2. Port Facility Improvement Planning

Countermeasures in response to the present problems concering basic port facilities are studied in this section based on the above port demand forecast. These problems are 1) sand sedimentation in the harbour, 2) insufficient berth length, and 3) an inefficient cargo handling system. In addition, two more problems— 4) necessity of improvement of the small craft basin and 5) superannuation of Puntarenas pier—are also discussed.

Concerning problem 1), the port layout planning should be conducted according to the study results in CHAPTER VI considering the importance of sedimentaion in the present maintenance project. Problem 3) is discussed in CHAPTER VIII based on the port layout presented in this chapter.

Thus, this section mainly focuses on problems 2), 4) and 5).

2. 1 Countermeasures against Sand Sedimentation

Countermeasures against sand sedimentation consist of the breakwater extension, the primary dredging and the maintenance dredging as discussed in CHAPTER VI. The breakwater layout and the dredging program are presented in that chapter.

According to the dredging program, periodic maintenance dredging will have to be carried out over a long period of time. The detailed primary and maintenance dredging plans are presented in CHAPTER IX.

2. 2 Facility Improvement Planning

This study is for the restoration of port functions by improving existing facilities and implementing an appropriate maintenance program. The study seeks cost minimization and the multipurpose use of facilities as much as possible. The improvement of existing facilities is discussed below.

2. 2. 1 Berth Allotment Planning and Project Target Year

In this section, berth allotment and the project target year are studied based on the estimated port cargo volume and the number of ship calls. The study assumes that Puntarenas pier is already superannuated, and that grain imports should be moved to the Port of Caldera.

(1) Required number of berths

1) Cargo handling capacity

In order to determine the required scale of the facilities for future cargo traffic, it is necessary to determine the port capacity. Since port capacity varies according to the type of cargo, size of lots, size of berths, loading and unloading capacity and other factors, it is often represented simply as the cargo volume handled at the port. The cargo handling capacity of the Port of Caldera is estimated in terms of total cargo volume converted into general cargo equivalent.

As for the cargo handling capacity, details are studied in CHAPTER Ⅷ. However, some of the data related to the handling of general cargo are assumed here as follows :

Table VII-28 Factors for Cargo Handling Capacity

Year	1984 (present)[1]	1992 (future)
Average loading unloading capacity per ship (tons/hour)	20	24
Average available hours per day (hours)	21	21
Working day per year (days)	350	350
Number of berths	Caldera 2 Puntarenas 1	Caldera 3
Number of gongs per ship	2	2
Cargo handling working efficiency	0.5	0.5

Source 1) : INCOP

Consequently, the port cargo handling capacity can be estimated in terms of total cargo volume converted into general cargo as follows :

Present : 20 tons/h・gang × 21 h × 2 gangs × 0.5 × 350 days/y × 3 berths
= 441,000 tons/year

Future : 24 tons/h・gang × 21 h × 2 gangs × 0.5 × 350 days/y × 3 berths

2) Cargo volume converted into general cargo

The overall cargo volume is converted into general cargo equivalent using the following coefficients.

Table VII-29 Coefficients to Convert to General Cargo Volume Equivalent

	Present	Future	Remarks
General cargo	1	1	*Assuming a future increase of cargo handling capacity.
Containerized cargo	0.5	0.25*	
Grain bulk cargo	0.5	0.25*	
Other bulk cargo	0.5	0.5	

Accordingly, cargo volume converted into general cargo can be calculated as follows :

Table VII-30 Cargo Volume Converted into General Cargo Volume Equivalent

(Unit : tons)

Year	1984	1992	1995
Cargo volume	375,551	502,775	500,050

3) Port working efficiency

Port working efficienty at the Port of Caldera can be calculated by the following equation.

$$\text{Port working efficiency} = \frac{\text{Cargo volume converted into general cargo}}{\text{Cargo handling capacity}}$$

Thus, the values of port working efficiency are as follows :

Table VII-31 Port Working Efficiency

Year	Working Efficiency(%)
1984	85.2
1992	95.0
1995	94.5

The above figures mean that the projected cago volume will approach the limit of the cargo handling capacity of the port, but that the port will be able to accommodate the forecast throughput if the restoration and maintenance measures proposed in this study are implemented.

(2) Target year of the project

This study is primrily a maintenance project which aims at the resolution of current problems so that the Port of Caldera can handle as much cargo as possible. Once these problems are resolved, the capacity and the cargo handlilng efficiency of the port will both increase. Current problems at the Port of Caldera are summarized in CHAPTER V. The most urgent matter is the establishment of countermeasures against sand sedimentation.

Due to the nature of the ongoing sedimentation, the earlier the countermeasures are implemented, the better the port will function. Approximately four and a half years may be appropriate as the construction period of the project from the viewpoints of engineering and finance. Maintenance works will, of course, follow after that.

In parallel with the above-mentioned countermeasures, the shortage of berth size should also be remedied as soon as possible. The construction period depends on the content of the construction work. However, the construction can be completed by the target year 1992, according to the analysis in CHAPTER IX.

Furthermore, if the plan is implemented, the Port of Caldera will be able to handle all the projected port cargoes in 1992 smoothly. Even in the case of a maintenance project such as this one, the port should be able to cope with all the possible port cargoes in the target year. Thus, it is appropriate to set the target year of this project as 1992.

(3) Alternative berth extension

As described in CHAPTER V, grain imports will be transferred to the Port of Caldera at the beginning of the project. To accept grain cargoes without any harmful influence on the port operations for other cargoes, it is necessary to improve quaywalls so that one grain vessel and one container ship can berth simultaneously at berths No.1 and No.2. Accordingly, the present berth length of 150 m should be extended to the appropriate length considering the ship length of grain carriers and container ships. There are three alternatives to extend the existing berth length of 150 m up to the necessary length (refer to Fig.VII-17).

Alternative A : To extend the berth length of the −11 m quaywall to the west
Alternative B : To construct a new pier in front of all three quaywalls
Alternative C : To deepen part of the existing −7.5 m berth up to −10 m

A detailed appraisal of the three alternatives is shown in Table VII-32. Unfortunately, Alternative C is not possible from the engineering standpoint as noted in CHAPTER X. Alternative B involves newly constructing a pier in front of all the existing wharfs to obtain a continuous, straight face line. However, this idea is very costly compared with Alternative A.

On the other hand, Alternative A involves extending the berth length of the −11 m quaywall and shifting the foot of the existing breakwater to the west. In this alternative, it is also possible to improve the existing mooring basin for small crafts simultaneously with the execution of the extension works (refer to Table VII-32). This would lead to the utilization of the existing −10 m berth up to its full capacity. Thus, Alternative A is selected as the best alternative to secure the necessary berth length of −10 m quaywall.

(4) Berth allotment planning

The berth allotment for berths No.1 and No.2 is studied according to the procedure shown in Fig.VII-18.

1) Berth allotment of the No.2 berth

The existing berth depth of the No.2 berth is −10.0 m. Generally speaking, 0.5~1.5 m is taken as the allowance depth for moorning for deep berths. 0.9 m is set as the allowance berth depth for the No.2 berth in this study. Then, the maximum full-load draft (d) comes to 9.1 m. That is, ships with a full-load draft up to 9.1 m will be able to berth at the No. 2 berth.

Fig.VII-19(1) and Fig.VII-19(2) show the standard relations between ship size (DWT) and overall length (L), and ship size (DWT) and full-load draft (d) of ships less than thirty

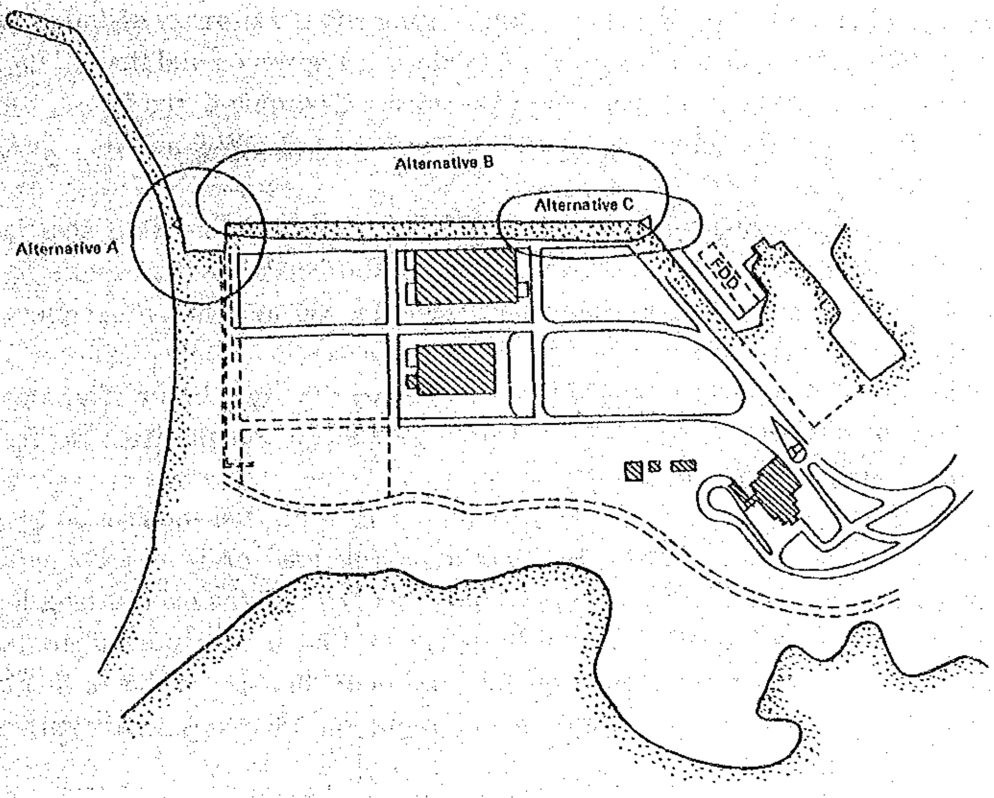


Fig. VII-17 Alternative Berth Extension Methods

Table VII-32 Appraisal of Alternative Berth Extension Methods

Appraisal viewpoints	Alternative A	Alternative B	Alternative C
Port layout	Necessary to shift the foot of an existing breakwater	The turning basin area becomes narrow.	The Launching area of FDD is disturbed.
Cargo handling efficiency	No problem	Locations of warehouses and a gantry crane railway become far from the face line of the quaywall	
Influenece on the small craft basin	Improvement is necessary	Improvement is necessary	No influence
Contribution to protection against sand sedimentation	●Much contribution	No contribution	No contribution
Influence on maneuvering	No problem	No problem	Influenced by launching from FDD
Engineering aspect	Possible	Possible	●Impossible
Construction cost	●Not so expensive	●Very expensive	●Expensive

Note ● : Decisive factors

years old listed in the Lloyd's Register of Ships, 1975, and the Register of Japanese Shipping, 1976. The dotted line indicates the estimated values of regression and the full line shows the values which cover seventy-five percent of the ships. According to the figures, the ship size, which corresponds to the full-load draft of 9.1 m is 15,000 DWT and its overall length is 162 m.

The standard mooring position for vessels of the maximum ship size is shown in Fig.VII-20(1) According to the figure, the required total berth length of the No.2 berth with a depth of −10 m is 185 m. The existing berth length is 150 m. Thus, the required extension berth length is 35 m, which will be secured using a section of the adjacent No.1 berth. Subsequently, the remaining existing berth length of the No.1 berth after deducting the length of the portion of the berth which will be used as part of the No.2 berth is 175 m.

2) Berth allotment of the No.1 berth

The existing berth depth of the No.1 berth is −11.0 m. 1.0 m is set as the allowance berth depth for this berth. Then, the maximum full-load draft (d) comes to 10.0 m. According to the relation between the full-load draft (d) and the overall length (L) shown in Fig.VII-19, the overall length (L) comes to 177 m, that is nearly equal to 180 m. The standard mooring position for vessels of the maximum ship size is shown in Fig.VII-20(2). According to the figure, the necessary berth length for this No.1 berth with a depth of −11.0 m is 210 m.

However, the following factors should be fully considered when extending the berth in this alternative.

(a) The berth is adjacent to the foot of the breakwater

(b) The berth is adjacent to the entrance channel to the small craft basin

(c) Appropriate allowance space for sand sedimentation should be considered so that the berth area will not shoal

(d) The largest berth at the port should accommodate the larger vessels as much as possible

Considering sedinentation, an additional allowance length of 15 m is planned here in extending the berth. Accordingly, the required berth length of the No.1 berth comes to 225 m. The remaining existing berth length of the No.1 berth which is available as part of the −11 m berth is 175 m. Thus, the required extension berth length for the No.1 berth is 50 m.

The necessary extension length should be secured by constructing a dolphin and a gangway as shown in Fig.VII-20 (2) from the viewpoint of economy. There will be no apron behind this gangway. However, this will not disturb reasonable cargo loading/unloading operations because only 20 m, at most, of the ship length will exceed the existing berth length which has a suitable apron. The detailed layout plan for the extension of the berth length including the improvement of the mooring basin for small crafts which is studied in the following section is shown in Fig.VII-21.

Based on the planning presented avove, the berth allotment presented in Fig.VII-21 should be appropriate for the Port of Caldera.

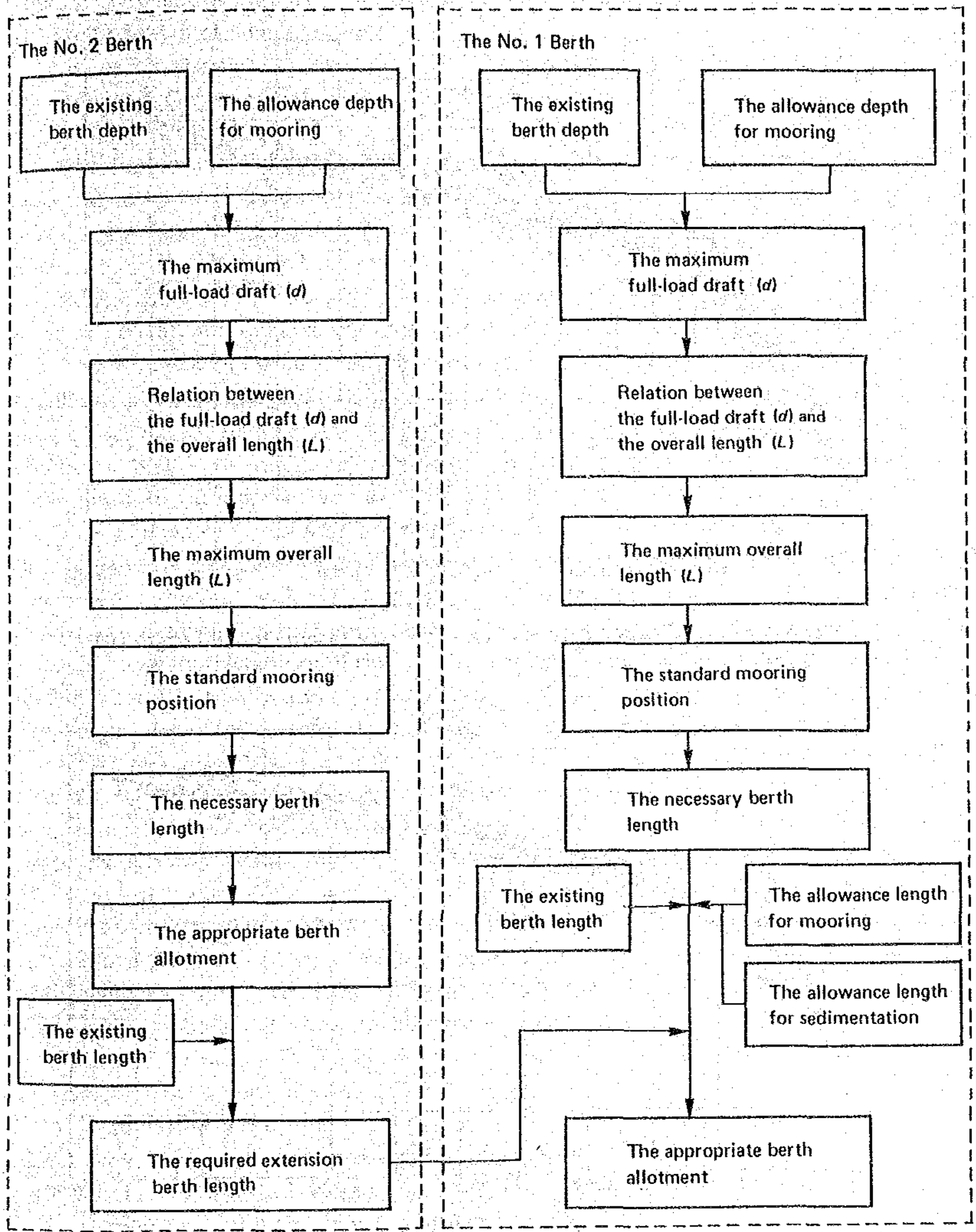


Fig. VII-18 Procedure of Berth Allotment Planning

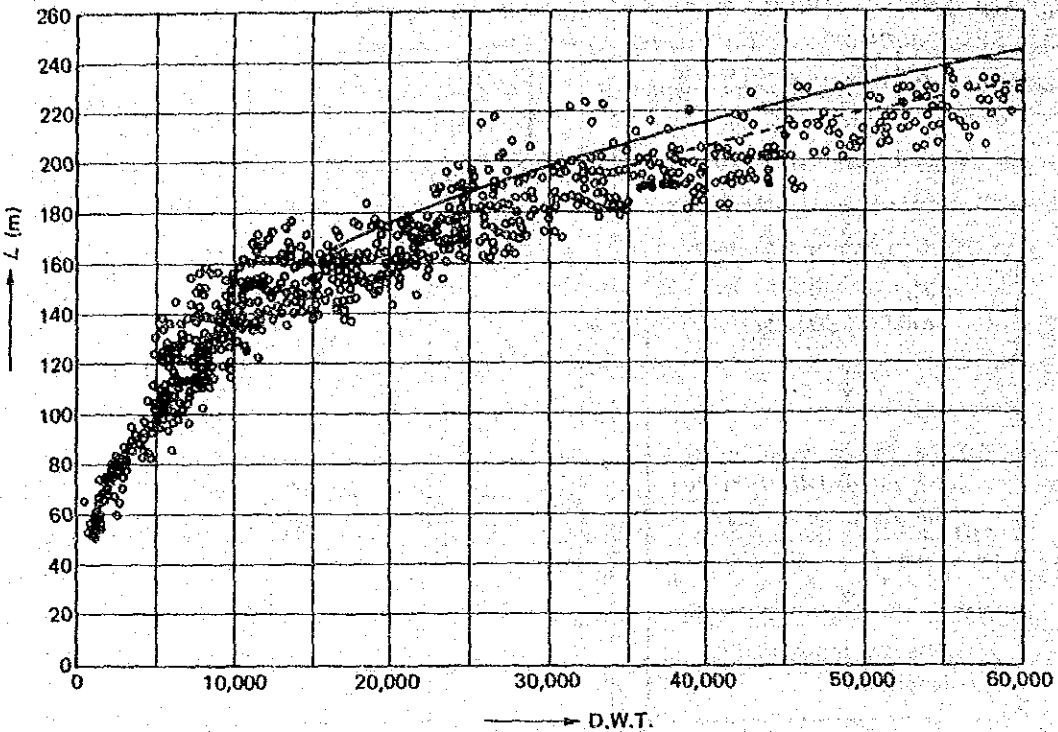


Fig. VII-19 (1) Relation between Ships Size (DWT) and Overall Length (L)

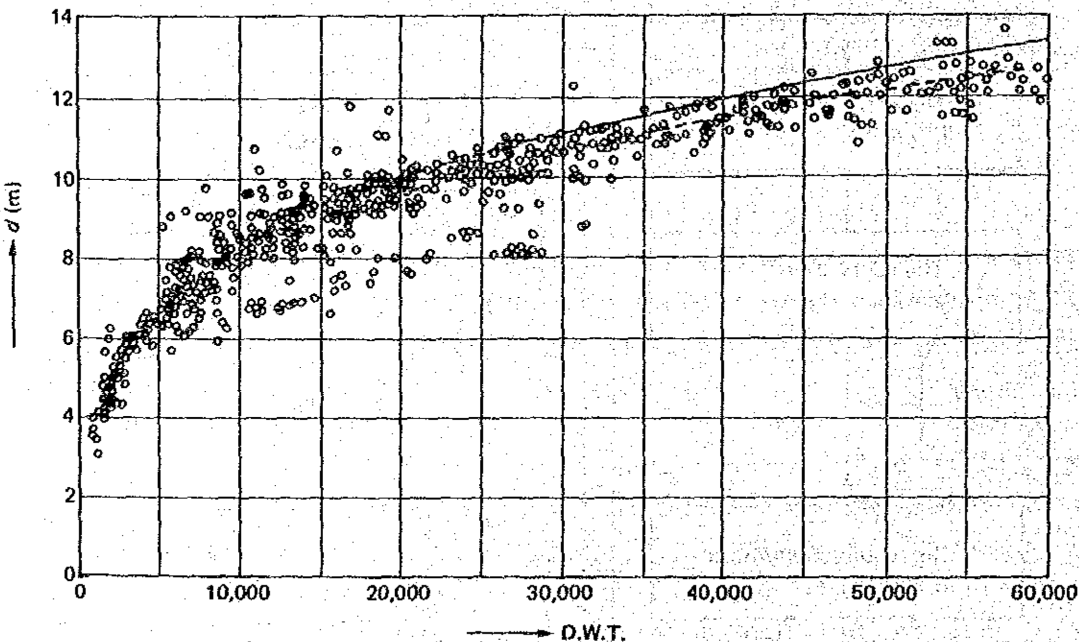


Fig. VII-19 (2) Relation between Ships Size (DWT) and Full-Load Draft (d)

(5) Assesment of port workability using a simulation model

1) Methodology of simulation tests

Simulation tests are carried out in order to ascertain whether or not the planned berth allotment is sufficient to handle the projected cargo volume. Simulation tests are useful as they employ queuing theory, and are therefore able to evaluate the efficiency of port operations in terms of port congestion as measured by ship waiting and staying periods. Such tests take irregularities in ship arrival time and working conditions into account, and thus the results of the simulation tests are more sophisticated than results based only on the projected cargo volume and the empirical cargo handling rate.

Ships calling at a port expect to be moored at a designated berth immediately, in the order of arrival, and to carry out cargo handling. If a ship is already berthed at the quay and there is no room, the latter ship has to wait until after the first ship completes its cargo handling and leaves. (The ship expects to be berthed as soon as it enters a port. However, the port management body wants to minimize the number of quays in order to increase efficiency, that is to minimize investment. Balancing these conflicting desires, namely, determining the appropriate service level, is an important aspect of port planning.)

This phenomenon of ships arriving and leaving a port can be analyzed by queuing theory, as in the analysis of the situation at a bank, where variables include the number of windows and the time each customer takes at the window. For a port, the variables include the arrival of ships, the number of berths and the berthing periods. Great efforts are being exerted to clarify the pattern of ship entries and berthing periods at ports. As to the pattern of ship entries, normally it is a random Poisson interval, that is, entry time intervals are of exponential distribution (refer to Fig.VII-22).

Here, simulation tests which determine the average waiting periods for vessels in 1992, after the completion of the maintenance project, are used to confirm the appropriateness of the planned number of berths (With Case−1). Simulation tests are also conducted based on the projected cargo volume in 1990, 1991 and 1992 under the existing facilitites (Without Case −1, 2 and 3). These show how long the waiting period and service period will be if no improvements are made at the port. An additional simulation is also made considering that only part of the proposed maintenance project is implemented (With Case−2). The details of the simulation tests are presented in the next section. The results of the simulation tests are useful for planning and for economic and financial analyses.

The flow of the simulation model used in this study is shown in Fig.VII-23.

2) Assessment of port workability

(a) Simulation cases

The simulations are conducted for the following purposes :

a) To confirm the limits of port availability with and without the implementation of the proposed maintenance project.

b) To clarify the effectiveness of the −10 m quaywall extension

Simulations are executed for the following five cases :

With Case −1 : For estimated cargo volume with planned facilities and equipment in 1992

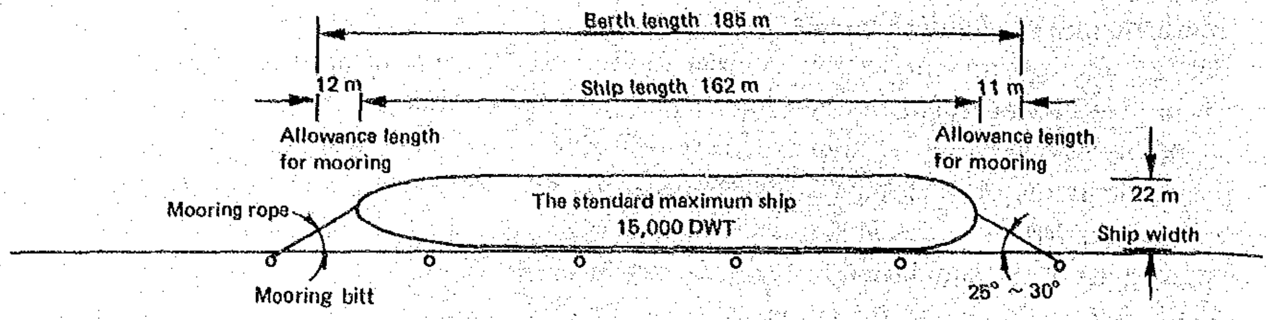


Fig. VII-20 (1) Berth Allotment of the No. 2 Berth

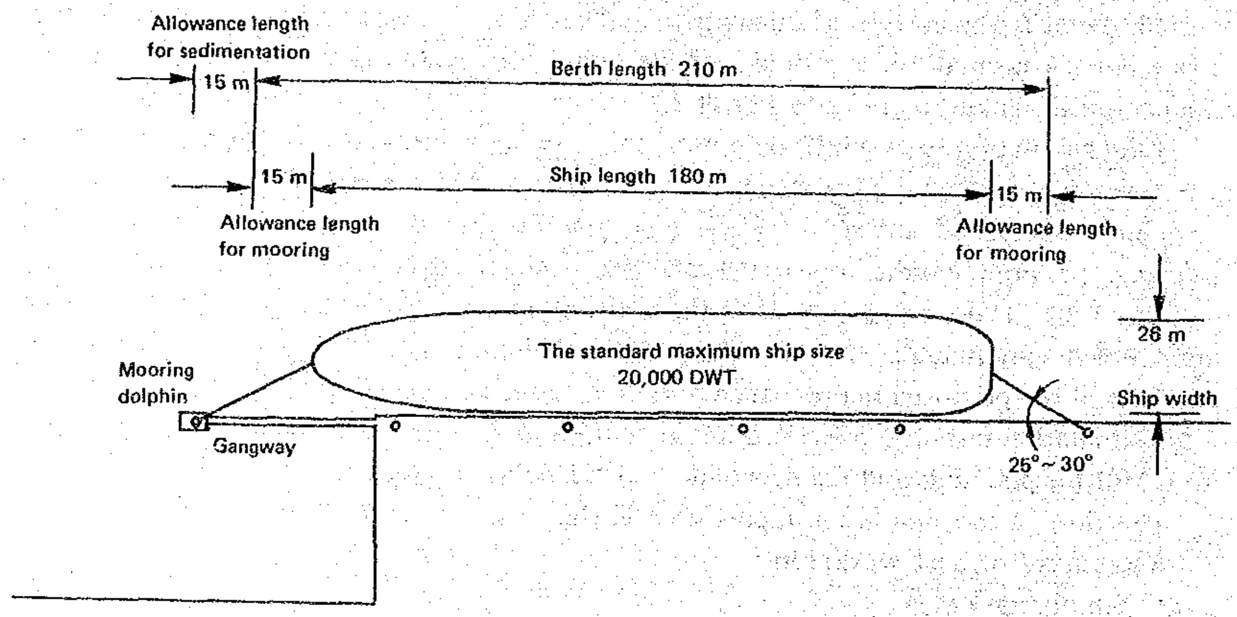


Fig. VII-20 (2) Berth Allotment of the No. 1 Berth

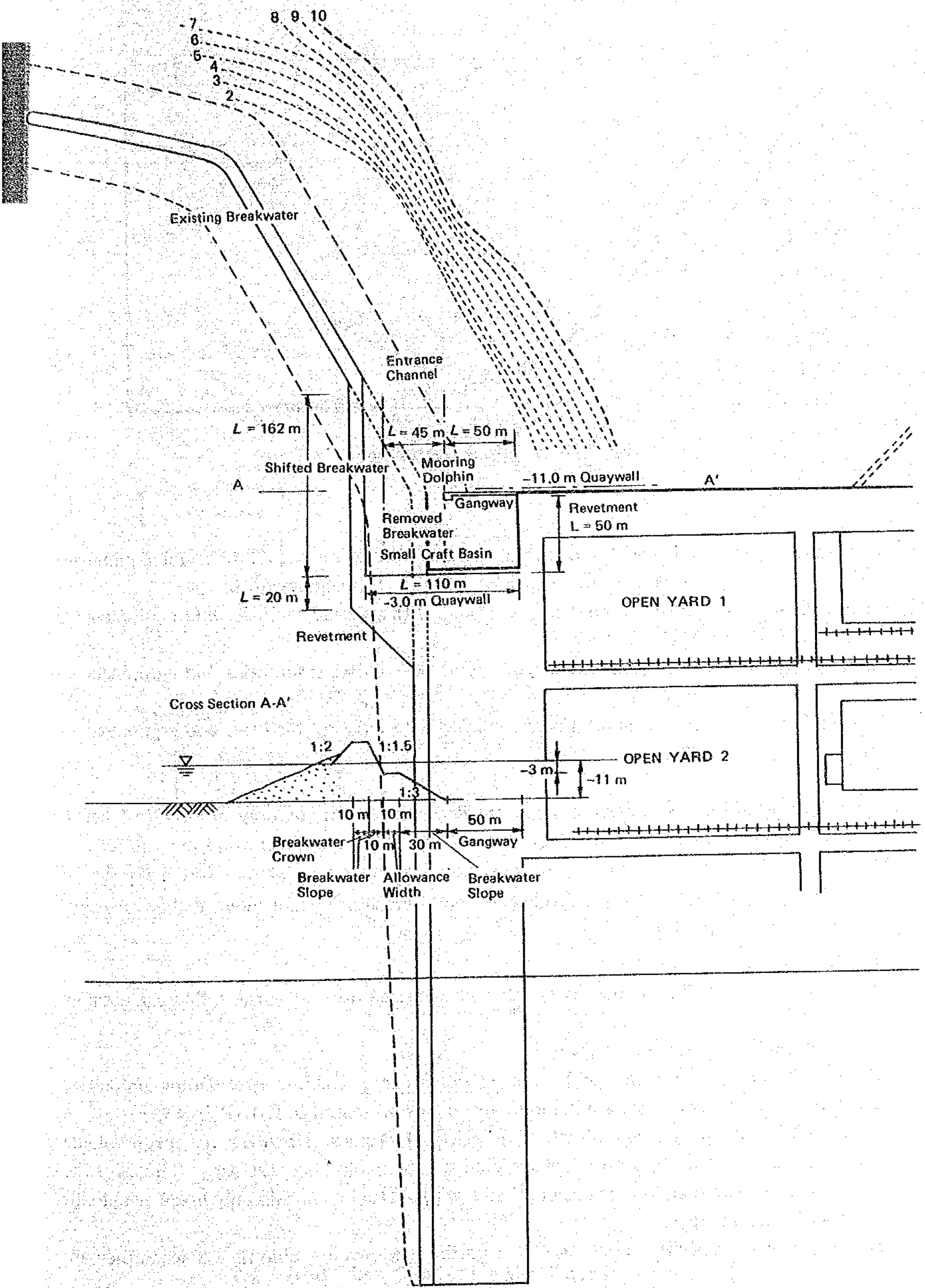


Fig. VII-21 Layout of Extended Berth, Shifted Breakwater and Improved Small Craft Basin

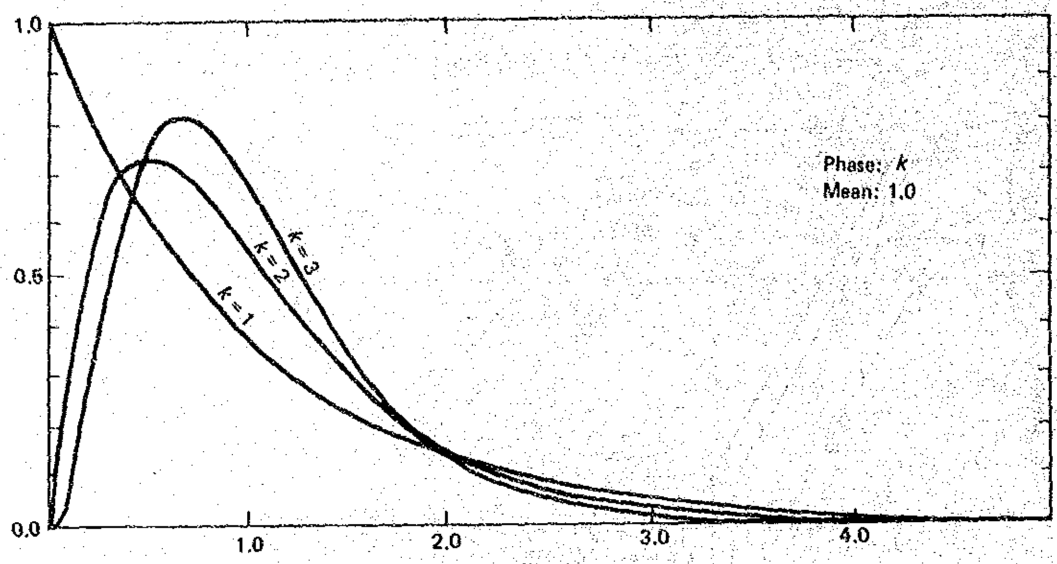


Fig. VII-22 Erlung Distribution

With Case −2	: For estimated cargo volume with planned facilities and equipment other than the extension of the −10 m quaywall in 1992
Without Case −1	: For estimated cargo volume with existing facilities and equipment in 1990
Without Case −2	: For estimated cargo volume with existing facilities and equipment in 1991
Without Case −3	: For estimated cargo volume with existing facilities and equipment in 1992

In all the above cases, certain ships are designated to moor only at the No.1 berth. Especially, in With Case-2, 52 of 103 20,000~30,000 DWT container ships and one of two 20,000~30,000 DWT grain carriers are designated to moor only at the No.1 berth due to their length. Thus, under the simulations certain large ships connot moor at the same time as certain other large ships.

(b) Premises for the simulation

The simulation tests for the above cases are carried out under the following assumptions.

a) Ships can enter and leave at any time.
b) Service periods are estimated by the type of cargo, per ship cargo loading/unloading volume and planned cargo handling capacity as presented in CHAPTER Ⅷ.
c) Many ships actually load and unload a variety of cargoes. However, the cargo volume by commodity and by ship is not clear in the available port statistics. Thus, for the simulation test, a simplified assumption is adopted that each ship only loads or unloads a single commodity.
d) Large ships can berth at No.1 and No.2 berths as shown in Table Ⅶ−33 when they are

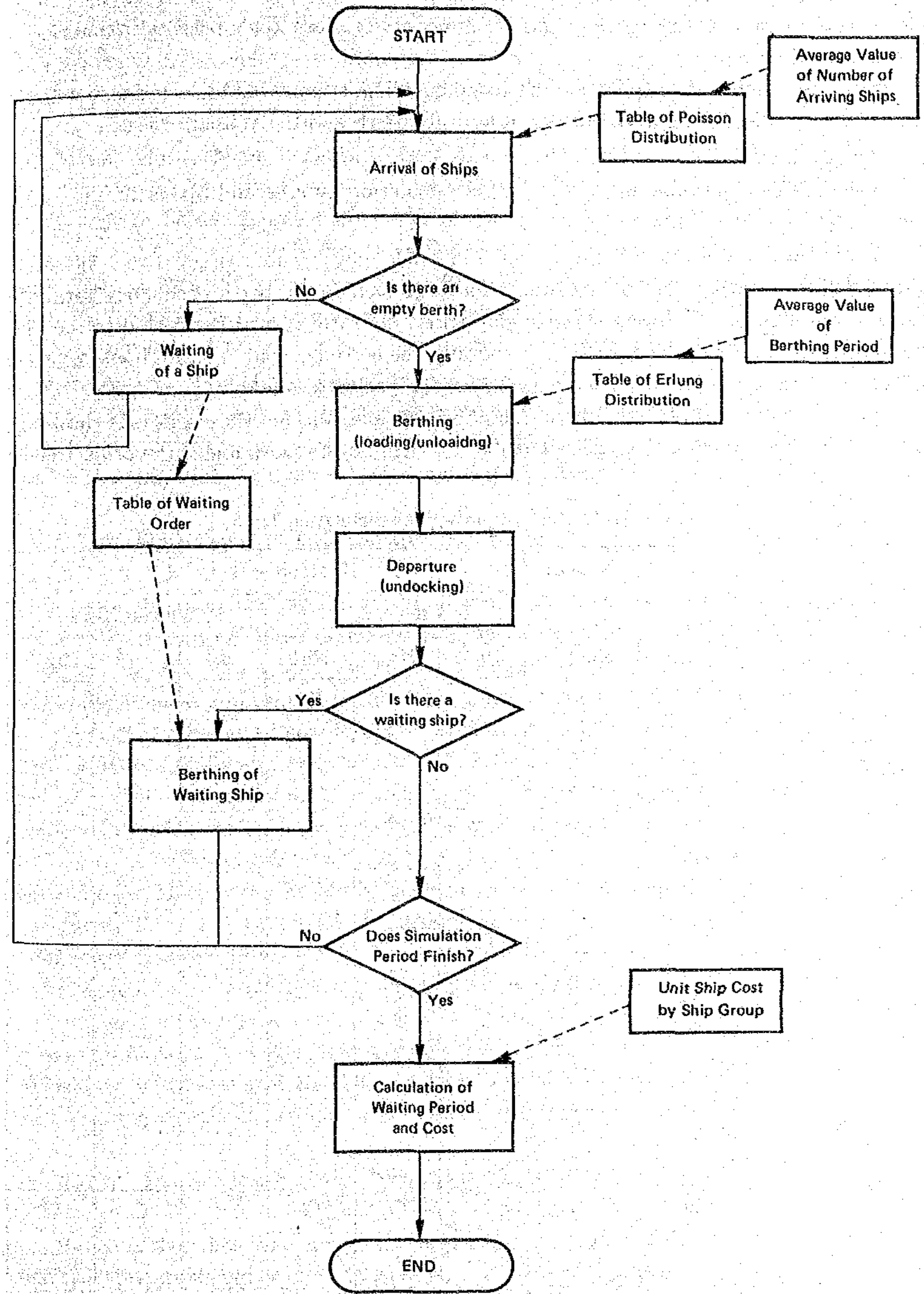


Fig. VII-23 Flow Chart of the Simulation Model

vacant.

e) Container ships, grain carriers and passenger cruisers are given priority in mooring at selected berths.

f) Grain is handled at the port and the cargo handling is improved in accordance with the study presented in CHAPTER Ⅷ in both the With and the Without Cases.

(c) Input data

Table Ⅶ-33 shows the input data for the simulation by case and by berth.

(d) Simulation test results

The results of the simulation are shown in Table Ⅶ-34, Table Ⅶ-35, Tabel Ⅶ-36 and Fig.Ⅶ-24. The output data of the simulation tests include the berth occupancy ratio, the ratio of the number of waiting ships to ship entry, the ratio of waiting period to mooring period and the waiting period per ship. Generally, the berth occupancy ratio should be under about 0.7. Thus, the proposed berth allotment for 1992 is acceptable.

The simulation results of Without Case-1 in 1990 and Without Case-2 in 1991 show high berth occupancy ratios, and suggest that the port will not be workable if the project is not

Table VII-33 Input Data for the Simulation Tests

Ship Group	Ship Size ('000 DWT)	Number of Entered Ships	Mooring Berth					
			With Case-1			Without Cases		
			No.1	No.2	No.3	No.1	No.2	No.3
General Cargo Ships	~5	26			○			○
	5~10	27	○	○	○	○	○	○
	10~20	70	○	○		○	○	
	20~	6	○			○		
Automobile Carriers	~10	19	○	○	○	○	○	○
	10~20	29	○	○		○	○	
●Container Ships	10~20	5	○	○		○	○	
	20~30	103	○	○		○		
●Grain Cargo Ships	~10	8	○	○		○	○	
	10~20	4	○	○		○	○	
	20~30	2	○	○		○		
	30~	1	○			○		
●Passenger Cruisers	10~20	3	○	○		○	○	
	20~30	13	○			○		
	30~	2	○			○		
Fertilizer Cargo Ships	~10	4		○	○		○	○
TOTAL		322						

Note ● : Ship groups given berthing priority implemented. However, these cases are simulated under the assumption that grian will be imported at the Port of Caldera even in 1990 and 1991 so that the results can be compared with the simulation results of Without Case-3 in 1992 under the same conditions. Thus, the simulation results of Without Case-1 in 1990 and Without Case-2 in 1991 show imaginary berth occupancy ratios. The port will not actually be so congested under the Without Cases in 1990 and 1991 as shown in Fig.VII-24 because grain importation is actually scheduled to be fully transferred from the Port of Puntarenas to the Port of Caldera in 1992.

To grasp the development effects in terms of preventing port congestion, we should compare the With Case with the Without Case in the same year. That is, we should compare With Case-1 with Without Case-3 in 1992. However, the simulation result of the No.1 berth in Without Case-3 is unrealistic because the port congestion is abnormally high judging from the calculated berth occupancy ratio as shown in Fig.VII-24. Thus, it is safe to compare With Case-1 (1992) with Without Case-2 (1991) in studying the port development effects. This will result in a conservative estimate of the positive results of the maintenance project. In fact, if the project is not implemented the port congestion as measured by the berth occupancy ratio at the berth No.1 will become extreme in 1992.

2. 2. 2 Improvement of the Small Craft Basin

The small craft basin at the corner of the breakwater and the −11 m quaywall has already shoaled due to sand sedimentation. Thus, the facility currently cannot be fully used. However, for the future port layout the present location is preferable because of the desirable calmness and overall protection against rough sea conditions.

As part of the overall countermeasures against sand sedimentation, the space between the foot of the breakwater and the quaywall will be kept clear of sediment. Accordingly, it will be efficient to maintain the small craft basin at the present location between the breakwater and the −11 m quaywall. The water depth at the entrance to the small craft basin will be sufficient because the −11 m berth will be extended to the west. However, sufficient clearance width should be planned to ensure safe maneuvering. Concerning this, a width of 45 m will be sufficient considering the two existing tugboats (1,600 PS and 1,700 PS), and the three existing launches.

The facilities related to the basin should be improved along with the extension of the −11 m quaywall and the shifting of the existing breakwater. In connection with this, the use of the two existing tugboats should be fully considered. Thus, a −3 m mooring facility is planned as shown in Fig.VII-25. This small craft basin will also be available as the basin for such working vessels as dredgers and launches during the maintenance works of the port.

2. 2. 3 Improvement of the Turning Basin

To date, there has been no problem in the size and layout of the turning basin. However, fine adjustments should be considered as part of the layout planning along with the extension of the wharf and the shifting of the foot of the breakwater.

Table VII-34 Ship Waiting Situation in Simulation Tests

Ship Type	With Case-1 (1992)			Without Case-2 (1991)			Without Case-3 (1992)		
	Ship Waiting Ratio (%)		Per Ship Waiting Period (hours)	Ship Waiting Ratio (%)		Per Ship Waiting Period (hours)	Ship Waiting Ratio (%)		Per Ship Waiting Period (hours)
	Waiting Ships to Entered Ships	Waiting Period to Mooring Period		Waiting Ships to Entered Ships	Waiting Period to Mooring Period		Waiting Ships to Entered Ships	Waiting Period to Mooring Period	
General Cargo Ships	43.3	44.1	33.0	55.4	102.3	77.5	60.3	125.5	110.4
Auto mobile Carriers	47.7	253.0	37.1	64.2	638.3	94.9	66.6	845.8	146.7
Container Ships	61.5	135.2	26.8	83.0	198.6	59.8	89.2	243.8	80.3
Grain Cargo Ships	55.8	42.8	15.4	72.7	103.0	32.7	79.9	105.3	38.9
Passenger Cruisers	64.4	128.3	32.1	79.3	235.4	62.1	74.9	270.8	58.1
Fertilizer Cargo Ships	22.2	9.2	32.1	24.4	20.2	15.1	30.6	20.0	17.6
Total	51.3	70.5	30.4	66.0	146.0	71.2	73.1	186.9	99.4

Table VII-35 (1) Ship Staying Periods

Ship Group No.	Ship Type	Ship Size ('000 DWT)	Number of Entered Ships	Ship Staying Periods (h)		Ship Staying Period Difference	
				With Case－1 (1992)	Without Case－2 (1991)	Total (h)	Per Ship (h/ship)
1	General Cargo	～5	28	1,322	1,599	277	9.9
2	Ships	5～10	30	2,426	4,241	1,815	60.5
3		10～20	72	10,095	16,704	6,609	91.8
4		20～	6	801	1,569	768	128.0
		Sub-total					
5	Automobile	～10	20	781	1,574	793	39.7
6	Carriers	10～20	32	1,903	4,499	2,596	81.1
		Sub-total					
7	Container	10～20	5	131	173	42	8.4
8	Ships	20～30	103	4,900	8,270	3,370	32.7
		Sub-total					
9	Grain Cargo	～10	10	400	568	168	16.8
10	Ships	10～20	5	320	451	131	26.2
11		20～30	2	107	231	124	62.0
12		30～	1	59	73	14	14.0
		Sub-total					
13	Passenger	10～20	3	140	182	42	14.0
14	Cruisers	20～30	11	682	1,049	367	33.4
15		30～	2	109	157	48	24.0
		Sub-total					
16	Fertilizer	～10	4	268	368	100	25.0
	Cargo Ships						
		TOTAL	334	24,444	41,708	17,264	51.7

Table VII-35 (2) Ship Staying Periods

Ship Group No.	Ship Type	Ship Size ('000 DWT)	Number of Entered Ships	Ship Staying Periods (h)		Ship Staying Period Difference	
				With Case−1 (1992)	With Case−2 (1992)	Total (h)	Per Ship (h/ship)
1	General Cargo	~ 5	28	1,322	1,310	− 12	− 0.4
2	Ships	5~10	30	2,426	2,262	− 164	− 5.5
3		10~20	72	10,095	10,155	60	0.8
4		20~	6	801	835	34	5.7
		Sub-total					
5	Automobile	~10	20	781	715	− 66	− 3.3
6	Carriers	10~20	32	1,903	1,852	− 51	− 1.6
		Sub-total					
7	Container	10~20	5	131	120	− 11	− 2.2
8	Ships	20~30	103	4,900	6,378	1,478	14.3
		Sub-total					
9	Grain Cargo	~10	10	400	389	− 11	− 1.1
10	Ships	10~20	5	320	412	92	18.4
11		20~30	2	107	157	50	25.0
12		30~	1	59	48	− 11	− 11.0
		Sub-total					
13	Passenger	10~20	3	140	159	19	6.3
14	Cruisers	20~30	11	682	739	57	5.2
15		30~	2	109	140	31	15.5
		Sub-total					
16	Fertilizer	~10	4	268	281	13	3.3
	Cargo Ships						
		TOTAL	334	24,444	25,952	1,508	4.5

Table VII-36 Berth Occupancy Ratio

Case	Year	Berth No.		
		No. 1	No. 2	No. 3
With Case-1	1992	0.679	0.708	0.250
With Case-2	1992	0.700	0.667	0.251
Without Case-1	1990	0.748	0.752	0.297
Without Case-2	1991	0.834	0.797	0.305
Without Case-3	1992	0.896	0.836	0.310

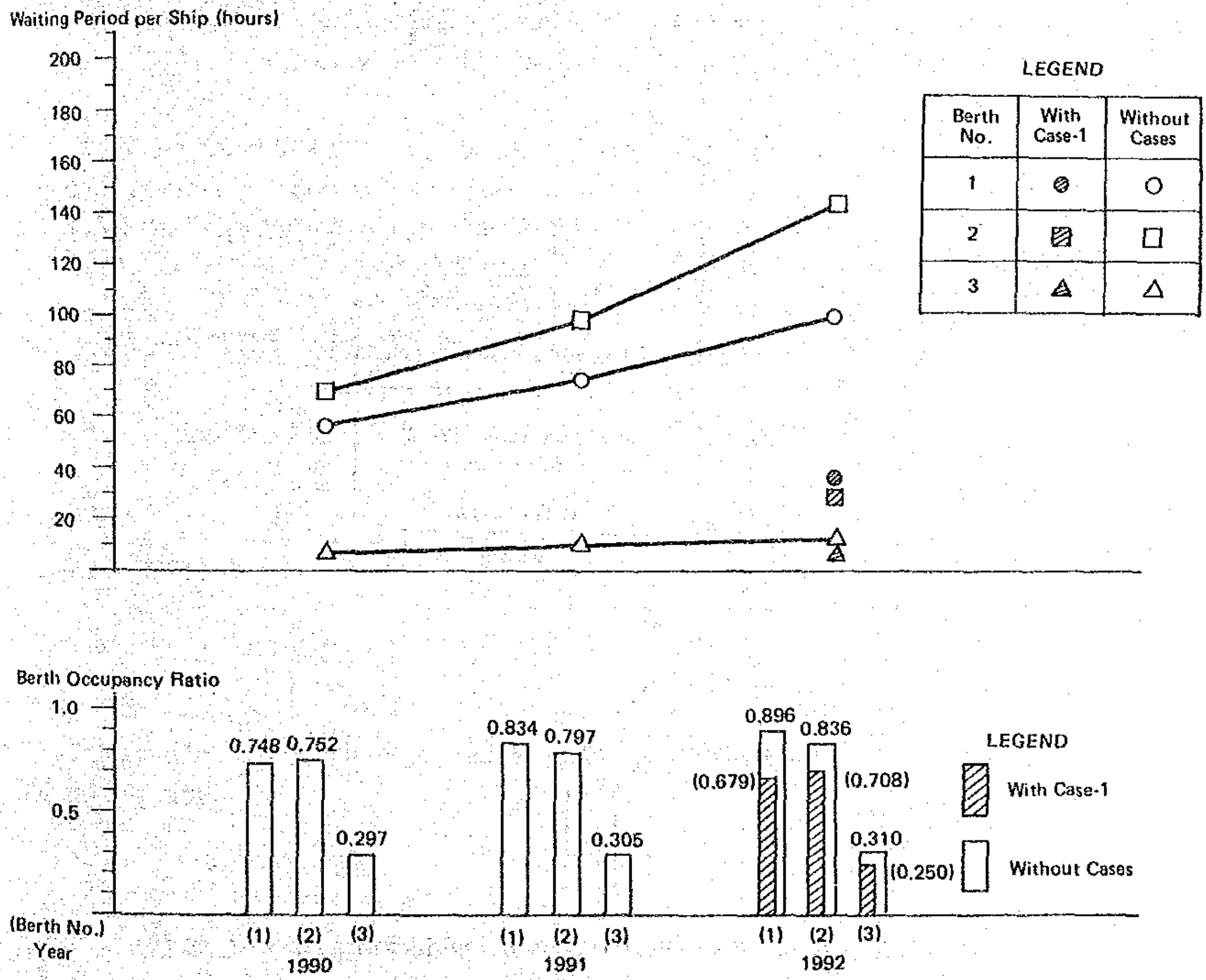


Fig. VII-24 Berth Occupancy Ratio and Waiting Periods

The extension of the quaywall and the shifting of the breakwater will not adversely affect the basin ; in fact these works will widen the turning basin. However, the north portion of the entrance should be widened along with the extension of the existing breakwater to ensure safe maneuvering, especially during the future maintenance dredging at the entrance channel proposed in CHAPTER VI. The recommended ship turning method is shown in Fig.VII-26.

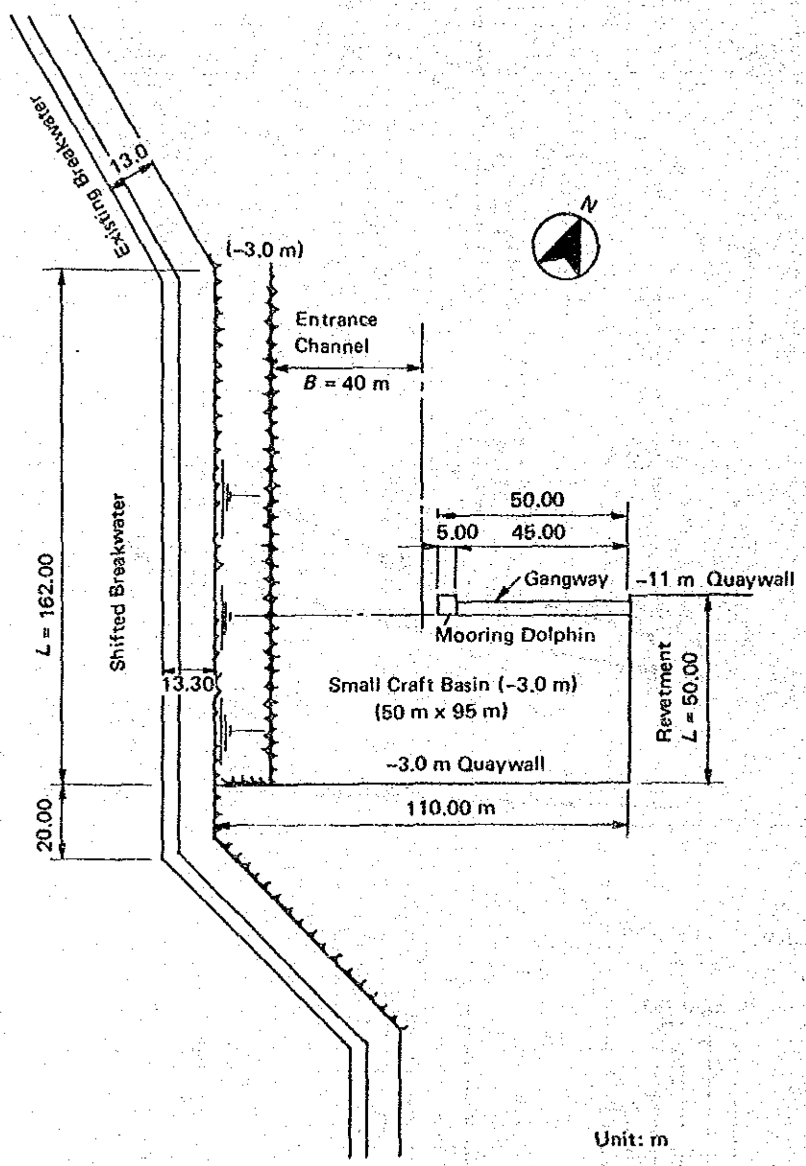


Fig. VII-25 The Small Craft Basin and Its Entrance

2. 2. 4 Anchorage Area Planning

(1) Ship queuing situation

The ship queuing situation off the port by ship size rank is summarized in Table Ⅶ-37 based on the results of the ship queuing simulation of With Case-1. The average ship waiting periods per ship are about two and a half days for both ship size ranks.

(2) Required number of anchorage areas off the port

The required number of anchorage areas off the port can be calculated by the following equation.

$$N = n \cdot p \cdot d/D$$

Where N : The required number of anchorage areas
n : The number of queuing ships in a year
p : The peak appearance rate (2 is adopted in this study)
d : Ship queuing periods (Unit : days)
D : Port workable days in a year (350 days are adopted)

Values in Table Ⅶ-37 are substituted into the about equation. Consequently, one anchorage area is required for ships less than 10,000 DWT and two anchorage areas are required for ships larger than 10,000 DWT.

Table VII-37 Average Waiting Periods

Ship Size Rank (DWT)	Number of Entered Ships	Number of Queuing Ships	Average Waiting Periods per Ship (days)
~10,000	92	30	2.38
10,000~	241	141	2.48

(3) Size of anchorage areas

The radius of an anchorage area is, generally, calculated by the following equation for single mooring.

$$R = L + 6h$$

Where R : The radius of the anchorage area for single mooring
h : The water depth of the anchorage area
L : Ship length

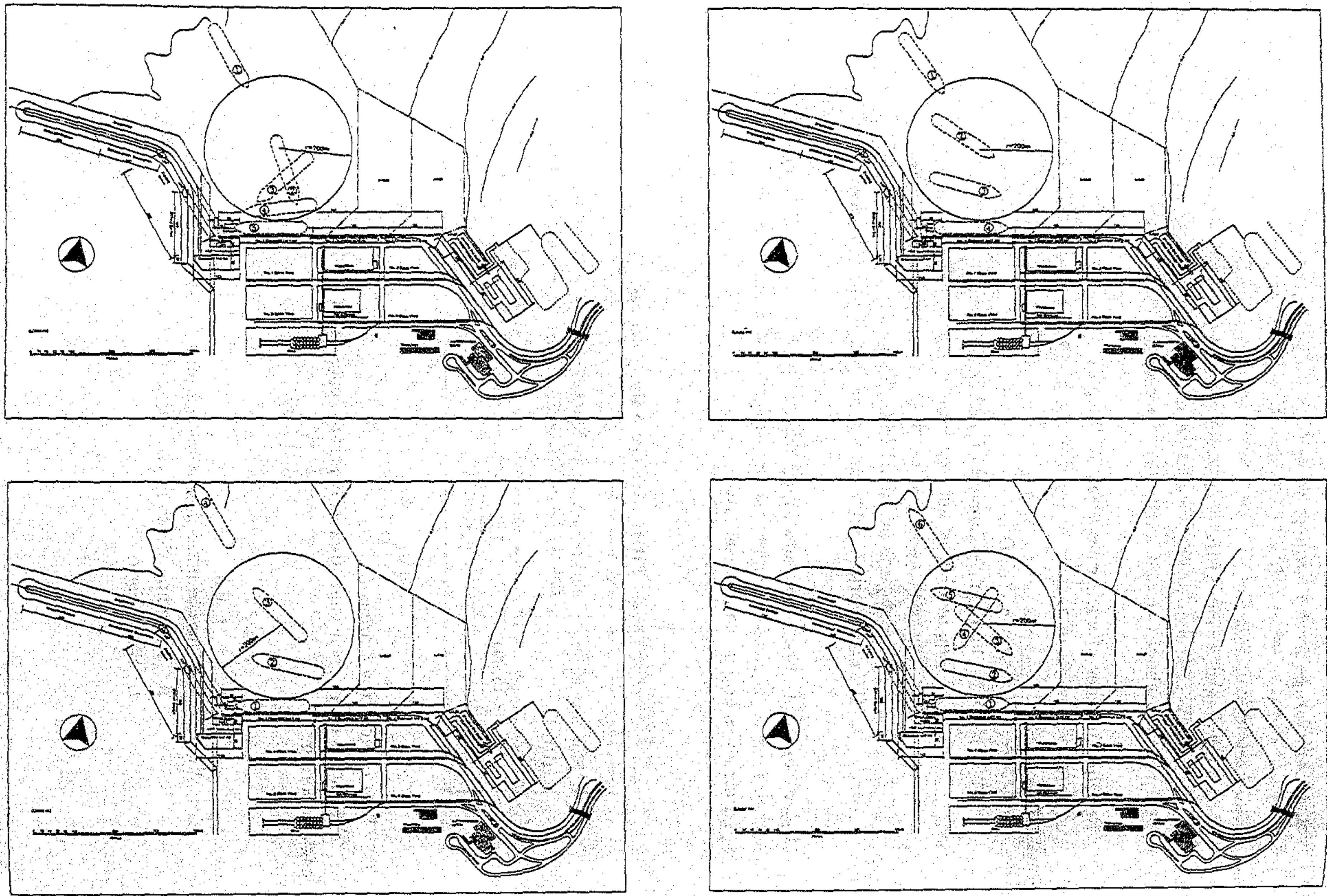


Fig. VII-26 Ship Turning Basin

In this study, 10,000 DWT and 20,000 DWT are taken as the representative ship sizes of each ship size rank. The standard length of 10,000 DWT and 20,000 DWT vessels are 144 m and 177 m respectively. The anchorage area depths for 10,000 DWT and 20,000 DWT vessels are 12 m and 14 m, respectively. Then, the radii of anchorage areas for ships less than 10,000 DWT and those for ships larger than larger than 10,000 DWT come to 220 m and 260 m, respectively.

(4) Layout of anchorage areas

Such factors as approach channels, water depth, soil conditions, water current, waves and sea topography are considered in selecting the locations of anchorage areas off the port. There is an existing anchorage area off the port. The area can sufficiently accommodate the required anchorage areas studied above. However, the location of the southern edge makes the entrance channel to the port narrow. Therefore, the southern edge should be deviated north not to disturb the approach of ships to the port. In spite of the deviation, the proposed comprehensive anchorage area, which covers the above respective anchorage areas, can accommodate all the queuing ships. The layout of the proposed anchorage area is shown in Fig.VII-27.

(5) Evacuation in emergency

The planned anchorage area is for use of ordingary queuing ships. However, the area is not well protected from rough seas. Thus, ships should evacuate from the proposed anchorage area to other safe water areas such as the inner areas of Nicoya Bay during adverse weather.

(6) Adjustment with fishing activities

There is, currently, no available data on fishing activities in the study area. The proposed anchorage area is studied without any data on fishing activities. Thus, it may be necessary to adjust the area with the fishing activity when the detailed data become available.

2. 2. 5 Port Layout Planning

In this section, the comprehensive port layout is studied based on the results of the respective related facility studies. Based on the comprehensive port layout, the calmness in the harbour and the harmony with possible future development after the present project is completed are considered.

(1) Facility Improvement Summary

The port facility improvement proposed in CHAPTERs VI and VII can be summarized as shown in Table VII-38. The port layout planning is studied based on the existing port facilities and the facilities listed in the table.

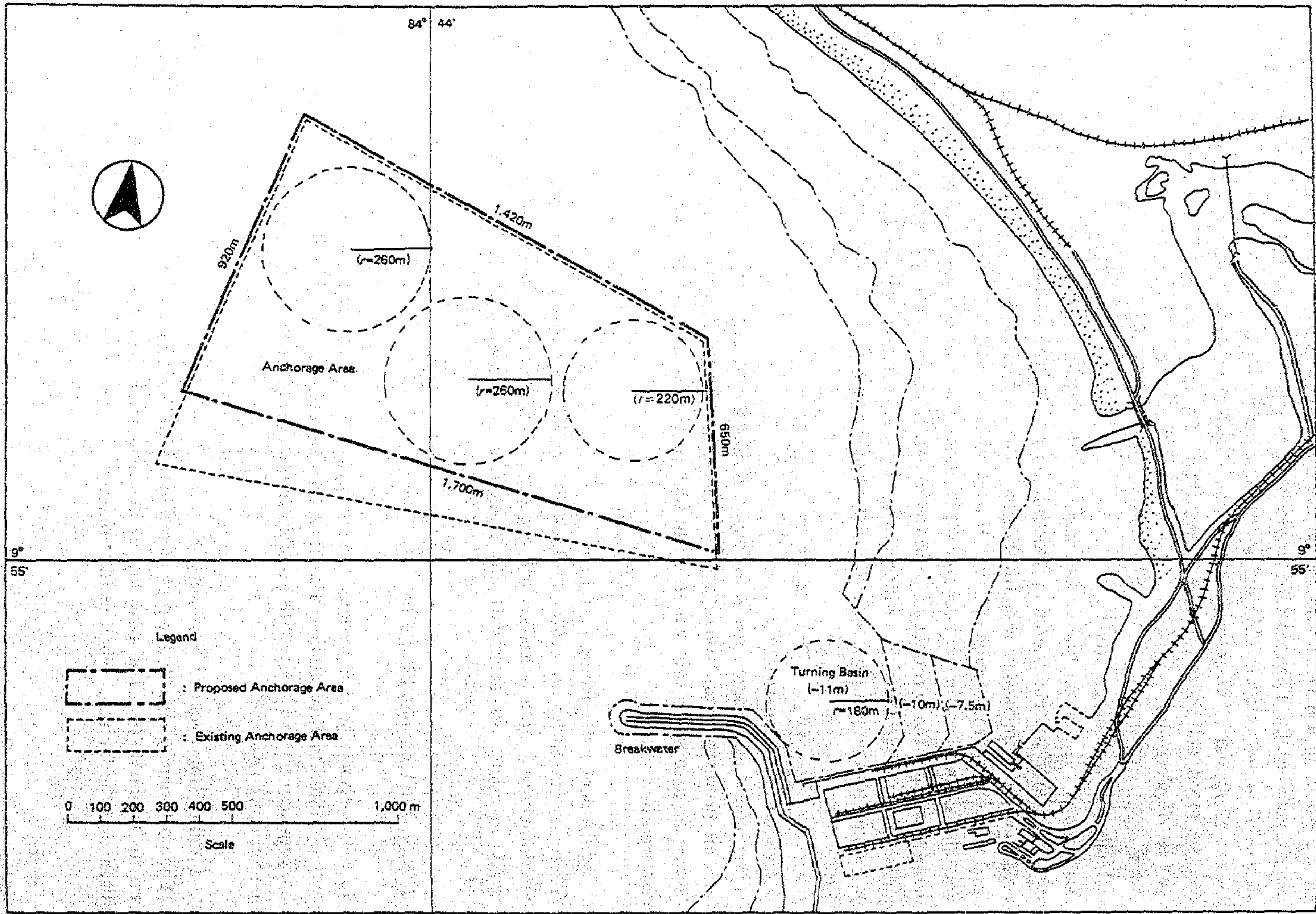


Fig. VII-27 Anchorage Area Layout

Table VII-38 Port Facility Improvement Summary Concerning Port Layout

Objectives	Improvement Works
1. Countermeasures against sand sadimentation	(1) 200m breakwater extension (2) 72,000m³ primary dredging of the turning basin
2. Enlargement of mooring capacity	(1) Shifting of the existing breakwater The length of the shifted breakwater section is 162m. (2) Improvement of the existing small craft basin The length of the −3.0m quaywall is 110m. (3) The construction of the mooring dolphin and the 45m long gangway adjacent to the existing quaywall

(2) Port layout planning

The prerequisites for port layout planning are as follows :

1) The layout of the breakwater to prevent sand drift should be fully respected in the entire port layout
2) Existing facilities should be utilized as much as possible in the future
3) The land area and the launching water area for the FDD, which is under construction, should be secured

First of all, the layout of the extended portion of the breakwater proposed in CHAPTER VI is agreeable from the viewpoint of protection against sand sedimentaion. This breakwater will be extended as proposed in CHAPTER VI for the protection of the harbour not from high waves but from sand drift. The foot of the existing breakwater will be shifted to the west as shown in Fig.VII-21 to ensure the required −11 m berth length.

This will not disturb the functions of the breakwater. It is greatly preferable to secure an area free from drift sand in between the breakwater and the turning basin than for sand to shoal over the design depth in an emergency in the far future. The cleared space will also be used as part of the entrance channel to the small craft basin.

Second, concerning moorning facilities, improvement is concentrated into the corner of the shifted breakwater and the extended −11 m quaywall. Construction of a 45 m long gangway and mooring dolphin is a very effective way to economically secure the needed berth length and improve the small craft basin. Thus, the proposed layout of mooring facilities in the previous section is completely agreeable in terms of the entire port layout planning.

Third, the terminal land use will not have to change greatly from the current usage. Detailed terminal land use allocation including storage facilities is studied in CHAPTER VIII.

Incorporating the conclusions of this chapter and the results of the analysis of counter-measures against sand sedimentation in CHAPTER VI, the future port layout in the target year is proposed as shown in Fig.VII-28.

(3) Ascertainment of the calmness in the harbour

To ascertain the port availability in terms of wave conditions, calmness in the harbour area is calculated by a computer using the occurrence probability of significant wave heights and periods of the incident waves listed in Table IV-4 in CHAPTER IV. The wave incidence direction in the calculation is N 225°, which is the most severe direction for the harbour. Concerning significant wave periods, 12 seconds and 18 seconds are adopted because the former is the median value and the latter is nearly the maximum value in the distribution of the significant wave periods observed offshore the port in the past (refer to Table IV-4).

The calculated diffraction chart is shown in Fig.VII-29. The calculated occurrence probability of significant wave heights and periods of incident waves is shown in Fig.VII-30. The study locations for the occurrence probability study are as follows :

(a) Front of the Ro/Ro pier
(b) Center of the −7.5 m quaywall
(c) Center of the −10 m quaywall
(d) Center of the −11 m quaywall
(e) Front of the small craft basin
(f) Ahead of the extended breakwater

The results show that under the proposed plan the harbour will be properly protected. For instance, the occurrence probability of wave heights less than 0.3 m is about 99%. Consequently, the Port of Caldera seems to be available almost all through the year. Details are discussed in the APPENDIX 8.

(4) Harmony with the future development after the maintenance project is completed

Port traffic will steadily increase in the future after the present Maintenance Project is completed. To cope with the future demand, it will become necessary to develop the port further along with the economic development. Furthermore, the port will greatly promote national and regional economic development if related industries locate within or near the port. Thus, there is a great possibility to construct such facilities as container terminals and to locate such industries as processing industries and commodity distribution centers at the north of the existing wharfs in the future.

Considering the above, it is recommendable to extend the breakwater in parallel with the direction of the shoreline of North Caldera beach after the present Maintenance Project is completed. The extended breakwater could then protect the future developed harbour area without any interference.

Consequently, we can say that the proposed layout plan will not disturb the future development of the port.

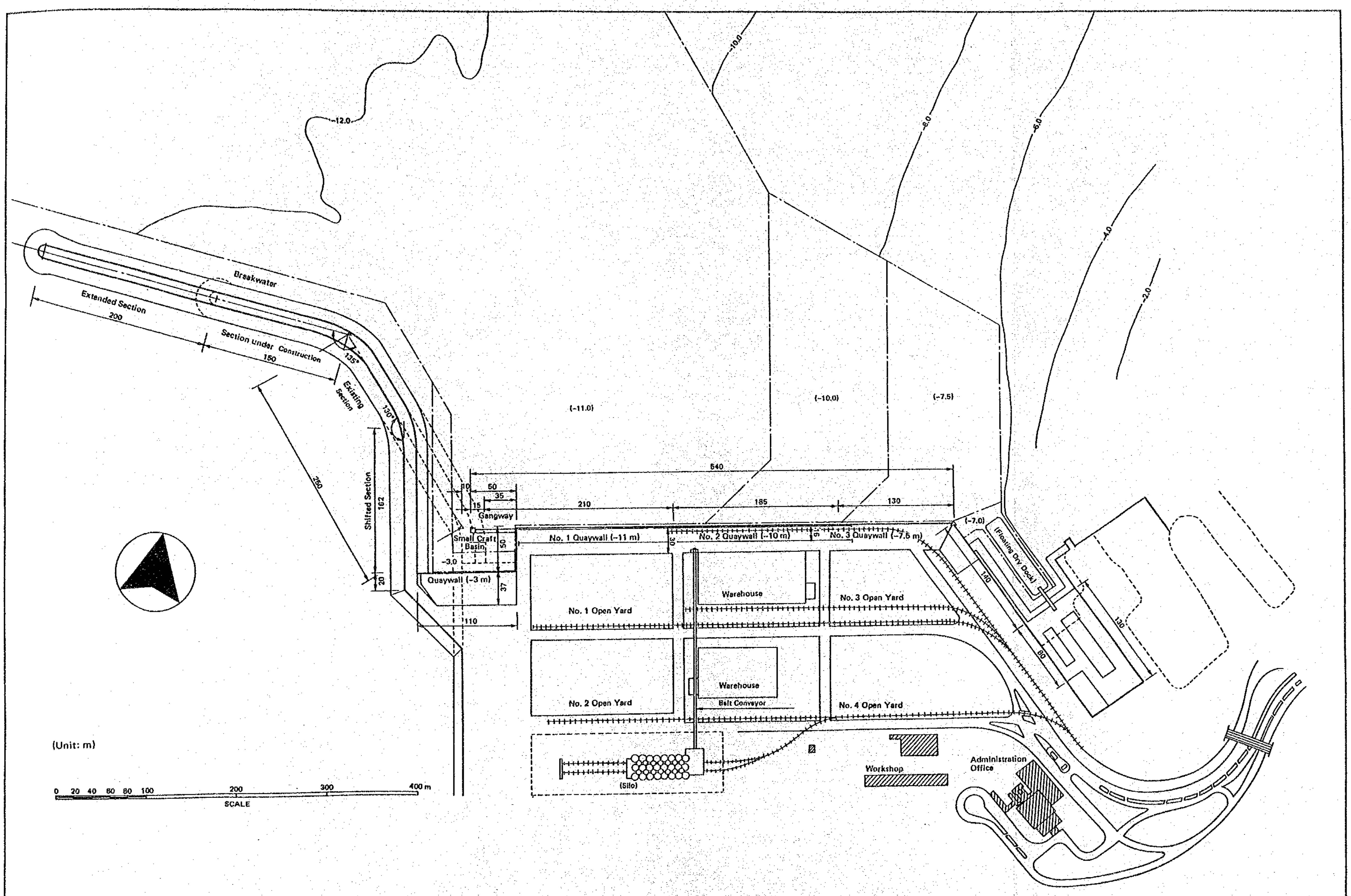
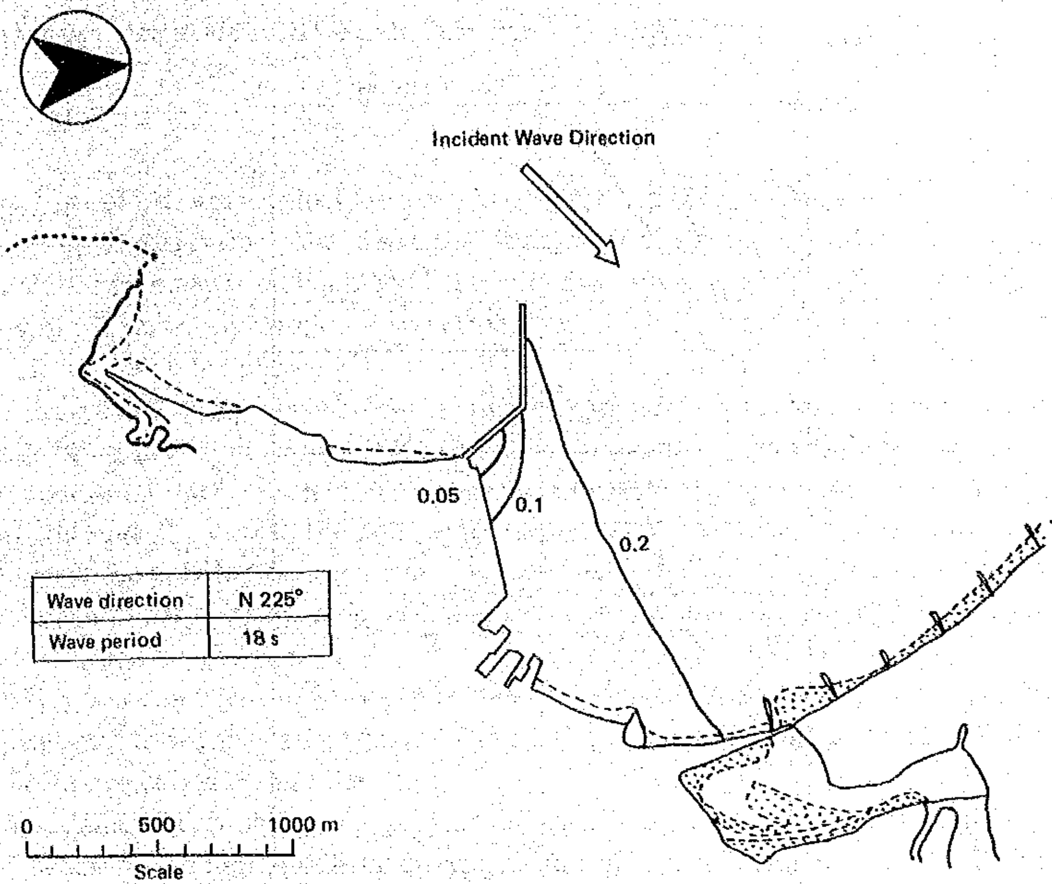
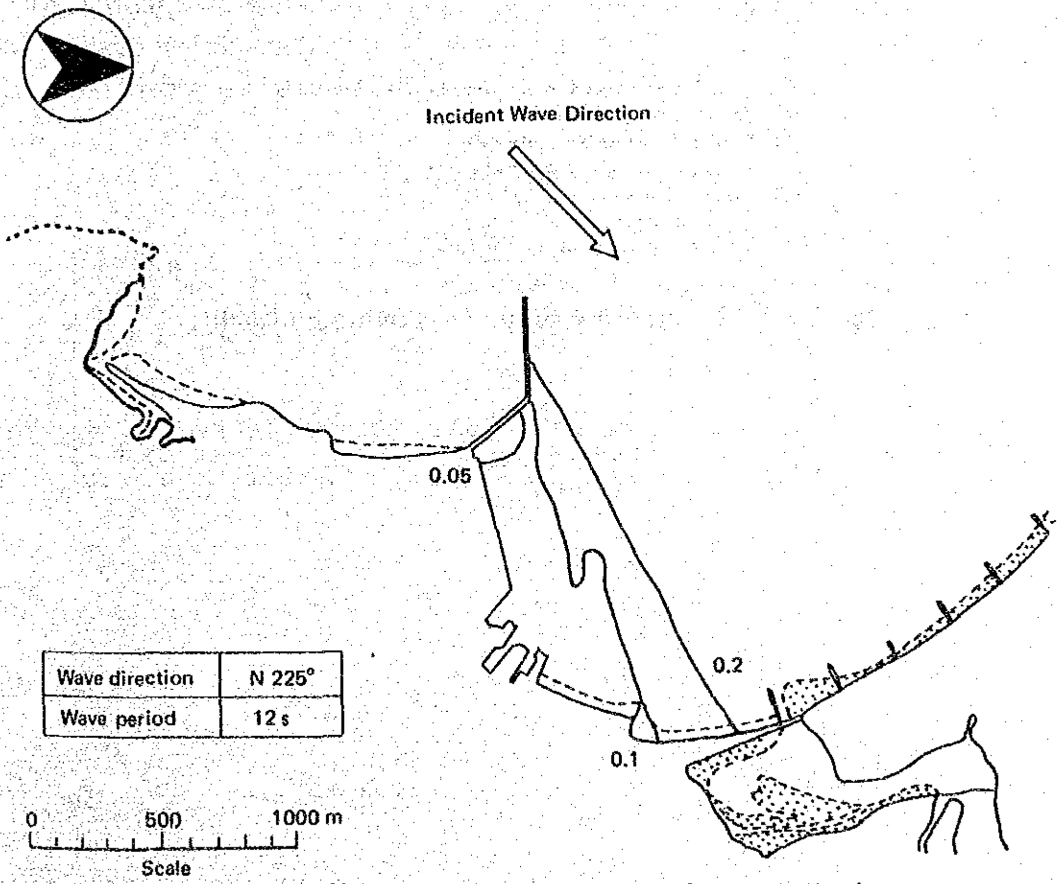


Fig. VII-28 Maintenance Plan of the Port of Caldera



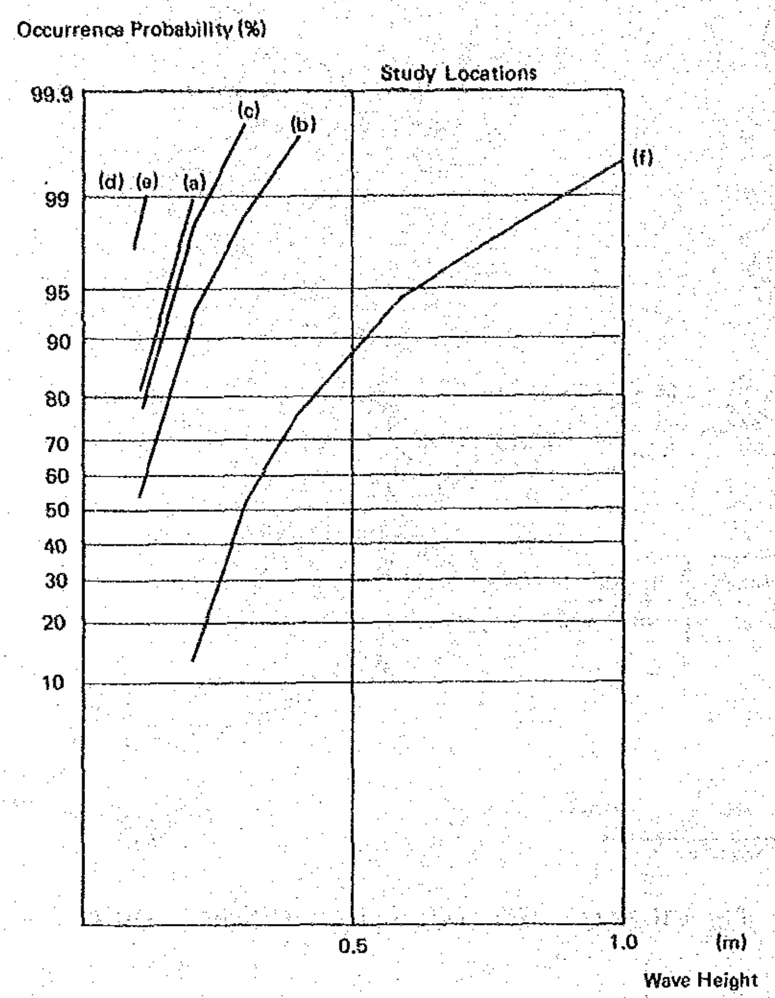
Wave direction	N 225°
Wave period	18 s

Fig. VII-29 (1) Wave Diffraction Coefficient Distribution



Wave direction	N 225°
Wave period	12 s

Fig. VII-29 (2) Wave Diffraction Coefficient Distribution



Note: The study locations for the occurrence probability study are as follows:
(a) Front of the Ro/Ro pier
(b) Center of the -7.5 m quaywall
(c) Center of the -10 m quaywall
(d) Center of the -11 m quaywall
(e) Front of the small craft basin
(f) Ahead of the extended breakwater

Fig. VII-30 Future Wave Height Occurrence Probability

CHAPTER VIII IMPROVEMENT PLAN FOR PORT OPERATIONS

1. General

The Port of Caldera opened in December 1981 when three berths were completed under the first stage construction plan. Since that time, most of the cargo which used to be handled at Puntarenas pier has been handled at the Port of Caldera, except for imported break bulk grain cargo. The second stage construction plan which includes a container terminal with gantry cranes has been postponed due to the recent worldwide economic recession.

As the second stage construction plan has been postponed, this current maintenance project is being prepared to maximize the use of the existing port facilities and to provide certain additional basic facilities which are necessary in order to handle the cargoes which will pass through the port in the immediate future. Concretely the cargo volume which will be handled at the port in the target year (1992) is estimated as 763,000 tons in CHAPTER VII. This volume includes imported break bulk grain cargo which will newly handled at the Port of Caldera in the target year.

The present condtions of the three berths and the condtions under the proposed improvement plan are shown in Table VIII—1. The berthing condtions of the No. 1 Berth and the No. 2 Berth are shown in Fig. VIII—1.

Thus, under this maintenance project the three existing berths and the handling yards located behind these berths will function as a multipurpose terminal which will be able to accomodate a wide variety of cargoes including general cargo, steel goods, automobiles, containers, and break bulk grain. For the multipurpose use of the terminal to function efficiently, systematic management and a well-coordinated operation system will be necessary as outlined in this study.

Table VIII-1 Berth Dimension

Berth No.	Present Conditions		Improvement Plan	
	Berth Depth	Berth Length	Berth Depth	Berth Length
No. 1	−11m	210m	−11m	210m
No. 2	−10	150	−10	185
No. 3	−7.5	130	−7.5	130
Total		490		525

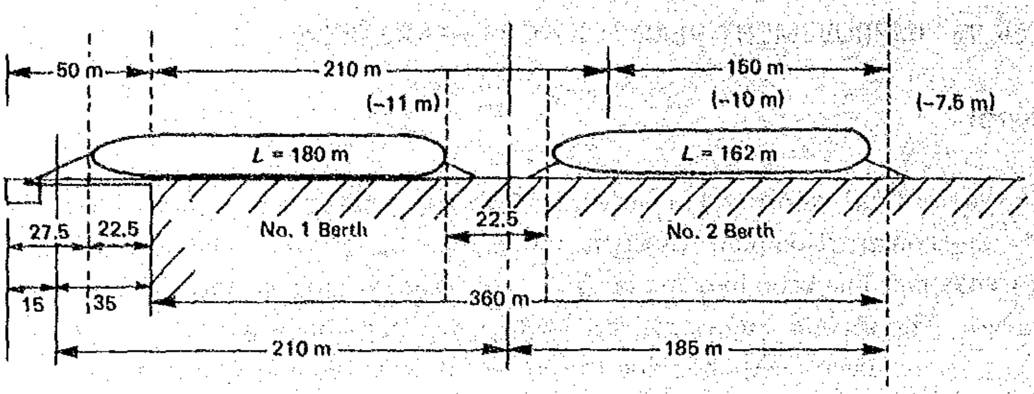


Fig. VIII-1 Berth Extension Plan

2. Actual Port Cargo Operations and Problems

Generally, port cargo operations consist of the following three operations.

(a) Stevedoring

(b) Shoreside cargo operations (overland transpotation of cargo within the port)

(c) Moving cargo in and out of warehouses, sheds and open yards

Barges are sometimes used between operations (a) and (b).

The three operations noted above are closely related, and problems in any one of these operations will affect the other operations. Thus, all of the cargo handling operations must be carefully coordinated.

2. 1 Stevedoring

Stevedoring involves unloading cargo from arriving vessels and loading cargo (which should be prepared beforehand) onto vessels safely and efficiently. Efficient stevedoring involves a great deal of planning and the timely flow of accurate information. Especially, in the case of multipurpose vessels which carry different kinds of cargoes at the same time, the planners must contact shipping companies or their agents before the vessels arrive. It is necessary to prepare a detailed cargo operation plan for eash vessel before the vessel arrives.

2. 1. 1 Actual Conditions and Problems

Table Ⅷ—2 shows the percentage of actual working hours to the hours gangs spent on board vessels in 1984 at the Port of Caldera.

According to Table Ⅷ—2, on the average about 40% of the total working hours are being wasted. Therefore, reducing this wasted time is a key point in improving port operations. Normally, in Japanese ports, such idle hours account for less than 20% of the time gangs are on board.

Table VIII-2 Actual Hours (%)

Month	(Actual Working Hours/Hours Gangs on board) ×100
January	59.5
February	69.7
March	63.2
April	56.9
May	59.6
June	49.5
July	67.8
August	48.9
September	54.5
October	52.8
November	63.8
December	65.3
Average	59.3

Proper planning will help to reduce this idle time. Generally, the following jobs must be executed by the stevedore planner.

1) Collecting data
2) Estimation of maximum cargo working hours
3) Arrangement of pilots and tugboats
4) Arrangement of stevedore workers (gangs)
5) Arrangement of cargo handling equipment
6) Arrangement of checkers (tally men)
7) Distribution of information
8) Sharing the cargo operation plan with concerned sections

At present, some of the wasted time during cargo handling operations at Caldera Port is due to inproper planning or to poor execution of the plans. If comprehensive plans for each vessel are drawn up in advance and carried out as outlined above, the efficiency of the stevedoring operations will certainly improve. As the stevedoring is presently a bottleneck in the cargo handling operations, the increase of the working efficiency of stevedoring will bring about an increase in the overall cargo handling efficiency, and will effectively expand the cargo handling capacity of the port.

2. 2 Shoreside Cargo Operations

At the Port of Caldera, no barge operations are planned. Thus, all cargoes will be unloaded directly from vessels onto the apron and then carried to storage facilities. The present situation of the shoreside cargo operations at the Port of Caldera is as follows :

(1) General cargo

The tractor driver drives from the shipside apron to the designated warehouse with palletized general cargo on the trailers. Each tractor tows 4~5 trailers as one train, with a total of 6 tractors and 24 trailers. Cargoes are sometimes transfered directly from the apron to the warehouse using 2~6 ton forklifts.

(2) Steel goods

Steel goods are transfered directly from shipside apron to the No.3 open yard by forklift. When ships berth at No.1 berth, trucks or trailers are used for transit. Steel pipes are tranfered by 40' container trailers.

(3) Containers

20'/40' container flat bed trailers (4 units) and tractors (2 units) shuttle between the apron and open yards No.1 and No.2. A 30 ton container frontloader is used to lift the containers on and off the trailers.

(4) Automobiles

Automobiles are driven one by one from the apron to open yard No.4. When the automobile engines do not work, the cars are towed by a tractor.

Overall, there does not seem to be any problem with the shoreside cargo operations. However, the increase of the cargo handling volume and the stevedoring working efficiency will result in a lack of cargo handling machinery and drivers for shoreside cargo handling operations in the target year, 1992 .

2. 3 Movement of Cargo in and out of Warehouses and Open Yards

2. 3. 1 General

This operation consists of three types of cargo movement as described below

(1) Moving cargo into storage areas

This involves moving cargo to designated places within the storage yards after unloading the cargo from trucks or railway cars in front of the storage area.

(2) Shifting cargo within the storage area

This involves shifting the cargo around within the storage area to make space for additional incoming cargo or to otherwise facilitate the smooth flow of cargo into and out of the storage area.

(3) Cargo out operation

This operation involves moving cargo out of the storage area based on the delivery orders of consignees or export cargo shipping orders. The cargo is loaded onto trucks or railway cars.

2. 3. 2 Actual Conditions and Problems

The cargo handling vehicles mainly used for these operations are folklifts (3~10 tons). Special cargo like rolled paper is handled by forklifts which are equipped with special attachments. In these operations, the required number of folklifts must be calculated considering the loss of time caused by tallying works. Tallying works involve confirming the number and the external conditions of cargoes. Especially when these operations are connected directly with stevedoring operations, the planner has to arrange for a sufficient number of forklifts so that the stevedoring operations are not interrupted.

It seems that at present there are no problems with this operation, and no problems are expected in the target year.

2. 4 Organization and Number of Workers for Cargo Handling Operations

The present cargo handling organization and number of workers are shown in Fig.VIII—2. As shown in this figure, 240 persons are working in the loading and unloading section. The number of workers per gang at the Port of Caldera is almost the same as in Japan as shown in Table VIII—3 except for the water man who is required due to the tropical climate at Caldera.

Table VIII-3 Stevedore gang members

Position	Ordinary Japanese Gang	Present Gang at Caldera Port
Hatch Bosses	1	1
Sigunalmen	1	1
Winchmen	2	2
Hold Workers	4	4
On Pier Workers	4	4
Watermen	—	1
Sub Total	12	13
Forklift Driver	1	1

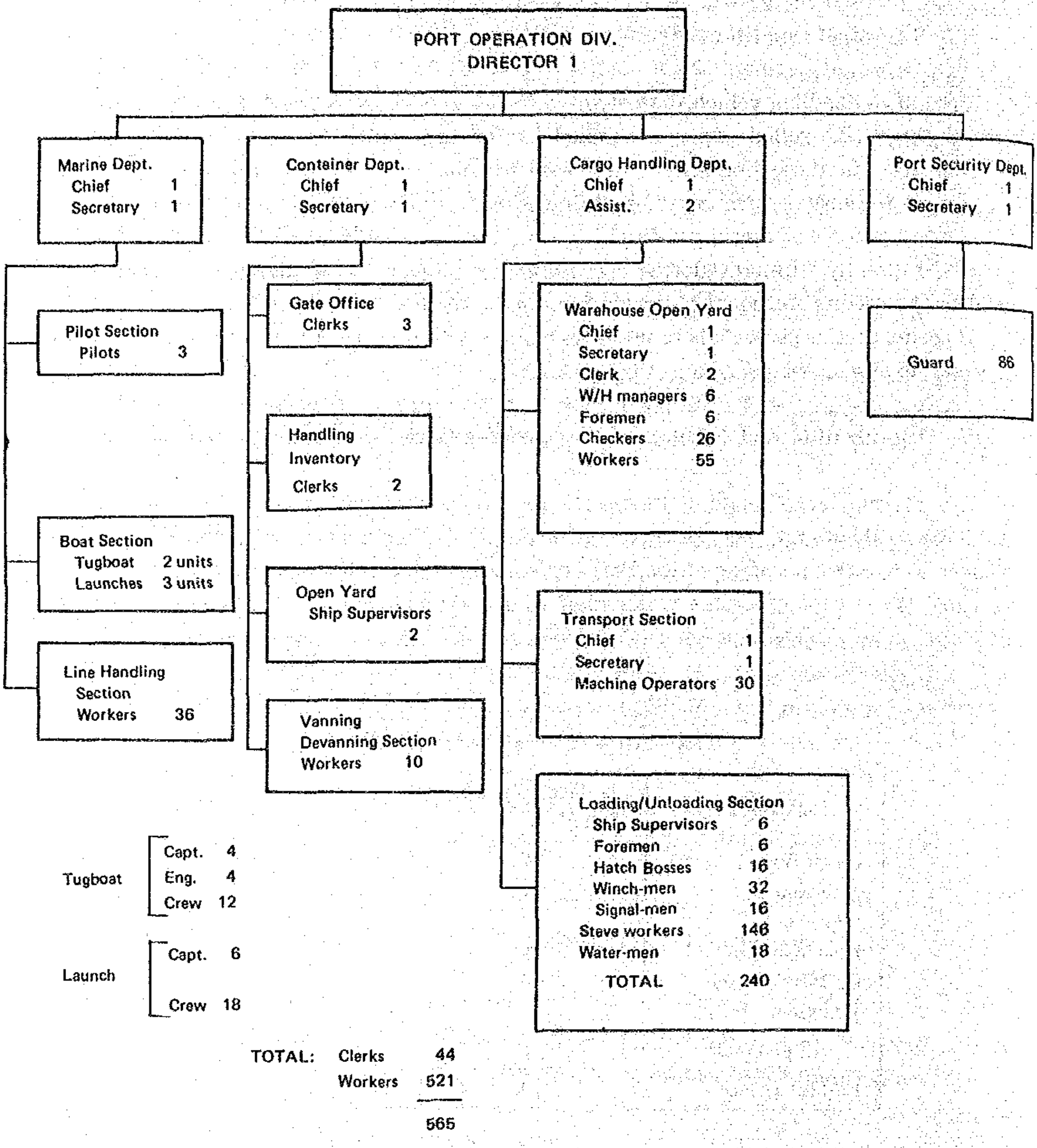


Fig. VIII-2 Present Organizational Chart of the Port of Caldera

3. Cargo Handling Improvement Plan

3.1 Cargo Handling Improvement Plan by Main Cargo Commodity

3.1.1 General Cargo

Basically, the cargo handling operation for general cargoes involves lifting cargo up and down using ships' cargo gear (cargo derricks or deck cranes). Ordinary cargo ships have one or two sets of cargo gear at each hatch (4~5 hatches per vessel). At present in the Port of Caldera an average of about 1,600 tons of cargo are handled per vessel, and cargo handling stevedore workers average about two gangs (26 men) per vessel.

Lately, as unitized cargo (palletized cargo or big size case goods) is increasing, it is necessary to use forklifts inside the hatches, and each gang has one forklift and one driver. Normally, when the average winch man drives a winch for general cargo operations, there are 20 slings per hour and the average sling weight is 1.5 metric tons. Thus, the average operation efficiency for general cargo is as follows :

1.5 metric tons/sling × 20 slings/h × 0.8 = 24 metric tons/h

This is equal to a 20% speed up of the present Caldera Port average general cargo working efficiency of 20 metric tons/h. If the current idle time ratio at Caldera which is 40% of working hours could be reduced, INCOP could achieve this 24 metric tons/h efficiency. Then, the handling tonnage per day per gang should be as follows :

24 metric tons/(h • gang • shift) × 7 h/day × 3 shifts = 504 metric tons/(gang • day)

Lately, on some shipping lanes (Persian Gulf-Japan, USA), a new roll on/roll off type vessel is beginning to be used, but at present only a few of these vessels are in operation. In the future, it is possible that this new kind of vessel will call at the Port of Caldera. But as this kind of cargo vessel has a higher cargo handling capability than ordinary lift on/off type cargo vessels, INCOP will not have to worry about increased ship congestion due to a change in the type of calling vessels in the future.

3.1.2 Steel Goods

(1) General

Ordinary steel goods are handled as follows :

(a) Steel sheet with skids

Usually, steel sheet is enveloped by thin steel plate and bundled with skids so that it can be moved by forklifts. The most popular weight is about two metric tons per bundle package.

(b) Steel sheet in coils

Steel sheet is sometimes rolled into coils with bands around them. The coils generally weigh from 5~10 metric tons.

(c) Steel pipe

Large size diameter pipe is shipped in pieces, and small size diameter pipe is bundled using steel bands. Each bundle weighs about one metric ton.

(d) Steel bars

Steel bars are handled wrapped by steel bands with one metric ton per bundle.

(2) Current cargo handling efficiency and improvement plan

During loading and discharging, 3~5 bundles are lifted on or off in one sling. The current cargo handling efficiency for handling steel goods is about 40 metric tons per hour. However, it should become possible to improve this efficiency to 48 metric tons per hour by reducing the idle time. Thus, the future cargo handling capacity per gang per day is estimated as follows :

$$48 \text{ metric tons/(h} \cdot \text{gang} \cdot \text{shift)} \times 7 \text{ h/day} \times 3 \text{ shifts}$$
$$= 1{,}008 \text{ metric tons/(gang} \cdot \text{day)}$$

A 3.5 ton forklift inside the vessel's hold and 5~10 ton folklifts on the pier will be used to handle steel goods.

3. 1. 3 Automobiles

(1) Lift on/Lift off type cargo operations

Automobiles transported by conventional cargo vessels with mixed stowage along with general cargo in the holds are often handled using a special car sling. In this case, the vessels generally carry 10~20 cars along with the general cargo. The cars are handled naked using the special sling, and it is important to handle the cars very carefully so that they are not dented or scratched.

The actual cargo handling efficiency seems to be 10~12 metric tons per hour. The average handling efficiency for this type of operation is generally about 25 slings per hour. The usual car weight is about one ton per car, and therefore, the cargo handling efficiency in the target year should be as follows

$$25 \text{ sling/(h} \cdot \text{gang} \cdot \text{shift)} \times 1 \text{ metric ton/sling} \times 0.8$$
$$= 20 \text{ metric tons/(h} \cdot \text{gang} \cdot \text{shift)}$$

Larger vehicles such as trucks and buses are more difficult to handle. The actual handling efficiency is somewhat uncertain, but it seems to be around 15 tons/h. The average efficiency is about 4 slings per hour. The weight of each unit varies from 5~10 metric tons. Therefore, the overall cargo handling efficiency in the target year should be as follows :

4 slings/(h • gang • shift) $\times$7 metric tons/sling$\times$0.8
≒22 metric tons/(h • gang • shift)

(2) Ro/Ro system automobile cargo handling

The Japanese cars which are imported into the Port of Caldera are sometimes carried by roll on/roll off exclusive car carriers. The cargo handling efficiency of Ro/Ro car carriers is 70~100 metric tons/h. This efficiency is quite high, but this kind of operation requires 30~50 drivers at one time.

(3) Improvement plan for the automobile cargo handling

The projected cargo handling efficiency for automobiles in the target year can be summarized as shown in Table Ⅷ—4.

Table VIII-4 Cargo Handling Efficiency for Automobiles

Actual Handling Efficiency	Handling Efficiency in The Target Year
12 metric tons/ (h•gang•shift)	20 metric tons/ (h•gang•shift)

3. 1. 4 Containers

The container handling volume in 1985 at the Port of Caldera is about 3,800 TEU. This is less than the handling volume in 1984 (4,084 TEU), largely because the full container liner service which called at the port until December 1984 discontinued its service. At present, all the containers are transported by conventional cargo vessels. The average number of containers handled per vessel is generally about 15~20 units.

As facilities for container operations, there are the No.1 berth (water depth —11 m, length 210 m) and next to it the No.1 (13,600 m²) and No.2 (13,600 m²) open yards. The No. 2 open yard is not yet paved, and is presently used only for storing empty containers. It is necessary to pave the No.2 open yard so that it can be used for full containers as well.

At present, the container handling efficiency for conventional vessels calling at the Port of Caldera is 7 units per hour, and this is not satisfactory compared with normal container stevedoring efficiency. It seems that the stevedoring operations and the movement of containers to the container yard are not coordinated well. Normally, using ship's cargo gear, it is not so difficult to maintain a handling efficiency of 12 containers per hour. The estimated maximum container handling efficiency per gang per day in the target year is as follows :

12 containers/(h • gang • shift) $\times$7 h/day$\times$3 shifts=252 containers/(day • gang)

For one year the capacity is as follows :

252 containers/(day • gang) $\times$365 days/year≒90,000 containers/(year • gang)

Normally, containers are handled by one gang. Therefore, this is the theoretical maximum container handling capacity at the Port of Caldera from the viewpoint of stevedoring. On the other hand, considering open yard space, the maximum container storage volume per year will become less than 90,000 tons.

3. 2 Summary of Cargo Handling Efficiency

The cargo handling efficiency by cargo commodity at present and in the target year can be summarized as shown in Table Ⅷ—5.

Table VIII-5 Cargo Handling Efficiency

Kind of Cargo	Cargo Handling Efficiency (per h per gang per shift)	
	1985	1992
General Cargo	20 metric tons	24 metric tons
Steel Goods	40 metric tons	48 metric tons
Automobiles	12 metric tons	20 metric tons
Containers	7 TEU	12 TEU

3. 3 Necessary Number of Stevedore Workers

The necessary numbers of stevedore workers per shift is shown in Table Ⅷ—6. As shown in this table, there are presently some excess stevedore workers.

Table VIII-6 Necessary Number of Stevedore Workers

Type of Workers	Present No. of Stevedore Workers (men)	Necessary No. of Stevedore Workers in 1992 (men/(gang•shift))×(gangs)×(shifts)=(men)	Difference (men)
Hatch Bosses	16	1×5×3=15	−1
Winchmen	32	2×5×3=30	−2
Signalmen	16	1×5×3=15	−1
Workers	146	8×5×3=120	−26
Watermen	18	1×5×3=15	−3
Total	228	195	−33

4. Break Bulk Grain Cargo Handling

The handling of break bulk grain cargo is considered separately in this section because grain cargo operations will have a great impact on the overall operations of the multipurpose terminal, and the handling of grain is a new project for the Port of Caldera which will require a large investment.

4.1 Current Situation of Break Bulk Grain Cargo Handling

About 104,600 tons of wheat and 53,800 tons of corn are imported per year as break bulk at the Puntarenas pier. The break bulk cargo can presently only be carried by railway cars because there are no facilities for trucks at the Puntareas pier. The sequence of grain cargo handling is ship hold ……pneumatic pump ……railway car……silo in Barranca or Alajuela. The bottleneck in the present cargo handling system is the time which is lost as railway cars are changed on the pier and when the cars travel between the Puntarenas pier and the silos.

The present maximum handling capacity per day (24 hours) is about 800 to 1,000 metric tons. Under the present system, it takes 20 days to discharge 20,000 tons of wheat which is uneconomical. Demurrage and other costs borne by shipping companies increase the real handling cost per ton.

4.2 Grain Cargo Handling System Planning

4.2.1 General

If the new handling system at Caldera were as inefficient as the current system at Puntarenas, the handling of break bulk grain would be a severe drain on the facilities of the port. In order to handling break bulk grain at Caldera, it is necessary to greatly improve the cargo handling efficiency. To improve the efficiency, it is necessary to separate the stevedoring operation and the operation of carrying the grain to silos located outside the port area. To separate these operations, it is necessary to construct a new silo at the port that has at least the same capacity as the maximum handling tonnage of one grain cargo vessel.

4.2.2 The Assumed Conditions for Grain Cargo Handling

The assumed conditions for grain cargo handling are as follows :

1) The maximum handling tonnage per vessel is 20,000 tons.
2) To minimize inconvenience to other cargo vessels each grain carrier should finish discharging operations within five days.
3) Grain will be handled mainly at the No.2 berth unless the ship's draft is too deep for the berth.
4) Silo location should be behind the No.2 open yard and silo capacity should be

20,000 tons (reserving an additional area for the future storage of another 10,000 tons).

4. 2. 3 Proposed Alternative Handling Systems

Under the above conditions, we consider four alternative handling systems, as follows :

(1) Alternative I

A large pneumatic unloader (capacity : 400~2,000 tons/h class) is installed on the existing rail at breth No.1 running to the No.3 apron which was designed to be used for a gantry crane. For the transit operation from ship to silo, the grain is carried by a belt conveyor which has the same capacity as the pneumatic unloader.

(2) Alternative II

Two movable (tire mount) pneumatic unloaders (capacity : 200 tons/h each) are installed on the pier and discharge grain to a belt conveyor (400 tons/h transit capacity) which carries the grain to the silo.

(3) Alternative III

Using special grab buckets (3.5 m^3 capacity) for grain cargo and ship's cargo gear (derricks and deck cranes), stevedore winchmen discharge grain cargo from ship' s holds to a hopper which is placed on the pier next to the ship. A movable conveyor belt set under the hopper and transfers the grain to the silo.

(4) Alternative IV

The unloading operation is the same as under system III, but instead of belt conveyor equipment, nine dump trucks are used for trasnsit operations from the bottom of the hopper to the silo.

4. 2. 4 Evaluation of the Alternatives.

(1) Alternative I

This system has a great capacity to unload grain (maximum 2,000 tons/h) ; it is an excellent system, usually used for exclusive grain cargo berths. However, the unloader itself is a large machine which can only be moved on the railway : the movable range is limited. When grain cargo vessels are not in the port, this machine may hinder other cargo handling operations. Furthermore, the installation coats of the unloader would be substantial. This system would not be economical if the port only handles 166,100 tons of grain per year as estimated. Thus, system I is not appropriate.

(2) Alternative II

In this system, the cargo handling capacity is lower than under Alternative I.

However, the unloader can easily be shifted to a place where it does not hinder other cargo operations, and thus the berth and apron can be used efficiently for handling a variety of cargoes.

1) Cargo Handling Capacity

The capacity of Alternative II is as follows:

- Ship's unloading capacity : 200 tons/(h • unit) ×2 units=400 tons/h
- Handling tonnage per day : 400 tons/h×21 h×0.8=6,720 tons/day
- Port staying days per vessel :
  - (a) 10,000 tons÷6,720 tons/day=1.488 days
  - (b) 15,000 tons÷6,720 tons/day=2.232 days
  - (c) 20,000 tons÷6,720 tons/day=2.976 days
  - (d) 25,000 tons÷6,720 tons/day=3.720 days

In all the above cases, vessels can complete cargo unloading operations within four days. In case (d), 5,000 tons of cargo would have to be transferred to other local silos over three days after the unloading operations commence. This would involve shifting 1,670 tons of cargo per day.

2) Necessary number of workers

The following workers are required for operations.

i) During unloading : Ship supervisor (1)
Hatch boss 1
Unloader operater 1
Workers in hatch 3
5+(1) men

ii) When the unloading operation is nearly finished, the following additional workers are needed to gather cargo from the four corners of the ship's hold.

Extra workerd 2
Bulldozer driver 1
3 men

One gang consists of 8 men. When two unloader are used, total of 17 men are required (2 gangs+1 supervisor).

3) Necessary machines

All the machined listed in Table VIII—7 will have to be purchased.

Table VIII-7 Necessary Machines for Alternative II

Machine	Capacity	Number of Unit
Pneumatic Unloader	200 t/h	2
Bucket Elevator	400 t/h	1
Belt Conveyor (Movable)	400 t/h, L=200 m	1
Belt Conveyor (Fixed)	400 t/h, L=250 m	1
Small Bulldozer	2 tons	2

4) Advantages of Alternative II

(a) Even for the maximum handling volume of 25,000 tons, the entire operation would be finished within four days.

(b) After grain cargo handling is completed, INCOP could clear the berth apron.

(c) Using a closed type belt conveyor, it would be easy to implement dust prevention countermeasures under this alternative.

(d) The number of operators could be minimized using a fully mechanized unloader. After starting the operations, nonstop unloading (24 h) would be possible.

5) Disadvantages of Alternative II

(a) The installation cost of Alternative II is less than that of Alternative I, but higher than that of Alternatives III and IV.

(b) The unloader is heavy (99 metric tons per unit, 32 tires, per tire weight 3,093 kgf).

(3) Alternative III

This Alternative requires more workers than Alternatives I and II, but the equipment cost is cheaper than Alternative II.

1) Cargo handling capacity

The cargo unloading capacity of Alternative III is as follows :

- Ship's unloading capacity : 3.5 tons/sling×30 slings/(h • gang • shift)
  =105 tons/(h • gang • shift)
- Working conditions :
  (a) Three gangs work at the same time.
  (b) Gangs work three shifts a day (21 hours).
- The unloading tonnage per day
  105 tons/(h•gang•shift)×3 gangs×7 h×3 shifts/day×0.8=5,292 tons/day
- Port staying days per vessel
  a) 10,000 tons÷5292 tons/day=1.889 days
  b) 15,000 tons÷5292 tons/day=2.834 days
  c) 20,000 tons÷5292 tons/day=3.779 days
  d) 25,000 tons÷5292 tons/day=4.724 days

In all cases, the entire unloading operation would be completed within five days. In case d), 5,000 tons of cargo would have to be transferred to other local silos over four days. That involves shifting 1,250 tons of cargo per day. However, if only two gangs could work at the same time due to the cargo stowage conditions, the unloading tonage per day would become 3,528 tons/day. Therefore, the port staying period would be as follows :

a) 10,000 tons÷3,582 tons/day=2.834 days
b) 15,000 tons÷3,582 tons/day=4.251 days
c) 20,000 tons÷3,582 tons/day=5.668 days
d) 25,000 tons÷3,582 tons/day=7.086 days

In cases c) and d), over 5 days of berthing time would be required. Thus, when only two gangs can work simultanecously, Alternative III is not practical.

2) Necessary number of workers

The following workers would be required.

Ship supervisor		1
Hatch bosses	1×3 gangs=	3
Signalmen	1×3 gangs=	3
Winchmen	1×3 gangs=	3
Hatch workers	5×3 gangs=	15
Bulldozer Drivers	1×3 gangs=	3 (driver)
		28 men

3) The necessary machines

The necessary machines are summarized in Table VIII—8

Table VIII-8 Necessary Machines for Alternetive III

Machines	Capacity	Number of Units	Remarks
Belt Conveyor	400 tons/h	1 set	$L=450$ m
Grab Bucket	3.5 tons	4 units	
Hopper	50 m^3	3 units	
Small Bulldozer	2 tons	3 units	
Machinery, Electric Equipment (Attached to Belt Conveyor)		1 set	

4) Disadvantages of Alternative III.

(a) While unloading, too much dust would be generated. This dust would seriously disturb the other cargo handling operations being conducted at the next berth, and would also impede shore side cargo operations being carried out near the grain vessel.

(b) For vessels while have insufficient cargo gear, the cargo handling rates noted above could not be maintained.

(c) Alternative III requires a large number of workers, and the operation depends on the workers' skill.

(d) The unloading efficiency is lower than under Alternative II.

(e) When it rains, unloading would be interrupted.

(4) Alternative IV

Alternative IV uses the same stevedoring operation as Alternative III, but for transit to the silo, Alternative IV would use nine dump trucks.

1) Cargo handling capacity
Unloading tonnages per day are the same as for Alternative III.

2) The necessary number of workers
The necessary number of workers in Alternative IV are as follows :

Ship supervisor		1
Hatch bosses	1×3 gangs=	3
Signalmen	1×3 gangs=	3
Winchmen	1×3 gangs=	3
Hatch workers	5×3 gangs=	15
Bulldozer drivers	1×3 gangs=	3
Dump truck drivers	3×3 units =	9
		37 men

Alternative IV requires the largest number of workers of the four Alternatives.

3) The necessary equipment.
The necessary equipment under Alternative IV is listed in Table VIII—9.

3) The necessary equipment.
The necessary equipment under Alternative IV is listed in Table VIII-9.

Table VIII-9 Necessary Equipment for Alternative IV

Machines	Capacity	Number of Units
Grain Cargo Dump Truck	18 tons	9 units
Grab Bucket	3.5 tons	4 units
Hopper	50 m^3	3 units
Small Bulldozer	2 tons	3 units

4. 2. 5 Appraisal Criteria

When comparing the above four alternatives, the following points must be considered.

1) It is necessary to minimize inconvenience to the other commomn users of Caldera Port. Grain carrier unloading should be mechanized, and high operation speed is required.
2) The system should be able to accommodate future increases of handling tonnage and further rationalization and mechanization.
3) The system should minimize dust pollution.
4) Operation costs should be minimized over the long term.

The appraisal of the alternatives is shown in Table VIII—10. The purchase and operation cost for such cargo handling equipment as pneumatic unloaders and belt conveyors will be

Table VIII-10 Appraisal of Alternatives

Item \ Alternative	A I	A II	A III	A IV
Operation Efficiency	Very high ○	High ○	Low △	Low △
Possiblity of Expanding Capacity Handling	Sufficient ○	Sufficient ○	Iusufficient △	Iusufficient △
Anti-dust Pollution Countermeasures	Easy ○	Easy ○	Hard ×	Hard ×
Labour/Cost	Low ○ (17men)	Low ○ (17men)	Higher △ (28men)	Highest × (37men)
Rain Work	Possible ○	Possible ○	Impossible ×	Impossible ×
Ship's Port Stay	Short ○	Short ○	Long △	Long △

recovered directly from the user through port charges. Thus, in the selection of an appropriate grain cargo handling system, we must consider whether or not the port charge is acceptable for the user and also whether the investment cost is reasonable for the investor.

If the investment cost is a reasonable one, the port operator will attempt to rationalize the system as much as possible to handle grain cargoes without interfering with the cargo handling of general and container cargoes. Therefore, in the selection of the system, the decisive factors will be as follows:

(a) The acceptability of the port use charges to the user.

(b) The extent of the rationalization of the system.

First, Alternative I is eliminated from viewpoint (a), that is under Alternative I the user fees necessary to recover the investment would be unreasonably high. Second, the most rationalized system other than Alternative I is Alternative II. Under this alternative, the investment in cargo handling facilities and machinery would reasonable for the user: the tariff for grain cargo handling would be less than that for general cargo. Cargo handling operations under alternatives III and IV could be interrupted by rainy weather. Besides, depending upon cargo stowage conditions, under Alternatives III and IV vessels might sometimes have to remain at berth as long as 7 days. Consequently, Alternative II is overall the most reasonable option.

4. 3 Evaluation of Another Alternative Grain Cargo Handling System

In this study, the construction of grain silos at the Port of Caldera with a capacity of 20,000 tons is proposed along with the transference of the grain import function from