Puntarenas pier to the Port of Caldera. Another alternative including construction of grain silos with a capacity of 5,000 tons is evaluated here.

4.3.1 Assumptions

(1) Grain cargo handling volume

1) Import volume per year

Grain import volume in the target year 1992 is assumed to be 166,100 tons.

2) Loaded grain volume per ship

Average loaded grain volume per ship is assumed to be 20,000 tons.

(2) Unloading capacity per day

Under this alternative system, the grain will be unloaded using 4 pneumatic unloaders and a belt conveyor. The capacity of the pneumatic unloaders is assumed to be 60 tons/h×4 unloaders. Thus, based on a working period of 18 h/day and a working efficiency of 80%, the unloading volume is as follows :

60 tons/(h • unloader) ×4 unloaders×18 h/day×0.8=3,456 tons/day

Two possible distribution systems are considered : one using railway cars and the other using trucks.

4.3.2 Study on Distribution by Railway

(1) Premises

There is only one sidetrack on the apron along the quaywall face line at the Port of Caldera. As it takes a long time to directly unload grain from grain vessels onto freight cars, a direct unloading system is not practical. It is also not practical to increase the number of sidetracks because additional tracks on the apron would interfere with the handling of other types of cargoes. In other words, the installation of additional tracks is not consistent with the multipurpose use of the terminal. Accordingly, under the system considered here, all grain will first be unloaded to buffer silos, and then be distributed by the railway to the storage silos located in Barranca and Molinos de Costa Rica.

(2) Transportation capacity

Each train is assumed to consist of ten freight cars. Four trains are assumed to operate each day. Given a freight car capacity of 30 tons/car, the transportation capacity of the trains is as follows:

30 tons/car×10 cars/train=300 tons/train

(3) Required distribution periods

Required distribution periods can be calculated using the following equation.

The required distribution period for each destination

=(a) Preparation period for unloading

+ (b) Loading period onto freight cars
+ (c) Transportation period
+ (d) Unloading period from freight cars
+ (e) Shuttling period

Accordingly, the required distribution periods are calculated as shown in Table Ⅷ−11.

Table VIII-11 Estimation of Required Distribution Periods (Railway)

	Operation	Distribution Period		
		Caldera-Barranca (Distance: 18km)	Caldera-Molinos de Costa Rica (Distance: 120km)	Average Velocity (km/h)
(a)	Prearation Period for Unloading	20 minutes	20 minutes	
(b)	Loaing Period onto Freight Cars	120	120	
(c)	Transportation Period	30	200	36
(d)	Unloading Period from Freight Cars	160	160	
(e)	Shuttling Period	30	200	36
	Total	360 ninutes (6h)	700 minutes (12h)	

(4) Transportation volume per day

Train operation frequency is 1 train/day to Barranca and 3 trains/day to Molinos de Costa Rica. Thus, the grain volume which can be transported by the railway per day is calculated as shown in Table Ⅷ−12.

Table VIII-12 Transportation Volume per Day

Item	Caldera-Barranca (Distance: 18km)		Caldera-Morinos de Costa Rica (Distance: 120km)	
	Calculation	Transport Volume	Calculation	Transport Volnme
Shuttling Period	$\frac{24}{6}\times 0.8$	3.2 times/day	$\frac{24}{12}\times 0.8$	1.6 times/day
Transport Volume per Day per Train	300×3.2	960 tons/day/train	300×1.6	480 tons/day/train
Total Transport Volume per Day	One train operation	960 tons/day	Three trains operation	1,440 tons/day

(5) Relation among unloading periods, distribution volume per day and silo storage volume

Under the assumptions that grain vessels each carry 20,000 tons of grain, the storage capacity of the port (buffer) silos is 5,000 tons and that all grain is distributed by the railway through these silos, the relation among unloading period, distribution volume and silo storage volume is as shown in Table Ⅷ—13. The calculation assumes that one-third of the cargo handling capacity is available the first day. Under this system, grain ships would be obliged to moor for seven days as shown in Table Ⅷ—13.

Table VIII-13 Unloading Period, Distribution Volume and Silo Storage Volume

Working Day	Unloding Volume per Day (tons/day)	Distribution Volume per Day (tons/day)		Storage Volume in Port Silos (ton)
		To Barranca (Distance : 18km)	To Molinos de Costa Rica (Distance : 120km)	
First Day	3,456	320	480	2,656
Second Day	3,456	960	1,440	3,712
Third Day	3,456	960	1,440	4,768
Fourth Day	2,632	960	1,440	5,000
Fifth Day	2,400	960	1,440	5,000
Sixth Day	2,400	960	1,440	5,000
Seventh Day	2,200	960	1,440	4,800

(6) Problems with the proposed distribution system by railway

There are various problems with the proposed sytstem as outlined below.

1) Necessity of executing unloading and distributing operations at the same time

Under this system, the port (buffer) silo has a capacity of only 5,000 tons. Thus, for a 20,000 DWT grain carrier, 15,000 tons would have to be distributed inland as part of the unloading operations. The unloading operations from the ship are dependent upon the distribution operations. If there were some problems with the land (railway) distribution system, the unloading of the grain from the vessel would also be delayed. This is the main defect of the proposed system. Under present conditions, it would be very difficult to operate the trains on a reliable, regular basis as proposed in this plan.

2) Long unloading period

Even if the land distribution by railway functioned exactly as planned, it would still take seven days to complete the unloading operation. The grain carrier would occupy the berth for too long a period of time, and this would interfere with the cargo handling of other cargoes. That is, the proposed system would interfere with the multipurpose use of the terminal.

3) Necessity of purchasing freight cars

The capacity of the freight cars which are currently being used is only

20 tons/car. Thus, it would be necessary to newly purchase forty freight cars to implement this plan.

4. 3. 3 Study on Distribution by Truck

(1) Premises

All grain would first be unloaded to buffer silos and then be distributed by truck to inland storage silos.

(2) Estimation of the required distribution periods

On the assumption that trucks with a capacity of twenty tons/truck would be used, the required distribution periods are estimated as shown in Table Ⅷ—14.

Table VIII-14 Estimation of Required Distribution Periods (Truck)

Operation	Distribution Period	
	Caldera-Barranca (Distance : 18km)	Caldera-Molinos de Costa Rica (Distance : 120km)
(a) Preparation Period for Unloading	20minutes	20minutes
(b) Loading Period onto Trucks	10	10
(c) Transportation Period	60	360
(d) Unloading Period from Trucks	10	10
(e) Shuttling Period	60	360
Total	160minutes (2h 40min)	760minutes (12h 40min)

(3) Estimation of the required number of trucks

If the trucks were to transport grain at the rate of 960 tons/day to Barranca and 1,440 tons/day to Molinos de Costa Rica (the same volumes as under the railway distribution plan), the number of necessary trucks is calculated as shown in Table Ⅷ—15 assuming a working efficiency of 80%. Thus, the number of required trucks is 55 as shown in Table Ⅷ—15.

Table VIII-15 Required Number of Trucks

Item	Caldera-Barranca (Distance : 18km)		Caldera-Molinos de Costa Rica (Distance : 120km)	
Shuttling Period	Calculation $\frac{24\times60}{160}\times0.8$	Transport Volume 7.2 times	Calculation $\frac{24\times60}{760}\times0.8$	Transport Volume (1.5) times
Transport Volume per Day per Truck	20×7.2	1.44 tons/day/truck	20×1.5	30 tons/day/truck
Total Transport Volume per Day	$\frac{960}{144}\fallingdotseq6.66$	7 trucks	$\frac{1,440}{30}\fallingdotseq48$	48 trucks

(4) Problems with the proposed distribution system by truck

There are various problems with the proposed system as follows.

1) Necessity of executing unloading and distributing operations at the same time

As with the railway distribution system, under the truck distribution plan grain would be unloaded from the grain carrier at the same time that grain would be distributed by trucks. Essentially, the cargo unloading operation would be dependent upon the distribution operation, and any delays in the distribution would cause delays in the cargo unloading. This is also the main defect of this plan.

2) Long unloading period

It would take seven days to complete grain unloading from each ship, the same length of time as under the railway distribution system. Again, this excessively long mooring period would be unacceptable as it would interfere with the multipurpose use of the terminal.

3) Necessity of purchasing trucks

It would be necessary to purchase fifty-five trucks to carry the cargo under this system.

4. 3. 4 Conclusions

The alternative to construct silos with a capacity of 5,000 tons using either trucks or railway cars for inland distribution does not seem to be feasible due to three main shortcomings :

1) Cargo unloading operations would have to be carried out in parallel with cargo distribution operations, and the smooth unloading of grain would thus become dependent upon the distribution system.

2) The required mooring period would be too long, and thus the handling of grain would interfere with the handling of other cargoes and be inconsistent with the multipurpose nature of the terminal.

3) The overall investment for these alternatives is almost the same as the investment cost of the grain cavgo handling system propsed by JST.

5. Storage Improvement Plan

5. 1 Presert Conditions and Improvement Plan

5. 1. 1 Warehouses

(1) Present conditions

Warehouse No.1 is mainly used for storage of general cargo for import and export, and it is also utilized as a Container Freight Station (C.F.S.). As most of the imported containers are delivered directly to the consignees, it is not necessary to build a new C.F.S.. Warehouse No.2 is mainly used to store imported large lot cargo such as roll paper and pulp. Table Ⅷ–16 lists the area and storage capacity of the warehouses.

Table VIII-16 Warehouses

Warehouse No.	$L \times W$ (m)	Floor Space (m^2)	Capacity (tons)
№ 1	120 × 60	7,200	3,600
№ 2	90 × 60	5,400	2,700
Total		12,600	6,300

For break bulk general cargo, the estimated throughput in the target year (1992) is about 320,600 tons, and the storage term of general cargo is assumed to be seven days on the average. This is a standard storage period generally adopted when calculating the storage capacity of C.F.S. and sheds. The present warehouse storage capacity per year is as follows:

$$6,300 \text{ tons} \times 365 \text{ days/y} \div 7 \text{ days} = 328,500 \text{ tons/y}$$

This present storage capacity will still be sufficient in the target year.

(2) Improvement Plan

The floors of both warehouses are presently only partially lined. To maximize the use of the available space it is essential to properly line and mark the floors of both warehouses completely. Lines should be clearly drawn defining suitable square meter units for storage. Each section should be clearly marked with its own section number. The tonnage capacity of the floor space can be calculated as follows :

$$12,600 \text{ m}^2 \times 0.7 \times 1.0 \text{ ton/m}^2 = 8,820 \text{ tons}$$

On the other hand, the present warehouse storage efficiency is as follows :

6,300 tons ÷ 12,600 m^2 = 0.5 tons/m^2

The warehouse storage efficiency can be increased to 0.7 tons/m^2. Then, the annual storage capacity in the target year will be as follows :

8,820 tons × 356 days/y ÷ 7 days = 459,900 tons/y.

5. 1. 2 Open Yards

(1) Present condition

There are presently four open storage yards as shown in Table VIII–17. At present, only the No.1 yard is paved. Thus, it is somewhat difficult to use forklifts in open yards No.2, 3, and 4. Moreover, the lack of pavement may cause flat tires.

Table VIII-17 Open Yards

Yard Number	Length (m)	Width (m)	Area (m^2)	Pavement	Usage
No. 1	160	85	13,600	yes	Containers
No. 2	160	85	13,600	no	Containers
No. 3	113	85	9,600	no	Steel Goods
No. 4	221	85	18,800	no	Vehicles and Containers
Total Area			55,600		

(2) Improvement Plan

Yards No.2, 3, and 4 sholud be paved completely. Yards No.1, No.2 and a part of No.4 should be lined with container storage slots, and yards No.3 and 4 should be lined with suitable area units, and for forklift passage. Fixed numbering of each area will makes it easy to manage open yard cargo storage.

Two-thirds of the space of the No.4 open yard (13,190 m^2) will provide sufficient space for the storage of automobiles after the paving works are finished. The storage capacity of the yard will be about 1,100 units. Part of the general cargoes such as steel goods and construction materials are stored in open yard No.3. The storage capacity of the No.3 open yard is estimated as about 7,000 tons. This is sufficient for these general cargoes.

5. 1. 3 Container Terminal

Open yards No.1 and No.2 and a part of open yard No.4 will be used for the container terminal. The details are described below.

(1) Present conditions

At present, mainly loaded containers are stored in the No.1 open yard (paved) and empty containers are stored in the No.2 open yard (not paved). As container handling machines, two 30 ton frontloaders, two tractors, and four container chassis are used. The number of storage slots is as follows :

(a) Loaded container storage slots

22 TEU/lane×8 lanes	=176	TEU
Reefer slots	= 20	TEU
Dry slots	= 16	TEU
Sub Total	=212	TEU
212 TEU/tier×2 tiers	=424	TEU

(b) Empty container storage slots

22 TEU/lane×6 lanes	=132	TEU
132 TEU/tier×2 tiers	=264	TEU

(2) Improvement plan

The proposed improvement plan is as follows:

1) Storage capacity of the container yards

No.1 Open Yard	13,600 m^2
No.2 Open Yard	13,600 m^2
No.4 Open Yard	5,610 m^2
	32,810 m^2

2) To pave the No.2 open yard and a part of the No.4 open yard (13,600 m^2+5,600 m^2) so they can also be used for loaded containers. Paving the yard will make it possible to use cargo handling equipment much more efficiently. The cargo handling rate will increase and the mechanical troubles of the cargo handling machines will decrease. Furthermore, once the yards are paved it will become possible to line clearly the yards which will further improve the handling efficiency and facilitate the management of the handling operations using a computer.

3) To make separate storage areas for loaded and empty containers : empty containers should be stored in a separate part of the No.2 open yard.

The maximum storage capacity for loaded and empty containers would be as follows :

(a) Loaded container storage slots

22 TEU/lane・tier×16 lanes×2 tiers	= 704	TEU
11 TEU/lane・tier× 8 lanes×3 tiers	= 264	TEU (No.4 yard)
Reefer slots	= 40	TEU
Dry slots	= 32	TEU
Sub Total	=1,040	TEU

Thus, a maximum of 1,040 TEU of containers can be stored using the frontloader system. Generally, the average yard staying time of containers is 7 days, so the storage capacity per year is as follows :

1,040 TEU×365 days/y÷7 days=54,230 TEU/y

Thus, under the present container handling system, the maximum container handling volume is determined by the open yard storage capacity (54,230 TEU) rather than by the stevedoring capacity.

The estimated container handling volume in the target year (1992) is about 21,360 TEU (161,700 tons), clearly within this maximum capacity (54,230 TEU). On the other hand, based on the computer storage simulation discussed later on, the maximum loaded container volume per day in 1992 may be less than 940 TEU with a 90% probability. In that case, 164 TEU of loaded containers may have to be stored in the No.4 open yard on a temporary basis.

(b) Empty container storage slots

24 TEU/lane • tier×4 lanes×3 tiers=288 TEU

(3) Layout of the container terminal

The proposed layout of the container termiral is shown in Fig. Ⅷ—3(a) and (b).

5. 1. 4 Other Facilities

Wharf apron length and width are shown in Table Ⅷ—18. The wharf apron width is designed as 30 m. This width is sufficient for forklift operations. The new mooring dolphin will effectively expand the length of the quaywall −10 m in depth enabling two large vessels to berth simultaneously.

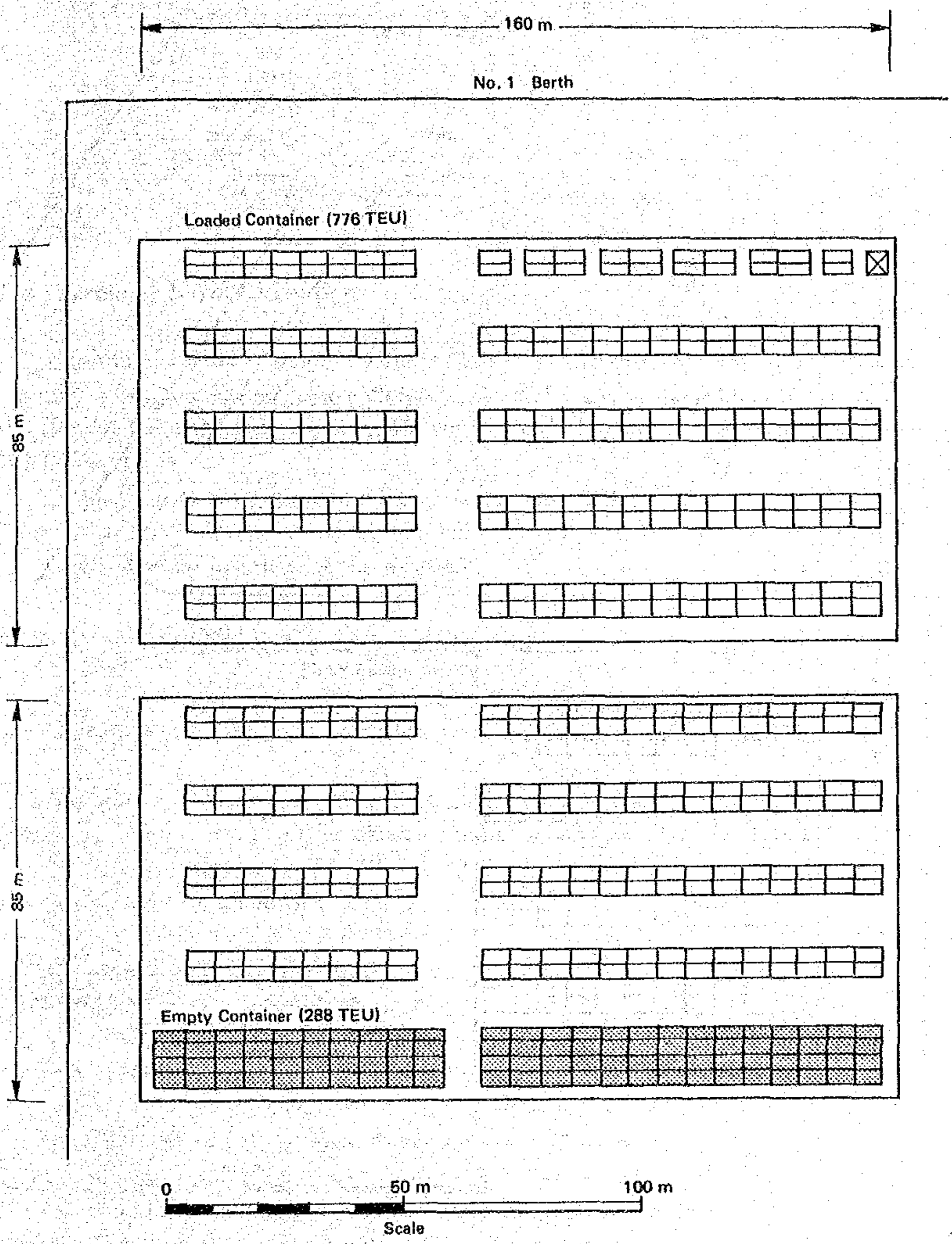


Fig. VIII-3 (a) Container Yard Slot Arrangement Plan

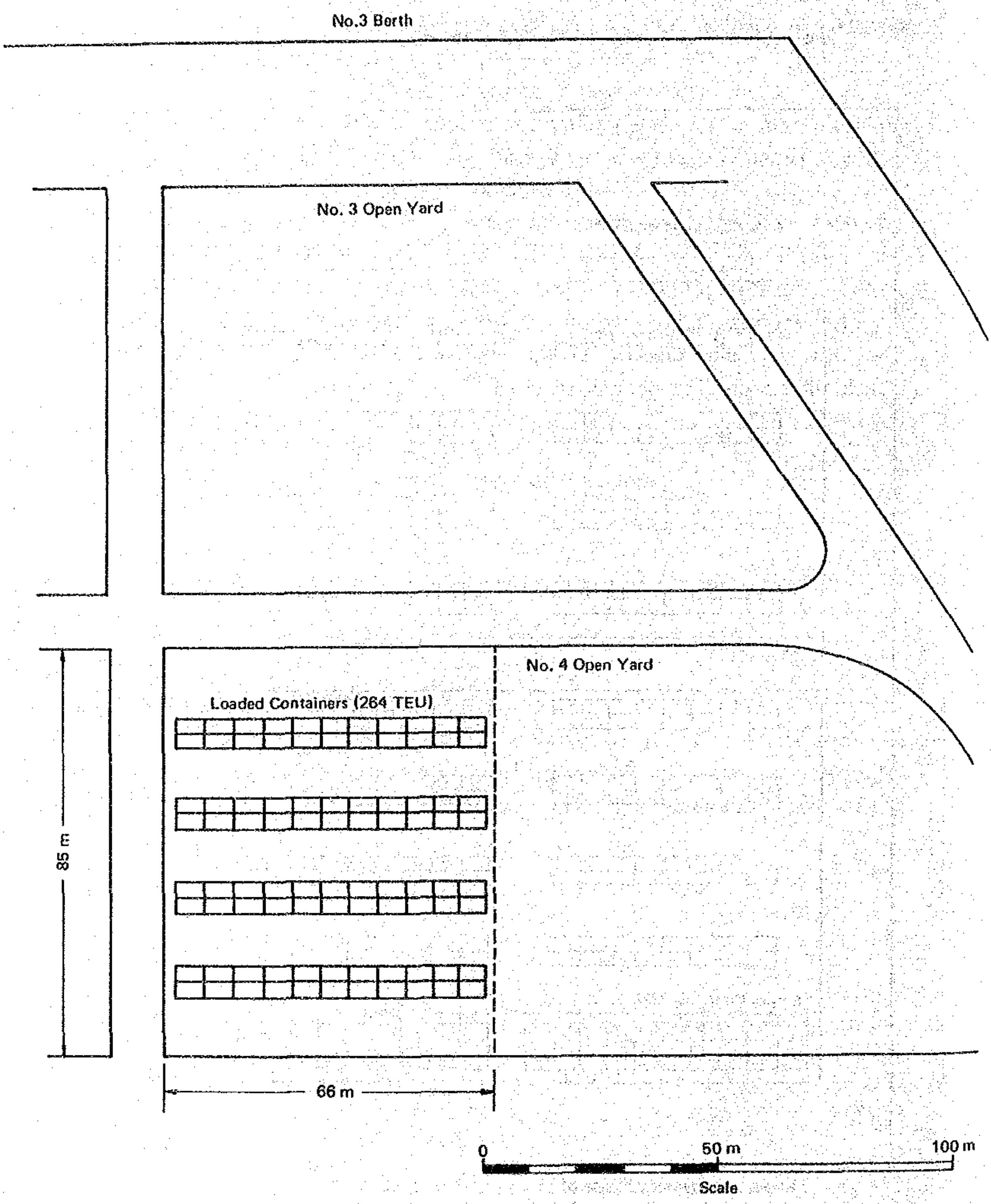


Fig. VIII-3 (b) Container Yard Slot Arrangement Plan

Table VIII-18 Wharf Apron Length and Width

	Wharf Length	Width	Depth
No.1 Berth	175m	30m	−11m
No.2 Berth	185m	30m	−10m
No.3 Berth	130m	30m	−7.5m
Total	490m		

5. 2 Terminal Layout Planning

The terminal layout planning is studied based on the existing layout and the results of the studies conducted earlier in this chapter. Basically, the proposed terminal layout is not very different from the existing one. However, the following items are different from the existing conditions.

(a) Open yards No.2, 3 and 4 will be paved and all the yards will be lined.
(b) A grain silo area will be located behind the open yard, and a fixed belt conveyor will also be installed at the terminal.

The overall terminal layout plan is presented in Fig. VIII—4.

5. 3 Cargo Storage Simulation Study

Cargo storage at the Port of Caldera in 1992 is simulated using a simulation model processed by computer. The flow chart of the simulation model is shown in Fig. VIII—5.

5. 3. 1 Study Commodities

Port cargoes are classified into grain, containers, automobiles, fertilizer and other general cargoes.

5. 3. 2 Input Data

(1) Number of calling ships by ship group and by berth:
output data of the ship waiting simulation in CHAPTER VII.
(2) Loading/unloading period by ship group and by commodity :
the same as the input data for the ship waiting simulation.
(3) Distribution of transport volume to/from storage facilities :
refer to Table VIII—19.

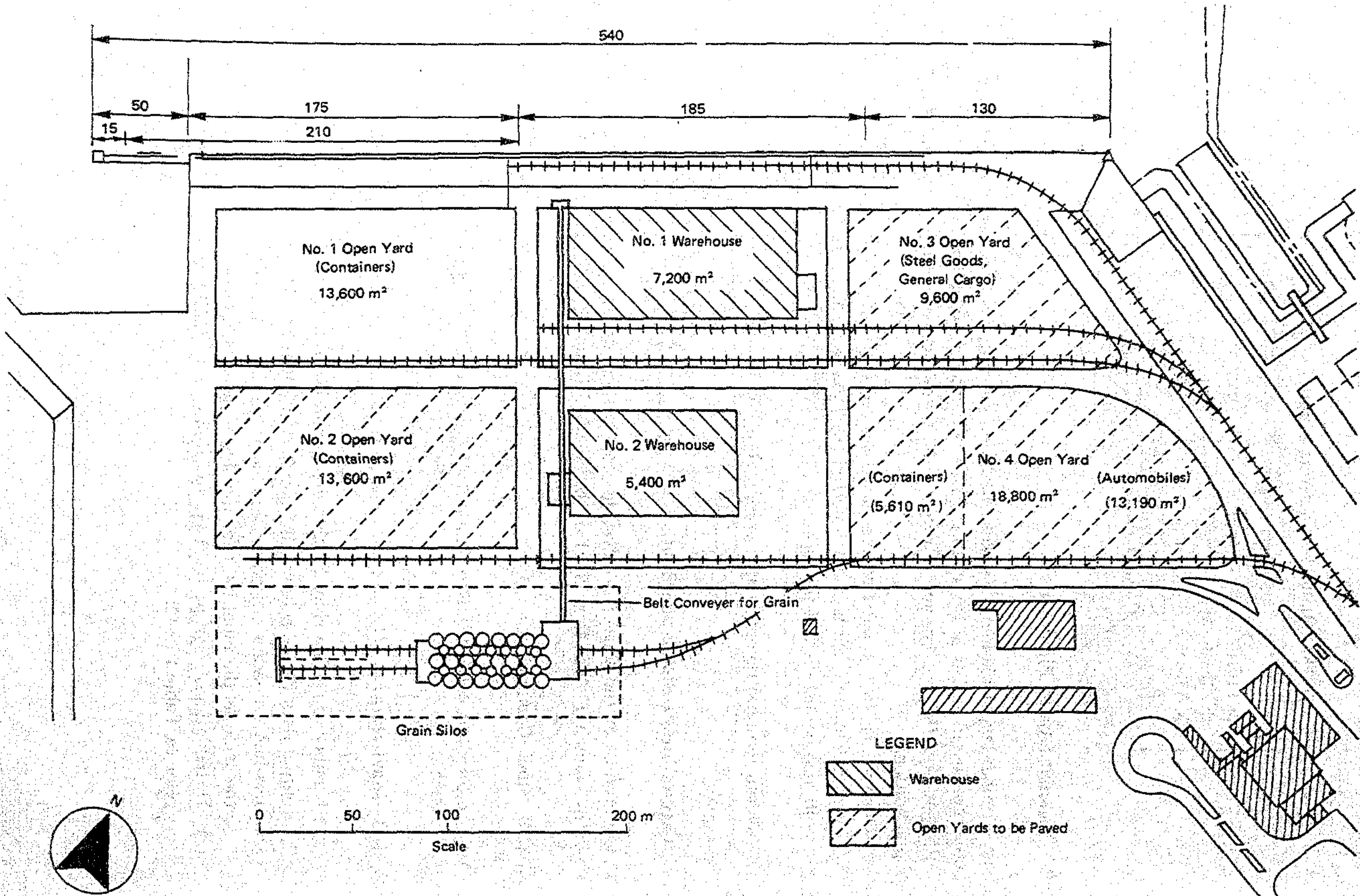


Fig. VIII-4 Terminal Layout

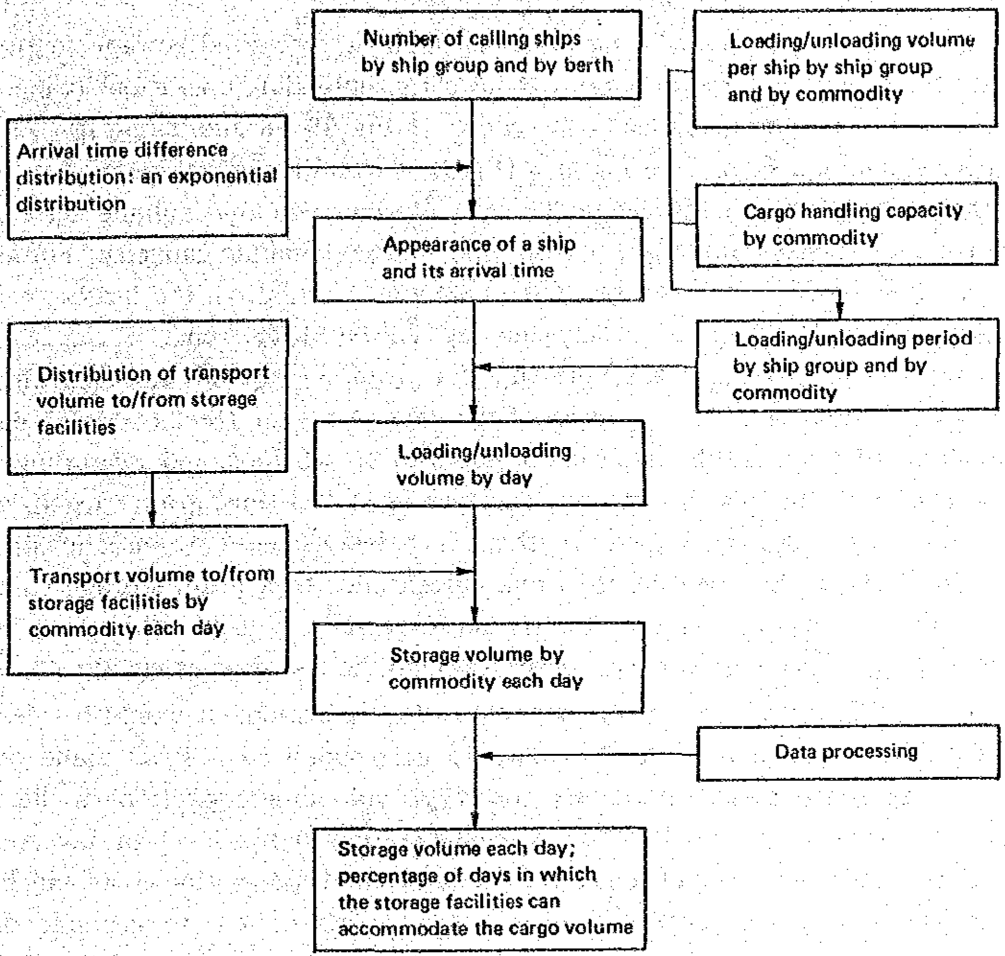
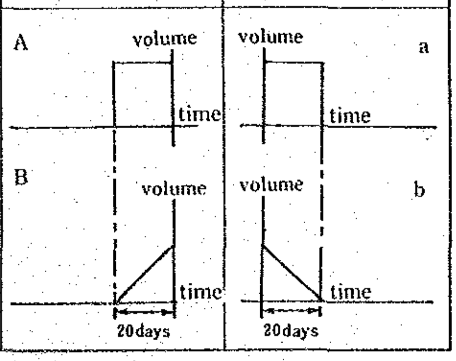


Fig. VIII-5 The Flow Chart of the Storage Simulation

Table VIII-19 Distribution Pattern of Carrying in/out

Commodity	Distribution Pattern		Remarks	
	Carrying in	Carrying out	Carrying in	Carrying out
Grain	—	a		
Containers (loaded)	B	a		
Containers (empty)	B	a		
Automobiles	—	a		
Fertilizer	—	a		
Other General Cargoes	B	a		

Note: Time periods for all commodities are assumed to be twenty days

5. 3. 3 Simulation Results

The percentage of accommodating days in which the proposed storage facilities can accomodate the projected cargo volume without cargo unloading operations being delayed because of insufficient storage capacity are shown in Fig. VIII—6 and Table VIII—20.

The percentage of accommodating days (PAD), shows the percentage of days per year in which the storage facilities can accommodate the projected cargo volume without cargo handling operations being delayed due to insufficient cargo handling capacity. For example, for grain cargoes, based on the results of the computer simulation, the largest volume of grain cargo which will be handled on any one day will be 31,245 tons.

Referring to Table VIII—20, a PAD of 100% for grain corresponds to this grain volume of 31,245 tons. This means that on 100% of the days in a year (that is on 365 days) the handling volume of grain will be less than or equal to 31,245 tons, and, accordingly, if the storage facilities were built with a storage capacity of 31,245 tons, grain cargoes could be unloaded from vessels 365 days a year without any delay caused by insufficient storage capacity. Similarly, a PAD of 60% for grain corresponds to a grain storage capacity of 9,345 tons. This means that based on the simulation results, on 60% of the days in a year (that is on 219 days) the handling volume of grain will be less than or equal to 9,345 tons.

Only considering the viewpoint of cargo unloading operations, it would be ideal if the storage capacity of the planned facilities would correspond to a PAD value of 100%. However, it may sometimes be necessary for cargo unloading operations to be delayed somewhat. Essentially, the goal is to determine a reasonable level of investment by balancing the construction costs of the storage facilities and the waiting costs which will be incurred on those days when the storage capacity is insufficient to accommodate the unloading cargo volume.

Table VIII—21 shows the relation between the projected storage volume and storage capacity. In this table, the projected storage volume corresponding to the 90% of the PAD is planned as the design storage capacity except for the grain cargo. In the case of grain cargo, 80% of the PAD value is used as the storage volume because the grain carriers will actually enter the port at a more regular interval than assumed in the simulation. It can be seen from this table that the storage capacity in 1992 will be sufficient for the projected cargo storage volume.

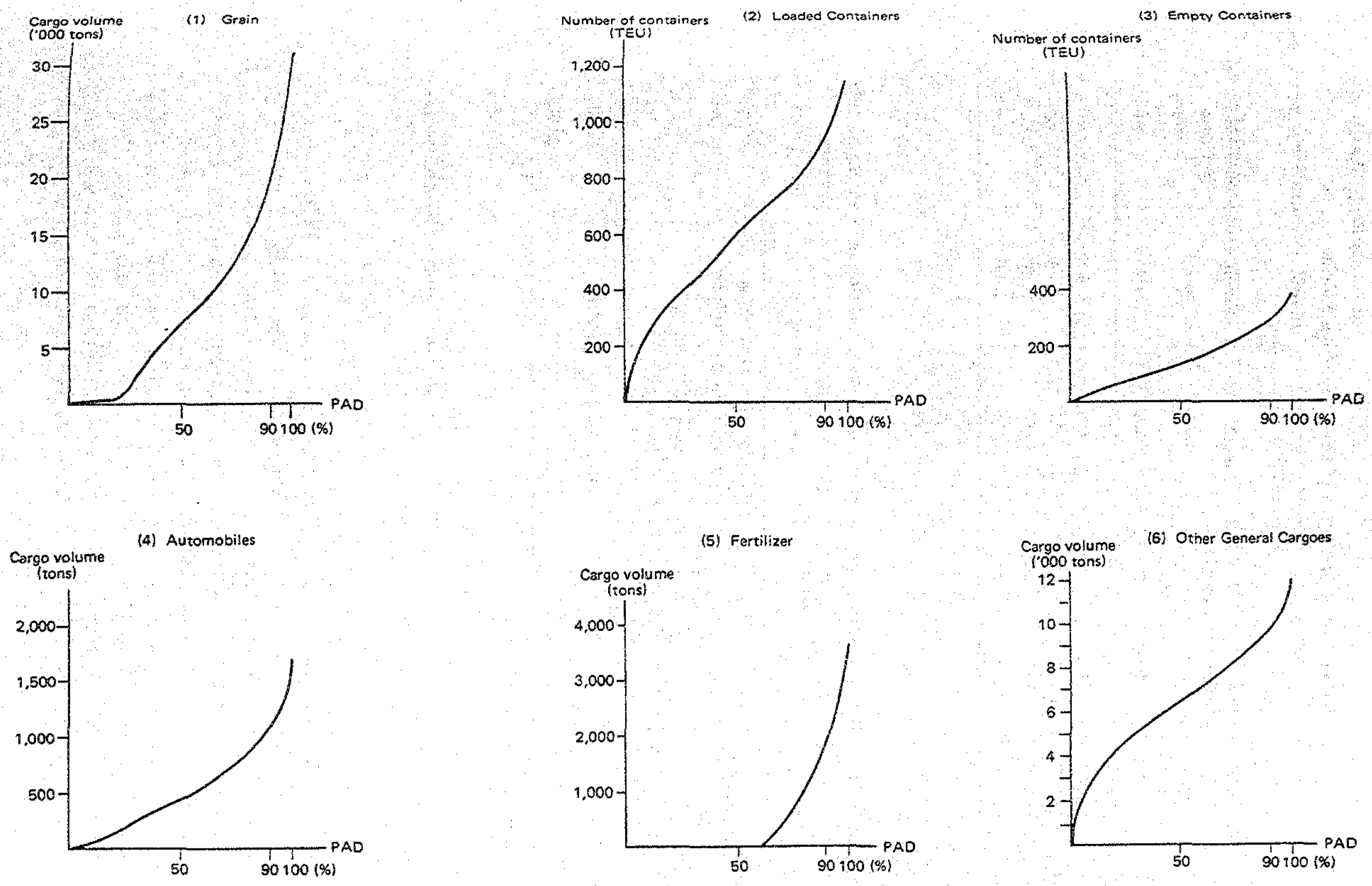


Fig. III-6 Distribution of Sufficiency of Storage Cargo Volume by Commodity

Table VIII-20 Distribution of Cargo Handling Volume

PAD (%)	Required Storage Capacity					
	Grain (tons)	Loaded Containers (TEU)	Empty Containers (TEU)	Automobiles (tons)	Fertilizer (tons)	Other General Cargoes (tons)
50	7,025	599	142	437	—	6,533
60	9,345	686	171	556	7	7,264
70	11,515	745	206	696	420	8,057
80	14,570	817	241	851	1,050	8,822
90	20,621	940	285	1,056	1,887	9,707
100	31,245	1,138	381	1,696	3,691	12,046

Table VIII-21 Relation between Projected Storage Volume and Storage Capacity in 1992

Kinds of Cargo	Maximum Storage Volume per Day	Storage Facilities	Storage Capacity
General Cargoes[1]	11,594 ton	Two Warehouses (12,600m²) Open yard No. 3 (9,600m²)	6,300 ton 7,000 ton
Automobiles	1,056 ton	Open yard No. 4 (13,190m²)	1,100 ton
Empty Containers	285 TEU	Open yard No.2	288 TEU
Loaded Containers	940 TEU	Open yard No.1, 2 and 4	1,040 TEU
Grain	14,570 ton	Grain Silo	20,000 ton

Note 1) : General cargoes include fertilizer.

6. Cargo Handling Machinery

6. 1 Cargo Handling Machinery Presently Owned by INCOP

The cargo handling machinery presently owned by INCOP is listed in Table Ⅷ—22.

Table VIII-22 Present Cargo Handling Machines

Type of vehicle	Capacity	Number of units	Remarks
Forklift	2.0 tf	7	Clark(5), Caterpiller(2)
	2.5	14	Komatsu(10), Nissan(4)
	3.0	2	Caterpiller(2)
	3.5	3	Clark(3)
	5.0	2	Clark(2)
	6.0	3	Komatsu(3)
	10.0	1	Clark(1)
Tractor	2.5	3	TCM(3)
	680 kgf	3	John Deere(3)
Trailer		24	
Container Tractor		2	
Container Chassis		4	
Mobile Crane	9.0 tf	1	Austin Western
	18.0	1	Made in USA
	25.0	1	P & H
	30.0	1	TCH(1)
Container Front-loader	30.0	2	TCM(1), Kalmar(1)
Total		74 units	

6. 2 Container Handling Machinery

6. 2. 1 Actual Conditions

The 2 container tractors, 4 container chassis and 2 container frontloaders in Table Ⅷ—22 are presently used for container cargo handling. The present container handling system involves lifting containers by ship's gear (cranes or derrick booms) and placing them on the apron. The containers are then picked up using frontloaders and placed up onto container chassis. Tractors are connected with the chassis, and are then used to pull the containers to the container yards. At the container yards, another frontloader picks up the containers off the chassis and moves them to their designated location within the yard.

For ordinary container operations, one gang will do, but sometimes it is necessary to work two gangs at the same time. At these times, as INCOP has only two tractor heads, it has to temporarily rent two more tractor heads from a private transportation company.

At present, empty containers are also handled using the frontloader system. This requires a lot of yard space, and the space use efficiency is very low. JST recommends a new exculsive empty container block storage system using a special frontloader. The empty containers would be stored in a special space within the No.2 yard. In this case, the purchase of one frontloader for the handling of empty containers will be necessary.

6. 2. 2 Reinforcement of the Container Cargo Handling Machinery

The necessary number of cargo handling machines using the frontloader system are listed below.

a) Ship side operations

35 ton frontloader : 1 unit

b) Transferring between ship side and container yards

Tractors : 4 units

Container chassis (20'/40') : 7 units

c) Container yard operations

35 ton frontloader : 2 units

One of these frontloaders would be used for connecting with ship side operations and the other would be used for regular moving of containers in and out of the container yard.

d) Empty container yard operations

10 ton frontloader : 1 unit

The required container handling machines in the target year (1992) are summarized in Table VIII—23.

Table VIII-23 Increase of Container Handling machines

Machine	Present Number of Units	Necessary Units in the Target Year	Increase (units)
35 ton Frontloader	2	3	+1
Tractor Head	2	4	+2
20/40' Chassis	4	7	+3
10 ton Frontloader	—	1	+1
Total	3 units	15 units	+7 units

6. 3 General Cargo and Steel Goods Handling Machinery

6. 3. 1 Present Situation

All of the machines listed in Table VIII—22, except those used for container handling are used for handling of general cargo and steel goods.

Some of the forklifts and mobile cranes have already been used for over 5 years and will have to be replaced before too long.

6. 3. 2 Reinforcement of the General Cargo and Steel Goods Handling Machines

(1) For ship operations

At the No.1 and No.2 berths, two large size ships may berth simultaneouly, and 4 gangs may work at the same time. At the No.3 berth, one small size ship may berth with one gang for loading and unloading cargo. Then, a total of 3 ships may berth and 5 gangs may work at the same time. The necessary number of forklifts are estimated as follows :

Ship side apron use	: 5 gangs×2 units/gang = 10 units	(3 tons capacity)
On board ship use	: 5 gangs×1 unit/gang = 5 units	(2.5 tons capacity)
Total	15 units	

(2) For yard operations (mainly No.3 and No.4 open yards)

Forklift	2 units	(3 tons capacity)
	3 units	(3.5 tons capacity)
	2 units	(5 tons capacity)
	3 units	(6 tons capacity)
	1 unit	(10 tons capacity)
	2 units	(20 tons capacity)
Tractors	6 units	
Small trailers	24 units	
Mobile cranes	4 units	
Total	47 units	

(3) For warehouse operations (two warehouses)

Forklift	7 units	(2 tons capacity)
	9 units	(2.5 tons capacity)
Total	16 units	

(4) Grand Total : 78 units

Comparing the necessary number of forklifts listed above with the number of existing forklifts listed in Table Ⅷ—22, ten additional 3.5 ton forklifts and two additional 20 ton forklifts will be necessary as shown in Table Ⅷ—24.

Table VIII-24 Required Cargo Handling Machines for General Cargo and Steel Goods

Machines	Capacity	Number of Units	Remarks
Forklift	3.5 ton	10 units	Diesel Engine
	20.0 ton	2 units	Diesel Engine
Total		12 units	

7. Repairing and Training

7. 1 Repair and Maintenance Facility

(1) Present conditions

There are two buildings in the port area used as INCOP maintenance and repair facilities for cargo handling equipment. One is a repair shop (about 90 m×20 m) and another is a warehouse (about 50 m×30 m). The cargo handling equipment owned by INCOP totals 74 units, and 21 new units will be obtained. Thus a total of 95 cargo handling machines will have to be maintaincd, inspected, and repaired on a regular basis. The present two shops will provide sufficient space for these activities in the target year (1992).

The present number of maintenance workers is as follows:

Mechanics	4 men
Secretary	1 woman
Workers	13 men
	18 persons

The main problems concerning repairs and maintenace are as follows.

(a) Of the present 74 machines, 61 are already over four years old, and only 13 of the machines are less than 3 years old. The repair costs are likely to increase in the near future.

(b) As the list shows, INCOP owns machines made by 6 different makers. Thus, it is difficult to obtain repair parts for all the machines in a timely manner.

(c) There is a shortage of expert mechanical engineers.

(d) There is a shortage of appropriate repairing instruments and tools.

(2) Improvement Plan

The main points of the improvement plan are outlined as follows:

(a) It is desirable to begin replacing older cargo handling machines. INCOP should select one or two makers to simplify repairs and maintenance.

(b) Parts generally have to be ordered from overseas, which takes a lot of time. Therefor, a sufficient quantity of spare parts should be kept in stock.

(c) INCOP has to keep excellent mechanical engineers.

(d) Necessary maintenance equipment should be supplied.

Since the Port of Caldera opened four years ago, the port authority has been exccuting repairs and maintenance works by themselves, except for major repairs. However, as most of the machines are becoming old, INCOP needs to reinforce its maintenance ability.

According to the JST study, the Port of Caldera presently lacks the following essential equipment for maintenance and repairs.

(a) Hot water pressure steam washer

(b) Micro centimeter gauge.

(c) Chain block for engine replacement.

(d) Shortage of general repairing tools

Including the above instruments, JST estimates the necessary maintenance instruments as shown in Table Ⅷ—25. Moreover, as a movable repair shop truck, one four ton truck is necessary, and this truck should be equipped with the necessary repairing instruments.

Table VIII-25 Necesary Repairing Equipment

Commodity	Quantity	Remarks
Hot Water Pressure Washer	1 unit	Body, Engine Steam Wash
Compressor with Engine	1 set	Compressed Air Supply
Electric Bench Grinder	1 unit	For Painting, Molding
Air Sander	1 unit	〃
Big Hammer	3 units	〃
Oxygen Welding Set	3 sets	〃
Dynamic Power-10 tons	1 set	〃
Hand Tool Set	5 sets	Assembly and Disassembly
Impact Wrench	2 sets	〃
Portable Lubricator for Grease	1 unit	〃
Bench Vise with Bed	2 units	〃
Electric Bench Drill	1 unit	〃
Portable Electric Drill	1 unit	〃
Pipe Wrench 450	3 units	〃
Monkey Wrench 4502	3 units	〃
15 tons Press	1 unit	〃
Portable Working Light	5 sets	〃
Parts Cleaning Basin	1 set	〃
Welder and Register	1 set	〃
Chain Block	1 set	〃
Welder with Engine	2 sets	〃
Hydraulic Jack-10 tons	3 units	Hydraulic Jack
Garage Jack 5-tons	2 units	〃
Micro Centimeter Counter	2 sets	〃
Various Tools	1 set	Tire Repair
5 HP Compressor	1 set	〃
TOTAL	49 packages	

7. 2 Training

(1) Port workers

For all port operations, appropriate facilities and cargo handling machines are essential. However, the ability of the workers who use these facilities and machines may be even more important. Ultimately, the cargo handling efficiency and all of the port operations depend upon the ability and attitude of the port workers. It is important to make efforts to train port workers in a systematic way.

The ship supervisor functions as the central coordinator of port cargo handling operations. The duties of the ship supervisor are especially important, and a special emphasis should be placed on training capable men.

Two possibilities of training such men are:

(a) Select several suitable candidates and send them overseas to take training courses (one to three months).

(b) Request a foreign expert who has extensive experience in this field, and have this expert come to Caldera to train capable men under actual local working conditions (three to six months).

When conventional cargo vessels are at berth (with the captain's permission), INCOP should direct winchmen and signalmen to practice cargo handling using ship's gear.

A part of one of the open yards should be set aside for a special training course to practice forklift and mobile crane operation. Furthermore, INCOP should hold a brief theoretical course for these operators explaining the basics of dynamics, mechanics and electricity.

(2) Maintenace and repair workers

Time lost due to mechanical trouble may reduce cargo handling efficiency, extending the time vessels remain in the port and increasing costs. A regular maintenance system is necessary to prevent untimely breakdown of crucial equipment.

(3) Mechanical engineers

(a) Mechanical engineers who have graduated from a technical college and entered the service section of the port should be sent overseas to the firms which produce the machines which are used at the port. The engineers can thereby gain maintenance and repair experience first hand at the maker's factories.

(b) INCOP should invite a special expert maintenance engineer who is familiar with all types of port equipment to teach maintenance and repair work to the mechanical engineers at the Port of Caldera.

(4) maintenance and repair workers

The special expert mentioned above should also prepare a training curriculum for general maintenance and repair workers including :

(a) hands on practical maintenace and repair training

(b) lectures on the basic principles of dynamics, mechanics, and electricity

Workers who excel in the training course should be promoted to assistant engineers and function as the leaders of the general maintenace and repair workers.

CHAPTER IX DREDGING PLAN

1. Review of the Current Dredging Method

1.1 Existing Dredging Equipment Owned by MOPT

MOPT owns one dredger and related equipment as described below.

(1) Dredger

Name	: Draga Marina
Dimensions (unit : m)	: $L \times B \times H \times D$
	36.5×8.6×18.6×1.6
Type	: Cutter Suction Type
Supplementary engine	: Caterpillar, Diesel 375 PS
Main engine	: Caterpillar, Diesel 850 PS
Size of main pump	: In ϕ 18″, Out ϕ 16″
Type of swing anchor	: Dunhorse, 1 tf
Built in	: U. S. A., 1970
Total weight	: 225 tf

(2) Discharge Pipeline

Type of joints	: Ball joints
Size of discharge pipe	: 15″ (38 cm) in diameter
Thickness of discharge pipe	: 9 mm (New)

(3) Anchor Boat

Dimensions (unit : m)	: $L \times B \times H \times D$
	10.4×3.2×4.0×1.0
Engine	: Caterpillar, Diesel 333 PS
Built in	: U. S. A.

1.2 Organization and Crew

The cutter suction dredger is the property of MOPT, and it is operated by 13 crew members : seven belong to MOPT and the other 6 belong to INCOP. Among the crew, the captain, assistant operators, and chief engineer are members of MOPT. All the crew members are under the supervision of the MOPT Caldera office (refer to Fig.IX-1).

The working day begins at 6:00 in the morning. When the dredger is operational, the working day ends at 10:00 at night. When the dredger is not operational, the working day ends at 5:00 in the evening. Lunch is taken in shifts. While the dredger is operating, the crew are not so busy. Only one operator on the bridge and one engineer in the engine room need to work continuously. Two or three crew members periodically check the suction mouth and

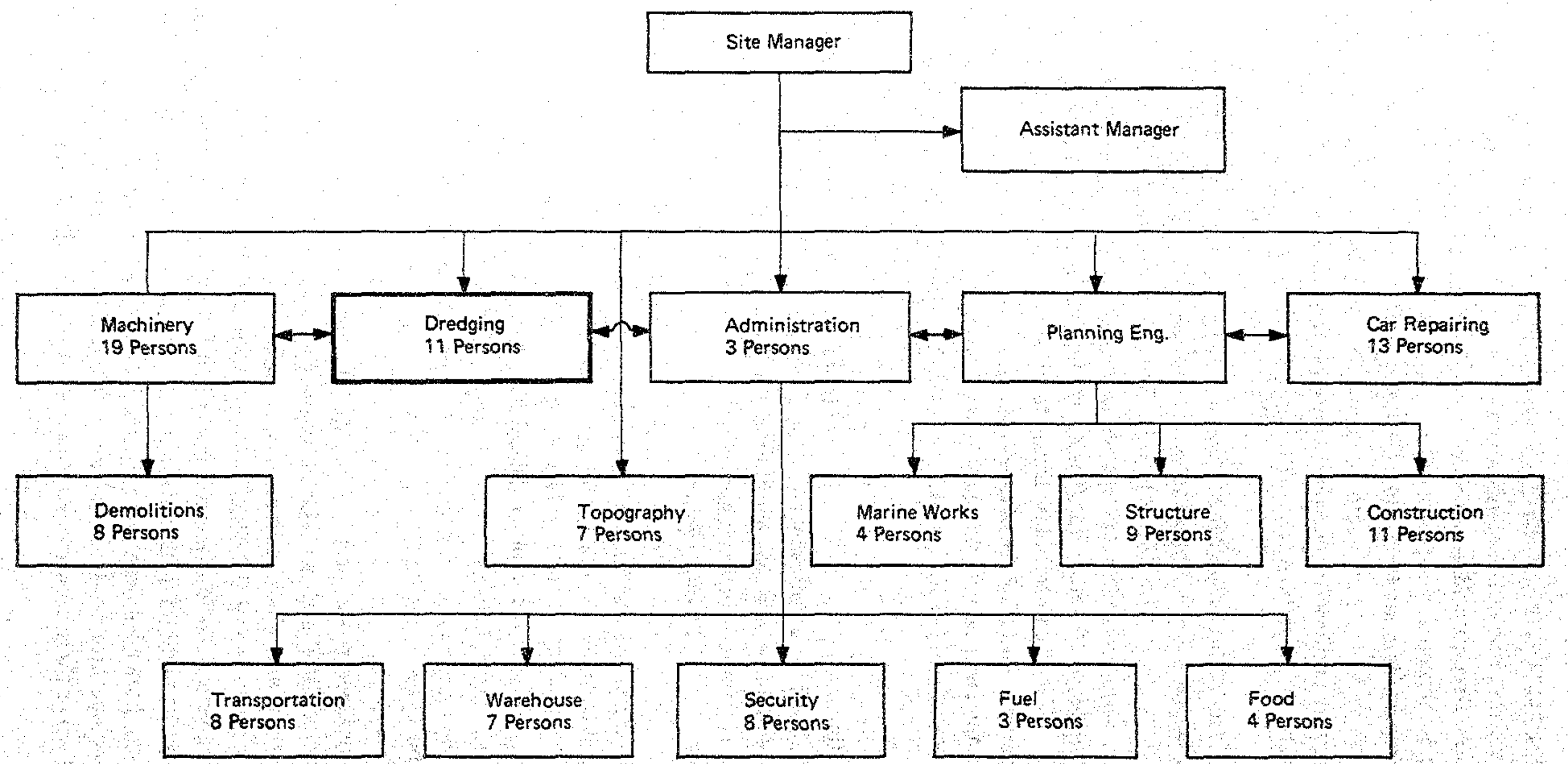


Fig. IX-1 Current Organization of MOPT Caldera Office take out obstructions after lifting the ladder. When the dredger stops because of accidents, the entire crew work at repairing the damaged parts. Some crew members occasionally board the anchor boat in order to change anchor position or to locate the end of a broken swing wire.

The main reasons why the dredger stops, in the order of time lost, are trouble with the discharge area on land, breaks or leakages of the pipeline, engine trouble, and broken swing wires.

1. 3 Recent Dredging Situation

The cutter suction dredger started to dredge the water area at the corner of the breakwater and the south marginal quaywall in July 1985. It still continues to dredge the harbour. The dredged materials are discharged into two ponds for settling in land areas 200 meters behind the corner. Dumped sand is then loaded by wheel loader on dumptrucks and transported to inland dumping areas (Fig.IX-2).

The dredger is currently engaged in dredging work in water areas ranging in depth from −7 m to −11 m, with silty sand ranging from 0 to 10 (average 5) in N−value.

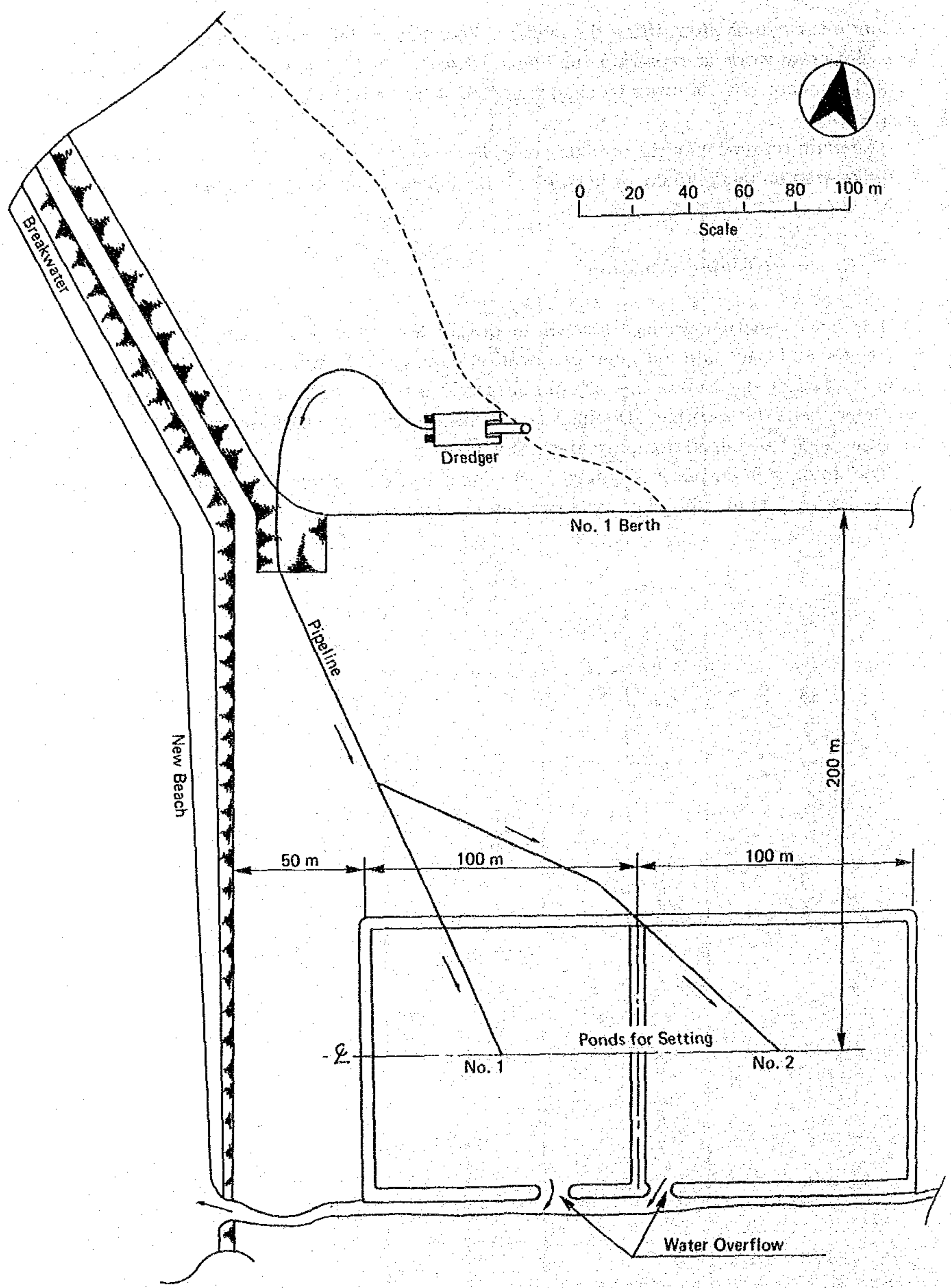


Fig. IX-2 Deposit Procedure of the Dredged Sand

2. Imminent Maintenance Dredging

Sand sedimentation has made it difficult for large vessels to berth at the −11 m berth in the Port of Caldera. MOPT, therefore, has decided to execute imminent maintenance dredging utilizing a foreign contractor.

An outline of the dredging work is as follows :

Dredging volume	: 300,000 m^3
Dredging period	: 30 days
Type of dredger	: Hopper suction dredger
Dumping area	: 2.5 miles from the dredging area

MOPT has requested the JICA Study Team to submit comments on this imminent dredging work from the viewpoint of engineering. A meeting was held between MOPT and the JICA Study Team concerning this matter on October 31, 1985. The comments presented by the JICA Study Team at the meeting are summarized in APPENDIX 10.

3. Appraisal of Alternative Dredging Methods

3.1 Relation to the Primary Construction Works

The construction proposals concerning the Maintenance Project of the Port of Caldera put forth in CHAPTER VI~CHAPTER VIII are summarized below.

1) Breakwater construction and dredging of harbour sedimentation as measures against sand sedimentation
2) Shift of the breakwater foot, and construction of a −3.0 m quaywall, mooring dolphin and gangway to enlarge the mooring facility capacity
3) Pavement of yards in order to improve the cargo handling system

The construction methods and stages of the construction works listed above (primary construction works) are considered in detail in CHAPTER X. These primary construction works will be completed within 2 to 3 years, after which maintenance dredging and other maintenance works will be carried out. Accordingly, sufficient thought must be given to the relationship between the dredging works and the construction works. Concretely speaking, one important point is whether the dredging fleet provided for the primary dredging and maintenance dredging can also be used for the primary construction works as well.

3.2 Alternative Dredging Methods

There are several common dredging methods. The best method for each particular location must be determined in light of the soil conditions, disposal method, disposal distance, soil treatment, water depth, dredging area, meteorological and marine conditions, working period and other relevant factors.

The five principal alternative methods for dredging are listed below.

(1) Dredging by cutter suction dredger (C)
(2) Dredging by grab bucket dredger (G)
(3) Dredging by dipper dredger (D)
(4) Dredging by hopper suction dredger (H)
(5) Dredging by bucket dredger (B)

3.3 Appraisal of Dredging methods

The five methods noted above are appraised below with respect to five different aspects of the work. Each method is indicated using the alphabetical abbreviations noted above, that is (C), (G), etc.

3. 3. 1 Soil Conditions

Methods (C), (G), and (H) are suitable for sandy soils with an N-value below 10. Method (B) is not suitable because the dredged soft soils are washed out from the buckets during the operation in the water. On the other hand, Method (D) is mainly used for hard soils with an N-value over 30.

3. 3. 2 Soil Disposal Area and Disposal Distance

Method (C) is most suitable for land disposal, and the other methods are suitable for sea disposal. In the case of the Port of Caldera it is impossible to obtain a suitable disposal site on land in the vicinity of the port. Furthermore, a certain amount of soil will return to the dredged area if the dredged soil is dumped nearby. Therefore, it is necessary to dispose of the soil at a great distance (over 2.5 miles) from the dredged area.

Method (C) can also be used for sea disposal, but only within a distance of 0.3~1.5 miles.

3. 3. 3 Suitability for Various Purposes

Construction works suggested in CHAPTER VI and CHAPTER VII include the breakwater extension, the shifting of the breakwater foot, the construction of the −3.0 quaywall and the moorning dolphin.

The grab bucket barge can be used like a crane barge in the construction of the breakwater by affixing a special attachment, and as shown in Fig.IX-3 and Fig.IX-4, it can also be used for piling work with a pile hammer and hammer guide. This is an important factor in the relative evaluation of the various alternatives.

3. 3. 4 Dredging Area

Dredging of the area adjacent to the mooring basin, quaywall, and breakwater from −7.5 m down to −11.0 m is necessary. Also, dredging of the area behind and as close as possible to the breakwater is desirable as a countermeasure against sand sedimentatian. As a result, it is likely that rubble material will also be dredged up with sediment sand.

Method (H) is recommended for works such as navigation channels or the like which have a long, narrow dredging area and a constant dredging depth. However the method is not ideal for dredging works executed adjacent to quaywalls and breakwaters. Also, the method is less accurate for works requiring variable depths.

Method (G) is more suitable in such cases. When the soil to be dredged contains several sizes of rubble stone, Methods (D) and (G) may be used, however Methods (C), (B), and (H) may not.

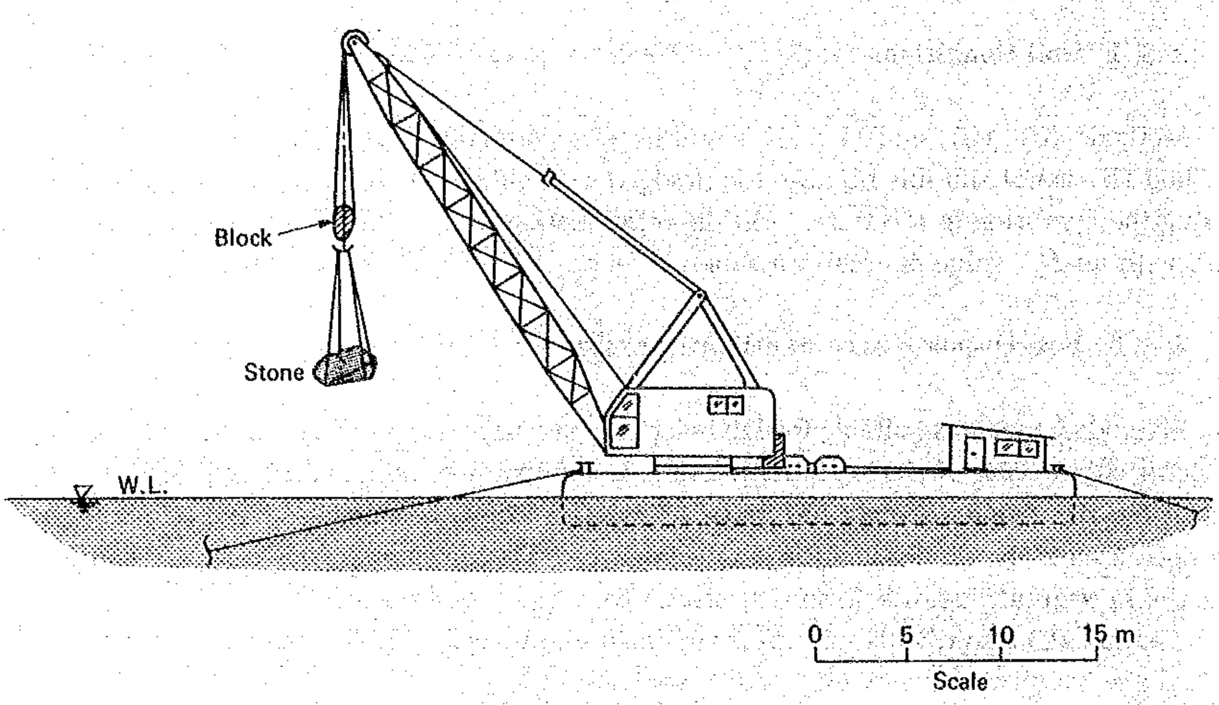


Fig. IX-3 Floating Crane Barge

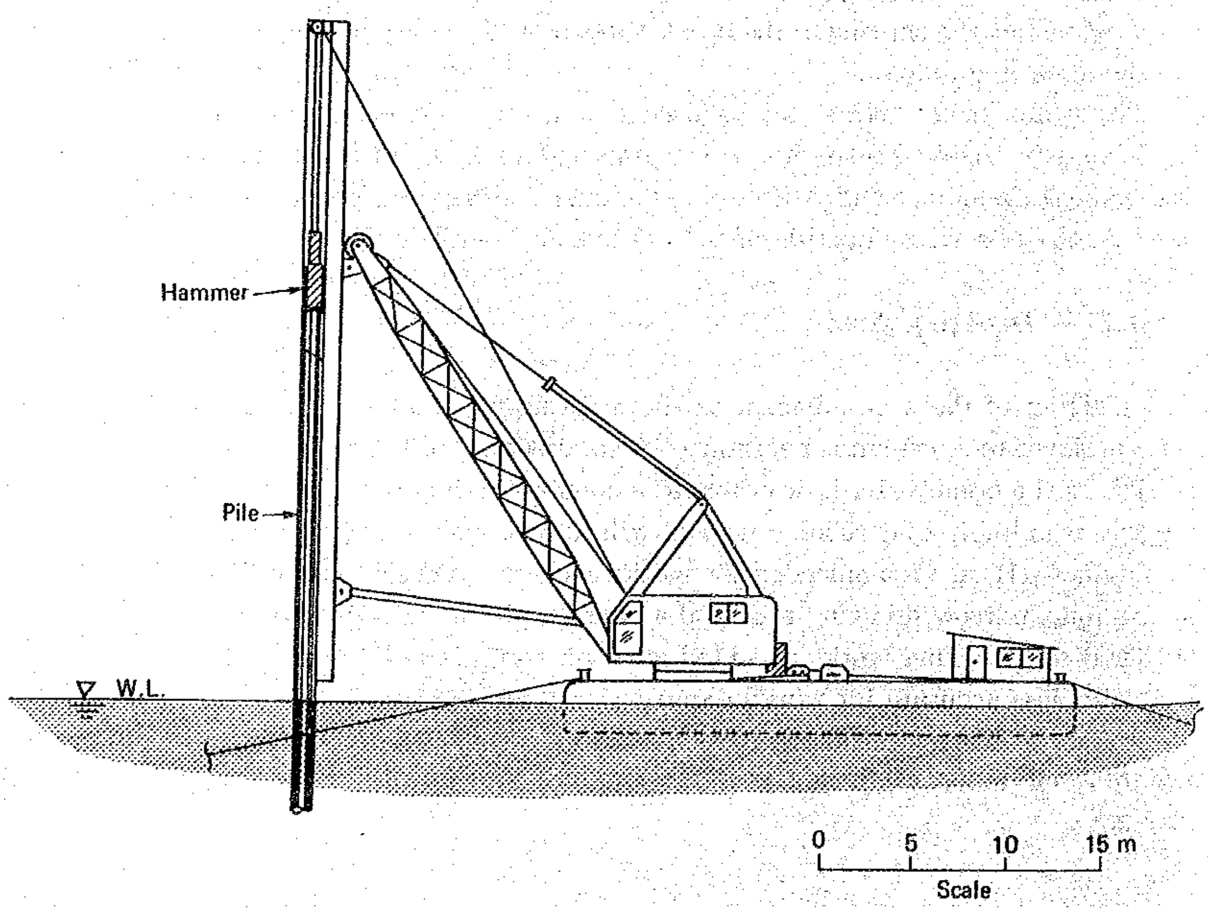


Fig. IX-4 Piling Barge

3. 3. 5 Economy (Cost of Equipment and Maintenance)

Assuming the same working conditions and the same work capacity (160 m^3/h), the order of the equipment costs from high to low is as follows :

Method (H), (C), (D), (B), (G)

The order of maintenance costs from high to low changes slightly because Method (C) requires a long floater and a pipe line :

Method (C), (H), (D), (B), (G)

3. 4 Dredging Method Recommendations

A consolidation of the evaluation presented above is shown in Table IX-1. As is clear from the table, the grab bucket method is the only suitable dredging method. Moreover, a grab dredger fleet could be practically and effectively utilized for other primary construction works.

Table IX-1 Evaluation of the Alternative Dredging Methods

Item	Kind of Soil	Hardness of Soil	Location of the Dumping Site	Applicability to the Other Works Construction	Dredging Area	Economy	Overall Appraisal
Conditions at the Site	Silty Sand	$N \leq 10$	2.5miles	Necessary	Corner and the Narrow Area	—	
Cutter Suction Dredger (C)	○	○			●	4	
Grab Bucket Dredger (G)	○	○	○	○	○	1	○
Dipper Dredger (D)	○		○		●	3	
Bucket Dredger (B)			○			2	
Hopper Suction Dredger (H)	○	○	○		●	5	

Remarks : ○ Suitable. ● Somewhat suitable. 1 (Most Economical) ~ 5 (Uneconomical)

4. Execution Plan

4.1 Dredging Volume

Dredging work may be divided into primary dredging and maintenance dredging.

Primary dredging is to be carried out following the completion of the 200 m breakwater extension for the purpose of removing the sediment accumulated behind the breakwater and of maintaining the projected basin water depth. The volume of material to be dredged is 72,000 m^3.

Maintenance dredging refers to the periodic dredging of the new sediment which will accumulate over time in the mooring basin and behind the breakwater after the primary dredging is completed. As noted in CHAPTER VI following the extension of the breakwater by 200 m, the annual volume of sand sediment will be 12,000 m^3. The first maintenance dredging will be carried out in 1991 at a dredged soil volume of 72,000 m^3. Subsequent maintenance dredging will be needed once every five years thereafter, and on each occasion dredged soil volume will be 60,000 m^3.

4.2 Dredging Method

In accordance with the above study, dredging is carried out using a grab dredger fleet.

In examining the dredging method, care must be taken that the execution of the dredging does not become an obstacle to the passage of ships using the harbour. A look at the volume of dredged sand involved in maintenance dredging indicates that the work period will be short, and if proper attention is paid to the operation of the dredger, no problems should arise.

Futhermore, the material dredged by the grab dredger is transported by hopper barge and disposed of at sea. Determination of the disposal site requires consideration of various factors, among them the fact that the water depth at the site should be great so there will be no possibility that once dumped the material will make its way back to the harbour, that the site should be as close as possible to the dredging area, and that there must be no obstruction to the passage of ships entering and exiting the harbour. As indicated in Fig.IX-5, the disposal site may be suitably located in the area offshore Roca Carballo, about 2.5 miles N 50° W from the No.2 buoy.

MOPT's present cutter suction dredger was built 12 years ago, and is considerably superannuated. If a cutter suction dredger is used to do the dredging work, the location of the disposal site will become a problem. Securing an appropriate disposal site on land in the vicinity of the Port of Caldera would be quite difficult. Futhermore, a consideration of the marine conditions in the area indicate that offshore disposal using a discharge pipeline is impossible. Accordingly, it must be said that using the present MOPT cutter suction dredger for future maintenance work will also be impossible.

Fig.IX-6 shows the area to be dredged. Region A in the drawing is the area which nust be dredged due to the sediment circulating around the tip of the breakwater. With respect to the sediment infiltrating to the back of the breakwater, it is particularly desirable as a

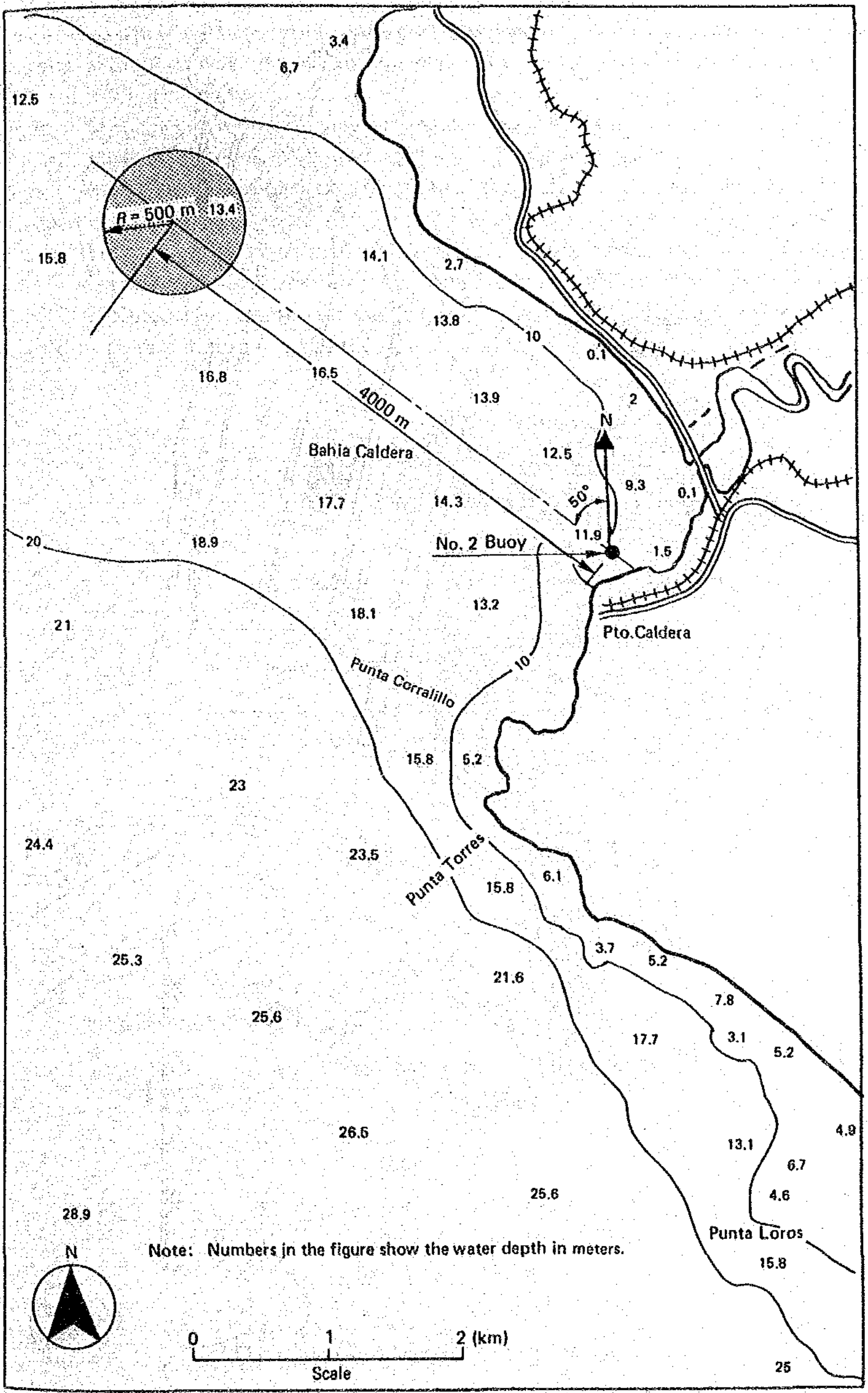


Fig. IX-5 Dumping Area

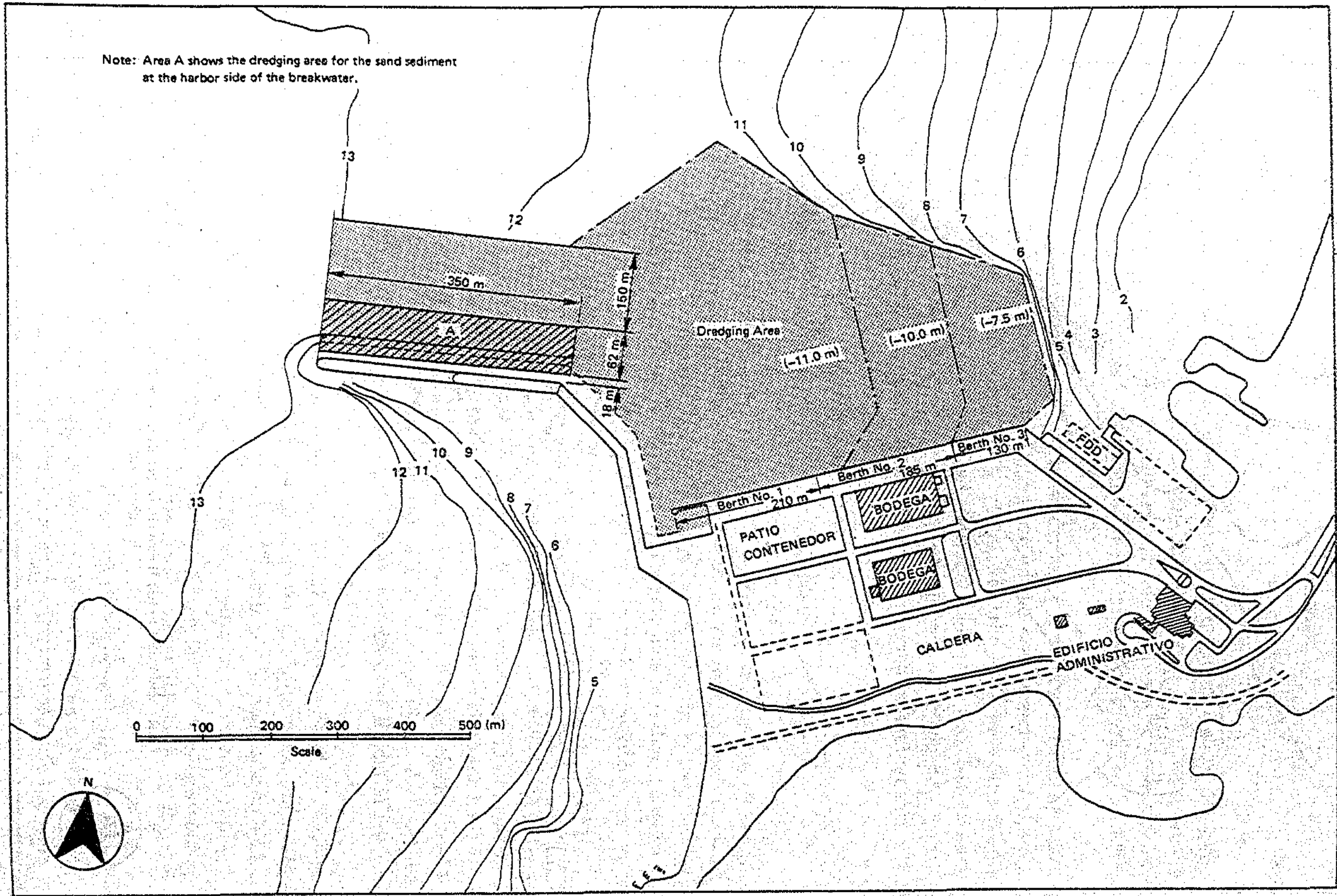


Fig. IX-6 Dredging Area

counter to the sand sedimention to remove as much as possible of the sand close to the breakwater without causing damage to the breakwater itself. Accordingly, dredging of the area shown in Fig.IX-7 is recommended.

In light of the necessity of carrying out maintenance dredging and maintenance works, MOPT will have to obtain a grab dredger fleet. Moreover, considering MOPT's limited capacity to carry out the primary construction works including the breakwater extension and the primary dredging, it seems that a foreign contractor will have to be commissioned to perform these works. The optimum solution is for MOPT to temporarily loan the grab dredger fleet to the contractor, and this is recommended in the present report. However, this point bears an integral relation with the primary construction works, and therefore it is considered in more detail in CHAPTER X.

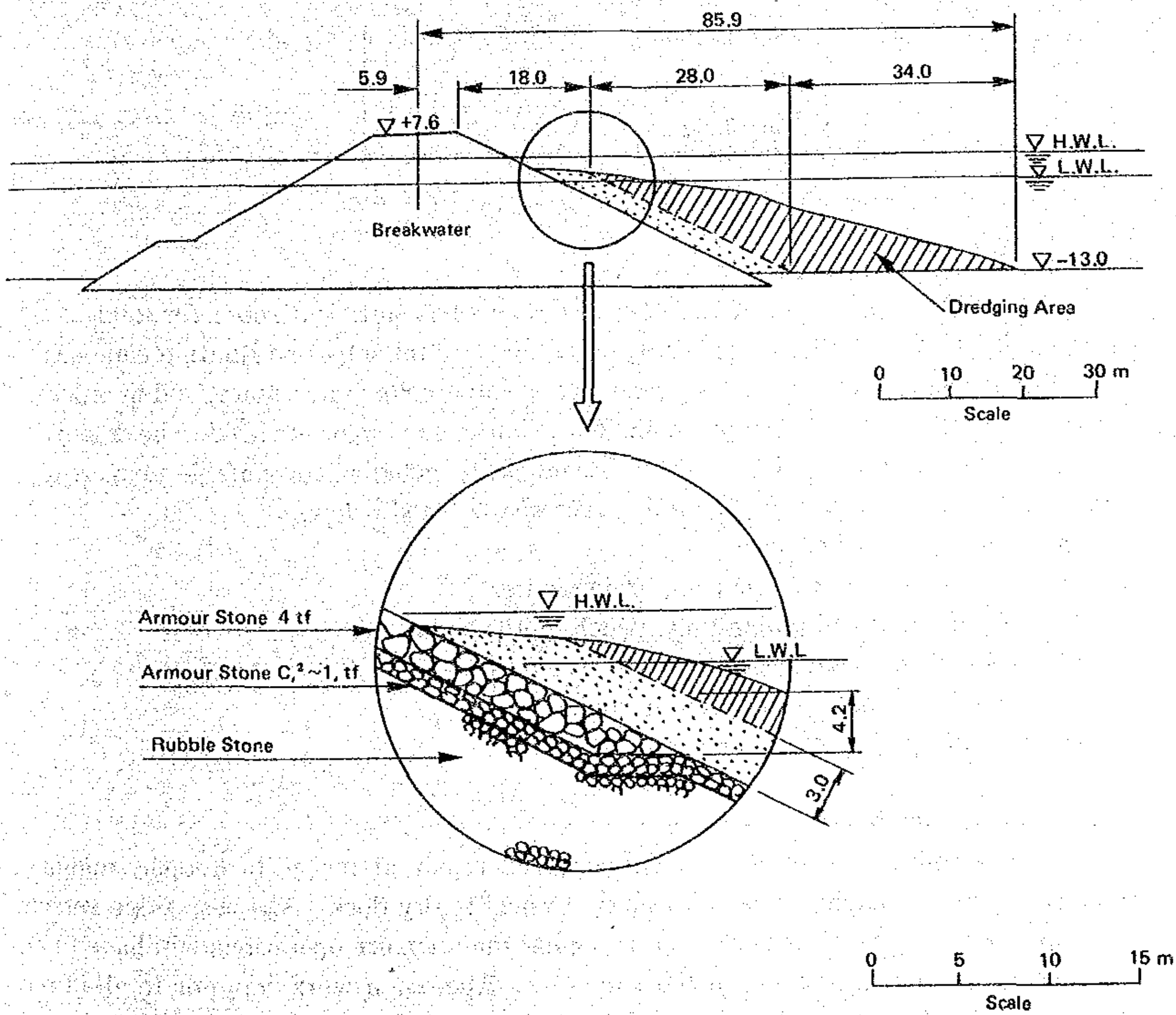


Fig. IX-7 Cross Section of Dredging Area A

5. Repairing the Grab Dredger Fleet and Training Crews

5.1 Repairing the Grab Dredger Fleet

The vessels of the grab dredger fleet are listed in Table IX-2. If MOPT obtains a grab dredger fleet, regular maintenance of the fleet will be necessary to keep all of the vessels in good operating condition. The fleet will require daily maintenance, occasional repair work and annual inspection and maintenance works.

Table IX-2 Grab Dredger Fleet

Vessel	Quantity
Grab Dredger	1
Tugboat	1
Hopper Barge	2
Anchor Boat	1
Jolly Boat	1

(1) Daily maintenance and repair work

The MOPT repair yard at the Port of Caldera has sufficient room for land-based equipment. However, there is presently no repair yard for ships and floating equipment.

With dredging equipment, daily maintenance and repair is necessary, and in order to carry it out efficiently, up to three maintenance and repair engineers need to be deployed. Their principal duties consist of always having parts including consumable items ready, stocking the storehouse, and performing the repairs listed below.

(a) Repairing bucket wear
(b) Re-connecting and replacing broken wires
(c) Dismantling and maintaining winch motor coils
(d) Adjusting hopper barge hydraulic systems
(e) Repairing and adjusting barge chains
(f) Repairing boat shafts and propellers

(2) Regular maintenance

Regular major inspection, maintenance, and repair of the grab dredger, tugboat, hopper barge, and anchor boat must be performed in dry dock. The respective vessels function together as a fleet ; hence these regular maintenance operations will have to be performed on all of the vessels at the same time. The repair work common to all of the ships consists of cleaning the hulls of the vessels, measuring the thickness of outer steel plates, painting, replacing the anti-corrosive zinc, cleaning the inside of the water tanks, and overhauling the engines. With the dredger, in particular, repairs which cannot be carried out during regular operations are to be performed at this time. An example is the lowering of the boom in order to inspect and replace transverse wires. Fortunately, construction of a ship repair yard equipped with a floating dry dock is planned within the Port of Caldera. This facility will be ideal for use as a dry dock for the regular maintenance works. Every year, a repair plan should be submitted to the ship repair company in advance, and maintenance must be carried out without fail during the planned period. Fig.IX-8 shows the disposition of the fleet on the floating dry dock.

5. 2 Training System

MOPT's new grab dredger will, as stated in CHAPTER X, be used constantly for the first 2 to 3 years for the construction of the breakwater, the execution of the primary dredging, and for a series of other primary construction works. For the maintenance dredging and other maintenace works subsequent to the primary construction works, it is necessary for MOPT's fleet crew members to undergo training so that they will acquire a basic knowledge of the vessels, learn relevant skills, and become familiar with the machinery they will handle.

(1) Crew members

The standard crews of each of the vessels in the dredger fleet are listed in Table IX-3. A classification of the above crew members by duty is shown in Table IX-4.

Table IX-3 Seamen List (1)

Vessel	Crew	Crew Number
Grab Dredger	6 Sailors, 2 Enginers	8
Anchor Boat	3 Sailors, 1 Engineer	– [1]
Tugboat	1 Captain, 1 Sailor, 1 Engineer	3
Jolly Boat	1 Captain	1
Total		12

Note: 1) The crew members of the grab dredger will also nerve as the crew of the anchor boat when necessary. Similarly, when the hopper barges are in operation, two sailors from the grab dredger will serve as the crew of the hopper barges.

Table IX-4 Seamen List (2)

Duty	Vessel	No. of Crew Members
Boat Captains	Tugboat, Jolly Boat, Anchor Boat	3
A Manager and Operators	Dredger	3
Sailors	Dredger, Anchor Boat, Barges	3
Engineers	Dredger, Anchor Boat, Tugboat	3
Total		12

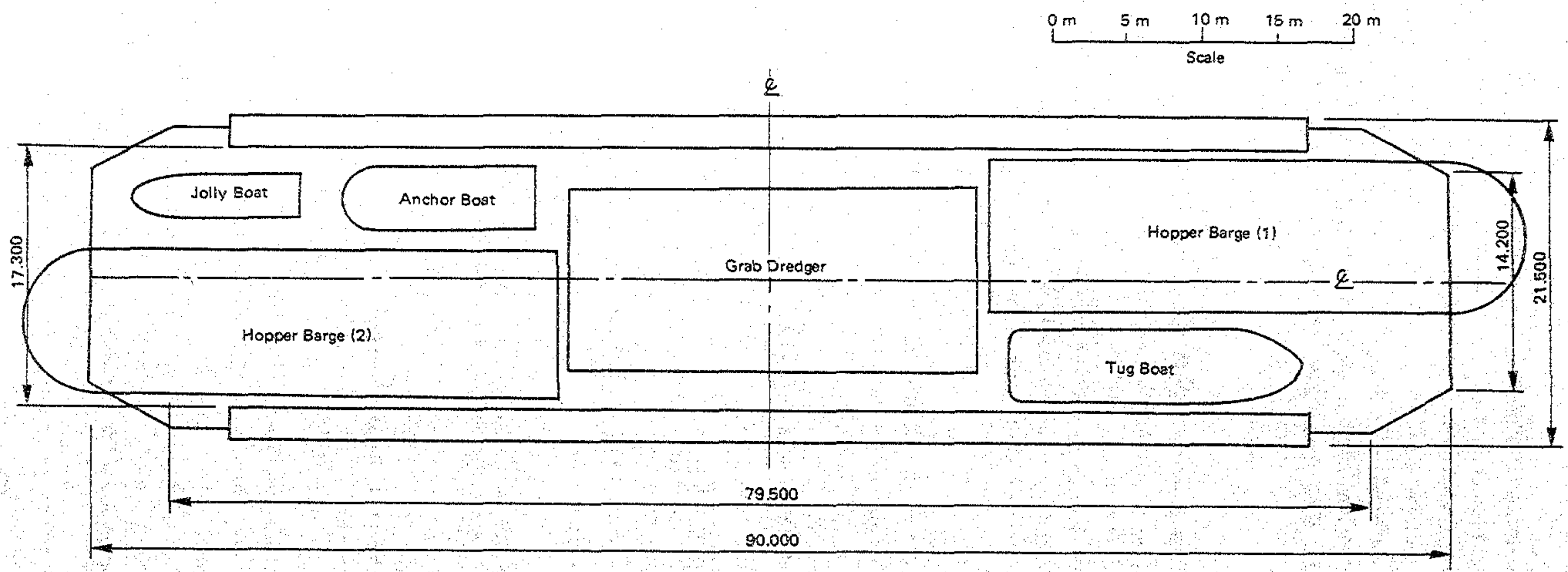


Fig. IX-8 Periodic Maintenance on Floating Dry Dock

(2) Contents of the training

The training program should consist not only of imparting necessary theoretical knowledge, but also of practical training. Also, the training team must perform actual dredging and construction works together with the trainees. Thus, experienced foreign seamen will be need to give man to man hands on educational instruction over a considerable period of time at the site in Costa Rica.

A list of the personnel to be dispatched and the contents of the training to be given is presented in Table IX−5.

Table IX-5 Dispatch List and Training Plan

Educational Supervisors		Personnel to Undergo Training		Contents of the Training
Duty	No.	Personnel Duty	No.	
Person in Charge	1	Entire Fleet Crew		General matters
Operator	2	Grad Dredger Captain, Operators, Sailors	6	Fleet maintenance, inspection, simple repairs, handling and safety procedures
Boat Captain	1	Boat Captains, Tugboat Sailors.	4	Handling of boats. Maintenance, inspection, repairs to deck and safety procedures
Chief Engineer	1	Dredger and Tugboat Engineer	2	Maintenance and inspection of fleet engines. Simple repairs and safety procedures
Electrician	1	Entire Fleet Crew		Maintenance inspection of fleet electrical apparatus, repairs and safety procedures
Total	6	——	12	——

(3) Training period

As indicated in Fig.IX-9, the necessary training period will be a minimum of 6 months. After receiving a half−month's language training and education about Costa Rica before departure, the 6 dispatched personnel will conduct training for 5.5 months while simultaneously carrying out actual construction at the Port of Caldera.

Month	1	2	3	4	5	6
Preparation (in the Foreign Country)	0.5					
Training (in Costa Rica)				5.5		

Fig. IX-9 Training Period

CHAPTER X DESIGN, CONSTRUCTION AND COST ESTIMATE

1. Designing of Structures

The structures which should be designed are as follows.

(a) As a countermeasure against sand sedimentation
Breakwater extension of 200 m

(b) To enlarge the mooring capacity of the wharfs
Shift of the existing breakwater foot
Construction of the −3.0 m quay in the small craft basin
Construction of the mooring dolphin and gangway
Shift of the light beacon

(c) To improve the cargo handling system
Pavement of open yards No.2, 3 and 4

1. 1 Design Conditions

(1) Design Waves

The design waves for the breakwater are waves with a probable recurrence period of 50 years, as described in CHAPTER IV, Section 3.1 Wave Conditions. The parameters are :

Significant wave height: $H_{1/3}=4.6$ m
Significant wave period: $T_{1/3}=18.8$ s

at the position where the wavemeter is set.

As there is practically no difference in the depth between the 13 m in the vicinity of the tip of the planned breakwater and the 13.5 m at the position where the wavemeter is set, and as according to the refraction diagram shown in APPENDIX I, Figs.M-2(5) and M-2(6) the orthogonal interval in the vicinity of the projected breakwater tip is nearly equal to that at the position where the wavemeter would be placed, the above values shall be used as they are for the design wave height of the breakwater.

(2) Design Height of Tides

As the design height of tides, N.H.H.W.L. shall be used for the high water level and N.L.L.W.L. for the low water level. The following values used for designing the first stage construction and the second stage expansion plan shall be adopted:

H.W.L. : +3.0 m
L.W.L. : ±0.0 m

(3) Design Seismic Coefficient

As mentioned in CHAPTER IV, 5.2 Distribution of Expected Seismic Acceleration

Values, the expected value of the ground acceleration due to earthquakes with a recurrence period of 50 years near the port of Caldera is estimated to be about 0.15 G, where G represents the acceleration of gravity. Noda et al. propose, on the basis of their analysis of past seismic damages of gravity type quaywalls, to adopt the lesser of the values that can be obtained using the following two formulas [1]. Also, Kitajima et al. claim that this proposed value can be applied to sheet pile quaywalls as well [2].

$$e_A = \frac{\alpha}{G}$$

$$e_A = \frac{1}{3} \times \left(\frac{\alpha}{G}\right)^{1/3}$$

Where, e_A : Design seismic coefficient
α : Seismic ground acceleration (Gal)
G : Gravity acceleration (=980 Gal)

So, when α/G is less than 0.192, that is, when α is 189 Gal, α/G will be used for the design seismic coefficient. Thus, for the vicinity of the port of Caldera, 0.15 shall be adopted.

Notwithstanding the above, since a design seismic coefficient of 0.10 was adopted for the existing wharfs constructed in the first stage construction, the design seismic coefficient for the mooring dolphin and the gangway on the −11 m wharf as well as for the −3 m small craft quay to be built as part of the present project shall also be set as 0.10 for consistency with the existing wharfs.

(4) Soil Conditions

As for soil conditions, according to the indications in CHAPTER IV 4, Soil Conditions, the conditions shown in Fig.X-1 shall be adopted for designing the breakwater, and those shown in Fig.X-2 shall be adopted for designing the mooring dolphin and gangway as well the −3.0 m quaywall.

(5) Stones

The stones produced in North Caldera with a specific weight of 2.35 and an internal friction angle of 35° should be used for the breakwater, the foundation mound and the

1) Setsuo Noda, Tatsuo Uwabe and Tadashi Chiba: Relation Between Seismic Coefficient and Ground Acceleration for Gravity Quaywalls, Report of the Port and Harbour Research Institute, (Ministry of Transport), Vol.14, No.4, pp.67~111, Dec. 1975, (in Japanese)
2) Shoichi Kitajima and Tatsuo Uwabe : Analysis on Seismic Damage in Anchored Sheet-piling Bulkheads, Report of the Port and Harbour Research Institute, (Ministry of Transport), Vol.18, No.1, pp.67~127, Mar.1979 (in Japanese)

Existing Seabed		
		$-11.5 \sim 13.5$ m
Sandy Soil	$\phi = 30°$	
	$\gamma' = 1.0$ tf/m^3	
		-20.0 m
Cohesive Soil	$c_u = 4.0 + 3.0\,z$	
	($z = 0$; -20 m)	
	$\gamma' = 0.7$ tf/m^3	
		-40.0 m
Bedrock		

Fig. X-1 Design Soil Conditions (for Breakwater)

Existing Seabed		
		-11.0 m
Sandy Soil	$\phi = 30°$	
	$\gamma' = 1.0$ tf/m^3	
		-17.0 m
Cohesive Soil	$c_u = 1.0 + 3.0\,z$	
	($z = 0$; -10 m)	
	$\gamma' = 0.7$ tf/m^3	
		-30.0 m
Bedrock		

Fig. X-2 Design Soil Conditions (for Small Craft Basin)

backfill of the −3.0 m quaywall. The specific weight is the average value obtained from the test results carried out by MOPT.

(6) Tractive Force of Ships

The tractive force of ships for designing the mooring dolphin shall be determined taking the 20,000 to 30,000 tf dead weight freighters or container ships that can be moored to the −11 m wharf as design vessels. As for the relationship between the dead weight tonnage of the freight vessels of 5,000 to 80,000 tons (including grain carriers) and the gross tonnage, the following formula is given by Terauchi et al.[3].

$$\text{Log G.T.} = -0.061 + 0.966 \log \text{D.W.}$$

Where, G.T. : Gross tonnage of the freight vessel (tons)
D.W. : Dead weight of the freight vessel (tf)

According to this equation, the gross tonnage of freight vessels 20,000 to 30,000 tons in dead weight is about 12,400 to 18,400 tons, and the container ships that can be moored to the −11m wharf, that is, container ships with a draft of more or less 10 m at full load, are generally ships with a gross tonnage of 15,000 tons. Therefore, here the tractive force for the bits to be located near the face line of the quay are based on vessels of 10,000 to 20,000 tons in gross tonnage.

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3) Kiyoshi Terauchi, Yukihide Yoshida and Yasuhide Okuyama: Analysis on the Interrelations among the Several Dimensions of Ships, Report of the Port and Harbour Research Institute, (Ministry of Transport), Vol.17, No.4, pp.265~327, Dec.1978 (in Japanese).