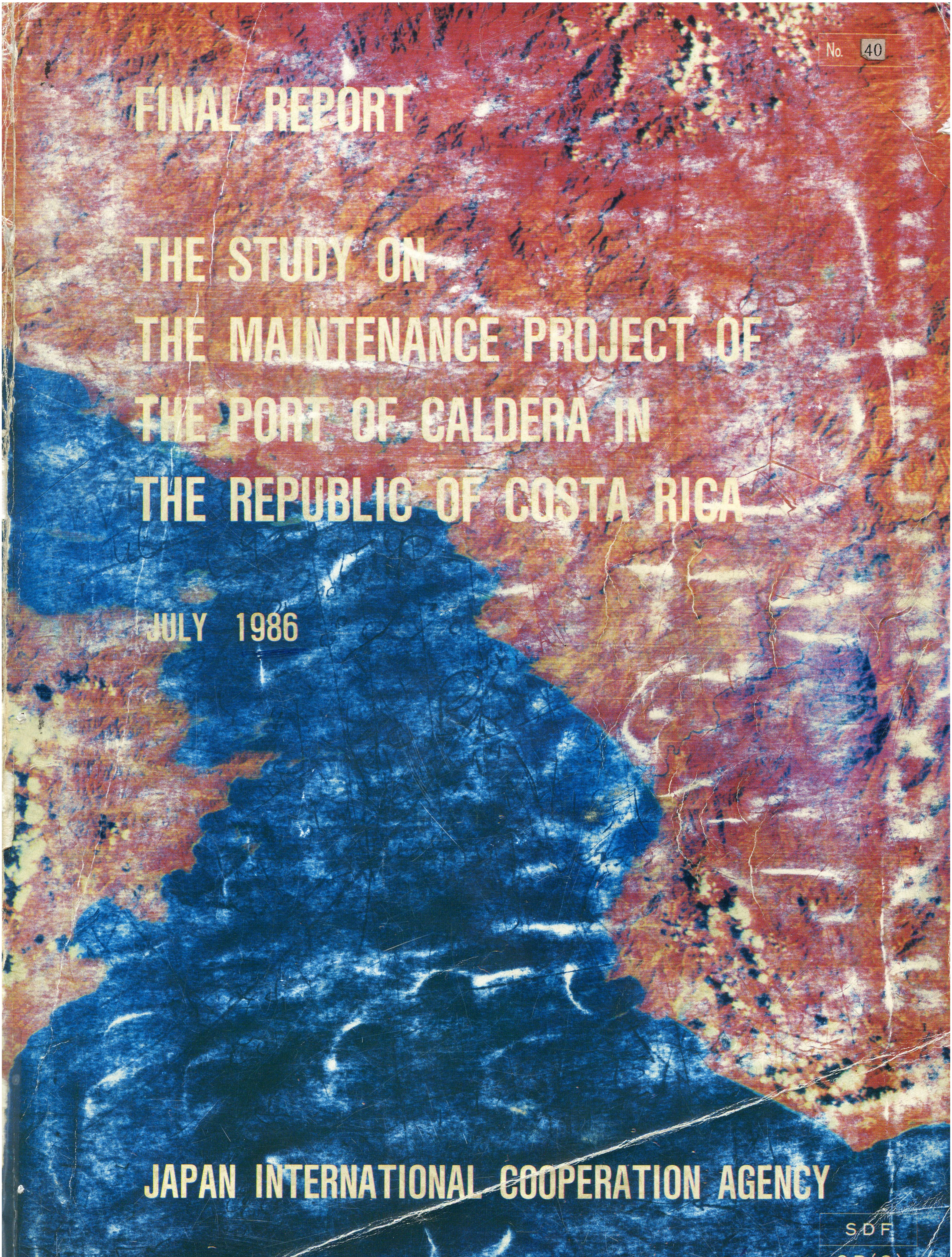


No. 40

FINAL REPORT

THE STUDY ON THE MAINTENANCE PROJECT OF THE PORT OF CALDERA IN THE REPUBLIC OF COSTA RICA

JULY 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to the request of the Government of the Republic of Costa Rica, the Government of Japan decided to conduct a study on the Maintenance Project of the Port of Caldera and entrusted the study to Japan International Cooperation Agency (JICA). JICA sent to Costa Rica a study team headed by Mr. Takashi Hazama, the Overseas Coastal Area Development Institute of Japan from September to November, 1985.

The team had discussion on the project with the officials concerned of the Government of the Republic of Costa Rica and conducted a field survey. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the authorities concerned of the Government of the Republic of Costa Rica for their close cooperation extended to the team.

July, 1986

Keisuke Arita

Keisuke Arita

President

Japan International Cooperation Agency

LETTER OF TRANSMITTAL

July 1986

Mr. Keisuke Arita
President
Japan International Cooperation Agency

Dear Sir:

It is my great pleasure to submit herewith a report on the Maintenance Project of the Port of Caldera, the Republic of Costa Rica.

This report describes the result of studies on the project carried out by the joint study team of the Overseas Coastal Area Development Institute of Japan (OCDI) and Central Consultant Incorporated (CCI) at the appointment of the Japan International Cooperation Agency (JICA). The study team started the study on September 20, 1985 and conducted a field survey on the project in Costa Rica, including a field survey on natural conditions at the site, for two months ending on November 22, 1985. This report describes the Maintenance Project and the economic and financial feasibility of the project studied based on the findings of the survey as well as on the data and information collected and analysed in Japan. The study shows that the project is extremely important for the development of Costa Rica. Therefore, we earnestly hope that the project will be implemented as soon as possible.

On behalf of the Japanese Study Team, I would like to express my deepest appreciation to the Government of the Republic of Costa Rica including the Ministry of Public Works and Transportation (MOPT) and the Costa Rican Pacific Ports Authority (INCOP), and to the other related agencies of the government for the unlimited cooperation and assistance and the warm hospitality they extended to the team during our stay in Costa Rica.

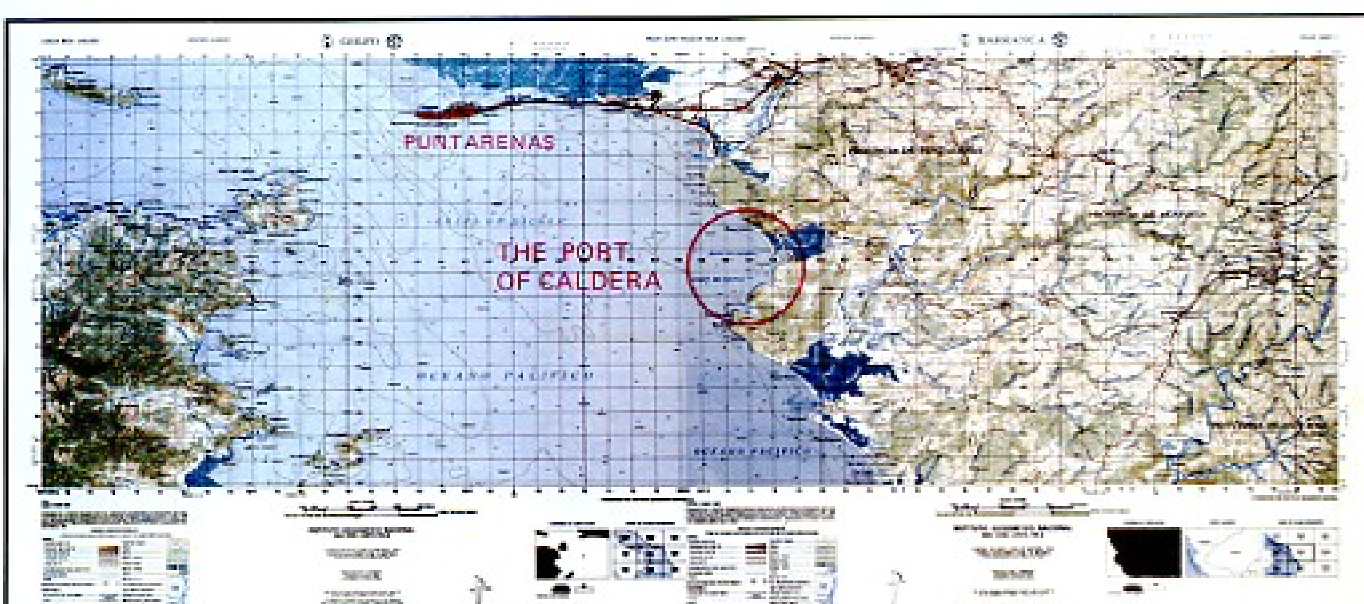
I am also greatly indebted to the Japan International Cooperation Agency, the Ministry of Transport, the Ministry of Foreign Affairs and the Japanese Embassy in Costa Rica for giving us valuable advice and assistance during the field survey and the preparation of this report.

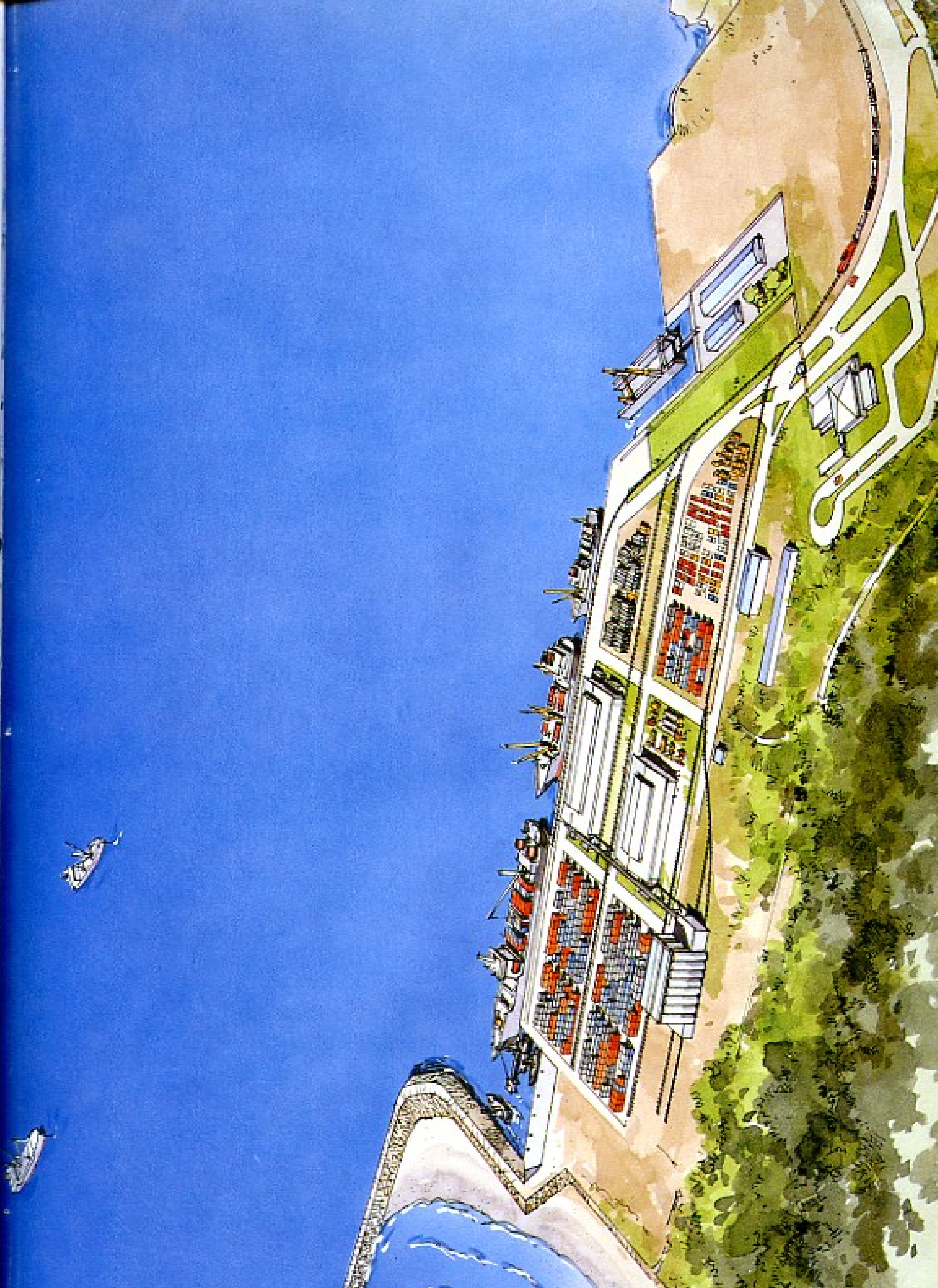
Sincerely yours,

T Hazama

Takashi Hazama
Head
Japanese Study Team for the Maintenance
Project of the Port of Caldera
(Senior Executive Director,
the Overseas Coastal Area Development
Institute of Japan)


COSTA RICA
NICARAGUA
LAGO DE NICARAGUA
MAR CARIBE
OCEANO PACIFICO
PANAMA
ZONA CENTRAL


PUNTARENAS
THE PORT OF CALDERA



ABBREVIATIONS

In this report, the following abbreviations are used :

ABBREVIATION	FULL NAME (SPANISH)	FULL NAME (ENGLISH)
BCCR	Banco Central de Costa Rica	Central Bank of Costa Rica
CACM	Mercado Común Centroamericano (MCCA)	Central American Common Market
CCI		Central Consultant Incorporated
CELADE	Centro Latinoamericano de Demografia	Latin-American Center of Demography
CEMPA	Cementos del Pacifico, S.A.	Pacific Cement-manufacturing Corporation
CEMPRO	Centro de Promoción de Exportaciones e Inversiones	Export and Investment Promotion Center
CINDE	Coalición Costarricense de Iniciativa para el Desarrollo	Costa Rican Coalition of Initiative for Development
CNP	Consejo Nacional de Producción	National Council of Production
COCOSA	Constructora Costarricense S.A.	Costa Rican Construction Co., Ltd.
DGEC, MEIC	Dirección General de Estadística y Censos, Ministerio de Economía, Industria y Comercio	Bureau of Statistics and Census, Ministry of Economy, Industry and Commerce
DGOPF	Dirección General de Obras Portuarias y Fluviales, MOPT	Bureau of Port and River Works, MOPT
DGP	Dirección General de Planificación, MOPT	Bureau of Planning , MOPT
DGTM	Dirección General de Transporte Maritimo MOPT	Bureau of Maritime Transport, MOPT
FECOSA	Ferrocarriles de Costa Rica S.A. (el antepasado de INCOFE presente)	Costa Rican Railway Corporation (the predecessor of the present INCOFE)
FERTICA	Fertilizantes de Centroamerica (Costa Rica) S.A.	Fertilizers of Central America (Costa Rica) Corp.
IDB	Banco Interamericano de Desarrollo	Inter-American Development Bank
IECES	Instituto de Investigaciones de la Escuela de Ciencias Económicas y Sociales de la Universidad de Costa Rica	Investigation Institute of the Economic and Social Science College, University of Costa Rica

ABBREVIATION	FULL NAME (SPANISH)	FULL NAME (ENGLISH)
IGN	Instituto Geográfico Nacional	National Geographic Institute
IMN	Instituto Meteorológico Nacional	National Meteorological Institute
INCOFE	Instituto Costarricense de Ferrocarriles	Costa Rican Railway Institute
INCOP	Instituto Costarricense de Puertos del Pacífico	Costa Rican Pacific Ports Authority
INVU	Instituto Nacional de Vivienda y Urbanismo	National Institute for Housing and City Planning
JAPDEVA	Junta de Administración Portuaria y de Desarrollo Económico de la Vertiente Atlántica	Authority for the Port Administration and Economic Development of the Atlantic Coast
JAPOQ	Junta Administrativa Portuaria de Quepos	Council for the Administration of the Port of Quepos
JICA	Agencia de Cooperación Internacional de Japón	Japan International Cooperation Agency
JST	Misión Japonesa de Investigación para el Estudio de Factibilidad del Proyecto de Mantenimiento del Puerto Caldera	Japanese Study Team for the Feasidility Study on the Maintenance Project of the Port of Caldera
LAICA	Liga Agricola Industrial de la Caña de Azúcar	Sugar-manufacturing Industry Corporation
MAG	Ministerio de Agricultura y Ganadería	Ministry of Agriculture and Stock Farming
MIDEPLAN	Ministerio de Planeación y Política Económica	Ministry of Economic Planning
MOPT	Ministerio de Obras Públicas y Transportes	Ministry of Public Works and Transports
OCDI	Instituto Japonés para el Desarrollo de Litorales en Ultramar	Overseas Coastal Area Development Institute of Japan
PHRI		Port and Harbour Research Institute, Ministry of Transport, Japanese Government
RECOPE	Refinadora Costarricense de Petroleo S.A.	Costa Rican Oil Refinery Corporation
SENARA	Servicio Nacional de Aguas Subterráneas, Riego y Avenamiento	National Agency for Underground Water, Irrigation and Drainage

ABBREVIATION	FULL NAME (SPANISH)	FULL NAME (ENGLISH)
SEPSA	Secretaria Ejecutiva de Planificación Sectorial, Agropecuaria y de Recursos Naturales Renovables	Executive Secretary's Office for Sectoral Planning, Agriculture and Renewable Natural Resources
SYSTAN		System International Inc.
ZONA FRANCA	Corporación Zona Franca de Exportaciones y Parques Industriales	Corporation of Free Zone for Exportation and Industrial Parks
CIF	coste, seguro y flete	cost, insurance and freight
EIRR	tipo interno economico de retorno	economic internal rate of return
FDD	dique flotante	floating dry dock
FIRR	tipo interno financiero de retorno	financial internal rate of return
FOB	franco a bordo	free on board
GDP	producto doméstico bruto	gross domestic product
Ro/Ro		roll on/roll off type sea transportation
N.H.H.W.L.	la pleamar más alta próximamente	nearly highest high water level
H.W.O.S.T.	pleamar media de marea viva	high water level of ordinary spring tide
M.H.H.W.	pleamar media más alta	mean higher high water
M.H.W.	pleamar media	mean high water
H.W.O.N.T.	pleamar media de marea muerta	high water level of ordinary neap tide
M.S.L.	nivel medio del mar	mean sea level
L.W.O.N.T.	bajamar media de marea muerta	low water level of ordinary neap tide
M.L.W.	bajamar media	mean low water
M.L.L.W.	bajamar media más baja	mean lower low water
L.W.O.S.T.	bajamar media de marea viva	low water level of ordinary spring tide
N.L.L.W.L.	la bajamar más baja próximamente	nearly lowest low water level
M_2		principal lunar constituent
S_2		principal solar constituent
K_2		lunisolar semidiurnal constituent
N_2		larger lunar elliptic constituent

ABBREVIATION	FULL NAME (SPANISH)	FULL NAME (ENGLISH)
K_1		lunisolar diurnal constituent
O_1		principal lunar diurnal constituent
P_1		principal solar diuranl constituent
Q_1		larger lunar elliptic constituent
M_4		lunar quarter diurnal constituent
MS_4		$M_2 + S_2$
A_0		mean sea level

ABBREVIATIONS (UNIT)

UNIT MARK	FULL NAME (ENGLISH)	QUANTITY
°C	degrees Celsius	temperature
cm/s	centimeters per second	velocity
d	days	time
DWT	dead weight tonnage	dead weight of vessels
Gal	gals	acceleration
GRT	gross registered tonnage	volume of vessels
h	hours	time
ha	hectare	area
kgf/cm^2	kilogram weight per square centimeter	stress, pressure
kgf/cm^3	kilogram weight per cubic centimeter	unit weight , coefficient of subgrade reaction
km	kilometers	distance
km/h	kilometers per hour	wind speed
kVA	kilovolt amperes	power
l	liters	volume
m	meters	depth, distance
m^2	square meters	area
m^3	cubic meters	volume
min	minutes	time
mm	millimeters	precipitation, distance
mon	months	time
m/s	meters per second	velocity
PS	horsepower	power
s	seconds	time, wave period
tf	ton weight	weight, dead weight of vessels
tf/m^2	ton weight per square meter	stress, load, surcharge, pressure
tf/m^3	ton weight per cubic meter	unit weight
TEU	twenty-foot equivalent units	containers
y	years	time
°	degrees	angle, latitude, longitude
'	minutes	angle, latitude, longitude
"	seconds	angle, latitude, longitude
"	inches	diameter, length
%	percent	percentage
¢	colon	monetary unit of Costa Rica

UNIT MARK	FULL NAME (ENGLISH)	QUANTITY
$	dollar	monetary unit of the United States of America
Y	yen	monetary unit of Japan

CONTENTS

CONTENTS OF THE APPENDIX

LIST OF FIGURES

CHAPTER I

CHAPTER II

CHAPTER III

CHAPTER VIII

CHAPTER IX

APPENDIX 1

APPENDIX 6

APPENDEX 8

APPENDIX 11

LIST OF TABLES

CHAPTER I

CHAPTER II

CHAPTER III

CHAPTER VIII

CHAPTER IX

CHAPTER X

CHAPTER XI

CHAPTER XII

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

[CONCLUSIONS]

1. Significance and Urgency of the Maintenance Project

The Port of Caldera is the major gateway for the international trade of Costa Rica on the Pacific coast, as well as the nearest port to the national capital, San José. The port leads the national economy and industry and supports the livelihood of the Costa Rican people through commodity supply. However, one of the three berths of the port, which is the deepest and most important, has not been fully available because of shoaling due to the sand sedimentation in the harbour. Furthermore, the pier at the Port of Puntarenas which handles all the grain imports for the nation has already become superannuated. Thus, the Port of Caldera is obliged to take over the function of handling grain imports in place of Puntarenas pier in the immediate future.

Accordingly, the Maintenance Project of the Port of Caldera is both serious and urgent.

2. The Maintenance Project

The target year of the Maintenance Project of the Port of Caldera should be 1992 considering the required construction period and the projected increase in port cargo volume. The project consists of the following three main programs :

(1) Countermeasures against sand sedimentation
- 1) Breakwater extenstion : 200 m long
- 2) Primary dredging in the harbour : Volume of 72,000 m^3
- 3) Periodic maintenance dredging : Approximately 60,000 m^3/five years

(2) Enlargement of mooring facility capacity in response to the necessity of handling grain imports and the progress of containerization in sea transportation
- 1) Shift of a section of the existing breakwater 50 m to the west : length 162 m
- 2) Restoration of the −3.0 m small craft basin : 50 m×90 m
- 3) Construction of the −3.0 m quaywall : 110 m long
- 4) Construction of the small pier (gangway) : 45 m long
- 5) Construction of the mooring dolphin : 1 dolphin (5 m×5 m)

(3) Reinforcement to cargo handling capacity in response to the necessity of handling grain imports and the multipurpose use of the terminal
- 1) Reinforcement of the cargo handling equipment
- 2) Pavement of the open yards : Area of 42,000 m^2

3. Construction Method

Construction works at the Port of Caldera consist of both primary works and maintenance works. To execute the planned construction works economically and rationally, the construction method should be as follows :

First, MOPT should obtain a new dredger fleet and construction machinery for the future maintenance dredging and other works after the primary construction works are completed.

Second, the dredger fleet and construction machinery purchased by MOPT should be lent to a foreign contractor to execute the primary works. MOPT personnel should also take part in the primary construction works which will be executed by the foreign contractor as a type of on the job training.

Finally, after the primary works are completed and the dredger fleet and machinery have been returned to MOPT, MOPT should execute periodic maintenance works including maintenance dredging itself, using its own dredger fleet and machinery.

4. Grain Import Function

It is crucial to transfer the function of handling imported grain from the superannuated Puntarenas pier to the Port of Caldera as smoothly and as promptly as possible. As the grain will be handled at a multipurpose terminal at the Port of Caldera, a new mechanized and rationalized cargo handling system for grain will have to be implemented to increase the cargo handling efficiency so as to minimize the effects of the handling of grain on the handling of other cargoes.

5. Required Amount of Investment and Construction Period

The total investment for the Maintenance Project including the purchase cost of the dredger fleet, construction machinery and cargo handling equipment is estimated as approximately 1,268 million colones at December 1985 prices. About 80.4% of the investment will be made using foreign currency. The total construction period for the Maintenance Project will be four years including the preliminary contract procedures and the purchase of a dredger fleet, construction machinery and cargo handling equipment.

6. Economic and Financial Analyses of the Maintenance Project

(1) Economic Analysis

The Maintenance Project is evaluated using the Economic Internal Rate of Return (EIRR) which is calculated based on a cost-benefit analysis from the viewpoint of the national economy. The main tangible benefit considered is the reduction in ships' staying cost at the port, while main costs are the construction, purchase, maintenance and administrative costs. The EIRR is calculated to be 23.7% using 30 years as the period of economic calculation. This shows that the Maintenance Project is advantageous from the viewpoint of the national economy.

(2) Financial Analysis

The analysis covers the costs of the newly improved facilities and procured equipment which will produce additional revenue, and the amount of the additional port revenue which will be generated by the improvements and procurements. The profitability of the project itself is analyzed based on the Financial Internal Rate of Return (FIRR) using the Discount Cash Flow Method. Domestic funds are assumed to come from government funds, and foreign funds from soft loans (annual interest rate : 4.75%, term of repayment : 25 years, grace period : 7 years). Revenues are assumed as port dues, wharfages and stevedoring charges according to the current Costa Rican tariffs. The analysis shows that the project is profitable with an FIRR of 8.26%. This exceeds the weighted average interest rate of the procured funds (3.62%).

Judging from the above, it can be concluded that the Maintenance Project with the target year of 1992 is feasible both economically and financially.

[RECOMMENDATIONS]

1. Necessity of Investment by the National Goverment

Such basic port facilities as the breakwater, the quaywall, the small craft basin and the turing basin should be constructed at the expense of the Costa Rican national government considering that all these items require a large amount of investment at one time and that other than the quaywall none of them will directly produce additional port income.

These basic facilities are all essential for the actual functioning of the port, and the entire port itself is a basic socioeconomic infrastructure which contributes both directly and indirectly to economy of Costa Rica and the livelihood of the Costa Rican people.

2. Future Reviews

The Maintenance Project with the target year of 1992 is formulated based on the projected socioeconomic frame. However, the economy is subject to constant flux, and the demand at the port may be greatly influenced by changes in the domestic and world economy. Thus, it is important to review the project along with any major future changes in the socioeconomic frame as needed.

3. Construction of Grain Silos with a Sufficient Storage Capacity

As grains will begin to be imported through the Port of Caldera, grain silos with a sufficient capacity of 20,000 tons should be constructed at the Port of Caldera by the agencies concerned by the target year of the Maintenance Project.

4. Conducting Regular Field Surveys

To accurately estimate the future sand sedimentation volume and to implement an economical and effective maintenance dredging program as a countermeasure against sand sedimentation, it will be necessary to periodically conduct field surveys related to sand sedimentation such as depth soundings, topographic surveys along the shoreline and wave observations as in the past.

SUMMARY

This summary covers the key items presented in CHAPTERS V through XII of the study.

I CURRENT PROBLEMS AND STUDY OBJECTIVES

The Port of Caldera has recently experienced such serious problems as sand sedimentation in the harbour, insufficient berth length and inefficient cargo handling. The problems affecting the Port of Caldera must be solved so that the port can fulfill its role as the main international gateway on the Pacific coast of Costa Rica. The current problems facing the port and the study objectives are summarized below.

1. Sand Sedimentation

There is sand drift along almost the entire east coast of Nicoya Bay. Measures must be taken to protect the Port of Caldera from sand drift and sedimentation. To put it concretely, the average annual sand sediment volume for the last three years is approximately 100,000 to 110,000 m³. The rate of sedimentation at the harbour side of the breakwater has been accelerating.

Particularly, the edge of the sediment at the harbour side of the breakwater has reached the −11 m quaywall. The berth area for the said quaywall has shoaled along a distance of about 100 m. Thus, large vessels of the design ship size are not able to load or unload cargoes at the wharf at present.

2. Insufficient Berth Size

The total berth length is 490 m, but the berth length where large vessels (15,000 to 20,000 DWT) can berth is only 360 m. Especially, the present berth length of the −10 m quaywall is short. Thus, at present, only one large vessel can berth at the Port of Caldera at one time. However, the port must have appropriate facilities to accomodate two vessels such as one container ship and one grain cargo carrier simultaneously.

3. Necessity of Improving the Cargo Handling Systems

The Port of Caldera handles a great variety of commodities and has a relatively large throughput with a small number of berths. This situation will develop further along with the increase of port cargo in the future. Particularly, the Port of Caldera will be obliged to handle imported grain which is currently handled at Puntarenas pier. Thus, it is necessary to improve the existing cargo handling system for multipurpose use of the terminal at the

4. Expected Port Functions and Study Objectives

The Port of Caldera is expected to function as the main international gateway on the Pacific coast. However, the port has experienced such serious problems as (1) sand sedimentation, (2) insufficient berth length and (3) inefficient cargo handling systems as noted above. The countermeasures to solve problem (1) will restore the potential capacity of the port. The countermeasures to solve problems (2) and (3) are means to enhance the existing port capacity by improving existing facilities and equipment. The capacity restored and enhanced by the above countermeasures must, of course, be maintained well even after these countermeasures are implemented.

Therefore, the study seeks to restore the potential port capacity, to enhance the port capacity by improving existing facilities and adding needed equipment, and to maintain the enhanced port capacity by procuring appropriate machinery and devising an appropriate maintenance system so that the port can function to the utmost of its potential. Thus, the study covers not only how to execute the primary construction work itself, but also how to execute the regular maintenance work after the primary construction work is completed. The composition of the study is shown in Table 1.

Table 1 Problems and Countermeasures

Problems	Countermeasures			Related CHAPTER in this report
	Restoration	Improvement	Maintenance	
(1) Sand sedimentation	○		○	VI, IX
(2) Insufficient berth length		○		VII
(3) Inefficient cargo handling		○	○	VIII

If proper countermeasures are properly implemented to solve these problems, the Port of Caldera will be able to fulfill its role as the main international gateway on the Pacific coast.

II COUNTERMEASURES AGAINST SAND SEDIMENTATION

1. Present Conditions

The past and present field surveys reveal some characteristic features of the sand drift and sedimentation around the Port of Caldera. The sand sedimentation in the harbour basin is caused by two distinct phenomena. The drift sand from New Beach moves around the head of the breakwater, goes toward the foot of the breakwater, and accumulates around there due to the wave action and the longshore current. This is one cause of the harbour sedimentation. The other phenomenon is the sedimentation of the entire basin with almost a uniform thickness. This is mainly caused by the wave action and the tidal current.

The sand sediment volume over a recent five year period is shown in Table 2.

Table 2 Sand Sediment Volume

Period	Sand Sediment Volume(m^3)		
	Harbour Side of the Breakwater	Turning Basin	Total
1980' 4 ~1981'10	12,000	—	—
1981'10~1982' 7	21,000	−26,000	−5,000
1982' 7 ~1983' 8	40,250	70,813	111,063
1983' 8 ~1984' 8	24,125	77,938	102,063
1984' 8 ~1985' 9	94,500*)	18,250	112,750

Note: *) This volume includes the dredged sand volume.

The first phenomenon is the littoral drift around the breakwater. The sand drift pattern at the southern beach of the breakwater is shown in Fig. 1. The littoral drift volume and also the sand sediment volume at the harbour side of the breakwater becomes greater as the seaside water depth of the breakwater becomes shallower. Fig. 2 shows the relation between D and Q_s. D is the distance between the head of the breakwater and the −2 m contour line in meters. Q_s is the annual sand sediment volume at the harbour side of the breakwater (m^3/year). The figure shows that the Q_s is determined only from the D value. When D is more than 60 m, Q_s is zero. If D becomes shorter, then Q_s becomes greater. Finally, Q_s approaches asymptotically to 112,000 m^3/year, that is the sum of the littoral drift volume at Corralillo Beach and New Beach.

In the harbour basin, there is also the other type of sedimentation, that is the accumulation of fine sand with an almost uniform thickness. The median grain diameter of this sediment sand is around 0.1 mm. This sediment is transported by the tidal current and the longshore current. The sand sediment rates and the annual sediment volume in the basin are shown in Fig. 3.

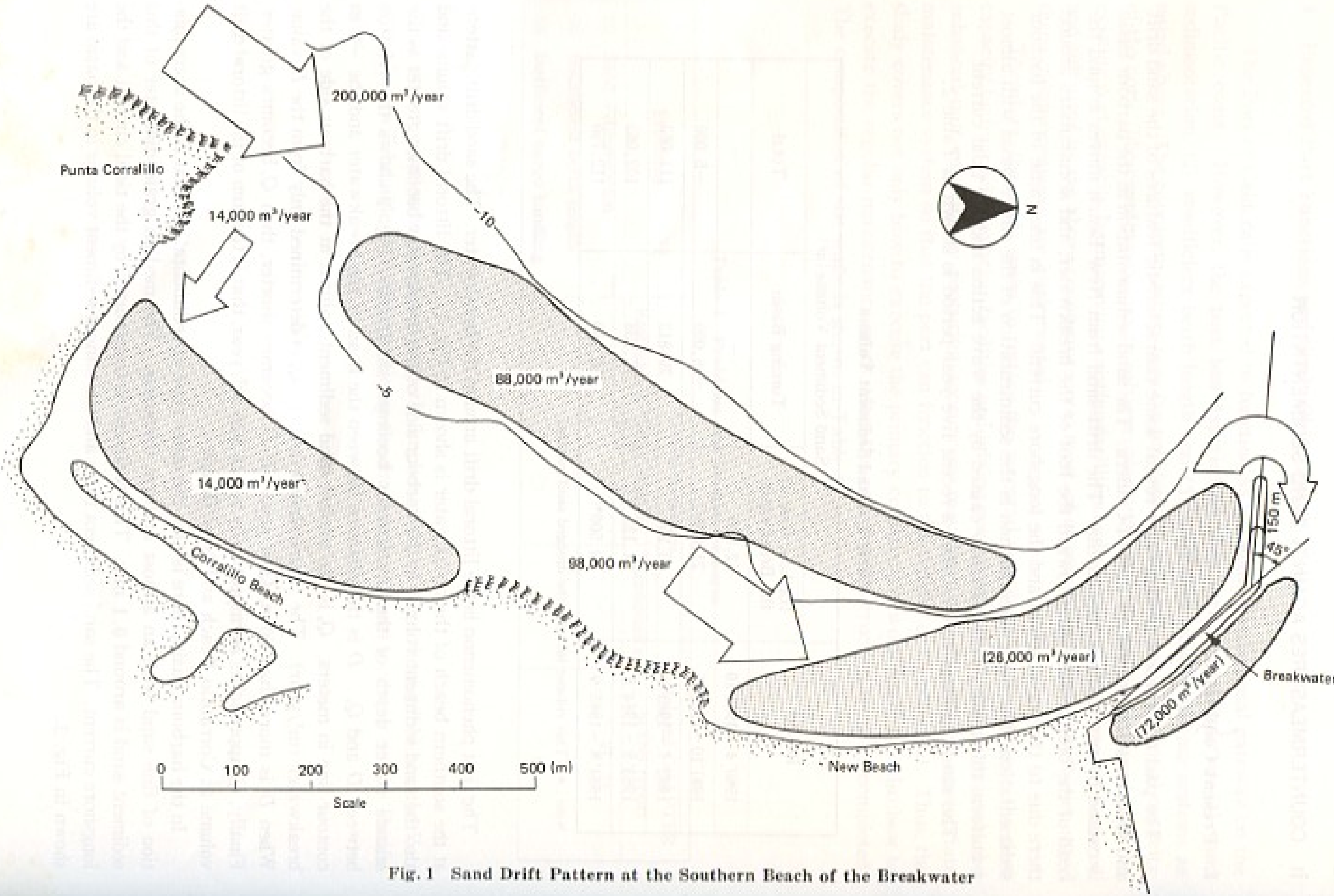


Fig. 1 Sand Drift Pattern at the Southern Beach of the Breakwater

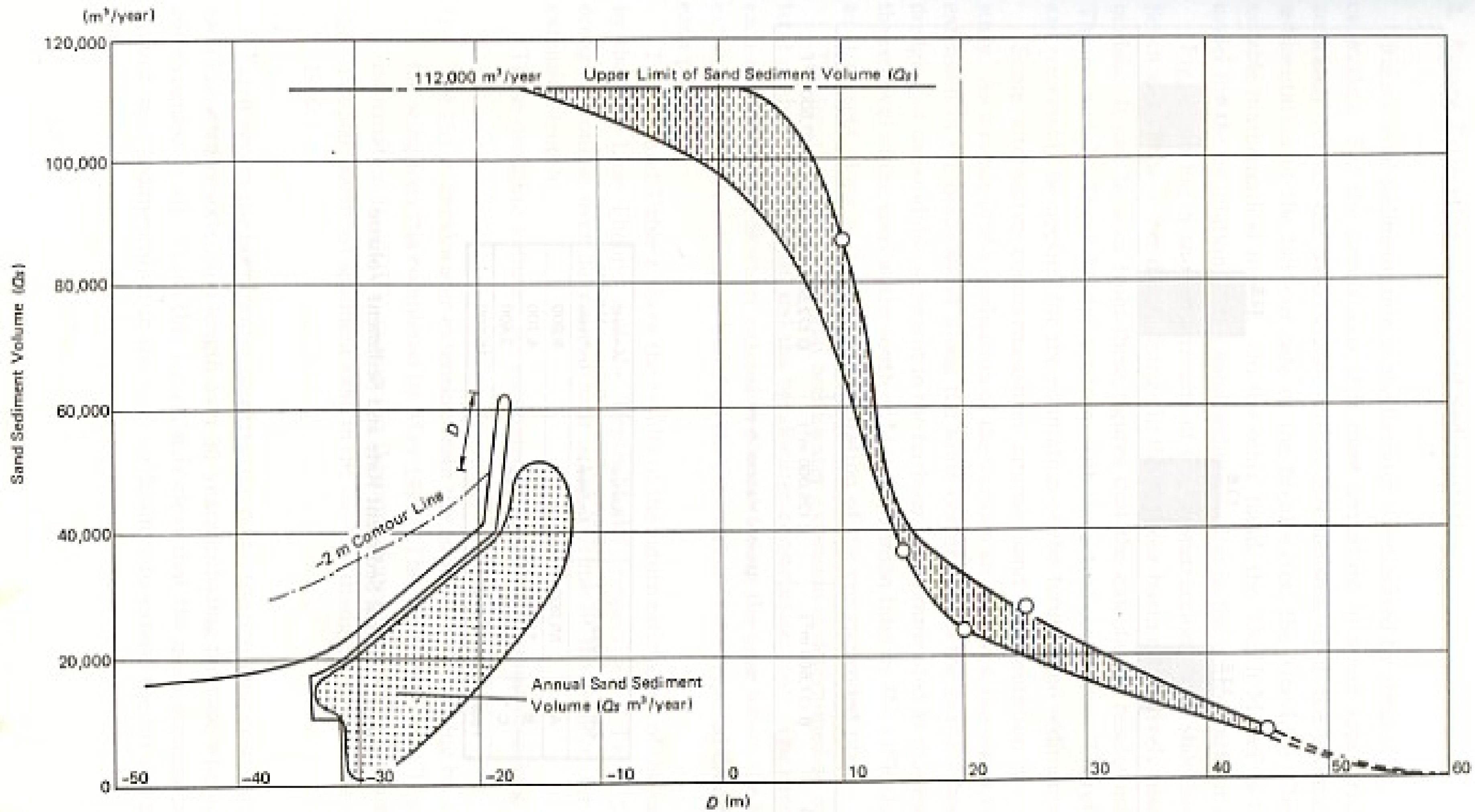
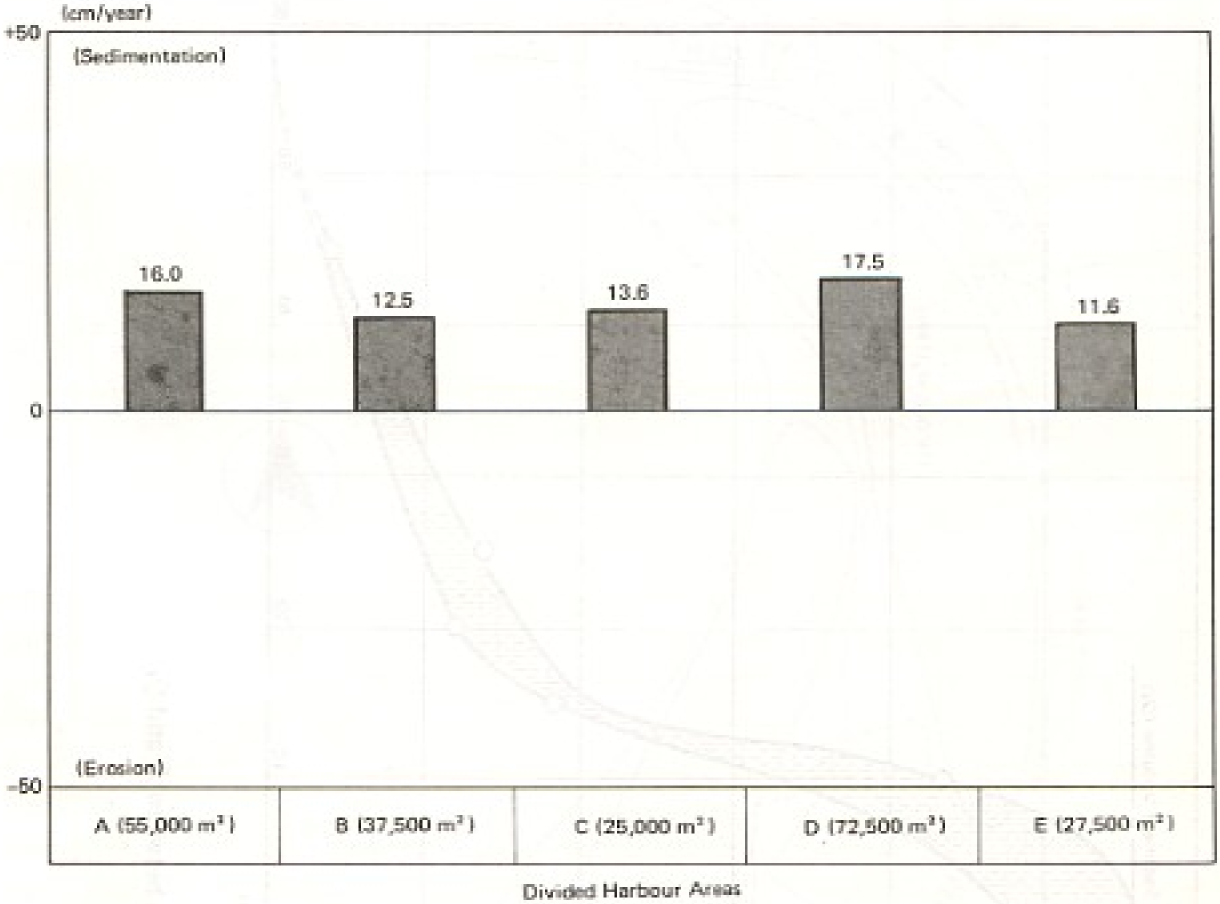


Fig. 2 Relation between D and Q_s



Zone	Area (m^2)	Annual Sediment Rate (m/year)	Annual Sediment Volume (m^3/year)
A	55,000	0.160	8,800
B	37,500	0.125	4,700
C	25,000	0.136	3,400
Total	117,500	—	16,900

Fig. 3 Annual Sediment Rate and Sediment Volume

2. Future Estimation of the Sand Sedimentation

Future sand sedimentation in the harbour is estimated by simulations using mathematical models. For the simulations, it is most important to select appropriate models which accurately reflect the sand sedimentation mechanisms. For the estimation of the sand sedimentation at the harbour side of the breakwater, the 'One-Line Theory' is the most suitable mathematical model. On the other hand, the 'Depth Model' is the most suitable model for the estimation of the sand sedimentation in the entire harbour basin.

Fig. 4 and Fig. 5 show the results of the reconstruction of the shoreline change at New Beach and of the water depth change in the harbour basin respectively using the simulation models. It can be seen from these figures that the calculation results using the 'One-Line Theory' and the 'Depth Model' conform with the actual conditions. Therefore, these models can reasonably be applied for the estimation of the future sand sedimentation.

Some alternative countermeasures against sand sedimentation are proposed in this study. As a result of the evaluation of the various alternatives, the alternative involving the extension of the breakwater along the same center line as the existing breakwater and the dredging of unavoidable sediment in the harbour is recommended as the best plan. Of course, the removal of the sand at the south of Mata de Limōn Inlet by INCOFE should be continued as at present along with the implementation of the recommended plan.

The length of the additional breakwater extension is determined so as to minimize the total of the dredging cost and the breakwater construction cost. The dredging costs under each alternative breakwater extension plan including the case where the breakwater is not extended at all are estimated based on the estimation of the required dredging volume under each plan.

Table 3 and Table 4 show the results of the future estimation of the sand sedimentation by the 'One-Line Theory' and the 'Depth Model', respectively. Table 5 shows the total dredging volume over 30 years, which is the lifetime of the project, for each breakwater extension length.

These dredging volumes are estimated under the following premises.

(1) The 150 m breakwater extension from the corner of the existing breakwater (a part of the wing jetty) is completed by May 1986. (The Japanese Study Team has given some information to MOPT concerning the immediate breakwater extension works.)

(2) The 300,000 m^3 of sediment sand in the basin is dredged by a foreign contractor by May 1986.

Fig. 6 shows the breakwater construction costs, the dredging costs and the total costs of each breakwater extension length over 30 years including the case where the breakwater is not extended at all. From this figure, it is clear that the most economical countermeasure against sand sedimentation in the harbour basin is to extend the breakwater by a length of 200 m.

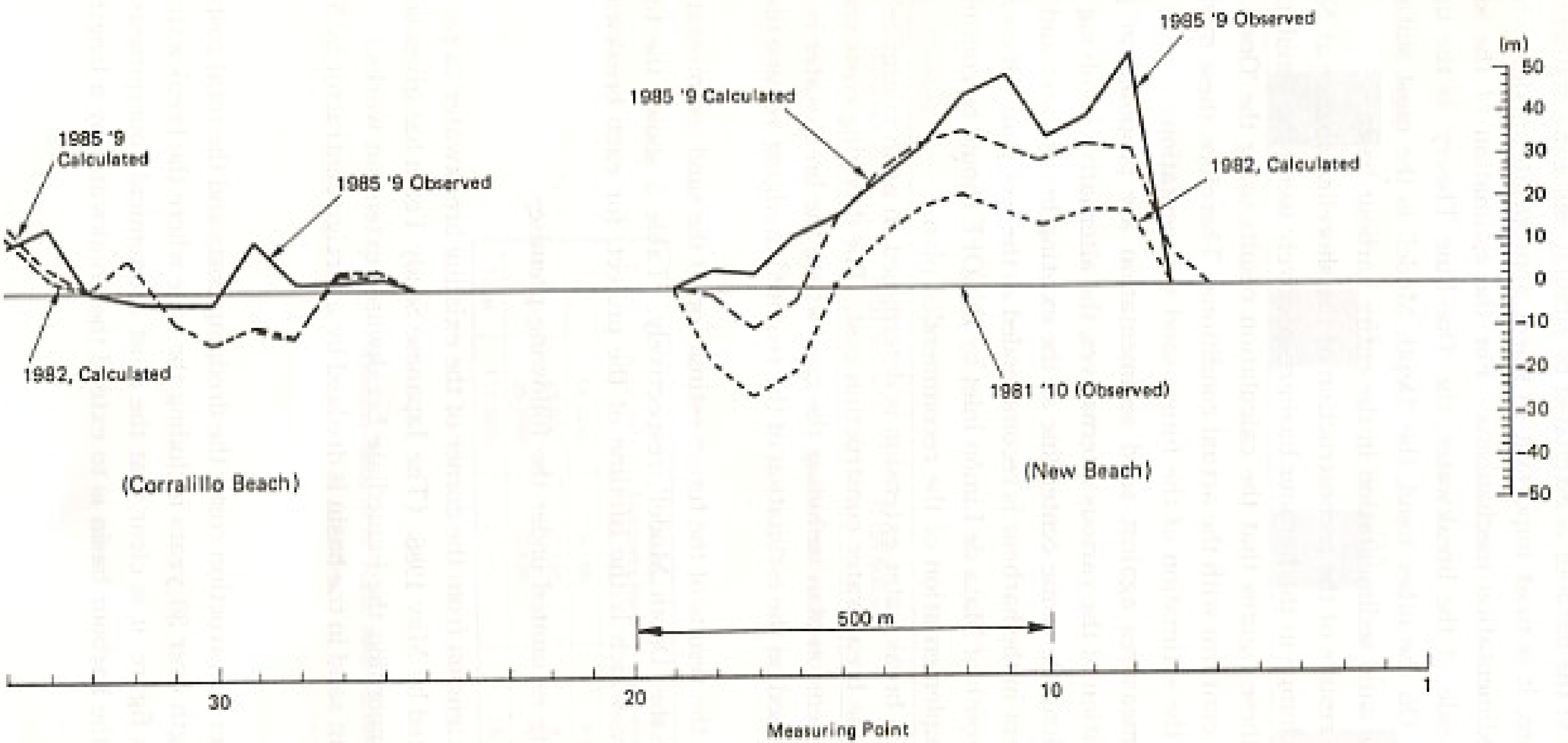
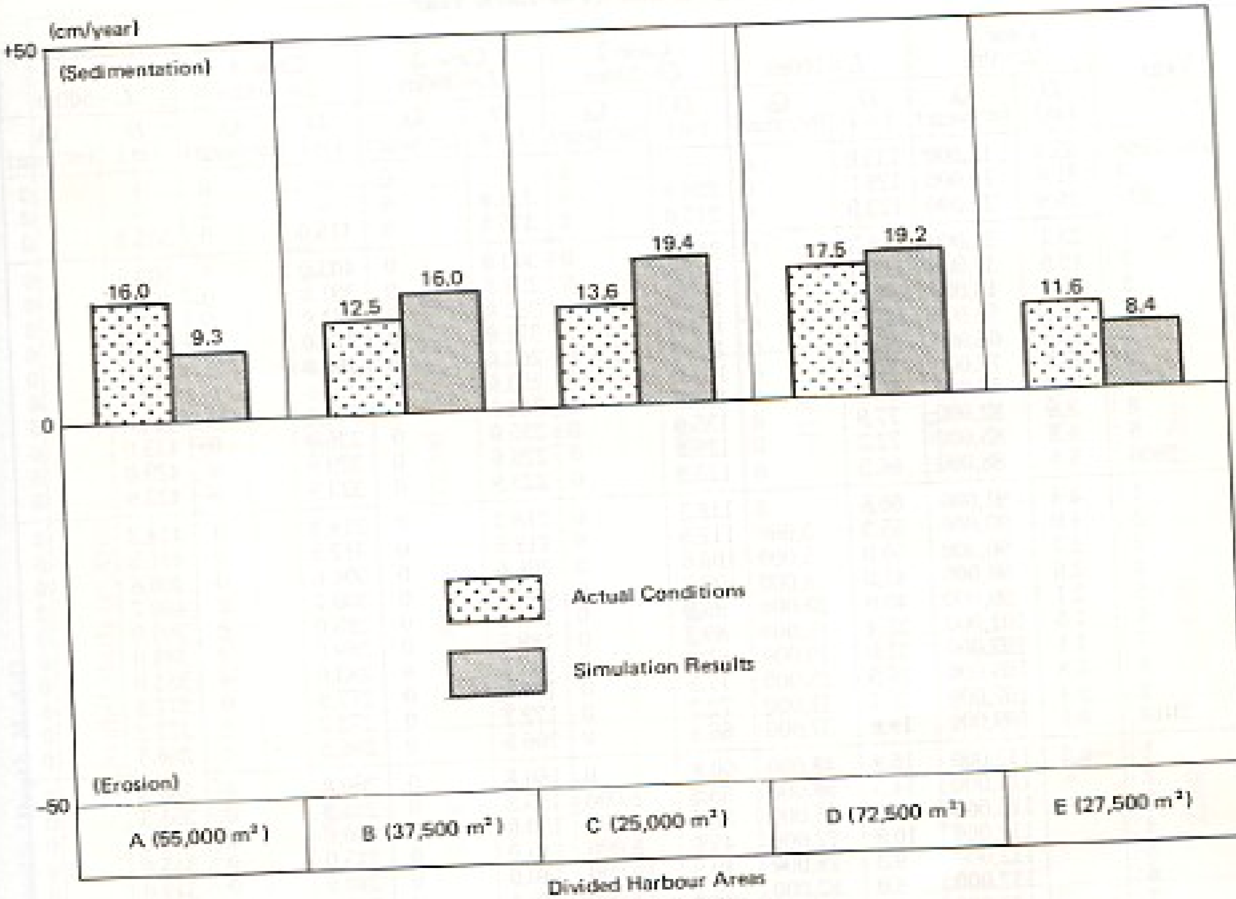


Fig. 4 Simulation Result by One-Line Theory
(Reconstruction of the Actual Shoreline Change)



Zone	Area (m²)	Actual or Simulation	Annual Sediment Rate (m/year)	Annual Sediment Volume (m³/year)
A	55,000	Actual Conditions	0.160	8,800
		Simulation Results	0.093	5,100
B	37,500	Actual Conditions	0.125	4,700
		Simulation Results	0.160	6,000
C	25,000	Actual Conditions	0.136	3,400
		Simulation Results	0.194	4,900
Total	117,500	Actual Conditions	–	16,000
		Simulation Results	–	16,900

Fig. 5 Reconstruction of the Depth Change

Table 3 D and Q_s of Each Year

Year	Case 1 L=0m		L=100m		Case 2 L=200m		Case 3 L=300m		Case 4 L=400m		L=500m	
	D (m)	Q_s (m³/year)	D (m)	Q_s (m³/year)	D (m)	Q_s (m³/year)	D (m)	Q_s (m³/year)	D (m)	Q_s (m³/year)	D (m)	Q_s (m³/year)
Jan., 1988	35.4	15,000	135.0	0	—	0	—	0	—	0	—	0
9	31.0	19,000	129.0	0	228.0	0	328.0	0	—	0	—	0
1990	26.9	25,000	123.9	0	215.0	0	315.0	0	415.0	0	515.0	0
1	23.1	31,000	118.3	0	203.0	0	303.0	0	403.0	0	503.0	0
2	19.6	37,000	112.5	0	191.0	0	291.0	0	391.0	0	491.0	0
3	16.8	48,000	106.6	0	181.0	0	281.0	0	381.0	0	481.0	0
4	14.5	58,000	100.7	0	171.0	0	271.0	0	371.0	0	471.0	0
5	12.5	66,000	95.0	0	162.0	0	262.0	0	362.0	0	462.0	0
6	10.8	72,000	89.3	0	153.0	0	253.0	0	353.0	0	453.0	0
7	9.3	77,000	83.6	0	144.0	0	244.0	0	344.0	0	444.0	0
8	8.0	82,000	77.9	0	135.0	0	235.0	0	335.0	0	435.0	0
9	6.8	85,000	72.2	0	129.0	0	229.0	0	329.0	0	429.0	0
2000	5.8	88,000	66.5	0	123.9	0	223.9	0	323.9	0	423.9	0
1	4.8	91,000	60.8	0	118.3	0	218.3	0	318.3	0	418.3	0
2	4.0	93,000	55.3	3,000	112.5	0	212.5	0	312.5	0	421.5	0
3	3.3	96,000	50.0	5,000	106.6	0	206.6	0	306.6	0	406.6	0
4	2.6	98,000	45.0	8,000	100.7	0	200.7	0	300.7	0	400.7	0
5	2.1	99,000	40.0	10,000	95.0	0	195.0	0	295.0	0	395.0	0
6	1.5	101,000	35.4	15,000	89.3	0	189.3	0	289.0	0	389.0	0
7	1.1	103,000	31.0	19,000	83.6	0	183.6	0	283.0	0	383.0	0
8	0.8	105,000	26.9	25,000	77.9	0	177.9	0	277.9	0	377.9	0
9	0.4	107,000	23.1	31,000	72.2	0	172.2	0	272.2	0	372.2	0
2010	0.1	109,000	19.6	37,000	66.5	0	166.5	0	266.5	0	366.5	0
1	−0.3	112,000	16.8	48,000	60.8	0	160.8	0	260.8	0	360.5	0
2		112,000	14.5	58,000	55.3	3,000	155.3	0	255.3	0	355.5	0
3		112,000	12.5	66,000	50.6	5,000	150.0	0	250.0	0	350.0	0
4		112,000	10.8	72,000	45.0	8,000	145.0	0	245.0	0	345.0	0
5		112,000	9.3	78,000	40.0	10,000	140.0	0	240.0	0	340.0	0
6		112,000	8.0	82,000	35.4	15,000	135.4	0	235.4	0	335.4	0
7		112,000	6.8	85,000	31.0	19,000	131.0	0	231.0	0	331.0	0
8		112,000	5.8	88,000	26.9	25,000	126.9	0	226.9	0	326.9	0
9		112,000	4.8	91,000	23.1	31,000	123.1	0	223.1	0	323.1	0
2020		112,000	4.0	93,000	19.6	37,000	119.8	0	219.8	0	319.6	0
1			3.3	96,000	16.8	48,000	116.8	0	216.8	0	316.8	0
2			2.6	98,000	14.5	58,000	111.5	0	211.5	0	311.5	0
3			2.1	99,000	12.5	66,000	106.1	0	206.1	0	306.1	0
4			1.5	101,000	10.8	72,000	100.8	0	200.8	0	300.8	0
5			0.8	105,000	9.3	78,000	95.4	0	195.4	0	295.4	0
6			0.4	107,000	8.0	82,000	90.1	0	190.1	0	290.1	0
7			0.1	109,000	6.8	85,000	84.7	0	184.7	0	284.7	0
8			−0.3	112,000	5.8	88,000	79.4	0	179.4	0	279.4	0
9				112,000	4.8	91,000	74.0	0	174.0	0	274.0	0
2030				112,000	4.0	93,000	68.7	0	168.7	0	268.7	0
1				112,000	3.3	96,000	63.3	0	163.3	0	263.3	0
2				112,000	2.6	98,000	58.1	1,000	158.1	0	258.1	0
3				112,000	2.1	99,000	53.2	4,000	152.8	0	252.8	0
4				112,000	1.5	101,000	48.4	6,000	147.7	0	247.7	0
5				112,000	0.8	105,000	43.7	8,000	142.6	0	242.6	0
6				112,000	0.4	107,000	39.2	11,000	137.7	0	237.7	0
7				112,000	0.1	109,000	34.9	15,000	132.7	0	232.7	0
8				112,000	−0.3	112,000	30.9	19,000	127.7	0	227.7	0
9				112,000		112,000	27.1	25,000	122.7	0	222.7	0
2040				112,000		112,000	23.5	30,000	117.7	0	217.7	0
1						112,000	20.2	35,000	112.2	0	212.2	0
2						112,000	17.5	45,000	107.7	0	207.7	0
3						112,000	15.2	54,000	102.7	0	202.7	0
4						112,000	13.3	62,000	97.7	0	197.7	0
5						112,000	11.6	69,000	92.7	0	192.7	0

Notes : 1) D is the distance between the head of the breakwater and the −2.0m contour line at the start of each period (m).
2) Q_s is the annual sand sediment volume (m³/year).
3) D and Q_s in the cases of L=100m and L=500m are assumed complementing the simulation results.

Table 4 Simulation Results (Depth Model)

Case	Sedimentation Rates	Divided Harbour Area						
		A(55,000m²)	B(37,500m²)	C(25,000m²)	Sub Total (117,500m²)	D(72,500m²)	E(27,500m²)	Total (217,500m²)
Actual Conditions	Depth Change (cm/year)	16.0	12.5	13.6	—	17.5	11.6	—
	Annual Sediment Volume(m³/year)	8,800	4,700	3,400	16,900	12,700	3,200	32,800
Case 1 Reconstruction of the Actual Conditions	Depth Change (cm/year)	9.3	16.0	19.4	—	19.2	8.4	—
	Annual Sediment Volume(m³/year)	5,100	6,000	4,900	16,000	13,900	2,300	32,200
Case 2 Breakwater Extension L=200m	Depth Change (cm/year)	8.0	10.4	13.0	—	17.8	9.0	—
	Annual Sediment Volume(m³/year)	4,400	3,900	3,300	11,600	12,900	2,500	27,000
Case 4 Breakwater Extension L=400m	Depth Change (cm/year)	5.6	7.2	9.3	—	16.9	6.3	—
	Annual Sediment Volume(m³/year)	3,100	2,700	2,300	8,100	12,300	1,700	22,100

Table 5 Total Amount of Dredging Volume for 30 Years

Breakwater Extension Length	Primary or Maintenance Dredging	Dredging Volume (m³)		
		Harbour Side of the Breakwater	Harbour Basin	Total
0m	Primary Dredging	0	0	0
	Maintenance Dredging	2,571,000	544,000	3,115,000
	Total	2,571,000	544,000	3,115,000
100m	Primary Dredging	72,000	0	72,000
	Maintenance Dredging	642,000	465,000	1,107,000
	Total	714,000	465,000	1,179,000
200m	Primary Dredging	72,000	0	72,000
	Maintenance Dredging	41,000	372,000	413,000
	Total	113,000	372,000	485,000
300m	Primary Dredging	72,000	0	72,000
	Maintenance Dredging	0	310,000	310,000
	Total	72,000	310,000	382,000
400m	Primary Dredging	72,000	0	72,000
	Maintenance Dredging	0	248,000	248,000
	Total	72,000	248,000	320,000
500m	Primary Dredging	72,000	0	72,000
	Maintenance Dredging	0	217,000	217,000
	Total	72,000	217,000	289,000

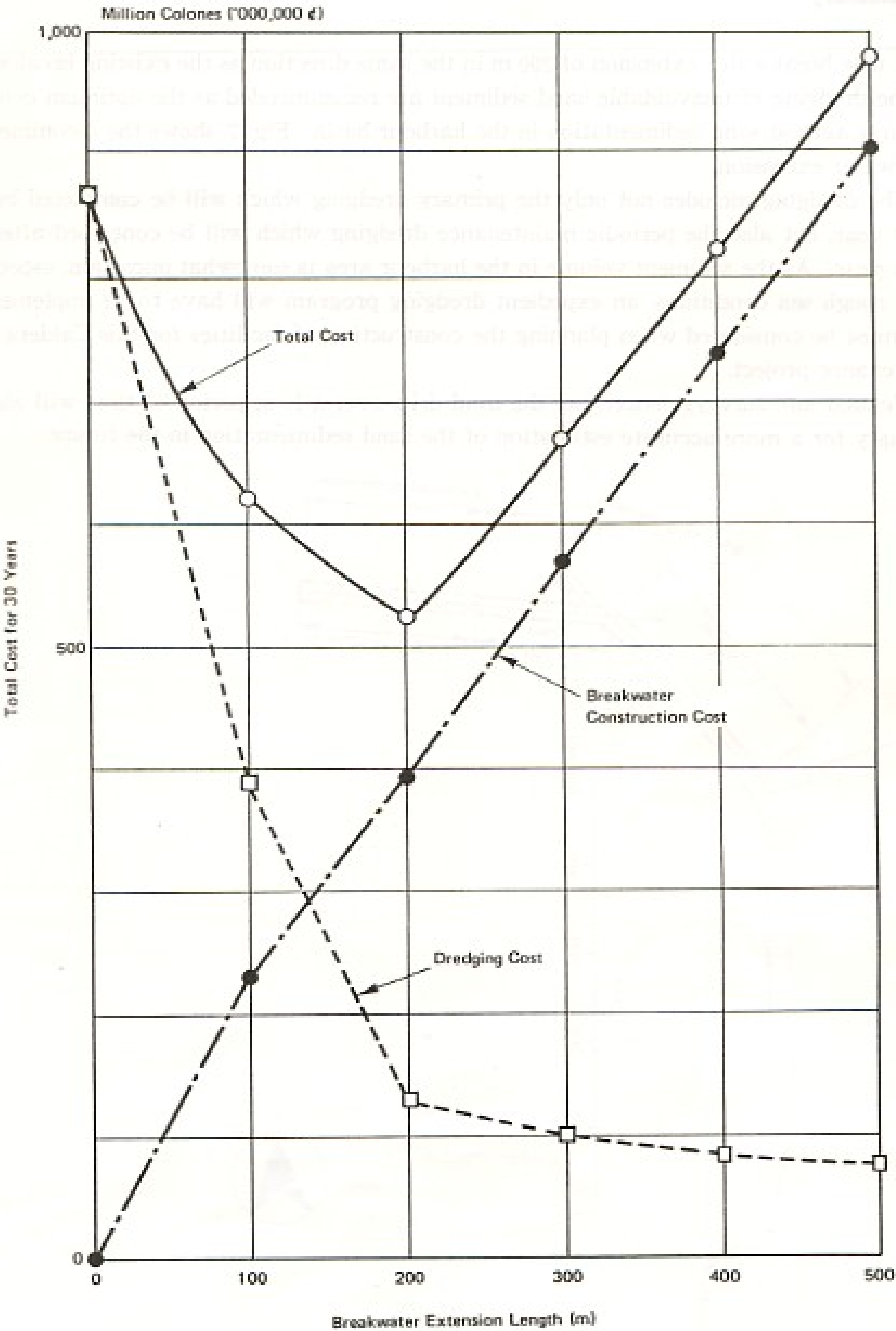


Fig. 6 Cost Comparison of Each Breakwater Length

3. Summary

A new breakwater extension of 200 m in the same direction as the existing breakwater and the dredging of unavoidable sand sediment are recommended as the optimum counter-measures against sand sedimentation in the harbour basin. Fig. 7 shows the recommended breakwater extension.

The dredging includes not only the primary dredging which will be completed by the target year, but also the periodic maintenance dredging which will be continued after the target year. As the sediment volume in the harbour area is somewhat uncertain, especially under rough sea conditions, an expedient dredging program will have to be implemented. This must be considered when planning the construction of facilities for this Caldera Port maintenance project.

Regular site surveys concerning the sand drift over a long period of time will also be necessary for a more accurate estimation of the sand sedimentation in the future.

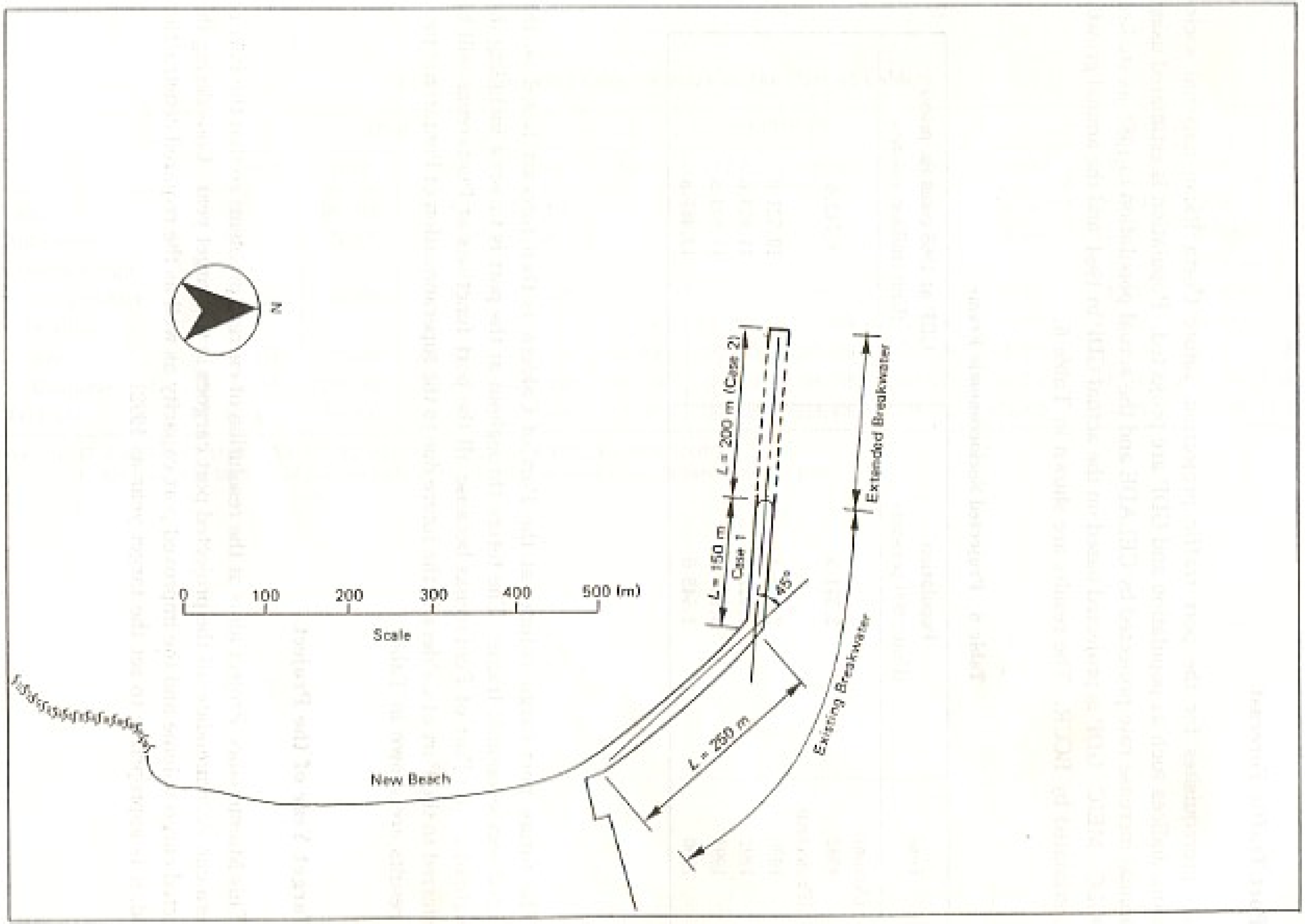


Fig. 7 Alternative Designs of the Breakwater Extension

1. Port Traffic Forecast

As prerequisites for the port traffic projection, future Costa Rican national socio-economic indices such as population and GDP are projected. Population is estimated using the annual increase rate projected by CELADE and the actual population in 1982 as studied by DGEC/MEIC. GDP is projected based on the actual GDP in 1984 and the annual growth rate estimated by BCCR. The results are shown in Table 6.

Table 6 Projected Socioeconomic Frame

Year	Population (Unit : '000 persons)	GDP at 1966 constant prices (Unit : million colones)
(Actual) 1982	2,371.5	8,742.6
(Projected) 1990	2,895.4	10,521.0
1992	3,027.7	11,053.6
1995	3,224.4	11,903.5
2000	3,545.0	13,467.8

The future port cargo volume at the Port of Caldera is then forecast based on the projected socioeconomic frame. The future throughput at the port is forecast including the throughput at the Port of Puntarenas because all the port functions at Puntarenas will be transferred to the Port of Caldera in the future due to the superannuation of Puntarenas pier. The results are shown in Table 7.

2. Target Year of the Project

This Maintenance Project aims at the resolution of current problems so that the Port of Caldera can accommodate all the projected port cargoes in the target year. Considering the projected cargo volume and the improved port capacity as well as the required construction period, it is appropriate to set the target year as 1992.

Table 7 Projected Cargo Volume at the Port of Caldera

	IMPORTS				EXPORTS				TOTAL			
	1984[1]	1992	1995	2000	1984[1]	1992	1995	2000	1984[1]	1992	1995	2000
Grain	131,167	166,100	158,900	149,200	—	—	—	—	131,167	166,100	158,900	149,200
Automobiles	4,816	21,900	24,700	29,900	—	—	—	—	4,816	21,900	24,700	29,900
General Cargo												
Iron and Steel	53,185	83,000	90,000	103,800	—	—	—	—	53,185	8,300	90,000	103,800
Fertilizer	—	—	—	—	5,500	10,000	12,000	16,000	5,500	10,000	12,000	16,000
Others	198,157	329,000	387,000	498,000	78,668	153,300	207,400	322,100	276,825	482,300	594,400	820,100
(Containerized)	(28,452)	(120,700)	(253,800)	(432,100)	(26,760)	(41,000)	(86,700)	(184,600)	(55,212)	(161,700)	(340,500)	(616,700)
TOTAL	387,325	600,000	660,600	780,900	84,168	163,300	219,400	338,100	471,493	763,300	880,000	1,119,000

Source 1) : CUADROS ESTADISTICOS SOBRE SECTOR TRANSPORTES 1984, DGP/MOPT
Note : Cargo volume at the Port of Caldera includes that handled at the Port of Puntarenas in the past.

3. Project Strategy

The overall strategy of this Maintenance Project for the Port of Caldera can be summarized as follows :

(1) To basically resolve the sand sedimentation problem in the harbour which has decisively interfered with the expected port functions.
(2) To cope with urgent factors such as the transference of the grain import function, the rapid progress of containerization in the maritime transportation and the increase of port cargoes.
(3) To minimize costs by aiming at multipurpose use of the terminal which will handle a variety of commodities with a few existing berths.

Port facility improvement planning is studied along with the strategy. This chapter mainly studies the mooring facility improvement planning and the overall port layout.

4. Extension of the −10m Quaywall

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 at the No. 2 berth should be extended to the appropriate length considering the ship length of large ships.

There are three alternatives to extend the existing berth length of 150 m up to the necessary length (refer to Fig. 8).

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

Alternative A is selected as the best alternative to secure the necessary berth length of −10 m quaywall. Accordingly, the existing No. 1 guaywall should be extended by 50 m. To secure the necessary berth length, it is sufficient to construct a 50 m long small pier (a gangway and mooring dolphin). However, the entrance channel to the small craft basin and an allowance for sand sedimentation should be fully considered when extending the berth.

5. Port Layout

Port facilities and equipment which require improvement in accordance with the strategy are as follows :

(1) Countermeasures against sand sedimentation
   1) Breakwater extension : 200 m long
   2) Primary dredging in the harbour : Volume of 72,000 m^3
   3) Periodic maintenance dredging : Approximately 60,000 m^3/five years
(2) Enlargement of mooring facility capacity in response to the necessity of handling grain imports and the progress of containerization in sea transportation
   1) Shift of the foot of the existing breakwater 50 m to the west : 162 m long
   2) Restoration of the −3.0 m small craft basin : 50 m × 90 m
   3) Construction of the −3.0 m quaywall : 110 m long
   4) Construction of the gangway : 45 m long
   5) Construction of the mooring dolphin : 1 dolphin
(3) Reinforcement of cargo handling capacity in response to the necessity of handling grain imports and the multipurpose use of the terminal
   1) Reinforcement of the cargo handling equipment
   2) Pavement of the open yards : Area of 42,000m^2

Incorporating the conclusions of this chapter and the results of the analyses of countermeasures against sand sedimentation and inefficient cargo handling systems, the proposed port layout in the target year is shown in Fig. 9.

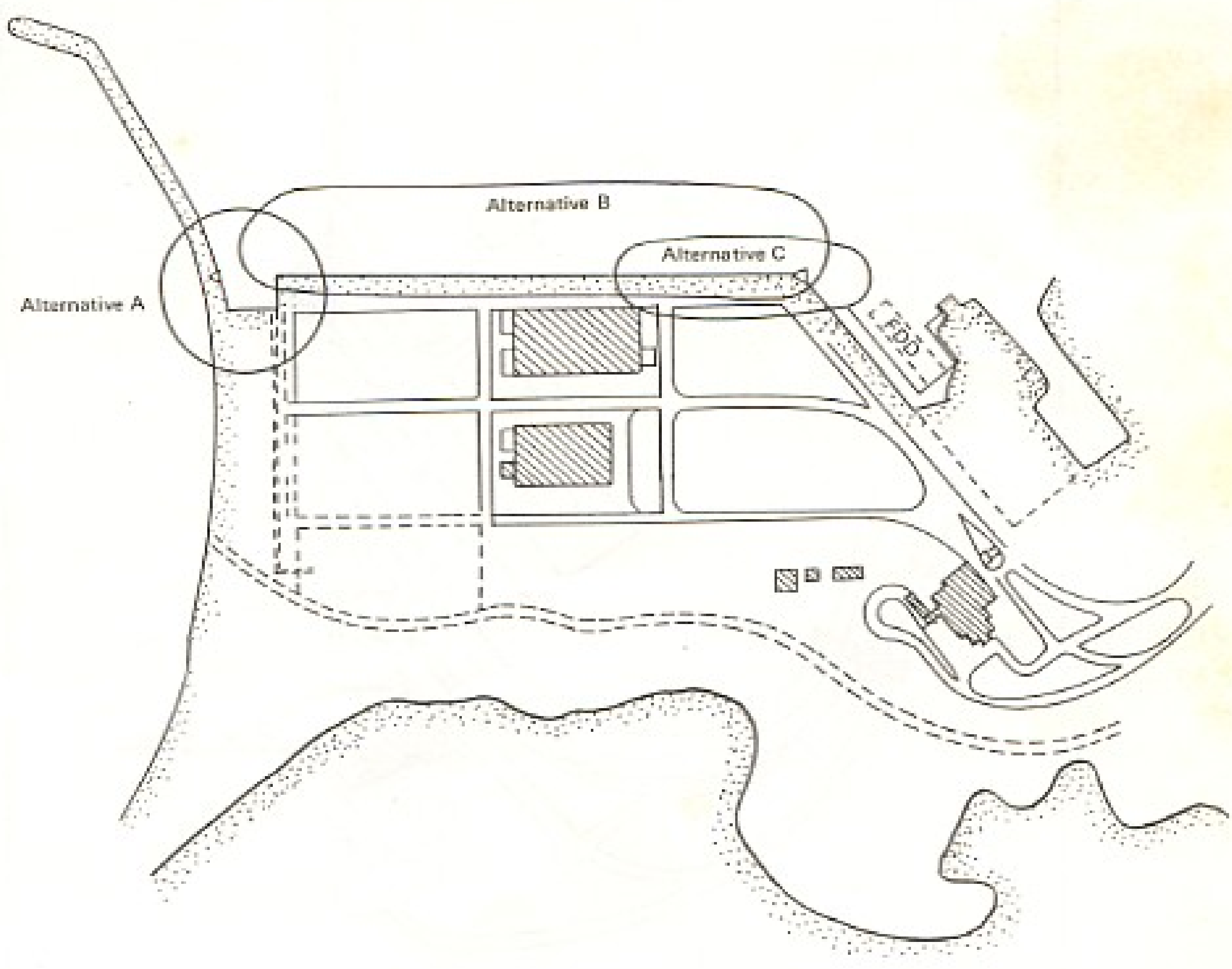


Fig. 8 Alternative Berth Extension Methods

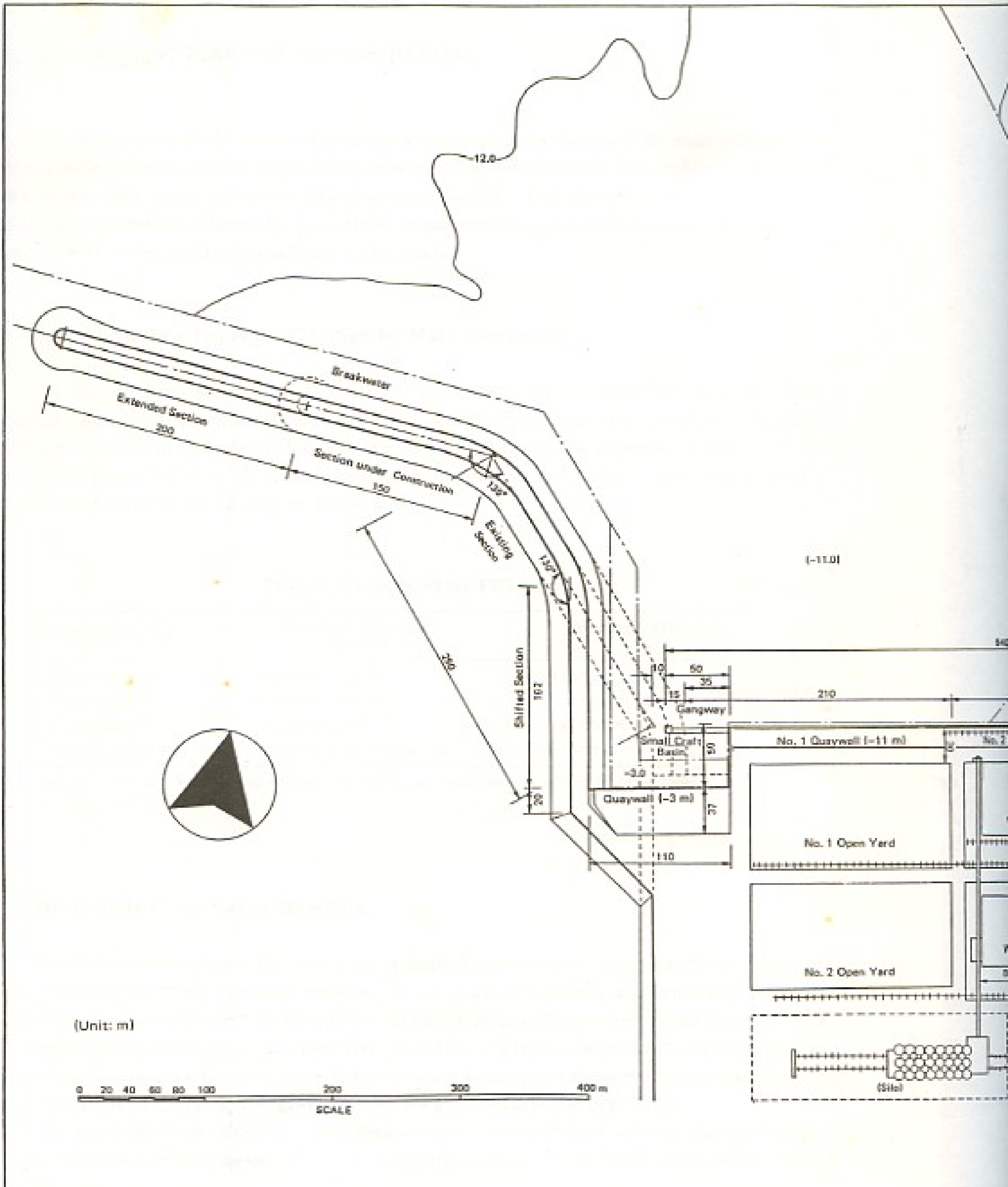
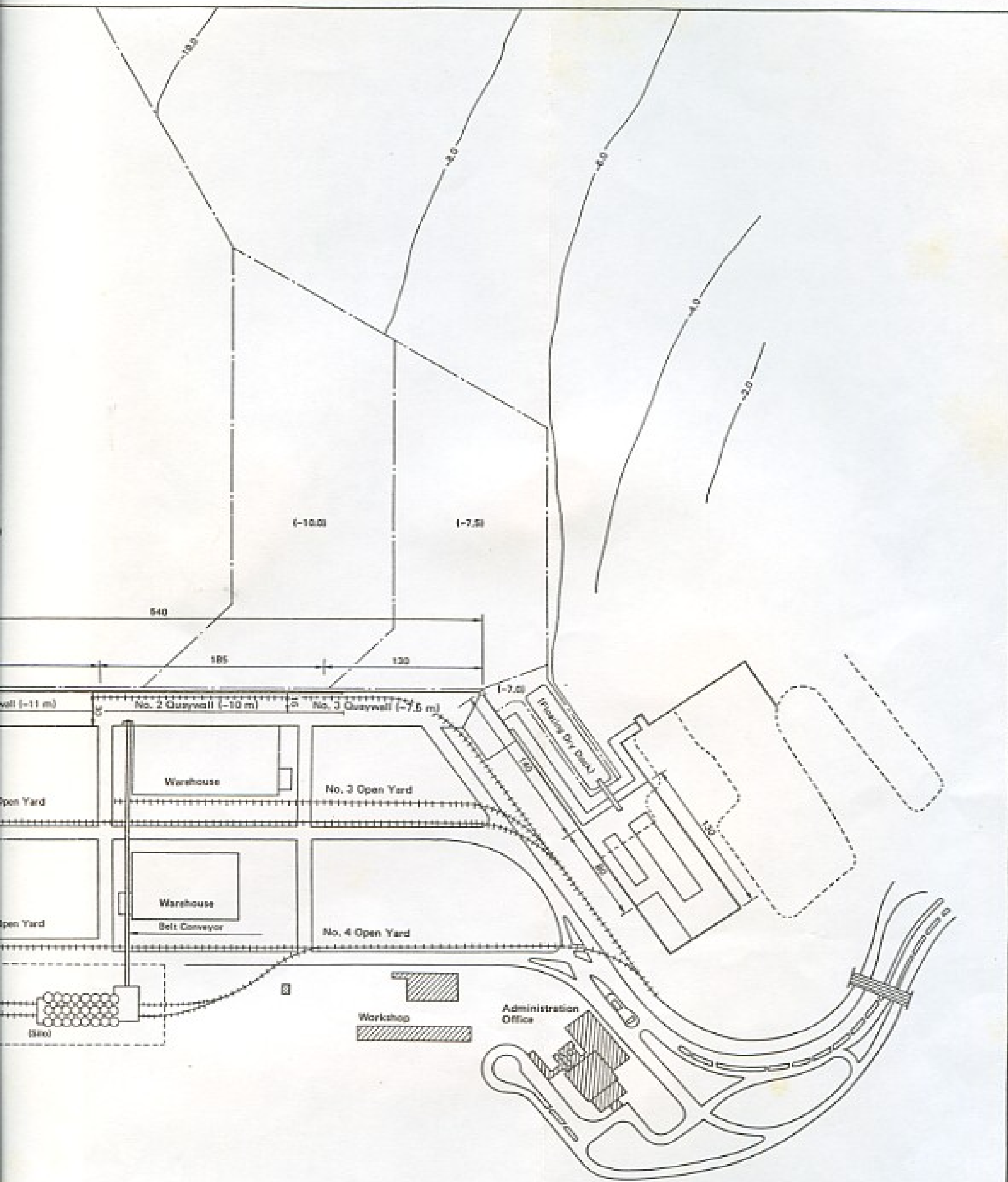


Fig. 9 Maintenance Plan of the



intenance Plan of the Port of Caldera

IV IMPROVEMENT PLAN FOR PORT OPERATIONS

The study aims at the multipurpose use of the terminal which will be able to accommodate a wide variety of cargoes including general cargo, steel goods, automobiles, containers, and break bulk grain using the existing three berths. For the multipurpose use of the terminal to function efficiently, systematic management and a well-coordinated operation system will be necessary as outlined in the study.

1. Cargo Handling Improvement Plan by Main Commodity

On the average, about 40% of the total working hours for handling cargo are being wasted. Reducing this wasted time is a key point of improving port operations. Actually, it is not possible to reduce this idle time to zero, but it should be possible to reduce it. The cargo working efficiency by cargo commodity at present and in the target year of 1992 at the Port of Caldera are shown in Table 8.

Table 8 Cargo Working Efficiency

Kind of Cargo	Working Efficiency in 1985	Working Efficiency in 1992
General cargo	20 metric tons/h	24 metric tons/h
Steel goods	40 metric tons/h	48 metric tons/h
Containers*)	7 containers/h	12 containers/h
Break bulk grain	20 metric tons/h/machine	200 metric tons/h/machine

Note: *) The container working efficiency in 1992 is assumed to be 80% of that in Japan under the same conditions.

2. Break Bulk Grain Cargo Handling

Grain cargo handling will have a great impact on the other cargo handling operations. The handling of grain is a new project for the Port of Caldera, and will require a large investment. The bottleneck in the present grain cargo handling system is the time lost when railway cars are changed on the pier and when the cars travel between Puntarenas pier and the silos. 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 operation, it is necessary to construct new silos at the port with at least the same capacity as the maximum handling tonnage of one grain cargo vessel, that is 20,000 tons.

For the grain cargo handling, the four alternatives shown below are studied.

Alternative I. 2,000 tons/h pneumatic unloader and a belt converyor of the same capacity (fully mechanized system).

Alternative II. Two 200 tons/h pneumatic unloaders and a 400 ton capacity belt converyor (fully mechanized system).

Alternative III. Unloading using ship's gear and unloading grab buckets, grain cargo is then carried by a belt conveyor system.

Alternative IV. Same unloading method as Alternative III, but grain cargo is carried to the silo by dumptrucks.

As noted in the study, Alternative II is recommended.

3. Storage Improvement Plan

The two existing warehouses and four existing open yards will be sufficient to cover demand in 1992. The overall layout plan is shown in Fig. 10.

Points to be improved are as follows :

(1) Yards No.2, 3, and 4 should be paved completely.

(2) Yards No.1, No.2 and part of No.4 should be lined with container slots.

(3) Yards No.3 and No.4 should be lined with suitable area units.

Fixed numbering of each area will make it easy to manage open yard cargo storage.

4. Terminal Improvement Plan

The maximum container storage capacity in 1992 is as follows:

Loaded containers : 1040 TEU

Empty containers : 288 TEU

The container yard allotment plan is shown in Figs. 11 (a) and 11 (b).

5. Cargo Handling Machinery

Cargo handling machinery presently owned by INCOP comprises 74 units as listed in Table 9. The additional machines recommended for the Port of Caldera are listed Tables 10 (a) and 10 (b).

6. Repairing and Training

Since the Port of Caldera opened in December 1981, INCOP has been directly executing repairs and maintenance works, except for major repairs. However, as most of the machines are becoming old, INCOP will need to reinforce its maintenance ability.

The cargo handling efficiency and all of the port operations depend upon the ability and attitude of the port workers. Thus, it is important to make efforts to train port workers in a systematic way.

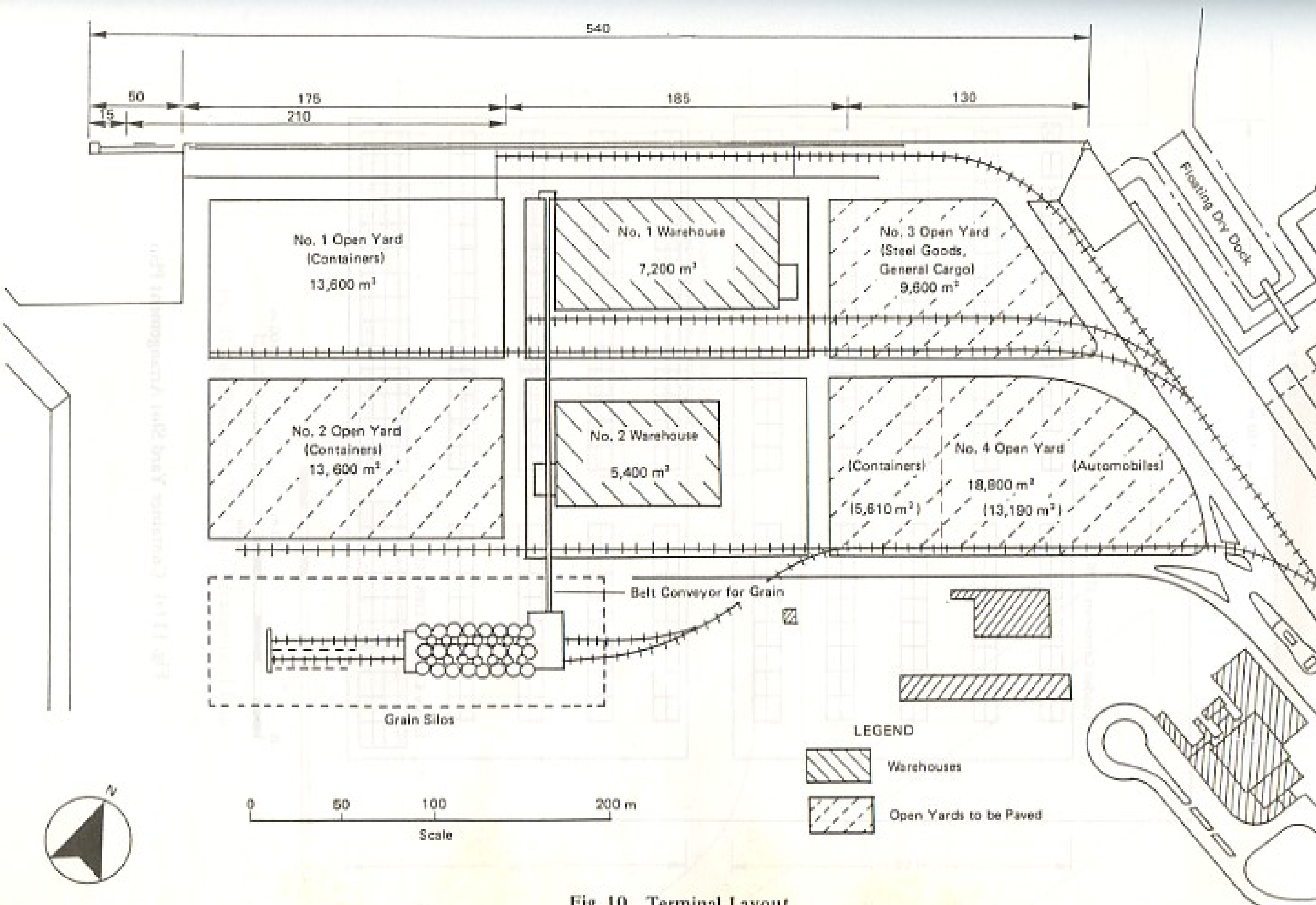


Fig. 10 Terminal Layout

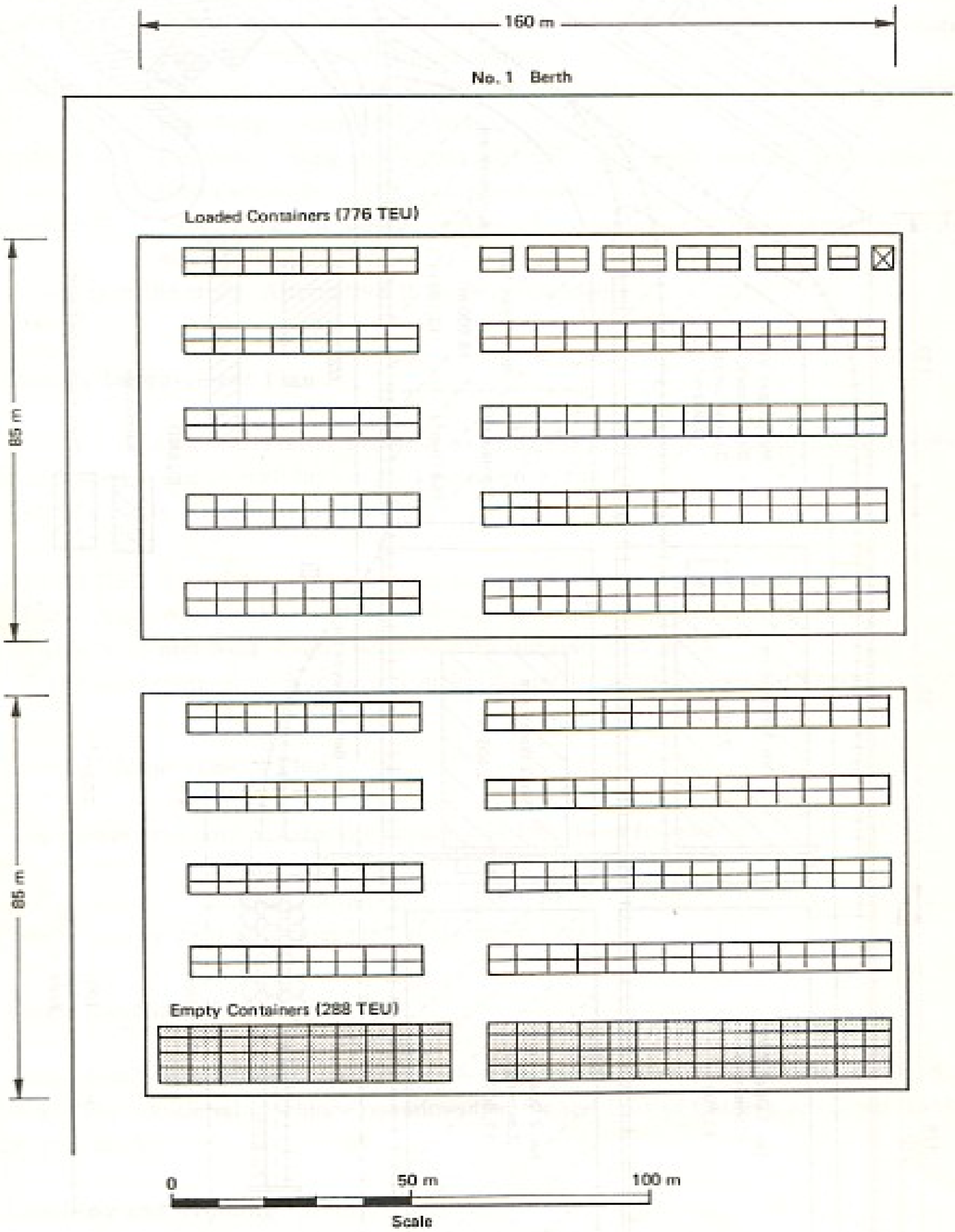


Fig. 11 (a) Container Yard Slot Arrangement Plan

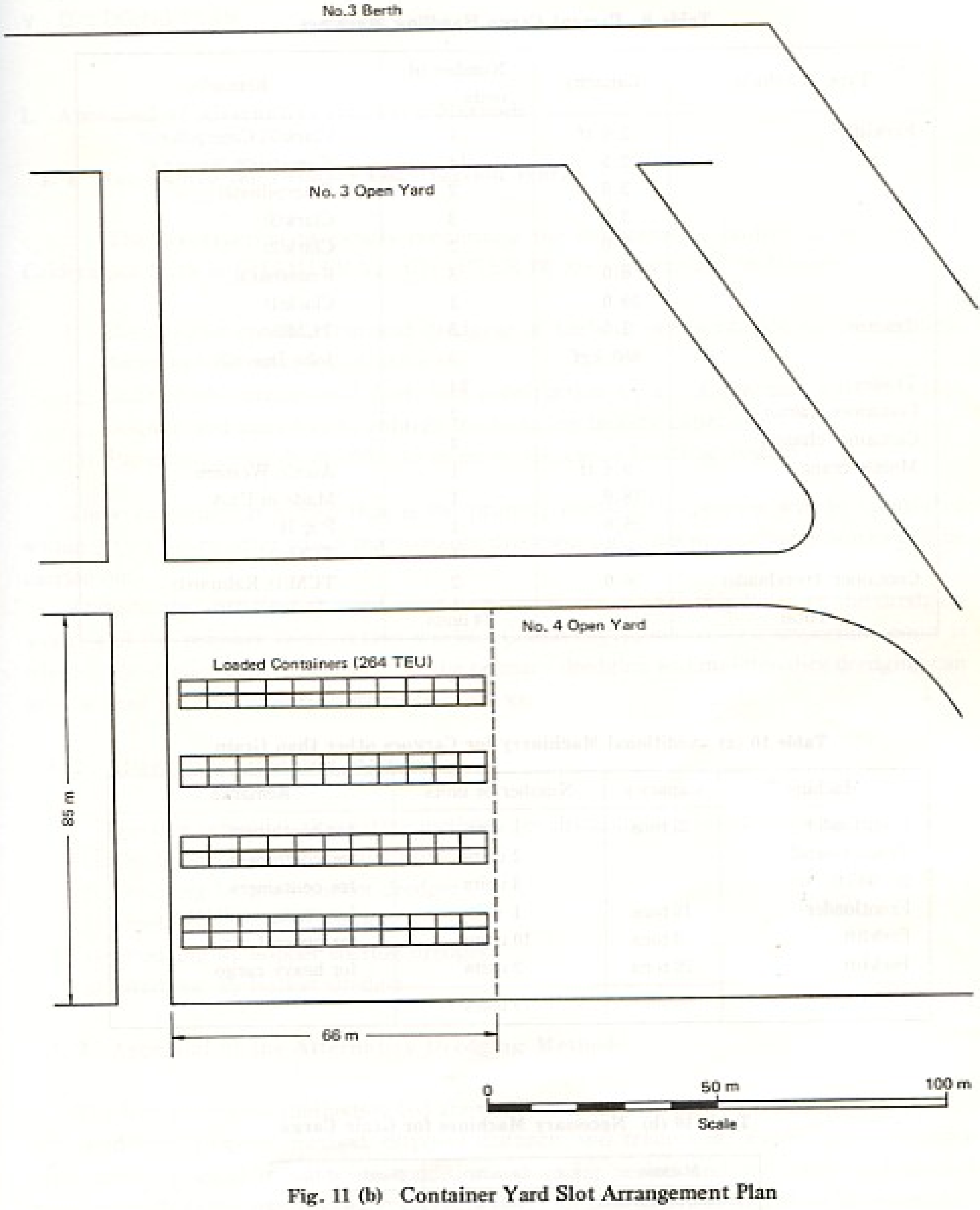


Fig. 11 (b) Container Yard Slot Arrangement Plan

Table 9 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	TCM(1)
Container frontloader	30.0	2	TCM(1), Kalmar(1)
Total		74 units	

Table 10 (a) Additional Machinery for Cargoes other than Grain

Machine	Capacity	Number of units	Remarks
Frontloader	35 tons	1 unit	for containers
Tractor head		2 units	for containers
20'/40'chassis		3 units	for containers
Frontloader	10 tons	1 unit	for empty containers
Forklift	3 tons	10 units	for general cargo
Forklift	20 tons	2 units	for heavy cargo
		19 units	

Table 10 (b) Necessary Machines for Grain Cargo

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

V DREDGING PLAN

1. Appraisal of Alternative Dredging Methods

1.1 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 as follows.

(1) Breakwater construction and dredging of harbour sedimentation as countermeasures 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

These construction works, that is the 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 primary 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.

1.2 Alternative Dredging Methods

The five principal alternative methods for dredging are listed below.

(1) Dredging by cutter suction dredger
(2) Dredging by grab bucket dredger
(3) Dredging by dipper dredger
(4) Dredging by hopper suction dredger
(5) Dredging by bucket dredger

1.3 Appraisal of the Alternative Dredging Methods

The five alternative methods noted above are evaluated in light of the following criteria: soil conditions, disposal method, disposal distance, soil treatment, water depth, dredging area, meteorological and marine conditions, working period and suitability for various purposes such as the breakwater construction. If an alternative is judged to be unsatisfactory in terms of any of these criteria, then that alternative cannot be recommended as the appropriate method for the dredging.

A consolidation of the evaluation is shown in Table 11. 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 11 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	$N \leqq 10$	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)

2. Execution Plan

2. 1 Dredging Volume

Dredging work may be divided into primary dredging and maintenance dredging. The 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 to maintain 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 when will accumulate over time in the mooring basin 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. Roughly speaking, subsequent maintenance dredging will be needed once every five years thereafter, and on each occasion dredged soil volume will be 60,000 m^3.

2. 2 Dredging Method

The material dredged by the grab dredger is to be transported by hopper barges and disposed of at sea. As indicated in Fig. 12, 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.

It must be noted that using the present MOPT cutter suction dredger for future maintenance work would not be possible.

Region A in Fig. 13 shows the area to be dredged, particularly 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 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 as shown in Fig. 14 is recommended.

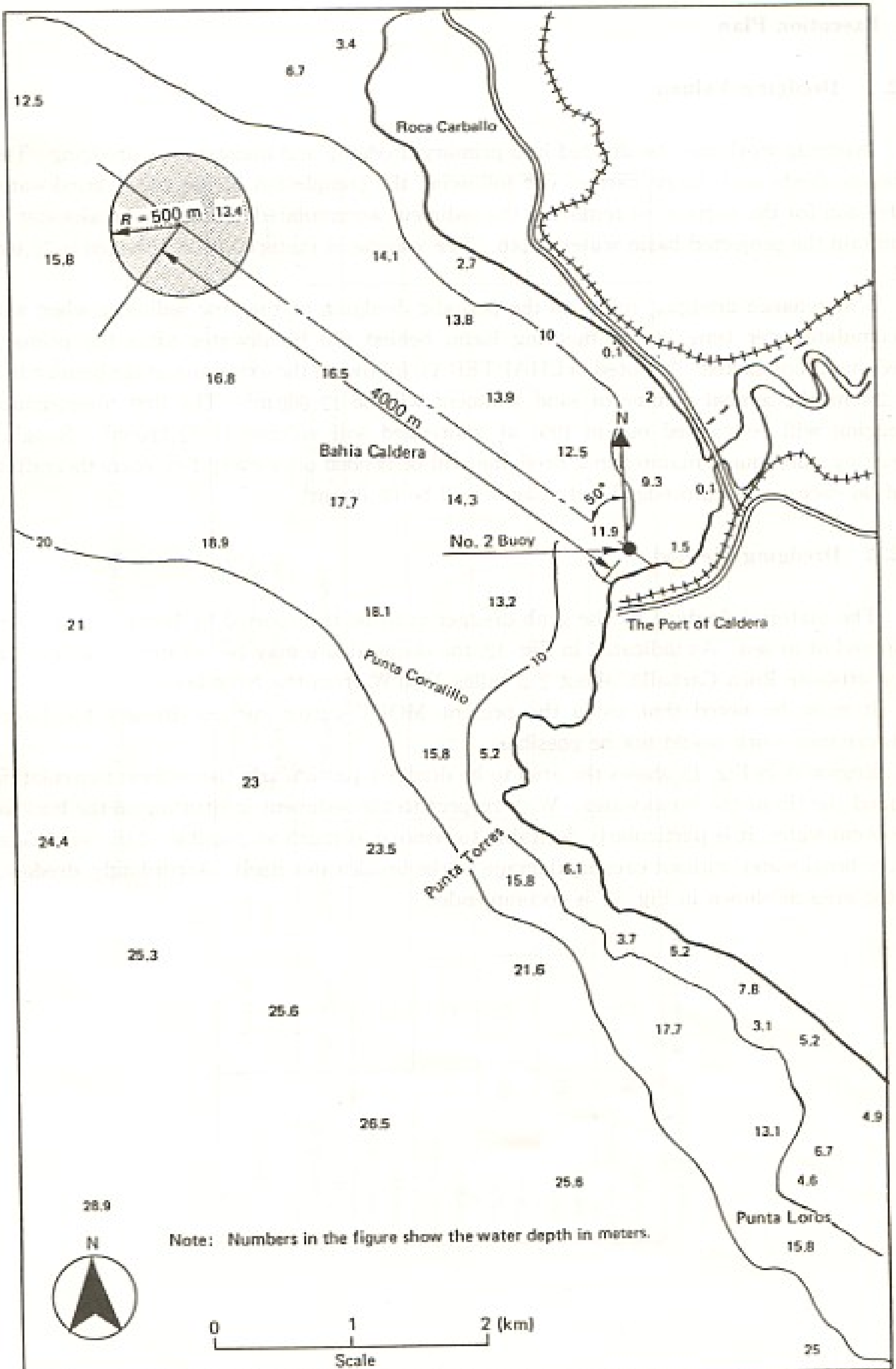


Fig. 12 Dumping Area

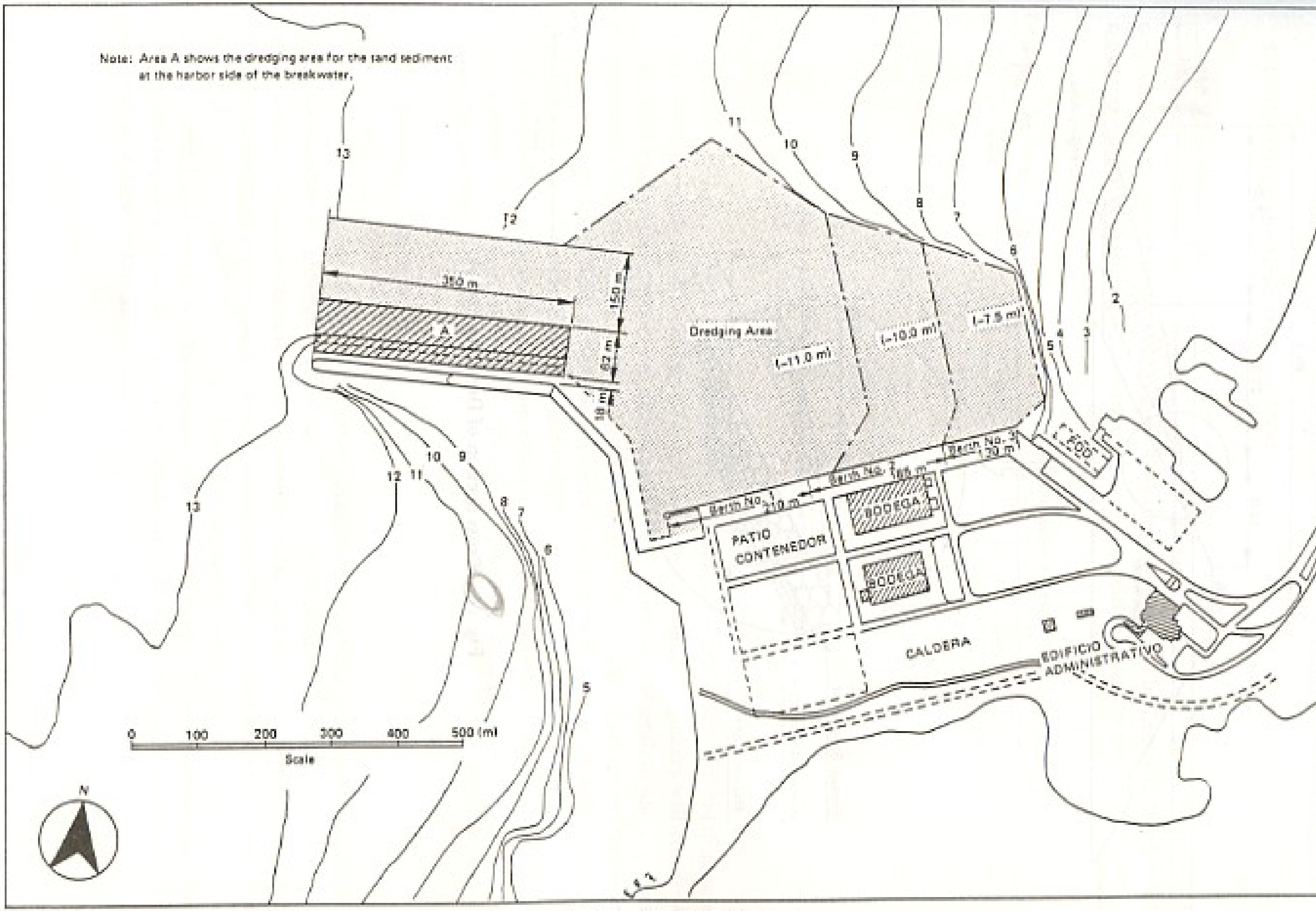


Fig. 13 Dredging Area

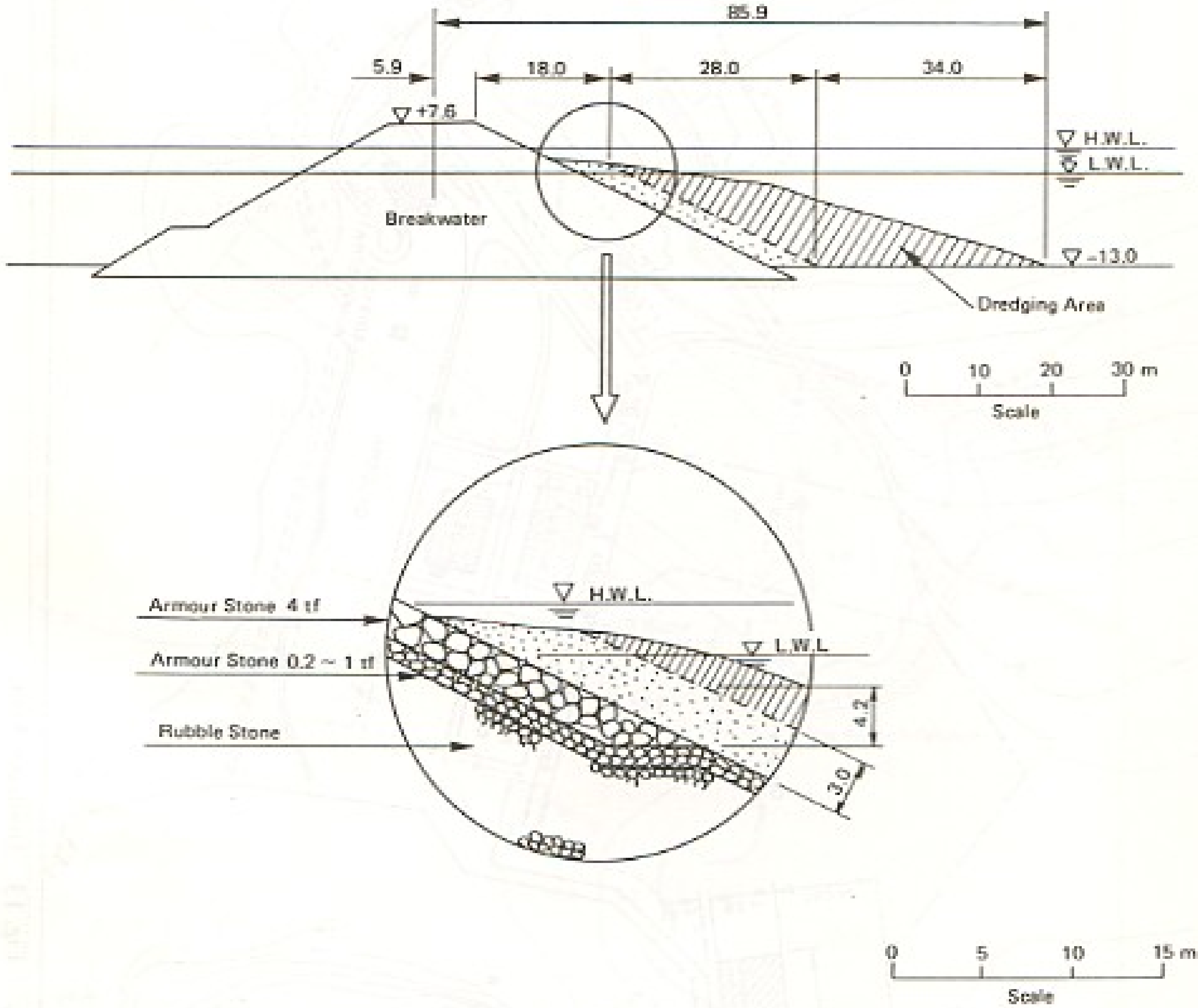


Fig. 14 Cross Section of Dredging Area A

3. Repairing the Grab Dredger Fleet and Training of Staff

3.1 Repairing the Grab Dredger Fleet

The vessels of the grab dredger fleet are listed in Table 12.

If MOPT obtains the 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 repairs and annual inspection and maintenance works.

Table 12 Grab Dredger Fleet

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

In order to carry out the daily maintenance and repair work efficiently, reinforcement of the existing repair facility and up to three maintenance repair engineers will be needed.

Regular major scale inspection, maintenance, and repair of the grab dredger, tugboat, hopper barges 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.

Fortunately, construction of a ship repair yard equipped with a floating dry dock is under way within the Port of Caldera. This facility will be ideal for use as a dry dock for the regular maintenance works.

3.2 Training System

For the maintenance dredging and other maintenance works, it is necessary for MOPT's fleet crewmembers 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.

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

VI 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
- Shift of the existing breakwater foot
- Construction of the −3.0 m quaywall 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

The designed cross-section of the extended breakwater is shown in Fig. 15

2. Implementation Plan of the Maintenance Project

2.1 Construction Execution Strategy

With respect to the countermeasures against sand sedimentation for the Port of Caldera specified in CHAPTER VI, the urgent extension of the breakwater, the primary dredging and the subsequent periodic maintenance dredging are all indispensable. Moreover, in order to support continued rational port activities at the port into the future, a comprehensive maintenance system for the various facilities must also be established.

The overall maintenance project at the Port of Caldera comprises the following two main parts.

(1) Construction of the various facilities and the procurement of a grab dredger fleet, construction machinery and cargo handling equipment.

(2) Subsequent regular maintenance dredging and maintenance works for the various port facilities after the target year.

The former, including the purchase of required cargo handling equipment, is hereafter referred to as the primary construction works and the latter as the maintenance works.

It would be ideal if MOPT could carry out the primary construction works itself. However, the projects are of a large scale and diverse makeup, and delays in implementing the countermeasures required to prevent sand sedimentation cannot be entertained. A consideration of MOPT's record of performance to date, as well as its present capacity to execute the various projects, indicates that the execution of primary construction works under direct MOPT management is not feasible. However, the maintenance works should be carried out directly by MOPT. Utilizing outside contractors for maintenance dredging

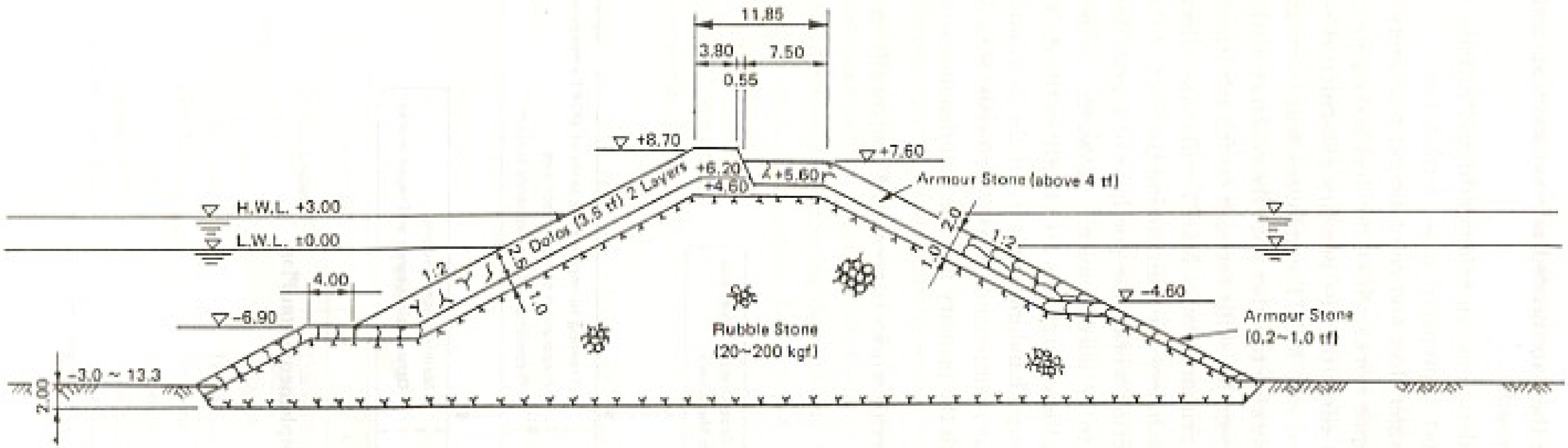


Fig. 15 Standard Cross Section of Rubble Mound Breakwater Armored by Dolos

and other maintenance works every time they are needed is uneconomical, and a timely response from contractors is not always possible.

Taking into account the above considerations, an economical and rational execution plan for the maintenance project of the port is prepared as set forth below.

MOPT will first procure the grab dredger fleet and construction machinery which are necessary to carry out the future maintenance works. Next, the fleet and equipment will be lent to the outside contractor engaged to carry out the primary construction works, and while the primary works are being carried out, MOPT employees will learn appropriate construction and dredging techniques by working together with the contractor while executing the primary works and thus acquire essential skills through on the job training.

Then, following the completion of the primary works, MOPT will make effective use of its grab dredger fleet and construction machinery for maintaining the Port of Caldera.

Only considering the primary construction works, the purchase of a grab dredger fleet and construction machinery would seem to be uneconomical. However, in the long run including the required maintenance period, these purchases are clearly justified. The vessels and tools are necessary to maintain the cargo handling capacity of the port, and, as noted above, it is not practical to have the regular maintenance works performed by a contractor. Considering the overall project, that is both the primary and the maintenance works, this is clearly the best plan.

This plan for the execution of the overall works is presented graphically in Fig. 16.

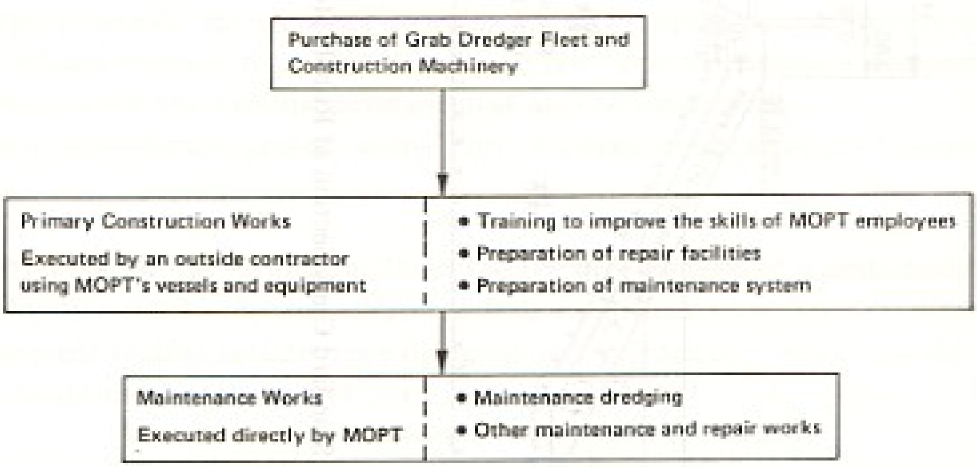


Fig. 16 Implementation Plan

2. 2 Excution Plan for Each Facility

2. 2. 1 Breakwater Extension

The extension of the breakwater is urgently needed to counter the sand sedimentation, and the extension must be completed within a short period of time to minimize the possibility that the breakwater might be damaged by rough sea conditions while under construction. Accordingly, in addition to the land-based construction carried out to date by MOPT, a combined method which includes sea-based construction work should also be considered.

The grab dredger fleet can be used for general maritime construction works by adopting various attachments, and hence it is ideal for the present project in which the breakwater extension and primary dredging are the principal primary works.

The construction work of the breakwater includes the construction of the temporary facilities such as the Dolos fabrication yard and the temporary loading pier for stones and other construction materials.

2. 2. 2 The Other Facilities

The agenda for other construction works is as follows :

(a) Shifting of the breakwater foot (including the shifting of the light beacon)
(b) Construction of a −3.0 m quaywall
(c) Construction of a mooring dolphin and gangway
(d) Construction of a repair facility for the grab dredger fleet and construction machinery
(e) Primary dredging
(f) Pavement of the yards

2. 3 Requisite Grab Dredger Fleet and Construction Machinery

The grab dredger fleet and construction machinery which should be obtained by MOPT are listed in Table 13 and Table 14.

Table 13 Grab Dredger Fleet

Vessels	Capacity	Quantity
Grab Dredger	D.E.640PS, 4.0m³	1
Hopper Barge	300m³	2
Tug Boat	D.400PS	1
Anchor Boat	D.90PS, 5 ton winch	1
Flat Barge	300 tons	1
Jolly Boat	D.100PS, 13 GT	1
Diving Boat	D.30PS, 3 ton winch	2
Survey Boat	D.40PS, 6 GT	1

Table 14 Construction Machinery

Machinery	Capacity	Quantity
Crawler Crane	80 ton	1
Crawler Crane	16 ton	2
Dump Truck	230PS, 18 ton	9
Bulldozer	141PS, D-6	3
Back Hoe	188PS, $2m^3$	1
Grader	108PS, 3.6m	1
Tyre Roller	85PS, 8 ~ 20tf	1
Wheel Loader	235PS, $3.5m^3$	1
Compressor	174PS, $17m^3/min$	1
Earth Drill	60-114mm	2
Vibrator	60 kVA	1
Trailer	320PS, 40ton	2
Generator	370PS, 300kVA	1

2. 4 Schedule of the Caldera Port Maintenance Project

The proposed schedule of the Caldera Port maintenance project is given in Fig. 17.

3. Cost Estimate

The cost estimate is presented in Table 15.

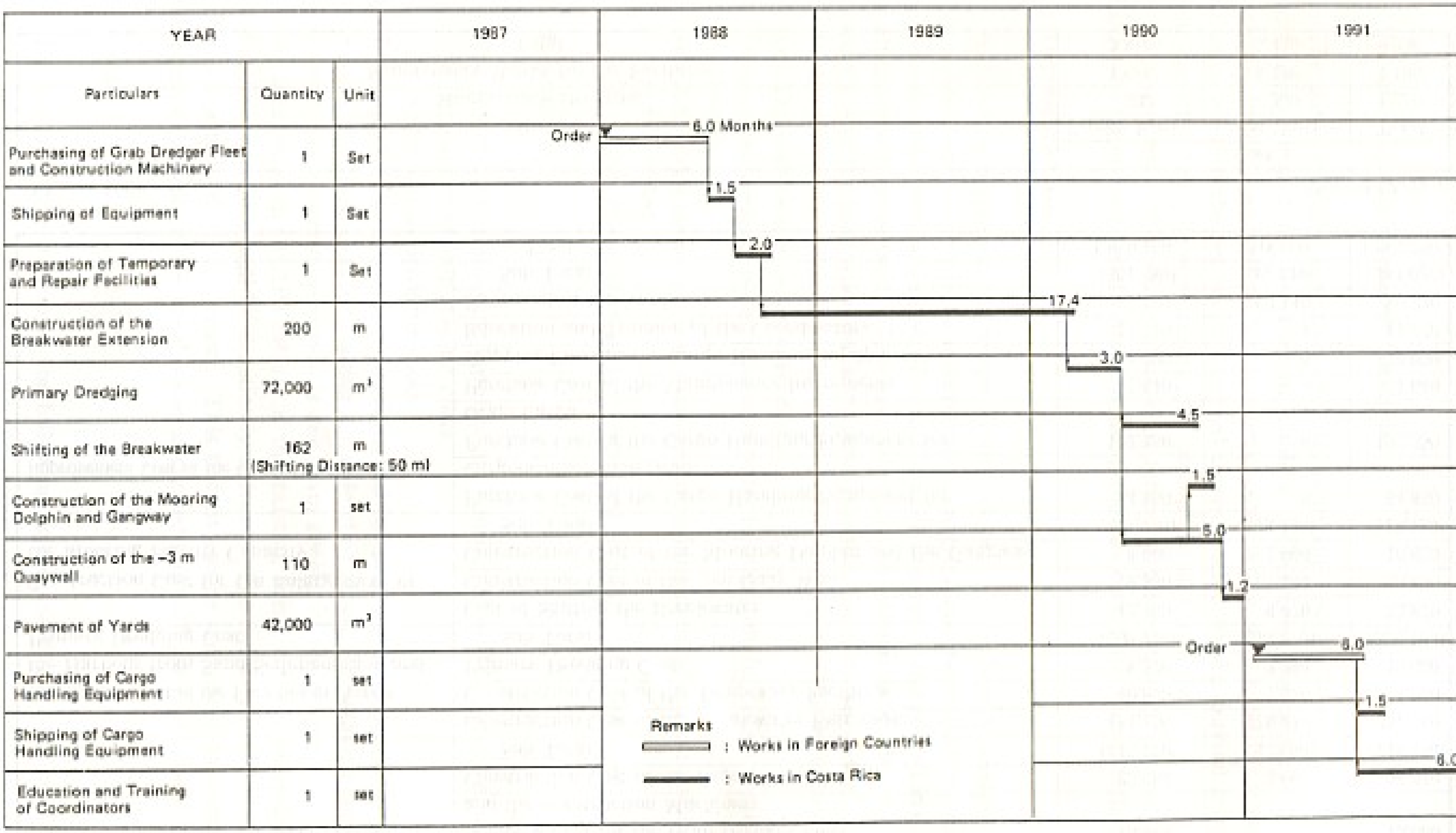


Fig. 17 Construction Schedule of the Project

Table 15 Total Cost of the Maintenance Project

(1) Project Cost

(Unit : '000 ¢)

Item	Sub Item	Cost		
		Foreign Portion	Local Portion	Total
Purchase Costs of the Grab Dredger Fleet and Construction Machinery, and Related Costs	Purchase Cost of the Grab Dredger Fleet	165,250	0	165,250
	Purchase Cost of the Construction Machinery	183,490	0	183,490
	Shipping Cost for the Grab Dredger Fleet and the Construction Machinery	73,080	0	73,080
	Construction Cost of the Repair Facilities	23,950	2,660	26,610
	Sub Total	(445,770)	(2,660)	(448,430)
Construction Cost of the Facilities to Protect the Harbour from Sand Sedimentation and Primary Dredging Cost	Construction Cost of the Breakwater Extension	181,150	116,410	297,560
	Construction Cost of the Temporary Facilities	10,890	1,070	11,960
	Primary Dredging Cost	8,270	2,390	10,660
	Sub Total	(200,310)	(119,870)	(320,180)
Construction Cost for the Enlargement of the Mooring Facility Capacity	Cost of Shifting the Breakwater	43,900	9,970	53,870
	Construction Cost of the -3m Quay Wall	19,230	31,400	50,630
	Construction Cost of the Mooring Dolphin and the Gangway	8,660	1,960	10,620
	Sub Total	(71,790)	(43,330)	(115,120)
Improvement Cost of the Cargo Handling System	Purchase Cost of the Cargo Handling Equipment for Cargoes other than Grain	64,850	0	64,850
	Purchase Cost of the Cargo Handling Equipment for Grain Cargo	192,350	0	192,350
	Purchase Cost of the Maintenance Instruments	1,640	0	1,640
	Shipping Cost for the Cargo Handling Equipment	24,090	0	24,090
	Education and Training of the Coordinators	11,770	0	11,770
	Pavement of the Yards	7,180	82,140	89,320
	Sub Total	(301,880)	(82,140)	(384,020)
Total		1,019,750	248,000	1,267,750

(2) Annual Maintenance Cost

(Unit : '000 ¢ /year)

Item	Cost		
	Foreign Portion	Local Portion	Total
Maintenance Dredging	930	300	1,230
Maintenance Works for the Facilities	1,980	5,120	7,100
Total	2,910	5,420	8,330

VII ECONOMIC ANALYSIS

1. Viewpoint of the Economic Analysis

The purpose of the economic analysis is to appraise the economic feasibility of the maintenance project for the Port of Caldera. Therefore, the analysis investigates the economic benefits as well as the economic costs which will arise from the project, and evaluates whether the net benefits exceed those which could be derived from other investment opportunities (the opportunity cost of capital) in Costa Rica.

The economic return is evaluated in terms of the economic internal rate of return (EIRR) based on cost benefit analysis using the Discount Cash Flow Method.

2. Alternative Case

In order to determine the return on the project, a cost benefit analysis is conducted. That is, the costs which will be incurred from carrying out the project are subtracted from the benefits which will be gained. To calculate the benefits of the project in economic terms, an alternative case is used. The case when an investment is made, the With Case, is compared with the case when no investment is made, the Without Case.

In this study, the following conditions are adopted as the Without Case :

(a) The breakwater is not extended.

(b) Annual dredging is carried out in order to maintain the design depth of the existing berths.

(c) Additional equipment and facilities for enlargement of cargo handling capacity are not provided.

(d) The same grain terminal is constructed as under the With Case.

3. Benefits

The following two tangible benefits, are considered in this statistical analysis :

(1) Reduction of ship staying costs

(2) Reduction of dredging costs

Investment in improved port facilities and equipment will reduce the waiting period for berth space and the period for loading and unloading cargo. The staying period of ships will be reduced, and this cost reduction is one main benefit of the project.

As mentioned in CHAPTER VI, if the existing breakwater is extended by 200 m, the sand sediment volume will be drastically reduced. The reduction of dredging costs is the other major benefit of the project. This benefit can be calculated by comparing the case where the extension of the breakwater is carried out with the case where it is not.

4. Costs

For calculation of the costs, the following prerequisites are considered :

(1) The period of economic calculation (project life) is assumed as 30 years from the beginning of the construction (i.e. from 1988 to 2017).

(2) For calculation of the construction cost of individual facilities such as the break-water extension and the shifting the breakwater foot and also for dredging costs, the concept of monthly rental fees against the purchase costs of the grab dredger fleet and construction machinery are applied. In the calculation of the rental fees, the lives of the fleet and repair facilities are estimated as 15 years, and the lifetime of the construction machinery is estimated as 7 years.

(3) The construction cost of the grain terminal is not included in the costs because the cost remains the same under both the With and Without Cases.

(4) Dreding costs are calculated based on the dredging volume in Fig. VI—26 (a).

(5) The life of the cargo handling equipment except for maintenance tools is estimated as 10 years, and the life of maintenance tools is estimated as 15 years.

(6) Maintenance costs for each piece of equipment and for each facility are considered.

(7) The salvage values of the cargo handling equipment and the maintenance tools in the With Case and the salvage value of the grab dredger fleet in the Without Case are considered in 2017.

5. Economic Profitability

The EIRR of the project is calculated to be 23.7%.

There are various views concerning the evaluation of the EIRR to guide the judgement as to whether a project is feasible or not. The leading view is that the project is feasible if the EIRR exceeds the local opportunity cost of capital.

In port investment projects, EIRRs usuall range from 10% to 20%. It is generally considered that a project with an EIRR of more than around 10% is economically feasible. In this case, only taking into consideration the two items which are easily quantified, the EIRR of the project is 23.7%. Therefore, the project is considered to be feasible.

6. Sensitivity Analysis

Sensitivity analysis is made for three cases as follows ;

(1) Case EA : The construction costs other than the costs of dredging and the purchase costs of the dredging fleet, construction machinery and cargo handling equipment increase by 10%.

(2) Case EB : The forecast port cargo volume decreases by 10%.

(3) Case EC : The ship costs decrease by 29%.

The calculation results of the sensitivity analysis prove that each case would be feasible.

7. Conclusion

From the viewpoint of the economic analysis, that is the benefit of the nation, this project can be regarded as feasible.

VII FINANCIAL ANALYSIS

1. Viewpoint of the Financial Analysis

The purpose of the financial analysis is to ascertain the financial viability of the project itself. The investment effects of this project are analysed based on the financial internal rate of return (FIRR) using the Discount Cash Flow Method.

The objects of this financial analysis are limited to the revenues and costs related to this project. The revenues which will be considered as arising from this project are the port tariffs on the incremental cargo volume except for grain cargo, i. e. on the cargo volume difference between the Without Case in 1991 and the With Case in 1992, and all the port tariffs which will be collected from the handling of grain cargo. Costs considered in this study are limited to the construction costs for enlargement of the cargo handling capacity as listed below.

(a) Shift of the foot of the existing breakwater
(b) Construction of the −3.0 m quaywall
(c) Construction of the mooring dolphin and gangway
(d) Pavement of the open yards
(e) Purchase of additional cargo handling equipment
(f) Purchase of grain cargo handling equipment

2. FIRR

The FIRR of the project is calculated as 8.26%.

The desirable level of FIRR varies depending on the time and place and the expectations of the lender and borrower. For borrowers, the average interest rate paid on borrowed funds is the lower limit. In this project, 76.3% of the overall construction cost is the foreign portion, and it is assumed to be raised through soft loans with a 4.75% interest rate. Therefore, the FIRR is required to exceed 3.62%, which is the weighted average interest rate for all the project funds. Judging from this point of view, this project can be regarded as feasible, since the FIRR of 8.26% is well above the weighted average interest rate.

3. Sensitivity Analysis

Sensitivity analysis is made for three cases as follows :

(1) The port tariff revenues decrease by 10% (Case FA)
(2) The construction costs increase by 10% (Case FB)
(3) The revenues decrease by 10% and the costs increase by 10% simultaneously (Case FC)

The FIRR is calculated for each of the 3 simulation cases. The calculations show that every FIRR exceeds the lower limit of 3.62%. The results of the sensitivity analysis thus prove that each case would be feasible.

4. Conclusion

From the viewpoint of the financial analysis, that is the profitability of the project itself, this project can be regarded as feasible.

INTRODUCTION

[INTRODUCTION]

1. The Background of the Study

The area of the Republic of Costa Rica is about 50,000 km^2, and the population is about 2.46 million as of 1984. The country's economy is centered on such agricultural products as coffee, bananas, sugar and beef, and the economy is quite active. The GDP per capita is higher in Costa Rica than in the other countries of Central America.

As for the foreign trade of Costa Rica, the main commodities are agricultural products such as coffee and bananas for export, and industrial products for import. Trade is conducted not only with Central American countries but also with Japan, Europe, Asia, and North and South America. For some years, marine trade in Costa Rica had been conducted mainly through the Port of Puntarenas on the Pacific coast and the Ports of Limón and Moin on the Atlantic coast.

However a few years aso, as the facilities at the Port of Puntarenas were becoming superannuated, it became necessary to develop new port for the Pacific coast trade. Rather than invest a large amount of capital to restore existing facilities and provide new facilities at Puntarenas, the Government of Costa Rica decided to construct the Port of Caldera, about 15 km from the old port at that time. The Port of Caldera was opened when the first stage construction work, including three quaywall, was completed in December 1981. Over time, the new Port of Caldera will take over all the port functions of the Port of Puntarenas.

However, it has become necessary to take appropriate measures against sand sedimentation at the present port. It has also become necessary to respond to such problems as a shortage of cargo handling equipment caused by the diversification of commodity items, and insufficient berth length because of increased ship size.

Moreover, the National Development Plan, 1982-1986 (1983, MIDEPLAN) is centered on the promotion of agriculture and industry and the development of such infrastructures as ports and roads. This plan shows the direction of the future socioeconomic development in Costa Rica. Therefore, the Port of Caldera will play an important role in the development of the national economy.

Along with this, it has become necessary to conduct a maintenance project for the existing first stage facilities at the Port of Caldera as stated in the National Transport Plan (November 1981, MOPT). This project will help to alleviate the urgent problems at the port through restoration and maintenance works on the existing structures. Thus, the Port of Caldera will continue to fulfill its vital role as a transportation center for the Pacific coast by utilizing the existing facilites to the utmost extent.

2. The Study Objectives

The objectives of this study are to establish measures to respond to such technical problems as sand sedimentation in the harbour, insufficient berth size, and a shortage of port cargo handling equipment, and to plan a maintenance project including a feasibility study based on the proposed measures so that the port can function as the main gateway on the

Pacific coast for the Republic of Costa Rica.

3. Circumstances

In response to a request from the Government of the Republic of Costa Rica to carry out a feasibility study on the Maintenance Project of the Port of Caldera, the Government of Japan dispatched a Contact Mission headed by Mr. Takashi Hashikawa, JICA to clarify the contents of the request in Februay 1985.

The Government of Japan thereafter decided to conduct the study, and dispatched the Preliminary Study Team headed by Dr. Isao Irie, JICA to form the Scope of Work for the study in May 1985. The team had a series of discussions about the study with Costa Rican government officials. The Scope of Work was agreed upon on May 27, 1985 by Ing. José G. Chacón L., Director General of DGOPF/MOPT and Dr. Isao Irie, Leader of the JICA Preliminary Study Team.

Based on the Scope of Work, JICA organized and dispatched a full-scale study team headed by Mr. Takashi Hazama, Senior Executive Director of OCDI. The study team then collected data and performed field surveys in Costa Rica. The study team prepared the Progress Report at the end of the field surveys.

The study team then analysed the data collected in Costa Rica and prepared the Draft Final Report. The study team submitted the Draft Final Report to MOPT and had a series of discussions on the report with MOPT as well as conducting seminars as a form of technology transfer in June 1986. MOPT, which is the counterpart aqency of the Costa Rican Government, generally aqreed upon the content of the Draft Final Report.

4. The Study Items

The study items are as follows :

- Demand Forecast
- Port and Harbour Planning
- Port Operation Planning
- Natural Conditions
- Countermeasures against Sand Sedimentation
- Dredging
- Design, Construction and Cost Estimate
- Economic Analysis
- Financial Analysis

5. Participants in the Study

5. 1 The JICA Study Team

DUTY	NAME	ORGANIZATION
Team Leader Overall Management	Takashi Hazama	OCDI (Senior Executive Director)
Sub-leader Demand Forecast and Port and Harbour Planning	Shigeru Murata	OCDI
Port Operation Planning	Satoshi Tanami	OCDI
Countermeasures against Sand Sedimentation	Hiroshi Okamoto	OCDI
Economic Analysis and Financial Analysis	Taketo Fujii	OCDI
Design, Construction and Cost Estimate	Takeo Katayama	CCI
Dredging	Jun Hamano	CCI
Natural Conditions	Yoshio Yano	CCI
Co-ordination	Atsushi Kawai	JICA
Co-ordination	Kohichi Aita	JICA
Co-ordination	Aiichiroh Yamamoto	JICA

5. 2 The Costa Rican Counterparts

(1) MOPT

NAME	POSITION
Ing. José G. Chacón Laurito	Director, Subdivision of Development,
Ing. Alfredo Wesson Acuña	Director General, DGOPF
Ing. Ronald Mesén Vega	Design Section, Chief, DGOPF
Ing. Edwin Rodriguez Aguilera	Maintenance and Conservation Section, Chief, DGOPF
Ing. José Fabio Gutierrez Jiménez	Engineering Survey Section, Chief, DGOPF
Ing. Aristides Romero Vargas	Engineering Survey Section, Assistant, DGOPF
Ing. Gilberto Rodriguez Pacheco	MOPT Caldera Office, Head
Ing. Jeannette Muñoz Vivas	Planning and Design Section, Assistant, DGOPF
Ing. Greevey Picado Soto	Design Section, DGOPF

(2) INCOP

NAME	POSITION
Sr. José Aponte Quirós	Planning and Development Direction, Chief
Sr. Tom Ingram Winfield L.	Port Operation Direction, Chief
Sr. Franklin Cerdas Delgado	Accounting, Administration and Financial Department
Ing. Hugo Chavarría B.	Storage and Port Operation Department.

6. The Field Surveys

6. 1 The Field Survey Periods

The field surveys in Costa Rica were conducted in the fall of 1985 and the early summer of 1986 as follows :

First Survey : September 24, 1985 ~ November 22, 1985
Second Survey : May 26, 1986 ~ June 14, 1986

6. 2 The First Field Survey Activities

During the first field survey, the study team held a series of discussion with representatives of the Costa Rican government and visited related government and other public offices and private companies in Costa Rica in order to collect data and information necessary for the execution of the study. The study team made several on-site inspections at the Port of Caldera to understand the present situation in detail, and visited related ports in Costa Rica to determine the relationship among these ports. Some study team members executed the natural conditions survey at the Port of Caldera with the full assistance of MOPT and INCOP during the period from Oct. 7 through Nov. 7. Two study team members visited a ship repair facility located in Panamá.

The rough itinerary during the first field survey of the study team is presented below.

Date	Activities
24 th Sep.~25 th Sep.	Departure from Japan
26 th Sep.~28 th Sep.	Meeting with MOPT Data collection in San José
29 th Sep.~2 nd Oct.	Field Survey at the Port of Caldera Data collection at Caldera and Puntarenas Interview survey.
3 rd Oct.~6 th Oct.	Data collection and interview survey in San José
7 th Oct.~9 th Oct.	Field survey in the hinterlands of the ports on the Pacific coast
10 th Oct.~16 th Oct.	Data collection and interview survey in San José
17 th Oct.	Flight tour around the Port of Caldera
18 th Oct.~20 th Oct.	Data collection and interview survey in Caldera and Puntarenas
21 st Oct.~27 th Oct.	Data collection and interview survey in San José
28 th Oct.~29 th Oct.	Field survey in the hinterland of the ports on

	the Atlantic coast
30 th Oct.～ 5 th Nov.	Data collection and interview survey in San José
6 th Sep.～13 th Nov.	Preparation of the Progress Report
14 th Nov.	Discussion on the Progress Report with MOPT
15 th Nov.～17 th Nov.	Data collection and field survey in San José
18 th Nov.	Discussion on the Minutes of Meeting with MOPT
19 th Nov.	Courtesy call to the agencies concerned
20 th Nov.～21 th Nov.	Leave for Japan

6. 3 The Second Field Survey Activities

During the second field survey, the study team presnted the Draft Final Report to the Costa Rican Government and had a series of discussions with MOPT, the counterpart agency of the Costa Rican Government, as well as holding seminars for technology transfer in San José and Puntarenas.

Based on the report and the discussions, the study team and MOPT exchanged the Minutes of Meeting, which note that MOPT generally agreed upon the contents of the Draft Final Report.

The rough itinerary during the second field survey of the study team is presented below.

Date	Activities
26 th May ～ 27 th May	Departure from Japan
28 th May ～ 1 st June	Meeting with MOPT
	Field Survey at the Port of Caldera
	Preparation for the seminar
	Interview Survey at IDB in Washington D.C.
2 nd June ～ 4 th June	Presentation of the Draft Final Report
5 th June ～	Seminar at INCOP
6 th June ～ 9 th June	Discussion on the Draft Final Report
10 th June	Presentation to the Minister and the Vice Minister of MOPT
11 th June	Agreement on the Minutes of Meeting
	Seminar in San José
12 th June ～ 14 th June	Leave for Japan

6. 4 Organizations Visited by the Study Team

Organizations visited by the study team are listed below :

[SPANISH]	[ENGLISH]
Astilleros Balboa, S. A.	Balboa Shipyard Co., Ltd.
Banco Central de Costa Rica	Central Bank of Costa Rica
Constructora Costarricense S. A.	Costa Rican Construction Co., Ltd.
Consejo Nacional de Producción	National Production Council
Corporación Zona Franca de Exportaciones y Parques Industriales	Export Free Zones and Industrial Parks Corporation
Fertilizantes de Centroamérica (Costa Rica) S. A.	Fertilizer Co. of Central America (Costa Rica), Ltd.
Flota Mercante Gran Colombia S. A.	Grand Colombia Merchant Marine Fleet Co., Ltd.
Galvatica S. A.	Galvatica Co., Ltd.
Tranp. Internacional GASH	Tranp. International GASH
Instituto Costarricense de Ferrocarriles	Costa Rican Railway Agency
Instituto Costarricense de Puertos del Pacífico	Costa Rican Pacific Ports Authority
Junta de Administración Portuaria y de Desarrollo Económico de Vertiente Atlántica.	Authority for the Port Administration and Economic Development of the Atlantic Coast
Laminadora Costarricense S. A.	Costa Rican Rolling Machine Co., Ltd.
Liga Agricola Industrial de la Caña de Azúcar	Sugar-manufacturing Industry Corporation

METALCO S. A.	METALCO Co., Ltd.
Ministerio de Planeación y Política Económica	Ministry of Economic Planning
Ministerio de Obras Públicas y Transportes	Ministry of Public Works and Transport
Náutica Centroamericana	Central American Navigation Co., Ltd.
Servicio Nacional de Aguas Subterráneas, Riego y Avenamiento	National Agency for Underground Water Irrigation and Drainage.
Secretaria Ejecutiva de Planificación Sectorial, Agropecuaria y de Recursos Naturales Renovables	Executive Secretary's Office for Sectoral Planning, Agriculture and Renewable Natural Resources.
SERVICA S. A.	SERVICA Co., Ltd.
Talleres Manley S. A.	Talleres Manley Co., Ltd.
Técnico en Planificación	Technical Planning Co., Ltd.
Tempisque Ferry Boat S. A.	Tempisque Ferry Boat Co., Ltd.
Textiles Industriales de Centroamérica S. A.	Central American Textiles Industry Co., Ltd.

STUDY RESULTS

CHAPTER I.–XII.

CHAPTER I OUTLINE OF COSTA RICA

1. Geography

Costa Rica extends from latitude N 11°13' to N 8°02'. It is a narrow country, located roughly between longitude W 83° and W 86°, comprising part of the Central American isthmus. Costa Rica is bordered on the north by Nicaragua, on the south by Panamá, on the west by the Pacific Ocean and on the east by the Atlantic Ocean.

The area of Costa Rica is about 51,000 km^2. The maximum length of the country from the Nicaraguan border to the Panamanian border is 484 km; its minimum width from the Pacific Ocean to the Atlantic Ocean is 119 km.

Mountain ranges run the length of Costa Rica from the northwest to the southeast, separating the Pacific and the Atlantic coastal areas. A volcanic range, the Guanacaste Mountains, begins near Nicaragua and meets the volcanic Central Mountains, which end in the center of the country. A higher non-volcanic range, the Talamanca Mountains, runs from the center to the southeastern border. There are more than ten peaks over 3,000 m in the Central Mountains and the Talamanca Mountains.

The Atlantic slope is mostly broad, gradual, and gentle; the Pacific slope is narrow, steep and hilly. There are rain forests in the northeast near the Atlantic Ocean and in the southwest lowlands on the Pacific side which still cover about a quarter of the country's area. By contrast, the tropical dry forest of the northwest has a long and severe dry season.

2. Demographic Profile

2. 1 Transition of Population

According to the Census of June 1984 executed by DGEC/MEIC, the population of Costa Rica in 1984 is 2,416,809.

Not until 1976 did the population pass the two million mark. The increase rate of the population has been gradually slowing down as shown in Table I −1. The growth rate in the 1960's was 3.25% per year, and the rate decreased to 2.66% per year in the 1970's. The decline of the population increase rate is mainly due to a decrease in the birth rate.

2. 2 Distribution of the Population

Casta Rica is composed of seven provinces divided into cantons which have many districts. There are a total of 81 cantons and 415 districts in the country. The area and the population of the provinces in June 1984 are shown in Table I−2. The transition of the population by province from 1973 to 1984 is shown in Table I−3.

According to the Census of June 1984, 63% of the Costa Rican people live in the Central Valley. The Central Valley is the area where the Central Mountains and the Talamanca Mountains nearly meet, and the valley runs from San Ramón in the west to Turrialba in the east. Altitudes on the valley floor range from about 800 m to 1,500 m averaging about 1,000 m.

Table I-1 Population in Costa Rica

Year	Population on July 1st	Annual Increase Rate (%)
1960	1,254,055	4.53
1965	1,489,825	3.53
1970	1,727,367	2.50
1975	1,968,438	2.44
1976	2,017,986	2.52
1977	2,070,560	2.61
1978	2,125,620	2.66
1979	2,183,625	2.73
1980	2,245,437	2.83
1981	2,307,290	2.75
1982	2,371,519	2.78

Source: Anuario Estadistico de Costa Rica, 1982 DGEC/MEIC

Table I-2 Area and Population of Each Province in June 1984

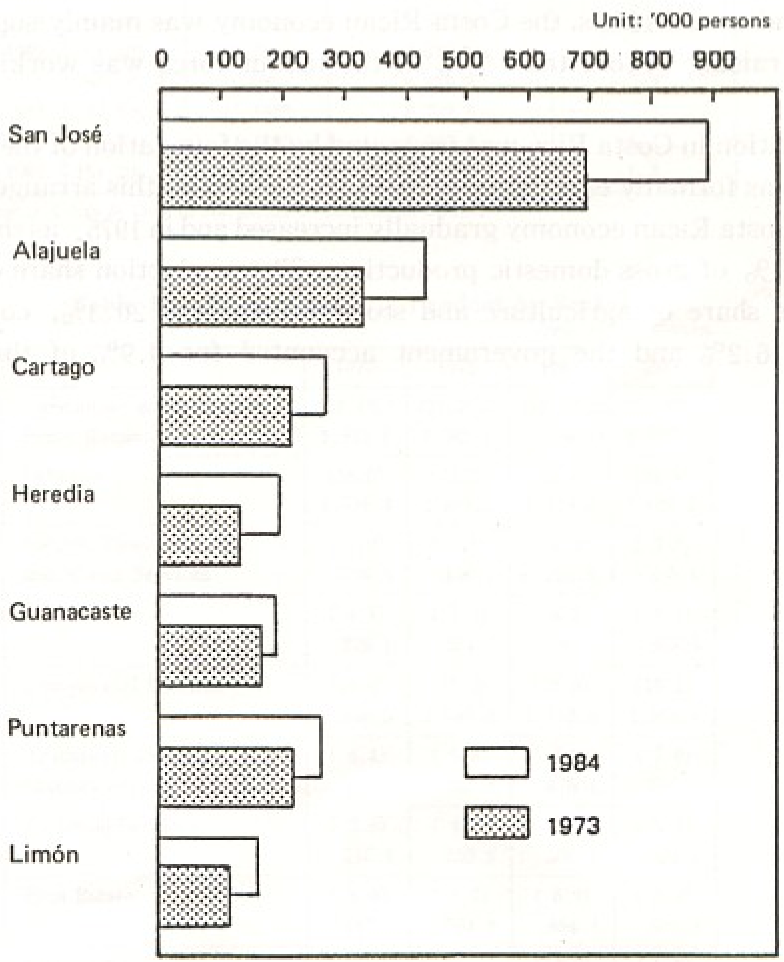
Province	Population		Area (km²)	
San José	890,434	36.8%	4,960	9.7%
Alejuela	427,962	17.7	9,753	19.1
Cartago	271,671	11.2	3,125	6.1
Heredia	197,575	8.2	2,657	5.2
Guanacaste	195,208	8.1	10,140	19.9
Puntarenas	265,883	11.0	11,276	22.1
Limón	168,076	7.0	9,189	18.0
TOTAL	2,416,809	100.0	51,100	100.0

Source: Octavo Censo Nacional de Población, Junio 1984 DGEC/MEIC

Table I-3 Population Census by Provice on July 10, 1984 and on May 14, 1973

Unit : persons

Province	1984		1973		Difference
San José	890,434	36.8%	695,163	37.1%	195,271
Alajuela	427,962	17.7	326,032	17.4	101,930
Cartago	271,671	11.2	204,699	10.9	66,972
Heredia	197,575	8.2	133,844	7.2	63,731
Guanacaste	195,208	8.1	178,691	9.5	16,517
Puntarenas	265,883	11.0	218,208	11.7	47,675
Limón	168,076	7.0	115,143	6.5	52,933
Total	2,416,809	100.0	1,871,780	100.0	545,029



Source: Octavo Censo Nacional de Población, Junio 1984 DGEC of MEIC

Fig. I-1 Population by Province

3. Economic Profile

3. 1 Economic Activities

Costa Rica maintained high economic growth throughout the 1960's and most of the 1970's. The averge annual growth rate of 5.1% in the early 1960's went up to 7.0% in the latter 1960's. The growth rate in the early 1970's was about 6.0%.

However, as shown in Table I −4, the economic growth rate rapidly declined from 1978. This decrease was mainly due to the fall in coffee prices and the second oil shock.

In 1984, the country's economic growth rate reached 6.3%, but due to the negative growth in the intervening years, the Costa Rican economy has only recently recovered the level of economic activity achieved in 1980.

3. 2 Industrial Structure

Until the end of the 1950's, the Costa Rican economy was mainly supported by agriculture and stock raising. More than 50% of the labour force was working in the primary sector.

Industrialization in Costa Rica was promoted by the foundation of the Central American Market which was formally established in 1963. Protected by this arrangement, the share of industry in the Costa Rican economy gradually increased and in 1975, as shown in Table I −5, accounted for 21% of gross domestic production. The production share of industry in 1984 was 21.9%, the share of agriculture and stock raising was 20.3%, commercial services accounted for 16.2% and the government accounted for 9.9% of the Gross Domestic Product.

Table I-4 Economic Growth in Costa Rica

Unit : million colones

Year	Current Price	Constant Price (1966 basis)		
		Deflator	Constant Price	Annual Growth Rate
1960	2,860.5	0.9238	3,096.5	6.1%
1965	3,928.5	0.9882	3,975.5	9.8
1966	4,288.4	1.0000	4,288.4	7.9
1967	4,633.9	1.0228	4,530.7	5.7
1968	5,126.7	1.0432	4,914.6	8.5
1969	5,655.3	1.0908	5,184.5	5.5
1970	6,524.5	1.1706	5,573.5	7.5
1971	7,137.0	1.1992	5,951.3	6.8
1972	8,215.8	1.2761	6,438.0	8.2
1973	10,162.4	1.4655	6,934.3	7.7
1974	13,215.7	1.8057	7,318.8	5.5
1975	16,804.6	2.2489	7,472.5	2.1
1976	20,675.6	2.6222	7,884.8	5.5
1977	26,330.7	3.0664	8,586.9	8.9
1978	30,193.9	3.3089	9,125.1	6.3
1979	34,584.4	3.6332	9,575.8	4.9
1980	41,405.5	4.2917	9,647.8	0.8
1981	57,102.7	6.0557	9,429.6	−2.3
1982	97,505.1	11.1529	8,742.6	−7.3
1983	126,337.1	14.1195	8,947.7	2.3
1984	151,303.8	15.9050	9,513.0	6.3

Source : Cifras de Cuentas Nacionales de Costa Rica, BCCR

Table I-5 Gross Domestic Product by Sector

Unit : million colones

	1970	1975	1980	1984
Agriculture and Stock Raising	(24.1%) 1,343.6	(21.2%) 1,585.7	(18.0%) 1,736.1	(20.3%) 1,929.4
Industry	(18.6) 1,036.3	(21.2) 1,585.1	(22.0) 2,119.6	(21.9) 2,080.1
Electric Power and Water Services	(1.9) 106.4	(2.1) 156.1	(2.3) 224.9	(3.3) 315.4
Construction	(4.1) 229.1	(5.1) 384.7	(6.2) 602.7	(4.1) 390.5
Commercial Services	(19.9) 1,109.5	(17.2) 1,288.0	(18.0) 1,740.8	(16.2) 1,544.7
Transportation and Communication	(4.4) 247.7	(5.8) 432.2	(7.0) 676.4	(7.0) 668.1
Financial Services	(3.9) 216.1	(4.8) 359.5	(5.2) 500.4	(5.5) 521.3
Real Estate	(8.0) 447.7	(7.6) 564.8	(6.9) 664.7	(7.4) 699.3
Goverment	(9.9) 549.2	(10.3) 769.8	(10.0) 966.7	(9.9) 945.2
Others	(5.2) 287.9	(4.6) 344.6	(4.3) 415.5	(4.4) 419.0
Total	(100.0) 5,573.5	(100.0) 7,472.5	(100.0) 9,647.8	(100.0) 9,513.0

Note : (1) GDP at 1966 Constant Prices
(2) Source : BCCR

4. Foreign Trade

4.1 Exports

As shown in Table I−6, exports increased at an average annual rate of about 5% in the latter 1960's, and by more than 15% per year in the early to middle 1970's. Attaining the highest rate in 1977, the annual growth rate of exports declined rapidly thereafter, and in 1982 exports decreased at a rate of 13.7% per year. The decreased growth rate of the value

Table I-6 Foreigh Trade in Costa Rica

Unit : million US$

	Export (F.O.B.)		Import (C.I.F.)		Difference
	Amount	Increase Rate	Amount	Increase Rate	
1960	85.8		110.4		−24.6
1965	111.8	−1.8%	178.2	28.6%	−66.4
1966	135.5	21.2	178.5	0.2	−43.0
1967	143.8	6.1	190.7	6.8	−46.9
1968	170.8	18.8	213.9	12.2	−43.1
1969	189.7	11.1	245.1	14.6	−55.4
1970	231.2	21.9	329.1	34.3	−97.9
1971	225.4	−2.5	349.7	6.3	−124.3
1972	280.9	24.6	372.8	6.6	91.9
1973	344.5	22.6	455.3	22.1	−110.8
1974	440.3	27.8	719.7	58.1	−279.4
1975	493.3	12.0	693.9	−3.6	−200.6
1976	592.9	20.2	770.4	11.0	−177.5
1977	828.2	39.7	1,021.4	32.6	−193.2
1978	864.9	4.4	1,165.7	14.1	−300.8
1979	934.4	8.0	1,396.8	19.8	−462.4
1980	1,001.7	7.2	1,523.8	9.1	−522.1
1981	1,008.1	0.6	1,208.5	−20.7	−200.4
1982	870.4	−13.7	893.2	−26.1	−22.8
1983	882.4	1.4	988.5	10.7	−106.1
1984	952.6	8.0	1,091.8	10.5	−139.2

Source : BCCR

of exports after 1977 is mainly due to the fall in the price of coffee as shown in Table I−7.

Most Costa Rican exports are traditional agricultural products, such as coffee and bananas. As shown in Table I−8, the share of traditional export products in 1965 was 81% of the total exports. However, with the progress of industry, the share of traditional products in total exports was reduced to 60.3% in 1983.

As shown in Table I−9, over half of the Costa Rican exports are shipped to the United States and to Central American Common Market (CACM) countries. However, the 52% share of the United States in 1960 has declined to about 30% of total exports in the 1980's.

4. 2 Imports

As shown in Table I−6, imports increased at an annual rate of about 10% in the early 1960's, and the rate of increase grew to about 17% per year in the latter 1970's.

However, as Costa Rica suffered a trade deficit of over $500 million in 1980, the national government introduced a policy to restrict imports, and imports were successfully reduced in 1981 by 20.1% and in 1982 by 26.1% over the respective previous years.

The shares of major commodity groups in total imports in 1983 are 24.5% for chemical products, 23.4% for semimanufactured goods, 18.6% for fuel and lubricants, 14.7% for transport machinery and materials and 9.6% for foods as shown in Table I−10. The share of fuel and lubricants increased from 10.6% in 1975 to 18.6% in 1983, and the share of chemical products increased from 19.2% in 1975 to 24.5%in 1983 due to the rise in oil price. The share of transport machinery and materials decreased from 31.5% in 1979 to 14.7% due to the import restriction policy.

In 1983, 38.4% of the total imports were from the United States. Imports from Japan accounted for 13.4% of the total in 1977. However, because of the reduction of vehicle and steel imports, the Japanese share was reduced to 4.2% of the total imports in 1982 as shown in Table I−11.

Table I-7 Exports of Coffee and Bananas (FOB)

	Coffee			Bananas		
	46kgf Sacks ('000)	Total Exports (Million $U.S.)	Price Per Sack ($U.S.)	Volume ('000 MT)	Total Exports (Million $U.S.)	Price Per kgf ($U.S.)
1965	1,050	46.6	44.43	316	28.3	0.09
1970	1,502	73.1	48.66	856	66.8	0.08
1971	1,390	59.3	42.67	922	64.0	0.07
1972	1,871	77.9	41.61	1,078	82.8	0.08
1973	1,585	94.0	59.31	1,179	90.7	0.08
1974	1,959	124.8	63.67	1,038	98.3	0.09
1975	1,673	96.9	57.93	1,105	144.1	0.13
1976	1,397	153.9	110.18	1,069	148.7	0.14
1977	1,470	319.2	217.17	1,003	150.3	0.15
1978	1,877	313.7	167.10	1,058	169.9	0.16
1979	2,117	315.4	148.95	1,025	190.5	0.19
1980	1,559	247.9	158.94	973	207.5	0.21
1981	2,093	240.0	114.68	1,002	224.8	0.22
1982	2,040	236.9	116.14	1,013	228.1	0.23
1983	2,352	230.0	97.74	1,007	233.1	0.23

Note: (1) Source: PRINCIPALES ESTADISTICAS SOBRE LAS TRANSACCIONES DE COSTA RICA CON EL EXTRANJERO, BCCR
(2) Frigures for 1983 are preliminary.

Table I-8 Composition of Exports (FOB)

Unit: Million US$

	1965	1970	1975	1976	1977	1978	1979	1980	1981	1982	1983
Coffee	(41.7%) 46.6	(31.7%) 73.1	(19.7%) 97.0	(25.9%) 153.9	(38.5%) 319.2	(36.2%) 313.6	(33.8%) 315.5	(24.7%) 247.9	(23.8%) 240.1	(27.2%) 236.9	(26.5%) 229.4
Bananas	(25.2) 28.2	(28.9) 66.8	(29.2) 144.2	(25.1) 148.6	(18.1) 150.3	(19.6) 169.9	(20.4) 190.5	(20.7) 207.5	(22.3) 224.8	(26.2) 228.1	(26.8) 233.1
Cacao	(2.0) 2.2	(0.8) 1.9	(1.0) 5.3	(1.2) 6.9	(2.1) 17.1	(1.7) 15.1	(1.0) 9.7	(0.4) 4.2	(0.3) 2.7	(0.3) 2.4	(0.1) 1.0
Meat	(4.7) 5.2	(7.8) 18.1	(7.7) 38.0	(7.7) 45.5	(6.2) 51.3	(7.1) 61.5	(8.8) 82.5	(7.2) 71.8	(7.6) 76.5	(6.3) 54.7	(3.5) 30.7
Sugar	(4.2) 4.7	(4.4) 10.1	(9.8) 48.2	(4.2) 24.7	(1.9) 15.6	(1.8) 15.9	(1.9) 17.5	(4.1) 40.7	(4.2) 42.0	(1.9) 16.6	(2.7) 23.9
Fertilizer	(3.2) 3.6	(1.0) 2.4	(3.7) 18.3	(2.8) 16.7	(1.7) 13.7	(1.3) 11.0	(1.0) 9.3	(1.0) 10.0	(1.5) 15.6	(0.9) 7.9	(0.7) 5.7
Total of Traditional Exports	(81.0) 90.5	(74.6) 172.4	(71.1) 351.0	(66.9) 396.3	(68.5) 567.2	(67.9) 587.0	(66.9) 624.9	(58.1) 582.1	(59.7) 601.7	(62.8) 546.6	(60.3) 523.8
Manufactured Goods	(14.2) 15.9	(22.1) 51.1	(24.0) 118.3	(28.2) 167.6	(26.1) 216.0	(24.6) 213.1	(27.0) 252.5	(33.4) 334.0	(34.2) 345.2	(30.7) 267.1	(39.7) 344.5
Other Agricultural and Marine Products	(4.8) 5.4	(3.3) 7.7	(4.9) 24.0	(4.9) 29.0	(5.4) 45.0	(7.5) 64.8	(6.1) 56.9	(8.5) 85.6	(6.1) 61.2	(6.5) 56.7	
Grand Total	(100.0) 111.8	(100.0) 231.2	(100.0) 493.3	(100.0) 592.9	(100.0) 828.2	(100.0) 864.9	(100.0) 934.4	(100.0) 1,001.7	(100.0) 1,008.1	(100.0) 870.4	(100.0) 869.3

Note: (1) Source: PRINCIPALES ESTADISTICAS SOBRE LAS TRANSACCIONES DE COSTA RICA CON EL EXTRANJERO, BCCR
(2) Figures for 1983 are preliminary

Table I-9 Main Destinations for Exports (FOB)

Unit : Million US$

	1977	1980	1981	1982	1983
CACM	(21.0%) 173.8	(27.0%) 270.3	(23.6%) 238.0	(19.2%) 167.2	(22.0%) 191.0
United States	(29.9) 247.7	(32.7) 327.5	(30.1) 303.5	(30.0) 261.2	(30.9) 268.4
Panamá	(2.7) 22.5	(4.1) 41.4	(4.6) 46.2	(4.7) 40.7	(4.0) 34.6
West Germany	(12.9) 106.8	(11.6) 116.3	(12.2) 123.3	(14.0) 122.2	(13.6) 117.9
Finland	(4.4) 36.1	(2.6) 25.6	(1.7) 17.5	(2.2) 19.3	(3.8) 33.1
England	(0.2) 2.0	(0.3) 2.7	(1.0) 10.5	(3.0) 26.1	(2.5) 22.1
Italy	(2.1) 17.6	(4.2) 42.2	(2.9) 29.1	(3.6) 31.6	(2.9) 25.2
Others	(26.8) 221.7	(17.5) 175.5	(23.9) 240.0	(23.3) 202.1	(20.3) 177.0
Total	(100.0) 828.2	(100.0) 1,001.7	(100.0) 1,008.1	(100.0) 870.0	(100.0) 869.3

Note : (1) Source : PRINCIPALES ESTADISTICAS SOBRE LAS TRANSACCIONES DE COSTA RICA CON EL EXTRANJERO, BCCR

(2) Figures for 1983 are preliminary.

Table I-10 Composition of Imports (CIF)

Unit: Million US$

	1975	1976	1977	1978	1979	1980	1981	1982	1983
Foods	(8.5%) 59.2	(7.2%) 55.6	(6.5%) 66.7	(6.2%) 72.5	(6.4%) 90.0	(7.6%) 115.6	(7.6%) 92.3	(8.1%) 72.5	(9.6%) 95.1
Tobacco and Beverages	(0.4) 2.5	(0.4) 3.0	(0.5) 5.6	(0.6) 7.0	(0.6) 8.4	(0.7) 10.2	(0.6) 7.6	(0.5) 4.8	(0.5) 5.1
Raw Materials except Fuel	(1.9) 13.5	(2.1) 16.0	(1.9) 19.6	(1.6) 18.3	(1.9) 26.5	(2.3) 35.7	(2.2) 26.4	(2.5) 22.6	(2.5) 24.4
Fuel and Lubricants	(10.6) 73.8	(9.6) 73.9	(10.0) 102.2	(10.1) 117.7	(13.6) 189.5	(15.0) 229.1	(17.0) 205.3	(21.2) 188.9	(18.6) 183.6
Animal and Vegetable Oil and Fat	(0.9) 6.0	(0.9) 7.2	(0.7) 7.3	(0.8) 8.9	(0.6) 8.4	(0.8) 11.5	(0.6) 7.3	(0.5) 4.5	(0.2) 1.9
Chemical Products	(19.2) 133.1	(16.8) 129.5	(17.2) 175.2	(16.3) 189.6	(16.4) 229.2	(18.0) 273.7	(19.6) 237.4	(22.5) 200.6	(24.5) 242.8
Semimanufactured Goods	(25.2) 175.1	(25.6) 197.1	(24.1) 245.7	(24.9) 290.0	(22.1) 309.1	(22.9) 348.9	(22.4) 271.0	(21.1) 188.2	(23.4) 231.2
Transport Machinery and Materials	(26.8) 186.1	(30.4) 234.4	(31.3) 318.8	(30.7) 359.2	(31.5) 439.4	(25.0) 380.9	(23.5) 283.2	(18.3) 163.5	(14.7) 145.0
Other Manufactured Goods	(5.9) 40.7	(6.3) 48.6	(6.7) 68.6	(7.9) 91.8	(6.8) 95.6	(7.2) 110.0	(5.7) 68.4	(4.4) 39.7	(5.5) 54.0
Others	(0.6) 4.0	(0.7) 5.1	(1.1) 11.7	(0.9) 10.7	(0.1) 0.7	(0.5) 8.2	(0.8) 9.6	(0.9) 7.9	(0.5) 5.4
Total	(100.0) 694.0	(100.0) 770.4	(100.0) 1,021.4	(100.0) 1,165.7	(100.0) 1,396.8	(100.0) 1,523.8	(100.0) 1,208.5	(100.0) 893.2	(100.0) 988.5

Note: (1) Source: PRINCIPALES ESTADISTICAS SOBRE LAS TRANSACCIONES DE COSTA RICA CON EL EXTRANJERO, BCCR
(2) Figures for 1983 are preliminary.

Table I-11 Main Origins of Imports (CIF)

Unit : Million US$

	1977	1980	1981	1982	1983
CACM	(16.4%) 167.9	(14.4%) 219.8	(12.6%) 152.3	(12.6%) 112.4	(12.1%) 120.1
United States	(33.5) 342.6	(33.0) 502.1	(33.2) 401.1	(35.5) 316.8	(38.4) 379.2
Panamá	(1.2) 12.1	(2.0) 30.2	(1.7) 20.3	(1.3) 11.8	(1.8) 17.4
Mexico	(2.3) 23.4	(6.4) 96.9	(9.2) 110.7	(9.0) 80.3	(8.1) 79.9
Venezuela	(3.5) 35.6	(6.9) 105.2	(7.6) 92.0	(12.0) 107.3	(7.4) 73.4
West Germany	(5.4) 55.6	(4.7) 70.9	(4.6) 55.4	(3.9) 35.1	(4.9) 48.1
Japan	(13.4) 136.4	(11.2) 171.3	(9.8) 118.3	(4.2) 37.2	(5.4) 53.0
Others	(24.3) 247.8	(21.4) 327.4	(21.3) 258.4	(21.5) 192.3	(21.9) 217.4
Total	(100.0) 1,021.4	(100.0) 1,523.8	(100.0) 1,208.5	(100.0) 893.2	(100.0) 988.5

Note: (1) Surce : PRINCIPALES ESTADISTICAS SOBRE LAS TRANSACCIONES DE COSTA RICA CON EL EXTRANJERO, BCCR

(2) Figures for 1983 are preliminary.

5. Transportation

5. 1 General Outlook

The total Costa Rican international trade cargo volume is about 1.72 million tons for imports and 1.76 million tons for exports in 1984. The import cargo volume is almost the same as the export cargo volume. The import cargo volume decreased in 1981 and 1982. However, it turned to an increase in 1983 and 1984. The export cargo volume increased in every recent year except for 1981. Especially, it drastically increased in 1984.

Maritime transportation took a share of 91.4% for imports and 92.6% for exports in the international trade cargo volume in 1984. Thus, maritime transportation is the major transportation mode for Costa Rican international trade as shown in Table I−12 and Fig. I−2.

5. 2 Maritime Transportation

There are several major shipping routes around Costa Rica. Major ports of call for the major shipping lines are the Ports of Caldera and Puntarenas on the Pacific coast, and the Ports of Limón and Moín on the Atlantic coast. The major shipping routes are shown in Table I−13 and Fig. I−3. However, according to INCOP, the full-container service between the Port of Caldera and Europe stopped from the end of 1984. Table I−14 shows the international cargo throughput at the Ports of Caldera and Puntarenas by trade counterpart region. The shares of the USA and Japan are 54.8% and 11.8% in 1984, respectively.

5. 3 Land Transportation

5. 3. 1 Railway Transportation

There are three railway networks in Costa Rica (refer to Fig. I−4). The Pacific railway which runs between the Ports of Caldera and Puntarenas and San José, and the Atlantic railway which runs between the Ports of Limón and Moín and San José are owned and operated by the national company, INCOFE. Although both of these lines terminate at San José, they are not interconnected. The routes are steep and winding in the mountainous areas. INCOFE has been under a sort of organizational reform due to its financial problems. Along with this reform, its name was changed from the former name, FECOSA, to the present name, INCOFE, in October 1985.

The third railway line is located on the Pacific side in the southern part of the nation and leads to an adjacent country, Panamá. This line has been developed and operated by a private fruit company. The number of passengers and cargo volume transported by each of the three railways in 1984 are shown in Table I−15. The distances by railway between major cities are shown in Table I−16.

Table I-12 International Trade Cargo Volume by Transportation Mode

Unit: '000 tons

	Year																	
	1976	%	1977	%	1978	%	1079	%	1980	%	1981	%	1982	%	1983	%	1984	%
[IMPORT]																		
Total	1546.9	100.0	1863.5	100.0	2034.4	100.0	2021.3	100.0	2056.4	100.0	1685.8	100.0	1598.7	100.0	1678.9	100.0	1723.7	100.0
Maritime Transportation	1278.0	82.6	1601.0	85.9	1784.2	85.6	1771.6	87.6	1772.2	86.2	1460.6	86.6	1435.8	89.8	1547.7	92.2	1575.7	91.4
Land Transportation	257.9	16.7	248.0	13.3	284.3	13.6	232.1	11.5	272.2	13.2	213.8	12.7	136.4	8.5	123.2	7.3	121.8	7.1
Through the north border	222.0		194.7		236.7		213.0		228.1		197.8		125.9		99.6		97.6	
Through the south border	35.9		53.3		47.6		19.1		44.1		16.0		10.5		23.6		24.2	
Air Transportation	10.9	0.7	14.4	0.8	15.7	0.8	17.5	0.9	11.7	0.6	11.2	0.7	26.4	1.7	8.2	0.5	12.3	0.7
Mail	0.1	—	0.1	—	0.2	—	0.1	—	0.3	—	0.2	—	0.1	—	0.1	—	—	—
Others	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13.9	0.8
[EXPORT]																		
Total	1539.0	100.0	1544.2	100.0	1592.5	100.0	1565.3	100.0	1545.1	100.0	1870.9	100.0	1574.3	100.0	1548.3	100.0	1762.1	100.0
Maritime Transportation	1370.2	89.0	1313.3	85.0	1383.1	86.8	1380.9	88.2	1292.9	83.7	1626.0	86.9	1397.1	88.8	1410.7		1631.5	92.6
Land Transportation	157.1	10.2	210.8	13.7	201.9	12.7	167.2	10.7	242.2	15.7	204.7	10.9	135.7	8.6	121.4	7.8	115.4	6.5
Through the north border	116.9		174.3		165.7		127.6		206.9		171.2		103.3		92.5		91.1	
Through the south border	40.2		36.5		36.2		39.6		35.3		33.5		32.4		28.9		24.3	
Air Transportation	11.7	0.8	20.1	1.3	7.5	0.5	10.1	0.6	10.0	0.6	11.2	0.6	12.5	0.8	14.2	0.9	15.1	0.9
Others	—	—	—	—	—	—	7.1	0.5	—	—	29.0	1.6	29.0	1.8	2.2	0.2	—	—

Source: CUADROS ESTADISTIOCOS SOBRE SECTOR TRANSPORTES 1984, DGP/MOPT

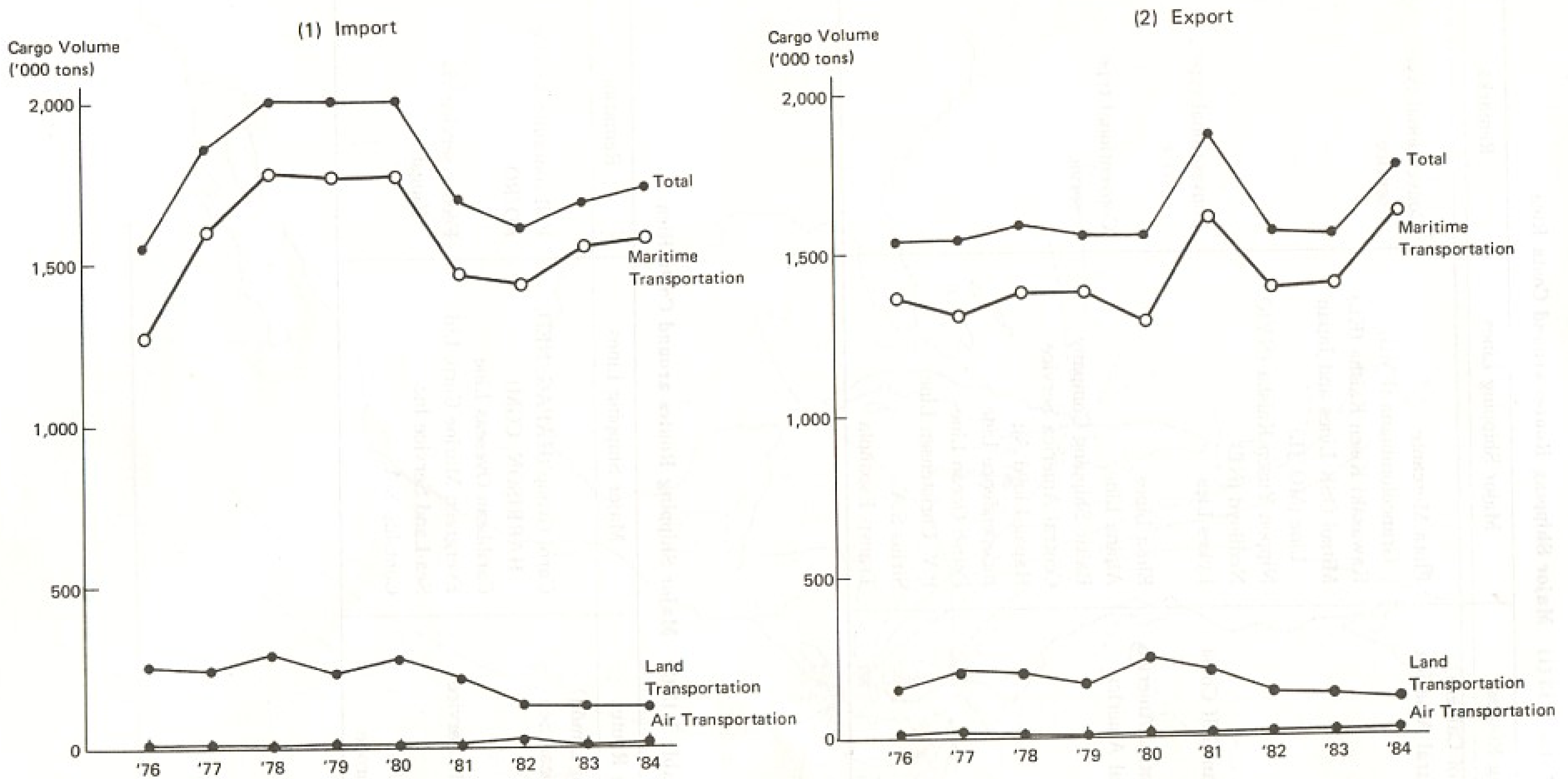


Fig. I-2 International Trade Cargo Volume by Transportation Mode

Table I-13 (1) Major Shipping Routes around Costa Rica

Major Shipping Routes	Major Shipping Lines	Remarks
〔Through the Port of Caldera〕		
P—1. Far East～Central America	Flota Mercante Grancolombiana (FMG) Kawasaki Kisen Kaisha (KL) Mitsui OSK Lines and Japan Line (MO/JL) Nippon Yusen Kaisha (NYK) Nedlloyd (NL)	Conventional type service
P—2. North American Gulf Coast ～Central America	Lykes Lies	Conventional type service
P—3. Argentine～Central America	Elma Lines	
P—4. Europe～Central America	Alpina Line Baltic Shipping Company Central America Service Hapag-Lloyd Ag Independence Line Polish Ocean Line P.V. Christensen Line Sirius S.A. Transp. Española	Conventional type service

Table I-13 (2) Major Shipping Routes around Costa Rica

Major Shipping Routes	Major Shipping Lines	Remarks
〔Through the Port of Limõn〕		
A—1. Europe～Caribbean Sea	Carol Group (HAPAG, NED, HARRISON, CGM) Caribbean Oveseas Line	Full-container service RO/RO
A—2. Round the World Service (Eastbound)	Evergreen Marine Corp. Ltd. Sea-Land Service Inc.	Feeder service via Kingston
A—3. East Coast of USA ～Caribben Sea～Europe	Contship S.A.	

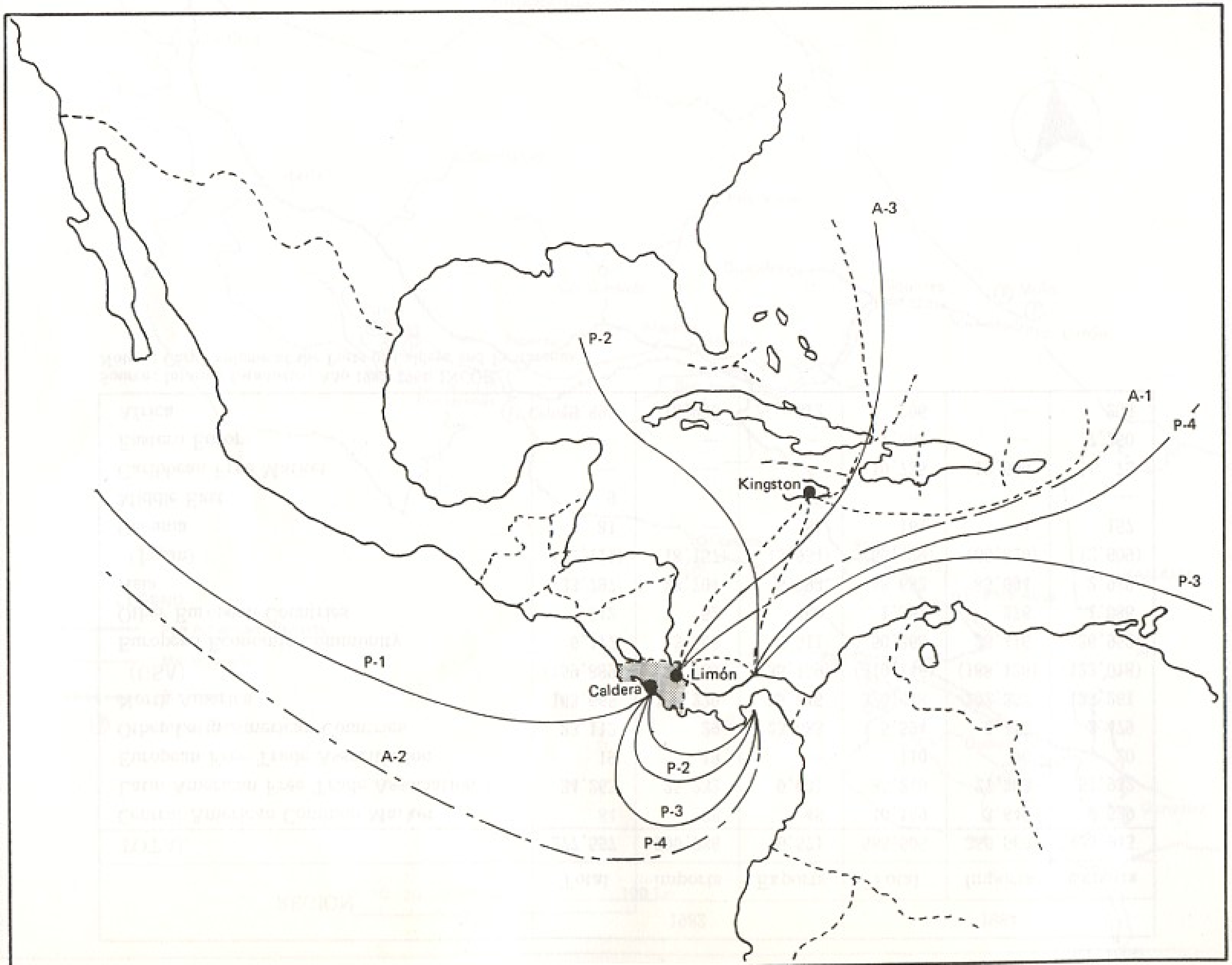


Fig. I-3 Conceptual Diagram of Major Shipping Routes around Costa Rica

Table I-14 Counterpart Regions of the Ports on the Pacific Coast

(Unit : tons)

REGION	1982			1984		
	Total	Imports	Exports	Total	Imports	Exports
TOTAL	277,557	200,986	76,571	585,505	356,560	228,945
Central American Common Market	84	38	48	10,169	3,640	6,529
Latin American Free Trade Association	34,263	25,232	9,031	85,240	27,303	57,932
European Free Trade Associtiation	19	19	—	110	90	20
Other Latin American Countries	23,112	29	23,083	5,594	3,115	2,479
North America	163,665	128,220	35,445	325,618	202,357	123,261
(USA)	(159,889)	(124,730)	(35,159)	(310,146)	(188,128)	(122,018)
European Economic Community	6,117	3,606	2,511	50,368	23,416	26,952
Other European Countries	512	52	460	1,362	276	1,086
Asia	33,797	28,704	5,093	88,682	85,694	2,988
(Japan)	(22,111)	(18,157)	(3,954)	(69,429)	(66,820)	(2,609)
Oceania	81	—	81	161	4	157
Middle East	9	—	9	—	—	—
Caribbean Free Market	—	—	—	10,735	10,660	75
Eastern Europe	—	—	—	7,260	—	7,260
Africa	15,898	15,086	812	206	—	206

Source : Informe Estadistico Año 1983, 1984, INCOP
Note : Cargo volume at the Ports of Caldera and Puntarenas

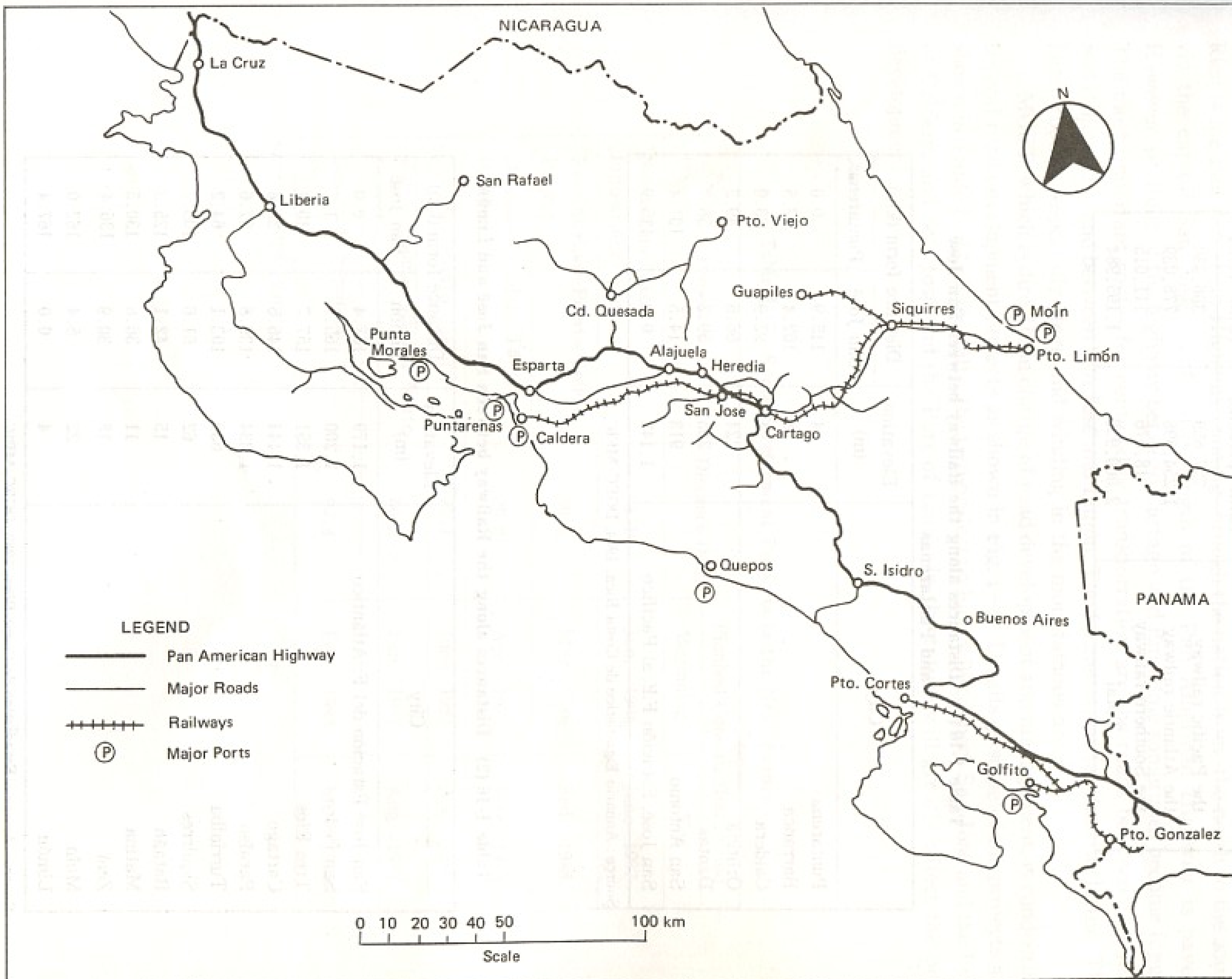


Fig. I-4 Land Transportation Networks in Costa Rica

Table I-15 Actual Records of Railway Transportation in 1984

Railway	Passengers (Unit : persons)	Cargoes (Unit : tons)
the Pacific railway	727,659	306,930
the Atlantic railway	1,254,698	778,039
the Southern railway	18,576	111,015
Total	2,000,933	1,195,984

Table I-16 (1) Distances along the Railway between San José and Puntarenas

City	Elevation (m)	Distance form (km)	
		San José	Puntarenas
Puntarenas	4	115.9	0.0
Barranca	28	102.4	13.5
Caldera	4	92.9	23.0
Orotina	224	66.6	49.3
Dantas	265	59.2	56.7
San Antonio	913	14.5	101.4
San José, Estación F.E. al Pacífico	1,142	0.0	115.9

Source: Anuario Estadístico de Costa Rica, 1984, DGEC/MEIC

Table I-16 (2) Distances along the Railway between San José and Limón

City	Elevation (m)	Distance form (km)	
		Limón	San José
San José Estación del F. Atlántico	1,179	167.4	0.0
San Pedro	1,200	165.7	1.7
Tres Ríos	1,351	157.7	10.1
Cartago	1,444	146.5	20.8
Paraíso	1,334	139.8	27.6
Turrialba	639	103.1	64.2
Siquirres	62	61.6	105.7
Bataán	15	42.1	125.3
Matina	11	36.8	130.5
Zent	18	30.9	136.4
Moín	22	5.4	162.0
Limón	4	0.0	167.4

Source: Anuario Estadístico de Cosat Rica, 1982, DGEC/MEIC

5. 3. 2 Road Transportation

The present road network in Costa Rica is shown in Fig. I−4. The central road in Costa Rica is the Pan American Highway running through the nation from the north to the south via the capital San José. The entire length of the Pan American Highway is paved. However, portions of the highway between Cartago and Empalme sometimes become foggy. The most important routes for commodity transportation are the roads between San José and Puntarenas, and between San José and Limón. The former is shorter than the latter. The latter road is especially steep and winding in the mountainous areas.

MOPT, which is directly in charge of road development and management, is conducting several road development projects as shown in Fig. I−5. Details of some of the projects are shown in Table I−17. Especially, the two projects which will connect San José and the Port of Caldera, and San José and the Port of Limón in the future will greatly affect the port development.

Table I-17 Road Development Projects in the Near Future

Project	Distance (km)	Planned Construction Period	
		Beginning	End
North Zone Road Infrastruture Project	9.1	Jan. 1986	June 1987
Rio Chirripo—Puerto Viejo Project	30.1	Mar. 1986	Fed. 1988
Orotina—Coyolar—Tárcoles Project	20.0	Apr. 1983	Mar. 1986
Coyolar—Puerto Caldera	20.1	June 1983	Apr. 1986
Baru—Piñuela—Palmar Norte Project	60.3	Feb. 1983	Aug. 1987
San José—Siquirres Project	94.4	Feb. 1983	Mar. 1986

Source : DGOPF/MOPT

5. 3. 2 Road Transportation

The present road network in Costa Rica is shown in Fig. I−4. The central road in Costa Rica is the Pan American Highway running through the nation from the north to the south via the capital San Josê. The entire length of the Pan American Highway is paved. However, portions of the highway between Cartago and Empalme sometimes become foggy. The most important routes for commodity transportation are the roads between San Josê and Puntarenas, and between San Josê and Limõn. The former is shorter than the latter. The latter road is especially steep and winding in the mountainous areas.

MOPT, which is directly in charge of road development and management, is conducting several road development projects as shown in Fig. I−5. Details of some of the projects are shown in Table I−17. Especially, the two projects which will connect San Josê and the Port of Caldera, and San Josê and the Port of Limõn in the future will greatly affect the port development.

Table I-17 Road Development Projects in the Near Future

Project	Distance (km)	Planned Construction Period	
		Beginning	End
North Zone Road Infrastruture Project	9.1	Jan. 1986	June 1987
Rio Chirripo—Puerto Viejo Project	30.1	Mar. 1986	Fed. 1988
Orotina—Coyolar—Tárcoles Project	20.0	Apr. 1983	Mar. 1986
Coyolar—Puerto Caldera	20.1	June 1983	Apr. 1986
Baru—Piñuela—Palmar Norte Project	60.3	Feb. 1983	Aug. 1987
San Josê—Siquirres Project	94.4	Feb. 1983	Mar. 1986

Source: DGOPF/MOPT

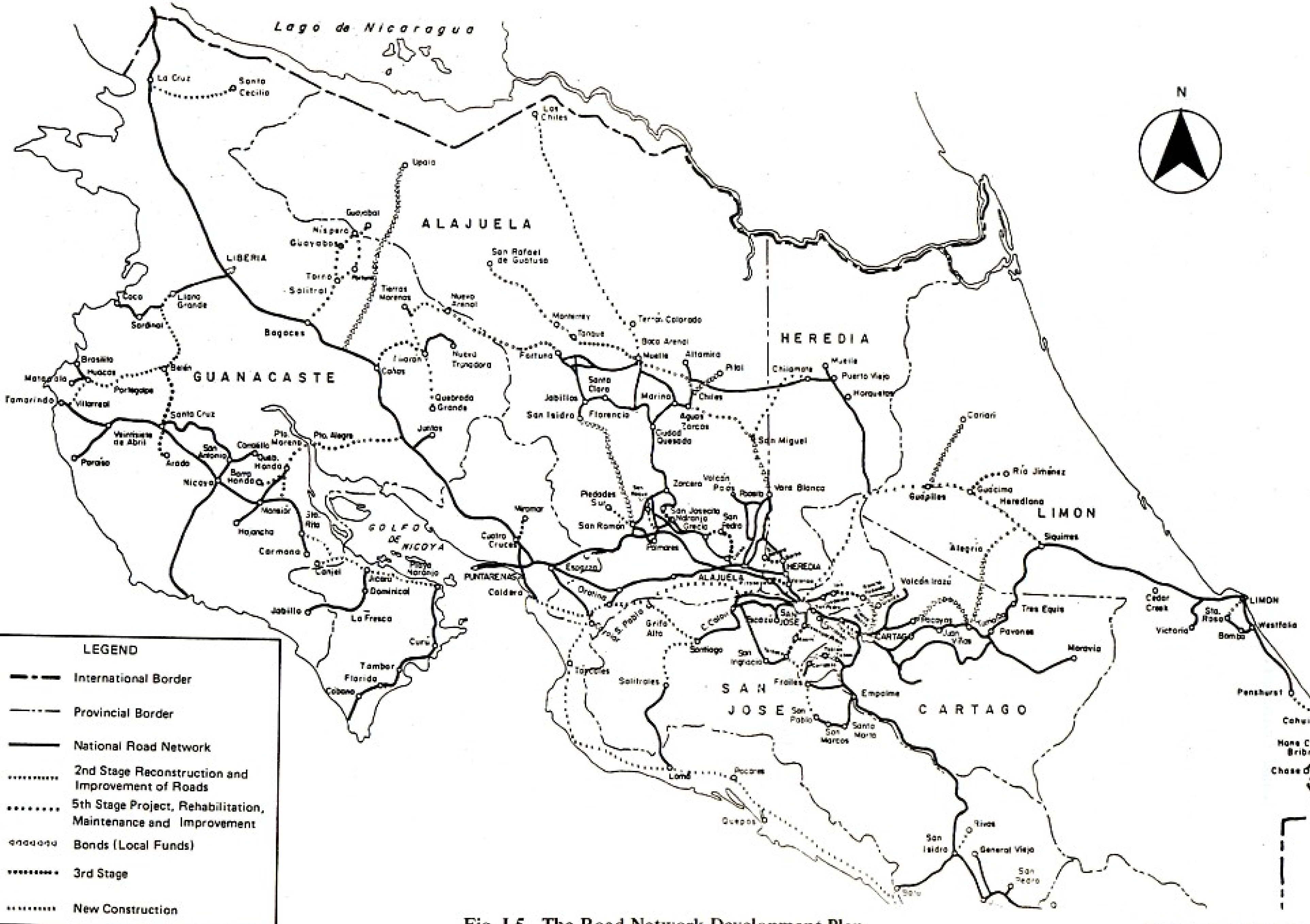


Fig. I-5 The Road Network Development Plan

Source: DGOPF/MOPT

6. Development Plans

6. 1 The National Devlopment Plan

The National Devlopment Plan (PLAN NACIONAL DE DESARROLLO, 1982−1986) was authorized by MIDEPLAN in December 1982. The project period is from 1982 through 1986. The socioeconomic indicators are shown in Table I−18. The plan aims at economic development by increasing the productivity of the primary sector. It states that to secure this objective, it is indispensable to further develop the transportation system, especially those transportation facilities to increase foreign trade such as port facilities.

Concerning port development, it specifically aims at the development of port facilities to increase foreign trade exports, the completion of the facilities and equipment for grain import and improvement of the management and operations at the Port of Caldera.

Table I-18 Socioeconomic Indicators of the National Development Plan

	1982	1986	Annual Growth Rate (%)
Population (Unit : '000 persons)	2,404.3	2,666.2	2.6
GDP at 1980 constant prices (Unit : million colones)	37,281.2	41,939.0	3.0

6. 2 The National Transportation Plan

The National Transportation Plan (PLAN NACIONAL DE TRANSPORTE) was formulated by DGP/MOPT in November, 1981. The target year of the plan is 2000. The plan projects the foreign trade cargo volume in the target year as 4,888 thousand tons for imports and 2,834 thousand tons for exports.

This plan highlights the improvement of the facilities to handle break bulk cargoes including grain and containerized cargoes at the Port of Caldera by 1991. This plan states that if these improvements are completed, the Port of Caldera will be able to accommodate all of the projected cargoes through 1995 without the construction of specialized terminals which would handle only grain or containers on an exclusive basis.

CHAPTER II PORT ACTIVITIES IN COSTA RICA

1. Historical Outline of Port Development

It is reported that the Port of Caldera and the Port of Matina were established in 1840 as official ports on the Pacific coast and the Atlantic coast, respectively, to develop foreign trade in Costa Rica. However, there were actually no port facilities at that time.

The port function on the Atlantic coast was transferred from Matina to Limón in 1867, and the first pier was constructed at the Port of Limón for banana exportation. Meanwhile, a pier for coffee exportation was constructed at Puntarenas around 1910, and the railways from the Central Valley to Puntarenas and Limón were constructed. Customs offices were also established at both ports.

At first, there was only one small pier at each of the ports for large and small vessels. Two piers, Muelle Metalico and Muelle Nacional, were then constructed at the Port of Limón, the first in 1901 and the other a few years later. Foreign trade with other Central American nations through Puntarenas subsequently increased greatly. The Government constructed Muelle de Puntarenas at the Port of Puntarenas in 1929.

Thereafter, banana plantations developed rapidly in the southern region. The piers of Golfito and Quepos were constructed by private banana companies in 1940. RECOPE constructed a mooring buoy and oil pipeline at Moín in 1960. Its function was later moved to a newly constructed marginal wharf at the same port. Two other marginal wharfs were also constructed there for banana exportation.

On the Atlantic coast, the Costa Rican Government improved the port of Limón with the construction of a concrete pier, Muelle 70. On the Pacific coast the Port of Punta Morales was constructed for sugar exportation in 1973.

Containerized sea transportation appeared in Costa Rica in the 1970's. New container terminals at the Ports of Caldera and Limón (on the Pacific coast and the Atlantic coast) were constructed in 1981 along with the development of containerization on Pacific and Atlantic shipping routes.

2. Administration and Organization

2. 1 Development and Management of the Ports

The development of Costa Rican ports is implemented by MOPT as shown in Fig.II-1 using funds appropriated in the national budget. Especially, DGOPF under the Public Works Division of MOPT as shown in Fig. II-2 is responsible for the planning and construction of port facilities, while such port management bodies as INCOP on the Pacific coast and JAPDEVA on the Atlantic coast are responsible for the management of the port facilities.

Requests for port development are proposed by INCOP, JAPDEVA, MOPT or other related governmental authorities. The requests are submitted to MIDEPLAN and through the deliberations of the Secretaria Sectorial del Sector Transporte the policy is decided. In the process of this debate, feasibility studies and financial analyses are implemented by

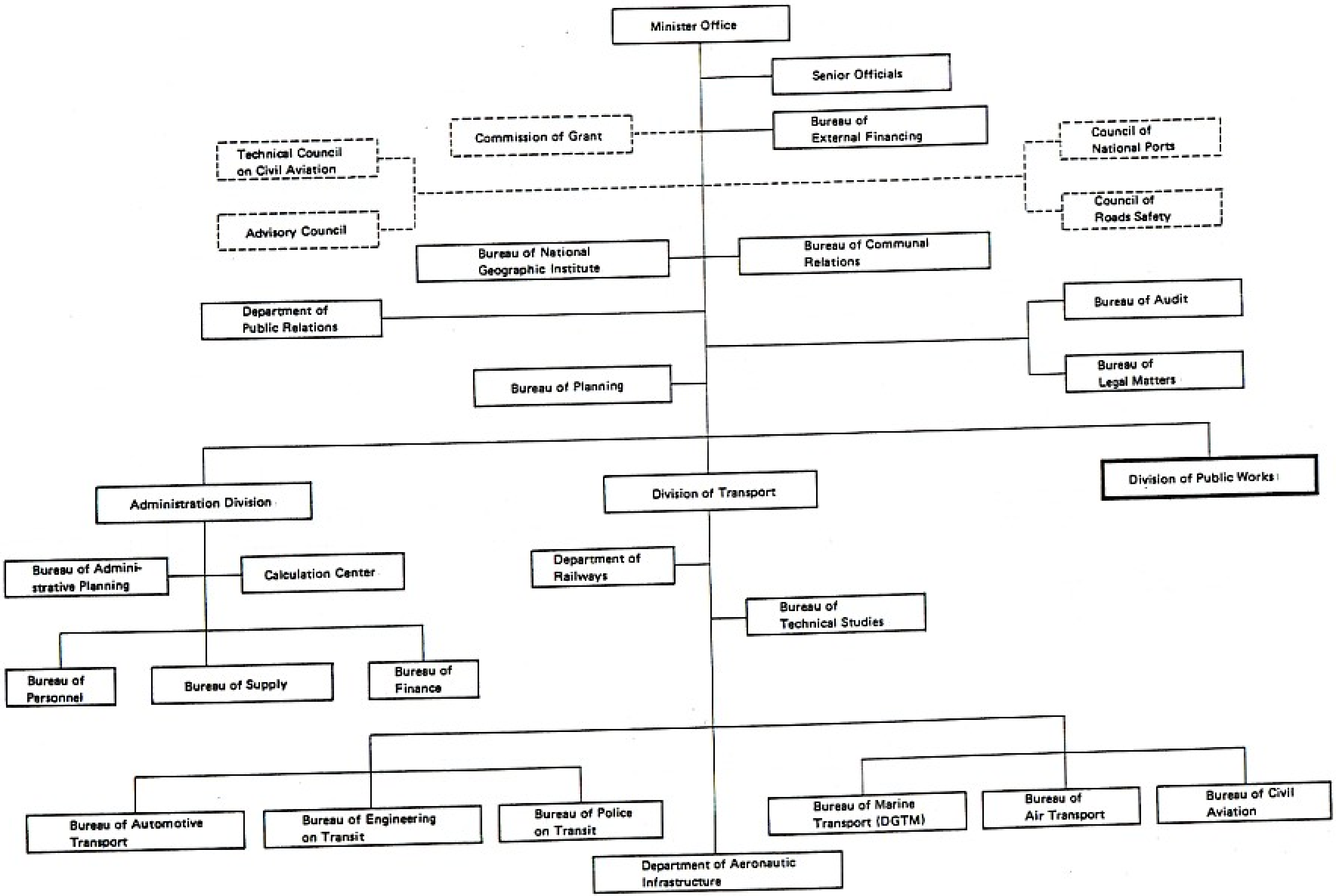


Fig. II-1 Organization of MOPT

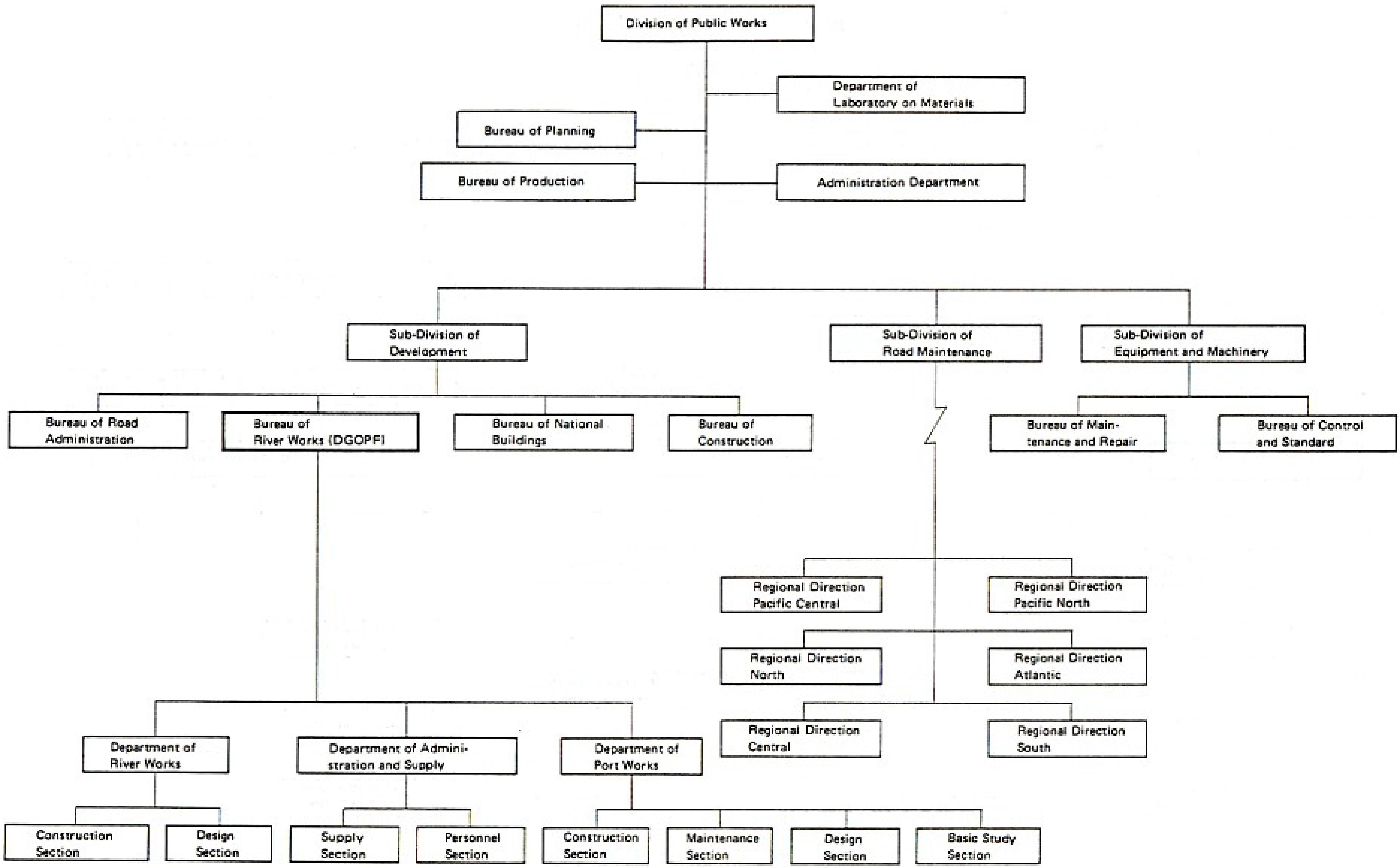


Fig. II-2 Organization of Public Works Division of MOPT

MIDEPLAN, and technical investigations and studies on port scale are carried out by DGOPF, MOPT. Studies on administration and operation are carried out by DGTM under the Transport Division of MOPT.

The Secretaria consists of five members : The Minister of MOPT, and one representative each from INCOP, JAPDEVA, RECOPE and INCOFE.

2. 2 Administration and Organization of DGOPF

MOPT is comprised of three divisions: Administration Division, Transport Division and Public Works Division. DGOPF, under the Public works division, has three departments : the Department of Port Works, the Department of Administration and Supply, and the Department of River Works.

The functions of DGOPF are as follows :

(1) To plan, design, coordinate and supervise the construction, improvement and maintenance of port and river works in accordance with the policy of the Sub-Division of Planning

(2) To decide the policies, standards and processes for the design, construction and maintenance of the port and river works.

(3) To supervise construction and maintenance works to ensure that the works which are executed by contractors are carried out in accordance with the terms of the contracts.

(4) To render technical assistance to the regional offices under the Sub-Division of Works and to supervise special technical operations and inform the Sub-Division of Planning about the progress of programmes and the type of technical procedures used.

(5) To prepare an annual budget and also to prepare the sections of the budgets of the regional offices related to the port and river works.

2. 3 Administration and Organization of INCOP

INCOP, the port management body for the ports on the Pacific side, was established by Law No. 1721 of Dec. 28, 1953, which was later amended by Law No.4964 of March, 1972. The organizational structure of INCOP is shown in Fig. II-3.

The Executive Board consisting of the Executive President and six directors appointed by the council of the Government and the Executive Secretary are in charge of INCOP. The Executive President is appointed by the President of Costa Rica.

The functions of INCOP are as follows :

(1) Planning of port facilities necessary for economic development on the Pacific side in compliance with the port development plans and policies determined by the government.

(2) Necessary construction works for supplying services at the ports, getting MOPT's approval in advance.

(3) Control of ship navigation within the ports located on the Pacific side.

(4) Purchase of real estate and buildings necessary for development of actual services in

compliance with the laws and rules concerned.

(5) Coordination between port services and related transportation development.

(6) Determination of port charges, getting approval from the government in advance.

2. 4 Administration and Organization of JAPDEVA

JAPDEVA, the port management body for the ports on the Atlantic side, was established by Law No. 3091 of Feb. 18, 1963. The organizational structure of JAPDEVA is shown in Fig. II-4. The Council of Administration consists of the Executive President, the Vice President and five directors appointed by a Government council.

As a port management body, JAPDEVA has the same functions as INCOP. However, JAPDEVA is also responsible for development projects in the fields of agriculture, stock farming and forestry. The Forestry Section is under the Department of Natural Resources, and the Department of Agriculture and Stock Farming is in charge of the management of agriculture and stock farming projects.

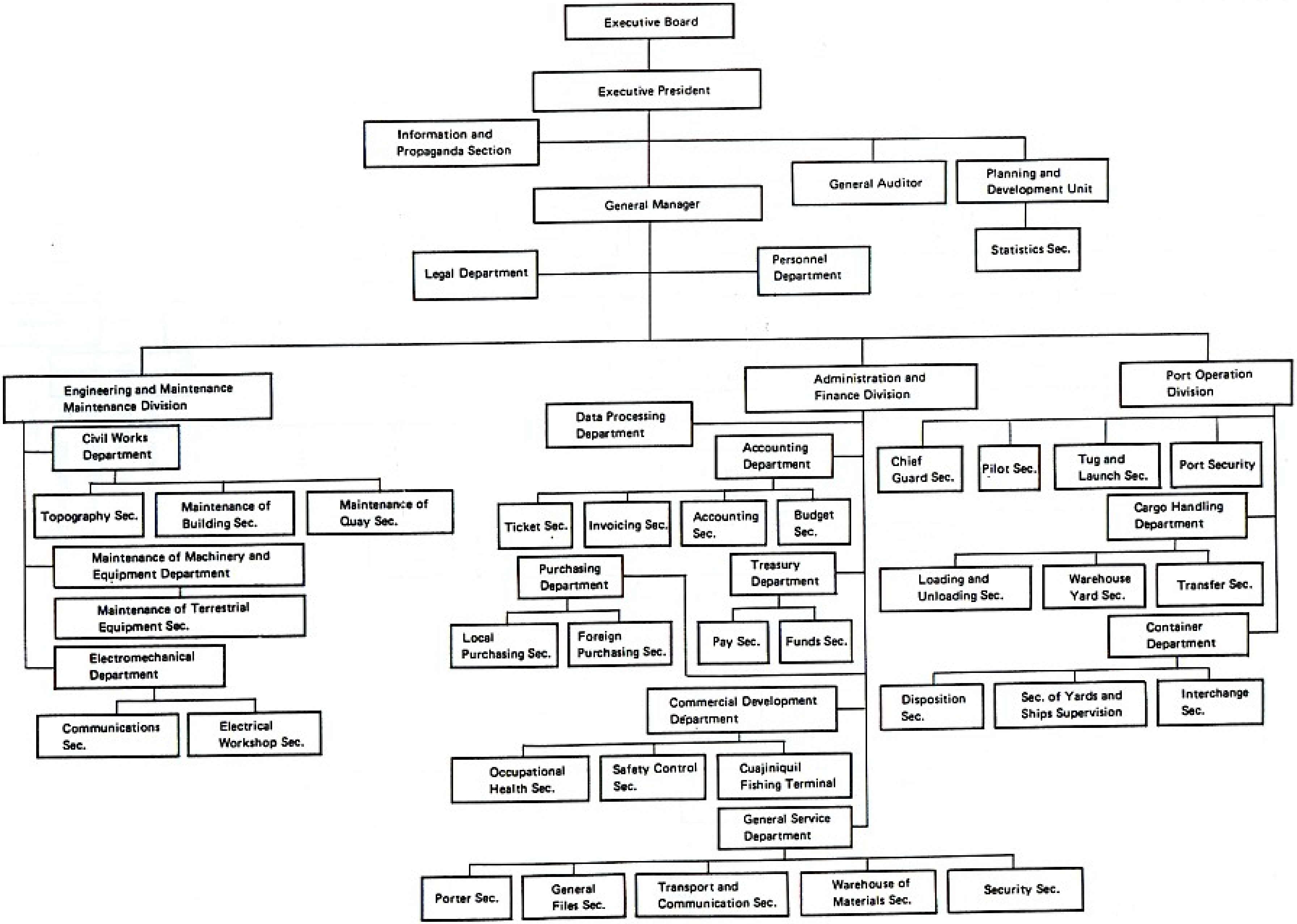


Fig. II-3 Organization of INCOP

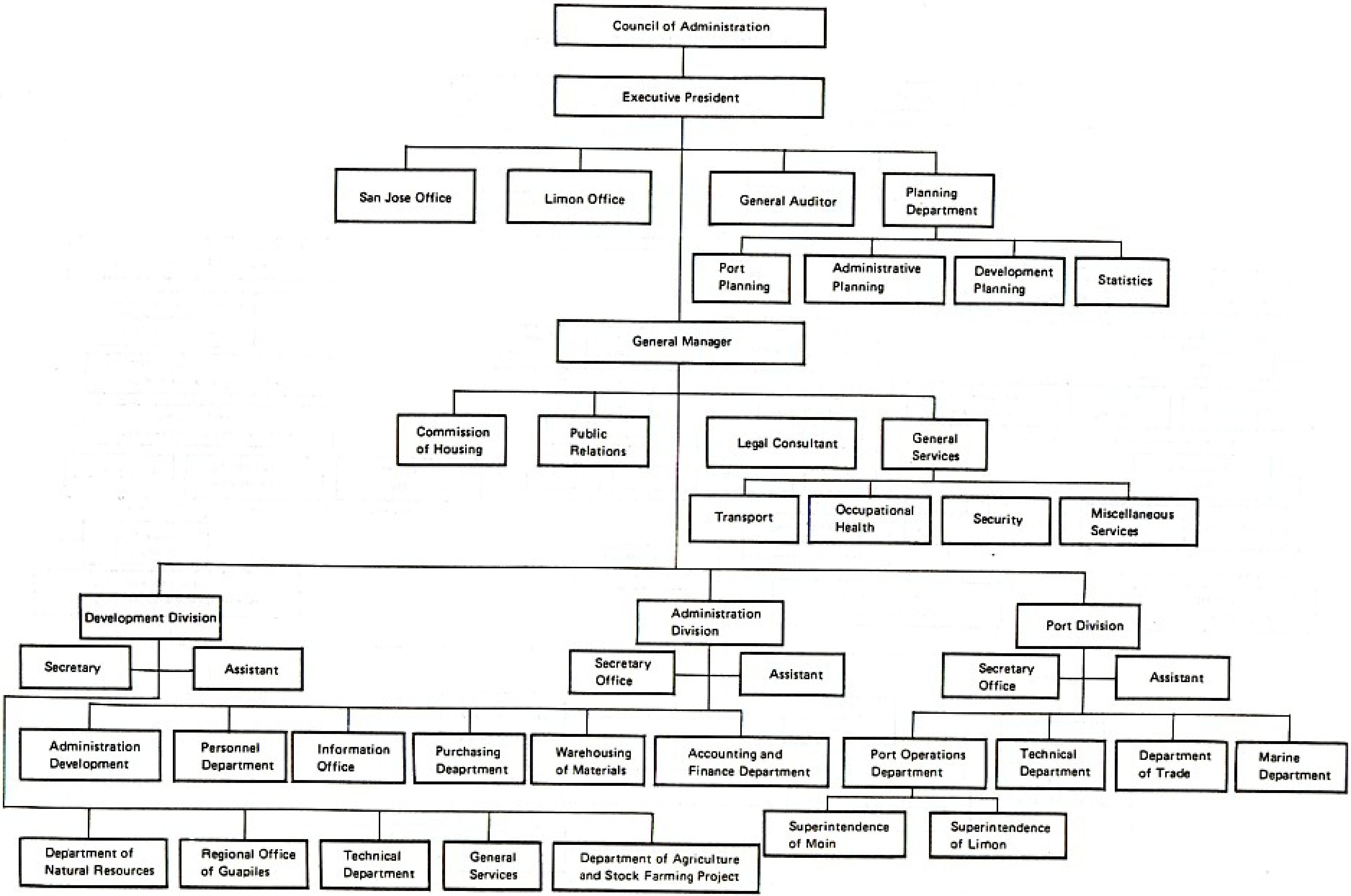


Fig. II-4 Organization of JAPDEVA

3. Port Activities

In Costa Rica, there are five major international ports … Caldera, Puntarenas, Punta Morales, Quepos and Golfito … on the Pacific coast, and two major international ports … Limón and Moín … on the Atlantic coast. The locations of these ports are shown in Fig. I −4.

The total port cargo throughput in Costa Rica is shown in Fig.II −5 and Table II −1 by coast. Overall, import cargo volume exceeds export cargo volume. About 75% of the total cargo volume is handled on the Atlantic coast. On the Atlantic Coast, large volumes of petrochemical products and bananas are imported and exported at the Port of Moín. The import cargo volume is larger than the export cargo volume on the Pacific coast. Generally, the total national throughput has been increasing. Especially, the cargo volume on the Pacific coast rapidly increased during the three years after the Port of Caldera was opened in 1982. Table II −2 shows port cargo throughput by major port and Table II −3 shows the number of calling ships by major port.

The major ports are briefly described below. Fig.II −6~Fig.II −10 show the port layouts of five of these ports. The most important Costa Rican ports are the Ports of Caldera and Puntarenas on the Pacific coast and the Ports of Limón and Moín on the Atlantic coast. The Port of Caldera is described in detail in CHAPTER III.

The Port of Puntarenas was constructed in 1927. It has an offshore type pier. This pier handled most of the public cargoes on the Pacific Coast until the Port of Caldera was opened. After the opening of the Port of Caldera, the pier has mainly been used to handle grain imports. However, this pier is already superannuated as noted in CHAPTER III and CHAPTER X. The Port of Caldera was constructed to take over the port functions of the Port of Puntarenas. The new port was opened in December 1981.

The Port of Punta Morales is owned and operated by the sugar-manufacturing company LAICA. There is one detached pier and a long pier with a belt conveyor. There is also a large warehouse for sugar exports. All these facilities are used exclusively for sugar exportation. The water area around the pier is shallow due to siltation.

The Port of Quepos was formerly owned and operated by a private banana company. It was used solely for the export of bananas. However, the ownership of the port was transferred to the joint port authority of MOPT and the local autonomous body, JAPOQ, after the withdrawal of the banana company. About five vessels loaded with palm oil from Southeast Asia enter the port to unload the cargo every year. The port is located at an estuary and faces the Pacific ocean almost directly. Thus, the berth area may be influenced by sand drift and rough sea conditions. MOPT has a plan to develop a fishing port by the foot of the pier.

The Port of Golfito is located in Golfito Bay, and the water area is well protected from the rough sea. The port had been owned and operated by a private banana company, but its ownership was transferred to MOPT at the end of 1985. The deep steel-frame pier has been well maintained. However, there is currently no plan to use this facility due to a lack of demand. However, port demand should grow in the future along with the development of agriculture in the hinterland of the port.

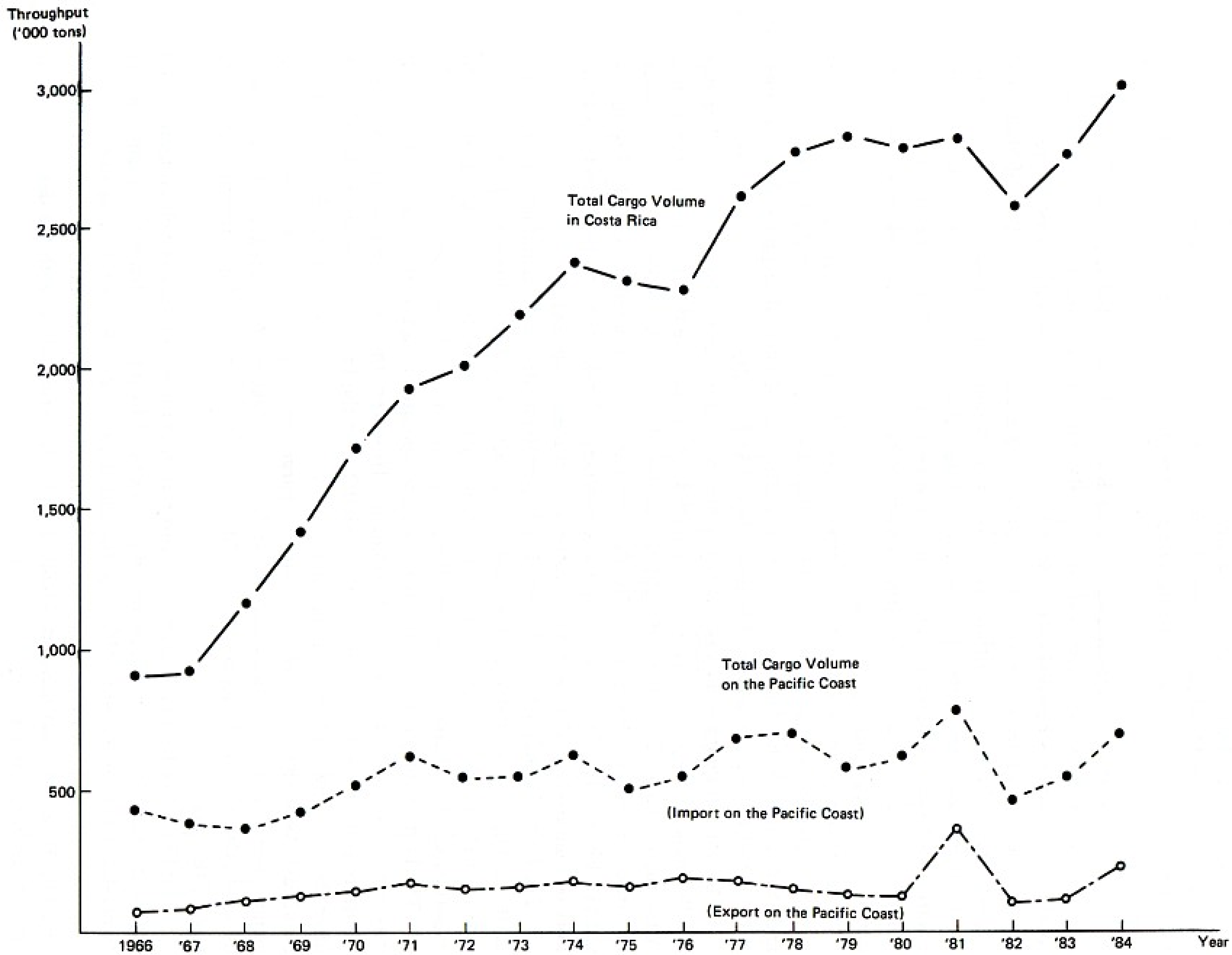


Fig. II-5 Port Cargo Throughput in Costa Rica

Table II-1 Port Cargo Throughput in Costa Rica

	Imports			Exports			Total			Share (%)		
Year	Puntarenas	Limón	Total	Puntarenas	Limón	Total	Puntarenas	Limón	Total	Punta-renas	Limón	Total
1966	361,079	224,675	585,736	82,371	250,593	333,324	443,450	475,250	918,700	48.3	51.7	100
1967	307,540	293,119	600,659	87,847	242,687	330,534	395,387	535,806	931,193	42.5	57.5	100
1968	255,912	443,300	699,212	119,758	366,922	486,680	375,670	810,222	1,185,892	31.7	68.3	100
1969	307,166	497,778	804,944	127,487	491,253	648,740	434,653	989,031	1,423,684	30.5	69.5	100
1970	390,173	559,615	949,788	152,539	615,757	768,296	542,712	1,175,372	1,718,084	31.6	68.4	100
1971	446,968	599,439	1,046,407	185,983	703,970	889,953	632,951	1,303,409	1,936,360	32.7	67.3	100
1972	392,115	649,236	1,041,351	159,618	826,118	985,736	551,733	1,475,354	2,027,087	27.2	72.8	100
1973	378,312	688,761	1,067,073	178,347	953,770	1,132,117	556,659	1,642,531	2,199,190	25.3	74.7	100
1974	457,967	844,343	1,302,310	190,247	896,257	1,086,504	648,214	1,740,600	2,388,814	27.1	72.9	100
1975	353,940	876,004	1,229,944	166,182	929,676	1,095,858	520,122	1,805,680	2,325,802	22.4	77.6	100
1976	360,584	856,960	1,217,544	200,999	864,801	1,065,800	561,583	1,721,761	2,283,344	24.6	75.4	100
1977	518,203	1,081,922	1,600,125	188,633	831,089	1,019,727	706,841	1,913,011	2,619,852	27.0	73.0	100
1978	554,356	1,179,524	1,733,880	167,273	881,488	1,048,761	721,629	2,061,012	2,782,641	25.9	74.1	100
1979	415,258	1,318,223	1,733,481	143,064	953,022	1,096,086	558,322	2,271,245	2,829,567	19.7	80.3	100
1980	502,111	1,232,267	1,734,378	127,343	930,018	1,057,361	629,454	2,162,285	2,791,739	22.5	77.5	100
1981	422,394	998,549	1,420,943	378,030	1,027,939	1,405,969	800,424	2,026,488	2,826,912	28.3	71.7	100
1982	372,208	1,031,103	1,403,311	109,148	1,074,261	1,183,409	481,356	2,105,364	2,586,720	18.6	81.4	100
1983	434,415	1,088,980	1,523,395	116,894	1,127,702	1,244,596	551,309	2,216,682	2,767,991	19.9	80.1	100
1984	470,945	1,082,131	1,553,076	246,088	1,218,490	1,464,578	717,033	2,300,621	3,017,654	23.8	76.2	100

SOURCE: CUADROS ESTADISTICOS SOBRE SECTOR TRANSPORTES, DGP/MOPT
NOTE : Cargo Volume at the Ports of Caldera and Moin is included in that at the Ports of Puntarenas and Limón, respectively.

Table II-2 Port Cargo Throughput by Major Port

	Year								
	1976	1977	1978	1979	1980	1981	1982	1983	1984
[IMPORT]									
Total	1178.0	1601.0	1784.2	1771.6	1772.2	1460.6	1435.8	1547.4	1575.9
The ports of Limón and Moín	856.9	1050.5	1179.5	1318.2	1232.5	998.5	1031.1	1089.0	1082.2
The Port of Puntarenas	260.7	503.2	554.4	415.3	502.1	422.4	335.0	253.4	—
The Port of Golfito	60.4	47.3	50.3	38.1	37.6	39.7	32.5	24.0	23.6
The Port of Caldera	—	—	—	—	—	—	37.2	181.0	470.1
[EXPORT]									
Total	1370.2	1313.3	1384.1	1380.9	1292.9	1626.0	1396.9	1410.7	1630.4
The ports of Limón and Moín	864.8	831.1	923.8	959.7	930.0	1028.0	1074.2	1127.7	1216.5
The Port of Puntarenas	205.9	182.7	165.3	144.1	127.4	185.0	95.4	1.9	—
The Port of Golfito	299.5	299.5	295.0	277.1	235.5	220.0	213.7	166.1	167.9
The Port of Caldera	—	—	—	—	—	193.0	13.6	115.0	246.0

Source: CUADROS ESTADISTICOS SOBRE SECTOR TRANSPORTES 1984, DGP/MOPT

Table II-3 Number of Calling Ships by Major Port

Year	Pacific Ocean					Caribbean Sea	Total
	Caldera	Puntarenas	Golfito	Quepos	Sub-toal	Limón/Moín	
1967	—	490	189	3	682	447	1129
1968	—	473	115	1	589	537	1126
1969	—	494	240	1	735	733	1468
1970	—	438	300	1	739	734	1473
1971	—	452	275	—	727	742	1469
1972	—	505	300	—	805	807	1612
1973	—	509	270	1	780	826	1606
1974	—	398	210	—	608	795	1403
1975	—	389	207	—	596	794	1390
1976	—	394	172	—	566	824	1390
1977	—	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1978	—	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1979	—	n.d.	n.d.	n.d.	n.d.	861	n.d.
1980	—	n.d.	n.d.	n.d.	n.d.	841	n.d.
1981	41	176	n.d.	n.d.	n.d.	830	n.d.
1982	109	48	n.d.	n.d.	n.d.	907	n.d.
1983	180	30	n.d.	n.d.	n.d.	933	n.d.
1984	156	26	n.d.	n.d.	n.d.	849	n.d.

Note) n.d. : no data

In addition to these major ports on the Pacific coast, there are also the FERTICA port with an approximately 360 m long and 3 to 2 m deep berth for fertilizer imports and exports and some fishing ports north of the Puntarenas peninsula. The water channel which leads to the above small ports is greatly affected by siltation. According to MOPT, it frequently requires maintenance dredging.

The cargo volume at the Port of Limón is the largest among all Costa Rican ports. It has one container berth and one roll on/roll off berth. There has also been sand sedimentation in the harbour at Limón.

The Port of Moín has two deep berths for banana exports and one berth for the import of petrochemical products. The former is managed and operated by JAPDEVA and the latter is run by RECOPE. The port suffers siltation from the river in the rainy season.

Major port facilities at the ports described above and at the Port of Caldera are summarized in Table II−4.

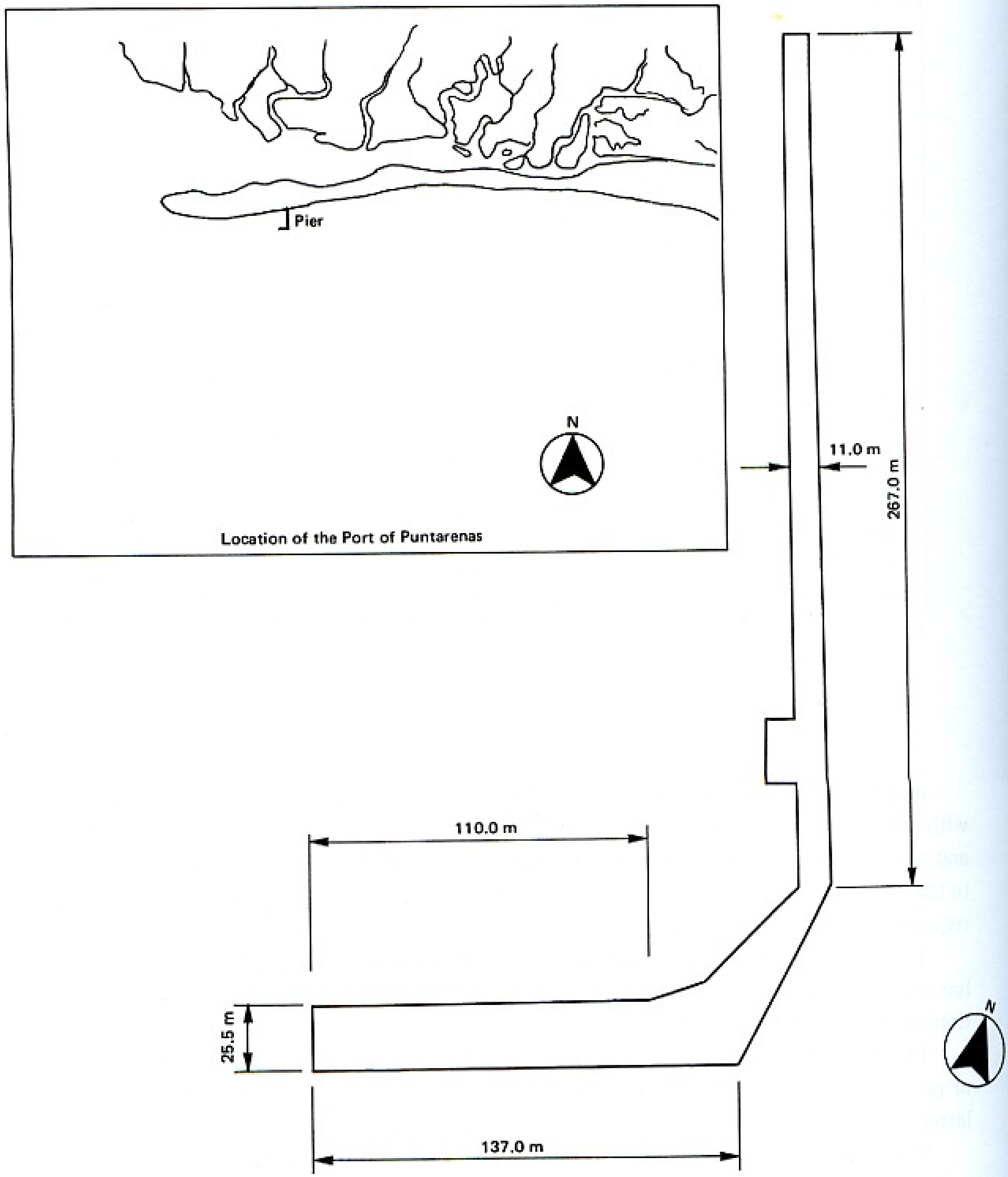


Fig. II-6 Port Layout of the Port of Puntarenas

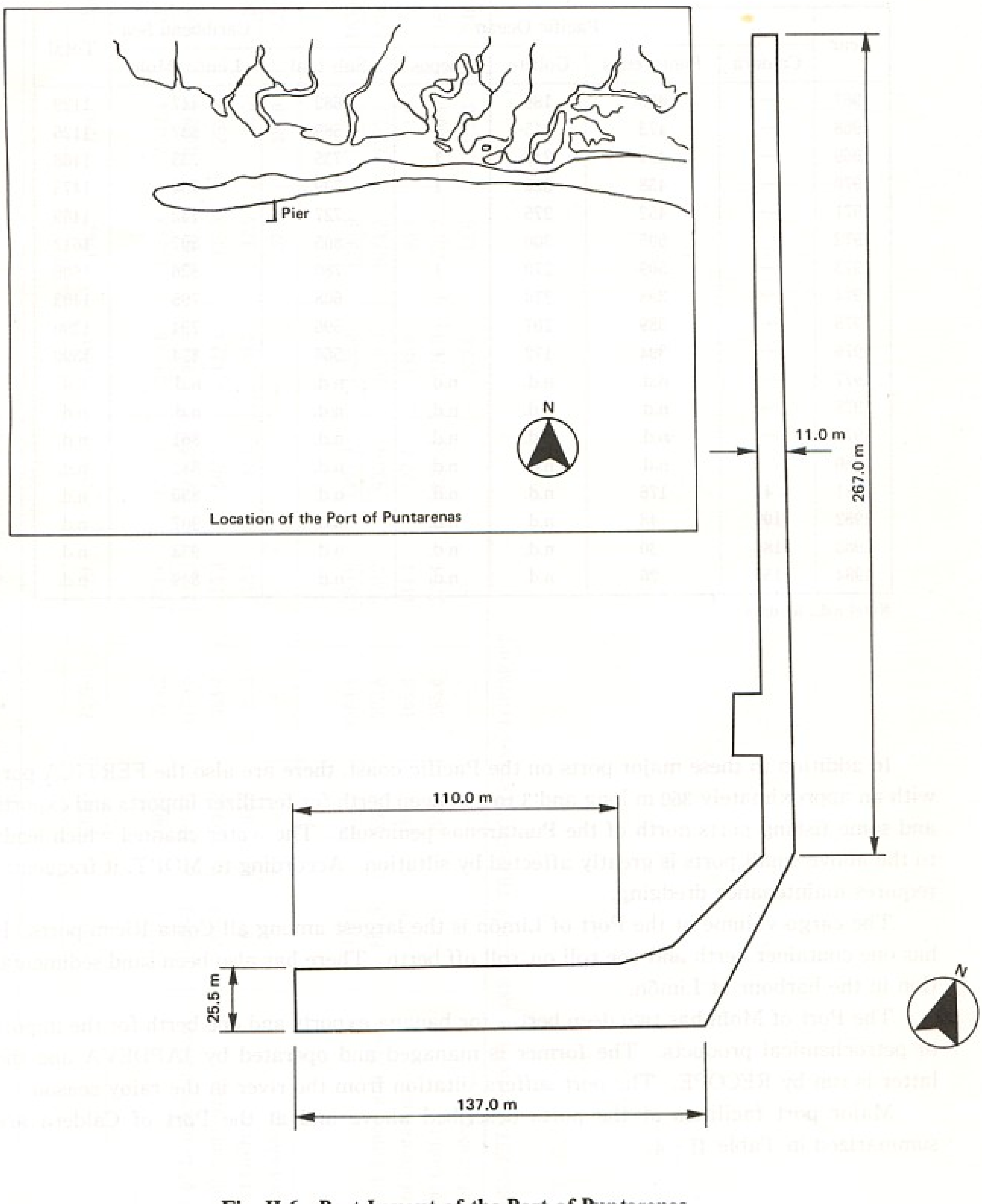
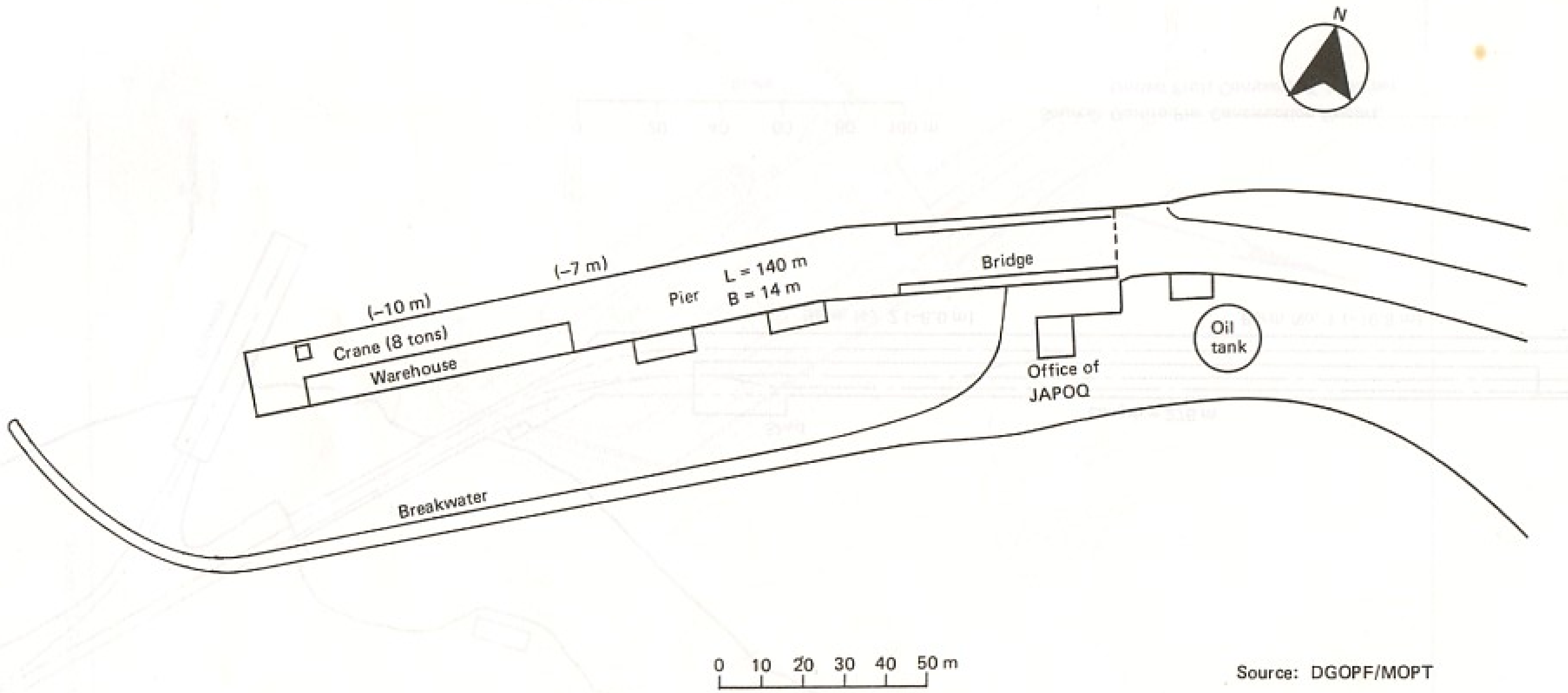
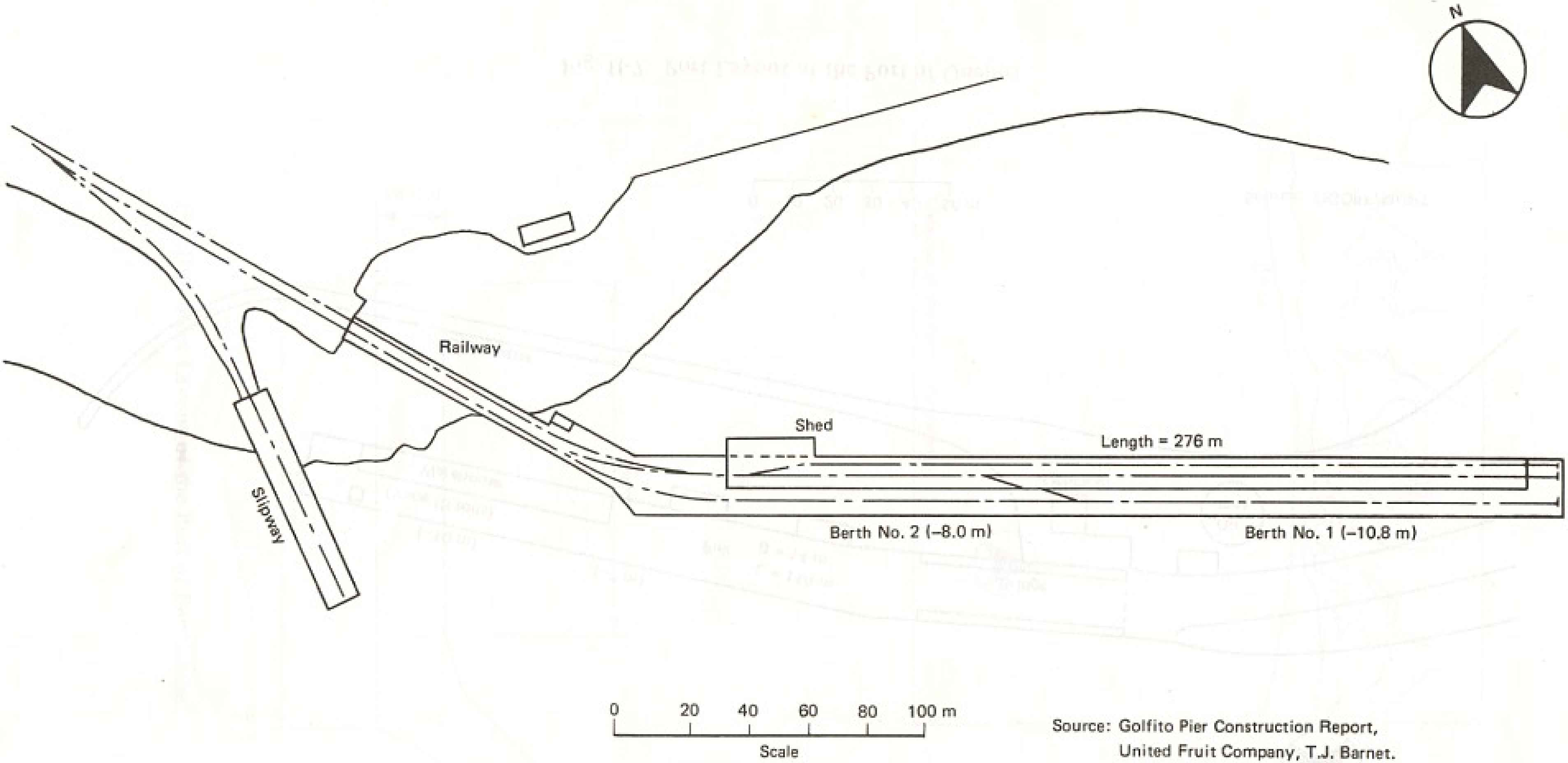


Fig. II-6 Port Layout of the Port of Puntarenas



Source: DGOPF/MOPT

Fig. II-7 Port Layout of the Port of Quepos



Source: Golfito Pier Construction Report,
United Fruit Company, T.J. Barnet.

Fig. II-8 Port Layout of the Port of Golfito

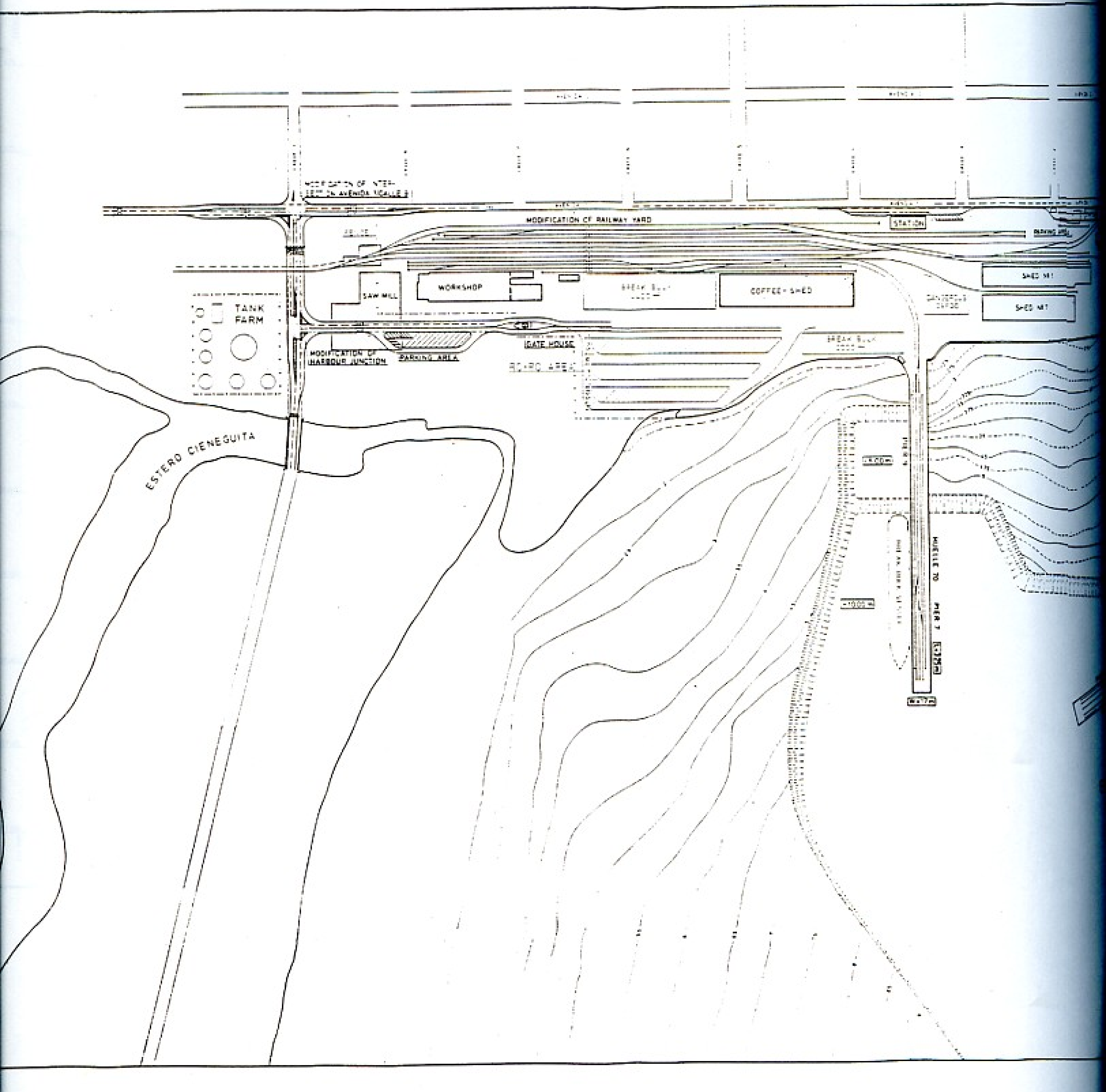
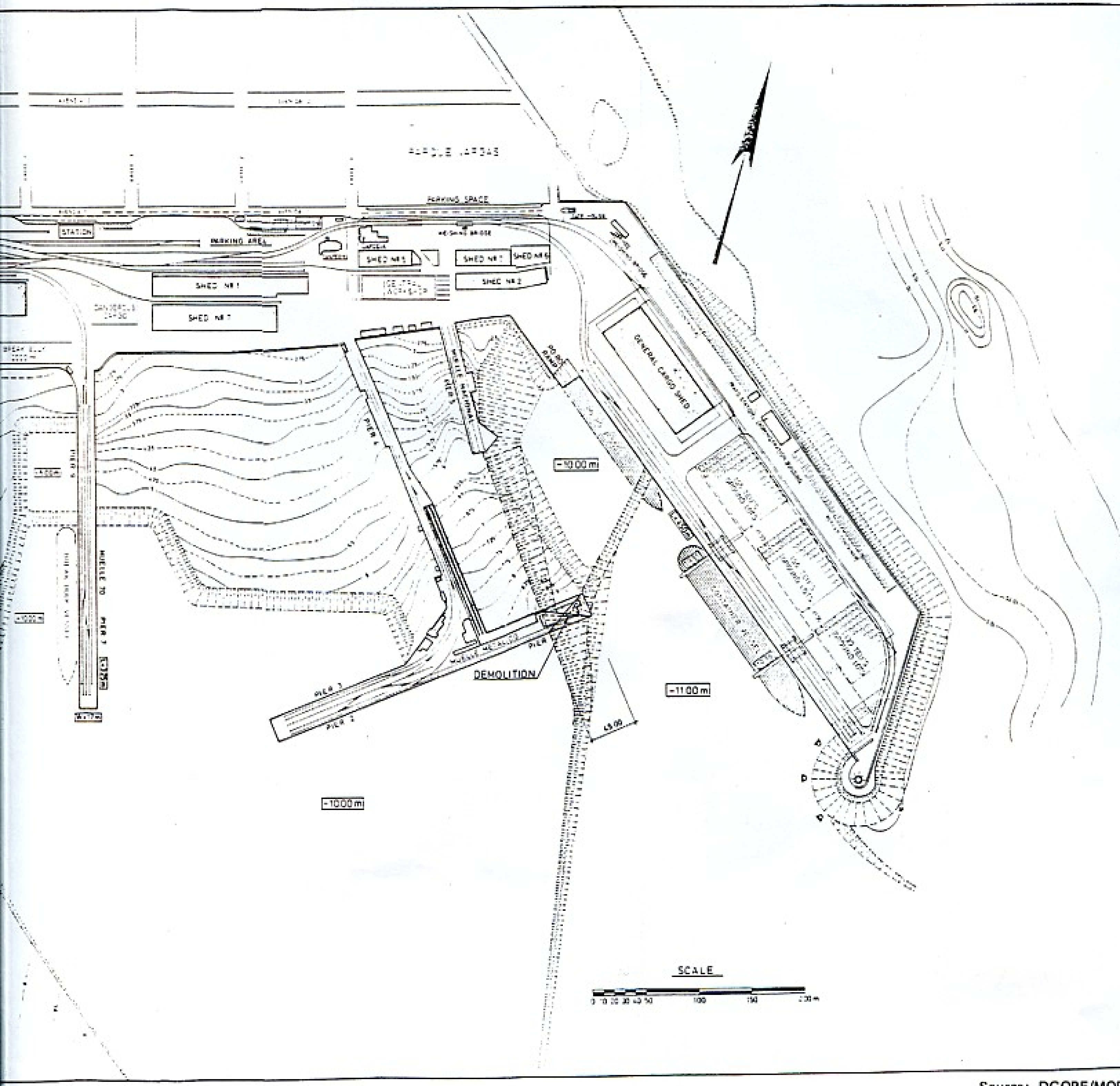


Fig. II-9 Port Layout of the Port of Limón



Source: DGOPF/MOP

Port Layout of the Port of Limón

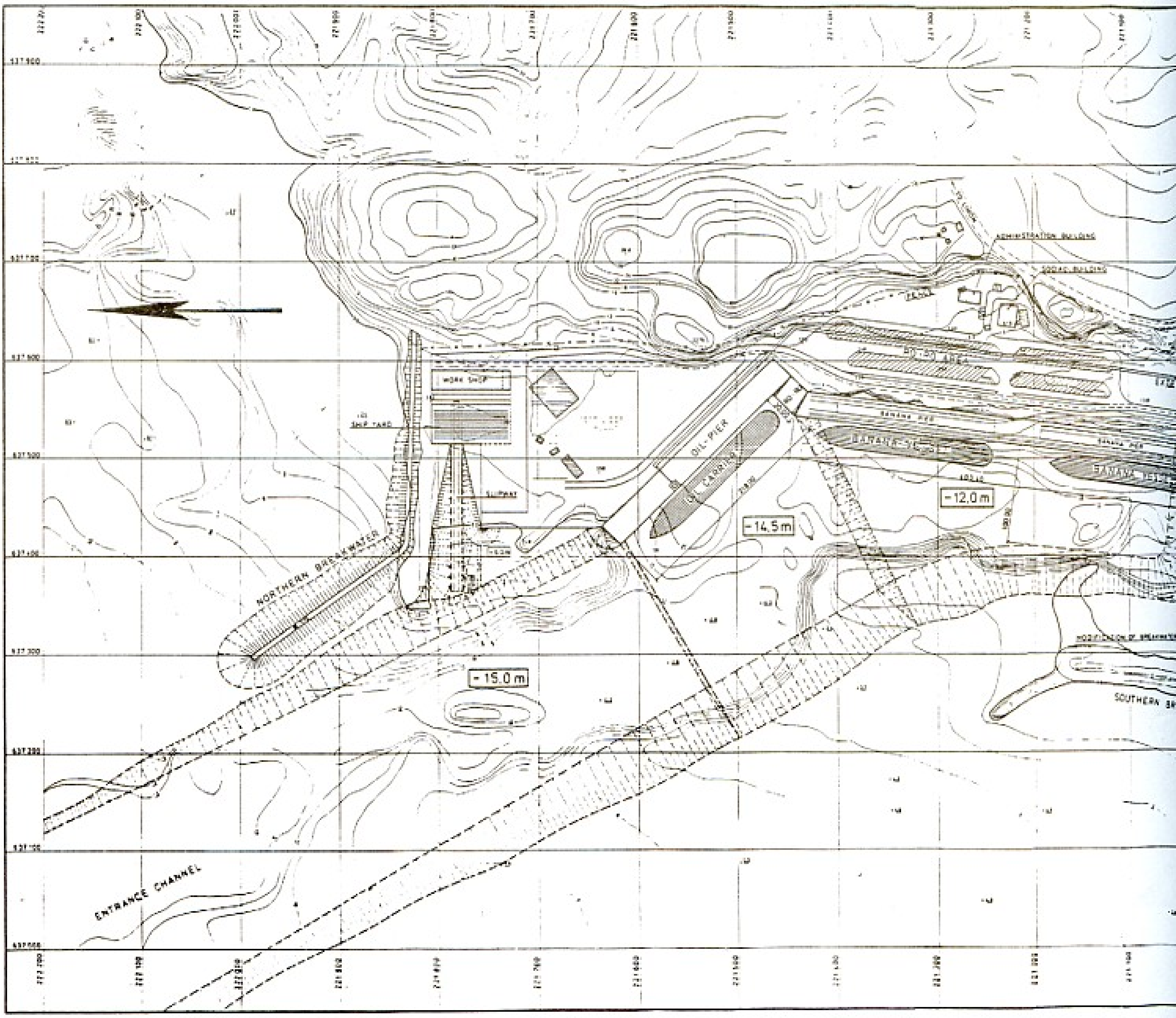
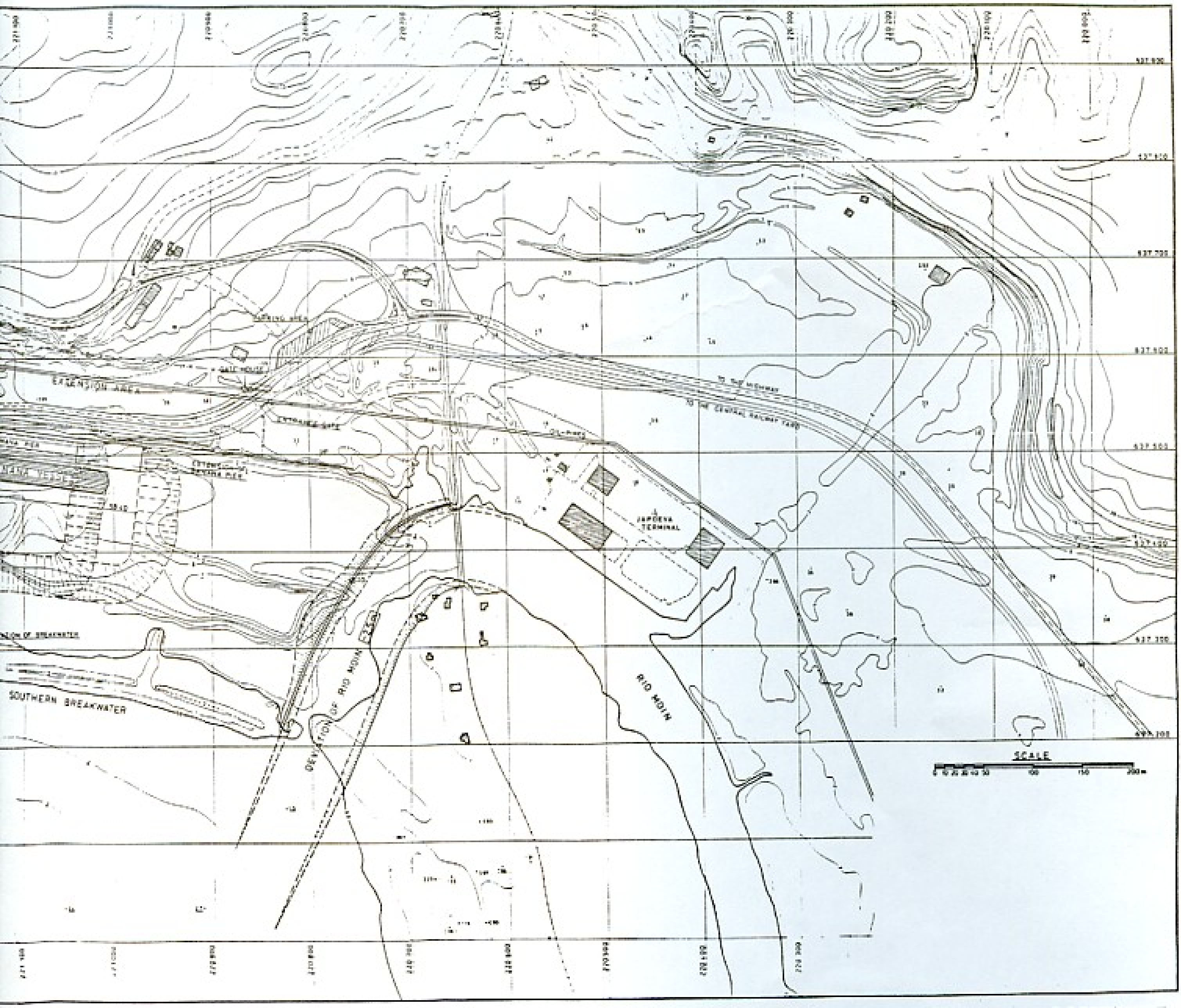


Fig. II-10 Port Layout o



Source: DGOPF/MOPT

Layout of the Port of Móin

Caldera	No.1 berth (steel sheet pile quaywall) : 210m long, −11.0m deep No.2 berth (steel sheet pile quaywall) : 150m long, −10.0m deep No.3 berth (steel sheet pile quaywall) : 130m long, −7.5m deep Ro/Ro pier : 1 berth Mooring basin : −11.0m deep, 148,000m² −10.0m deep, 43,000m² − 7.5m deep, 28,000m² Breakwater (rubble mound breakwater) : Main breakwater : 250m long Wing jetty : 115m long (as of Oct.1985) Transit shed : 7,200m² Warehouse : 5,400m² Open storage yards : for general cargo : 25,440m² for container : 34,000m² Cargo handling equipment : 2 units Forklift : 32 units Mobile crane : 4 units Container Tractor : 2 units Mobile chassis : 4 units Others : 30 units	Administration : INCOP Start of use : 1981
Puntarenas	Steel pile pier : 140m long, 24m wide Connecting bridge : 320m long, 9m wide No.1 berth : 137m long, −9.1 & −12.2m deep No.2 berth : 110m long, −7.6 & −10.7m deep Ancillary facilities : Railway sidings	Administration : INCOP Start of use : 1929

Punta Morales	Dolphin 1 berth : −12∼−14m deep Ancillary facilities: Belt conveyors	Administration: INCOP Start of use: 1976 Exclusively for export of sugar
Quepos	Pier (Steel H pile and concrete cylinder pile pier) 140m long, −7∼−10m deep	Administration: JAPOQ
Golfito	Whart 2 berths: 276m long, −7∼−10m deep	Administration: JAPDEVA
Limón	Muelle Metalico (steel-piled pier.): 320m long, 24m wide Connecting bridge: 366m long No.1 berth: 160m long, −8.8m deep No.2 berth: 160m long, −7.9m deep No.3 berth: 122m long, −6.7m deep Ancillary facilities: Railway sidings, belt conveyors for loading of bananas. Muelle Nacional (steel-piled Pier): 156m long, −6∼−7m deep Ancillary facilities: Railway sidings Muelle Setenta (concrete-piled pier) 340m long, 17m wide 2 berths: −9m deep 1 berth : −6m deep Ancillary facilities: Railway sidings 20 tf crane Ro/Ro berth: −8m deep Proyecto Aleman (concrete-piled open-type wharf): 360m long, −11m deep Ro/Ro berth (concrete-block wharf): 90m long, −10m deep	Administration: JAPDEVA Start of use: 1904
Moín	Pertroleum unloading facility (mooring buoy) Crude oil berth (steel-piled open-type wharf): 200m long, −14m deep Ro/Ro berth: 30m wide, −12m deep Banana handling berth (steel-piled open-type wharf): 400m long, −12m deep	Administration: RECOPE Start of use: Jan. 1979

1. 1 Administrative Structure

INCOP is a service enterprise with administrative autonomy and with its own legal personality, belonging to the nation. The organization is comprised of three divisions: Engineering and Maintenance, Administration and Finance, and Port Operations. In addition to these, there is a Planning and Development Unit which functions as an advisor to the three divisions.

As of December 1985, the total number of INCOP personnel is 986. The Engineering and Maintenance Division consisting of three Department, i.e. Civil Works, Maintenance of Machinery and Equipment, and Electromechanical, employs 152 personnel. The Port Operation Division which is in charge of ship operations, cargo handling including cargo storage and port security employs 604 personnel.

1. 2 Relations with Other Institutions

(a) Port tariffs
The port tariffs are approved by MOPT.

(b) Budget
The budget of INCOP is approved by the Board of Audit of the Government.

(c) Investment
The investment budget is approved by MIDEPLAN.

(d) Development Projects
The port development projects to be executed directly by INCOP are approved by MOPT.

1. 3 Financial Situation

As shown in Table III−1 7 INCOP's total assets at the end of September 1985 were 449 million colones consisting of 127 million colones of current assets (28% of the total), 318 million colones of fixed assets (71% of the total), and 4 million colones of deferred charges (1% of the total). The net worth ratio, i.e. capital divided by total assets, was 32% at the end of September 1985.

As shown in Table III−2, INCOP has maintained a good financial situation for many years except for 1982 when INCOP went into the red because of a sudden decrease in cargo volume.

Almost all of the revenues of INCOP come from port tariffs. Port tariffs have been reduced gradually as shown in Table III−3, taking into consideration the balance between revenues and expenses.

Current Assets	12,745	17,141	88,718	126,746
Cash and Temporary Investment	1,171	10,014	14,308	10,904
Trade Receivables	5,401	△ 599	54,099	81,007
Inventories of Materials and Supplies	5,293	6,468	13,926	18,601
Other Assets	880	1,258	6,385	16,234
Fixed Assets	107,990	188,130	315,665	317,538
Land	35,835	35,835	35,835	35,835
Plant and Equipment of INCOP	164,832	187,771	179,203	179,172
Depreciation of Plant and Equipment	△ 119,356	△ 128,365	△ 138,106	△ 145,086
Plant and Equipment of Caldera		7,018	158,546	165,662
Depreciation of Plant and Equip of Caldera		△ 391	△ 859	△ 1,340
Construction in Progress	26,679	83,417	78,287	80,581
Other Assets	0	2,845	2,759	2,714
Deferred Charges		788	2,042	4,374
Total Assets	120,735	206,058	406,425	449,454
Current Liabilities	62,066	85,362	140,722	178,323
Long-Term Liabilities	7,191	66,416	134,184	128,962
Shareholders' Equity	51,478	54,279	131,520	142,169
Initial Capital	7,612	7,612	7,612	7,612
Contribution	1,196	− 3,259	35,357	37,833
Retained Earnings		36,728	36,923	82,799
Net Income	42,670	13,198	51,628	13,925
Total Liabilities and Shareholders' Equity	120,735	206,058	405,425	449,454

Table III-2 Revenue and Expense

Unit : '000 colones

Year	Revenue	Expense	Profit
1976	61,764	57,853	3,911
1977	56,359	39,607	16,752
1978	60,749	55,652	5,097
1979	64,330	61,221	3,109
1980	75,365	75,145	220
1981	106,935	103,380	3,555
1982	108,591	121,653	−13,196
1983	232,278	219,079	13,199
1984	373,224	321,596	51,028

(1) Charge for usage of navigation aids (by T.R.B.)	[illegible]	[illegible]	[illegible]			
(2) Charge for towing service (by T.R.B.)	9.00	→	→	→	→	→
(3) Charge for pilotage (by T.R.B.)	1.50	→	→	→	→	→
(4) Charge for mooring and untying (by T.R.B.)	8.00	→	→	→	→	→
(5) Charge for use of quaywall (by ship length/day)	350.00	347.00	341.00	332.00	320.00	290.00
(6) Charge for cleaning wharves (by M.T of cargo)	7.00					
(7) Charge for use of wharves (by M.T of cargo)						
(a) Genera cargo	485.00	484.40	483.10	481.20	478.70	472.40
(b) Bulk cargo	120.00	119.40	118.10	116.20	113.70	107.40
(8) Loading/unloading charges (by M.T of cargo)						
(a) Importation						
○ General cargo	216.00	212.70	206.10	196.20	183.00	150.00
○ Vehicles	216.00	212.70	196.10	196.20	183.00	150.00
○ Cargo larger than 6㎥	266.00	262.70	256.10	246.20	233.00	200.00
○ Cargo longer than 5m	216.00	212.70	206.10	196.20	183.00	150.00
(b) Exportation						
○ General cargo	166.00	162.70	156.10	146.20	133.00	100.00
○ Cargo brought alongside	116.00	112.70	106.10	96.20	83.00	50.00
(9) Port dues (by M.T of cargo)						
(a) Importation						
○ Cargo to be divided	83.00	80.50	75.50	68.00	58.00	33.00
○ Containerized cargo	96.00	93.50	88.50	81.00	71.00	46.00
○ Roll-on, Roll-off	120.00	107.50	102.50	95.00	85.00	60.00
○ Bulk cargo	100.00	97.50	92.50	85.00	75.00	50.00
(b) Exportation						
○ Cargo to be divided	80.00	77.50	72.50	65.00	55.00	30.00
○ Containerized cargo	96.00	93.50	88.50	81.00	71.00	46.00
○ Roll-on, Roll-off	110.00	107.50	102.50	95.00	85.00	60.00
○ In transit	100.00	97.50	92.50	85.00	75.00	50.00

Note: T.R.B. means gross registered tonnage.

Fig. III−1 shows the layout of the Port of Caldera. There are three berths as shown in Table III−4. In addition, there are a small roll−on/roll−off pier and a small craft basin. The berths are located along a marginal wharf with a length of 490 m. There is a turning basin in front of the wharf. The turning basin is divided into three sections. Their depths are −11.0 m, −10.0 m and −7.5 m, respectively, in accordance with the berth depths. To protect the harbour area there is a 250 m long breakwater with a 115 m long wing jetty to the south of the wharf. Overall, the harbour is well protected from rough sea conditions.

Table III-4 Present Berth Allotment

Berth No.	Depth (m)	Length (m)
No. 1	−11.0	210
No. 2	−10.0	150
No. 3	− 7.5	130

2. 2 Basic Port Facilities

2. 2. 1 Main Facilities at the Port of Caldera

The structure and other particulars of the principal port facilities are briefly described below. Standard cross−sections of the items are shown in Figs. III−2〜III−7.

1) Breakwater

Type of structure : Rubble mound type breakwater
Length : First Stage Construction Project 250 m
Subsequent extension 115 m (as of October, 1985)
Crown height : First Stage Construction Project +8.2 m
: Subsequent extension +8.4 m
Date of completion : October 1980

2) Seawall and Revetment

Type of Structure : Rubble mound type seawall and revetment
Length : Seawall 500 m (outside the port)
Revetment 340 m (inside the port)
Crown height : Seawall +7.5 m
Revetment +5.0 m
Date of completion : October 1980

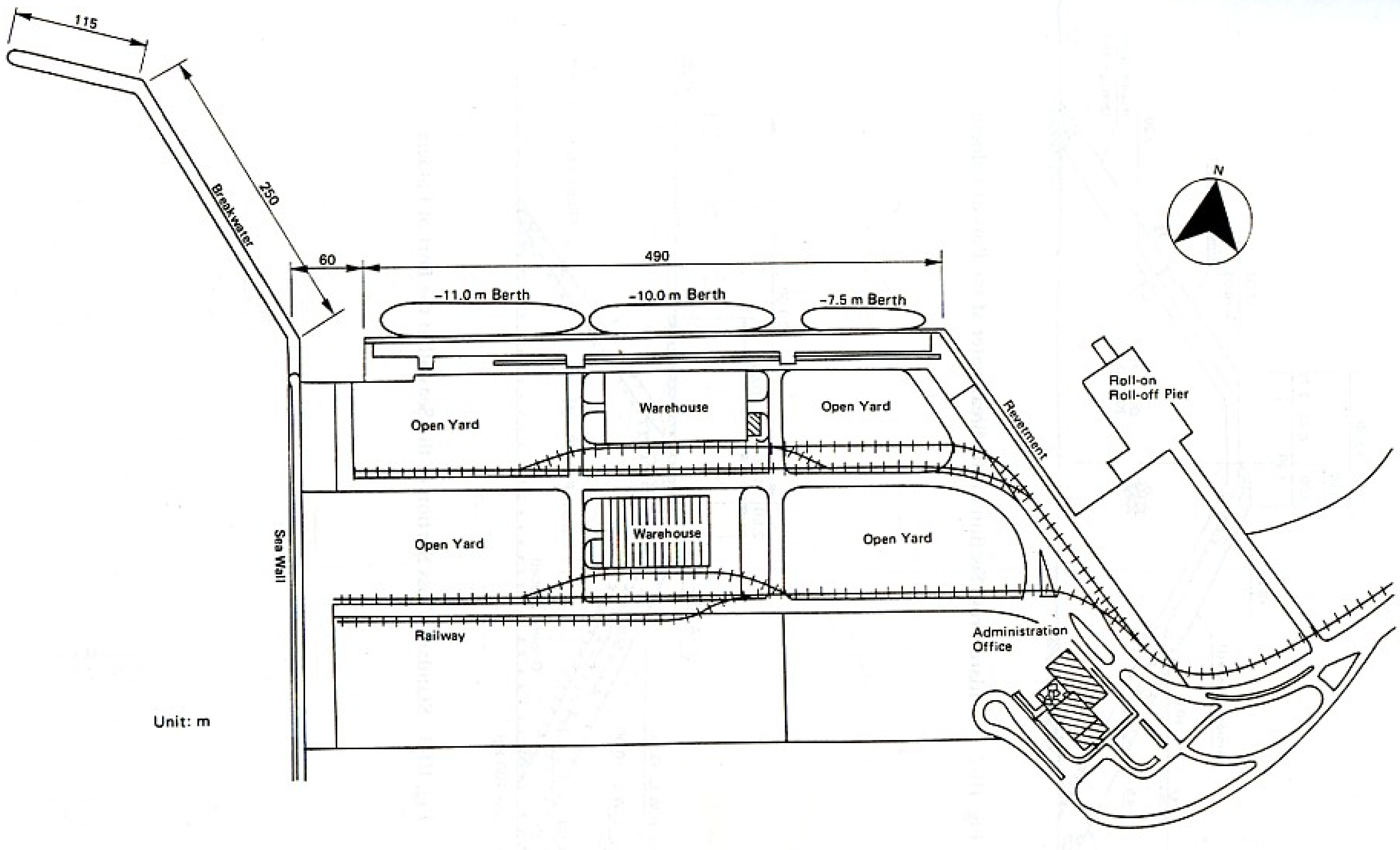


Fig. III-1 Layout of the Port of Caldera

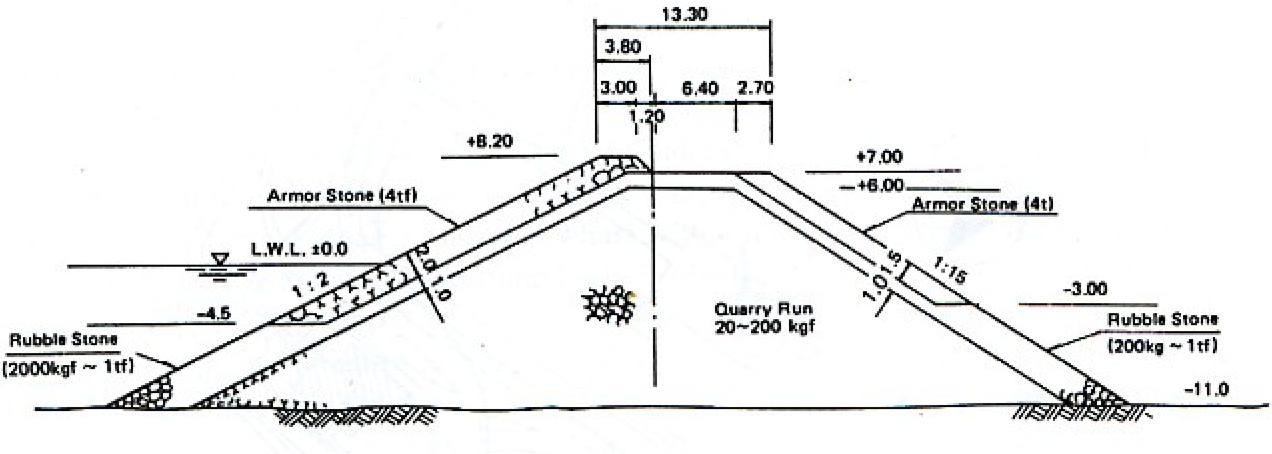


Fig. III-2 Standard Cross Section of the Breakwater at the Port of Caldera

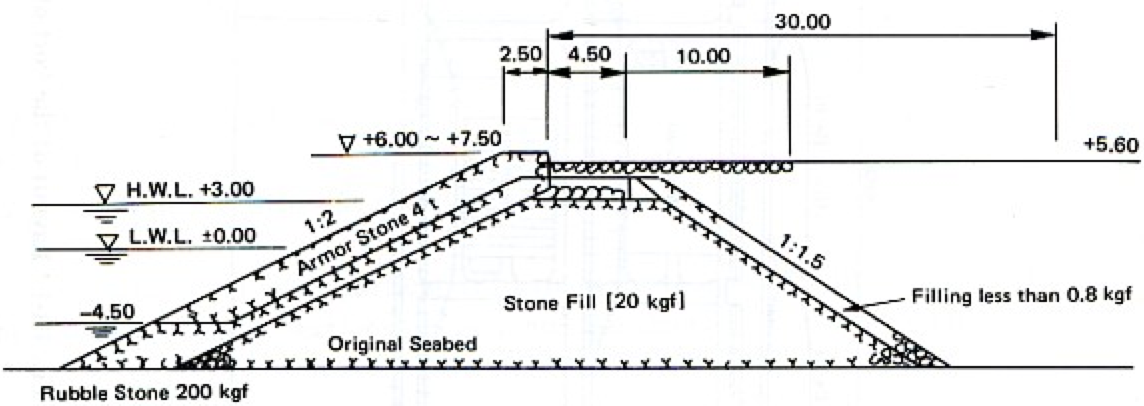
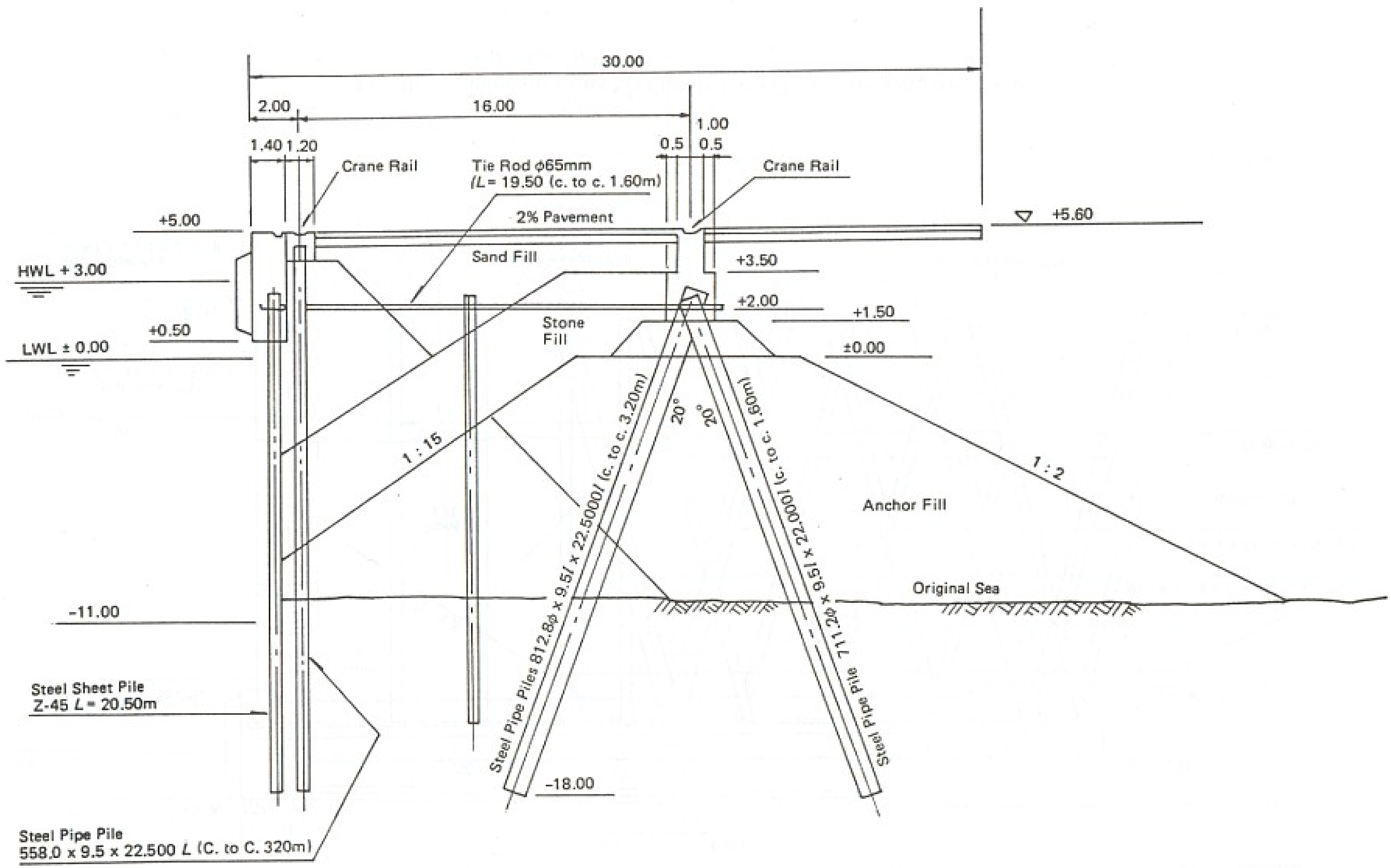
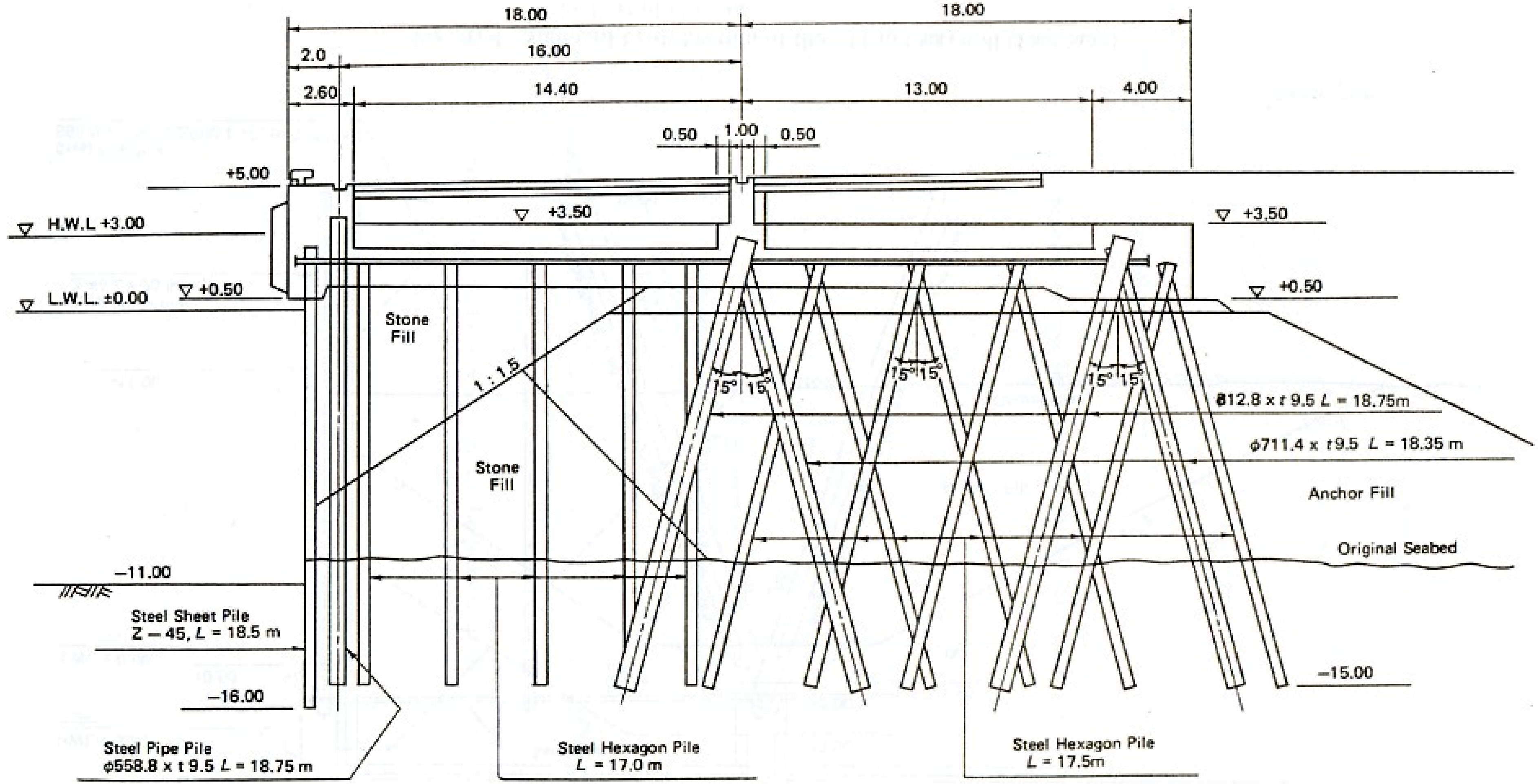


Fig. III-3 Standard Cross Section of the Seawall at the Port of Caldera



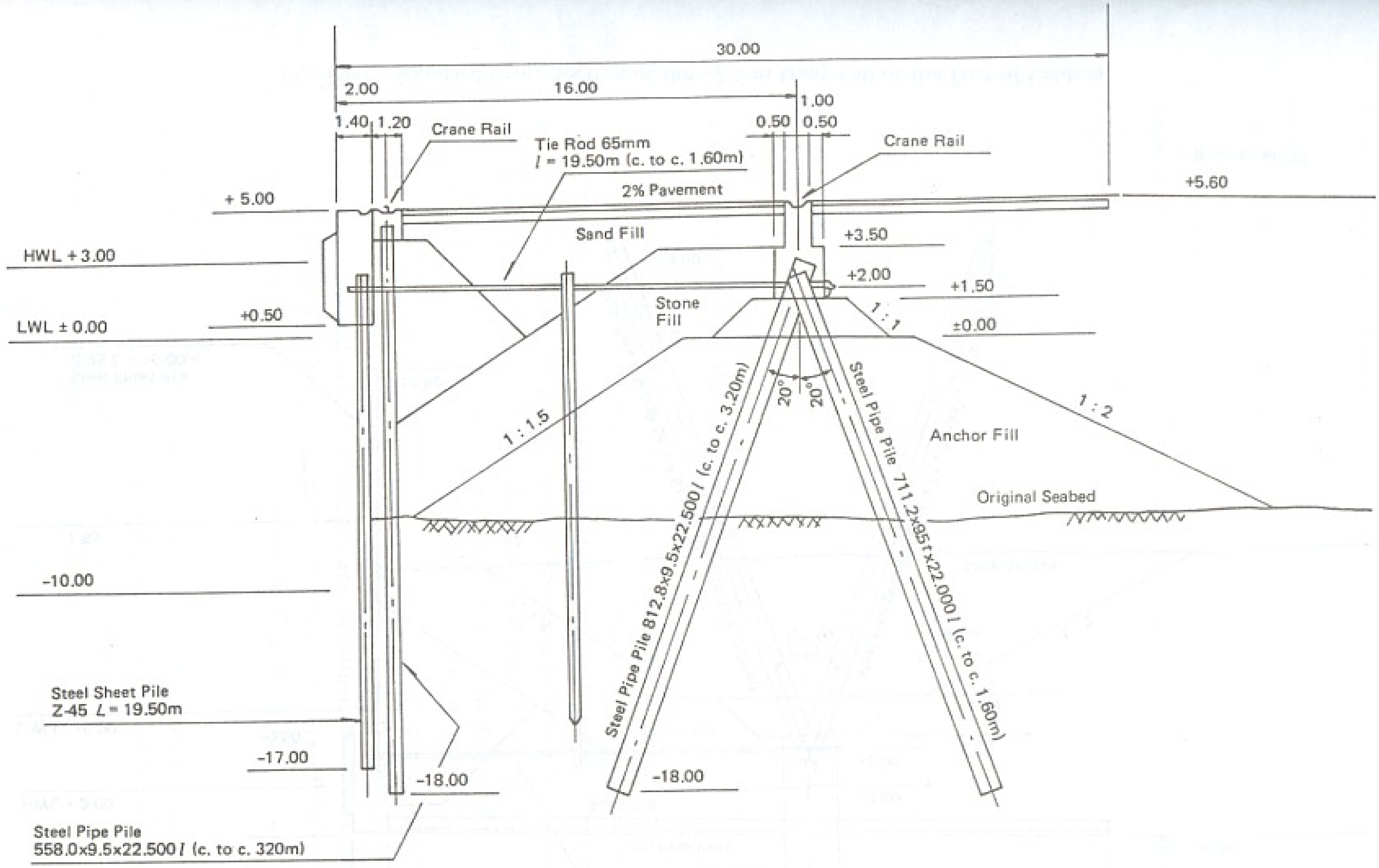
Source: MOPT

Fig. III-4 Standard Cross Section of the –11 m Quaywall (East Side) of the Port of Caldera



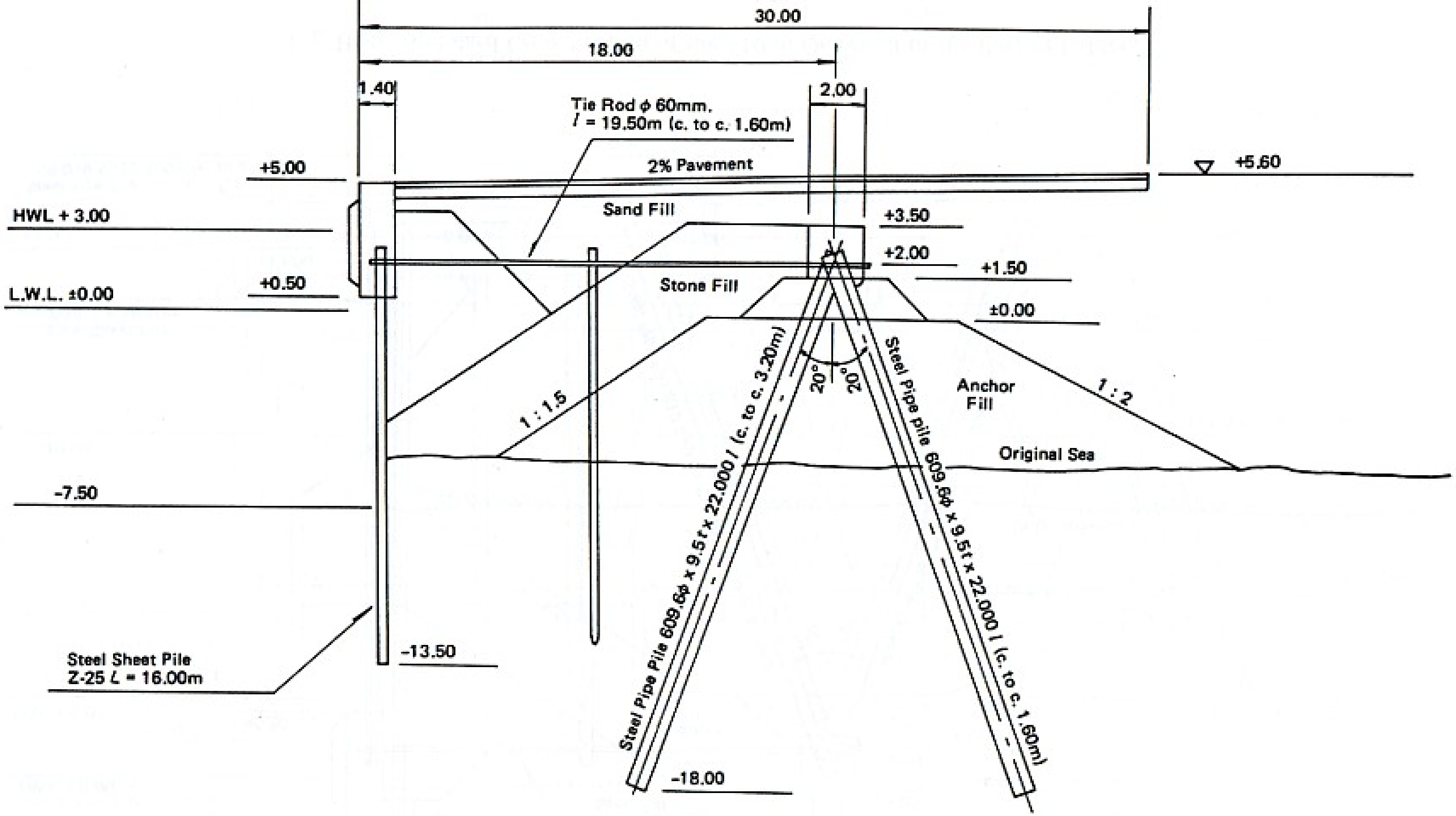
Source: MOPT

Fig. III-5 Standard Cross Section of the −11 m Quaywall (West Side) of the Port of Caldera



Source: MOPT

Fig. III-6 Standard Cross Section of the –10 m Quaywall of the Port of Caldera



Source: MOPT

Fig. III-7 Standard Cross Section of the −7.5 m Quaywall of the Port of Caldera

3) Quaywall

a) −11 m Quaywall

Type of structure : Coupled anchoring pile type steel sheet pile quaywall
(the western end is provided with a 43.5 m relieving platform)

Length : 210 m

Date of completion : February 1982

b) −10 m Quaywall

Type of structure : Coupled anchoring pile type steel sheet pile quaywall

Length : 150 m

Date of completion : June 1980

c) −7.5 m Quaywall

Type of structure : Coupled anchoring pile type steel sheet pile quaywall

Length : 130 m

Date of completion : June 1980

d) Mooring Basin

Volume of dredged material : 355,535 m^3

Date of completion : August 1980

2. 2. 2 Main Facilities at the Port of Puntarenas

The Port of Puntarenas comprises the national pier (Muelle Nacional) on the southern side of the Puntarenas Peninsula which provides a mooring facility for oceangoing ships, a municipal pier (Muelle Municipal) which faces the estuary (El Estero) on the northern side of the Puntarenas Peninsula and which provides mooring facilities for small coastal ships and ferries bound for the Nicoya Peninsula, and additional mooring facilities used by a number of fishing vessels and pleasure boats. Also, MOPT is in the midst of reclaiming land for the construction of a new wharf for use as a fishery harbour which will face the estuary.

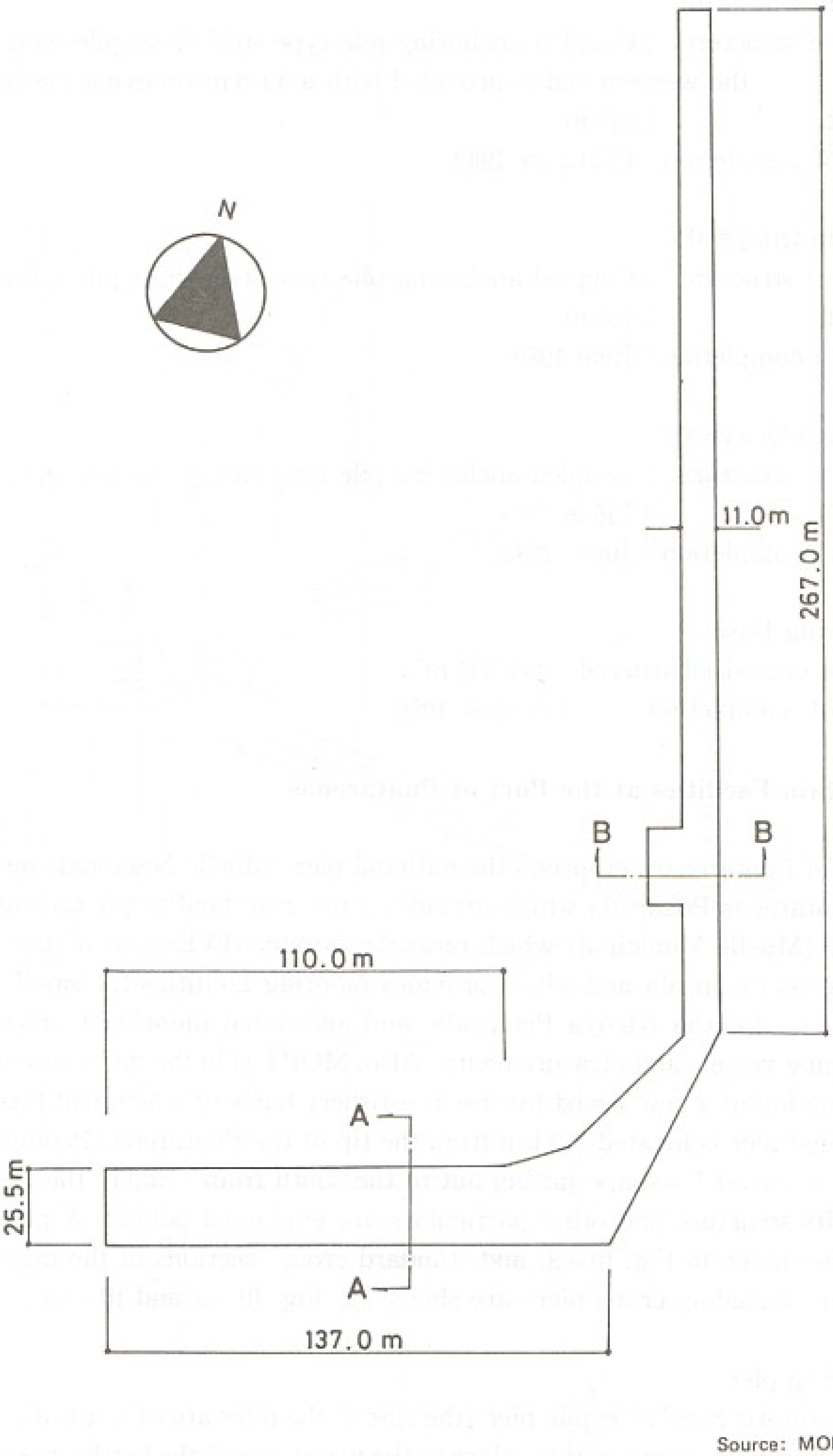
The national pier is located 2.3 km from the tip of the Puntarenas Peninsula and takes the form of a reversed L−shape jutting out to the south from roughly the center of urban Puntarenas. Its structure and other particulars are explained below. A plan view of the national pier is shown in Fig. III−8, and standard cross−sections of the mooring pier and the access pier (including crane pier) are shown in Fig. III−9 and III−10.

1) Mooring pier

Type of struture: Steel pipe pile pier (the tips of the piles are of a spiral configuration). Double column support configurations close to the water line of the berths intergrate the tops of four radiating steel piles by means of concrete cylinders.

Water depth : South side berth ··· minimum −9.1 m
North side berth ··· minimum −7.6 m

Length : South side berth ··· 137 m



Source: MOPT

Fig. III-8 Plan View of the National Pier at the Port of Puntarenas

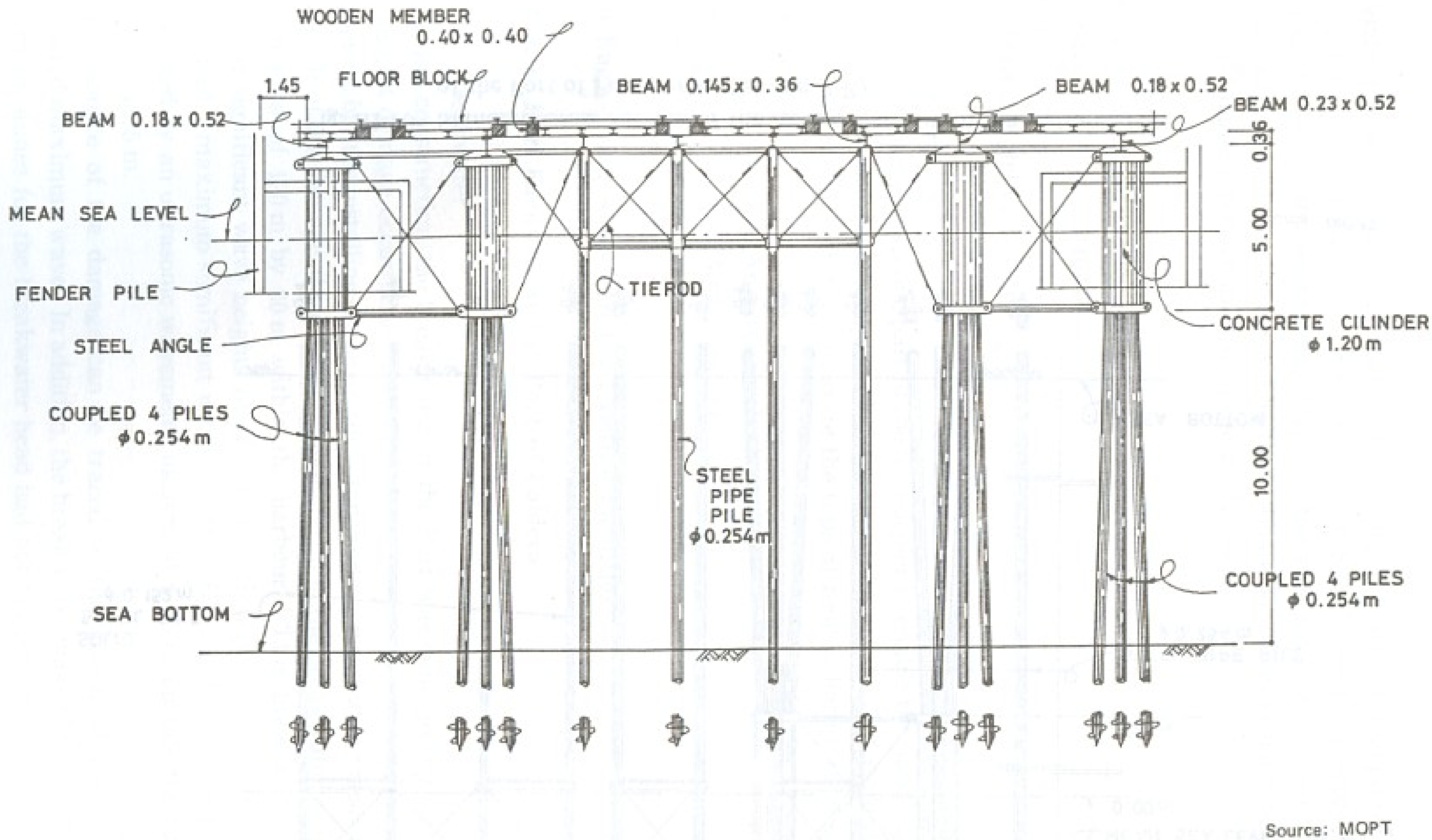
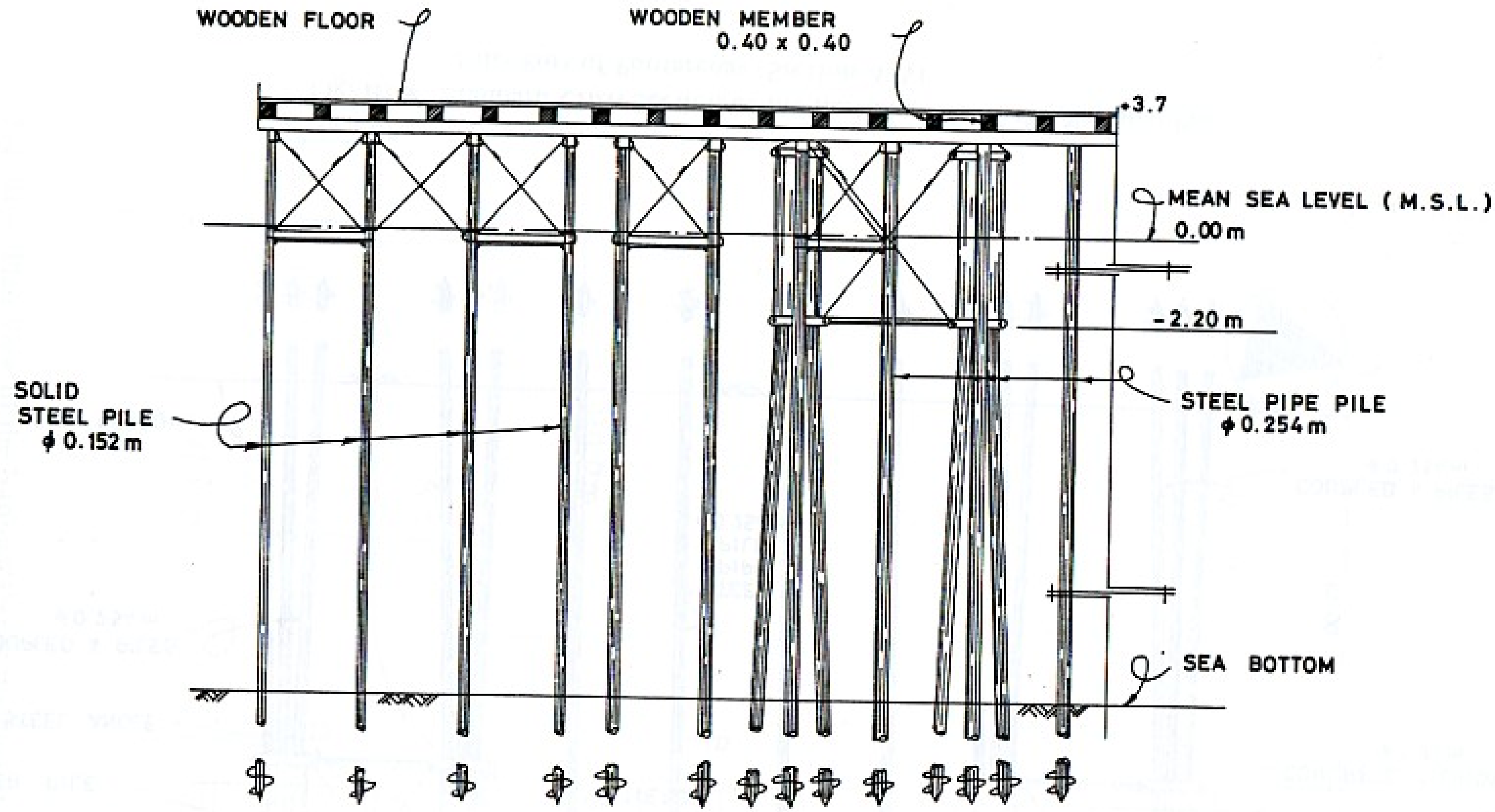


Fig. III-9 Standard Cross Section of the Berthing Pier of the National Pier at the Port of Puntarenas (Section A-A)



Source: MOPT

Fig. III-10 Standard Cross Section of the Access Platform of the National Pier of the Port of Puntarenas (Section B-B)

North side berth … 110 m

Width of pier : 25.5 m

Date of completion : 1929

Fender pilings of frame construction comprising H—shaped steel piles and hexagonally shaped piles have been furnished at the front surfaces of each berth (completed in 1979) to cancel the affect of ship berthing force on the pier structure. Two buoys are placed offshore each berth to which ships are berthed using a special mooring rope. In this manner, ships do not make direct contact with the fender pilings.

2) Access Pier

Type of structure : Pier using solid steel cylinder pilings.

Length : 167 m

Pier width : 11 m

Date of completion : 1929

3) Crane Pier

This crane pier widens one part of the access pier to enable the handling of barge cargo.

Type of structure: Steel pipe pile pier (the tips of the piles are of a spiral configuration.). Four of the supporting columns integrate the tops of four radiating steel piles by means of concrete cylinders.

Length : Approximately 28 m

Width : Approximately 10 m

Date of completion : 1961

2. 3 Engineering Aspects of the Existing Facilities

2. 3. 1 Port Facilities at the Port of Caldera

(1) Breakwater

During construction, the breakwater at the Port was damaged by waves several times. The biggest damage occurred on May 21, 1981. The breakwater had reached the planned 250 meters, but the installing of the armour stones on the breakwater head was not complete. As a result of the damage, the rubble filling material in the breakwater proper was scattered over an area of 120 m by 80 m within the harbour. This breakwater was designed to withstand significant wave heights of $H_{1/3}=3$ m. However, the waves which caused the damage had a maximum significant wave height of $H_{1/3}=3.55$m, and a period of $T_{1/3}=18$s as measured by an ultrasonic wavemeter located at a point outside the harbour at a water depth of −13.5 m.

The source of the damage can be traced to the action of waves in excess of the anticipated maximum wave. In addition, the breakwater was only partially constructed and the armour stones for the breakwater head had not yet been installed, or had not yet been installed in the correct interlocking arrangement. The precision of the armour stone arrangement must, at a minimum, be brought up to a level equivalent to that of the breakwater at the Port of Moín.

On September 13, 1985, the breakwater extension portion suffered damage despite the fact the maximum significant wave height at the time was only $H_{1/3}$ =2.77 m. An additional hypothesis to explain the damage is that the Tertiary sedimentary rock quarried in North Caldera and used as armour stone had a mean specific gravity of only 2.35, less than the value of 2.6 called for in the design specifications. When the specific gravity is low like this, armour stone of approximately 1.5 times the design weight is considered necessary.

(2) Mooring Basin

The mooring basin in front of the −11 m quaywall is shoaling and becoming shallower due to sand sedimentation. In September 1985, the water depth at a 100 m portion at the south end of the quaywall was shallower than −10 m and the water depth at the western corner was no more than −1 m. The water depth at other portions of this berth have become less than the planned −10 m water depth over an area extending approximately 200 m from the front of the face line of the wharf.

The mooring basin in front of the −10 m quaywall has become somewhat shallower than the projected water depth. However, the prescribed design water depth of −10 m is being maintained throughout most of the basin. The prescribed design depth of −7.5 m is being maintained at the mooring basin in front of the −7.5 m quaywall.

(3) Other Facilities

Other harbour facilities are generally being maintained in a satisfactory condition.

2. 3. 2 Port Facilities at the Port of Puntarenas

The steel piles of the national pier at Puntarenas have served more than 50 years since their installation in 1929 and are extremely corroded. Piles in which the entire circumference of the steel pipe portion near the waterline has been pitted due to corrosion are a common sight.

MOPT investigated the corrosion of this pier, and in March 1984 prepared a maintenance and repair plan with a goal of providing 10 additional years of serviceable life. The principal construction method for the repair work for the mooring piers comprises the driving of hexagonal hollow steel piles into the space between support pillars, said support pillars integrating, by means of concrete cylinders, the top portions of four steel pipe pilings furnished in a radiating configuration. Then, while supporting the coping by means of I-beams, the hexagonal steel piles are mutually coupled and integrated with bracing and tie rods to substitute for the original support pillars. A construction method has been proposed in which the corroded portions of the single steel piles of the mooring pier and the solid steel piles of the coupling pier which are corroded over their entire circumference would be replaced, and the other piers would be reinforced at their corroded portions by means of semicircular steel plates provided with flanges and attached with securing bolts. In addition, the performance of necessary repairs to the concrete cylinders and the coping is also planned.

The maintenance and repair plan will be carried out by INCOP under the planning and supervision of MOPT. Construction work has already been completed on the connection between the east edge of the mooring pier and the access pier, the area with the most advanced degree of corrosion.

The cost of this construction work has been estimated at approximately 20 million colones. Construction has been estimated to require 50 weeks; however, considering the financial situation of INCOP and interruptions due to cargo handling work, completing the work within this period will be very difficult.

2. 4 Storage Facilities and Cargo Handling Equipment

2. 4. 1 Storage Facilities

There are two warehouses at the Port of Caldera. The No.1 warehouse is located behind the apron of the −10 m berth. The No.2 warehouse is located behind the No.1 warehouse. The No.1 warehouse is mainly for general cargoes. Part of the warehouse is used as a container freight station. The No.2 warehouse is mainly used for large lot imported cargoes. The size and capacity of these warehouses are shown in Table III−5. The total floor space is 12,600 m^2 and the total storage capacity is 6,300 tons.

Table III-5 Existing Warehouses at the port of Caldera

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

Existing open yards consist of four sections, with a total area of 55,600 m^2. However only the No.1 yard behind the −11 m berth is paved. As it is not desirable to use forklifts for handling containers in unpaved yards, the pavement of these yards is an urgent matter for cargo handling. Details of the open yards at the Port of Caldera are shown in Table III−6 .

Table III-6 Existing Open Yards at the Port of Caldera

Yard No.	Length (m)	Width (m)	Area (m^2)	Pavement	Usage
No. 1	160	85	13,600	paved	for containers
No. 2	160	85	13,600	not paved	for containers
No. 3	113	85	9,600	not paved	for steel goods
No. 4	221	85	18,800	not paved	for vehicles
Total			55,600		

2. 4. 2 Cargo Handling Equipment

The cargo handling machinery currently owned by INCOP is shown in Table III−7. These machines are for general cargoes and containerized cargoes. INCOP owns variety of machines manufactured by different makers, and spare parts are currently insufficient. This causes serious problems for cargo handling.

The apron, which is 490 m × 30 m, is paved with small concrete blocks.

Table III-7 Existing Cargo Handling Machinery

Type of Machinery	Capacity (tons)	Number of Units(1985)	Remarks
Forklift	2~2.5	21	for general and steel goods
	3~3.5	5	〃
	5~6	5	〃
	10	1	〃
	20	0	〃
Tractor	0.7~2.5	6	〃
Trailer	−	24	〃
Mobile Crane	9~30	4	〃
Container Frontloader	30~35	2	for loaded containers
	10	0	for empty containers
Container tractor		2	for containers
Chassis		4	for containers
Sub total		74	

3. Port Operations

3.1 Port Services

At present, all port operations in Caldera and Puntarenas ports are under the control of INCOP. As cargo handling services are described in detail in CHAPTER VIII, only other services such as pilots, tug boats, water supply, and line handling are considered here.

(1) Ship's calling schedule list

Shipping companies or their agents report their ship's calling schedule to the INCOP office about one month before arrival. INCOP then makes an overall calling schedule list and delivers it to related sections.

(2) Pilot service

Shipping companies or their agents inform the INCOP operations division about ship's precise arrival times two days before arrival. The marine department pilot section has three pilots, and pilot service is available 24 hours a day including Sundays and holidays.

(3) Tug boat service

There are two tug boats with 1800 PS and 1700 PS engines and three launches. The newest one (1800 PS) was purchased from Argentine in 1984. The purchase date of the old one (1700 PS) may be before 1940.

(4) Water supply service

Water is supplied to calling vessels from pierside water pipes.

(5) Line handling

36 line handling labourers are separated into three shifts. Thus 12 men are always available 24 hours a day.

(6) Fuel service for ships

INCOP does not supply ships with fuel. If needed, shipping agents have to arrange for transport of fuel by tank truck.

3.2 Port Cargo Operations, Stowage and Distribution Systems

(1) Port cargo operations

All port cargo operations are carried out by INCOP workers using a direct landing system. No cargo landing (barge) operations are executed (details are presented in CHAPTER VIII).

(2) Cargo stowage system

Within the Caldera port area there are two warehouses which are mainly utilized for export and import cargo while awaiting customs procedures or ship's arrival. Part of one of these warehouses is also utilized as a container freight station for container cargo.

(3) Inland distribution systems

There are two main methods of transporting the cargo : one is by the railway between Puntarenas–Caldera–San José, and the other is by trucks or trailers with tractors. The railways in Costa Rica are outdated. They are mostly still single track. On the other hand, trucking transportation is more modernized and road conditions are getting better. The present inland distribution system is shown in Table III−8.

Table III-8 Present Inland Distribution System

Cargo Type	Transportation	Destination
General Cargo	By truck	Central Highland
Containers	By truck	Central Highland
Automobiles	Self Moving	Central Highland
Iron/Steel Goods	By Railway	Central Highland
Bulk wheat (25%)	By Railway	Barranca Silo
Bulk wheat (75%)	By Railway	Molinos de C.R. Silo

3. 3 Customs Clearance

Generally, there are two ways to clear customs for imported cargo at the Port of Caldera. The procedure can only be executed by customs forwarders.

3. 3. 1 Customs Clearance at the Port

One is the execution of customs procedures including collection of import taxes at the Port of Caldera.

Necessary documents are as follows :

1) Import Declaration (Official form)
2) Original Invoice
3) Original Bill of Lading (2 copies)
4) Import Authorization (Issued by the Central Bank)
5) Packing List
6) Health Certificate, if any
7) Other Documents as Required

Usually, clients receive their cargo 5 or 6 days after the ship's arrival.

3. 3. 2 Customs Clearance in San José

The other is the execution of customs procedures at the main customs office in San José. Cargoes are transported under bonded conditions with the permission of Caldera customs office. It takes half a day to get a bond transportation permit from the Caldera customs office. If the consingnee so desires, cargo such as steel goods, automobiles and containers can be moved from ship side directly onto trailers. These cargoes are then transfered to the consignee's bonded warehouse which has already been approved by the main customs office in San José. There are 15 to 20 such bonded warehouses around San José City. In this case, it takes 12 to 13 days for the cargoes to be delivered to consignees after the ship's arrival.

4. Port Traffic

4.1 Port Cargo Volume

The cargo volume handled at the Ports of Caldera and Puntarenas over the last nineteen years is shown in Fig. III−11. According to the figure, the overall cargo volume has generally been increasing. It drastically decreased in 1982 due to economic recession. However, it has been recovering rapidly since 1982.

Roughly speaking, import cargo volume accounts for about 70%, and export cargo volume accounts for about 30% of the total cargo volume. The total cargo volume at the Ports of Caldera and Puntarenas was 717,033 tons in 1984 including the cargoes handled at the Port of Punta Molares and the FERTICA berths. The breakdown of the cargo volume by major commodity by package type is shown in Table III−9. Most of the cargoes at the Ports of Caldera and Puntarenas are such general cargoes as iron and steel, fertilizer and containerized cargoes.

Table III-9 Actual Cargo Volume Composition

(Unit : tons)

	Imports	Exports	Total
The ports of Caldera and Puntarenas			
Grain	131,167	—	131,167
Automobiles	4,816	—	4,816
General Cargo			
Iron and Steel	53,185	—	53,185
Fertilizer	—	5,500	5,500
Others	198,157	78,668	276,825
(Containerized)	(28,452)	(26,760)	(55,212)
Sub-total	387,325	84,168	471,493
FERTICA			
Fertilizer	83,620	21,970	105,590
Punta Morales	—	139,950	139,950
Sugar			
Total	470,945	246,088	717,033

Source : Cuadro Estadisticos Sobre Sector Transportes, 1984, DGP/MOPT
Note : These figures are provisionally issued by DGP/MOPT

4. Port Traffic

4. 1 Port Cargo Volume

The cargo volume handled at the Ports of Caldera and Puntarenas over the last nineteen years is shown in Fig. III−11. According to the figure, the overall cargo volume has generally been increasing. It drastically decreased in 1982 due to economic recession. However, it has been recovering rapidly since 1982.

Roughly speaking, import cargo volume accounts for about 70%, and export cargo volume accounts for about 30% of the total cargo volume. The total cargo volume at the Ports of Caldera and Puntarenas was 717,033 tons in 1984 including the cargoes handled at the Port of Punta Molares and the FERTICA berths. The breakdown of the cargo volume by major commodity by package type is shown in Table III−9. Most of the cargoes at the Ports of Caldera and Puntarenas are such general cargoes as iron and steel, fertilizer and containerized cargoes.

Table III-9 Actual Cargo Volume Composition

(Unit : tons)

	Imports	Exports	Total
The ports of Caldera and Puntarenas			
Grain	131,167	—	131,167
Automobiles	4,816	—	4,816
General Cargo			
Iron and Steel	53,185	—	53,185
Fertilizer	—	5,500	5,500
Others	198,157	78,668	276,825
(Containerized)	(28,452)	(26,760)	(55,212)
Sub-total	387,325	84,168	471,493
FERTICA			
Fertilizer	83,620	21,970	105,590
Punta Morales	—	139,950	139,950
Sugar			
Total	470,945	246,088	717,033

Source : Cuadro Estadisticos Sobre Sector Transportes, 1984, DGP/MOPT
Note : These figures are provisionally issued by DGP/MOPT

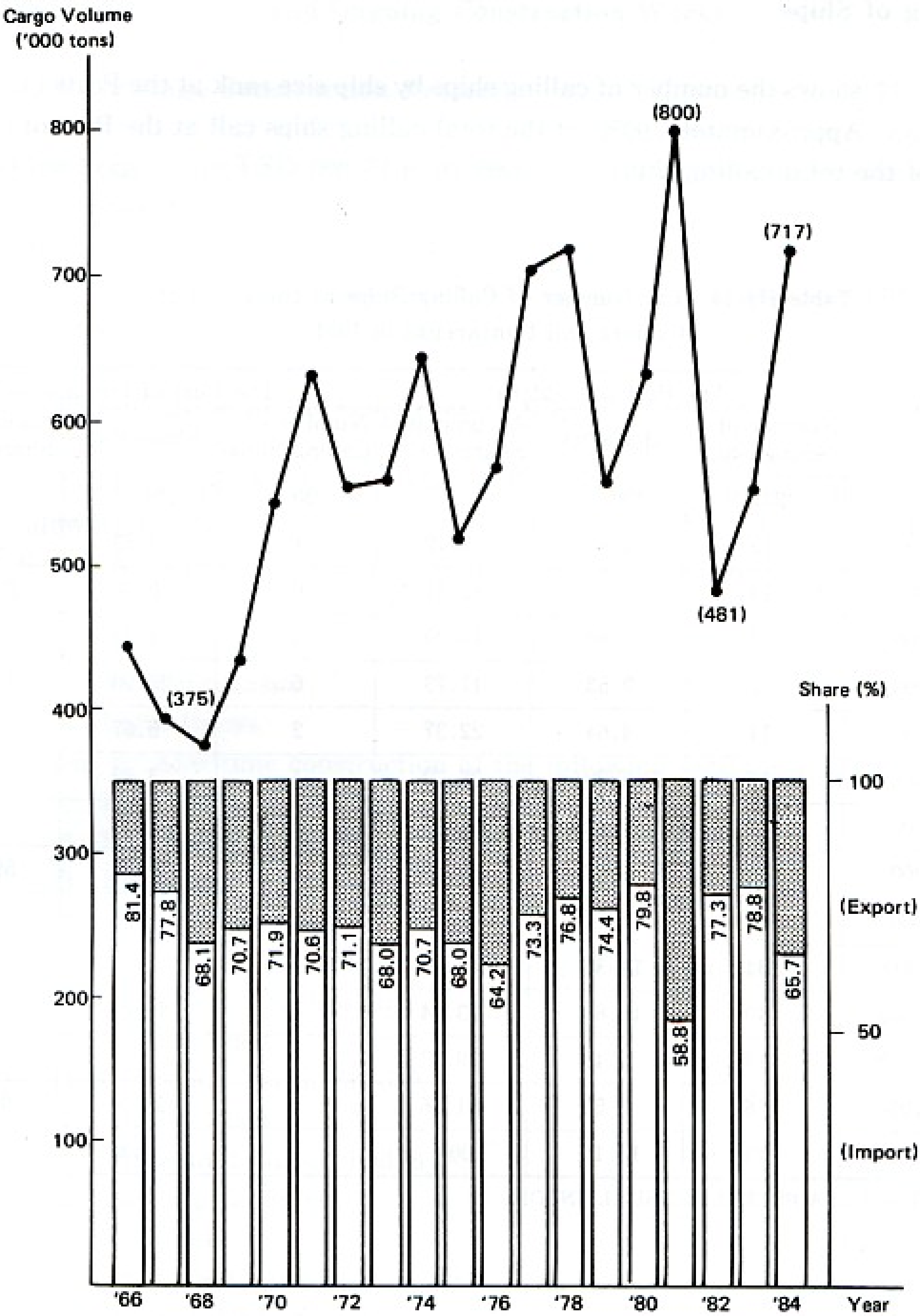


Fig. III-11 Cargo Volume at the Ports of Caldera and Puntarenas

Source: Cuadro Estadisticos Sobre Sector Transportes 1984, DGP/MOPT
Note: Cargo volume at the Ports of Punta Morales and FERTICA are included.

4. 2 Calling of Ships

Table III−10 shows the number of calling ships by ship size rank at the Ports of Caldera and Puntarenas. Approximately, 90% of the total calling ships call at the Port of Caldera. About 20% of the total calling ships are larger than 15,000 GRT.

Table III-10 The Number of Calling Ships at the Ports of Caldera and Puntarenas in 1984

Ship Size Rank (GRT)	The Port of Caldera			The Port of Puntarenas		
	Number of Calling Ships	Share(%)	Accumulated Share(%)	Number of Calling Ships	Share (%)	Accumulated Share (%)
TOTAL	237	100		30	100	
~1,000	13	5.49	5.49	1	3.33	3.33
1,001~2,000	19	8.02	13.51	6	20.00	23.33
2,001~3,000	4	1.69	15.20	1	3.33	26.66
3,001~4,000	6	2.53	17.73	6	20.00	46.66
4,001~5,000	11	4.64	22.37	2	6.67	53.33
5,001~6,000	15	6.33	28.70	1	3.33	56.66
6,001~7,000	1	0.42	29.12	—	—	—
7,001~8,000	15	6.33	35.45	1	3.33	59.98
8,001~9,000	17	7.17	42.62	—	—	—
9,001~10,000	34	14.34	56.96	4	13.34	73.33
10,001~12,000	40	16.88	73.84	3	10.00	83.33
12,001~15,000	13	5.49	79.33	—	—	—
15,001~20,000	6	2.53	81.86	4	13.34	96.67
20,001~28,000	43	18.14	100	1	3.33	100

Soace : INFORME ESTADISTICO MENSUAL, INCOP

5. Past Port Development and Ongoing Construction Works

5.1 The First Stage Construction Project

The First Stage Construction Project at the Port of Caldera got under way in November 1974 and was completed in February 1982. The reclamation of the site and the construction of the breakwater commenced in 1974 under the direct management and control of MOPT. The construction of mooring facilities was undertaken in 1978 by a Costa Rican construction company, Carrez S.A.

5.1.1 Classification of the Construction Works

The works of the First Stage Construction Project for the Port of Caldera were divided into the following groups.

Group A : Maritime construction of the following facilities :

1. Wharfs
2. Light Beacon
3. Mooring Basin
4. Light Buoys

Group B : Maritime construction of the following facilities :

1. Breakwater
2. Seawall
3. Revetment
4. Land Reclamation

Group C : On land construction of the following facilities :

1. Administration Building
2. Transit Shed A
3. Office in Transit Shed A
4. Transit Shed B
5. Office in Transit Shed B
6. Lighting facilities
7. Railroad
8. Drainage Channel
9. Water Supply System
10. Pavement
11. Fence and Gate
12. Security Station

The items in Group B were constructed directly by MOPT, and the items in Groups A and C were carried out under contract by Carrez S.A.

5.1.2 Outline of the Construction Works

The principal maritime construction works of the first stage of construction at the Port of Caldera are summarized below :

(1) Wharf Site Land Reclamation

Most of the reclamation material for the wharf site consists of Tertiary sedimentary rock found in the mountains immediately behind the wharf. The material was excavated using earth moving equipment and then conveyed to the reclamation site and dumped. Near the end of the reclamation work, part of the wharf site immediately behind the −7.5 m quaywall was reclaimed using material dredged from the forward mooring basin using a cutter suction dredger owned by MOPT.

(2) Breakwater, Seawall and Revetment

The rubble material for breakwater, seawall, and revetment construction was excavated at the Dantas quarry, managed by MOPT, where located approximately 30 km east of the Port of Caldera. The rubble was conveyed to Caldera by rail, whereupon it was reloaded into dump trucks, transported to the site, and dumped. The armour stones for the breakwater and seawall were lifted and positioned using a 127 ton capacity mobile crane furnished with a grab bucket.

The rubble material used for the 115 m extension constructed subsequent to the completion of the original 250 meters was excavated at the North Caldera quarry located approximately 6 km north-northwest of Caldera, and then conveyed to the site and dumped. All of this work was done under the supervision of MOPT using bulldozers, wheel-loaders, mobile cranes, and dump trucks owned by MOPT. The rubble quarried in North Caldera is Tertiary sedimentary rock and its mean specific gravity in comparison to the igneous rock quarried at Dantas is a light 2.35. Further, its durability is also inferior; however, the transport costs from Dantas are high, and since there are limits to the transport capacity of the railway, the quarry was switched accordingly.

(3) Quaywall

The steel sheet piles and steel pipe piles for sheet pile type quaywalls and relieving platform type sheet pile quaywalls were driven from temporary piers constructed on the sea. The equipment used for driving the pipe and sheet piles are listed below.

Mobile cranes	: 80 ton capacity (1)
	45 ton capacity (1)
	40 ton capacity (2)
	30 ton capacity (2)
Diesel pile hammers	: K− 45 (1)
	K− 35 (1)
Vibro hammer	: VS−400 (1)

The length and number of pipe piles and sheet piles driven are listed below.

Steel sheet piles : Z-45 type, length 22 m, 1,410

Steel pipe piles : diameter 61−81 cm, length 22 cm, 537

Temporary pile driving piers were erected on top of 12 inch and 14 inch H−shaped steel piles which were driven using pile driving scaffolding furnished on pontoons. The driving of the H−shaped steel piles was accomplished with a K−13 diesel pile driving hammer, and subsequently extracted upon completion of the construction work by a 40 ton capacity mobile crane and a VS-400 vibro hammer.

Quaywall backfill material was quarried from the riverbed of the Barranca River approximately 10 km north of the Port of Caldera, transported to the site by dump truck, and dumped from the temporary pier.

(4) Dredging

Most of the dredging work was carried out by means of a hopper suction dredger owned by a Dutch construction company, Volker Stevins, and the dredged matter was disposed of at sea. Part of the dredging work was accomplished with a 375 PS cutter suction dredger owned by MOPT, and this dredged material was used for land reclamation immediately behind the −7.5 m quaywall. Bottom materials in front of the quaywall were excavated by a mobile crane furnished with a grab bucket positioned on top of the quaywall.

5. 1. 3 Construction Expenses

The construction costs of each of the harbour facilities in the First Stage Contruction at the Port of Caldera are shown in Table III−11.

Table III-11 Construction Costs of the First Stage Construction at the Port of Caldera

(Unit : '000 ¢)

	Description	Cost
Land	Reclamation and Dredging	98,991
Amortized Assets	Breakwater	33,590
	Wharf, seawall and revetment	316,020
	Administration building	47,710
	Related facilities	116,150
	Transit shed and offices	40,430
	Navigation aids	2,460
	Dock railway sidings	29,960
	Pavement	43,920
	Electric power, water supply, and sewage	26,920
	Cargo handling equipment	24,590
	Sub Total	681,750
Total		780,741

Source : MOPT

5. 2 Ongoing Construction Works

5. 2. 1 Breakwater Extension at the Port of Caldera

MOPT has been extending the breakwater 150 meters from its turn point (refer to Fig. III−1). As of the end of September 1985, the length of the extension had reached 115 m. A standard cross−section of the extension is shown in Fig. III−12. The construction method of constructing the breakwater extension is basically similar to the method used for constructing the breakwater in the First Stage Construction. However, the rubble and the armour stones currently being used are Tertiary sedimentary rock quarried in North Caldera rather than the igneous rock quarried at Dantas. During the rainy season, there are times when work must stop due to breakdowns in the construction equipment and the like, and at these times, 4 to 8 ton stones are used to cover the breakwater head. When work resumes, these stones are reinstalled as armour stones for the breakwater extension.

This breakwater frequently suffers from wave damage during rainy season construction, and the completion of the breakwater to the prescribed length has been delayed. As an example, the length of the breakwater on September 11, 1985 had reached 133 m, however setbacks due to wave action were suffered on September 12 and 13, 1985, and 20 m of the breakwater were lost.

5. 2. 2 Floating Dry Dock at the Port of Caldera

Construction of a floating dry dock for fishing boat repair in the water expanse between the −7.5 m quaywall and the roll on / roll off pier has been planned by a private corporation, and work is already underway. This plan is further based on an agreement between the governments of Costa Rica and Italy. A plan of the proposed construction and a cross-sectional view of the floating dry dock are shown in Figs. III−13 and III−14, respectively.

An outline of the ship repair company is given below.

Name of Company	: U.C.S.A.
Capital	: US $ 500,000
Shareholders	: Dena S.A. 51%, INCOP 49%
Number of Employees	: 100
Ship Repair Capacity	: Fishing boats (Length by Width by Depth) 50 m by 10 m by 3 m

Construction began in October 1985, and completion was planned for April 1986. In November, 1985 the foundation pilings of the structure were being driven. The body of the dry dock is fabricated in Italy. The dry dock placement site had a water depth of −3 m in November 1985 ; however, dredging to −7.0 m by April 1986 is planned. The volume of material to be dredged is approximately 35,000 m^3, and the plan is to carry out the operation using MOPT's cutter suction dredger.

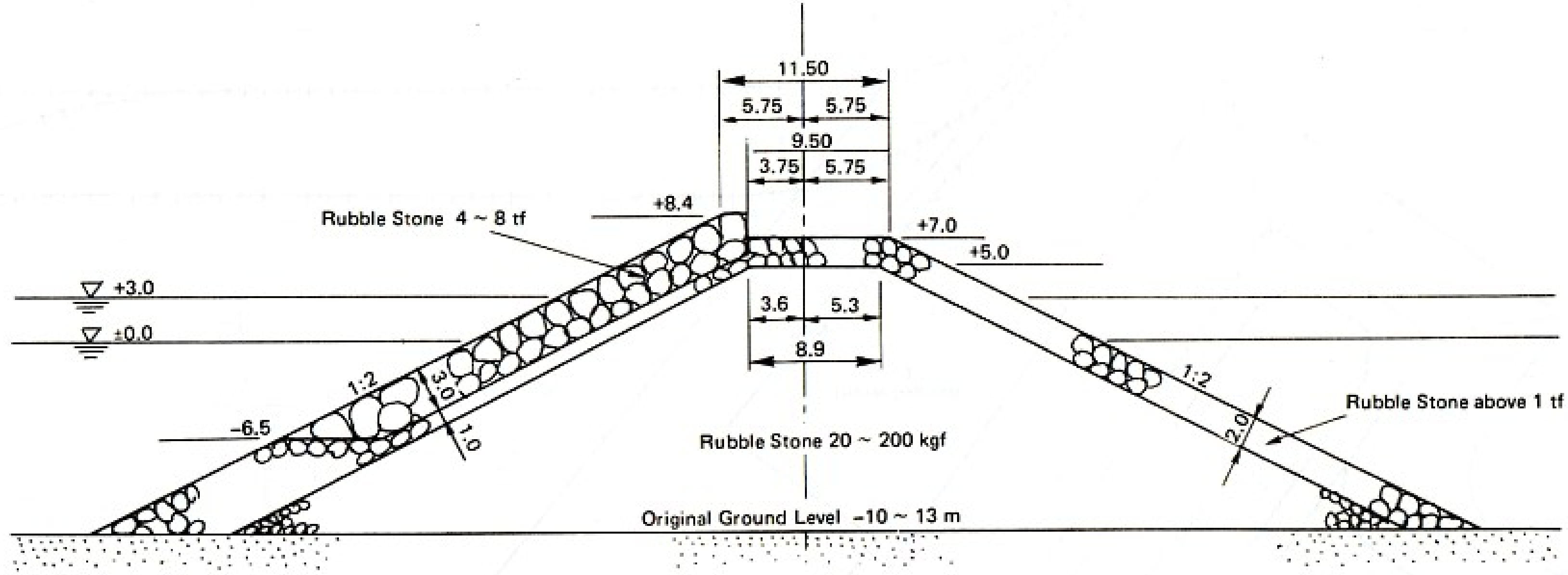
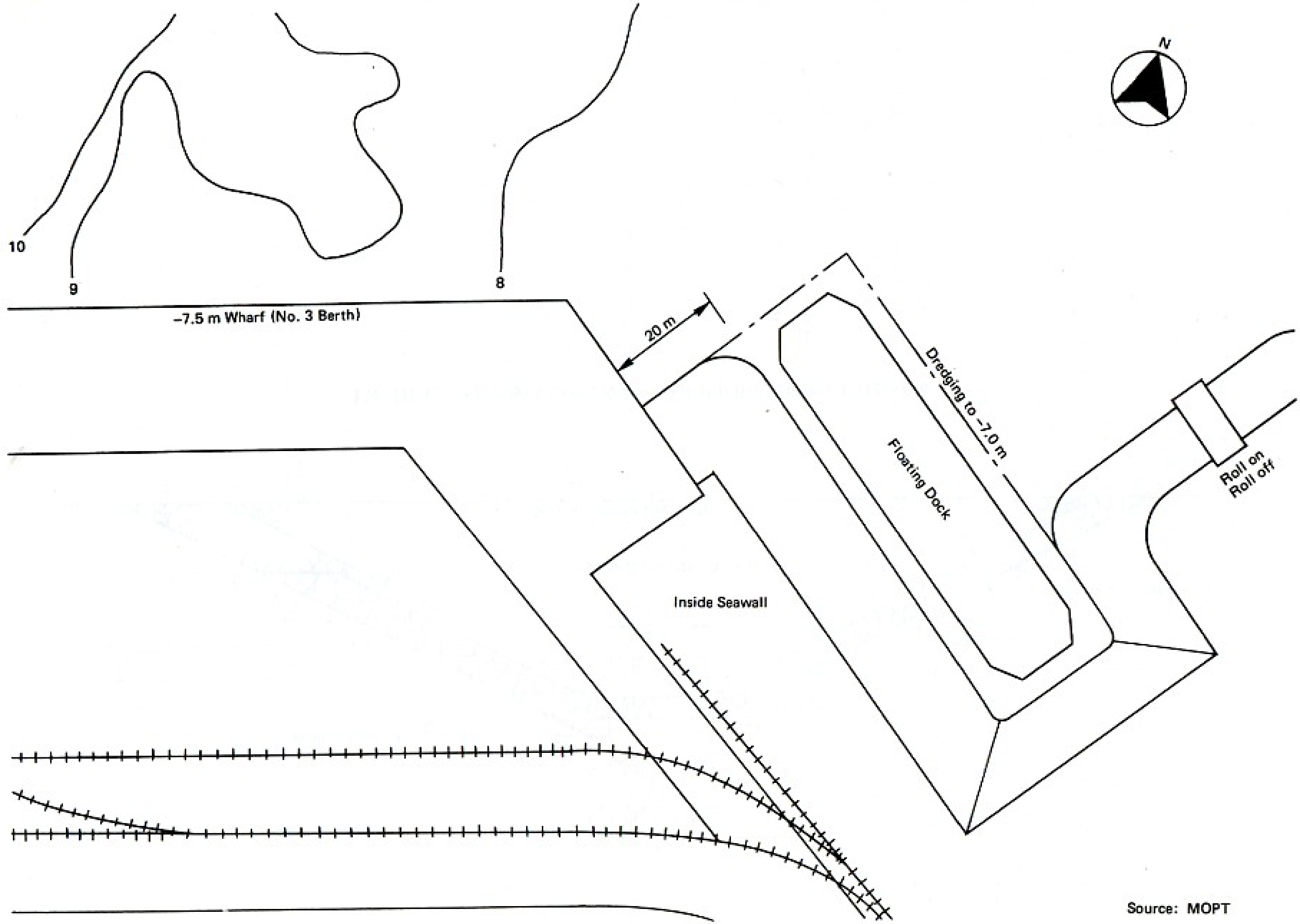
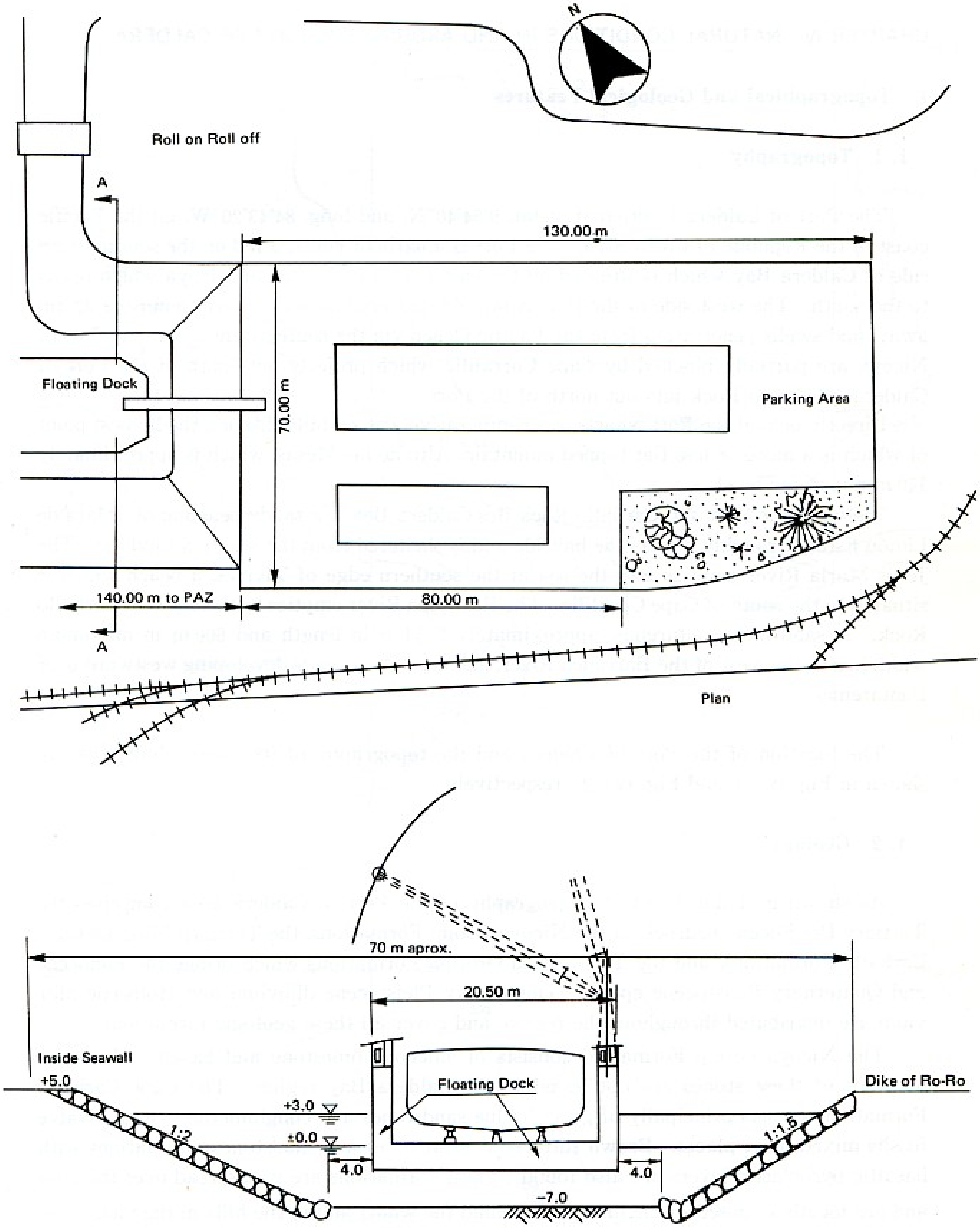


Fig. III-12 Standard Cross Section of the Breakwater Extension



Source: MOPT

Fig. III-13 Plan View of the Planned Floating Dock at the Port of Caldera



Source: MOPT

Fig. III-14 Standard Cross Section of the Planned Floating Dock at the Port of Caldera

1. Topographical and Geological Features

1. 1 Topography

The Port of Caldera is situated at lat. 9°54′40″N. and long. 84°43′20″W. on the Pacific coast of the Republic of Costa Rica. The Port is a harbour constructed on the southeastern side of Caldera Bay which is situated on the east bank of the Gulf of Nicoya which opens to the south. The west side of the Port is largely sheltered by the Nicoya Peninsula 22 km away, and swells penetrating from the Pacific Ocean via the southern mouth of the Gulf of Nicoya are partially blocked by Cape Corralillo which projects out south of the Port of Caldera. Carballo Rock juts out north of the Port.

Directly behind the Port wharfs is a comparatively steep hilly district, the highest point of which is a more or less flat-topped mountain, Alto de las Mesas, which is approximately 140 m above sea-level.

Between the Port and Carballo Rock lies Caldera Beach a sandy beach area. Mata de Limõn Estuary roughly bisects the bayside and is sheltered from the sea by a sand bar. The Jesús Maria River empties into the sea at the southern edge of Tivives, a beach which is situated to the south of Cape Coralillo. The Barranca River empties to the north of Carballo Rock. A sand bar, Puntarenas, approximately 7.5 km in length and 600 m in maximum width lies to the west of the Barranca River, and an urban area is developing westward over Puntarenas.

The location of the Port of Caldera and the topography of its surrounding area are shown in Fig. IV−1 and Fig. IV−2, respectively.

1. 2 Geology[1)]

As shown in Table IV−1, the geography of the Port of Caldera area comprises the Tertiary Pre-Eocene bedrock of the Nicoya Group Formations, the Tertiary Miocene Cape Carballo Formations, and the Tivives and Orotina Formations which bridge the Pleiocene and Quaternary Pleistocene epochs. Quaternary Pleistocene diluvium and Holocene alluvium are distributed throughout the region, and cover all these geologic formations.

The Nicoya Group Formation consists of siliceous limestone and basalt. However, outcrops of these stones are not found in the Caldera Bay region. The Cape Carballo Formation consists principally of greyish blue sandstones and conglomerates, with bivalve fossils mixed in at places. Brown tuffaceous sandstones and mudstones alternations with basaltic pyroclastic layers are also found. These formations are widespread over the area and are locally exposed in the hilly area behind the wharf and in the hills in the vicinity of

1) Rodolfo Madrigal G : Geologia de Mapa Basico "Barranca", Casta Rica, Informes Tenicos y Notas Geologicas, Ciudad Universitaria "Rodorigo Facio", Casta Risa, 1970

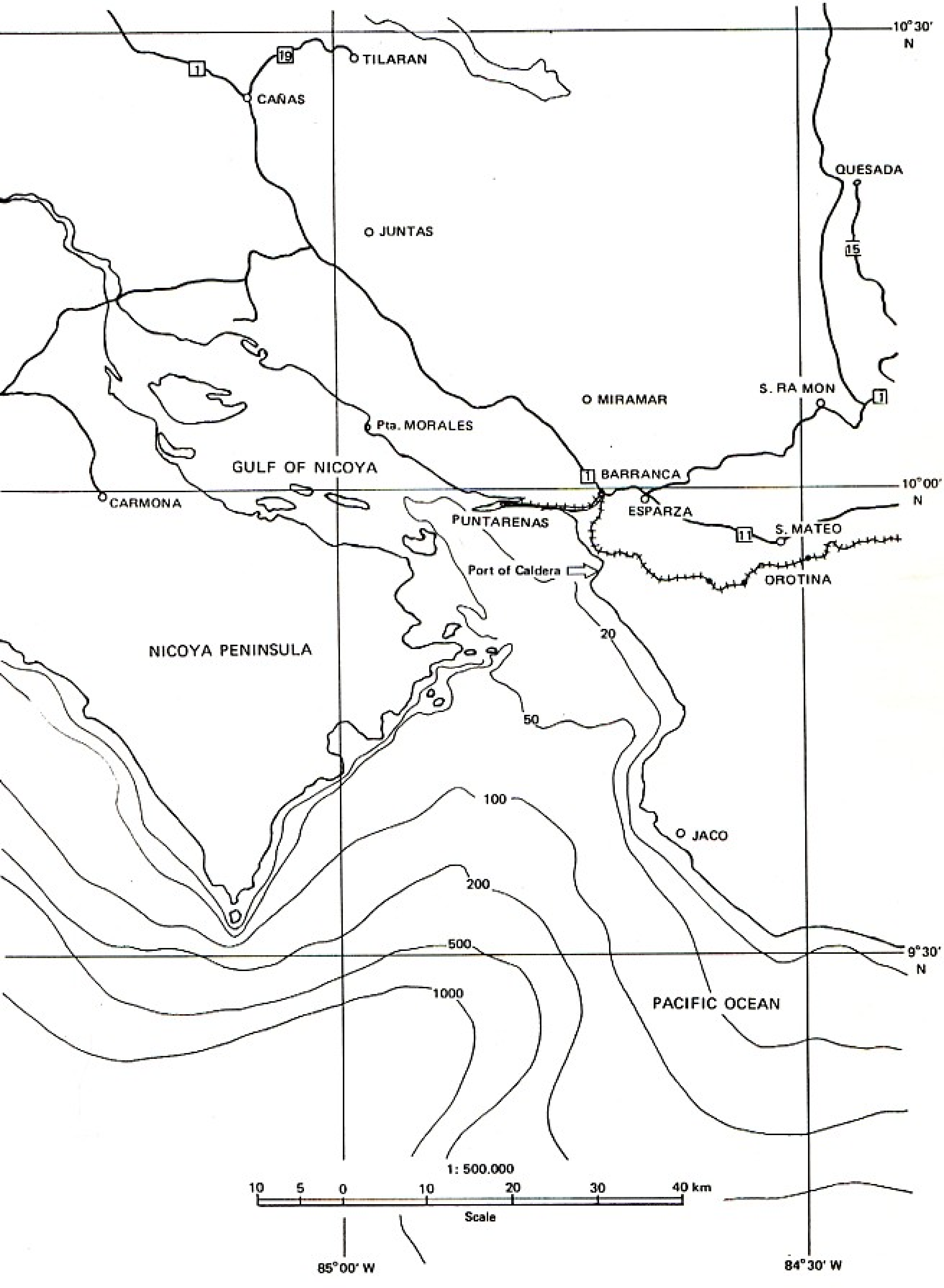


Fig. IV-1 Map of the Location of the Port of Caldera

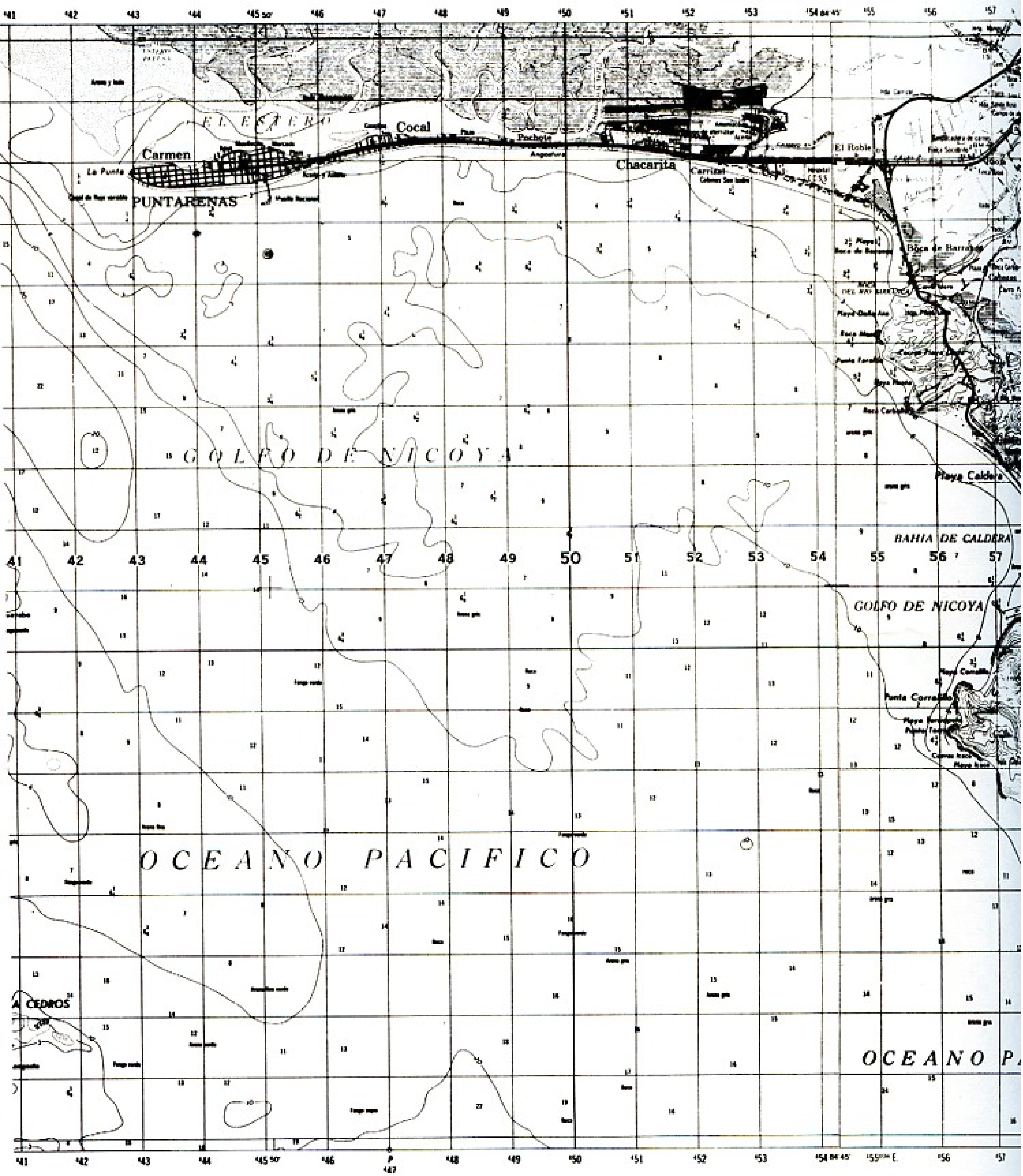
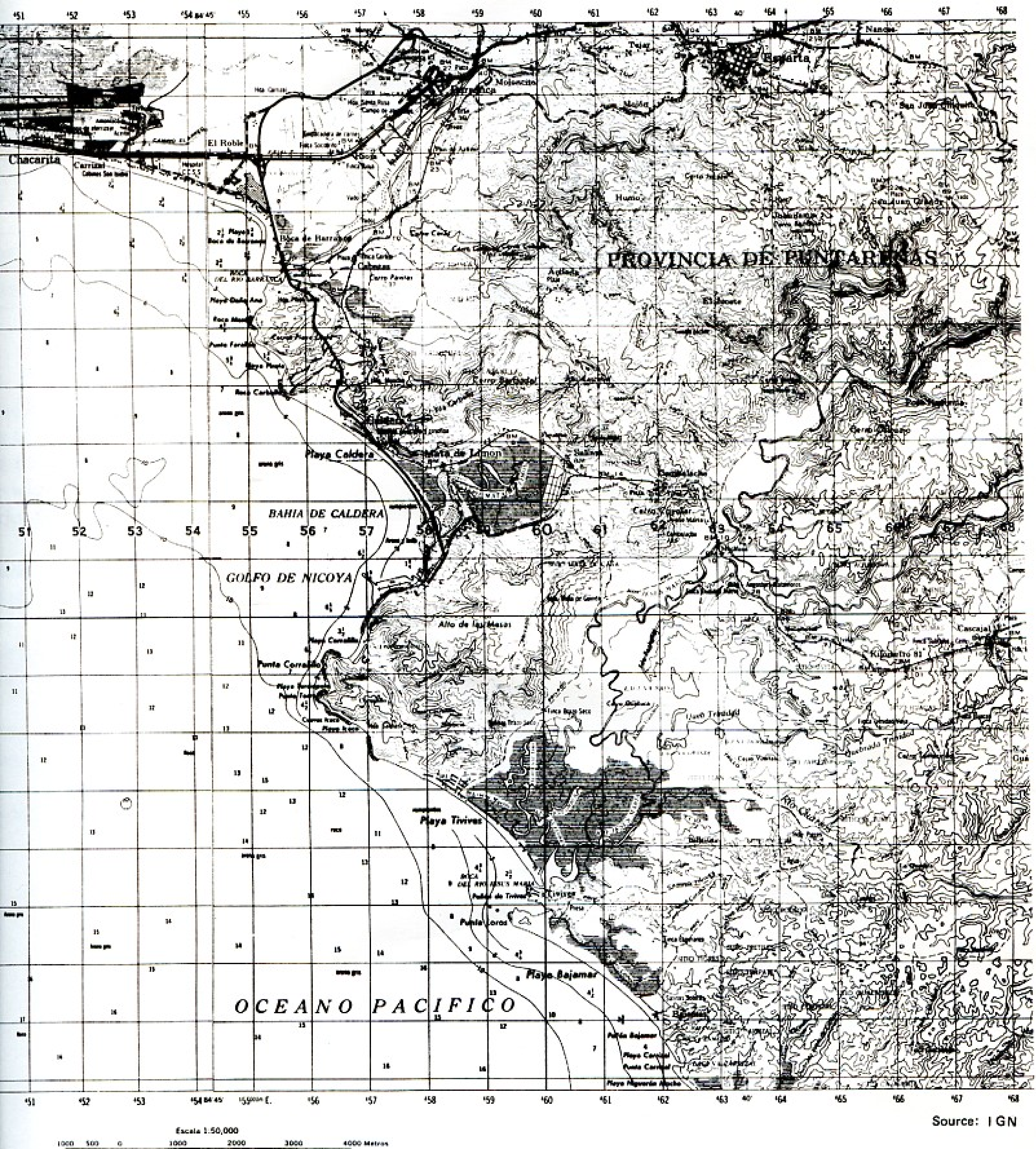


Fig. IV-2 Topographical Map of the Port of Caldera and the



Topographical Map of the Port of Caldera and the Surrounding Region

Table IV-1 Geologic Formations is the Port of Caldera Region[1]

PERIOD	EPOCH	FORMATION
Quaternary	Holocene	Alluvium
	Pleistocene	Diluvium
		Orotina Formation
Tertiary	Pliocene	Tivives Formation
	Miocene	Cape Carballo Formation
	Pre-Eocene	Nicoya Group Formation

Source: Rodolfo Madrigal G.

Mata de Limón Station. The bedrock, described in Section 4 below is of a similar geologic formation. The Tivives Formation consists of agglomerates and lava flows. Depending on the spot, the massive agglomerates are interspersed with tuff and tuff-breccia. These formations are distributed at the peaks of the hills and behind the wharf. The Orotina Formation consists of welded tuff and is widespread in the hilly district on the left bank of the Jesús María River in the southwest.

The diluvium and alluvium consist of soft unconsolidated clay, sand, and gravel. They are found in the Mata de Limón Estuary flatlands, the river basins and plains, and the seabed of the Port of Caldera.

As stated above, the outermost stratum comprises a comparatively new Tertiary Period geologic formation which, in concert with the lack of river improvement, causes great effusion of sand and becomes an abundant source of littoral drift.

Several faults running NE and NW are found in the area. The faults have been observed only in the Cape Carballo Formation regions, and are believed to have been created by the Central American Organic Movement.

The geologic formations of the Port of Caldera Region are shown in Fig. IV－3.

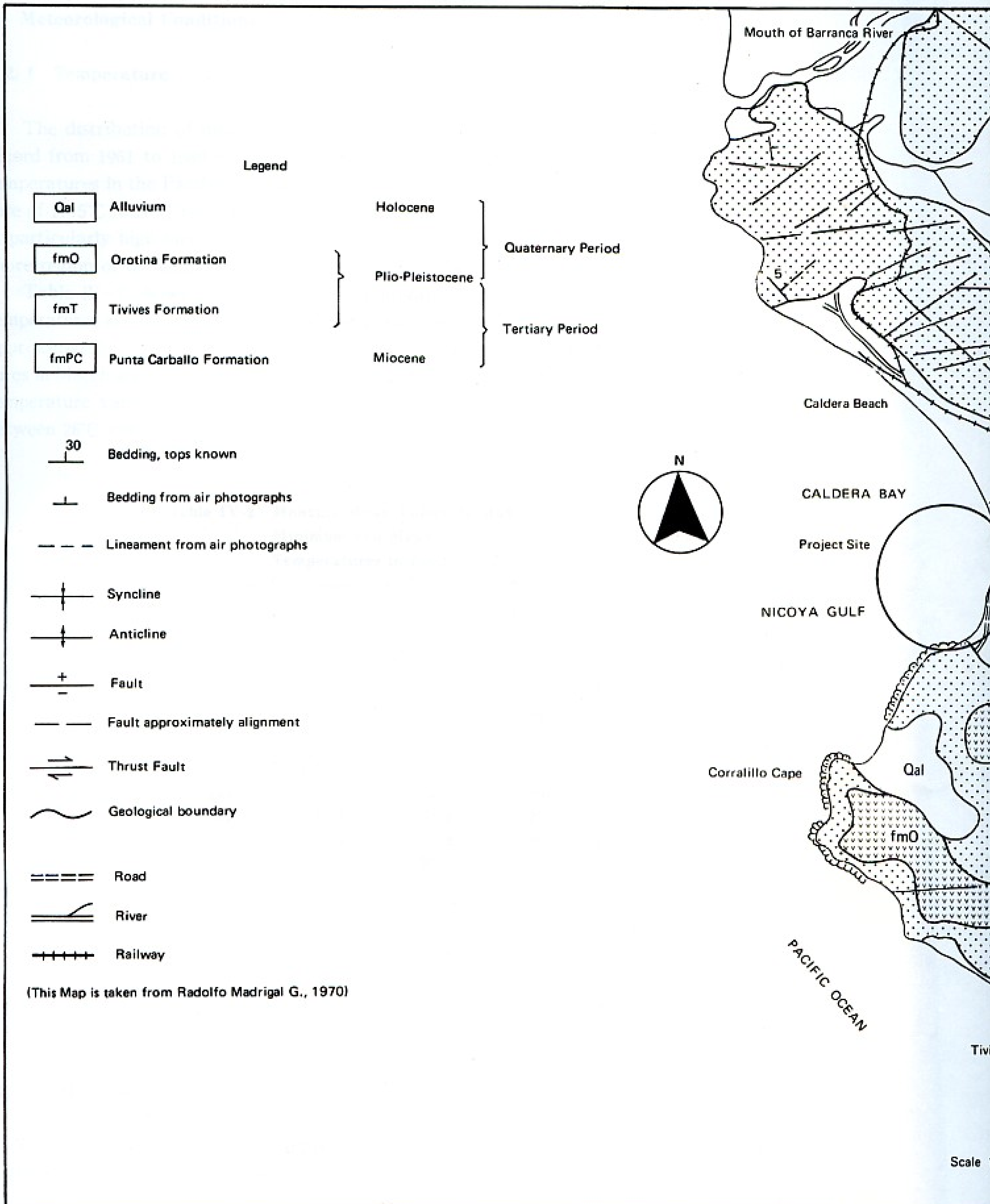
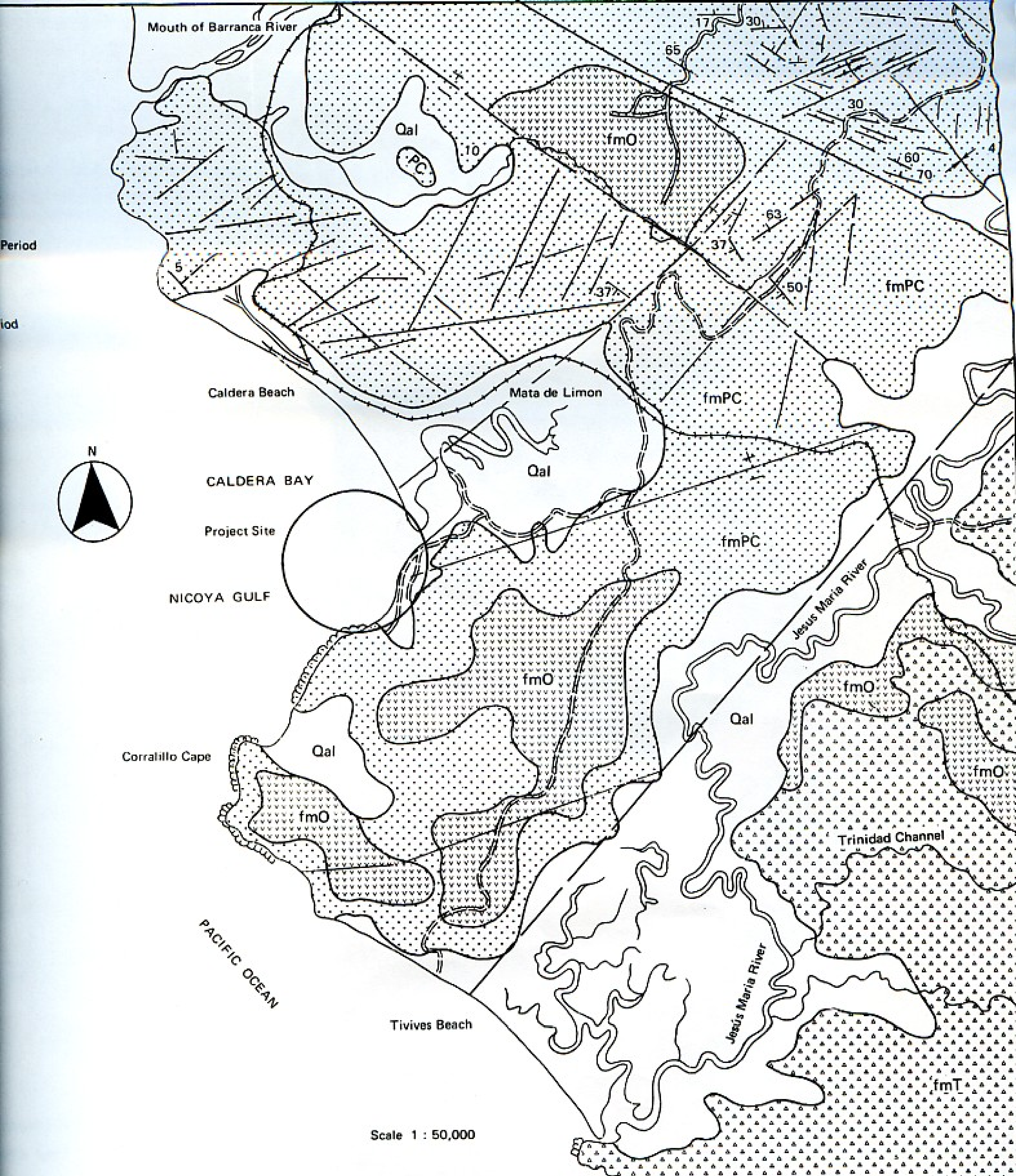


Fig. IV-3 Geological Map of the Port of Caldera and the Surrour



Geological Map of the Port of Caldera and the Surrounding Region

Source: Rodolfo Madrigal G

2. Meteorological Conditions

2.1 Temperature

The distribution of mean annual temperature in Costa Rica based on a twenty year record from 1961 to 1980 is shown in Fig. IV−4. As may be seen in the figure, the mean temperatures in the Pacific and Caribbean coast regions are higher than the mean temperature of 17.5°C to 20°C recorded in the central highlands which include the Capital, San José. A particularly high mean temperature of approximately 27.5°C was recorded on the east shore region of the Gulf of Nicoya which includes the Port of Caldera.

Table IV−2 shows the mean values by month of the maximum, minimum, and mean temperatures in Puntarenas over a 20 year period from 1965 to 1984. Puntarenas is situated approximately 15 km west-northwest of the Port of Caldera. The table shows high temperatures in March and April, and low temperatures from September to December. However, the temperature variation throughout the year is small with the mean temperature ranging between 26°C and 29°C.

Table IV-2 Monthly Mean Values of Maximum, Minimum and Mean Temperatures in Puntarenas

(Average Over Twenty Years from 1965 to 1984 ; Unit : °C)

Month	Max. Temp.	Min. Temp.	Mean Temp.
Jan.	33.6	21.6	27.1
Feb.	34.5	21.9	27.7
Mar.	35.3	22.6	28.1
Apr.	34.9	23.5	28.5
May	33.2	23.6	27.6
Jun.	32.4	23.3	26.9
Jul.	32.5	22.9	26.8
Aug.	32.6	22.8	26.6
Sep.	32.1	22.8	26.4
Oct.	31.5	22.8	26.2
Nov.	31.8	22.4	26.3
Dec.	32.5	21.5	26.5
Annual Mean	33.1	22.6	27.1

Source : IMN

2.2 Precipitation

The distribution of mean annual precipitation in Costa Rica is shown in Fig. IV−5 based on the record from 1961 to 1980. Precipitation along the Nicoya Gulf Coast region is

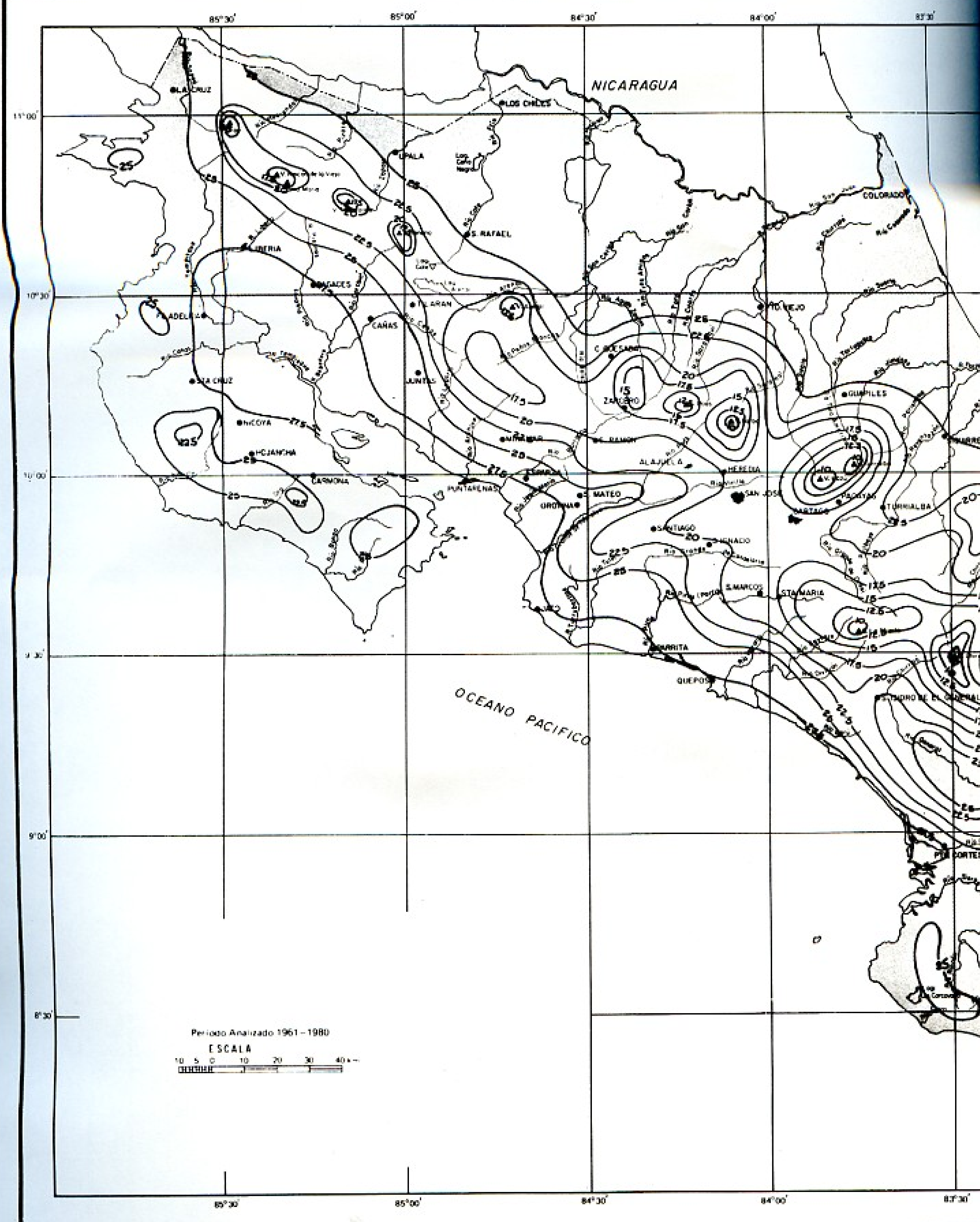


Fig. IV-4 Annual Mean Temperature Distribution in Costa Rica

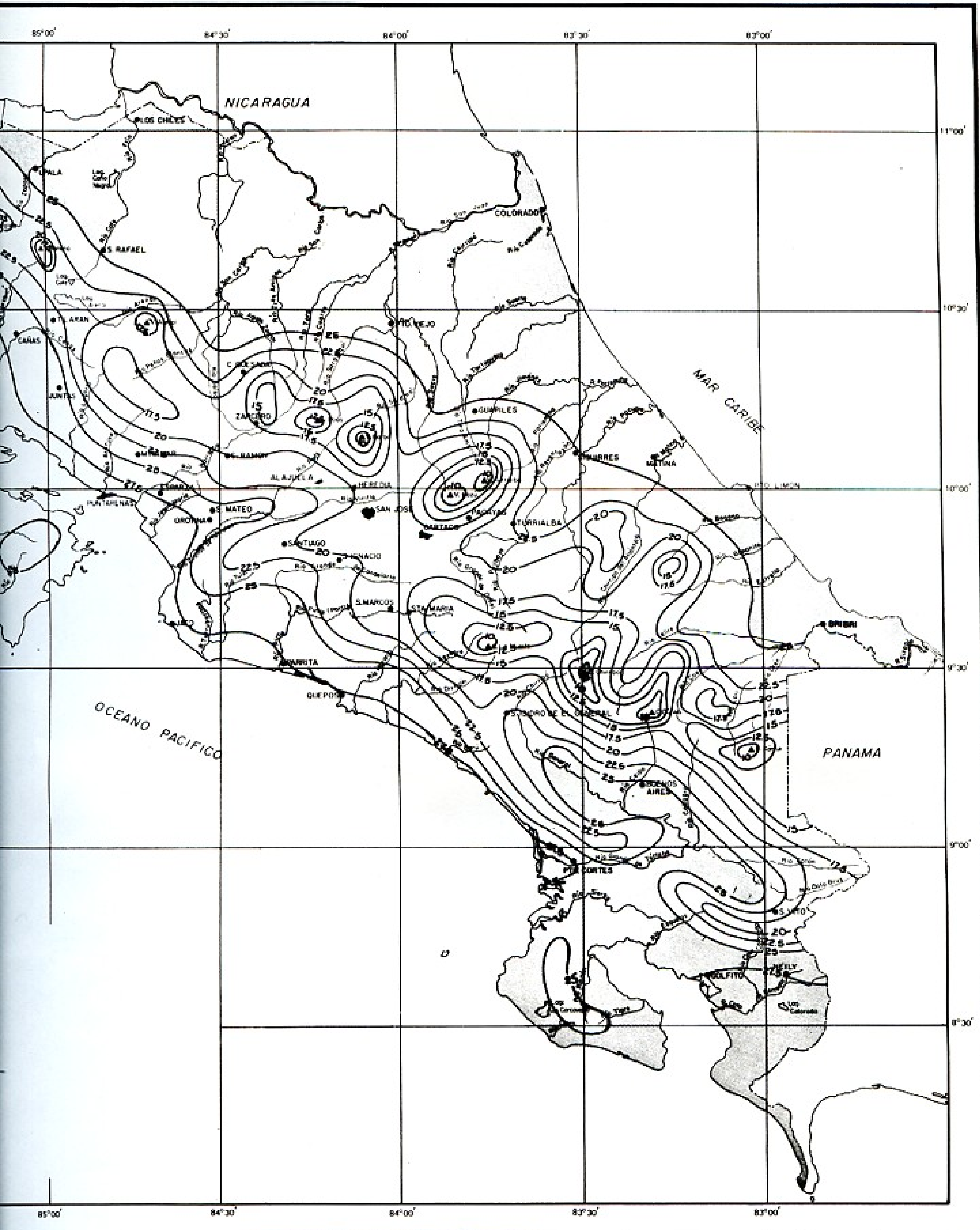


Fig. IV-4 Annual Mean Temperature Distribution in Costa Rica approximately 1,600 mm per annum. Along with the central plateau this region has the lowest precipitation in Costa Rica.

The monthly precipitation in Puntarenas over a twenty year period from 1964 to 1984 is shown in Table IV−3 (In 1968, the six months from May to October were improperly measured, hence the year 1968 is omitted from the record.). The mean annual precipitation during this period was 1,677 mm. A maximum single year precipitation of 2,115 mm was recorded in 1981 and a minimum value of 1,081 mm was recorded in 1965. As may be verified by the table, there is a clear demarcation between the rainy season (winter) which lasts from May to November and the dry season (summer) which lasts from December to April. The rainy season months from August to October see particularly heavy rainfall. During this period, rainfall from afternoon to evening is normal. On the other hand, there is virtually no precipitation during the dry season months from January to March.

2. 3 Wind

Fig. IV−6 shows hourly wind direction and wind speed percentages by month at Chacarita Airport in Puntarenas based on wind measurement records from 1970 to 1971[2]. Fig. IV−7 shows the distribution of mean wind speeds (unit : km/h) in prevailing wind directions and in all wind directions, plotted by month and hour.

According to the figures, northerly, northeasterly and easterly land breezes and trade-winds prevail during the nighttime hours from 7 PM to 8 AM. During the day, southerly and southwesterly winds prevail. These are sea breezes and equatorial westwinds. The winds in the dry season from December to April are sea breezes. However, during the rainy season when equatorial west winds blow, sea breezes and equatorial west winds intermingle. Between June and February, southeasterly winds prevail between 5 PM and 8 PM.

Wind speed is high during the day, and particularly so during the dry season from December to May.

2) Eladio Zarate H.; Comportamiento del Viento en Costa Rica, Nota de Investigación, No. 2, Instituto Meteorológico Nacional, Dec. 1978, 31 p.

Table IV-3 Monthly Precipitation in Puntarenas
(1964 – 1984; Unit: mm)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1964	0.0	0.0	0.0	81.0	93.9	320.2	251.6	209.6	—	—	59.2	56.5	1072.0
1965	0.0	0.0	0.0	0.0	105.0	166.7	158.8	198.8	286.1	73.7	72.5	19.5	1080.8
1966	0.0	0.0	34.5	0.0	343.0	312.5	122.4	219.0	122.3	417.2	42.1	17.9	1630.9
1967	0.3	14.5	0.0	88.9	39.0	248.2	266.5	90.6	372.1	191.8	29.6	98.3	1440.4
1969	2.5	0.0	1.2	12.0	134.8	253.1	124.6	364.6	319.0	357.7	250.5	0.3	1820.3
1970	13.0	2.9	29.8	43.8	167.6	147.6	417.3	321.2	269.5	418.8	38.5	61.0	1931.0
1971	0.3	1.3	13.6	95.9	448.7	203.5	53.3	317.6	455.1	178.5	83.4	1.8	1853.1
1972	35.3	0.0	0.9	29.6	289.6	140.6	81.8	384.9	469.2	330.4	208.5	108.8	2079.6
1973	0.0	—	1.5	18.6	307.6	266.7	166.4	496.0	403.3	290.3	77.1	0.0	2027.5
1974	0.0	0.0	11.4	39.7	133.2	197.8	136.3	262.8	587.1	213.1	9.3	9.5	1600.2
1975	0.0	1.4	16.5	0.0	108.3	168.8	224.9	334.3	374.3	163.3	239.7	17.0	1648.5
1976	0.0	0.0	0.0	2.6	157.6	376.4	33.6	142.3	140.3	237.7	176.3	0.8	1268.2
1977	0.0	0.0	0.0	15.5	61.6	261.8	117.2	181.9	313.0	199.6	181.8	10.9	1343.3
1978	0.0	0.0	0.0	10.3	220.4	141.7	206.7	255.1	196.0	309.1	49.3	50.0	1129.5
1979	0.0	0.0	0.0	41.3	158.8	321.7	116.5	622.3	341.5	366.9	84.1	14.8	2067.9
1980	58.4	9.7	0.0	21.9	193.7	160.4	172.0	123.1	233.8	395.5	248.4	36.4	1654.3
1981	0.0	0.0	5.3	96.8	508.4	503.4	151.2	325.5	249.8	225.9	63.6	87.2	2215.1
1982	51.0	0.0	0.0	18.8	502.3	166.6	155.7	46.1	315.3	152.0	76.3	0.0	1484.1
1983	0.0	4.7	15.3	35.9	48.4	348.6	303.9	278.1	347.6	265.9	152.6	148.0	1949.0
1984	0.0	23.0	6.9	62.6	345.0	159.8	200.1	182.2	254.2	82.8	42.5	0.4	1359.5
Mean	8.1	3.0	6.8	35.3	218.2	243.3	173.0	267.8	318.4	256.3	109.3	37.0	1677.0

Source: IMN

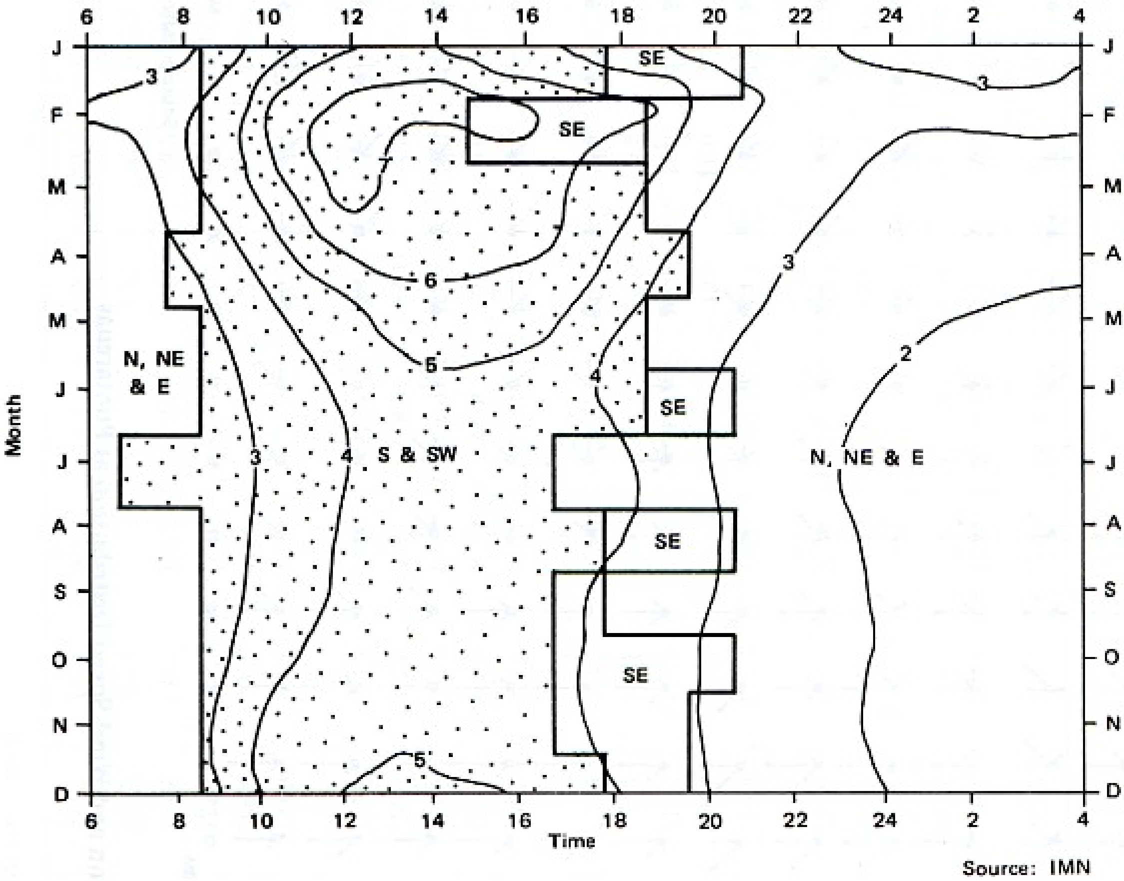


Fig. IV-7 Hourly and Monthly Prevailing Wind Direction and Mean Wind Speed

3. Marine Conditions

3. 1 Wave Conditions

Wave observation at the Port of Caldera began on June 15, 1978 using an ultrasonic wavemeter installed at a spot approximately 1.8 km offshore at a waterdepth of −13.5 m. This observation continues to the present. (Refer to Fig. IV−8). The periods in which data were obtained up to November 14, 1985 are shown in Fig. IV−9. During a wave observation period of 7.3 years, there were 3.3 years for which data were obtained. In July 1980, a significant wave calculation apparatus was furnished and significant wave height, maximum wave height, 1/10 maximum wave height, and mean wave height, as well as their respective periods, were automatically calculated and displayed.

Table IV−4 was prepared based on the record during the observation period, and shows the crossing frequency table between significant wave height and significant wave period. Fig. IV−10 and Fig. IV−11 show cumulative probable distribution of significant wave height and significant wave period respectively. The probability of significant wave heights between 0.5 m and 1.0 m is 65.4%. Ninety percent of significant wave heights are between 0.5 m and 1.5 m. 87.3% of significant wave periods are 9.5 s or greater. Dr. Goda, Director General of the PHRI, infers that this type of long period swell is generated in the long distance wind regions formed along the pressure incline between extensive high pressure and low pressure formations which are found in the South Pacific region between lat. 50° to 60°S. and long. 120° to 160°W. Accordingly, it is estimated that these waves are propagated over distances of 7,000 km to 9,000 km[3]. It is believed, therefore, that the directional dispersion of the waves is extremely small and that the waves exhibit behavior approaching that of regular waves.

Table IV−5 is a ranking in descending order of extremely large waves of a significant wave height greater than 1.5 m recorded during the observation period. Using the data of the 29 waves of significant wave height greater than 1.8 m, suitable probable wave heights and their corresponding periods which are estimated using the 3.3 year period in which data were obtained are shown in Table IV−6. The probable wave heights were calculated by adapting the above data to Gumbel and Weibull distributions, selecting the functions most compatible with the data, and extrapolating an equation for the inferred relationship. The distribution with the highest level of compatibility is a Weibull distribution with an exponent of 1.25, the equation for which is stated below.

$$P[H \leqq x] = 1 - \exp\left[-\left(\frac{x-1.694}{0.689}\right)^{1.25}\right]$$

Where, H : wave height (m)

x : wave height of a certain fixed value (m)

$P[H \leqq x]$: probability that wave height H will not exceed x

---

3) Yoshimi Goda; Analysis of Wave Grouping and Spectra of Long-travelled Swell, Report of the Port and Harbour Research Institute, Vol. 22, No. 1, March 1983, pp. 3 ∼ 41.

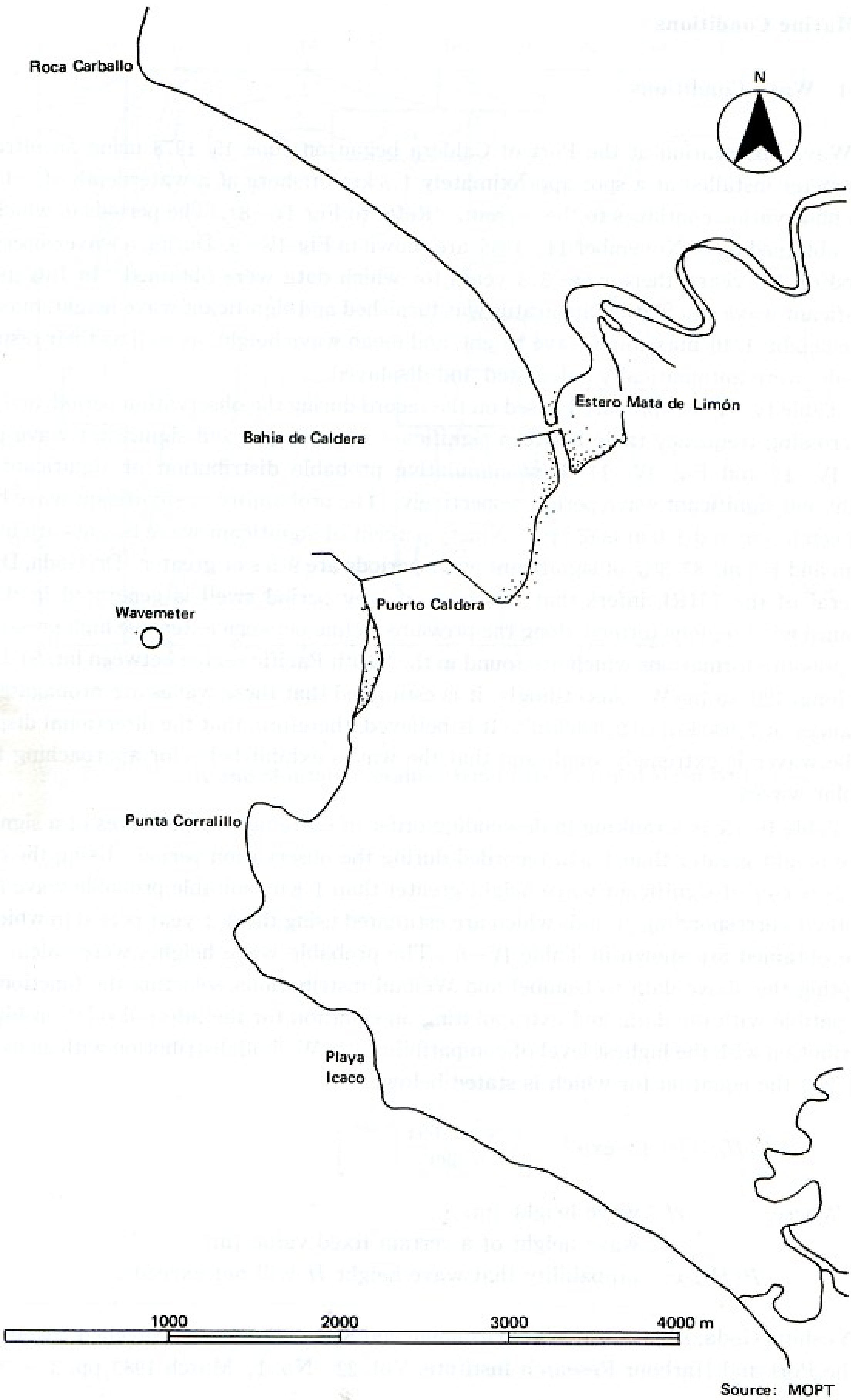
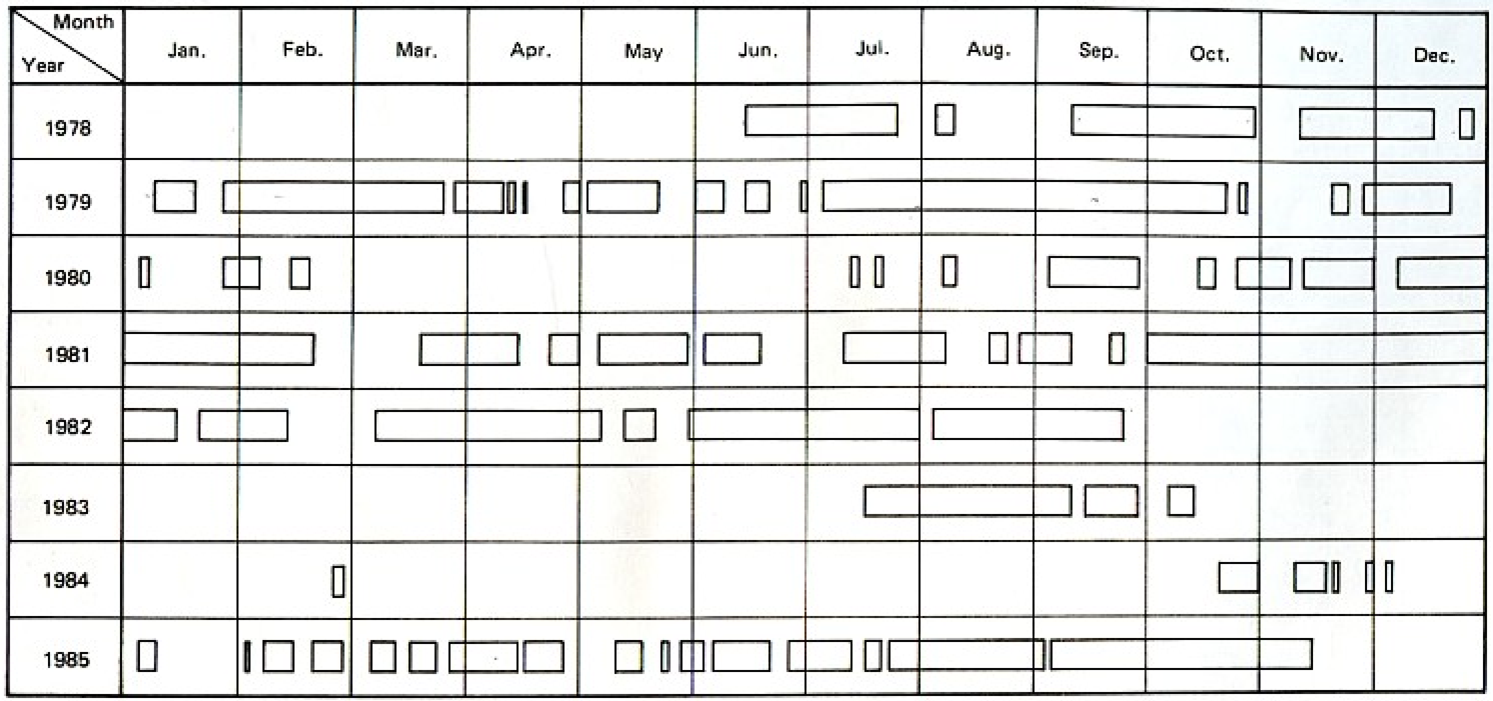


Fig. IV-8 Location Map of Wavemeter



Source: MOPT

Fig. IV-9 Period of Wave Observation

Table IV-4 Wave Occurance Probability by Significant Wave Height and Significant Wave Period (Observation Period : June 15, 1978～Nov. 14, 1985 ; Ratio of Observed Waves : 45.2%)

$H_{1/3}$ (m) \ $T_{1/3}$ (s)		≦ 3.5	3.5 ～ 4.5	4.5 ～ 5.5	5.5 ～ 6.5	6.5 ～ 7.5	7.5 ～ 8.5	8.5 ～ 9.5	9.5 ～ 10.5	10.5 ～ 11.5	11.5 ～ 12.5	12.5 ～ 13.5	13.5 ～ 14.5	14.5 ～ 15.5	15.5 ～ 16.5	16.5 ～ 17.5	17.5 ～ 18.5	18.5 <	Total	Cumulative Probability (%)
≦0.5	Frequency				8	26	46	66	112	141	104	80	41	15	19	6	3	2	669	
	Probability				0.1	0.2	0.4	0.6	1.0	1.2	0.9	0.7	0.4	0.1	0.2	0.1	0.0	0.0	5.8	5.8
0.5 ～1.0	Frequency	2	3	11	38	132	357	689	1020	1340	1390	1211	821	346	98	28	12	8	7506	
	Probability	0.0	0.0	0.1	0.3	1.2	3.1	6.0	8.9	11.7	12.1	10.6	7.2	3.0	0.9	0.2	0.1	0.1	65.4	71.3
1.0 ～1.5	Frequency		1	1	5	14	15	39	119	191	352	544	634	435	187	74	15	5	2631	
	Probability		0.0	0.0	0.0	0.1	0.1	0.3	1.0	1.7	3.1	4.7	5.5	3.8	1.6	0.6	0.1	0.0	22.9	94.2
1.5 ～2.0	Frequency	1						3	5	9	15	34	82	145	93	44	18	6	455	
	Probability	0.0						0.0	0.0	0.1	0.1	0.3	0.4	1.3	0.8	0.4	0.2	0.1	4.0	98.2
2.0 ～2.5	Frequency						1	2	1				4	24	49	35	14	5	135	
	Probability						0.0	0.0	0.0				0.0	0.2	0.4	0.3	0.1	0.0	1.2	99.3
2.5 ～3.0	Frequency													1	10	27	9	4	51	
	Probability													0.0	0.1	0.2	0.1	0.0	0.4	99.8
3.0 ～3.5	Frequency														2	14	8		24	
	Probability														0.0	0.1	0.1		0.2	100.0
3.5 ～4.0	Frequency																1		1	
	Probability																0.0		0.0	100.0
4.0<	Frequency																			
	Probability																			
Total	Frequency	3	4	12	51	172	419	799	1257	1681	1861	1869	1582	966	458	228	80	30	11,472	
	Probability	0.0	0.0	0.1	0.4	1.5	3.7	7.0	11.0	14.7	16.2	16.3	13.8	8.4	4.0	2.0	0.7	0.3	100.0	
Cumulative Probability	%	0.0	0.1	0.2	0.6	2.1	5.8	12.7	23.7	38.4	54.6	70.9	84.6	93.1	97.1	99.0	99.7	100.0		

Unit of Probability : %

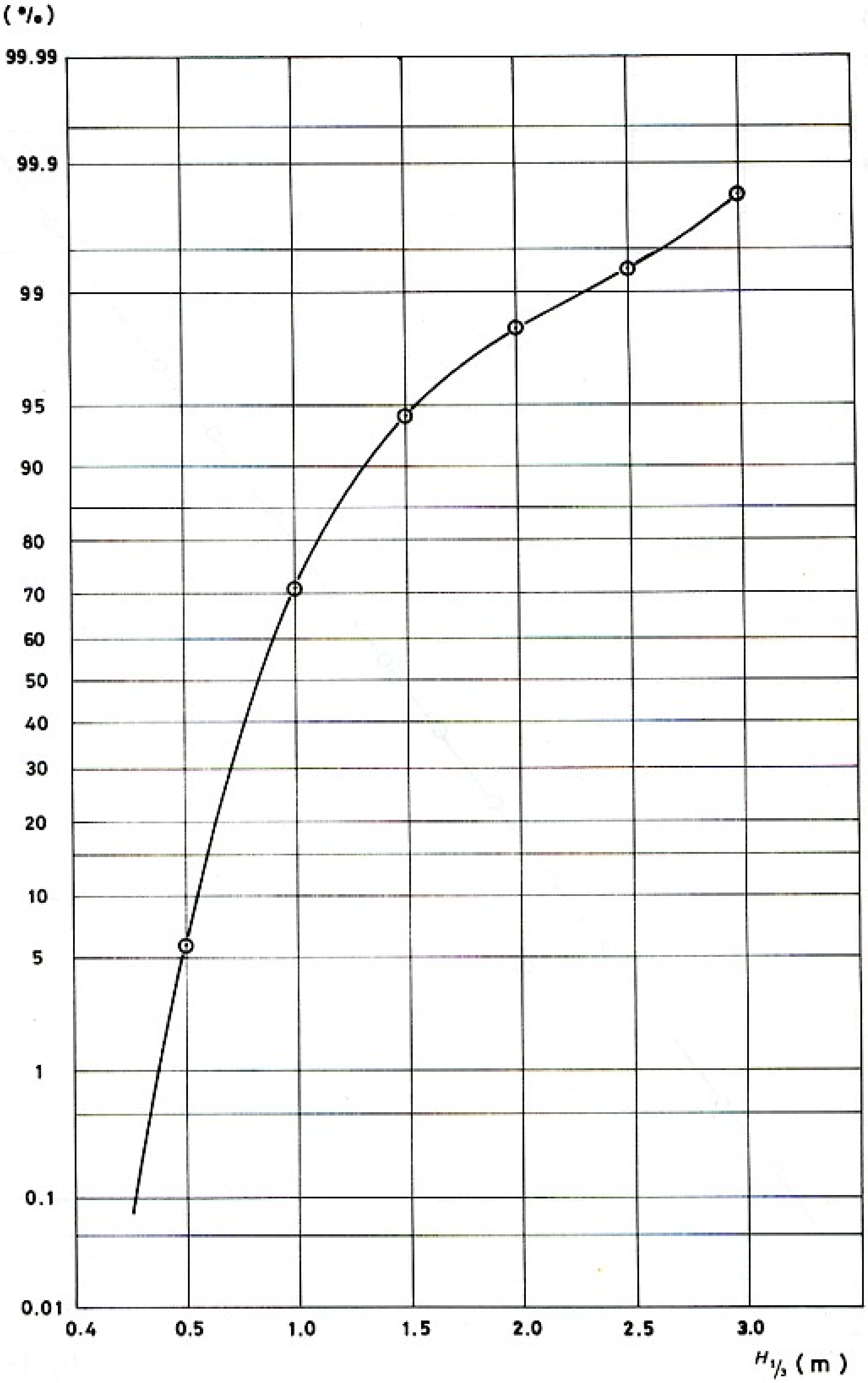


Fig. IV-10 Cumulative Occurrence Probability of Significant Wave Height

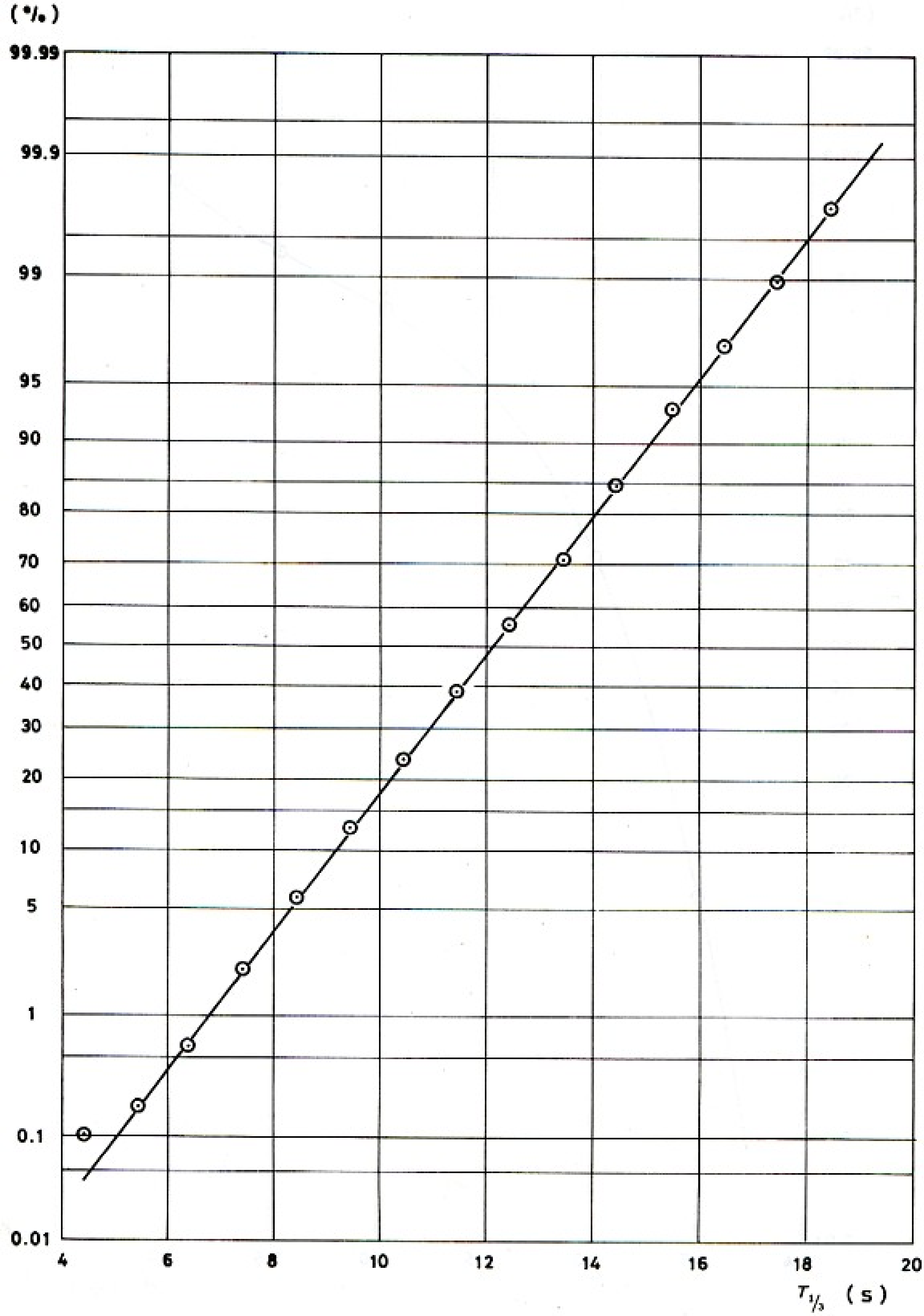


Fig. IV-11 Cumulative Occurrence Probability of Significant Wave Period

Table IV-5 Record of Observed Wave Heights above 1.5m

Rank	Date of Observation	Time	H_{max} (m)	T_{max} (s)	$H_{1/10}$ (m)	$T_{1/10}$ (s)	$H_{1/3}$ (m)	$T_{1/3}$ (s)	H_{mean} (m)	T_{mean} (s)
1	1981. 5.21	16	5.44	16.9	4.17	17.8	3.55	17.9	2.19	15.1
2	1983. 7.18	4	4.44	16.8	4.09	17.2	3.47	17.1	2.31	16.1
3	1978. 6.18	8	4.10	18.0	3.90	17.8	3.30	17.5	1.90	15.0
4	1985. 5.28	17	4.17	16.3	3.74	17.7	2.94	17.8	1.85	15.5
5	1982. 3.18	12	3.83	15.7	3.10	16.1	2.86	15.9	1.33	12.3
6	1985. 9.13	17	3.66	19.8	3.47	17.7	2.77	17.6	1.73	13.0
7	1981. 5. 6	18	3.98	20.0	3.43	16.7	2.74	17.4	1.58	12.0
8	1983. 8. 7	24	3.80	16.9	3.27	17.3	2.66	17.5	1.71	16.0
9	1980.11. 5	8	3.36	17.7	2.95	17.6	2.53	17.1	1.55	12.5
10	1985.10. 2	23	3.22	17.6	2.83	17.3	2.49	17.0	1.54	12.3
11	1981.11.29	2	3.14	17.5	2.93	16.4	2.44	16.4	1.50	13.9
12	1980.10.16	22	3.55	18.1	3.11	17.3	2.22	17.1	1.30	12.4
13	1985.10.27	7	2.92	17.5	2.75	17.1	2.20	17.3	1.33	14.5
14	1982. 6.12	4	2.75	13.9	2.53	14.5	2.13	15.7	1.38	12.8
15	1978. 9.18	4	3.20	9.0	2.70	8.6	2.10	8.9		
16	1985. 5.17	18	3.05	16.9	2.55	17.3	2.10	16.1	1.26	10.7
17	1981.11.20	24	3.10	16.1	2.37	15.5	2.06	15.9	1.41	13.9
18	1985. 8.18	8	2.88	14.2	2.56	15.6	2.06	15.6	1.26	12.9
19	1981. 7.10	20	2.69	17.6	2.30	14.6	2.02	15.4	1.21	11.0
20	1978.10. 3	16	3.00	15.0	2.50	16.0	2.00	16.0		
21	1979. 8. 7	16	2.50	20.0	2.30	19.0	2.00	18.2	1.40	16.2
22	1981. 3.21	18	2.48	14.3	2.29	15.5	2.00	15.7	1.21	13.0
23	1981.11. 1	20	2.99	16.3	2.40	16.4	1.99	16.1	1.23	18.3
24	1978. 8. 6	4	3.20	14.0	2.40	14.5	1.90	14.5		
25	1979. 5.20	24	2.50	17.0	2.30	16.0	1.90	16.0	1.30	15.0
26	1985. 4.17	15	3.00	12.9	2.41	9.6	1.88	12.3	1.08	8.5
27	1985. 9.26	9	2.48	15.7	2.30	16.3	1.85	16.3	1.13	13.4
28	1985. 6.30	13	2.50	14.3	2.18	12.1	1.81	12.7	1.12	8.5
29	1979. 9. 7	16	2.70	18.0	2.30	16.0	1.80	15.4	1.10	12.2
30	1982. 8. 7	18	2.62	16.0	2.26	16.2	1.79	16.5	1.06	11.8
31	1985. 8. 5	11	2.45	17.8	2.17	16.3	1.75	16.5	1.16	13.7
32	1985. 3.19	2	2.53	16.0	2.12	17.0	1.74	16.7	1.16	13.7
33	1979. 9.25	16	2.50	16.0	2.10	16.0	1.70	15.0	1.20	12.0
34	1985. 9. 8	15	2.46	15.0	2.04	14.3	1.70	14.5	1.07	12.2
35	1981. 1.17	6	2.26	13.8	1.98	13.9	1.67	14.2	1.01	13.0
36	1982. 3. 9	14	2.35	14.3	2.03	13.7	1.61	13.5	0.96	9.7
37	1978. 9.12	20	2.70	14.0	2.00	15.4	1.60	15.0		
38	1983. 9. 9	6	2.45	15.6	1.98	14.9	1.60	15.0	1.01	11.4
39	1978. 7. 9	16	2.00	16.0	1.90	15.9	1.60	16.0		
40	1985. 7.17	4	1.93	16.0	1.80	15.7	1.58	16.1	1.06	14.0
41	1982. 5.19	10	2.42	14.9	1.93	14.9	1.57	14.8	1.00	12.5
42	1981. 2. 7	22	2.40	14.3	1.96	14.2	1.57	14.3	0.97	13.1
43	1982. 8.15	6	2.55	15.8	1.99	15.2	1.56	15.5	1.00	11.9
44	1984. 2.26	22	1.89	13.4	1.59	14.7	1.56	11.3	0.90	9.5
45	1985. 6.15	7	2.29	13.1	2.04	13.3	1.51	13.3	0.91	11.6
46	1983. 8.15	22	2.12	12.8	1.90	13.7	1.51	13.7	0.93	9.9
47	1980. 9.11	22	2.06	11.5	1.82	11.8	1.51	11.7	0.97	9.7
48	1978.10.15	4	1.90	16.0	1.70	15.0	1.50	14.0		

Table IV-6 Probable Wave Heights Corresponding to Respective Recurrence Periods

Recurrence Period (Years)	Significant Wave Height $H_{1/3}$ (m)	Significant Wave Period $T_{1/3}$ (m)
5	3.692	17.97
10	3.980	18.26
20	4.259	18.50
25	4.348	18.57
30	4.419	18.62
40	4.531	18.71
50	4.617	18.78
100	4.881	18.97

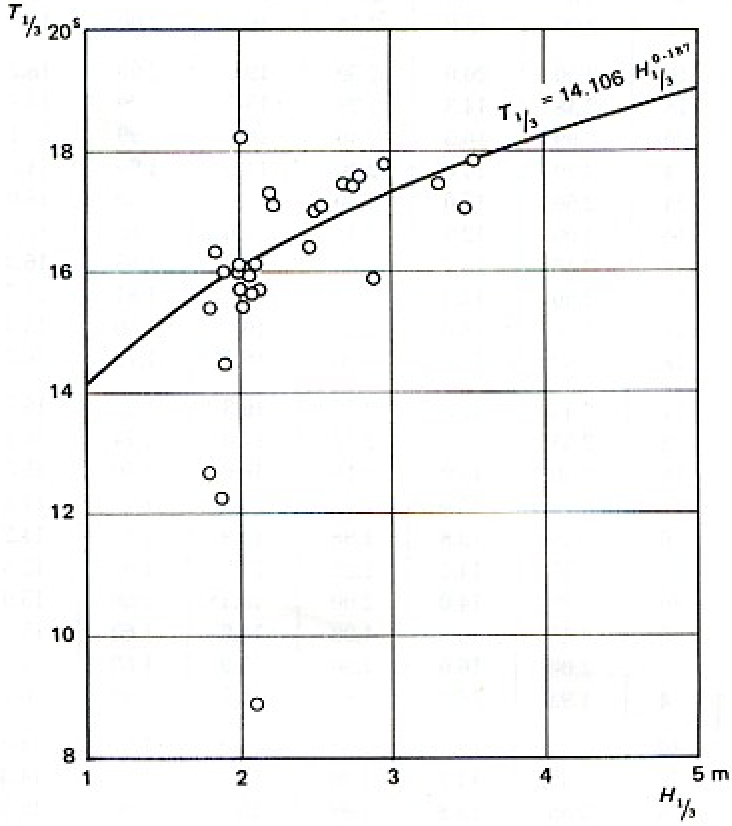


Fig. IV-12 Relationship between Significant Wave Height and Significant Wave Period of Extremely Large Waves

The significant wave period of each probable wave shown in Table IV-5 is, as shown in Fig. IV-12, estimated from the relationship between the significant wave height and the significant wave period of extremely large waves.

3. 2 Direction of Wave Incidence and Wave Refraction Coefficients in the Port of Caldera Area

In order to find the direction of wave incidence and the wave refraction coefficients in the Port of Caldera area, refraction calculations were carried out as part of the Feasibility Study on the Second Stage Expansion Project of the Port of Caldera performed in 1981.[4] The refraction calculations were carried out using the orthogonal method, and, as stated above, the waves in this sea area are believed to exhibit behaviour similar to regular waves. Hence for the purposes of calculation, the waves are assumed to be regular waves. A refraction calculation was first performed north of lat. 9°36′N. in a rectangular sea area with a north-south dimension of 40 km and an east-west dimension of 50 km. Then, a greatly reduced refraction chart was prepared for an area to the north side of the parallel passing through the southern edge of Icaco Beach south of Cape Carralillo. The prepared refraction chart is shown in APPENDIX 1.

The refraction coefficients and wave directions along the parallel of latitude passing through the southern edge of Icaco Beach south of Cape Corralillo are shown in Table IV-7 and Table IV-8. The direction of wave incidence near the tip of the Port of Caldera breakwater is shown in Table IV-9. Despite their having deep water wave directions and periods, the direction of waves incident to the tip area of the Port of Caldera breakwater are, with little variation, between N 220° to 230°.

3. 3 Tidal Conditions

Simple water pressure type tide measurements were performed at the roll-on/roll-off pier at the Port of Caldera between October 8 and November 15, 1985. A harmonic analysis was performed using data obtained on the 15 days and nights from midnight October 17, 1985 to 11 PM October 31. The obtained harmonic constants of a principal ten component tide are shown in Table IV-10. The tidal constant of the Port of Puntarenas [5] is also noted in the table. According to the table, the harmonic constants of the two ports are similar, and the tidal fluctuations are roughly the same. At both ports, a half-day periodic component prevails. The single day periodic component is minute. According to the tide table of the British Navy, the seasonal mean water level fluctuation in October is 0.0 m; hence it is likely that the mean water level at the time of the observations was virtually the same as the annual mean water level.

---

4) Japan International Cooperation Agency: The Feasibility Study on the Second Stage Expansion Project of the Port of Caldera, Republic of Coast Rica, Dec. 1981, 343 p.
5) Hydrographer of the Navy (G.B.); Admiralty Tide Table, Vol. 3, Pacific Ocean Ed., 1980, 452 p.

Table Ⅳ-7 Refraction Co-efficient along the Parallel of Latitude Passing through the Southern Edge of the Icaco Beach

Wave Direction / Wave Period (s)	157.5° SSE	180.0° S	191.3°	202.5° SSW	213.8°	225.0° SW
8	—	0.87	1.00	0.84	0.67	0.33
10	0.30	1.00	1.00	0.82	0.42	0.16
12	0.40	0.91	0.80	0.88	0.35	< 0.15
14	0.55	0.88	0.60	0.79	0.25	< 0.15
16	0.65	0.84	0.83	0.75	0.20	< 0.15
18	0.70	1.34	1.33	0.77	0.17	< 0.15
20	0.30	1.27	1.41	0.75	0.15	< 0.15

Source : JICA

Table Ⅳ-8 Wave Direction along the Parallel of Latitude Passing through the Southern Edge of the Icaco Beach

Wave Direction / Wave Period (s)	157.5° SSE	180.0° S	191.3°	202.5° SSW	213.8°	225.0° SW
8	—	182°	193°	205°	216°	—
10	—	183°	195°	208°	217°	—
12	—	185°	196°	210°	217°	—
14	—	186°	198°	211°	217°	—
16	—	189°	199°	212°	218°	—
18	—	191°	202°	214°	219°	—
20	—	193°	204°	215°	219°	—

Source : JICA

Table Ⅳ-9 Incident Wave Direction at the Port of Caldera

Wave Direction / Wave Period (s)	191.3°	202.5° SSW
12	220°	224°
16	223°	228°
20	225°	229°

Source : JICA

Fig. IV-13 was calculated according to the amplitude of a principal four tidal constituent in Table IV-10, and shows the principal tide levels at the Port of Caldera and the Port of Puntarenas. The tidal ranges of the two ports are compared in Table IV-11. Each tidal range at the Port of Puntarenas is 11 to 19 cm greater. However, the values for the Port of Caldera are based on observation data taken over a 15 day period, and hence it is not clear how significant the differences are. It may be safer to assume that there are only negligible differences.

Table IV-10 Harmonic Constants of Tides

(1985.10.17~31)

Tidal Constituent	Caldera			Puntarenas		
	Amp.	Lag		Amp.	Lag	
	H (m)	k (°)	g (°)	H (m)	k (°)	g (°)
M_2	1.025	80.3	75.8	1.10	76.5	72
S_2	0.270	136.1	125.5	0.25	136.6	126
K_2	0.047	136.1	125.5			
N_2	0.211	64.1	62.9			
K_1	0.087	342.4	336.9	0.10	349.5	344
O_1	0.045	14.8	15.8	0.04	22.9	24
P_1	0.029	342.4	337.4			
Q_1	0.023	45.5	49.8			
M_4	0.011	180.9	171.9			
MS_4	0.008	301.3	286.3			
A_0	1.496					

Note 1) The latitude and longitude of each port are,
Caldera : N 9° 54′ 42″, W84° 43′ 1″
Puntarenas : N 9° 58′, W84° 50′
2) In the Lag column,
k indicates Costa Rican time standard
g indicates Greenwich standard

Table IV-11 Tidal Range at Caldera and Puntarenas

	Caldera	Puntarenas
Large Tidal Range (m)	2.590	2.70
Mean Tidal Range (m)	2.050	2.20
Small Tidal Range (m)	1.510	1.70

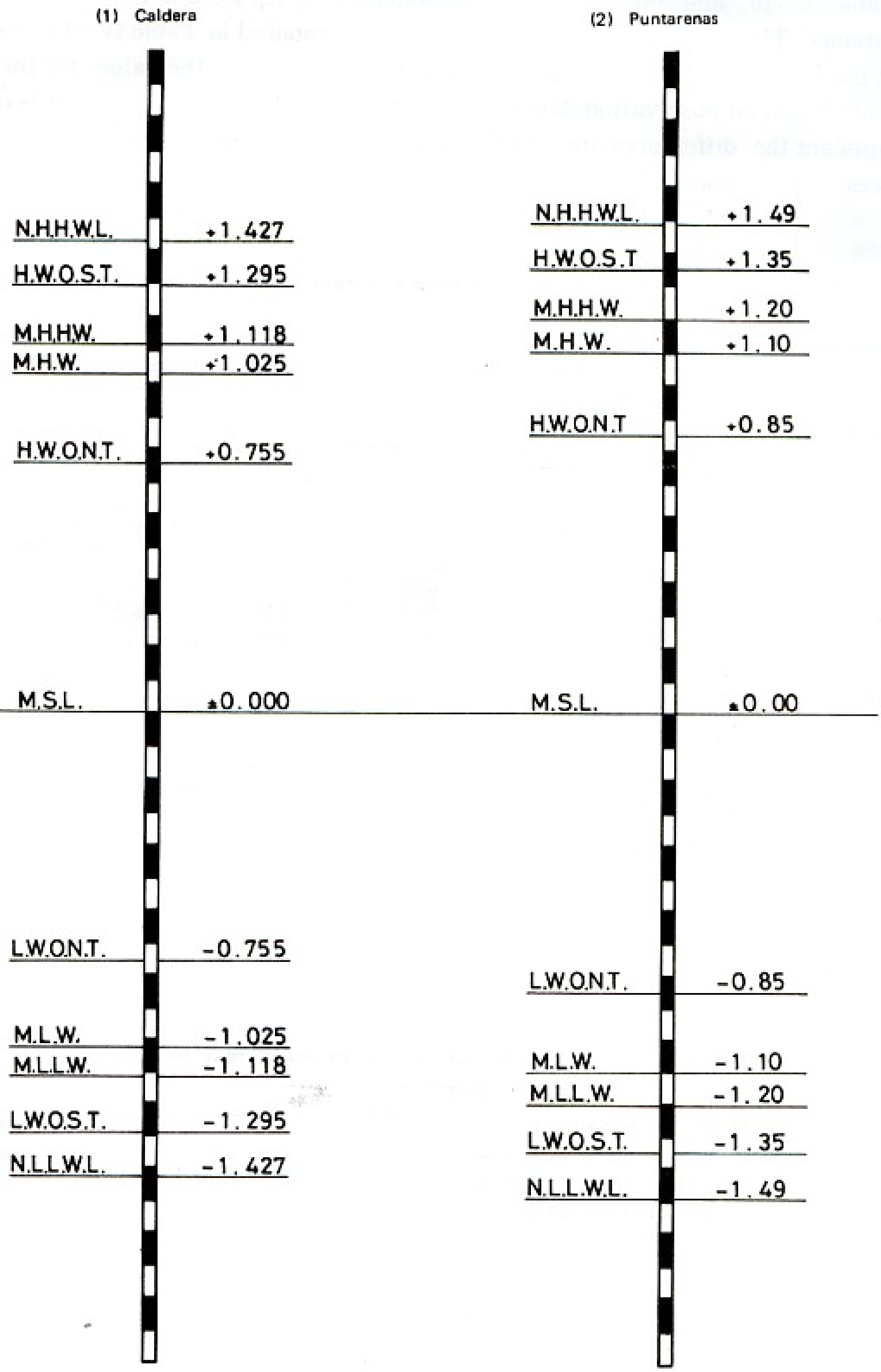


Fig. IV-13 Tide Levels at Caldera and Puntarenas

3. 4 Current

Current observation was performed by JST in cooperation with MOPT at the Port of Caldera and the surroundings area between October 9 and November 8, 1985, for the purpose of understanding the local sand drift phenomenon. Current observation comprised round the clock fixed point observations (4 locations) over 15 days using an Ono−type current meter, and double tide and single tide observations (15 locations) performed by a CM−2 D current meter for interpolating the above observations. The details of current observations and their results are shown in APPENDIX 3.

Fig. IV−14 and Fig. IV−15 shows current distribution during maximum northward and southward currents.

According to these figures, northward current during flood and southward current during ebb prevail in the offshore area of the Port of Caldera. The maximum current velocity is approximately 22 cm/s offshore of the New Beach. On the other hand, in the harbour area, a clockwise current always prevails. In this area, maximum velocity is approximately 7 cm/s during ebb.

3. 5 Sand Drift

Depth sounding, shoreline measuring, sediment sampling and analysis, fluorescent sand analysis, and a sectional study at the mouth of the Mata de Limón Estuary were performed between October 9 and November 7, 1985 at the Port of Caldera and the surrounding shoreline and sea area for the purpose of understanding the local sand drift phenomenon. The details of these studies and their results are shown in CHAPTER VI.

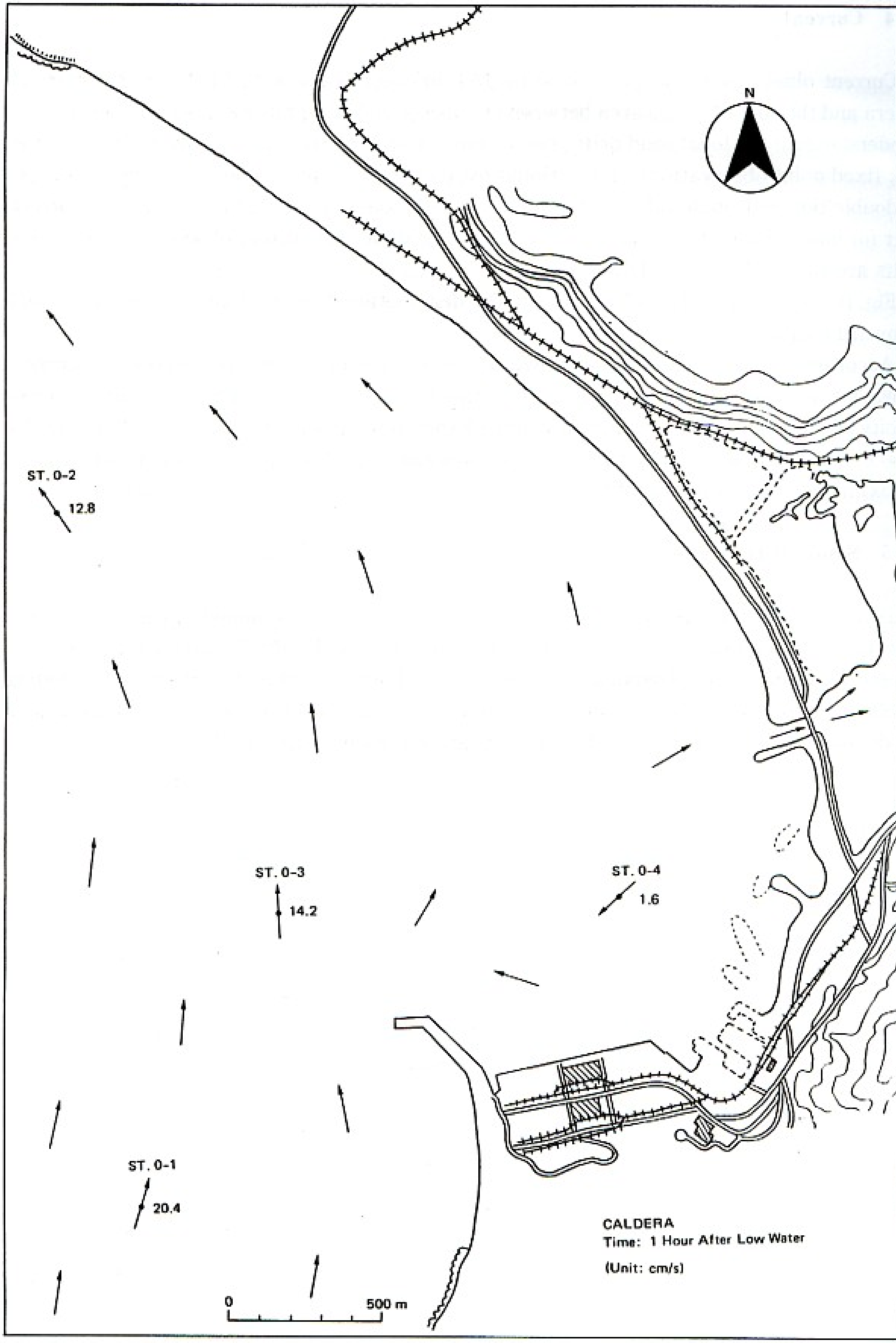


Fig. IV-14 Mean Current Distribution at Spring Tide (Northward Current)

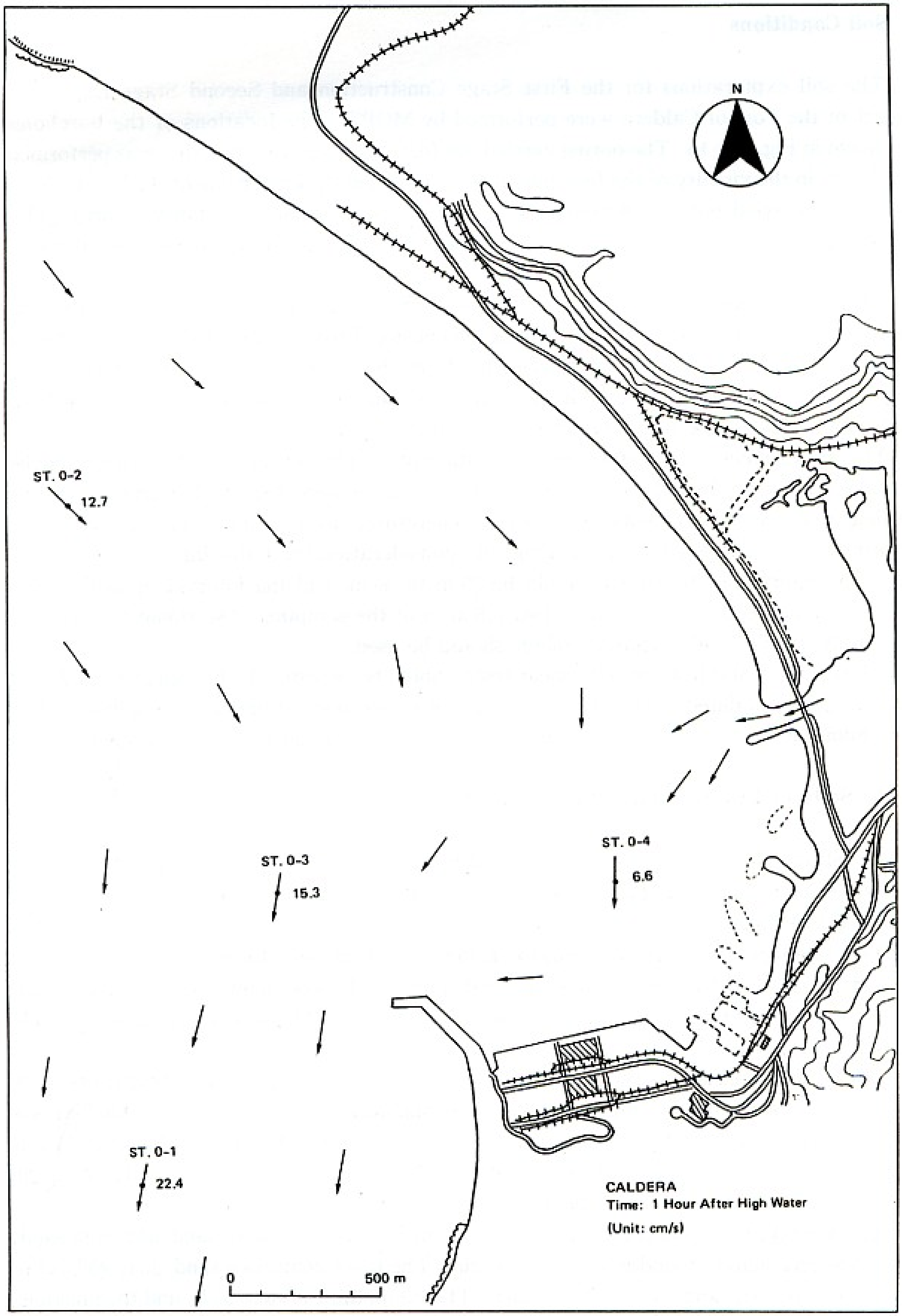


Fig. IV-15 Mean Current Distribution at Spring Tide (Southward Current)

4. Soil Conditions

The soil explorations for the First Stage Construction and Second Stage Expansion Project of the Port of Caldera were performed by MOPT. The locations of the boreholes are shown in Fig. IV−16. The boring carried out for First Stage Construction was performed principally in the vicinity of the face line of the wharf and the center line of the breakwater. The boring carried out to consolidate the Second Stage Expansion Plan was principally performed in the vicinity of the center line of the planned breakwater extension and the area around the planned wharf expansion zone.

Boring was carried out by the wash method. Sea scaffolding for boring performed in relation to consolidating the Second Stage Expansion Project plan made use of a tower constructed of steel tubing with attached floats in the zones for the planned breakwater extension, and pontoons were used in other areas. Sampling for the soil test was carried out using a BX Shelby tube (open sampler of 50 mm diameter).

The above mentioned soil investigation did not supply sufficient data concerning the shearing strength of the cohesive layer, and some samples were disturbed. Furthermore, the coefficient of consolidation was not reported. Therefore, further soil investigation should be performed for the detailed design, taking into consideration the following.

a) The interval of boreholes should be 25 m to 50 m, and the interval of undisturbed sampling depth should be less than 1.5 m. For the sampling, a stationary piston thin wall sampler with 75 mm diameter should be used.

b) Laboratory soil tests, mainly shear tests, should be performed. The shear tests should be unconsolidated-undrained triaxial compression tests as much as possible, and in addition to the above consolidated-undrained tests should also be performed.

4. 1 Soil Conditions around the Extended Breakwater

An estimated soil profile at the extended center line of the trunk part of the existing breakwater is shown in Fig. IV−17. The results of the soil tests at each of the boreholes are shown in APPENDIX 2.

The submarine soil strata comprise a layer of Tertiary Miocene sedimentary rock covered by deposited cohesive alluvium, and a layer of loose sand. This alluvium may generally be divided into three layers, namely Sa, Mb, and Mc, in descending order. The characteristics of each layer are given below.

The Sa bed consists of fine to very fine black sand mixed with shell fragments. The lower portion of the bed becomes silty in nature, and occasionally intercalates thin layers of silt. The sand content of Sa is 5to40% and is classified as SM. Layer thickness is 7 to 10 meters. The *N* value based on the standard penetration test is generally 10 to 20, however silty areas may drop to below 10.

The Mb layer consists principally of sandy silt or silt mixed with sand, although sandy layers are occasionaly found interposed therein. The layer comprises sand, 20 to 40%, clay, approximately 20%, and silt, the remainder. The liquid limit is 40 to 55%, and the plasticity index is 10 to 20, which means the plasticity is slightly low. The soil is classified as ML, CH,

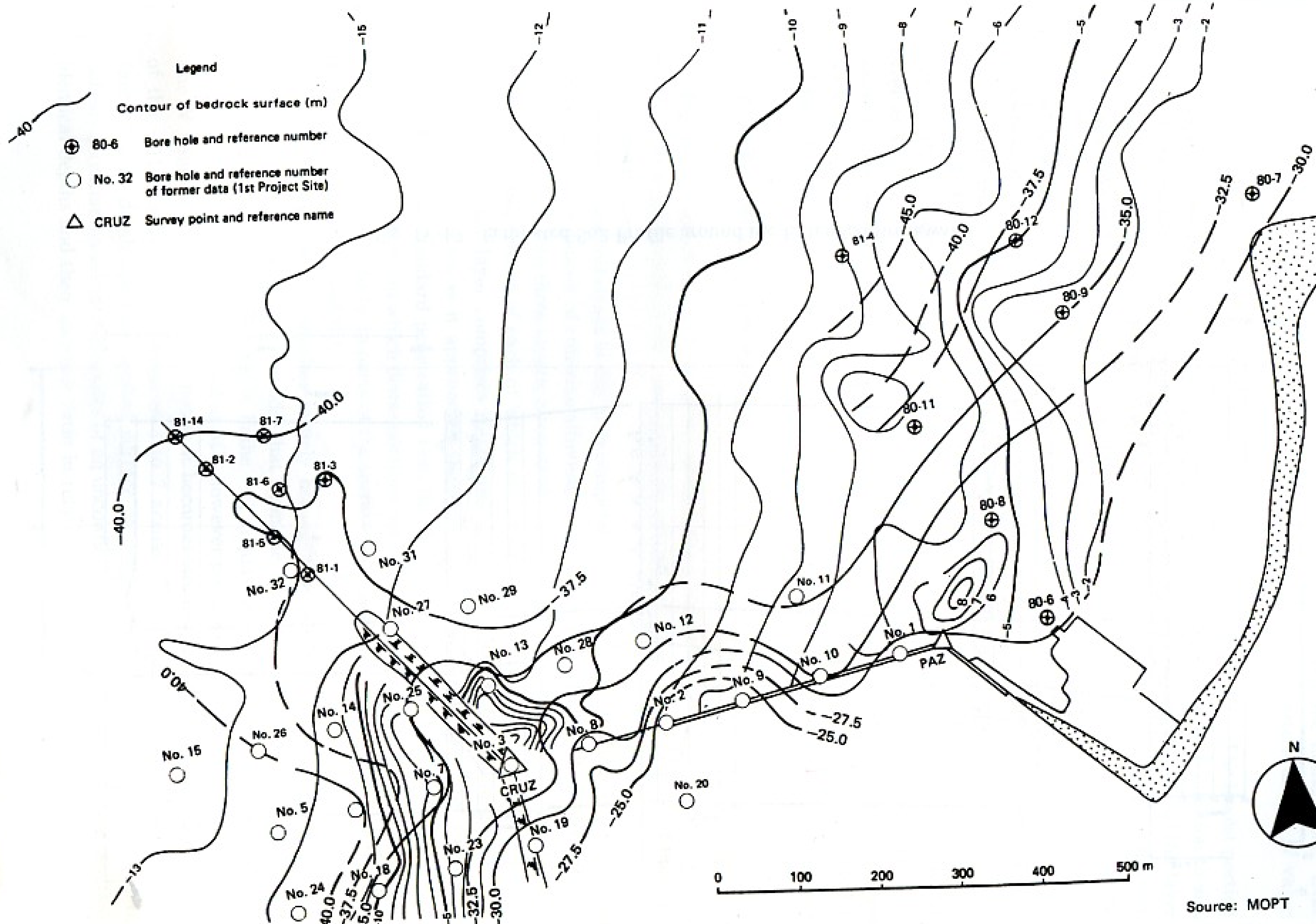
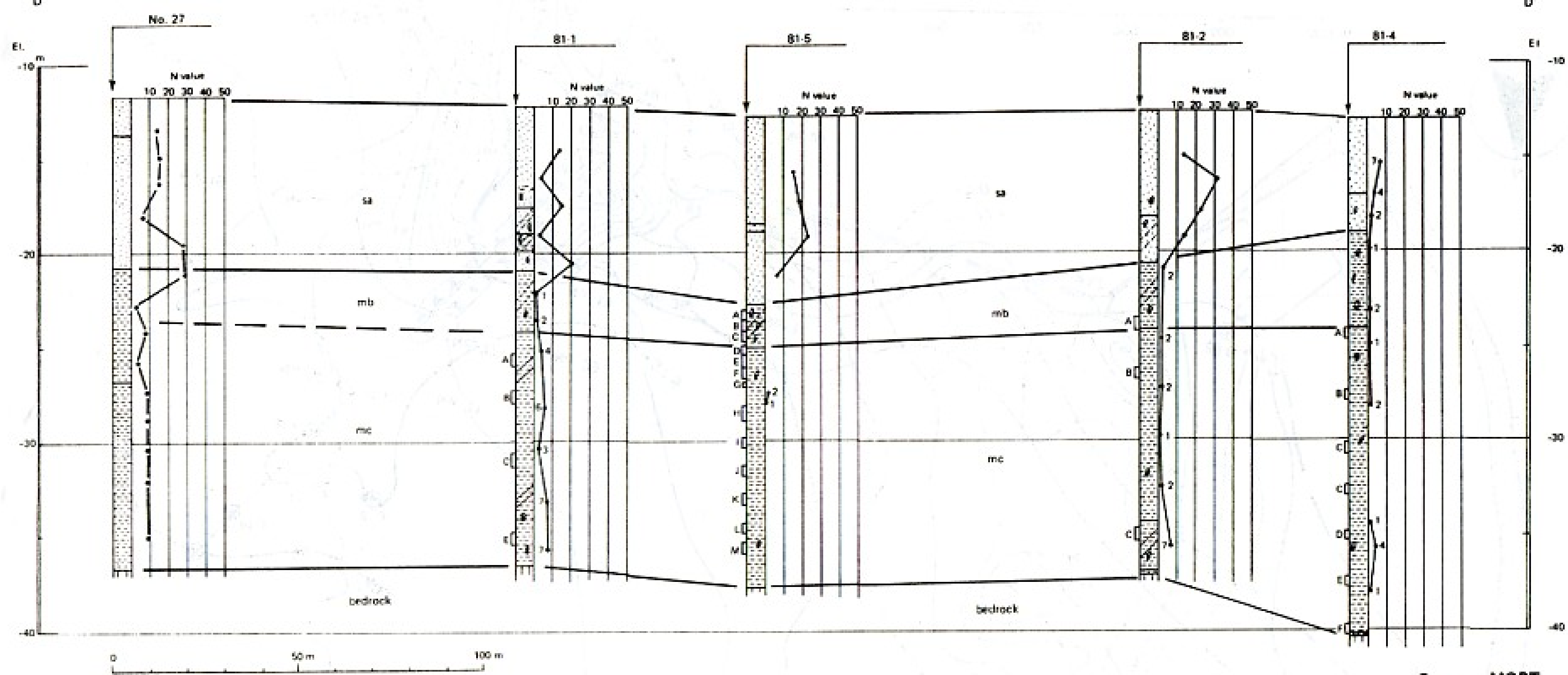


Fig. IV-16 Map of Borehole Locations



Source: MOPT

Fig. IV-17 Estimated Soil Profile around the Extended Breakwater and MH. Natural moisture content is 47% to 57% which is near the liquid limit. Unit weight is 1.66 to 1.74 tf/m³. The layer has a thickness of 2.5 to 7 meters, and an N value of 1 to 4.

The Mc layer is mostly silt with a small amount of shell fragments. The lowest portion of the layer occasionaly interposes thin gravelly layers mixed with silt. In addition to silt, texture composition is 2 to 15% sand, and 10 to 30% clay. The upper portion of the layer has a slightly greater sand component, while the lower portion has a greater clay component. The liquid limit is 52 to 62%, and the plasticity index is 20 to 30, which means that the plasticity is somewhat moderate. The soil is classified as MH. Natural moisture content is 48 to 57% which is near the liquid limit. Unit weight is 1.68 to 1.74 tf/m^3. The layer has a thickness of 10 to 16 meters, and an N value of 1 to 7.

The unconfined compression strength and unit weight of the Mb and Mc layers are plotted by depth in Fig. IV−18. Fig. IV−19 shows a plot of cohesion according to an unconsolidated undrained triaxial compression test. The cohesion of the Mb and the Mc layer is 4 tf/m^2 at the top edge of the layer, and 8 tf/m^2 at the bottom of the layer. A consolidation test was performed, though only the consolidation yield stress and compression index results were reported. The consolidation yield stress was reported as being 1.3 to 1.7 kgf/cm^2, and the compression index as 0.43 to 0.47.

4. 2 Soil Conditions along the Face Line of the Wharf

Fig. IV−20 shows the estimated soil profile along the face line of the wharf which is based on an examination of the soil conditions carried out during the planning of the First Stage Construction.

The submarine soil strata in this area comprise a layer of Tertiary Miocene sedimentary rock covered by a deposit of cohesive alluvium, and a layer of loosesand. This alluvial layer can be subdivided into three layers, a top sandy layer, a cohesive layer, and a bottom sandy layer, the characteristics of each of which are explained below.

The top sandy layer comprises rough and fine sand, and has a thickness of 7 to 15 meters which narrows as it approaches the western side, i.e. the breakwater foundation. According to the standard penetration test, the N value is generally between 20 and 50, with a variable density in which dense portions are numerous. However, there are instances where the value drops to 10 in parts of the surface layer and in the silty portions. This layer is classified as S, SW, and SP.

The cohesive layer comprises largely homogenous, slightly hard silt, and is thicker towards the west. On its eastern side, that is, in the −7.5 m quay area, it is 2 to 4 meters thick, and on its western side, that is, in the −11 m quay area, it is 3 to 11 meters thick. The soil in this layer is mostly classified as ML, however portions of MH and CH are also found. The N value is mostly 4 to 15, though it becomes smaller towards the west. At the edge of the −11 m quay area it becomes 3 to 7 across all layers. Fig. IV−21 shows a plot (according to depth using the seabed surface as a standard) of the shear strength of this cohesive stratum based on the results of an unconfined compression test. Shear strengths at identical depths and their increase ratio in relation to depth have similar values along the

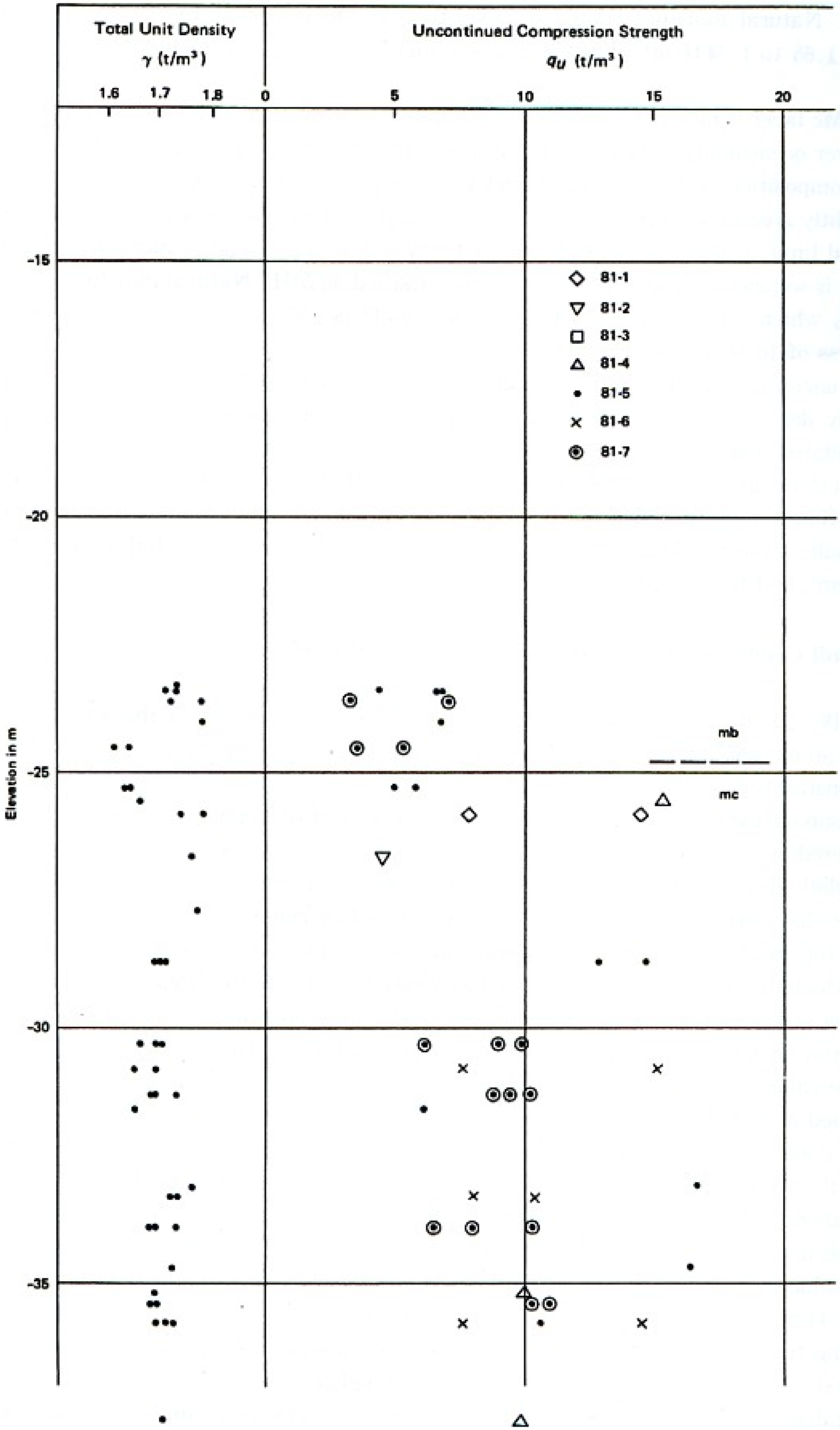


Fig. IV-18 Unit Weight and Unconfined Compression Strength of the Cohesive Layer around the Extended Breakwater

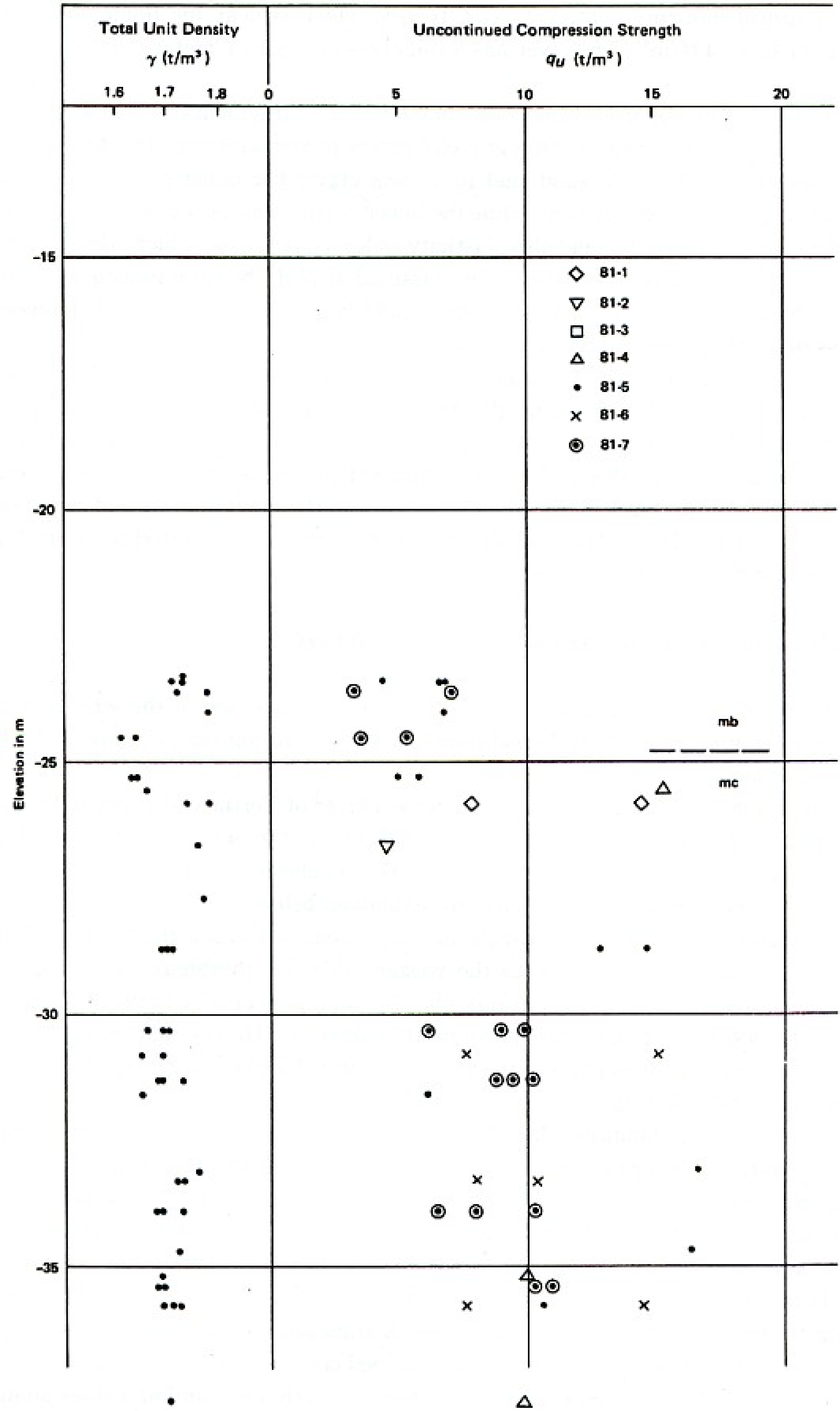


Fig. IV-18 Unit Weight and Unconfined Compression Strength of the Cohesive Layer around the Extended Breakwater

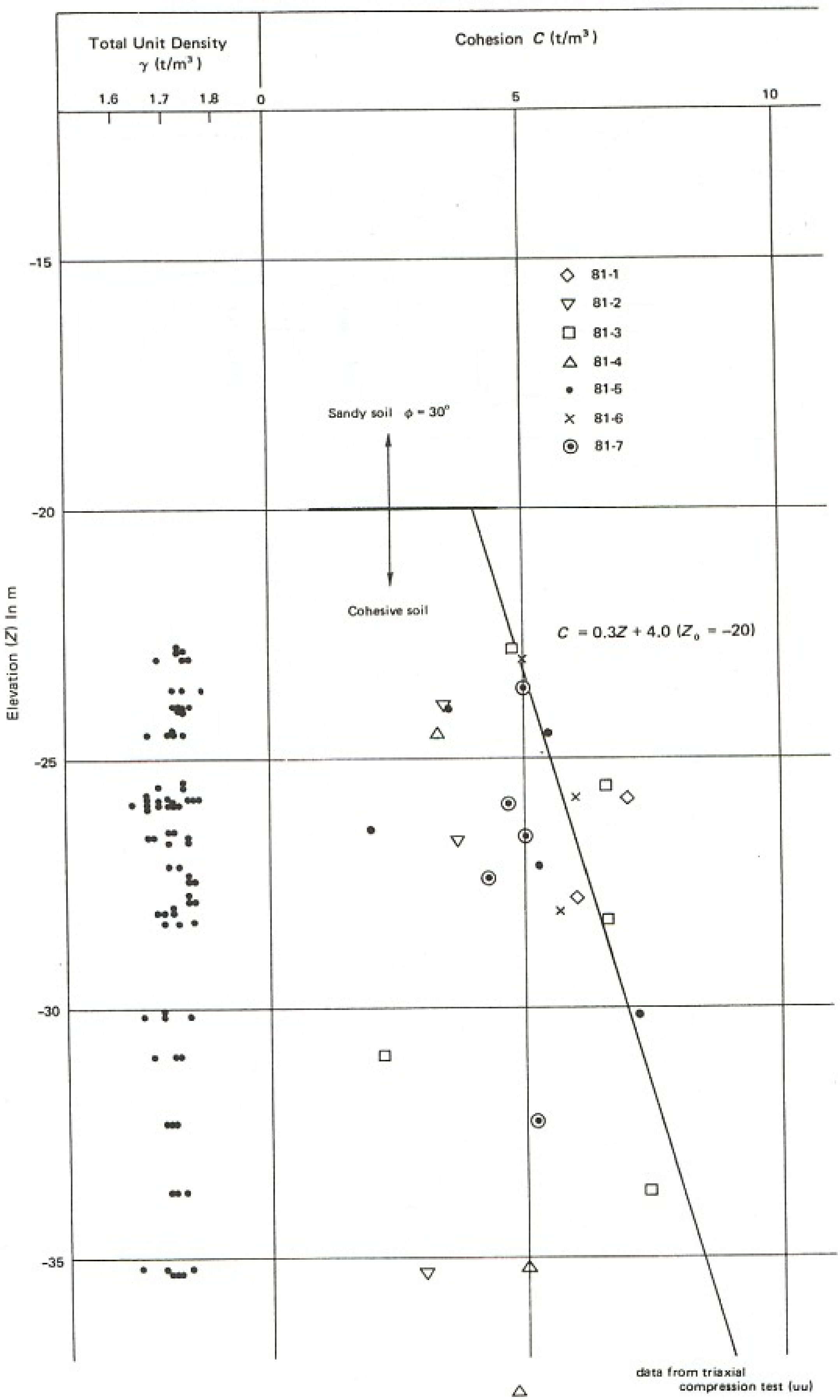


Fig. IV-19 Cohesion of the Cohesive Layer around the Extended Breakwater according to a Triaxial UU-Test

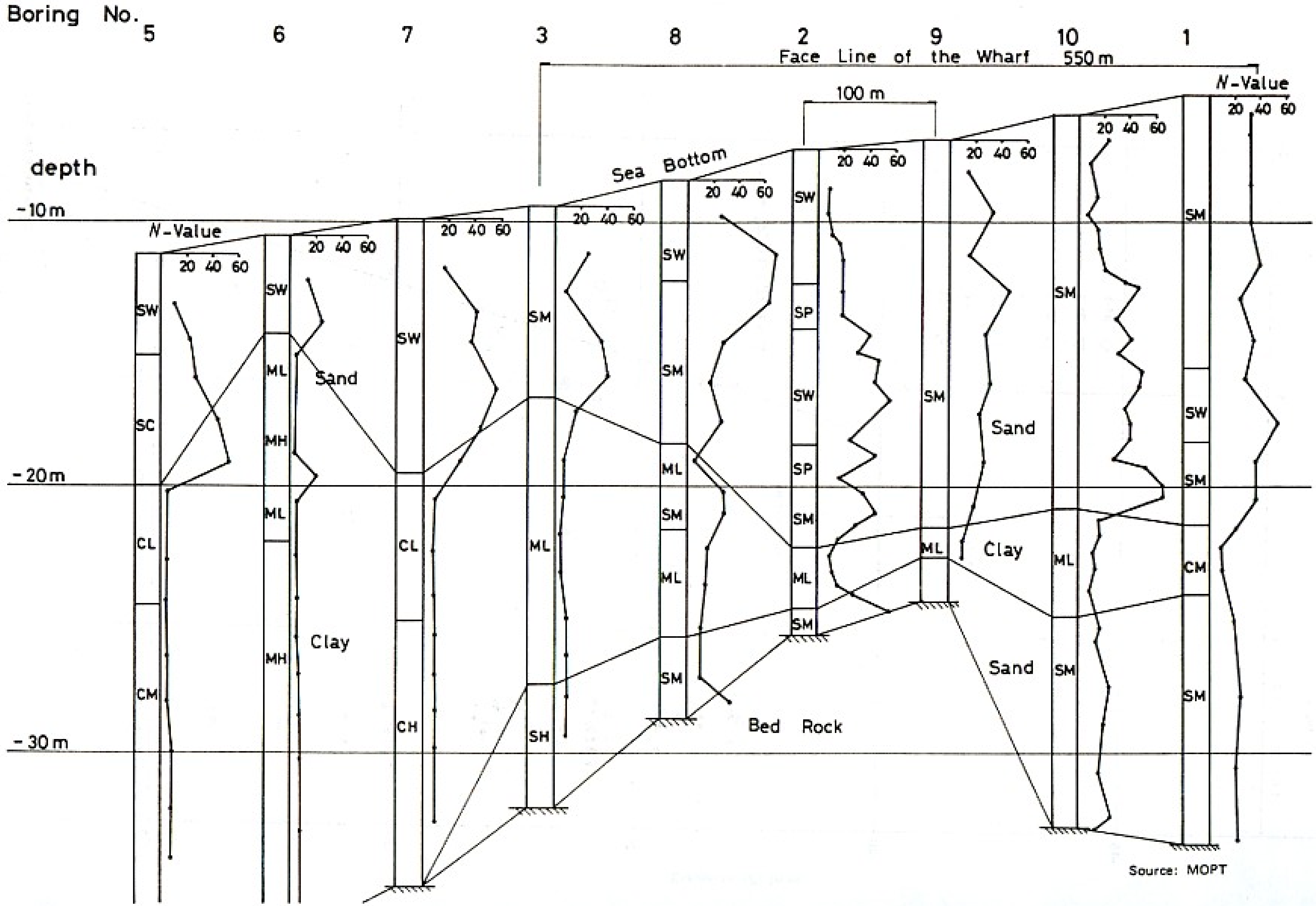
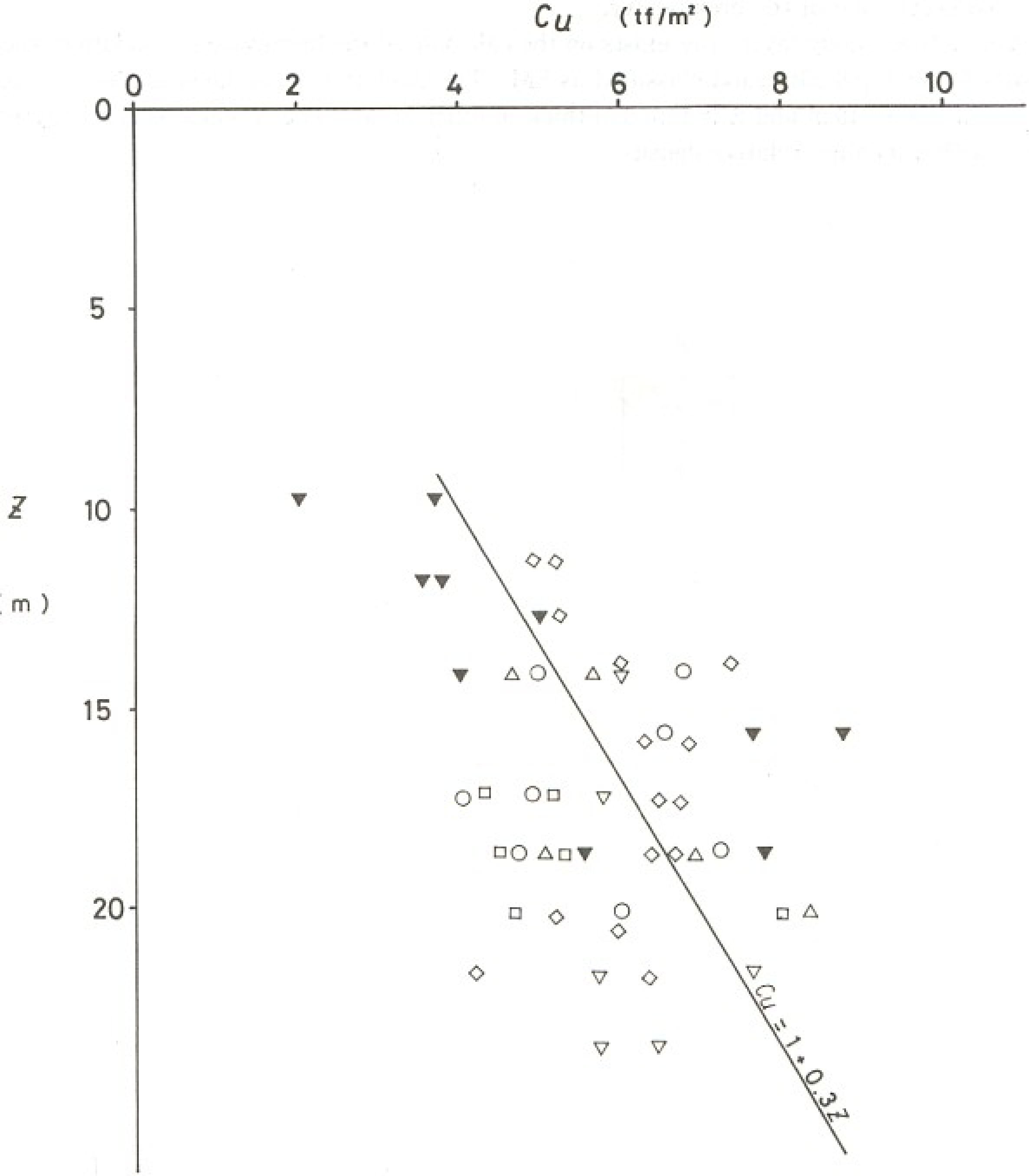


Fig. IV-20 Estimated Soil Profile along the Face Line of the Wharf



Source: MOPT

Fig. IV-21 Cohesion of the Cohesive Layer along the Face Line of the Wharf according to an Unconfined Compression Test extended center line of the breakwater.

The bottom sandy layer only exists on the east side of the breakwater foundation, and consists of sand and silty sand classified as SM. The thickness of the layer at the −7.5 m quay area is 8 to 10 m and it is 1 to 5 m thick in other areas. The N value is generally 10 to 20, with a medium relative density.

5. Earthquakes

5. 1 Earthquake Activity in Costa Rica

As indicated by Fig. IV−22, Costa Rica may be divided into three regions based on past earthquake records and a geological study relating to the development mechanics, magnitude, depth of focus and topographic distribution as follows [6].

(1) Pacific Coast Border Region
(2) Valley and Mountain Region
(3) Northern and Atlantic Coast Plain Region

Fig. IV−22 shows the locations of epicenters and origins of earthquakes occuring between 1888 and 1983 which were of considerable intensity or caused significant damage. Table IV−12 indicates the date of occurence, the region, the magnitude and a summary of the damage from all the earthquakes occuring between 1756 and 1983 which were of considerable size or caused significant damage.

The characteristics of earthquake activity in the three regions are explained below.

(1) Pacific Coast Border Region

This region is vulnerable to earthquakes caused by the subduction of the Carib Plate on which the Costa Rican territory is situated by the Cocos Plate of the Pacific sea bottom which is creeping below the Carib Plate offshore at the Pacific Central American Trench. These earthquakes move inland, and accordingly are charactrerized by deepening focuses, the maximum values of which reach 200 km.

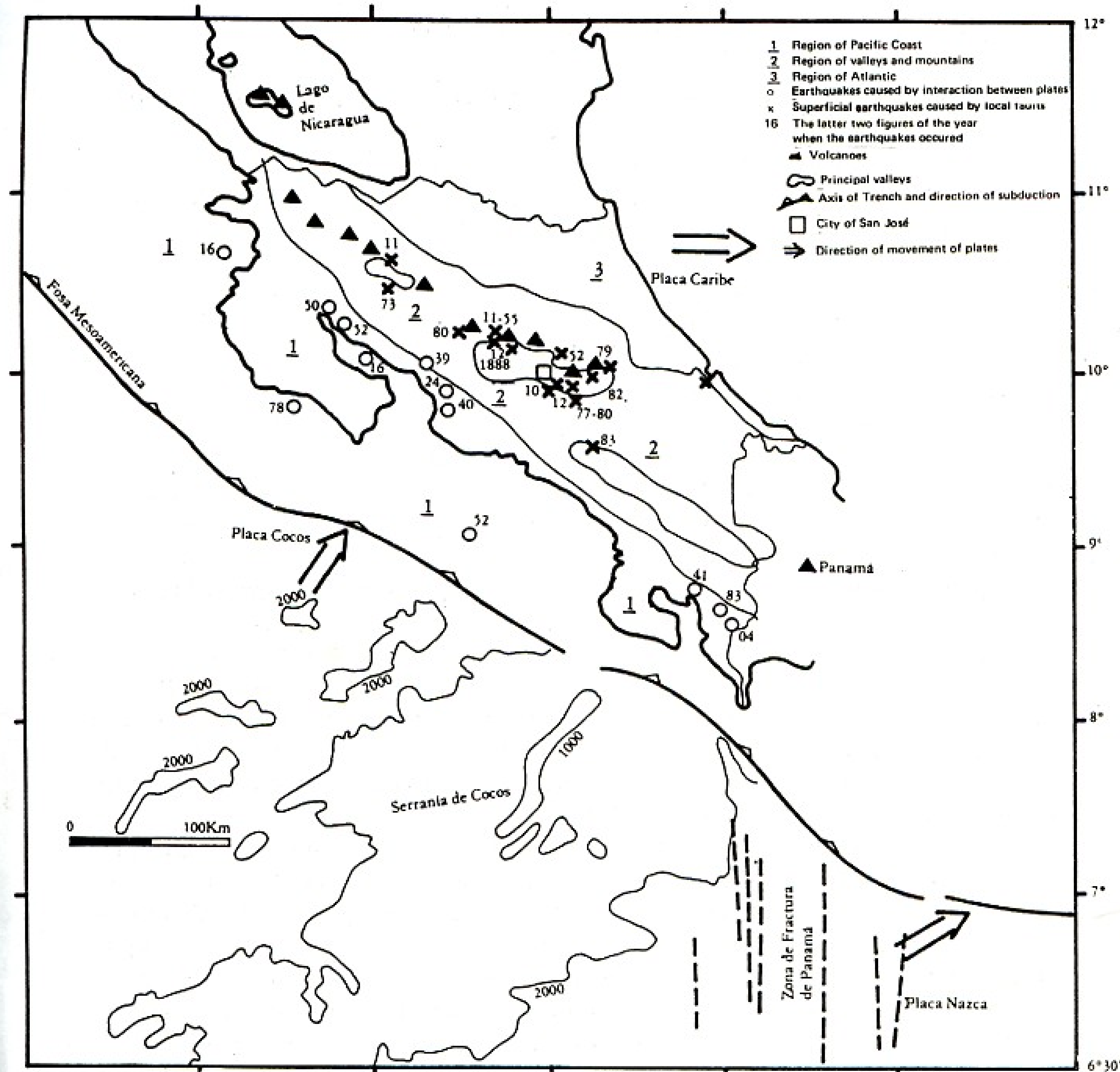
The scale of earthquakes caused by subduction of the plate is potentially very great, and an earthquake of 7.75 in magnitude was recorded in 1904. As a result, the energy of these earthquakes accounts for the major portion of the earthquake energy released in Costa Rica, although the resulting damage is not great. The reason for this is that although the depths of the focuses in the Pacific Coast. Region are undoubtedly comparatively shallow (20 km or more), they travel inland and their focuses deepen, hence the strength of the tremors become smaller. In general, the earthquakes in this region almost never exceed VII on the Modified Mercalli intensity scale. The Holy Saturday earthquake that occured on April 2, 1983 had an intensity in the central highlands of VI∼VII.

(2) Valley and Mountain Region

Earthquakes in this area are caused principally by localized faults. They are moderate in scale, with magnitudes of 6.5 or less. However, their focuses are shallow, and they occur close to areas of concentrated human population. Hence not only do tremors reach a powerful IX on the Modified Mercalli intensity scale, damage also increases due to addi-

---

6) Luis Diego Morales M.; Los Temblores, sus Causas, Medición y Efectos, Setiembre Cientifico, Vol. 2, Sep. 1985, pp. 43∼83



Source: Luis Diego Morales M.

Fig. IV-22 Seismic Regions and Epicenters of Principal Earthquakes which Occurred between 1888 ~ 1983 in Costa Rica

Table Ⅳ-12 Important Earthquakes which Occurred in Costa Rica *

Year	Date	Region	Magnitude	Coment
1756	14 Jul.	Earthquake of San Buenaventura (Epicentre is indefinite)	—	Damages in Cartago
1798	22 Feb.	Earthquake of Matina (Epicentre is indefinite)	—	
1822	7 May.	Earthquake of Matina (Epicentre is indefinite)	—	Damages throughout the region
1841	2 Sep.	Earthquake of Santa Mónica near Cartago	—	Primary destruction in Cartago
1851	18 Mar.	Strong earthquake near Alajuela	—	Damages in Alajuela and San José
1888	30 Dec.	Earthquake of Fraijanes	—	Damages in Alajuela and San José, Lake of Fraijanes created
1904	20 Dec.	Strong earthquake near the Panamá border	7.75	No damage was reported
1910	13 Apr.	Earthquake of Tablazo	<5.5	Damages in San José
1910	4 May.	Earthquake of Cartago	≦5.5	Secondary destruction of Cartago, 362 dead.
1911	28 Aug.	Earthquake of Toro Amarillo	—	Moderate damages and landslides
1911	10 Oct.	Earthquake of Guatuso (north of Lake of Arenal)	**	Landslides, cracks in the ground
1912	6 Jun.	Earthquake of Sarchí (hill of Palomo)	**	Large damages, landslides and damming of river from debris.
1916	27 Feb.	Earthquake (near Playa del Coco in Golfo de Papagayo)	7.5	Damages in Sardinal and Santa Cruz
1924	4 Mar.	Earthquake of Orotina (San Mateo-San Ramón)	7.0	Violently shaked Central Valley, damages throughout the region
1939	21 Dec.	Strong earthquake, region of Golfo de Nicoya	7.3	No damage was reported
1941	5 Dec.	Strong earthquake near Golfito	7.5	No damage was reported
1950	5 Oct.	Earthquake of Guanacasute (mouth of Río Tempisque)	7.7	Damages in Puntarenas
1952	30 Dec.	Earthquake of Patillos (northwest slope of Volcán Irazú)	**	21 dead in landslide
1953	7 Jan.	Earthquake of Limón	**	Moderate damages in Limón
1955	1 Sep.	Earthquake of Toro Amarillo (Grecia)	**	Damages in the Valley of Río Toro Amarillo
1973	14 Apr.	Earthquake of Tilarán	6.5	Damages in the region of Tilarán, 23 dead
1983	2 Apr.	Earthquake of Osa-Golfito	7.3	Moderate damages throughout the region including San José, 1 dead
1983	3 Jul.	Earthquake of Pérez Zeledón	6.1	Important damages in the northen region of San Isidro and moderate damages in San Isidro, 1 dead

* It is a partial list including only earthquakes which which were large or which caused significant damage.

** Estimated magnitude is $5 \leqq M_S \leqq 6.5$.

Source : Luis Diego Morales M.

tional disasters caused by landslides and floods from damaged dams. Damage-causing earthquakes in Coast Rica occur principally in this region, and as shown in Fig. IV−22, and often originate invalley areas.

The Cartago earthquake which occured on May 4, 1910 caused the greatest level of earthguake damage. In more recent years, the Pérez Zeledõn earthquake occured in this area on July 3, 1983 between Buena Vista and Divisiõn which are located in the northern district of San Isidro.

(3) Northern and Atlantic Coast Plain Region

From the view point of techtonics, this is a quiet region in Costa Rica with little earthquake activity. The locations of earthquake occurances tend to be spread out (refer to Fig. IV−22). However, an earthquake with powerful tremors hit the City of Limõn on January 7, 1953 and caused great damage.

5. 2 Distribution of Expected Seismic Acceleration Values

Fig. IV−23 and Fig. IV−24 show the distribution of expected ground acceleration values calculated for Costa Rica over a 50 year recurrence period and a 100 year recurrence period. The values are based on the record of past earthquakes occuring between 1883 and 1975 and were calculated by C. P. Mortgat, T. C. Zsutty, H. C. Shah, and L. Lubetkin.[7]

According to these figures, expected ground acceleration values are small along the Caribbean Coast and high in the Pacific Coast region, particularly near Golfito. The expected ground acceleration value in the Port of Caldera area is 0.15 G over a 50 year recurrence period, and 0.175~0.20 G over a 100 year recurrence period, where G is equal to the acceleration of gravity.

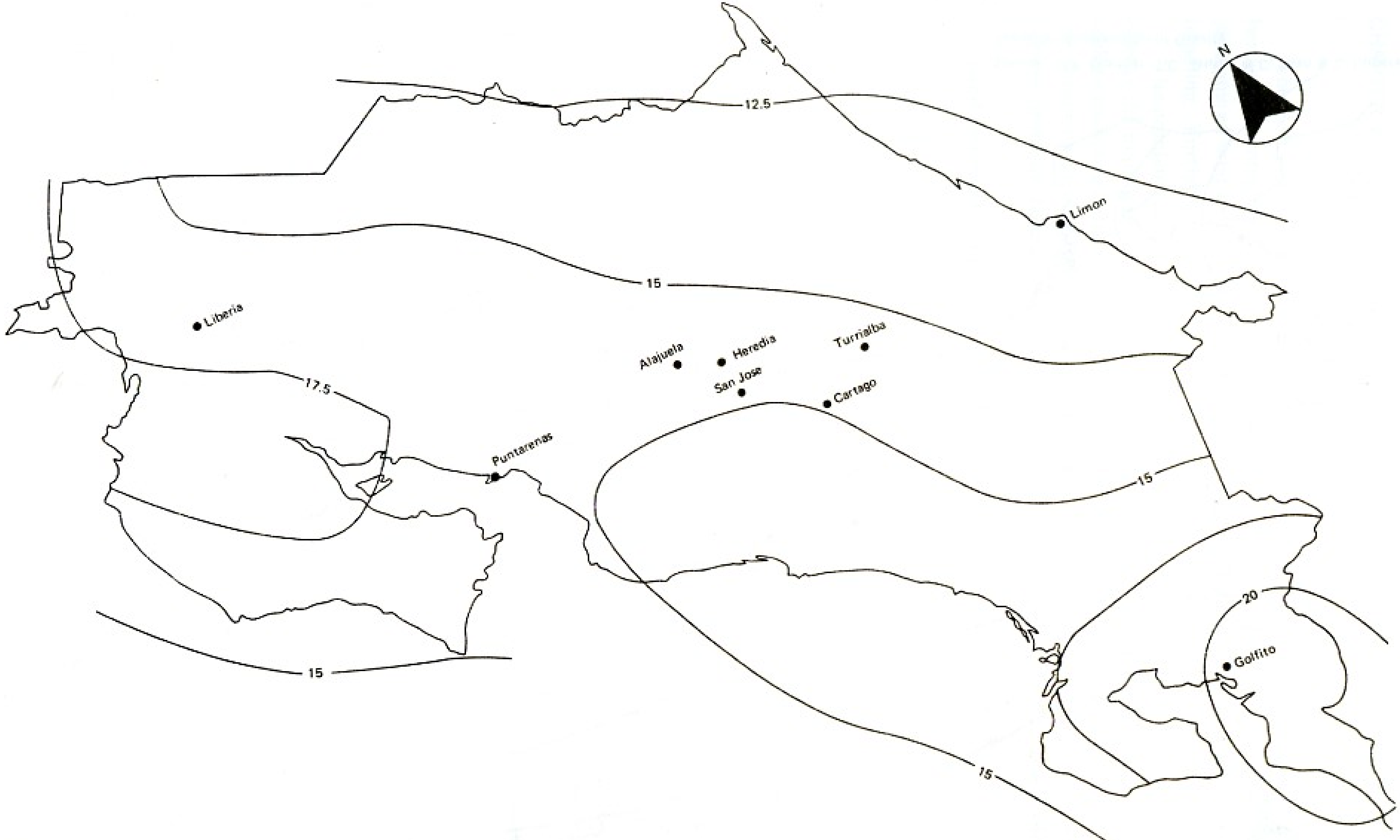
5. 3 Tsunamis

It has been reported that the possiblity of tsunamis occuring in Costa Rica in slight considering the characteristics of the seismic faults which cause tsunamis.[8]

---

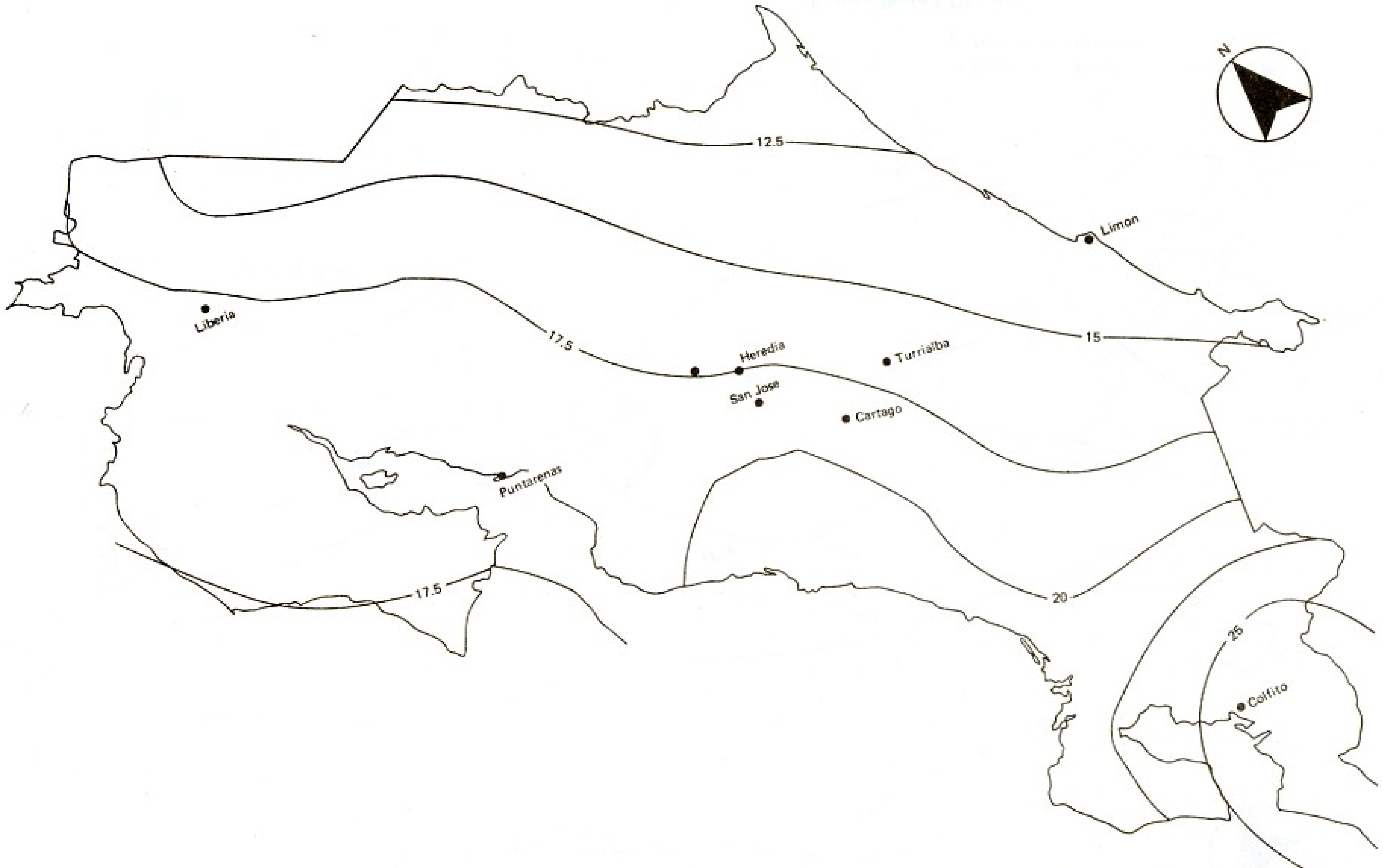
7) Christian P. Mortgat, Theodore C. Zsutty, Haresh C. Shah & Lester Lubetkin; A Study of Seismic Risk for Costa Rica, Rep. No. 25, The John A. Blume Earthquatke Engineering Center, Dep. of Civil Engineering, Stanford Univ., Apr. 1977, 359 p.

8) Luis Diego Morales M.; Los Temblores, sus Causas, Mediciõn y Efectos, Setiembre Cientifico, Vol, 2, Sismos, Sep. 1985, pp. 43 ~ 83



Source: C.P. Mortgat, T.C. Zsutty, H.C. Shah & L. Lubetkin
Note, G: Acceleration of Gravity

Fig. IV-23 Iso-Acceleration Map (% of G) (Return Period 50 years)



Source: C.P. Mortgat, T.C. Zsutty, H.C. Shah & L. Lubetkin
Note, G: Acceleration of Gravity

Fig. IV-24 Iso-Acceleration Map (% of G) (Return Period 100 Years)

The Port of Caldera was opened when the first stage construction work, including three berths, was completed in December 1981. The Port has recently experienced such serious problems as sand sedimentation in the harbour, insufficient berth length and inefficient cargo handling. Furthermore, port cargo demand in Costa Rica is increasing year by year.

The problems affecting the Port of Caldera must be solved so that the port can fulfill its role as the main gateway on the pacific coast of Costa Rica. The study should, of course, seek to minimize costs. The present capacity of the port may basically be able to cope with the future cargo demand if effective measures are taken to solve these problems. The current problems facing the port and possible countermeasures are discussed below.

1. Sand Sedimentation

There is littoral drift along almost the entire east coast of Nicoya Bay. In addition, sand movement always occurs when structures are constructed along natural sand beaches, and the Port of Caldera is no exception. Measures must be taken to protect the Port of Caldera from littoral sand drift. To put it concretely, the average annual sand sediment volume for the last three years is approximately 100,000 m^3 to 110,000 m^3. Since the first half of 1984, the rate of sedimentation at the harbour side of the breakwater has been accelerating.

Particularly, the edge of the sediment at the harbour side of the breakwater has reached the −11 m quaywall. The berth area for the said quaywalll has shoaled along a distance of about 100 m. Thus, large vessels of the design ship size are not able to load or unload cargoes at the wharf at present. Furthermore, the sedimentation has also caused some troubles for the maneuvering of large vessels in the turning basin. One large vessel touched bottom in July, 1985. The vessel stopped calling at the Port of Caldera at that time, and detoured to the Port of Limón because of the accident. Thus, the sand sedimentation has completely disturbed the expected port functions.

The sedimentation is causing a decrease in the number of ship calls and in the cargo volume, and this will significantly affect not only the finances of INCOP, but also the national economy and the people's livelihood in terms of stable commodity supply and low transportation cost. This will be all the more serious considering that international trade between Costa Rica and such Asian countries as Japan, Korea and Taiwan has been increasing. Thus, the sand sedimentation has become a serious and urgent matter to be solved at the Port of Caldera.

Generally speaking, there are two principal methods to protect harbour areas from sand sedimentation : dredging of deposited sand and construction of jetties. Both of these methods involve the investment of a large amount of capital. Therefore, related technical investigations should be carried out fully before making a decision concerning which countermeasures should be implemented at the port. Thus, the mechanism of sand drift and sedimentation should first be analysed based on such natural conditions as waves, water currents and topographical soundings over a wide water area and a long period of time. After the completion of said surveys, appropriate long-term countermeasures should be determined based on the careful analysis of the data collected. In this study, a computer simulation model is adopted to analyse the sand sedimentation mechanism and the proposed countermeasures.

Fortunately, some of the necessary data such as part of the required wave and sounding data have already been recorded by various JICA experts under the full cooperation of MOPT and INCOP in the past. Thus, the present JICA study team conducted only water current observation, sea bottom soundings and a topographic survey along the seashore. The countermeasures against sand sedimentation and the proposed construction works are discussed in CHAPTERS VI, IXand X, respectively.

2. Insufficient Berth Length

The existing quaywall is described in Chapter III. The total berth length is 490 m, but the berth length where large vessels (approximately 15,000 to 20,000 DWT) can berth is only 360 m. Especially, the present berth length of the −10 m quaywall is short. Thus, at present, only one large vessel can berth at the Port of Caldera at one time.

This problem of insufficient berth length will be serious for the port in the future considering the following facts :

(1) Grain cargoes will be handled at the Port of Caldera in the near future because Puntarenas pier has already become superannuated.
(2) Along with the recent advancement of containerization, more container ships will call at the port in the near future.

Thus, the port must have appropriate facilities to accommodate two vessels such as one container ship and one grain cargo carrier simultaneously.

This problem should be resolved as soon as possible because items (1) and (2) noted above are imminent. One possible alternative, of course, is to construct a new wharf to cope with the increased cargo demand. However, the most reasonable countermeasure is the extension of the existing No. 2 quaywall considering the urgency of the problem and the required amount of investment. Thus, this study will examine the best method of extending this quaywall. The sediment which has deposited in front of the wharf will, of course, have to be removed within the project period.

3. Necessity of Improving the Cargo Handling System

The Port of Caldera handles a great variety of commodities and has a relatively large throughput with a small number of berths. This situation will develop further along with the increase of port cargo in the future. Particularly, as mentioned in the previous section, the Port of Caldera will be obliged to handle imported grain which is currently handled at Puntarenas pier.

To cope with this imminent situation, the following two countermeasures can be considered :

(1) To aim at the rationalization of cargo handling through specialization of wharfs by constructing new quaywalls
(2) To create a multipurpose terminal which can handle any type of cargo at the most appropriate berth when necessary by improving existing facilities and increasing cargo handling efficiency without constructing any additional berths.

It is recommendable to construct a specialized container terminal and a grain terminal in the long term. However, it is preferable to establish a multipurpose terminal for the time being considering the ideal use of limited investment capital and the current financial situation of Costa Rica.

The essential aspects of the multipurpose terminal are the rationalization of cargo handling and the minimization of cargo handling costs. Thus, it is necessary to improve the existing cargo handling system at the port. The current cargo handling capacity is not fully utilized due to a shortage of spare parts and a lack of expertise on the part of the operators and workers.

Therefore, the study will seek means of improving the existing cargo handling system establishing a multipurpose use of the terminal to accommodate future port demand. This improvement will covers the entire cargo handling system including equipment, repair facilities, storage facilities and training of personnel. Through this program, it should become possible to efficiently handle the future cargo throughput in the short term without constructing any additional quaywalls.

4. Expected Port Functions and Study Objectives

Costa Rica is an isthmus lying between two oceans : the Atlantic and the Pacific. In the past, Costa Rican trade was conducted mainly through the Atlantic coast because of Costa Rica's strong historical ties with European and Caribbean countries. However, since World War II, Costa Rican trade through the Pacific coast has become prosperous, growing along with the economic development of Japan, Korea and Taiwan and the development of maritime transportation in the Pacific ocean. The Port of Caldera is the only international commercial port on the Pacific coast of Costa Rica. Thus, the port is expected to function as the international gateway on the Pacific coast as the Ports of Limón and Moín serve as Costa Rica's main international ports on the Atlantic coast.

However, the port has experienced such serious problems as (1) sand sedimentation, (2) insufficient berth length and (3) inefficient cargo handling systems as noted above. The countermeasures to solve problem (1) will restore the potential capacity of the port. The countermeasures to solve problems (2) and (3) are means to enhance the existing port capacity by improving existing facilities and equipment. The capacity restored and enhanced by the above countermeasures must, of course, be maintained well even after these countermeasures are implemented.

Therefore, the study seeks to restore the potential port capacity, to enhance the port capacity by improving existing facilities and adding needed equipment, and to maintain the enhanced port capacity by procuring machinery and devising an appropriate maintenance system so that the port can function to the utmost of its potential. Thus, the study covers not only how to execute the primary construction work itself, but also how to execute the regular maintenance work after the primary construction work is completed. The composition of the study is shown in Table V-1.

If proper countermeasures are implemented to solve these problems, the Port of Caldera will be able to properly fulfill its role as the main international gateway on the Pacific coast.

Table V-1 Problems and Countermeasures

Problems	Countermeasures			Related CHAPTER in this report
	Restoration	Improvement	Maintenance	
(1) Sand sedimentation	○		○	VI, IX
(2) Insufficient berth length		○		VII
(3) Inefficient cargo handling		○	○	VIII

1. Sand Drift and Sand Sedimentation

1.1 General

The coast around the Port of Caldera has much littoral drift as revealed by the huge sand spit of Puntarenas. Rivers and sea cliffs supply sand, and swells and tidal currents transport it. The coastline consists of some pocket beaches surrounded by rocky headlands on both ends. One of them is Caldera Bay. The area from Roca Carballo through the Barranca River and Boca de Barranca Beach towards Puntarenas is at the north end of a series of pocket beaches. Caldera Bay is next to the southern part of Roca Carballo. Tivives Beach, which is another pocket beach, is located south of Caldera Bay. The Tivives River flows into Tivives Beach.

These two pocket beaches, Caldera Bay and Tivives Beach, seem to be quite similar from the viewpoint of sand transportation. Northward littoral drift is predominant offshore and southward littoral drift is predominant near the shore. The topographical features of the shoreline of these beaches repeat seasonally. However, over time the northen parts of these beaches are eroding and the southern parts are accreting.

The littoral drift phenomena in Caldera Bay have become more complicated due to the construction of Caldera Port and the existence of Estero Mata de Limón.

The topography around Caldera Bay is shown in Fig.VI-1.

1.2 Results of the Study on Natural Conditions

The following surveys were performed at the site as part of the examination of natural conditions related to sand drift.

(a) Hydrographic Sounding
(b) Topographic Survey along the Shoreline
(c) Water Current Observation
(d) Tide Observation
(e) Measurement of the Riverine Cross-Section Area
(f) Grain Size Distribution Analysis
(g) Sand Drift Survey using Fluorescent Sand

In addition to the above, the wave data observed by the wavemeter offshore the Port of Caldera are analyzed. The location map of these field surveys is shown in Fig.VI-2. The results of these surveys and the wave data analysis are shown in APPENDIX 3. They can be summarized as follows.

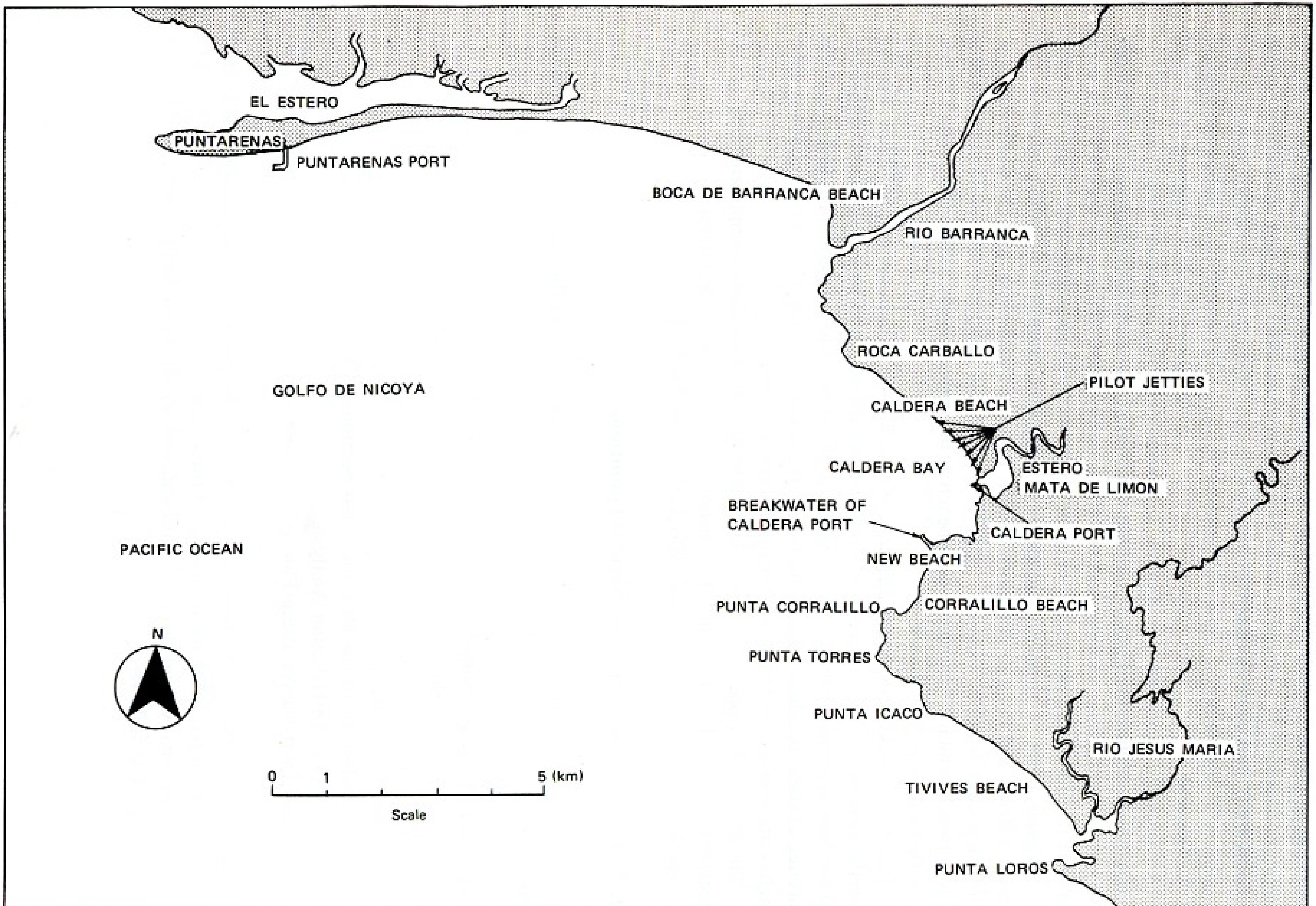


Fig. VI-1 Topography around Caldera Bay

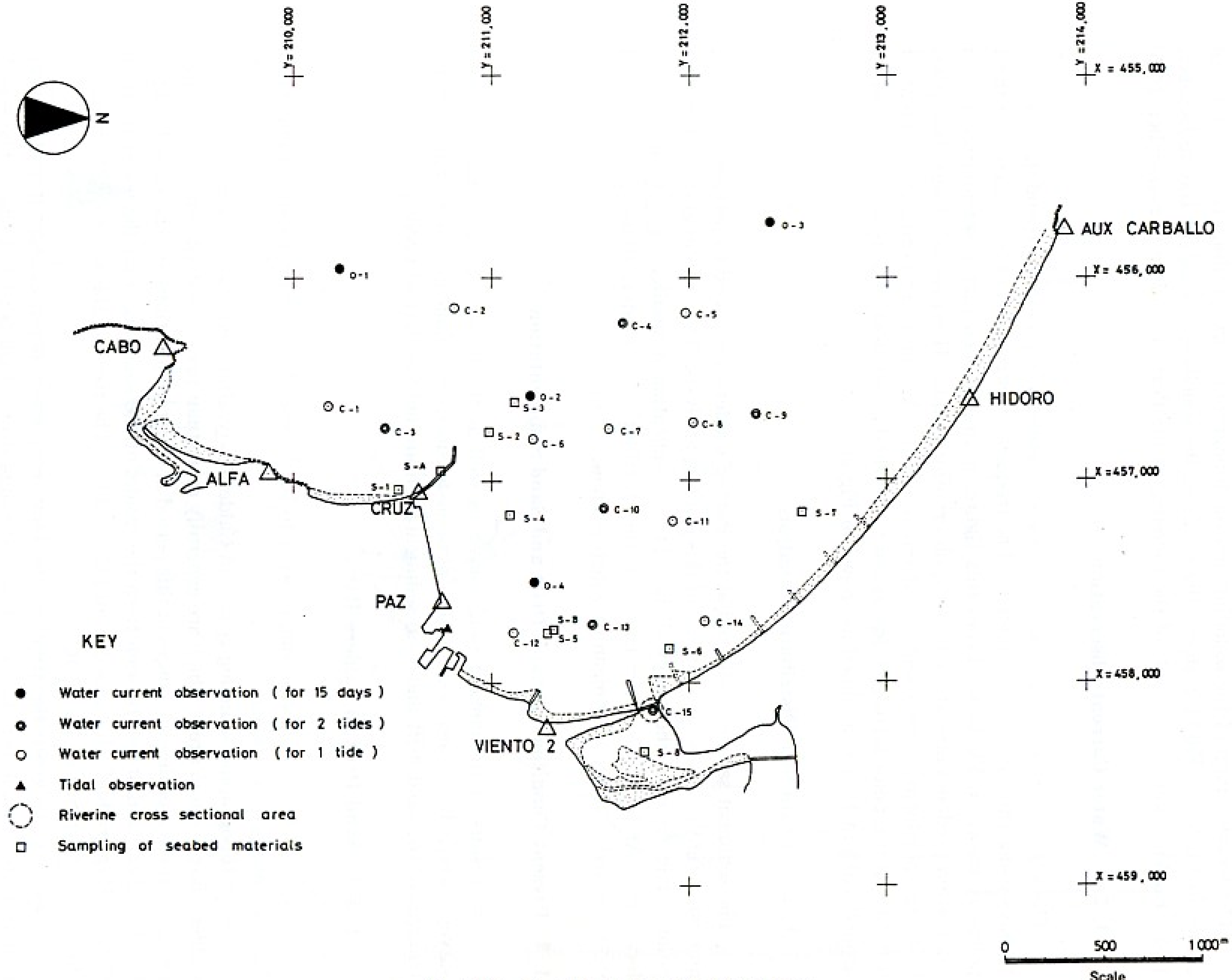


Fig. VI-2 Location Map of Field Surveys

1. 2. 1 Hydrographic Sounding and Topographical Survey

The location map of the sounding and the topographic surveys along the coastline are shown in Fig.VI-3. Fig.VI-4 shows the result of the sounding of Caldera Bay in October, 1985. Fig.VI-5 shows the result of the sounding of the Port of Caldera in September, 1985.

1. 2. 2 Water Current Observation

The water current at four fixed points was continuously observed around the clock for 15 days using Ono-type current meters. The frequency distribution of each current at the 4 points is shown in Fig.VI-6. From this figure, it can be seen that a semidiurnal period fluctuation predominates at each of the observation points. However, at observation point O-4, the northward component is extremely small. A southward permanent current of 0.04 m/s at this point is roughly equivalent to the tidal component. The typical tidal current around Caldera Port is assumed as shown in Fig.VI-7.

1. 2. 3 Grain Size Distribution Analysis

The sediment samples collected at the Port of Caldera were used to perform a grading analysis. Fig.VI-8 shows the results of this grading analysis. The median grain diameter at point S-4 in front of the quaywall is 0.14 mm, indicating a smaller value than at other locations. At locations other than S-4, the distribution of median diameter is between 0.24 mm and 0.34 mm, the mean of which is about 0.3 mm.

1. 3 Present Conditons of Sand Drift and Sand Sedimentation

The results of the current field survey as well as the results of many valuable field surveys which have been executed continuously since 1973 indicate some characteristic features of the sand drift and sand sedimentation around the Port of Caldera.

1. 3. 1 Sand Drift in Caldera Bay

The main sources of sand supply seem to be the sea cliffs of Punta Caldera and Roca Carballo and Tivives Beach.

Some topographic sounding results in Caldera Bay after 1981 show a slight shoaling in Caldera Bay, even in areas which are generally more than 10 m in waterdepth. The average trends of the water depth changes in this period at different locations are shown in Fig.VI-9. On the other hand, it can be seen from the results of the soundings that the water depth in Caldera Bay gradually increased from 1973 to 1981. The trend of the water depth change in this period is shown in Fig.VI-10.

Therefore, to grasp the trend of the long term water depth change, it will be very important to execute periodic soundings extending over a long period of time. The soundings should include some fixed points in Caldera Bay and offshore Puntarenas.

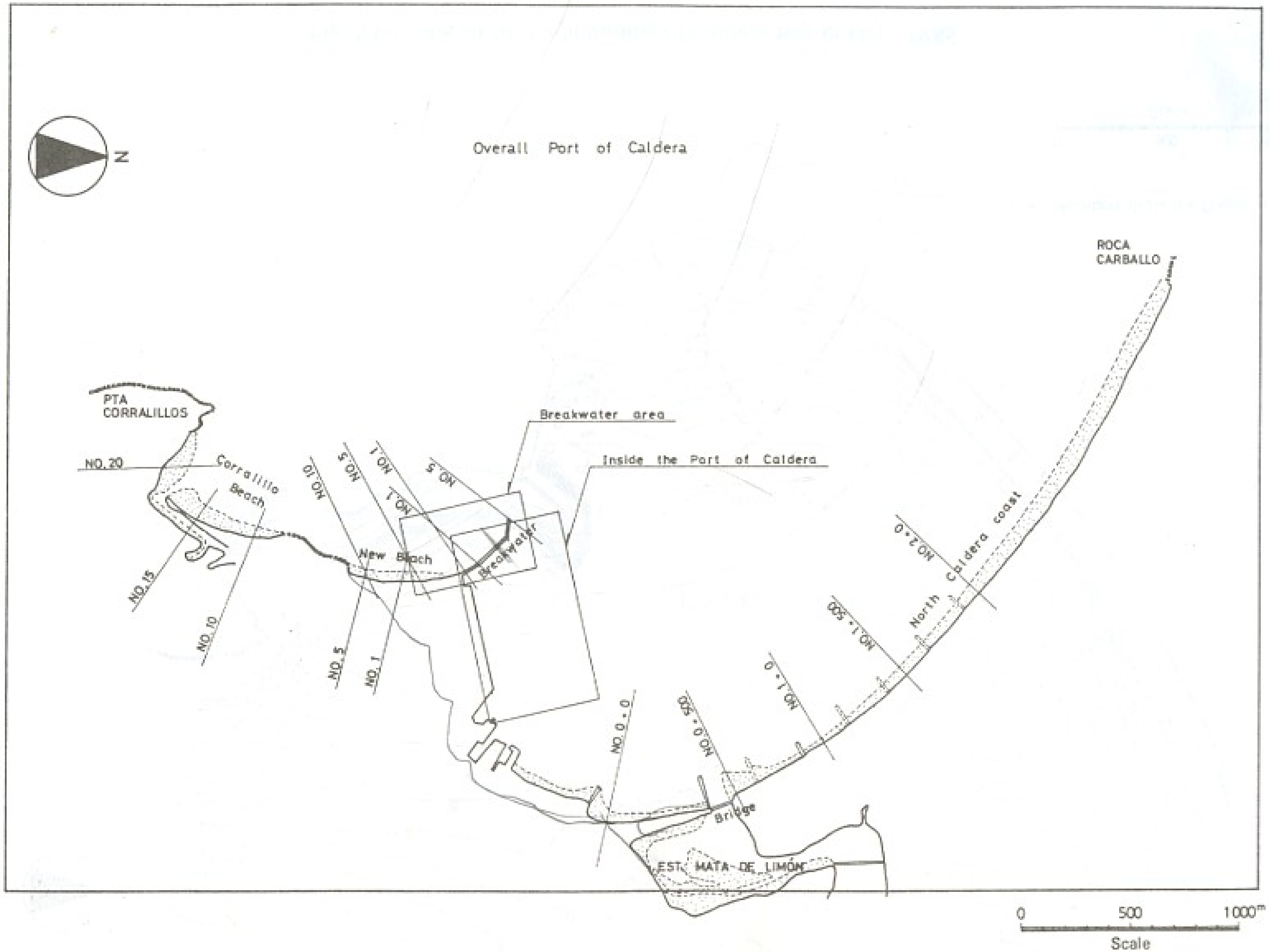


Fig. VI-3 Location Map of the Sounding and the Topographic Surveys

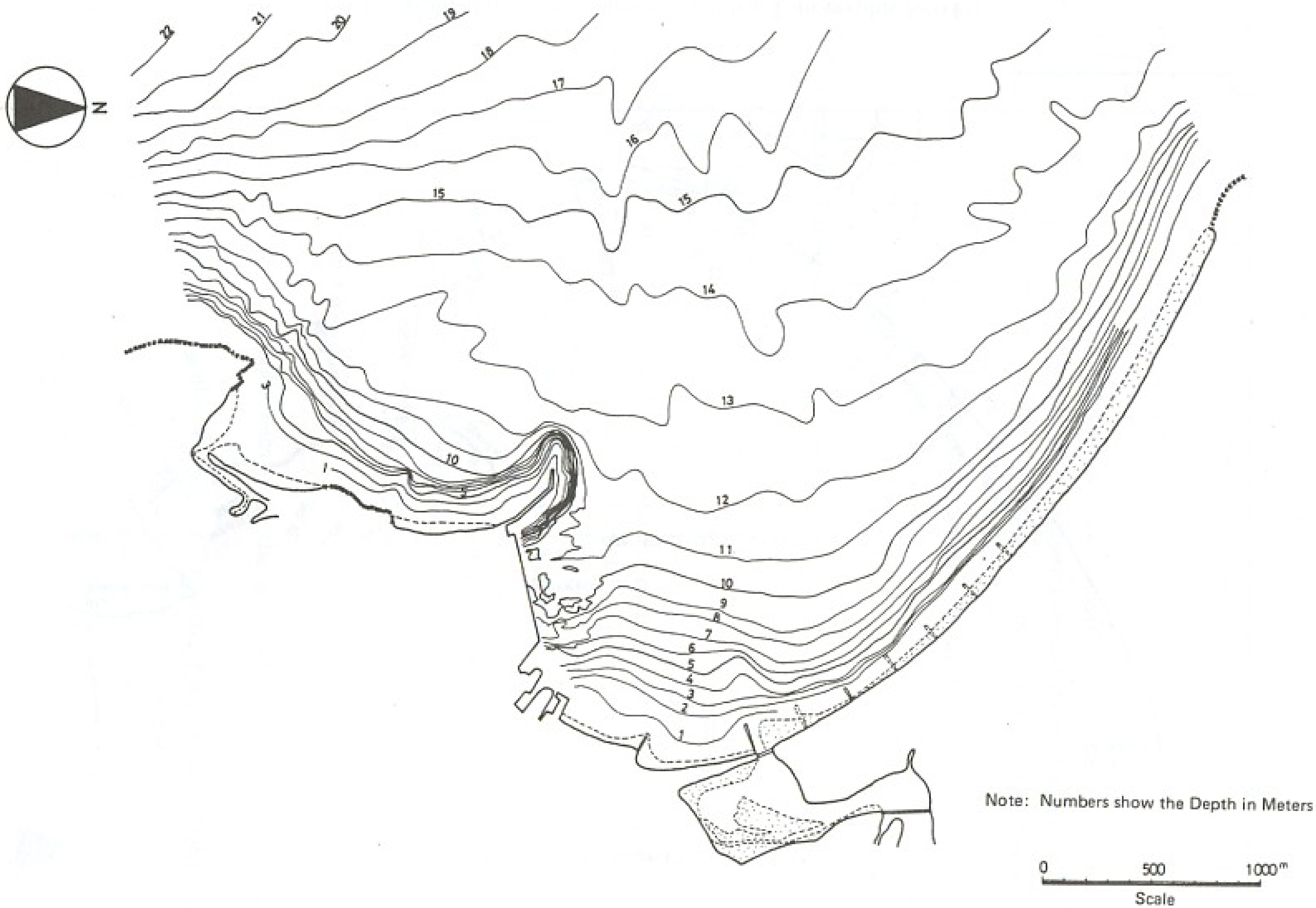


Fig. VI-4 Result of the Sounding of Caldera Bay in Oct. 1985

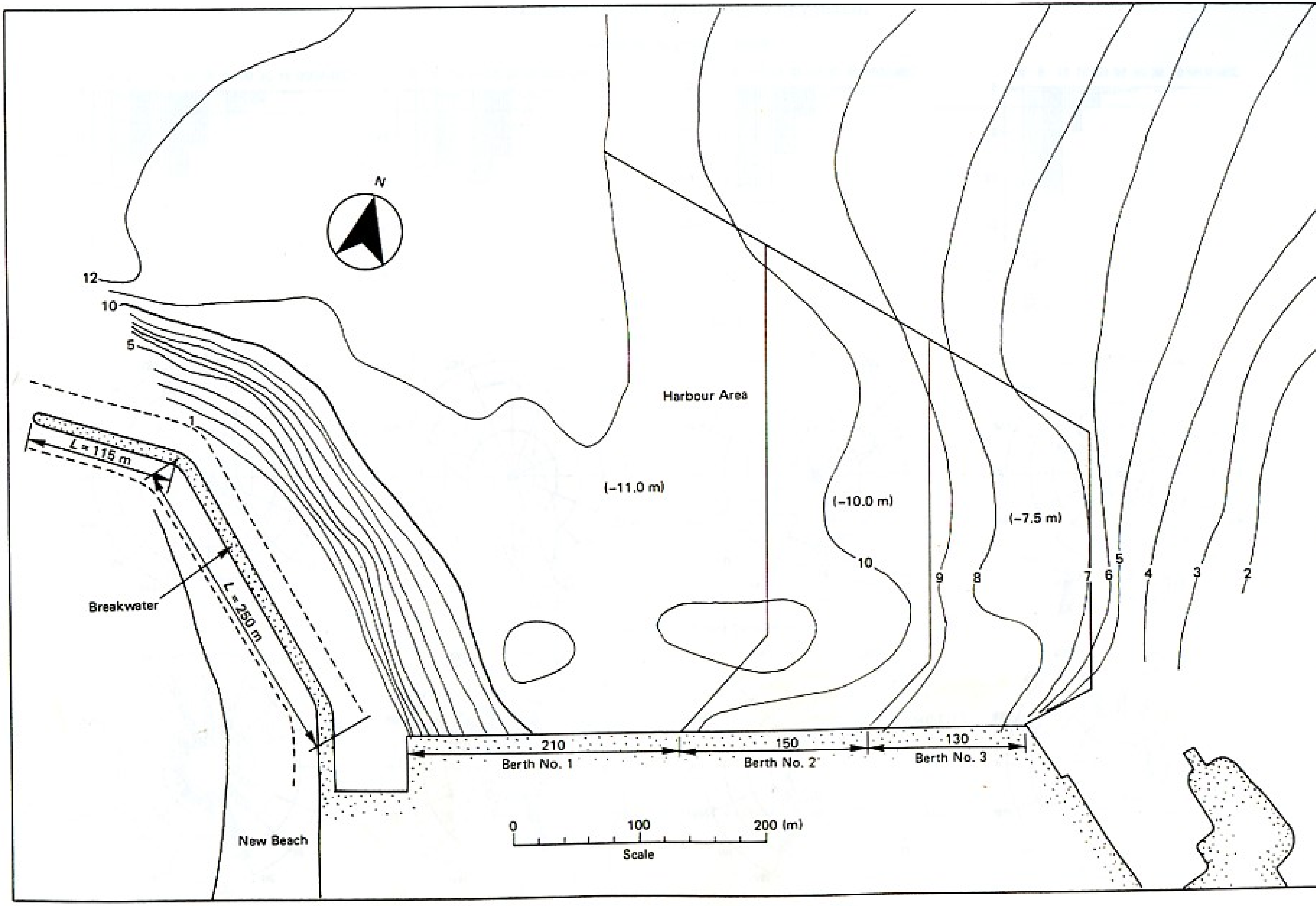


Fig. VI-5 Sounding Result (September 1985)

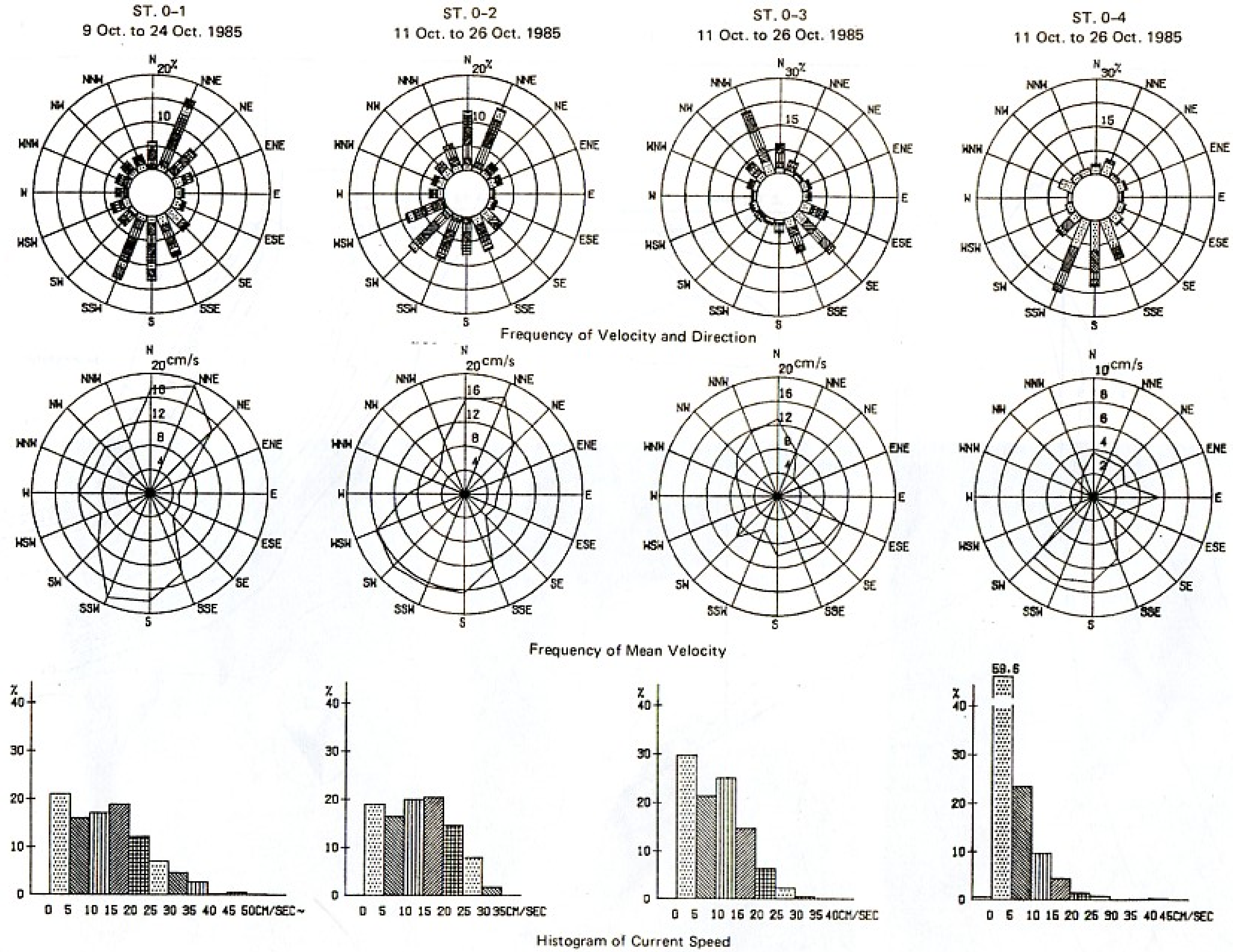
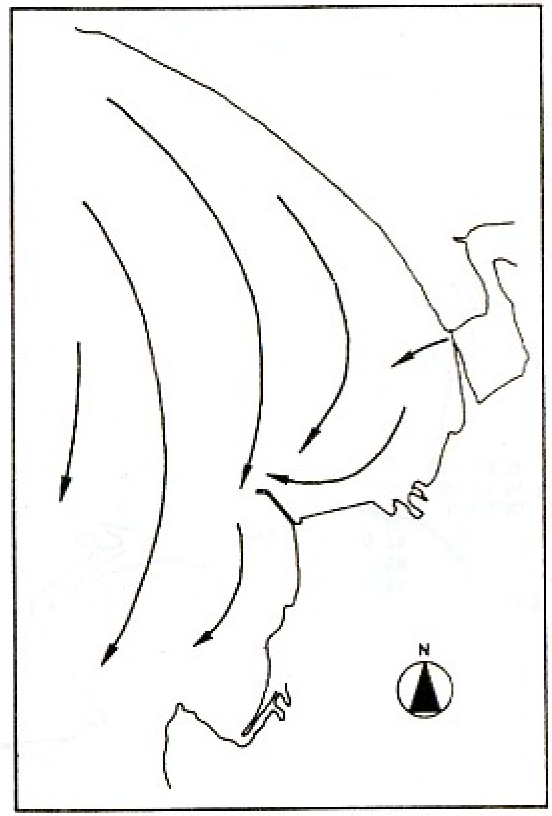
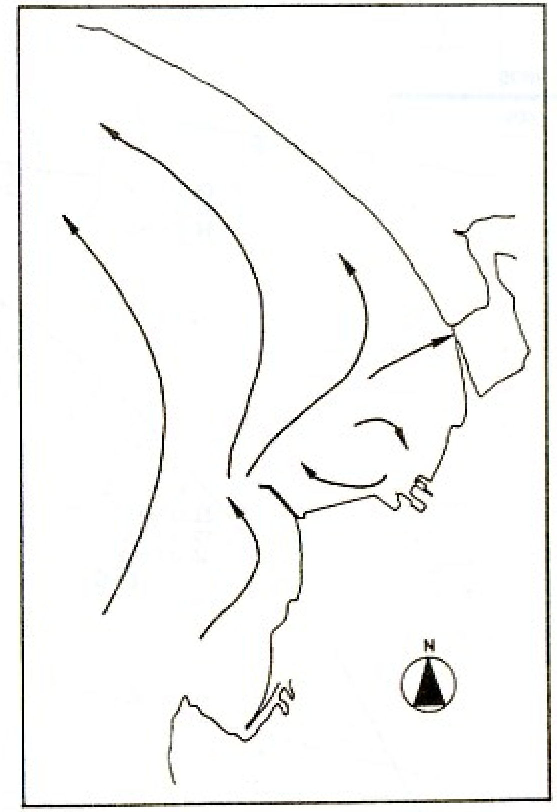


Fig. VI-6 Frequency Distribution of Current



SOUTHWARD CURRENT



NORTHWARD CURRENT

Fig. VI-7 Typical Tidal Current around Caldera Port

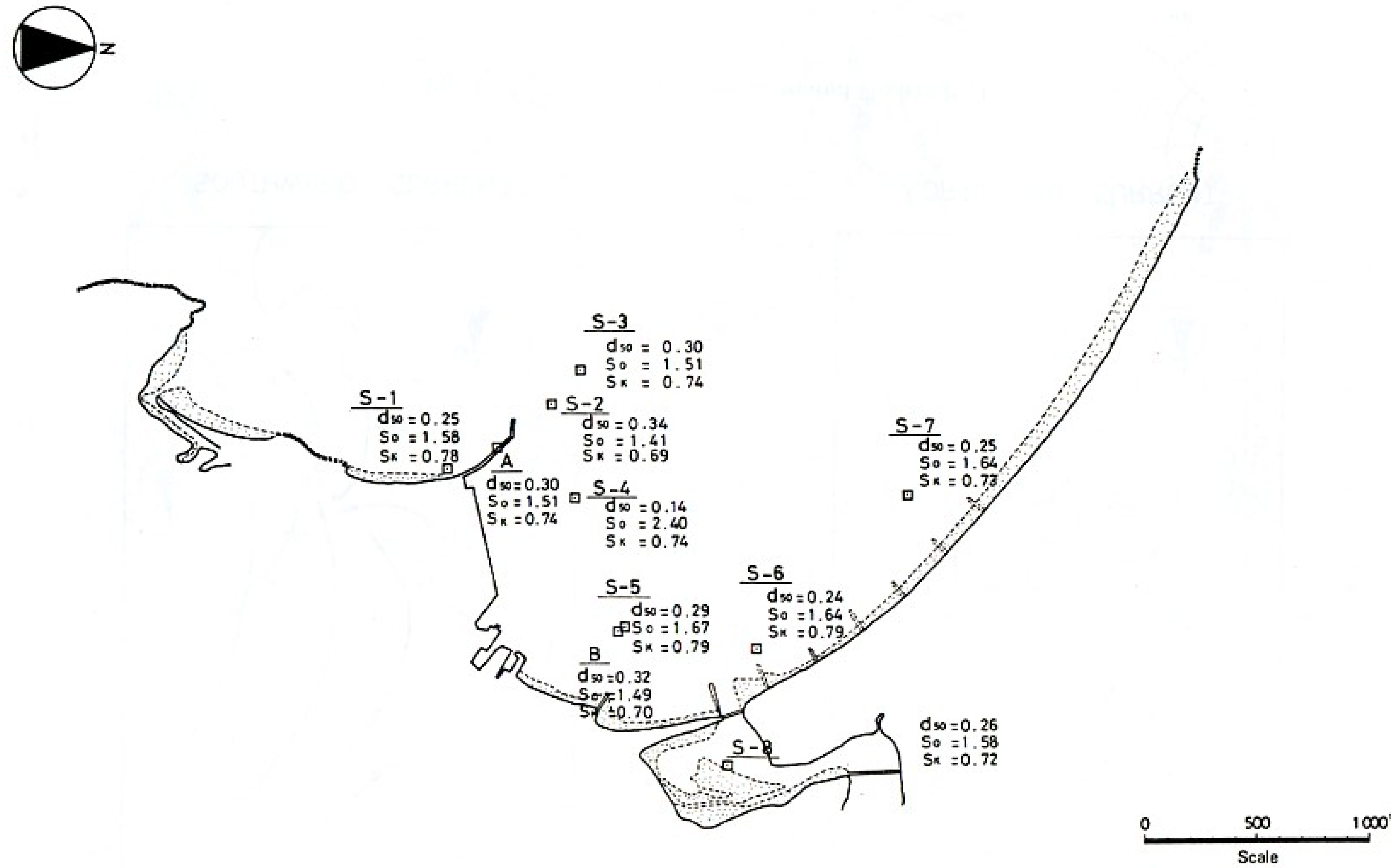
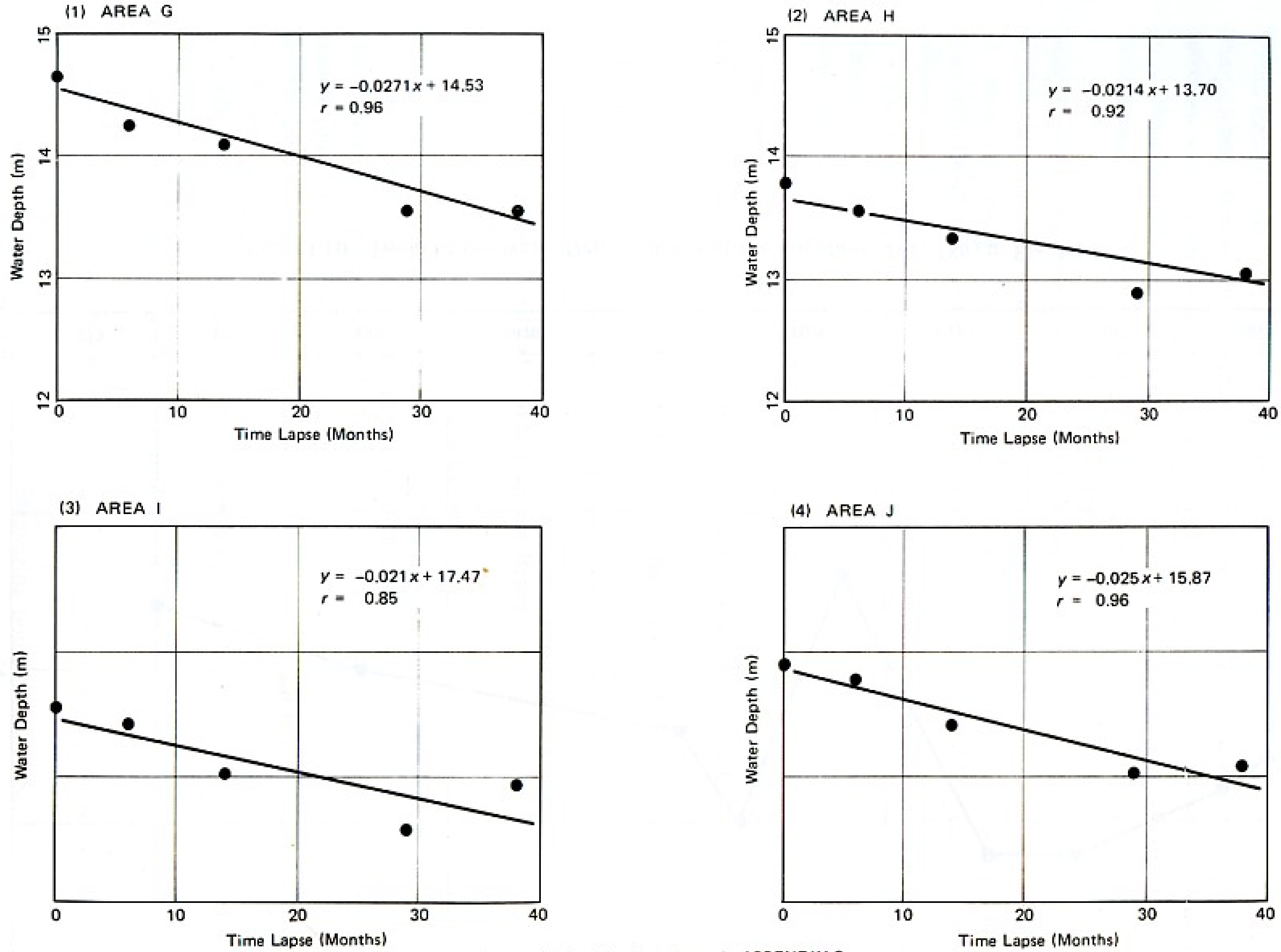


Fig. VI-8 Results of the Grading Analysis



Notes: 1) AREAS G, H, I, J are shown in APPENDIX 6.
2) The observation period is Apr. 1982 ~ Oct. 1985.
3) r means the correlation coefficient.

Fig. VI-9 Average Trend of the Water Depth Change

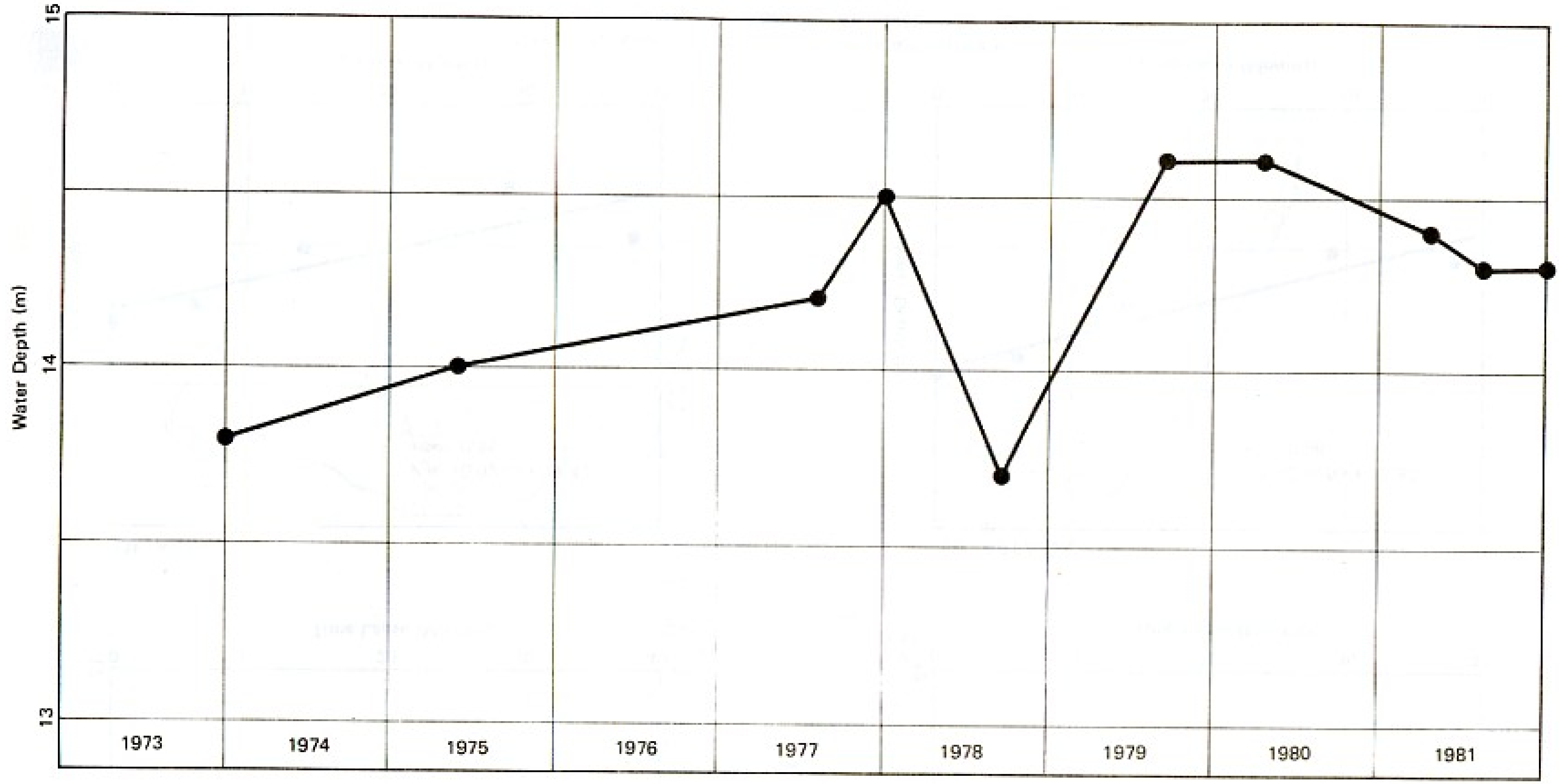


Fig. VI-10 Trend of the Water Depth Change at the Location (211, 456) in Fig. VI-2

1. 3. 2 Littoral Drift towards the Breakwater

The sources of sand supply seem to be the sea cliffs of Punta Caldera and Tivives Beach. Punta Caldera consists of three sea cliffs. They are Punta Corralillo, Punta Torres and Punta Icaco. Before the construction of the Port of Caldera, there was no beach at the northern part of Corralillo Beach. New Beach appeared after the construction of the Port of Caldera started. New Beach is gradually growing along with the extension of the breakwater. The process of the growth of New Beach is shown in Photo.VI-1.

In our site survey, new sand sedimentation between New Beach and Corralillo Beach was observed forming a pocket beach extending from Punta Corralillo to the breakwater. Within this new pocket beach the shoreline of New Beach is presently advancing continuously. However, the breakwater is too short to keep the littoral drift sand at New Beach and Corralillo Beach. The extension of the breakwater, therefore, would be a very effective way to keep sand in this area.

The rough littoral drift pattern in areas less than −10 m deep is shown in Fig.VI-11. This pattern is estimated based on the results of soundings which have been executed several times since 1981.

The annual northward drift sand volume offshore Punta Corralillo is estimated as 200,000 m^3/year. Within this sand volume, the sand sediment volume between the −5 m and −10 m contour line is estimated as 88,000 m^3/year. A sand volume of 14,000 m^3/year accumulates at Corralillo Beach, and 98,000 m^3/year is supplied to New Beach.

Part of the sand supplied to New Beach, which is estimated as about 26,000 m^3/year, accumulates there. The rest passes by the head of the breakwater, goes toward the north side of the foot of the breakwater and accumulates around there.

1. 3. 3. Littoral Drift at North Caldera Beach

The littoral drift pattern at North Caldera Beach is roughly shown in Fig. VI-12, based on the results of soundings which have been executed since October 1981.

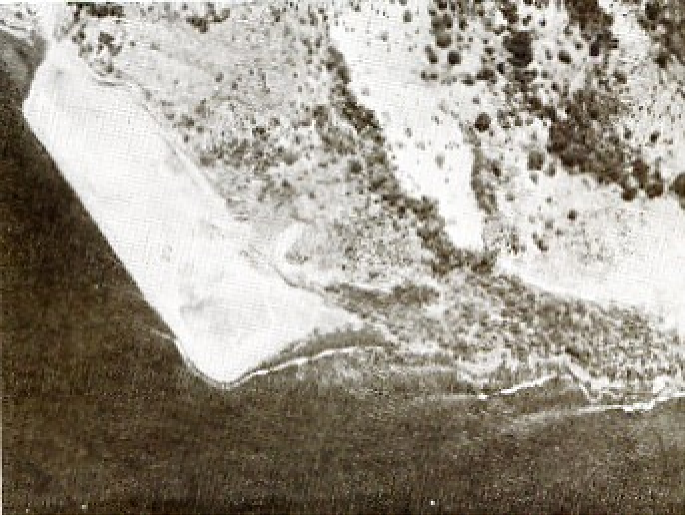
The shoreline at the northern part of North Caldera Beach is receding. On the contrary, the shoreline at the south side of Mata de Limón Inlet is advancing continuously. There are several pilot jetties at the south end of North Caldera Beach. The shoreline change is small in this area. Sand is accumulating on the north side of each jetty. These facts show that southward littoral drift is predominant near the shore at North Caldera Beach.

The sand volume change in the sea areas less than 5 m in water depth is as follows :

(a) North Caldera Beach (Measuring point No.1 to No. 41)
−37,000 m^3/year

(b) North of Mata de Limón Inlet (Measuring point No.42~No.60)
+ 3,000 m^3/year

(c) South of Mata de Limón Inlet (Measuring point No.61 to No.70)
+45,000 m^3/year



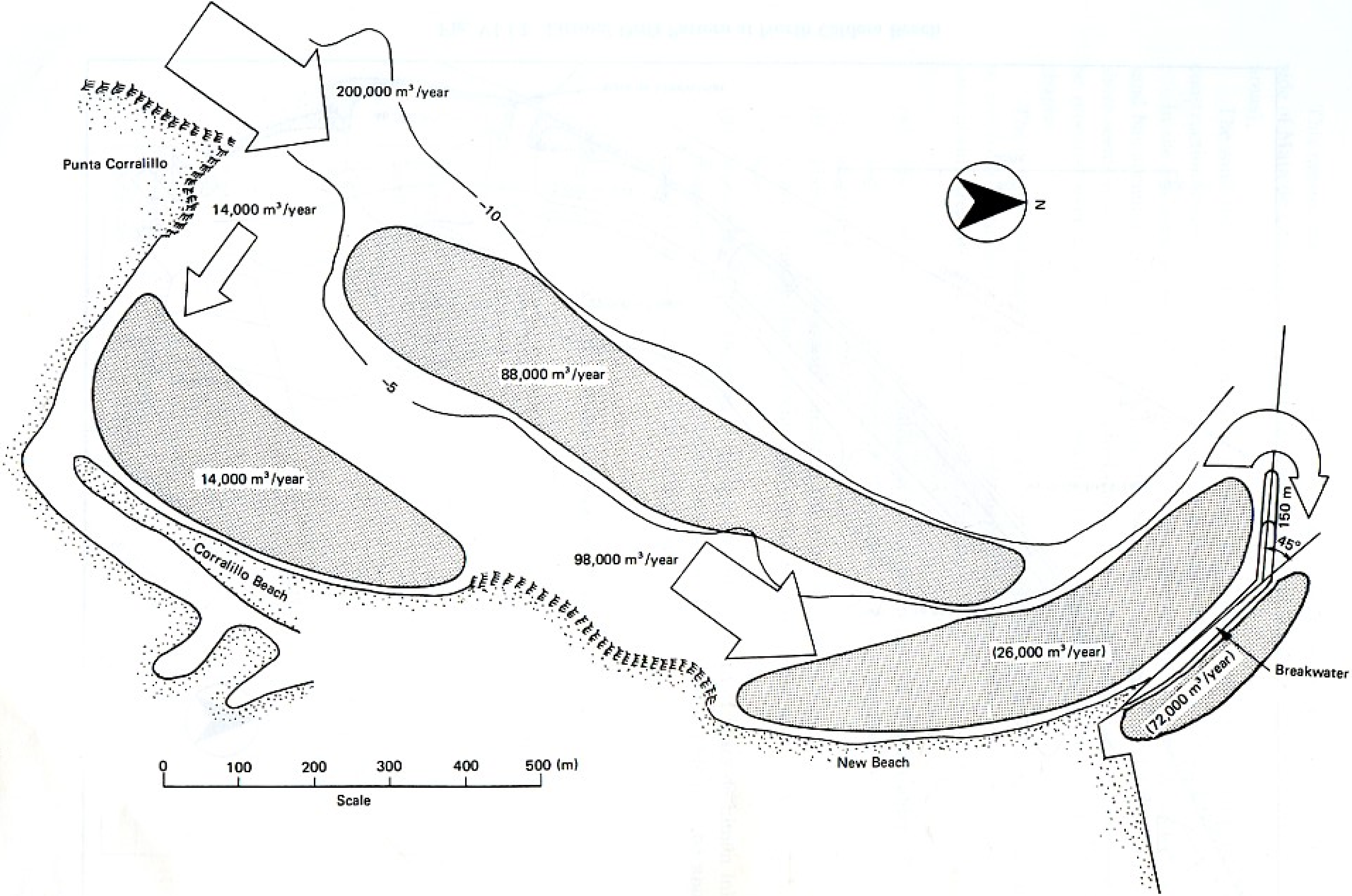


Fig. VI-11 Sand Drift Pattern at the Southern Beach of the Breakwater

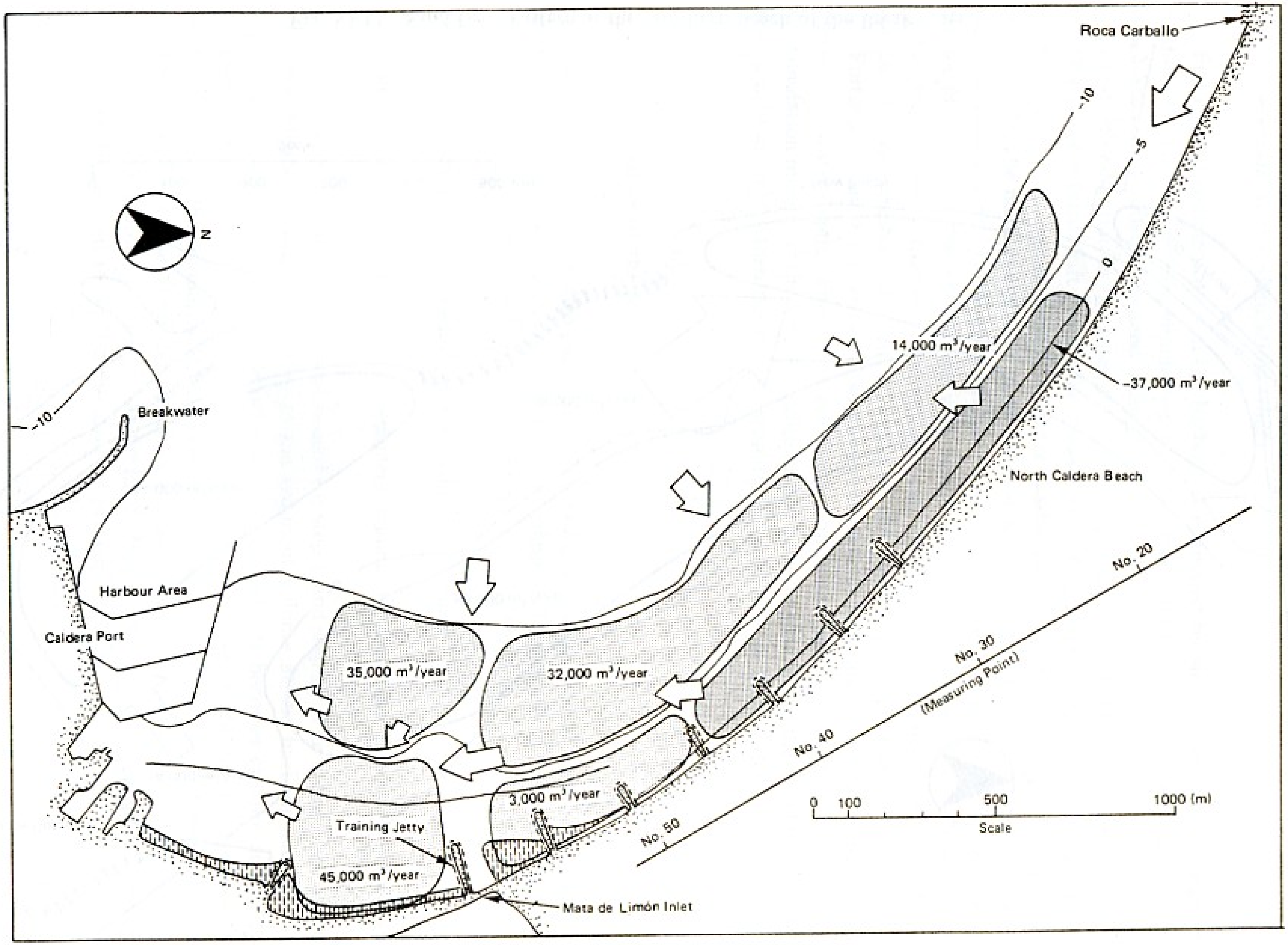


Fig. VI-12 Littoral Drift Pattern at North Caldera Beach

This means that the north side of North Caldera Beach is being eroded, and the south side of Mata de Limón Inlet is accreting (measuring point No.41 is the border between these areas).

The sand volume of 46,000 m^3/year includes the sand removed by INCOFE for use as construction material. The volume of sand removed by INCOFE is shown in Table VI-1.

In the sea area between the −5 m and −10 m contour lines the North Caldera Beach sand has accumulated from October 1981 through September 1985. Sand drift towards the shore seems to be included in this accumulation. The water depth change in this area may be repeated over a period of more than ten years as mentioned in section 1.3.1 of this chapter.

The behavior of sand drift in this area is very complicated because of the strong current to and from Mata de Limón Inlet caused by the tidal current. The characteristics of drift sand in this area are roughly summarized as follows ;

(a) The sand from Roca Carballo and the northern part of North Caldera Beach is transported along the shore to the south, and also southwest away from the shoreline.

(b) There is also some sand supply to the nearshore by the on-off shore sand drift.

(c) A large volume of sand accumulates in the sea area to the south of Mata de Limón Inlet.

(d) Moreover, part of the sand in the sea area at the south of Mata de Limón Inlet is transported to the harbour basin and accumulates there. This may be another cause of the sedimentation of the harbour.

Table VI-1 Volume of Sand Removed by INCOFE

(Unit :m^3)

	1983	1984	1985
January	0	1916	1824
February	0	2532	2064
March	0	2424	1668
April	0	1848	960
May	0	2160	1692
June	0	2844	756
July	0	1812	888
August	0	1416	—
September	0	1968	—
October	0	984	—
November	0	2556	—
December	1500	468	—

Note : Total removed sand volume in this period is 34,100m^3

1. 3. 4 Present Situation of Sand Sedimentation in the Harbour

Sand sedimentation in the basin is caused by the two phenomena. As mentioned above, the drift sand from New Beach passes by the head of the breakwater, goes toward the foot of breakwater, and accumulates around there. This is one cause of the harbour sedimentation. This sediment volume is called 'sediment volume at the harbour side of the breakwater' hereafter. The other phenomenon is the sedimentation of the whole basin with almost a uniform thickness.

These two different sedimentation mechanisms are clearly distinguished in Fig.VI-5 by a thick contour line of −10 m. The breakwater side represents the former, the harbour side the latter. The result of the grain size analysis also reveals the different sedimentation mechanisms. The median grain diameter around the breakwater is around 0.3 mm. On the other hand, that of the whole basin is around 0.1 mm.

Table VI-2 shows the sand sediment volume since April, 1980. This volume is calculated based on the sounding results. About 30,000 m^3 of sand has been dredged by MOPT since MOPT started the dredging on July 10 th, 1985. All of the dredged sand had accumulated at the harbour side of the breakwater. This volume, therefore, is included in the volume in Table VI-2.

Table VI-2 Sand Sediment Volume

Period	Sand Sediment Volume (m_3)		
	Harbour Side of the Breakwater	Turning Basin	Total
1980' 4 ~1981'10	12,000	—	—
1981'10~1982' 7	21,000	−26,000	−5,000
1982' 7 ~1983' 8	40,250	70,813	111,063
1983' 8 ~1984' 8	24,125	77,938	102,063
1984' 8 ~1985' 9	94,500*)	18,250	112,750

Note : ※) This volume includes the dredged sand volume

(1) Sand sediment at the harbour side of the breakwater

Littoral drift around the breakwater is considered to be mainly composed of sand drift in bed load. Therefore, as the seaside water depth of the breakwater becomes shallower, the littoral drift volume and also the sediment volume at the harbour side of the breakwater becomes greater. The New Beach shoreline advances year by year, and therefore, the sediment volume at the harbour side of the breakwater changes year by year. Shoreline changes and the length of the wing jetty in each year are shown in Fig.VI-13. In this figure, the −2 m contour line is shown instead of the shoreline. The wing jetty is generally referred to as the breakwater in this report.

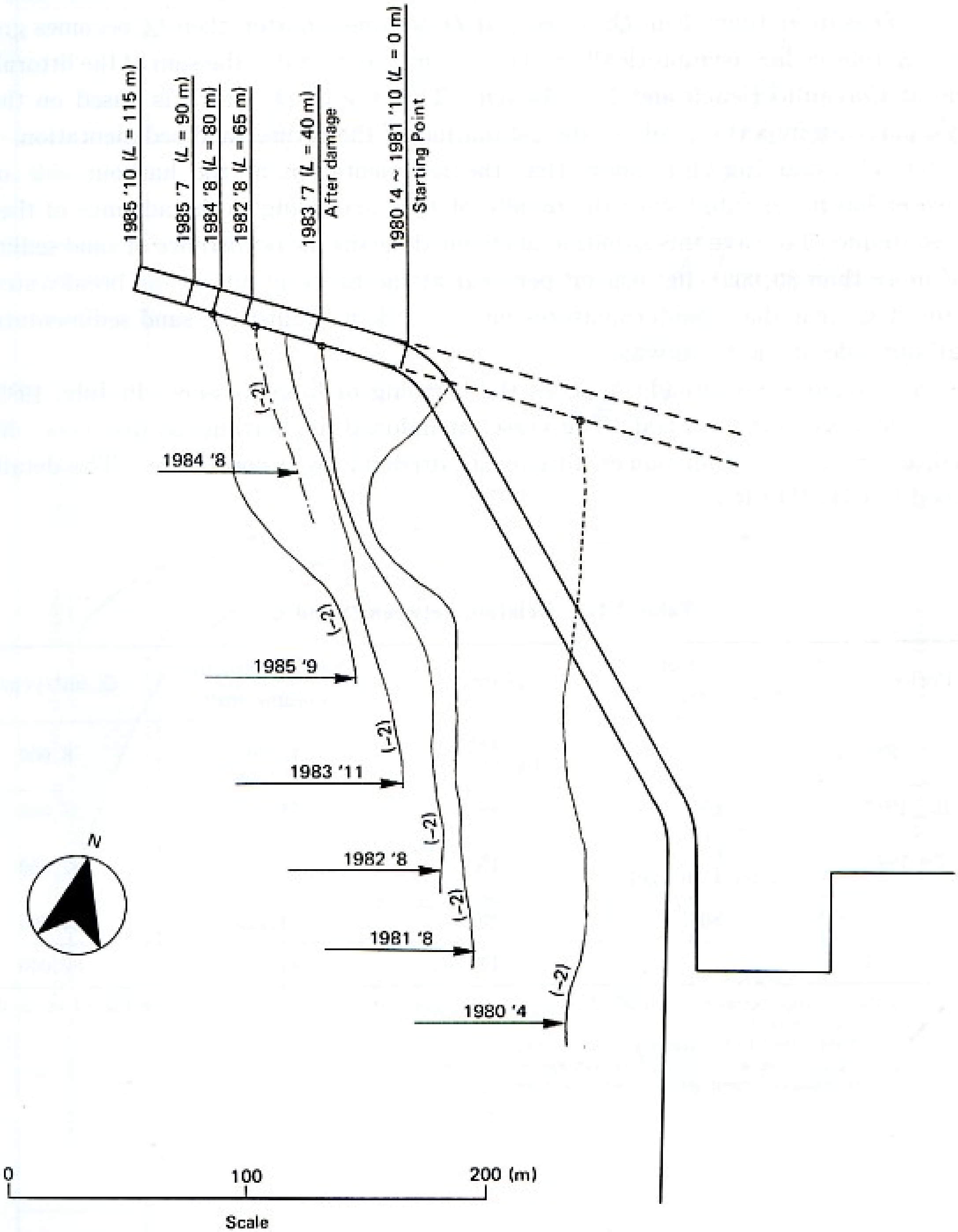


Fig. VI-13 Shoreline Changes and the Breakwater Length

The distance between the head of the breakwater and the −2 m contour line (D), and the sediment volume at the harbour side of the breakwater of each period since April 1984 are shown in Table VI-3. In this table, Q_s is the sand sediment volume per year. Fig.VI-14 shows the relation between D and Q_s. This figure shows that the Q_s is determined only from D. When D is more than 60 m, Q_s is zero. If D becomes shorter, then Q_s becomes greater. Finally, Q_s approaches asymptotically to 112,000 m^3/year, that is the sum of the littoral drift volume at Corralillo Beach and New Beach. This Fig.VI-14, which is based on the site surveys, plays an important role in the estimation of the future sand sedimentation.

Table VI-3 and Fig.VI-14 show that the sedimentation at the harbour side of the breakwater has accelerated since the middle of 1984 according to the advance of the New Beach shoreline. To leave this situation unchanged means the occurrence of sand sedimentation of more than 80,000~100,000 m^3 per year at the harbour side of the breakwater. At any rate, it is clear that countermeasures must be taken against the sand sedimentation at the harbour side of the breakwater.

Such sedimentation already impedes the berthing of large vessels. In July, 1985, one large vessel touched the sea bed. The vessel abandoned the berthing at that time. MOPT decided, under these circumstances, to execute dredging by a contractor. The details are described in CHAPTER IX.

Table VI-3 Relation between D and Q_s

Period	Length of Wing Jetty (m)	D (m)[1]	Sand Sediment Volume (m^3)	Q_s (m^3/year)[4]
1980. 4 ~1981.10	0	45[2] (Average)	12,000	8,000
1981.10~1982. 7	65	25	21,000	28,000
1982. 7 ~1983. 8	65[3] (After Damage)	15	40,250	37,000
1983. 8 ~1984. 8	80	20	24,125	24,000
1984. 8 ~1985. 9	90	10	94,500	87,000

Notes: 1) D is the distance between the head of the breakwater and the −2.0 m contour line (See Fig. VI-13) at the start of each period.
2) D in 1980'4~1981'10 is assumed as an average value.
3) The length of the wing jetty after damage in july 1983 is assumed as 65 m.
4) Q_s is the sand sediment volume per year (See Fig. VI-14).

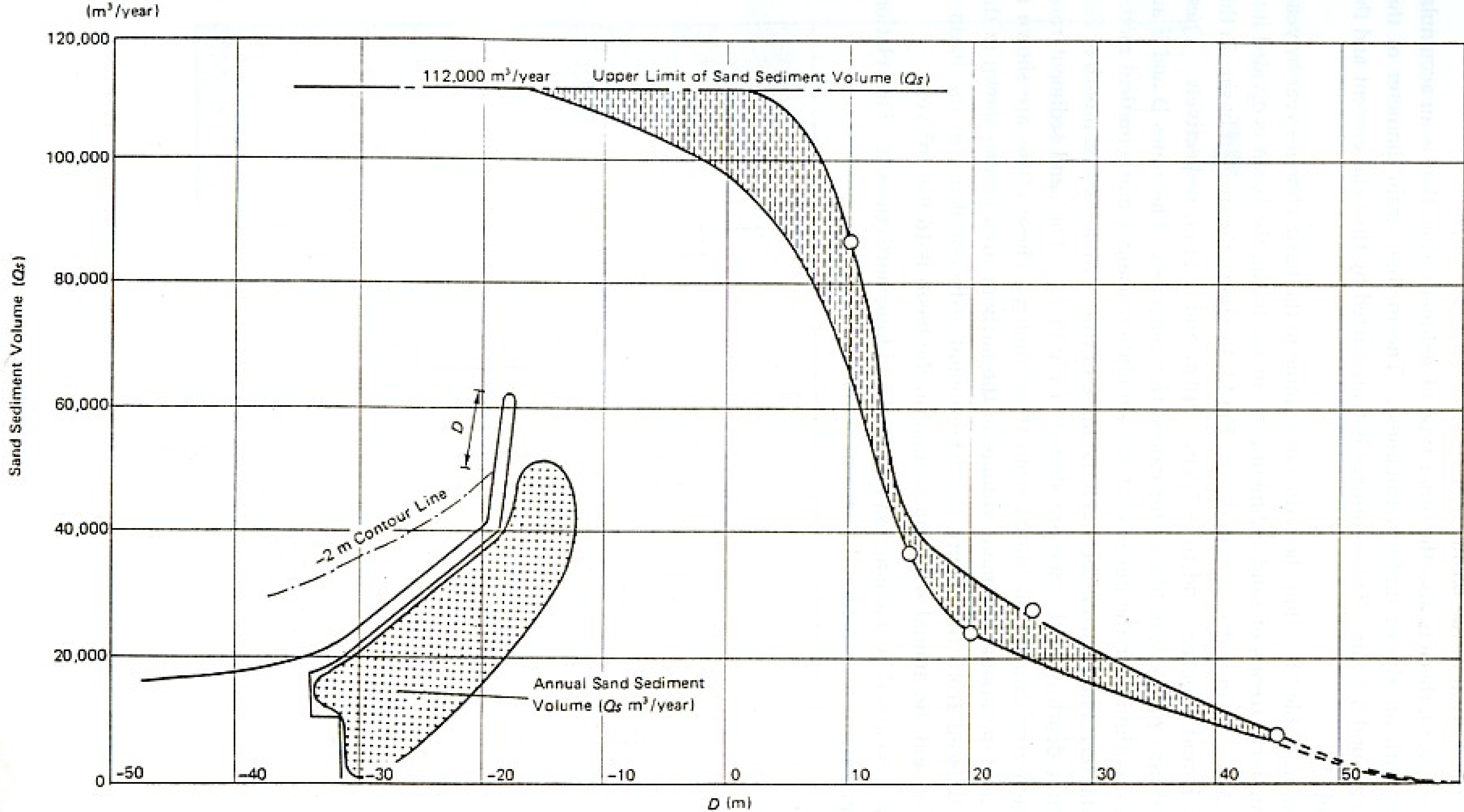


Fig. VI-14 Relation between D and Q_s

(2) Sand sedimentation in the basin

In the harbour basin, there is also the other type of sedimentation, that is an accumulation of fine sand with an almost uniform thickness. The median grain diameter of this sediment sand is around 0.1 mm. This sediment is transported by the tidal current and the longshore current.

It can be seen in Table VI-2 that the sediment volume in the basin changes year by year. To grasp the long-term trends of sand sedimentation in the basin, the basin is divided into three zones, −7.5 m, −10 m and −11 m in depth. Fig.VI-15 shows the divided basin. In this figure, zones A, B and C correspond to −7.5 m, −10 m and −11 m, respectively. These zones are divided into 20 m×20 m blocks for calculation purposes. The zones D and E are also included in this figure for the purpose of the simulation using a mathematical model. This is described later. The relations between the lapse of time with a starting month of Feb. 1982 and the water depth of each zone are shown in Fig.VI-16. The sand sediment rates (cm/year) of each zone can be calculated from these figures. These ratios are shown in Fig.VI-17. The average annual sediment volume in the harbour area is also shown in this figure. It can be seen from this figure that the annual sediment depth in the basin is 12.5~16 cm/year, and the annual sediment volume in the basin is 16,900 m^3/year.

This sediment is caused by wave action and tidal and longshore currents. The relations among these factors will be considered later on.

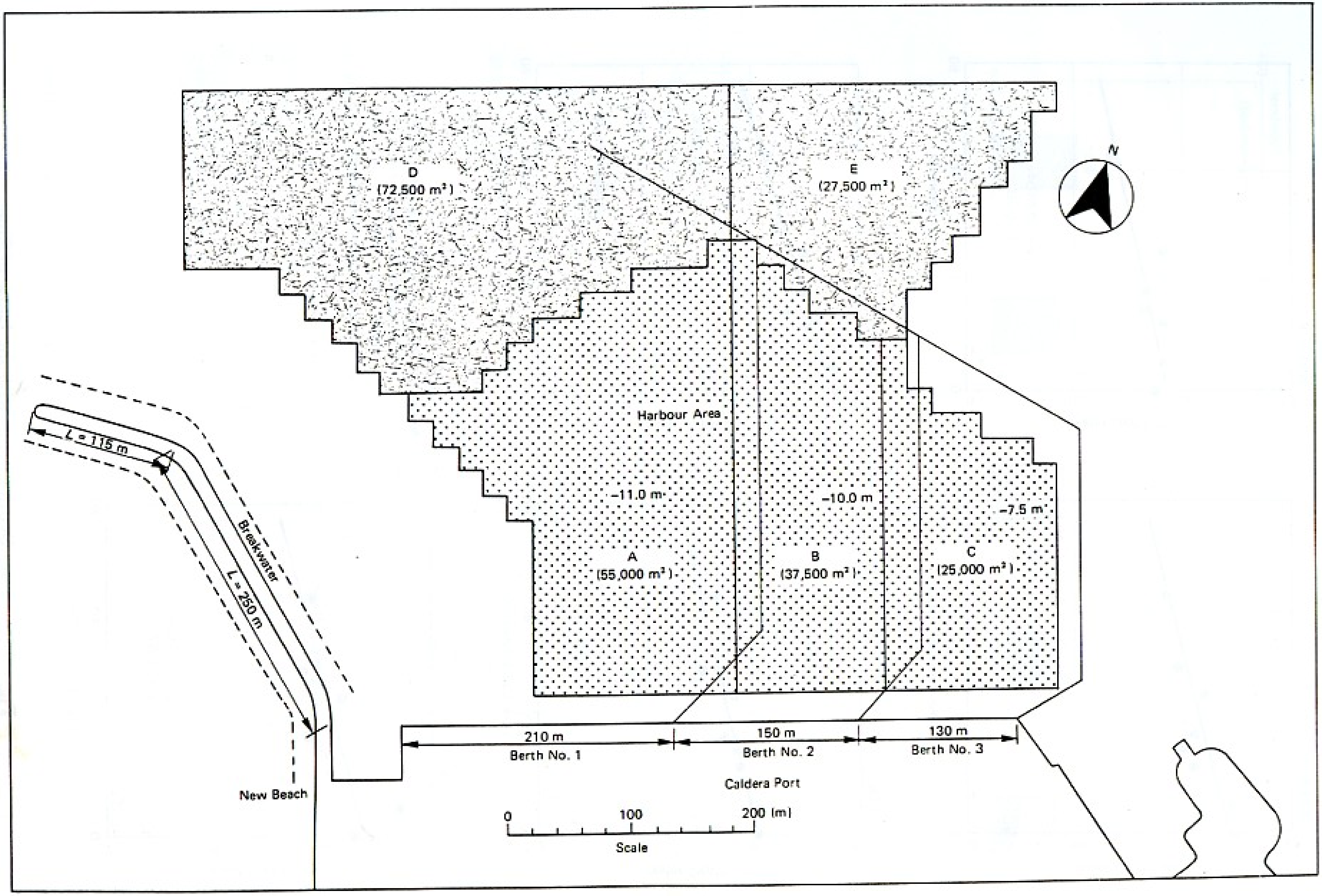
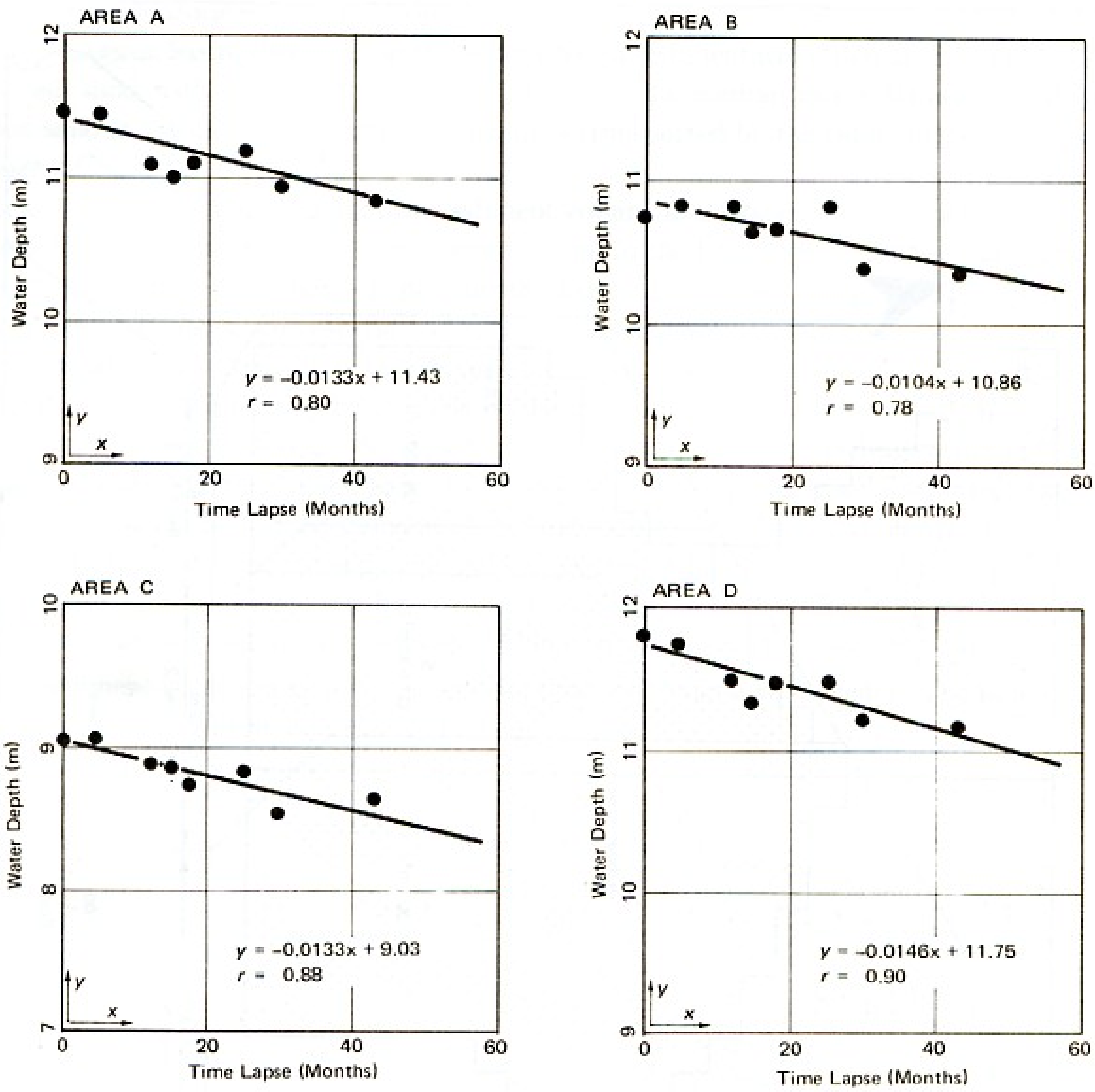
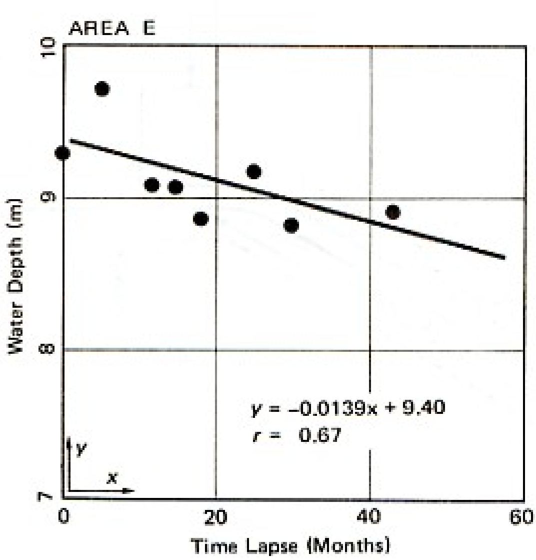


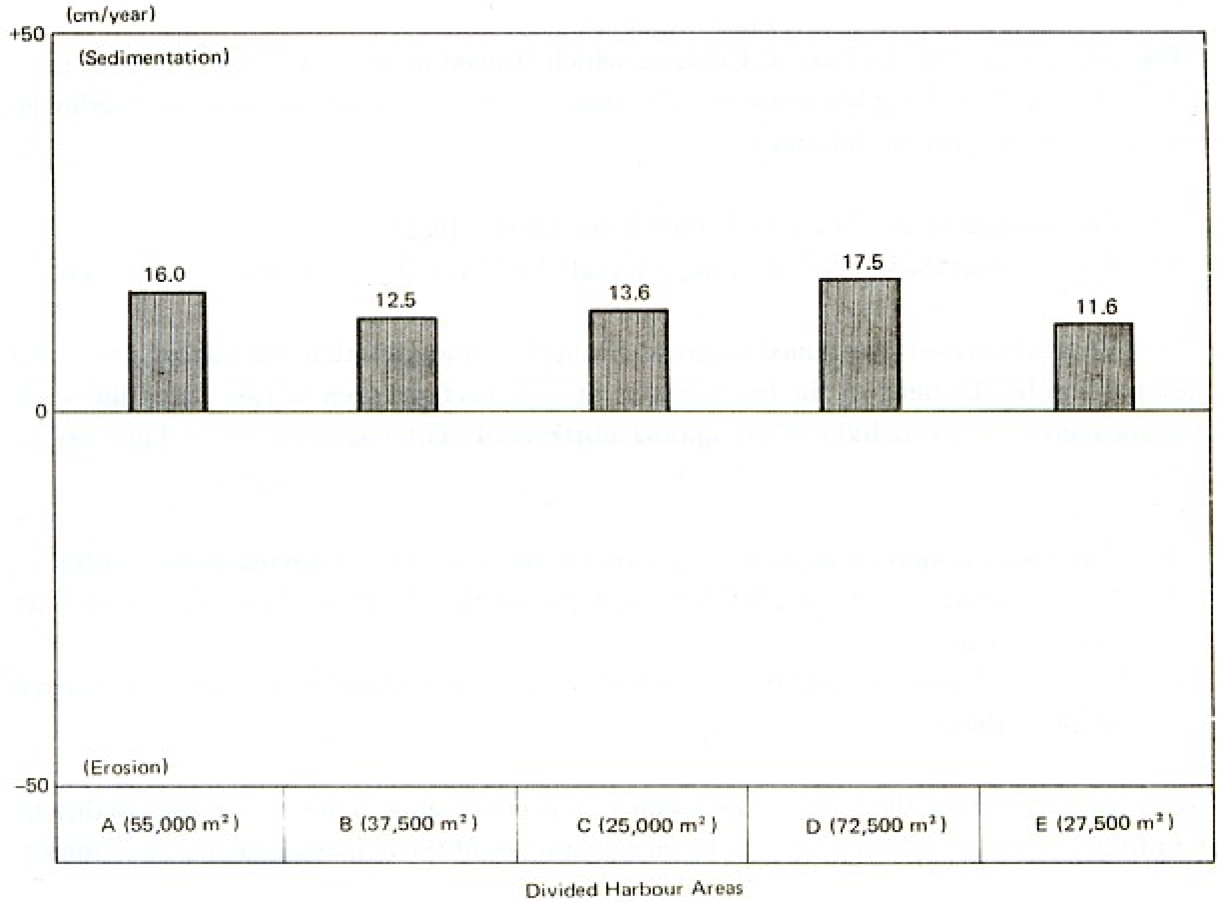
Fig. VI-15 Divided Harbour Area





Notes: 1) Areas A ~ E are shown in Fig. VI-15.
2) The observation period is Feb., 1982 ~ Sept., 1985
3) r is the correlation coefficient

Fig. VI-16 Water Depth Change with the Lapse of Time



Zone	Area (m²)	Annual Sediment Rate (m/year)	Annual Sediment Volume (m³/year)
A	55,000	0.160	8,800
B	37,500	0.125	4,700
C	25,000	0.136	3,400
Total	117,500	–	16,900

Fig. VI-17 Annual Sediment Rate and Sediment Volume

2. Review of Past Countermeasures against Sand Sedimentation

The construction of the Port of Caldera, which started in 1974, was completed in Dec., 1981 including a 250 m long breakwater. The major countermeasures against sand sedimentation of this period are as follows :

(a) The change of the Mata de Limón Inlet (1981~1982)
(b) The construction of the training jetty at the Mata de Limón Inlet (1981~1982)

New Beach, however, continued to grow. It can be estimated that the littoral drift sand started passing by the head of the breakwater into the harbour area in 1981. The full-scale countermeasures which include those against northward drift began in 1982. They are as follows :

(a) The construction of an 80 m long breakwater extension (started in Feb., 1982)
(b) The construction of the pilot jetties at the north side of the Mata de Limón Inlet (1982~1983)
(c) Removal of sand by INCOFE at the south beach of the Mata de Limón Inlet (Started in Dec., 1983)

The construction of the breakwater extension is continuing under severe sea conditions with limited construction machinery. The circumstances of the construction are as follows :

(a)	Feb. 1982	: The construction of the breakwater extension started.
(b)	Aug. 1982	: 65 m long breakwater extension was completed.
(c)	The end of 1982	: 80 m long breakwater extension was completed.
(d)	July 17 and 18, 1983	: The head of the breakwater extension was damaged, reducing the breakwater extension to 40 m.
(e)	From 1983 to 1984	: The breakwater was extended after the repair of its head.
(f)	Apr. 8, 1985	: The length of the breakwater extension reached 90 m.
(g)	Apr. 1985~	: The breakwater is being extended despite severe damage. The length of the breakwater extension was 115 m in Oct. 1985.
(h)	From July 10, to Sept.,1985	: MOPT dredged 30,000 m^3 of sediment sand at the harbour side of the breakwater.
(i)	January, 1986~	: MOPT started to construct an additional breakwater extension. The breakwater extension will be completed at a length of 150 m (a part of the wing jetty) in May 1986. In this study, this imme-

diate breakwater extension work is regarded completed. Concerning this work, the Japane Study Team has given some information to MO ; the details are shown in APPENDIX 4.

(j) In 1986 : According to the information from MOI $300,000\ m^3$ of sediment sand in the basin will dredged by a contractor. In this study, this dre ing is regarded as completed by May, 1986.

The circumstances show that the construction of the breakwater extension has met w serious difficulties since July, 1983.

Meanwhile, the sand sediment at the harbour side of the breakwater continues to gr After the storm in July, 1983, the crown of the sand sediment, which was formerly under sea, appeared at last above the sea surface. This new beach, which is located just behind breakwater, is called 'New Beach Junior'. New Beach Junior has continued to grow.

3. Alternative Countermeasures against Sand Sedimentation

3. 1 Basic Alternative Countermeasures

The countermeasures against sand sedimentation can be roughly divided into two methods : to reduce the sand sediment in the harbour as much as possible, and to dredge the sediment in the harbour immediately. Specifically, alternative options to reduce sand sedimentation in the harbour include :

(a) Extension of the existing breakwater
(b) Construction of a new jetty at the upper side of the littoral drift
(c) Extension of the existing training jetty at Mata de Limón Inlet
(d) Removal of the sand at the southern beach of Mata de Limón Inlet
(e) Removal of the deposited sand at the seashore of New Beach

3. 2 Selection of the Countermeasures

3. 2. 1 Evaluation of each Countermeasure

The length of the existing breakwater is not sufficient to keep the northward drift sand in the pocket beach consisting of New Beach and Corralillo Beach as described above. A small extension of the breakwater would be greatly effective in keeping the drift sand within the pocket beach. Taking this fact into consideration it is clear from the observation data analysis that the extension of the existing breakwater is the most urgent and the most important countermeasure against sand sedimentation.

It would also be effective to construct a new jetty at the upper side of the littoral drift. The location of the new jetty would be between Tivives Beach and New Beach. It would not be effective to construct a new jetty at the rocky shore between New Beach and Corralillo Beach, because some of the drift sand is supplied from the offshore of Punta Corralillo to New Beach directly. Therefore, if it is necessary to construct the new jetty, the location should be at Punta Caldera. There is no approach road for the new jetty construction there at present. Temporary works such as the construction of an approach road would be very expensive. Construction of the new jetty from the sea using a construction ship would also be very expensive. Thus, the construction of a new jetty is uneconomical compared with the extension of the breakwater. Moreover, even if a new jetty were constructed, the drift sand at New Beach would continue to settle at the harbour side of the breakwater for a while after the new jetty was completed. This alternative is, therefore, not selected at present. However, it should be studied further if the New Beach shoreline advances and the sedimentation at the harbour side of the breakwater begins again in the future.

One possible countermeasure against the accumulation of fine sand with almost a uniform thickness in the harbour basin is to extend the training jetty at Mata de Limón Inlet. However, this should not be given top priority because of following reasons :

(a) The annual sediment is currently 12.5~16 cm. As discussed later on, this sediment rate will not increase so much even if the breakwater is extended. Therefore, countermeasures against this sedimentation are not so urgent. Dredging once in five years may be a reasonable countermeasure against this sedimentation.

(b) There is an accumulation of sediment at the north side of the basin. The annual sediment depth of this area is around 30 cm. Some of this sediment sand may be come into the north part of the harbour basin in the future. However, it is very difficult to estimate the future trends of this accumulation over a long period of time. The effectiveness of the training jetty extension is also difficult to estimate from the results of the observation data analysis because the tidal and the longshore currents around Mata de Limón Inlet are very complex. Therefore, long term observation of the water depth change is necessary. The extension of the training jetty should be studied after observation data are collected.

Removing the sand at the south of Mata de Limón Inlet is currently undertaken by INCOFE for the purpose of utilizing the sand as a material for civil works. This is an effective way to prevent the sand sedimentation of the harbour basin. It is preferable to remove the sand as frequently as possible.

Removing the sand at the seashore of New Beach is also an effective way to prevent sedimentation in the harbour if the sand can be utilized for other purposes. However, there seems to be no demand to use this sand at present. Therefore, this is not adopted as one of the countermeasures against sand sedimentation.

3. 2. 2 Urgent Countermeasures

As a result of the evaluation of the various alternative countermeasures against sand sedimentation, the extension of the breakwater and the dredging of unavoidable sediment in the harbour are recommended as urgent countermeasures. Of course, the removal of the sand by INCOFE shoud be continued.

(1) Extension of the existing breakwater

The extension of the breakwater is the main countermeasure against the sand sedimentation at the harbour side of the breakwater. Six alternative plans for the breakwater extension are studied. As shown in Fig.VI-18, and Table VI-4, two alternative centerlines for the extension of the breakwater are considered. One is in the same direction as the existing breakwater, and the other is 45° away from the existing breakwater. These alternatives are evaluated later on using the simulation method 'One-Line Theory'.

(2) Primary dredging and maintenance dredging

As mentioned above, the sand sedimentation at the harbour side of the breakwater has already caused some difficulties for berthing and other ship operations in the harbour. The immediate dredging will be completed by a foreign contractor by May 1986 as planned by MOPT. The rest of the sand sediment and additional sediment should be dredged as soon possible after the breakwater construction is completed. This dredging is called the mary dredging. Further periodic maintenance dredging will be necessary even if the eakwater is extended. The extension of the existing breakwater will greatly affect the edging. Therefore, not only the dredging volume but also the time schedule of the eakwater extension and of the dredging itself are studied and adjusted in CHAPTER IX. d CHAPTER X.

Table VI-4 Alternative Designs of the Breakwater Extension

Direction of the Breakwater Extension	Breakwater Extension Length	Case
Without Extension		1
Same Direction as the Existing Breakwater	200m	2
	300m	3
	400m	4
45° from the Existing Breakwater	200m	5
	400m	6

as possible after the breakwater construction is completed. This dredging is called the primary dredging. Further periodic maintenance dredging will be necessary even if the breakwater is extended. The extension of the existing breakwater will greatly affect the dredging. Therefore, not only the dredging volume but also the time schedule of the breakwater extension and of the dredging itself are studied and adjusted in CHAPTER IX. and CHAPTER X.

Table VI-4 Alternative Designs of the Breakwater Extension

Direction of the Breakwater Extension	Breakwater Extension Length	Case
Without Extension		1
Same Direction as the Existing Breakwater	200m	2
	300m	3
	400m	4
45° from the Existing Breakwater	200m	5
	400m	6

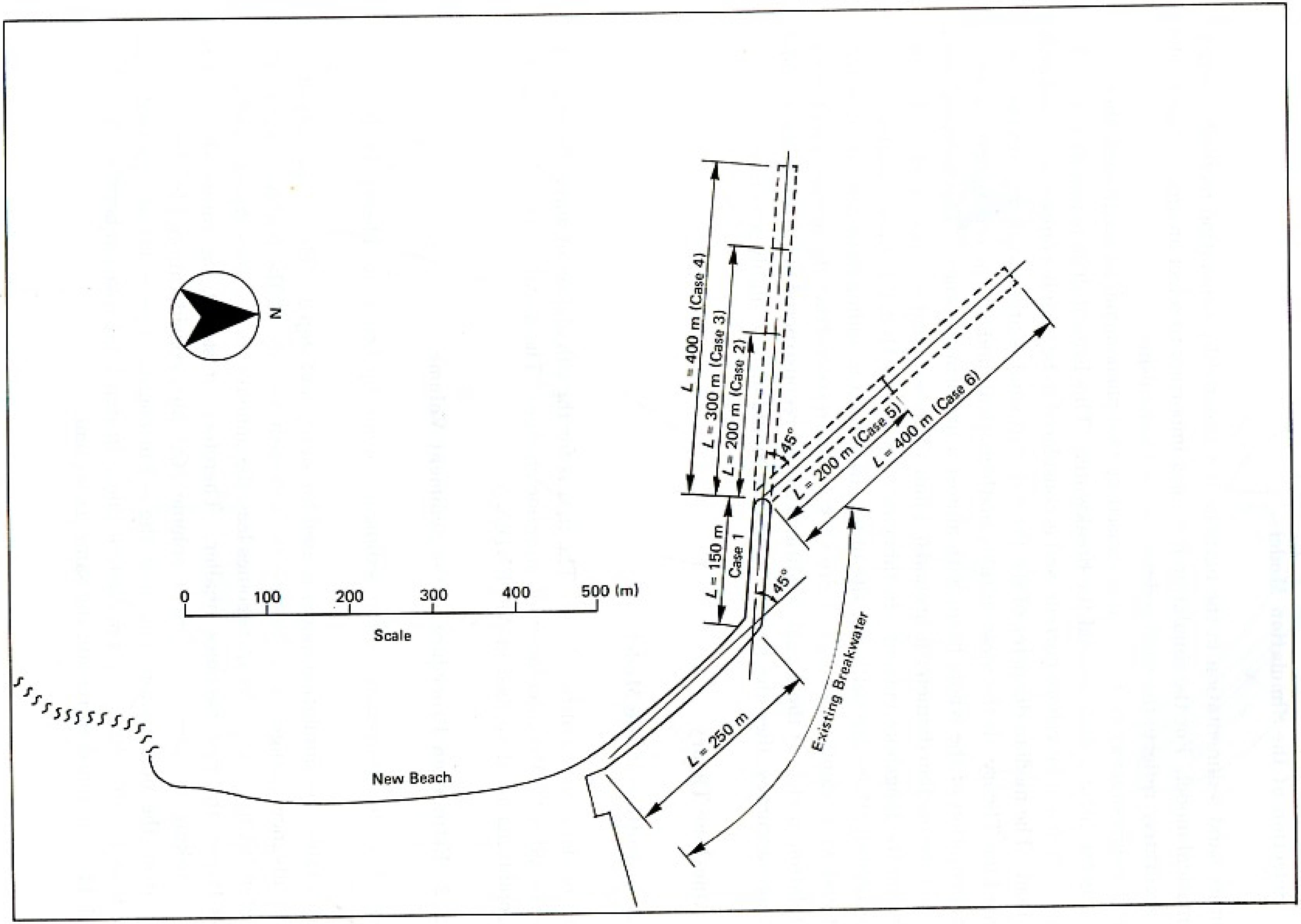


Fig. VI-18 Alternative Designs of the Breakwater Extension

4. Simulation using a Mathematical Model

4. 1 Selection of the Simulation Model

Future sand sedimentation in the harbour is estimated by simulation methods using a mathematical model. For the simulation it is most important to select an appropriate model which accurately reflects the sand sedimentation mechanisms.

Sand sedimentation in the basin is caused by two phenomena, as mentioned above.

One is the littoral drift around the breakwater. This littoral drift is mainly caused by the wave action and longshore current, and is considered to be mainly composed of sand drift in bed load. The median diameter of the littoral drift sand is around 0.3 mm. In this case, the ' One-Line Theory ' is the most suitable mathematical model. The other phenomenon is the sedimentation of the whole basin with almost a uniform thickness. The sediment sand is fine, and the median diameter is around 0.1 mm. This sediment is transported by the tidal current and the longshore current. In this case, the 'Depth Model' is most suitable.

Fortunately, there are sufficient site observation data including data concerning waves, current and water depth. These data are very useful to reconstruct the actual conditions in the simulation model. If the actual conditions can be reconstructed in the simulation model with a high accuracy, then the future estimation should also be highly accurate.

4. 2 One-Line Theory

4. 2. 1 Outline of the Model

This model consists of two parts. The first is for the calculation of wave deformation, and the second is for the calculation of shoreline changes. The details of the Model and the initial conditions are described in APPENDIX 5.

4. 2. 2 Estimation Procedure of the Sediment Volume

The estimation procedure of the sediment volume by One-Line Theory is shown in Table VI-5.

In this table, the simulation model is used for step 1 and step 2. The annual rate of the shoreline advance changes according to the sediment volume at the harbour side of the breakwater (Q_s m³/year). As Q_s becomes less, the annual rate becomes greater, and as Q_s becomes larger, the rate becomes smaller. Therefore, at step 2, the future shoreline is calculated taking the annual sediment volume (Q_s) into consideration. In step 3, it is assumed from the observation data that the -2 m contour line is always located 68 m offshore from the shoreline ($+1.4$ m contour line). In step 4, the relation between D and Q_s in Fig.VI-14, is assumed to remain the same as present.

Table VI-5 Estimation Procedure of the Sediment Volume

Step 1	Reconstruction of the actual shoreline change using the simulation model
	⇩
Step 2	Future estimation of the shoreline change
	⇩
Step 3	Calculation of the distance between the head of the breakwater and the −2m contour line (D)
	⇩
Step 4	Estimation of the annual sediment volume at the harbour side of the breakwater (Q_s) using Fig. VI-14

4. 2. 3 Reconstruction of the Actual Shoreline Change

(1) New Beach and Corralillo Beach

Fig.VI-19(a),(b) shows the simulation result of the shoreline change, with the following conditions.

a) Supplied sand volume to New Beach : 98,000 m^3/year
b) Sediment sand volume at New Beach : 26,000 m^3/year
c) Sediment sand volume at the harbour side of the breakwater : 72,000 m^3/year

In this figure, the calculation period of the shoreline change is from Sept., 1981 to Sept., 1985. The actual shoreline change in this period is also shown in this figure. The figure shows that the actual shoreline change and the calculated shoreline change are quite similar. Therefore, this model can reasonably be applied for the future estimation of the shoreline change.

(2) North Caldera Beach

Fig.VI-20 shows the simulation result of the shoreline change with the following conditions :

(a) Supplied sand volume from both ends of the calculation area : 0 m^3/year
(b) Supplied sand volume from the offshore area at the south of Mata de Limón Inlet : 25,000 m^3/year

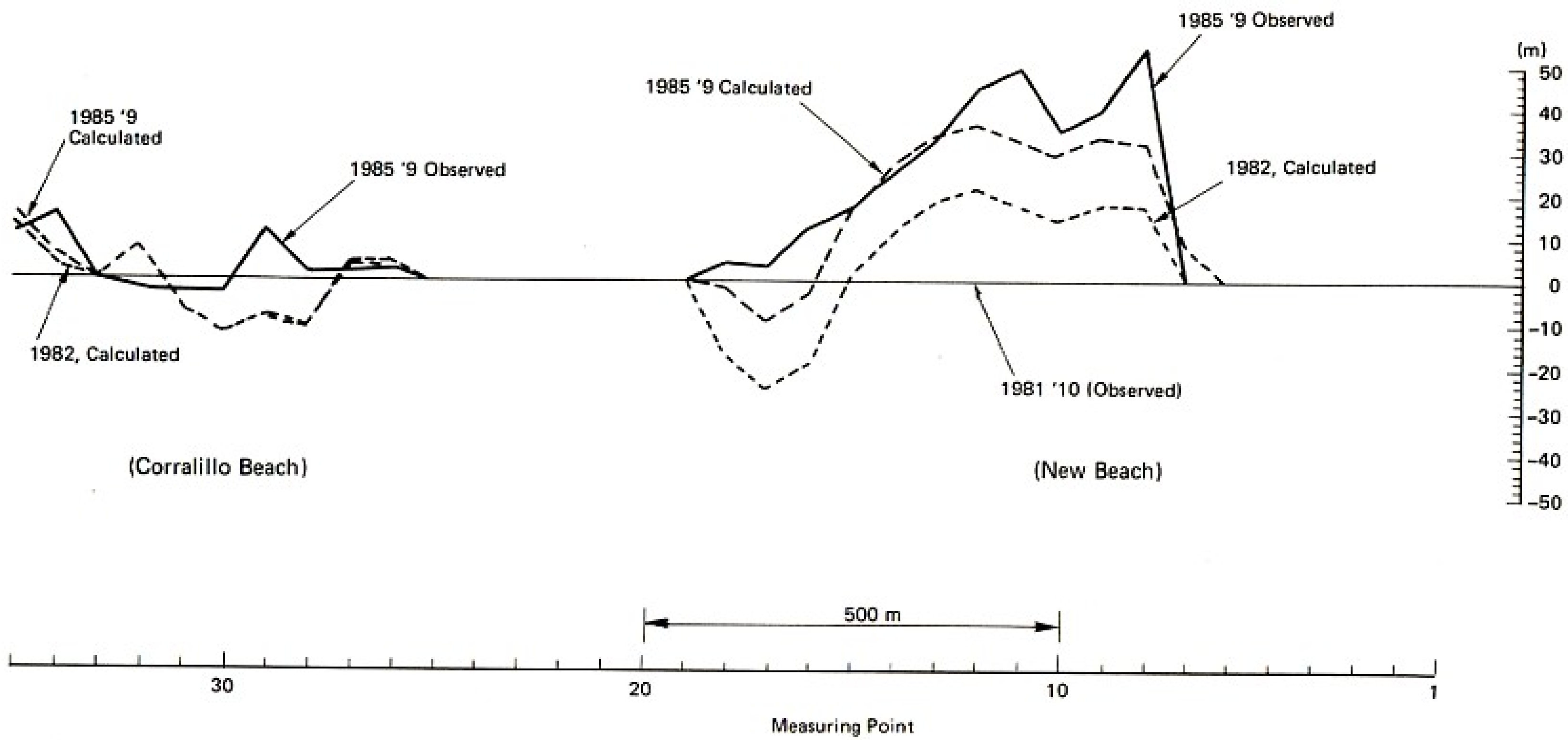
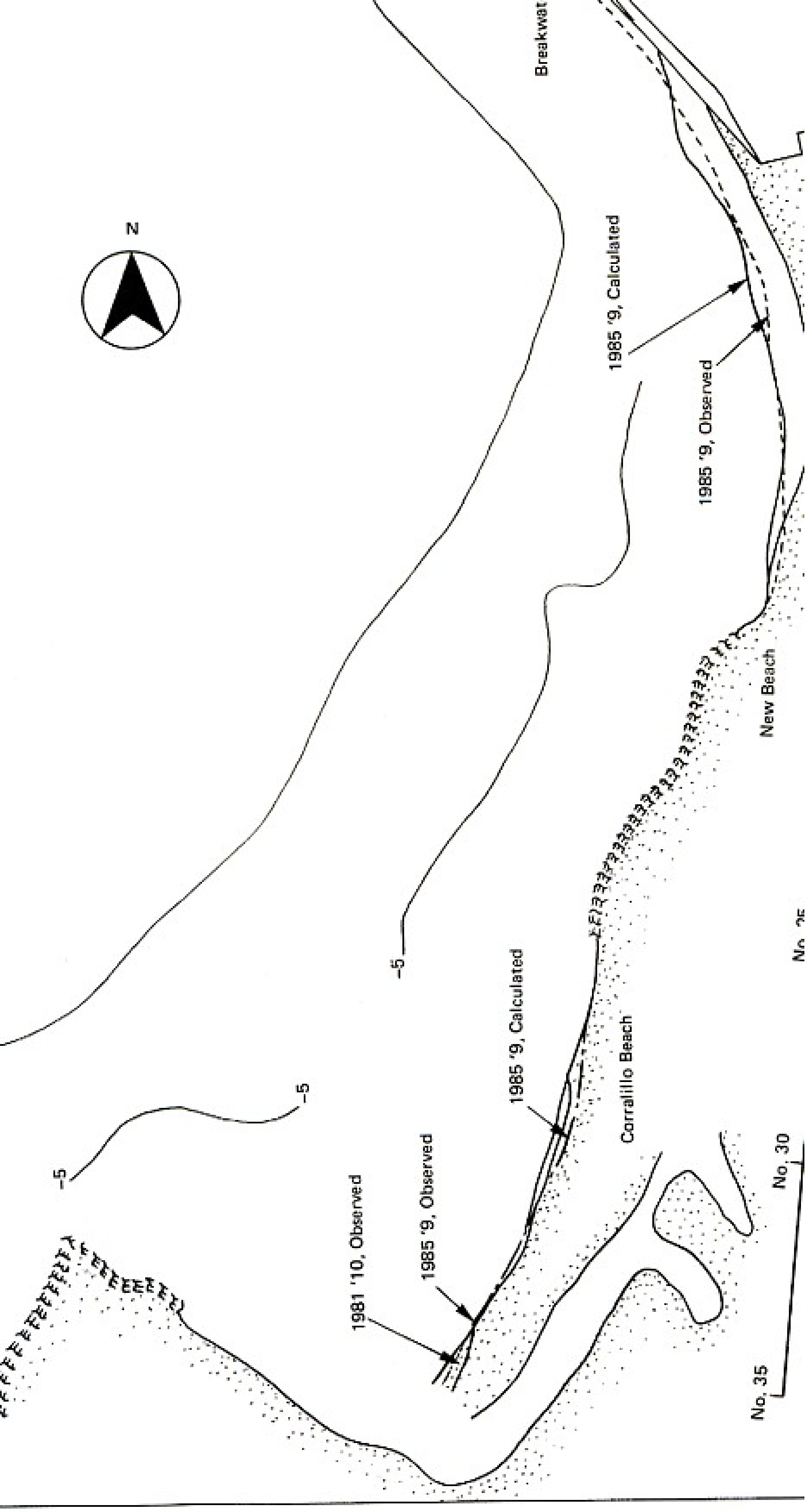


Fig. VI-19 (a) Simulation Result by One-Line Theory
(Reconstruction of the Actual Shoreline Change)


N
1985 '9, Calculated
1985 '9, Observed
-5
-5
-5
New Beach
Carralillo Beach
1985 '9, Calculated
1985 '9, Observed
1981 '10, Observed
No. 30
No. 35

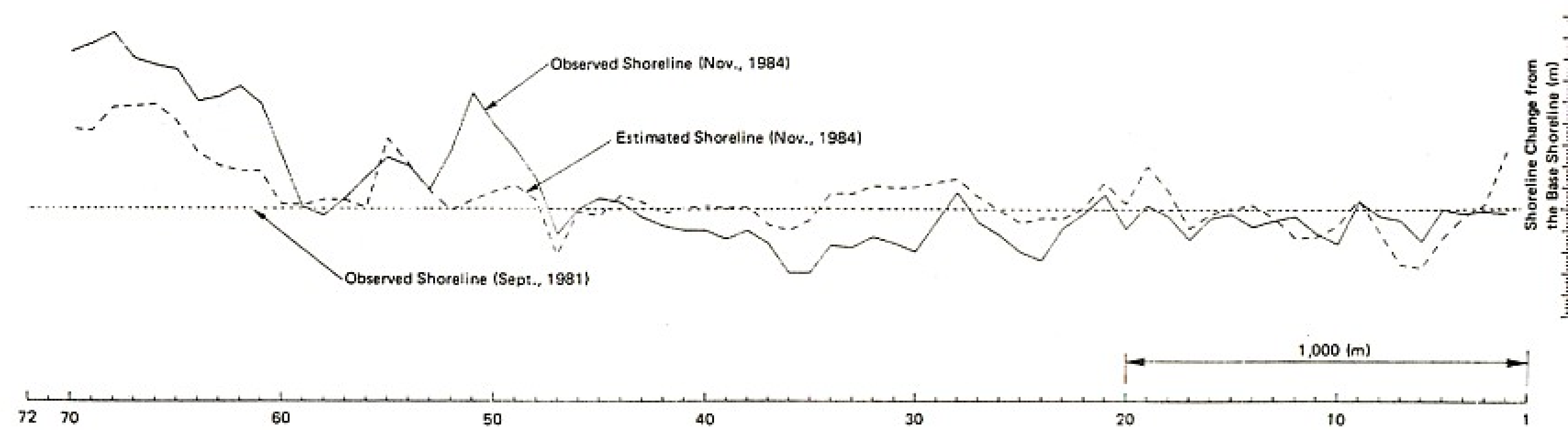
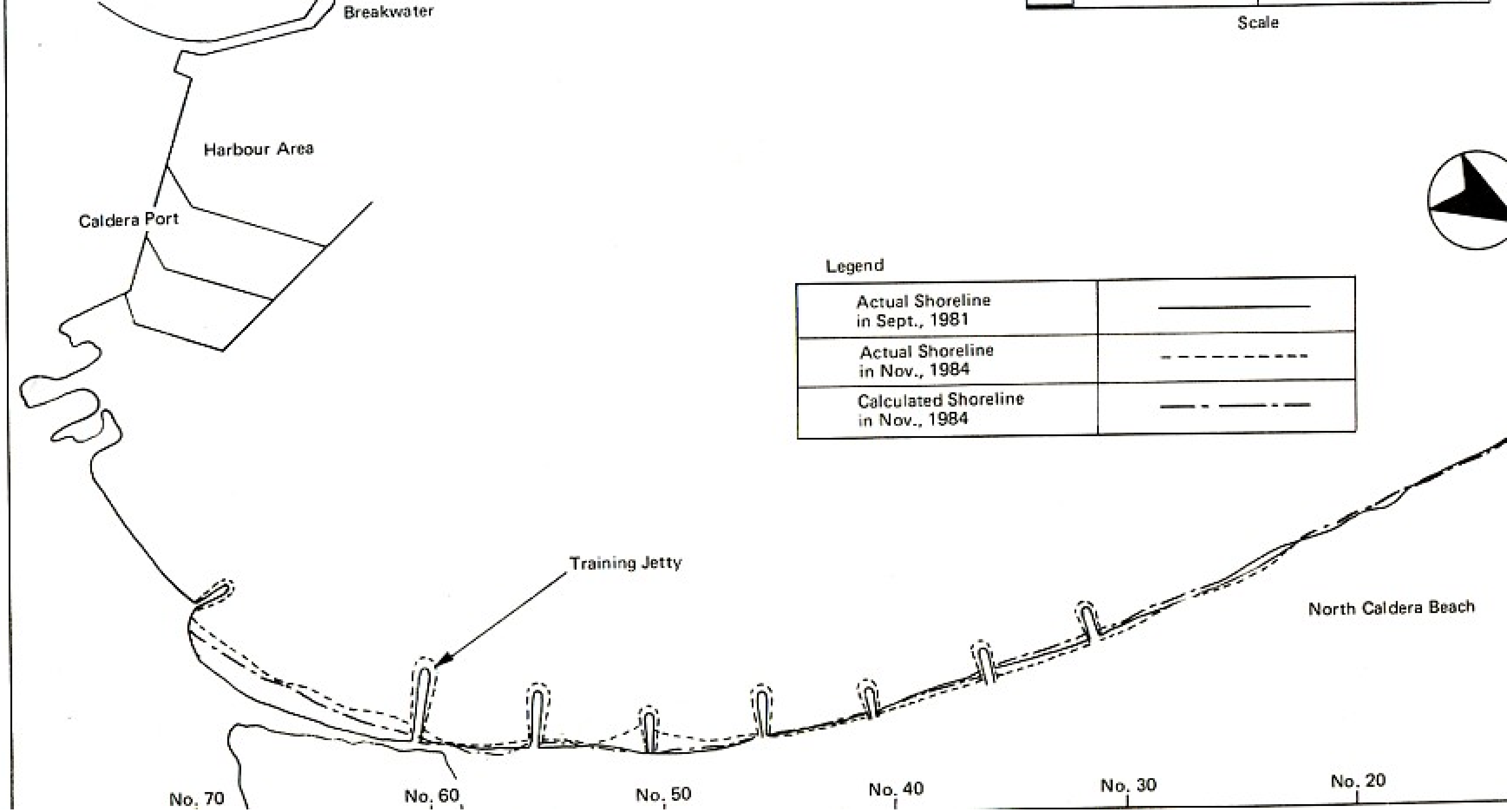


Fig. VI-20 (a) Reconstruction of the Shoreline Change by One-Line Theory (North Caldera Beach)



Breakwater
Harbour Area
Caldera Port
Scale
Legend
Actual Shoreline in Sept., 1981
Actual Shoreline in Nov., 1984
Calculated Shoreline in Nov., 1984
Training Jetty
North Caldera Beach
No. 70
No. 60
No. 50
No. 40
No. 30
No. 20

change is estimated using this model under the same conditions.

4 Future Estimation

Advance of New Beach and Corralillo Beach shoreline

calculated future shoreline is shown in Fig.VI-21. As shown in tl shoreline advance rate before the year 2,000 is 7 m/year. The an after the year 2,000 becomes less because the water depth grad nd therefore the same supply of sand brings less shoreline advance.

Evaluation of the alternatives concerning the center line of the breakw relation between the center line of the breakwater extension and th 2015 estimated by the One-Line Theory is shown in Fig.VI-22. It g the breakwater along same center line as the existing breakwat s more effective than extending it at an angle (Cases 5 and 6) becau distance between the head of the breakwater and the −2 m conto y shorter. Thus, the sand sedimentation will start earlier in the latte Therefore, the former case is selected as the preferable alternative ation.

Estimation of the future sand sediment volume

en the distance between the breakwater head and the −2 m con less than 60 m, the sedimentation at the harbour side of the breakwa the shoreline advance rate becomes less as shown in Fig. VI-21. It is n contour line is always 68 m offshore from the shoreline (D.L.+1.4 annual sediment volume at the harbour side of the breakwater ed based on the estimated results using Fig.VI-14.

le VI-6 shows the D and the Q_s of each year and of each breakw It can be seen from this table that if the extension length of the bre the sedimentation will start in the year 2012 and Q_s will reach 72,000 4.

North Caldera Beach shoreline change

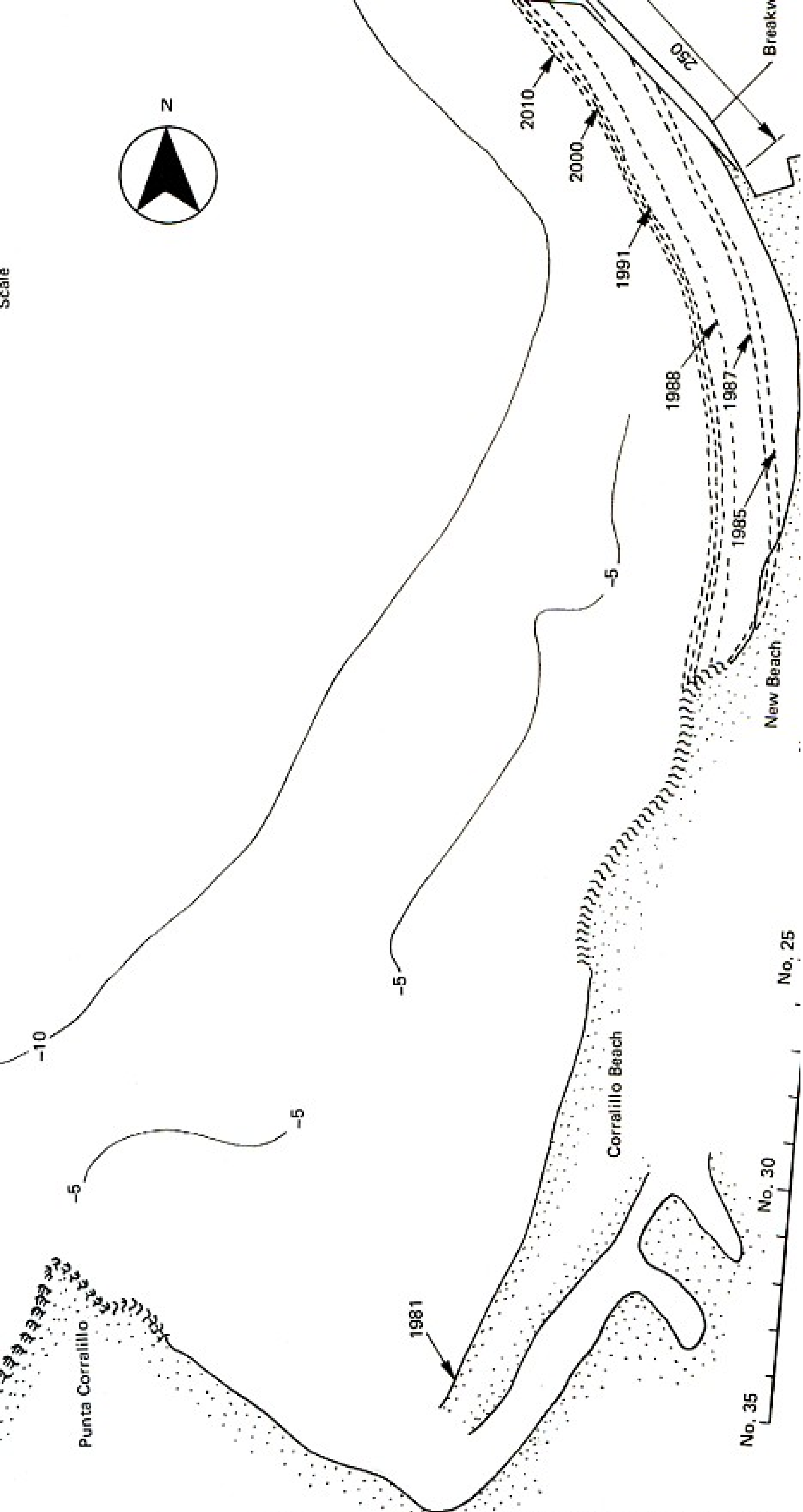
ulated future shorelines are shown in Fig.VI-23. From this figure,

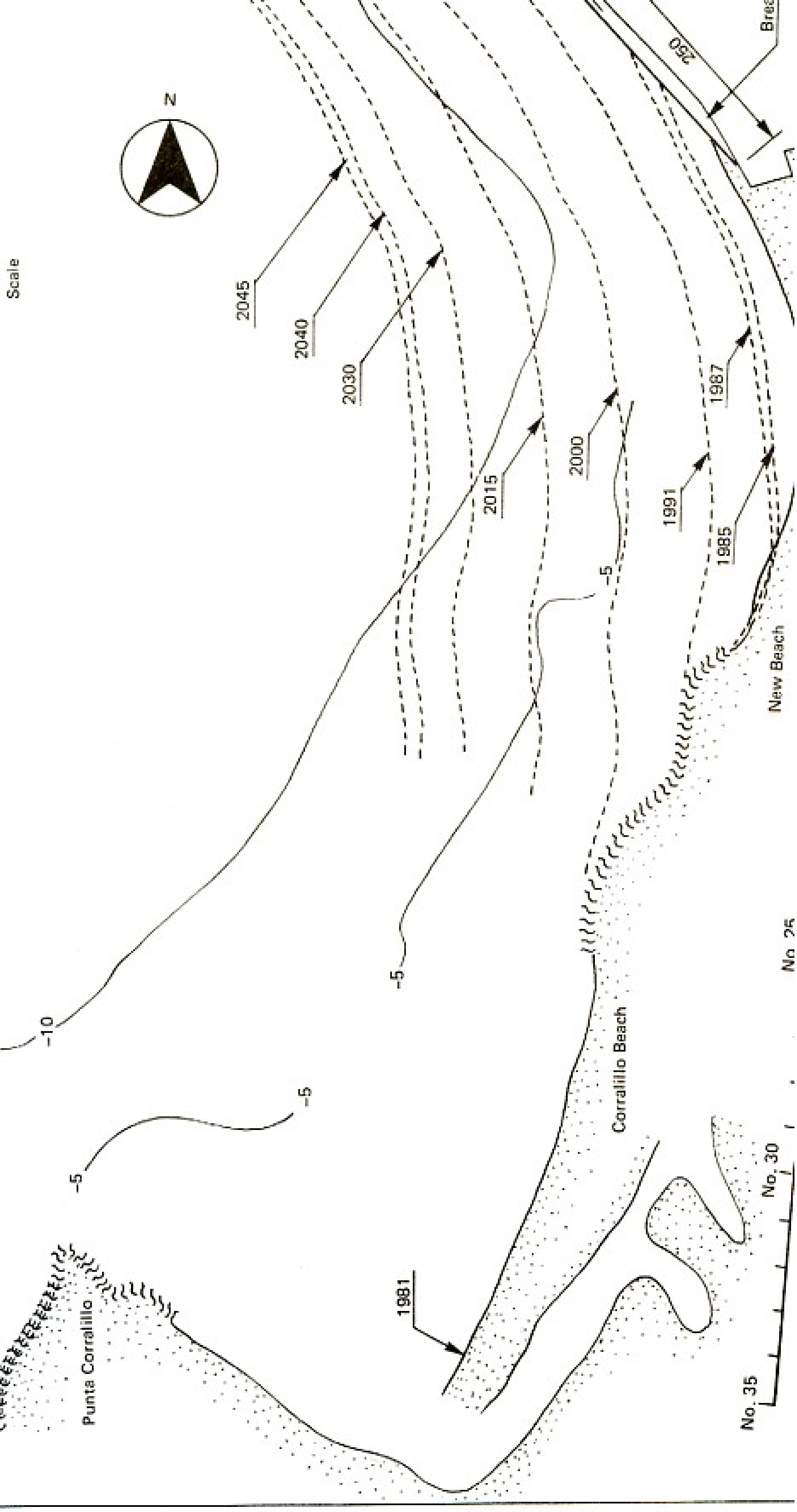
) the breakwater extension does not significantly influence the N Beach shoreline change,

) the shoreline change at the north side of Mata de Limón Inlet is

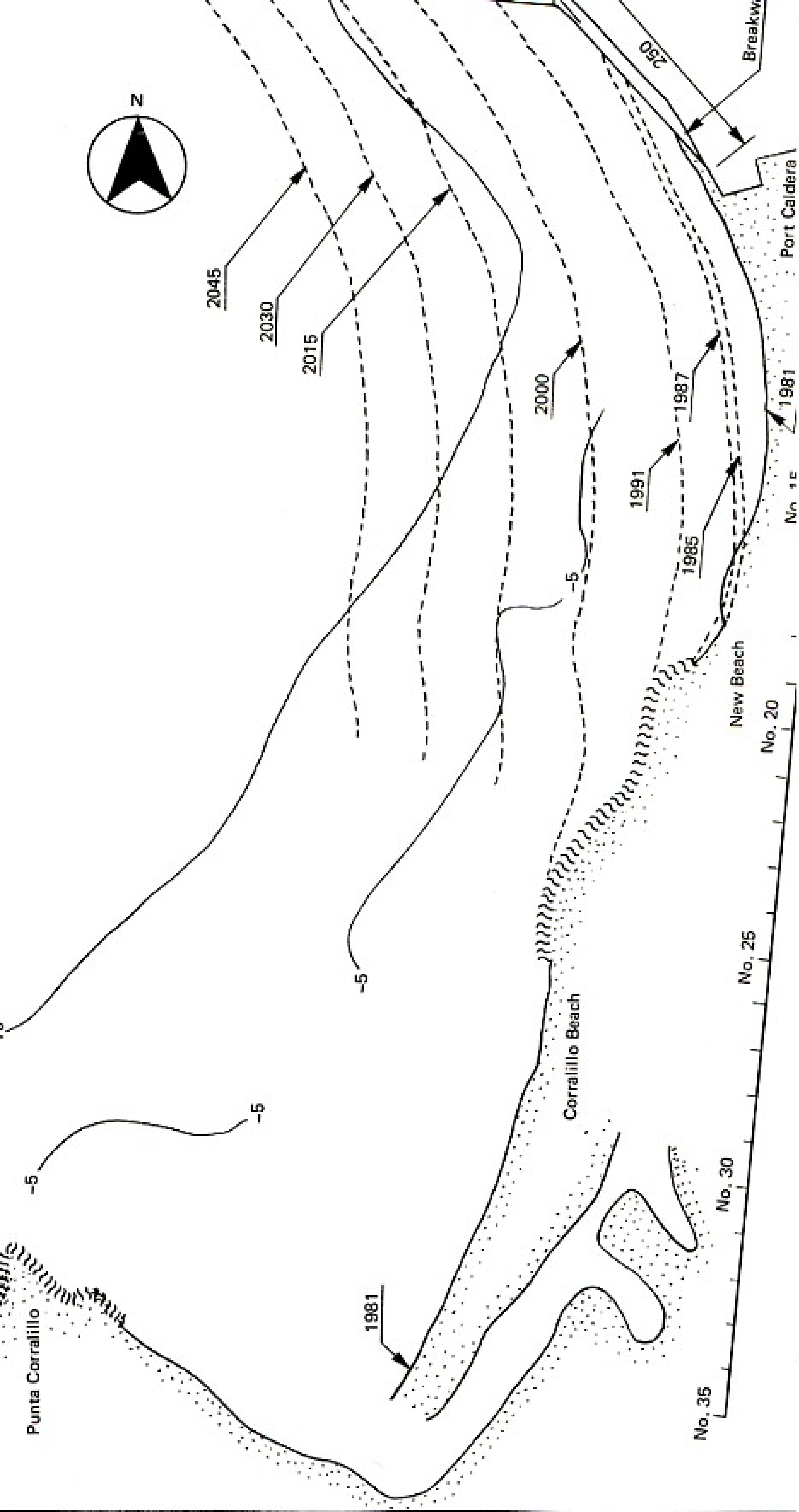
) the shoreline at the south of Mata de Limón Inlet will advance y

result of the shoreline advance at the south beach of Mata de Lim obtained from the assumption that a sand volume of 25,000 m³/yea


N
Scale
250
2010
2000
1991
1988
1987
1985
New Beach
No. 25
No. 30
No. 35
Corralillo Beach
1981
Punta Corralillo
-5
-5
-5
-5
-10



Scale
N
2045
2040
2030
2015
2000
1991
1987
1985
1981
250
-5
-10
New Beach
Corralillo Beach
Punta Corralillo
No. 30
No. 35


N
2045
2030
2015
2000
1991
1987
1985
1981
1981
-5
-5
-5
-5
250
Port Caldera
New Beach
No. 20
No. 25
No. 30
No. 35
Corralillo Beach
Punta Corralillo

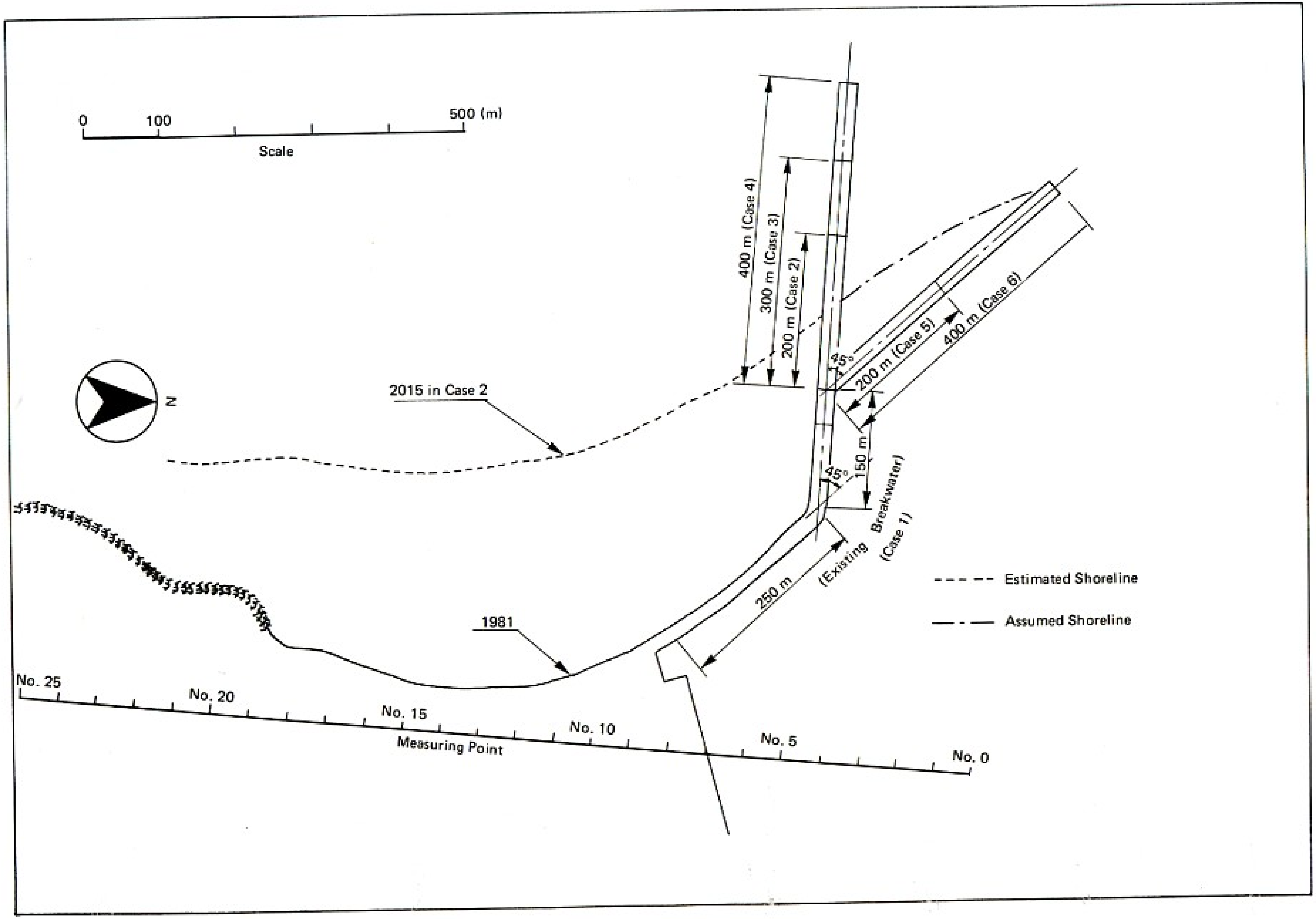


Fig. VI-22 Relation between the Breakwater Center Line and the Future Shoreline

Table VI-6 D and Q_S of Each Year

Year	Case 1 L=0m		L=100m		Case 2 L=200m		Case 3 L=300m		Case 4 L=400m		L=500m	
	D (m)	Q_S (m³/year)	D (m)	Q_S (m³/year)	D (m)	Q_S (m³/year)	D (m)	Q_S (m³/year)	D (m)	Q_S (m³/year)	D (m)	Q_S (m³/year)
Jan., 1988	35.4	15,000	135.0	0	—	0	—	0	—	0	—	0
9	31.0	19,000	129.0	0	228.0	0	328.0	0	—	0	—	0
1990	26.9	25,000	123.9	0	215.0	0	315.0	0	415.0	0	515.0	0
1	23.1	31,000	118.3	0	203.0	0	303.0	0	403.0	0	503.0	0
2	19.6	37,000	112.5	0	191.0	0	291.0	0	391.0	0	491.0	0
3	16.8	48,000	106.6	0	181.0	0	281.0	0	381.0	0	481.0	0
4	14.5	58,000	100.7	0	171.0	0	271.0	0	371.0	0	471.0	0
5	12.5	66,000	95.0	0	162.0	0	262.0	0	362.0	0	462.0	0
6	10.8	72,000	89.3	0	153.0	0	253.0	0	353.0	0	453.0	0
7	9.3	77,000	83.6	0	144.0	0	244.0	0	344.0	0	444.0	0
8	8.0	82,000	77.9	0	135.0	0	235.0	0	335.0	0	435.0	0
9	6.8	85,000	72.2	0	129.0	0	229.0	0	329.0	0	429.0	0
2000	5.8	88,000	66.5	0	123.9	0	223.9	0	323.9	0	423.9	0
1	4.8	91,000	60.8	0	118.3	0	218.3	0	318.3	0	418.3	0
2	4.0	93,000	55.3	3,000	112.5	0	212.5	0	312.5	0	421.5	0
3	3.3	96,000	50.0	5,000	106.6	0	206.6	0	306.6	0	406.6	0
4	2.6	98,000	45.0	8,000	100.7	0	200.7	0	300.7	0	400.7	0
5	2.1	99,000	40.0	10,000	95.0	0	195.0	0	295.0	0	395.0	0
6	1.5	101,000	35.4	15,000	89.3	0	189.3	0	289.0	0	389.0	0
7	1.1	103,000	31.0	19,000	83.6	0	183.6	0	283.0	0	383.0	0
8	0.8	105,000	26.9	25,000	77.9	0	177.9	0	277.9	0	377.9	0
9	0.4	107,000	23.1	31,000	72.2	0	172.2	0	272.2	0	372.2	0
2010	0.1	109,000	19.6	37,000	66.5	0	166.5	0	266.5	0	366.5	0
1	−0.3	112,000	16.8	48,000	60.8	0	160.8	0	260.8	0	360.5	0
2		〃	14.5	58,000	55.3	3,000	155.3	0	255.3	0	355.5	0
3		〃	12.5	66,000	50.0	5,000	150.0	0	250.0	0	350.0	0
4		〃	10.8	72,000	45.0	8,000	145.0	0	245.0	0	345.0	0
5		〃	9.3	78,000	40.0	10,000	140.0	0	240.0	0	340.0	0
6		〃	8.0	82,000	35.4	15,000	135.4	0	235.4	0	335.4	0
7		〃	6.8	85,000	31.0	19,000	131.0	0	231.0	0	331.0	0
8		〃	5.8	88,000	26.9	25,000	126.9	0	226.9	0	326.9	0
9		〃	4.8	91,000	23.1	31,000	123.1	0	223.1	0	323.1	0
2020		〃	4.0	93,000	19.6	37,000	119.6	0	219.6	0	319.6	0
1			3.3	96,000	16.8	48,000	116.8	0	216.8	0	316.8	0
2			2.6	98,000	14.5	58,000	111.5	0	211.5	0	311.5	0
3			2.1	99,000	12.5	66,000	106.1	0	206.1	0	306.1	0
4			1.5	101,000	10.8	72,000	100.8	0	200.8	0	300.8	0
5			0.8	105,000	9.3	78,000	95.4	0	195.4	0	295.4	0
6			0.4	107,000	8.0	82,000	90.1	0	190.1	0	290.1	0
7			0.1	109,000	6.8	85,000	84.7	0	184.7	0	284.7	0
8			−0.3	112,000	5.8	88,000	79.4	0	179.4	0	279.4	0
9				〃	4.8	91,000	74.0	0	174.0	0	274.0	0
2030				〃	4.0	93,000	68.7	0	168.7	0	268.7	0
1				〃	3.3	96,000	63.3	0	163.3	0	263.3	0
2				〃	2.6	98,000	58.1	1,000	158.1	0	258.1	0
3				〃	2.1	99,000	53.2	4,000	152.8	0	252.8	0
4				〃	1.5	101,000	48.4	6,000	147.7	0	247.7	0
5				〃	0.8	105,000	43.7	8,000	142.6	0	242.6	0
6				〃	0.4	107,000	39.2	11,000	137.7	0	237.7	0
7				〃	0.1	109,000	34.9	15,000	132.7	0	232.7	0
8				〃	−0.3	112,000	30.9	19,000	127.7	0	227.7	0
9				〃		〃	27.1	25,000	122.7	0	222.7	0
2040				〃		〃	23.5	30,000	117.7	0	217.7	0
1						〃	20.2	35,000	112.2	0	212.2	0
2						〃	17.5	45,000	107.7	0	207.7	0
3						〃	15.2	54,000	102.7	0	202.7	0
4						〃	13.3	62,000	97.7	0	197.7	0
5						〃	11.6	69,000	92.7	0	192.7	0

Notes : 1) D is the distance between the head of the breakwater and the −2.0m contour line at the start of each period (m).
2) Q_S is the annual sand sediment volume (m³/year).
3) Dand Q_S in the cases of L=100m and L=500m are assumed complementing the simulation results.

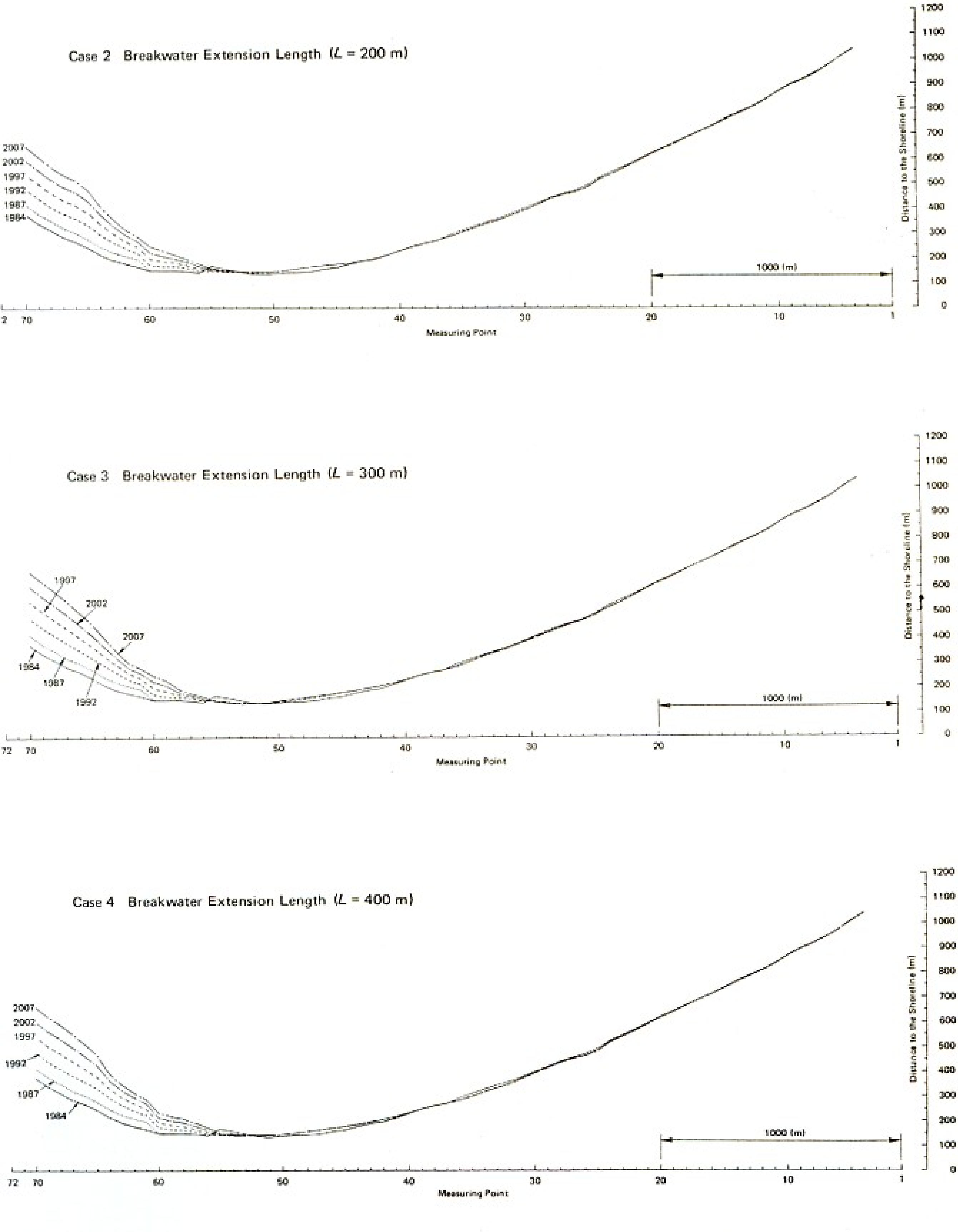


Fig. VI-23 Calculated Future Shorelines at North Caldera Beach

to be supplied every year. However, it is not clear at present if the sand supply will continue for a long term. Therefore, it will be necessary to observe the sand accumulation at the offshore area less than 10 m deep south of Mata de Limón Inlet over a long period of time.

4. 3 Depth Model

4. 3. 1 Outline of the Model

The depth model is to estimate the water depth change caused by the sand which is rolled up from the sea bottom by wave action and transported by the tidal and longshore currents. The sand accumulates where the waves and currents are less. The outline of the model and the primary conditions are described in APPENDIX 6.

Two calculation areas are selected. One includes almost all of Caldera Bay, and the other only includes the harbour basin and its immediate area. The calculation procedure is shown in Fig.VI-24.

4. 3. 2 Estimation Method of Sand Sediment Volume

The calculation area is divided into several portions. The average water depth changes of each portion are calculated by the simulation model. The sand sediment volumes are calculated by multiplying each area by each annual depth change rate (cm/year).

4. 3. 3 Reconstruction of the Actual Water Depth Change

(1) Trend of the water depth change

The harbour basin and the area around the basin are divided into five areas as shown inFig.VI-15. The average depth change rates per year of each area are shown in Fig.VI-17.

(2) Reconstruction of the actual depth change

Calculated depth changes of each area are compared with the actual depth changes as shown in Fig.VI-25. It can be seen from this figure that the calculation results conform with the actual conditions. Thus, the future depth changes can be accurately estimated using this mathematical simulation model.

4. 3. 4 Future Estimation

The depth change rates and sand sediment volume under each breakwater extension length are estimated as shown in Table VI-7. It can be seen from this table that the sand sediment rates becomes less as the breakwater extension length increases. The sand sediment volumes of each breakwater extension length are as follows :

Breakwater Extension Length	Annual Sand Sediment Volume
200 m	12,000 m^3/year
300 m	10,000 m^3/year
400 m	8,000 m^3/year

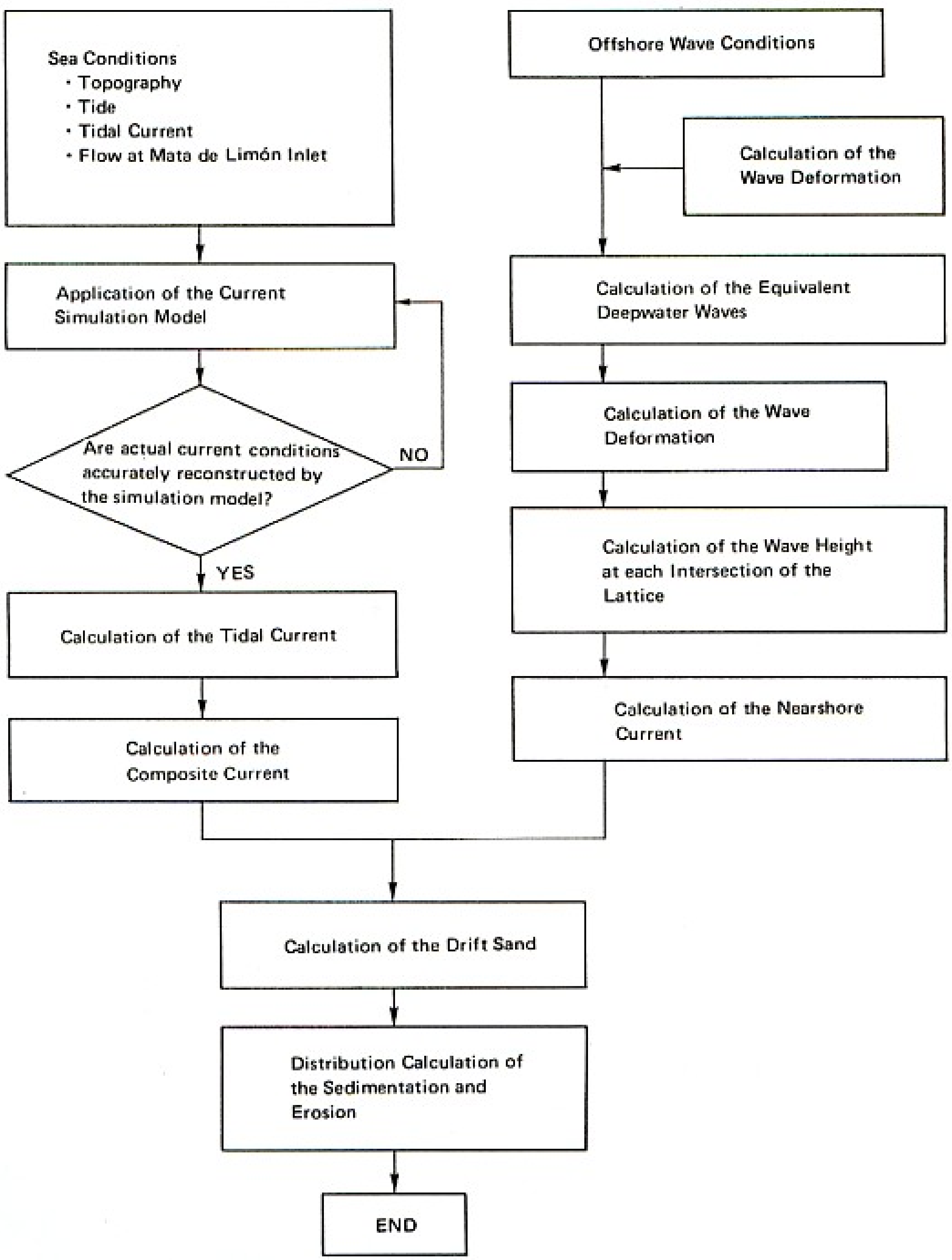
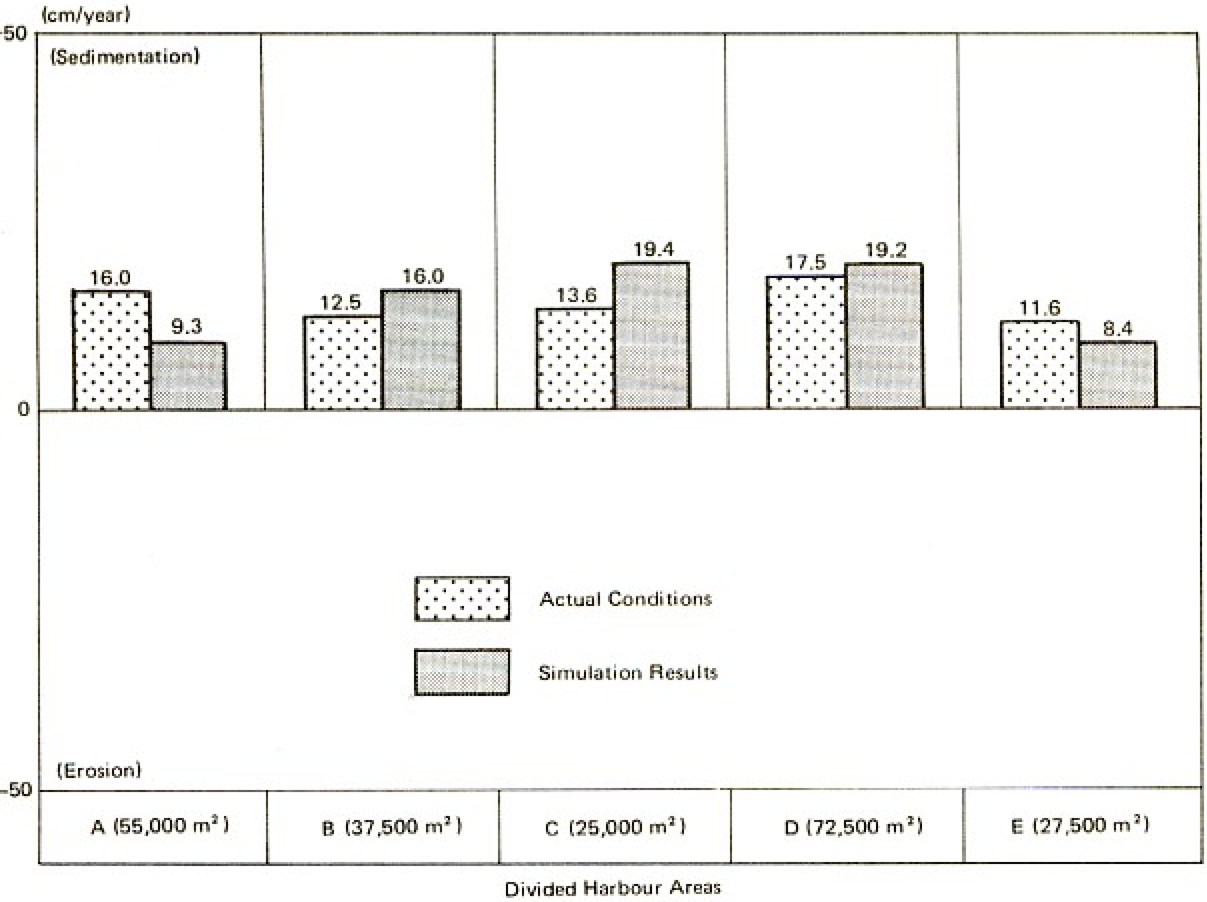


Fig. VI-24 Calculation Procedure of the Depth Change Using the Simulation Model



Zone	Area (m²)	Actual or Simulation	Annual Sediment Rate (m/year)	Annual Sediment Volume (m³/year)
A	55,000	Actual Conditions	0.160	8,800
		Simulation Results	0.093	5,100
B	37,500	Actual Conditions	0.125	4,700
		Simulation Results	0.160	6,000
C	25,000	Actual Conditions	0.136	3,400
		Simulation Results	0.194	4,900
Total	117,500	Actual Conditions	–	16,000
		Simulation Results	–	16,900

Fig. VI-25 Reconstruction of the Depth Change

Table VI-7 Simulation Results (Depth Model)

Case	Sedimentation Rates	Divided Harbour Area						
		A (55,000m²)	B (37,500m²)	C (25,000m²)	Sub Total (117,500m²)	D (72,500m²)	E (27,500m²)	Total (217,500m²)
Actual Conditions	Depth Change (cm/year)	16.0	12.5	13.6	—	17.5	11.6	—
	Annual Sediment Volume (m³/year)	8,800	4,700	3,400	16,900	12,700	3,200	32,800
Case 1 Reconstruction of the Actual Conditions	Depth Change (cm/year)	9.3	16.0	19.4	—	19.2	8.4	—
	Annual Sediment Volume (m³/year)	5,100	6,000	4,900	16,000	13,900	2,300	32,200
Case 2 Breakwater Extension $L=200$m	Depth Change (cm/year)	8.0	10.4	13.0	—	17.8	9.0	—
	Annual Sediment Volume (m³/year)	4,400	3,900	3,300	11,600	12,900	2,500	27,000
Case 4 Braekwater Extension $L=400$m	Depth Change (cm/year)	5.6	7.2	9.3	—	16.9	6.3	—
	Annual Sediment Volume (m³/year)	3,100	2,700	2,300	8,100	12,300	1,700	22,100

5. Optimum Urgent Countermeasures against Sand Sedimentation

5. 1 Optimum Breakwater Length

Now, it is possible to estimate the future sediment volume in the harbour basin by using the mathematical simulation results. Fig.VI-26 shows the estimated annual dredging volume of each year of each breakwater extension length. The required dredging volumes in the cases of 100 m and 500 m extensions in addition to the simulation cases are also included in this figure. The maintenance dredging volume when the breakwater is not extended at all is also included. In this figure, it is assumed that the sediment in the harbour basin except at the harbour side of the breakwater will be dredged once every five years.

The total dredging volume over 30 years for each breakwater extension length is shown in Table VI-8.

Table VI-9 shows the total cost over 30 years for the alternative countermeasures against sand sedimentation. Fig.VI-27 shows the breakwater construction costs, the dredging costs and the total costs of each breakwater extension length over the lifetime of this project, including the case where the breakwater is not extended at all. These costs are estimated assuming the most reasonable procedures for the breakwater construction and the dredging. The details are discussed in CHAPTERS. XI and X. From this figure, it is clear that the most economical countermeasure against sand sedimentation in the harbour basin is to extend the breakwater by a length of 200 m.

5. 2 Optimum Urgent Countermeasures

A new breakwater extension of 200 m in the same direction as the existing breakwater and the dredging of unavoidable sand sediment are recommended as the optimum countermeasures against sand sedimentation in the harbour basin.

The dredging includes not only the primary dredging which will be completed by the target year, but also the periodic maintenance dredging which will be continued after the target year.

As the sediment volume in the harbour area is somewhat uncertain, especially under rough sea conditions, an expedient dredging program will have to be executed. This must be considered when planning the construction of facilities for this Caldera Port maintenance project. Continuous site surveys concerning the sand drift over a long period of time will also be necessary for a more accurate estimation of the sand sedimentation in the future.

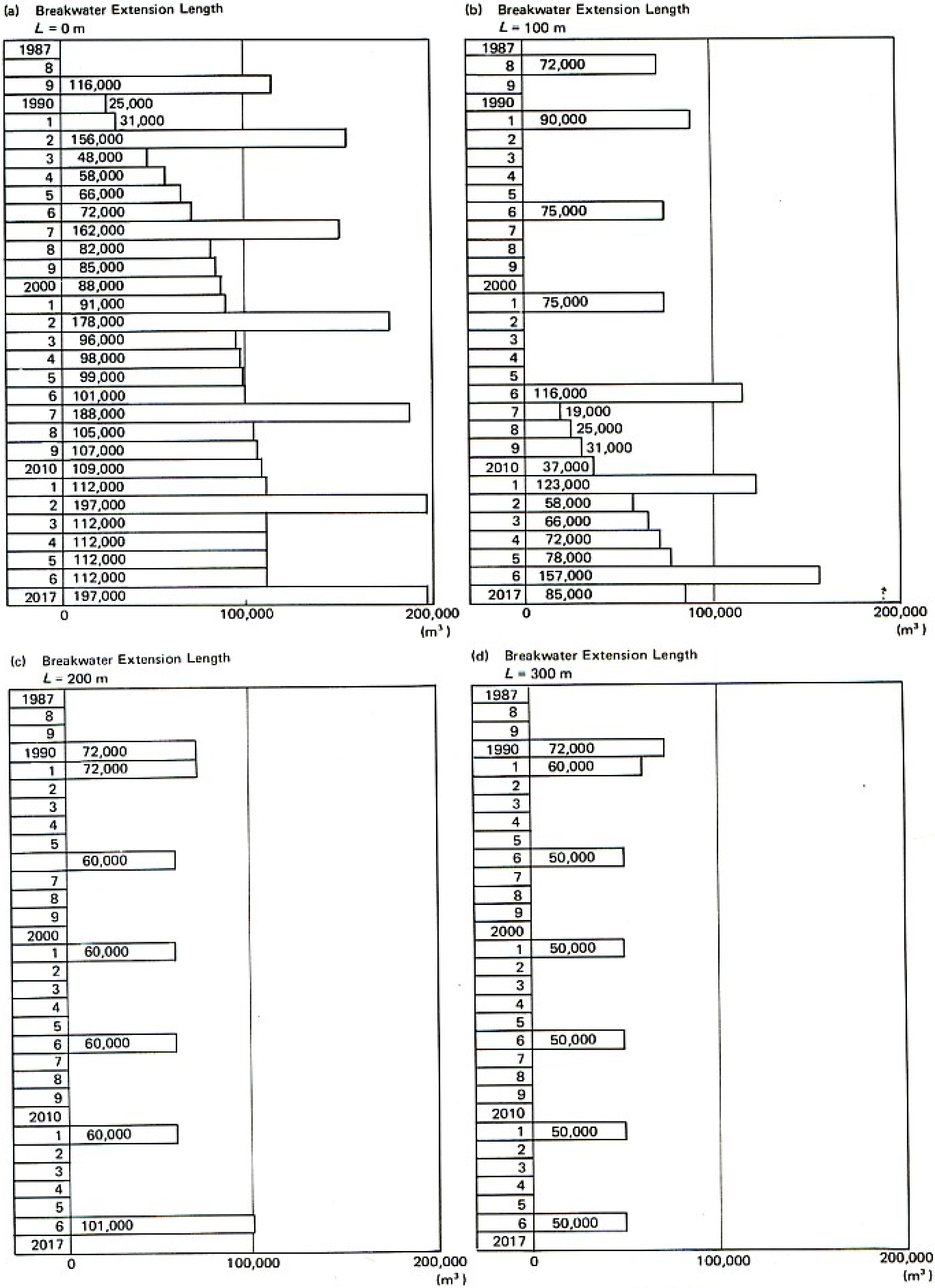


Fig. VI-26 (a) Estimated Dredging Volume of Each Year

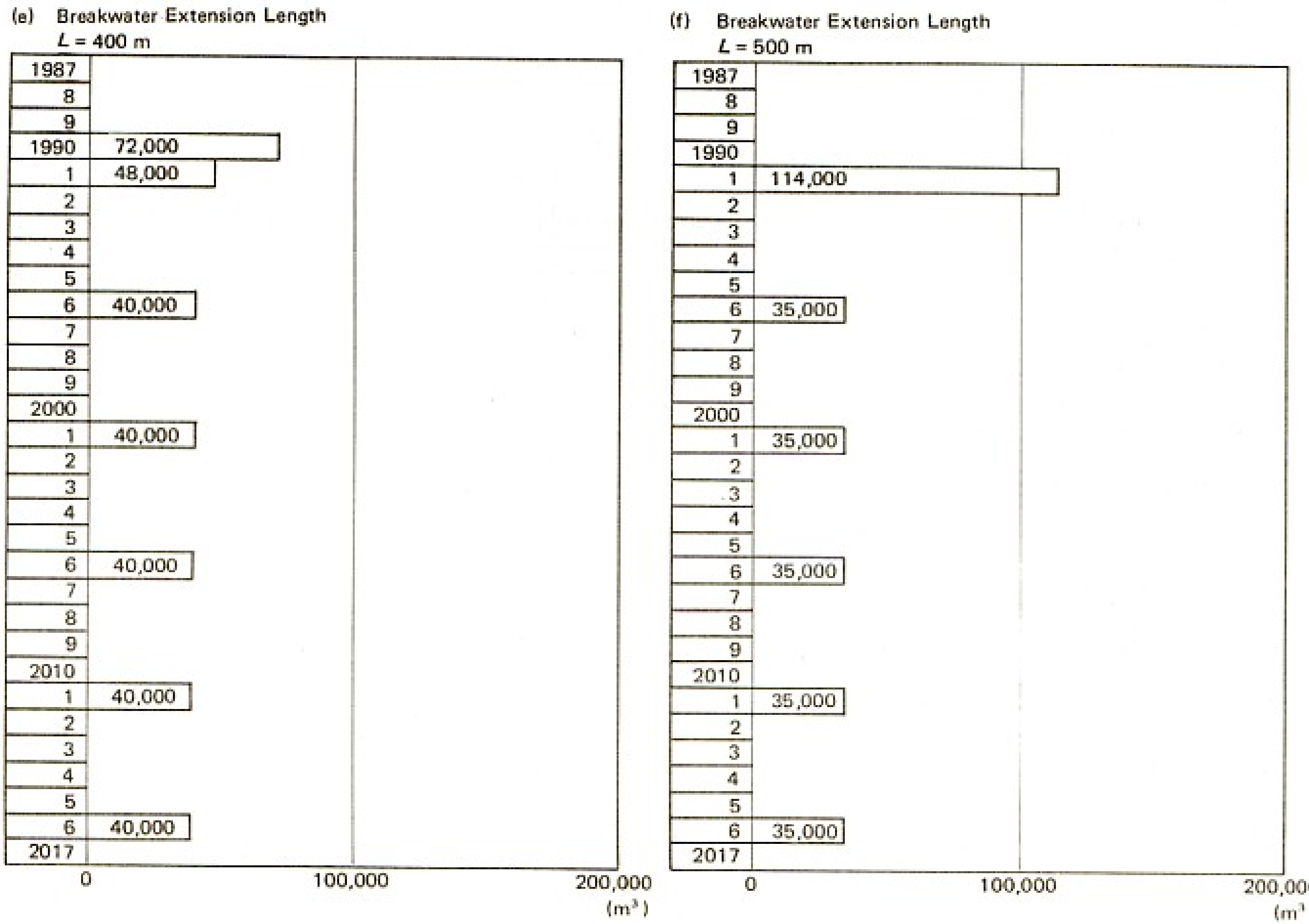


Fig. VI-26 (b) Estimated Dredging Volume of Each Year

Table VI-8 Total Amount of Dredging Volume for 30 Years

Breakwater Extension Length	Primary or Maintenance Dredging	Dredging Volume (m^3)		
		Harbour Side of the Breakwater	Harbour Basin	Total
0 m	Primary Dredging	0	0	0
	Maintenance Dredging	2,571,000	544,000	3,115,000
	Total	2,571,000	544,000	3,115,000
100m	Primary Dredging	72,000	0	72,000
	Maintenance Dredging	642,000	465,000	1,107,000
	Total	714,000	465,000	1,179,000
200m	Primary Dredging	72,000	0	72,000
	Maintenance Dredeging	41,000	372,000	413,000
	Total	113,000	372,000	485,000
300m	Primary Dredging	72,000	0	72,000
	Maintenance Dredging	0	310,000	310,000
	Total	72,000	310,000	382,000
400m	Primary Dredging	72,000	0	72,000
	Maintenance Dredging	0	248,000	248,000
	Total	72,000	248,000	320,000
500m	Primary Dredging	72,000	0	72,000
	Maintenance Dredging	0	217,000	217,000
	Total	72,000	217,000	289,000

Table VI-8 Total Amount of Dredging Volume for 30 Years

Breakwater Extension Length	Primary or Maintenance Dredging	Dredging Volume (m^3)		
		Harbour Side of the Breakwater	Harbour Basin	Total
0 m	Primary Dredging	0	0	0
	Maintenance Dredging	2,571,000	544,000	3,115,000
	Total	2,571,000	544,000	3,115,000
100m	Primary Dredging	72,000	0	72,000
	Maintenance Dredging	642,000	465,000	1,107,000
	Total	714,000	465,000	1,179,000
200m	Primary Dredging	72,000	0	72,000
	Maintenance Dredeging	41,000	372,000	413,000
	Total	113,000	372,000	485,000
300m	Primary Dredging	72,000	0	72,000
	Maintenance Dredging	0	310,000	310,000
	Total	72,000	310,000	382,000
400m	Primary Dredging	72,000	0	72,000
	Maintenance Dredging	0	248,000	248,000
	Total	72,000	248,000	320,000
500m	Primary Dredging	72,000	0	72,000
	Maintenance Dredging	0	217,000	217,000
	Total	72,000	217,000	289,000

(Uuit: '000,000 Colone

Breakwater Extension Length(m)	Remarks; Cost	Breakwater Construction Cost				Dredging Cost				Total Cost
		Construction Cost	Equipment Cost on Land	Equipment Cost on Sea	Sub Total	Primary Dredging Cost	Maintenance Dredging Cost	Equipment Cost on Sea	Sub Total	
0	Remarks	—	—	—	—	Volume: $0m^3$	Volume: $3,115,000(m^3)$ @102.3¢/m^3	Purchase and Maintenance of the Equipment	—	866.5
	Cost	0	0	0	0	0	318.7	547.8	866.5	
100	Remarks	Including Temporary Facilities	$2,861\times10^3$ ¢/Month 12.5 Months	$1,580\times10^3$ ¢/Month 12.5 Months	—	Volume: $72,000(m^3)$ @148.0¢/m^3	Volume: $1,107,000(m^3)$	1.58×10^6 ¢/Month 48 Months	—	619.3
	Cost	175.1	35.8	19.8	230.7	10.7	302.0	75.9	388.6	
200	Remarks	Including Temporary Facilities	18.5 Months	18.5 Months	—	Volume: $72,000(m^3)$ @148.0¢/m^3	Volume: $413,000(m^3)$	20 Months	—	524.4
	Cost	309.5	52.9	29.3	391.7	10.7	90.4	31.6	132.7	
300	Remarks	Including Temporary Facilities	27.5 Months	27.5 Months	—	Volume: $72,000(m^3)$ @148.0¢/m^3	Volume: $310,000(m^3)$	16 Months	—	669.8
	Cost	447.2	78.7	43.5	569.4	10.7	64.4	25.3	100.4	
400	Remarks	Including Temporary Facilities	35.5 Months	35.5 Months	—	Volume: $72,000(m^3)$ @148.0¢/m^3	Volume: $248,000(m^3)$	14 Months	—	822.5
	Cost	580.5	101.6	56.1	738.2	10.7	51.5	22.1	84.3	
500	Remarks	Including Temporary Facilities	42.5 Months	42.5 Months	—	Volume: $72,000(m^3)$ @148.0¢/m^3	Volume: $217,000(m^3)$	12 Months	—	978.7
	Cost	715.1	121.6	67.2	903.7	10.7	45.1	19.0	74.8	

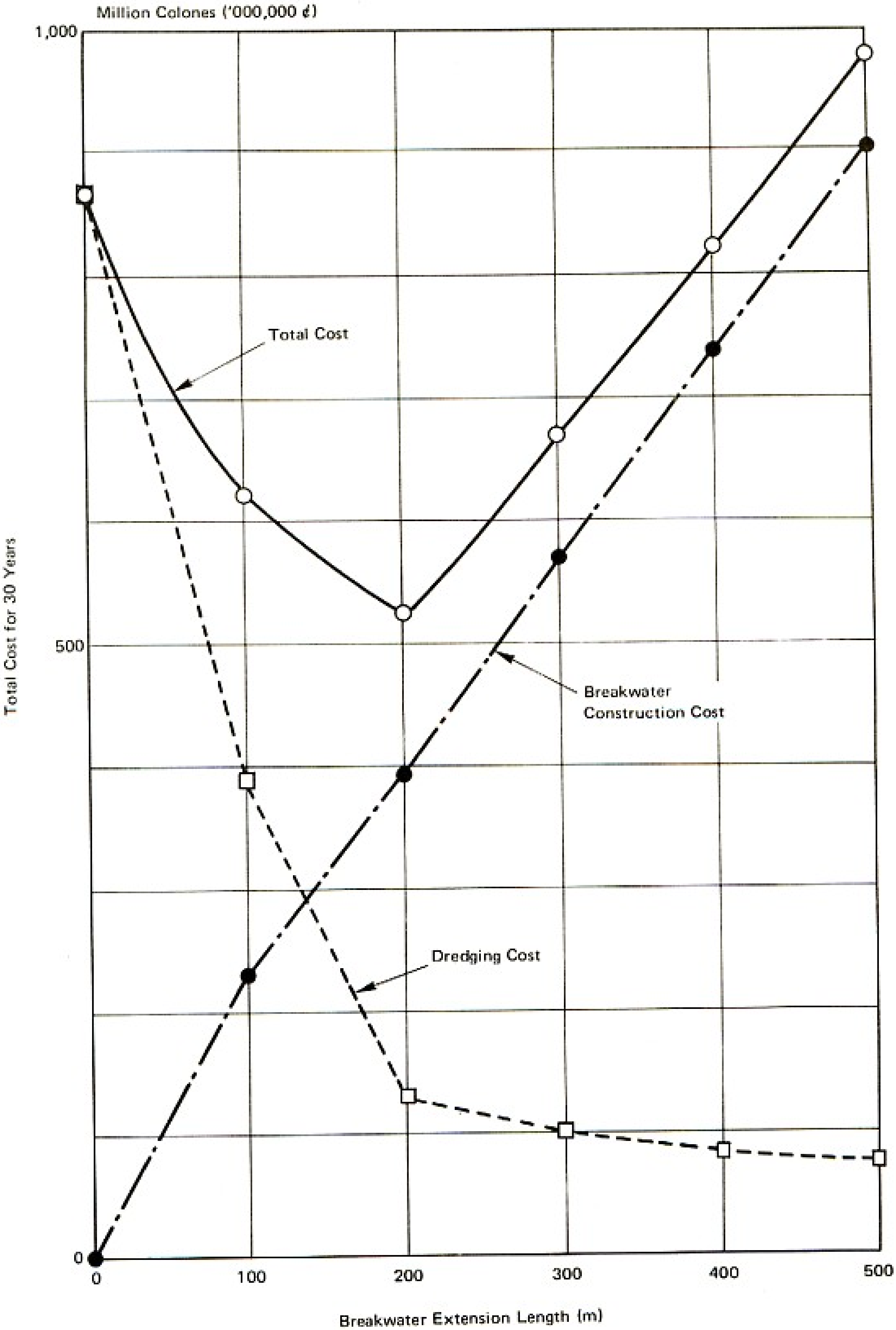


Fig. VI-27 Cost Comparison of Each Breakwater Length

The required type and number of port facilites and cargo handling equipment and the target year of the project should be determined based on the port demand forecast. In this study, port traffic is forecast based on the socioeconomic forecast, and port facility improvement planning is studied based on the said port traffic forecast.

1. Port Traffic Forecast

1. 1 Socioeconomic Frame for the Traffic Forecast

The future population and GDP are forecast here as prerequisites for the port traffic projection.

1. 1. 1 Population Projection

Generally speaking, historical data over a long period of time as well as the most recent data are required for making population projections. Population statistics by DGEC as showm in Table I-1 are adopted in this study. The most recent figures show the population of Costa Rica as about 2.4 million in 1982. The population doubled in the twenty years from 1962 to 1982. Past population trends and projections by various agencies should be fully considered in making the population projection.

As for the future population of Costa Rica, two agencies, CELADE and MOPT, have made projections for the years 2025 and 2010, respectively, as shown in Table VII-1. Historically, the compound increase rate has been gradually decreasing. Generally, population increase rates decrease along with economic growth, and Costa Rica is no exception. The Costa Rican economy will continue to grow in the future as discussed in the following section. Thus, we can predict that the compound increase rate will continue to gradually decrease in the future.

The future increase rate projected by CELADE shows a gradual decrease. This tendency is reasonable. However, the increase rate projected by MOPT remains the same throughout the period from 1985 through 2010. This seems unreasonable considering the decreasing trend. CELADE made three population projections as shown in Table VII-1. Case B with a medium increase rate seems most reasonable because its decreasing trend is most consistent with the actual historical data. Therefore, the compound increase rate in Case B estimated by CELADE is adopted in this study.

However, the projection base year of the CELADE estimate is 1980. As rule, the latest data should be used as the base data whenever possible in making population projections. The latest population data available are from 1982 according to "Anuario Estadístico de Costa Rica, DGEC". Then, the base year for the projection should be 1982.

Thus, in this study the population is projected using the base year of 1982 and the medium compound increase rate of Case B estimated by CELADE. The results of the projection are shown in Table VII-2 and Fig.VII-1. Population in 1990 is predicted to be abou 3 million.

Table VII-1 Costa Rican Population Projected by CELADE and MOPT

Year	CELADE [1/]						MOPT [2/]	
	Case A (High increase rate)		Case B (Medium increase rate)		Case C (Low increase rate)			
	Population (persons)	Increase rate(%)	Population (persons)	Increase rate(%)	Population (persons)	Increase rate(%)	Population ('000 persons)	Increase rate(%)
1980	2,278,506		2,278,506		2,278,506		2,245.4	
1985	2,604,173	14.3	2,599,503	14.1	2,595,214	13.9	2,500.4	11.4
1990	2,952,474	13.4	2,936,983	13.0	2,921,733	12.6	2,787.9	11.5
1995	3,304,932	11.9	3,270,965	11.4	3,237,134	10.8	3,108.3	11.5
2000	3,657,485	10.7	3,595,947	9.9	3,534,437	9.2	3,465.6	11.5
2005	4,015,608	9.8	3,919,005	9.0	3,824,230	8.2	3,864.0	11.5
2010	4,381,177	9.1	4,239,367	8.2	4,103,482	7.3	4,308.1	11.5
2015	4,747,759	8.4	4,548,508	7.3	4,362,334	6.3	—	
2020	5,106,834	7.6	4,836,575	6.3	4,590.623	5.2	—	
2025	5,453,914	6.8	5,098,604	5.4	4,783,836	4.2	—	

Source 1/ : COSTA RICA, ESTIMACIONES Y PROYECCIONES DE POBLACION 1950-2025, CELADE
2/ : DGP/MOPT
Note : The increase rate figures denote the increase over previous five years.

Table VII-2 Projected Population

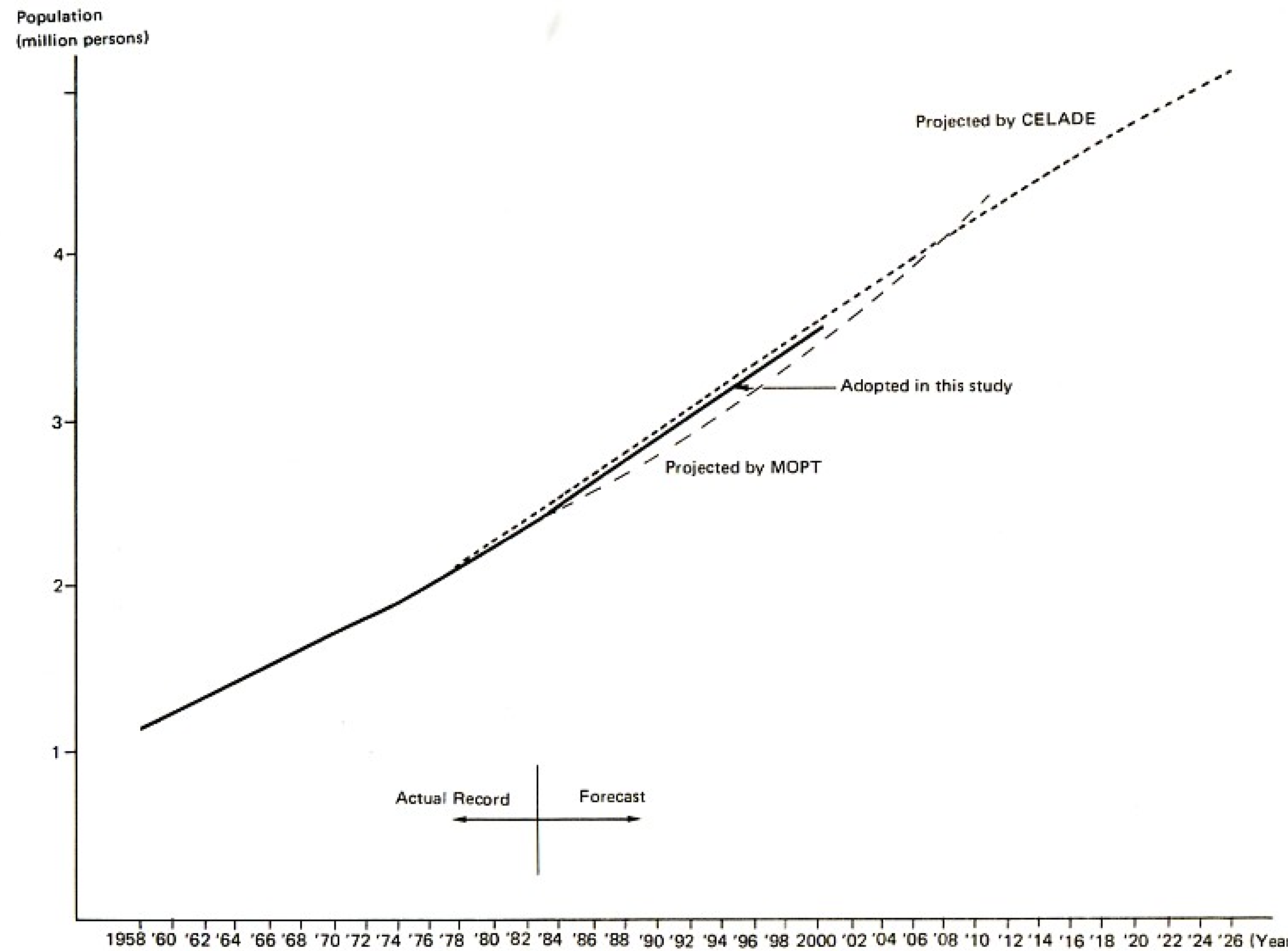
Year	Population (persons)	Compound increase rate (%)
1982	2,371,519	2.78
1985	2,569,597	2.58
1990	2,895,381	2.35
1992	3,027,731	2.23
1995	3,224,405	2.06
2000	3,545,017	1.38

Source : COSTA RICA, ESTIMACIONES Y PROYECCIONES DE POBLACION 1950-2025, CELADE

1. 1. 2 GDP Projection

Actual Costa Rican GDP is shown in Table I-4. The Costa Rican economy gr smoothly through 1979. Costa Rica suffered an economic recession from 1980 through 19 However, the country is currently in a period of economic recovery. In the GDP projecti the recent economic situation should be fully considered.

Concering Costa Rican GDP, BCCR and DGP/MOPT have made projections. At the e of 1985, BCCR made a projection through 1990. Only the BCCR projection reflects the lat economic situation ; the projected values are shown in Table VII-3. To confirm the app priateness of the BCCR projection, two other cases, Case 1 and Case 3, are added



Source of Data in the Past: Anuario Estadístico de Costa Rica, Dirección General de Estadística y Censos

Fig. VII-1 (1) Population Data and Projections

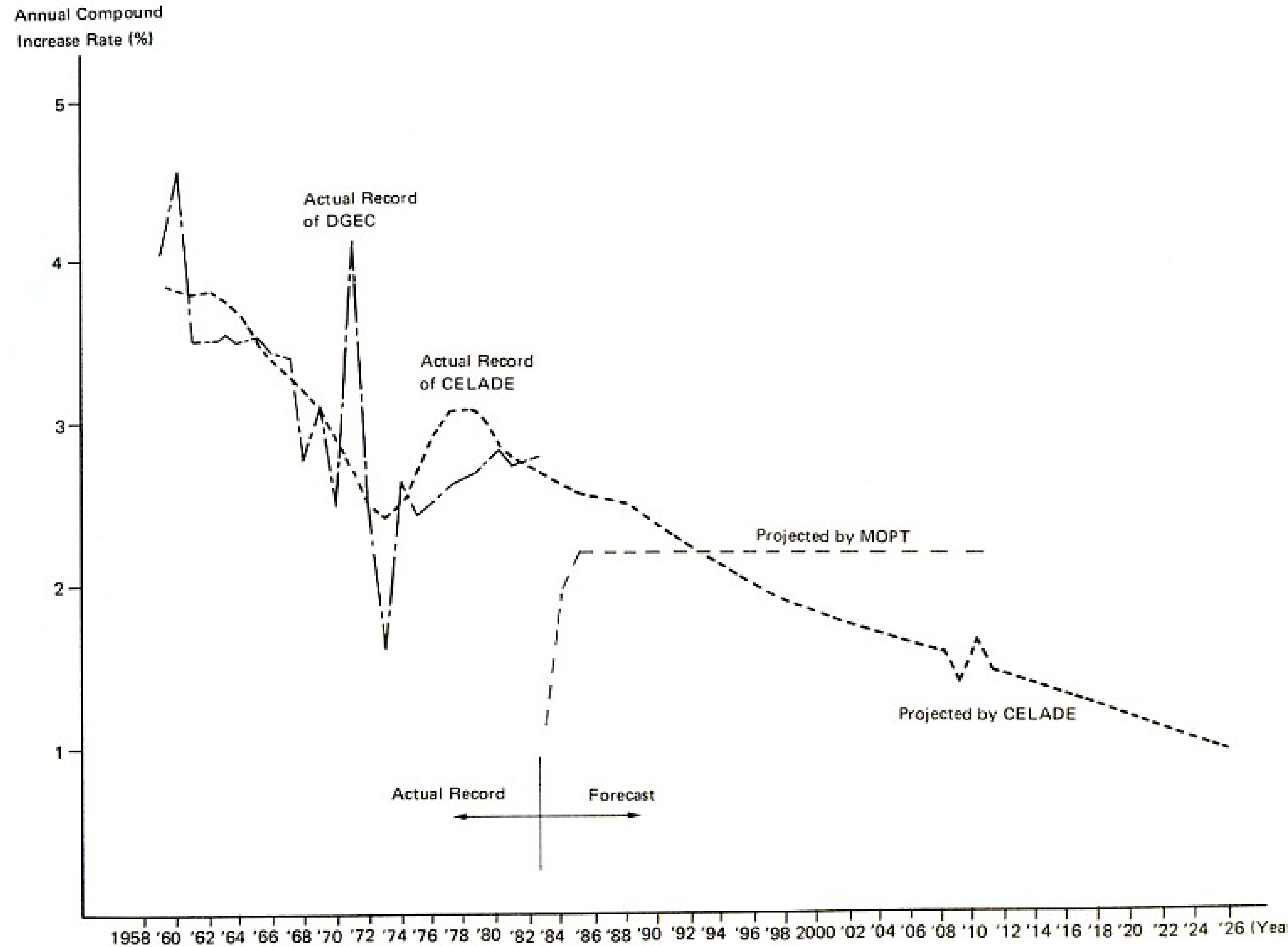


Fig. VII-1 (2) Population Data and Projections

The BCCR projection is the most authoritative and up to date, and seems to most curately reflect the current economic situation in Costa Rica. Therefore, in this study, se 2 is adopted for the future national economic indicators. According to the projection, e Costa Rican economy should grow steadily in the future. Per capita GDP is projected sed on the population projection in the previous section. The result is shown in ble Ⅶ-5.

1. 2 Port Traffic Forecast

In forecasting future cargo volume, two different approaches are used and an accurate rgo forecast is made by comparing the forecast results from the two methods. In general, e cargo volume handled at ports is closely linked with the economic activities in their iterlands.

Following this, the first approach is a macroscopic method, namely, regression analysis the basis of commonly used economic indices such as GDP. The second approach is a croscopic method, meaning that the throughput of selected major cargo items are individu- y forecast. In the microscopic approach, the following items are considered :

- Demand and supply balances of commodities in the region ;
- Trends in producing and consuming districts outside of the region ;
- Cargo movement and cargo distribution among major ports on the Pacific and Atlantic coasts.

1. 2. 1 Macroscopic Forecast

As mentioned above, regression analysis is generally applied in forecasting cargo lume. The historical total port cargo throughput at the Ports of Caldera and Puntarenas nnot solely be used for the regression analysis because it has fluctuated greatly by year. stead, the total national port cargo throughput in Costa Rica is adopted in this analysis. ne correlation between total port cargo volume in Costa Rica and GDP for the period from 66 through 1984 is shown below, and the future total national port cargo throughput is imated using the equation.

$$Y = 349.35X - 387{,}796.31 \quad (R = 0.975)$$

Where X : GDP in Costa Rica (unit : million colones at 1966 constant prices)
Y : Total cargo throughput in Costa Rica (unit : tons)
R : Correlation coefficient

Year	BCCR		DGP/MOPT	
	GDP (at 1966 constant prices)	Annual Growth Rate (%)	GDP (at 1966 constant prices)	Annual Growth Rate (%)
1980			9,647.8	0.75
1981			9,429.6	−2.26
1982			8,742.6	−7.29
1983			8,947.7	2.35
1984	9,513.0	6.3	9,541.8	6.64
1985	9,426.2	−0.9	9,780.3	2.50
1986	9,540.9	1.2	10,024.9	2.50
1987	9,750.8	2.2	10,275.5	2.50
1988	10,014.1	2.7	10,532.4	2.50
1989	10,274.4	2.6	10,795.7	2.50
1990	10,521.0	2.4	11,065.6	2.50
1991			11,342.2	2.50
1992			11,625.8	2.50
1993			11,916.4	2.50
1994			12,214.3	2.50
1995			12,519.7	2.50
1996			12,832.7	2.00
1997			13,153.5	2.00
1998			13,482.3	2.00
1999			13,819.4	2.00
2000			14,164.9	2.00
2001			14,519.0	2.50
2002			14,882.0	2.50
2003			15,254.0	2.50
2004			15,635.4	2.50
2005			16,026.2	2.50
2006			16,426.9	2.00
2007			16,837.6	2.00
2008			17,258.5	2.00
2009			17,690.0	2.00
2010			18,132.2	2.00

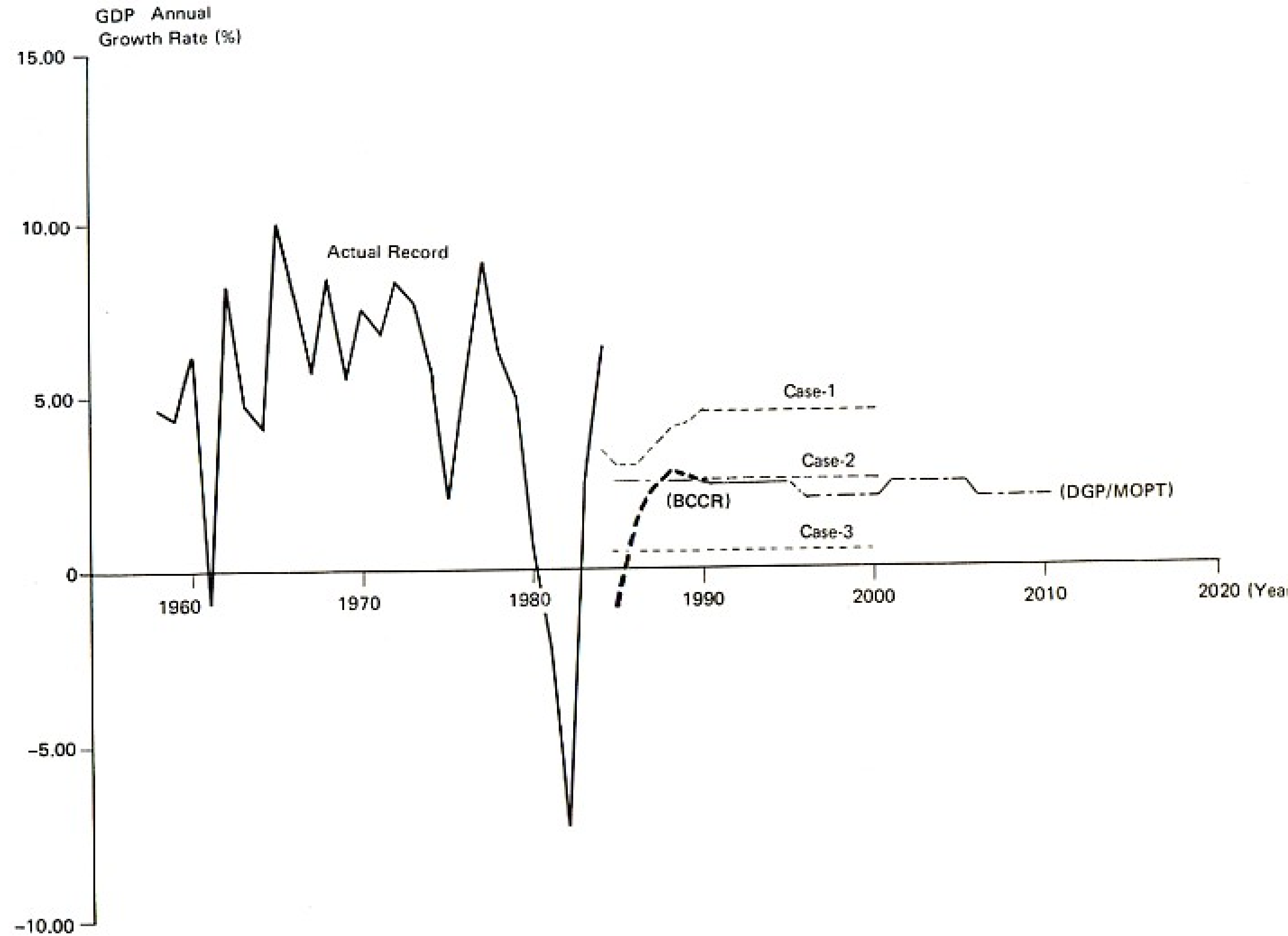
Source 1) : BCCR
2) : DGP/MOPT

Year	Case 1		Case 2		Case-3	
	GDP (at 1966 constant prices)	Annual Growth Rate (%)	GDP (at 1966 constant prices)	Annual Growth Rate (%)	GDP (at 1966 constant prices)	Annual Growth Rate (%)
1983	8,947.7	2.4			8,947.7	2.4
1984	9,251.9	3.4	9,513.0	6.32	9,251.9	3.4
1985	9,529.5	3.0	9,426.2	−0.9	9,298.2	0.5
1986	9,815.4	3.0	9,540.9	1.2	9,344.7	0.5
1987	10,158.9	3.5	9,750.8	2.2	9,391.4	0.5
1988	10,565.3	4.0	10,014.1	2.7	9,438.3	0.5
1989	11,009.0	4.2	10,274.4	2.6	9,485.5	0.5
1990	11,504.4	4.5	10,521.0	2.4	9,532.9	0.5
1991	12,022.1	4.5	10,784.0	2.5	9,580.6	0.5
1992	12,563.1	4.5	11,053.6	2.5	9,628.5	0.5
1993	13,128.4	4.5	11,330.0	2.5	9,676.7	0.5
1994	13,719.2	4.5	11,613.2	2.5	9,725.0	0.5
1995	14,336.6	4.5	11,903.5	2.5	9,773.7	0.5
1996	14,981.7	4.5	12,201.1	2.5	9,822.5	0.5
1997	15,655.9	4.5	12,506.2	2.5	9,871.6	0.5
1998	16,360.4	4.5	12,818.8	2.5	9,921.0	0.5
1999	17,096.6	4.5	13,139.3	2.5	9,970.6	0.5
2000	17,866.0	4.5	13,467.8	2.5	10,020.5	0.5

ource : Data for the period from 1984 through 1990 are from BCCR

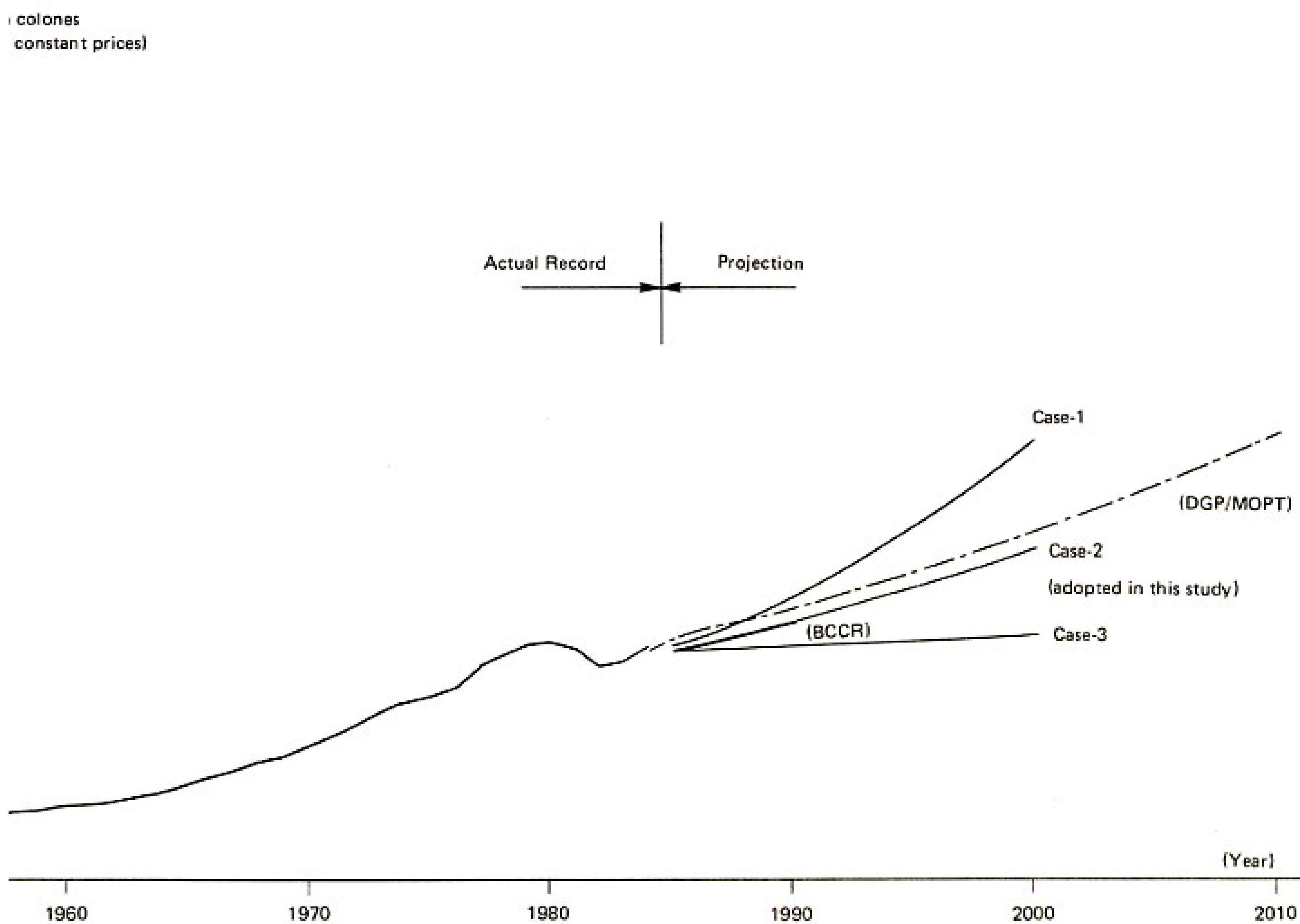
Table VII-5 Projected per Capita GDP

Year	GDP at 1966 constant prices (million colones)	Population ('000 persons)	Per capita GDP ('000 colones/person)
1990	10,521.0	2,895.4	3.63
1992	11,053.6	3,027.7	3.65
1995	11,903.5	3,224.4	3.69
2000	13,467.8	3,545.0	3.80



Source of Data in the Past: Cifras de Cuentas Nacionales de Costa Rica, BCCR

Fig. VII-2 Trends and Projection of GDP Annual Growth Rate



Source of Past Data: Cifras de Cuentas Nacionales de Costa Rica, BCCR

Fig. VII-3 Historical and Projected GDP

To divide the above total cargo volume into cargo volume on the Pacific and Atlantic coasts, the future share of the cargo volume on the Pacific coast is calculated. The following two cases are studied in this section.

Case－A : Where the share is the same as in 1984

Case－B : Where the share will grow until 1990 at the same rate as it did from 1982 through 1984, and then remain constant after 1990.

For Case－B, the correlation between the share of the Pacific coast ports and the year is shown below.

$$Y = 0.0857X + 51.15 \qquad (R = 0.961)$$

Where X : Year minus 1900

Y : The share of cargo volume handled at ports on the Pacific coast (to the total cargo volume of Costa Rica)

R : Correlation coefficient

However, it seems that the share grows unrealistically in Case－B. Thus, as a moderate estimate in this report the average value of Case－A and Case－B is calculated and adopted. Accordingly, the total cargo volume on the Pacific coast is obtained as shown in Table VII-6. However, it should be noted that this table includes the cargo volume at the Ports of Punta Morales and FERTICA. These volumes should be deducted from this table to obtain the cargo volume at the Ports of Caldera and Puntarenas.

Table VII-6 Macroscopic Forecast

Year	GDP at 1966 constant prices (million colones)	Costa Rican Port Cargo Volume ('000 tons)	The Pacific Coast Ports			
			Share (%)			Total Cargo Volume ('000 tons)
			Case-A	Case-B	Average	
(Actual)						
1980	9,647.8	2,791.7			22.5	628.1
1984	9,513.0	3,017.7			23.8	717.0
(Projected)						
1985	9,426.2	2,905.2	23.8	26.0	24.9	723.4
1990	10,521.0	3,287.7	23.8	39.0	31.4	1,032.3
1992	11,053.6	3,473.8	23.8	39.0	31.4	1,090.8
1995	11,903.5	3,770.7	23.8	39.0	31.4	1,184.0
2000	13,467.8	4,317.2	23.8	39.0	31.4	1,355.6

Note 1) Share : The share of the cargo volume handled at the Pacific coast ports in the total cargo volume in Costa Rica.

2) Case-A : Where the share is the same as in 1984

3) Case-B : Where the share will grow until 1990 at the same rate as it did from 1982 through 1984, and then remain constant after 1990.

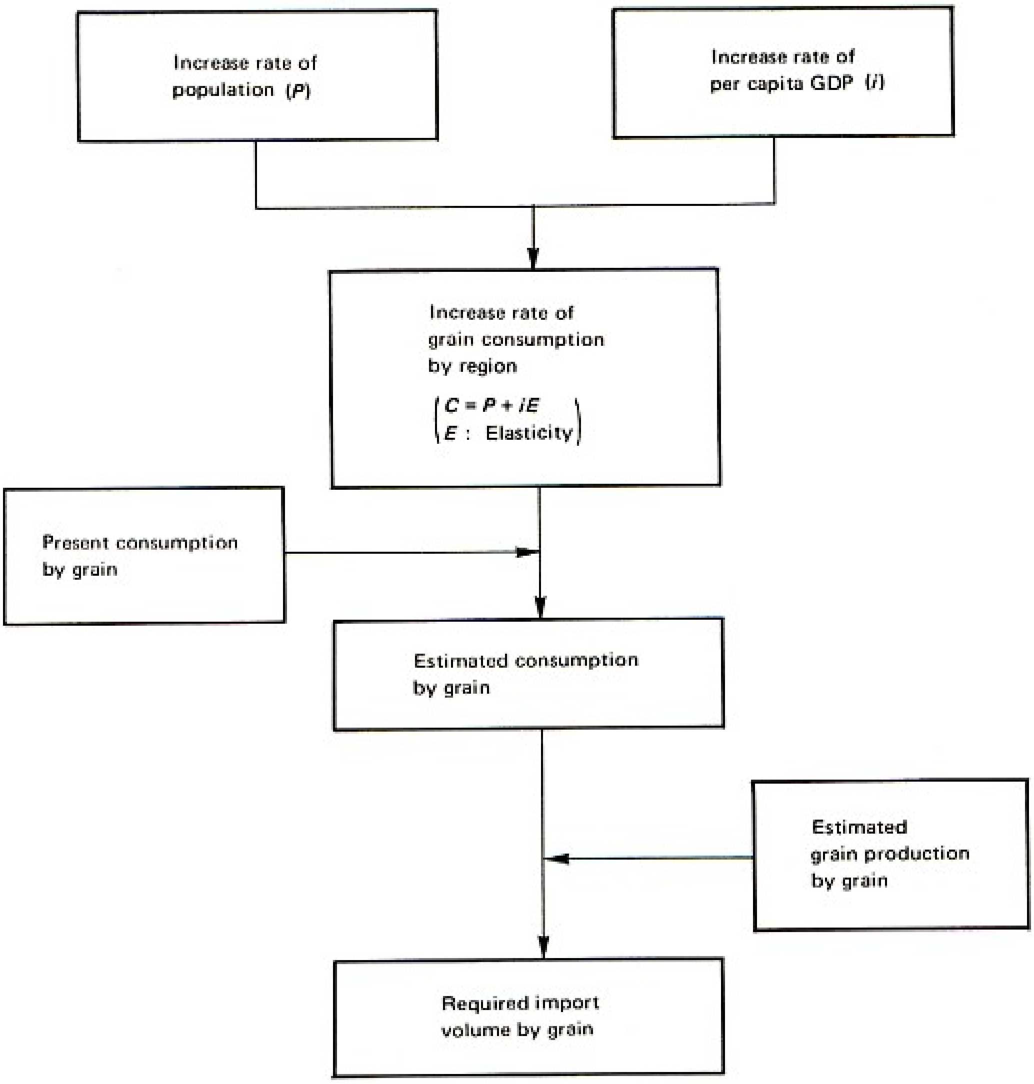


Fig. VII-4 Forecast Procedure of Grain Import for Human Consumption

Table VII-7 Grain Consumption Projection

Year	Total	Human Consumption				Feed Consumption
		Cleaned Rice	Beans	White Corn	Wheat	Yellow Corn and Sorghum
1984	426,400	115,100	22,900	63,400	104,600	120,400
1990	502,100	133,500	26,500	73,200	121,300	147,600
1992	528,600	139,800	27,700	76,200	127,000	157,900
1995	569,300	149,000	29,400	80,700	135,400	174,800
2000	640,900	164,300	32,300	87,900	149,200	207,200

Source 1984-1992 : Dirección de Planificación del CNP
1993-2000 : JST

Table VII-8 Net Grain Production Volume Projection

Year	Total	Cleaned Rice	Beans	White Corn	Yellow Corn	Sorghum
1984	280,600	129,000	21,700	63,300	18,100	48,500
1990	159,200	151,700	25,600	72,500	26,200	83,200
1992	382,700	160,000	26,600	76,100	27,500	92,500
1995	434,500	172,200	29,500	81,500	32,500	118,800
2000	544,000	194,500	34,900	91,400	42,600	180,600

Source 1984-1993 : Dirección de Planificación, CNP
1994-2000 : JST

Table VII-9 Projected Grain Import Volume

Year	Total	Human Consumption				Feed Consumption
		Cleaned Rice	Beans	White Corn	Wheat	Yellow Corn and Sorghum
1984	159,700	—	1,200	100	104,600	53,800
1990	161,100	—	900	800	118,500	38,000
1992	166,100	—	1,100	100	127,000	37,900
1995	158,900	—	—	—	135,400	23,500
2000	149,200	—	—	—	149,200	—

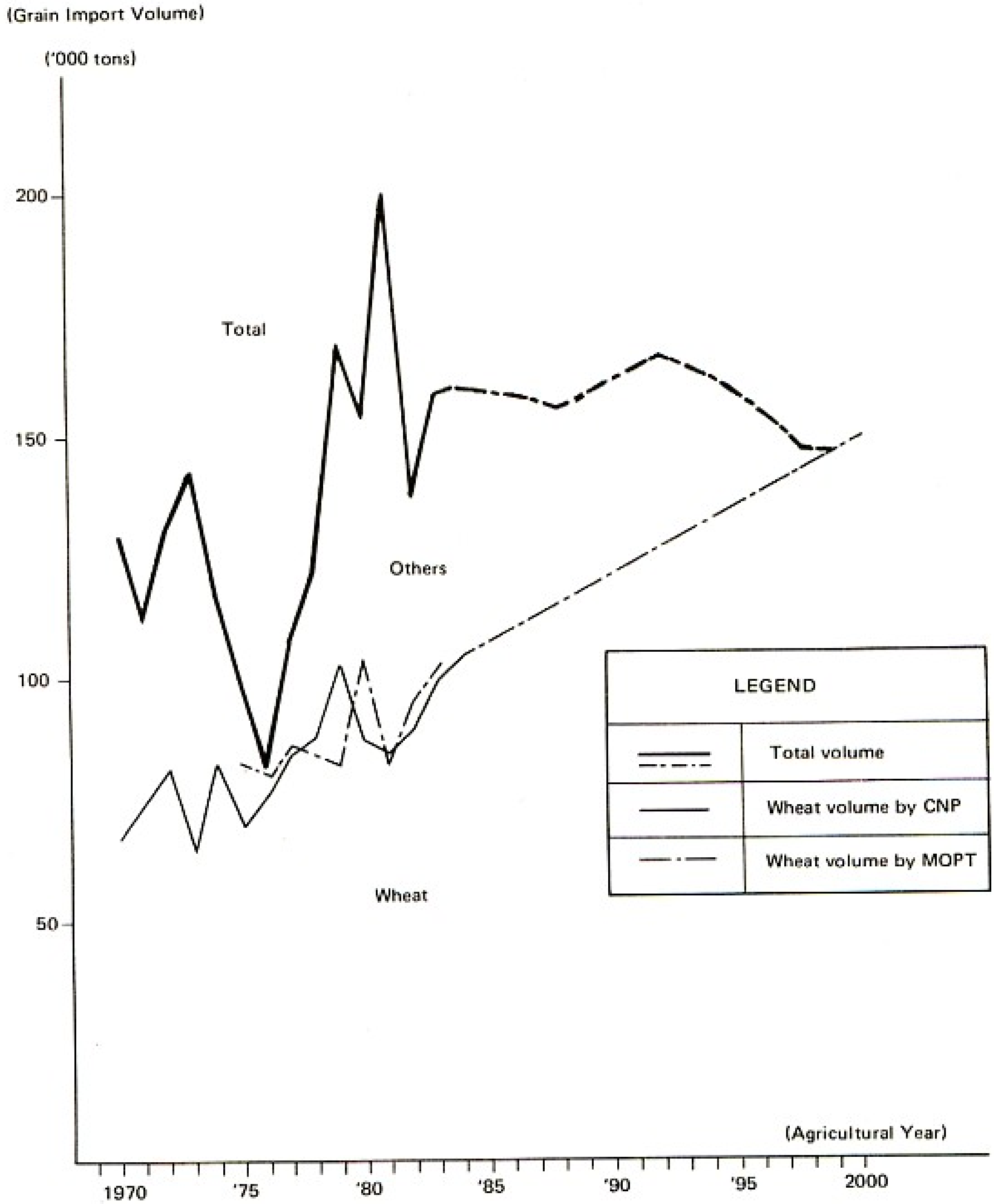


Fig. VII-5 Grain Import Forecast

aldera due to the superannuation of Puntarenas pier.

(2) Automobiles

Total automobile imports in Costa Rica including automobile imports handled at the orts of Caldera and Puntarenas rapidly increased up to 1980. However, after that, Costa ican automobile imports drastically decreased due to the economic recession and the large ustoms duties imposed on imported automobiles (refer to Fig.VII-6).

However, Costa Rica is presently undergoing an economic recovery, and when the omestic economy recovers the large customs duties on imported automobiles may by educed to the lower tariff levels which were charged before 1980. Thus, we assume that utomobile imports will increase in the future.

The correlation between automobile imports and GDP for the period from 1969 through 980 can be shown as follows :

$$Y = 4.925X - 21,821 \quad (R = 0.906)$$

Where X : GDP (unit: '000 colones at 1966 constant prices)
Y : Automobile import volume (unit : tons)
R : Correlation coefficinet

In calculating the above equation, of course, data after 1980 are excluded. The future are of the Port of Caldera in the total automobile import volume in Costa Rica is assumed be the average share of 67.1% of the period from 1969 through 1980. Consequently, the ture automobile import volume at the Port of Caldera is forecast as shown in Table VII-10.

Table VII-10 Automobile Import Forecast

(Unit : tons)

Year	Caldera and Puntarenas (share %)	Limón and Moín	Total
(Actual)			
1970	5,467 (83.1)	1,110	6,577
1975	8,019 (57.2)	5,993	14,012
1980	15,279 (75.5)	4,953	20,232
1984	4,816 (65.8)	2,507	7,323
(Projected)			
1990	20,100 (67.1)	9,900	30,000
1992	21,900 (67.1)	10,700	32,600
2000	29,900 (67.1)	14,600	44,500

ource of Actual Data : CUADROS ESTADISTICOS SOBRE SECTOR TRANSPORTES, DGP/MOPT

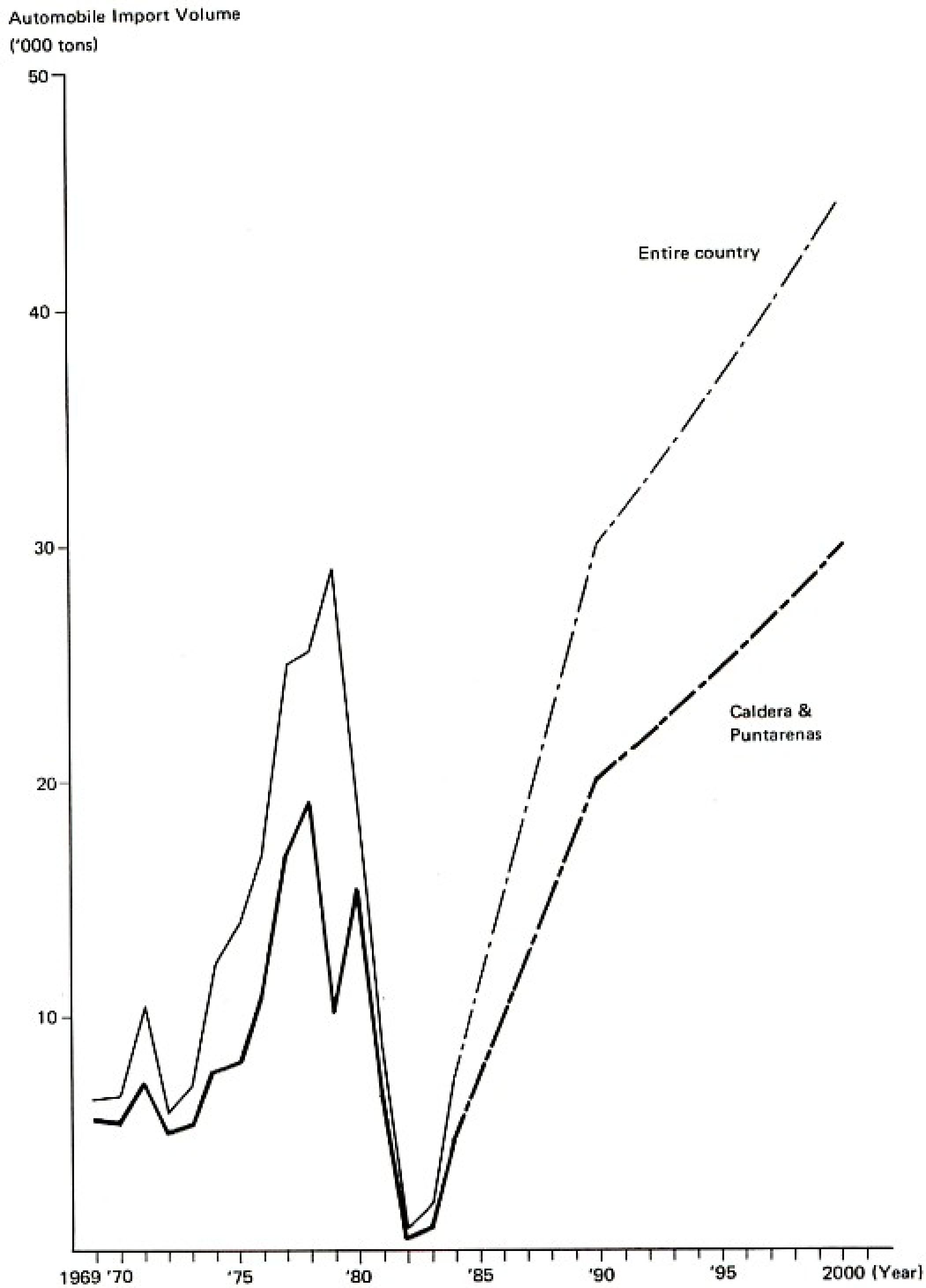


Fig. VII-6 Automobile Import Volume

(3) Iron and Steel

The flow chart for the iron and steel import forecast is shown in Fig.VII-7. As seen in this figure, first, the national iron and steel consumption is estimated. The import volume at the Port of Caldera is then forecast using the share of the port in the national imports.

National iron and steel consumption is obtained using the following equation based on Fig.VII-8 and Table VII-11.

$$Y = 22.64X - 32.32 \quad (R = 0.765)$$

Where X : Per capita GDP (unit : thousand colones per person at 1966 constant prices)
Y : Per capita iron and steel consumption (unit : kgf/person)
R : Correlation coefficient

To analyse the relation between per capita GDP and per capita iron and steel consumption, data from 1969 through 1980 are used and data after 1980 are not used because these are influenced by the economic recession during that time. Total future national iron and steel consumption can be obtained by multiplying per capita consumption from the above equation by the future national population. There is no steel plant in Costa Rica. Thus, all consumption must be imported.

The share of the Port of Caldera in national iron and steel imports has fluctuated in the past. The average share of 54.5% for the last 16 years from 1969 through 1984 is adopted in this study.

Consequently, iron and steel import volume at the Port of Caldera is forecast as shown in Table VII-12. The historical volume of iron and steel imports and the future projections are presented graphically in Fig.VII-9.

(4) Fertilizer

FERTICA which is one of the two Costa Rican fertilizer companies operates a fertilizer plant at Puntarenas. Most Costa Rican fertilizer is produced at this plant. Thus, almost all the country's fertilizer exports are shipped from the Pacific coast. FERTICA has its own private wharf facilities where fertilizer materials and products are loaded and unloaded.

As large vessels cannot dock directly at the FERTICA wharf, fertilizer cargoes are carried by barges between the FERTICA facilities and the large vessels which anchor offshore.

1) Imports

In the past, fertilizer imports have rarely been handled at the public Ports of Caldera and Puntarenas. Such imports have sometimes been handled in a spotty way at the ports, but the volume has not been significant. Thus, almost all of the fertilizer imports have been handled at the private wharf of FERTICA, and this situation is expected to continue in the future. Nonetheless, the fertilizer handled at the FERTICA facilities results in tariff income to INCOP. The future fertilizer import cargo volume is forecast below.

In estimating future fertilizer import volume, it is assumed that fertilizer imports will increase along with the production increase of such basic grains as rice, beans, sorghum and yellow and white corn. SEPSA has a plan to increase the domestic production of these basic

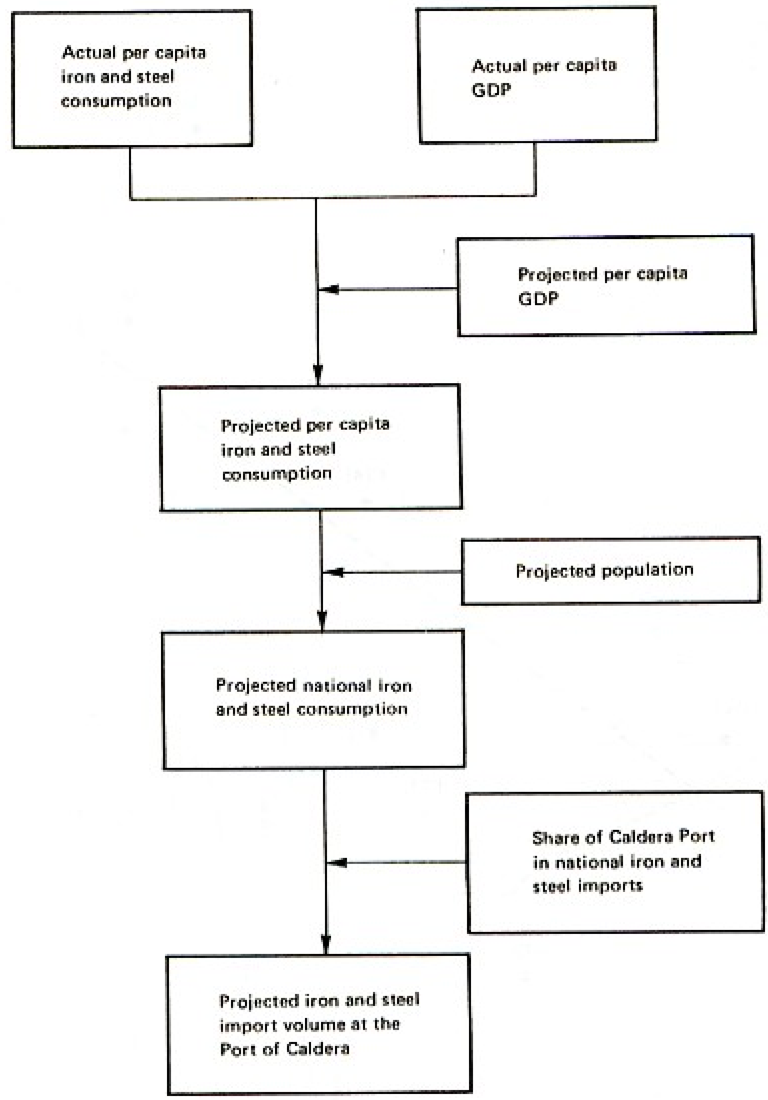


Fig. VII-7 Flow Chart of Iron and Steel Import Volume Projection

Table VII-11 Actual Iron and Steel Imports

Year	National Iron and Steel Import Volume[1] (tons)	Per capita Steel Consumption (kgf/person)	Per capita GDP (at 1966 constant prices) ('000 colones)	Imports through Caldera and Puntarenas (tons) (share %)
1970	85,915	49.74	3.23	45,023 (52.4)
1975	87,182	44.29	3.80	43,072 (49.4)
1980	134,765	60.02	4.30	90,190 (66.9)
1984	132,677	53.11	3.81	53.185 (40.1)

Source 1) : CUADROS ESTADISTICOS SOBRE SECTOR TRANSPORTES, DGP/MOPT

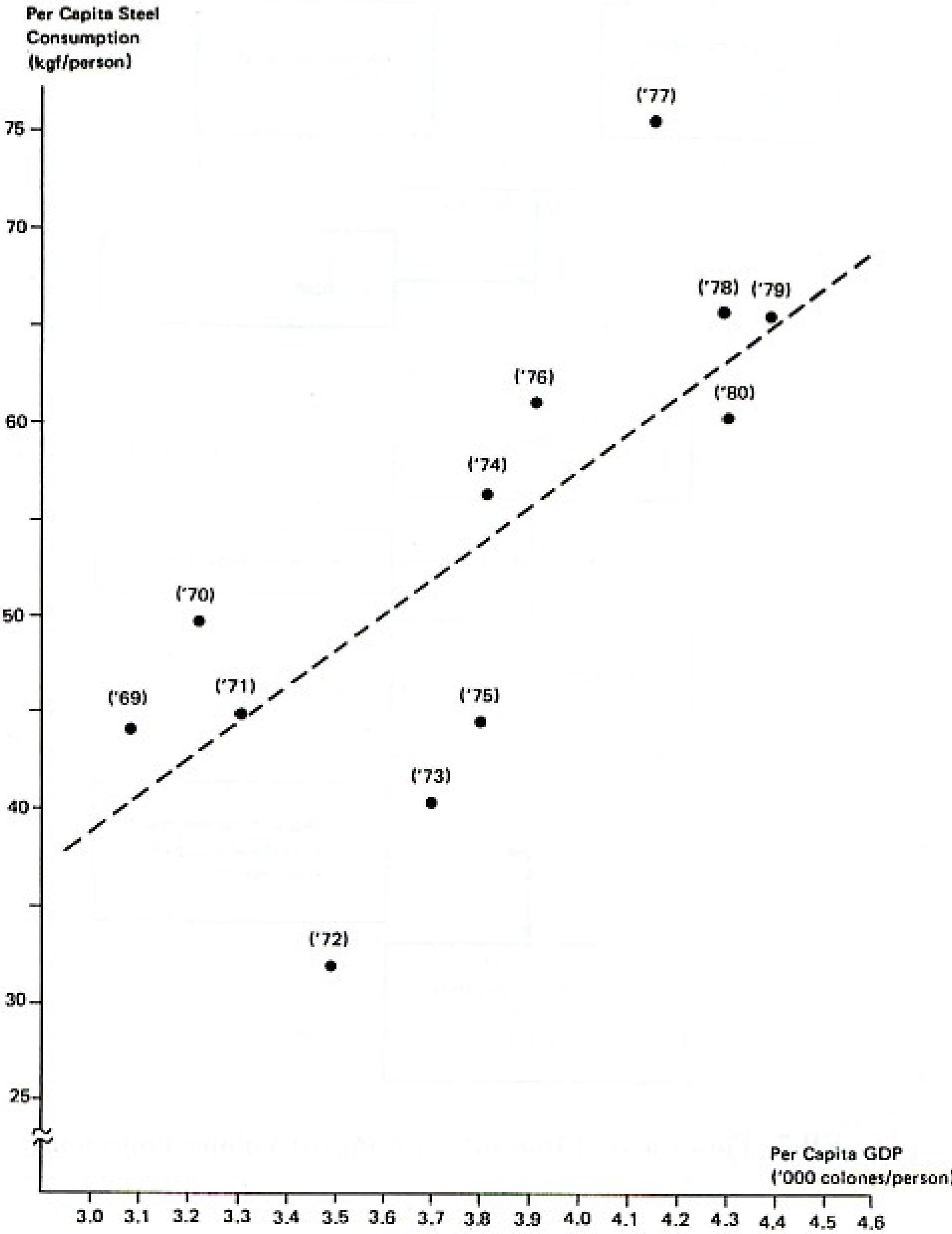


Fig. VII-8 Per Capita Iron and Steel Consumption

Table VII-12 Projected Iron and steel Imports

Unit : tons

Year	The entire nation	The Port of Caldera
1990	144,000	78,700
1992	152,000	83,000
1995	165,000	90,000
2000	190,000	103,800

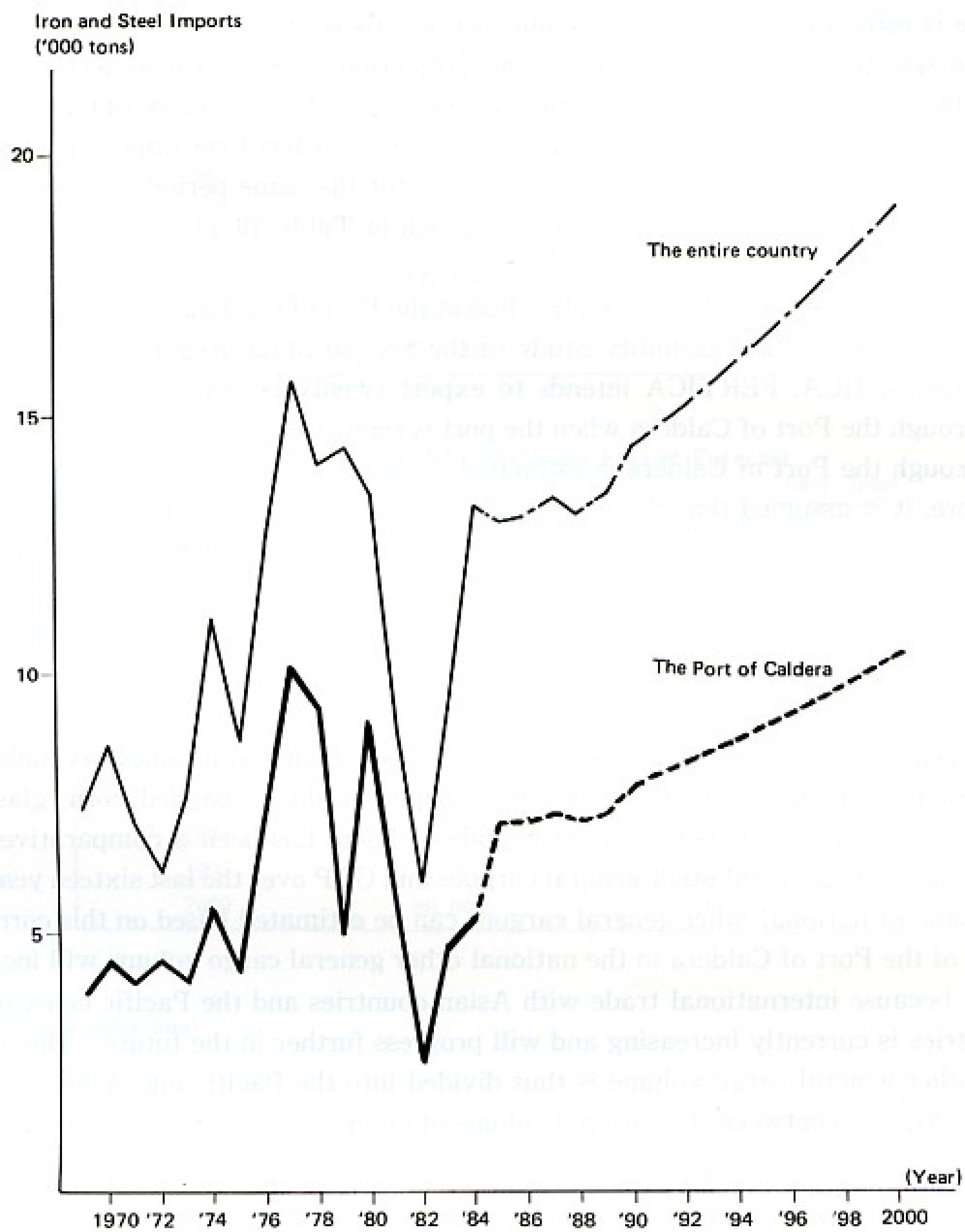


Fig. VII-9 Iron and Steel Import Volume

grains at an annual increase rate of 3.61 for the period from 1983 through 1992. This rate of increase is estimated to continue through 2000 in this study.

1982 is selected as the base year for the projection. The national fertilizer import volume in the base year is assumed to be the average value of 100,000 tons of the period from 1980 through 1984. The share of FERTICA in the national fertilizer import volume in the base year is assumed to be 82%, the average value for the same period. Accordingly, the fertilizer import cargo volume is projected as shown in Table VII-13.

2) Exports

Fertilizer exports have seldom been handled at the Port of Caldera. However, according to the Final Report of the Feasibility Study of the Second Stage Expansion Project at the Port of Caldera, JICA, FERTICA intends to export twenty percent of its total fertilizer exports through the Port of Caldera when the port is renovated. Therefore, fertilizer export volume through the Port of Caldera is estimated in this study based on the FERTICA plan. Furthermore, it is assumed that the total fertilizer export volume of FERTICA will reach eighty thousand tons in the year 2000. The estimates are presented in Table VII-14 and Fig.VII-10.

(5) Other general cargoes

1) Imports

Other general cargoes include processed foods, such chemical products as rubber products, chemical medicines and plastic products, paper products, bagged corn, glasswares, metals other than iron and steel, and automobiles. There has been a comparatively close correlation between national other general cargoes and GDP over the last sixteen years. The future volume of national other general cargoes can be estimated based on this correlation. The share of the Port of Caldera in the national other general cargo volume will increase in the future because international trade with Asian countries and the Pacific coast of American countries is currently increasing and will progress further in the future. The projected national other general cargo volume is thus divided into the Pacific and Atlantic shares.

The correlation between the national volume of other general cargoes and GDP is shown below.

$$Y = 158.29X - 239.338 \qquad (R = 0.938)$$

Where X : GDP in Costa Rica (unit : million colones at 1966 constant prices)
Y : National other general cargo volume (unit: tons)
R : Correlation coefficient

The future share of cargo volume on the Pacific coast in the nationl other general cargo volume is calculated based on the data from 1976 through 1984. The correlation equation is shown below.

Table VII-13 Fertilizer Import Forecast

(unit : tons)

	Costa Rica	The Pacific coast
(Actual)		
1980	130,590	72,179
1984	86,214	83,620
(Projected)		
1990	132,800	108,900
1992	142,600	116,900
1995	158,600	130,100
2000	189,300	155,200

Table VII-14 FERTICA Fertilizer Export Forecast

(unit : tons)

Year	FERTICA Fertilizer Export Volume	
	Total	The Port of Caldera
(Actual)		
1976	92,261	—
1981	68,016	—
1984	27,470	—
(Projected)		
1990	48,000	10,000
1992	53,000	10,000
1995	62,000	12,000
2000	80,000	16,000

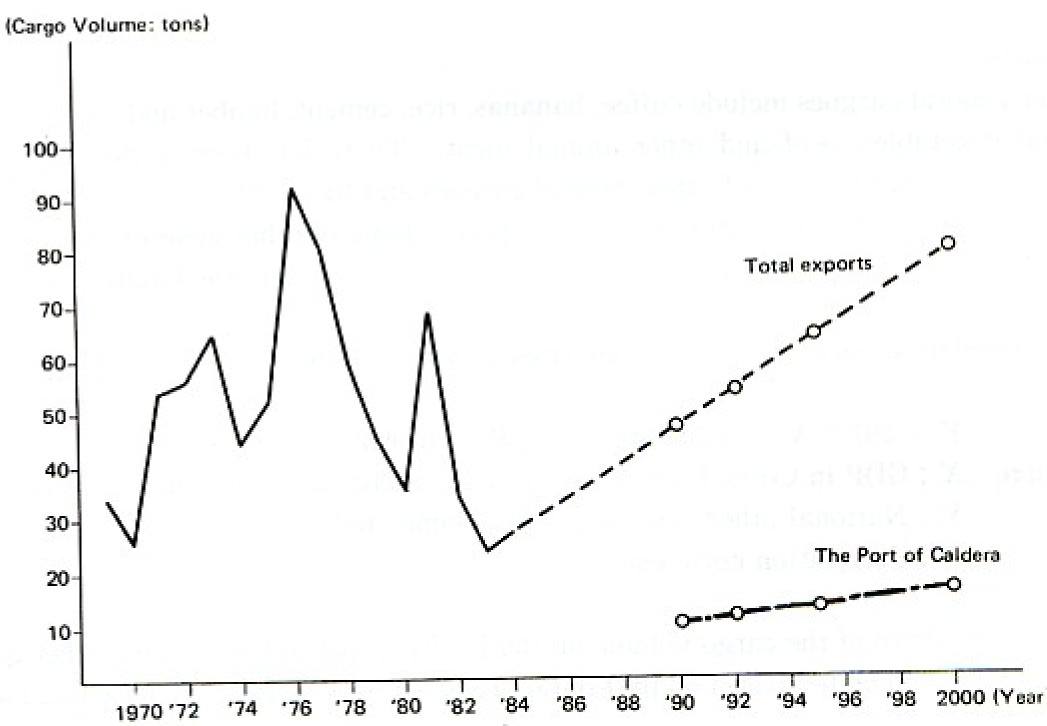


Fig. VII-10 Fertilizer Export Forecast

$$Y = 0.572X - 30.83 \quad (R=0.526)$$

Where X : Year minus 1900

Y : The share of other general cargo volume on the Pacific coast, that is at the Port of Caldera

R : Correlation coefficient

Consequently, the other general cargo import volume at the Port of Caldera is obtained as shown in Table VII-15 and Fig.VII-11.

Table VII-15 Other General Cargo Import Forecast

Year	National Total (tons)	The port of Caldera	
		Share (%)	Cargo Volume (tons)
(Actual)[1]			
1970	668,526	30.6	204,851
1975	898,881	14.8	133,203
1980	1,345,962	16.5	221,661
1984	1,175,471	16.9	198,157
(Projected)			
1990	1,426,000	20.7	294,000
1992	1,510,000	21.8	329,000
1995	1,645,000	23.5	387,000
2000	1,892,000	26.3	498,000

Source 1): CUADROS ESTADISTICOS SOBRE SECTOR TRANSPORTES, DGP/MOPT

Note : Cargo volume at the Port of Caldera includes that handled at the Port of Puntarenas in the past.

2) Exports

Other general cargoes include coffee, bananas, rice, cement, lumber and wood products, fruits and vegetables, beef and other animal meat. There has been a close correlation between the national exports of other general cargoes and the GDP for the last three years. Based on the correlation, the future national export volume of other general cargoes can be estimated. The estimated national volume is then broken down into the Pacific and Atlantic shares.

The correlation between the national other general cargoes and GDP is shown below.

$$Y = 297.6X - 1,567,280 \quad (R = 0.995)$$

Where X : GDP in Costa Rica (unit : million colones at 1966 constant prices)

Y : National other general cargo volume (unit: tons)

R : Correlation cofficient

The future share of the cargo volume on the Pacific coast in the national other general caego volume is calculated based on past data. The correlation equation, based on the past

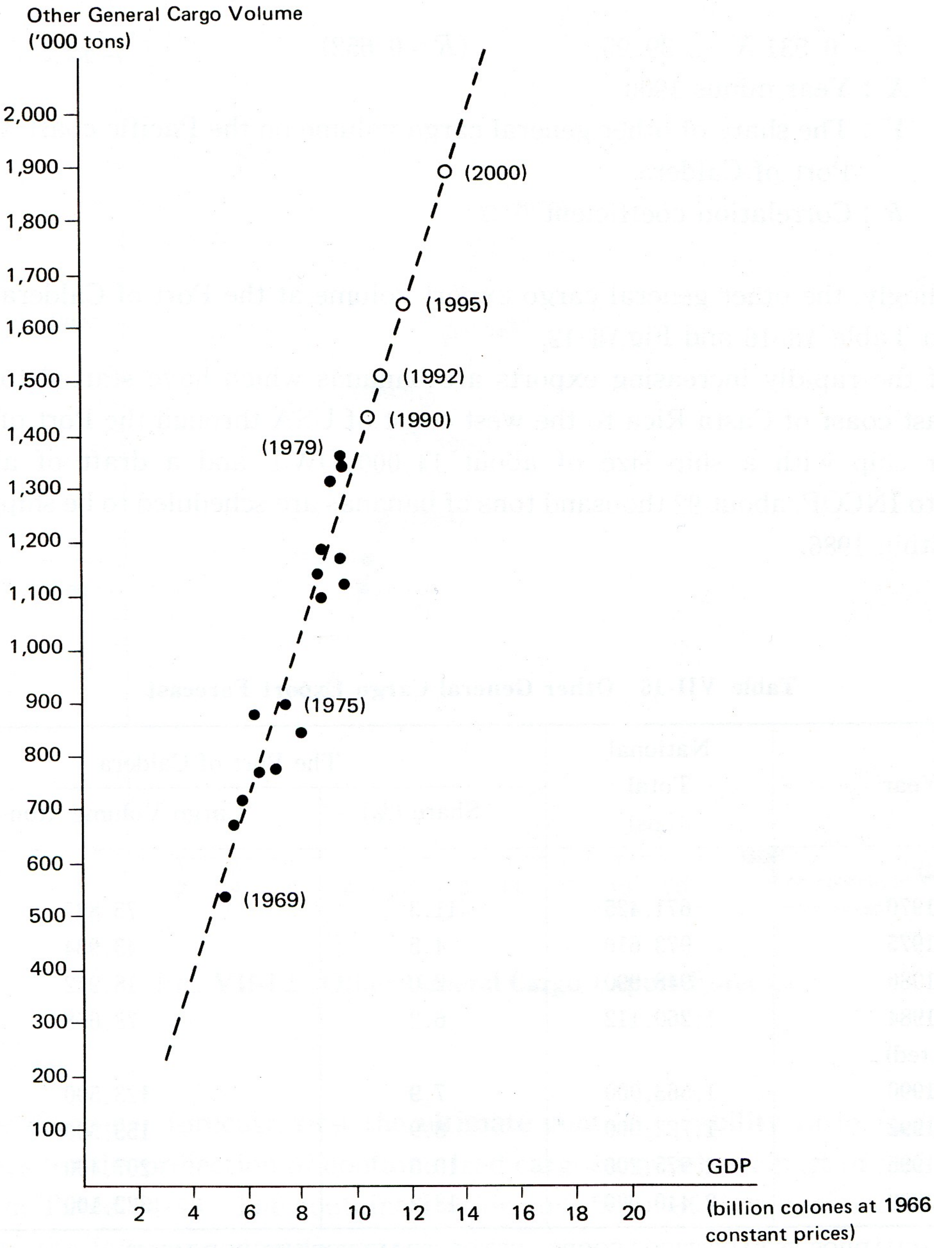


Fig. VII-11 Other General Cargo Import Forecast

trend for the period from 1979 through 1984, is shown below.

$$Y = 0.531X - 39.95 \qquad (R = 0.652)$$

Where X : Year minus 1900

Y : The share of other general cargo volume on the Pacific coast, that is at the Port of Caldera

R : Correlation coefficient

Accordingly, the other general cargo export volume at the Port of Caldera is obtained as shown in Table VII-16 and Fig.VII-12.

Part of the rapidly increasing exports are bananas which have started to be shipped from the east coast of Casta Rica to the west coast of USA through the Port of Caldera by refrigerator ship with a ship size of about 14,000 DWT and a draft of about 8.8 m. According to INCOP, about 92 thousand tons of bananas are scheduled to be shipped through the port within 1986.

Table VII-16 Other General Cargo Export Forecast

Year	National Total (tons)	The Port of Caldera	
		Share (%)	Cargo Volume (tons)
(Actual)[1]			
1970	671,425	11.3	75,887
1975	973,610	4.5	43,934
1980	948,990	2.0	18,972
1984	1,260,112	6.2	78,668
(Projected)			
1990	1,563,000	7.9	123,500
1992	1,722,000	8.9	153,300
1995	1,975,200	10.5	207,400
2000	2,440,000	13.2	322,100

Source 1): CUADROS ESTADISTICOS SOBRE SECTOR TRANSPORTES, DGP/MOPT
Note : Cargo volume at the Port of Caldera includes that handled at the Port of Puntarenas in the past.

(6) Containerized Cargo

Part of the general cargoes are transported in containers. In this section, the containerized cargo volume of general cargoes is projected. Port cargoes other than grain bulk and automobiles are taken to be general cargoes in this study.

The flow chart of the containerized cargo volume forecast is shown in Fig.VII-13. Detailed past data concering individual commodity items and their respective containerized cargo volume are not available. However, containerized cargoes totalling 28,452 tons for import and 26,760 for export were handled at the Ports of Caldera and Puntareas in 1984.

trend for the period from 1979 through 1984, is shown below.

$$Y = 0.531X - 39.95 \qquad (R = 0.652)$$

Where X : Year minus 1900

Y : The share of other general cargo volume on the Pacific coast, that is at the Port of Caldera

R : Correlation coefficient

Accordingly, the other general cargo export volume at the Port of Caldera is obtained as shown in Table VII-16 and Fig.VII-12.

Part of the rapidly increasing exports are bananas which have started to be shipped from the east coast of Casta Rica to the west coast of USA through the Port of Caldera by refrigerator ship with a ship size of about 14,000 DWT and a draft of about 8.8 m. According to INCOP, about 92 thousand tons of bananas are scheduled to be shipped through the port within 1986.

Table VII-16 Other General Cargo Export Forecast

Year	National Total (tons)	The Port of Caldera	
		Share (%)	Cargo Volume (tons)
(Actual)[1]			
1970	671,425	11.3	75,887
1975	973,610	4.5	43,934
1980	948,990	2.0	18,972
1984	1,260,112	6.2	78,668
(Projected)			
1990	1,563,000	7.9	123,500
1992	1,722,000	8.9	153,300
1995	1,975,200	10.5	207,400
2000	2,440,000	13.2	322,100

Source 1): CUADROS ESTADISTICOS SOBRE SECTOR TRANSPORTES, DGP/MOPT
Note : Cargo volume at the Port of Caldera includes that handled at the Port of Puntarenas in the past.

(6) Containerized Cargo

Part of the general cargoes are transported in containers. In this section, the containerized cargo volume of general cargoes is projected. Port cargoes other than grain bulk and automobiles are taken to be general cargoes in this study.

The flow chart of the containerized cargo volume forecast is shown in Fig.VII-13. Detailed past data concering individual commodity items and their respective containerized cargo volume are not available. However, containerized cargoes totalling 28,452 tons for import and 26,760 for export were handled at the Ports of Caldera and Puntareas in 1984.

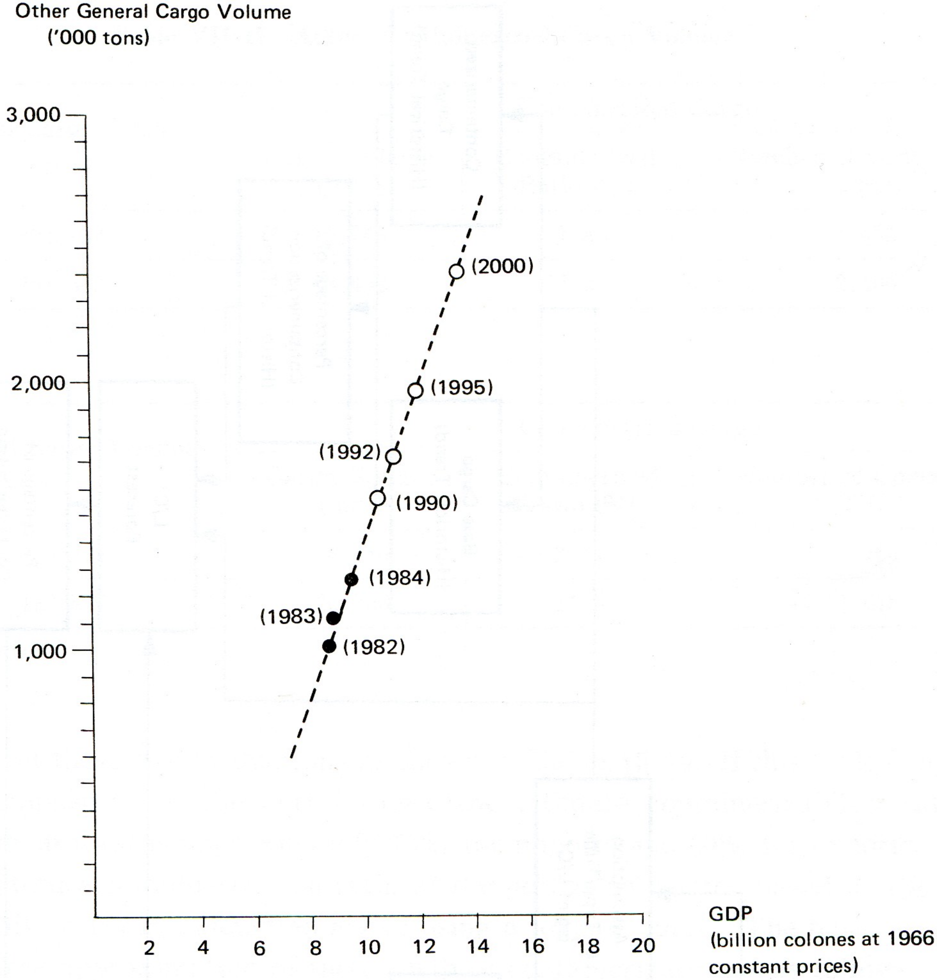


Fig. VII-12 Other General Cargo Export Forecast

For the container forecast, first the ultimate containerizability ratio P_m is calculated. Base cargoes for the projection of containerized cargoes, which are part of general cargoes, are shown in Table VII-18. The containerization suitability of each commodity is classified according to the following classification.

A : Cargo suited for containerization

B : Item containing both cargo suited for containerization and cargo not suited for containerization

C : Cargo not suited for containerization

The likelihood that individual cargo items will be containerized also varies by cargo route. Thus, the commodities are also classified by trade route as follows.

A : Cargo traded mainly with North America, Europe and the Far East ;

B : Cargo unable to be classified as either A or C ;

C : Cargo traded mainly with Central American countries.

The base cargoes are evaluated in Table VII-18 based on their suitability for containerization and their trade routes. The overall containerizability of each commodity is based on

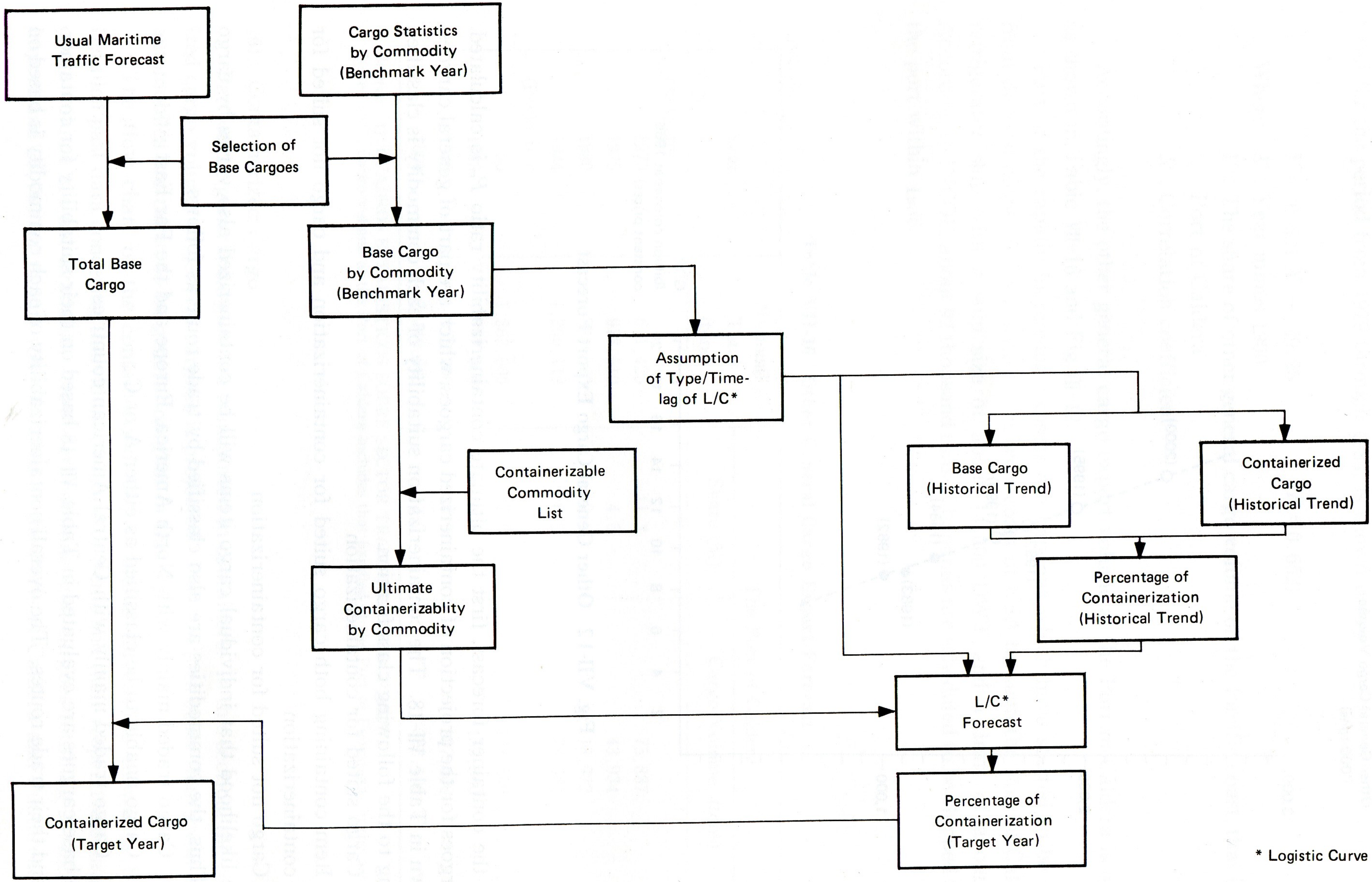


Fig. VII-13 Flow Chart of Containerized Cargo Forecast

Table VII-17 Actual Containerized Cargo Volume

(Imports)

Year	General Cargo Volume (tons)	Containerized Cargo		
		Cargo Volume (tons)	Containerized Ratio (%)	Number of Contatiners (TEU)
1983	202,732	15,743	7.8	1,452
1984	251,342	28,452	11.3	2,406

(Exports)

Year	General Cargo Volume (tons)	Containerized Cargo		
		Cargo Volume (tons)	Containerized Ratio (%)	Number of Containers (TEU)
1983	139,922	28,486	20.4	1,764
1984	183,892	26,760	14.6	1,678

Source : DGOPF/MOPT

a combination of these two evaluations as shown in Table VII-19. If this table is applied to commodity composition at the port in 1983, the ultimate containerizability ratio P_m of general cargoes in total is approximately 75% for imports and 60% for exports.

Next, the future containerization ratio at the port is calculated based on the ultimate containerizability ratio P_m calculated above using a logistic curve. The basic equation for the logistic curve approximation of the growth of containerization is as follows :

$$P = \frac{P_m}{1+C^{(t-t_0)}}$$

Where P : Percentage of containerization by route at year t

P_m : Ultimate containerizability by route which is defined as "percent age of containerization by route at the fully containerized stage"

C : A parameter

t : Year

t_0 : Time lag in years

Usually, the values of parameters C and t_0 and the starting point of t are obtained based on regression analysis of containerization in the past. However, such exceptional circumstances as shown below should be fully considered at the Port of Caldera.

1) Data on past containerization is available for only two years.
2) The containerized ratio for export unexpectedly decreased from 1983 to 1984.
3) The tendency of containerization in the past cannot be assumed to continue in the future without any change because the operation of full-container ships between the Port of Caldera and Europe has been suspended.

Table VII-18 Suitability of Containerization and Trade Routes

IMPORTS			EXPORTS		
Commodity Groups	Suitability	Route	Commodity Groups	Suitability	Route
Agricultural and Food Products	A	C	Processed and Agricultural Products	A	A
Rubber Products and Cement	A	B	Fruits and Vegetables	A	C
Chemical Products	A	A	Lumber, Wood Products and Pulp	A	C
Machinery and Parts	A	A	Others	A	C
Vehicles and Construction Machinery	B	B			
Paper and Cartons	A	A			
Manufactured Metal	A	A			
Clothes, Glass Products and Pulp	B	B			
Others	A	A			

Table VII-19 Containerizability corresponding to Suitability and Trade Routes

IMPORTS			EXPORTS		
Suitability	Trade Route	Containerizability (%)	Suitability	Trade Route	Containerizability (%)
A	A	95	A	A	95
A	B, C	50	A	C	20
B	A, B, C	10	B	C	10
C	A, B, C	0	C	A, C	0

Thus, the following approach is adopted in this study.

1) The study mainly aims at the projection of containerization after 1990. Calculated containerized ratios from 1985 through 1989 can be considered imaginary.
2) Values in Table VII-20 which are calculated by regression analysis based on the past data on the containerized shipping routes between Japan and various developing countries are adopted for parameters C and t_0 in this study.
3) The starting point of t is set as 1980 considering the fact that the operation of full-container ships has been suspended. Subsequently, the suspension will delay the containerization at the Port of Caldera by about five years in the future compared to the imagingary containerization ratios.

Table VII-20 Values of Parameters C and t_0

	C	t_0 (years)
Imports	0.72	13
Exports	0.64	13

The time progression of the calculated containerizability is shown in Fig.VII-14. Consequently, the future containerized ratios, containerized cargo volume and the number of containers at the Port of Caldera are projected as shown in Table VII-21 and Table VII-22, respectively.

(7) Sugar

The sole Costa Rican sugar plant, LAICA, is located at the Port of Punta Morales. The plant has its own private pier for sugar exportation. Sugar exports will also be handled at the port in the future. The estimation equation is as follows :

Sugar export volume = Sugar cane area (ha) × Export volume per hectare (tons/ha)

The crop area is estimated using the correlation with the year. The correlation equation is as follows :

$$Y = 0.381X + 2.122 \qquad (R = 0.928)$$

Where X : Year minus 1900
Y : The sugar cane crop area ('000 ha)
R : Correlation coefficient

The projected exports are shown in Table VII-23.

Table VII-21 Projected Containerized Cargo Volume

EXPORTS				
Year	General Cargo Volume (tons)	Containerized Ratio (%)	Containerized Cargo Volume (tons)	Number of Containers (TEU)
(Actual)				
1983	139,922[1)]	20.4	28,486[2)]	1,761
1984	183,892	14.6	26,760	1,678
(Projected)				
1992	163,300	25.1	41,000	3,340
1995	219,400	39.5	86,700	7,050
2000	338,100	54.6	184,600	15,010

	IMPORTS			
Year	General Cargo Volume (tons)	Containerized Ratio (%)	Containerized Cargo Volume (tons)	Number of Containers (TEU)
(Actual)				
1983	202,732[1)]	7.8	15,743[2)]	1,452
1984	251,342	11.3	28,452	2,406
(Projected)				
1992	412,000	29.3	120,700	10,680
1995	477,000	53.2	253,800	22,460
2000	601,800	71.8	432,100	38,240

Source 1) : CUADROS ESTADISTICOS SOBRE SECTOR TRANSPORTES, DGP/MOPT
2) : DGOPF/MOPT

Table VII-22 Number of Loaded and Empty Containers

Unit : TEU

Year	Export/Import	Loaded	Empty	Total
1992	Export	3,340	7,340	10,680
	Import	10,680	—	10,680
	Total	14,020	7,340	21,360
2000	Export	15,010	23,230	38,240
	Import	38,240	—	38,240
	Total	53,250	23,230	76,480

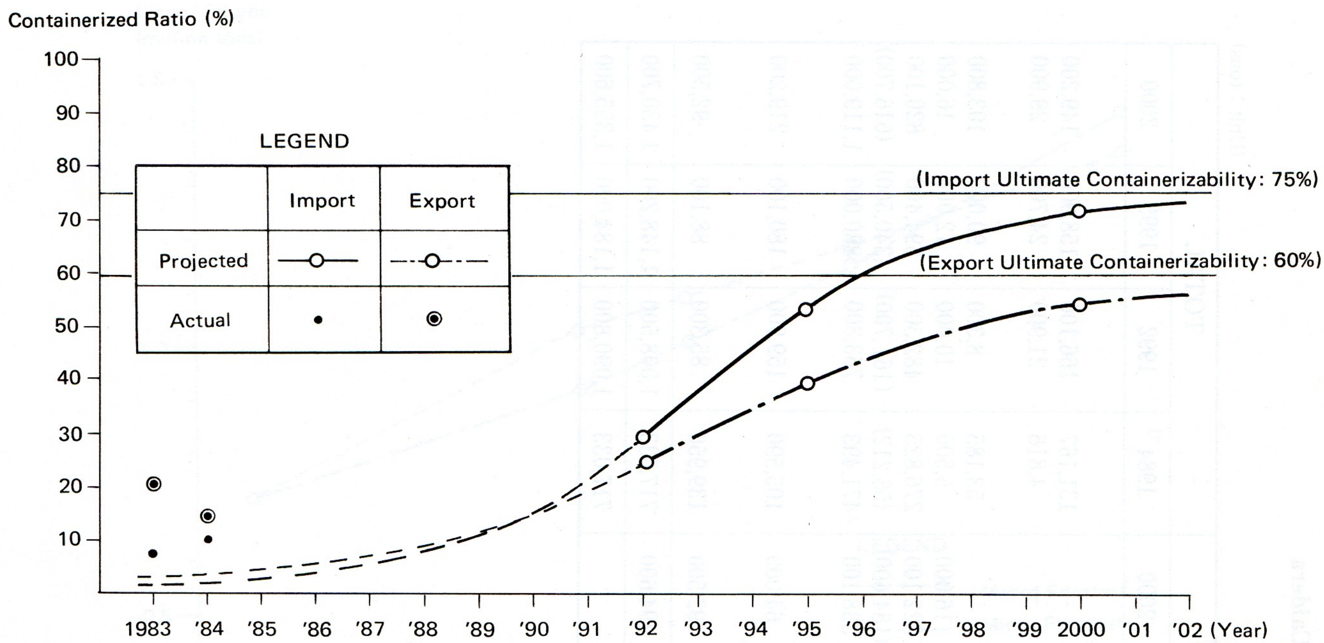


Fig. VII-14 Containerizability Time Progression

Table VII-23 Sugar Export Forecast

Year	Export Cargo Volume (tons)	Sugar Cane Crop Area ('000 ha)
(Actual)[1]		
1980	72,430	32.2
1984	58,000	34.1
(Projected)		
1992	85,300	37.1
1995	88,100	38.3
2000	92,500	40.2

Source 1): CUADROS ESTADISTICOS SOBRE SECTOR TRANSPORTES DGP/MOPT

1. 2. 3 Cargo Forecast Summary

As a conclusion, Table VII-24 shows a summary of the cargo forecasts. Fig.VII-15 is a comparison of the cargo volumes obtained by the macro and micro forecast methods described in Section 1. 2. There is scarcely any discrepancy between the macro and micro forecasts. Hereafter, in this study, the total cargo volumes handled at the Port of Caldera in the target years as forecast by the micro method are adopted.

Table VII-24 Projected Cargo Volume at the Port of Caldera

(Unit : tons)

	IMPORTS				EXPORTS				TOTAL			
	1984 1)	1992	1995	2000	1984 1)	1992	1995	2000	1984 1)	1992	1995	2000
〔The Port of Caldera〕												
Grain	131,167	166,100	158,900	149,200	—	—	—	—	131,167	166,100	158,900	149,200
Automobiles	4,816	21,900	24,700	29,900	—	—	—	—	4,816	21,900	24,700	29,900
General Cargo												
Iron and Steel	53,185	83,000	90,000	103,800	—	—	—	—	53,185	8,300	90,000	103,800
Fertilizer	—	—	—	—	5,500	10,000	12,000	16,000	5,500	10,000	12,000	16,000
Others	198,157	329,000	387,000	498,000	78,668	153,300	207,400	322,100	276,825	482,300	594,400	820,100
(Containerized)	(28,452)	(120,700)	(253,800)	(432,100)	(26,760)	(41,000)	(86,700)	(184,600)	(55,212)	(161,700)	(340,500)	(616,700)
Sub-Total	387,325	600,000	660,600	780,900	84,168	163,300	219,400	338,100	471,493	763,300	880,000	1,119,000
〔FERTICA〕												
Fertilizer	83,620	116,900	130,100	155,200	21,970	43,000	50,000	64,000	105,590	159,900	180,100	219,200
〔Punta Morales〕												
Sugar	—	—	—	—	139,950	85,300	88,100	92,500	139,950	85,300	88,100	92,500
Micro Forecast TOTAL	470,945	716,900	790,700	936,100	246,088	291,600	357,500	494,600	717,033	1,008,500	1,148,200	1,430,700
Macro Forecast									717,033	1,090,800	1,184,000	1,355,600

Source 1) : CUADROS ESTADISTICOS SOBRE SECTOR TRANSPORTES 1984, DGP/MOPT
Note : Cargo volume at the Port of Caldera includes that handled at the Port of Puntarenas in the past.

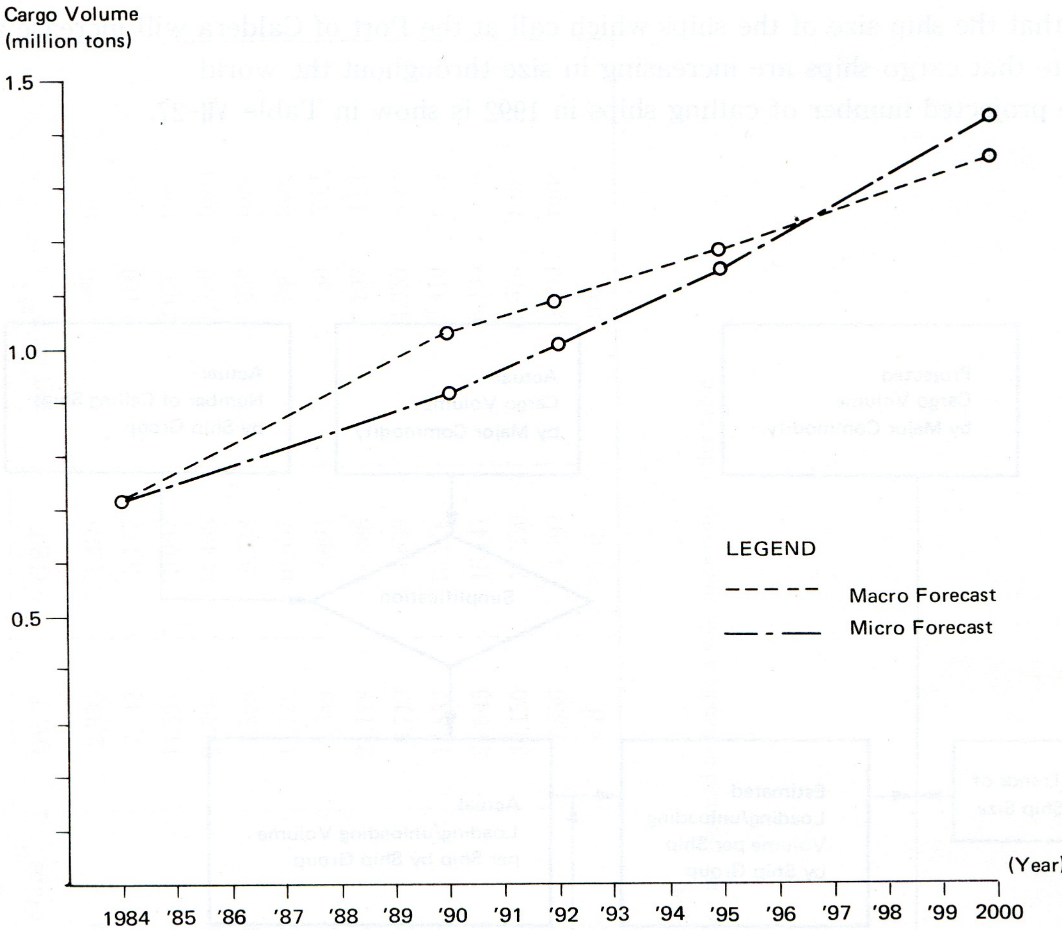


Fig. VII-15 Comparison between Macro and Micro Forecast Results

1. 3 Estimation of Calling Ships

The number of calling ships is estimated according to the procedure shown in Fig.VII-16. In the analysis of the existing statistical data, we made the following three simplifications :

(1) Ships are classified into the ship groups shown in Table VII-25.

(2) Ships that call at the Port of Caldera are classified by individual commodity despite the fact that many of them actually carry a variety of commodities.

(3) Ships are assumed to load or unload a sole specialized commodity although most of them actually load or unload a variety of commodities.

The actual number of calling ships in 1984 is shown in Table VII-25 based on the monthly statistical reports of INCOP. The actual loading/unloading volume per ship is obtained analyzing the data of the MOPT statistical reports in conjunction with the above data. The results are shown in the same Table VII-25. The past loading/unloading volume per ship has been too small ; however, it is tending to increase. The increase rate from 1983 to 1984 is about 11.6%. This point be should considered. The ship size of cargo ships all over the world has not changed drastically over a long period as shown in Table VII-26. Thus, we assume that the ship size of the ships which call at the Port of Caldera will increase at the same rate that cargo ships are increasing in size throughout the world.

The projected number of calling ships in 1992 is show in Table VII-27.

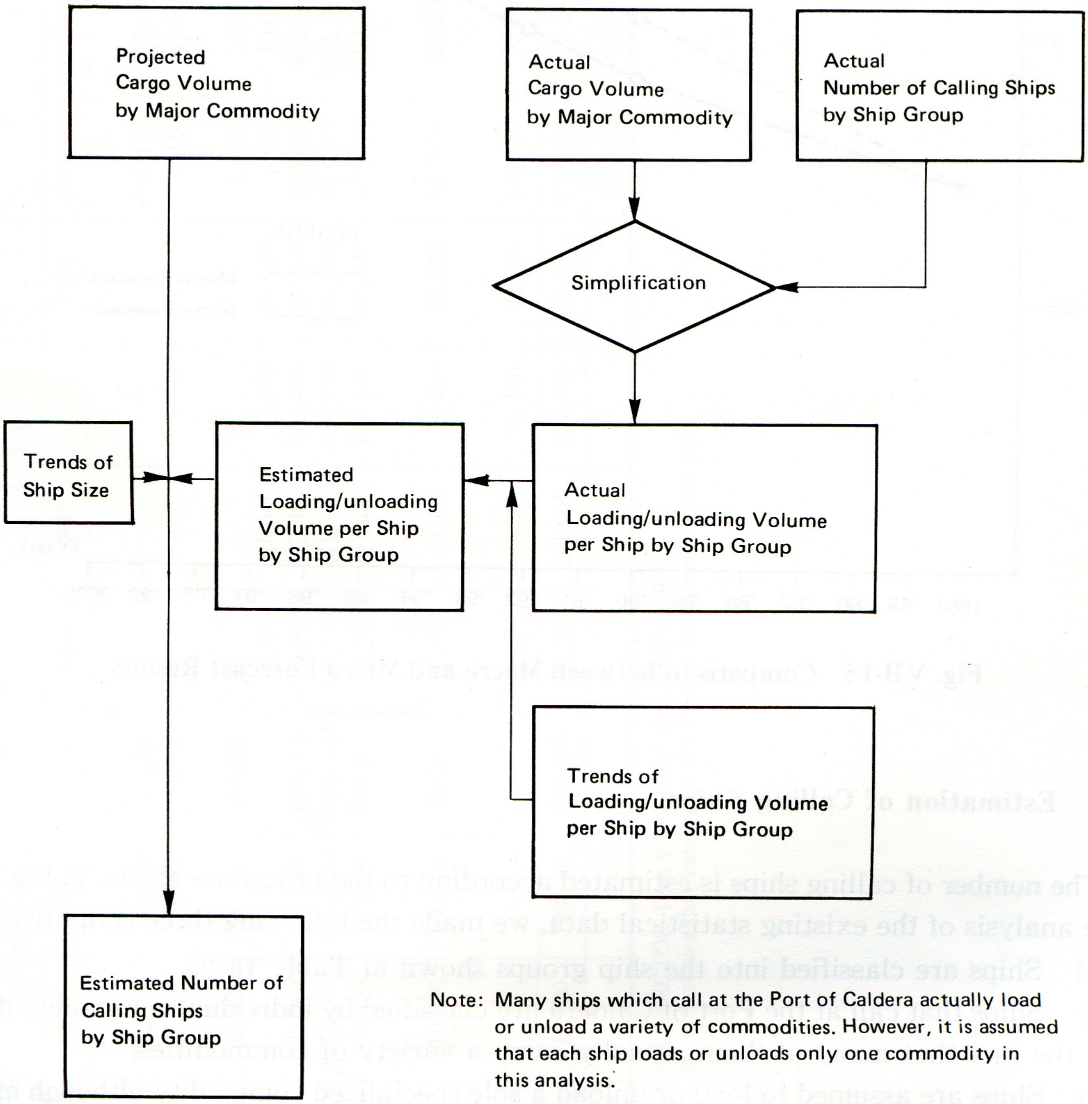


Fig. VII-16 Estimation Procedure of the Number of Calling Ships

Table VII-25 Actual Calling Ships at the Ports of Caldera and Puntarenas in 1984

Ship Group Number	Ship Type[3)]	Ship Size Rank ('000 DWT)	Number of Calling Ships[1)]	Average Ship Size[1)] DWT	Average Ship Size[1)] GRT	Loading/unloading Volume per Ship[2)]
1	General Cargo Ships	~ 5	34	2,339	1,450	860 tons
2		5 ~ 10	38	7,942	5,177	1,160 tons
3		10 ~ 20	93	14,597	10,001	2,020 tons
4		20 ~	8	20,996	14,468	1,750 tons
5	Automobile Carriers	~ 10	8	7,899	9,338	250 tons
6		10 ~ 20	12	11,726	10,657	240 tons
7	Container Ships	~ 20	2	3,549	3,694	50 TEU
8		20 ~ 30	44	24,118	28,086	107 TEU
9	Grain Cargo Carriers	~ 10	12	6,713	4,633	4,030 tons
10		10 ~ 20	6	13,837	10,218	7,410 tons
11		20 ~ 30	4	26,045	15,141	6,430 tons
12		30 ~	1	30,130	17,250	12,670 tons
13	Fertilizer Cargo Ships	~ 10	5	7,856	4,703	1,100 tons
14	Passenger Cruisers		15	n.d.	n.d.	n.d.

Source 1) : INFORME ESTADISTICO MENSUAL, INCOP
2) : CUADROS ESTADISTICOS SOBRE SECTOR TRANSPORTES 1984, DGP/MOPT
Note 3) : Almost all ships actually load or unload a variety of commodities. However, they are assumed to handle a sole commodity in this table.

Table VII-26 Worldwide Trends of Ship Size

Year	Number of Ships	Total Gross Tonnage ('000 GRT)	Average Ship Size (GRT/ship)	Increase Rate (1975 : 1.000)
1950	28,694	67,409	2,349	1.168
1955	28,917	74,114	2,563	1.274
1960	31,768	88,305	2,780	1.382
1965	35,155	86,589	2,463	1.225
1970	43,813	94,698	2,161	1.075
1975	52,989	106,557	2,011	1.000
1980	62,014	135,311	2,182	1.085
1984	64,192	142,885	2,226	1.107

ource : LLOYD Statistical Tables
Vote : Present ships include cargo and fishing boats other than oil tankers and ore bulk carriers.

Table VII-27 Estimated Calling Ships in 1992

Ship Group Number	Ship Type	Ship Size Rank ('000 DWT)	Number of Calling Ships
1	General Cargo Ships	～ 5	26
2		5 ～ 10	27
3		10 ～ 20	70
4		20 ～	6
5	Automobile Carriers	～ 10	19
6		10 ～ 20	29
7	Container Ships	～ 20	5
8		20 ～ 30	103
9	Grain Cargo Carriers	～ 10	8
10		10 ～ 20	4
11		20 ～ 30	2
12		30 ～	1
13	Fertilizer Cargo Ships	～ 10	5
14	Passenger Cruisers		18

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

Concerning problem 1), the port layout planning should be conducted according to t study results in CHAPTER VI considering the importance of sedimentaion in the prese maintenance project. Problem 3) is discussed in CHAPTER VIII based on the port layc 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, t primary dredging and the maintenance dredging as discussed in CHAPTER VI. T breakwater layout and the dredging program are presented in that chapter.

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

2. 2 Facility Improvement Planning

This study is for the restoration of port functions by improving existing facilities a implementing an appropriate maintenance program. The study seeks cost minimization a the multipurpose use of facilities as much as possible. The improvement of existing faciliti 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 t estimated port cargo volume and the number of ship calls. The study assumes th Puntarenas pier is already superannuated, and that grain imports should be moved to t 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 necessary to determine the port capacity. Since port capacity varies according to the ty of cargo, size of lots, size of berths, loading and unloading capacity and other factors, it often represented simply as the cargo volume handled at the port. The cargo handli capacity of the Port of Caldera is estimated in terms of total cargo volume converted in general cargo equivalent.

As for the cargo handling capacity, details are studied in CHAPTER Ⅷ. However, ome 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 olume 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 oefficients.

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 followi 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 t cargo handling capacity of the port, but that the port will be able to accommodate t forecast throughput if the restoration and maintenance measures proposed in this study a implemented.

(2) Target year of the project

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

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

In parallel with the above-mentioned countermeasures, the shortage of berth size shou also be remedied as soon as possible. The construction period depends on the content of th 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

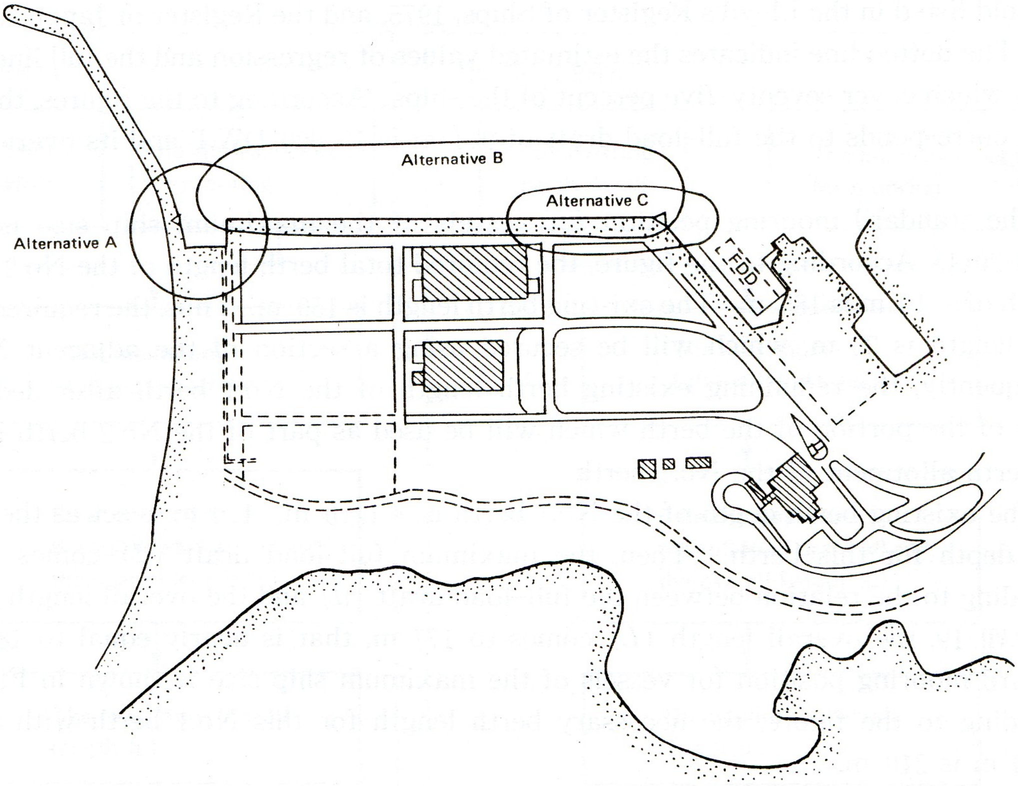


Fig. VII-17 Alternative Berth Extension Methods

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.

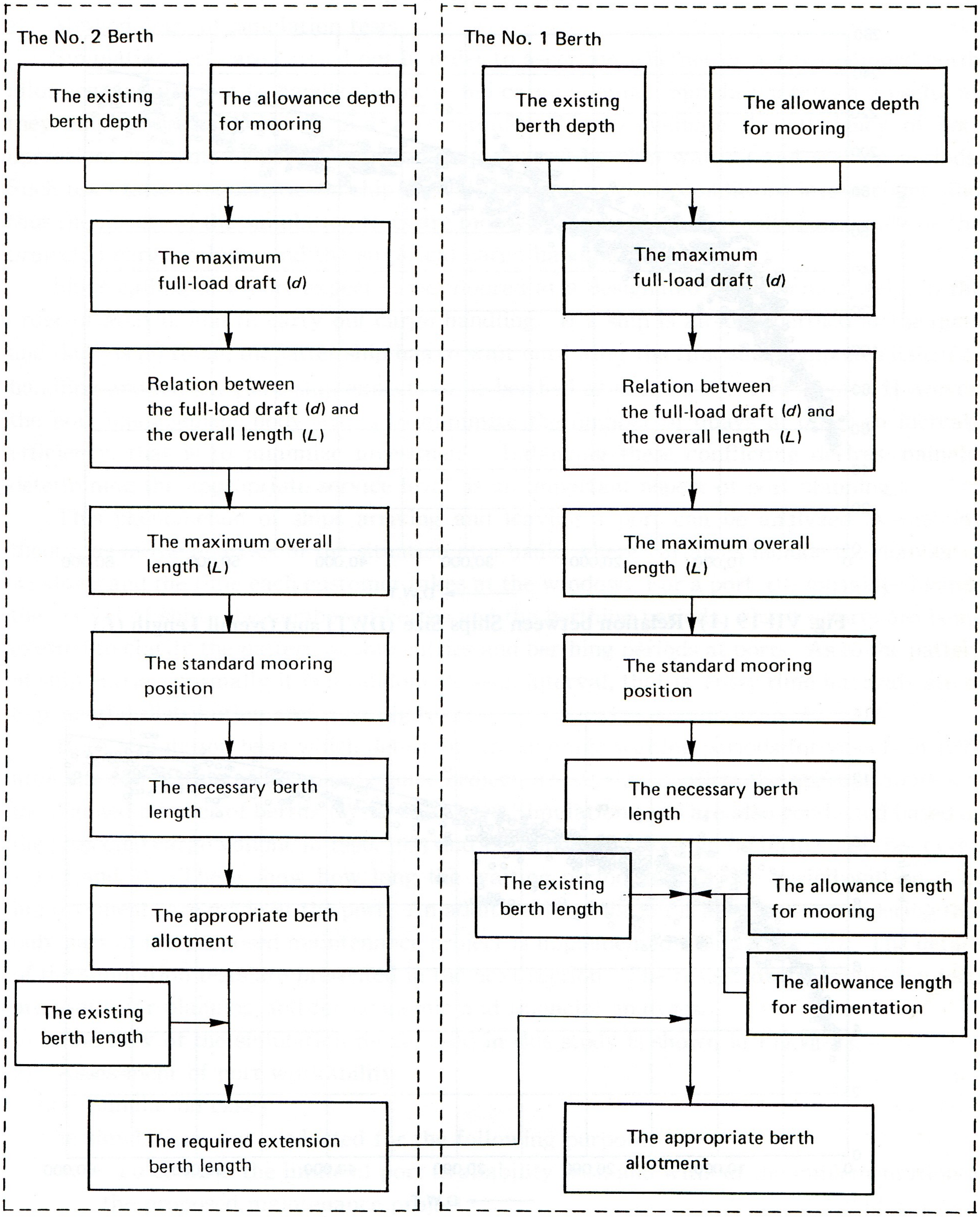


Fig. VII-18 Procedure of Berth Allotment Planning

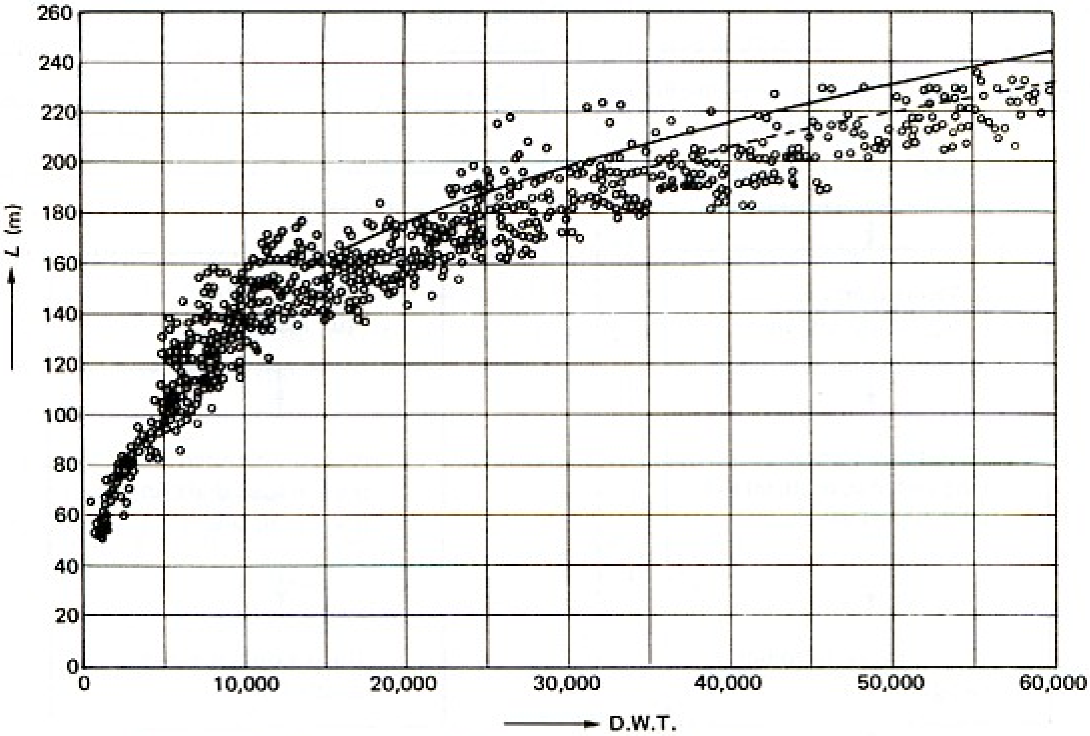


Fig. VII-19 (1) Relation between Ships Size (DWT) and Overall Length (L)

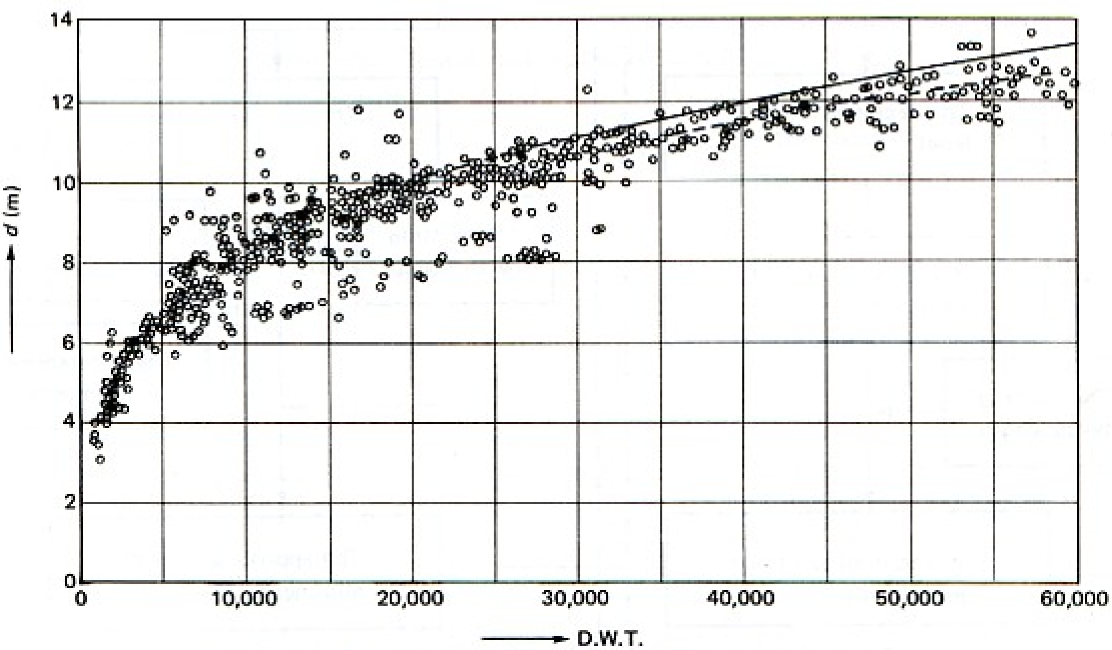


Fig. VII-19 (2) Relation between Ships Size (DWT) and Full-Load Draft (d)

(5) Asssesment 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

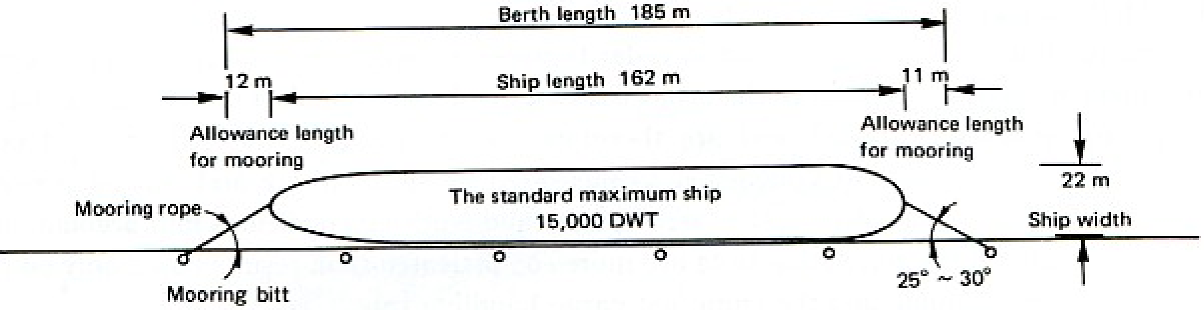


Fig. VII-20 (1) Berth Allotment of the No. 2 Berth

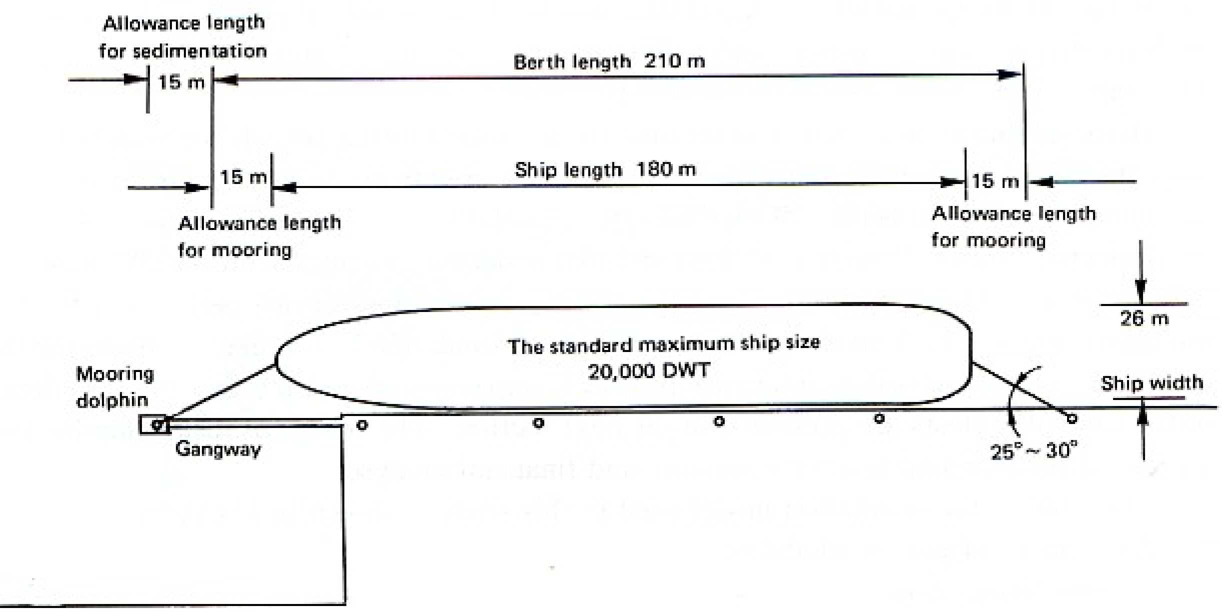


Fig. VII-20 (2) Berth Allotment of the No. 1 Berth

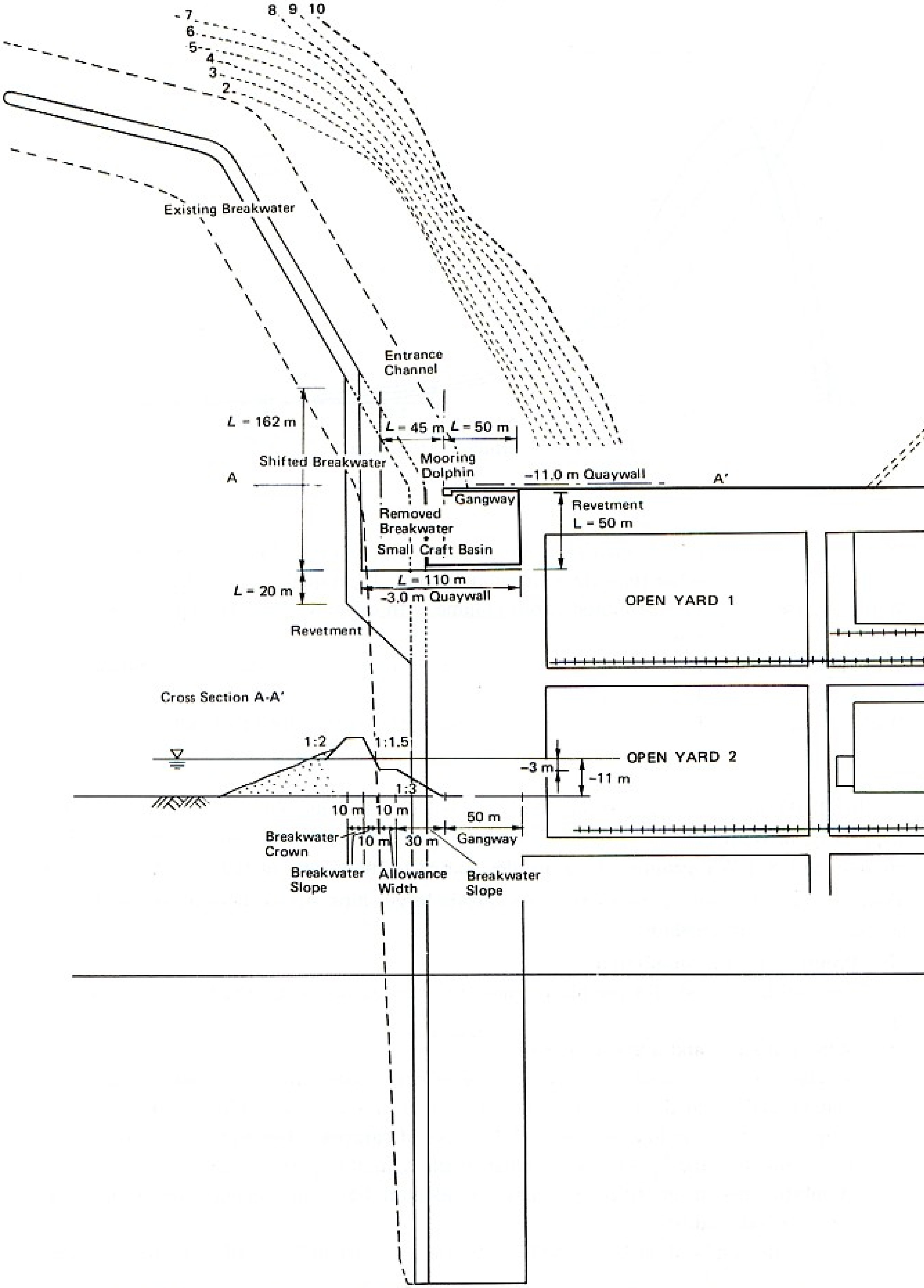


Fig. VII-21 Layout of Extended Berth, Shifted Breakwater and Improved Small Craft Basin

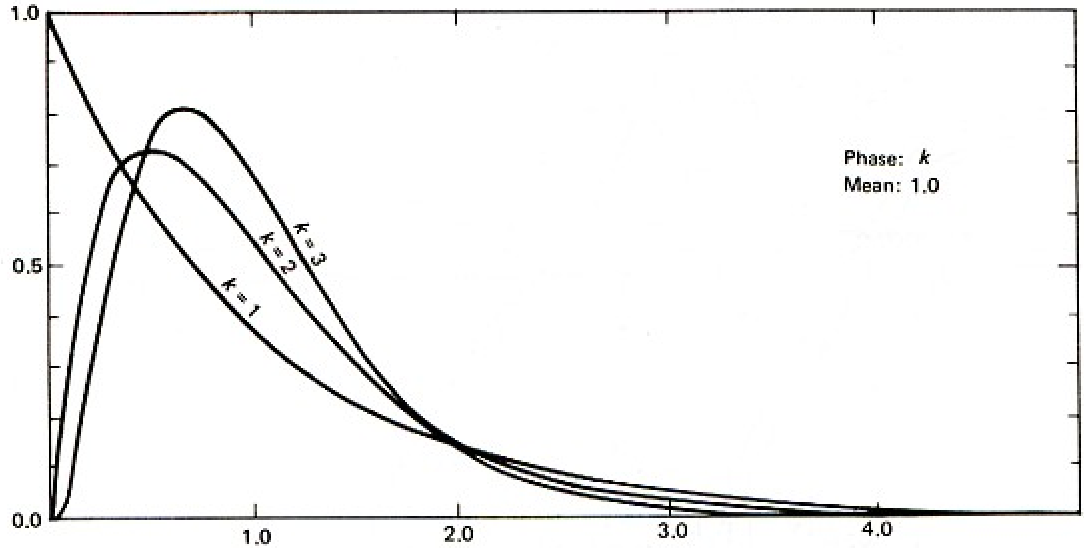


Fig. VII-22 Erlung Distribution

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

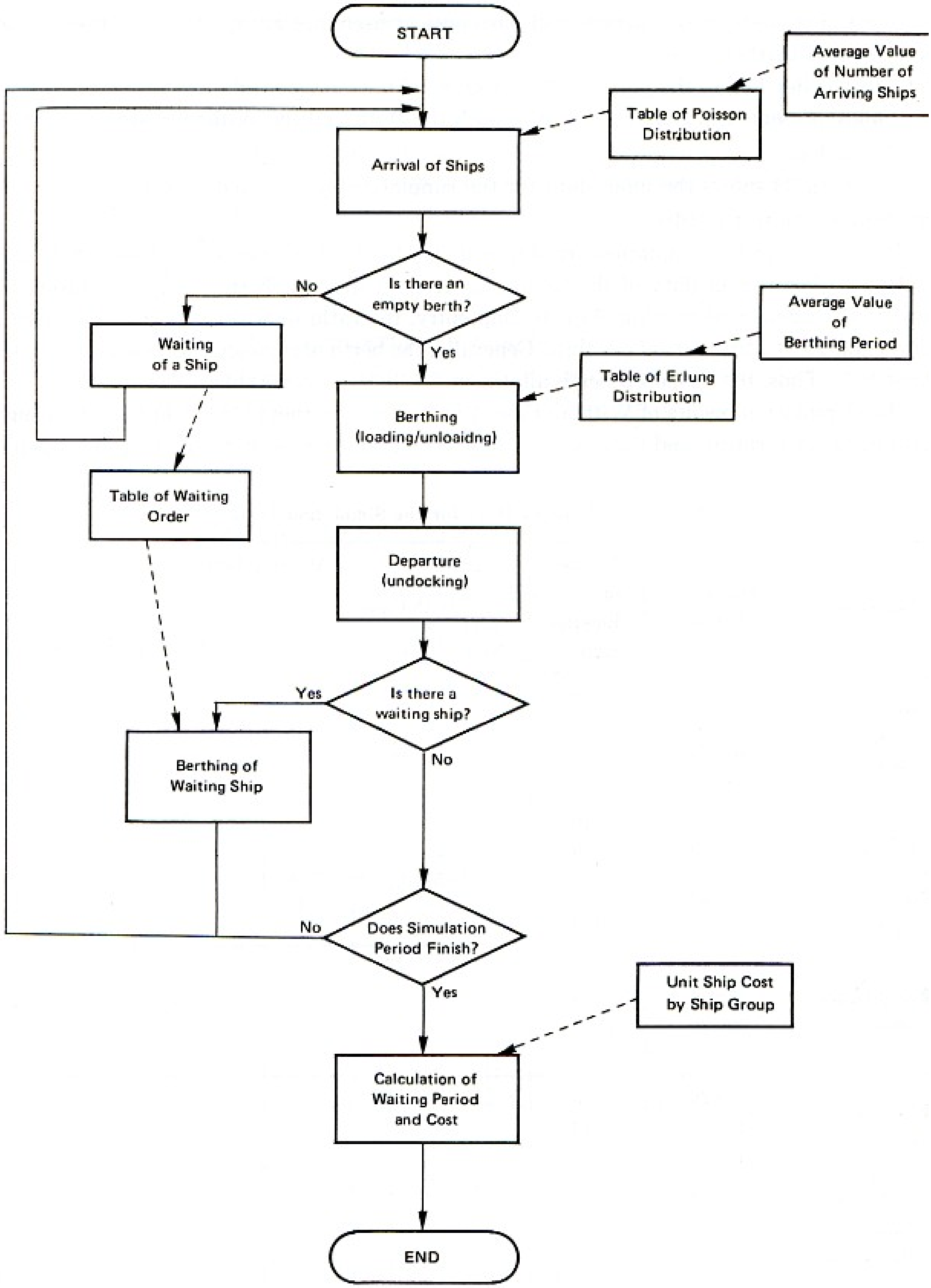


Fig. VII-23 Flow Chart of the Simulation Model vacant.

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

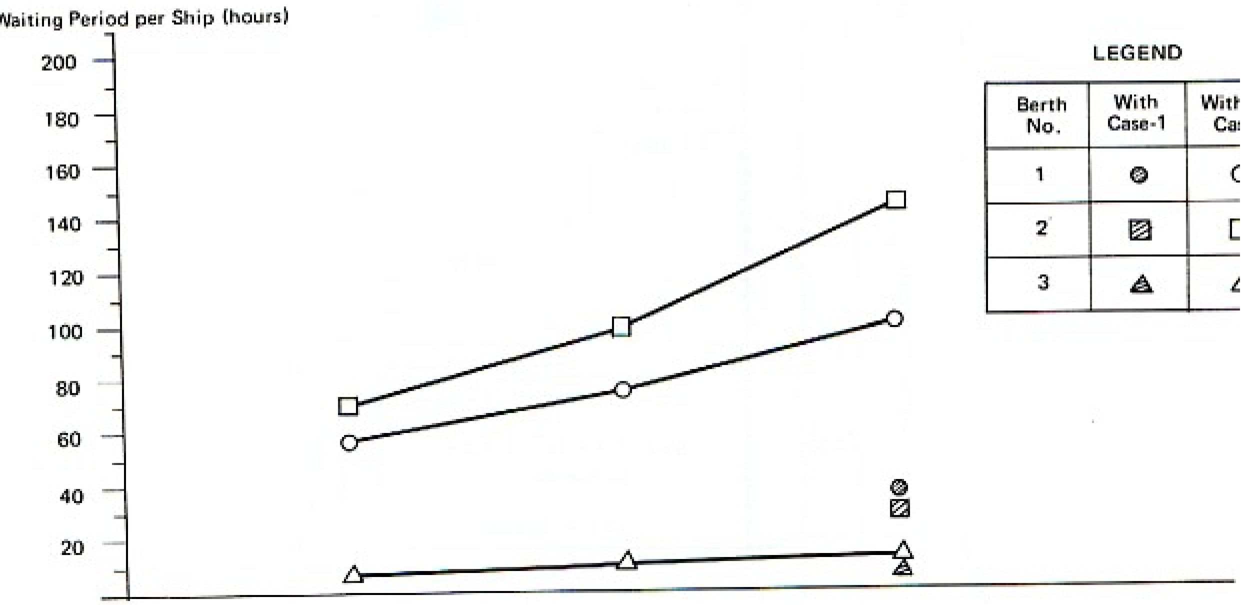
Number of Entered Ships	Ship Staying Periods (h)		Ship Staying Period Difference	
	With Case−1 (1992)	Without Case−2 (1991)	Total (h)	Per Ship (h/shi
28	1,322	1,599	277	9.9
30	2,426	4,241	1,815	60.5
72	10,095	16,704	6,609	91.8
6	801	1,569	768	128.0
20	781	1,574	793	39.7
32	1,903	4,499	2,596	81.1
5	131	173	42	8.4
103	4,900	8,270	3,370	32.7
10	400	568	168	16.8
5	320	451	131	26.2
2	107	231	124	62.0
1	59	73	14	14.0
3	140	182	42	14.0
11	682	1,049	367	33.4
2	109	157	48	24.0
4	268	368	100	25.0
334	24,444	41,708	17,264	51.7

Table VII-35 (2) Ship Staying Periods

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)
28	1,322	1,310	− 12	− 0.4
30	2,426	2,262	− 164	− 5.5
72	10,095	10,155	60	0.8
6	801	835	34	5.7
20	781	715	− 66	− 3.3
32	1,903	1,852	− 51	− 1.6
5	131	120	− 11	− 2.2
103	4,900	6,378	1,478	14.3
10	400	389	− 11	− 1.1
5	320	412	92	18.4
2	107	157	50	25.0
1	59	48	− 11	− 11.0
3	140	159	19	6.3
11	682	739	57	5.2
2	109	140	31	15.5
4	268	281	13	3.3
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



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.

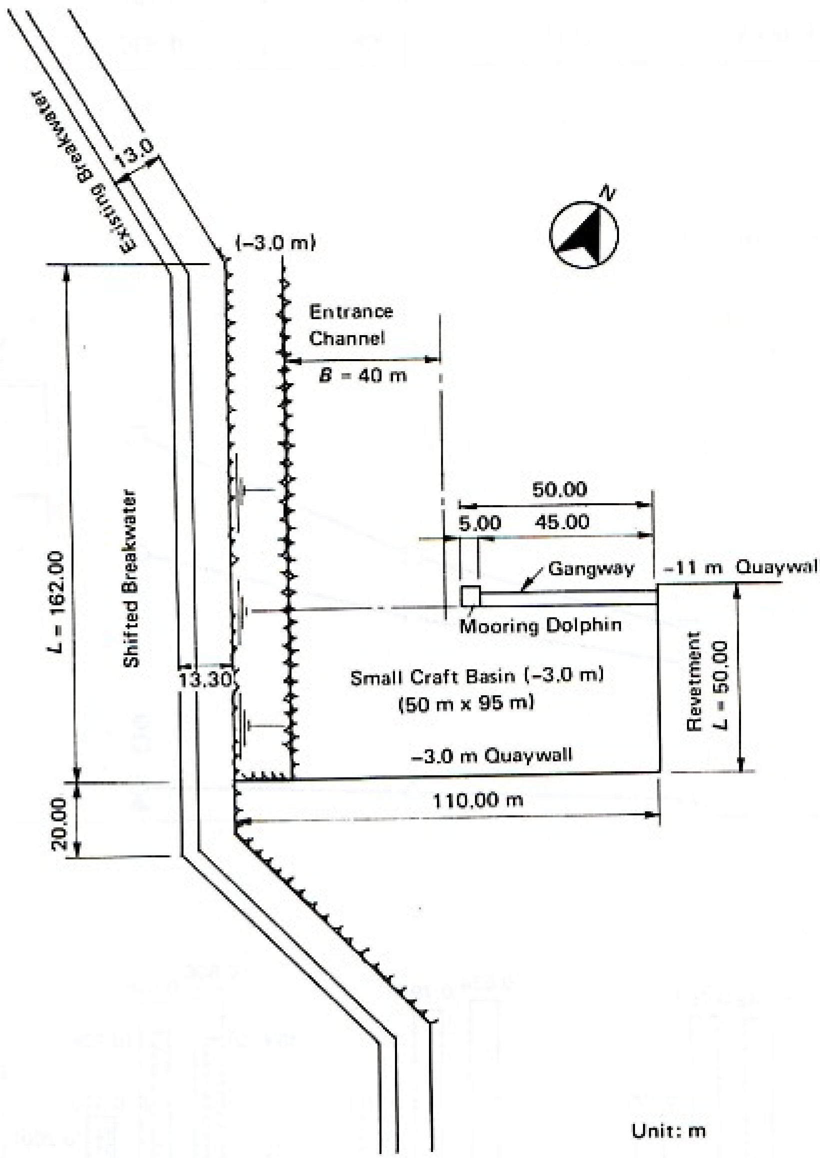


Fig. VII-25 The Small Craft Basin and Its Entrance

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

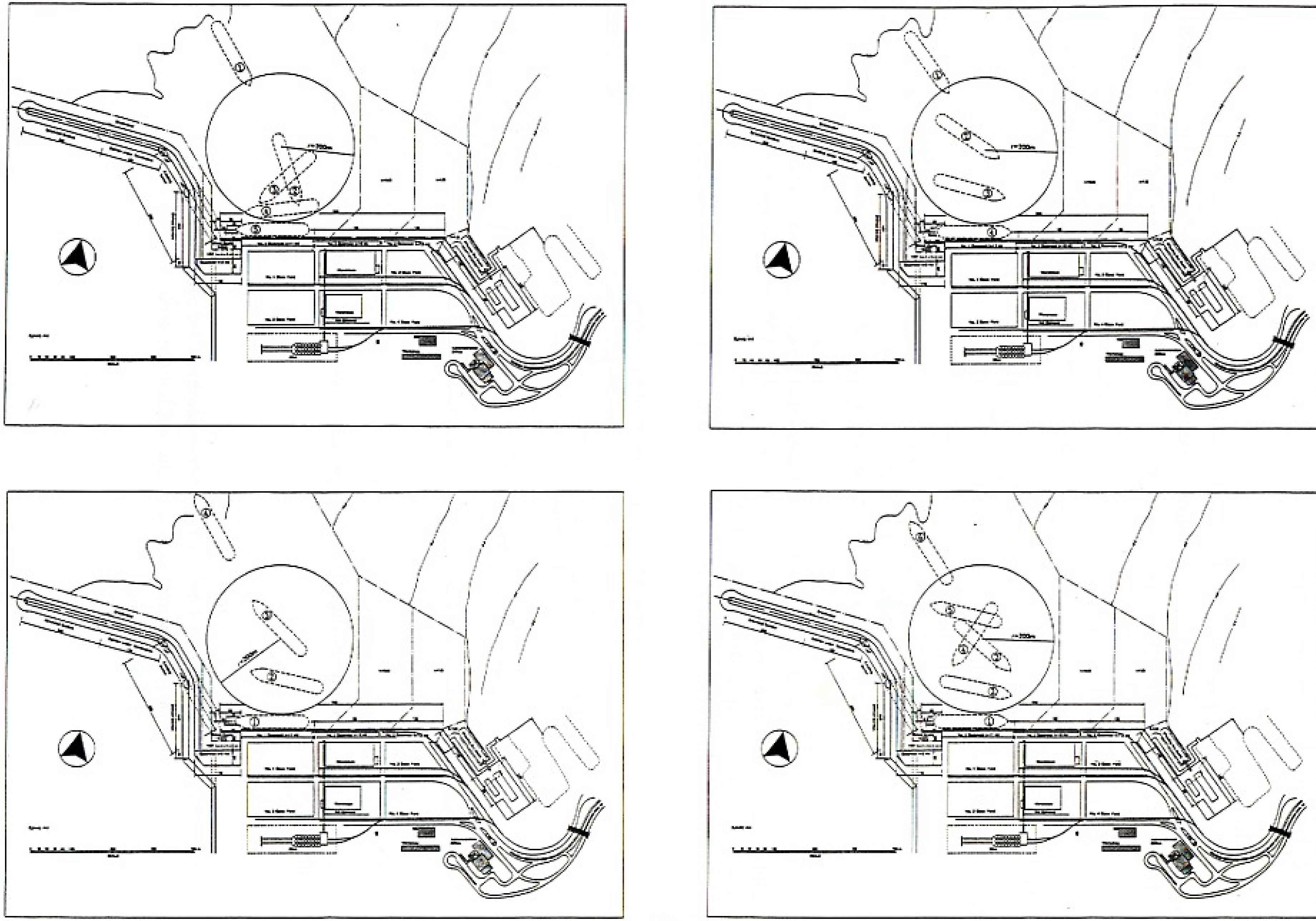


Fig. VII-26 Ship Turning Basin

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.

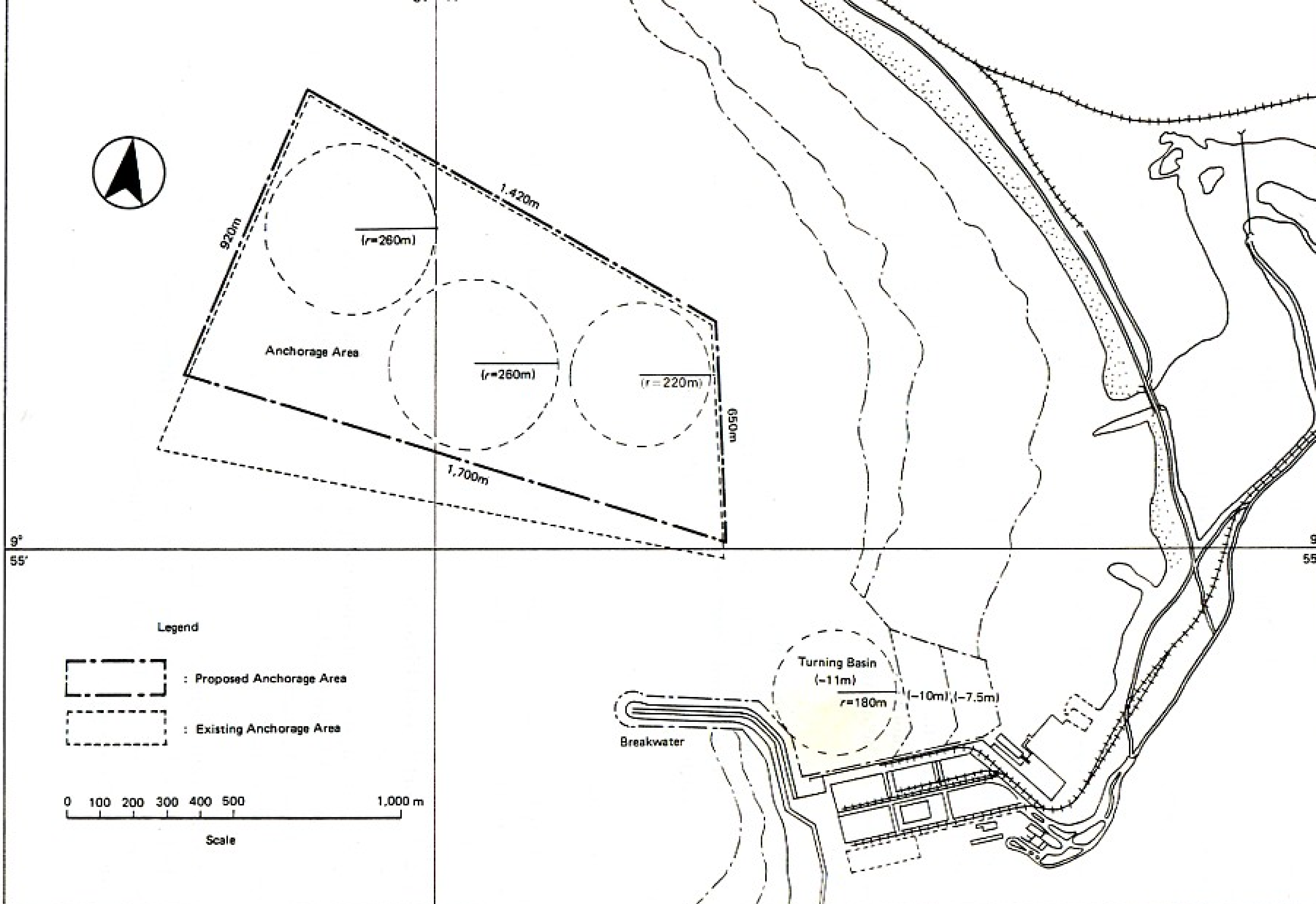


Fig. VII-27 Anchorage Area Layout

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.

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

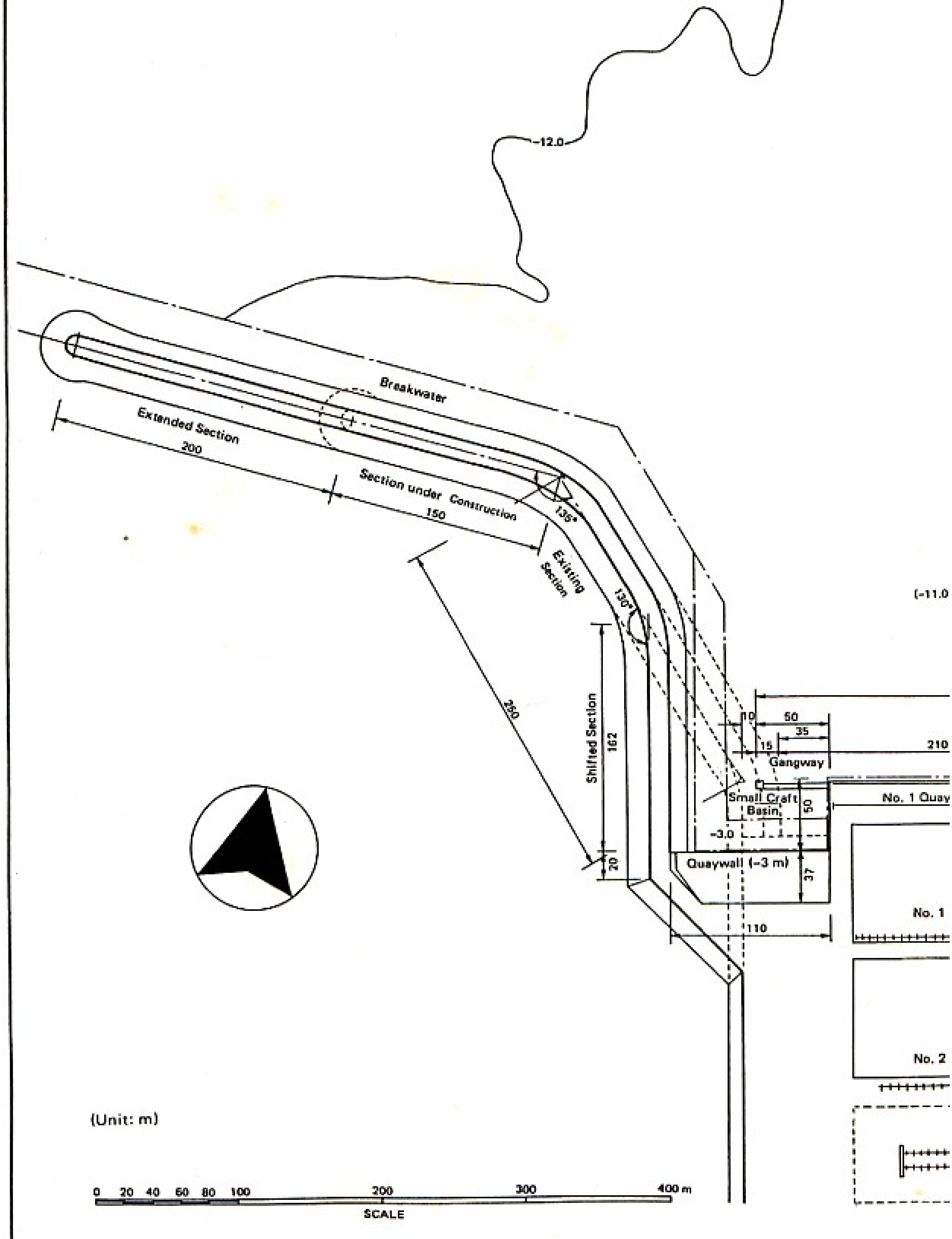
The results show that under the proposed plan the harbour will be properly protected. For instance, the occurrence probability of wave heights less than 0.3 m is about 99%. Consequently, the Port of Caldera seems to be available almost all through the year. Details are discussed in the APPENDIX 8.

(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.

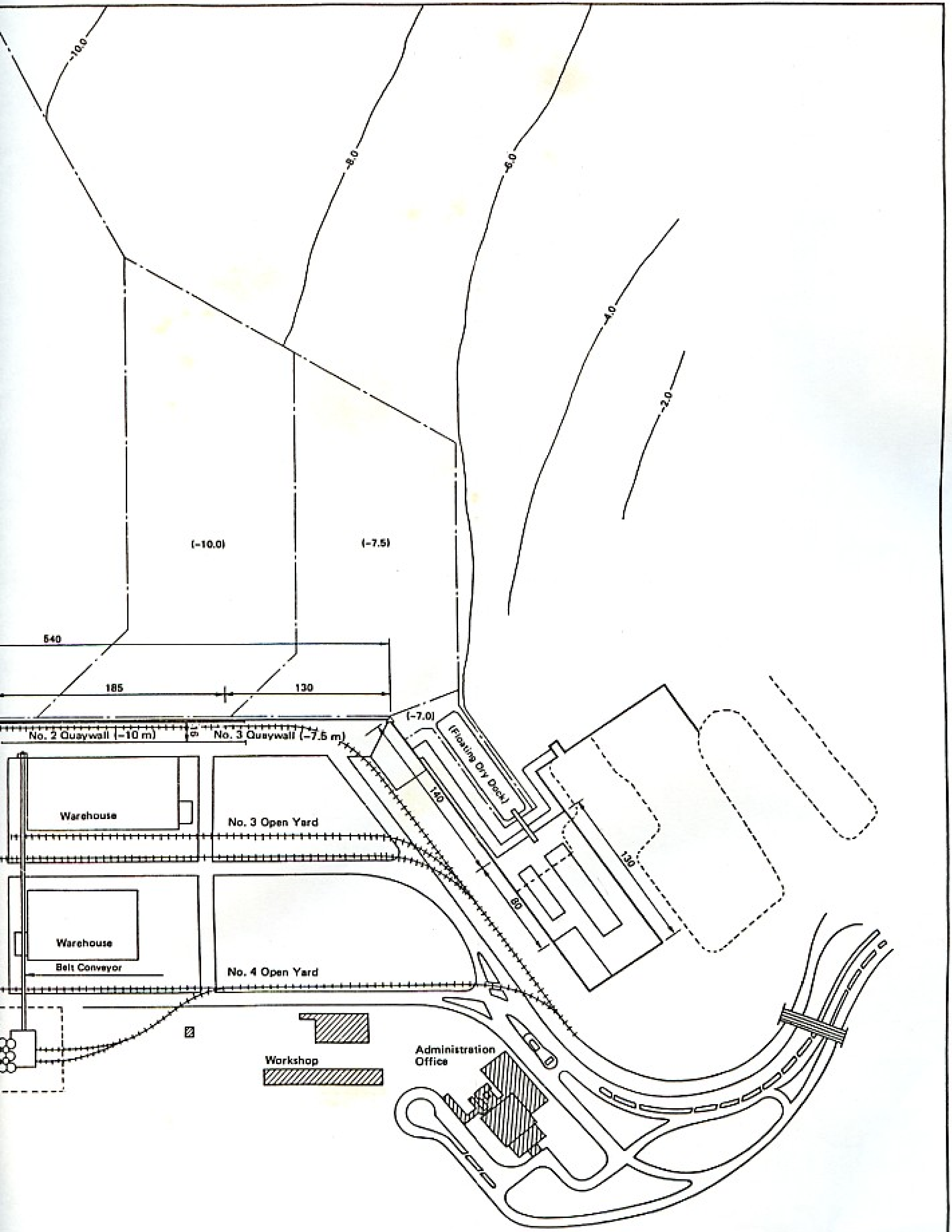
Considering the above, it is recommendable to extend the breakwater in parallel with the direction of the shoreline of North Caldera beach after the present Maintenance Project is completed. The extended breakwater could then protect the future developed harbour area without any interference.

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



-12.0
Breakwater
Extended Section
200
Section under Construction
150
135°
Existing Section
130°
250
Shifted Section
162
20
(-11.0
10
50
35
15
210
Gangway
Small Craft Basin
50
No. 1 Quay
-3.0
Quaywall (-3 m)
37
110
No. 1
No. 2
(Unit: m)
0 20 40 60 80 100 200 300 400 m
SCALE

Fig. VII-2



nce Plan of the Port of Caldera

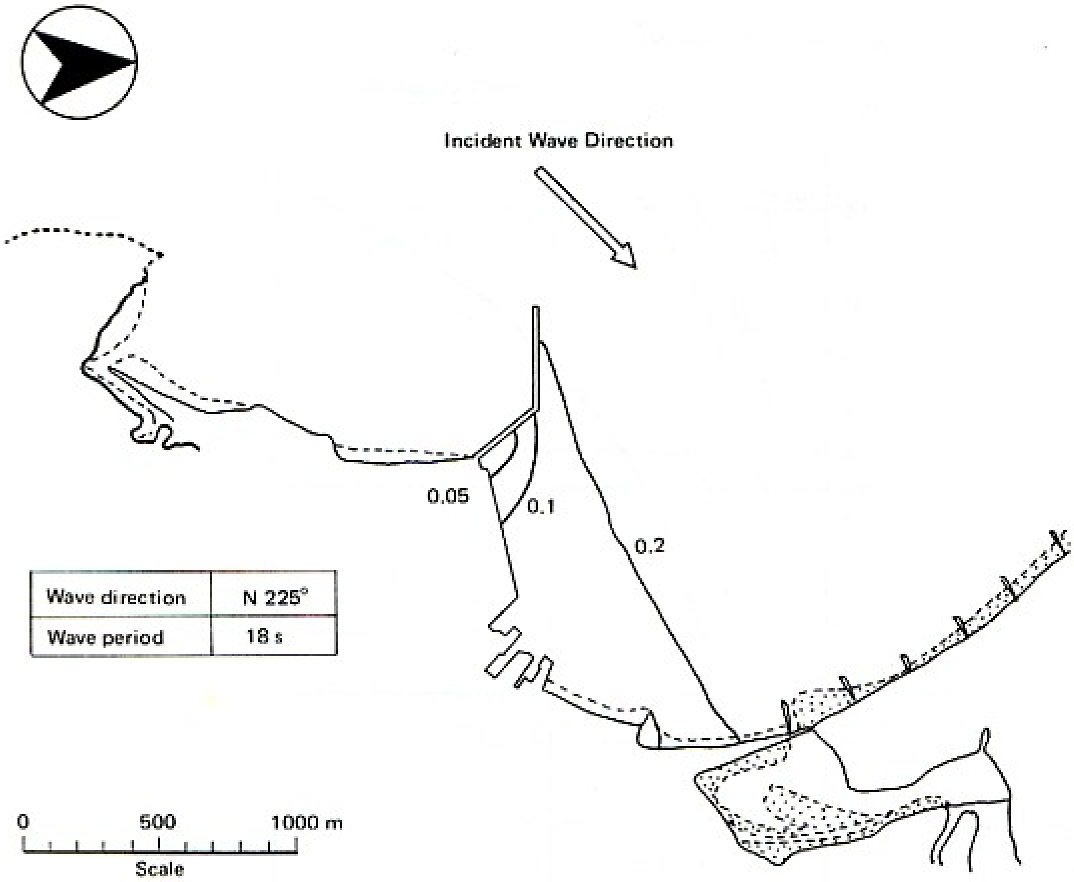


Fig. VII-29 (1) Wave Diffraction Coefficient Distribution

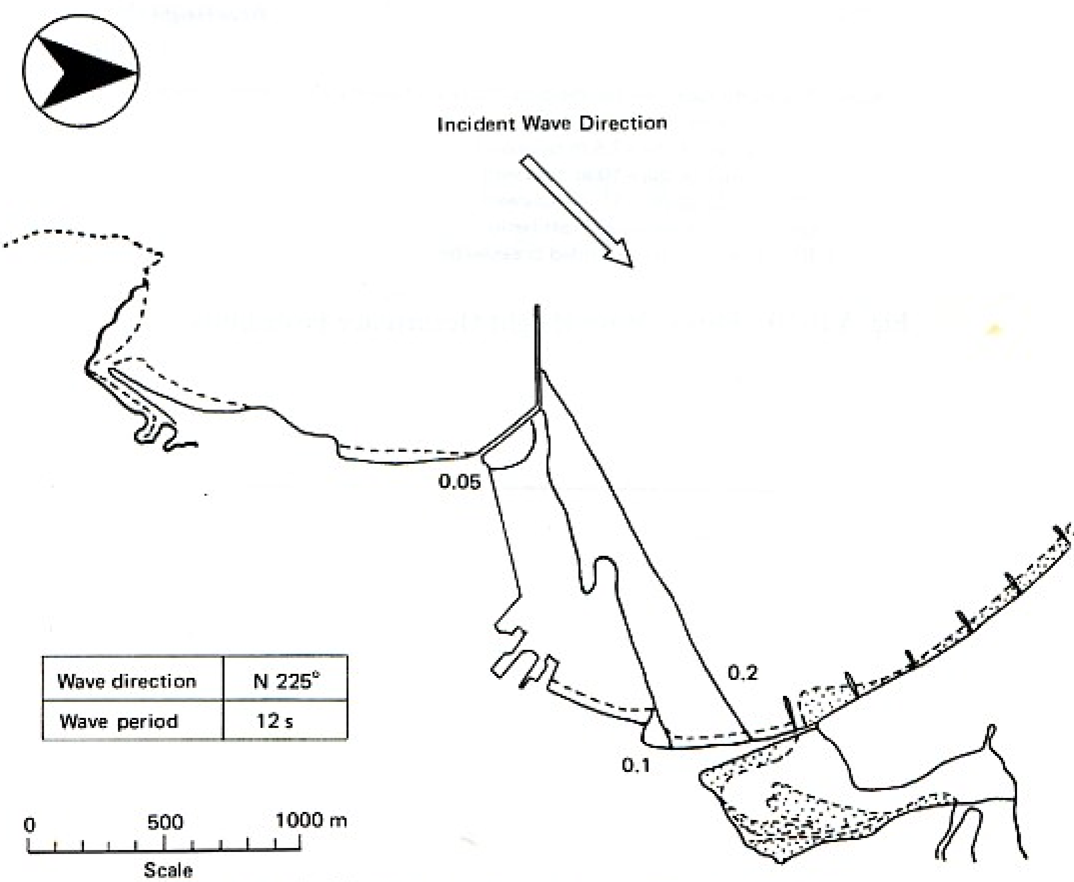
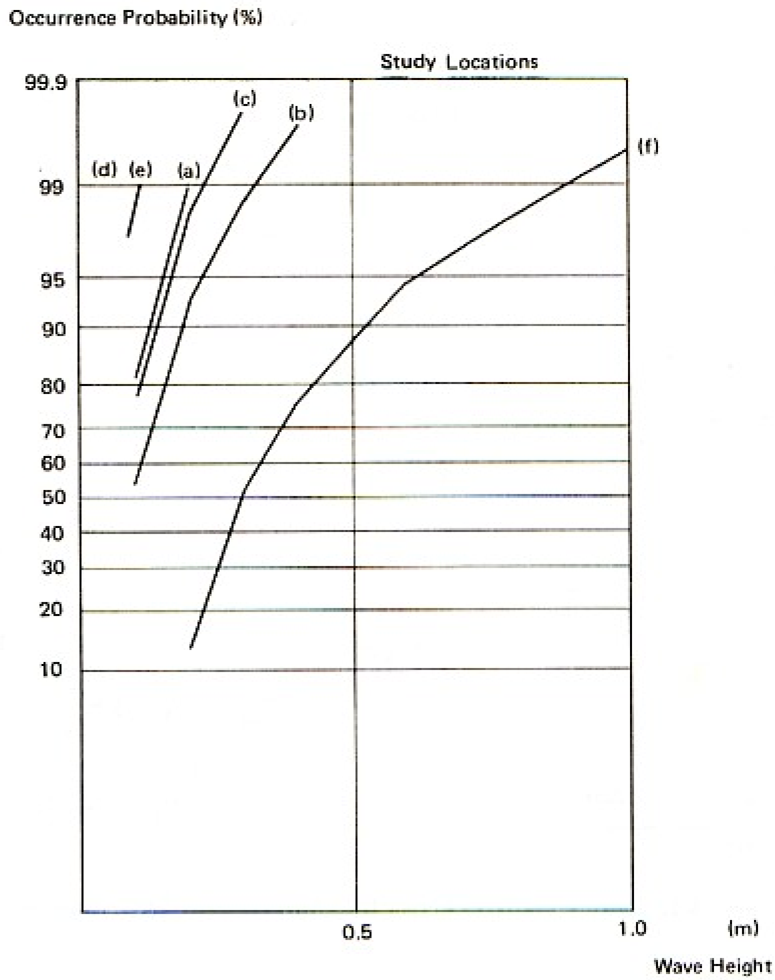


Fig. VII-29 (2) Wave Diffraction Coefficient Distribution



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

1. General

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

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

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

Thus, under this maintenance project the three existing berths and the handling y located behind these berths will function as a multipurpose terminal which will be ab accomodate a wide variety of cargoes including general cargo, steel goods, automol containers, and break bulk grain. For the multipurpose use of the terminal to fun(efficiently, systematic management and a well-coordinated operation system will be n sary 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

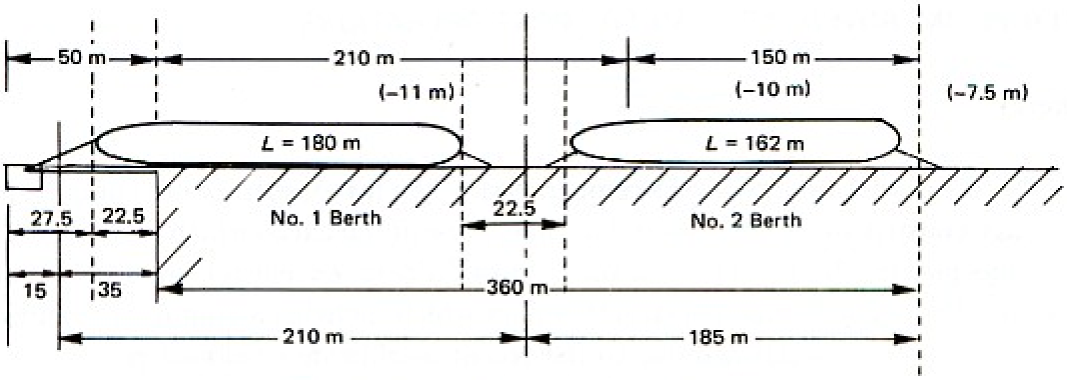


Fig. VIII-1 Berth Extension Plan

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 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 P is due to inproper planning or to poor execution of the plans. If comprehensive plans each vessel are drawn up in advance and carried out as outlined above, the efficiency of ı stevedoring operations will certainly improve. As the stevedoring is presently a bottlene in the cargo handling operations, the increase of the working efficiency of stevedoring v bring about an increase in the overall cargo handling efficiency, and will effectively expa 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 unloaded directly from vessels onto the apron and then carried to storage facilities. T 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.

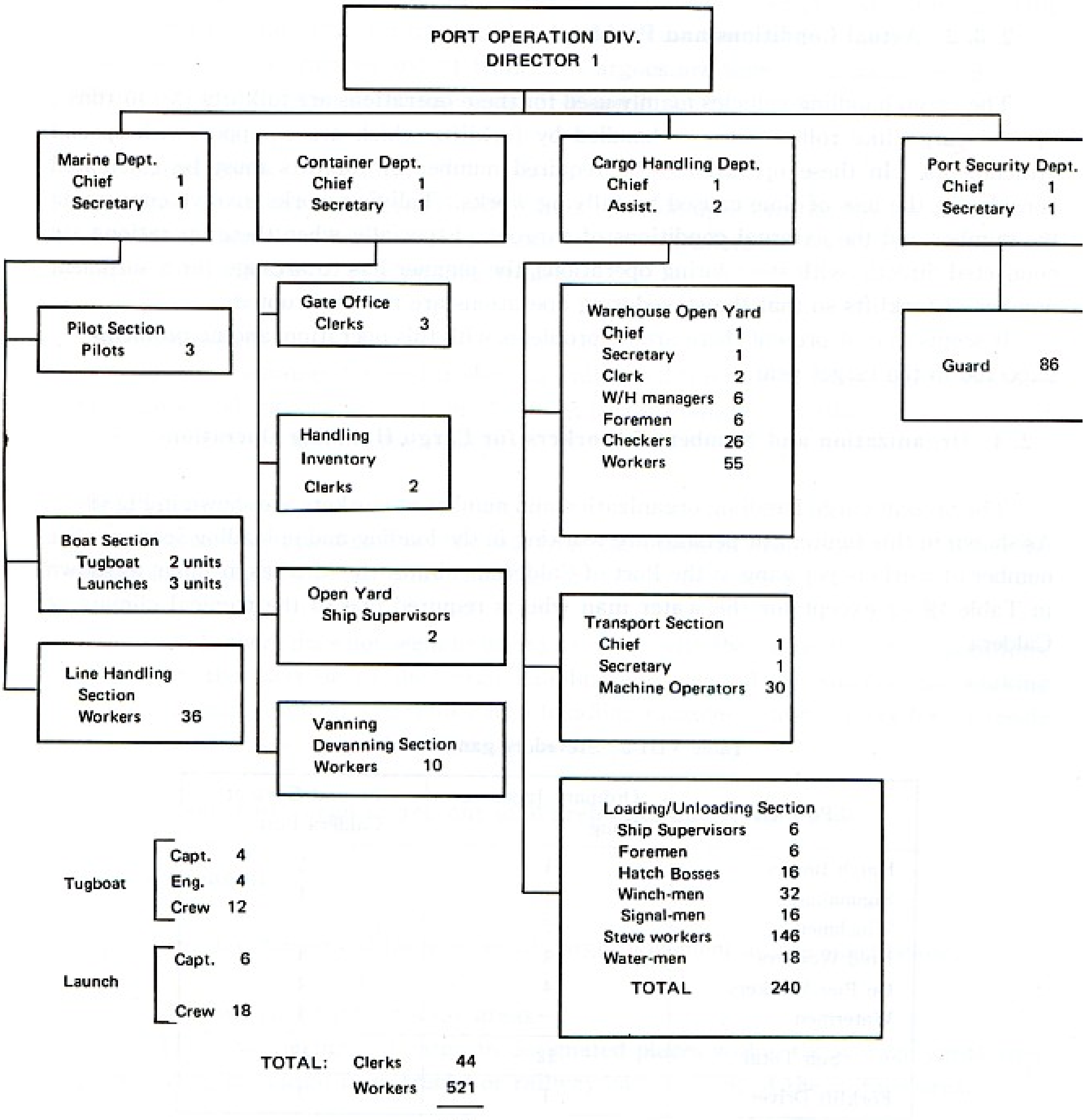
It seems that at present there are no problems with this operation, and no problems are expected in the target year.

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


PORT OPERATION DIV.
DIRECTOR 1
Marine Dept.
Chief 1
Secretary 1
Container Dept.
Chief 1
Secretary 1
Cargo Handling Dept.
Chief 1
Assist. 2
Port Security Dept.
Chief 1
Secretary 1
Pilot Section
Pilots 3
Gate Office
Clerks 3
Warehouse Open Yard
Chief 1
Secretary 1
Clerk 2
W/H managers 6
Foremen 6
Checkers 26
Workers 55
Guard 86
Handling
Inventory
Clerks 2
Boat Section
Tugboat 2 units
Launches 3 units
Open Yard
Ship Supervisors
2
Transport Section
Chief 1
Secretary 1
Machine Operators 30
Line Handling
Section
Workers 36
Vanning
Devanning Section
Workers 10
Loading/Unloading Section
Ship Supervisors 6
Foremen 6
Hatch Bosses 16
Winch-men 32
Signal-men 16
Steve workers 146
Water-men 18
TOTAL 240
Tugboat
Capt. 4
Eng. 4
Crew 12
Launch
Capt. 6
Crew 18
TOTAL: Clerks 44
Workers 521

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 :

$$1.5 \text{ metric tons/sling} \times 20 \text{ slings/h} \times 0.8 = 24 \text{ metric tons/h}$$

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 :

$$24 \text{ metric tons/(h} \cdot \text{gang} \cdot \text{shift)} \times 7 \text{ h/day} \times 3 \text{ shifts} = 504 \text{ metric tons/(gang} \cdot \text{day)}$$

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

(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

4 slings/(h・gang・shift) ×7 metric tons/sling×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, 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	[illegible]	[illegible]	[illegible]

4. Break Bulk Grain Cargo Handling

The handling of break bulk grain cargo is considered separately in this section becaus grain cargo operations will have a great impact on the overall operations of the multipu pose terminal, and the handling of grain is a new project for the Port of Caldera which wi 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 brea bulk at the Puntarenas pier. The break bulk cargo can presently only be carried by railwa cars because there are no facilities for trucks at the Puntareas pier. The sequence of grai cargo handling is ship hold ……pneumatic pump ……railway car……silo in Barranca c Alajuela. The bottleneck in the present cargo handling system is the time which is lost a railway cars are changed on the pier and when the cars travel between the Puntarenas pie and the silos.

The present maximum handling capacity per day (24 hours) is about 800 to 1,0C metric tons. Under the present system, it takes 20 days to discharge 20,000 tons of whe: which is uneconomical. Demurrage and other costs borne by shipping companies increas 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 ɛ Puntarenas, the handling of break bulk grain would be a severe drain on the facilities of tł port. In order to handling break bulk grain at Caldera, it is necessary to greatly improve tł cargo handling efficiency. To improve the efficiency, it is necessary to separate tł stevedoring operation and the operation of carrying the grain to silos located outside tł port area. To separate these operations, it is necessary to construct a new silo at the poı that has at least the same capacity as the maximum handling tonnage of one grain carg vessel.

4. 2. 2 The Assumed Conditions for Grain Cargo Handling

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 m³ 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

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

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 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

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.

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, 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

+(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
	24		24	

(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)
No. 1	120 × 60	7,200	3,600
No. 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 :

$$6,300 \text{ tons} \div 12,600 \text{ m}^2 = 0.5 \text{ tons/m}^2$$

The warehouse storage efficiency can be increased to 0.7 tons/m². Then, the annual storage capacity in the target year will be as follows :

$$8,820 \text{ tons} \times 356 \text{ days/y} \div 7 \text{ days} = 459,900 \text{ tons/y.}$$

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 m²) 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 :

$$1,040 \text{ TEU} \times 365 \text{ days/y} \div 7 \text{ days} = 54,230 \text{ TEU/y}$$

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.

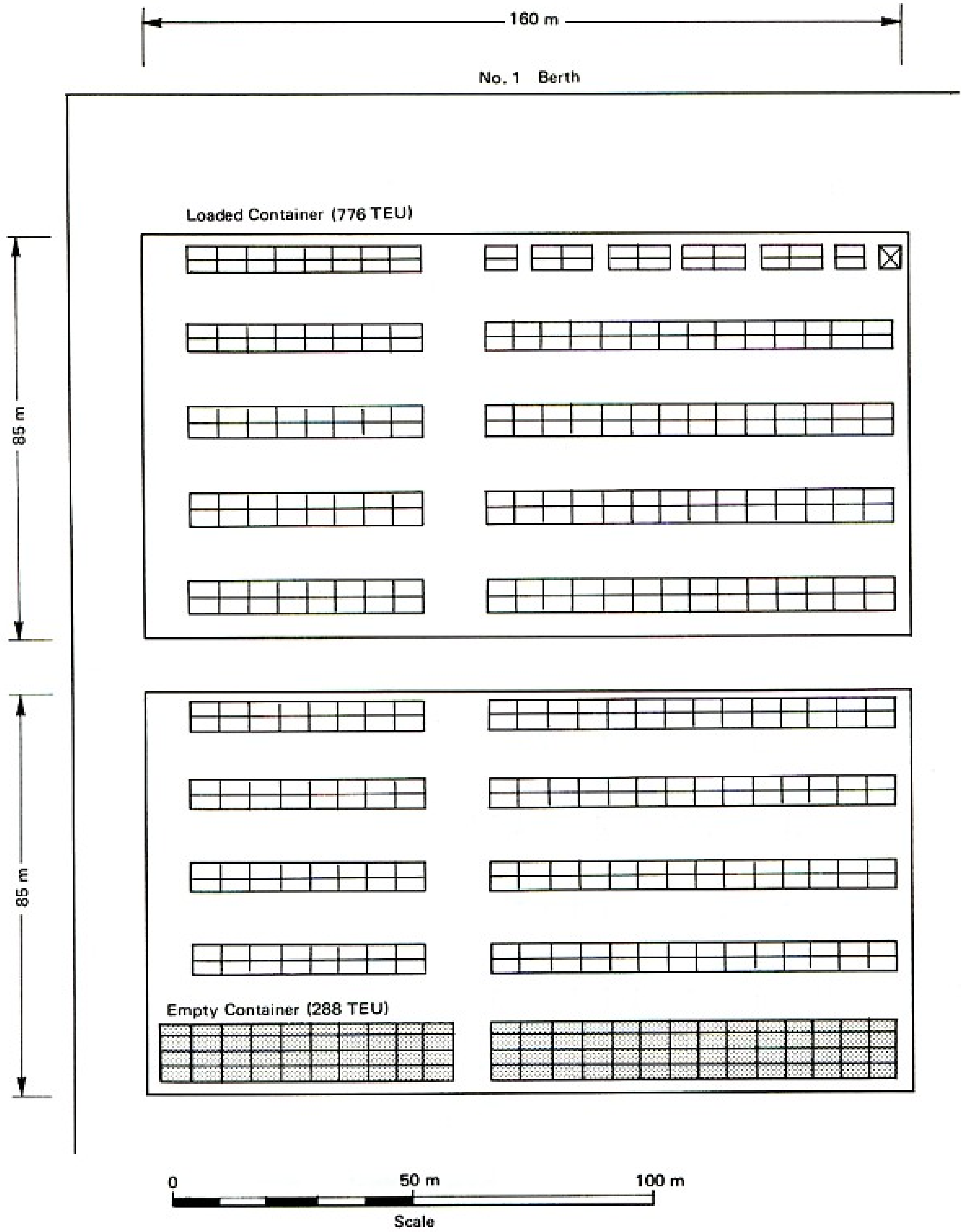


Fig. VIII-3 (a) Container Yard Slot Arrangement Plan

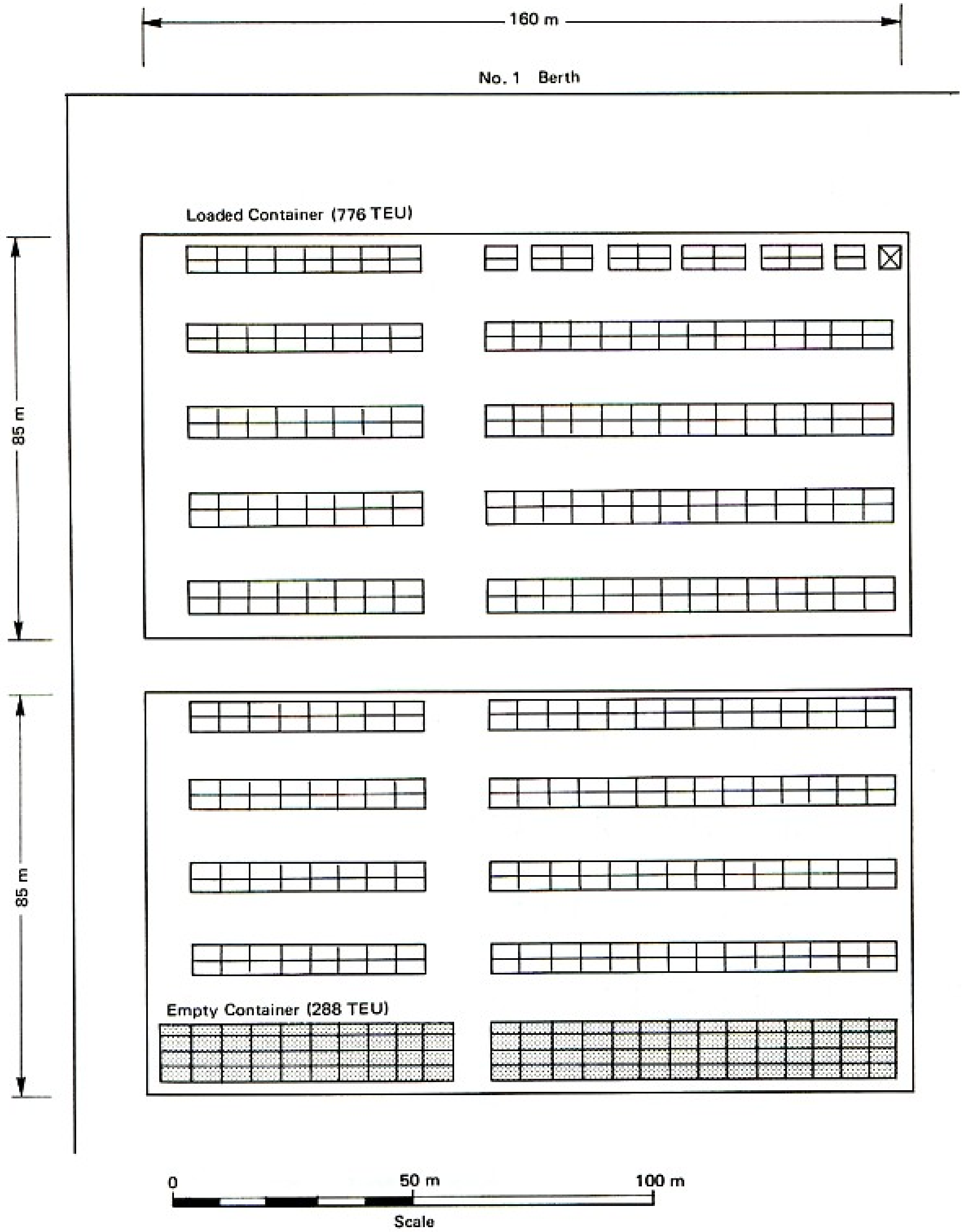


Fig. VIII-3 (a) Container Yard Slot Arrangement Plan

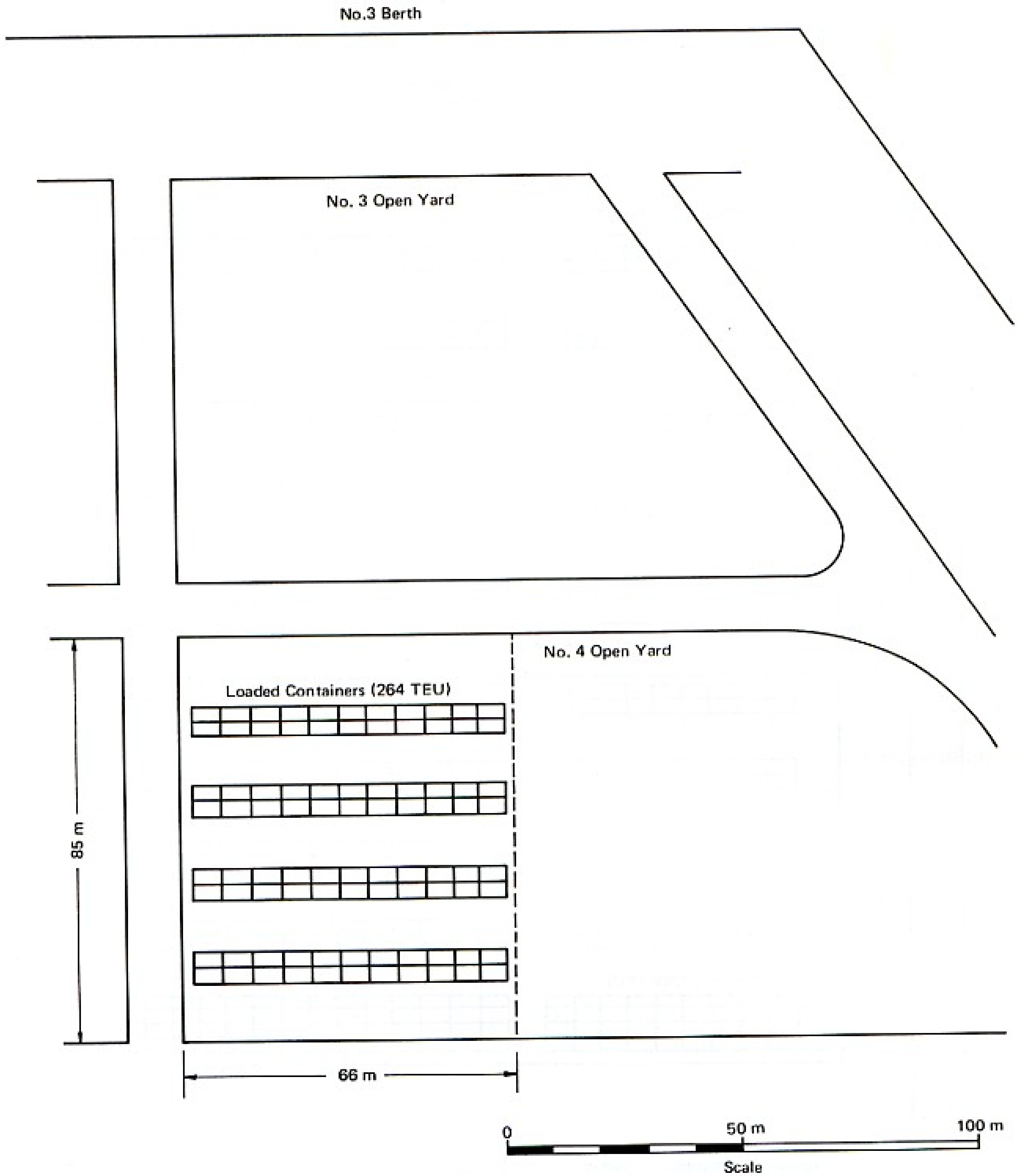


Fig. VIII-3 (b) Container Yard Slot Arrangement Plan

Table VIII-18 Wharf Apron Length and Width

	Wharf Length	Width	Depth
№ 1 Berth	175m	30m	−11m
№ 2 Berth	185m	30m	−10m
№ 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.

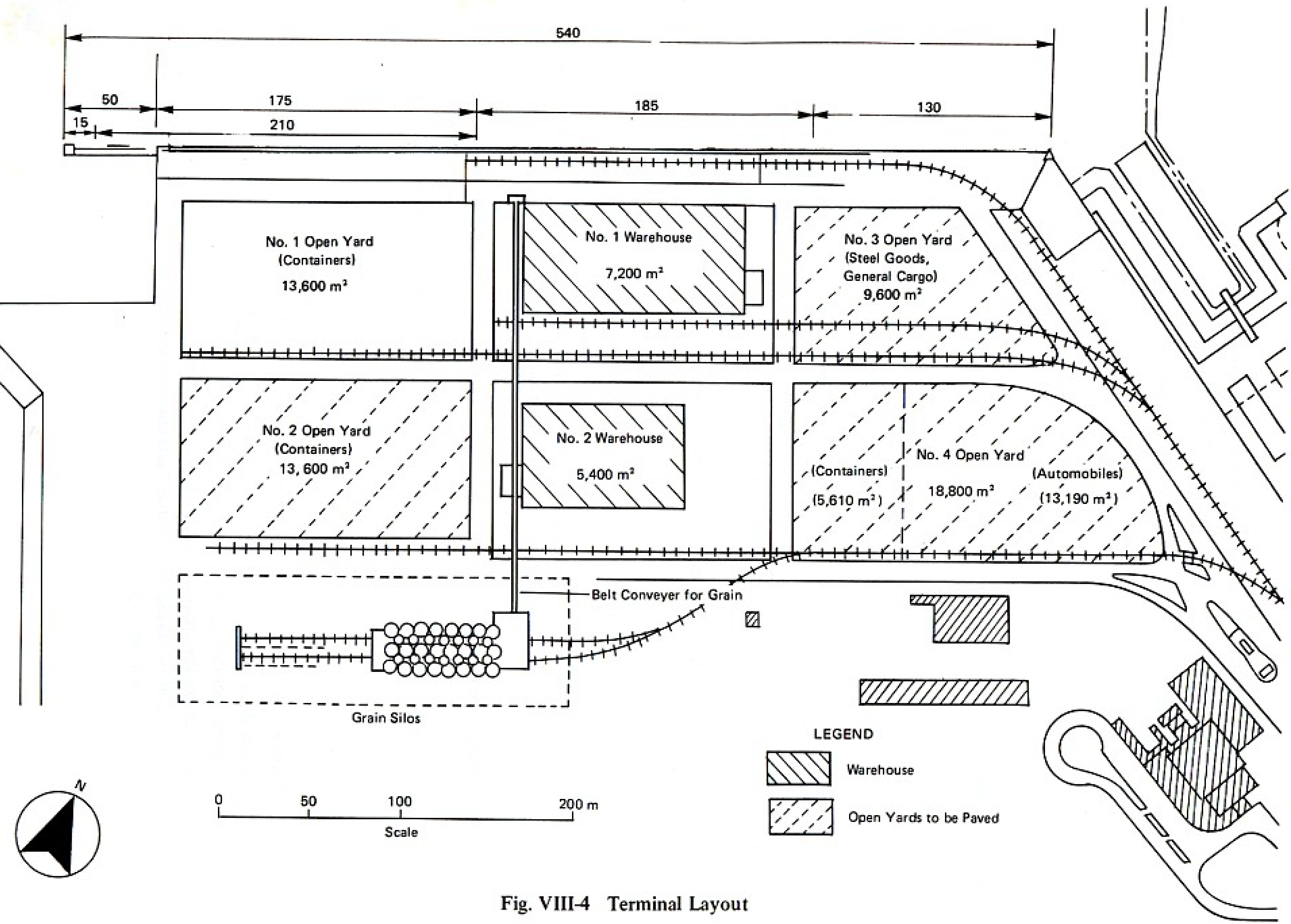
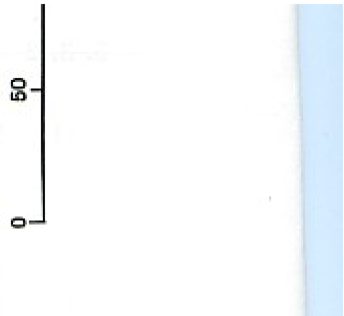
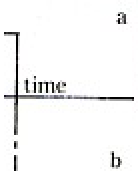


Fig. VIII-4 Terminal Layout


50
0

rying out



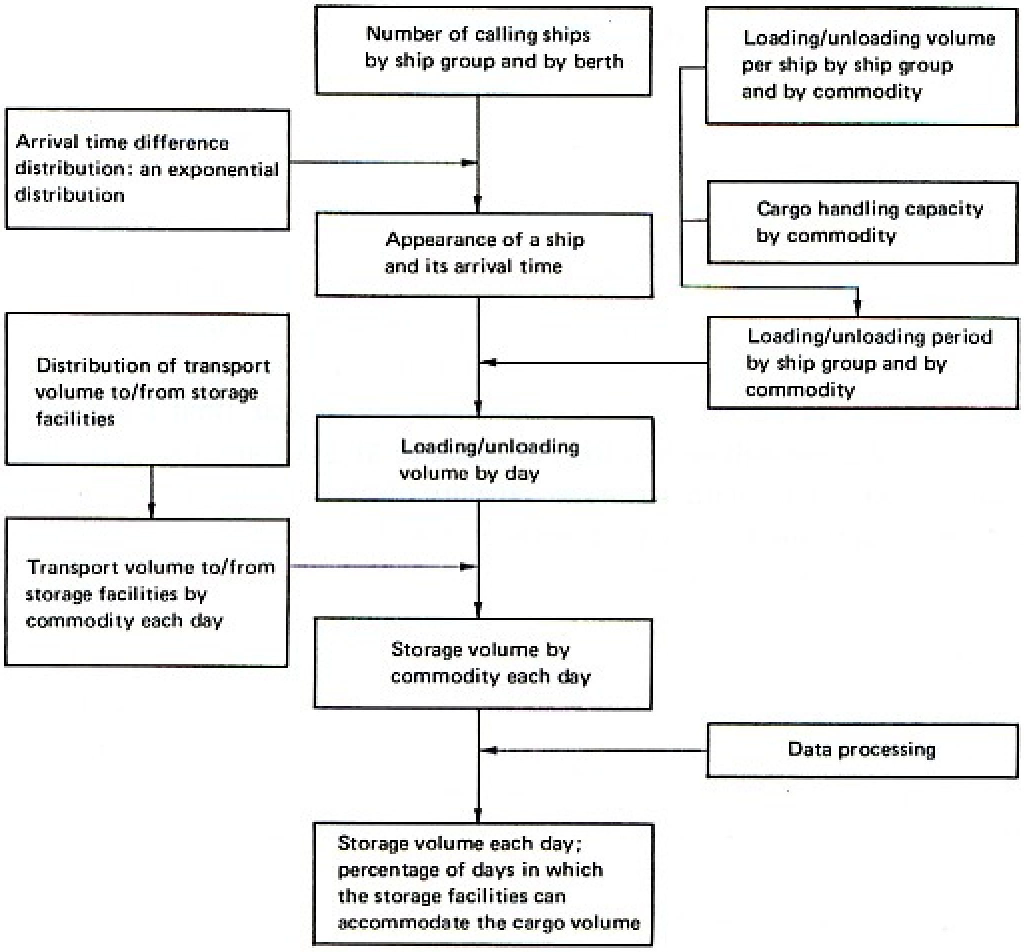
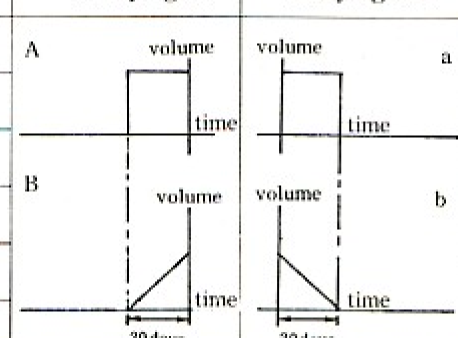


Fig. VIII-5 The Flow Chart of the Storage Simulation

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.

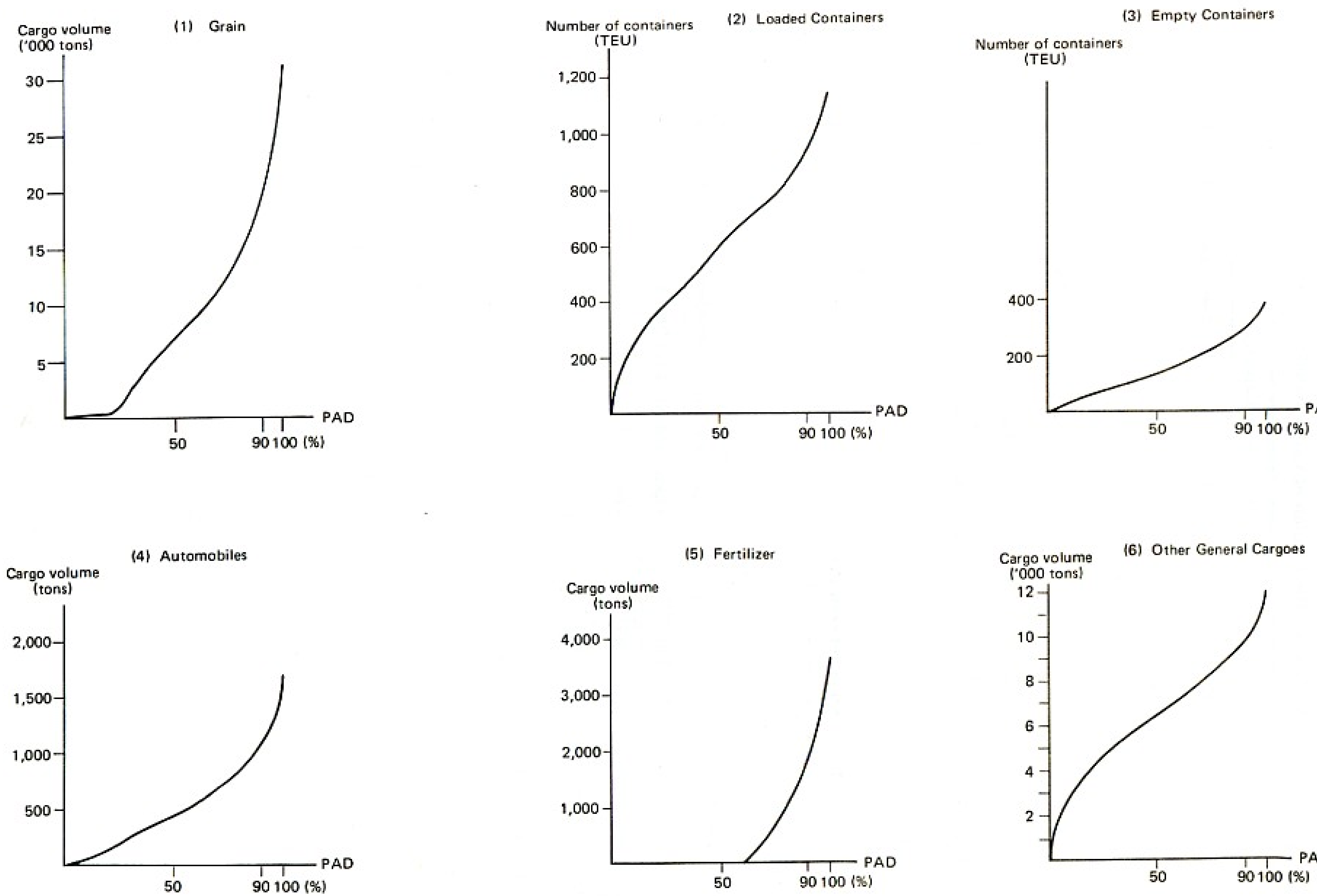


Fig. III-6 Distribution of Sufficiency of Storage Cargo Volume by Commodity

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 (12,600 m²) Open yard No. 3 (9,600 m²)	6,300 ton 7,000 ton
Automobiles	1,056 ton	Open yard No. 4 (13,190 m²)	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

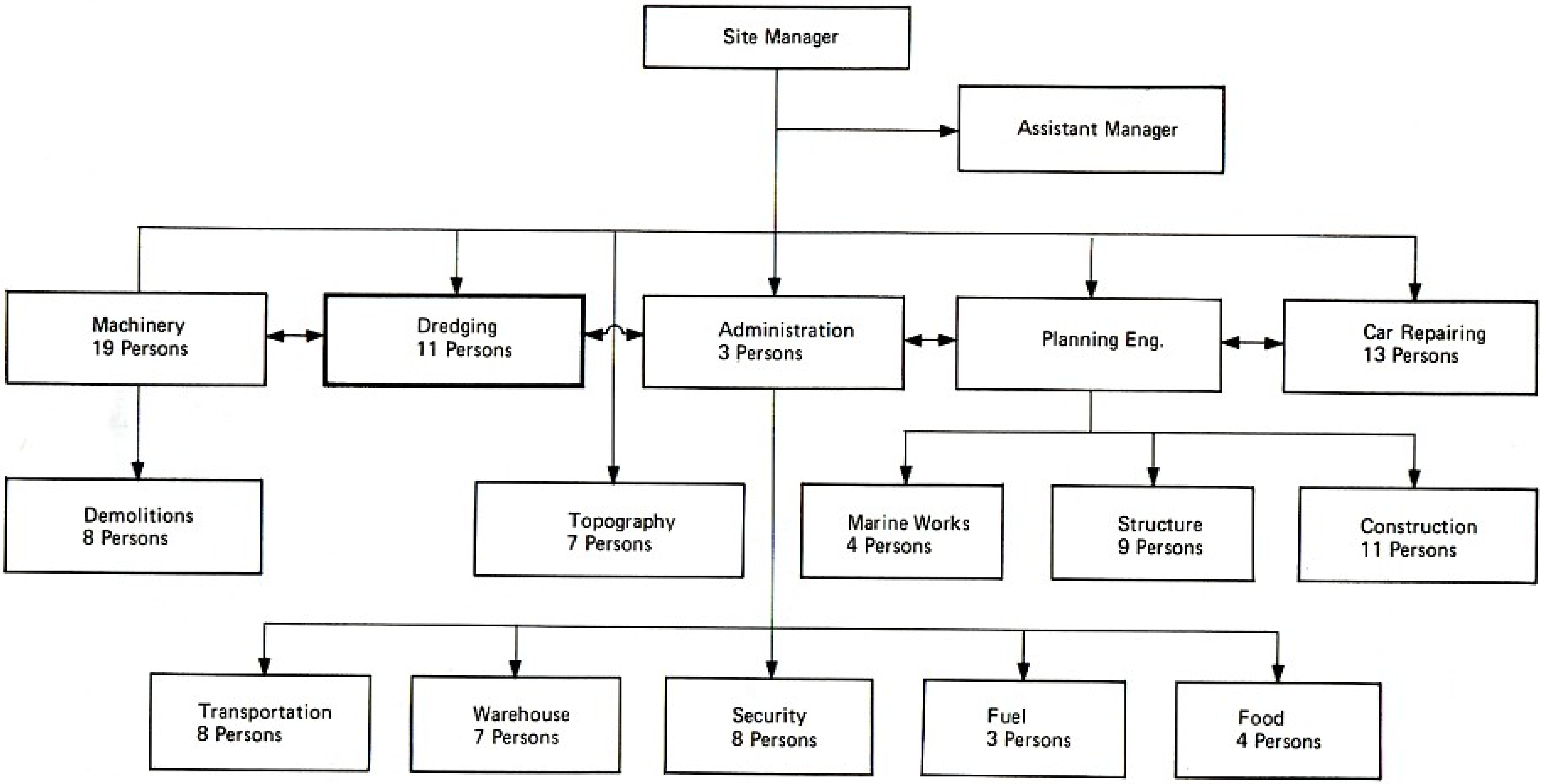


Fig. IX-1 Current Organization of MOPT Caldera Office take out obstructions after lifting the ladder. When the dredger stops because of accidents, the entire crew work at repairing the damaged parts. Some crew members occasionally board the anchor boat in order to change anchor position or to locate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

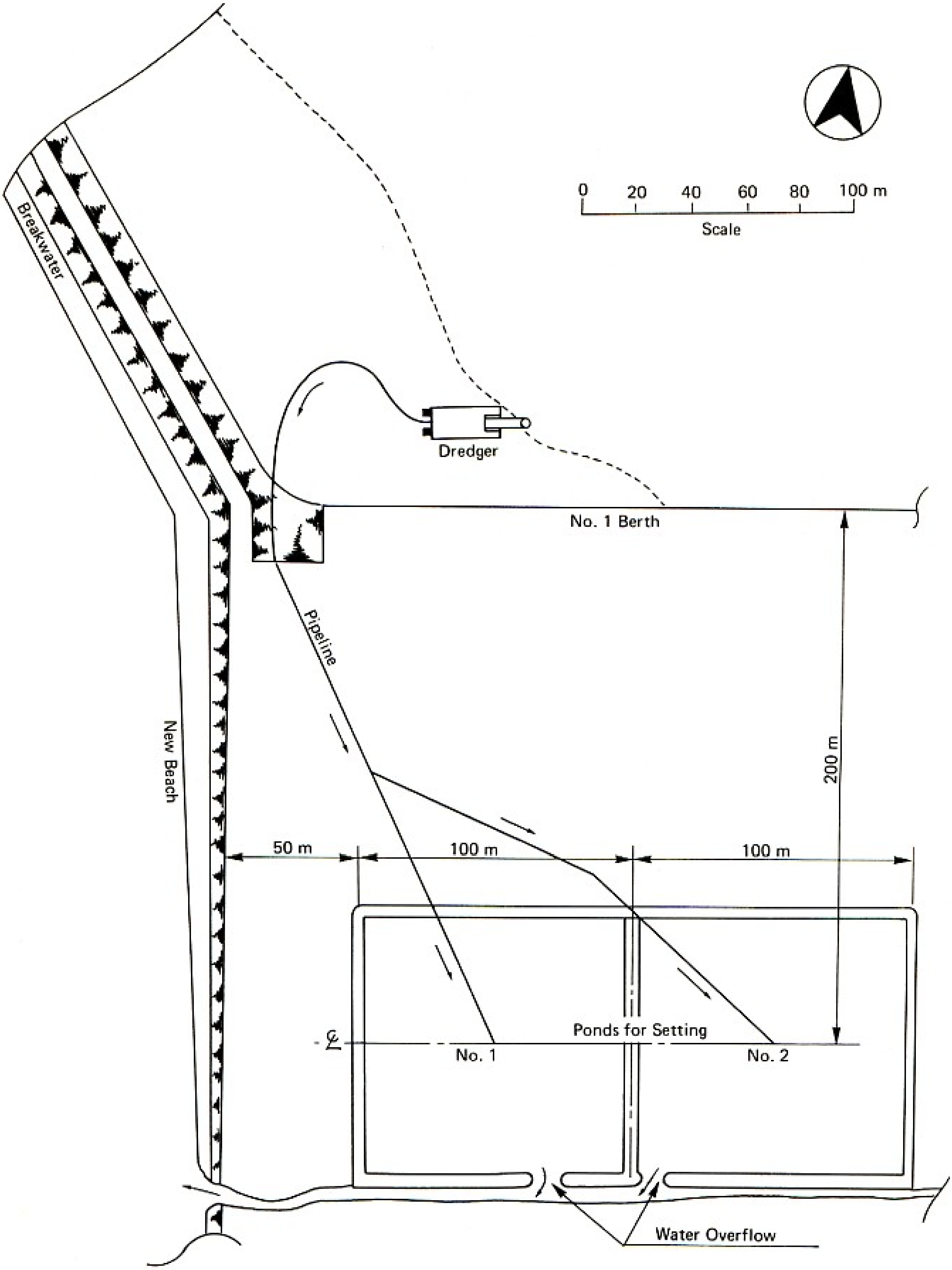


Fig. IX-2 Deposit Procedure of the Dredged Sand

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.

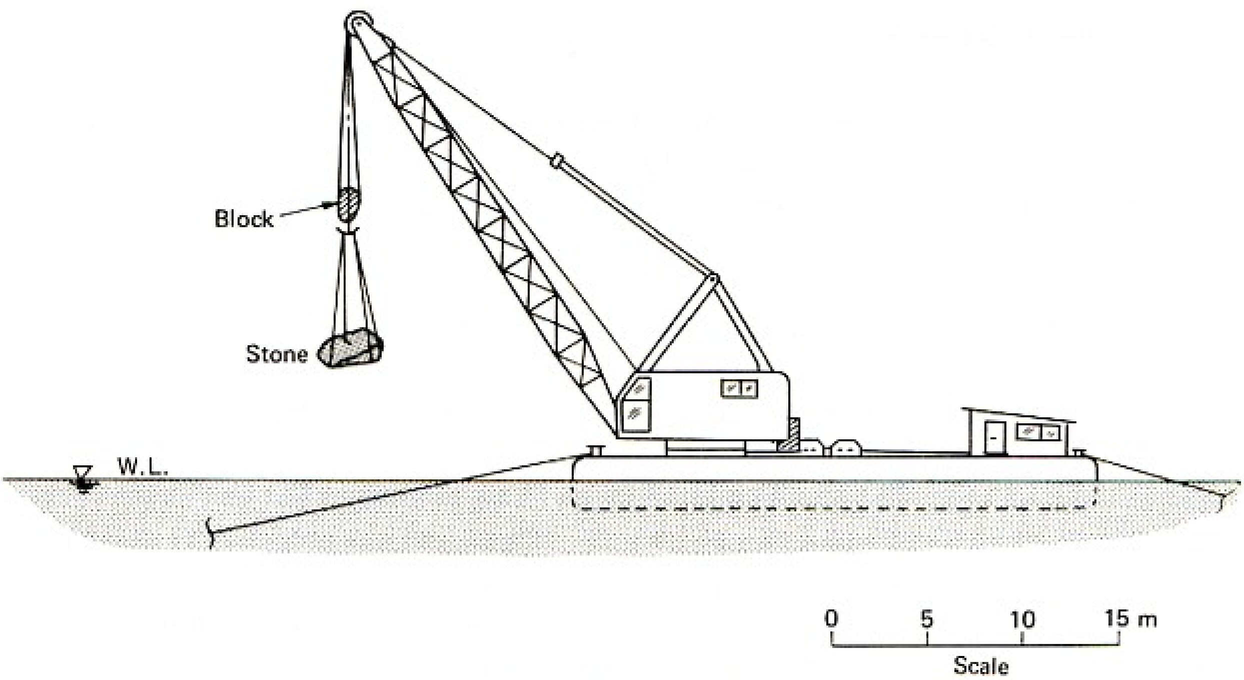


Fig. IX-3 Floating Crane Barge

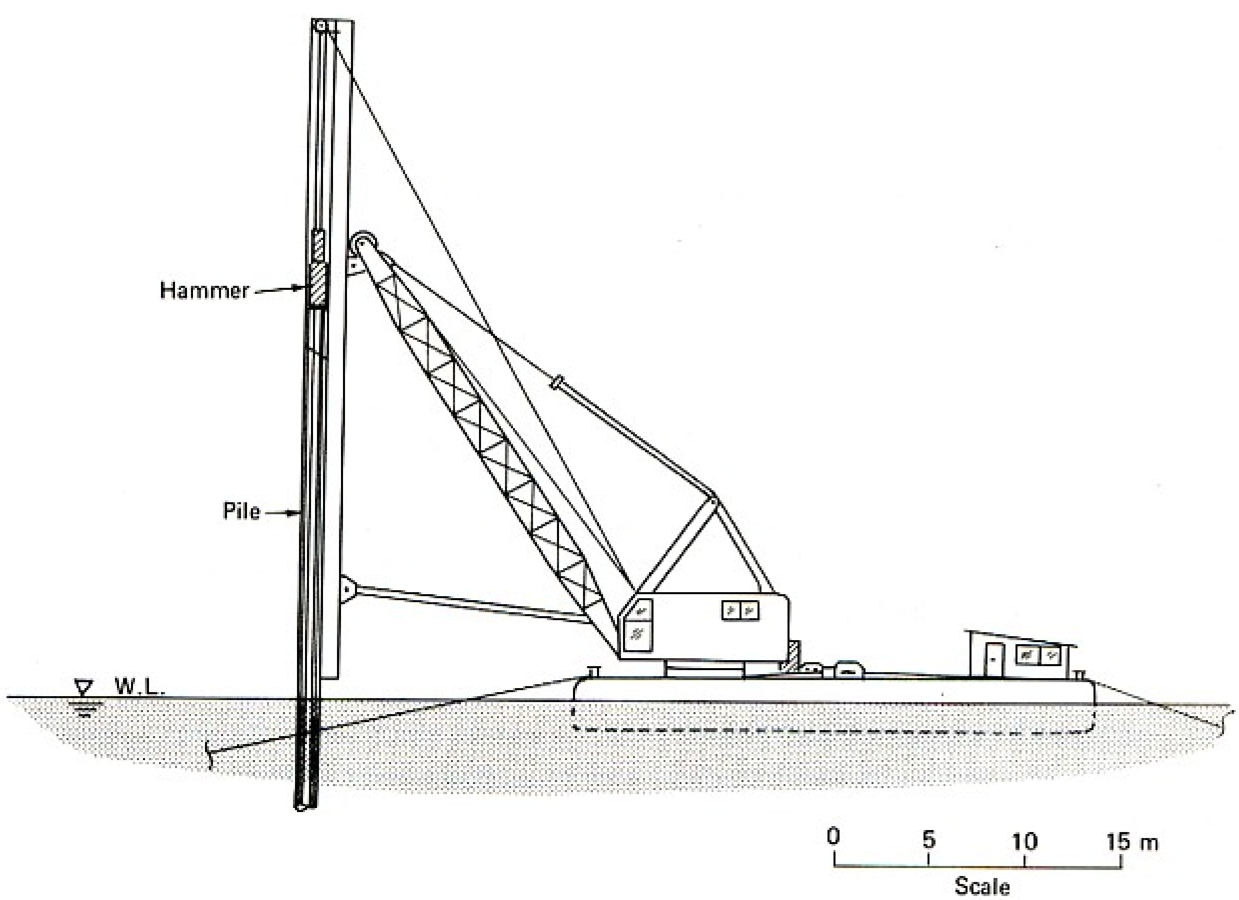


Fig. IX-4 Piling Barge

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	$N \leqq 10$	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

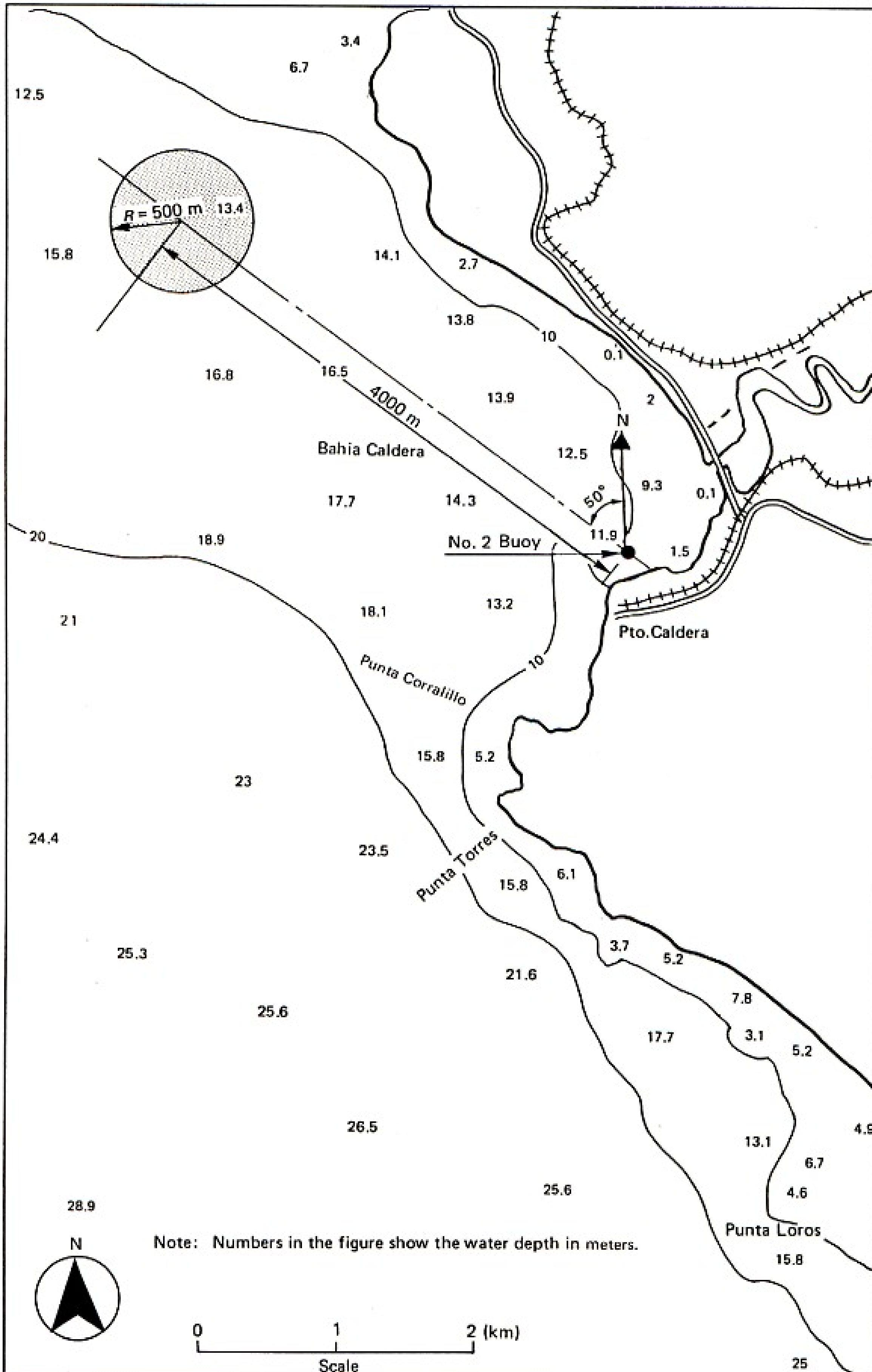


Fig. IX-5 Dumping Area

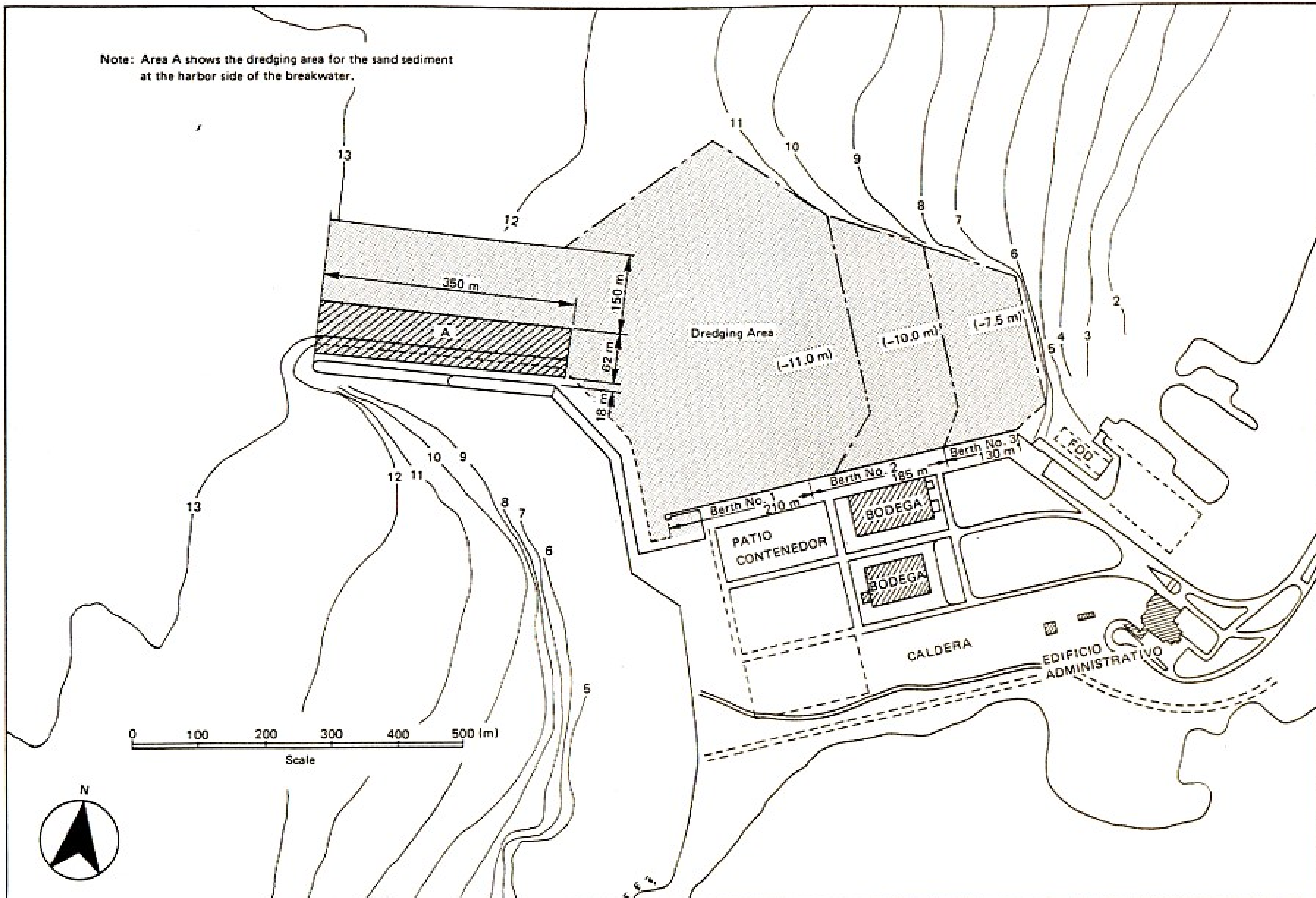


Fig. IX-6 Dredging Area

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.

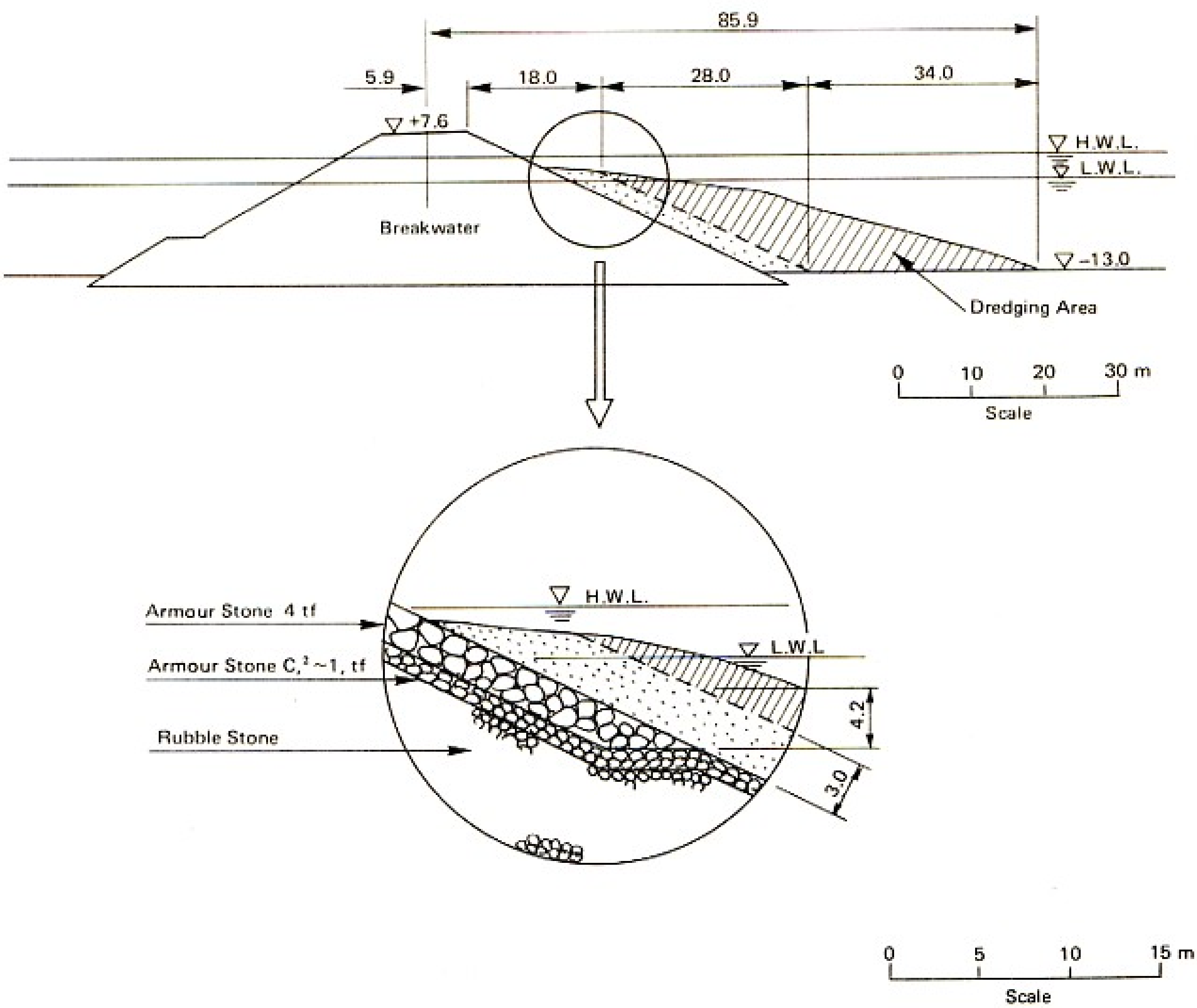


Fig. IX-7 Cross Section of Dredging Area A

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

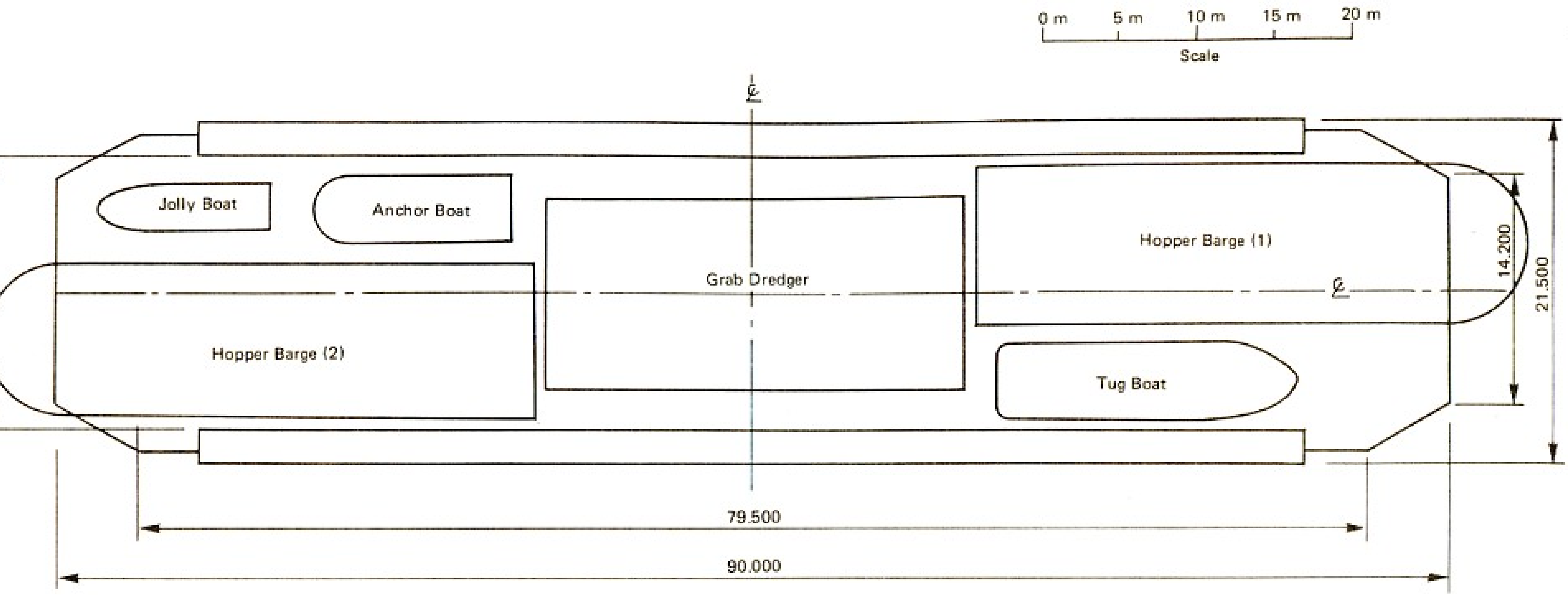


Fig. IX-8 Periodic Maintenance on Floating Dry Dock

(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.

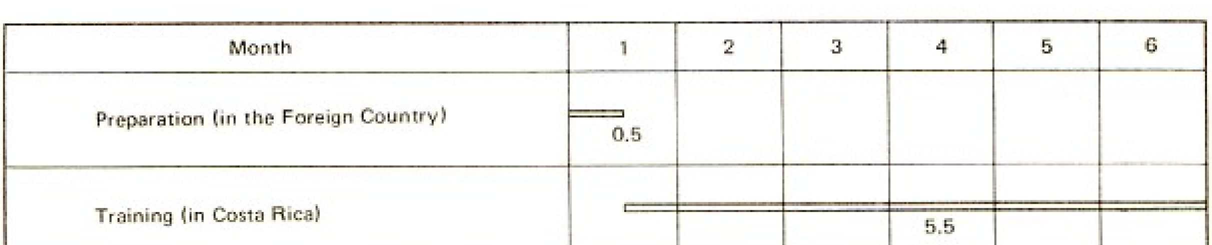


Fig. IX-9 Training Period

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 ~ 13.5 m

Sandy Soil	$\phi = 30°$ $\gamma' = 1.0\ \mathrm{tf/m^3}$	
		-20.0 m
Cohesive Soil	$c_u = 4.0 + 3.0\ z$ $(z = 0;\ -20\ \mathrm{m})$ $\gamma' = 0.7\ \mathrm{tf/m^3}$	
		-40.0 m
Bedrock		

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

Existing Seabed

-11.0 m

Sandy Soil	$\phi = 30°$ $\gamma' = 1.0\ \mathrm{tf/m^3}$	
		-17.0 m
Cohesive Soil	$c_u = 1.0 + 3.0\ z$ $(z = 0;\ -10\ \mathrm{m})$ $\gamma' = 0.7\ \mathrm{tf/m^3}$	
		-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.

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).

According to the technical standard for port facilities in Japan [4], a tractive force of 50 tf shall be used. This tractive force is the same as the one used for designing the existing −11 m wharf.

(7) Surcharge and Live Load

The surcharge used for designing the mooring dolphin and gangway assumes 0.5 tf/m^2 as the human load. Also, the load from automobiles is considered as 14 tf in total. The surcharge for the −3.0 m quaywall at the small craft basin is 2.0 tf/m^2 under ordinary conditions and 1.0 tf/m^2 under seismic conditions.

1. 2 Breakwater Extension and Shift of Breakwater

1. 2. 1 Extension of the Breakwater

Comparative studies of three types of breakwater extensions are executed in order to determine the best type of structure for the breakwater to be extended. The three types considered are rubble mound breakwater, artificial concrete block armoured rubble mound breakwater and caisson type composite breakwater. These three alternatives are selected for the following reasons :

(a) Rubble mound breakwater

This is the type of structure adopted for the breakwater sections under the first stage construction works and the second stage expansion project.

(b) Artificial concrete block armoured rubble mound breakwater

The design waves established on the basis of the data obtained from the recent wave observation are larger than those adopted for the first stage construction works and the second stage expansion project. The Tertiary period sedimentary rocks produced at North Caldera used as armour stones are smaller in their specific weight than the igneous rocks produced at Dantas, so it was necessary to use stones as large as 17 tf/piece, hence the difficulty in mass quarrying, transporting and installation. Consequently, the alternative of using Dolos as an armour unit (it has been used successfully at the port of Limón) was chosen as one possible solution.

(c) Caisson type composite breakwater

There is no record in Costa Rica of manufacturing caissons in the past, but when the floating dock for repairing fishing boats now under construction at the north side of the −7.5 m wharf is completed, manufacture of caissons will become possible, so the caisson type composite breakwater is also proposed as an alternative.

---

4) Bureau of Ports and Harbours, Ministry of Transport, Port and Harbour Research Institute, Ministry of Transport : Technical Standards for Port and Harbour Facilities in Japan, 1980.

Standard cross sections and cross sections of the tip for each alternative are shown in Fig.X-3 to X-8. Points to be noted in these comparative designs are as follows.

(a) Crown Height

As in the first stage construction works and the second stage expansion project, the crown height of the breakwater should be high enough that almost no waves will be able to pass the top of the breakwater. Specifically, the height should be 1.25 times the design significant wave height ($H_{1/3}$=4.6 m) at the hight water level (+3.0 m), that is, +8.7 m.

(b) Type and Weight of Armour Units

For calculating the weight of armour units, Hudson's formula is adopted, and the adopted K_D values for a damage ratio less than 1%, are 3.2 for armour stones, and 20 for Dolos. For the second stage expansion project, a damage ratio of 10% was admitted, and the weight of armour stones was reduced to less than 1/2. The breakwater now under extension (weight of armour stones : 4 to 8 tf) is often damaged by waves and this is a major factor hindering the progress of the work. In order to secure a safety factor equivalent to the other alternatives, we have adopted this new damage ratio (less than 1%). In adopting Dolos as the armour unit, the fact that 50 sets of steel moulds used for 3.5 tf Dolos at Limón Port (among which about 30 sets are in fine condition) are available within Costa Rica was taken into consider-ation.

(c) Armour Units for the Breakwater Head

Usually, the armour units used for the head part of breakwaters should be 1.5 times heavier than those used for the trunk parts. However, in this case the problem is solved by making the gradient of slope of the breakwater gentler because heavier stones are more difficult to quarry and to handle. 26 tf stones are extremely difficult to quarry and set and if Dolos were used an additional type of moulds would be necessary which would increase the cost and prolong the term of work.

(d) Shape of Caissons

The shape adopted for the caissons is one that could be manufactured on the floating dry dock that is now under construction.

The estimated construction cost of each alternative is as follows :

Rubble mound type breakwater	US$ 4,698,000
Dolos armoured rubble mound breakwater	US$ 4,252,000
Caisson type composite breakwater	US$ 4,558,000

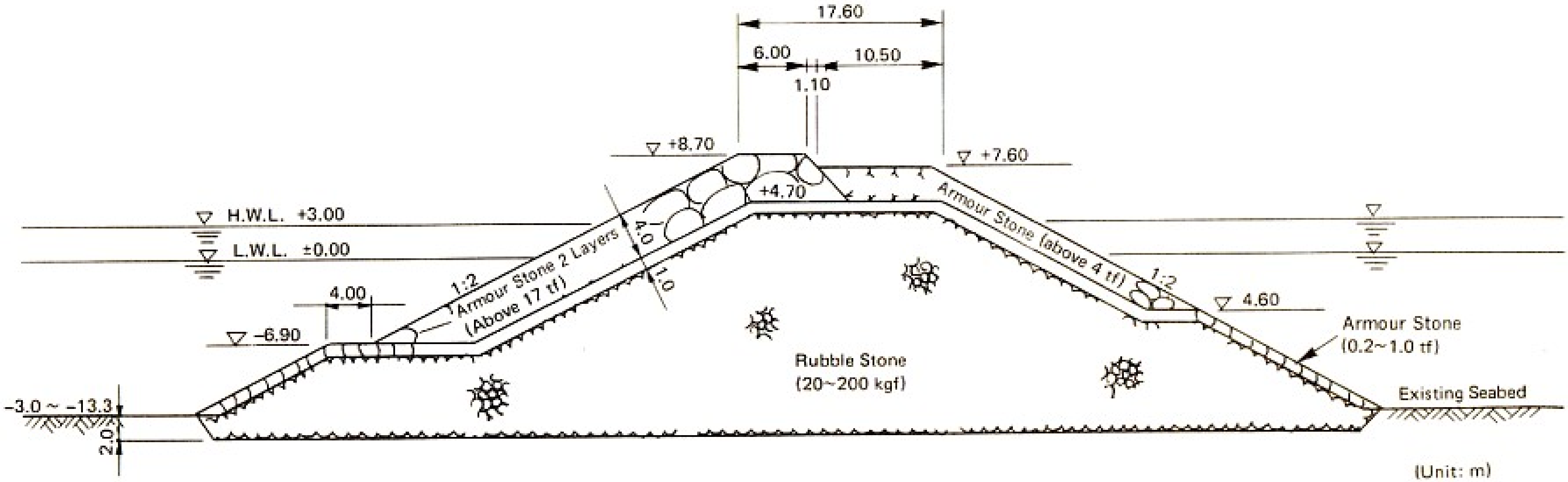


Fig. X-3 Standard Cross Section of Rubble Mound Breakwater

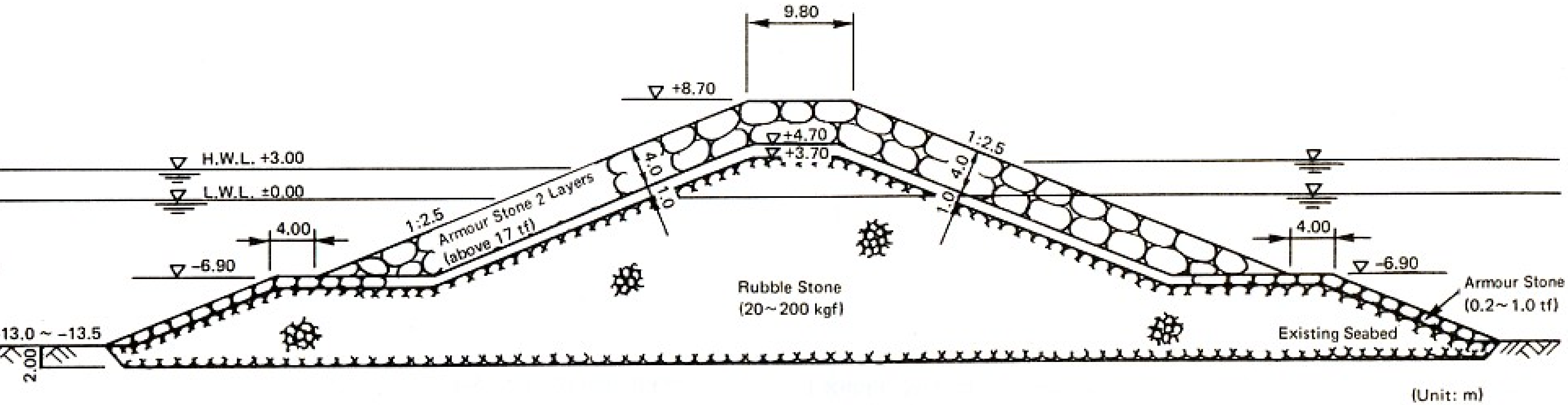


Fig. X-4 Cross Section of End Part of Rubble Mound Breakwater

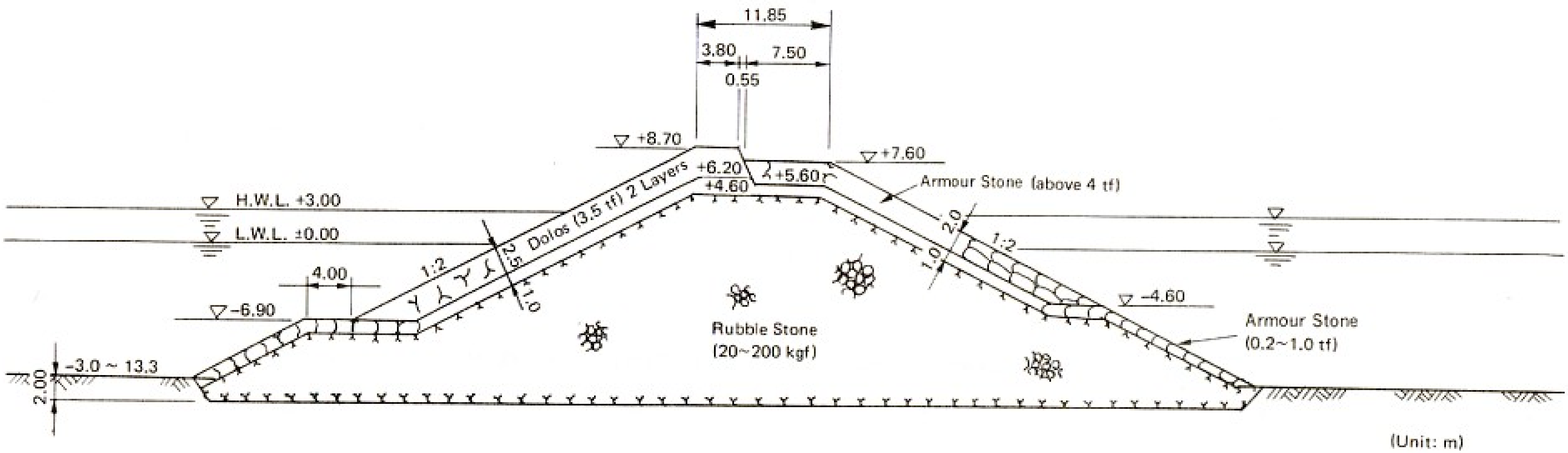


Fig. X-5 Standard Cross Section of Rubble Mound Breakwater Armoured by Dolos

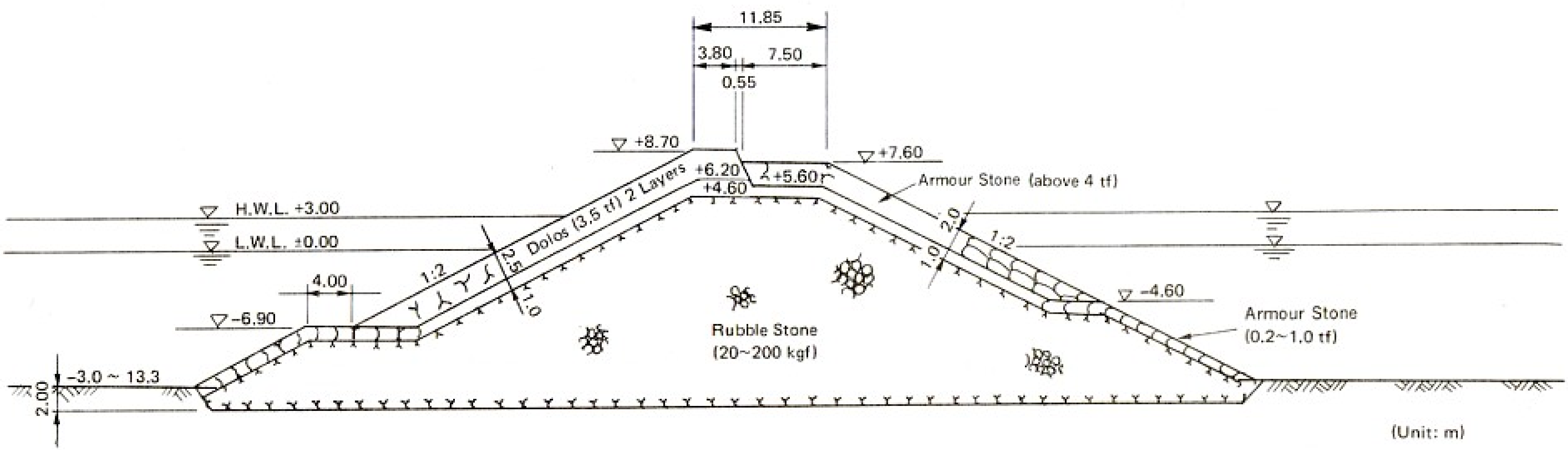


Fig. X-5 Standard Cross Section of Rubble Mound Breakwater Armoured by Dolos

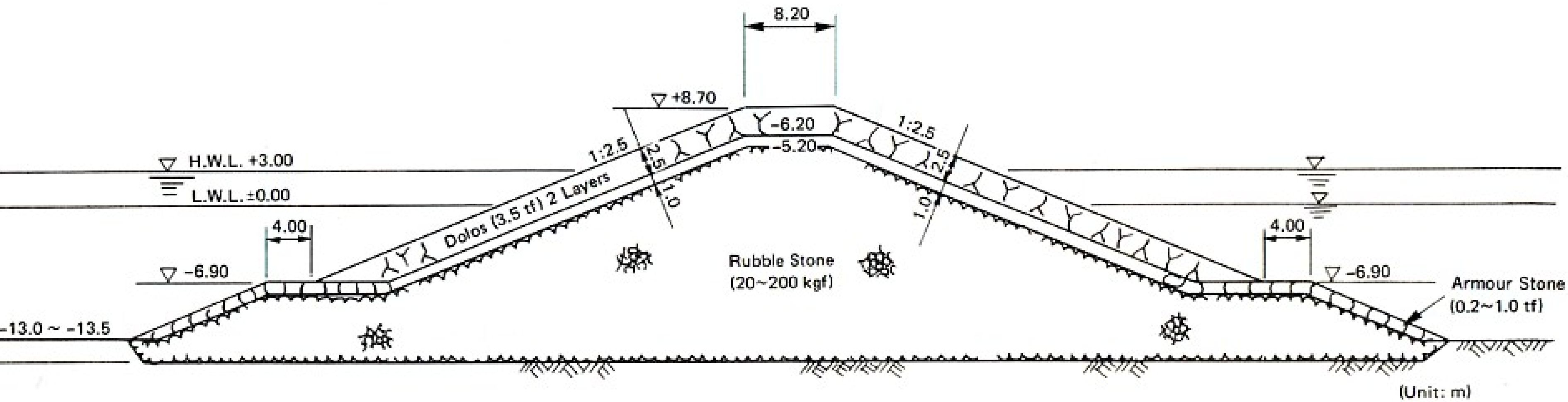


Fig. X-6 Cross Section of End Part of Rubble Mound Breakwater Armoured by Dolos

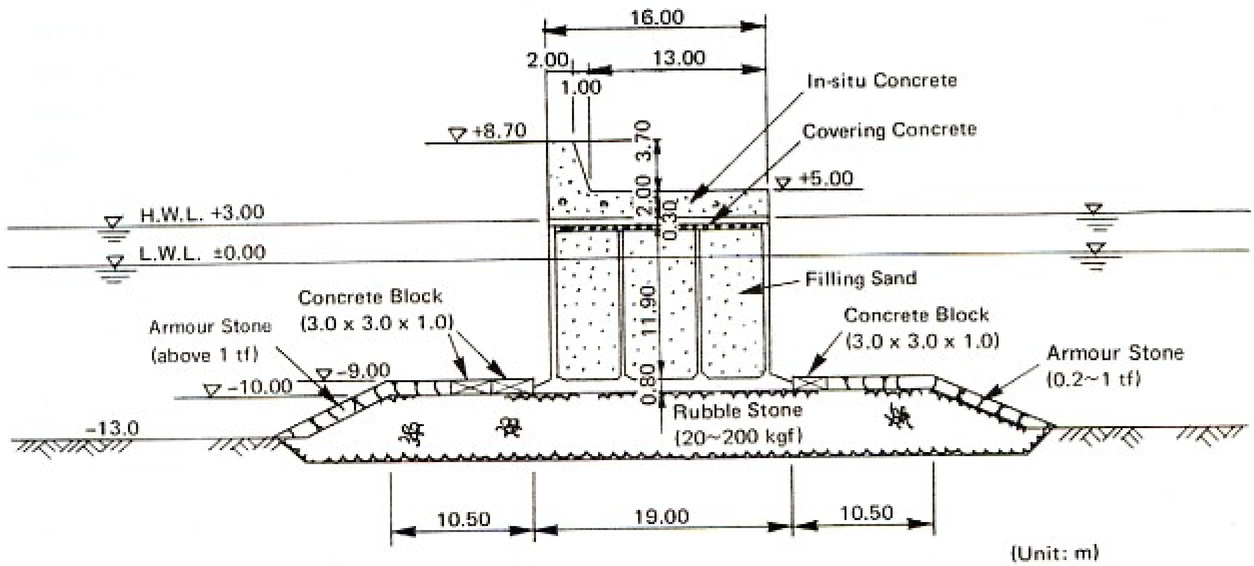


Fig. X-7 Standard Cross Section of Caisson Type Composite Breakwater

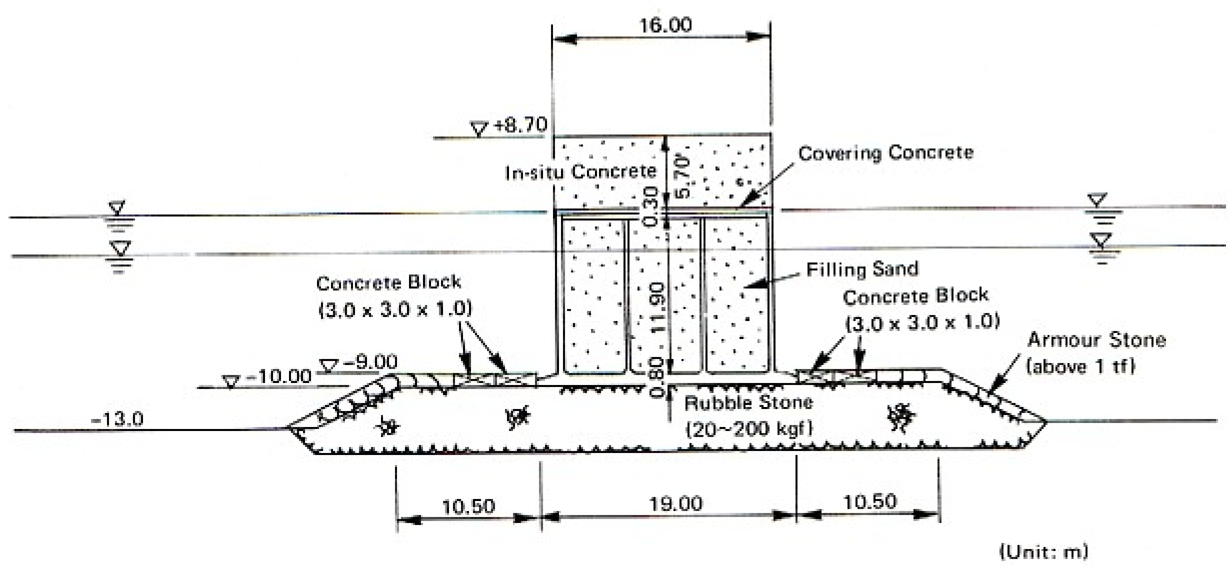


Fig. X-8 Cross Section of End Part of Caisson Type Composite Breakwater

The estimated construction cost for the Dolos armoured rubble mound type is the most economical. Furthermore, both the rubble mound breakwater and the caisson type composite breakwater would be extremely difficult to construct and the stability and durability of the rubble mound type might be problematic. Thus, we adopt the Dolos armoured rubble mound breakwater alternative. The problems involved with the rubble mound type and the caisson type are noted below.

(a) The rubble mound breakwater requires armour stones of 17 tf. However, judging from the conditions of the quarry at North Caldera, it is presumed to be difficult to obtain a sufficient quantity of such stones.

Thus, if this alternative were adopted, it would be difficult to execute the work promptly.

(b) The precision of setting the armour stones on the breakwater now under extension is not always sufficient, and this is considered to be one of the reasons for the repeated damage caused by waves. If the rubble mound type were adopted, it would be necessary to improve the precision of setting stones, and precisely installing armour stones with a weight as high as 17 tf would be difficult. On the contrary, Dolos can be dispended in small weights and as the Dolos will be in a shape that is easily engaged, this method will provide far better stability.

(c) The armour stones produced at North Caldera are soft rock of the Tertiary period, and they are inferior in durability and strength.

(d) In general, caisson installing works are only possible when the significant wave height is less than 0.5 m, and when long period waves predominate as at Caldera, the installation work requires advanced technology even when the wave height is less than 0.5 m. As indicated in CHAPTER III, 3.1 Wave Conditions, when the rate of generation of significant wave height of 0.5 m or less is as low as 6% and when the number of workable days for the construction is limited, the term of work would be greatly prolonged, even without counting the days spent in preparation. Also, for installation of the first caisson foundation, it would be necessary to install concrete blocks beforehand.

(e) For the installation of the caisson, the surface of the mound would have to be made smooth to within ±5 cm using a diver. However, this precision work would be extremely difficult under the conditions of being exposed to long period swell, and consequently it would be difficult to ensure the timely completion of the work.

Advantages and disadvantages of each alternative are shown in Table X-1.

Table X-1 Advantages and Disadvantages of Each Alternative Breakwater Extension Plan

Items	Rubble Mound Breakwater	Dolos Armoured Rubble Mound Breakwaoer	Caisson Type Composite Breakwater
Direct Construction Cost ('000 US$)	4,693	4,252	4,558
Possibility of Obtaining a Sufficient Quantity of Armour Units	×	○	○
Required Precision of Setting the Armour Units	×	○	△
Necessity of High Grade Smoothing of the Surface of the Mound	unnecessary	unnecessary	necessary
Ease of Insuring Workable Days for Marine Works	○	○	×
Possibility of Rapid Construction	×	○	×

1. 2. 2 Shift of the Existing Breakwater

As part of the development project, the wharf side section (the foot) of the existing breakwater will be shifted to the west. As the tip of the breakwater will also be extended, the beach on the south side of the existing breakwater will become even larger, and no large wave force will strike the base of the breakwater at its new location.

Thus, there should be no difficulty in using the original section of the breakwater at the new location; that is the base of the existing breakwater will simply be moved to the new location without making any modifications. The plan of the breakwater which will be shifted is shown in Fig.X-10, and the standard cross section is shown in Fig.X-11.

Before beginning to actually move the breakwater, the new site will be excavated to the −3.0 m level and rubble stones at least 3.0 m in thickness will be placed between the existing breakwater mound and the new site to ensure that no sedimentation takes place while the breakwater is being moved.

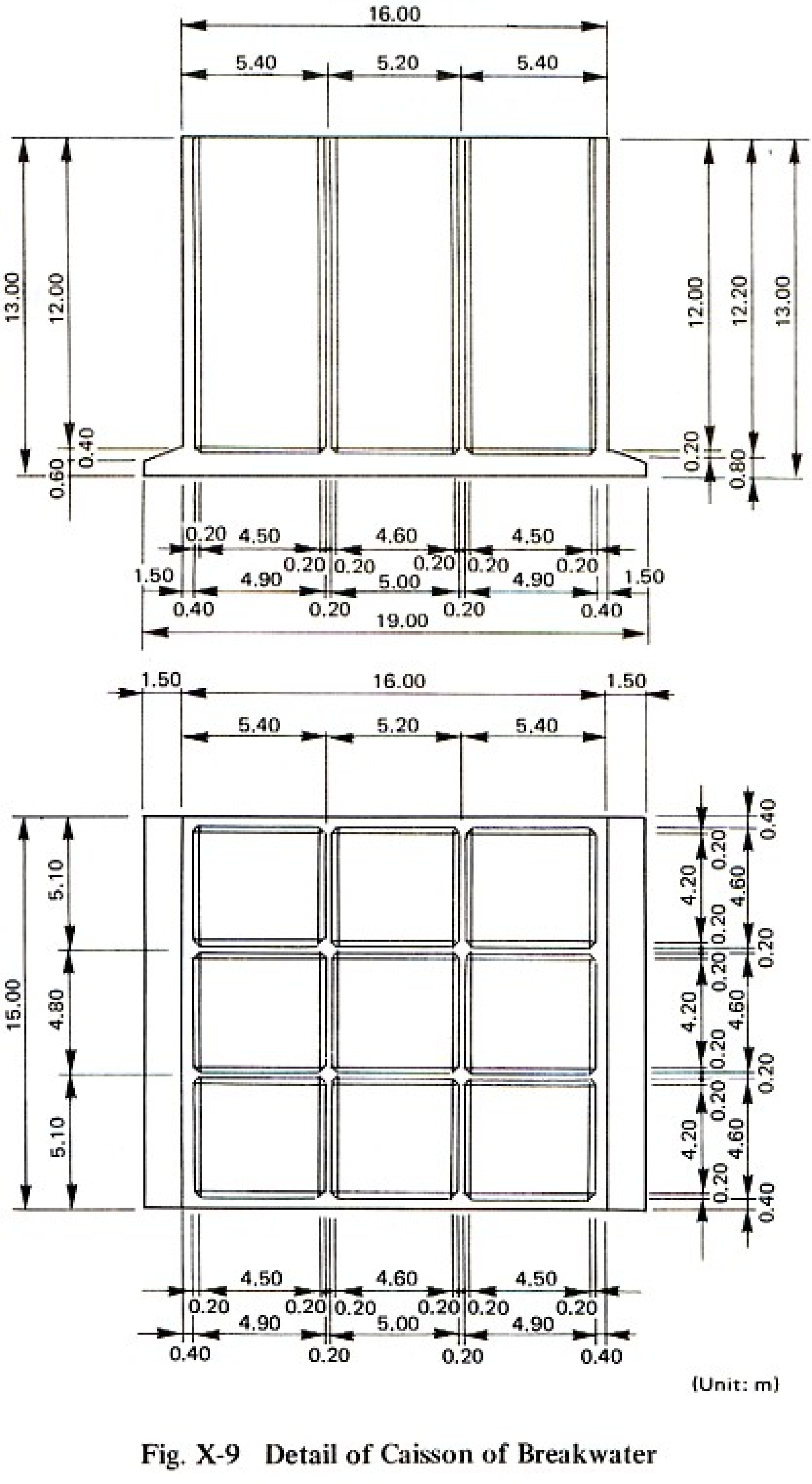
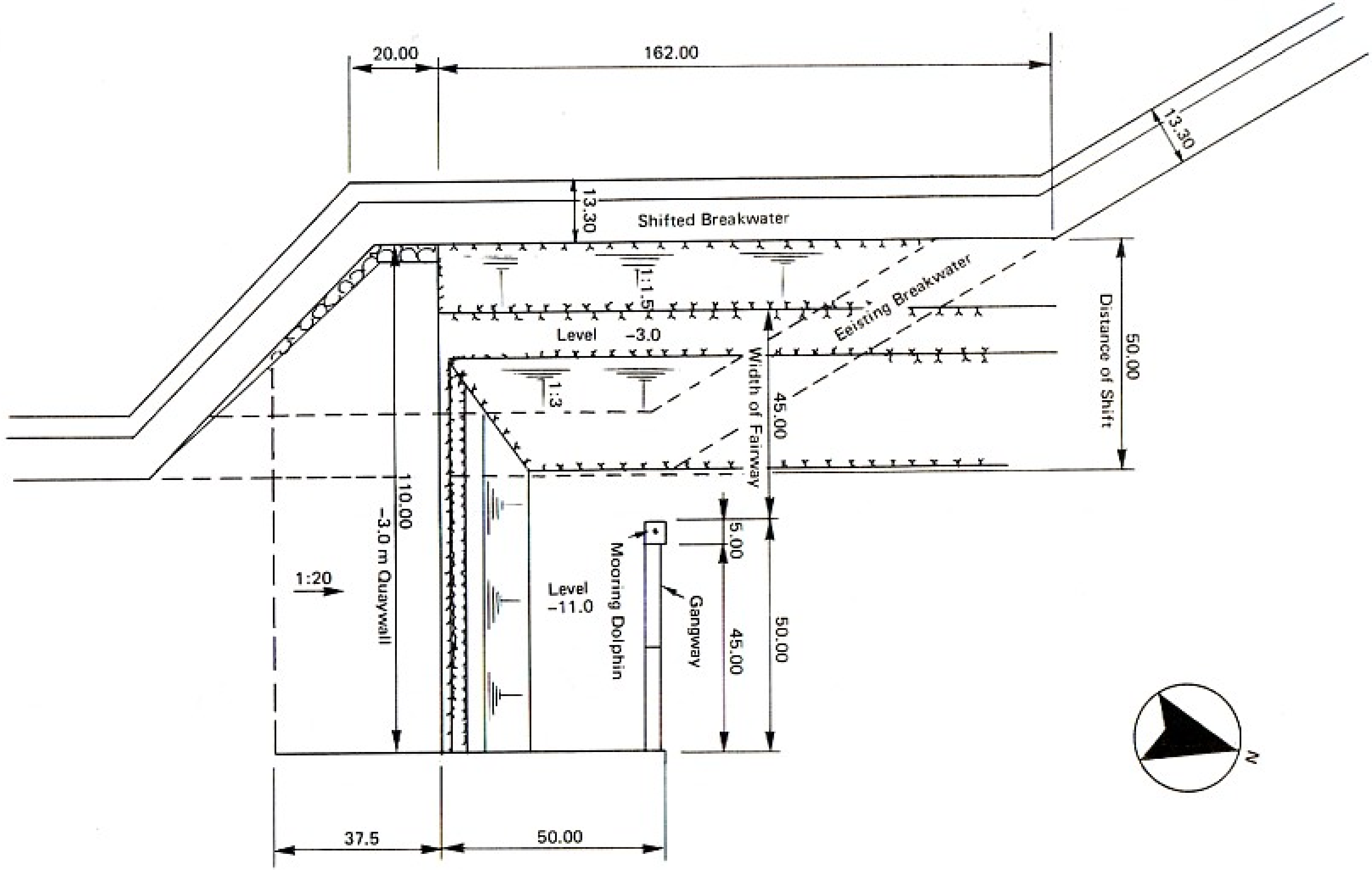
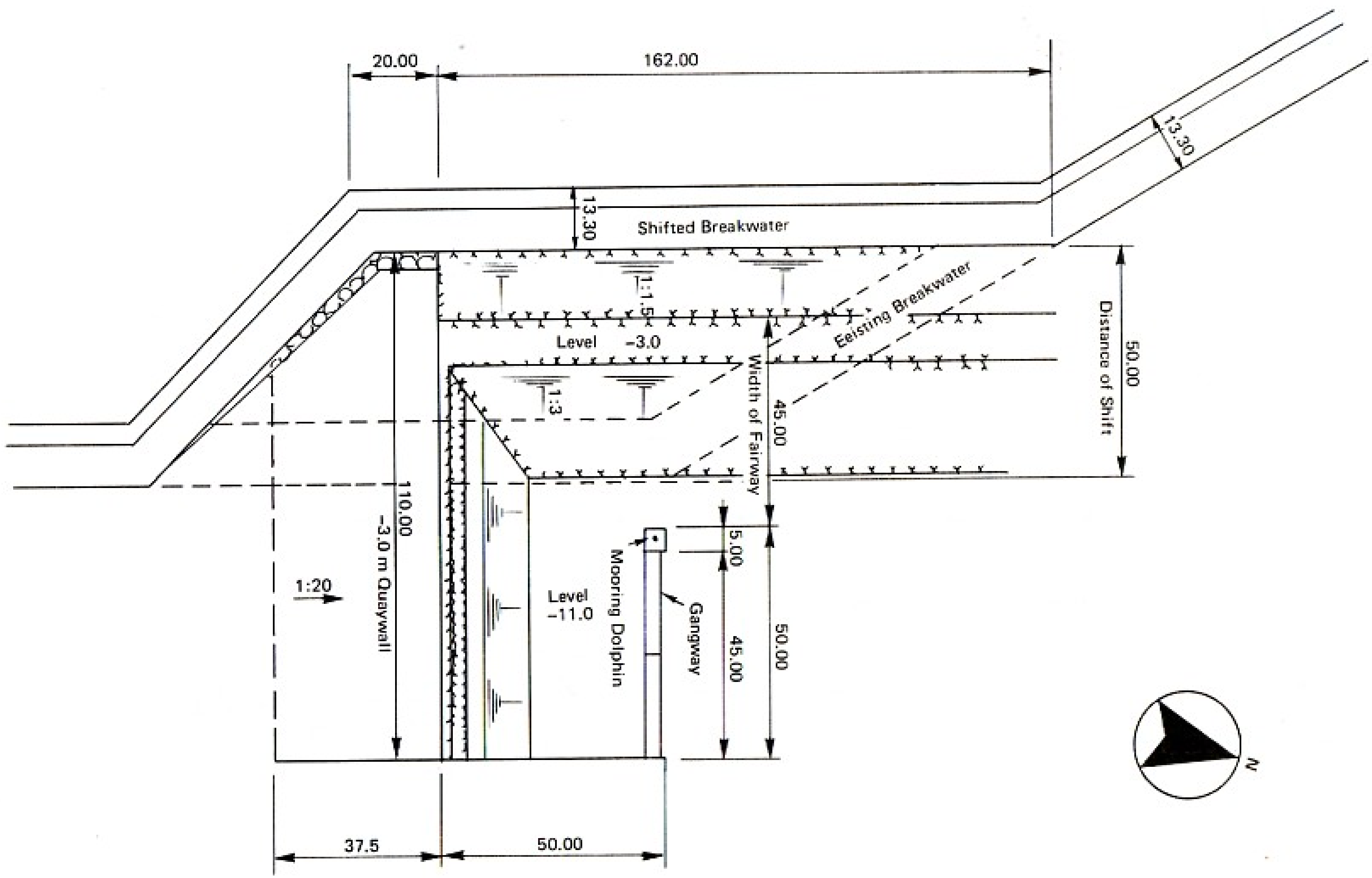


Fig. X-9 Detail of Caisson of Breakwater



(Unit: m)

Fig. X-10 Plan for the Enlargement of the Mooring Capacity



(Unit: m)

Fig. X-10 Plan for the Enlargement of the Mooring Capacity

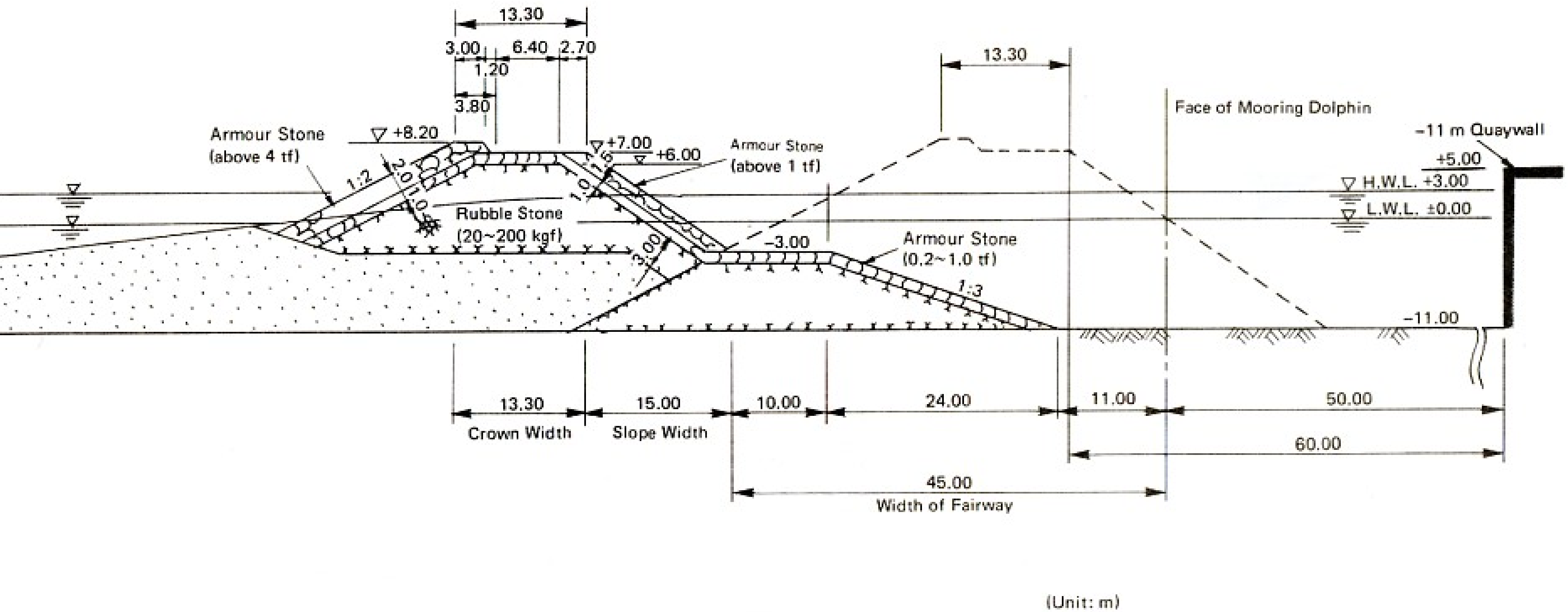


Fig. X-11 Standard Cross Section of Shifted Breakwater

1. 3 −3.0m Quaywall

For the −3.0 m quaywall in the small craft basin, a gravity type structure shall be adopted. Two gravity type structures are considered, namely the concrete block quaywall type and the L-shaped block quaywall type. The reason why we did not consider the sheet pile wall or the piled platform type is that as the installation site of this quaywall is on a rubble mound revetment, it would be difficult to drive in sheet piles or piles at the site, and a large quantity of rubble stones would have to be removed. The gravity types require no such toil, and the lower part of the rubble stones could be used as a foundation mound. Another advantage is that a grab type dredger could be used for installing concrete blocks.

As for the crown height of this quaywall, considering that the vessels using this wharf will mainly be service vessels for the port operations such as tug boats and plying boats having a lower freeboard, 0.5 m above the high water level, that is, +3.5 m is adopted. An apron with a gradient of 1 : 20 will be constructed adjacent to the wharf. Also, a retaining wall will be provided as the boundary between the −11 m wharf and this wharf.

Standard cross sections of each alternative are shown in Fig.X-12 and Fig.X-13. The approximative cost for each alternative is :

Concrete block quaywall	US$ 645,000
L-shaped block quaywall	US$ 665,000

The concrete block quaywall would cost somewhat less and as the manufacture of the blocks is simpler and easier and their installation is also easier, the construction period is shorter. Thus, we adopt the concrete block type quaywall.

1. 4 Mooring dolphin and Gangway

For the mooring dolphin and the gangway, a vertical steel pipe pile system shall be adopted. Generally, for structures of this kind, comparative designs should be made for vertical pile structures and batter pile structures. However, as explained below, we have come to the conclusion that the adoption of a batter pile structure is not suitable.

The mooring dolphin at the end of the gangway will be located rather close to the side of the existing breakwater. When the bottom rubble mound of this breakwater was constructed, it is reasonable to assume that some of the rubble stones may have rolled off the side slope of the breakwater towards the area where the mooring dolphin will be located. Also, although there is now a sandy beach on the south side of the existing breakwater, at the time the breakwater was constructed there was no such beach and the breakwater was directly exposed to strong waves which might have passed over the top of the breakwater and pushed some of the rubble stones down the slope.

Thus, if we were to adopt a batter pile structure, the bottom of some of the piles would probably strike some rubble stones. These stones would have to be removed before the construction could proceed which would necessitate additional expense and prolong the construction period.

The structural drawing of the mooring dolphin and the gangway is shown in Fig.X-14.

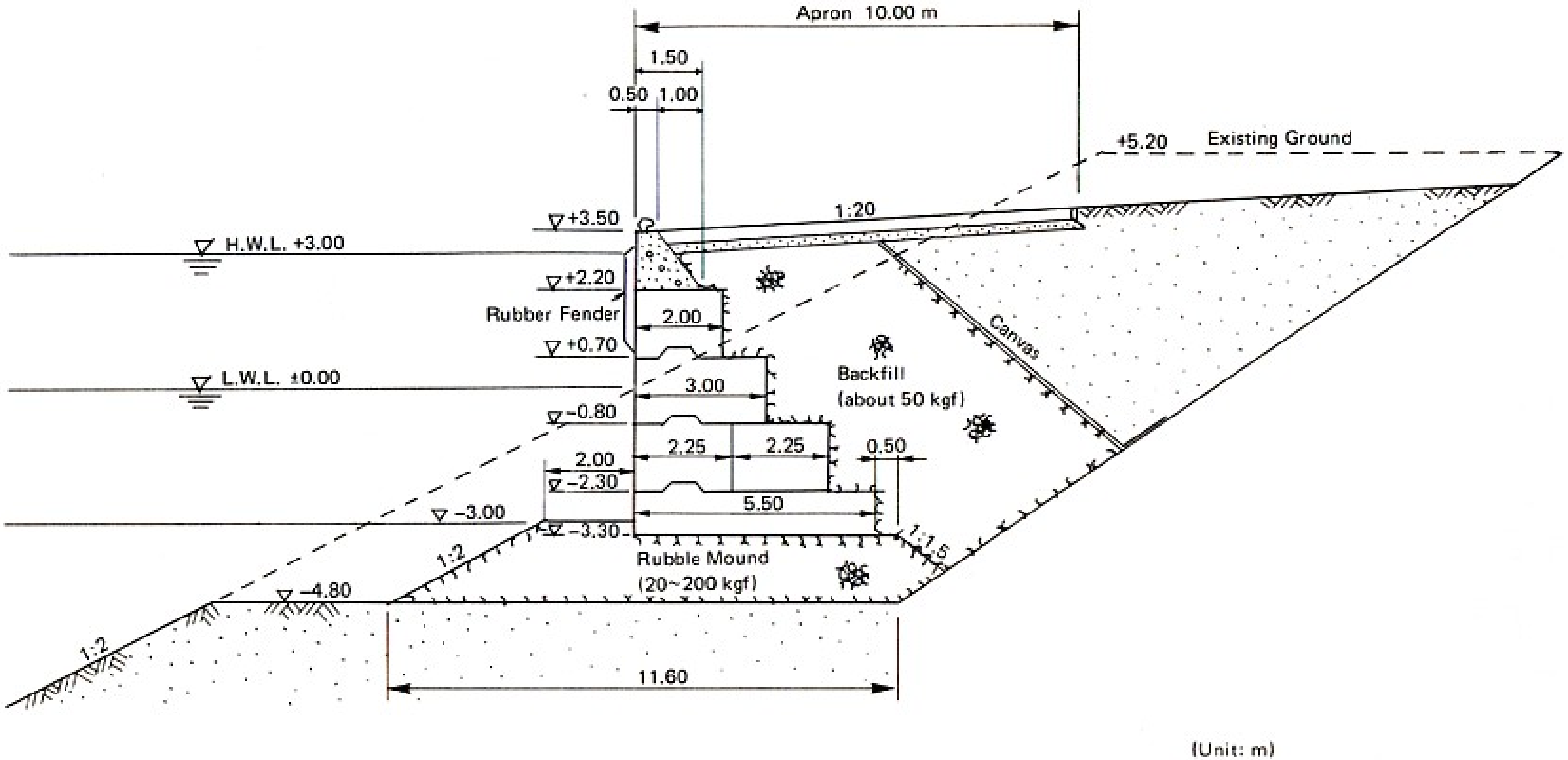
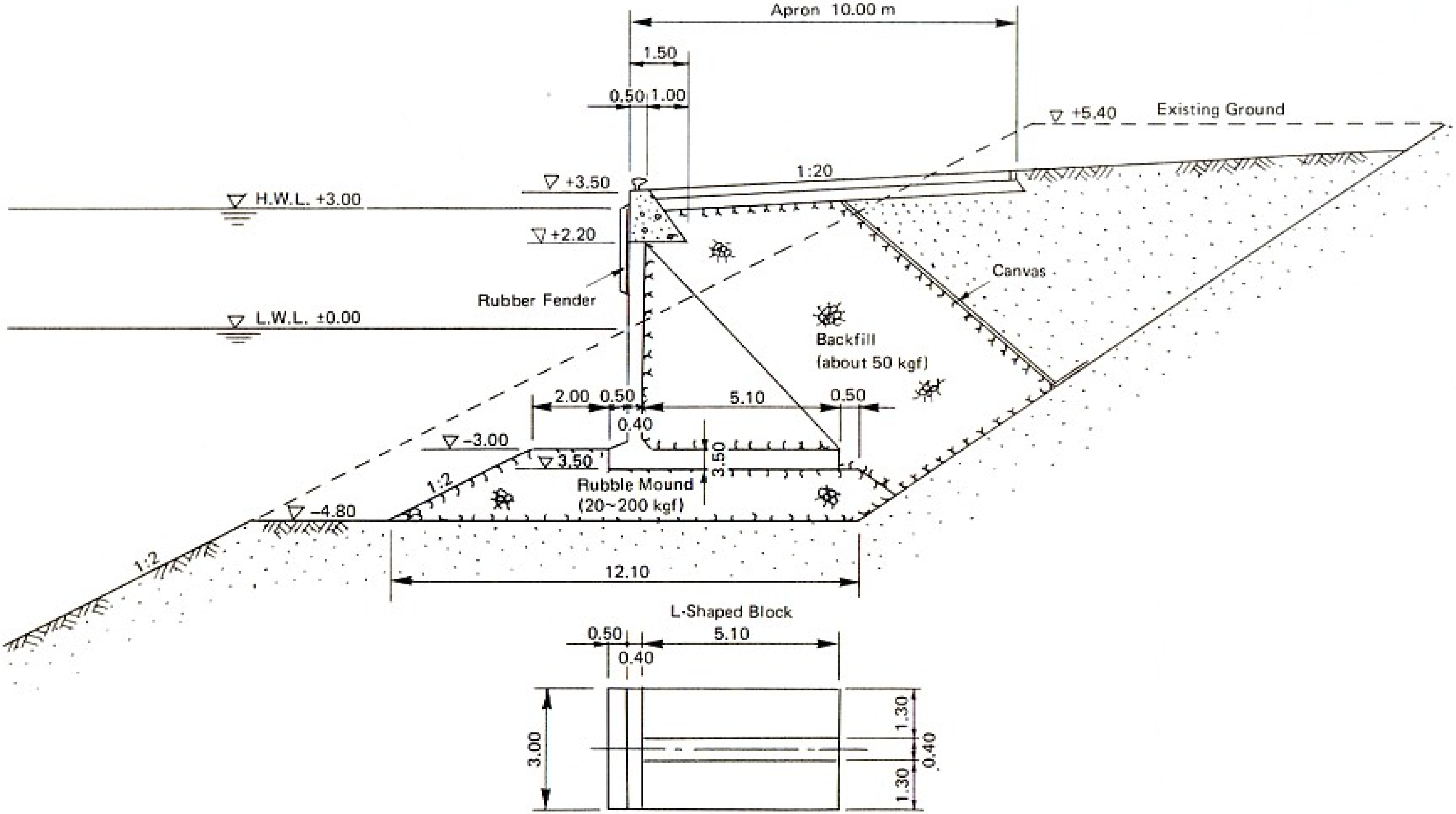


Fig. X-12 Standard Cross Section of −3.0 m Quaywall (Concrete Block Type)



(Unit: m)

Fig. X-13 Standard Cross Section of −3.0 m Quaywall (L-shaped Block Type)

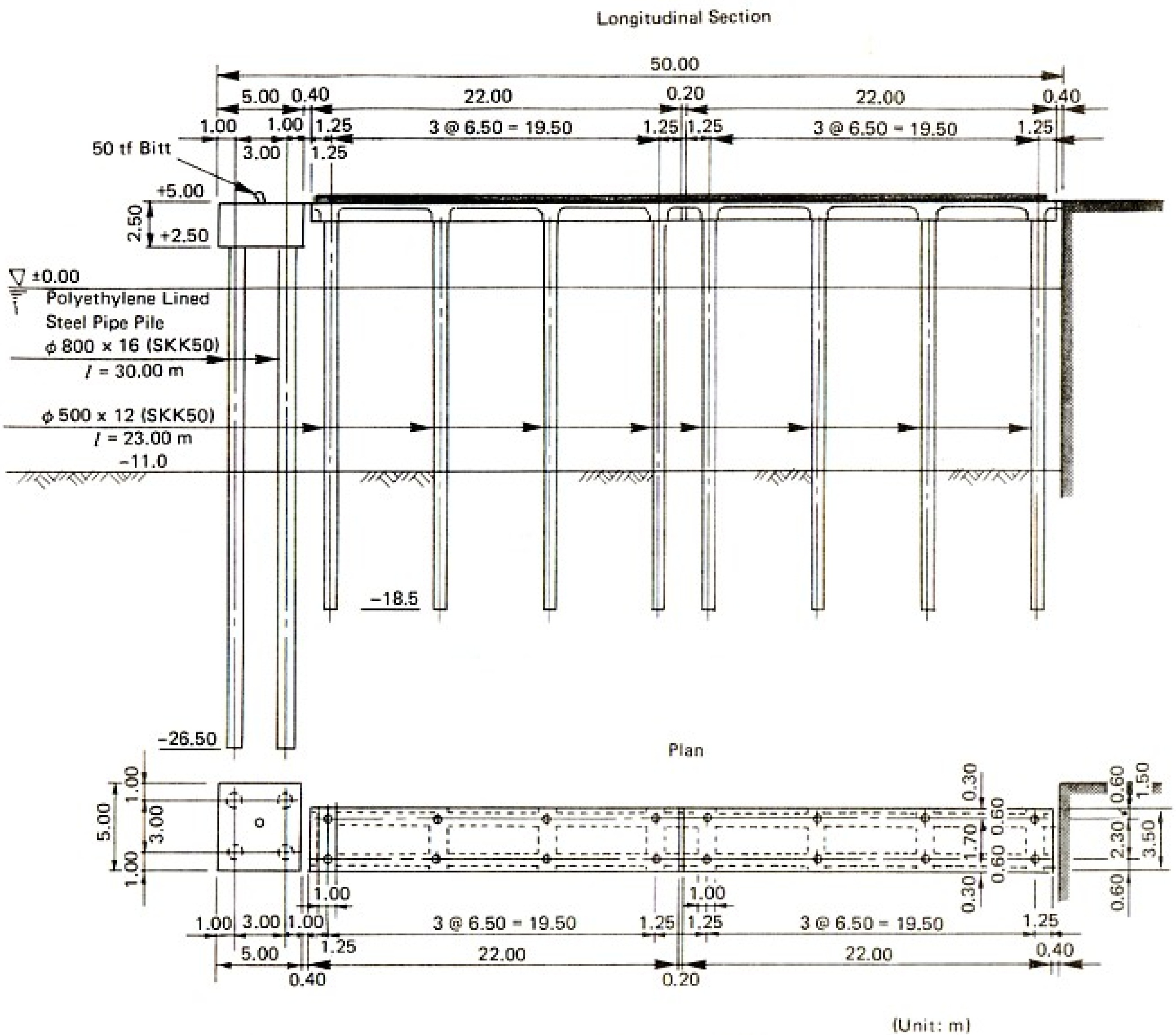


Fig. X-14 Mooring Dolphin and Gangway

The steel pipe piles used for this installation shall be SKK-50 covered with polyethylene in the factory to protect from corrosion. The superstructure shall be made of reinforced concrete.

A bitt of 50 tf in tractive capacity shall be mounted on the surface of the dolphin along the direction of the mooring line (angle from the face line of the −11 m wharf: about 25°), and an area of 5.0 m × 5.0 m shall be secured. For the gangway, a strip of space 3.5 m in width (effective width of 3.0 m) will be secured to permit the use of light vehicles for towing the mooring line. In designing, the load due to vehicles shall be taken into consideration. Also, for securing safe operations, a hand rail shall be provided on both sides. In order to avoid contract as much as possible with the side of vessels, the outer face of the gangway will be installed receding 1.5 m from the face line of the −11 m wharf.

1. 5 Navigation Aids

The light beacon installed at the tip of the breakwater during the first stage construction works shall be transferred to the new tip of the breakwater after the extension works are completed.

1. 6 Pavement of the Yards

In order to improve the cargo handling efficiency, open storage yards No.2, 3 and 4 will be paved. About 5 years have passed since the land on which these yards are constructed was reclaimed, so no further settlement is expected. These yards should be paved with highly durable concrete which will withstand the regular passage of cargo handling equipment. As yard No.2 will be used for containers, the loads of equipment which will handle full containers should be taken into consideration when determining the design load of the pavement.

2. Implementation Plan of the Maintenance Project

The execution of the maintenance project at the Port of Caldera as proposed in CHAPTER VI~CHAPTER IX which encompasses such things as construction of port facilities, dredging and purchase of the related dredger fleet, construction machinery, and cargo handling equipment is considered in this section.

Additionally, this section also examines the construction plans of the individual structures and facilities set forth in Section 1.

2. 1 Construction Execution Strategy

With respect to the countermeasures against sand sedimentation for the Port of Caldera specified in CHAPTER VI, the urgent extension of the breakwater, the primary dredging and the subsequent periodic maintenance dredging are all indispensable. Moreover, in order to support continued rational port activities at the Port into the future, a comprehensive maintenance system for the various facilities must be established.

The overall maintenance project at the Port of Caldera comprises the following two main parts :

(1) Construction of the various facilities and the procurement of a grab dredger fleet, construction machinery, and cargo handling equipment.

(2) Subsequent continued maintenance dredging and maintenance works for the various port facilities and equipment including the breakwater itself after the target year.

The former, including the purchase of required cargo handling equipment, is hereafter referred to as the primary construction works, and the latter as the maintenance works.

It would be ideal if MOPT could carry out the primary construction works itself. However, the projects are of a large scale and diverse make-up, and delays in implementing the countermeasures required to prevent sand sedimentation cannot be entertained. A consideration of MOPT's record of performance to date, as well as its present capacity to execute the various projects, indicates that the execution of primary construction works under direct MOPT management is not feasible. However, the maintenance works should be carried out directly by MOPT. Utilizing foreign contractors for maintenance dredging and other maintenance works every time they are needed is uneconomical, and a timely response from contractors is not always possible.

Taking into account the above considerations, an economical and rational execution plan for the maintenance project of the Port is prepared as set forth below.

MOPT will first procure the grab dredger fleet and construction machinery which are necessary to carry out the future maintenance works. Next, the fleet and equipment will be lent to the foreign contractor engaged to carry out the primary construction works, and while the primary works are being carried out, MOPT employees will learn appropriate construction and dredging techniques by working together with the contractor while executing the primary works and thus acquire essential skills through on the job training.

Then, following the completion of the primary works, MOPT will make effective use of its grab dredger fleet and construction machinery for maintaining the Port of Caldera and also for necessary dredging operations and construction works at other ports.

Only considering the primary construction works, the purchase of a grab dredger fleet and construction machinery would seem to be uneconomical. However, in the long run, these purchases are clearly justified. The vessels and tools are necessary to maintain the port facilities and as noted above, it is not practical to have the regular maintenance works performed by a foreign contractor.

Considering the overall project, that is both the primary and the maintenance works, this is clearly the best plan. This plan for the execution of the overall works is presented graphically in Fig. X-15. A suggested MOPT management organizational structure for the primary construction and the regular maintenance works is presented in Fig. X-16 and Fig. X-17.

2. 2 Primary Construction Works and Construction Volume

The primary construction works and construction volumes are listed in Table X-2. Each of the major work items is presented below with respect to the method of execution and the construction period.

2. 2. 1 Breakwater Extension

The extension of the breakwater is urgently needed to counter the sand sedimentation, and the extension must be completed within a short period of time. Accordingly, in addition to the land-based construction carried out to date by MOPT, a combined method which includes sea-based construction work should also be considered.

The grab dredger fleet can be used for general maritime construction works by adopting various attachments, and hence it is ideal for the present project in which the breakwater extension and primary dredging are the principal primary works. The placement of rubble stones, armour stones and Dolos is to be carried out from on top of the existing breakwater using a crawler crane and a bulldozer, as well as from the sea using a dredger, a flat barge, and two hopper barges.

The stone quarrying and transport volume will also increase in proportion to the above work. Essentially the foundation layer of rubble stone is first placed using a barge which dumps the stone directly at the breakwater site. Further layers of rubble stone, armour stone and Dolos are then placed as appropriate using vessels on the inside of the breakwater and various equipment on top of the existing breakwater. This method will enable the smooth progress of the breakwater construction despite the significant waves which will strike the outside of the breakwater. The details are presented below.

(1) Workable rates

The workable rates of the respective breakwater construction stages are shown in Table X-3. The method of calculation used to arrive at these workable rates is shown in APPENDIX 11.

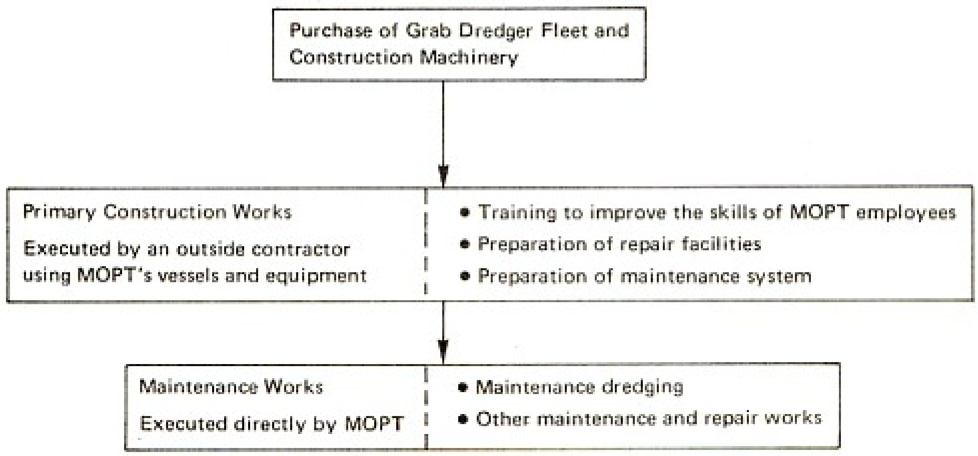


Fig. X-15 Implementation Plan

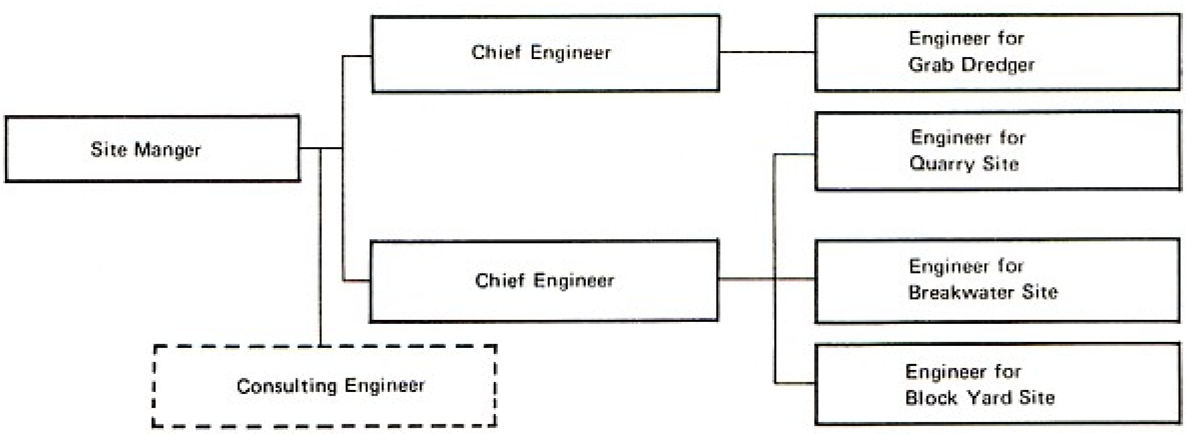


Fig. X-16 The Management Organization for the Primary Works

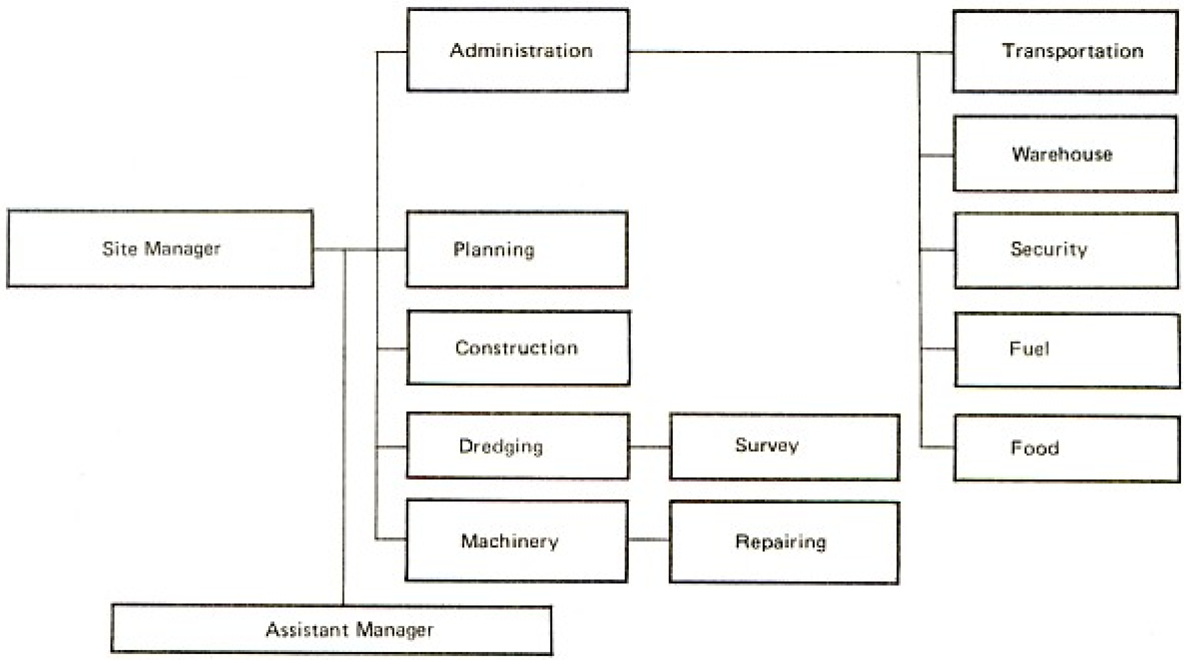


Fig. X-17 The Management Organization for the Maintenance Works

(2) Repeat execution

The breakwater is comprised of comparatively small stones at its center covered by larger armour stones and Dolos for protection. The armour stones and Dolos must be quickly placed over the core stones after filling in order to prevent washing away due to storm activity. Therefore, construction entails the continued repetition of this kind of work.

(a) Work agenda

The construction work is divided into land based operations (operations executed from on top of the breakwater) and maritime operations.

a) Land based operations

The land based operations include :

i) Deposition of the upper layer of rubble stones by dumptrucks and a bulldozer.

ii) Trimming of the mound by a backhoe.

iii) Transportation of armour stones (0.2~1.0 tf) by dumptrucks for the south side of the breakwater, and placement by a crawler crane (followed by underwater trimming by diving boat).

iv) Tranportation of Dolos (3.5 tf) by dumptrucks and placement by a crawler crane.

Table X-2 Facilities and Main Construction Materials for the Primary Works

Facilities			Main Materials							
			Stone (m^3)							
Item	Sub Item	Description	Gravel	Rubble Stone (0.02~0.2tf)	Armour Stone (0.2~1tf)	Armour Stone (over 4tf)	Concrete (m^3)	Steel (tf)	Dredging (m^3)	Remarks
Countermeasure against Sand Sedimentation	Extension of the Breakwater	Length : 200m	—	200,930	30,380	13,000	※ 11,963	—	—	※Dolos : 3.5tf/p.c. 7,860p.c.
	Primary Dredging	Grab Dredger Fleet	—	—	—	—	—	—	72,000	
Enlargement of Mooring Facility Capacity	Shifting of the Breakwater *	Length : 162 m 50m to the West	—	43,370	16,290	—	—	—	36,380	※Including the shift of a beacon
	-3.0m Quaywall	Length : 110m	—	7,140	—	—	※3,319		14,250	※Precast Concrete Blocks 30tf/p.c. 260p.c.
	Mooring Dolphin and Gangway	1 Dolphin and 45m Gangway	—	—	—	—	180	※ 90	—	※Pipe-Piles : ϕ500~900mm
Improvement of the Cargo Handling System	Pavement of Open Yards	No.2~No.4	10,500	—	—	—	8,400	—	—	42,000m^2
Preparation Works	Temporary Facilities	Loading Pier	—	940			18	※ 80		※Pipe-Piles : ϕ300~400mm, H-beams : H-200~300mm
Total			10,500	252,380	46,670	13,000	23,880	170	122,630	

Table X-3 Estimated Workable Rates for Breakwater Construction

Item		Workable Rate
Marine Works	Installation of Underwater Mound	70%
	Installation of Armour Stones	70%
Works Executed from on Top of the Breakwater		85%

b) Maritime operations

Maritime operations include :

i) Deposition of rubble stones for the lower mound (foundation layer) by hopper barges.

ii) Transportation of armour stones (0.2~1.0 tf) for the north side of the breakwater by flat barges and placement by a grab dredger ; underwater trimming by a diving boat.

iii) Works using armour stones (over 4.0 tf) similar to the works described in (ii) above.

(b) Sequence of execution

The sequence of the works is as follows :

i) Deposition of rubble stones for the lower mound (foundation layer) using hopper barges.

ii) Deposition of upper mound rubble material using dumptrucks and a bull-dozer.

iii) Mound trimming using a backhoe.

iv) Transportation by flat barges of armour stones (0.2~1.0 tf) for the inner harbour (the north side of the breakwater) and placement by a grab dredger : similar activities for the outer harbour (south side of the breakwater) executed using dumptrucks and a crawler crane.

v) Underwater trimming of armour stones (0.2~1.0 tf) using a diving boat.

vi) Transportation by flat deck barges of armour stones (over 4.0 tf) for the inner harbour and placement by dredger ; similar transportation and place-ment of Dolos (3.5 tf) for the outer harbour using trailers and a crawler crane.

vii) Underwater trimming of armour stones (over 4.0 tf) using a diving boat.

Item i) will be executed continuously and Items ii) ~ vii) will be carried out at 1.7 month intervals. Item i) will proceed in advance of Item ii) by approximately 50 m in length.

The top level of the lower mound will be −5.6 m, a height determined in accordance with the 2.8 m full draft of the hopper barges, the approximately, 1.7 m maximum clearance over the mound, and the 0.5 ~ 0.6 m maximum half wave height permissable during operations. Fig. X-18 shows the above work sequence.

(3) Construction Volumes and Schedule

Construction volumes and the construction schedule are shown in Fig. X-19.

(4) Major Temporary Facilities

The major temporary facilities required for the construction of the breakwater are summarized below.

(a) Dolos fabrication yard

In order to fabricate the Dolos (3.5 tf) used to armour the breakwater, a suitable yard must be prepared near the breakwater.

Fig. X-20 shows a layout plan wherein the fabrication yard is set at the north side of the floating drydock. This layout plan was made based on the assumption that 30 Dolos per day can be fabricated using 90 sets of steel forms, and that a temporary storage capacity for 1,875 pieces will be made available.

Side forms for the Dolos are removed after 3 days of curing and bottom forms are removed after 5 days.

The dimensions of the areas provided for each purpose are as follows :

Fabrication	: area of 1,200m²
Material storage	: area of 300m² (including bar bending area)
Temporary storage	: area of 7,200m²
Access road, etc.	: area of 16,900m²

The construction work for the above yard will take approximately one month to complete.

(b) Temporary loading pier

For loading rubble onto the hopper barges, a temporary loading pier such as the one shown in Fig. X-21 will be constructed. This construction work will require approximately 24 days to complete. For loading armour stones onto the flat barges, the existing roll on/roll off pier will be used. These major temporary facilities may also be used as necessary for other primary construction works.

2. 2. 2 Construction Works for the Other Facilities

The agenda is as follows:

(a) Shifting of the breakwater foot (including the shifting of the light beacon)

(b) Construction of a −3.0 m Quaywall

(c) Construction of a mooring dolphin and gangway

(d) Construction of a repair facility for the grab dredger fleet and construction machinery

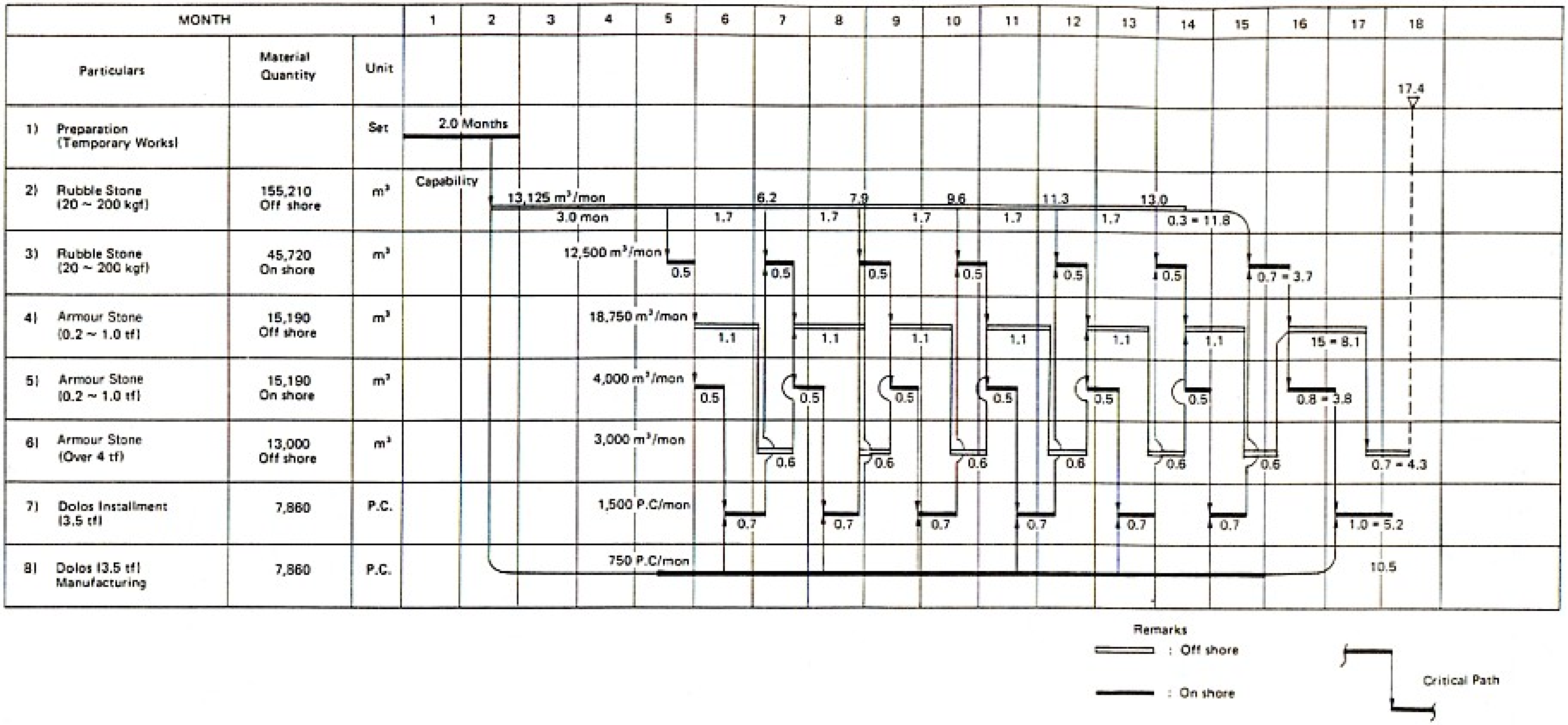


Fig. X-19 Construction Schedule and Material Quantity List for Breakwater Extension

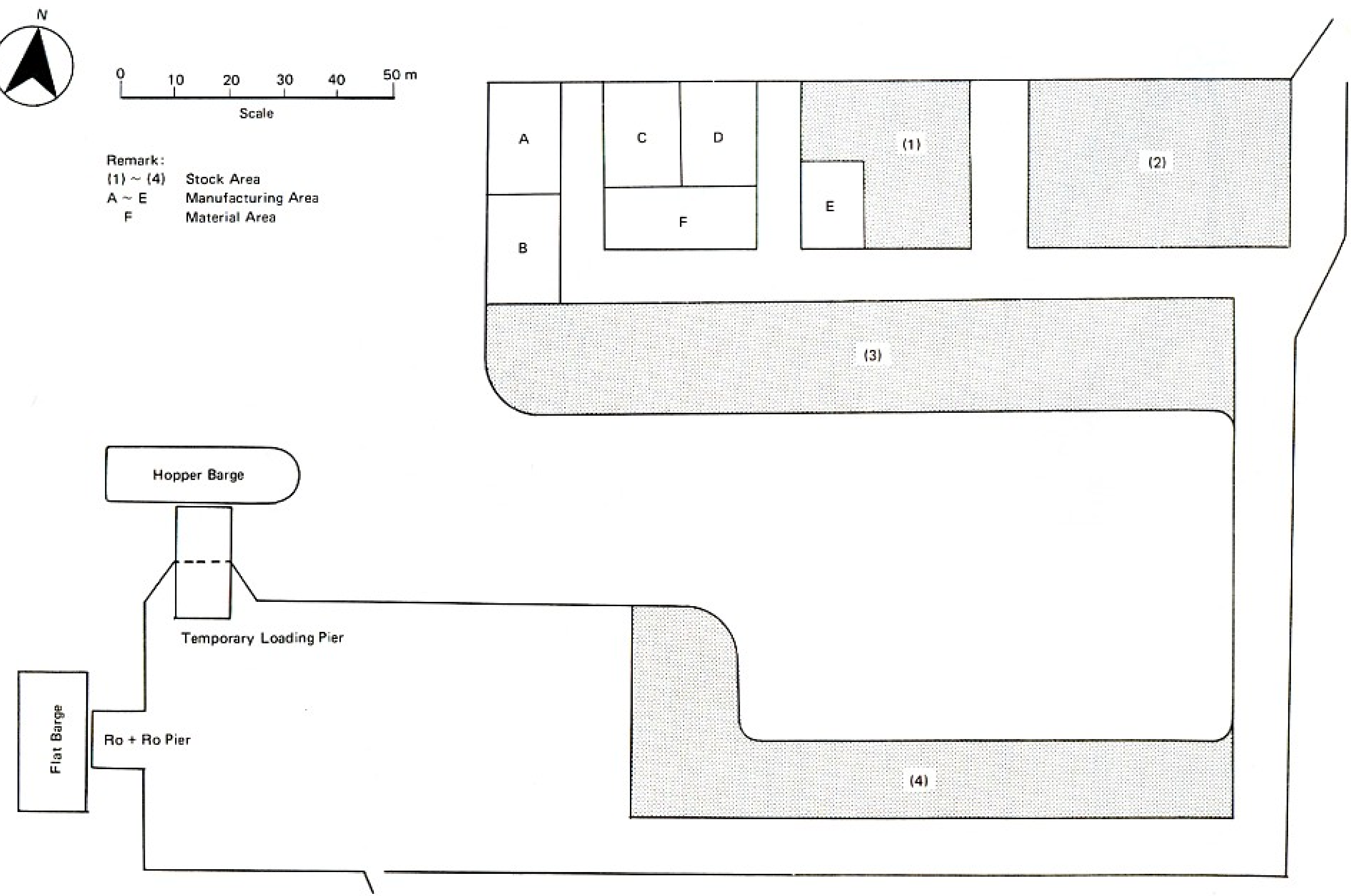
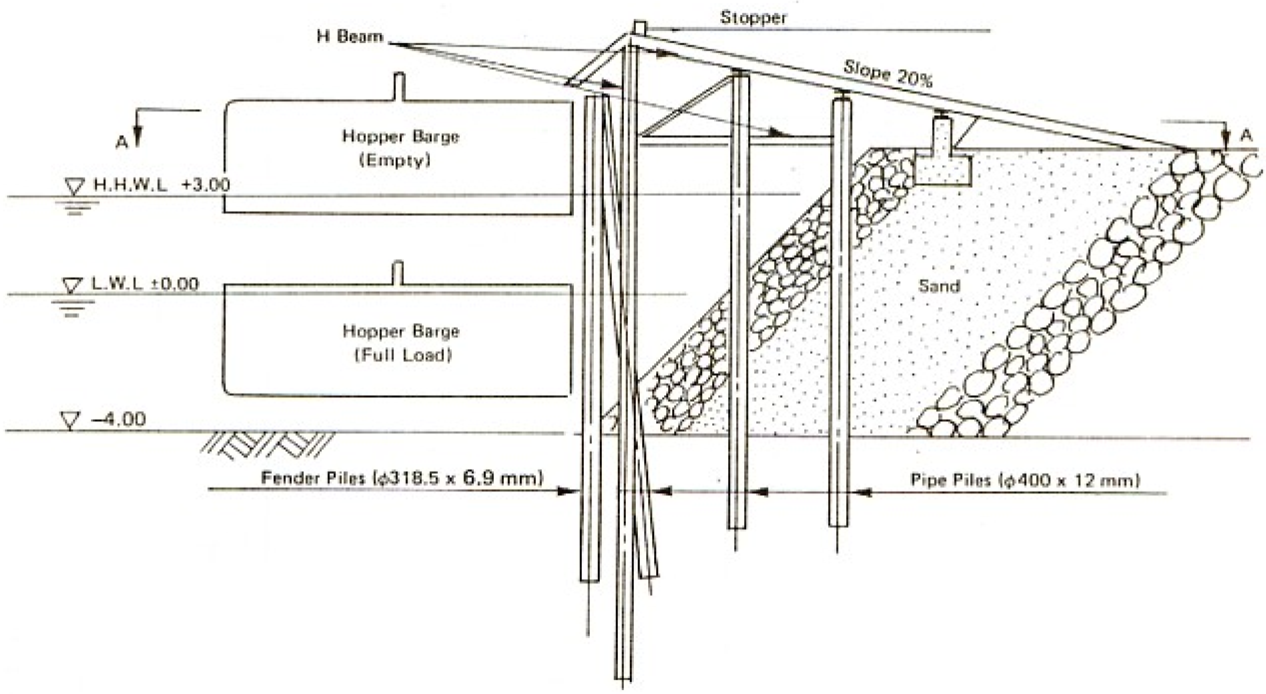


Fig. X-20 Plan of Dolos Manufacturing Yard



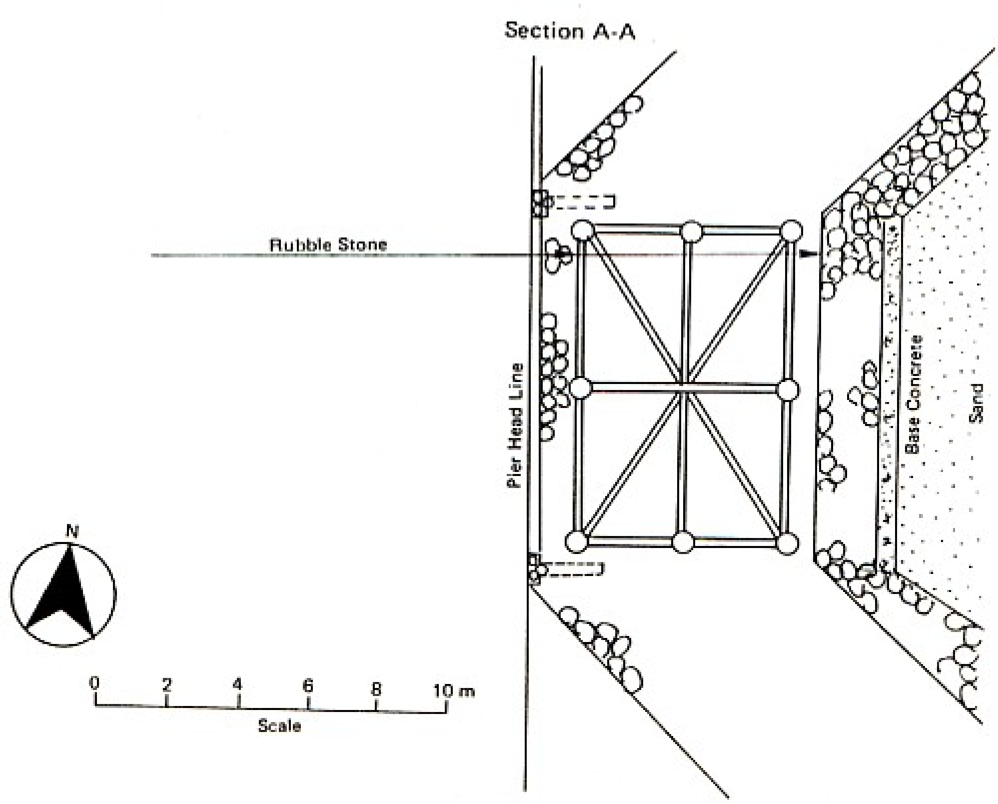


Fig. X-21 Temporary Loading Pier

(e) Primary dredging work
(f) Pavement of the yard to improve the cargo handling system

The construction procedure is shown in Fig. X-22.

2. 3 Requisite Grab Dredger Fleet and Construction Machinery

In order to carry out the primary construction works as well as the subsequent periodic maintenance dredging and other maintenance works, MOPT should obtain a grab dredger fleet and construction machinery as listed in Table X-4 and Table X-5. In Table X-4, a flat barge is included in the grab dredger fleet for the construction of the breakwater.

2. 4 Schedule of the Caldera Port Maintenance Project

The schedule for the project execution which is to be completed by the end of 1991 gives priority to the immediate countermeasures against sand sedimentation, subsequent to which the enlargement of the mooring facility capacity and the improvement of the cargo handling system are to be executed. The sequence of construction works is shown in Fig. X-23.

Economy and practicality suggest that the introduction of cargo handling equipment should take place in 1991. The proposed schedule of the maintenance project of the Port of Caldera is given in Fig. X-24.

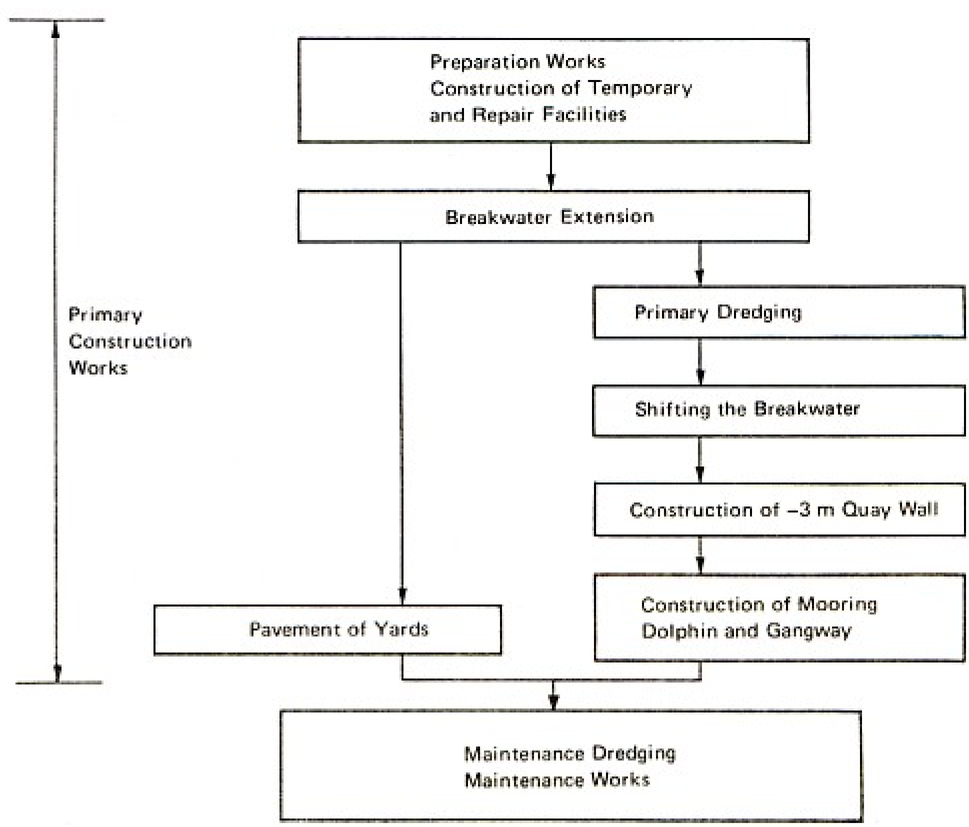


Fig. X-22 Construction Procedure

Table X-4 Grab Dredger Fleet

Vessels	Capacity	Quantity
Grab Dredger	D.E.640 PS, 4.0 m^3	1
Hopper Barge	300 m^3	2
Tug Boat	D.400 PS	1
Anchor Boat	D.900 PS, 5 ton winch	1
Flat Barge	300 tf	1
Jolly Boat	D.100 PS, 13 GT	1
Diving Boat	D.30 PS, 3 ton winch	2
Survey Boat	D.40 PS, 6 GT	1

Table X-5 Construction Machinery

Machinery	Capacity	Quantity
Crawler Crane	80 tf	1
Crawler Crane	16 tf	2
Dump Truck	230 PS, 18 tf	9
Bulldozer	141 PS, D-6	3
Back Hoe	188 PS, 2 m^3	1
Grader	108 PS, 3.6 m	1
Tyre Roller	85 PS, 8-20 tf	1
Wheel Loader	235 PS, 3.5 m^3	1
Compressor	174 PS, 17 m^3/min	1
Earth Drill	60-114 mm	2
Vibrator	60 kVA	1
Trailer	320 PS, 40 tf	2
Generator	370 PS, 300 kVA	1

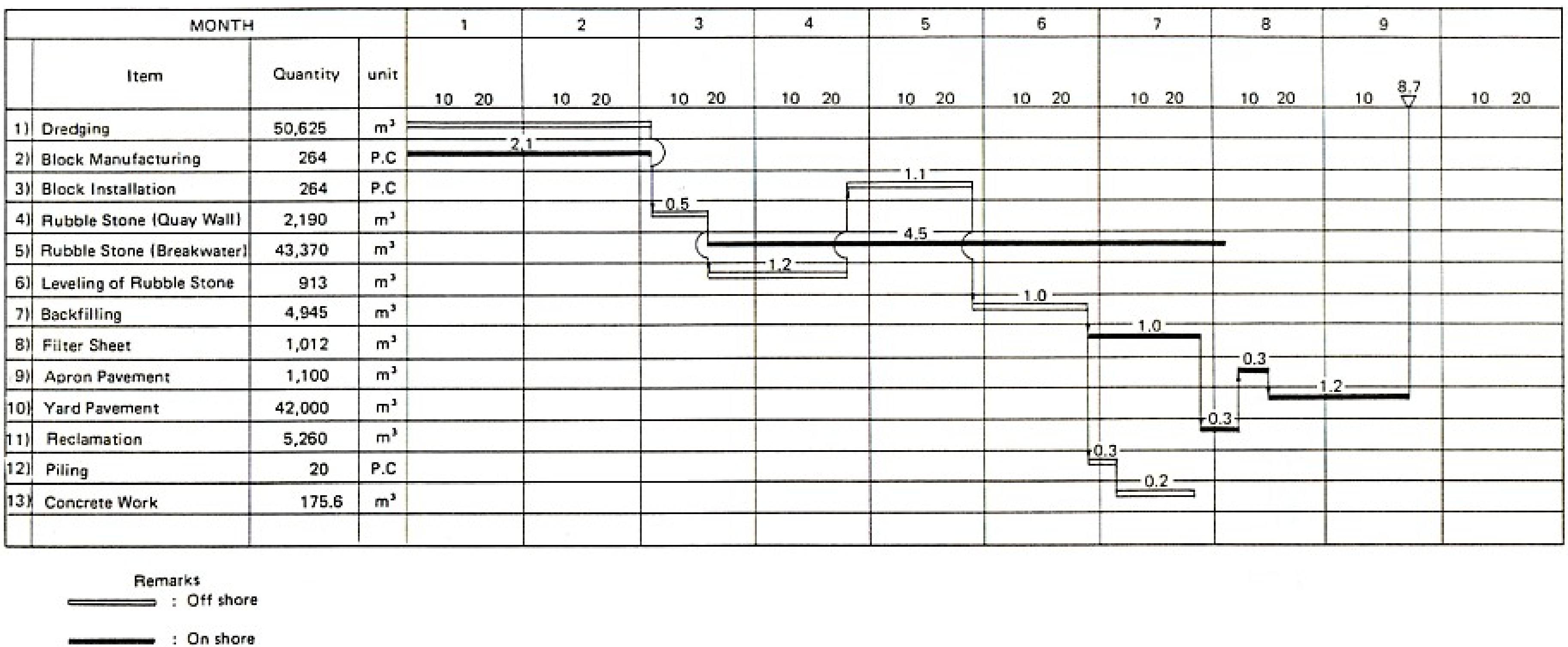


Fig. X-23 Construction Schedule of the Facilities except for the Breakwater Extension

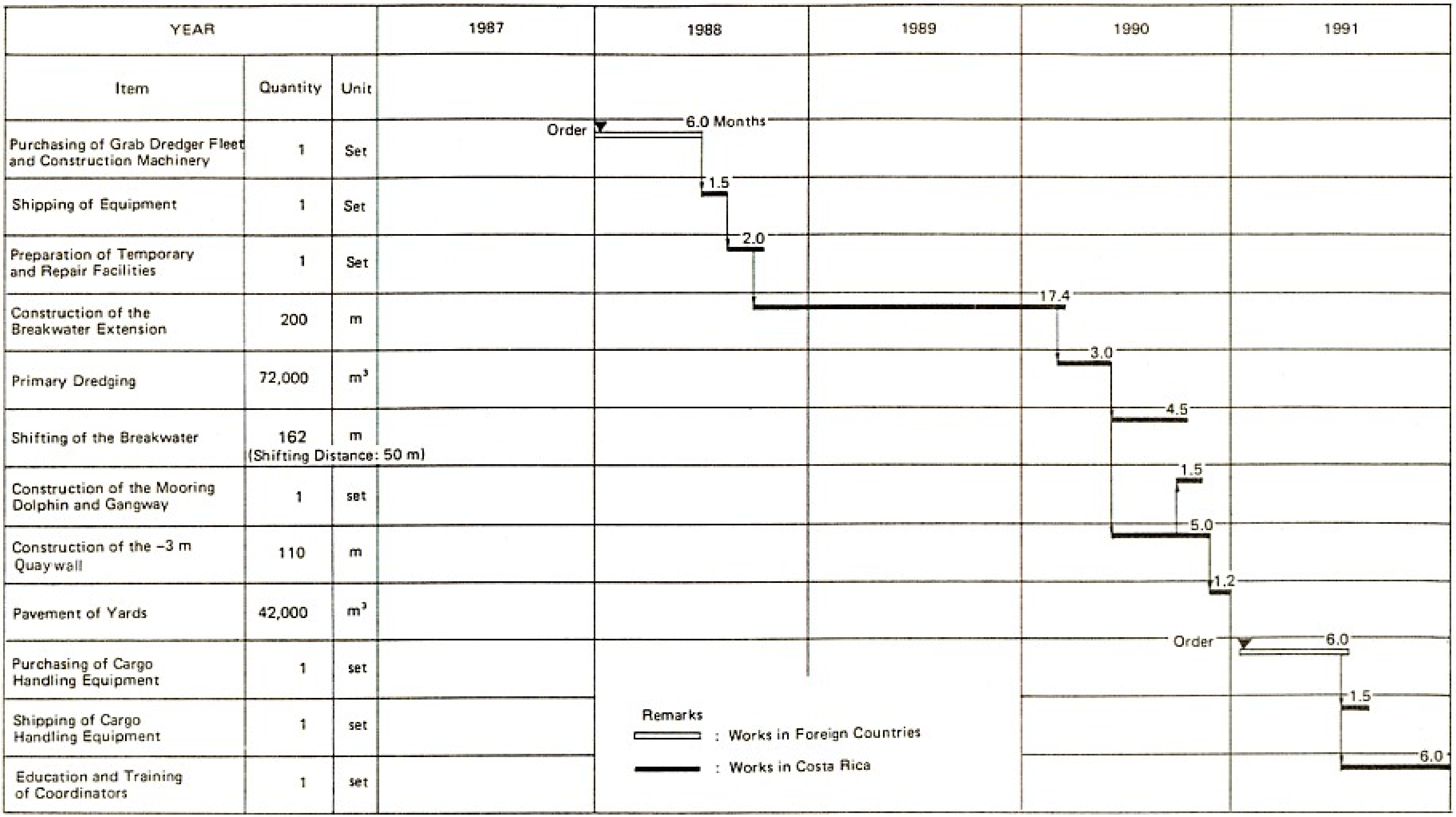


Fig. X-24 Construction Schedule of the Project

3. Cost Estimate

3.1 Scope of the Cost Estimate

As mentioned above, MOPT will first obtain the grab dredger fleet and the construction machinery, and then the primary construction works will be executed by a contractor using MOPT's vessels and equipment. After the completion of the primary works, the maintenance dredging and the maintenance works for the port facilities will be executed directly by MOPT utilizing its own equipment.

3.1.1 Estimate Items for the Primary Construction Works

The estimate items are listed in Table X-6.

3.1.2 Estimate Items for the Maintenance Dredging and the Maintenance Works

(a) Maintenance dredging
Periodic maintenance dredging of the harbour

(b) Maintenance works
Maintenance works for the facilities included in the primary construction works.

3.2 Premises for the Cost Estimate

(1) Estimate limits

Some limits for the estimate are as follows.

Land rents, compensations, customs duties on the imported goods and port charges are excluded from the estimate.

(2) Local and foreign portion

In general, the cost of the foreign portion includes the following :

(a) Articles and goods which have never been produced domestically.
(b) Articles and goods which are seldom produced domestically.
(c) Articles and goods which cannot be supplied locally because of low domestic production and high domestic consumption.

Based on the above criteria, the foreign portion comprises

(a) Purchase costs of the grab dredger fleet, construction machinery and cargo handling equipment
(b) Shipping cost of the equipment
(c) Labour cost of the foreigners who work for foreign contractors
(d) Steel articles
(e) Fuel
(f) A part of the maintenance and repair cost for the equipment

Table X-6 Items of the Cost Estimate

Item	Sub Item	Remarks
Purchase Costs of the Grab Dredger Fleet and Construction Machinery, and Related Costs	Purchase Cost of the Grab Dredger Fleet	
	Purchase Cost of the Construction Machinery	
	Shipping Cost for the Grab Dredger Fleet and Construction Machinery	
	Construction Cost of the Repair Facilities	
Construction Cost of the Facilities to Protect the Harbour from Sand Sedimen-tation and Primary Dredging Costs	Construction Cost of the Breakwater Extension	
	Construction Cost of the Temporary Facilities	
	Primary Dredging Cost	
Construction Cost for the Enlargement of the Mooring Facility Capacity	Cost of Shifting the Breakwater	Includes the Cost of Shifting the Light Beacon
	Construction Cost of the −3 m Quaywall	
	Construction Costs of the Mooring Dolphin and Gangway	
Improvement Cost of the Cargo Handling System	Purchase Cost of the Cargo Handling Equipment for Cargoes other than Grain	
	Purchase Cost of the Cargo Handling Equipment for Grain Cargo	
	Purchase Cost of the Maintenance Instruments	
	Shipping Cost for the Cargo Handling Equipment	
	Education and Training of the Coordinators	
	Pavement of the Yards	

(g) The consulting fee, and the education and training fee

(3) Exchange rates

The exchange rates among the U.S. $, the Costa Rican Colon and the Japanese Yen are assumed as follows (at Dec. 31, 1985):

1 U.S. $ = 53.15 Colon = 200.35 Yen

All foreign portions except fuel are estimated in Japanese price.

(4) Consultant fee

All the estimated costs for the construction works (except maintenance dredging and maintenance works) include a 7% consultant fee for the contract amount.

(5) Physical contingency

Estimated costs except for equipment include a 10% physical contingency. The physical contingency for equipment is 5%.

(6) Unit price

Unit price applied in this project are shown in Table X-7.

Table X-7 Unit Price

(Unit: ¢)

Item		Unit	Foreign Portion	Local Portion	Total Cost
Material					
Fuel for Diesel Engine		l	19.13	0	19.13
Concrete σ_{28} = 240 kgf/cm²		m³	0	4,000	4,000
Reinforcement D9~19mm		kgf	28.17	0	28.17
Shuttering (Playwood)		m²	0	312	312
Rubble Stone (20~200kgf)		m³	100	25	125
Armour Stone (0.2~1.0 tf)		〃	120	30	150
〃 〃 (Over 4.0 tf)		〃	160	40	200
Labours					
Unskilled Labour	(Local)	day	0	510	510
Skilled Labour	(〃)	〃	0	680	680
Machine Operator	(〃)	〃	0	760	760
Captain of Dredger	(〃)	〃	0	1,190	1,190
Engineer	(〃)	〃	0	2,100	2,100
Skilled Labour	(Foreign)	〃	5,580	3,720	9,300
Diver	(〃)	〃	7,975	5,330	13,300

3. 3 Cost Estimate of the Primary Construction Works

3. 3. 1 Purchase Costs of the Grab Dredger Fleet and Construction Machinery, and Related Costs

Costs are as follows :

(a) Purchase cost of the grab dredger fleet
The purchase cost is shown in Table X-8.

(b) Purchase cost of construction machinery
The purchase cost is shown in Table X-9.

Table X-8 Purchase Cost of the Grab Dredger Fleet

Vessels	Capacity	Quantity	Amount (colones)
Grab Dredger	D.E.640 PS, 4.0 m³	1	79,677,000
Hopper Barge	300 m³	2	33,554,000
Tug Boat	D.400 PS	1	24,305,000
Anchor Boat	D.90 PS, 5 ton winch	1	11,316,000
Flat Barge	300 tf	1	6,840,000
Jolly Boat	D.100 PS, 13 GT	1	3,072,000
Diving Boat	D.30 PS, 3 ton winch	2	4,991,000
Survey Boat	D.40 PS, 6 GT	1	1,494,000
Sub Total			165,249,000

Table X-9 Purchase Cost of the Construction Machinery

Machinery	Capacity	Quantity	Amount (colones)
Crawler Crane	80tf	1	24,481,000
Crawler Crane	16tf	2	13,261,000
Dump Truck	230 PS, 18 ton	9	48,420,000
Bulldozer	114 PS, D-6	3	14,749,000
Back Hoe	188 PS, 2 m³	1	20,059,000
Grader	108 PS, 3.6 m	1	23,146,000
Tyre Roller	85 PS, 8-20 tf	1	22,509,000
Wheel Loader	235 PS, 3.5 m³	1	7,760,000
Compressor	174 PS, 17 m³/min	1	1,945,000
Earth Drill	60-114mm	2	4,140,000
Vibrator	60kVA	1	8,159,000
Trailer	320 PS, 40 tf	2	11,417,000
Generator	370 PS, 300 kVA	1	3,449,000
Sub Total			183,495,000

(c) Shipping cost for the grab dredger fleet and construction machinery

It is assumed that this equipment will be transported using a lift barge. The estimated shipping cost is as follows :

(Unit : '000 ¢)

Foreign Portion	Local Portion	Total Cost
73,080	0	73,080

(d) Construction cost of the repair facilities

The construction cost of the repair facilities consists of 5% of the purchase cost of the grab dredger fleet and 10% of the purchase cost of the construction machinery. The construction cost is estimated as follows:

(Unit : '000 ¢)

Foreign Portion	Local Portion	Total Cost
23,951	2,661	26,612

The purchase costs of the grab dredger fleet and construction machinery, and related costs are summarized in Table X-10.

3. 3. 2 Contruction Costs of the Facilities to Protect the Harbour from Sand Sedimentation and Primary Dredging Cost

The items included in this section are :

(a) Construction cost of the breakwater extension

The cost includes the construction cost of the 200 m breakwater extension and the temporary facilities.

(b) Primary Dredging Cost

The primary dredging cost is the cost of dredging a sand volume of 72,000 m³. The construction costs of the facilities to protect the harbour from sand sedimentation and the primary dredging cost are summarized in Table X-11.

3. 3. 3 Construction Costs for the Enlargement of the Mooring Facility Capacity

The items included in this category are :

(a) Cost of shifting the breakwater

The cost includes the cost of shifting the light beacon.

Table X-10 Purchase Costs of the Grab Dredger Fleet and Construction Machinery, and Related Costs

(Unit: '000 ¢)

Item	Remarks	Cost		
		Foreign Portion	Local Portion	Total
Purchase Cost of the Grab Dredger Fleet	Refer to Table X-8	165,249	0	165,249
Purchase Cost of the Construction Machinery	Refer to Table X-9	183,494	0	183,494
Shipping Cost of the Grab Dredger Fleet and the Construction Machinery	With Lift-Barge	73,080	0	73,080
Construction Cost of the Repair Facilities	—	23,951	2,661	26,612
Total		445,774	2,661	448,435

Table X-11 Construction Cost of the Facilities to Protect the Harbour from Sand Sedimentation and Primary Dredging Costs

(Unit: '000 ¢)

Item	Construction Volume and Dimensions	Cost		
		Foreign Portion	Local Portion	Total
Construction Cost of the Breakwater Extension	$L=200$m	181,150	116,410	297,560
Construction Cost of the Temporary Facilities	Dolos Fabrication Yard and Loading Pier	10,890	1,070	11,960
Primary Dredging Cost	72,000m³	8,270	2,390	10,660
Total		200,310	119,870	320,180

(b) Construction cost of the −3 m quaywall
(c) Construction costs of the mooring dolphin and gangway

The construction costs for the enlargement of the mooring facility capacity are summarized in Table X-12.

3. 3. 4 Cost of the Improvement of the Cargo Handling System

The related costs are as follows :

(a) Purchase cost of the cargo handling equipment

The cost consists of the purchase cost of the cargo handling equipment for cargoes other than grain and that for grain cargo. The purchase costs are summarized in Table X-13.

(b) Purchase cost of the maintenance instruments

This is the purchase cost of the maintenance instruments which will reinforce the existing repair facilities and equipment. The purchase cost is estimated as follows.

(Unit : '000 ¢)

Foreign Portion	Local Portion	Total Cost
1,638	0	1,638

(c) Shipping costs for the cargo handling equipment

The cost consists of following three parts :

i) Shipping cost for the cargo handling equipment for cargoes other than grain

ii) Shipping cost for the cargo handling equipment for the grain cargo

iii) Shipping cost for the maintenance instruments

The shipping costs are summarized in Table X-14.

(d) Cost for education and training of the coordinators

The cost is estimated as follows :

(Unit : '000 ¢)

Foreign Portion	Local Portion	Total Cost
11,774	0	11,774

Table X-12 Construction Cost for Enlargement of the Mooring Facility Capacitv

((Unit: '000 ¢))

Item	Construction Volume	Cost		
		Foreign Portion	Local Portion	Total
Cost of Shifting the Breakwater	Length : 162 m Shifiting Distance: 50m	43,900	9,970	53,870
Constructwion Cost of the −3 m Quaywall	Length: 110m	19,230	31,400	50,630
Construction Costs of the Mooring Dolphin and the Gangway	Mooring Dolphin: 1 Gangway: 45m	8,660	1,960	10,620
Total		71,790	43,330	115,210

Table X-13 Purchase Cost of the Cargo Handling Equipment

Item	Equipment	Capacity	Quantity	Purchase Cost
Cargo Handling Equipment for Cargoes other than Grain	Forklift	3.5 tf	10	11,220
		20 tf	2	17,950
	Front loader	35 tf	1	16,905
		10 tf	1	11,172
	Tractor Head	For Chassis	2	5,651
	Chassis	20/40′	3	1,779
	Wireless Phone		1	174
	Sub Total			64,851
Cargo Handling Equipment for Grain Cargo	Pneumatic Unloader	200 tf/h	2	138,300
	Bucket Elevator	400 tf/h	1	9,735
	Belt Conveyor (Movable)	400 tf/h, L = 200 m	1	15,150
	Belt Conveyor (Fixed)	400 tf/h, L = 250 m	1	24,011
	Bulldozer	2 tf	2	5,050
	Sub Total			192,346
Total				257,197

Table X-14 Shipping Cost for the Cargo Handling Equipment

(Unit : '000 ¢)

Item	Cost		
	Foreign Portion	Local Portion	Total
Cargo Handling Equipment for the Cargoes other than the Grain Cargo	8,098	0	8,098
Cargo Handling Equipment for the Grain Cargo	15,742	0	15,742
Maintenance Instruments	246	0	246
Total	24,086	0	24,086

(e) Cost of paving the open yards

This is the cost of the concrete pavement of open yards No.2, No.3 and No.4 (Area : 42,000 m^2). The cost is estimated as follows :

(Unit : '000 ¢)

Foreign Portion	Local Portion	Total Cost
7,180	82,140	89,320

The overall cost of the improvement of the cargo handling system is summarized in Table X-15.

3. 4 Maintenance Dredging Cost and the Cost of Maintenance Works

3. 4. 1 Maintenance Dredging Cost

The annual maintenance dredging cost in the harbour to be executed by MOPT itself is estimated as follows :

(Unit : '000 ¢ /year)

Foreign Portion	Local Portion	Total Cost
930	300	1,230

Actually, the maintenance dredging will be executed once in five years.

Table X-15 Improvement Cost of the Crago Handling System

(Unit : '000 ¢)

Item	Remarks	Cost		
		Foreign Portion	Local Portion	Total
Purchase Cost of the Cargo Handling Equipment for Cargoes other than Grain	Refer to Table X-13	64,851	0	64,851
Purchase Cost of the Cargo Handling Equipment for Grain Cargo	Refer to Table X-13	192,346	0	192,346
Purchase Cost of the Maintenance Instruments		1,638	0	1,638
Shipping Cost for the Cargo Handling Equipment	Refer to Table X-14	24,086	0	24,086
Education and Training of the Coordinators		11,774	0	11,774
Pavement of the Open Yards	Yard No.2, No.3, No.4 42,000 m²	7,180	82,140	89,320
Total		301,875	82,140	384,015

3. 4. 2 Cost of the Maintenance Works

This is the cost of the mainterance works for the port facilities to be executed by MOPT. The scope of the works covers the maintenance of the newly constructed facilities as shown in Table X-16.

3. 4. 3 Total Maintenance Cost

The annual maintenance costs are summarized in Table X-17.

3. 5 Summary of the Cost Estimate

The cost estimate results are shown in Table X-18. In this table, figures are rounded off to the nearest 10,000 ¢.

3. 6 Annual Project Investment

The annual project investment for the primary construction works is summarized in Table X-19.

Table X-16 Facilities for the Maintenance Works

Item	Construction Cost of the Facilities ('000 ¢)	Annual Maintenance Cost[1]
Breakwater (L=200m)	297,560	0.5%
Shifted Breakwater (L=162m)	53,870	1%
−3.0m Quaywall (L=110m)	50,630	
Mooring Dolphin and Gangway	10,620	
Pavement of the Yards	89,320	5%

Note : 1) Expressed as a percentage of the construction cost.

Table X-17 Annual Maintenance Cost of the Facilities

(Unit : '000 ¢ /year)

Item	Cost		
	Foreign Portion	Local Portion	Total
Maintenance Dredging (12,000 m^3/y)	930	300	1,230
Maintenance Works for the Facilities	1,980	5,120	7,100
Total	2,910	5,420	8,330

Table X-18 Total Cost of the Maintenance Project

(1) Project Cost

(Unit : '000 ¢)

Item	Sub Item	Cost		
		Foreign Portion	Local Portion	Total
Purchase Costs of the Grab Dredger Fleet and Construction Machinery, and Related Costs	Purchase Cost of the Grab Dredger Fleet	165,250	0	165,250
	Purchase Cost of the Construction Machinery	183,490	0	183,490
	Shipping Cost for the Grab Dredger Fleet and the Construction Machinery	73,080	0	73,080
	Construction Cost of the Repair Facilities	23,950	2,660	26,610
	Sub Total	(445,770)	(2,660)	(448,430)
Construction Cost of the Facilities to Protect the Harbour from Sand Sedimentation and Primary Dredging Cost	Construction Cost of the Breakwater Extension	181,150	116,410	297,560
	Construction Cost of the Temporary Facilities	10,890	1,070	11,960
	Primary Dredging Cost	8,270	2,390	10,660
	Sub Total	(200,310)	(119,870)	(320,180)
Construction Cost for the Enlargement of the Mooring Facility Capacity	Cost of Shifting the Breakwater	43,900	9,970	53,870
	Construction Cost of the -3m Quay Wall	19,230	31,400	50,630
	Construction Cost of the Mooring Dolphin and the Gangway	8,660	1,960	10,620
	Sub Total	(71,790)	(43,330)	(115,120)
Improvement Cost of the Cargo Handling System	Purchase Cost of the Cargo Handling Equipment for Cargoes other than Grain	64,850	0	64,850
	Purchase Cost of the Cargo Handling Equipment for Grain Cargo	192,350	0	192,350
	Purchase Cost of the Maintenance Instruments	1,640	0	1,640
	Shipping Cost for the Cargo Handling Equipment	24,090	0	24,090
	Education and Training of the Coordinators	11,770	0	11,770
	Pavement of the Yards	7,180	82,140	89,320
	Sub Total	(301,880)	(82,140)	(384,020)
Total		1,019,750	248,000	1,267,750

(2) Annual Maintenance Cost

(Unit : '000 ¢ /year)

Item	Cost		
	Foreign Portion	Local Portion	Total
Maintenance Dredging	930	300	1,230
Maintenance Works for the Facilities	1,980	5,120	7,100
Total	2,910	5,420	8,330

(Unit : '000 ¢)

Item	1991			Total		
	Foreign Portion	Local Portion	Sub-Total	Foreign Portion	Local Portion	Total
Purchase Costs of the Grab Dr				165,250	0	165,250
and Construction Machinery, a				183,490	0	183,490
Costs				73,080	0	73,080
				23,950	2,660	
				(445,770)	(2,660)	(448,430)
Construction Cost of the Facili				181,150	116,410	297,560
Protect the Harbour from San				10,890	1,070	11,960
ion and Primary Dredging Cos				8,270	2,390	10,660
				(200,310)	(119,870)	(320,180)
Construction Cost for the Enla				43,900	9,970	53,870
the Mooring Facility Capacity				19,230	31,400	50,630
				8,660	1,960	10,620
				(71,790)	(43,330)	(115,120)
Improvement Cost of the Carg System	64,850	0	64,850	64,850	0	64,850
	192,350	0	192,350	192,350	0	192,350
	1,640	0	1,640	1,640	0	1,640
	24,090	0	24,090	24,090	0	24,090
	11,770	0	11,770	11,770	0	11,770
				7,180	82,140	89,320
	(294,700)	0	(294,700)	(301,880)	(82,140)	(384,020)
	294,700	0	294,700	1,019,750	248,000	1,267,750

X-19 Annual Project Investment

(Unit : '000 ¢)

	1989			1990			1991			Total		
Sub-Total	Foreign portion	Local Portion	Sub-Total	Foreign Portion	Local Portion	Sub-Total	Foreign Portion	Local Portion	Sub-Total	Foreign Portion	Local Portion	Total
165,250										165,250	0	165,250
183,490										183,490	0	183,490
73,080										73,080	0	73,080
26,610										23,950	2,660	
(448,430)										(445,770)	(2,660)	(448,430)
52,510	127,870	82,170	210,040	21,310	13,700	35,010				181,150	116,410	297,560
11,960										10,890	1,070	11,960
				8,270	2,390	10,660				8,270	2,390	10,660
(64,470)	(127,870)	(82,170)	(210,040)	(29,580)	(16,090)	(45,670)				(200,310)	(119,870)	(320,180)
				43,900	9,970	53,870				43,900	9,970	53,870
				19,230	31,400	50,630				19,230	31,400	50,630
				8,660	1,960	10,620				8,660	1,960	10,620
				(71,790)	(43,330)	(115,120)				(71,790)	(43,330)	(115,120)
							64,850	0	64,850	64,850	0	64,850
							192,350	0	192,350	192,350	0	192,350
							1,640	0	1,640	1,640	0	1,640
							24,090	0	24,090	24,090	0	24,090
							11,770	0	11,770	11,770	0	11,770
				7,180	82,140	89,320				7,180	82,140	89,320
				(7,180)	(82,140)	(89,320)	(294,700)	0	(294,700)	(301,880)	(82,140)	(384,020)
512,900	127,870	82,170	210,040	108,550	141,560	250,110	294,700	0	294,700	1,019,750	248,000	1,267,750

Table X-19 Annual Pr

Item	Sub Item	1988			
		Foreign Portion	Local Portion	Sub Total	Foreig portio
Purchase Costs of the Grab Dredger Fleet and Construction Machinery, and Related Costs	Purchase Cost of the Grab Dredger Fleet	165,250	0	165,250	
	Purchase Cost of the Construction Machinery	183,490	0	183,490	
	Shipping Cost for the Grab Dredger Fleet and the Construction Machinery	73,080	0	73,080	
	Construction Cost of the Repair Facilities	23,950	2,660	26,610	
	(Sub Total)	(445,770)	(2,660)	(448,430)	
Construction Cost of the Facilities to Protect the Harbour from Sand Sedimentation and Primary Dredging Cost	Construction Cost of the Breakwater Extension	31,970	20,540	52,510	127,8
	Construction Cost of the Temporary Facilities	10,890	1,070	11,960	
	Primary Dredging Cost				
	(Sub Total)	(42,860)	(21,610)	(64,470)	(127,8
Construction Cost for the Enlargement of the Mooring Facility Capacity	Cost of Shifting the Breakwater				
	Construction Cost of the -3m Quay Wall				
	Construction Cost of the Mooring Dolphin and the Gangway				
	(Sub Total)				
Improvement Cost of the Cargo Handling System	Purchase Cost of the Cargo Handling Equipment for Cargoes other than Grain				
	Purchase Cost of the Cargo Handling Equipment for Grain Cargo				
	Purchase Cost of the Maintenahce Instruments				
	Shipping Cost for the Cargo Handling Equipment				
	Education and Training of the Coordinators				
	Pavement of the Yards				
	(Sub Total)				
Total		488,630	24,270	512,900	127,8

4. Possibility of Deepening the −7.5m Quaywall

The existing quays at the Port of Caldera consist of three berths, namely, the −11 m quay, the −10 m quay and the −7.5 m quay which are 210 m, 150 m and 130 m in length, respectively. The total length of the quays of more than −10 m in depth is not sufficient for two 15,000 to 20,000 dead weight ton vessels to berth simultaneously. If it were possible to deepen the −7.5 m quay down to −10 m, simultaneous mooring of two large sized ships would be possible. Thus, we study the possibility of increasing the depth through reinforcement of this quay.

If the water depth is deepened by dredging the front part of the sheet pile quaywall, the depth of the penetration will be shortened, and therefore it will be difficult to stabilize the penetration so that the passive earth pressure in front of the penetration can be reduced. Moreover, the active earth pressure will be increased and the member stress acting on the sheet piles and anchors will also be increased.

Generally, one of the following two methods is adopted to cope with these conditions:

a) The reduction of the active earth pressure acting on the back of the sheet pile wall.

b) The lengthening of the penetration and the reinforcement of the sheet piles and anchors.

In the first case, the general practice is to provide a pile foundation behind the sheet pile wall. This is to transmit a part of the surcharge and overburden pressure through the piles to deep ground and to reduce the active earth pressure acting on the sheet pile wall at the same time. Also, by the lateral resistance of the pile foundation, the tie–rod tension is reduced.

In the second case, the construction method is to expand the penetration length of the sheet pile wall by driving in new sheet piles of sufficient length in the front or the rear of the existing sheet piles, and at the same time, to reinforce the tie–rods and anchor piles.

However, since rubble stones of good quality were used for the backfill and foundation of this quay, it would be extremely difficult to drive in piles or sheet piles behind the existing sheet piles. Consequently, we consider one method of construction which would mitigate the active earth pressure on the back of the sheet pile wall by replacing the upper part of the backfill with a light weight box structure, and another possible method of providing a piled platform in front of the sheet pile wall.

4. 1 Method of Replacing the Upper Part of the Backfill with a Box Structure

As shown in Fig.X–25, this method consists in replacing the upper part of the backfill to the rear of sheet piles with a box culvert made of reinforced concrete as shown in Fig.X–26. By changing the position of the bottom of the box, the water depth increase could be achieved. The design conditions adopted for this study are those noted in Fig.X–25 which include the following two modifications of the original design conditions. First, the internal friction angle of the backfill which was 35° in the original is assumed as 38°, equal to the original design angle of the −10 m quay considering that the same backfilling materials were actually used for both structures. Similarly, the surcharge in the original design was 3.0 tf/m² under normal conditions and 1.5 tf/m² under seismic conditions. However, as such heavy cargoes will seldom be handled on the apron, we have adopted the same conditions as at the general cargo wharf, that is, 2.0 tf/m² under normal conditions and 1.0 tf/m² under seismic conditions.

Fig. X–27 shows the relationship between water depth at sight and the height of the box bottom from the viewpoint of the stability of the embedment of the sheet pile wall. In this, we have adopted a safety factor of 1.5 for normal conditions and 1.2 for seismic conditions for the stability. Fig. X–28 shows the similar relationship seen from the viewpoint of the maximum bending stress of the sheet piles, and the water depth attaining the allowable bending stress constitutes the critical depth. In this case, the corrosion of the sheet piles over 5 years is considered. We have carried out similar studies on the tension of tie–rods, and we have concluded that they have not reached this limit even at a water depth of 10 m. As is obvious from these studies, the excavable depth is determined by the stability of the embedment, and the critical depth, putting the box bottom to ±0.0 m, would be −8.35 m. Considering overdredge at the time of dredging, the limit of the water depth at the quay would be −8.0 m. Further deepening the box bottom would involve substantial difficulties. Thus, it is technically impossible to increase the water depth of the −7.5 m quay down to −10 m using a box structure.

4. 2 Method of Providing a Platform in Front of the Sheet Pile Wall

If we were to provide a platform in front of the sheet pile wall for which vertical steel pipe piles would be used, a structure such as the one shown in Fig. X–29 would be necessary. The design conditions adopted for this study are the same as those of the original design : the berthing velocity of the vessels is 0.15 m/s, the surcharge is 3.0 tf/m² under normal conditions and 1.5 tf/m² under seismic conditions, the average N value of the botom subgrade is 25, and the coefficient of horizontal subgrade reaction is 3.8 kgf/cm³. The critical external force is the berthing force of the vessels. The width of the platform is determined by the stability of embedment of the sheet pile wall.

If this type of structure were adopted, in order to secure the continuity of the three existing quays, it would be necessary to provide a platform not only in front of the −7.5 m quay but also along all these berths, so the construction cost would be increased drastically: it is anticipated to come to as much as US $ 6,800,000. Thus, the method to increase the depth of the −7.5 m quay up to −10.0 m by providing a platform in front of the existing sheet pile wall is not economically feasible.

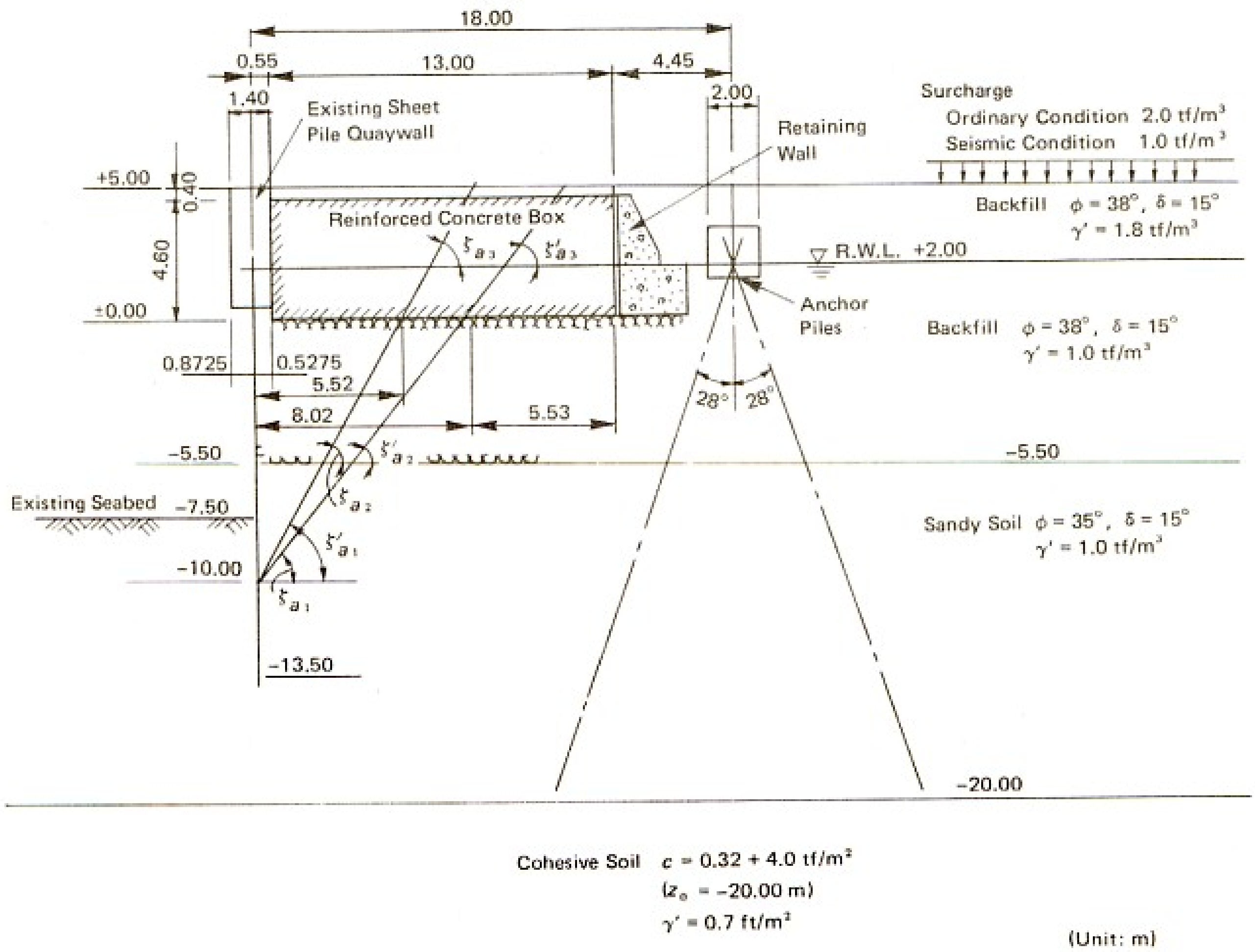


Fig. X-25 Examination of the Possibility Increasing the Water Depth of the −7.5 m Quaywall (Replacement of Backfill with Light Weight Concrete Box)

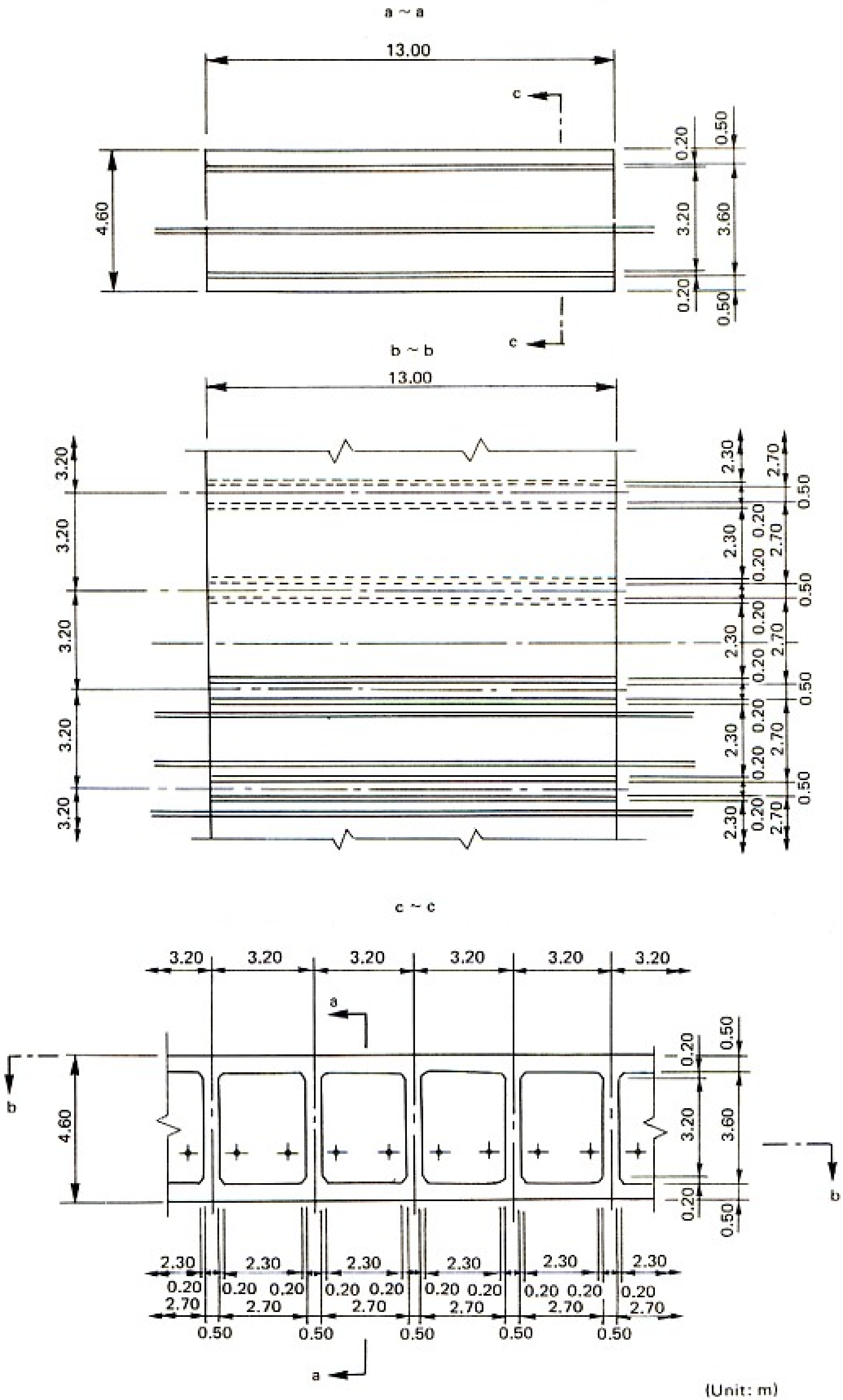


Fig. X-26 An Example of a Light Weight Reinforced Concrete Box

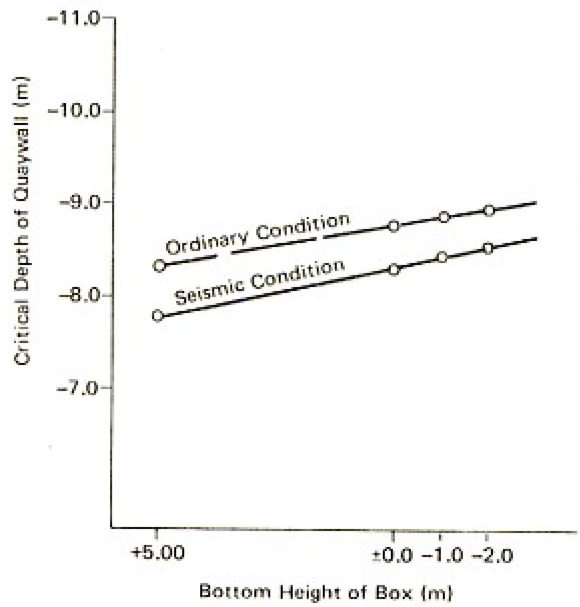


Fig. X-27 Relation between Bottom Height of Box and Critical Quaywall Depth Based on the Penetration Stability of the Sheet Piles

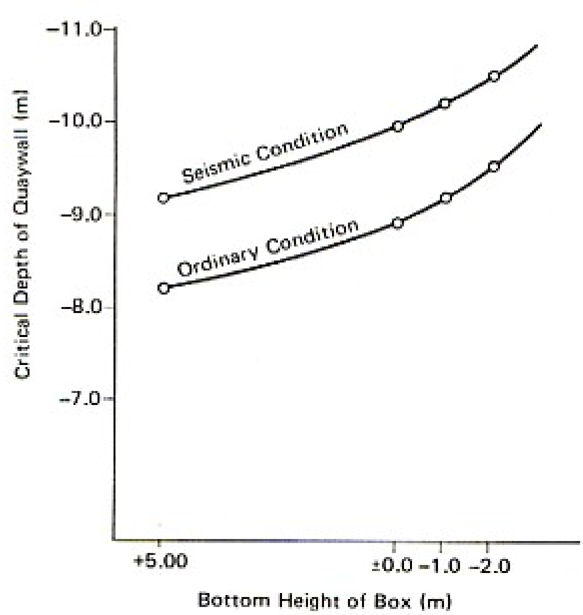
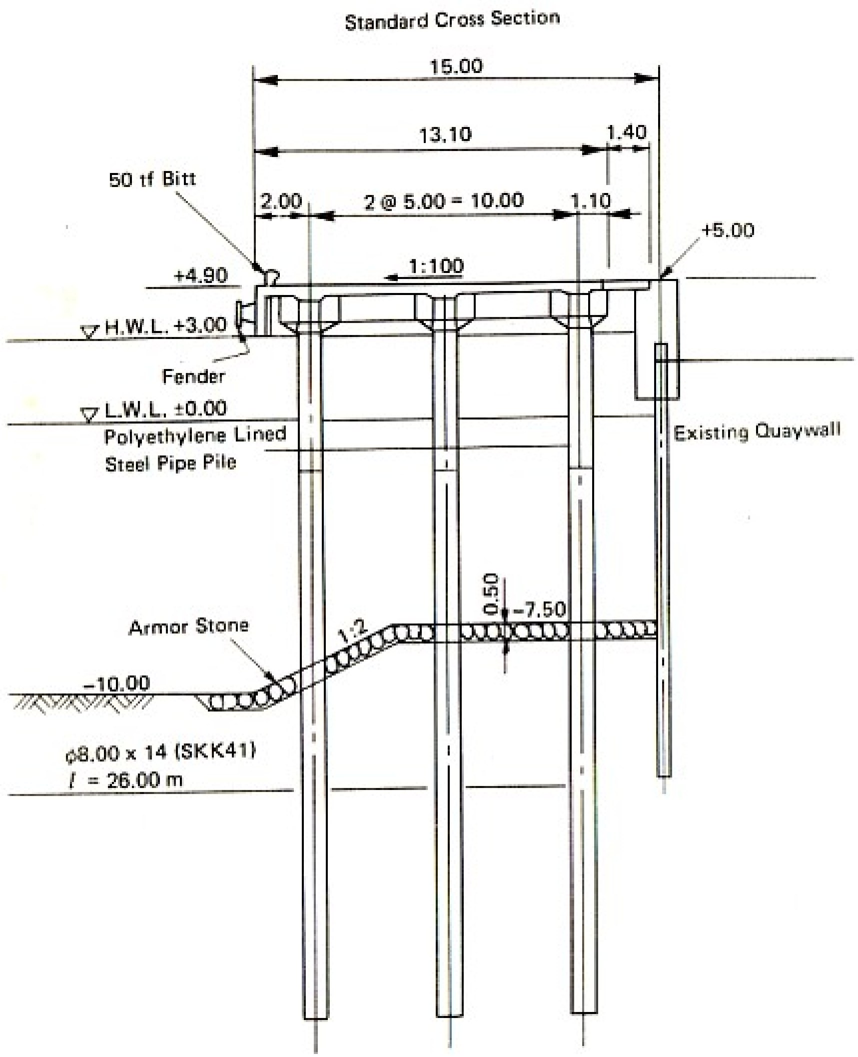


Fig. X-28 Relation between Bottom Height of Box and Critical Quaywall Depth Based on the Bending Stress of the Sheet Piles



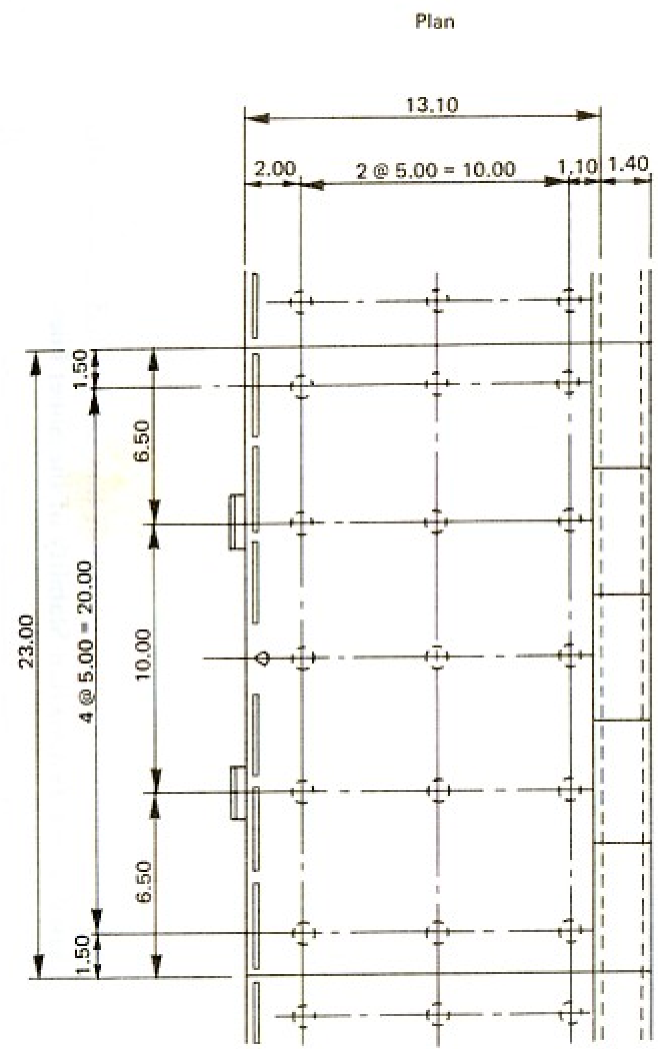


Fig. X-29 Examination of the Possibility of Increasing the Water Depth of the −7.5 m Quaywall (Addition of Platform)

5. Assessment of the National Pier of Puntarenas Port

The steel piles of the National Pier at the Port of Puntarenas are in a state of advanced corrosion, and there are many steel pipe piles whose entire external surface has been eaten away due to extreme corrosion at the low water level : there are still more piles which are partially corroded. As these piles receive no corrosion prevention treatment at all, the corrosion is continuing to advance. If the piles corrode completely, they will no longer withstand horizontal forces such as seismic force and the tractive force of ships as well as surcharge and dead load, and accidents during operation may occur.

MOPT has made an investigation of the state of corrosion of this pier, and on the basis of the investigation, they designed a maintenance and repair plan for the pier in March 1984 aimed at extending its use for 10 more years. Following this plan, INCOP has started repair work beginning with piles which are particularly corroded. This repair operation is considered urgent. However, even if the operation is carried out, the useful lifetime of the pier will not be extended by many years.

If Puntarenas Port continues its cargo handling activities in the future, the pier will have to be completely rebuilt or a new pier will have to be constructed. If the existing pier were rebuilt, it is difficult to expect that the existing structural members would be sufficiently strong. Therefore, the costs of rebuilding the existing pier would almost equal the costs of building a new structure. However, a new pier would be structually more sound.

Furthermore, the repair work would have to take place while no cargo is being handled. Thus, the work period would be quite long, and this would also contribute to high costs.

Consequently, the National Pier of the port of Puntarenas cannot be expected continue to function beyond the immediate future due to its superannuation. The estimated cost for constructing a new pier is about US$ 13,400,000.

CHAPTER XI ECONOMIC ANALYSIS

1. Purpose and Methodology of the Economic Analysis

1.1 Purpose

The purpose of the economic analysis is to appraise the economic feasibility of the maintenance project for the Port of Caldera presented in the previous chapters. The evaluation of a project should show whether the project is feasible from the economic point of view by assessing its contribution to the national economy.

Therefore, the purpose of this chapter is to investigate the economic benefits as well as the economic costs which will arise from the project, and to evaluate whether the net benefits exceed those which could be derived from other investment opportunities (the opportunity cost of capital) in Costa Rica.

1.2 Methodology

The economic return is evaluated in terms of the economic internal rate of return (EIRR) based on cost benefit analysis using the Discount Cash Flow Method.

The EIRR is a discount rate which makes the costs and benefits of a project equal, and it is calculated using the following formula :

$$\sum_{i=0}^{n} \frac{B_i - C_i}{(1+r)^i} = 0$$

n : Calculation period
B_i : Benefit in i-th year
C_i : Cost in i-th year
r : Discount rate

For this project, costs have been calculated based upon international prices.

2. Prerequisites of the Economic Analysis

2.1 Objects of the Analysis

The following items are defined as the objects of the economic analysis for the project.

(a) Countermeasures against sand sedimentation :

i) Extension of the existing breakwater

ii) Primary and maintenance dredging

(b) Enlargement of the cargo handling capacity by :

i) Shifting of the breakwater foot

ii) Construction of the −3.0 m quaywall

iii) Construction of the mooring dolphin and gangway

iv) Pavement of the open yeads

v) Reinforcement of cargo handling equipment

vi) Reinforcement of maintenance equipment

(c) Construction of a grain cargo terminal (20,000 ton storage capacity)

i) Construction of a grain silo

ii) Construction of cargo handling facilities for grain

2.2 Alternative Case

In order to determine the return on the project, a cost benefit analysis is conducted. That is, the costs which will be incurred from carrying out the project are subtracted from the benefits which will be gained.

To calculate the benefits of the project in economic terms, an alternative case is used. The case when an investment is made, the With Case, is compared with the case when no investment is made, the Without Case.

In this study, the following conditions are adopted as the Without Case :

(a) The breakwater is not extended.

(b) Annual dredging is carried out in order to maintain the design depth of the existing berths.

(c) Additional equipment and facilities for enlargement of cargo handling capacity are not provided.

(d) The same grain terminal is constructed as under the With Case.

2.3 Retirement of the Existing Puntarenas Pier

The existing Puntarenas Pier will be retired in 1992 when the construction of this project is completed due to its superannuation. Although the costs of replacing this pier are not considered in this economic analysis, the pier is closely related to this project. After the pier is retired, the following two options may be considered ;

(a) Construction of a grain silo and cargo handling facilities near the Ports of Limón and Moín

In this case, in addition to the construction costs of the grain terminal the transportation costs between this location and the location of grain storage silos in Barranca which is the hinterland of Puntarenas would also have to be considered.

(b) Construction of a new pier of the same scale near the existing Puntarenas Pier

However, there is no space where the grain cargo terminal could be constructed close to the existing Pier. The construction costs for the new pier are described in CHAPTER X.

Considering this situation, we have decided to include the costs of constructing the grain terminal in both the With and the Without Cases as this terminal, or equivalent facilities, will have to be built whether or not the Port of Caldera is improved as proposed in this feasibility study.

2. 4 Project Life

The period of economic calculation (project life) is assumed as 30 years from the beginning of the construction (i.e. from 1988).

2. 5 Exchange Rate

The foreign currency exchange rate used in this study is

1 US dollar = 53.15 colones

1 Colon = 3.770 Japanese yen

3. Benefits

3.1 Benefit Items

The benefits brought about by the project include :

(a) Reduction of staying costs, that is, the costs associated with waiting for unoccupied berths and waiting while cargo is being loaded and unloaded after docking

(b) Reduction of dredging costs by the extension of the breakwater

(c) Improvement of the calmness in the port by the extension of the breakwater

(d) Improvement of cargo handling

Many of the expected benefits cannot be evaluated in strictly monetary terms. However, the two benefits which can be evaluated monetarily and are considered in the statistical analysis are :

(a) Reduction of staying costs

(b) Reduction of dredging costs

The other benefits are intangible or difficult to quantify, so only a qualitative analysis is undertaken.

3.2 Reduction of Ships' Staying Costs

The volume of cargo handled at the Ports of Caldera and Puntarenas is increasing. Investment in improved port facilities and equipment will reduce the waiting period for berth space and the period for loading and unloading cargo. The staying period of ships will be reduced, and this cost reduction is one major benefit of the project.

The benefit that will accrue to Costa Rica from the reduced staying period due to improved facilities and equipment at the Port of Caldera can be calculated by comparing the With Case versus the Without Case. The calculation formula is presented below.

[Reduction of Ships' Staying Costs(Benefit)] = [Difference in Ships' Staying Period between With and Without Cases] × [Staying Costs (per Unit Time)] × [Share of Benefits Accruing to Costa Rica]

3.2.1 Difference in Ships' Staying Period

The average waiting period is estimated in sub-paragraph 2.2.1 of CHAPTER VII from the results of the simulation using Queuing Theory. The difference of the total staying period including ships' berthing period between the With Case in 1992 and the Without Case in 1991 is shown in Table XI—1. To grasp the actual development effects in terms of preventing port congestion, we should compare the With Case with the Without Case in the same year.

However, using the projected figures for the Without Case in 1992 is unrealistic because the port congestion is projected as being abnormally high judging from the calculated berth occupancy ratio as shown in Fig. VII—24. Therefore, in this study the With Case in 1992 is compared with the Without Case in 1991. This results in a conservative estimation of the benefits of the project.

Table XI-1 Total Ships' Staying Period

Unit : Hours

Cargo Type	Without Case (1991)	With Case (1992)	Difference
General Cargoes	24,113	14,644	9,469
Automobiles	6,073	2,684	3,389
Containers	8,443	5,031	3,412
Grain	1,323	886	437
Fertilizer	368	268	100
Total	40,320	23,513	16,807

3. 2. 2 Calculation of Ships' Staying Costs

"Staying Costs" are the costs incurred while a vessel is within the port. There are two main methods for calculating staying costs, i.e. (1) calculating staying costs from various ship costs including depreciation costs and other expenses such as labour and fuel costs, and (2) calculating staying costs based on the time charterage of cargo vessels.

(1) Ship costs

Based upon ship cost data gathered by a Japanese research institute, the following correlation is prepared. Data sources are shown in APPENDIX 12 :

$$Y = 6624.97 - 1134.29 \cdot \ln(X) \quad (R = 0.959)$$

where, X : Ship size ('000 DWT)

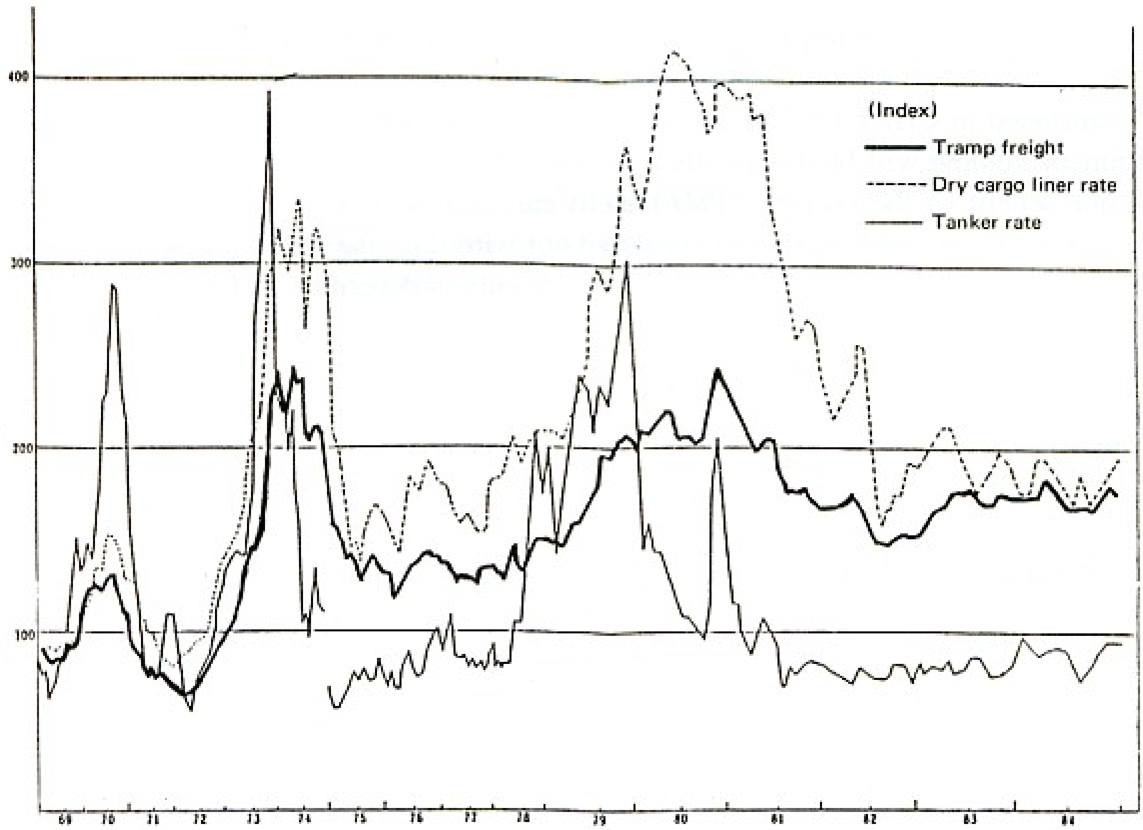
Y : Ship cost (Japanese Yen/DWT/Month)

ln : Natural logarithm

R : Correlation coefficient

(2) Time charterage of cargo vessels

As shown in Fig. XI—1, charter rates fluctuate by a large margin, and acoording to the staffs of Japanese shipping companies, the charter rates (market rates) in 1973 and 1980 were adequate for them, that is the shipping companies were able to realize a reasonable profit at these rates.



Note: The scale of the index presented in this figure is not constant, but changes as follows: 1) from 1966, the index value of 100 is equal to the average rate from July 1965 through June 1966; 2) however, from 1972 for liner vessels only the index value of 100 is equal to the average rate of 1971.
For tankers, the index is based on the single navigation flat rate. From 1975, the index is based on the rates for small size (30-60 thousand D/T) oil tankers.

Source: Norwegian Shipping News

Fig. XI-1 Charter Rate Index (Monthly Average)

Based on item (1) and (2) above, 70% of the calculation costs from the correlation presented in item (1) are adopted as the staying costs for this study. For example, 807 ¢ (15.2 $)/DWT/Month for 7,500 DWT vessels, 662 ¢ (12.5 $)/DWT/Month for 15,000 DWT vessels, and 554 ¢ (10.4 $)/DWT/Month for 25,000 DWT vessels are sample adopted rates using this calculation method.

3. 2. 3 Share of the Benefits Accruing to Costa Rica

The savings in ships' staying costs are primarily realized by shipping companies. For foreign ships, therefore, the benefits accrue to foreign countries. However, some portion of these benefits should be returned to Costa Rica. In this study, it is assumed that 50% of the costs saved by foreign ships accrue to Costa Rica.

3. 3 Reduction of Dredging Costs by the Extension of the Breakwater

As mentioned in CHAPTER VI, if the existing breakwater is extended by 200 m, the sand sediment volume will be drastically reduced. The reduction of dredging costs is the other major benefit of the project. This benefit can be calculated by comparing the case where the extension of the breakwater is carried out with the case where it is not—the With Case versus the Without Case. The calculation formula is described as follows :

[Reduction of Dredging Costs (net benefit)] = [Dredging Volume] × [Dredging Cost (per Unit Volume)]

— under the "Without" Case —

− ([Dredging Volume] × [Dredging Cost (per Unit Volume)] + [Construction Cost of the Breakwater Extension])

— under the "With" Case —

3. 4 Other Intangible Benefits

3. 4. 1 Improvement of Calmness in the Port by the Extension of the Breakwater

The wave height distribution in the harbour is calculated using a computer simulation. The details are shown in APPENDIX 8. The results show that the occurrence probability of significant wave heights less than 30 cm at the No. 1 and No. 2 berths increases and that the calmness in the harbour is improved to some extent by extending the breakwater. This should decrease the ship movement at berth. Consequently, it may bring about an increase in cargo handling efficiency.

3. 4. 2 Improvement of Cargo Handling

From the rationalization of the cargo handling system, the following benefits are expected :

(a) The progress of containerization will significantly reduce the cargo damage.

(b) The cargo turnover will increase and consequently the warehouses and open yards will be used more efficiently.

(c) The pavement of the open yards will reduce the cargo damage within these yards.

4. Costs

4. 1 Costs under the With Case

Table XI—2 shows the total costs under the With Case throughout the project life, i.e. from 1988 to 2017. The prerequisites of the calculation are as follows :

(1) The costs are calculated based on the costs shown in Table X—18. For calculation of the construction cost of individual facilities such as the breakwater extension, the shifting of the breakwater foot and the construction of the mooring dolphin and gangway, and also for dredging costs, the concept of monthly rental fees against the purchase costs of the grab dredger fleet and construction machinery are applied. Generally, in economic analyses, the concept of salvage value is adopted when some equipment or facility can be used for other projects after the subject project is finished. However, in this case, the fleet and the construction machinery will be used for various purposes, and the equipment costs have to be allocated to each construction item in proportion to the estimated number of months the eqipment will be used to construct each item. This is the reason why the concept of monthly rental fees is applied herein. In the calculation of the rental fees, the lives of fleet and repair facilities are estimated as 15 years, and the life of the construction machinery is estimated as 7 years.

(2) The construction cost of the grain terminal is not listed in Table XI—2 because the cost under both the With and the Without Cases remains the same.

(3) Dredging costs are calculated based on the dredging volume in Fig. VI—26(a).

(4) The life of the cargo handling equipment except for maintenance tools is estimated as 10 years, and the life of maintenance tools is estimated as 15 years.

(5) Maintenance costs for the breakwater extension per annum are estimated as 0.5% of the construction costs, and annual maintenance costs for the enlargement of the mooring facility capacity are estimated as 1% of the construction costs. Maintenance costs for the cargo handling equipment and the pavement of the yards are estimated as 5% of the construction costs per annum.

(6) Maintenance costs for the cargo handling equipment are not estimated for the years when equipment is replaced.

(7) The salvage values of the cargo handling equipment and maintenance tools in 2017 are considered.

(8) The cargo handling equipment cost in 1991 includes training fees for INCOP personnel, but in the costs for renewal in 2001 and 2011, training fees are not included.

4. 2 Costs under the Without Case

Table XI—3 shows the total costs under the Without Case throughout the project life, i. e. from 1988 to 2017.

The prerequisites of the calculation are as follows :

(1) If the breakwater were not extended, sediment sand would have to be dredged by a contractor with an appropriate dredger fleet. However, taking into consideration the

Table XI-2 Costs under the With Case

Cost Item / Year	Extension of the Breakwater		Dredging Cost	Mooring Facility*3)		Pavement of the Yards		Cargo Handling Equipment		Total
	Cost*1)	Maintenance Cost*2)		Cost	Maintenance Cost	Cost	Maintenance Cost	Cost	Maintenance Cost	
1988	84,455									84,455
1989	263,332	422								263,754
1990	43,892	1,739	15,400	141,771		92,181				294,983
1991		1,958	12,106		1,418		4,609	86,605		106,696
1992		1,958			1,418		4,609		3,647	11,632
1993		1,958			1,418		4,609		3,647	11,632
1994		1,958			1,418		4,609		3,647	11,632
1995		1,958			1,418		4,609		3,647	11,632
1996		1,958	10,088		1,418		4,609		3,647	21,720
1997		1,958			1,418		4,609		3,647	11,632
1998		1,958			1,418		4,609		3,647	11,632
1999		1,958			1,418		4,609		3,647	11,632
2000		1,958			1,418		4,609		3,647	11,632
2001		1,958	10,088		1,418		4,609	72,949		91,022
2002		1,958			1,418		4,609		3,647	11,632
2003		1,958			1,418		4,609		3,647	11,632
2004		1,958			1,418		4,609		3,647	11,632
2005		1,958			1,418		4,609		3,647	11,632
2006		1,958	10,088		1,418		4,609	1,884	3,647	23,604
2007		1,958			1,418		4,609		3,647	11,632
2008		1,958			1,418		4,609		3,647	11,632
2009		1,958			1,418		4,609		3,647	11,632
2010		1,958			1,418		4,609		3,647	11,632
2011		1,958	10,088		1,418		4,609	72,949		91,022
2012		1,958			1,418		4,609		3,647	11,632
2013		1,958			1,418		4,609		3,647	11,632
2014		1,958			1,418		4,609		3,647	11,632
2015		1,958			1,418		4,609		3,647	11,632
2016		1,958	16,652		1,418		4,609		3,647	28,284
2017		1,958			1,418		4,609 4,609	△ 377 △21,885		△10,630
Total	391,679	55,027	84,510	141,771	38,286	92,181	124,443	212,125	87,528	1,227,550

Note : *1) Cost is the primary construction cost.
*2) Maintenance cost is the annual maintenance cost.
*3) Cost items of mooring facility capacity consist of construction costs for shifting the breakwater foot, the −3m quaywall and the mooring dolphin and gangway.

past results, i.e. sudden sand sediment in the harbour within a few days caused by extraordinary waves, it is assumed that the grab dredger fleet is purchased by MOPT and should solely be engaged in the maintenance dredging at the Port of Caldera.

(2) Dredging costs are calculated based on the dredging volume in Fig. VI—26(a).

(3) The life of the grab dredger fleet is estimated as 15 years, and the salvage values of the fleet in 2017 are considered.

(4) In Table XI—3 the maintenance costs of the fleet are included in the dredging costs.

Table XI-3 Costs under the Without Case

Unit : '000 colones

Cost Item \ year	1989	1990	1991	1992	1993	1994
Purchase of the Fleet	263,685					
Dredging	13,090	4,420	4,998	16,898	6,613	7,565
Total	276,775	4,420	4,998	16,898	6,613	7,565

Cost Item \ year	1995	1996	1997	1998	1999	2000
Purchase of the Fleet						
Dredging	8,330	8,891	17,459	9,843	10,132	10,421
Total	8,330	8,891	17,459	9,843	10,132	10,421

Cost Item \ year	2001	2002	2003	2004	2005	2006
Purchase of the Fleet				263,685		
Dredging	10,710	18,989	11,186	11,373	11,458	11,662
Total	10,710	18,989	11,186	275,058	11,458	11,662

Cost Item \ year	2007	2008	2009	2010	2011	2012
Purchase of the Fleet						
Dredging	19,941	12,036	12,223	12,410	12,699	20,791
Total	19,941	12,036	12,223	12,410	12,699	20,791

Cost Item \ year	2013	2014	2015	2016	2017	Total
Purchase of the Fleet					△17,579	509,791
Drdeging	12,699	12,699	12,699	12,699	20,791	355,725
Total	12,699	12,699	12,699	12,699	3,212	865,516

5. Shadow Pricing

5. 1 Calculating Shadow Prices

The costs and benefits considered in previous paragraphs are calculated based on market prices (international prices and domestic prices). However, the values of goods quoted in a given marketplace do not always represent the true value of those goods to the nation. Thus, "shadow pricing" is often used to examine the costs of labour, capital, and imported goods, as well as the benefits of development, to evaluate a project from the economic viewpoint. There are several ways of applying the concept of shadow pricing, but in this study, the prices of domestic goods and services are revised.to shadow prices in order to determine a more rational valuation. These shadow prices are intended to represent the international market prices of these goods and services.

5. 1. 1 Exclusion of Transfer Items

The costs in Table XI—2 and XI—3 should be divided into local currency and foreign currency portions for shadow pricing. The foreign currency portion of the imported equipment and services do not include import duties or sales tax. Thus, these figures are a reasonable statement of the economic value of these goods and services.

On the other hand, the local currency portion of the construction costs include both sales tax and import duties. These are merely transfer items, which do not actually reflect the consumption of any national resources. Therefore, these transfer costs should be excluded from the economic analysis of the value of the project.

5. 1. 2 Method of Applying Conversion Factors

Generally, all benefits and costs are divided into labour, traded goods and non-traded goods. Labour is further divided into skilled labour and unskilled labour. The cost of skilled labour is obtained by multiplying its market price by the conversion factor for consumption (CFC), and the cost of unskilled labour is calculated by multiplying its market price by a ratio of the shadow wage rate and the CFC. Traded goods are expressed by the CIF value for imports and by the FOB value for exports. As world prices cannot be directly applied in the case of non-traded goods, a second level analysis is made of the items required for the production of non-traded goods. These items are, in turn, divided into the categories of labour, traded goods and non-traded goods. The standard conversion factor (SCF) is then applied to the remaining value of non-traded goods.

5. 2 Calculation of the Conversion Factors

5. 2. 1 The Standard Conversion Factor (SCF)

Import duties and export subsidies create a price differential between the domestic market and the international market. For the purpose of analysing benefits and costs within the domestic market, the standard conversion factor is applied in order to convert domestic prices to international market prices.

The standard conversion factor is obtained using the following formula :

$$SCF = \frac{I + E}{I + D_i + E - D_e}$$

where, I : Total Amount of Imports
E : Total Amount of Exports
D_i : Total Amount of Import Duties
D_e : Total Amount of Export Duties

The standard conversion factors in 1984 and 1985 are listed in Table XI—4. In this study, the mean value for the two year period is used. Thus, the standard conversion factor has a value of 0.983.

Table XI-4 Standard Conversion Factors (SCF)

Unit: '000,000 colones

Item	1984	1985	Total
Imports (CIF)	48,560	56,282	104,842
Exports (FOB)	44,684	48,678	93,362
Import Duties	4,165	5,360	9,525
Export Duties	3,165	2,970	6,135
SCF	0.989	0.978	0.983

Note : 1) The source of data for import and export volumes (US$ basis) is BCCR. Exchange rates between US$ and colones are as follows :
1 US$ = 44.40 colones in 1984
= 50.55 colones in 1985
2) The source of data for import and export duties is the Intermodel Commission of Cargo consisting of the Ministry of Finance and the Board of Audit.
3) Import and export figures for 1985 are preliminary.

5. 2. 2 Conversion Factor for Consumption (CFC)

This factor is used for converting the prices of consumer goods from domestic to international prices. This is particularly required to convert domestic labour costs to the corresponding international prices. The conversion factor for consumption is usually calculated in the same manner as the standard conversion factor, replacing total imports and total exports by imports and exports of consumer goods only. However in this case, due to a lack of the required data such as duty revenue figures, the conversion factor for consumption could not be calculated.

5. 3 Shadow Prices of Benefit Items

5. 3. 1 Reduction in Staying Costs

The calculation of the reduction in ships' staying costs is quoted at international prices. Thus, this figure does not have to be converted for economic analysis.

5. 4 Shadow Prices of Cost Items

Table XI—5 and Table XI—6 show the breakdown of construction costs divided into the foreign portion and the local portion on a market price basis.

As imported equipment for the project is exempt from import duties, the foreign portion is quoted at CIF prices. Also, almost all of the equipment and tools listed as trade goods in Table XI—5 and Table XI—6 purchased by MOPT without any tax are quoted at CIF prices. For the other items (the local portion except for traded goods), the conversion factor coefficients are calculated. Table XI—7 and Table XI—8 show the calculated conversion coefficients of the costs.

Table XI-5 Construction Costs from 1988 to 1991

Unit: '000 colones

Item	Total	Foreign Portion	Local Portion				
			Sub Total	Traded Goods	Non Traded Goods	Skilled Labour	Unskilled Labour
Extension of the Breakwater	386,854	274,199	112,655	44,379	10,386	34,979	22,911
Primary Dredging	15,400	13,010	2,390	1,190	0	730	470
Maintenance Dredging in 1991	12,106	10,339	1,767	961	0	488	318
Enlargement of the Mooring Facility	140,432	98,441	41,991	15,883	5,960	12,821	7,327
Pavement of the Yards	88,793	10,041	78,752	31,112	6,712	22,051	18,877
Cargo Handling Equipment	86,605	86,605	0	0	0	0	0
Total	730,190	492,635	237,555	93,525	23,058	71,069	49,903

Note: 1) Sales tax in the local portion is excluded.

Table XI-6 Costs under the Without Case from 1989 to 2017

Unit: '000 colones

Item	Total	Foreign Portion	Local Portion				
			Sub Total	Traded Goods	Non Traded Goods	Skilled Labour	Unskilled Labour
Purchase of the Fleet	509,791	509,791	0	0	0	0	0
Dredging	355,725	241,475	114,250	38,127	0	60,236	15,887
Total	865,516	751,266	114,250	38,127	0	60,236	15,887

In this study, taking into consideration the low share of consumer goods in imports as shown in Table I—10, it is assumed that the CFC is equal to the SCF.

5. 2. 3 Shadow Wage Rate

(1) Evaluation of skilled labour

For economic analysis, labour costs are usually measured in terms of their opportunity costs, that is the value of lost marginal product for other purposes arising from additional employment of labourers for a given project.

In this project, the cost of skilled labour is calculated based on actual market wages, assuming that the market mechanism is functioning properly. However, as these are domestic costs, they are converted to international prices by multiplying the local wage by the conversion factor for consumption.

Thus, the conversion factor for skilled labour

= (nominal wage rate) × (CFC)

= 1 × 0.983

= 0.983

(2) Evaluation of unskilled labour

For unskilled labour, the economic costs are calculated based on a simplified measure of the opportunity cost. Generally, as the wages paid to unskilled labourers by a project are usually far above the opportunity cost, these market wages should not be used for calculating the economic value of the unskilled labourers.

The opportunity cost is estimated by calculating the per-capita-GDP of workers in the agriculture, forestry, hunting and fishery sectors. The total GDP of these sectors is estimated as 38,296 million colones by multiplying the 33,014 million colones value in the sectors in 1984 by the increase rate of the total GDP in 1985 over 1984. The number of workers in the sectors in March, 1985 was 226,765 according to the national employment survey carried out by the Ministry of Labour and National Security. By division, the per capita daily GDP comes to 563 colones, assuming 25 working days in a month.

On the other hand, the nominal daily wage in this project for unskilled labourers including social benefits paid by the employer was 560 colones. As the result of the calculation, it can be said that the opportunity cost estimated from the per capita agricultural GDP is almost the same as the nominal wage for unskilled labour. This is probably because the Costa Rican unemployment rate in 1985 was about 6%, much less than the very high unemployment rate in most other developing countries. It is considered, therefore, that the nominal wage for unskilled labour in Costa Rica approximately represents its economic value.

Thus, the conversion factor for unskilled labour

= (nominal wage rate) × (CFC)

= 1 × 0.983

= 0.983

Table XI-7 Conversion Coefficients of Construction Costs

Item	Foreign Portion	Local Portion					
		Traded Goods	Non Traded Goods	Skilled Labour	Unskilled Labour	Sub Total	Total Conversion Factor
Conversion Factor	1.000	1.000	0.983	0.983	0.983	–	
Extension of the Breakwater	(70.9%) 0.709	(11.5%) 0.115	(2.7%) 0.027	(9.0%) 0.088	(5.9%) 0.058	(29.1%) 0.288	(100.0%) 0.997
Primary Dredging	(84.5%) 0.845	(7.7%) 0.077	– –	(4.7%) 0.046	(3.1%) 0.030	(15.5%) 0.153	(100.0%) 0.998
Maintenance Dredging in 1991	(85.4%) 0.854	(8.0%) 0.080	– –	(4.0%) 0.039	(2.6%) 0.026	(14.6%) 0.145	(100.0%) 0.999
Enlargement of the Mooring Facility	(70.1%) 0.701	(11.4%) 0.114	(4.2%) 0.041	(9.1%) 0.089	(5.2%) 0.051	(29.9%) 0.295	(100.0%) 0.996
Pavement of the Yards	(11.3%) 0.113	(35.0%) 0.350	(7.6%) 0.075	(24.8%) 0.244	(21.3%) 0.209	(88.7%) 0.878	(100.0%) 0.991
Cargo Handling Equipment	(100.0%) 1.000	– –	– –	– –	– –	– –	(100.0%) 1.000

Table XI-8 Conversion Coefficients of Costs under the Without Case

Item	Foreign Portion	Local Portion					
		Traded Goods	Non Traded Goods	Skilled Labour	Unskilled Labour	Sub Total	Total Conversion Factor
Conversion Factor	1.000	1.000	0.983	0.983	0.983	–	
Purchase of the Fleet	(100.0%) 1.000	– –	– –	– –	– –	– –	(100.0%) 1.000
Dredging	(67.9%) 0.679	(10.7%) 0.107	– –	(16.9%) 0.166	(4.5%) 0.044	(32.1%) 0.317	(100.0%) 0.996

6. Economic Profitability

As mentioned above, the economic profitability of the project is evaluated based on the EIRR. The EIRR of the project is 23.7% as shown in Table XI—9.

There are various views concerning the evaluation of the EIRR to guide the judgement as to whether a project is feasible or not. The leading view is that the project is feasible if the EIRR exceeds the local opportunity cost of capital. In port investment projects, EIRRs usually range from 10% to 20%. It is generally considered that a project with an EIRR of more than around 10% is economically feasible. In this case, only taking into consideration the two items which are easily quantified, the EIRR of the project is 23.7%. Therefore, the project is considered to be feasible.

Table XI-9 EIRR Calculation

EIRR=23.7%

Unit: '000 Colones

Year	Benefits	Costs			Benefits −Costs	Present Value in 1988		
		With Case	Without Case	Net Cost		Benefits	Net Costs	Benefits −Net Costs
1988	–	83,163	–	83,163	−83,163	–	83,163	−83,163
89	–	259,725	276,723	−16,998	16,998	–	−13,745	13,745
90	–	288,167	4,402	283,765	−283,765	–	185,555	−185,555
91	61,846	106,426	4,978	101,448	−39,602	32,703	53,643	−20,941
92	123,693	11,374	16,830	−5,456	129,149	52,890	−2,333	55,223
93	123,693	11,374	6,587	4,787	118,906	42,769	1,655	41,114
94	123,693	11,374	7,535	3,839	119,854	34,585	1,073	33,511
95	123,693	11,374	8,297	3,077	120,616	27,967	696	27,271
96	123,693	21,452	8,855	12,597	111,096	22,615	2,303	20,312
97	123,693	11,374	17,389	−6,015	129,708	18,288	−889	19,177
98	123,693	11,374	9,804	1,570	122,123	14,788	188	14,600
99	123,693	11,374	10,091	1,283	122,410	11,958	124	11,834
2000	123,693	11,374	10,379	995	122,698	9,670	78	9,592
1	123,693	90,753	10,667	80,087	43,606	7,820	5,063	2,757
2	123,693	11,374	18,913	−7,539	131,232	6,323	−383	6,709
3	123,693	11,374	11,141	233	123,460	5,113	10	5,104
4	123,693	11,374	275,013	−263,639	387,332	4,135	−8,813	12,948
5	123,693	11,374	11,412	−38	123,731	3,344	−1	3,345
6	123,693	23,336	11,615	11,721	111,972	2,704	256	2,448
7	123,693	11,374	19,861	−8,487	132,180	2,186	−150	2,336
8	123,693	11,374	11,988	−614	124,307	1,768	−9	1,777
9	123,693	11,374	12,174	−800	124,493	1,430	−9	1,439
2010	123,693	11,374	12,360	−986	124,679	1,156	−9	1,165
11	123,693	90,754	12,648	78,106	45,587	935	590	345
12	123,693	11,374	20,708	−9,334	133,027	756	−57	813
13	123,693	11,374	12,648	−1,274	124,967	611	−6	618
14	123,693	11,374	12,648	−1,274	124,967	494	−5	499
15	123,693	11,374	12,648	−1,274	124,967	400	−4	404
16	123,693	28,009	12,648	15,361	108,332	323	40	283
17	123,693	−10,888	3,129	−14,017	137,710	261	−30	291
Total	3,277,864	1,208,378	864,091	344,287	2,933,577	307,991	307,991	0

7. Sensitivity Analysis

7. 1 Assumption of Cases

Sensitivity analysis is made for three cases as follows :

(1) Case EA : The construction costs other than the costs of dredging and the purchase costs of the dredging fleet and cargo handling equipment increase by 10%. In other words, the construction costs of the extended and shifted breakwater, the gangway and the small craft basin as well as the pavement cost of the open yards increase by 10%.

(2) Case EB : The forecast port cargo volume decreases by 10%.

(3) Case EC : The ship costs decrease by 29%. The ship costs decrease by 50% of the figure calculated in APPENDIX 13. The comparison with the base case, the decrease rate is 29%.

7. 2 Results

The EIRR is calculated for each of the three simulation cases. The results are shown in Fig. XI—2. Every EIRR exceeds 10%. The results of the sensitivity analysis thus prove that each case would be feasible.

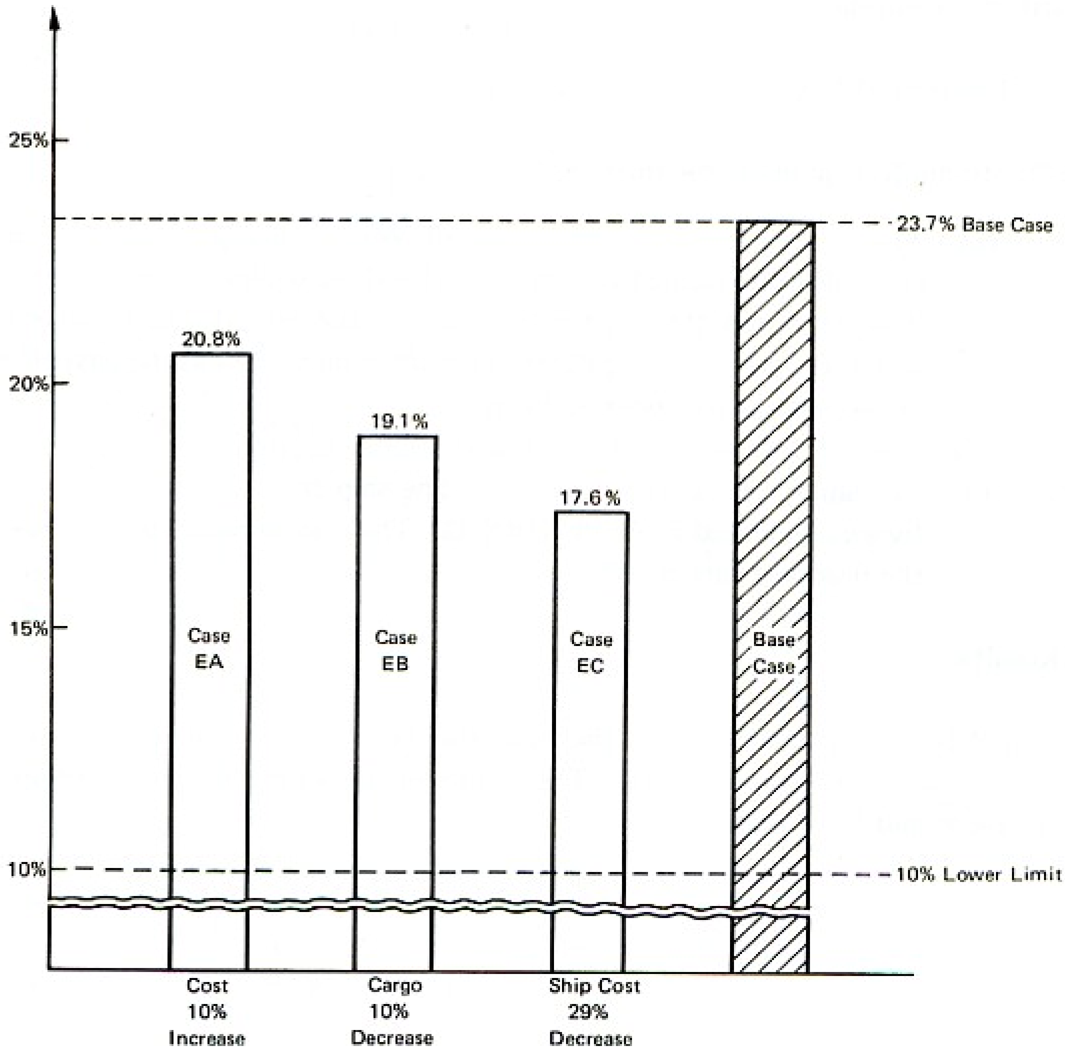


Fig. XI-2 Sensitivity Analysis

8. Conclusion

From the viewpoint of the economic analysis, that is the benefit of the project to the nation, this project can be regarded as feasible.

CHAPTER XII FINANCIAL ANALYSIS

1. Purpose and Methodology of the Financial Analysis

1. 1 Purpose

In the preceding CHAPTER XI, the economic effectiveness of the investment is studied from the viewpoint of the national economy. The purpose of the financial analysis is to ascertain the financial viability of the project itself.

1. 2 Methodology

The investment effects of this project are analysed by the financial internal rate of return (FIRR) using the Discount Cash Flow Method. The FIRR is a discount rate which makes the net present value of the cash flow (revenue minus cost) equal to zero.

2. Prerequisites of the Financial Analysis

2. 1 Objects of the Financial Analysis

The objects of this analysis are limited to the revenues and costs related to this project.

2. 1. 1 Revenues

For this financial analysis, the revenues which will be considered as arising from this project are the port tariffs on the incremental cargo volume, that is the difference in cargo volume between the Without Case in 1991 and the With Case in 1992, and all the port tariffs which will be collected from the handling of grain cargo.

2. 1. 2 Costs

Costs considered in this study are limited to the construction costs for enlargement of the cargo handling capacity listed below. Labour costs are not considered as the cargo volume estimated under the With Case can be handled using the existing number of INCOP personnel.

(a) Shifting of the breakwater foot
(b) Construction of the −3.0 m quaywall
(c) Construction of the mooring dolphin and gangway
(d) Pavement of open yards
(e) Purchase of additional cargo handling equipment
(f) Construction of grain cargo handling facilities

According to Costa Rican law, all of the fixed assets in ports on the ocean side of an imaginary line running 30 m behind the face line of quaywalls including channels, basins, breakwaters and the quays themselves are national property, not the property of the local port authority. Thus, based on this law items (a) through (c) above are national property. Nevertheless, herein these items are also considered as objects of the financial analysis in order to consider the relation between the revenues and the costs arising from the enlargement of the cargo handling capacity.

2. 2 Period of Financial Analysis

The financial analysis covers the 30 years from 1988 to 2017.

2. 3 Necessary Funds

The funds necessary to execute the construction works are to be raised as follows :

(a) Local currency portion : Self finance

(b) Foreign currency portion : Loans from a foreign country under the following conditions

1) Interest rate : 4.75% per annum

2) Repayment terms : 25 years (including a 7 year grace period)

3. Revenues

The revenues are calculated using the port tariff rates set by INCOP. The types of dues and charges are described in Table XII—1. As a result of the calculation, port tariff revenues arising from grain cargo in 1992 will total 51,306 thousand colones and those from other cargo will total 23,585 thousand colones.

The revenues in 1991 are estimated to equal one-half of the projected revenues in 1992 because the construction works to enlarge the cargo handling capacity will all be completed by the end of 1991, and many of these works will be completed earlier in 1991, effecfively expanding the cargo handling capacity during that year.

Table XII-1 Outline of Port Tariffs

Unit : Colones

Revenue Item	Unit Charge
(a) Pilotage, charges for usage of navigation aids, towing service and mooring or untying	21.00/Gross Registered Tonnage
(b) Charge for use of quaywall	290.00/meter length of ship/day
(c) Charge for cleaning wharves	7.00/MT of cargo
(d) Charge for use of wharves	
i) General cargo	472.40/MT of cargo
ii) Bulk cargo	107.40/MT of cargo
(e) Loading/unloading charges	(Colones/MT of cargo)
i) Importation	
○ Grain cargo	120.00
○ General cargo	150.00
○ Vehicles	150.00
○ Cargo larger than 6m^3	200.00
○ Cargo longer than 5m	150.00
ii) Exportation	(Colones/MT of cargo)
○ General cargo	100.00
○ Cargo brought alongside	50.00
(f) Port dues	(Colones/MT of cargo)
i) Importation	
○ Cargo to be divided (LCL cargo)	33.00
○ Containerized cargo	46.00
○ Bulk cargo	50.00
ii) Exportation	
○ Cargo to be divided (LCL cargo)	30.00
○ Containerized cargo	46.00

Note: Grain is currently being handled at Puntarenas Pier by INCOP personnel together with CNP personnel in charge of loading grain into boxcars with low rate payment of unloading charges to INCOP. After the grain cargo handling is transferred to Caldera, CNP will pay unloading charges of grain to INCOP based on the construction costs of the cargo handling facilities and the labour costs incurred by INCOP.

4. Costs

Total costs arising from 1990 to 2017 are listed in Table XII—2. The prerequisites of the calculation are as follows :

(1) The life of the cargo handling equipment except for maintenance tools is estimated as 10 years, and the life of the maintenance tools as 15 years.

(2) The lives of pneumatic unloaders, the bucket elevator and the movable belt conveyor are estimated as 20 years, and the life of the fixed belt conveyor is estimated as 30 years.

(3) Cost items listed under the column "Breakwater etc" in Table XII—2 are cost items (a) Shifting of the breakwater foot, (b) Construction of the −3.0 m quaywall and (c) Construction of the mooring dolphin and gangway.

(4) The maintenance costs for the breakwater, etc per annum are estimated as 1% of the construction costs, and the maintenance costs for the other cost items are estimated as 5% of the construction cost per year.

(5) Maintenance costs are not estimated for these years when equipment or facilities are renewed totally or partially.

(6) The salvage values in 2017 are considered.

(7) The cargo handling cost in 1991 includes training fees for INCOP personnel, but in the costs for renewal in 2001 and 2011 training fees are not included.

Table XII-2 Costs for the Study

Unit: '000 colones

Cost Item / Year	Breakwater Foot and Others		Pavement of the Yards		Cargo Handling Equipment		Grain Cargo Handling Equipment		Total
	Cost *)	Mt. Cost *)	Cost	Mt. Cost	Cost	Mt. Cost	Cost	Mt. Cost	
1990	141,771		92,181						233,952
1991		1,418		4,609	86,605		208,088		300,720
1992		↓		↓		3,647		10,404	20,078
1993		↓		↓		↓		↓	↓
1994		↓		↓		↓		↓	↓
1995		↓		↓		↓		↓	↓
1996		↓		↓		↓		↓	↓
1997		↓		↓		↓		↓	↓
1998		↓		↓		↓		↓	↓
1999		↓		↓		↓		↓	↓
2000		↓		↓		↓		↓	↓
2001		↓		↓	72,949			↓	89,380
2002		↓		↓		3,647		↓	20,078
2003		↓		↓		↓		↓	↓
2004		↓		↓		↓		↓	↓
2005		↓		↓		↓		↓	↓
2006		↓		↓	1,884	↓		↓	21,962
2007		↓		↓		↓		↓	20,078
2008		↓		↓		↓		↓	↓
2009		↓		↓		↓		↓	↓
2010		↓		↓		↓		↓	↓
2011		↓		↓	72,949		177,571	1,526	258,073
2012		↓		↓		3,647		10,404	20,078
2013		↓		↓		↓		↓	↓
2014		↓		↓		↓		↓	↓
2015		↓		↓		↓		↓	↓
2016		↓		↓		↓		↓	↓
2017		↓		↓	-22,262	↓	-118,473	↓	-120,657
Total	141,771	38,286	92,181	124,443	212,125	87,528	267,186	261,626	1,225,146

* "Cost" is the primary construction cost. "Mt. Cost" is the annual maintenance cost.

5. FIRR

The FIRR of the project is calculated as 8.26% as shown in Table Ⅻ—3. The desirable level of FIRR varies depending on the time and place, and the expectations of the lender and the borrower. For borrowers, the average interest rate paid on borrowed funds is the lower limit.

In this project, 76.3% of the overall construction cost is the foreign portion as shown in Table Ⅻ—4, and the foreign portion is assumed to be raised through loans with a 4.75% interest rate. Therefore, the FIRR is required to exceed 3.62%, which is the weighted average interest rate for all the project funds. Judging from this point of view, this project can be regarded as feasible, since the FIRR is 8.26%, well above the weighted average interest rate.

6. Sensitivity Analysis

6. 1 Assumption of Cases

Sensitivity analysis is made for three cases where (1) the port tariff revenues will decrease by 10%, (2) the construction costs will increase by 10%, and (3) the revenues will decrease by 10% and the costs will increase by 10% simultaneously. These different assumptions for the sensitivity tests are outlined as follows :

(a) Case FA : revenues decrease by 10%
(b) Case FB : costs increase by 10%
(c) Case FC : revenues decrease by 10% and costs increase by 10% at the same time.

6. 2 Results

The FIRR is calculated for each of the three simulation cases. The results are shown in Fig. Ⅻ—1. Every FIRR exceeds the lower limit of 3.62%. The results of the sensitivity analysis thus prove that each case would be feasible.

7. Conclusion

From the viewpoint of the financial analysis, that is the profitability of the project itself, this project can be regarded as feasible.

Table XII-3 FIRR Calculation

FIRR = 8.26%

Unit: '000 colones

Item / Year	Cost	Benefit	Benefit-Cost	Present Value in 1988		
				Cost	Benefit	Benefit-Cost
1988						
1989						
1990	233,952		−233,952	199,609		−199,609
1991	300,720	37,445	−263,275	236,996	29,510	−207,486
1992	20,078	74,891	54,813	14,616	54,517	39,901
1993				13,501	50,357	36,857
1994				12,470	46,514	34,044
1995				11,519	42,965	31,446
1996				10,640	39,686	29,047
1997				9,828	36,658	26,830
1998				9,078	33,860	24,783
1999				8,385	31,277	22,891
2000	↓		↓	7,745	28,890	21,145
2001	89,380		−14,489	31,848	26,685	−5,163
2002	20,078		54,813	6,608	24,649	18,041
2003				6,104	22,768	16,664
2004				5,638	21,031	15,392
2005	↓		↓	5,208	19,426	14,218
2006	21,962		52,929	5,262	17,943	12,681
2007	20,078		54,813	4,443	16,574	12,131
2008				4,104	15,309	11,205
2009				3,791	14,141	10,350
2010	↓		↓	3,502	13,062	9,560
2011	258,073		−183,182	41,577	12,065	−29,511
2012	20,078		54,813	2,988	11,145	8,157
2013				2,760	10,294	7,534
2014				2,549	9,509	6,959
2015				2,355	8,783	6,428
2016	↓		↓	2,175	8,113	5,938
2017	−120,657	↓	195,548	−12,073	7,494	19,567
Total	1,225,146	1,984,611	759,465	653,226	653,226	0

Table XII-4 Costs for Financial Analysis

Unit : '000 colones

	Foreign Portion	Local Portion	Total
Breakwater, etc.	98,441	43,330	141,771
Pavement of the yards	10,041	82,140	92,181
Cargo handling equipment	86,605	0	86,605
Grain cargo handling equipment	208,088	0	208,088
Total	(76.3%) 403,175	(23.7%) 125,470	(100.0%) 528,645

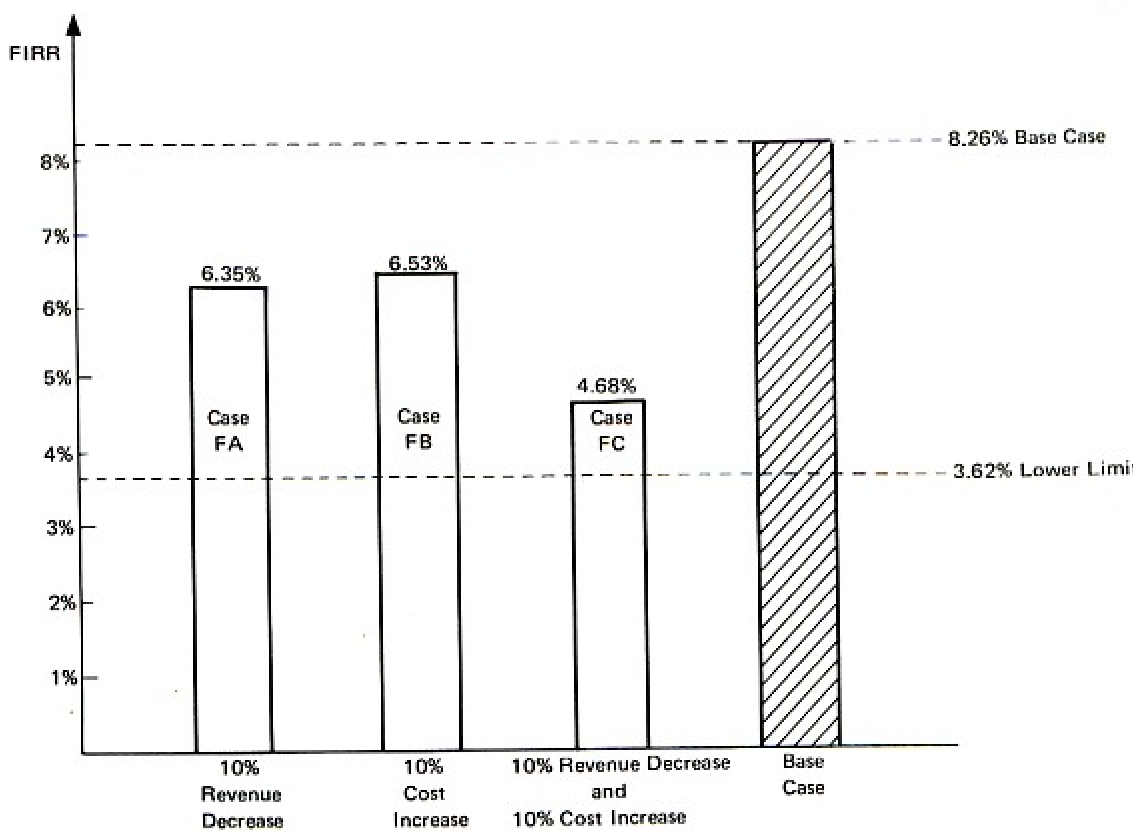


Fig. XII-1 Sensitivity Analysis

northward current reaches maximum velocity 1 hour after low water. The aberration in tide time between the observation points is extremely low, and the current becomes strong and weak in concert over the entire region.

The diurnal component is small in comparison with the semidiurnal component, hence even in summer and winter diurnal inequality is small and the fluctuation of the semidiurnal period is significant.

3. Tide Observation Results

An examination of the harmonic analysis using the observation records of the Port of Caldera is given in CHAPTER IV, 3.3.

4. Wave Observations Results

Significant wave frequency distribution and cumulative probability distribution using wave records of the Port of Caldera are given in CHAPTER IV, 3.1.

5. Results of Sediment Sampling and Analysis

The documents collected in Caldera were used to perform a grading analysis and to prepare a grain size accumulation curve at MOPT's soil test laboratory.

Table M−2 displays values found according to the grain size accumulation curve for sorting coefficient and the polarized distortion degree which become an index of the bottom materials grading characteristics.

Sorting coefficient $S_0 = d_{75}/d_{25}$

Polarized distortion degree $S_k = d_{75} \times d_{25}/(d_{50})^2$

Where, d_{50} : cumulative 50% corresponding grain size (median diameter)

d_{75} : cumulative 75% corresponding grain size

d_{25} : cumulative 25% corresponding grain size

According to the index of the bottom materials grading characteristics, the median grain diameter at the point S−4 in front of the quaywall is 0.14 mm, indicating a smaller value than at other locations. The sorting coefficient is 2.40 which means that the slope sorting of the bottom materials is poor.

At locations other than S−4, a distribution of median diameter between 0.24 mm ~ 0.34 mm is found, the mean of which is about 0.3 mm. The sorting coefficient is between 1.4 and 1.7, which indicates a normal slope sorting of bottom materials. Near the tip of the breakwater, grain size is slightly larger, and a trend towards favorable slope sorting of bottom materials may be observed. However, considering these bottom materials to be similar to those found at locations other than S−4 will not pose any problems.

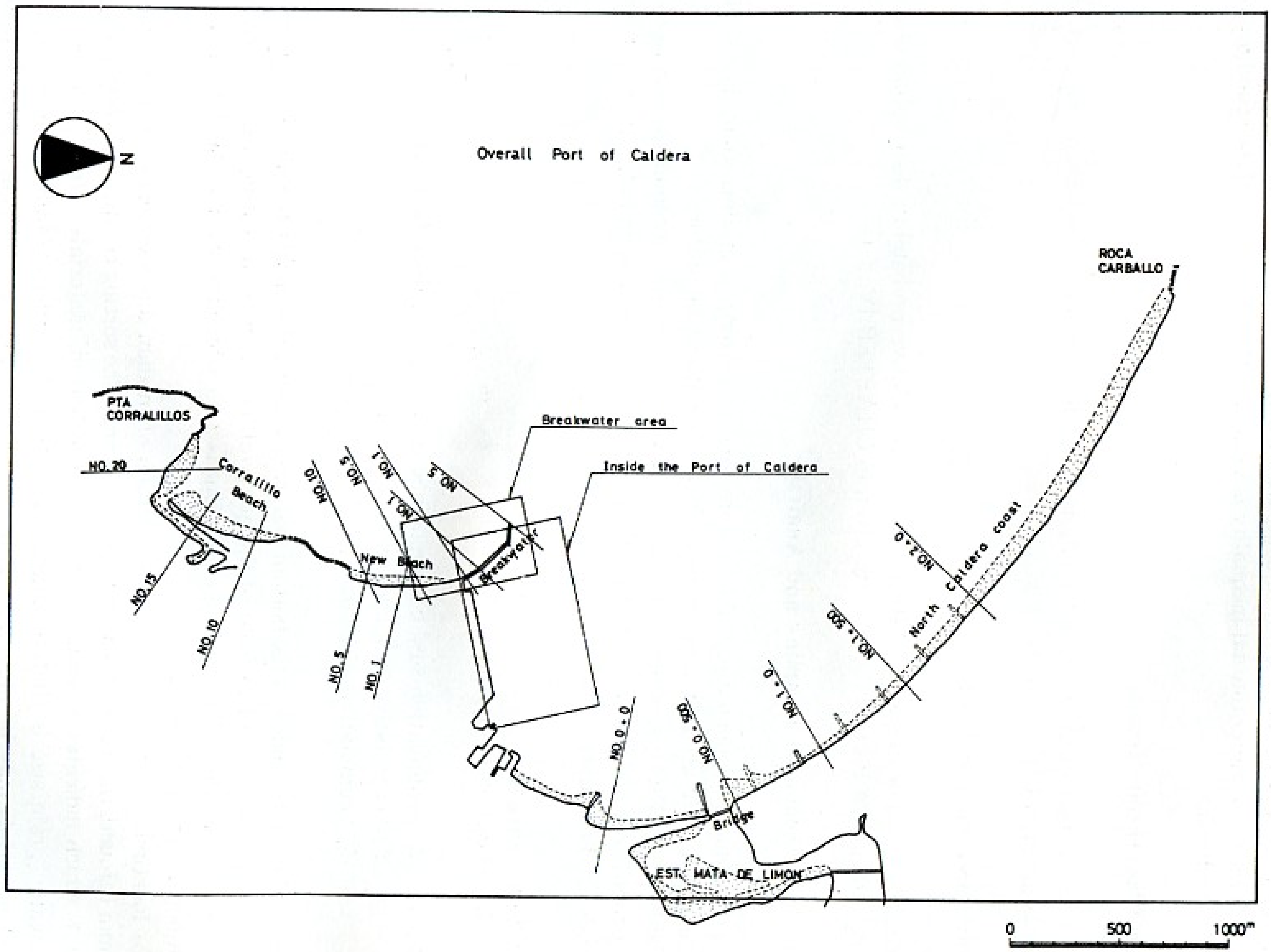


Fig. M-1 Location Map of Sounding and Topography Survey along the Shoreline

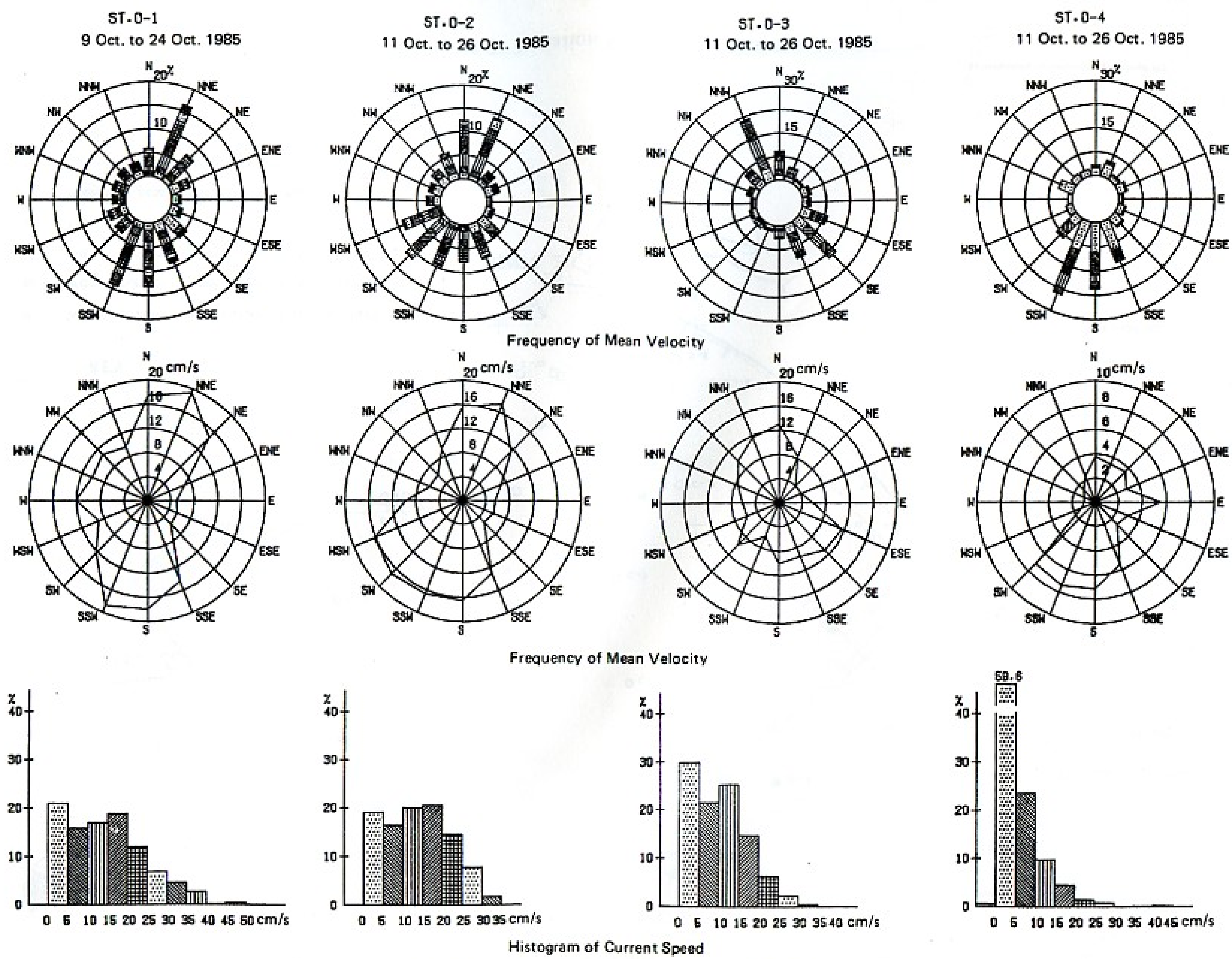
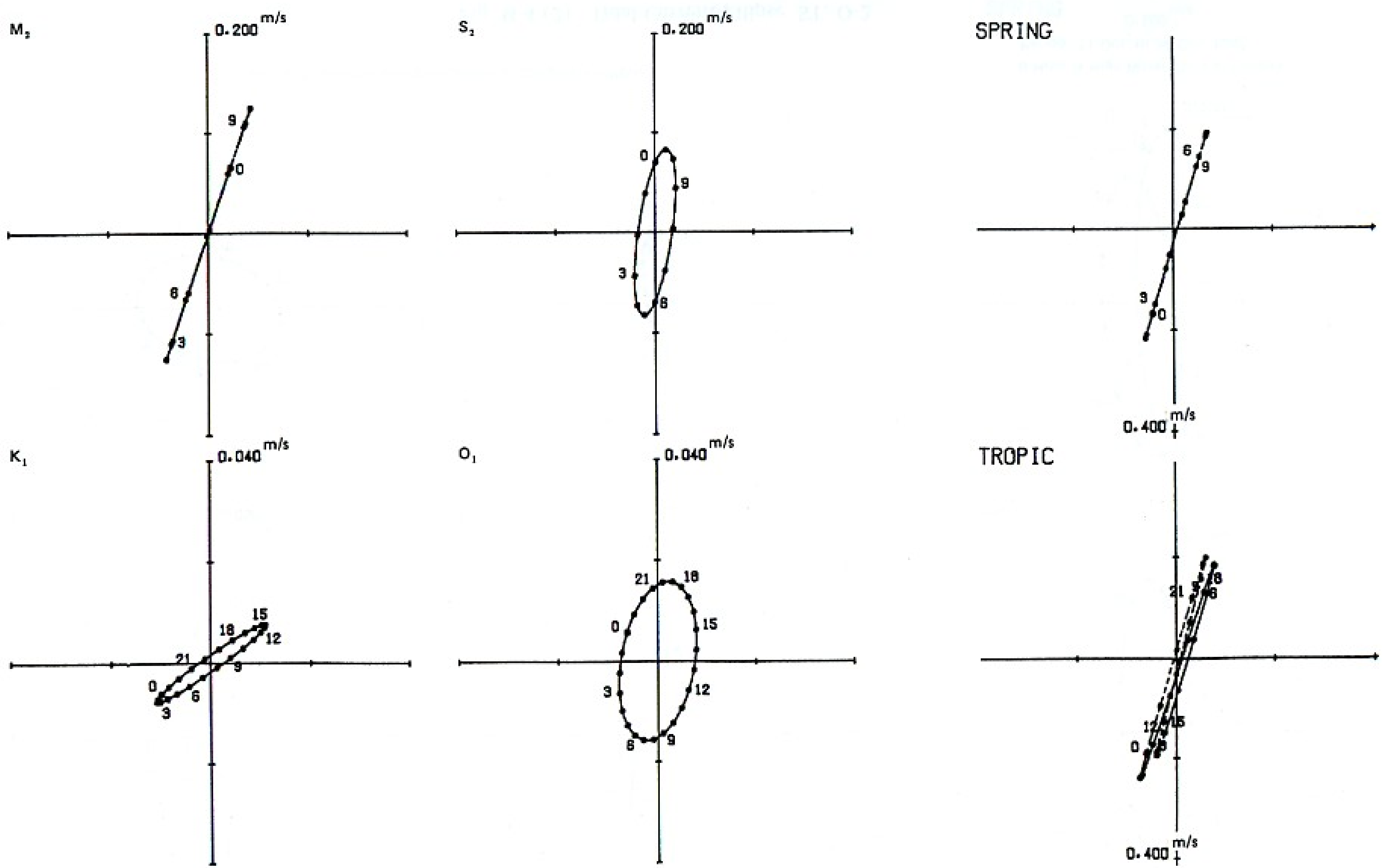


Fig. M-3 Frequency of Current Distribution



0 Hour is Transit Time of Component at Observation Point

0 Hour is High Water Time at Caldera
Period: 9 OCT. to 24 OCT. 1985

Fig. M-4 (1) Tidal Current Ellipse ST. O-1

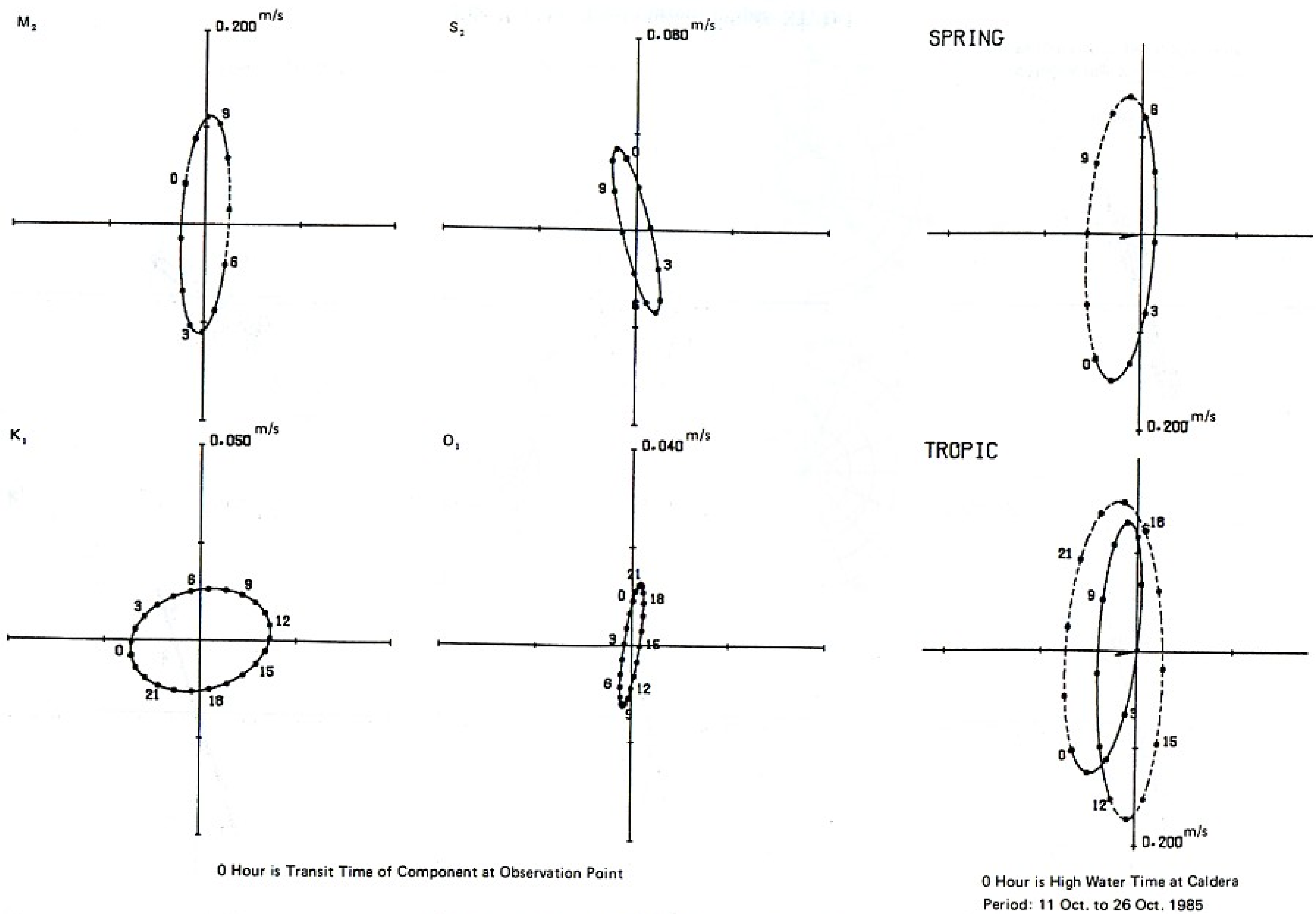
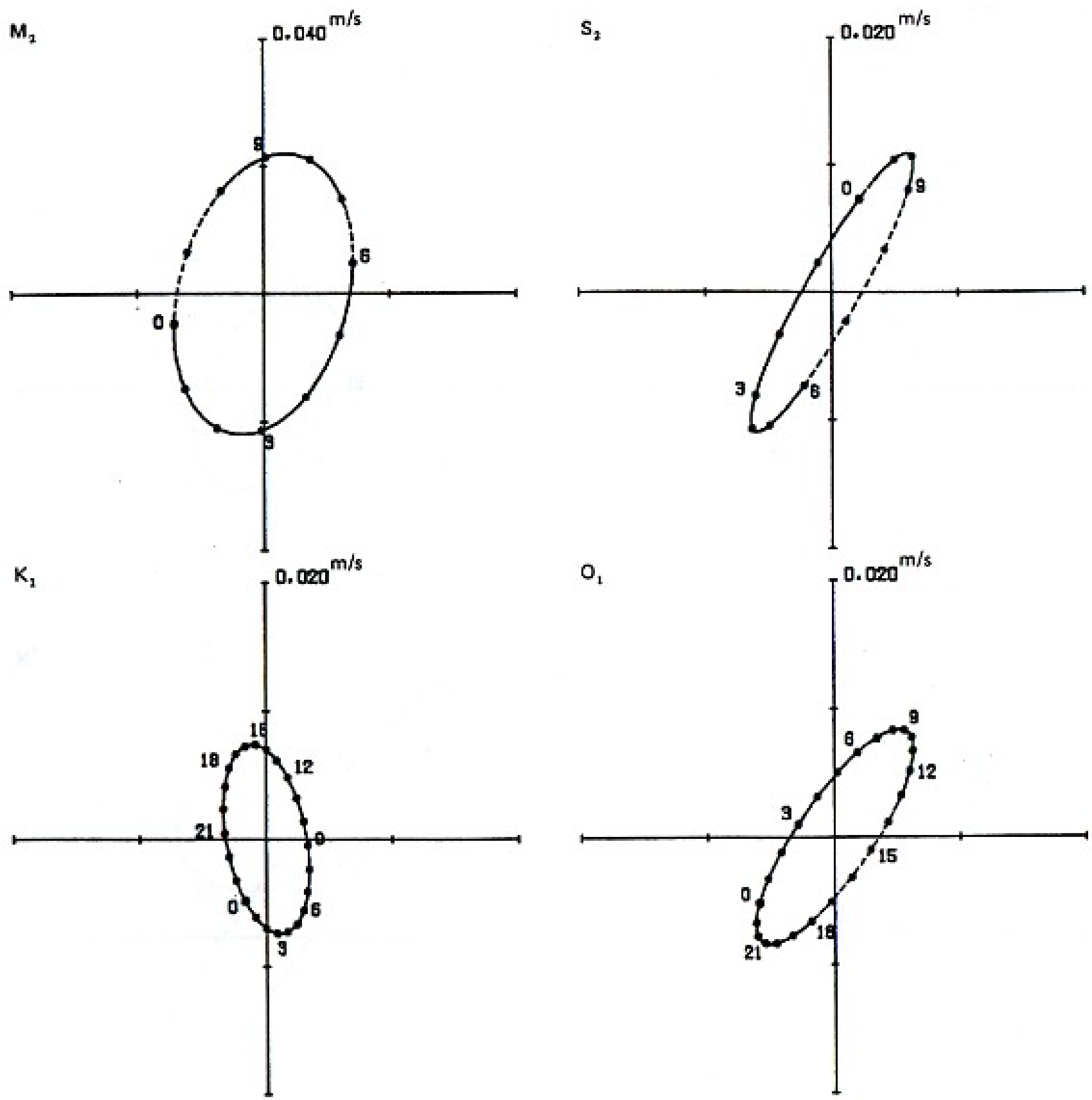
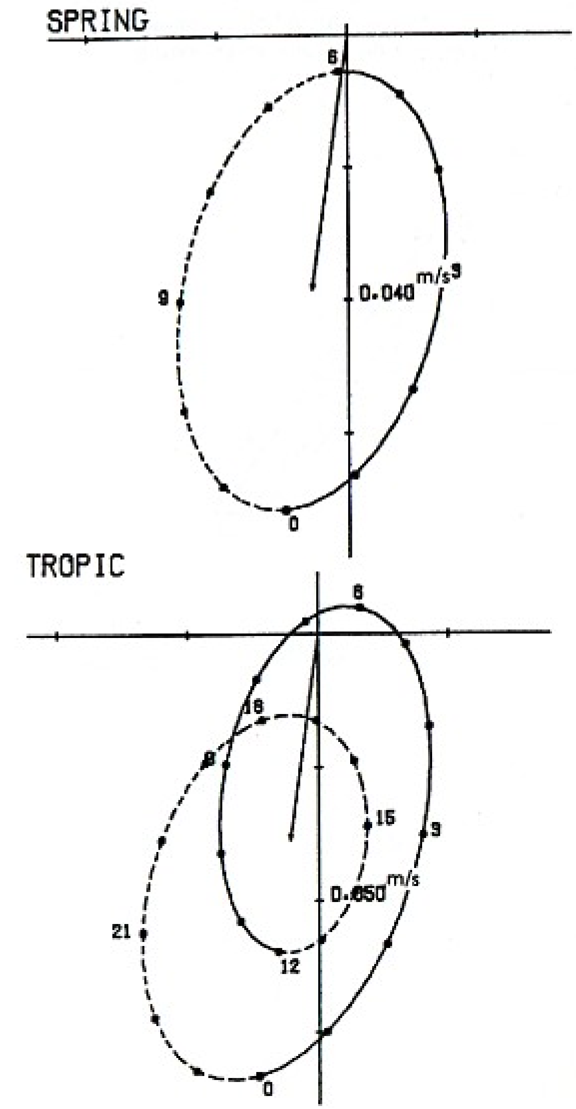


Fig. M-4 (2) Tidal Current Ellipse ST. O-2

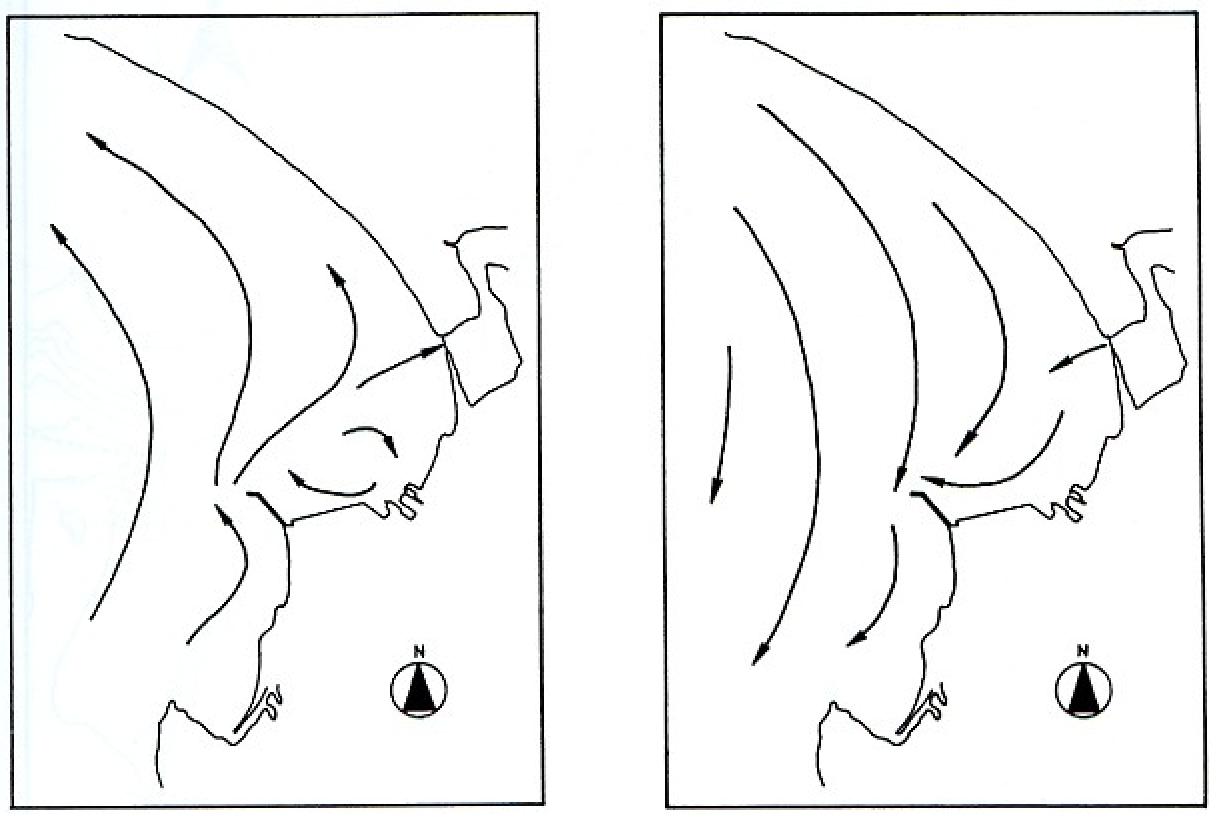


0 Hour is Transit Time of Component at Observation Point



0 Hour is High Water Time at Caldera
Period: 11 Oct. to 26 Oct. 1985

Fig. M-4 (4) Tidal Current Ellipse ST. O-4



Northward Current

Southward Current

Fig. M-5 Typical Tidal Current

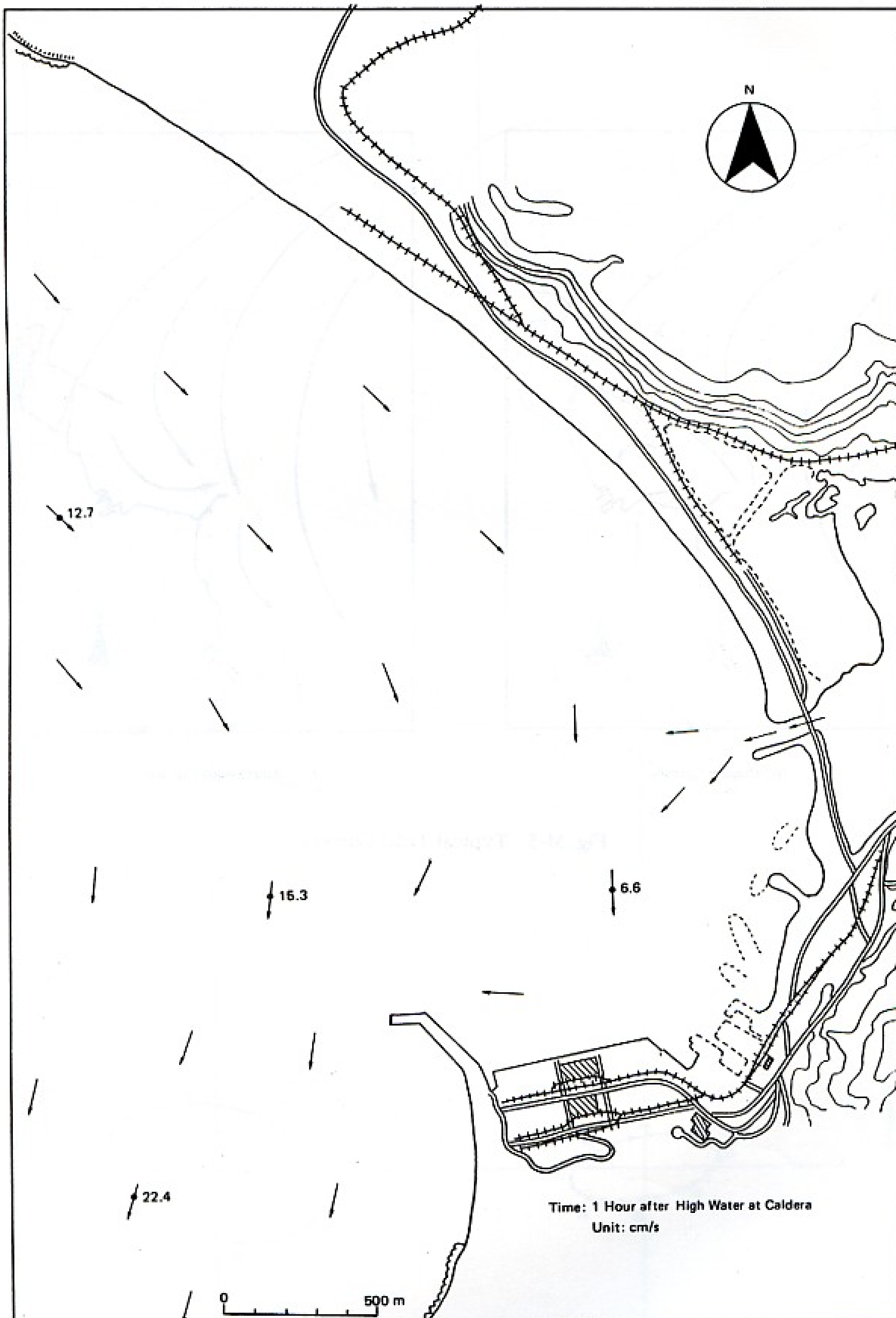


Fig. M-6 (1) Main Current Distribution at Spring Tide

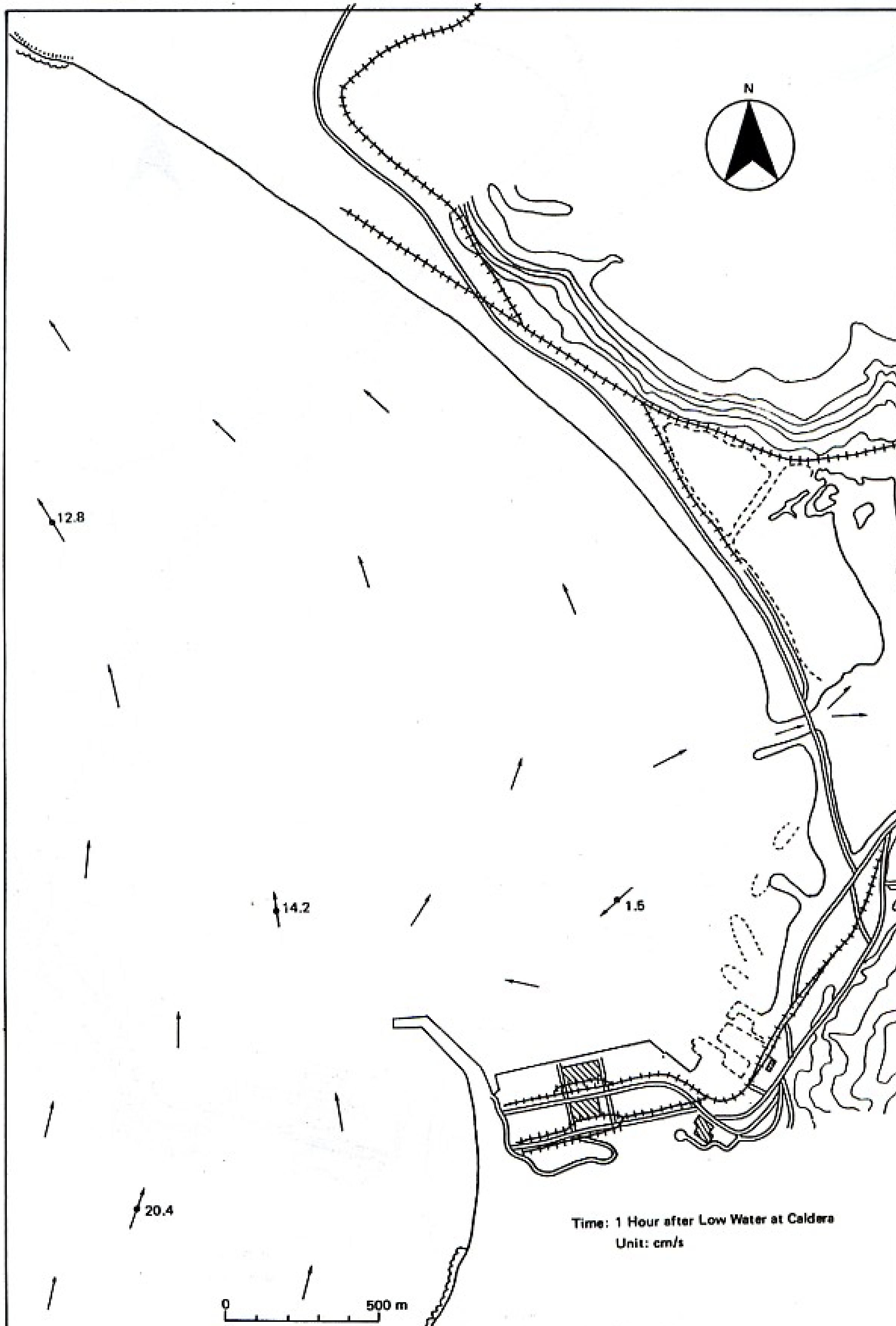


Fig. M-6 (2) Main Current Distribution at Spring Tide

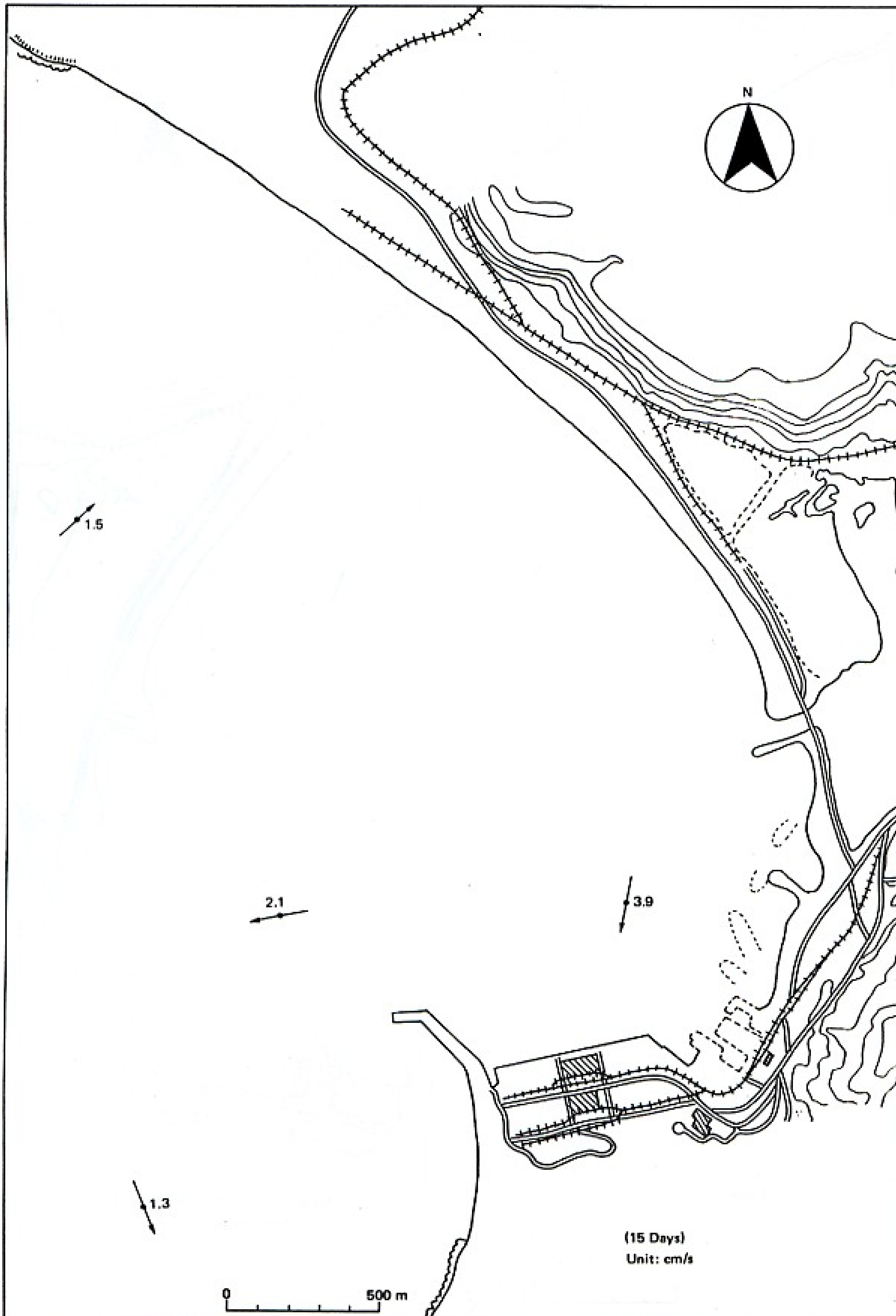


Fig. M-7 Permanent Current

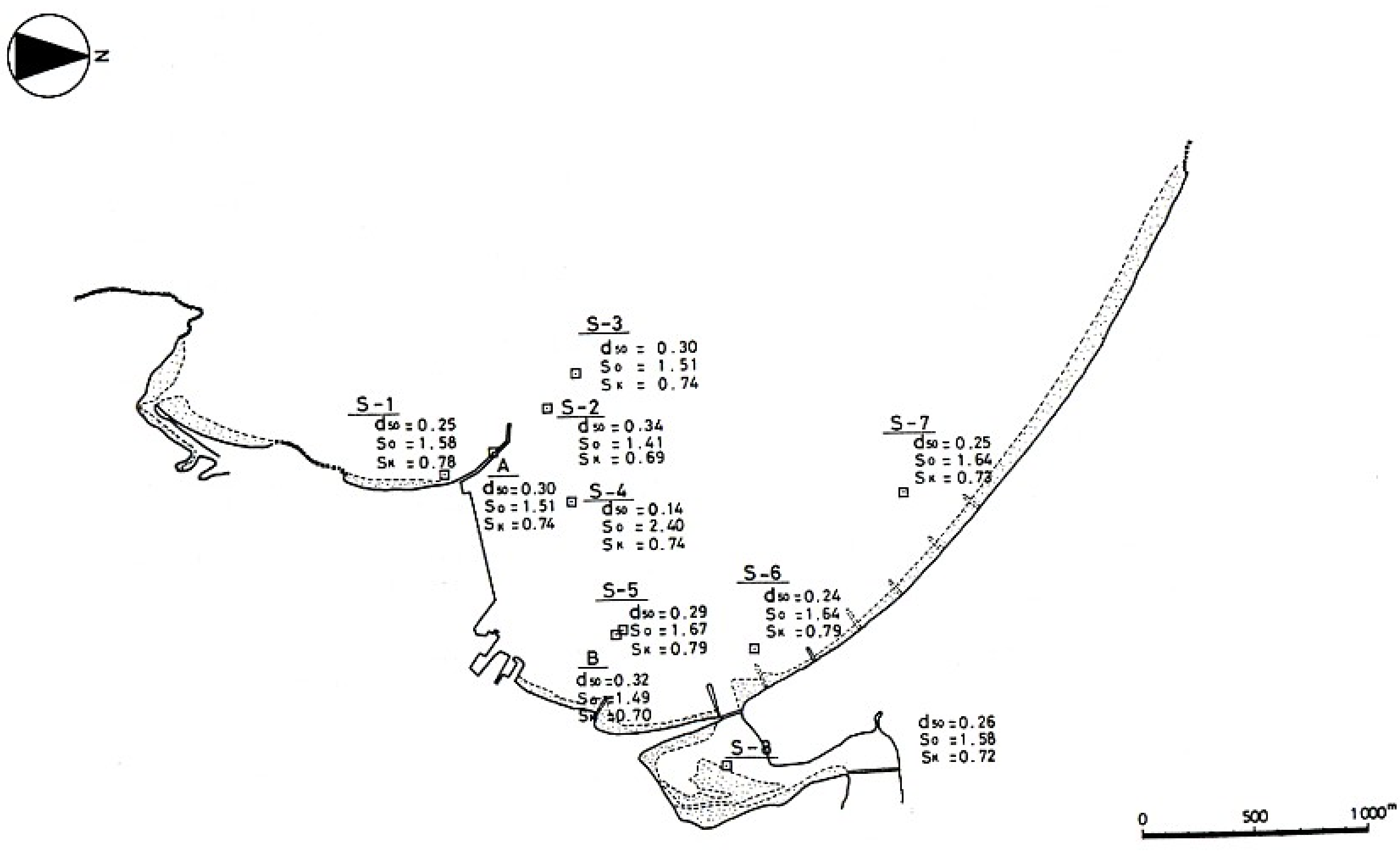


Fig. M-8 Bottom Materials Grading Characteristics

Table M-1 Maximum Current Velocity Values

Observation point	Main direction	Maximum observed velocity in main direction			Maximum observed velocity in anti-main direction		
		Time of appearance	Velocity	Direction	Time of appearance	Velocity	Direction
O—1	20°	16 Oct.22:20	0.56m/s	12°	14 Oct.5:20	0.45m/s	178°
O—2	15°	20 Oct. 2:20	0.33	22°	19 Oct.8:20	0.34	221°
O—3	340°	26 Oct. 9:00	0.38	350°	13 Oct. 4:00	0.34	114°
O—4	20°	16 Oct. 6:20	0.17	85°	15 Oct. 5:00	0.45	181°

Table M-2 Non-harmonic Constants

Observation point	M_2+S_2	K_1+O_1	$M_2+S_2+K_1+O_1$	$\frac{K_1+O_1}{M_2+S_2}$	$\frac{K_m}{29}$
Tide	1.295m	0.135 m	1.427m	0.10	2.8h
O—1	21.5m/s	12.6m/s	24.1m/s	0.12	10.4
O—2	14.3	17.0	17.0	0.19	10.0
O—3	13.2	16.4	16.4	0.24	10.6
O—4	3.4	5.1	5.1	0.50	8.5

APPENDIX 4 IMMEDIATE BREAKWATER EXTENSION WORKS

This information concerning the immediate extension works of the breakwater is prepared by the Japanese Study Team (JST) of JICA in compliance with the Minutes of Meeting between DGOPF/MOPT and JST dated November 18, 1985. The meeting was held in San José, Costa Rica.

1. Introduction

The littoral drift at the Port of Caldera which causes the forward movement of the shoreline of New Beach due to drift sand coming from the south is quite rapid. The depth at the head of the breakwater has become very shallow, about 3 m to 5 m ; consequently, the volume of drift sand going round the head of the breakwater is considerable.

Furthermore, the annual rate of littoral drift has been increasing. It is estimated that between August 1982 and August 1984 64,000 m^3 of sand entered the harbour from the south. However, from August 1984 to August 1985 an estimated 95,000 m^3 of sediment entered the harbour. Thus, the annual rate of littoral drift in 1984/85 was roughly 3 times the average annual rate over the preceeding two years.

Among the various countermeasures to prevent sedimentation in the harbour, extension of the breakwater is clearly the most important and should be completed as soon as possible. MOPT has been working at extending the breakwater for some time, but it is necessary to expedite the construction works to prevent further sedimentation of the harbour.

2. Center Line and Extension Length of the Breakwater

As of November 1985, the length of the wing jetty was 115 m. The wing jetty should be extended to 150 m, and the center line of the extension works should be in accordance with the center line of the existing wing jetty.

3. Improvement of the Construction Procedure

(1) Improvenment of the structural sections

When constructing a rubble mound breakwater on a sandy base, it is necessary to take sufficient countermeasures to prevent scours and sinkages at the base of the breakwater , particularly at the toe. The main countermeasures for the construction at Caldera are :

(a) Rubble stones shall be thrown in advance, and these rubble stones which will sink due to wave action will stabilize the base of the breakwater. The sinkage of the rubble stones shall be estimated as about 2 m. Furthhermore, the total volume of rubble stones necessary shall be calculated with an allowance of 20%.

(b) As armour stones rapidly sink if they are placed directly on the sand, the armour stones shall be carefully placed on the rubble foundation.

(c) The toe of the rubble shall be sufficiently long to prevent sinkage of armour stones which would otherwise be caused by scours of the toe of the rubble foundation. Accordingly, we propose that the extension be constructed as shown in Figure 1.

(2) Improvenment of construction schedule and construction management

In order to build the extension successfully, it is crucial to prepare a detailed construction schedule and to execute the construction works on schedule. Although the machinery at the site is limited, any delay in the placement of the stoned would cause a serious disruption of the project. The proposed construction schedule is presented as Table 1. The construction shall proceed as follows :

(a) First of all, the rubble mound shall be constructed in advance. This mound will soon be deformed by wave action.

(b) In accordance with the construction schedule, additional rubble stones shall then be placed, and the final rubble mound shall be formed (see Fig. 2).

(c) Thereafter, at intervals of about 5 m, the armour stones shall be set without delay (see Fig. 3).

(d) Construction steps 8 and 9 (in Fig. 3) shall be executed from the head of the breakwater as the final part of the 150 m wing jetty.

(e) Armour stones of 6~8 tons unit weight shall be temporarily placed at the head of the breakwater. A slope of one to one shall be used for the placement. The armour stones shall be directly placed on the rubble foundation.

(f) The construction volume at the breakwater head is also shown in Figs. 2 and 3.

(g) The production volume of the 6~8 ton armour stones is estimated as 50 m^3/day based upon the field survey.

(h) The two items noted below are the most important items in the construction schedule :

1) The 120 ton lifting capacity truck crane shall be operated on the breakwater for the placement of stones.

2) The 6~8 ton unit weigth armour stones shall be produced by Komatsu wheel loaders at an average volume of 50 m^3/day.

The production and construction works shall take place simultaneously. The production period is estimated as 105 days.

(i) Any reduction in the operation rates of the truck crane (P & H) or the wheel loader (Komatsu) would create a bottleneck in the construction. As construction delays must be avoided at all costs, it is essential to create a regular maintenance system for these machines and to ensure that sufficient spare parts are available on site.

(3) Improvement of the armour stone placement procedure

The stability of breakwater against wave action primarily depends on the accuracy of the armour stone placement.

Generally, the requisite weight of an armour stone is calculated using Hudson's formula.

$$W=\frac{\gamma_r H^3}{K_D(S_r-1)^3\ \cot\alpha}$$

Where, W : Requisite weight of an armour stone

r_r : Unit weigth of the armour stone in air

S_r : Specific gravity of the armour stone in sea water

α : Angle of the slope to the horizontal plane

H : Design wave height ($H_{1/3}$)

K_D : Constant determined by the armouring material and damage rate

The K_D value in Hudson's formula indicates the stability of each individual armour unit. This value changes greatly depending on the accuracy of the armour stone placement. When the accuracy is better, the K_D value is higher. The present procedure of the armour stone placement seems to have some problems.

The method described below should be followed.

(a) A placement table for the operator of the truck crane should be prepared for the accurate placement of the armour stone. This can be made as follows.

a) All locations of the armour stone to be placed will be decided by the planned breakwater plane and sectional figures.

b) These locations can be represented by the boom length and the lifting angle of the boom.

(b) The operator will place each armour stone setting the boom length and lifting angle at the same values indicated on the table in Fig. 4.

The accuracy of the armour stone placement will increase using this method.

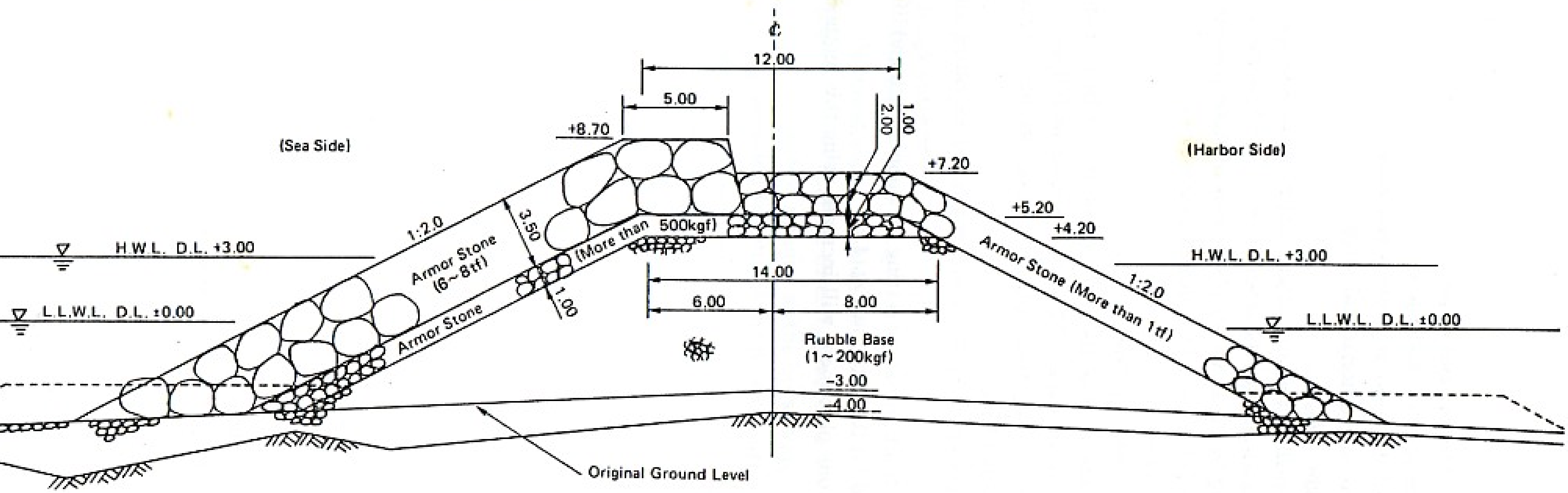
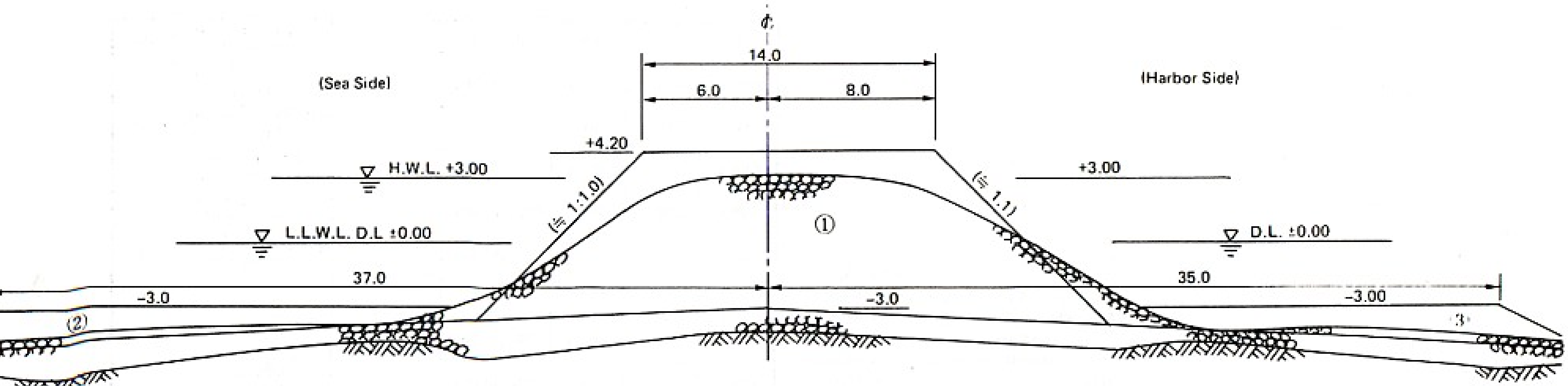


Fig. 1 Standard Cross Section of the Breakwater

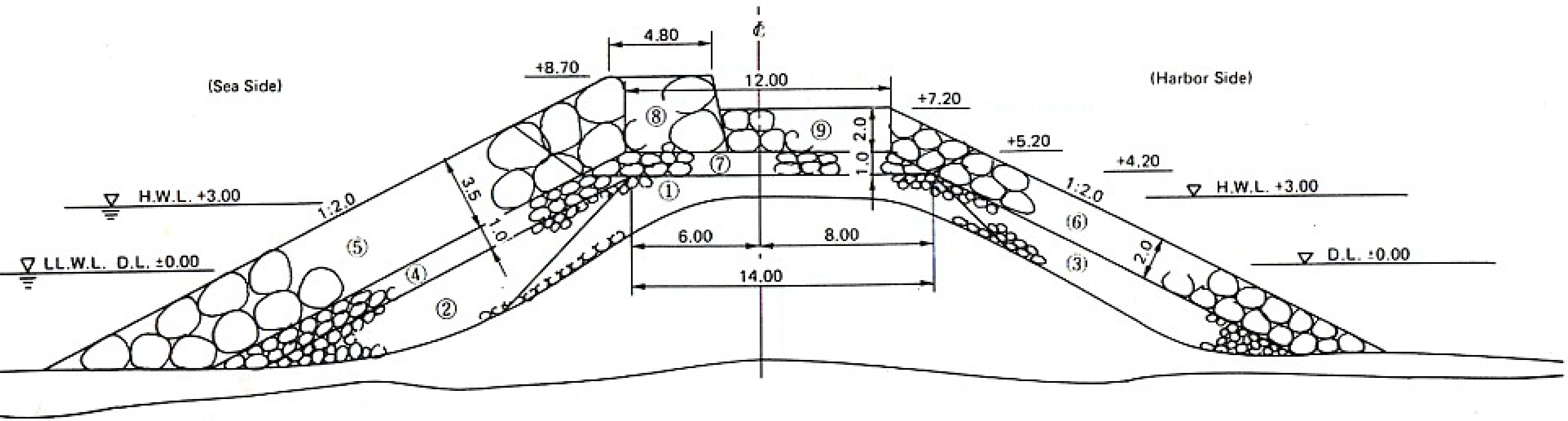


Construction Volume

Order	Material	Construction Machine	Capability	Construction Volume (m³)		
				Trunk	Head	Total
(1)	Rubble Stone (1 ~ 200 kgf)	Bulldozer (Komatsu)	500 m³/day	7,280	0	7,280
(2)	"	Truck Crane (120tf, P/H)	250 m³/day	840	4,520	6,445
(3)	"	"	"	1,085		

Note: (1) ~ (3) show the order of construction

Fig. 2 Preceding Rubble Foundation Subjected to Wave Erosion (Including the Estimated Deformation)



Construction Volume

Order	Material	Construction Machine	Capability	Construction Volume (m³)		
				Trunk	Head	Total
(1)	Rubble Stone (1 ~ 200 kgf)	Bulldozer (Komatsu)	400 m³/day	1,400	800	2,200
(2)	"	Trunk Crane (120tf, P/H)	250 m³/day	1,190	600	2,840
(3)	"	"	"	1,050		
(4)	Armor Stone (More than 500kgf)	"	160 m³/day	770	530	1,300
(5)	Armor Stone (6 ~ 8tf)	"	140 m³/day	2,240	1,200	3,440
(6)	Armor Stone (More than 1tf)	"	160 m³/day	1,540	0	1,540
(7)	Armor Stone (More than 500kgf)	"	"	490	340	830
(8)	Armor Stone (6 ~ 8tf)	"	140 m³/day	1,050	600	1,650
(9)	Armor Stone (More than 1tf)	"	160 m³/day	840	0	840

Notes:

Notes:

1) ① ~ ⑨ shows the order of construction
2) Items ⑧ and ⑨ are constructed from the top of the breakwater
3) Armor stones (6 ~ 8T) are temporarily installed at the head of the breakwater

Fig. 3 Construction Procedure of the Breakwater

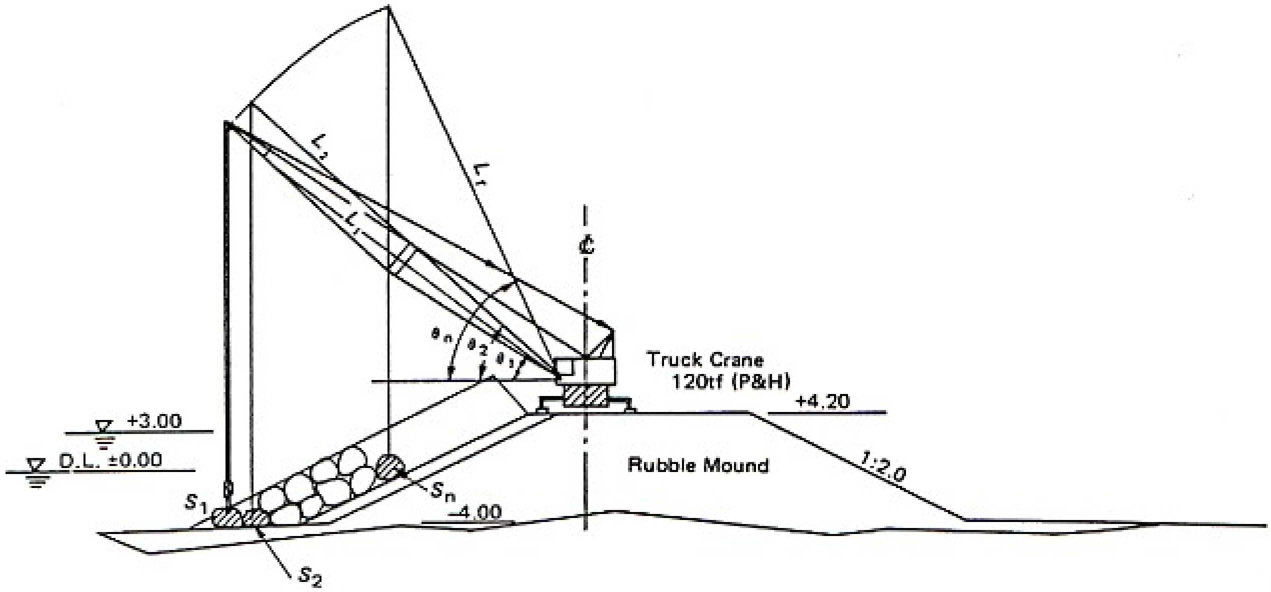


Table for Armor Stone Placement

Line	θ, L	S_1	S_2		S_n
1	θ	$\theta_{1.1}$	$\theta_{1.2}$		$\theta_{1.n}$
	L	$L_{1.1}$	$L_{1.2}$		$L_{2.2}$
2	θ	$\theta_{2.1}$	$\theta_{2.2}$		$\theta_{2.n}$
	L	$L_{2.1}$	$L_{2.2}$		$L_{2.n}$
⋮					
m	θ	$\theta_{m.1}$	$\theta_{m.2}$		$\theta_{m.n}$
	L	$L_{m.1}$	$L_{m.2}$		$L_{m.n}$

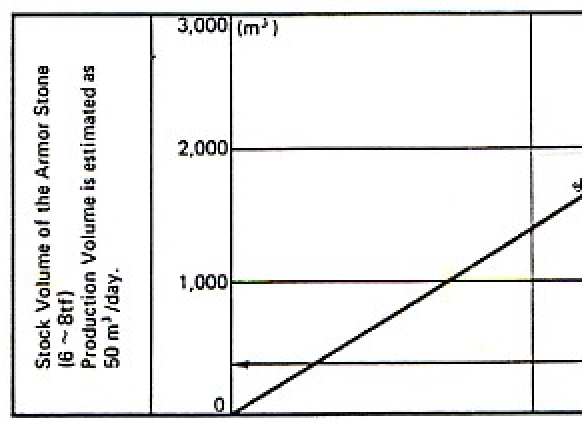
Fig. 4 Method of Armour Stone Placement

Table I Construction Schedule of the Exten

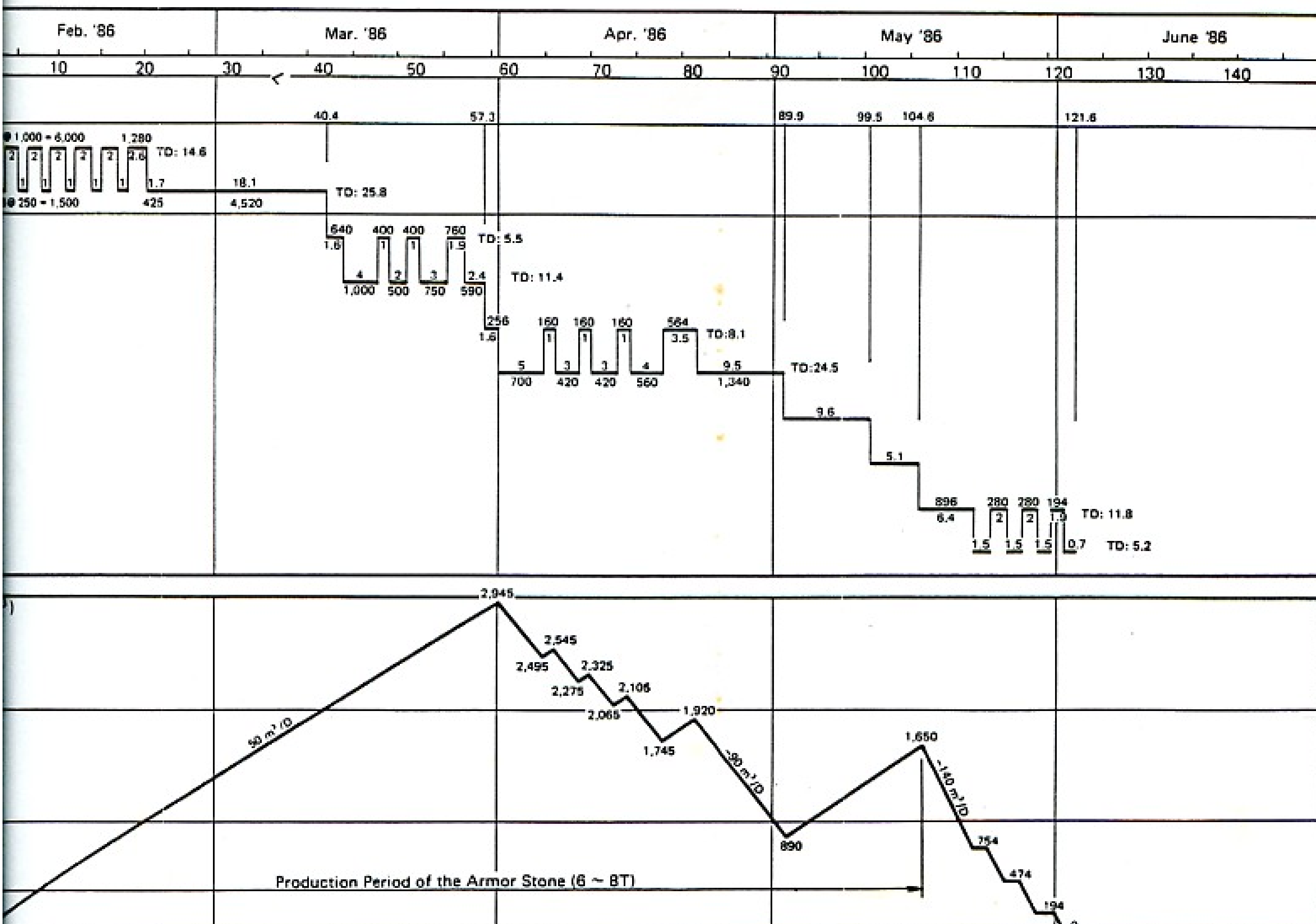
Cross Section	The Order of the Construction	Material	Construction Machine	Construction Volume (m³)	Capability (m³/day)	Date: Feb. '86 (0 10 20 30)
Preceding Rubble Foundation (Fig. 2)	①	Rubble Stone (1~200 kgf)	Bulldozer	7,280	500	6@1,000 = 6,000 1,280 TD: 14.6
	②, ③	"	Truck Crane	6,445	250	6@250 = 1,500 425 1.7 18.1 4,520
Completed Cross Section of the Breakwater (Fig. 3)	①	"	Bulldozer	2,200	400	
	②, ③	"	Truck Crane	2,840	250	
	④	Armor Stone (More than 500kgf)	"	1,300	160	
	⑤	Armor Stone (6 ~ 8tf)	"	3,440	140	
	⑥	Armor Stone (More than 1tf)	"	1,540	160	
	⑦	Armor Stone (More than 500kgf)	"	830	160	
	⑧	Armor Stone (6 ~ 8tf)	"	1,650	140	
	⑨	Armor Stone (More than 1tf)	"	840	160	

Notes:

1) T.D. shows the total days
2) m³/D shows the production volume per day
3) The capability of stone placement of each construction step is estimated based on the field survey of the Study Team



Construction Schedule of the Extended Breakwater (L = 35 m)



APPENDIX 5 DETAILS OF THE SIMULATION METHOD USING THE MATHEMATICAL MODEL "ONE-LINE THEORY"

1. General

1. 1 Outline of the Model

One-line theory is one of the methods used to estimate future shoreline changes caused by the littoral drift. The conception is shown in Fig. M-1.

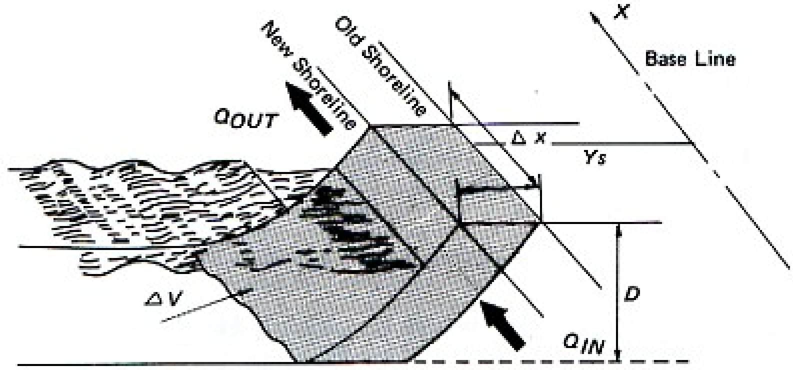


Fig. M-1 The Conception of the Shoreline Change

In this figure, the littoral drift sand volume at one end is Q_{IN}, and that at the other end is Q_{OUT}. The difference of the littoral drift sand volume ΔV equals $Q_{OUT}-Q_{IN}$. If Q_{OUT} is less than Q_{IN}, then the remaining drift sand is left in the divided mesh, and therefore, the shoreline advances. On the other hand, when Q_{OUT} is more than Q_{IN}, then ΔV becomes negative, and therefore, the shoreline recedes. The shoreline change Δy can be calculated using the following relation.

$$\Delta V = D \cdot \Delta x \cdot \Delta y \qquad \cdots\cdots (1)$$

D is the depth of the sand drift zone.

This numerical model consists of two parts. The first is for the calculation of the wave deformation, and the second is for the calculation of the local littoral drift sand volume changes and the consequent shoreline changes.

1. 2 Calculation of Wave Deformation

(1) Deep water region

Wave deformation in the large area is calculated using the energy equilibrium equation as follows.

$$\frac{\partial D}{\partial t}+\nabla\ (D\vec{V})-Q=0 \quad \cdots\cdots(2)$$

in which,

$$\nabla=\left\{\frac{\partial}{\partial x},\ \frac{\partial}{\partial y},\ \frac{\partial}{\partial f},\ \frac{\partial}{\partial \theta}\right\} \quad \cdots\cdots(3)$$

$$\vec{V}=\left\{\begin{matrix} V_x \\ V_y \\ V_f \\ V_\theta \end{matrix}\right\}=\left\{\begin{matrix} C_g\ \cos\ \theta \\ C_g\ \sin\ \theta \\ \frac{\partial f}{\partial t} \\ \frac{C_g}{C}\ (\frac{\partial C}{\partial x}\ \sin\ \theta+\frac{\partial C}{\partial y}\ \cos\ \theta) \end{matrix}\right\} \quad \cdots\cdots(4)$$

C_g : Wave group velocity $\left\{=\frac{C}{2}\ (+\frac{2\ kh}{\sinh\ 2\ kh})\right\}$ ⋯⋯(5)

C : Celerity

k : Wave number

h : Water depth

Q : The net rate of energy added

The equations presented above are solved using the finite difference method under the conditions below.

(a) Deep water is assumed to be in a steady state

(b) The period of component waves does not change

(c) Q is assumed to be zero

(2) Shallow water region

The wave refraction, diffraction and shoaling are calculated independently and superposed as in Eq. (6). The wave refraction factor (K_r) is obtained solving Eq. (7)～Eg. (10).

$$H=K_r\cdot K_d\cdot K_s\cdot H_0 \quad \cdots\cdots(6)$$

$$\frac{D^2\beta}{Dt^2}+p\cdot\frac{D\beta}{Dt}+q\cdot\beta=0 \quad \cdots\cdots(7)$$

$$p=-2\ (\frac{\partial C}{\partial x}\ \cos\alpha+\frac{\partial C}{\partial y}\ \sin\alpha) \quad \cdots\cdots(8)$$

$$q=C\ (\frac{\partial^2 C}{\partial x^2}\ \sin^2\ \alpha-2\frac{\partial^2 C}{\partial x\cdot\partial y}\ \sin\alpha\ \cos\alpha+\frac{\partial^2 C}{\partial y^2}\ \cos^2\ \alpha) \quad \cdots\cdots(9)$$

$$K_r\ =\ (\beta)^{-1/2} \quad \cdots\cdots(10)$$

And the wave direction is obtained from Eq. (11),

$$\frac{D\alpha}{Dt} = \sin\alpha\frac{\partial C}{\partial x} - \cos\alpha\frac{\partial C}{\partial y} \quad \cdots\cdots (11)$$

Where C represents the wave velocity, t is time, α is the angle from the X-axis and H_0 is the wave height in deep water.

The diffraction factor (K_d) is obtained by Mitsui's method which uses the first term of the asympototic expansion of the Sommerfeld resolution of the Helmholtz equation. The shoaling factor (K_s) is obtained by Eq. (12) and Eq. (13),

$$K_s = \sqrt{\frac{C_0}{2\,nC}} \quad \cdots\cdots (12)$$

$$n = \frac{1}{2}\ \{1 + \frac{4\,\pi\ h/L}{\sinh\ (4\,\pi\ h/L)}\} \quad \cdots\cdots (13)$$

Where C represents the wave velocity, h is the water depth, L is the wave length, and C_0 is the wave velocity in deep water.

The initial line of breaking is determined by Eq. (14), which was proposed by Goda,

$$\frac{H_b}{L_0} = A\ \{1 - \exp\ [-1.5\frac{\pi h_b}{L_0}\ (1 + 15\ \tan^{4/3}\theta)]\} \quad \cdots\cdots (14)$$

Where H_b is the breaking wave height, L_0 is the wave length in deep water, h_b is the breaking water depth, $\tan\theta$ is a gradient of the seabed, and A is a constant (0.12~0.18).

The breaking energy flux is calculated by Eg. (15). Energy fluxes of diffracted waves coming from differernt directions are added as vectors.

$$F_b = \frac{1}{8}\rho g H_b^2\ C_g \quad \cdots\cdots (15)$$

Where ρ is the density of sea water, g is the acceleration due to gravity, and C_g is the group velocity of the waves.

1. 3 Calculation of Shoreline Changes

Two equations are necessary to calculate the shoreline change. One is Eq. (16) which is for the continuity of sand transport in the alongshore direction,

$$\frac{\partial y}{\partial t} + \frac{1}{h}\cdot\frac{\partial Q_1}{\partial x} = 0 \quad \cdots\cdots (16)$$

Where h is the vertical range of the profile change, y is the shoreline location, and Q_1 is the volume of littoral sand drift.

The other is Eq. (17) which is for alongshore sediment transport,

$$Q_1 = \frac{\xi}{r_s}\ (EC_g)\ b\ (\sin\ 2\,\alpha_b - 3.24\frac{\partial H_b}{\partial x}\cot\beta\ \cos\alpha_b) \quad \cdots\cdots (17)$$

Where $(EC_g)\cdot b$ is the breaking wave energy flux, ξ is a constant and α_b is the angle the wave crest makes with the shoreline when breaking. r_s is the density of beach material in place, and β is the slope of the beach.

2. Calculation Conditions

2. 1 Wave Conditions

Based on the observed wave date described in CHAPTER IV, the wave period is calculated by Eq. (18).

$$T_n = \sum_{i=1}^{N} T_i / N \quad \cdots\cdots (18)$$

Where T_n is the representative wave period for the calculation, T_i is the wave period of each observation, and N is the total number of observation data.

The representative wave height (H_n) is calculated using Eq. (19), so that $H_n{}^2 \times C_{gn}$ equals the total amount of the wave energy fluxes.

$$\left(\sum_{i=1}^{N} H_i^2 \; C_{gi}\right) / N = H_n^2 \; C_{gn} \quad \cdots\cdots (19)$$

Where H_i is the height of each observation, C_{gi} is the group velocity of each wave, and C_{gn} is the group velocity corresponding to the representative wave period T_n. The calculation results of the representative wave conditions are as follows :

$H_n = 1.0$ m
$T_n = 12.0$ s
Wave Direction N 210° (S 30°W)
S_{max} (directional spreading parameter) = 75

2. 2 Tidal Condition

The tidal condition for the calculation is as follows :

M.S.L. = D.L. + 1.40 m

2. 3 The Grain Size for the Calculation

A median diameter of 0.3 mm is used for the calculation.

2. 4 The Depth of the Sand Drift Zone

The depth of the sand drift zone is decided from the wave up-rush height and the critical water depth for sediment movement. The result is as follows :

Wave Up-rush Height	3.2 m (above D.L. + 1.40 m)
Critical Water Depth for Sediment Movement	5.4 m (below D.L. + 1.40 m)
Depth of Sand Drift Zone, (*D*)	8.6 m

There is some modification of the above D value in the process of the calculation.

2. 5 Alternative Breakwater Extension Lengths

The length of the alternative breakwater extension plans are shown in Fig. M—2.

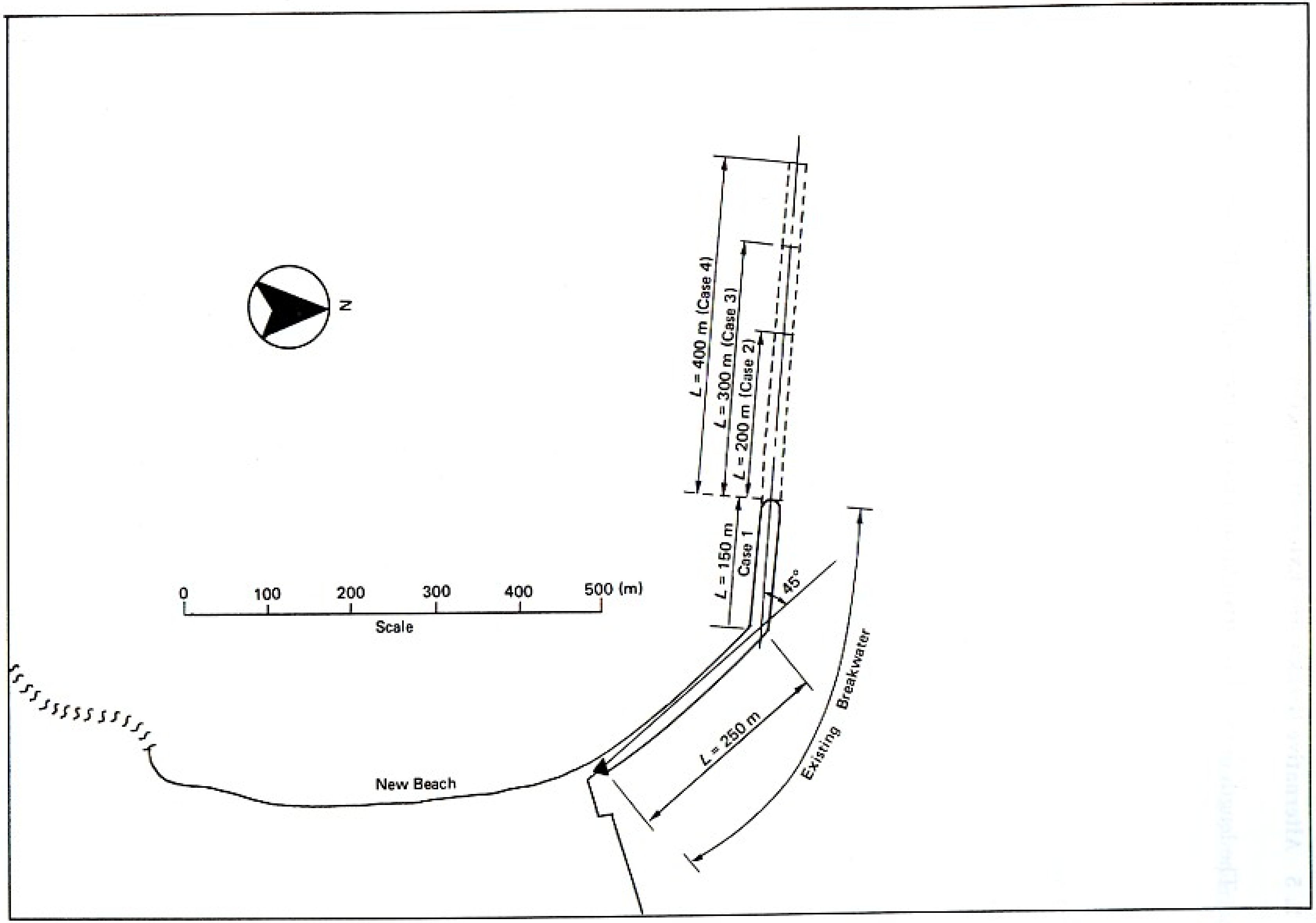


Fig. M-2 Alternative Designs of the Breakwater Extension

APPENDIX 6 DETAILS OF THE SIMULATION METHOD USING THE MATHEMATICAL MODEL: "DEPTH MODEL"

The depth model consits of 4 calculation programs. They are :

(1) Tidal Current Simulation Program
(2) Longshore Current Simulation Program
(3) Wave Deformation Calculation Program
(4) Sand Transport Simulation Program

The flow chart of these programs is shown in Fig. M—1.

1. Current Simulation Model

The governing equations consist of the continuity equation and the equations of motions as shown below.

$$\frac{\partial \zeta}{\partial t}+\frac{\partial}{\partial x}\left[(\zeta+h)\ u\right]+\frac{\partial}{\partial y}\left[(\zeta+h)\ v\right] \quad \cdots(1)$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-fv-g\frac{\partial \zeta}{\partial x}+A_x\frac{\partial^2 u}{\partial x^2}+A_y\frac{\partial^2 u}{\partial y^2}-r_b{}^2\frac{u(u^2+v^2)^{1/2}}{(\zeta+h)} \quad \cdots(2)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-fu-g\frac{\partial \zeta}{\partial y}+A_x\frac{\partial^2 v}{\partial x^2}+A_y\frac{\partial^2 v}{\partial y^2}-r_b{}^2\frac{v(u^2+v^2)^{1/2}}{(\zeta+h)} \quad \cdots(3)$$

where u, v: component of the mean horizontal velocity in the x, y direction, respectively
ζ: free surface displacement
h: water depth
t: time
f: coriolis parameter
g: gravitational acceleration
γ_b^2: bottom friction coefficient
A_x, A_y: lateral mixing coefficient

2. Longshore Current Simulation Model

In the model, mostly wave induced currents are considered. The following equations including radiation stress terms due to waves are used to calculate the current distribution.

$$\frac{\partial \zeta}{\partial t}+\frac{\partial}{\partial x}\{u\ (\zeta+h)\}+\frac{\partial}{\partial y}\{v\ (\zeta+h)\} \quad \cdots(4)$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+g\frac{\partial \zeta}{\partial x}+\frac{F_x}{(\zeta+h)}-A_l\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)+R_x=0 \quad \cdots(5)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+g\frac{\partial \zeta}{\partial y}+\frac{F_y}{(\zeta+h)}-A_l\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+R_y=0 \quad \cdots(6)$$

where u, v: component of the mean horizontal velocity in the x, y direction, respectively

ζ: mean free surface displacement

F_x, F_y: bottom friction terms in the x, y direction, respectively

A_l: lateral mixing coefficient

R_x, R_y: radiation stress terms in the x, y direction, respectively

3. Sand Transport Simulation Model

In this study, Bijker's Formula is used to estimate the sand sedimentation in the harbour basin. The influence of currents and waves is considered through the introduction of an increased bed shear and a subsequently higher diffusion coefficient. The sedimentation process and the estimation method are outlined as follows.

The vertical distribution of the suspended sediment is described by the following basic equation.

$$WC + \varepsilon \frac{dC}{dz} = 0 \quad \cdots\cdots (7)$$

where W: fall velocity of the sediment in still water

C: concentration at height z above the bed

ε: diffusion coefficient for the suspended material at height z

The sedimentation process is shown in Fig. M—2. The total suspended load at section ① is expressed by :

$$S_{s1} = C_1 \cdot V_1 \cdot h_1 \quad \cdots\cdots (8)$$

Immediately after the change of depth from h_1 to h_2, that is in section ②, the value of $\bar{C}$ will remain constant. However, the vertical gradient of the sediment concentration will decrease by a factor h_1/h_2 and sedimentation $S_v(0)$ will occur due to the velocity decrease. At the voluntary section x, the sediment $S_v(x)$ will be found under the condition of $\bar{C}_2(x)$ and this situation will continue to section ③. If the channel width is large enough, the concentration will be settled and no sediment will occur in section ④.

In practice, the sedimentation in the channel is limited to $S_v = \int_0^B S_v(x)$.

Since the actual sedimentation, or vertical transport is determined by the condition just above the bed, the sedimentation is expressed by :

$$S_v = WC_{b2} + \varepsilon (dc/dz)_b \quad \cdots\cdots (9)$$

in which the subscript b indicates the situation at the bed.

Where, $\varepsilon = 0.18\ V_*\ h$

$$C = C_b \exp(-wz/\varepsilon) \quad \cdots\cdots (10)$$

$$\bar{C} = (C_b \cdot \varepsilon/wh)\ [1-\exp(-wh/\varepsilon)] \quad \cdots\cdots (11)$$

The wave and current effects are taken into account through an increased bed shear.

$$V_{*cw} = V_{*c} \left[1 + 1/2 \ (\xi u/\bar{V})^2\right] \quad \cdots\cdots (12)$$

in which V_{*cw} and V_{*c} are the bed shear velocities due to wave and current.

$$\xi = C \ (f_w/29)^{1/2} \quad \cdots\cdots (13)$$

Where, f_w : friction coefficient by Jonsson

u : amplitude of the horizontal orbital velocity at the bed

From equation (9)

$$S_v(0) = WC_{b2} \ (1 + \frac{h_1 \varepsilon_2}{h_2 \varepsilon_1}) \quad \cdots\cdots (14)$$

The vertical transport S_v is expressed in m^2/s per unit of bed surface.

If we assume that $S_s(x)$ decreases exponentially with x,

$$S_s(x) = f \ (\exp \ (-\beta x)) \quad \cdots\cdots (15)$$

With the boundary conditions shown in Fig. M—2, equation (9) can be written as :

$$S_v(x) = \beta(\beta s_1 - \beta s_2) \exp \ (-\beta x) \quad \cdots\cdots (16)$$

These equations make it possible to compute in a quick and simple manner the sedimentation in the channels.

4. Divided Area in Caldera Bay

The trend of the water depth change from August 1982 to September 1985 is calculated based on the sounding results of Caldera Bay. The calculation area is divided into 9 as shown in Fig. M—3.

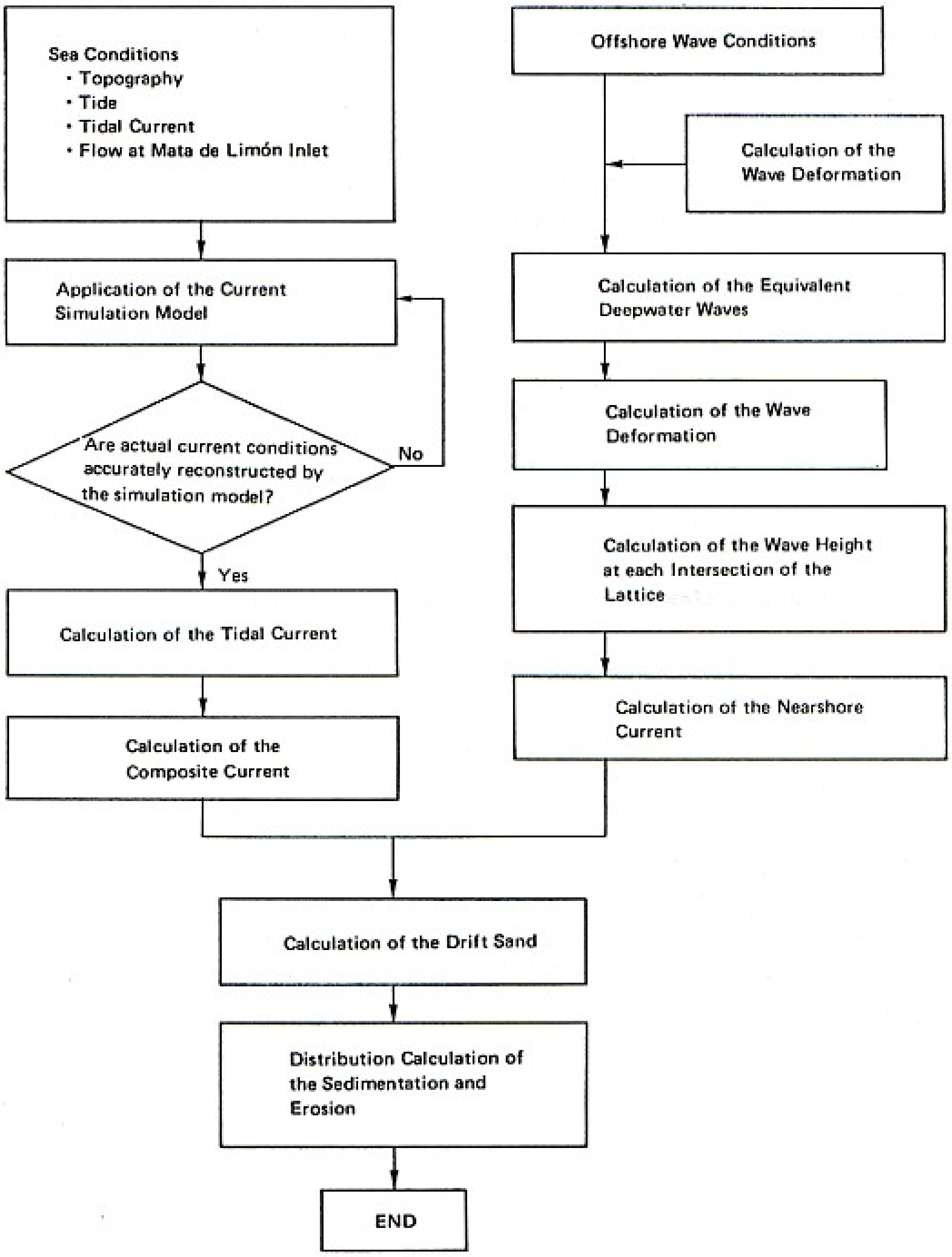


Fig. M-1 Calculation Procedure of the Depth Change Using the Simulation Model

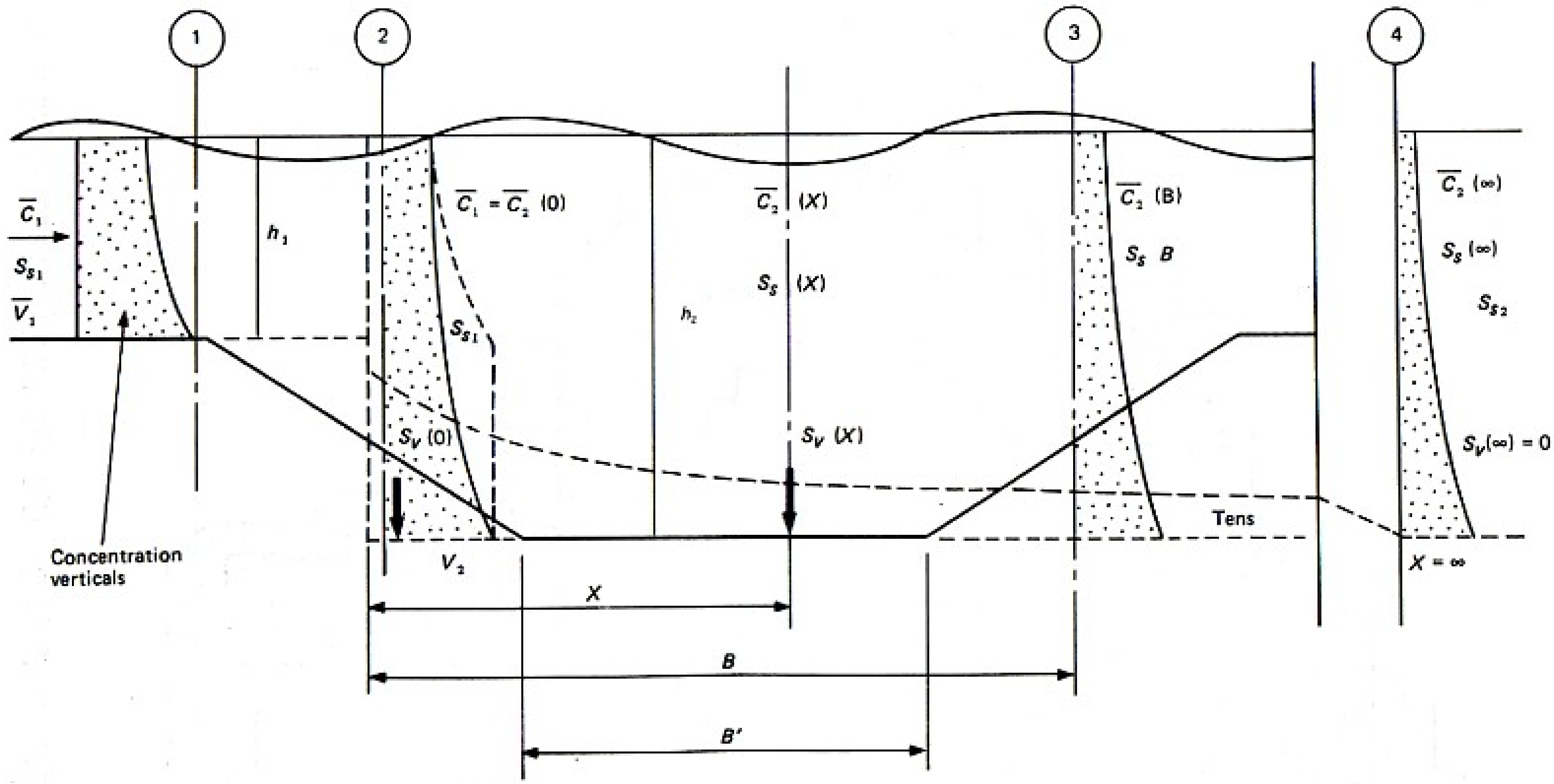


Fig. M-2 Mechanism of Sedimentation

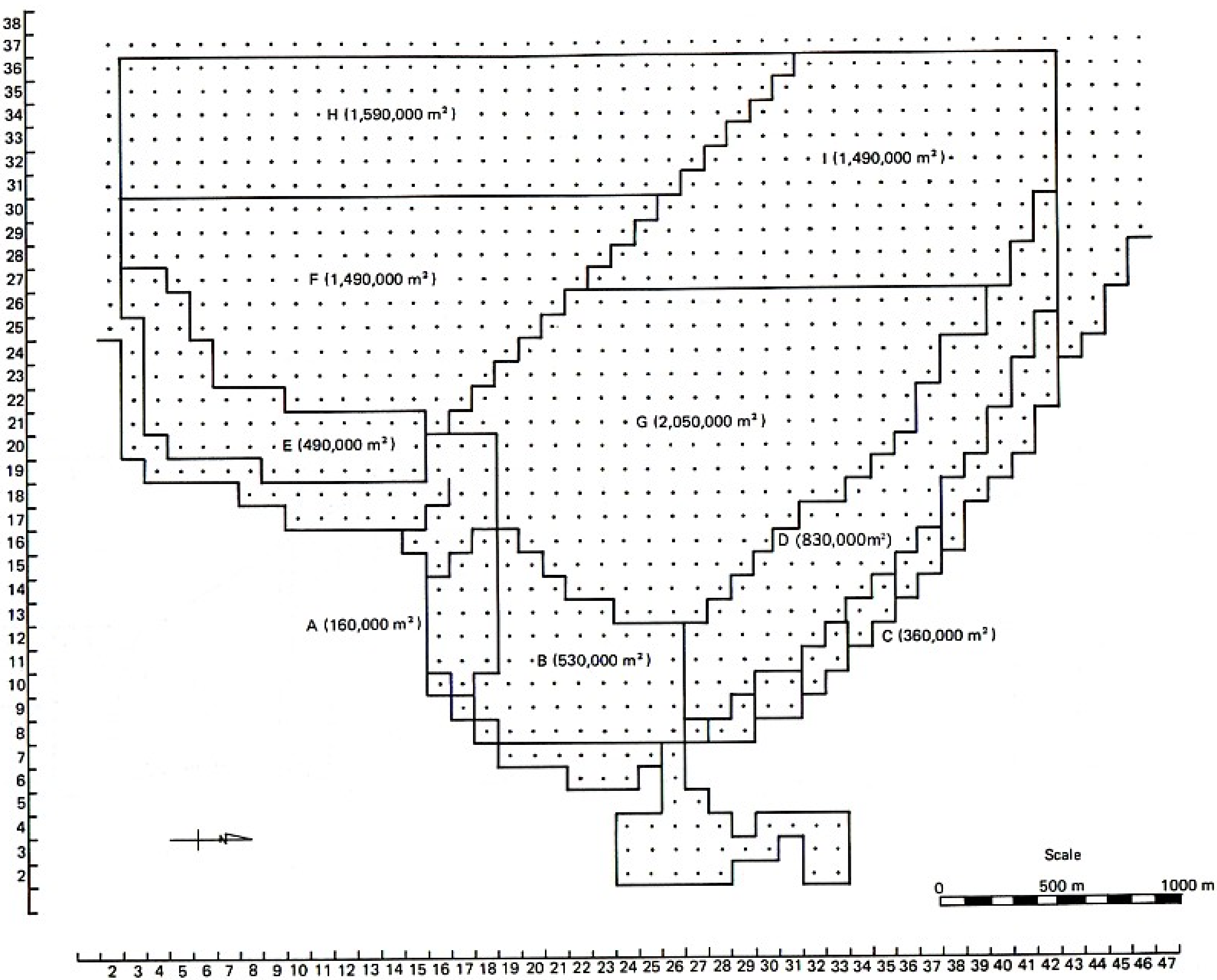


Fig. M-3 Divided 9 Areas in Caldera Bay

APPENDIX 7 PROJECTED SOCIOECONOMIC FRAME

The major projected national socioeconomic indices, that is population and GDP, are listed in Table M−1 and M−2, respectively.

Table M-1 Projected Population

Year	Population (persons)	Compound increase rate (%)
1982	2,371,519	2.78
1983	2,434,601	2.66
1984	2,498,145	2.61
1985	2,569,597	2.58
1986	2,628,199	2.56
1987	2,694,693	2.53
1988	2,761,790	2.49
1989	2,828,902	2.43
1990	2,895,381	2.35
1991	2,961,685	2.29
1992	3,027,731	2.23
1993	3,093,735	2.18
1994	3,159,323	2.12
1995	3,224,405	2.06
1996	3,289,215	2.01
1997	3,353,355	1.95
1998	3,417,404	1.91
1999	3,481,309	1.87
2000	3,545,017	1.83

Table M-2 Projected GDP

Year	GDP at 1966 constant prices (Unit : million colones)
1983	8,947.7
1984	9,513.0
1985	9,426.2
1986	9,540.9
1987	9,750.8
1988	10,014.1
1989	10,274.4
1990	10,521.0
1991	10,784.0
1992	11,053.6
1993	11,330.0
1994	11,613.2
1995	11,903.5
1996	12,201.1
1997	12,506.2
1998	12,818.8
1999	13,139.3
2000	13,467.8

APPENDIX 8 CALMNESS IN THE HARBOUR FOR THE BREAKWATER EXTENSION ALTERNATIVES

We calculated the calmness in the harbour area of the Port of Caldera for each of the following alternatives for the breakwater extension and the existing state of the breakwater. Each calculation case is shown in Fig. M−1.

a) Case 1 : Existing state (length of the breakwater from its turn point : 150 m)
b) Case 2 : Breakwater extension length : 200 m, Direction of extension : the same direction as the end part of the existing breakwater
c) Case 3 : Breakwater extension length : 300 m, Direction of extension : the same direction as the end part of the existing breakwater
d) Case 4 : Breakwater extension length : 400 m, Direction of extension : the same direction as the end part of the existing breakwater
e) Case 5 : Breakwater extension length : 200 m, Direction of extension : parallel to the trunk part of the existing breakwater
f) Case 6 : Breakwater extension length : 400 m, Direction of extension : parallel to the trunk part of the existing breakwater

1. Diffraction Calculation

As a diffraction calculation method, we adopted Takayama's Method [1] which considers the wave reflection of irregular waves. For the spectum of irregular waves, $S(f, \theta)$, are used in the following formulae. These are Bretschneider-Mitsuyasu's Formula for the frequency spectrum, $S(f)$, and Mitsuyasu's Formula for the directional spreading function, $G(f, \theta)$.

$$S(f,\ \theta)=S(f)G(f,\ \theta)$$

$$S(f)=0.257\ (\frac{H_{1/3}}{T_{1/3}})^2\ f^{-5}\ \exp[-1.03(T_{1/3}f)^{-4}]$$

$$G(f,\ \theta)=\frac{1}{\pi}\ 2^{2s-1}\ \frac{\Gamma^2(S+1)}{\Gamma(2S+1)}\cos^{2s}\frac{\theta}{2}$$

$$S=\begin{cases} S_{max}\ (f/f_p)^{-2.5} & (f>f_p) \\ S_{max}\ (f/f_p)^{5} & (f\leqq f_p) \end{cases}$$

$$f_p=\frac{1}{1.05\ T_{1/3}}$$

Where, f : frequency
θ : angle of deviation from the principal direcion of the wave
$H_{1/3}$: significant wave height

---

1) Tomotsuka Takayama ; Wave Diffraction and Wave Height Distribution inside a Harbour, Technical Note of The Port and Harbour Research Institute (Ministry of Transport), No. 367, Mar. 1981, 1～140 p.

$T_{1/3}$: significant wave period

f_p : peak frequency of the frequency spectrum

S : parameter showing the degree of directional concentration of the wave

S_{max} : S at the peak frequency, f_p

The wave conditions to be used in the diffraction calculation are as follows.

a) Direction of wave incidence : The following values are used with reference to the refraction charts shown in the APPENDIX 1.

N 229° for the existing state

N 225° for the breakwater extension alternatives

b) Significant wave period : 12 s and 18 s are used for the significant wave periods. The former value is the median of the distribuion of the significant wave period observation values which are shown in Table IV–4 (CHAPTER IV), and the other is nearly the maximum value of this distribution.

c) Degree of directional concentration : The major part of the incident waves to the Port of Galdera region are long period swells which are propagated over long distances, therefore S_{max} =75 was adopted.

d) Wave reflection coefficient : A wave reflelection coefficient of 90% is used for the vertical walls, 40% for the rubble mound slopes, and 10% for the sand beaches. The wave reflelection coefficient used for each waterline in the Port of Galdera area is shown in Fig. M–1.

The diffraction charts which were calculated using the above-mentioned method are shown in Fig. M–2(1) to Fig. M–2(12).

2. Calmness in the Harbour Area

For the following six points which are shown in Fig. M–1. we calculated the calmness, using the results of the above mentioned diffraction calculation and the occurrence probability of significant wave heights and the periods of the incident waves which are shown in Table IV–4 (CHAPTER IV).

① : Front of the roll–on/roll–off pier

② : Center of the −7.5 m berth

③ : Center of the −10 m berth

④ : Center of the −11 m berth

⑤ : Front of the small craft basin

⑥ : Point 100 m inside from the center of the extended breakwater

Points ② to ④ are selected to estimate the workable days for the cargo handling works at each berth, point ⑤ is for the mooring works of the small crafts in the basin, point ① is for the loading works of rubble stones and armour materials, and point ⑥ is for the maintenance dredging.

The cumulative occurrence probabilities of significant wave heights at each point which were calculated for each breakwater extension alternative and the existing state are shown in Table M−1(1) to (6) and Fig. M−3(1) to (6)

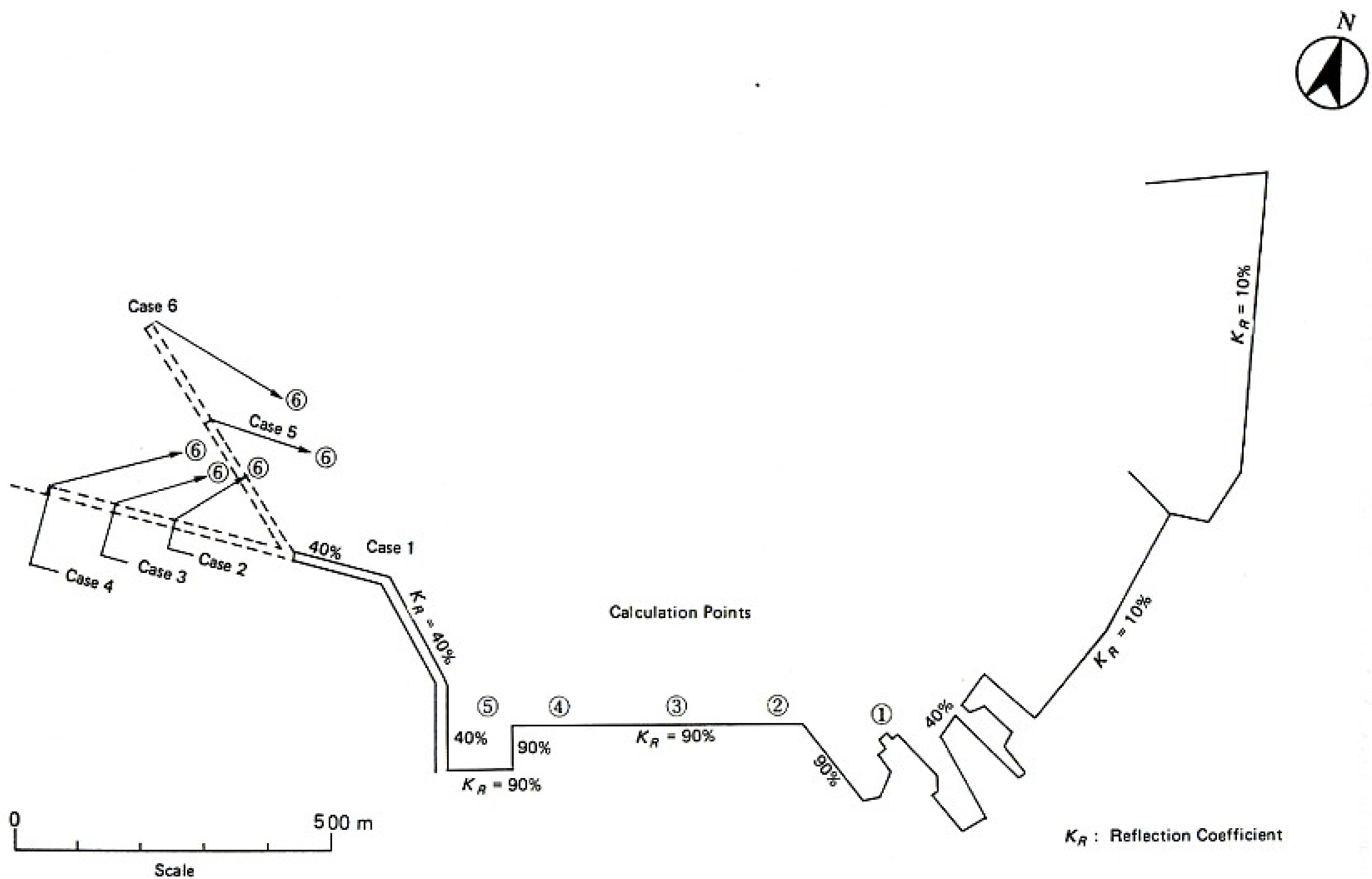


Fig. M-1 Breakwater Extension Alternatives and the Calculation Points for Calmness

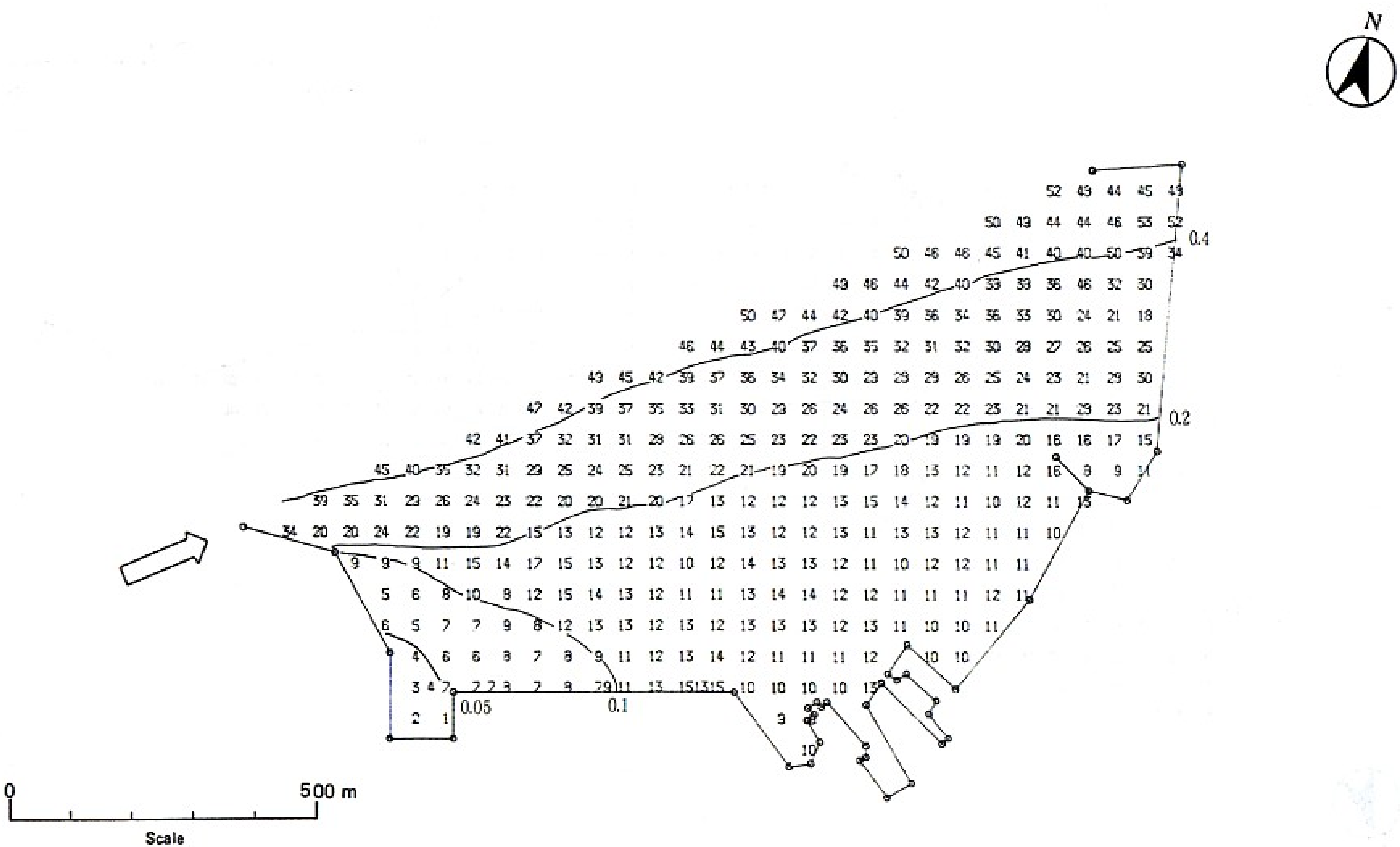


Fig. M-2 (1) Diffraction Chart (Case 1, $T_{1/3} = 12s$), Unit: %

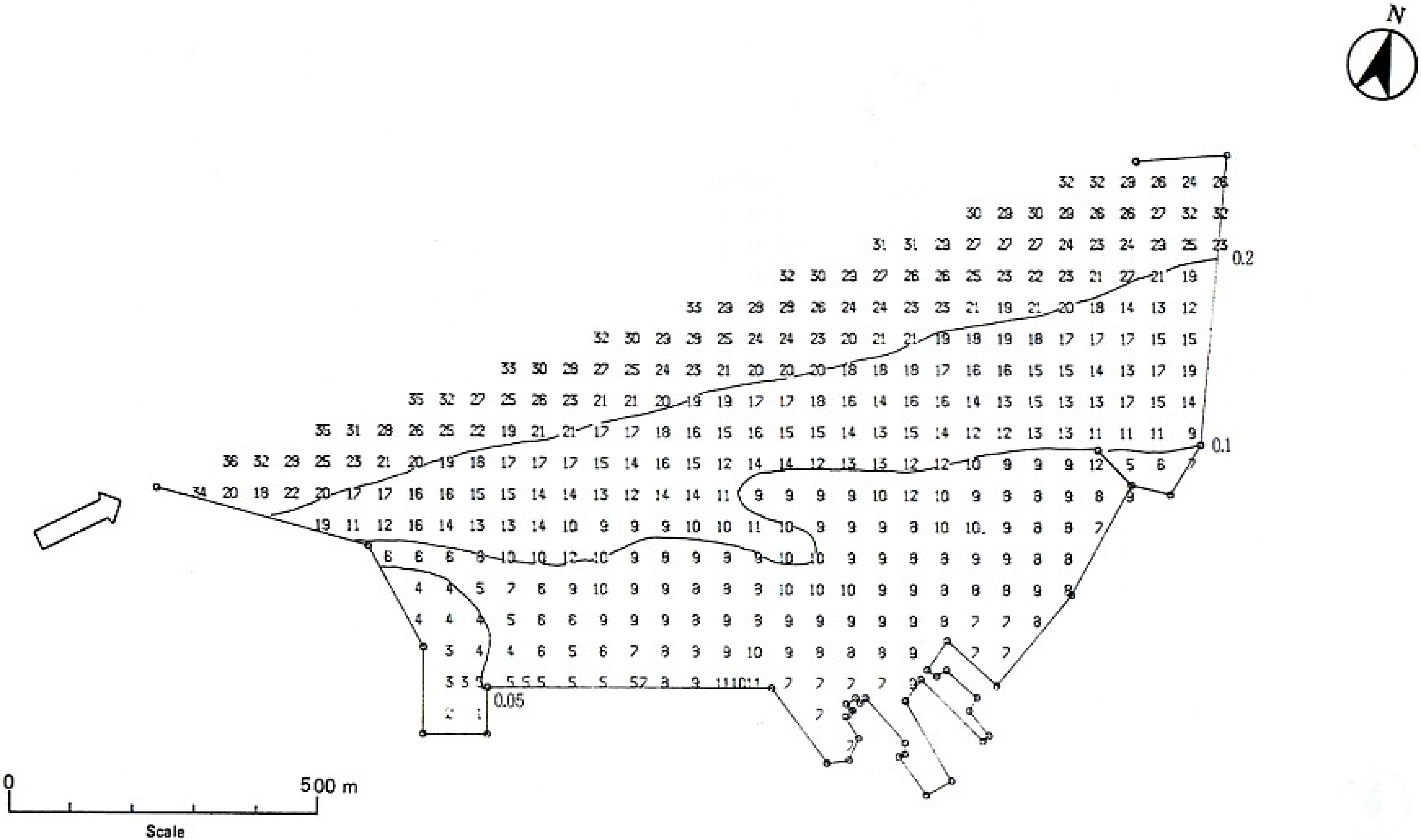


Fig. M-2 (2) Diffraction Chart (Case 2, $T_{1/3} = 12s$), Unit: %

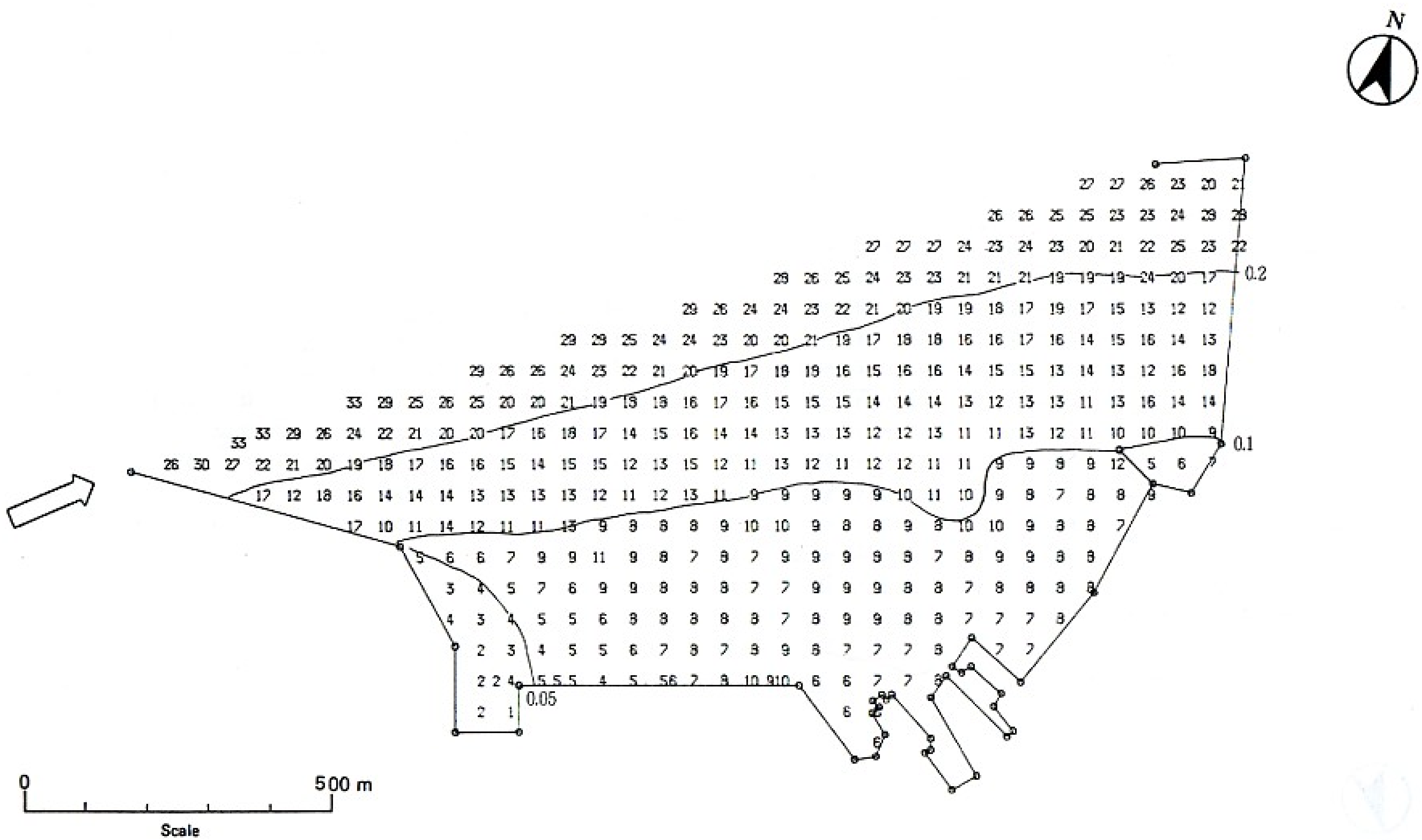


Fig. M-2 (3) Diffraction Chart (Case 3, $T_{1/3} = 12s$), Unit: %

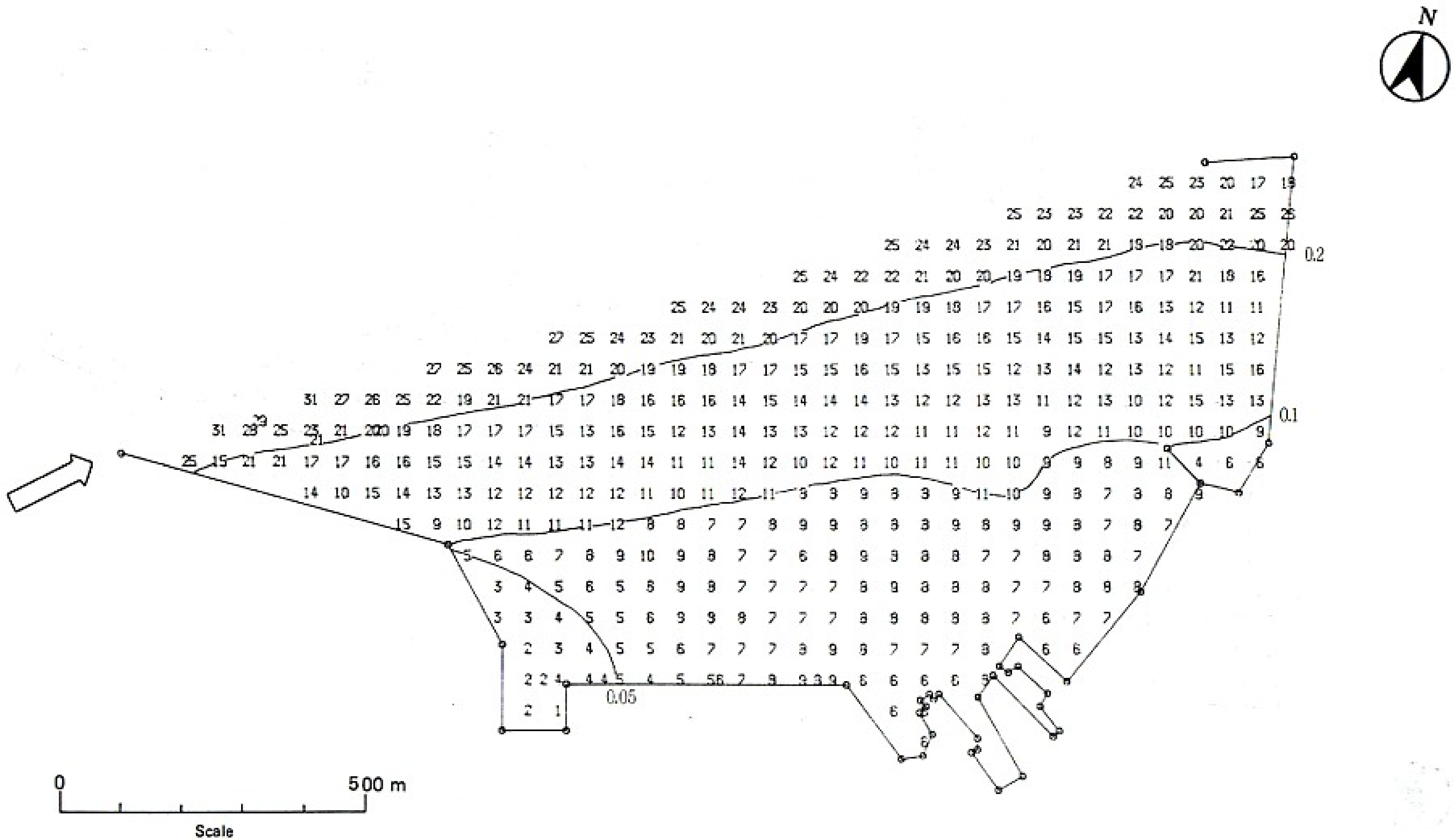


Fig. M-2 (4) Diffraction Chart (Case 4, $T_{1/3} = 12s$), Unit: %

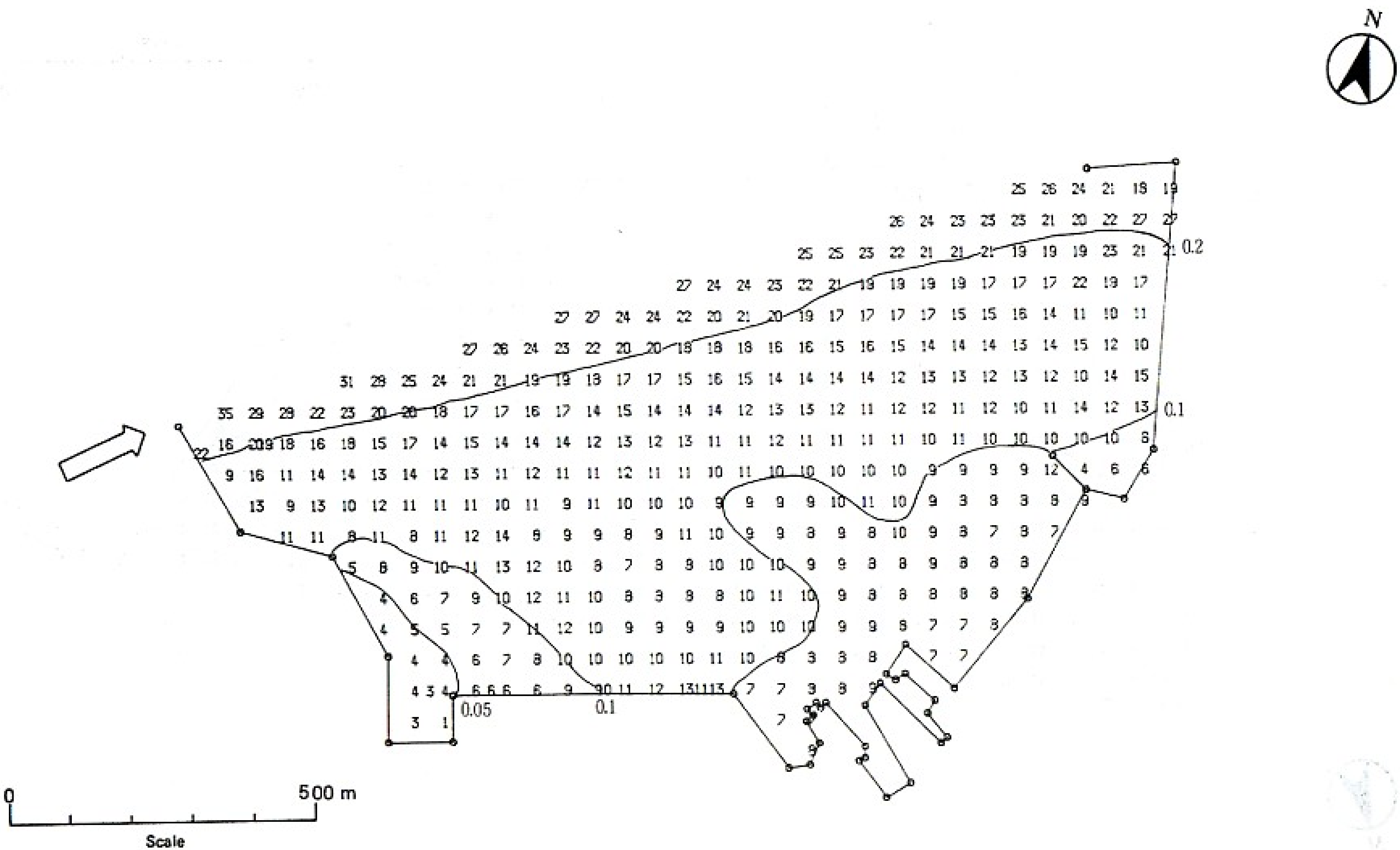


Fig. M-2 (5) Diffraction Chart (Case 5, $T_{1/3} = 12s$), Unit: %

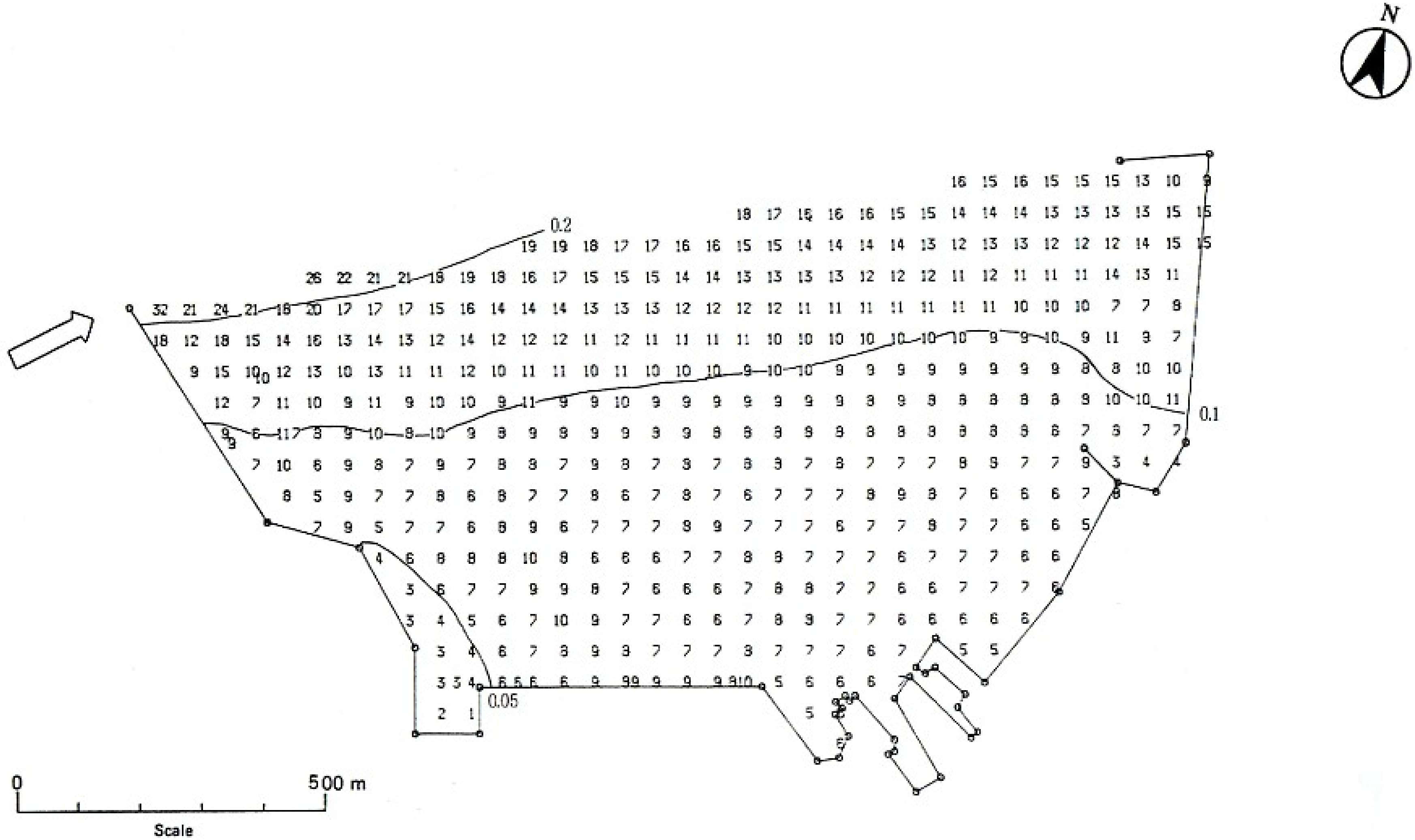


Fig. M-2 (6) Diffraction Chart (Case 6, $T_{1/3}$ = 12s), Unit: %

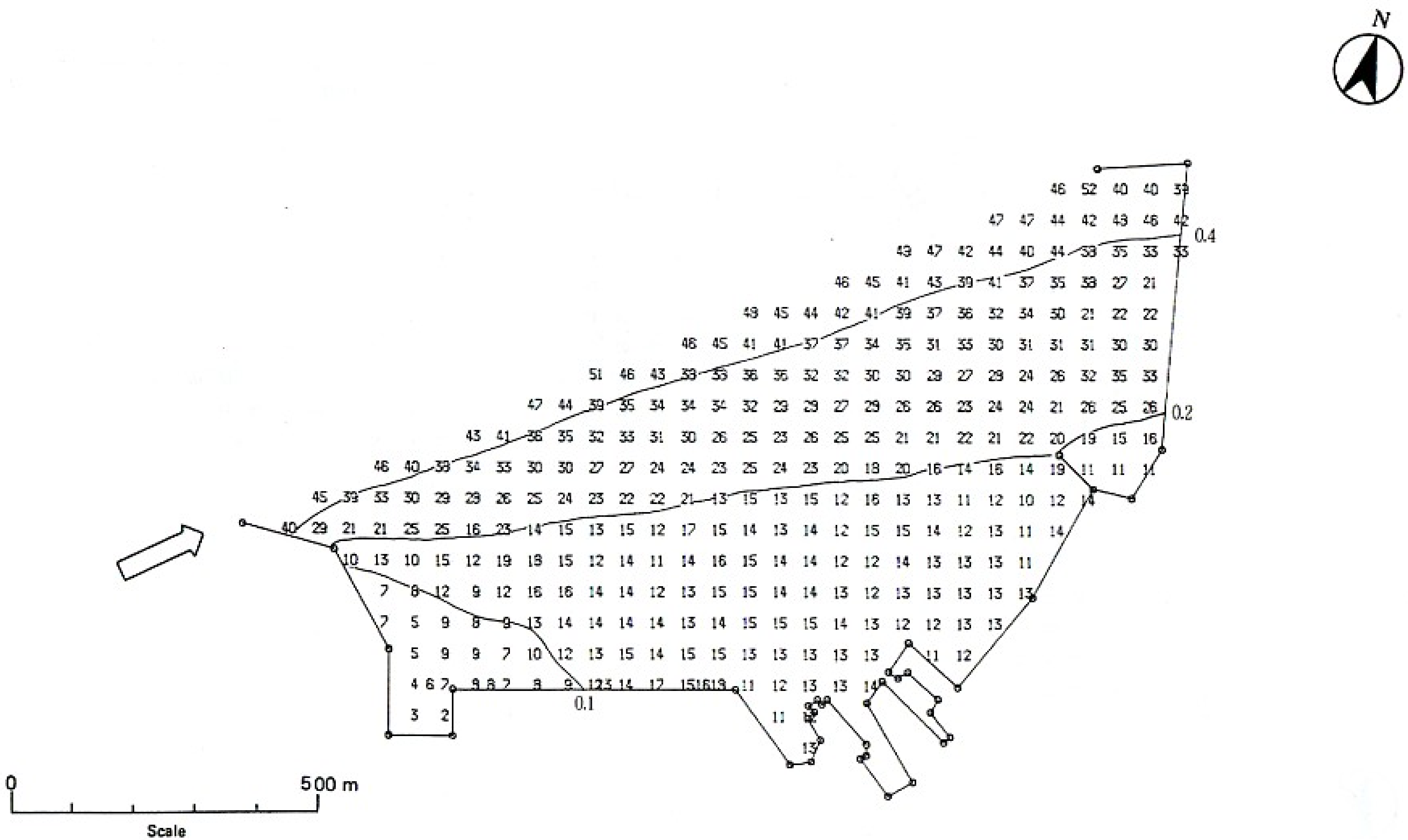


Fig. M-2 (7) Diffraction Chart (Case 1, $T_{1/3} = 18s$), Unit: %

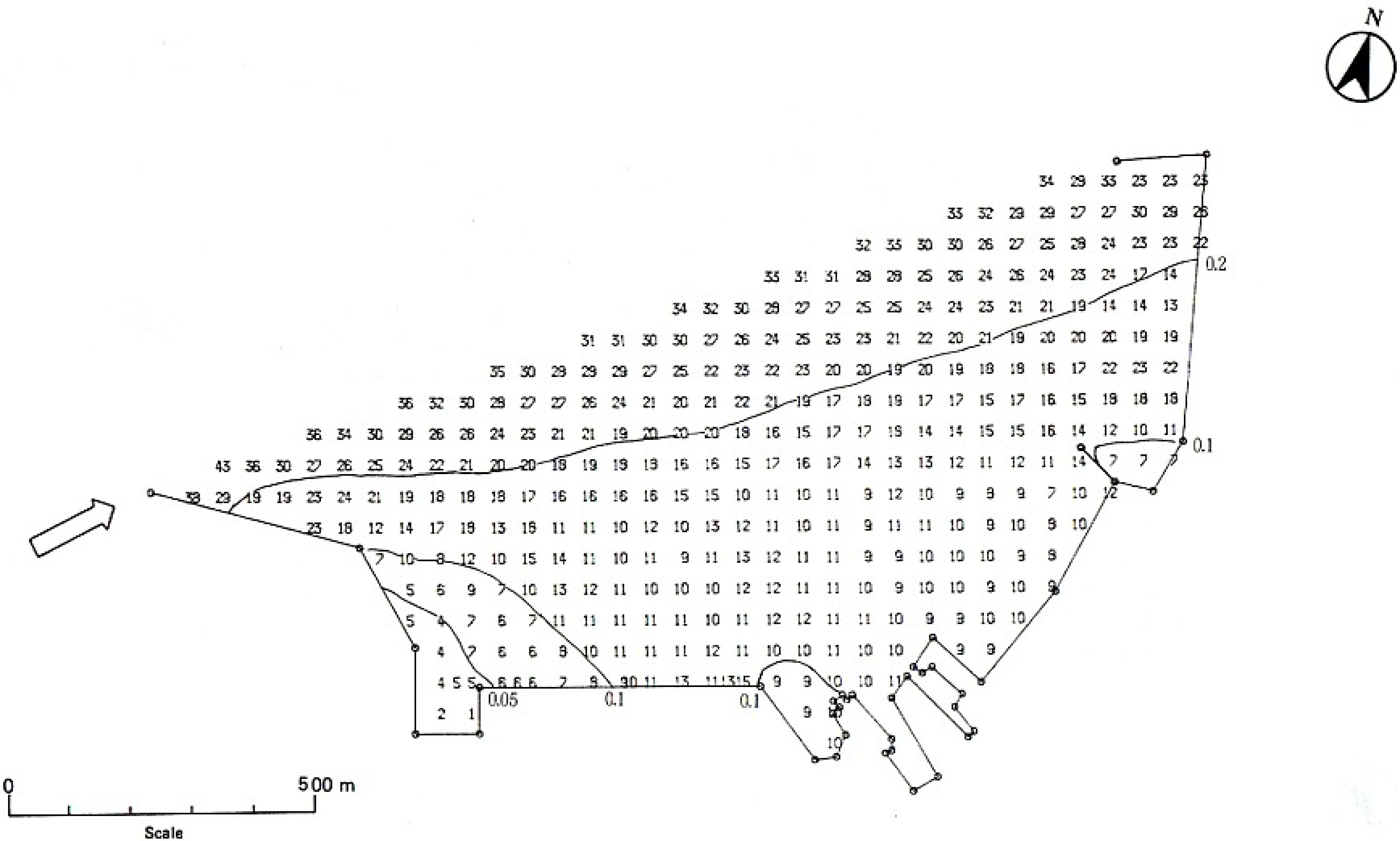


Fig. M-2 (8) Diffraction Chart (Case 2, $T_{1/3}$ = 18s), Unit: %

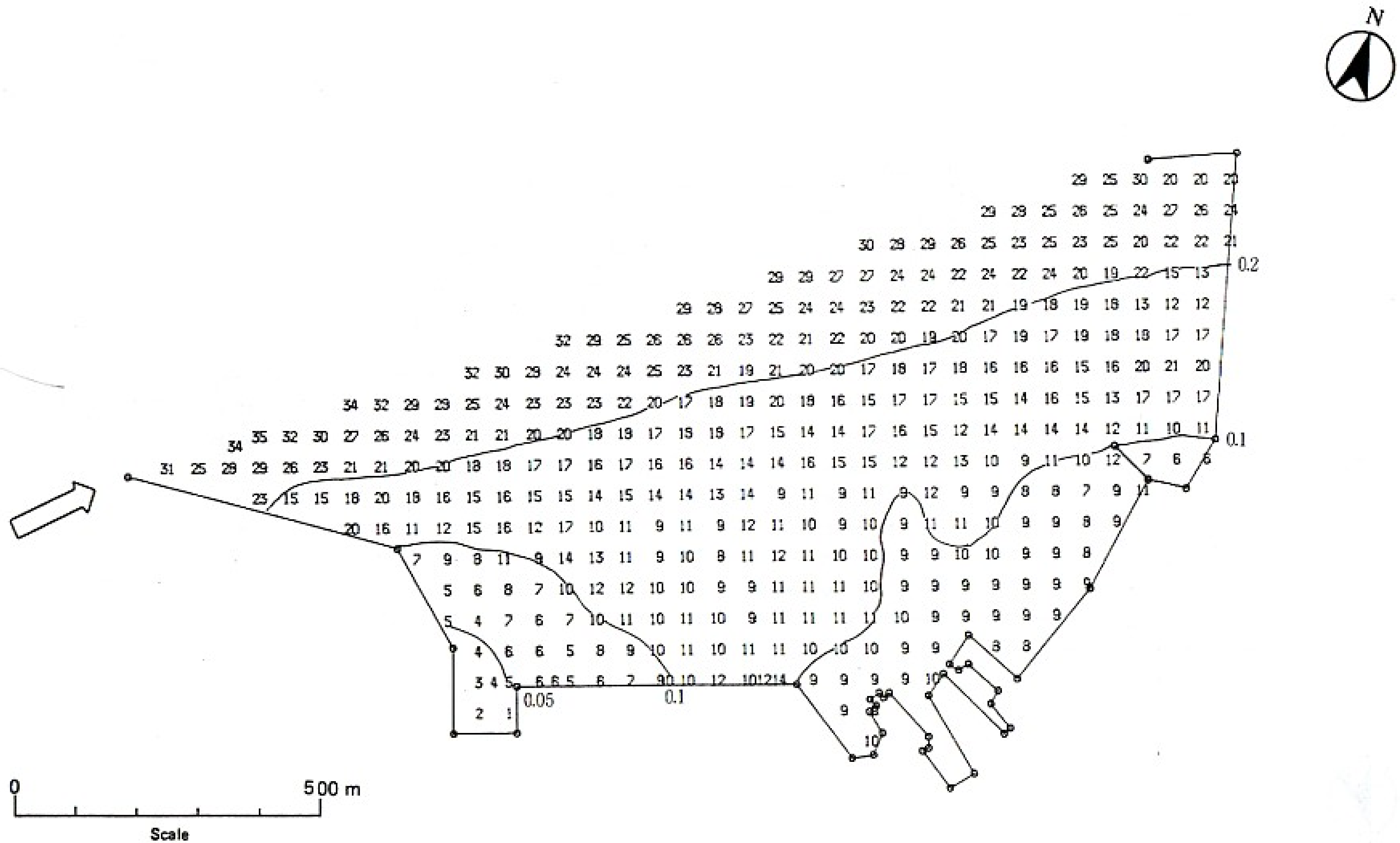


Fig. M-2 (9) Diffraction Chart (Case 3, $T_{1/3}$ = 18s), Unit: %

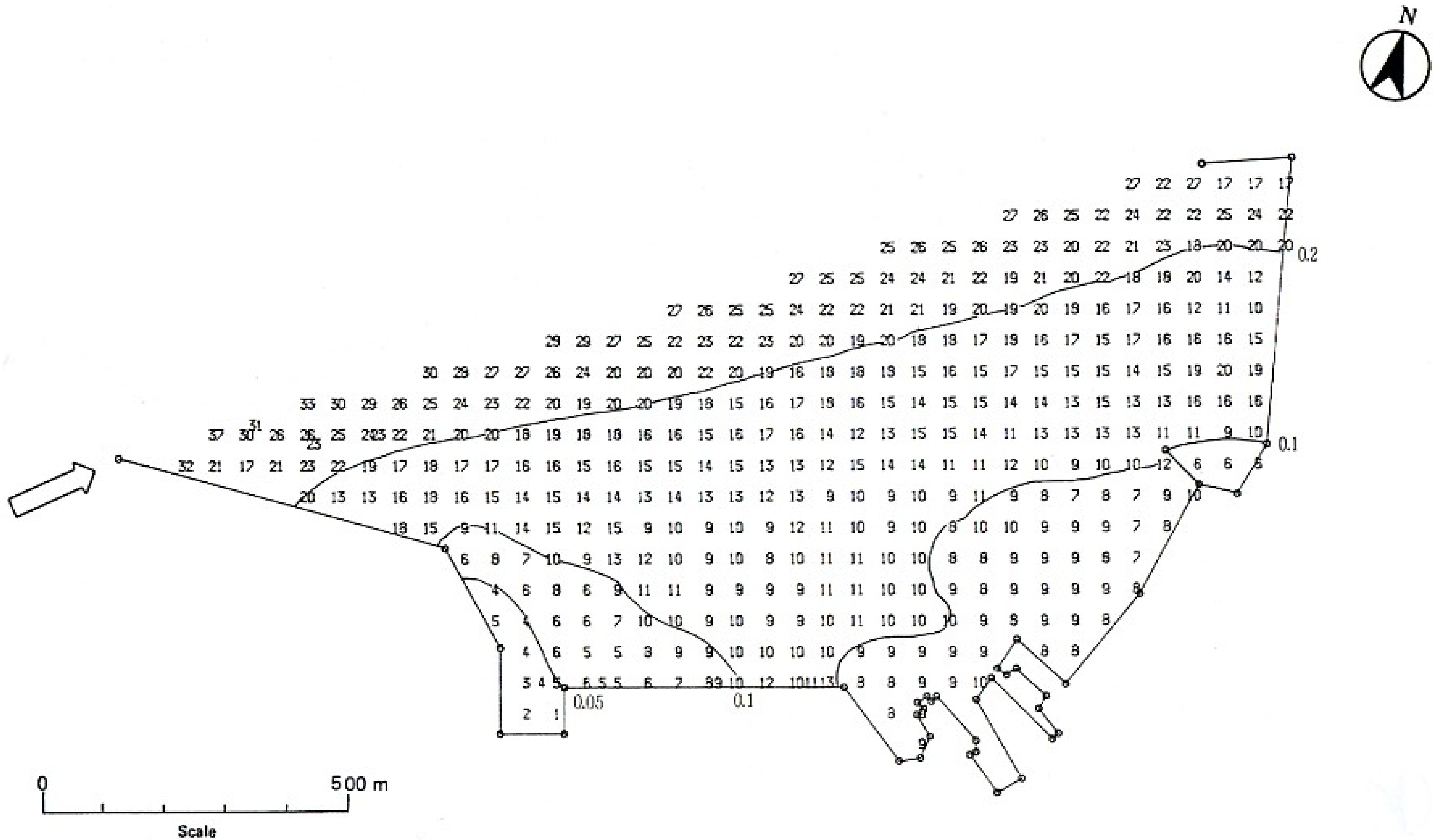


Fig. M-2 (10) Diffraction Chart (Case 4, $T_{1/3}$ = 18s), Unit: %

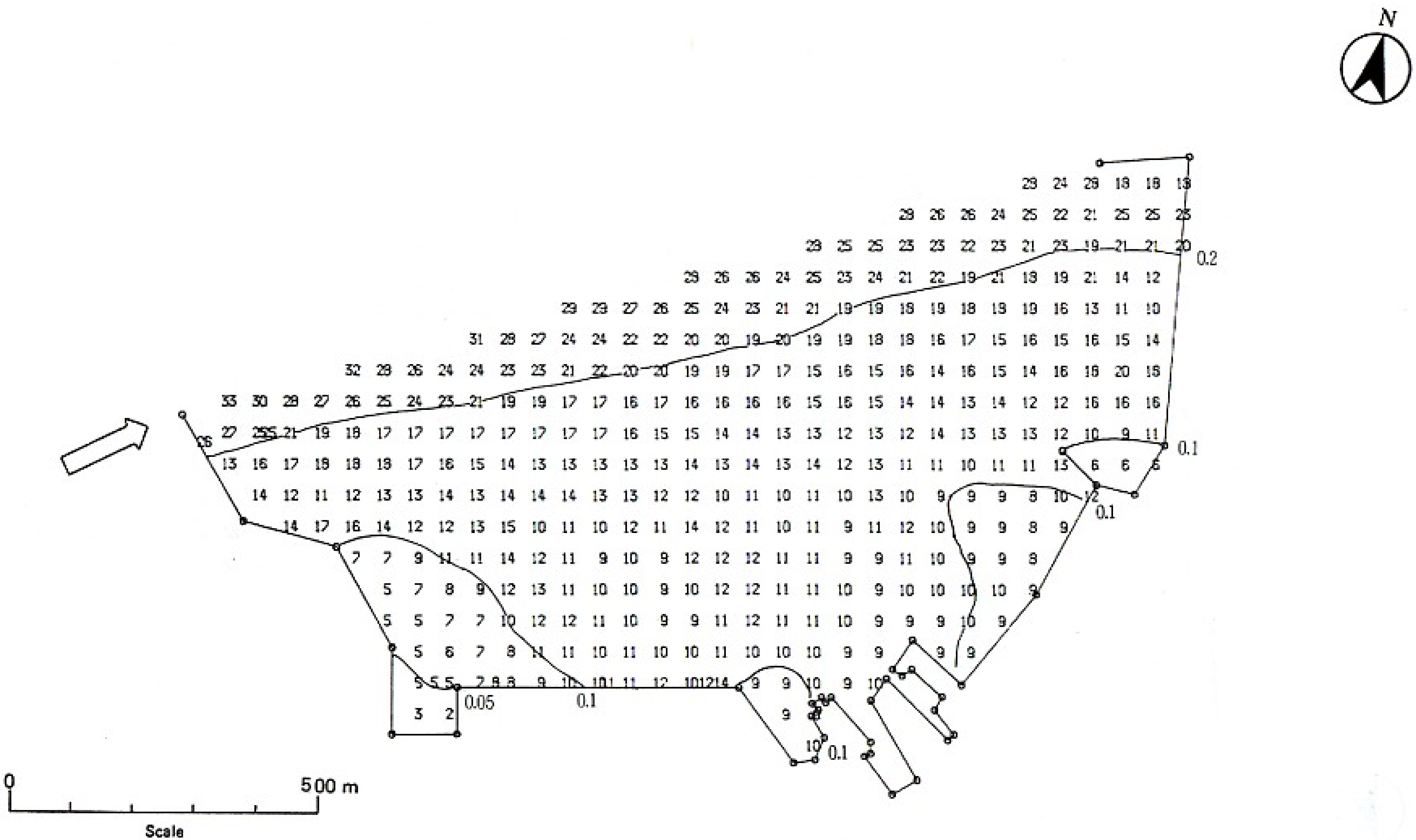


Fig. M-2 (11) Diffraction Chart (Case 5, $T_{1/3}$ = 18s), Unit: %

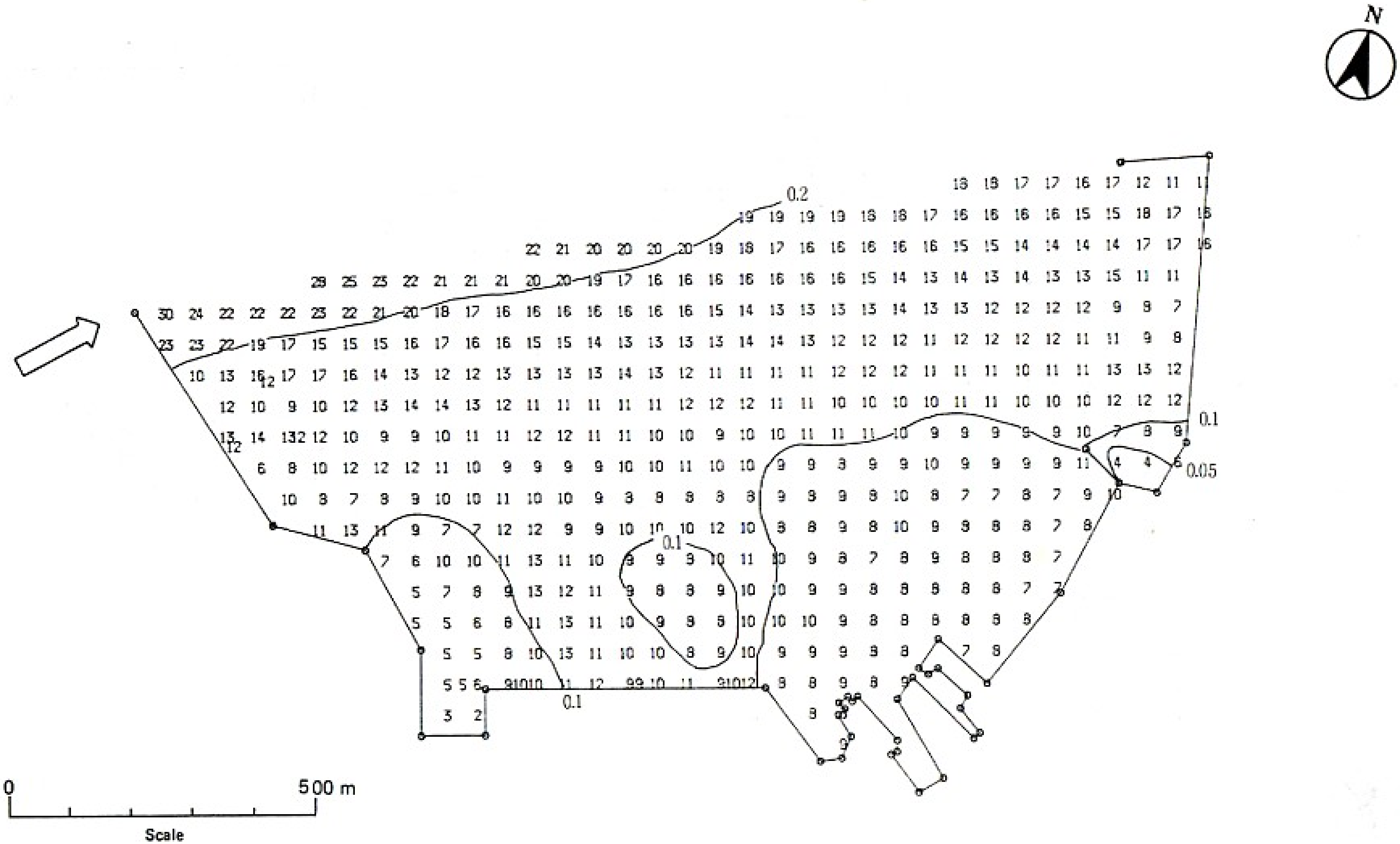


Fig. M-2 (12) Diffraction Chart (Case 6, $T_{1/3}$ = 18s), Unit: %

Table M-1(1) Cumulative Occurrence Probabilities of Significant Wave Heights in the Harbor Area (Case 1)

Unit : %

Calulation points	①	②	③	④	⑤	⑥
Significant wave height 0.10m	62.6	23.3	55.4	90.1	96.2	
0.20m	95.9	86.8	94.1	99.7	100.0	
0.30m	99.4	97.5	99.0	100.0		
0.40m	100.0	99.4	100.0			
0.50m		100.0				
0.60m						
0.75m						
1.00m						
1.25m						
1.50m						

Table M-1 (2) Cumulative Occurrence Probabilities of Significant Wave Heights is the Harbor Area (Case 2)

Unit : %

Calulation points	①	②	③	④	⑤	⑥
Significant wave height 0.10m	81.6	54.5	76.5	98.2	98.2	
0.20m	98.9	92.7	98.2	100.0	100.0	13.4
0.30m	100.0	98.6	99.8			52.3
0.40m		99.7	100.0			76.5
0.50m		100.0				88.1
0.60m						94.7
0.75m						97.7
1.00m						99.5
1.25m						100.0
1.50m						

Table M-1 (3) Cumulative Occurrence Probabilities of Significant Wave Heights in the Harbor Area (Case 3)

Unit : %

Calulation points	①	②	③	④	⑤	⑥
Significant wave height 0.10m	86.2	57.8	75.3	98.2	98.2	
0.20m	99.4	94.1	98.9	100.0	100.0	20.3
0.30m	100.0	99.0	100.0			68.4
0.40m		100.0				87.1
0.50m						95.3
0.60m						97.7
0.75m						99.3
1.00m						100.0
1.25m						
1.50m						

Table M-1 (4) Cumulative Occurrence Probabilities of Significant Wave Heights in the Harbor Area (Case 4)

Unit : %

Calulation points	①	②	③	④	⑤	⑥
Significant wave height 0.10m	86.4	64.8	75.3	98.2	98.2	
0.20m	99.4	95.9	98.9	100.0	100.0	33.0
0.30m	100.0	99.4	100.0			77.6
0.40m		100.0				92.4
0.50m						96.7
0.60m						98.6
0.75m						99.6
1.00m						100.0
1.25m						
1.50m						

Table M-1 (5) **Cumulative Occurrence Probabinities of Significant Wave Heights in the Harbor Area (Case 5)**

Unit : %

Calulation points	①	②	③	④	⑤	⑥
Significant wave height 0.10m	81.0	40.1	77.0	90.9	98.2	8.2
0.20m	98.9	92.5	98.2	99.7	100.0	65.5
0.30m	100.0	99.0	99.8	100.0		88.1
0.40m		100.0	100.0			96.4
0.50m						98.7
0.60m						99.5
0.75m						100.0
1.00m						
1.25m						
1.50m						

Table M-1 (6) **Cumulative Occurrence Probabilities of Significant Wave Heights in the Harbor Area (Case 6)**

Unit : %

Calulation points	①	②	③	④	⑤	⑥
Significant wave height 0.10m	86.4	66.8	80.2	81.8	98.2	66.8
0.20m	99.4	96.8	98.9	98.9	100.0	96.8
0.30m	100.0	99.6	100.0	100.0		99.6
0.40m		100.0				100.0
0.50m						
0.60m						
0.75m						
0.75m						
1.00m						
1.25m						
1.50m						

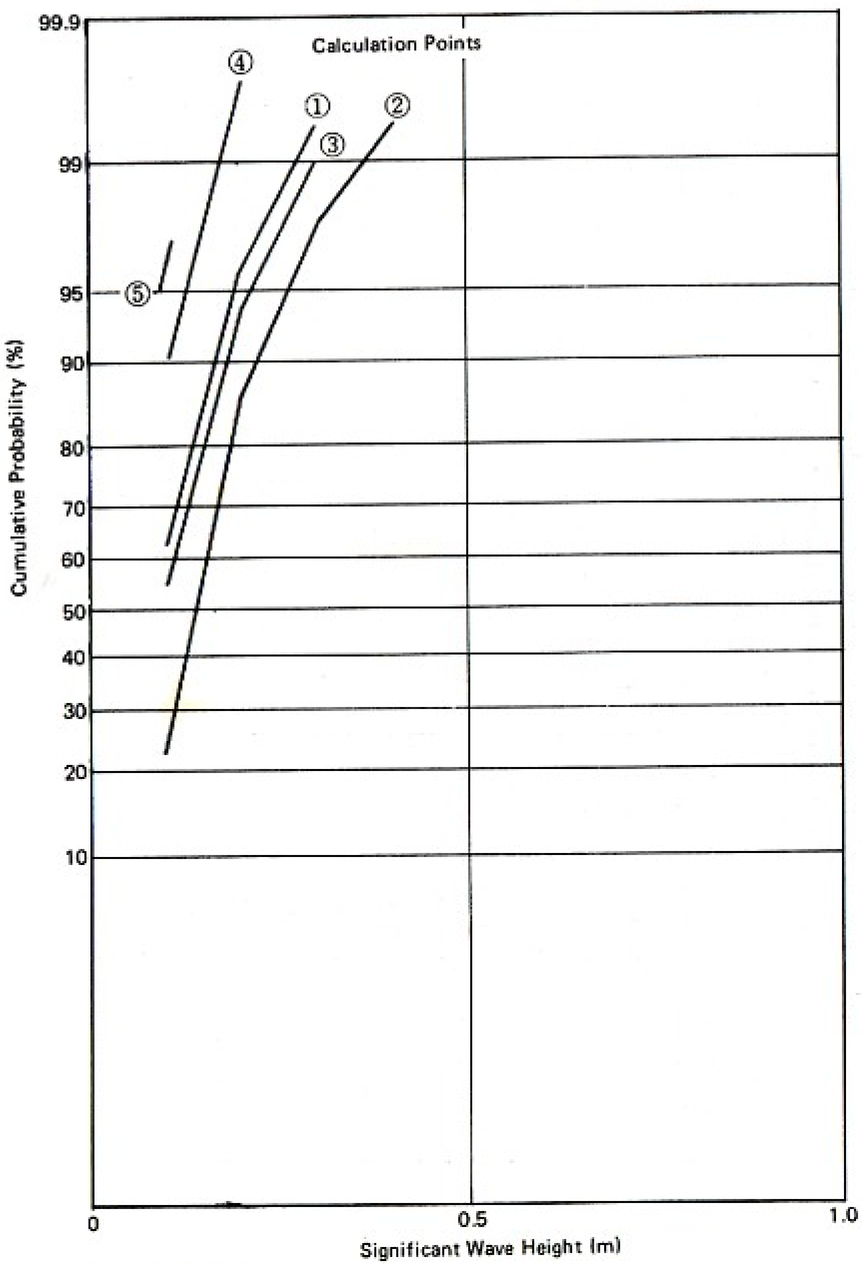


Fig. M-3 (1) Cumulative Occurrence Probabilities of Significant Wave Heights in the Harbor Area (Case 1)

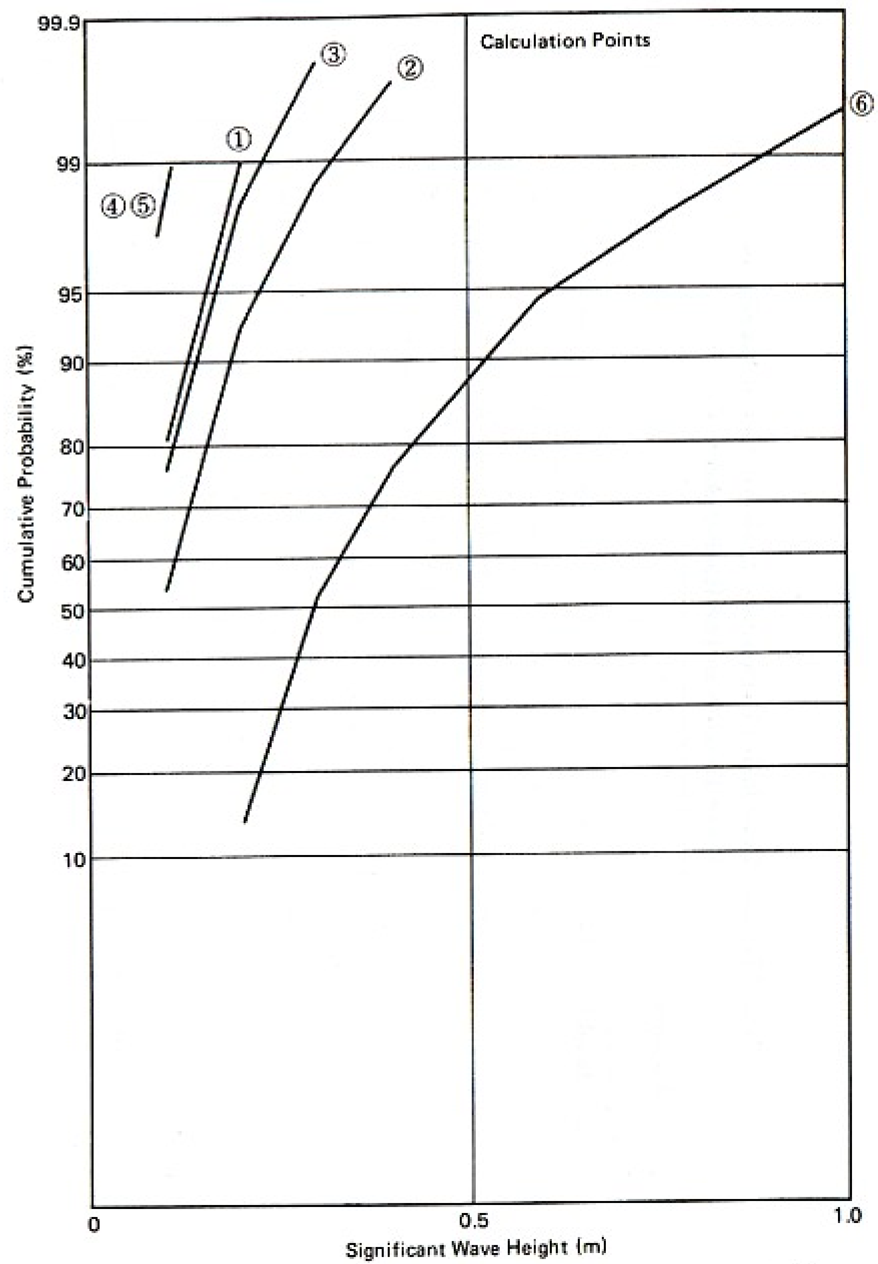


Fig. M-3 (2) Cumulative Occurrence Probabilities of Significant Wave Heights in the Harbor Area (Case 2)

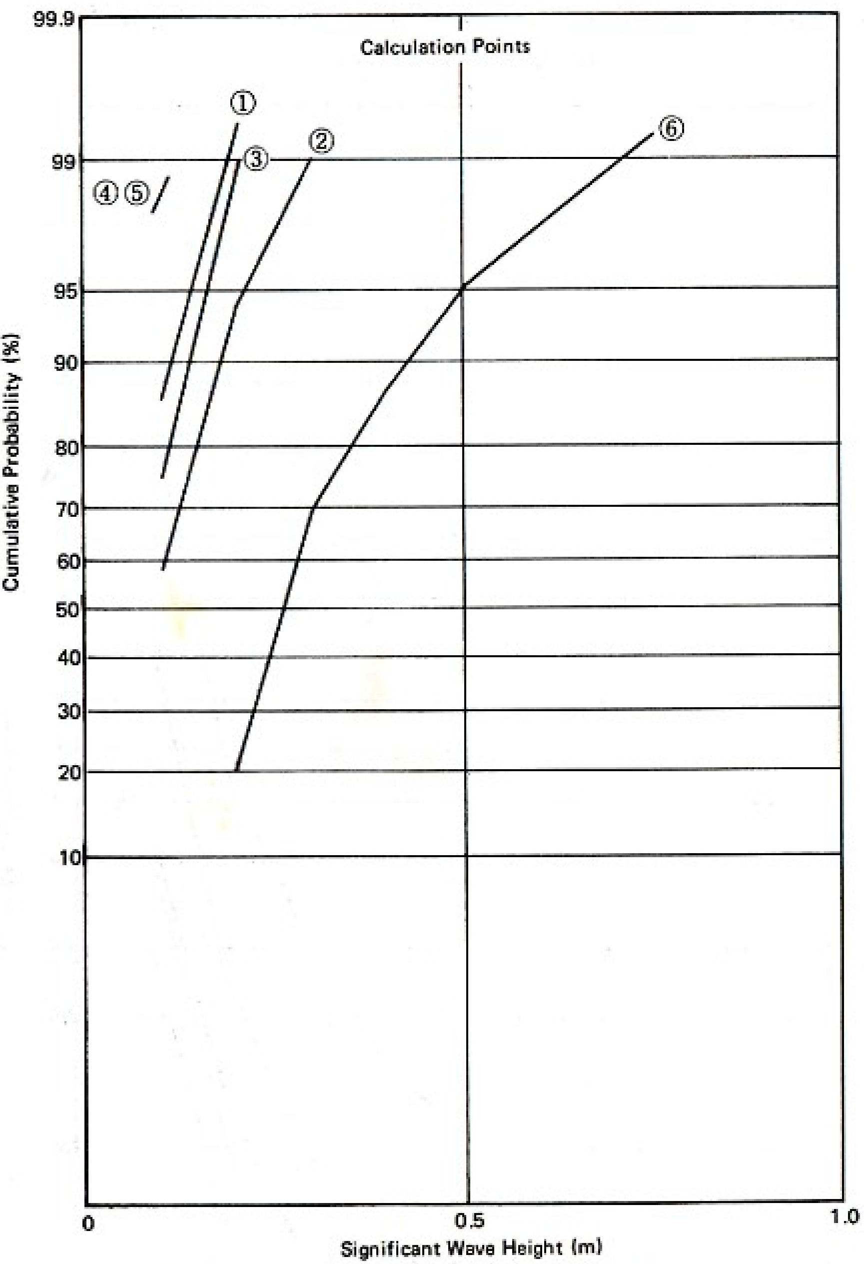


Fig. M-3 (3) Cumulative Occurrence Probabilities of Significant Wave Heights in the Harbor Area (Case 3)

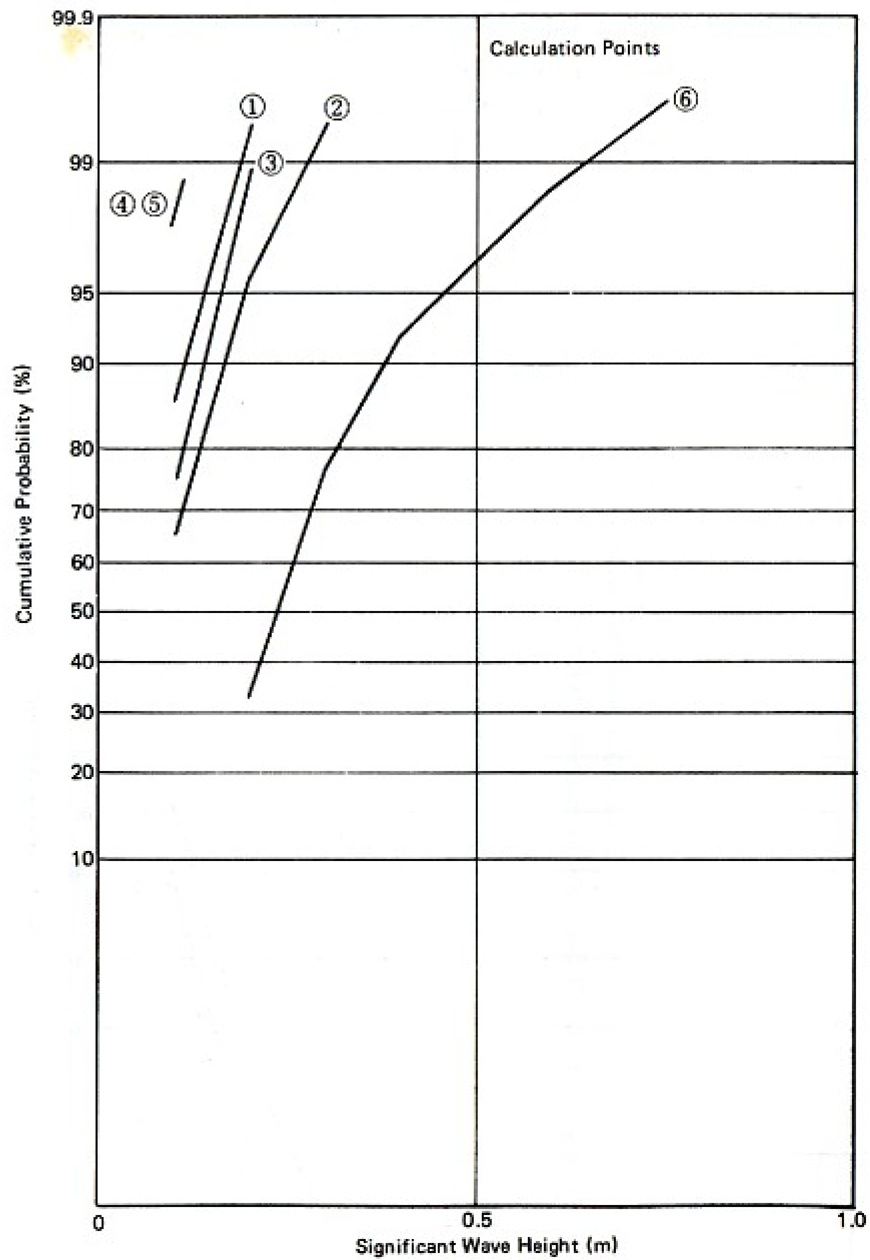


Fig. M-3 (4) Cumulative Occurrence Probabilities of Significant Wave Heights in the Harbor Area (Case 4)

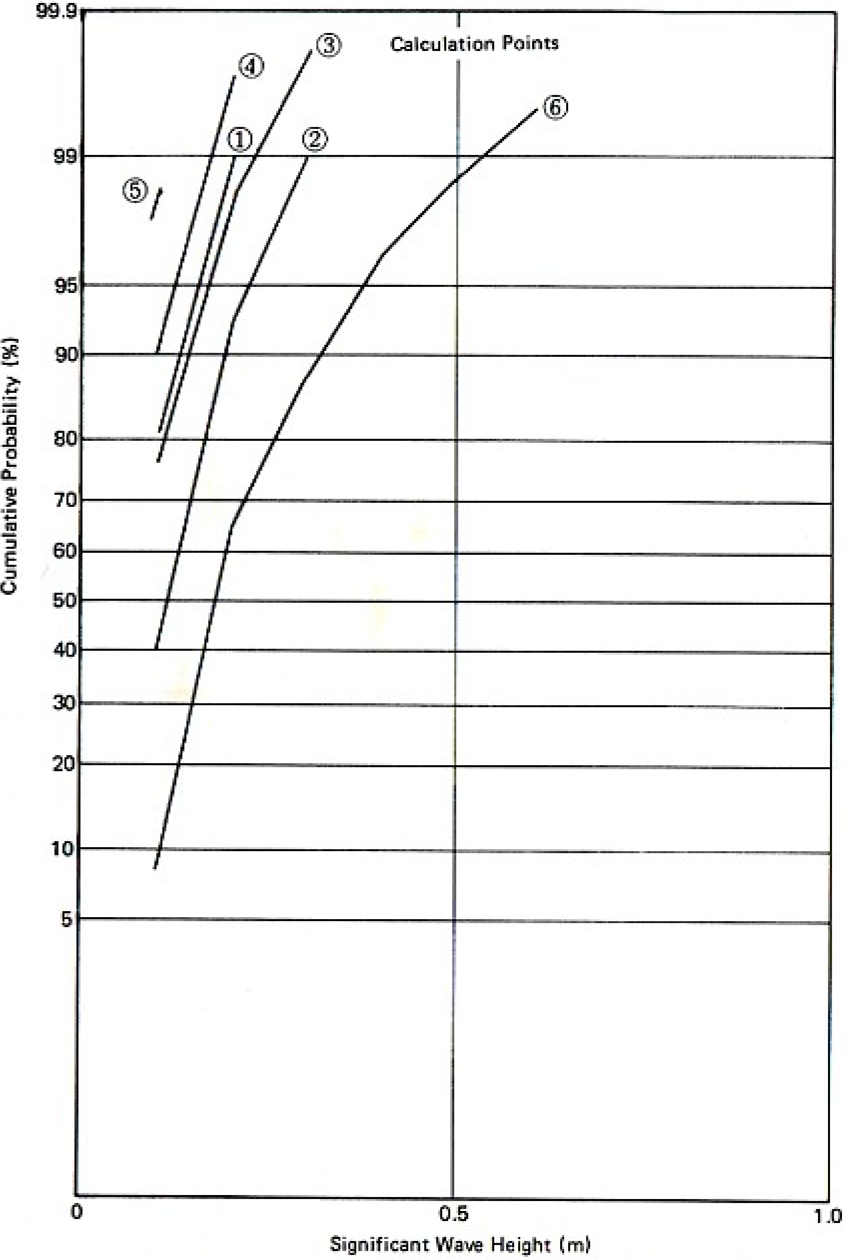


Fig. M-3 (5) Cumulative Occurrence Probabilities of Significant Wave Heights in the Harbor Area (Case 5)

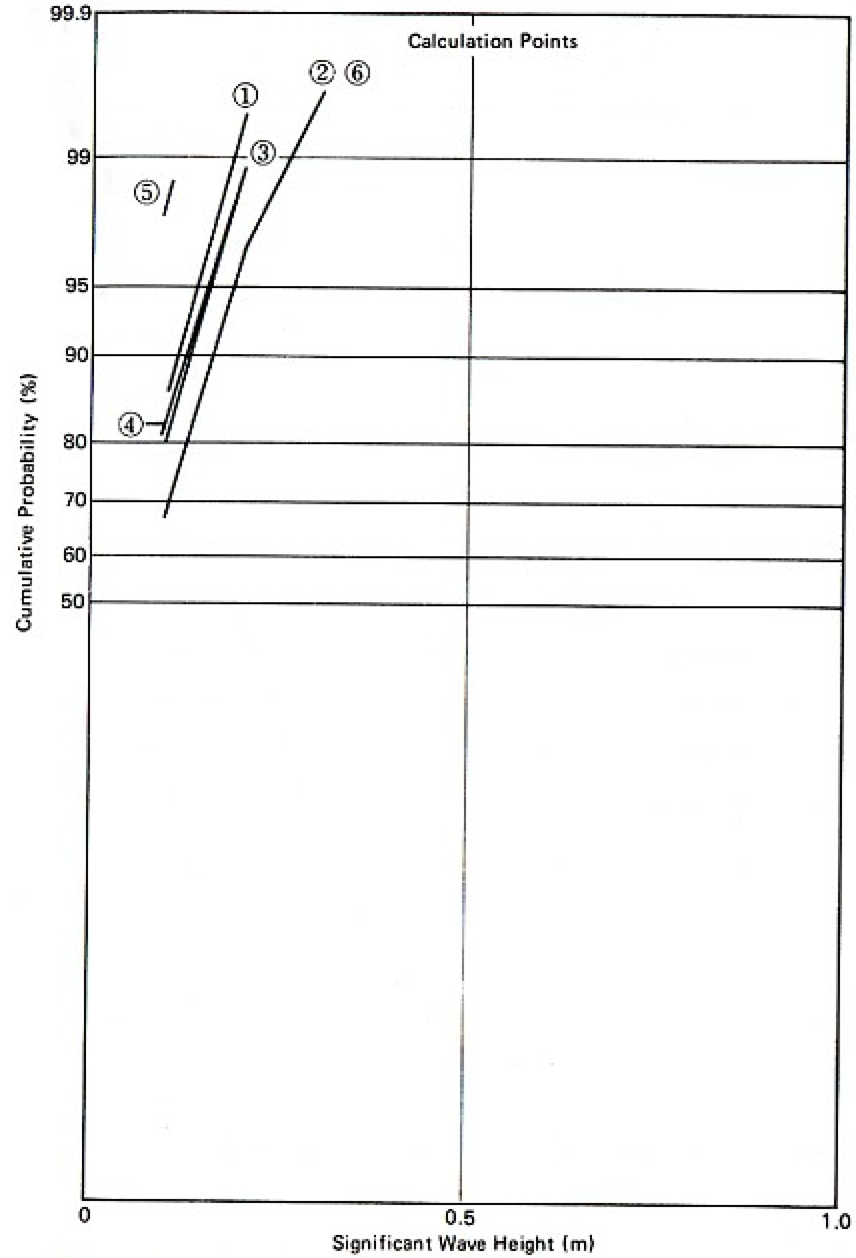


Fig. M-3 (6) Cumulative Occurrence Probabilities of Significant Wave Heights in the Harbor Area (Case 6)

APPENDIX 9 CARGO HANDLING CAPACITY AFTER THE TARGET YEAR

The present terminal facilities and number of workers will be sufficient, if the proposed project is implemented, to handle the estimated cargo volume of 763,300 tons in the target year (1992). However, the total cargo throughput will continue to increase after that time. A rough estimation of the cargo volume increase from 1992 through 1995 has been executed, and two suggestions concerning the appropriate means to expand the handling capacity in order to accommodate the additional cargo volume are presented below.

(1) Increasing the working efficiency per gang per hour

If the systematic program for training workers described in the main body of this study is implemented, we expect that the cargo handling efficiency will increase by approximately 20% in 1992 due to improved working methods as outlined in Table M—1.

However, the increases in cargo handling efficiency in 1995 predicted in the table are based upon the assumption that an effective training program will be implemented, that is, that the workers will be trained in such a way that the handling efficiency will increase. Naturally, JST cannot guarantee that the forecast handling rates will actually be achieved after 1992. Nonetheless, there is every reason to believe that if a systematic training program is implemented, the cargo handling rate should improve by at least 20% by 1995 as a result of the training program and improved working methods.

Table M-1 Estimated Future Cargo Handling Efficiency

Kind of Cargo	Present Handling Efficiency	Efficiency in the Target Year 1992	Efficiency in 1995
General	20 MT/h	24 MT/h	29 MT/h
Steel Goods	40 MT/h	48 MT/h	58 MT/h
Container	7 TEU/h	12 TEU/h	15 TEU/h
Break Bulk	20 MT/h	200 MT/h	200 MT/h

note. MT : Metric ton

(2) Increasing the number of gangs per vessel

As noted in the study, the average number of gangs per vessel up to the target year is 2. By expanding the number of gangs per vessel to 3, the cargo handling capacity of the port may increase by as much as 50% without investing in any additional physical infrastructures. However, it would, of course, become necessary to purchase some additional forklifts. Besides, the ability to use three gangs simultaneously depends on various conditions such as the cargo loading conditions and the number of hatches on each vessel.

Based on the recommendations presented in (1) and (2), INCOP may be able to handle the forecast cargo in the year 1995 without constructing any additional mooring facilities.

APPENDIX 10 COMMENTS ON THE IMMINENT DREDGING PLAN AT THE PORT OF CALDERA

COMMENTS ON THE IMMINENT DREDGING PLAN
AT
THE PORT OF CALDERA

Nov. 4, 1985

THE JICA STUDY TEAM
FOR
THE MAINTENANCE PROJECT OF THE PORT OF CALDERA

The sand sedimentation has caused some difficulties for the berthing of large vessels at the -11 m berth at the Port of Caldera. MOPT, therefore, decided to execute urgent maintenance dredging, and requested the JICA study team to submit comments on the said dredging from the viewpoint of engineering. MOPT and the JICA study team held a meeting concerning this matter on Oct. 30, 1985.

This paper is a summary of the comments presented by the JICA study team at this meeting.

1. Location of the dumping site for the dredged sand.

The offshore area of Roca Carballo in the direction N 50°W from the No. 2 Buoy near the anchorage is recommendable as the dumping site for the dredged sand to prevent the dumped sand from returning to the dredged area. This water area is vast and deep to accept the dredged materials.

2. Dredging depth and areas.

(1) The berth area just in front of the quaywall, with a design depth of -11 m should not be dredged over the design depth plus the maximun allowance so as not to cause the collapse of the quaywall.

(2) The water area at the corner between the breakwater and the marginal quaywall should be given priority to be positively dredged because of its importance in firmly securing the berth area.

(3) The dredging depth allowance in the turning basin with a depth of -11 m, should be deepened as much as possible.

3. Dredging at the harbour part around the breakwater head.

The dredging of the deposited sand at the harbour part around the breakwater head, the length of which is about 100 m, is recommendable because it would be ineffecfive without further extension of the existing breakwater.

The detailed dredging plan for this water area will be studied as a part of the basic countermeasures against littoral drift sand by the JICA study team. Thus, this water area should be dredged after the completion of the said study.

4. Dredging methods.

(1) Such areas as the corner between the breakwater and the marginal wharf cannot be dredged using a hopper dredger and a blade dragger. Thus, the suction dredger owned by MOPT should be used to reliably dredge these water areas.

(2) There is a sand layer of a certain depth on top of the stones scattered by past high waves in certain harbour areas. Thus, a hopper dredger should dredge the sand layer up to the depth of the surface of the scattered stones. The scattered stones

themselves should not necessarily be dredged in the present dredging work considering the difficulty of such dredging.

5. Inspection of the dredged sand volume.

The volume of dredged sand should be confirmed based on the difference between soundings before and after the dredging. The soundings should be implemented by MOPT itself.

6. Safe maneuvering of general vessels.

The dredging work should not hinder the safe maneuvering of general vessels and the execution of regular port operations. Therefore, detailed adjustment must be worked out in advance between the dredging work and the maneuvering of general vessels.

APPENDIX 11 ESTIMATE OF WORKABLE DAYS FOR BREAKWATER CONSTRUCTION

The workable days of the breakwater construction are estimated using the following method.

1. Workable Days for Construction Works Executed from on Top of the Existing Breakwater

The critical wave height for the works executed from on top of the existing breakwater and their cumulative occurrence probability are estimated as follows, using the limit of uprush.

1. 1 Study Conditions

- ○ Tide level : M.H.W. +2.5 m
- ○ Crown height of the breakwater above the M.H.W. : 4.6−2.5=2.1 m
- ○ Water depth under the M.H.W. : $h=7.0+2.5=9.5$ m
- ○ Water period : $T_{1/3}=12$ s
  (Using the median of the occurrence probabilities : refer to CHAPTER VII, Fig.VII−11)
- ○ Deep water move length : $L_0=1.56\ T^2=225$ m

1. 2 Uprush Heights and their Occurrence Probability

According to the experimental results achieved by Toyoshima and et al.[1] (Fig.M−1), the uprush heights R and their occurence probabilities $P\ [H \leqq x]$ are calculated as shown in Table M−1.

Table M-1 Relations between Uprush Heights and their Cumulative Occurrence Probabilities

$H_{1/3}$ (m)	H_0/L_0	h/L_0	R/H_0	R (m)	$P\ [H \geqq x]$ (%)
1.5	0.0067	0.042	1.7	2.55	—
1.3	0.0058	0.042	1.6	2.08	90
1.2	0.0053	0.042	1.6	1.92	85

1) Osamu Toyoshima, Nobuo Shuto and Hiroshi Hashimoto ; Uprush Height against Seawall −Bottom Slope 1 : 30−, No. 11 Coastal Engineering Lectures, 1964, pp. 260∼265

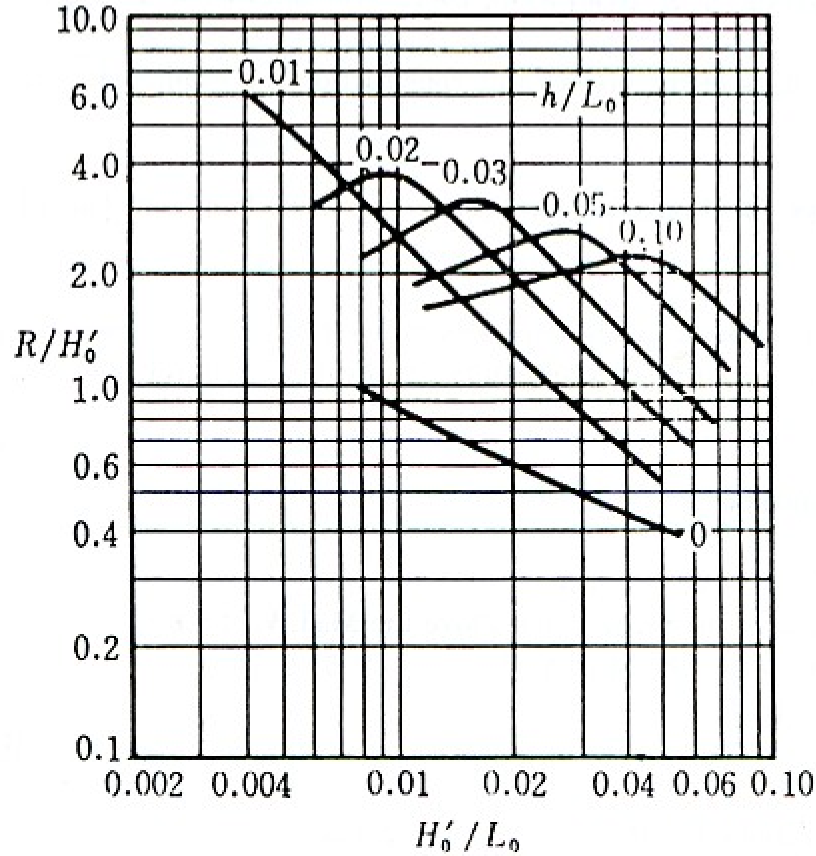


Fig. M-1 Uprush Height
(Slope of Seawall 1:2, Bottom Slope 1:30)

1. 3 Unworkable Days for Construction Works Executed from on Top of the Breakwater

As the above calculations were made based on the significant wave height, waves larger than these will occur at a probability of above 13%. However, considering that the tide levels are usually lower than M.H.W. and the uprush height against the slope of the rubble should be smaller than the values calculated above because Toyoshima's experiment was conducted using a smooth face, it should be possible to work on the breakwater when $H_{1/3}$ is less than or equal to 1.2 m. Thus, the construction will probably have to be stopped due to high waves at a probability of about 15%.

2. Workable Days of Marine Works

2. 1 Installation of Rubble Mound Under Water

The occurrence probability of unworkable days due to poor marine conditions for the installation of the rubble mound under water using barges is estimated to be 30%, assuming that the critisal workable significant wave height for the installation is 1.0 m (refer to CHAPTER IV, Fig.IV—10).

2. 2 Installation of Armour Units

If the critical significant wave height for installation of the armour unit of the breakwater is 0.5 m, the occurrence probability of workable days for this work is estimated to be only 6% (refer to CHAPTER IV, Fig.IV—10). Thus, it will not be efficient to install the Dolos using a floating crane from the outside harbour. Accordingly, the Dolos will be installed using mobile crane or a crawler crane on the breakwater.

The armour stones will be installed using a floating crane, where the diffraction rates on the inside of the harbour are less than 0.5. In this case, the occurrence probability of unworkable days is 30% because $H_{1/3}$ will be 1.0 m.

3. Estmated Workable Rate for Breakwater Construction

The estimated workable rate for each of the above construction works is summarized in Table M—2.

Table M-2 Estimated Workable Rate for Breakwater Construction

Item		Workable Rate
Marine Works	Installation of Underwater Mound	70%
	Installation of Armour Stones	70%
Works Executed from on Top of the Breakwater		85%

APPENDIX 12 SHIP COSTS

Ship costs consist of the price of the ship itself, the crew's wages, equipment cost, machine oil cost, insurance cost, repair cost, depreciation cost, miscellaneous costs, and other costs. Accordingly, the total ship cost depends on the price of the ship itself and the price of the other expenditures.

The price of ships is shown in Table M—1. *)

Table M-1 The Price of Ships

Ship Size ('000 DWT)	10	20	30	40	65	125	250
Price (Million Yen/ship)	1,300	2,250	3,100	3,800	4,750	6,450	9,850

The other costs are projected based on past costs and the projected rate of increase. Consequently, the ship costs are estimated as shown in Table M—2. *)

Table M-2 Estimation of Total Ship Cost

Ship Size ('000 DWT)	10	20	30	40	65	125	250
Ship Cost (Yen/DWT/Month)	4,635	3,002	2,402	2,200	1,750	1,105	754

*) Source : The Report for the Study on the International Commodity Distribution Center Development Project in the Bay of Shibushi, March 1984, The Transport Economy Research Institute of Japan.

APPENDIX 13 EIRR CALCULATION FOR SENSITIVITY ANALYSIS

Sensitivity analysis is made for three cases where

(1) Case EA : The construction costs other than that of dredging, and the purchase costs of the dredging fleet, construction machinery and cargo handling equipment, increase by 10%. In other words, the construction costs of such structures as the extended and shifted breakwater, the gangway and the small craft basin including the pavement cost of open yards increase by 10%.

(2) Case EB : The forecast port cargo volume decreases by 10%.

(3) Case EC : The ship costs decrease by 29%. The ship costs decrease by 50% of that calculated in APPENDIX 12. A ship cost decrease of 30% is adopted as the base case in the main body of the report.

The EIRR is calculated for each of the three simulation cases. The calculation results of each case are shown in Table M—1~Table M—3.

Table M-1 Calculation of the EIRR

Case EA The construction costs other than that of dredging, and the purchase costs of the dredging fleet, construction machinery and cargo handling equipment increase by 10%.

EIRR = 20.8%

(Unit: '000 Colones)

Year	Benefits	Costs			Benefits −Costs	Present Value in 1988		
		With Case	Without Case	Net Cost		Benefits	Net Costs	Benefits −Net Costs
1988		91,479		91,479	−91,479	–	91,479	−91,479
89		285,698	276,723	8,975	−8,975	–	7,430	- −7,430
90		315,446	4,402	311,044	−311,044	–	213,196	−213,196
91	61,846	107,199	4,978	102,221	−40,375	35,095	58,006	−22,911
92	123,693	12,147	16,830	−4,683	128,376	58,111	−2,200	60,311
93	123,693	12,147	6,587	5,560	118,133	48,110	2,163	45,948
94	123,693	12,147	7,535	4,612	119,081	39,831	1,485	38,346
95	123,693	12,147	8,297	3,850	119,843	32,976	1,026	31,949
96	123,693	22,225	8,855	13,370	110,323	27,301	2,951	24,350
97	123,693	12,147	17,389	−5,242	128,935	22,602	−958	23,560
98	123,693	12,147	9,804	2,343	121,350	18,713	354	18,358
99	123,693	12,147	10,091	2,056	121,637	15,492	258	15,235
2000	123,693	12,147	10,379	1,768	121,925	12,826	183	12,643
1	123,693	91,527	10,667	80,860	42,833	10,619	6,942	3,677
2	123,693	12,147	18,913	−6,766	130,459	8,791	−481	9,272
3	123,693	12,147	11,141	1,006	122,687	7,278	59	7,219
4	123,693	12,147	275,013	−262,866	386,559	6,026	−12,805	18,831
5	123,693	12,147	11,412	735	122,958	4,989	30	4,959
6	123,693	24,109	11,615	12,494	111,199	4,130	417	3,713
7	123,693	12,147	19,861	−7,714	131,407	3,419	−213	3,633
8	123,693	12,147	11,988	159	123,534	2,831	4	2,827
9	123,693	12,147	12,174	−27	123,720	2,344	−1	2,344
2010	123,693	12,147	12,360	−213	123,906	1,940	−3	1,944
11	123,693	91,527	12,648	78,879	44,814	1,606	1,024	582
12	123,693	12,147	20,708	−8,561	132,254	1,330	−92	1,422
13	123,693	12,147	12,648	−501	124,194	1,101	−4	1,106
14	123,693	12,147	12,648	−501	124,194	912	−4	915
15	123,693	12,147	12,648	−501	124,194	755	−3	758
16	123,693	28,782	12,648	16,134	107,559	625	81	543
17	123,693	−10,115	3,129	−13,244	136,937	517	−55	573
Total	3,277,864	1,290,817	864,091	426,726	2,851,138	370,269	370,269	0

Table M-2 Calculation of the EIRR

Case FB The forecast port cargo volume decreases by 10%.

EIRR = 19.1%

(Unit: '000 Colones)

Year	Benefits	Costs			Benefits −Costs	Present Value in 1988		
		With Case	Without Case	Net Cost		Benefits	Net Costs	Benefits −Net Costs
1988	–	83,163	–	83,163	−83,163	–	83,163	−83,163
89	–	259,725	276,723	−16,998	16,998	–	−14,274	14,274
90	–	288,167	4,402	283,765	−283,765	–	200,092	−200,092
91	48,429	106,426	4,978	101,448	−53,019	28,675	60,069	−31,393
92	96,857	11,374	16,830	−5,456	102,313	48,158	−2,713	50,871
93	96,857	11,374	6,587	4,787	92,070	40,440	1,999	38,441
94	96,857	11,374	7,535	3,839	93,018	33,958	1,346	32,612
95	96,857	11,374	8,297	3,077	93,780	28,515	906	27,609
96	96,857	21,452	8,855	12,597	84,260	23,945	3,114	20,831
97	96,857	11,374	17,389	−6,015	102,872	20,107	−1,249	21,356
98	96,857	11,374	9,804	1,570	95,287	16,884	274	16,611
99	96,857	11,374	10,091	1,283	95,574	14,178	188	13,990
2000	96,857	11,374	10,379	995	95,862	11,906	122	11,783
1	96,857	90,754	10,667	80,087	16,770	9,997	8,266	1,731
2	96,857	11,374	18,913	−7,539	104,396	8,395	−653	9,048
3	96,857	11,374	11,141	233	96,624	7,049	17	7,033
4	96,857	11,374	275,013	−263,639	360,496	5,920	−16,113	22,032
5	96,857	11,374	11,412	−38	96,895	4,971	−2	4,973
6	96,857	23,336	11,615	11,721	85,136	4,174	505	3,669
7	96,857	11,374	19,861	−8,487	105,344	3,505	−307	3,812
8	96,857	11,374	11,988	−614	97,471	2,943	−19	2,962
9	96,857	11,374	12,174	−800	97,657	2,472	−20	2,492
2010	96,857	11,374	12,360	−986	97,843	2,075	−21	2,097
11	96,857	90,754	12,648	78,106	18,751	1,743	1,405	337
12	96,857	11,374	20,708	−9,334	106,191	1,463	−141	1,604
13	96,857	11,374	12,648	−1,274	98,131	1,229	−16	1,245
14	96,857	11,374	12,648	−1,274	98,131	1,032	−14	1,045
15	96,857	11,374	12,648	−1,274	98,131	867	−11	878
16	96,857	28,009	12,648	15,361	81,496	728	115	612
17	96,857	−10,888	3,129	−14,017	110,874	611	−88	699
Total	2,566,711	1,208,378	864,091	344,287	2,222,424	325,940	325,940	0

Table M-3 Calculation of the EIRR

Case EC The ship costs decrease by 29%

EIRR = 17.6%

(Unit: '000 Colones)

Year	Benefits	Costs			Benefits −Costs	Present Value in 1988		
		With Case	Without Case	Net Cost		Benefits	Net Costs	Benefits −Net Costs
1988	–	83,163	–	83,163	-83,163	–	83,163	-83,163
89	–	259,725	276,723	-16,998	16,998	–	-14,457	14,457
90	–	288,167	4,402	283,765	-283,765	–	205,274	-205,274
91	44,176	106,426	4,978	101,448	-57,272	27,180	62,418	-35,238
92	88,352	11,374	16,830	-5,456	93,808	46,235	-2,855	49,090
93	88,352	11,374	6,587	4,787	83,565	39,324	2,131	37,193
94	88,352	11,374	7,535	3,839	84,513	33,446	1,453	31,993
95	88,352	11,374	8,297	3,077	85,275	28,447	991	27,456
96	88,352	21,452	8,855	12,597	75,755	24,195	3,450	20,745
97	88,352	11,374	17,389	-6,015	94,367	20,578	-1,401	21,979
98	88,352	11,374	9,804	1,570	86,782	17,502	311	17,191
99	88,352	11,374	10,091	1,283	87,069	14,886	216	14,670
2000	88,352	11,374	10,379	995	87,357	12,661	143	12,519
1	88,352	90,754	10,667	80,087	8,265	10,769	9,761	1,007
2	88,352	11,374	18,913	-7,539	95,891	9,159	-782	9,941
3	88,352	11,374	11,141	233	88,119	7,790	21	7,769
4	88,352	11,374	275,013	-263,639	351,991	6,626	-19,770	26,396
5	88,352	11,374	11,412	-38	88,390	5,635	-2	5,638
6	88,352	23,336	11,615	11,721	76,631	4,793	636	4,157
7	88,352	11,374	19,861	-8,487	96,839	4,076	-392	4,468
8	88,352	11,374	11,988	-614	88,966	3,467	-24	3,491
9	88,352	11,374	12,174	-800	89,152	2,949	-27	2,976
2010	88,352	11,374	12,360	-986	89,338	2,508	-28	2,536
11	88,352	90,754	12,648	78,106	10,246	2,133	1,886	247
12	88,352	11,374	20,708	-9,334	97,686	1,814	-192	2,006
13	88,352	11,374	12,648	-1,274	89,626	1,543	-22	1,565
14	88,352	11,374	12,648	-1,274	89,626	1,313	-19	1,331
15	88,352	11,374	12,648	-1,274	89,626	1,116	-16	1,132
16	88,352	28,009	12,648	15,361	72,991	949	165	784
17	88,352	-10,888	3,129	-14,017	102,369	808	-128	936
Total	2,341,328	1,208,378	864,091	344,287	1,997,041	331,902	331,902	0

APPENDIX 14 FIRR CALCULATION FOR SENSITIVITY ANALYSIS

Sensitivity analysis is made for three cases as follows :

(1) the port tariff revenues decrease by 10% (Case FA),

(2) the construction costs increase by 10% (Case FB),

(3) the revenues decrease by 10% and the costs increase by 10% simultaneously (Case FC).

The FIRR is calculated for each of the 3 simulation cases. The results are shown in Table M—1~Table M—3.

Table M-1 Calculation of the FIRR

Case FA The case in which the port tariff revenues decrease by 10%

FIRR=6.35%

Unit : '000 Colones

Year	Cost[1]	Benefit	Benefit −Cost	Present Value in 1988		
				Cost	Benefit	Benefit−Cost
1988						
89						
90	233,952		−233,952	206,864		−206,864
91	300,720	33,701	−267,019	250,034	28,021	−222,013
92	20,078	67,402	47,324	15,698	52,697	37,000
93	20,078	67,402	47,324	14,761	49,553	34,792
94	20,078	67,402	47,324	13,880	46,596	32,716
95	20,078	67,402	47,324	13,052	43,815	30,763
96	20,078	67,402	47,324	12,273	41,201	28,928
97	20,078	67,402	47,324	11,541	38,742	27,201
98	20,078	67,402	47,324	10,852	36,430	25,578
99	20,078	67,402	47,324	10,204	34,256	24,052
2000	20,078	67,402	47,324	9,595	32,212	22,617
01	89,380	67,402	−21,978	40,167	30,290	−9,877
02	20,078	67,402	47,324	8,484	28,482	19,998
03	20,078	67,402	47,324	7,978	26,783	18,805
04	20,078	67,402	47,324	7,502	25,185	17,682
05	20,078	67,402	47,324	7,054	23,682	16,627
06	21,962	67,402	45,402	7,256	22,269	15,013
07	20,078	67,402	47,324	6,238	20,940	14,702
08	20,078	67,402	47,324	5,865	19,690	13,825
09	20,078	67,402	47,324	5,515	18,515	13,000
10	20,078	67,402	47,324	5,186	17,410	12,224
11	258,073	67,402	−190,671	62,684	16,371	−46,312
12	20,078	67,402	47,324	4,586	15,384	10,809
13	20,078	67,402	47,324	4,312	14,476	10,164
14	20,078	67,402	47,324	4,055	13,612	9,557
15	20,078	67,402	47,324	3,813	12,800	8,987
16	20,078	67,402	47,324	3,585	12,036	8,451
17	−120,657	67,402	188,059	−20,260	11,318	31,578
Total	1,225,146	1,786,153	561,007	732,775	732,775	0

Note : 1) The costs include minus costs (benefits).

Table M-2 Calculation of the FIRR

Case FB The case in which the construction costs increase by 10%

FIRR=6.53%

Unit : '000 Colones

Year	Cost[1]	Benefit	Benefit −Cost	Present Value in 1988		
				Cost	Benefit	Benefit−Cost
1988						
89						
90	257,347		−257,347	226,786		−226,786
91	330,792	37,445	−293,347	273,653	30,977	−242,676
92	22,086	74,891	52,805	17,152	58,160	41,008
93	22,086	74,891	52,805	16,101	54,597	38,496
94	22,086	74,891	52,805	15,115	51,253	36,138
95	22,086	74,891	52,805	14,189	48,114	33,924
96	22,086	74,891	52,805	13,320	45,166	31,846
97	22,086	74,891	52,805	12,504	42,400	29,896
98	22,086	74,891	52,805	11,738	39,803	28,064
99	22,086	74,891	52,805	11,019	37,365	26,345
2000	22,086	74,891	52,805	10,344	35,076	24,732
01	98,318	74,891	−23,427	43,227	32,927	−10,300
02	22,086	74,891	52,805	9,116	30,910	21,795
03	22,086	74,891	52,805	8,557	29,017	20,460
04	22,086	74,891	52,805	8,033	27,240	19,206
05	22,086	74,891	52,805	7,541	25,571	18,030
06	24,158	74,891	50,733	7,743	24,005	16,261
07	22,086	74,891	52,805	6,646	22,534	15,889
08	22,086	74,891	52,805	6,238	21,154	14,916
09	22,086	74,891	52,805	5,856	19,858	14,002
10	22,086	74,891	52,805	5,498	18,642	13,144
11	283,880	74,891	−208,989	66,335	17,500	−48,835
12	22,086	74,891	52,805	4,845	16,428	11,583
13	22,086	74,891	52,805	4,548	15,422	10,874
14	22,086	74,891	52,805	4,269	14,477	10,208
15	22,086	74,891	52,805	4,008	13,590	9,582
16	22,086	74,891	52,805	3,762	12,758	8,995
17	−132,723	74,891	207,614	−21,225	11,976	33,201
Total	1,347,664	1,984,611	636,947	796,920	796,920	0

Note : 1) The costs include minus costs (benefits).

Table M-3 Calculation of the FIRR

Case FC The case in which the revenues decrease by 10% and the costs increase by 10% simultaneously

FIRR=4.68%

Unit : '000 Colones

Year	Cost[1]	Benefit	Benefit −Cost	Present Value in 1988		
				Cost	Benefit	Benefit−Cost
1988						
89						
90	257,347		−257,347	234,854		−234,854
91	330,792	33,701	−297,091	288,385	29,381	−259,005
92	22,086	67,402	45,316	18,394	56,135	37,741
93	22,086	67,402	45,316	17,572	53,625	36,054
94	22,086	67,402	45,316	16,786	51,228	34,442
95	22,086	67,402	45,316	16,036	48,938	32,902
96	22,086	67,402	45,316	15,319	46,751	31,432
97	22,086	67,402	45,316	14,634	44,661	30,027
98	22,086	67,402	45,316	13,980	42,664	28,684
99	22,086	67,402	45,316	13,355	40,757	27,402
2000	22,086	67,402	45,316	12,758	38,935	26,177
01	98,318	67,402	−30,916	54,255	37,195	−17,061
02	22,086	67,402	45,316	11,643	35,532	23,889
03	22,086	67,402	45,316	11,123	33,944	22,821
04	22,086	67,402	45,316	10,625	32,427	21,801
05	22,086	67,402	45,316	10,150	30,977	20,827
06	24,158	67,402	43,244	10,606	29,592	18,986
07	22,086	67,402	45,316	9,263	28,270	19,006
08	22,086	67,402	45,316	8,849	27,006	18,157
09	22,086	67,402	45,316	8,454	25,799	17,345
10	22,086	67,402	45,316	8,076	24,645	16,570
11	283,880	67,402	−216,478	99,160	23,544	−75,617
12	22,086	67,402	45,316	7,370	22,491	15,121
13	22,086	67,402	45,316	7,040	21,486	14,446
14	22,086	67,402	45,316	6,726	20,526	13,800
15	22,086	67,402	45,316	6,425	19,608	13,183
16	22,086	67,402	45,316	6,138	18,731	12,594
17	−132,723	67,402	200,125	−35,236	17,894	53,130
Total	1,347,664	1,786,153	438,489	902,742	902,742	0

Note: 1) The costs include minus costs (benefits).