, thereby contributing to the reorganization and rational allocation of functions at Sri Lanka's ports.

- It will allow the port of Colombo to relieve the present congestion and to accommodate future traffic demand.

- It will reduce unnecessary traffic on the national road A2 (from Colombo to Hambantota via Galle) and the railway of coast line, which otherwise might be paralyzed due to the increasing demand and progress of motorizations as a whole.

- It will enable the exploitation of the benefit of maritime containerization, thereby improving the service quality and cost condition for the shippers/consignees in Galle's hinterland.

- It will boost regional economy as the Port of Galle become a hub port on international shipping routes.

- It will contribute to the development of an Export Processing Zone (EPZ) in Kogalla in the Galle District. As the port area is developed, the number of the factories located in Kogalla, as well as production generally, will increase.

- It will provide a growth core in the Southern Province, and contributing to revitalization of the economy through industrialization. In particular, the cement factory behind the port and the flour mill to be located near the port will be developed in the near future.
- It will have a good effect on agriculture in the Southern

Province due to savings in land transportation costs, compared with to and from Colombo.

- Finally, construction and management of the port combined with the development of local industries, will increase employment opportunities, thereby raising income levels in the Southern Province.

Clearly, the development of the Port of Galle will lead to ongoing regional expansion in the Southern Province.

PART III SHORT TERM PLAN AND FEASIBILITY STUDY

1 PLANNING PREMISES

The mouth of Galle bay faces Southwest, and high waves attack the Bay frequently in the southwest monsoon season. Several marine incidents have occurred in the approaching channel over the past 15 years mainly because of rough sea conditions. It is considered that the rough sea conditions are one of the key reasons the Port of Galle is in a stagnant situation. Therefore, this important problem should be solved urgently.

Considering this situation, we proposed measures to counter the sea conditions as our urgent plan (please refer to appendix III-1) for the port. In the preparation of the Short-term Development Plan, we incorporated the urgent plan.

1-1 Cargo volume

To conduct a Feasibility Study of the Short-term Development Plan up to the year of 1997 of the Port of Galle, a "Demand Forecast" is carried out to determine the cargo volume handled at the Port of Galle in the target year. An analysis of the share and the shift of traffic from the Port of Colombo is to be included.

For details of "Demand Forecast", turn to Chapter 3 of Part II.

The cargo volume, handled at the Port of Galle, by commodity is shown in Table 1-1-1. The cargo volume by handling mode is shown in Table 1-1-2.

Table 1-1-1 Cargo Volume at the Port of Galle by Commodity

(Unit: '000 tons)

	1997
(Import)	
Bulk Wheat	100
Bulk Fertilizer	84
Bulk Cement	0
Bulk Clinker	194
Flour (Coastal)	113
Sugar	41
General Cargo	162
Total	694
(Export)	
Containerized Flour	65
Tea	75
Rubber	14
Coconuts & Coconut Products	25
General Cargo	71
Total	250

Table 1-1-2 Cargo Volume at the Port of Galle by Handling Mode

	1997
(Import)	
Bulk ('000 tons)	378
Break Bulk ('000 tons)	202
Container ('000 tons)	114
Loaded ('000 TEUs)	8.5
Empty ('000 TEUs)	4.4
Total ('000 TEUs)	12.9
(Export)	
Bulk ('000 tons)	0
Break Bulk ('000 tons)	17
Container ('000 tons)	233
Loaded ('000 TEUs)	18.7
Empty ('000 TEUs)	4.7
Total ('000 TEUs)	23.3
(Total)	
Bulk ('000 tons)	378
Break Bulk ('000 tons)	219
Container ('000 tons)	347
Loaded ('000 TEUs)	27.1
Empty ('000 TEUs)	9.1
Total ('000 TEUs)	36.2

Table 1-1-3 and 1-1-4 show the total container throughput in Sri Lanka and at the Port of Colombo, respectively. Table 1-1-5 shows the total cargo throughput at the Port of Galle.

Table 1-1-3 Total Container Throughput in Sri Lanka

		1997
Discharged	Container ('000 TEUs)	211
Loaded	Container ('000 TEUs)	151
Sub Total	Container ('000 TEUs)	362
Transshipment	Container ('000 TEUs)	1,244
Total	Container ('000 TEUs)	1,606

Table 1-1-4 Total Container Throughput at the Port of Colombo

		1997
Discharged	Container ('000 TEUs)	198
Loaded	Container ('000 TEUs)	128
Sub Total	Container ('000 TEUs)	326
Transshipment	Container ('000 TEUs)	1,054
Total	Container ('000 TEUs)	1,380

Table 1-1-5 Total Cargo Throughput at the Port of Galle

			1997
Discharged	Bulk	('000 Tons)	378
	Break Bulk	('000 Tons)	202
	Container	('000 TEUs)	13
Loaded	Break Bulk	('000 Tons)	17
	Container	('000 TEUs)	23
Sub Total	Bulk	('000 Tons)	378
	Break Bulk	('000 Tons)	219
	Container	('000 TEUs)	36
Ttansshipment	Container	('000 TEUs)	190
Total	Conventional	('000 Tons)	597
	Container	('000 TEUs)	226

1-2 Vessel Size and Berth Dimensions

(1) Container Cargo

Size of objective vessel is set as the same as that of 2005. In the examination of the container vessel size of 2005, larger vessels running on main shipping routes were mainly considered. Here, the size of the feeder vessel is examined.

In the case of envisaging transshipment using small number of berths, it is better to prepare facilities for a mother vessel and a feeder vessel to berth simultaneously.

Container ship size distribution is shown in 4-2 of Part II, and it is understood that more than 50% of container vessels belong to the category of 100 ~ 600 TEUs. It is considered that ships belonging to this category would be feeder vessels.

The table below was made by using the service schedule of feeder vessels calling at the Jaye Container Terminal. This shows the proportion of each category of TEU in number.

Table 1-2-1 Distribution of Feeder Vessel Size

Unit: %

<100	100~199	200~299	300~399	400~499	500~599	600~
0.0	15.6	36.6	19.7	4.5	18.2	5.4

The maximum vessel size is 916 TEUs, and this ship provides service on the route between Singapore and Karachi. From this table, it is understood as follows:

i) More than 75% of the feeder vessels are less than 500 TEUs.

ii) The most popular feeder vessel size is 200 ~ 299 TEUs.

According to statistic data from SLPA, container vessel size distribution by DWT is shown in Figure 1-2-1. In this figure, vessels of more than 18,000 DWT are excluded, and 57% of all container vessels that visited the port of Colombo in 1989 are included.

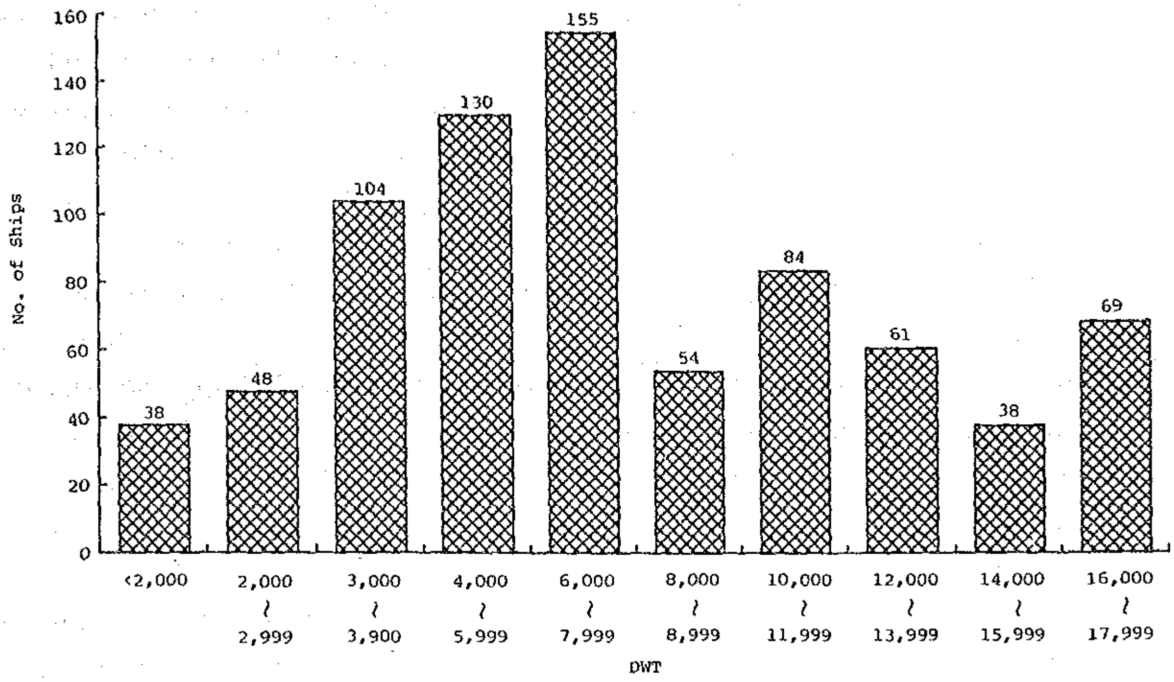


Fig. 1-2-1 Distribution of Ship Size (1989)

In which category, around 80% is less than 12,000 DWT.

On the other hand, the relationship between TEU and DWT is shown in figure below:

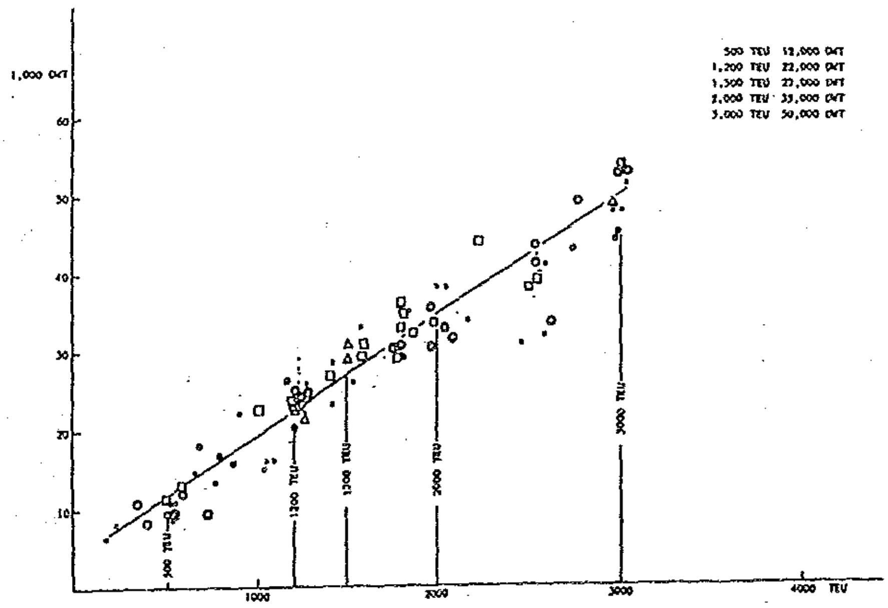


Fig. 1-2-2 Relationship Between DWT and TEU

From this figure 1-2-2, it could be judged that a vessel of 500 TEUs has about 12,000DWT. Considering these situations described above, 12,000DWT, 500TEU type is adopted as objective feeder vessel size. Accordingly, the required berth dimensions are as follows :

Container berth length = 330 - 350m   Depth = - 14m
Feeder berth length = 170m   Depth = - 9m

In the case of Short-term Development Plan, 330m is adopted as the length of container berth.

(2) Bulk Cargo

The cargo volume of wheat to be handled at the Port of Galle in 1997 is only 100,000 tons. To convey such a small volume per year, a vessel of 65,000 DWT assumed for 2005 will not be used. As such, up to the year 1997 the size of the ship for conveying wheat is assumed to be smaller than 30,000 DWT. The size of the vessel for conveying other cargo such as fertilizer and so on are assumed to be a little smaller or the same as 2005. On the other hand, the size of 25,000 - 30,000 DWT is very popular in bulk carrier. Accordingly, 30,000 DWT is adopted as the maximum vessel size and the required berth dimension is as follows :

Berth Length = 240m   Depth = - 12m

(3) Others

According to the plan of the Ceylon Petroleum Corporation, the vessel size is set to be 5,000 DWT.

Berth Length = 120m   Depth = - 7.5m

2 MAIN FACILITY PLAN

2-1 Berths

2-1-1 Container Berth

The volume of container cargo to be handled at the Port of Galle is expected to be 226,000 TEUs in 1997. The average cargo handling volume per container vessel is assumed to be 900 TEUs considering the volume handled at the Jaye Container Terminal in 1988. The 20/40 feet container ratio is assumed at 60:40 in 1997, expecting a little increase in the proportion of 40 feet container in total.

Other parameters such as cargo handling hours per day, the annual number of workable days and so on are assumed as the same as those in formulating the master plan.

Under these conditions, the number of calling container vessels would be 251.1 and the service time for one vessel is assumed to be 0.743 days. Accordingly, the berth occupancy rate can be calculated as follows:

Number of Berths	Berth Occupancy Rate
1	0.524
2	0.262

Although more than one berth is required, two full-scale berths will provide more than enough capacity. In the case of the Port of Galle, 84% of container cargo would be transshipment and around 50% of calling vessels for container handling would be feeder vessels, assuming conditions are in line with those in the Port of Colombo.

In the Colombo Port, the south side of the Jaye Container Terminal is used as a feeder berth. There is no handling equipment at the quay, and cargo handling is being conducted by ship gears.

Recent cargo volumes handled there are as follows:

Year	Month	TEUs
1990	October	1621
	November	2278
	December	2512
1991	January	4185

From these data, the maximum capacity can be assumed to be around 40,000 - 50,000 TEUs.

In view of these conditions, it can be judged that one berth for a mother vessel and one berth for a feeder vessel will be required. The cargo handling capacity is estimated to be 268,000 TEUs.

2-1-2 General/Bulk Cargo Berth

We have planned a General/Bulk Cargo Berth that can be used for handling break bulk, wheat, fertilizer and clinker. The capacity of the existing berths is assumed to be 220,000 tons of break bulk cargo considering present stevedoring productivity. At an estimated 219,000 tons, the break bulk cargo volume to be handled at the Port of Galle in 1997 will be less than the capacity of the existing berths. However, some parts of them will be conveyed by larger vessel than 10,000 DWT which cannot enter existing basin. Then, the cargo volumes to be handled at the general/bulk cargo berth are assumed to be 19,000 tons for break bulk, 100,000 tons for wheat, 84,000 tons for fertilizer and 194,000 tons for clinker. It is assumed that the cargo volume per vessel for these cargoes are 3,000 tons/vessel, 15,000 tons/vessel, 10,000 tons/vessel and 20,000 tons/vessel respectively. Unloading of all these cargoes will be carried out by ship gears. Using the same method taken for calculation in procedure in 2005, the berth occupancy rate can be calculated as follows:

Berth Number	Berth Occupancy Rate
1	0.39

Accordingly, it is judged that one berth is enough.

2-1-3 Oil Berth

One oil products berth is planned for accommodating a 5,000 DWT tanker and bunkering inside the existing breakwater.

2-1-4 Summary

Through the calculations described above, the following facilities are planned:

Berth	Objective Vessel	Length	Depth	Number
Container Berth	50,000 DWT	330	- 14	1
	12,000 DWT	170	- 9	1
General/Bulk Cargo Berth	30,000 DWT	240	- 12	1
Oil Berth	5,000 DWT	120	- 7.5	1

2-2 Storage Facilities/Handling Equipment

2-2-1 Container Berth

(1) Handling System

For the container berth, a lift-on, lift-off system on the quay wall and a transfer crane system will be applied. For a feeder berth, however, loading and unloading containers will be carried out by ship gears. In this case, cargo handling between the apron and the yard will be done by a top lifter and tractor-trailers.

(2) Container Yard

Through the same procedure taken for calculation in 2005, the required storage number of containers is estimated, and the required number of ground slots under the same conditions taken in 2005 is calculated to be around 2000.

(3) Container Freight Station

The required area for the CFS can be calculated to be 1200 m^2, based on the same condition of the Port of Colombo. In the case of the Port of Colombo, there are many inland depots which carry out the CFS's functions. However, there are no such facilities around the Port of Galle. Thus, some 2025m^2 should be prepared for CFS in view of the current lack of facilities.

(4) Cargo Handling Equipment

The calculation is carried out by using the same formula of 2005. The following equipment will be required:

Container crane	2
Transfer crane	5
Tractor - Trailer	14
Tractor	1
Trailer	10
Top Lifter (40 ton)	2
Folk Lift (2 ton)	2

(5) Others

Other facilities to be installed at the container terminal are as follows:

Administration Office	800 m^2
Maintenance Shop	1000 m^2
Cleaning Facilities	400 m^2

2-2-2 General/Bulk Cargo Berth

(1) Handling System

The volume of fertilizer, clinker and wheat to be handled at this berth is not enough to install some special handling equipment at quay side. Then, unloading of these bulk cargoes and handling of break bulk cargo will be carried out by ship gears. Fertilizer after bagging and break bulk will be stored at the shed, and wheat will be stored at the silo, while most of the clinker will be directly delivered to the outside the port. Handling cargoes between the apron and the storage facilities will be done by forklifts and trucks.

(2) Scale of Storage Facilities

The shed will be planned for storing break bulk and fertilizer. Using the same formula and consideration written in Chapter 4 of Part II, the required storage facilities area is calculated to be 4000 m^2.

For storing wheat, 30,000 ton silo is required considering the lot size of it.

(3) Cargo Handling Equipment

According to the handling method written in handling system, following are required.

Fork Lifts (3 ton)	11 Units
Packer	3 Units
Hopper	3 Units
Trucks	6 Units

2-3 Other Facilities

2-3-1 Breakwater, Channel

The length of breakwaters will be decided through a calmness study on each alternative. (See next section)

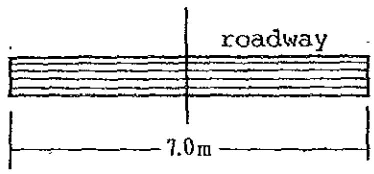
As the maximum objective vessel is assumed as in 2005, the same scale of the channel will be planned.

The east channel is used for entering the existing berths.

2-3-2 Land Transportation Facilities

(1) Road

Taking the same procedure in 2005, it is planned to have a two-lanes road. As the road to be constructed behind the container terminal will be expanded to four-lanes in the future, it is necessary to reserve space for expansion. The standard cross section is shown below:



(2) Railway

As it is considered that the railway system will be introduced after 1997, necessary space is reserved in this plan.

2-3-3 Navigational Aids

It is necessary to introduce more powerful tug boats to cater to big container vessels. It is prohibited for vessels to enter the port in the night now. But after the completion of new facilities, entering of vessels