REPUBLIC OF COSTA RICA

REPORT ON FEASIBILITY STUDY OF EXTENSION AND CONSTRUCTION OF PUNTARENAS PORT

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REPUBLIC OF COSTA RICA

REPORT ON FEASIBILITY STUDY OF EXTENSION AND CONSTRUCTION OF PUNTARENAS PORT

FEBRUARY, 1973

OVERSEAS TECHNICAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

PREFACE

The government of Japan, in response to the request made by the Government of the Republic of Costa Rica, decided to undertake the feasibility study on the extension and construction of the Punt Arenas port and entrusted Overseas Technical Cooperation Agency (hereinafter referred to as OTCA) with the execution.

In order to exercise the assignment, OTCA, with the help of the Japanese Government and of its Agencies, organised the survey team consist of eight members headed by Mr. Shigeo Morimoto and sent it to the Republic of Costa Rica for a period of one month starting from October 28, 1972.

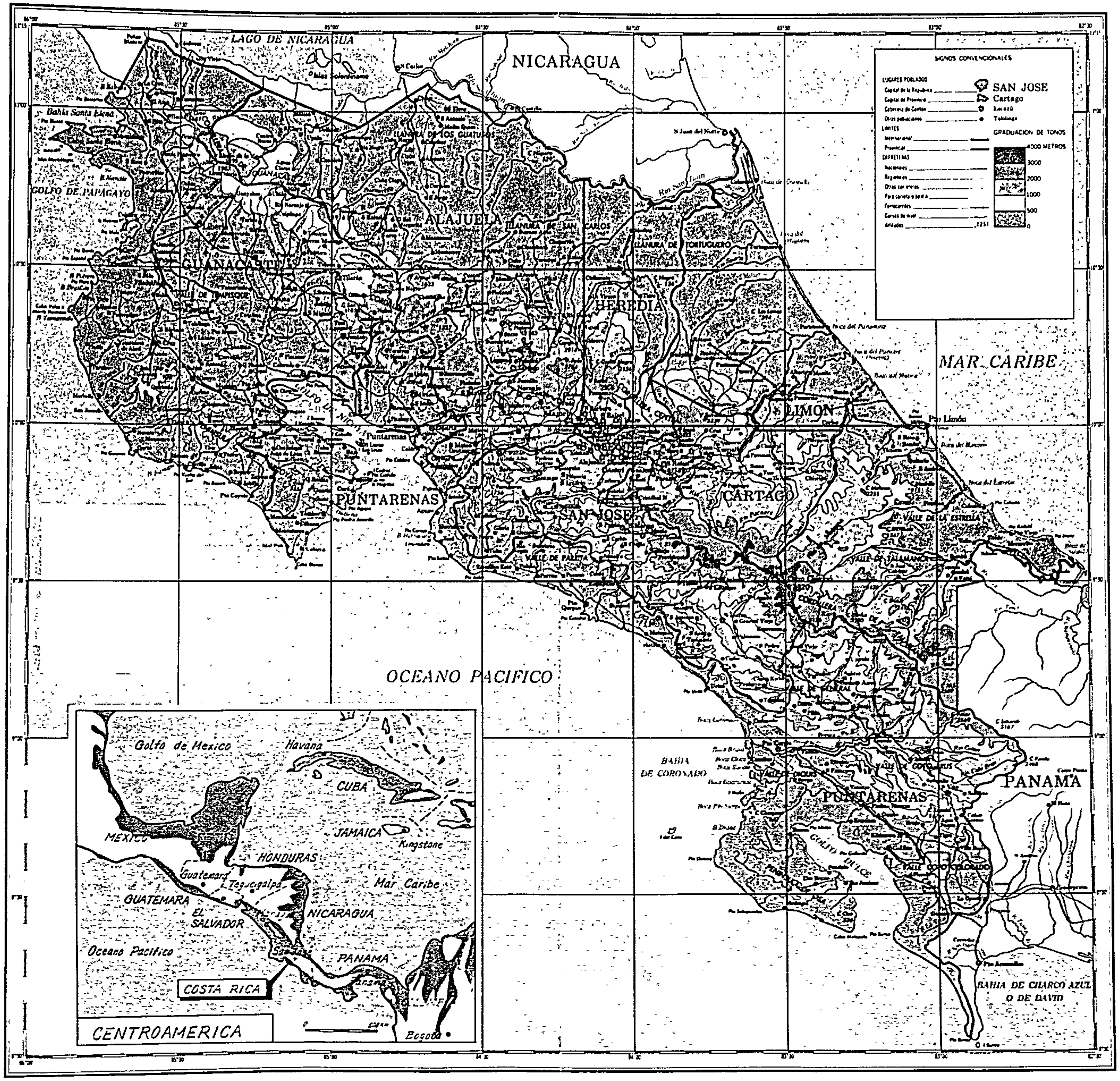
Under the kind and coadial auspices of the Costarican Government, the survey team could have made a very successful study, which enable the team to submit to the Government of Costa Rica the "Interim Report" on the basis of the results and findings during its stay in the country. Upon returning to Japan, the data and materials collected have been studied and analised in detail and the final report is now ready for presentation.

It is my pleasure if the report can be conducive to the promotion and fostering of the port construction and of the regional development in the country as well as of friendship between the Republic of Costa Rica and Japan.

Finally, I sincerely extend my deep appreciation and gratitude to the friendly and active cooperation provided by the Government of Costa Rica and the staff concerned and to the efforts made by the Japanese Embassy to the Costa Rica.

February 1973

Keiichi Tatsuke
Director General,
Overseas Technical Cooperation Agency


LAGO DE NICARAGUA
NICARAGUA
SIGNOS CONVENCIONALES
SAN JOSE
Cartago
GRADUACION DE TONOS
Bahia Santa Elena
GOLFO DE PAPAGAYO
ALAJUELA
LLANURA DE SAN CARLOS
LLANURA DE TORTUGUERO
GUANACASTE
HEREDIA
MAR CARIBE
LIMON
Pto Limón
Puntarenas
PUNTARENAS
CARTAGO
SAN JOSE
VALLE DE LA ESTRELLA
VALLE DE TALAMANCA
VALLE DE PARRITA
OCEANO PACIFICO
BAHIA DE CORONADO
PUNTARENAS
GOLFO DULCE
PANAMA
BAHIA DE CHARCO AZUL O DE DAVID
Golfo de Mexico
Havana
CUBA
MEXICO
JAMAICA
Kingstone
HONDURAS
Guatemala
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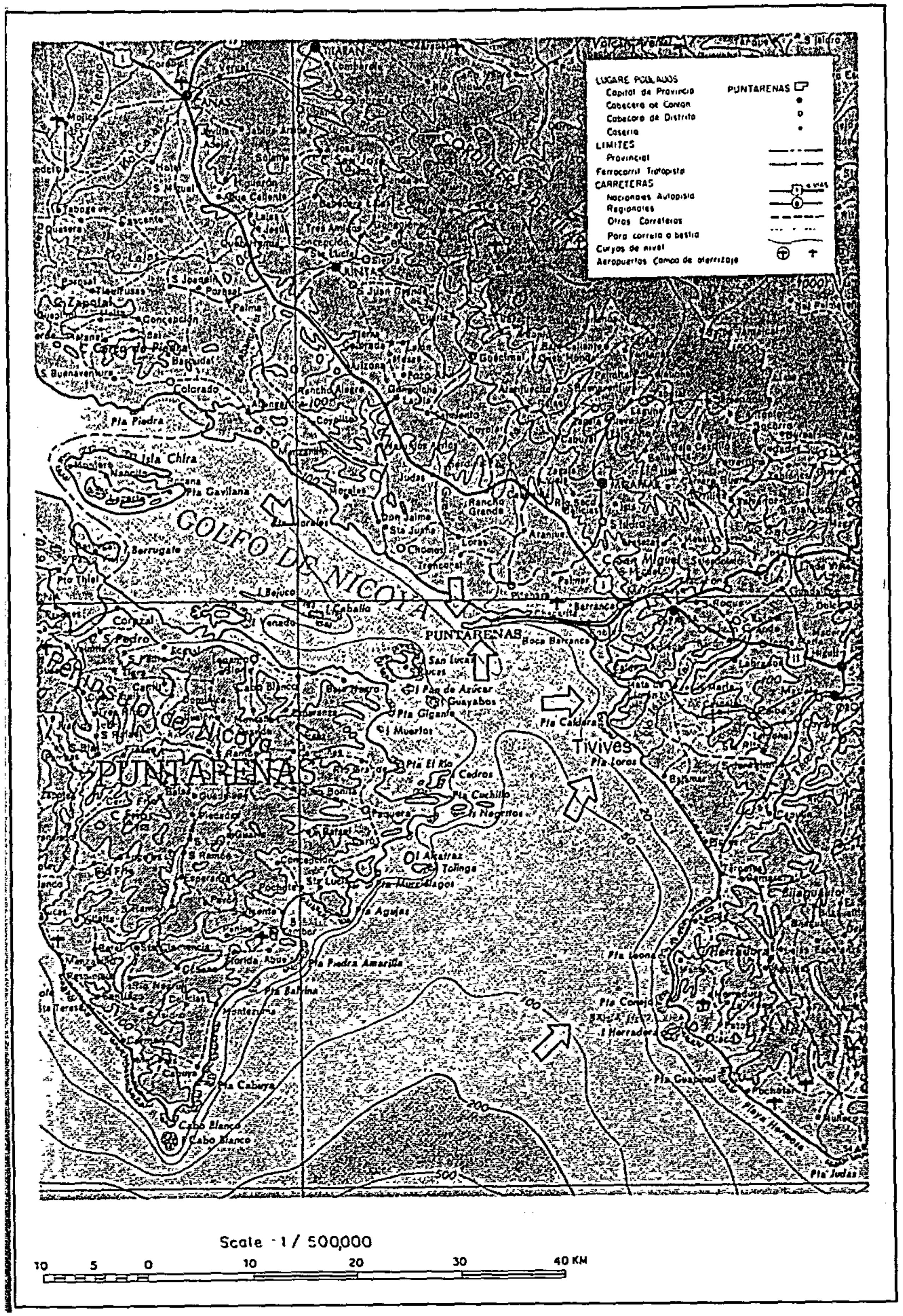
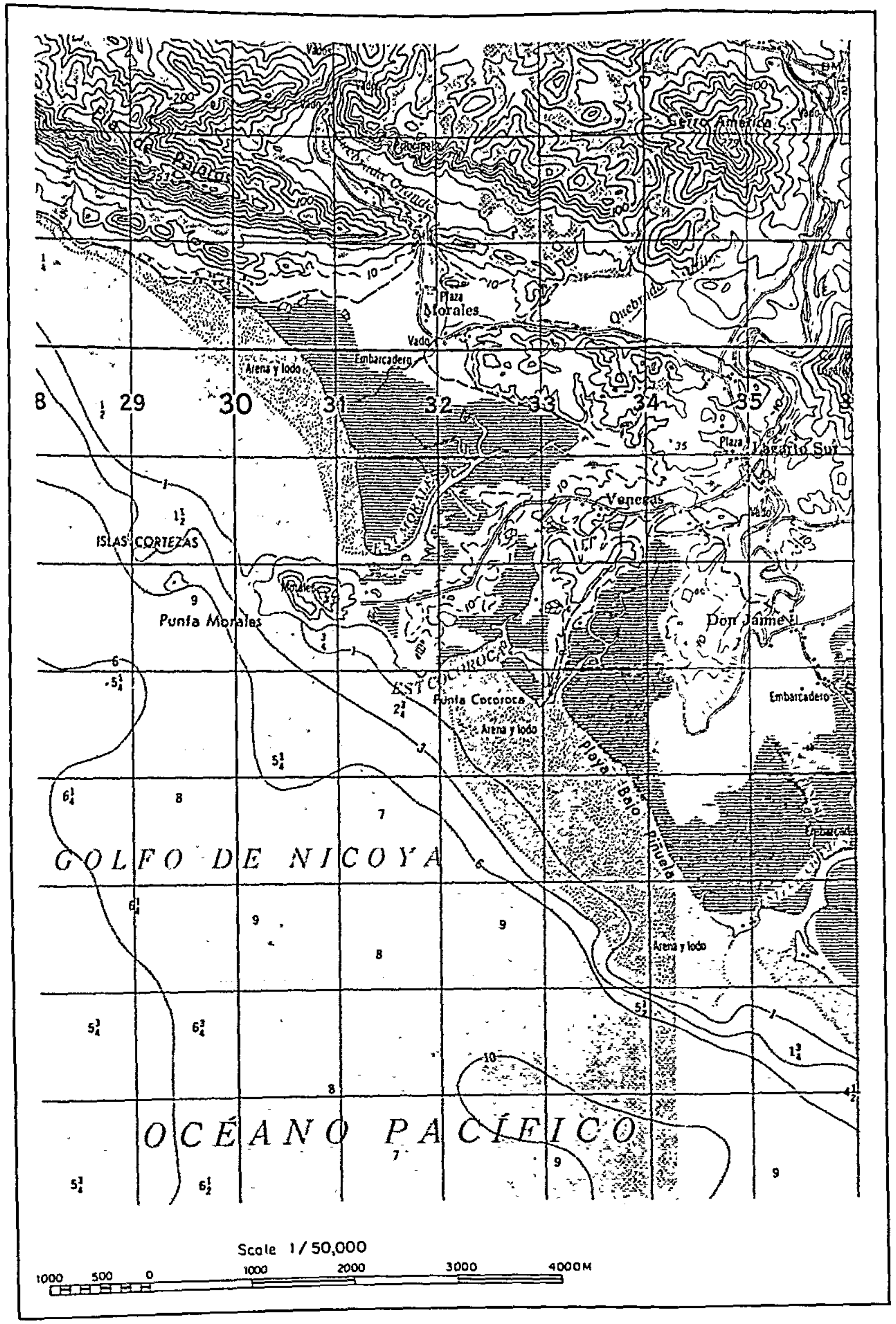
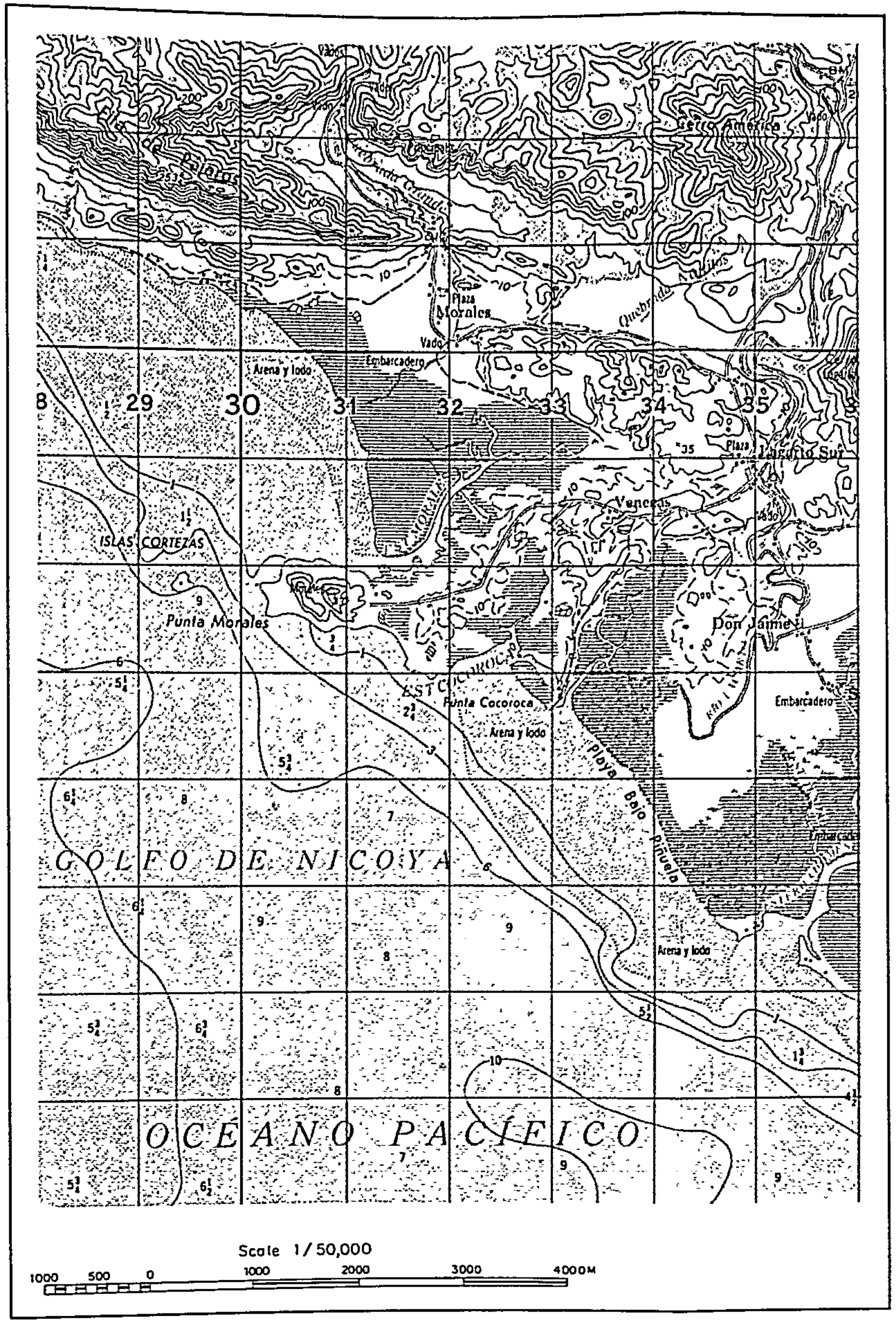


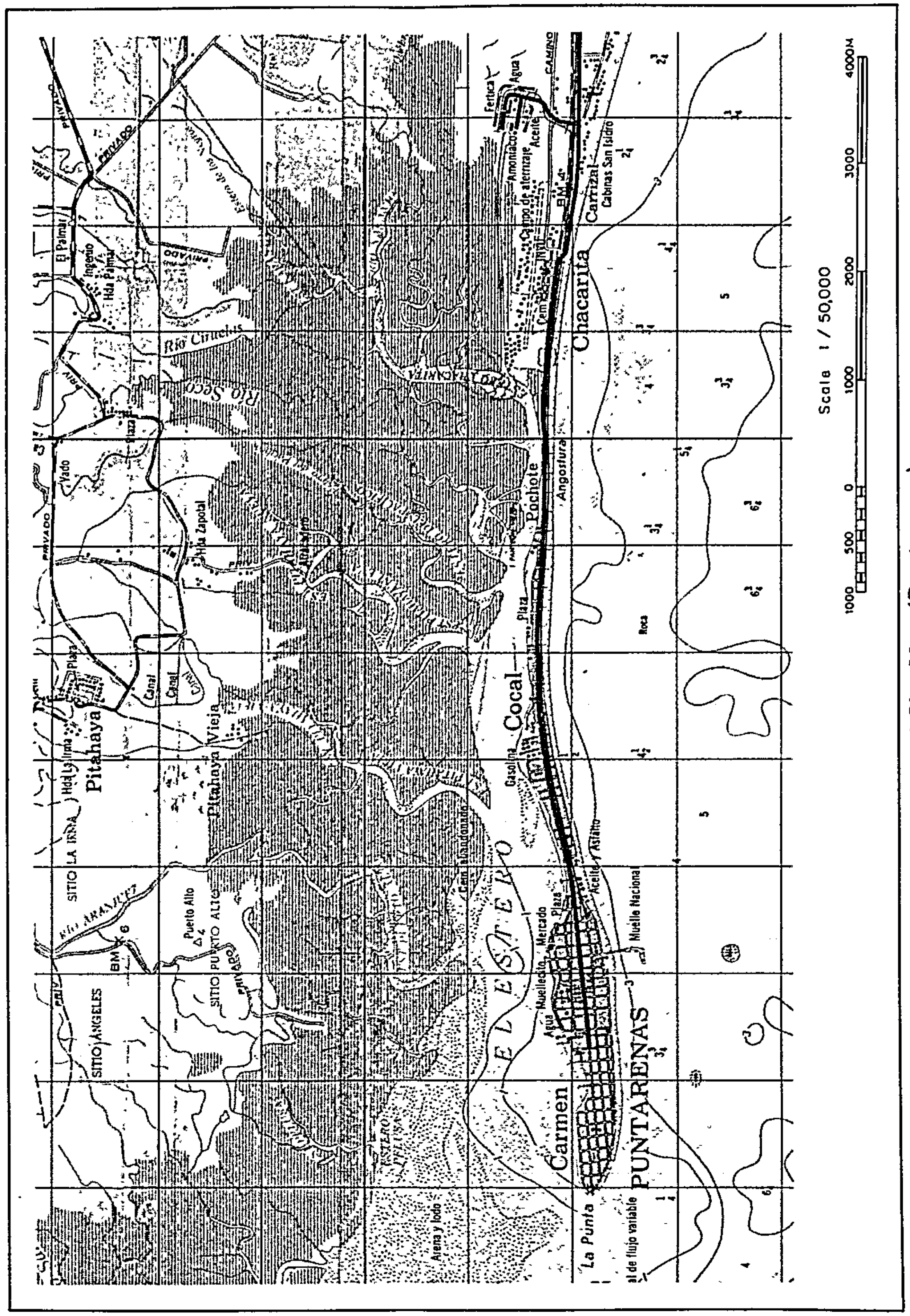
Location Map (Proposed Sites on Pacific Coast)



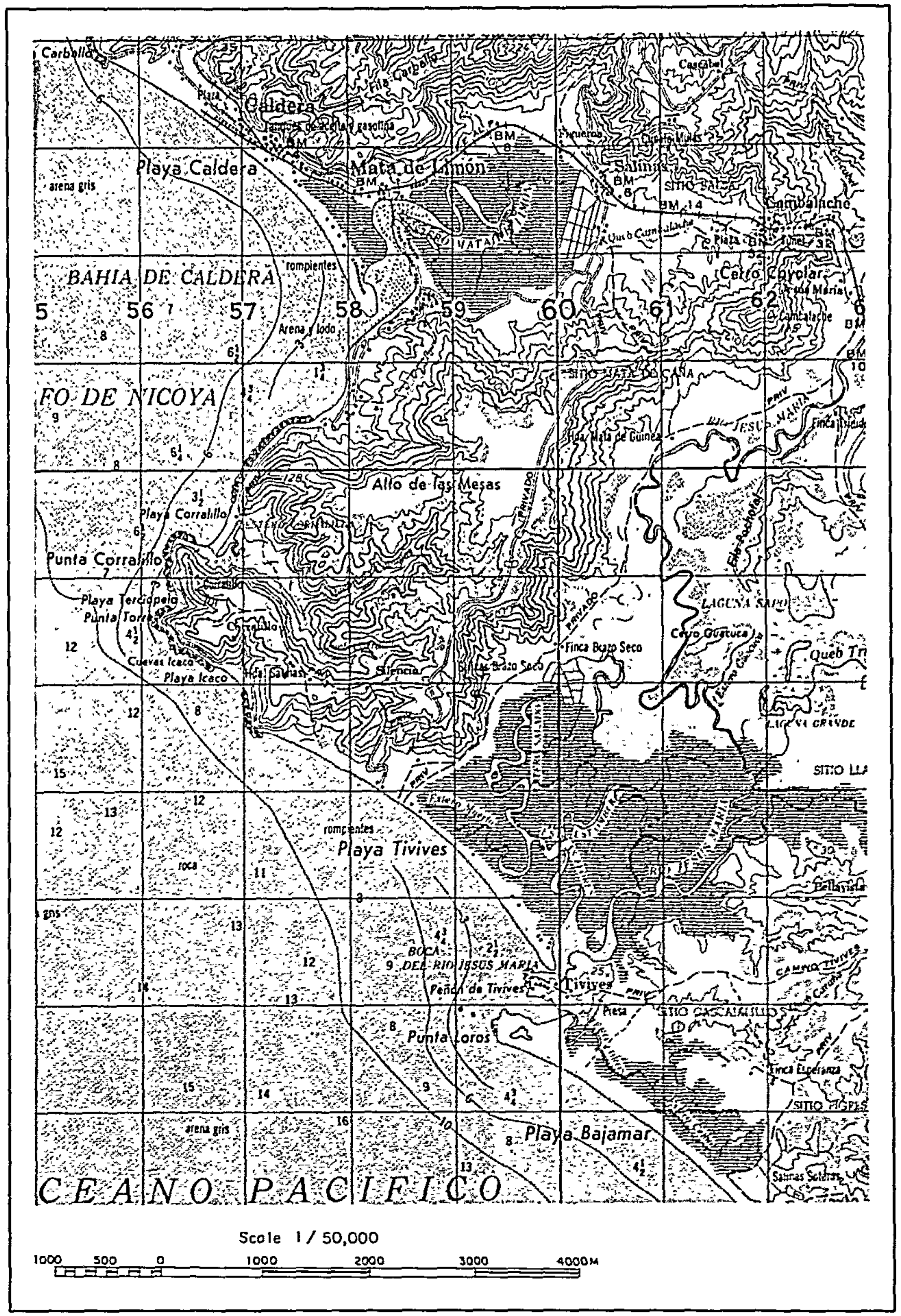
Proposed Site Map (Punta Morales)



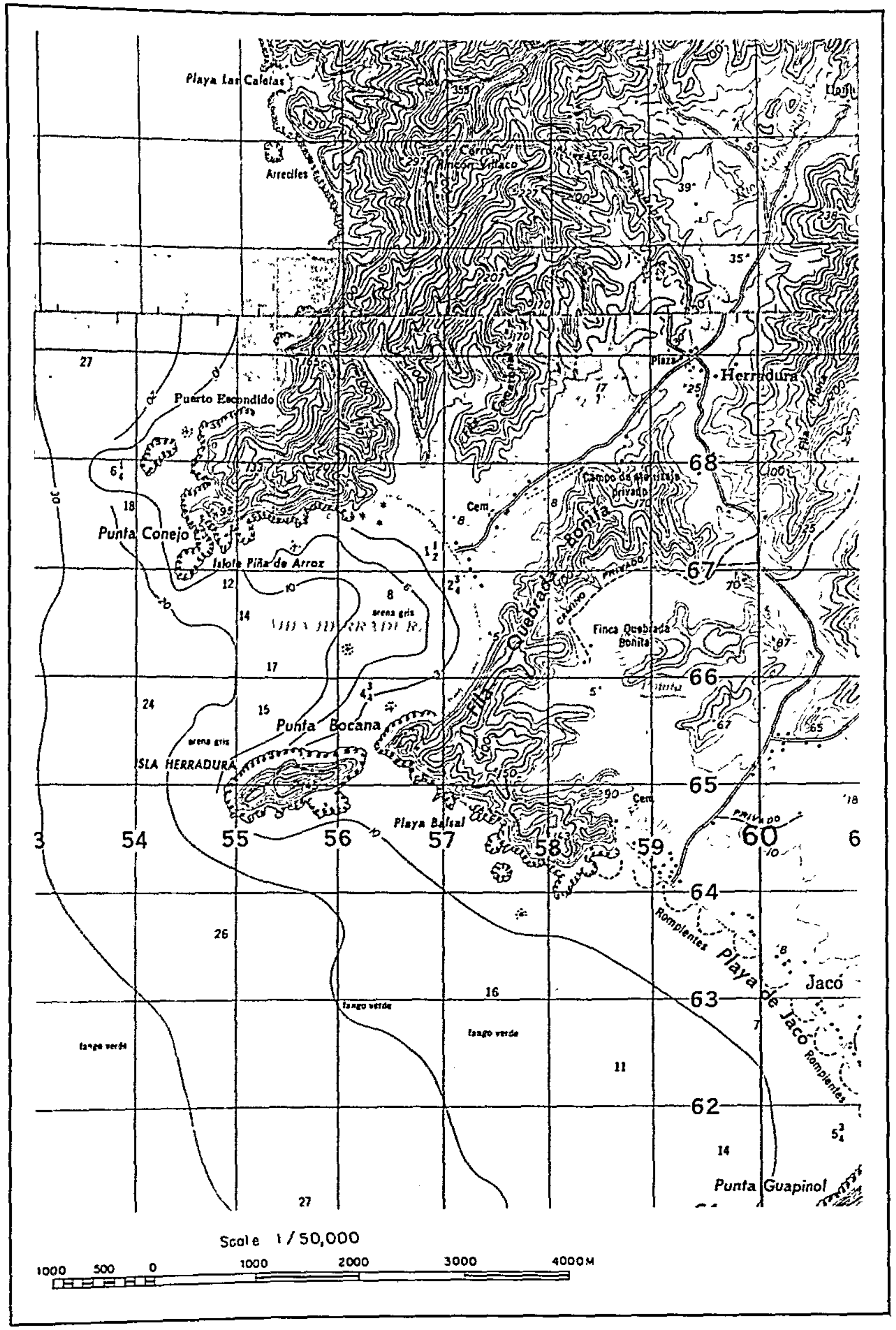
Proposed Site Map (Punta Morales)



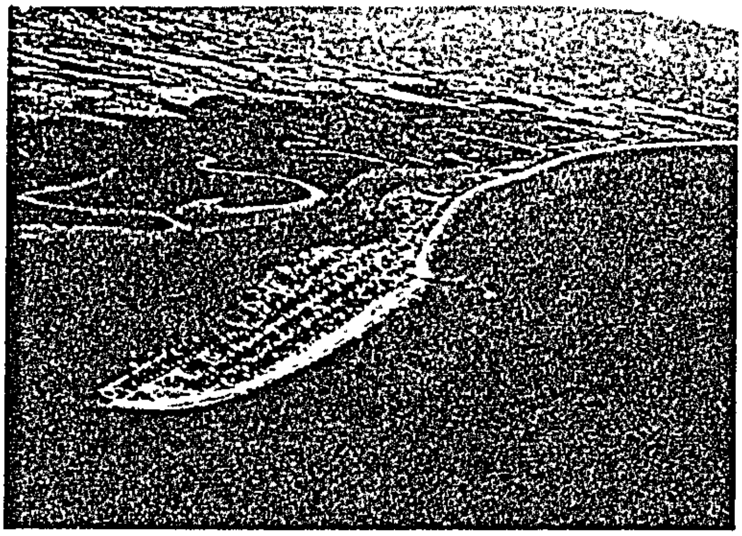
Proposed Site Map (Puntarenas)



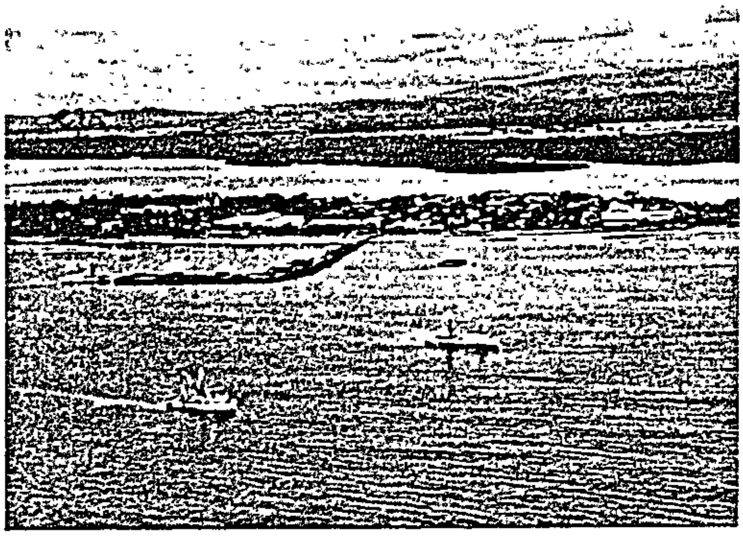
Proposed Site Map (Caldera, Tivives)



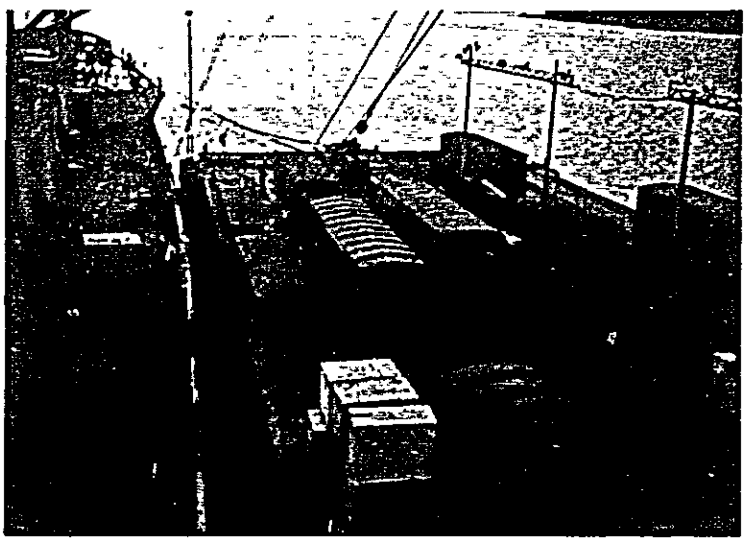
Proposed Site Map (Herradura)



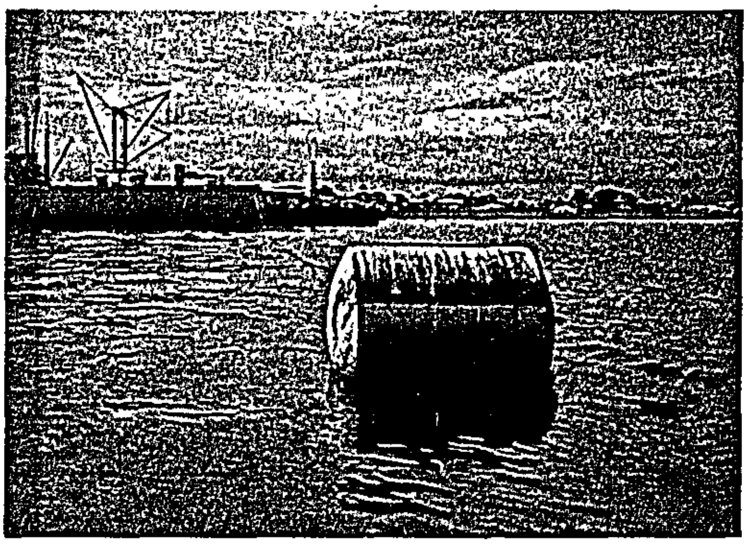
View of Puntarenas Sand Pit



Muelle Nacionál and City Area with El Estero District Area behind



Cargo Handling Work on Muelle Nacionál

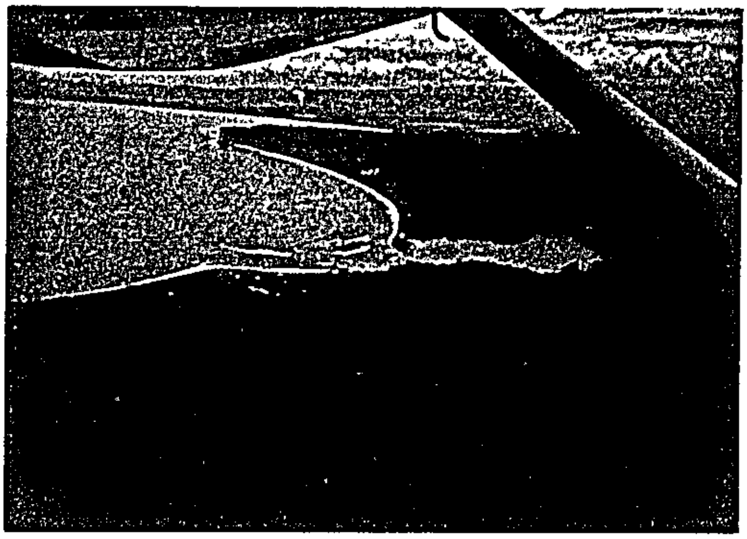


Off-shore Buoys for Mooring Vessels

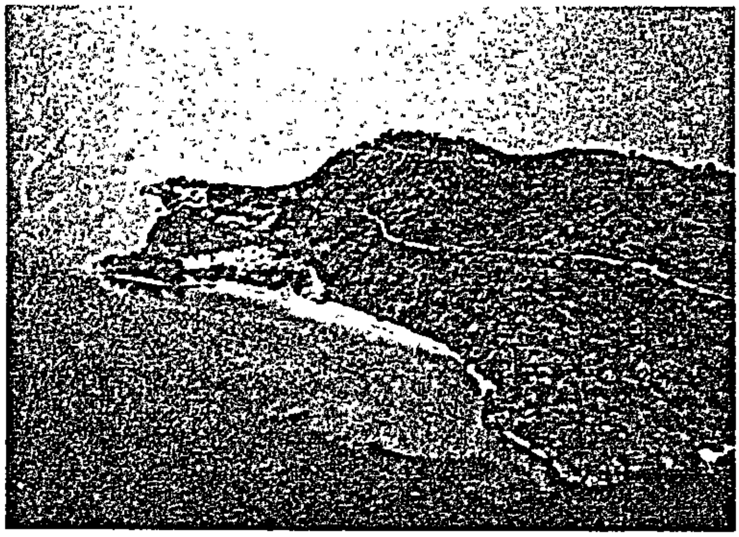
South Caldera (viewed from the west side)

South Caldera (viewed from the east side)

Proposed Construction Site at South Caldera

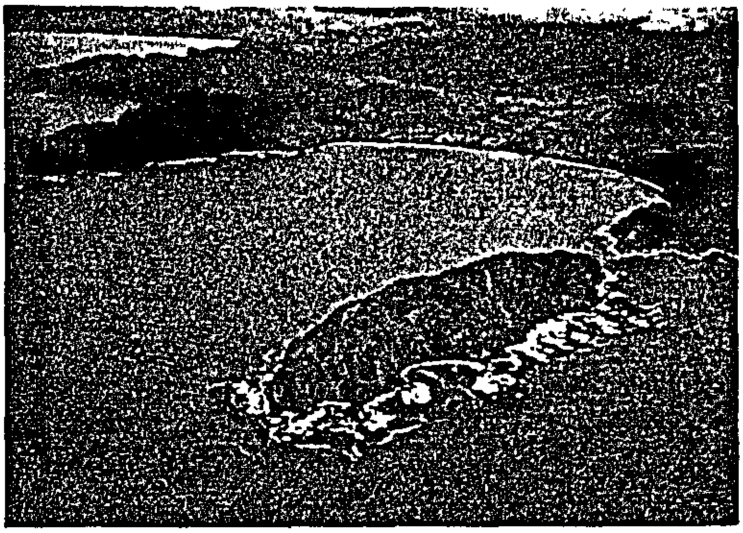


North Caldera

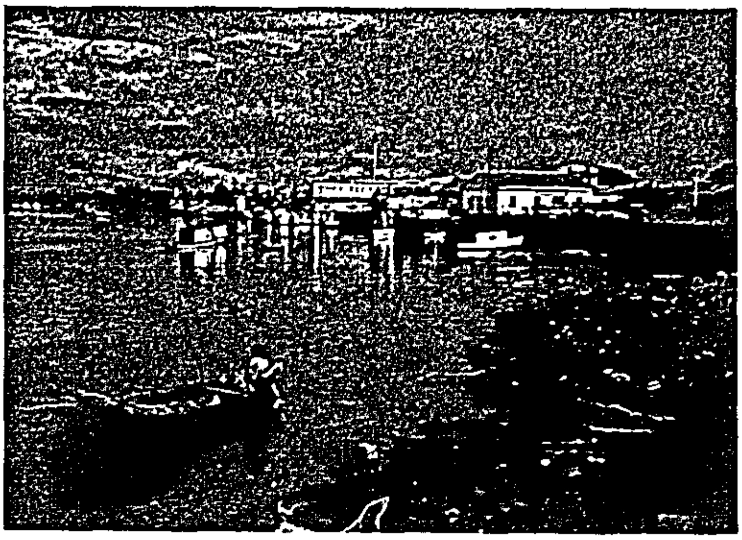


Punta Morales

Tivives



Herradura



Muelle Municipal

Limón Port

CONTENT

Page

List of Figures (Main Text)

List of Figures (Appendix)

SUMMARY

Chapter I Analysis of the State of the Port of Puntarenas

In Costa Rica the area extending from Meseta Central to the Pacific coast forms a main economic sphere where the population, industry and transport facilities are concentrated. The port of Puntarenas (Puerto de Puntarenas) is a port located closest to the capital city of San Jose and has been playing a major role as a gateway to this economic sphere. The cargo handled in the port in 1971 amounted to 633,000 tons reaching the capacity of the port and therefore, there is a pressing need for expansion of port facilities.

The cargo accounting for more than 60% of the total inbound and outbound cargo handled in the port of Puntarenas is transported through the Panama Canal. This is due to the fact that marine transport is more economical than land transport covering a long distance from the ports on the Atlantic coast even when the passage fee of the Panama Canal is taken into consideration. A sample calculation for the cargo bound for San Jose shows a difference of 18.43 colon per ton in the freight between sea-bound transport and land transport.

A survey of the Panama Canal conducted under such a circumstances has confirmed that both the passage fee and the traffic capacity of the canal cause no obstructions to the development of the port of Puntarenas. For the future planning of the port of Puntarenas, therefore, it is appropriate to recommend not only measures to counter the present situation but more comprehensive propositions including measures for the future expansion.

Chapter II Determination of Port Size

In consideration of the rate of economic, population and industrial growth of Costa Rica, it is anticipated that the volume of cargo handled in the port of Puntarenas in 1977 will amount to 1.09 million tons. This volume represents the cargo which is related directly to the people's life such as industrial products and foodstuffs. On the basis of this estimated cargo volume, construction of one berth of 10m in depth for the 15,000 D/W class vessels, two berths of 7.5m in depth for the 5,000 D/W class vessels and other related facilities by 1977 may be considered

Chapter III Natural Conditions on the East Coast of Gulf of Nicoya

In this chapter the topography, geology and climate around Puntarenas will be discussed in general. Then, attempts will be made to calculate wind waves and swells from the limited meteorological data available. Because of lack of meteorological data over a long period of time, it is almost impossible to determine the extreme value of incoming waves. For the present the swells with a significant wave height of about 3m will be assumed at the entrance of the gulf of Nicoya. Design wave for the proposed site will have to be calculated by taking into account the refraction and diffraction of waves in the gulf. For the maximum value of the waves generated by local wind in the gulf, a wave height of about 1m is to be adopted. Further efforts should be made to gather more meteorological data in this connection.

This chapter will also deal with the tide, tidal current, bottom materials, soil condition, earthquakes and tsunami. A design seismic coefficient of 0.1 is to be adopted. Judging from the available sounding on topographic maps compiled for a period of nearly a century and other various data the littoral drift is generally considered to be in the state of stability except for local and temporary transformation of beach observed in several locations.

Chapter IV Selection of Site for Port Construction

In consideration of socio and economic conditions in Costa Rica a site for the construction of a new port will be sought on the east coast of the Gulf of Nicoya and a total of seven alternative sites ranging from Punta Morales to Herradura will be selected for a comprehensive study of social and economic conditions and technical requirements. A summary of the findings is shown in Table S-1 below.

On the basis of the foregoing evaluation, South Caldera is considered best as a site for port construction. As an alternative, Punta Morales will be considered as a second choice.

Chapter V New Port Plan

A new port plan for South Caldera is shown in Fig. S-1. An alternative plan for Punta Morales is also shown in Fig. S-2. In the project planning special emphasis was placed on the materialization of modernized physical distribution and future expansion of the port facilities.

In the case of South Caldera,not only the construction of quays at the initial stage will be relatively easy but the expansion of facilities in stages in proportion to the development of the country will be possible. In the rear of the quay, cargo handling facilities, storage facilities and port transport facilities will be arranged appropriately. Construction of a 200m breakwater will ensure the calmness of the basin.

For Punta Morales, a plan of the same degree as for South Caldera may be considered,but the condition of the former is considered inferior to that of the latter in various requirements and there is little hope for the future development of Punta Morales.

For preliminary design of main port facilities, steel sheet pile construction will be adopted for quays and rubble construction will be adopted for the breakwater and revetments. Soil condition in South Caldera is considered favorable and therefore requires no further improvement while the soft silty stratum in Punta Morales requires improvement by removal and replacement.

Construction time is estimated to be four years beginning with the construction of the quay for vessel of 15,000 D/W and the initial operation aimed for September 1974. Construction cost is estimated at 139 million colon for South Caldera and 165 million colon for Punta Morales.

Chapter VI Cost-Benefit Analysis

A cost-benefit analysis will be made in order to determine the economic feasibility of the new port project. The project cost will include construction cost and maintenance cost and the benefit will include the mitigation of shipping congestion and congestion of cargo, savings of transport cost and the increase in the revenue of the port. With these cost and benefit and the presumed project life of 20 years, the internal rate of return is estimated to be 16. 0%, which fully justifies the feasibility of the project.

A trial calculation for the reduced plan with the number of berths limited to two gives 12. 3% of internal rate of return. This plan also justifies the feasibility of the project but is inferior to the original plan. This plan also involves serious problems such as inadaptability to the growth of port demand (see appendix 2).

Fig. S-1 Project Plan (For South Caldera)
Fig. S-2 Project Plan (For Punta Morales)

Conclusions and Recommendations

(1) As a result of a study made on the present state and possible future development of industry, economy and foreign trade of the Republic of Costa Rica, it is obvious that, in order to meet the ever increasing port demand in this country in which the economy has been growing at the annual rate of about 9%, it is essential to augment the port functions of the nation as soon as possible either by drastically expanding the existing port facilities or by constructing a new modernized efficient port.

(2) In consideration of the fact that the center of population, industry and land transport network leans toward the Pacific coast, that the future development is expected to point strongly to the Pacific coast, that the existing and future traffic capacity of the Panama Canal will cause no obstructions to the export and import trade via the Atlantic Ocean and that the sea transport cost of such import and export cargo even including the charge of the canal is lower than the land transport cost, the enhancement port functions must be aimed mainly for the Pacific coast. Judging from the present and the anticipated future development of the central district and the Pacific coast, the development of a port should be limited to the east coast of the Gulf of Nicoya between Punta Morales and Herradura Bay. As a result of a comparative study of the seven alternative sites including the improvement of the present port of Puntarenas, the southern coast of Caldera Bay is considered best as a site for new port construction.

(3) In order to meet port demand up to 1977, it is necessary to provide the proposed Caldera port with a series of facilities of the minimum requirement including such main facilities as three berths for large vessels (one berth of 10m in depth and two berths of 7. 5m in depth), a breakwater which protects the basin in front of the berth from the invading waves, sheds and warehouses and temporary storage of cargo and port traffic facilities by the end of 1976.

The project cost required for the above is estimated at 139 million colon at the price of November 1972 and the result of a cost-benefit analysis shows the internal rate of return of 16. 0%, which fully justifies the feasibility of the project.

(4) As a means to meet growing port demands expected after 1977, the proposed Caldera port leaves sufficient room for the future expansion and has a potentiality to grow as a world's leading port when the extensive development from the bay scale to the further south to the Tivives coast is taken into consideration. Besides, the proposed site has in the immediate hinterland a vast flat highland consisting of tertiary deposit where a comfortable and efficient port city may be planned in any form. Moreover, the proposed site occupies an important position which could easily become a pivotal point of inland transport network. In order to develop the proposed site as a base for generating the motive power for the prosperity of the nation by making the best of these various favorable conditions, intensive and systematic implementation of all related projects must be planned from a long-range point of view for the development of the country.

(5) Coordination with the existing industries already developing in and around Caldera Bay such as the tourist industry, fishery, stock-farming and petro cargo handling along with the progress of the new port project is very important. While the site suitable for the construction of a port and a port city is very limited in area there is much room for taking substitute measures for other industries In view of such a fact, it is important to secure a water front and land space sufficient enough for the construction of a port and a port city, as well as to take an immediate step to make adjustments or eradicate the root of trouble or elements which might be the cause of obstructions to the future development. For this purpose, a strong determination on the part of the government backed by the concensus of the people will be required.

(6) It cannot be said that the data on various natural conditions required for the construction of a new port is complete yet. For the time being, it is necessary to make a detailed study of the depth distribution of base rock and physical and mechanical properties of soils between the bottom materials and the base rock for the design of port facilities. It is also desirable to conduct a study of the same degree in the entire area including the bay and the surrounding area for the future planning. Observations of wave direction and wave height for the waves invading the bay are also desirable. Since the construction of the proposed port itself presents valuable data essential to the future expansion, various phenomena observed during construction must be analyzed and preserved carefully. Even during the construction period these data will be very useful for the revision of plans or for the improvement of construction methods required for the construction of a better port.

Introduction

1. Bakcground

The Government of the Republic of Costa Rica, in the belief that the construction of a new port on the Pacific coast is indispensable as a basis of the economic and social development of the country, has long been making a technical and economic study for the construction of a new port through its own surveys and investigations and through consultants firms from advanced countries. However, the findings so far have been short of providing any final conclusions.

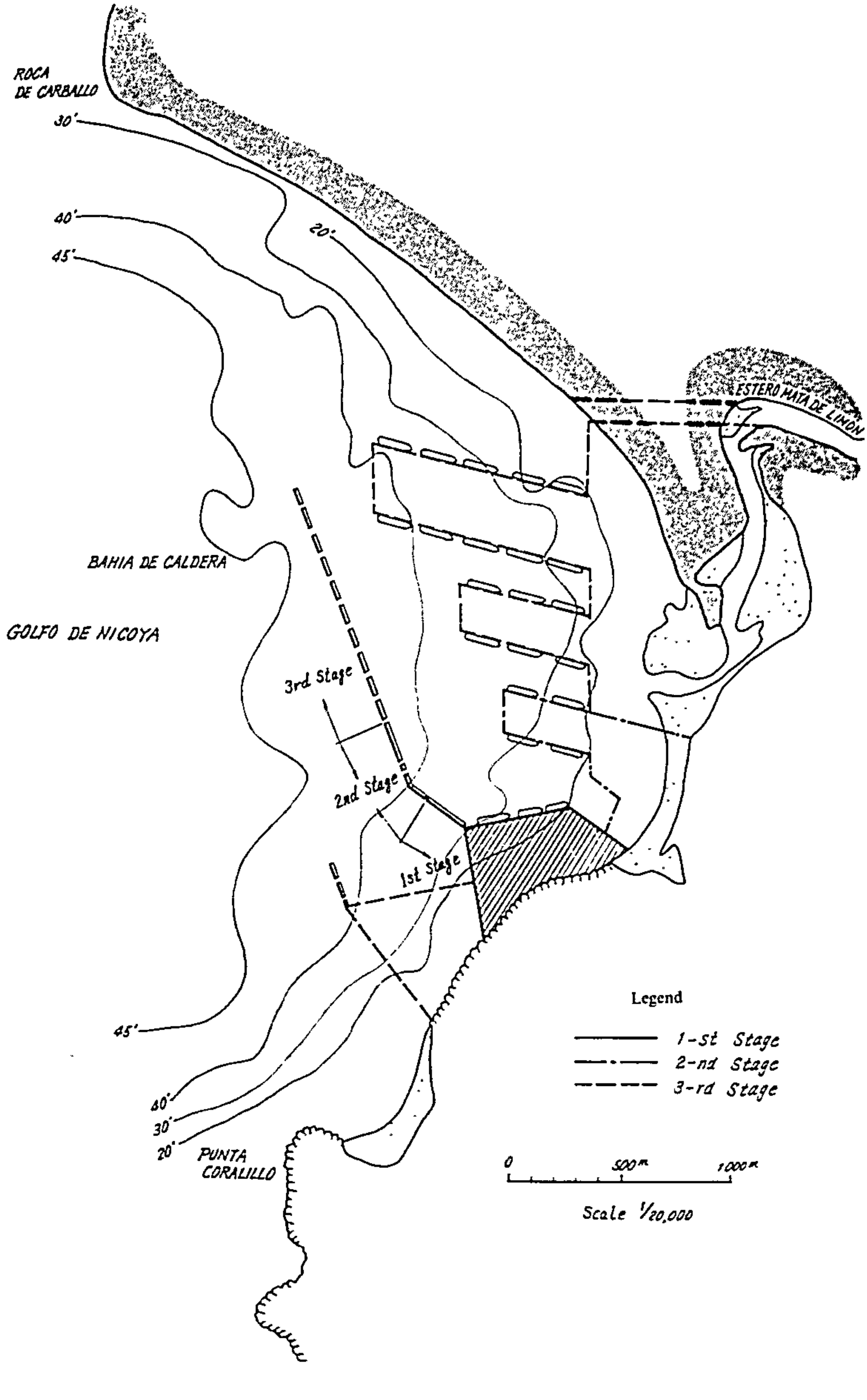


Fig. S-1 Ground Plan for South Caldera

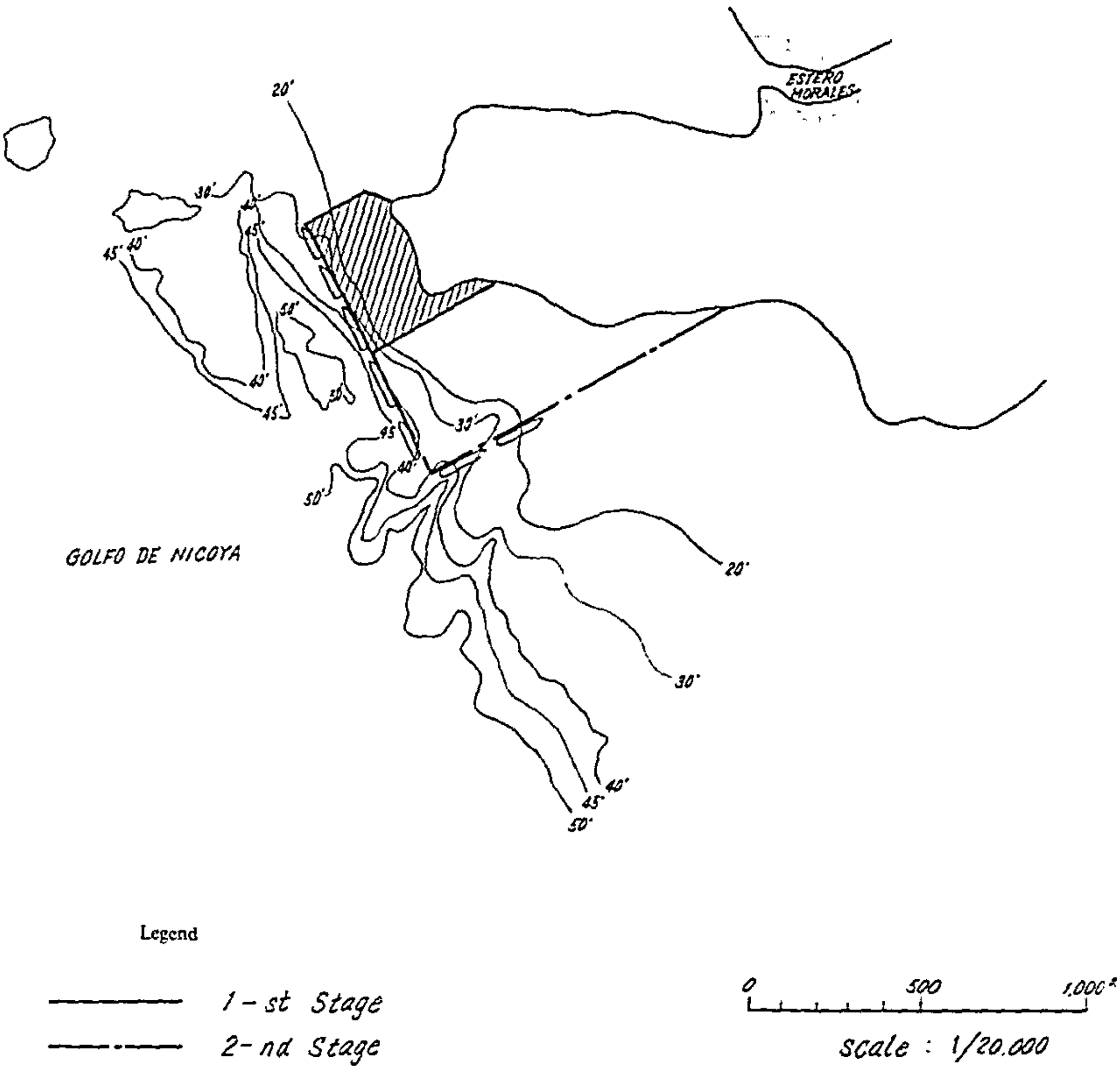


Fig. S-2 Ground Plan for Punta Morales

Under the circumstances, the Costa Rica government made a request to the Japanese government in 1971 to send a survey team to the country so as to put an end to this problem. In response to this request, the Japanese government sent the first survey team to Costa Rica in February 1972. This survey team pointed out problems of the existing conditions of Port of Puntarenas and recommended the basic plicy for the planning of a new port and provisional measures to be taken for port of Puntarenas. To finalize the project planning on the basis of this recommendation the Costa Rica government again requested the Japanese government to undertake a survey for the new port construction project for the Pacific coast.

Upon this, the Japanese government held consultations with the Costa Rica government in August 1972 on survey items, survey period and preparation of a survey report and decided to send a survey team for the economic development of Costa Rica in October 1972.

Implementation of the survey was entrusted to the Overseas Technical Cooporation Agency, an executive organ of the Japanese government.

2. Purpose and Scope of Survey

The purpose of this survey was to make final selection of a site and determine the size and facility arrangement for the new port construction project proposed by the Costa Rica government and to study the feasibility of the project through calculation of construction cost in compliance with the request of the same government.

For the purpose, surveys and studies were made mainly for the following.

1. Present state of Port of Puntarenas
2. Economic and social conditions in the hinterland.
3. Natural conditions and economic and social conditions in and around the proposed construction site.
4. Planning of port construction
5. Economic analysis of new port

3. Composition of Survey Team

	Name	Responsibility	Occupation
Head:	Shigeo Morimoto	Overall	Director-General, First District Port Construction Bureau, Ministry of Transport
Member:	Yoshiyuki Ito	Coastal engineering	Doctor of Engineering; Director, Hydraulic Division, Port and Harbour Research Institute, Ministry of Transport
Member:	Takeo Katayama	Port & Harbour construction	Head, Niigata Investigation and Design Office, First District Port Construction Bureau, Ministry of Transport

Member:	Shuhei Konno	Port planning	Deputy Director,Division of Waterfront Industrial Areas, Bu Bureau of Ports and Harbours, Ministry of Transport
Member:	Akio Someya	Transport economy	Deputy Chief, Planning Section, Second District Port Construction Bureau, Ministry of Transport
Member:	Kohei Nagai	Euvironmental conditions	Chief Researcher, Marine Hydrodynamics Division, Port and Harbour Research Institute, Ministry of Transport
Member:	Yasuaki Fujimori	Socio-economy	Chief, First Investigation Section, Planning Division Bureau of Ports and Harbours, Ministry of Transport
Member:	Hiroshi Maeda	Port and administration	Administrative Official, Administration Division, Bureau of Ports and Harbours, Ministry of Transport

(Occupations shown obove are those as of October - November, 1972, when the investigation was conducted.)

4. Itinarary of Survey Team

The field survey covering a period from October 28th to November 26th, 1972, included collection of data and information, reconnaisance and exchange of views with organizations concerned and a draft report of survey was submitted to the Costa Rica Government upon completion of the survey. The outline of itinerary of the survey team is as follows.

Date (1972)	Outline of Activities
Oct. 28 (Sat.)	The survey team departed from Tokyo.
Oct. 29 (Sun.)	The team arrived in San Jose (Costa Rica). Consultation was held with the Ambassador to Costa Rica and Secretary of embassy about the itinerary of the survey team and others, in a conference room of the airport.
Oct. 30 (Mon.)	After having paid a courtesy call at the Japanese Embassy and holding consultation again the team paid a courtesy call at the Ministry of Public Works and Transport, Government of the Republic of Costa Rica, and had a discussion on the details of the survey. Also, the team presented to the Ministry a list of data required by it and held consultation on the details of facilities to be rendered to the team.
Oct. 31 (Tue.)	After having collected data at the National Geographical Institute of the Costa Rican Government, the team left San Jose and moved to Puntarenas observing the state of affairs

on the way. Also, the team conducted a field survey travelling through the land and sea areas in and around the Port of Puntarenas and Punta Morales.

Nov. 1 (Wed.)	The team made aerial observation of Ponta Morales, Puntarenas, Caldera, Tivives and Herradura, all of which being the alternative sites for the construction of a new port, and their surrounding areas. In the afternoon, the team was divided into two groups, A and B. A group (Morimoto, Ito, Katayama and Nagai) surveyed Caldera and Tivives and their vicinities from the sea and B group (Konno, Someya, Fujimori and Maeda) investigated the present state of operation and administration of existing facilities at the Port of Puntarenas.
Nov. 2 (Thu.)	A group surveyed Caldera, the port of Puntarenas and their vicinities, while B group moved to San Jose where it collected data at the Ministry of Public Works and Transport and also conducted a field investigation of the present state of industrialization in and around San Jose.
Nov. 3 (Fri.)	A group, after having compiled data gathered by the field survey, moved to San Jose, while B group gathered data at the Ministry of Public Works and Transport and INCOP.
Nov. 4 (Sat.)	The team engaged in the compilation of data and information obtained from the organizations concerned and gathered by the field survey.
Nov. 5 (Sun.)	The team surveyed the economic and social conditions in and around Cartago, and had a pleasant talk with Mr. and Mrs. Vice President Aguiral at the foot of Volcan Irazu.
Nov. 6 (Mon.)	The team moved from San Jose to Limon while observing the vicinities of San Jose and the Port of Limon from the air. The team visited the Limon Port Authorities, heard the state of affairs and inspected the port of Limon.
Nov. 7 (Tue.)	After having investigated the vicinity of the Port of Limon the team returned to San Jose, gathered data at the Ministry of Public Works and Transport and others, and engaged in the analysis of data obtained.
Nov. 8 (Wed.)	The analysis of data was continued and along with it a request made again to the Ministry of Public Works and Transport for further cooperation for gathering necessary data. Also, consultation was held to consider the best course to deal with the inadequacy of data.
Nov. 9 (Thu.) ~ 11 (Sat.)	Morimoto, Konno and Someya moved to Panama and remained there until Nov. 11th to investigate the present state and prospects of the Panama Canal. Ito and Nagai moved to Puntarenas and remained there until Nov. 11th to make again field investigations of Punta Morales,

Herradura and other alternative sites for the construction of new port.
Katayama, Fujimori and Maeda stayed in San Jose to gather data at INCOP, Ministry of Agriculture and Stock-Farming, Economic Planning Agency, Tourist Institute and the Central Bank, etc.

Nov. 12 (Sun.) The team engaged in the analysis of data.

Nov. 13 (Mon.) The analysis of data was continued and arrangements were made as to the details of draft report.

Nov. 14 (Tue.) The analysis of data was continued.

Nov. 15 (Wed.) Morimoto and Ito conducted a field investigation again in Tivives. Other members continued the analysis of data.

Nov. 16 (Thu.) The analysis of data was continued and along with it the preparation of draft report of survey conducted. Also, the members discussed the findings of survey and their future activities.

Nov. 17 (Fri.) Arrangements were made with the Japanese Embassy as to the future activities of the team and the content of survey report, and as to the latter arrangements were made also with the Costa Rican Government.

Nov. 18 (Sat.) ~ Nov. 20 (Mon.) The preparation of manuscript of and the translation of report were conducted.

Nov. 21 (Tue.) The preparation of manuscript of and the translation of report were continued and along with them the printing of report was set about.

Nov. 22 (Wed.) The report was completed and submitted to the Costa Rican Government.

Nov. 23 (Thu.) The team paid a call at the Japanese Embassy to bid farewell to the Ambassador and the embassy staff. Also the team visited the Ministry of Public Works and Transport to express farewell and after that had a talk with the President of Costa Rica at his private residence.
Morimoto, Konno, Someya, Fujimori and Maeda departed from Costa Rica to return to Japan via Mexico.
Ito, Katayama and Nagai remained in Costa Rica to provide advices on the construction of breakwater at the Port of Limon.

Nov. 26 (Sun.) Morimoto, Konno, Someya, Fujimori and Maeda arrived in Tokyo. Ito, Katayama and Nagai departed from Costa Rica to return to Japan via Mexico.

Nov. 28 (Tue.) Ito, Katayama and Nagai arrived in Tokyo.

5. Acknowledgements

The survey team received kind cooperation and advices from many quarters in the course of its investigation works and expresses its sincere gratitude particularly to the following persons. (Honorific titles are not mentioned.)

Government of the Republic of Costa Rica:

Rodolfo Silva Vargas	Minister of Public Works and Transport
Leon Venegas Morens	Director, Bureau of Ports and Harbours, Ministry of Public Works and Transport
Olman Elizondo Morales	Ass't Director, Bureau of Ports and Harbours, Ministry of Public Works and Transport
Luis Guillermo Calderon Coto	Chief, Design Division, Bureau of Port and Harbour, Ministry of Public Works and Transport

INCOP:

Cludis J. Volio

Japanese Embassy in Costa Rica:

Tetsusaburo Hitomi	Ambassador
Katsuya Maehara	Secretary
Masateru Kakizaki	Consul
Yoshiharu Chibana	Staff
Toyoko Ito	Staff

Japanese residents in Costa Rica including:

Etsuyoshi Okamoto	(Nissho-Iwai Co., Ltd.)
Akio Saruwatari	(Mitsui & Co., Ltd.)
Kiyoji Tanaki	(Nissho-Iwai Co., Ltd.)
Yoshinao Tsujita	(Kanematsu-Gosho, Ltd.)
Kenji Nagaoka	(Mitsui & Co., Ltd.)
Toshihiko Fujiwara	(Kanematsu-Gosho, Ltd.)
Shiro Mukai	(Marubeni-Iida Co., Ltd.)

Also the survey team is sincerely thankful to the organizations shown below for special support and assistance extended to the team in the collection of data and in other matters in Costa Rica and Japan,

Government of the Republic of Costa Rica:

Ministerio de Agricultur y Ganaderia

Oficina de Planificacion

Servicio Meteorologico

Instituto Geografico Nacional

Banco Central de Costa Rica

Universidad de Costa Rica

Instituto Costarricense de Turismo

JAPDEVA (Junta de Administración Portuaria y de Desarrollo Economico de la Vertiente Atlántica)

Japanese Embassy in Panama

Panama Canal Company

Planning Department, Nippon Yusen Kaisha

Port and Harbour Project Office, Kawasaki Kisen Kaisha, Ltd.

M.S. Spain-maru (Kawasaki Kisen Kaisha, Ltd.)

Chapter I Analysis of Present State of the Port of Puntarenas

1. Present State of Port Facilities and Volume of Port Cargo

1.1 Outline of the Port of Puntarenas

The Republic of Costa Rica is situated in Central America bordering on the Republic of Nicaragua to the north and the Republic of Panama to the south. As the 10th parallel north latitude cuts across the central part of the country, the west coast facing the Pacific Ocean and the lowland on the east coast facing the Caribbean Sea are under the influence of tropical climate.

The lowland area on the Caribbean Sea coast is covered with vast tropical jungles. Because of the relatively mild climate on the highland, high density of population and development of cities are observed in Meseta Cental*. The main industry of Costa Rica is agriculture and stock-farming with main products being coffee, sugar, beef and banana.

The coastline on the Carribean Sea extends about 200 km and the Port of Limon (Puerto Limon) is situated almost in the center of this extension. On the Pacific coast the Peninsula of Nicoya (Pensinsula de Nicoya) and the Peninsula of Osa (Peninsula de Osa) shoot out into the sea forming the Gulf of Nicoya (Golfo de Nicoya) and the Gulf of Dulce (Golfo Dulce), and the total length of coastline is about 457 km. The Port of Puntarenas (Puerto de Puntarenas) is located almost at the central part of the Gulf of Nicoya and is closest to Meseta Central. The Port of Golfito (Puerto Golfito) in the Gulf of Dulce is a privately owned port and therefore has a nature different from that of the afore-mentioned two ports.

At the Port of Puntareans a total of 633,000 tons of cargo was handled and 426 vessels were called in 1971. The volume of import cargo amounted to 447,000 tons or about 70% of the total cargo handled in 1971, and the volume of export cargo was less than one half of that of import cargo, indicating that the port has excessive imports over exports. The volume of cargo has been increasing year after year since 1966 and the volume of cargo handled in 1971 increased about 1.7 times greater than that in 1968 and exceeded 561,000 tons over that in 1965, an alltime high of the past (Table 1.1).

The basis of the economy in Costa Rica takes the form of exporting coffee, sugar, banana and beef and importing industrial products, wheat and industrial raw materials, showing a trade structure that has excess of imports over exports. Reflecting such an economic structure of Costa Rica, main export cargo handled in the Port of Puntarenas consists mainly of coffee, sugar and beef and import cargo includes mainly industrial products (steel, automobiles, electric equipments, etc.), wheat, petroleum, chemical fertilizers and raw materials of chemical fertilizers. Since plantations of banana, one of the main products in Costa Rica, are concentrated around the Ports of Limon and Golfito, banana is handled mainly in these two ports and is not handled at the Port of Puntarenas. On this point, it may be said that the Ports of Puntarenas, Limon and Golfito have different natures with each other. Of these trade items handled at the Port of Puntarenas, the increase in the export of sugar, coffee and fertilizer and in the import of petroleum, wheat and industrial products is especially remarkable.

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* A proper name of the highland region with an altitude of 1,000 to 1,400m located in the central part of the country and may be called the Central Highland in English.

In general, the port handles a very small quantity of bulk cargo and may be said to handle mainly general cargo.

Main facilities of the Port of Puntarenas are the national pier (Muelle Nacional) consisting mainly of two berths for large vessels and the municipal pier (Muelle Municipal) comprising mainly small coastal ship facilities. The national pier extends from almost the center of the urban area of Puntarenas, at a point 2.3 km from La Punta (the head of the Peninsula) on the south side of the Peninsula of Puntarenas. The municipal pier faces El Estero on the north side of the Peninsula of Puntarenas and is located symmetrically with the national pier. Besides, there are some small craft berths on the side of El Estero in the eastern suburbs of Puntarenas.

The plane configuration of the national pier is in L-shape as shown in Fig. 11 and two berths for large vessels are provided at the points beyond the solid angle. The south berth has a length of 139.2m and a minimum depth of about 8.5m and the north berth has a length of 110.45m and a minimum depth of about 7.9m. These depths of water are still maintained despite the fact that no maintenance dredging has been performed in the past. Both of large berths are equipped with two buoys located some distance and special cables are used to moor vessels so that vessels may not come in direct contact with the pier. This arrangement is aimed at preventing contact of vessels with the pier by the rolling of vessels caused by inshore swells and vessels are generally moored with a clearance of about one meter from the pier. Part of the approach pier between the shore and the large berths is being widened for cargo handling by barge. The main pier has six railraod tracks and the small pier for barge cargo has one track. Freight cars are used for cargo handling.

This steel pile pier was constructed around 1929 and the designs of the large berth and the approach pier are shown in Fig. 1.2 and Fig. 1.3 respectively.

Since this pier is over 40 years old, corrosion of materials is excessive and some piles have even holes in them. For this reason, a survey was conducted in 1967 to examine the progress of corrosion. As a result, a plan was drawn up to repair 100 piles except those with a rate of corrosion less than 10% and with a smaller depth of corrosion. By the time of our survey, repair of 80 piles had been completed. The method used to repair piles was to cut off the portion with excess corrosions and replace it with a new steel pipe having the same length using a coupling shown in Fig. 1.4.

INCOP*, which has administrative jurisdiction over the pier, has drawn up a plan for the introduction of the trailer-truck system with the aim of increasing the cargo handling capacity of the pier and is now replacing wooden decks of the pier with T-shape beams or slabs of pre-cast concrete. This work is expected to be completed in 1973.

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* Abriviation of Instituto Costarricense de Puertos del Pacifico which had been under the control of Pacific Electric Railway (Ferrocarril Electrico al Pacifico) until March 1972 and was reorganized through revisions of the law to promote the national interest in ports and harbours and railways

1.2 Role of the Port of Puntarenas in Overall Transport System

The land transport system of Costa Rica consists of about 20,000 km of road and about 1,400 km of railroad. The trunk road is the Inter American Highway (Carretera Interamericana) which, in Costa Rica, starts in the northern border with Nicaragua, runs along the Pacific coast, passes through Meseta Central and the mountain area, runs again along the Pacific coast and reaches Panama. In Meseta Central there is a dense road network centering on the Inter American Highway and there is also a relatively improved road network on the Pacific coast. In contrast, the Carribean Sea coast, covered with extensive tropical jungles, has a very few roads and there is no complete rout opened between the capital city of San Jose and Limon, the largest city on the Carribean coast.

The main railroad lines in Costa Rica are INCOP between San Jose and Puntarenas and JAPDEVA* between San Jose and Limon. Besides, there are branch lines linking with Heredia and Alajuela and freight railroad lines aimed mainly for transporting banaba cargo booked in and around Limon and Golfito (Fig. 1.6).

Air routes are open to Puntarenas, Limon, Liberia and others from St. Maria International Airport (Aeropuerto Internacional de Santa Maria) located in the suburbs of San Jose.

For inland water transport, construction of a canal is under way on the Carribean coast with the improvement of a natural waterway along the coast, which is expected to provide a passage from the Port of Limon to San Juan River (Rio San Juan) near the border of Nicaragua in the near future. In such an event, navigation up to Lake Nicaragua (Lago de Nicaragua) located in southern Nicaragua will be possible.

Among these various transport systems, the Port of Puntarenas is closest to Meseta Central and is also in close proximity to the Inter American Highway (about 15 km). The capital city of San Jose is only 116 km apart from the port by electrified railroad and can be reached in three hours by express. There are three roads connecting the port with San Jose and the distance may be covered in about two hours if the shortest route is chosen.

Such a position of the Port of Puntarenas inevitably provides the port with the function of the front door of the economy of Costa Rica. The port of Limon has become a port handling exclusively the export of banana and the import of crude oil for oil refineries. The fact that cargos handled at the Port of Limon are entirely different from those at Puntarenas is probably characterized by the difference of their geographical locations.

Of the total cargo handled in the Port of Puntarenas, more than 60% are transported via the Panama Canal (Fig. 1.7). This fact is naturally understood in view of such factors as the geographical location of trading partners, the short distance from the port to Meseta Central, the center of the economy in Costa Rica, and the function bore by the port of Puntarenas. Besides, economic exchange is very active with the Pacific coast of North America and Asia (mainly Japan). All cargo with the exception of banana in the trade with the Pacific region is handled at the port of Puntarenas.

* abreviation of Junta de Administraction Portuaria y de Desarrollo Economico de la Vertiente Atlantica

Transportation of the bulk of cargo via the Panama Canal means that the Port of Puntarenas is under strong influence of the Canal. This influence may be considered for the present and the future. First of all,that the cargo is transported via the Panama Canal means the increase in sea freight including the charge of the Canal. However, if the land transport cost is lower than the increased sea freight, the total transport cost will be cheaper after all. The cargo transported via the Panama Canal and unloaded at the Port of Puntarenas is the proof that the present cargo transport pattern complies with this principle (Table 1. 2).

Secondly, there is a doubt that the annually increasing tonnage passing through the Panama Canal may prove an obstacle to the future management of the Port of Puntarenas. (Fig. 1. 8). For this reason, the survey team made a trip to Panama to gather and analyze various data on the Panama Canal. The team met with the top management of Panama Canal Company (Governor: Mr. David Stuart Parker and Comptroller: Mr. Philip L. Steers) and confirmed the following as a result of this meeting.

(1) While the tonnage that passes the Canal will continue to increase in the future and is expected to reach 168 million tons in 1985, the Canal will be capable to meet the demand for the time being in respect of the capacity.

(2) At present, the charge of 90 cents per ton is levied on all vessels using the Canal. The increase of the charge, if required in the future, will be limited to 25% in consideration of the cost required for the passage of the Strait of Magellan.

(3) A survey is being made for the planning of a second Panama Canal.

From the above facts, it has been concluded that the Panama Canal will exert little effect on the Port of Puntarenas in respect of economy (effect on sea freight) and the capacity of the Canal.

Formation of land transport system from now on will greatly contribute to the promotion of the economy and industry in Costa Rica. Improvement of road network is considered to bring about the change of the location of industry and warehouses from along the railroad to along the road. The largest road construction project under plan is the South Coast Highway (Carretera Costanera Sur) with a total length of about 222 km planned between Esparta and Palmar Norte (Fig. 1. 9). Upon completion, this road will not only contribute to the regional development on the Pacific coast south of Puntarenas but will also play the role of a bypass of the Inter American Highway. As a result, the Port of Puntarenas is expected to play a greater role.

With such transport systems as background, Costa Rica depends mainly on land transport for trade with Central American countries and marine transport for trade with other countries. Accordingly, marine transport accounts for about 90% of the total foreign trade of Costa Rica (Table 1. 3).

Costa Rica has an extreme excess of import at present and shows a pattern of a typical developing country that exports primary products and imports industrial products. It is not conceivable that the present trade structure will undergo a basic change in a short period of time. Progress of industrialization will probably be a conclusive factor for the improvement of this structure. In any event, trade volume will triple in ten years if the present growth rate continues in the future. While the USA has an overwhelmingly large share in both export and import to the present, trade volume with Central American, Asian and European countries is expected to increase in the future. It is obvious that,as a result, the role of the Port of Puntarenas will accordingly become more important.

1.3 Utilization of the Port of Puntarenas

Ships from various countries of the world call at the Port of Puntarenas (Table 1.4). Some of them come across the Pacific Ocean and, because of this, many large vessels call at the port (Table 1.5). Besides, it is understood that the size of ships calling at the port becomes greater year by year. The typical route on which large ships have been operating so far is the Central American West Coast - Japan route and the specifications of representative ships operating on this route are shown in Table 1.6. Spain Maru (registered in Japan), which has just been put on this route, is far greater than ships that have been operating on the route. Because of this fact and the limit of the capacities of ports' facilities in other countries on the Central American West Coast - Japan route, it is not likely that ships larger than her will be put on this route for the time being.

As for the operation of container ships, there is no definite plan for placing them on the route and a study will have to be made as a question for the West Coast of Central America as a whole.

The present wharf facilities of the Port of Puntarenas consist mainly of two berths for large vessels. The average berthing time per ship in 1970 was 115.05 hours and the total berthing time was 52,475 hours. Although some cargoes are handled by barge for vessels lying at anchor, the wharf facilities are being utilized at a higher rate. The average volume of cargo handled per hour is 10.34 tons and the working cargo handling capacity is estimated at about 10 tons per gang per hour.

Reasons for longer berthing time may be as follows.

(1) A complicated method is being used for mooring ships as a step to counter swells. As a result, a longer time is required from the time of entry to the time of berthing.

(2) Because of lack of tugboats, a longer time is required for berthing operation.

(3) Restrictions are imposed on cargo handling by natural conditions (swells, afternoon showers in the rainy season, etc.).

(4) As cargo is loaded and unloaded directly on freight cars, handling of the whole cargos from the wharf is impossible.

(5) Efficiency of cargo inspection is quite low.

(6) Insufficient facilities entails longer berth waiting time.

(7) It takes longer waiting time of cargo handling for a ship because of the greater distance between anchor berth and barge anchorage.

Despite such restrictive conditions stated above are fully recognized, the efforts of the port management in achieving the improvement of cargo handling efficiency year by year are conceivable. However, there should be a limit unless there are some changes in the existing facilities and ships.

Other ships and craft using the Port of Puntarenas include ferryboats plying between the port and the Peninsula of Nicoya, small craft on domestic route, fishing boats and pleasure boats. All of these ships and craft use the El Estero side of the Peninsula of Puntarenas and operate far from the national pier. However, part of cargo handled by barge is landed from facilities on the approach pier of the national pier and part is routed around La Punta and landed at the El Estero side.

2. Land Transport and Cargo Handling

2.1 State of Railroad and Road Facilities

Of the total length of more than 20,000 km of road in Costa Rica, paved and improved all weather roads have a length of only about 6,500 km, and many are unimproved roads which become inoperative during the rainy season (April ~ November). (Table 2.1 and 2.2).

Puntarenas is linked to the Inter American Highway (Corretera Interamericana) by the completely paved State Highway 17 at Barranca at the point about 15 km to the west of Puntarenas. Each of the three routes to the capital city of San Jose has a width of over 6 m and 2 ~ 4 lanes but has been disrupted at times due to fall of rocks and landslides in part of mountain region.

The Inter American Highway is completely paved and the road surface is almost in perfect condition.

The Peninsula of Nicoya (Peninsula de Nicoya), which is linked with the Port of Puntarenas (Puerto de Puntarenas) by ferry, has many unpaved roads but has State Highway 21 running lengthwise and connecting to Liberia, the central city in the northern part of the Pacific coast.

Within the city of Puntarenas, the roads that connect directly with port facilities are paved with a few exceptions but many cross the railroad at grade (Fig. 2.1). There is a clear distinction between travelled ways and sidewalks and traffic is not so heavy as to require signals at the intersection.

The railroad between San Jose and Puntarenas having a total length of 116 km is a single track line with 56 passenger stations and 20 freight stations (with spur tracks). The entire length except sidings is electrified and six passenger trains are operated every day. There are bridges spanning deep gorges and tunnel sections in between, and the railroad is very steep as a whole with the maximum slop of 34%. For this reason, the most powerful electric locomotive has the maximum traction force of 265 tons for the east bound train. (Table 2.3, Fig. 2.2 and Fig. 2.3). This line connects to the JAPDEVA line in the city of San Jose but there is no mutual train operation between the two lines since they are under different managements even though the same track gauge of 1,067 mm is used for both of them.

In addition to these land transport systems, there is a canal about 2.5 km in length extending from the mouth of Estero Chacarita and the operation of barges is possible up to Carrizal Fertica Amoniaco, the largest up to date fertilizer plant in Costa Rica.

2.2 Land Transport of Port Cargo

Transport routes of cargo handled in the Port of Puntarenas are shown in Fig. 2.4. The main route is the railroad route extending to the hinterland and it is assumed that approximately 70% of the total cargo is transported through this route (Table 2.4). Of the remaining 30%, two-thirds are presumed to be transported to and from Carrizal Fertica Amoniaco and one-third is presumed to be transported by truck.

Several reasons are conceivable for using the railroad as a chief means of transport in the hinterland.

Firstly, cargo handling in the Port of Puntarenas depends entirely on the railroad. For this reason, transport by truck involves comparatively higher freight because the cargo once warehoused has to be taken out for loading.

Secondly, major factories and warehouses, which are related to foreign countries in one way or another in respect of cargo transport, are located closer to the railroad and many of them have sidings for their exclusive use.

Thirdly, the railroad cuts through the center of economy and industry of Costa Rica and the factories located within the reach of three hours by railroad from the Port of Puntarenas account for more than 80% of the total factories in the country (Table 2.5) (Factories located along the railroad having a total length of 1,389 km account for 97% of the total factories).

As mentioned above, industry is located centering around the railroad and the characteristic of transport system is that ports and harbours are linked only with the railroad for cargo transport. In actuality, however, the delivery of cargo unloaded from the ship at the Port of Puntarenas to San Jose takes seven days at the earliest, 10 to 14 days on the average and 20 to 28 days at the latest. This delay in delivery of cargo is mainly due to the longer time required for various formalities before clearance and also due to inefficient cargo handling at the Port of Puntarenas and irrational transport systems in the hinterland. When the cargo is cleared in San Jose, delivery usually takes 2 or 3 extra days as compared with the case in which the cargo is cleared at the Port of Puntarenas and then delivered to San Jose.

2.3 Cargo Handling

Cargo handling at the Port of Puntarenas (Puerto de Puntarenas) is undertaken by INCOP single-handedly. A total of about 700 people are engaged in cargo handling, of which 522 people or more than 70% are day laborers (Table 2.6). The 24 hour cargo handling system is being employed. Straight time hours are 11 hours from 7 AM to noon and from 1 PM to 7 PM and overtime hours are five hours from 7 PM to midnight and from 1 AM to 5 AM. From 5 AM to 7 AM, noon to 1 PM and midnight to 1 AM are designated as rest time for meals and other purposes but can be utilized for overtime work hours.

Since the cargo handled is mainly general cargo, a gang of 24 people is generally organized— 12 on board and 12 on pier. A total of 9 gangs are usually available and there seems to impose no restrictions on cargo handling for the shortage of laborers as many day laborers are available.

Cargo handling capacity is estimated at about 10 ton/hr in terms of general cargo but the handling capacity of automobiles and steel materials exceeds this level.

The problem of cargo handling at the Port of Puntarenas may be seen in the environmental conditions and the characteristics of facilities rather than in longshoremen. As is generally common to all ports in Central American countries, this port is also unable to overcome natural elements such as the direct invasion of swells and are taking the following precautionery measures for berthing of ships.

(1) A clearance of about 3 feet is maintained between the ship and the pier to allow room for the rolling of the ship.

(2) Mooring of one side of a ship to a buoy located 480 ft. from the berth and to a buoy located 700 ft. from the berth with long ropes minimizes motion of the ship.

(3) A net is stretched between the ship and the pier to prevent accidents.

(4) The gangway ladder is not used in some cases since the rolling of the ship and the freight car may obstruct its use.

(5) Large fenders and special mooring ropes are provided.

However, the above-mentioned measures do not eliminate the problem completely in the port where no preventative measures could be taken against the swell and,as a result, the following adverse situations are observed in respect of cargo handling.

(1) Berthing operation for a large ship requires about two hours, thereby causing a great time loss.

(2) Oscillation of ships decreases the efficiency of cargo handling greatly. Solution of this problem alone will increase the efficiency in handling general cargo to 15 ton/hr.

(3) Oscillation of ships is considered to be a major cause of accidents involving workers, damage to cargo and fall of cargo into the sea.

Besides, the afternoon shower in the rainy season and strong sunlight are also aggravating working conditions. However, the most serious problem with the existing cargo handling method will probably be the fact that cargo handling depends entirely on freight cars on the narrow pier. The basic pattern of the present cargo handling is to turn over the cargo for inspection in the hold while hoisting it with a derick crane, unload it once on the flatcar waiting on the front track on the pier and then load it on the freight car parked on the second track (Fig. 2. 5). Therefore, longshoremen have to be assigned to both the flatcar and the freight car and the derick crane is operated with the speed of loading of cargo on the freight car. Upon completion of loading a car (18 ton-car, 20 ton-car and 25 ton-car are available), all works have to be suspended during the shunting of freight cars. The flatcar and the freight car are parked to the position of the hatch of the ship. However, there is no crossover between the second track and the third track and the shunting must be made after the last car is loaded even when the unloading from all the hatches is started simultaneously. Therefore, all the freight cars brought out are led to the warehouse track for sorting of cargo.

This pattern of cargo handling is compared with other patterns as follows:

Port of Puntarenas: Flatcar ⟶ Freight car ⟶ Warehouse ⟶ Freight car,

Other ports: ⟶ Apron ⟶ Forklift ⟶ Shed ⟶ Truck or freight car

While efforts are being made to improve the present pier so as to provide an access to trucks, the existing facilities and cargo handling method will see a limit eventually.

3. Suitability as a Port City

Puntarenas had a population of 31,880 (within city limit) in 1971 and is the fourth largest city in Costa Rica following San Jose, Alajuela and Heredia in respect of population density.

Functional division of regional structure is developing in the city of Puntarenas under the influence of the arrangement of various city facilities (ports and harbours, fishing ports, roads, railroad, beaches as health resorts, etc.) and is possible fairly distinctly (Fig. 3. 1).

Industrial basis of Puntarenas may be said to include a function as a commercial city being the center of the Pacific coast region, a function as a fishing town centering on the fishing port, and a function as the largest sea resort town in Costa Rica. Although the city is the center of administration in the Province of Puntarenas (Provincia de Puntarenas) its role as the administrative center is considered insignificant in Costa Rica where local governments have limited executive authority and therefore does not seem to play a major role in the concentration of city functions. Besides, there are lumber yards, shipyards and food processing plants in the city and fertilizer plants and flour-mills here and there in the outlying area.

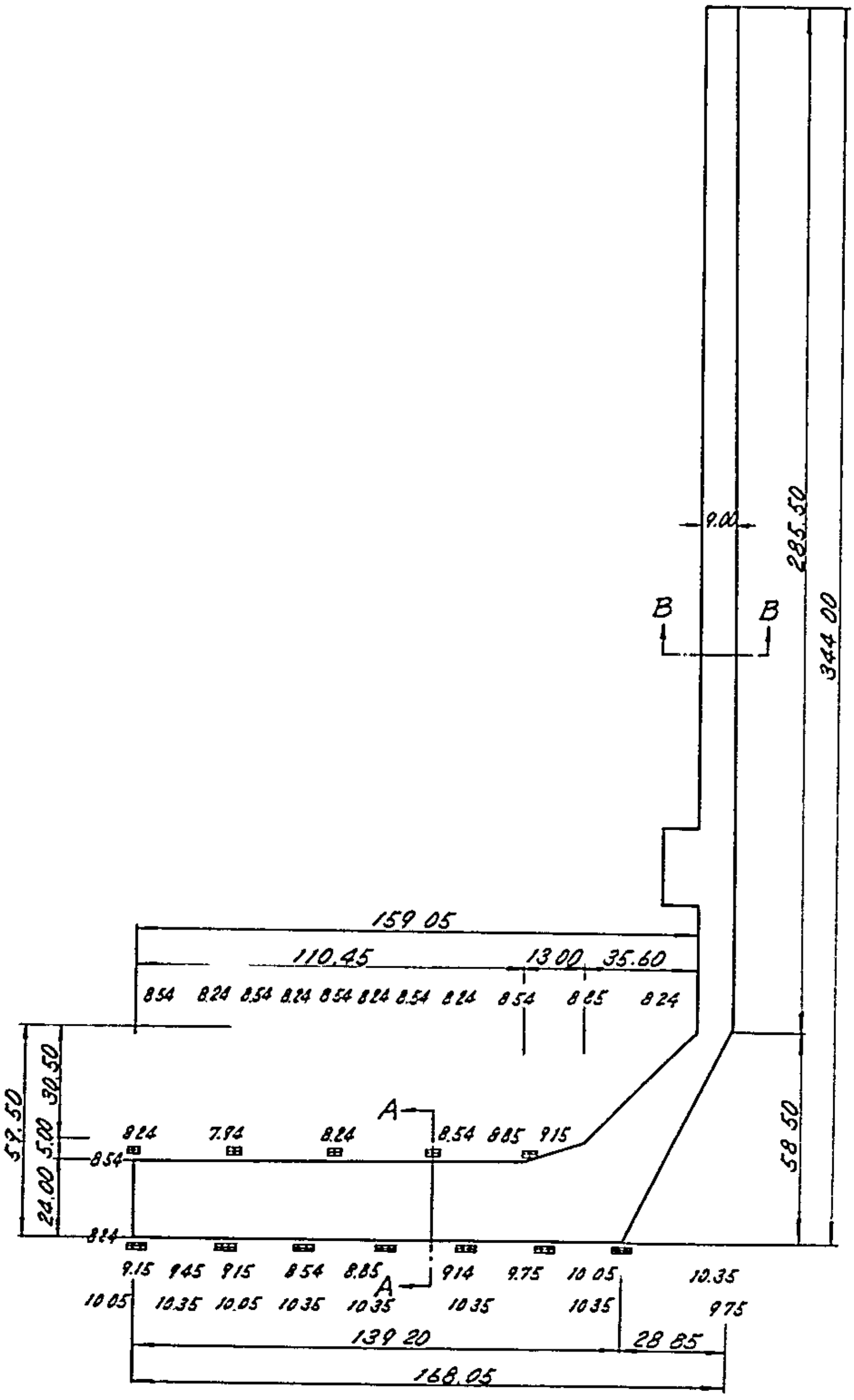
The central commercial district of Puntarenas is directly linked with the municipal pier (Muelle Municipal), a key point of passenger sea routes to various points of the Gulf of Nicoya, and has such establishments as markets, banks and shopping districts. The shopping center is also in close proximity to the bus terminal and proves that Puntarenas has a big function as a central local city. This fact may be easily conjectured from the process of development of Puntarenas. (Fig. 3. 2).

As far as the city function such as the concentration of commerce, service, transport and administration is concerned, Puntarenas is one of the most suitable port cities in the area. On the other hand, however, the city of Puntarenas has developed on a sand spit surrounded by sea on its three sides, the entire spit has already been urbanized and part of the urban area has turned to over-populated residential districts. Development of the city while adhering to the idea of maintaining a port in this city may lead to the loss of some of the functions possessed by the city. It is also feard that the further progress of urbanization will deteriorate life environments of the city.

Under such circumstances, physical distribution systems such as warehouse, oil storage and port railroad, which is an integral part of the port functions, are located adjacent to or are mixed with residential, commercial and resort areas and show unfavorable aspects as physical distribution systems. As the future question, various facilities that support the port functions seem to have no space for expansion.

Excess urbanization of Puntarenas has been advancing gradually and approached near Chacarita. Advancement or construction of industrial plants, warehouses, high-class residences, a hospital and an airport is in progress, which is an indication that the city is loosing space gradually.

Unit: m



Source: 611)

Fig. 1.1 Plan of Muelle National in the Port of Puntarenas

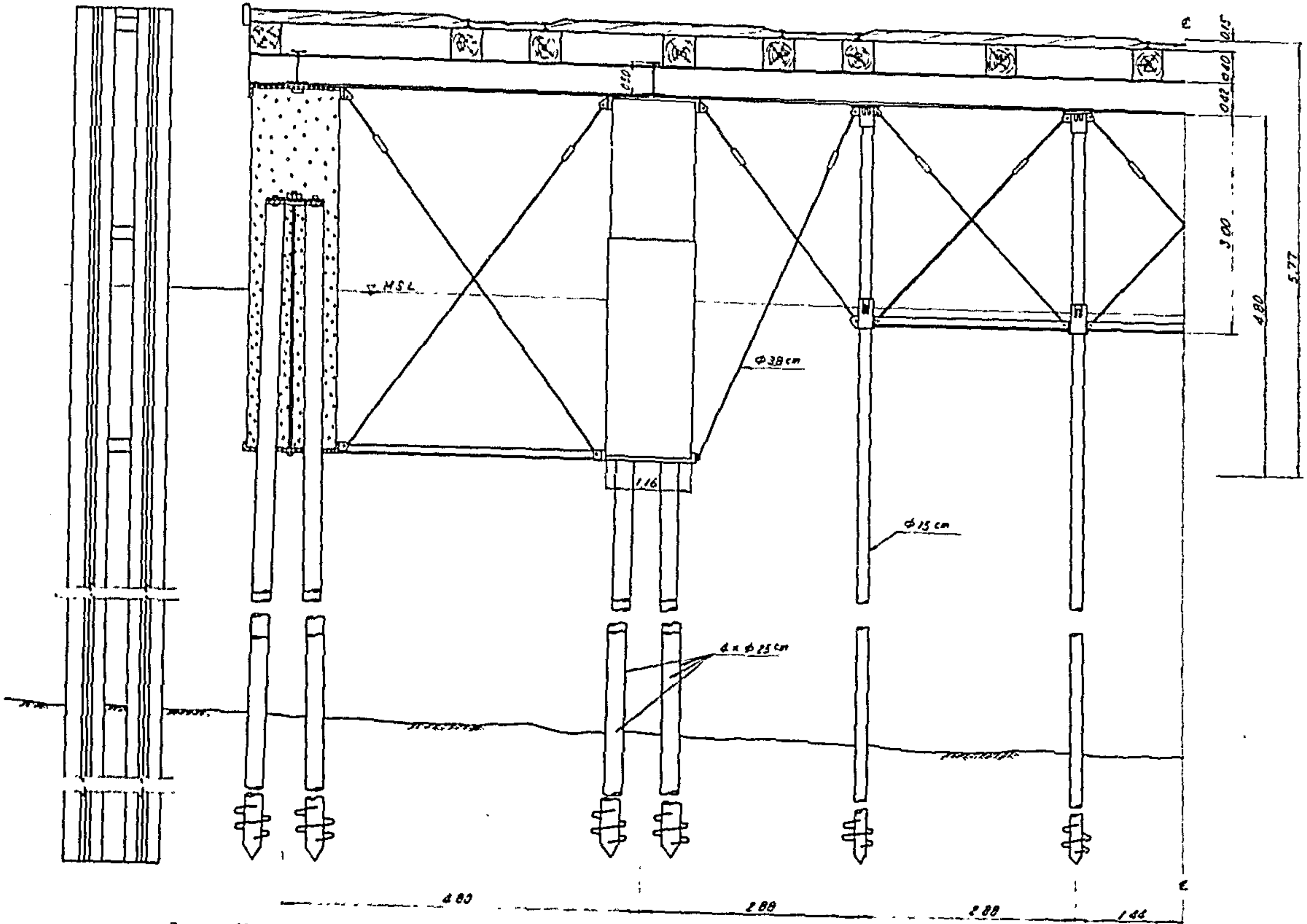


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Fig. 1.2 Standard Cross -Section of Muelle National in the Port of Puntarenas

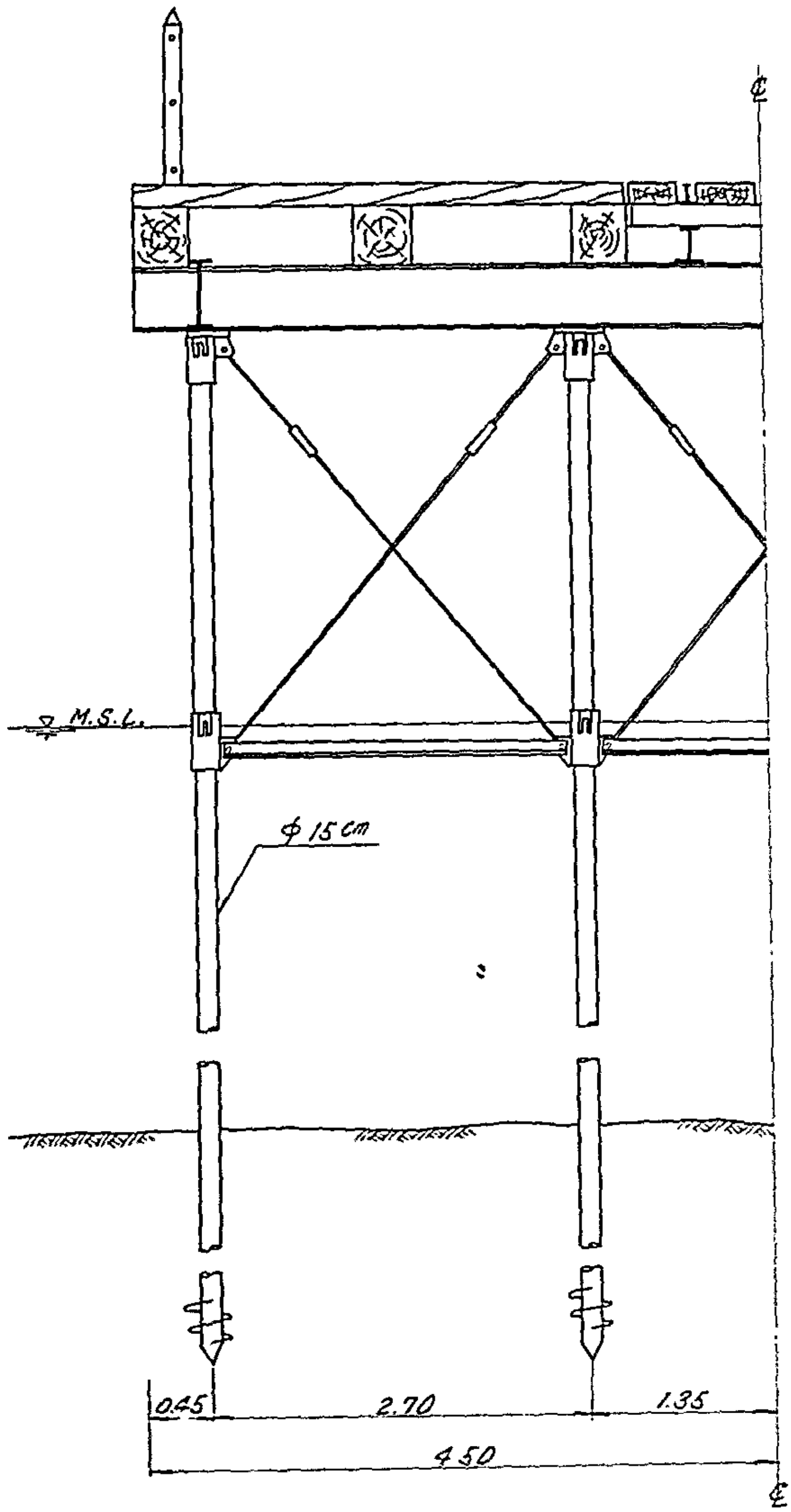

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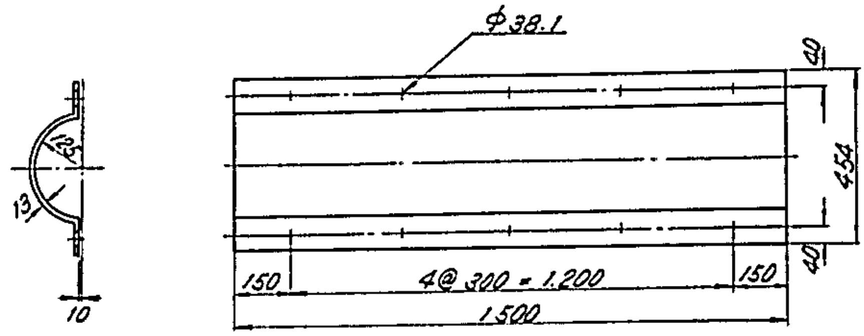
Fig. 1.3 Muelle National (B-B Cross-Section) in the Port of Puntarenas

Unit: mm



Note). Prepared from data provided by INCOP

Fig. 1.4 Joint for Repairing Steel Pipe Pile

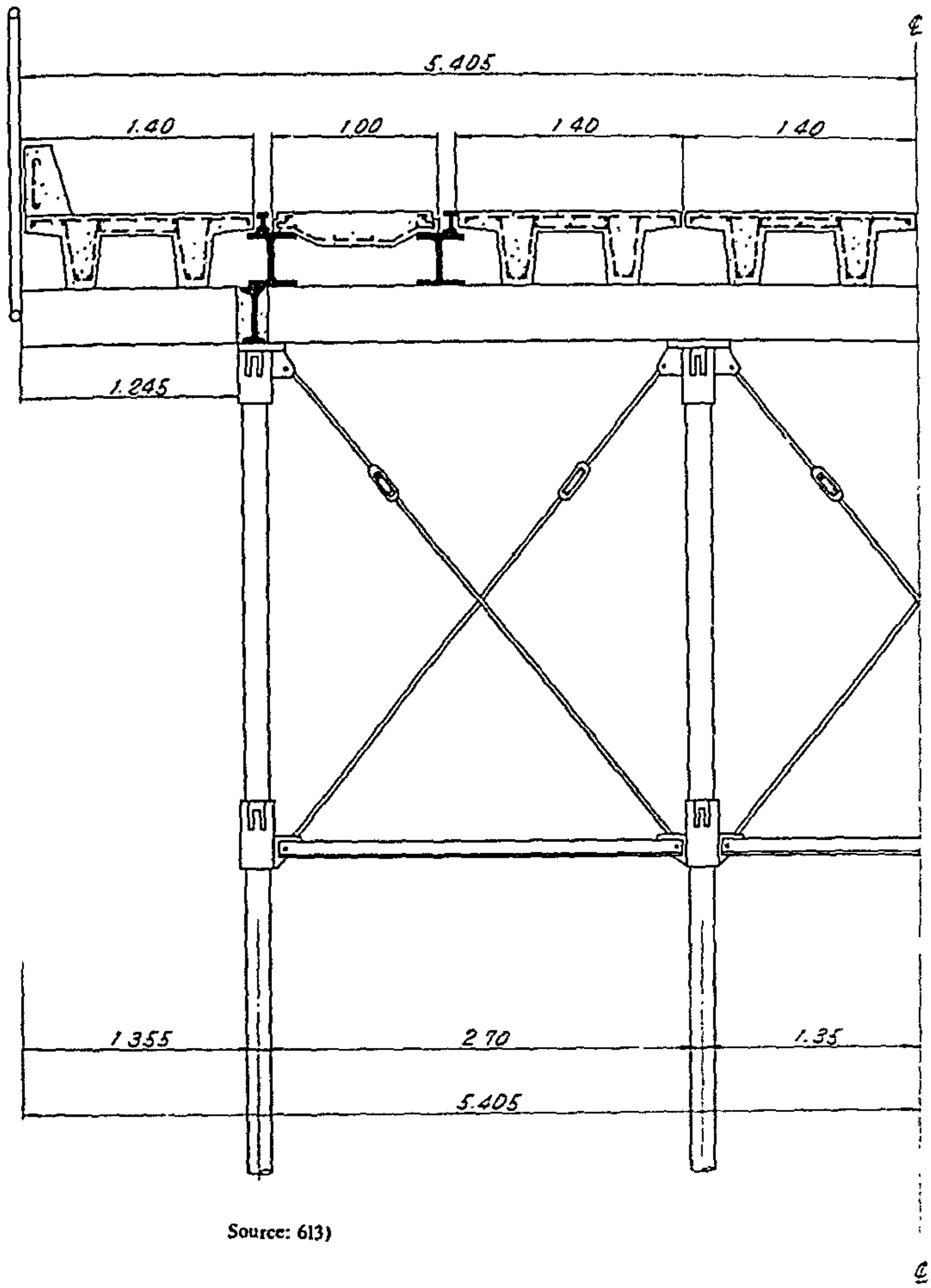


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Fig. 1.5 Cross-Section (B-B Cross-Section) of Improved Muelle National

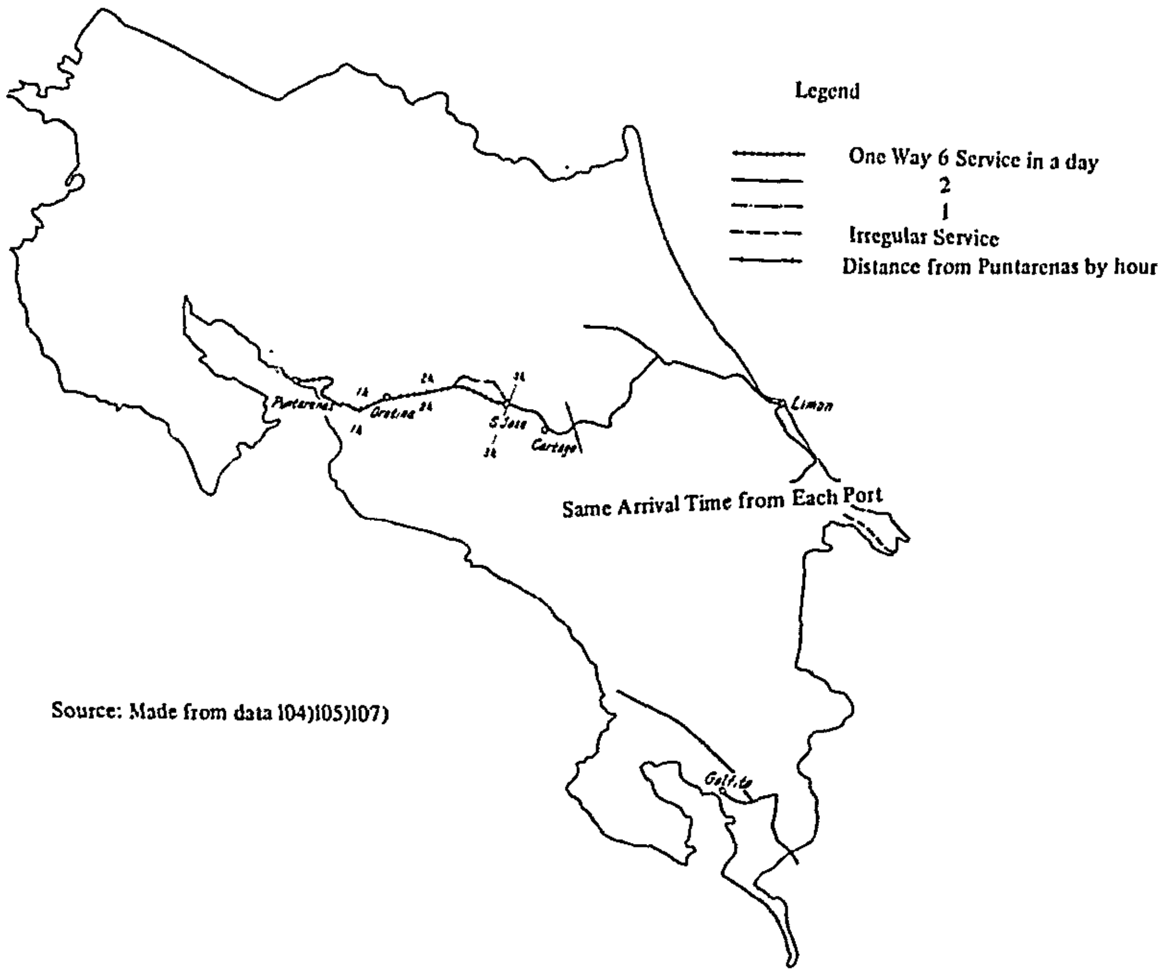
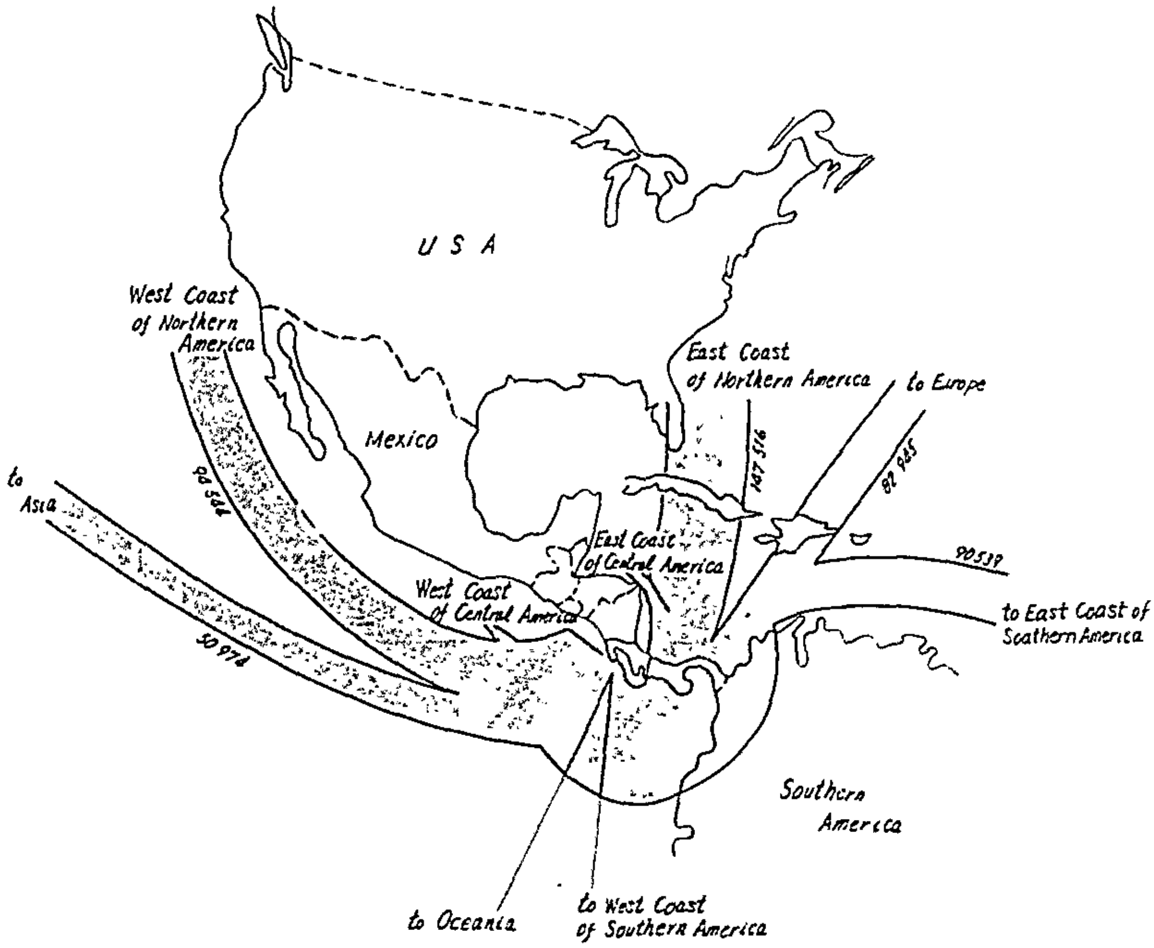
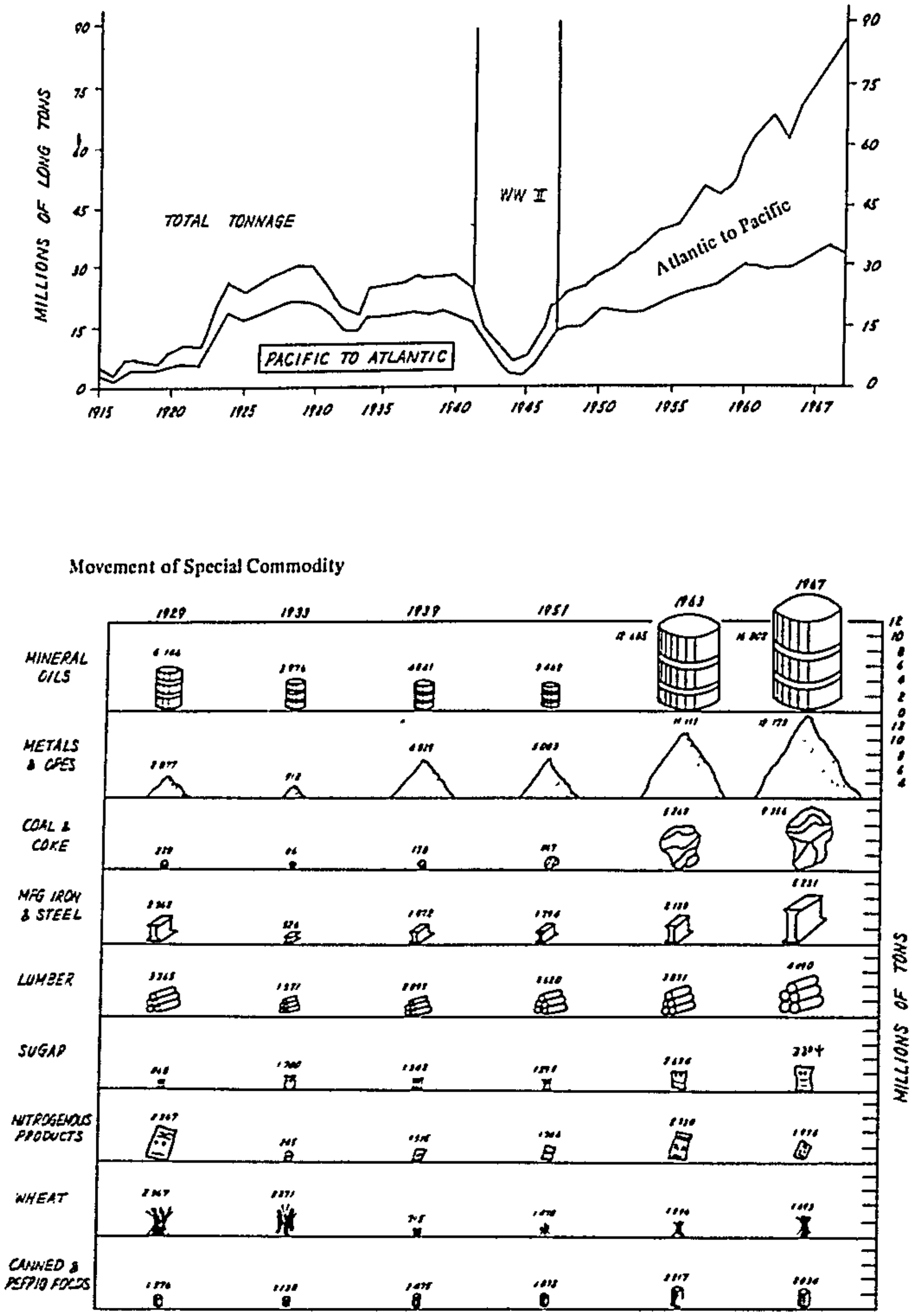


Fig. 1.6 Railroad in Costa Rica



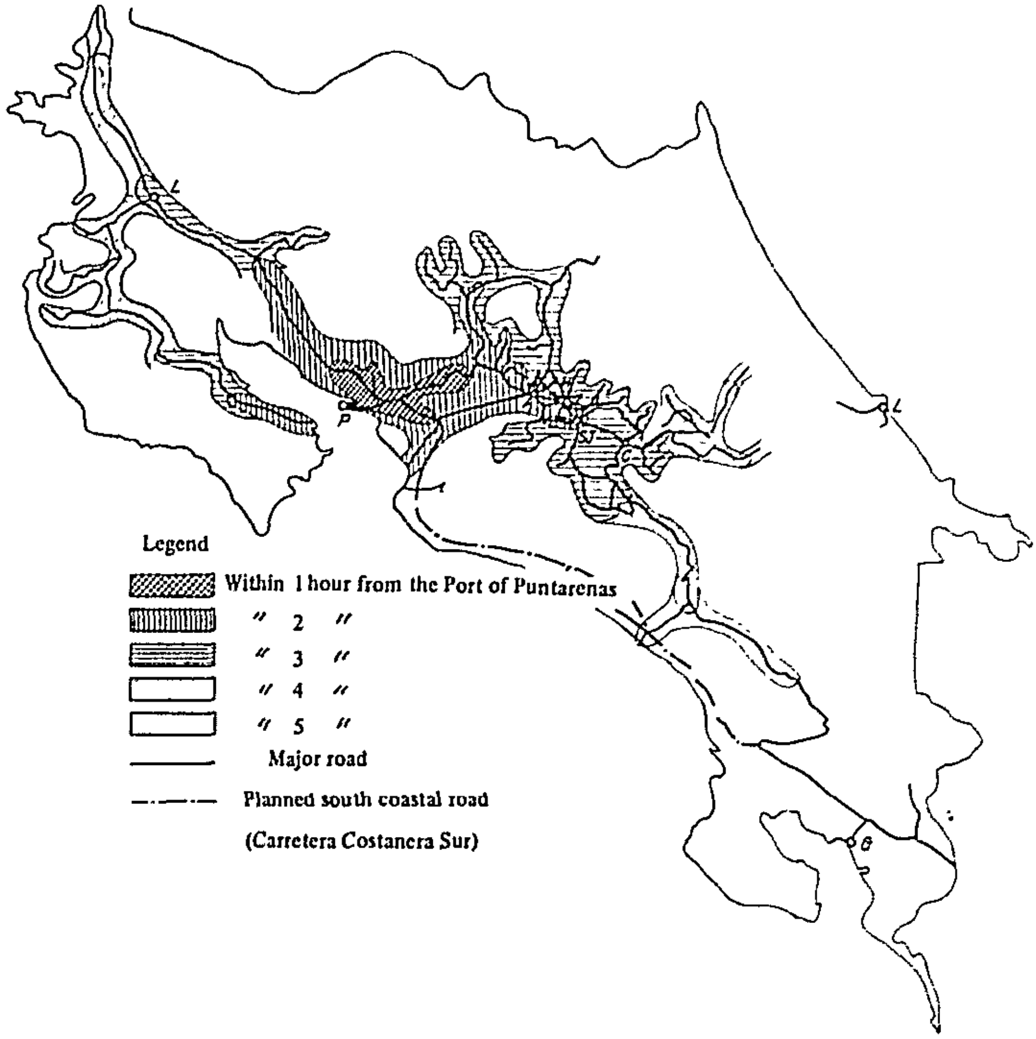
Data Source: 108)

Fig. 1.7 Origin and Destination of Cargo Handled at the Port of Puntarenas



Data Source: 108)

Fig. 1.8 Cargo Movement of Panama Canal (1915-1967)



Source: 105) 111)

Fig. 1.9 Conterline of Arrival Time from Puntarenas and Distribution of Main Road in Costa Rica.

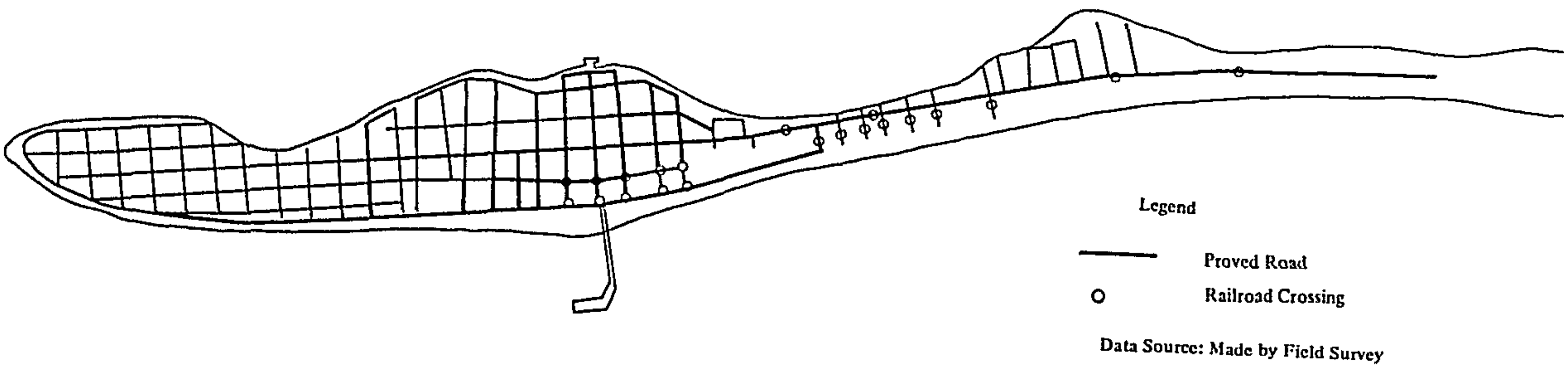
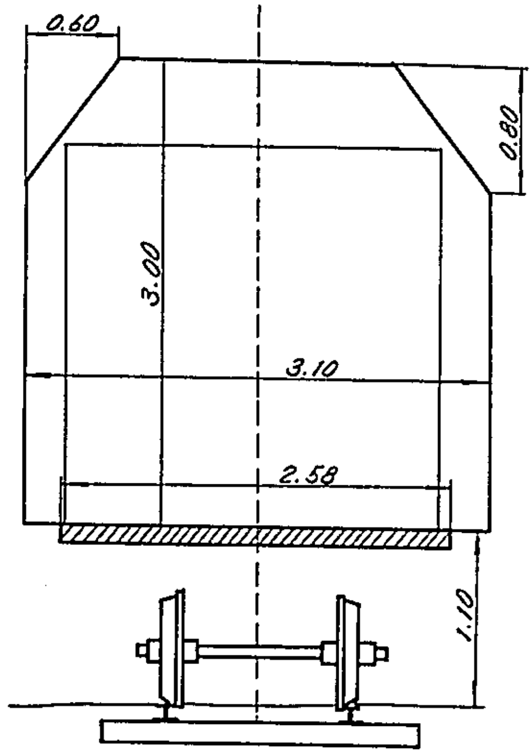


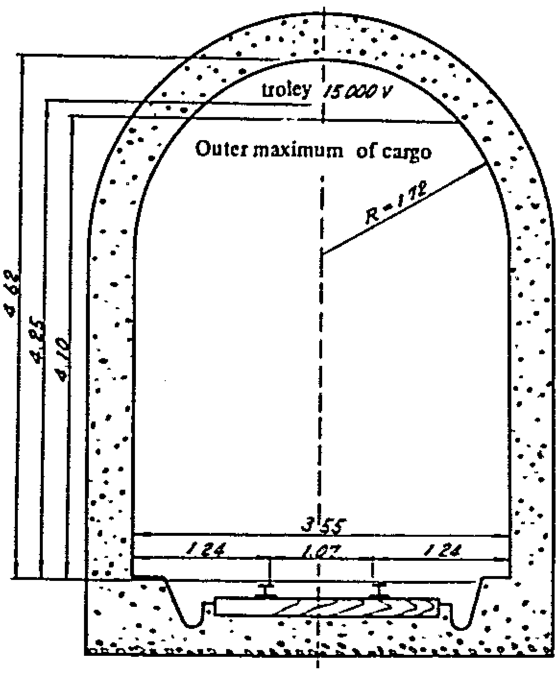
Fig. 2.1 Road Condition in the City of Puntarenas



Unit: m

Data Source: 104)

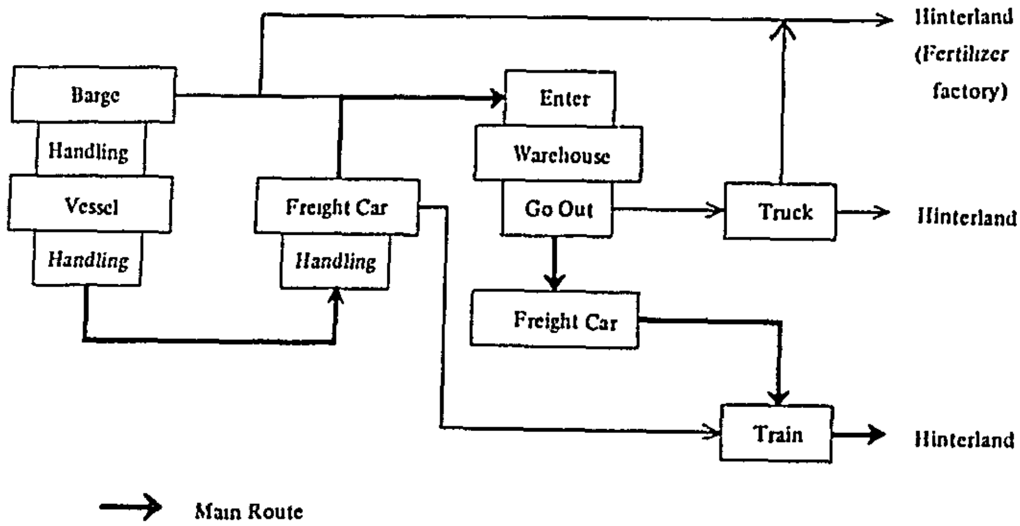
Fig. 2.2 Maximum Dimension for Special Cargo in Flat Cars



Data Source:104)
Lemgth 288m

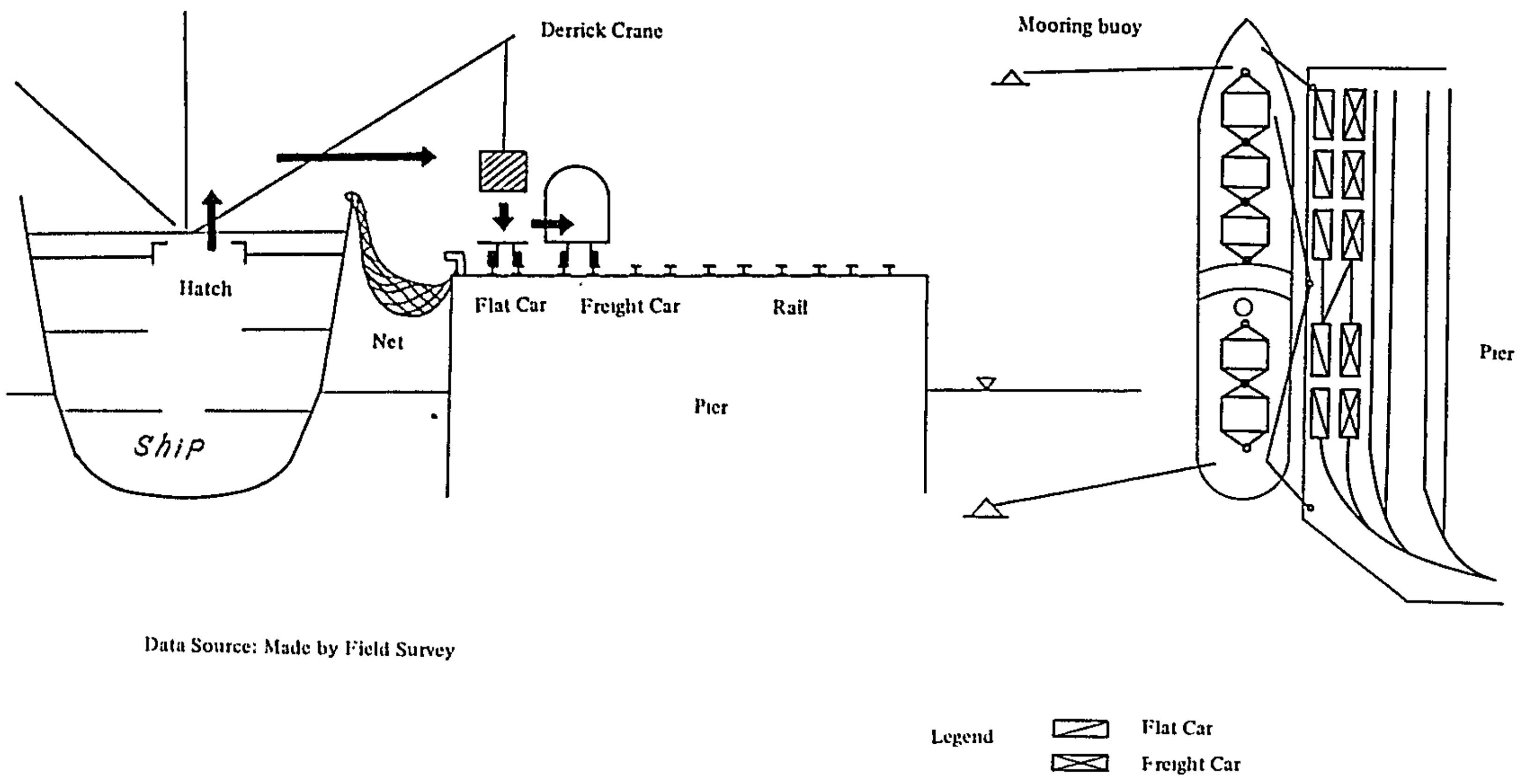
Unit: m

Fig. 2.3 Transversal Section of Cambalache Tunnel



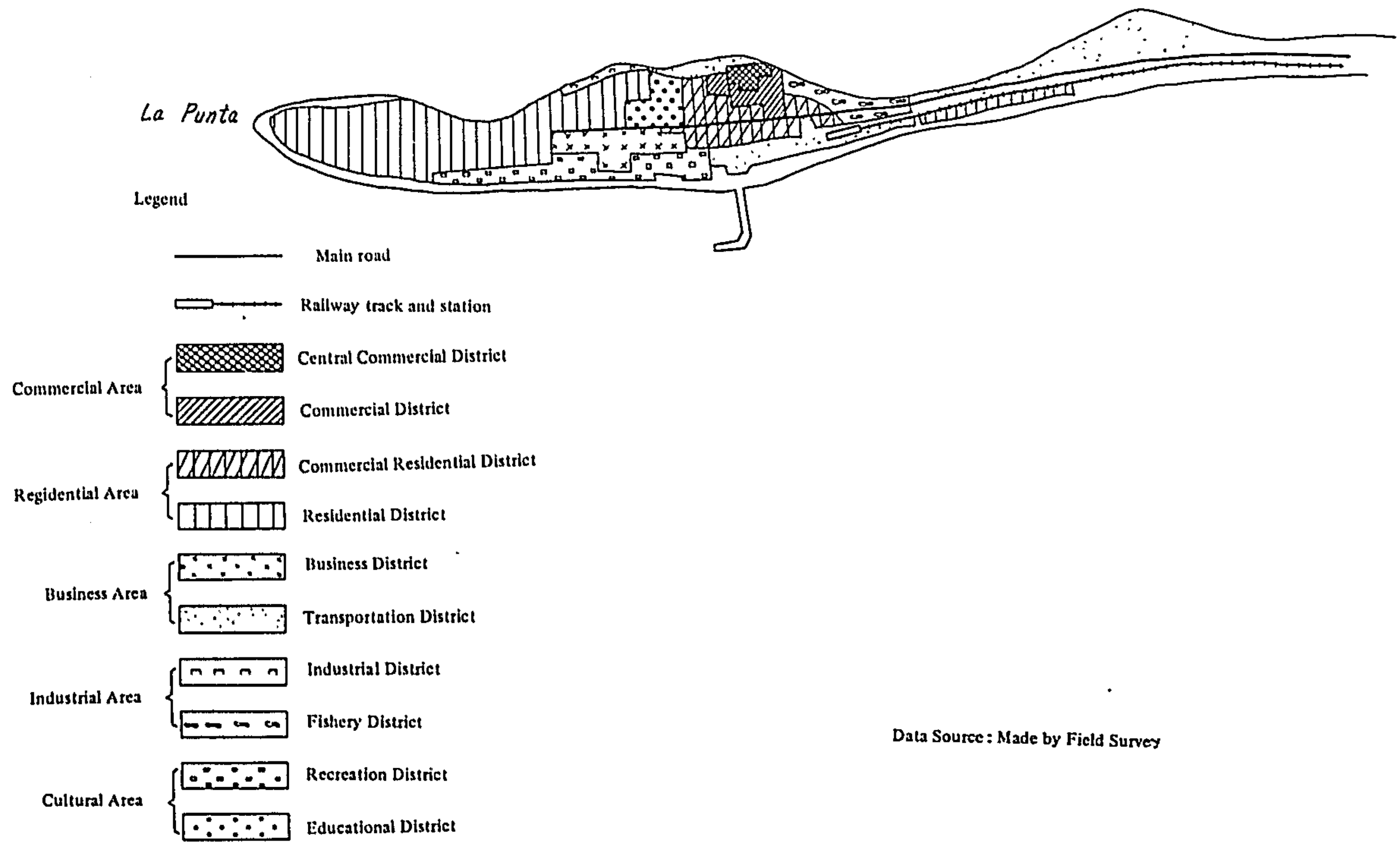
Data Source: Made by Field Survey

Fig. 2.4 Block Chart of Cargo Flow from Vessel at the Port of Puntarenas



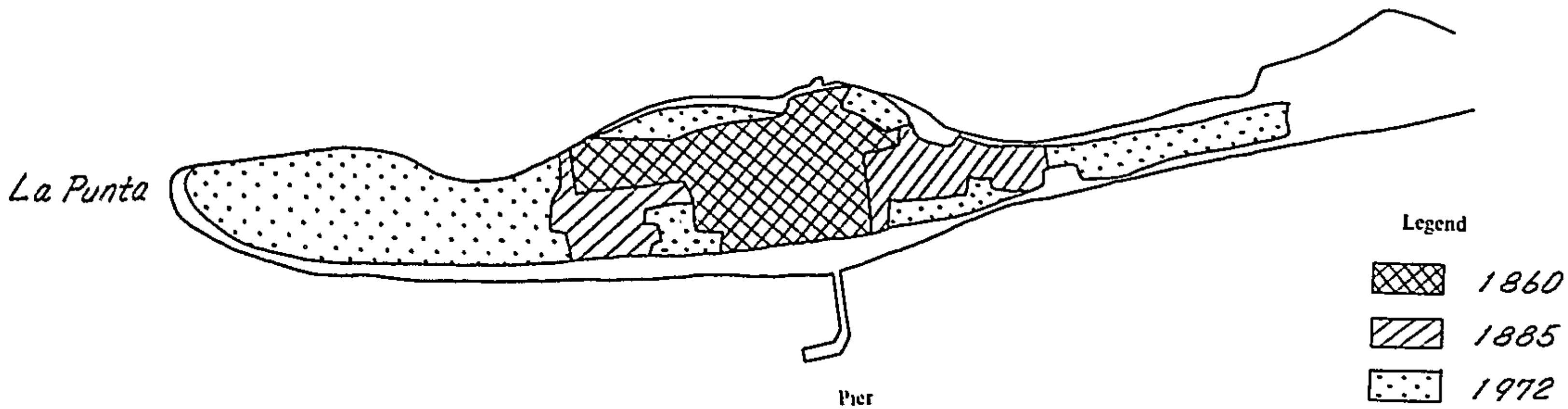
Data Source: Made by Field Survey

Fig. 2.5 Status of Cargo Handling in the Post of Puntarenas



Data Source: Made by Field Survey

Fig. 3.1 Regional Structure of the City of Puntarenas



Data Source: 203) 204) 212)

Fig. 3.2 Development Process of the City of Puntarenas

Table-1.1 Changes in Volume of Cargo Handled in the Port of Puntarenas by Commodity

Export (Unit: ton)

	1965	1966	1967	1968	1969	1970	1971
Live Beef Cattle	4,217	2,970	1,114	6	59	-	1,100
Beef	4,217	6,194	7,423	5,299	13,068	11,798	12,000
Sugar	8,395	13,260	32,742	32,902	28,176	50,651	62,734
Coffee	11,258	13,356	18,056	20,388	29,356	42,893	34,361
Cocoa	351	675	650	1,130	1,532	903	10
Loge and Lumber	1,705	590	105	424	1,573	206	-
Cotton	2,057	2,741	2,803	3,972	3,110	545	241
Manufactured Fertilizers	33,786	22,783	18,185	44,815	33,694	26,001	53,681
Wood Veneers and Plies	5	125	36	441	1,981	622	153
Others	801	19,677	6,733	10,381	14,938	19,120	21,623
Total	66,136	82,371	87,841	119,758	127,487	152,539	185,983

Import

	1965	1966	1967	1968	1969	1970	1971
Wheat	51	-	43,077	62,613	77,977	68,006	58,565
Rice	329	8,936	4,763	154	1	60	7,962
Flour	24,879	23,677	11,423	60	220	273	32
Oilseed Cake and Flour	45	264	865	1,069	3,827	5,661	6,204
Animal Foods	1,262	546	142	-	322	812	1,654
Fuels and Lubricants	169,958	189,731	106,253	28,373	29,469	76,606	78,013
Natural Gas	1,832	2,420	2,736	3,557	3,775	3,287	2,318
Inorganic Chemicals	6,185	9,059	9,959	3,033	3,951	5,895	6,816
Miscellaneous Organic Compounds	251	351	523	902	1,242	1,230	1,905
Fertilizers and Fertilizer Materials	136,897	42,056	51,937	67,457	70,192	66,756	131,987
Synthetic Plastic Materials	1,547	2,276	2,149	2,283	3,391	6,645	12,787
Insecticides, etc.	860	1,079	1,221	1,516	2,005	2,286	2,221
Paper, Cardboard and Manufactures	9,384	11,132	11,830	8,730	12,054	18,475	13,844
Cotton Fabric	1,281	1,062	600	460	339	571	111
Cement	16,244	5,799	2,796	2,060	1,952	2,370	2,864
Glass Bottles	2,841	3,007	1,586	1,195	2,146	2,013	1,460
Iron and Steel	21,333	15,030	20,715	25,983	38,748	45,023	49,543
Construction Equipment	444	954	458	256	556	1,600	710
Machinery & Parts (Except Electrical)	856	1,245	1,049	801	1,777	1,624	806
Passenger Car	3,388	2,061	1,855	2,057	3,747	2,945	4,495
Bus and Truck		1,037	964	1,223	1,883	2,522	2,869
Others	95,186	31,587	31,589	42,130	48,492	77,593	60,987
Total	495,056	361,079	307,540	255,912	307,166	390,173	446,968

Table 1.2 Comparison of Freight from Port

unit: colon

	San Jose-Puntarenas	San Jose - Limon
Freight of Railway	15.87	34.30
Charge of Panama Canal	6.4	-
Total	22.27	34.30

Table 1.3 Foreign Cargo Volume by Transportation Facility in Costa Rica

unit: ton

	Export	Import	Total	Rate
Marine Traffic	943,821	870,966	1,814,787	89.5 %
Road Traffic	76,485	128,139	204,624	10.1
include Northern Boundary	71,646	123,725	195,371	
Southern Boundary	4,839	4,414	9,253	
Air Lines Traffic	1,678	4,788	6,466	0.3
Postage	4	225	229	0.0

Data Source: 101)

Table 1.4 Calling Vessel in the Port of Puntarenas (1970)

Kind of Vessel	Numbers	Nation of Vessel	Average Tonnage
General Carrier	45	Germany	3,573 G/T
	37	Panama	1,593
	35	Liberia	3,491
	28	Holland	2,051
	28	Sweden	5,209
	26	Japan	8,377
	22	U. K.	4,782
	20	Mexico	1,484
	18	Nicaragua	2,364
	17	Norway	5,939
	16	Costa Rica	213
	16	Denmark	3,043
	15	Columbia	7,075
Oil Tanker	30	Liberia	6,622
	11	Norway	6,702

Data Source: 102)

Table 1.5 Classification of Size of Vessel in the Port of Puntarenas

	1970	1971
- 3,000 G/T	207	204
3,001 - 5,000	77	53
5,001 - 10,000	96	125
10,000 -	56	44
	436	426

Data Source : INCOP

Table 1.6 Size of Vessels in the Port of Puntarenas (Example)

unit: m

	Satsuma-maru	Groria-maru	Spain-maru
Length	156.7	146.28	179.5
Width	19.5	19.0	22.0
Depth	12.3	11.8	?
Draft	9.023	8.9	9.622

Data Source: Hearing at Kawasaki Line Company

Table 2.1 Length of Transportation Facility in Costa Rica

unit: km

	1965	1966	1967	1968	1969	1970
Total Length of Road	17,610	17,670	18,050	18,321	18,742	20,575
include Pave	1,148	1,161	1,180	1,289	1,393	1,455
Improve	4,462	4,561	4,692	4,742	5,044	5,022
Soil	12,000	11,948	12,178	12,290	12,305	14,100
Total Length of Railway						1,389
include Trunk						628
Brunch						442
Sidetruck						259
etc.						60

Data Source: 102)

Table 2.2 Status of Major Road

Highway No.	Location	Length	Type of Surface	Condition	Width
1	San Jose - Peñas Blancas	313.7 km	Asphalt	Good	6.0 - 6.5 m
2	San Jose - Panama Boundary	351.4	"	"	6.0 - 7.0
3	San Joxe - San Ramon	55.9	"	"	6.2 - 7.3
4	San Jose - San Ignacio	29.1	"	"	6.0
5	San Jose - Heredia	9.9	"	"	6.5
6	San Jose - La Turbina	35.9	Asphalt, Improve	"	5.3
7	San Jose - Puris	43.0	" "	"	6.0
8	Cartago - Vol. Irazu	31.5	" "	"	4.7
9	Hereaia - Pto Viejo	86.9	" "	"	4.5
10	Cartago - Siguirres	92.2	" "	"	5.5
11	Alajuela - Esparta	62.0	" "	Good, Poor	5.5
17	Barranca - Puntarenas	15.1	Asphalt	Good	7.3
21	Liberia - Carmona	117.2	Asphalt, Improve	"	6.0

Data Source: Data of Ministry of Transportation

Table 2.3 Status of Railway Facility (San Jose - Puntarenas)

Gage	1,067 mm	Max. Force of Traction	265 ton (Barranca-San Jose)
Overhead Conductors	15,000 volts	Electric Locomotive	13
Rail Weight	25 - 40 kg/m	Diesel Locomotive	4
Rail Length	9 - 12 m	Freight Cars	378
Max. Grade	34/1,000	Coaches	48
Min. Radius	80 m	Special Purpose Cars	24
Max. Length of Bridge	208 m		
Major Bridge	9		

Data Source : 104), 105)

Table 2.4 Rate of Foreign Trade Cargoes Carried by Railroad from the of Puntarenas

unit : ton

	1969			1970		
	Export	Import	Total	Export	Import	Total
(A) Cargo Volume handled at the Port of Puntarenas	127,487	307,163	434,650	152,539	390,173	542,712
(B) Transit Cargo Volume by Railway	90,672	203,263	293,935	110,616	259,434	370,050
(B)/(A) (%)	71.7	66.1	67.6	72.5	66.4	68.1

Data Source : 102), 106)

Table 2.5 Location of Factory along Railroad from Sea Port

	from Puntarenas	from Limon
inner 1 h	14	6
" 2 h	0	0
" 3 h	539	2
" 4 h	(88)	6
" 5 h		16
" 6 h		72
No Connection	20	
Total	553 (641)	102
%	81.5 3.0	15.5

( ) Number of factory which locates easter than San Jose

Data Source: 105)

Table 2.6 Status of Port Labor in the Port of Puntarenas

Stevedore	698	(regular employer 176 a day labores522)
Clane Driver	14	
Foyboatman	11	
Wharf overseer	4	
Guardman	106	
Pilot	2	
Checker, Tallyman and Warehouseman	5	

Data Source : INCOP

4. Analysis of Economic Activities

4.1 National Economy

The economy of Costa Rica has shown a rapid growth in recent years. The Gross Domestic Product (GDP) (real term) showed a high average growth rate of 8.4% during the five year period from 1965 to 1969 and ranks Costa Rica as a top-class country among the five Central American countries in terms of gross domestic product. While the growth rate of GDP remained at 5% in 1970, the economy regained a high growth again in 1971 and the GDP (nominal term) amounted to 6,930 million colon with a growth rate of 8.2% over the previous year (Table 4.1).

Because of the sharp increase of population at an average annual growth rate of 4.1%, however, the average annual growth rate of the GDP per capita is only about 5%.

The basis of the economy is centered on agriculture and stock-farming with main products being coffee, banana, sugar and beef cattle. Agricultural, forestry and fishery production had a share of 22% in the GDP in 1971. However, this share shows a declining tendency at present. Manufacturing and commerce are other major industries after agriculture, accounting for 19.2% and 16.7% of the GDP respectively. The above three account for 57.9% of the GDP and this share is almost leveling off though there have been some fluctuations depending on the year (Table 4.2).

As for prospects of the future economy in Costa Rica, an economic plan for the period 1974-1978 is now being worked out, mainly by the Planning Office (Oficina de Planificacion) but no definite information on these matters was available at the time this report was prepared. Then, the forecasting of the GDP is carried out, one of the economic indicators of a country, on the basis of the information on the prospects of the Costa Rica economy obtained from experts at the Planning Office and Central Bank (Banco Central de Costa Rica), etc.

For the future economic policy of Costa Rica, the enlargement of national income and improvement of trade balance will be the basic proposition and for this purpose, vigorous drive of take-off toward the industrial promotion is very important. Accordingly, efforts will be made for the promotion of industry by making the best of abundant labor force backed by high educational standards at first and emphasis will be placed on the measures for the improvement of productivity of the primary industry as the second step. With the evolution of such economic measures, the growth rate of the GDP will never drop below the past level but will maintain a slightly higher level instead.

On the basis of the above prediction of the economy in Costa Rica, the growth rate of the GDP in the period 1972 - 1977 was assumed to be 9% on the average. On this assumption, the GDP in the target year of 1977 is estimated at 9,600 million colon (at 1962 price), 1.67 times greater than that in 1971 (Fig. 4.1).

4.2 Population

The population of Costa Rica as of 1971 was 1,762,462 (877,345 men and 885,177 women) and the annual growth rate of population has reached 4.1%. Of this population, about 35% is city population and the population in the primary industry accounts approximately half of the total population (Table 4.3). A sharp increase of population is seen both in the urban area and the rural area but San Jose and Province of Puntarenas (Provincia de Puntarenas) show the highest growth rate (Table 4.4).

As for population distribution, Meseta Central has an overwhelmingly large concentration and, in the other areas, population density is also high in the Pacific coastal region while the lowland on the Atlantic coast is almost deserted (Fig. 4.2). As a result, the center of population distribution is slightly to the west of San Jose. With the central watershed as the center line, the population on the pacific side accounts for 77.5% of the total population and it is obvious that the center of economic activities is maldistributed on the Pacific side (Fig. 4.3).

According to calculations by the Costa Rica government, the future population is estimated at 249 million in 1980 and 349 million in 1990 but the actual figures up to 1971 were slightly below the estimated figures (Fig. 4.4). Composition of population by age shows a large base as a result of a sharp increase of younger generations, which is a promising sign of natural increase and the increase of younger working force in the future. (Fig. 4.5).

Despite this sharp increase of population centering on younger generations as a result of natural increase, the growth rate of the GNP exceeds the growth rate of population (Fig. 4.6). This is a clear indication of annual growth of the GNP per capita and in order to maintain future economic growth at the rate higher than that of the population as in the past, it is necessary to make efforts to expand industry at the rate higher than this.

4.3 Industry

Production of sugar, one of the major products in Costa Rica, has increased by more than twofold in the past 10 years. This increase is also attributable largely to the increase of productivity per unit area by about 1.3 times. If this trend is maintained in the future, production of sugar is expected to exceed 5 million quintares in 1977 (Fig. 4.7) but will also involve the problem of international agreement on sugar production.

Coffee is cultivated at Meseta Central and the Pacific coastal area. Production of coffee has increased rapidly in recent years as in the case of sugar; i.e. the production in the period 1971~1972 increased by 1.8 times per unit area as compared with that in 1963. Coffee production is also influenced by the international price and the international production agreement, but the coffee has a high export rate and is one of the most important products in the country. It is anticipated that the production in 1977 will increase about 1.5 times compared with 1977 (Fig. 4.8).

As for the livestock industry, more than 1.5 million cattles are being raised at present. In 1970, meat production exceeded 200,000 cattles and the production in 1977 is expected to exceed 300,000 cattles (Fig. 4.9).

Other primary industries beside agriculture are fishery and forestry but these are small in scale and therefore cannot be considered as key industries.

Manufacturing industry of Costa Rica has so far been centered on foodstuffs, beverage, and tobacco but such industries as textile, electric equipment, oil refining, chemical and automobile assembly have been making advancement recently under foreign capitals. However, the share of light industry is still large and the progress of industrialization cannot be said to have attained a high rate as compared with other Central American countries. However, high educational standards of the people and political stability of the nation provide the country with a high potentiality for industrial location; e. g. the location of an aluminum refinery is being considered as a definite plan. Distribution of industrial plants is now concentrated in and around San Jose (Fig. 4. 10) and these plants are heavily dependent on the Port of Puntarenas.

5. Estimation of Cargo Volume

5. 1 Volume of Sea-bound Cargo in Costa Rica

Because of the fact that the trade partners of Costa Rica include many countries such as North and South America, European countries and Japan as well as those countries of the Central American Common Market, that the long narrow topography extending from north to south inevitably makes the distance of land transport greater and that the land transport facilities are not sufficient, approximately 90% of foreign cargo in Costa Rica depend on marine transport.

The three ports - the Port of Puntarenas (Puerto de Puntarenas), Limon Port (Puerto Limon) and Golfito Port (Puerto Golfit) - act as the window of foreign trade in this country and handle almost all the sea-bound cargos. The volume of sea-bound cargo centering on these three ports has been increasing rapidly in recent years following the expansion of the economy and the rise of consumption level. (Table 5. 1).

The fact of the transport of foreign cargo depending almost entirely on marine transport and the share of each transport system are not considered to undergo a drastic change as compared with the present pattern for the time being. For the future volume of sea-bound cargo in Costa Rica, therefore, it will be possible to make an accurate forecast directly from the past record of sea transport instead of predicting the overall trade volume first and then estimating the volume of sea-bound cargo from the share of each transport system.

For the estimation of the future volume of sea-bound cargo in Costa Rica, therefore, the total volume of cargo handled in the Port of Puntarenas, Limon Port and Golfito Port will be assumed to be the same as the volume of all sea-bound cargo in Costa Rica. Then the volume of export cargo, import cargo and these sum, the total volume of cargo, will be estimated by correlating them directly with an economic indicator having close relations with port activities. GDP (Gross Domestic Product) will be used as the economic indicator and the period of correlation will be taken as 11 years from 1961 to 1971.

According to this correlation, the volume of sea-bound cargo in Costa Rica in 1977 is estimated at 2. 62 million tons for export and 1. 93 million tons for import, for a total of 4. 5 million tons (Fig. 5. 1). These figures represent increases of 1.98 times (1.32 million tons in 1971), 1.68 times (1.146 million tons) and 1.85 times (2.466 million tons) respectively over the cargo volume in 1971 and are an indicative of the continuation of the increase in the volume of sea-bound cargo reflecting the high growth rate of the economy in Costa Rica.

By commodity, export of coffee, sugar, banana and meat, traditional and key export commodity of the country, will continue to grow with the improvement of productivity and the export of industrial products will also be promoted following the progress of industrialization of the country. For the import, meanwhile, imports of crude oil for oil refining, fertilizers and their raw material, steel and wheat will be increased as a result of positive implementation of industrial promotion measures and the imports of industrial products and general consumption goods will be promoted further following the rise of the living standards.

5.2 Cargo Volume Handled in the Port of Puntarenas

(1) Cargo Volume Handled in the Port of Puntarenas

As previously mentioned in paragraph 1.1, each of the three major ports in Costa Rica has a different character resulting from the difference in the sphere of hinterland and the type of cargo handled etc. This tendency is expected to become stronger with the expansion of economic and social activities in the country.

Therefore, the future character and role of the port of Puntarenas Puerto de Puntarenas) must be determined in the light of overall land use such as the distribution of population and urban area, agricultural and marine production, trend of industrial location, and the completeness of transport systems, from which the cargo volume handled in the ports must be estimated. From this point of view, the cargo volume will be estimated for major commodities according to the following process (Fig. 5.2).

1 Cargo volume handled in the Port of Puntarenas and the Port of Limon (Puerto Limon) and that in the Port of Golfito (Puerto Golfito) will be estimated through primary correlation with GDP and by the trend. The value thus estimated will be checked with the volume of sea-borne cargo in Costa Rica mentioned in 5.1 used as control total.

2 With the use of the volume of cargo handled in the Port of Puntarenas and the Port of Limon estimated in 1 as control total, the cargo volume handled in both ports will be estimated for export and import by commodity from the prospects of agriculture, industrial production, economic activities and population and the trend.

3 From this, the cargo volume handled in the Port of Puntarenas will be estimated with due consideration given to the distribution of population and urban area, agricultural and industrial activities by region and the completeness of transport systems.

For cargo commodities to be included in the estimation, the following will be considered. For export, coffee, sugar and beef cattle, which are traditional agricultural products and are contributing and will contribute greatly to the expansion of economy in Costa Rica, and fertilizer production of which has already attained a fairly high level and is expected to grow further will be taken up. For import, on the other hand, fertilizer and fertilizer and fertilizer material, iron and steel, petroleum products, wheat and vehicles, which are the main export cargos and are the basic cargo for the maintenance of city functions and industrial production, will be considered.

As a result, export cargo in the port of Puntarenas is expected to consist of 100,000 tons of coffee, 110,000 tons of sugar, 20,000 tons of beef cattle and 80,000 tons of fertilizers, for a total of 340,000 tons. These figures represent the increase of 2.91 times (1971=34,000 tons), 1.75 times (63,000 tons), 1.52 times (12,000 tons), 1.49 times (54,000 tons) and 1.83 times (186,000 tons), respectively as compared with 1971. The volume of import cargo, meanwhile, is estimated at 190,000 tons of fertilizers and fertilizer materials, 110,000 tons of iron and steel, 160,000 tons of petroleum products, 110,000 tons of wheat and 16,000 tons of vehicles, for a total of 750,000 tons. These figures represent the increase of 1.45 times (131,000 tons), 2.22 times (50,000 tons), 2.05 times (78,000 tons), 1.88 times(59,000 tons), 2.20 times (7,000 tons) and 1.68 times respectively compared with 1971.

From the above, the total cargo volume handled in the port of Puntarenas in 1977 is estimated at 1,090,000 tons, an increase of 1.72 times from 633,000 tons handled in 1971. Such a sharp increase in the volume of export and import cargo bespeaks the importance of the role played by the port in the future economy of Costa Ric (Table 5.2, Fig. 5.3).

Cargo handled in the port of Limon and the port of Golfito estimated according to the process shown in Fig. 5.2 are shown in Fig. 5.4 and Fig. 5.5 respectively.

The methods used for the estimation of the volume of export and import cargo by commodity handled in the port of Puntarenas are as follows.

Exports

Coffee· Production and the volume of coffee export in Costa Rica are estimated by the trend and the whole volume is estimated to be handled at the port of Puntarenas from taking into consideration the distribution of production area and transport conditions. (Fig. 5.6).

Sugar, Beef cattle· Basing the prospect of volume of production and export in Costa Rica made by the government, the whole volume of this export is estimated to be handled at the port of Puntarenas by considering the distribution of production area and transport conditions (Fig. 5.7, Fig. 5.8).

Fertilizers· Production of fertilizers is estimated first and then the volume of export is estimated from this growth rate of production and the trend of past export (Fig. 5.9).

Other cargoes: The total volume of export of other cargoes is estimated from the trend of past export and the volume handled in the port of Puntarenas is estimated from this total volume and the share of the port determined on the basis of the change in the share (Fig. 5.10).

Imports

Fertilizers and fertilizer material using the total volume of import of fertilizers and fertilizer materials in Costa Rica determined on the basis of the growth rate of agricultural production as control total, the volume handled in the port is estimated from the trend of import in the past (Fig. 5. 11).

Iron and Steel: Estimated from the trend (Fig. 5. 12).

Petroleum products: The number of automobiles owned is estimated from the diffusion rate of automobile determined by the trend and the volume of petroleum import handled in the port is estimated through multiplication of number of automobiles (Fig. 5. 13, Fig. 5. 20, Fig. 5. 21).

Wheat: Volume of wheat import in past is firstly estimated by converting flour to wheat at the conversion rate of 1/0. 9 and the volume of import is estimated from the future value of that per capita determined by the trend, total volume of which will be handled in the port (Fig. 5. 14).

Vehicles: Total import of vehicles is estimated using the multiplicator of the number of automobiles owned and then the volume of import handled in the port is determined by distributing the total import by the percentage of population in the sphere of hinterland of the port of Puntarenas and the port of Limon (Fig. 5. 15).

Other cargoes: Total import of other cargoes is estimated from the past trend of import and the volume handled in the port is estimated from the total import and the share of the port of Puntarenas determined from the change in the past achievements (Fig. 5. 16).

Besides, the volume of the following cargo, which are handled only in the port of Limon, is estimated for use in the determination of the total volume handled in both the port of Puntarenas and the port of Limon. For additional information, the method used for the estimation is described below.

Exports

Banana: Estimated from the past trend of export (Fig. 5. 17).

Petroleum products: Estimated using the value of multiplicator of the import of fuel and lubricants. However, the volume of export for 1969 and 1970 was estimated from the ratio of export of petroleum products to the export volume of cargo other than petroleum products (Fig. 5. 18).

Imports

Fuel and lubricants: Estimated from the past trends of import (Fig. 5. 19)

(2) Cargo Volume to be Handled in New Port

Assuming the capacity of the existing facilities of the port of Puntarenas is 633, 000 tons, the cargo amounting to 457, 000 tons, the difference between this volume and the estimated volume of cargo in 1977 amounting to 1, 090, 000 tons, will have to be handled in the new port. However, 160, 000 tons out of the estimated total volume of cargo in 1977 are petroleum products meaning an increase of 80, 000 tons from the present volume. If the increased portion of the petroleum cargo can be handled by the existing sea-berth, the volume to be handled by new port facilities is estimated to be 377, 000 tons. Estimation of the volume of cargo by commodity is shown in Table 5. 3.

6. Facilities Required and Their Size

6.1 Size and Number of Ships Calling at Ports

Among the ships of various countries calling at the Port of Puntarenas at present, Japanese ships have the largest average ship size, followed by ships of such European countries as Norway, Sweden, etc. In contrast, ships of Central and North American countries including Panama, Liberia (mostly US capital), Mexico and Nicaragua have an average size of 2,304 G/T. The average size of oil tankers is 6,700 G/T (Table 6.1).

With the above preconditions and in consideration of the trend toward the increase in ship size, and the size of ships operating on the routes to Asia and Europe and on the routes to Central and North American countries is expected to increase to 10,000 G/T (15,000 D/W) and 3,500 G/T (5,000 D/W) respectively. Accodingly, the sizes of ships calling at the new port from the Asian and European countries and from Central and North American countries are presumed to be 15,000 D/W and 5,000 D/W respectively. Of the ships of the 5,000 D/W class having the origin and destination in Central and North America, those carrying such bulk cargoes as sugar and wheat are presumed tc be tramper bulk carriers and other vessels are presumed to be liner general cargo ships.

For tramper bulk carriers, full load of every ship is considered. Since the export of sugar and import of wheat have the origin and destination in the USA respectively, about half of the number of ships are considered to carry cargo on round trips.

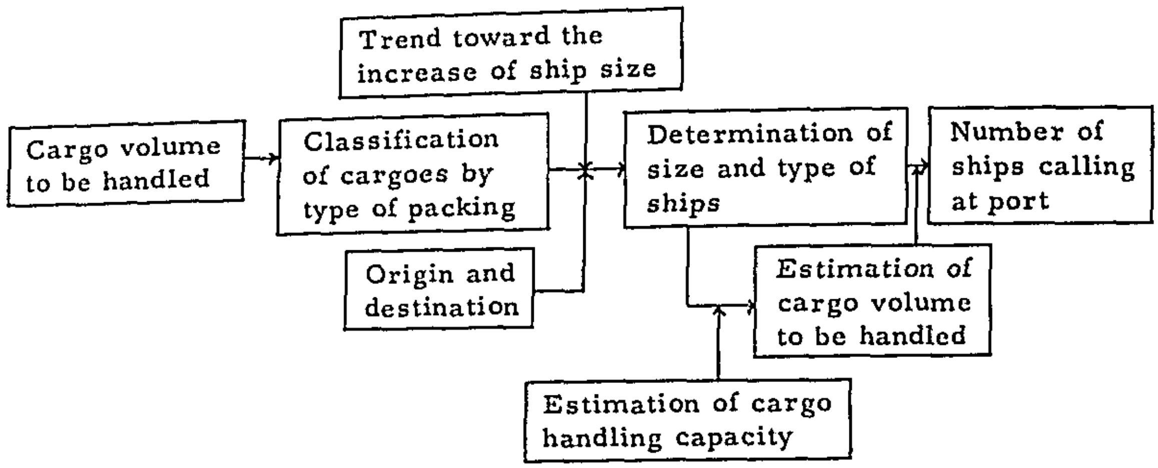
For liners, meanwhile, it is presumed that a vessel of the 15,000 D/W class will carry 4,000 tons of cargo and that of the 5,000 D/W class will carry 2,000 tons of cargo.

As a result, the total number of ships calling at the port annually is estimated to be 142. In actuality, however, ships classified as large ships may have the tonnage smaller than 15,000 D/W and those classified as medium sized ships may be smaller than 5,000 D/W and it is very probable that the total number of ships calling at the port will exceed the above mentioned 142.

Cargo handling pattern used as a precondition for the above estimate will of course take the far advance form as compared with the present cargo handling pattern. For handling general cargo, use of pallet and forklift in combination with modern facilities such as a spacious apron and transit shed immediately behind is considered.

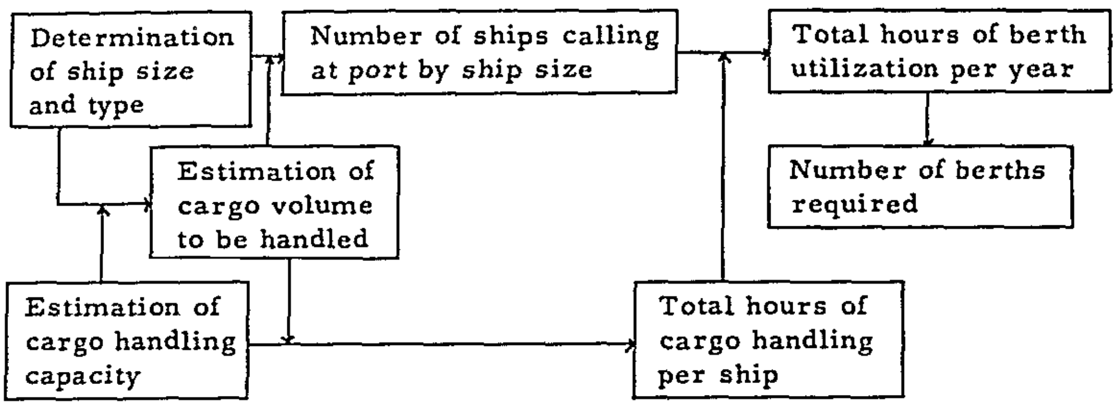
For bulk cargo, use of bucket crane hoppers and belt-conveyors will be general practice, but the installation of a pneumatic unloader should be decided upon careful study of the cargo volume to be handled.

The outline of the above method of estimation may be illustrated as follows.



6.2 Size of Berth and Cargo Handling and Storage Facilities Required

The number of berths required will be determined with the following method as a rule.



The number of ships calling at the new port was estimated to be 24 general cargo vessels of the 15,000 D/W class, 95 general cargo vessels of the 5,000 D/W class and 33 bulk carriers of the 5,000 D/W class. On the assumption that a vessel of the 15,000 D/W class has six hatches and that of the 5,000 D/W class has 3 hatches, simultaneous use of six gangs of stevedors and 3 gangs of stevedors for respective ship size will be possible.

While the present cargo handling capacity of the Port of Puntarenas is estimated at 10 ton/hr per gang in terms of general cargo, increase of the capacity to 15 ton/hr per gang for general cargo and 50 ton/hr for bulk cargo through modernization of wharf facilities and introduction of cargo handling equipment will be possible without difficulty. Though the 24 hour working system is employed for cargo handling at present, cargo handling capacity calculated on the basis of the 8 working hour system will be as shown in Table 6.2.

Since there is still room for the increase of cargo handling capacity and the increase to 20 ton/hr per gang in terms of general cargo may be easily attained without the extension of working hours, the actual cargo handling capacity may be considered to be 500,000 ton/year on the basis of 8 working hours. However, a conseruative estimate was made on this occasion in consideration of such adverse conditions as regular afternoon rainfall in the rainy season and strong sunlight and high temperature during the daytime.

As a result, the total number of berthing days is estimated at 803 and the coefficient of berth utilization will be 73.3%.

Length and water depth of berths will be determined from the size of vessels as shown in Table 6.3 and one berth of 10.0m of water depth and 180m length and two berths of 7.5m of water depth and 130m length will be planned.

For the calculation of the size of cargo handling and storage facilities to be estimated from the cargo volume handled, the following method will be used.

$$W = \frac{N}{R}$$

$$Q = \frac{W}{w}$$

where: W = Capacity of cargo storage (ton)

N = Cargo volume handled annually (ton)

R = Turnover (times/year)

Q = Area required (m^2)

w = Cargo volume stored per unit area (ton/m^2)

In this case, the turnover of transit shed is to be 24 per year and that of warehouse is to be 6 per year. The cargo volume to be stored in warehouse is estimated to be one half of the volume stored in transit shed.

Size of transit shed for general cargo:

Capacity (transit shed): $W = \frac{157,000 \text{ ton}}{24} = 6,540 \text{ ton}$

Floor area of transit shed required: $Q = \frac{6,540 \text{ ton}}{3.0 \text{ t/m}^2} = 2,180 \text{ m}^2$

Size of warehouse for bulk cargo:

Capacity for bulk cargo: $W = \frac{220,000 \text{ ton}}{12} = 18,500 \text{ ton}$

Floor area of warehouse required: $Q = \frac{18,500 \text{ ton}}{3.0 \text{ t/m}^2} = 6,170 \text{ m}^2$

Size of warehouse for general cargo:

Capacity (Warehouse): $W = \frac{157,000 \text{ ton} \times \frac{1}{2}}{6} = 13,080 \text{ ton}$

Floor area of warehouse $Q = \frac{13,080 \text{ ton}}{3.0 \text{ ton/m}^2} = 4,360 \text{ m}^2$

Since the size of transit shed and warehouse varies greatly depending on the requirements of hinterland and local conditions, figures shown above are to be used only as a guideline and the determination of the size should be made after a thorough and careful study of these conditions. It will also be necessary to assume the capacity of the new port to be 500,000 ton/year as the basis for future calculation.

6.3 Determination of Size of Related Facilities

The capacity of the new port is assumed to be 500,000 tons and the size of related facilities is to be determined on this assumption.

Assuming that the cargo amounting to 500,000 tons annually is handled throughout the year except Saturdays, Sundays and holidays and that the rate of peak cargo movement is 1.5 in view of the fluidity of cargo movement, daily cargo movement is estimated as follows.

$$\frac{500,000 \text{ tons}}{250 \text{ days}} \times 1.5 = 3,000 \text{ ton/day}$$

Assuming the ratio of railroad and automobile in transport is 50:50, each system must carry 1,500 tons of cargo every day. Accordingly, the daily traffic may be calculated as follows.

Railroad:

Arriving cargo: 40% ~ 600 ton/day

Departing cargo: 60% ~ 900 ton/day

(The ratio of arriving and departing cargoes was determined from the ratio of export and import)

In view of the traction capacity of 250 tons per train between Caldera and San-Jose, four round trips of freight train will be required per day and the average load factor is estimated to be 75%.

Truck:

Assuming the capacity of a truck to be 4 tons and the rate of related vehicles is to be 100%, the daily traffic of vehicles may be calculated as follows.

$$\frac{1500 \text{ ton}}{4 \text{ ton}} \times 2 \text{ (round trips)} = 750 \text{ truck/day (traffic of truck)}$$

750 vehicle × 2 (rate of related vehicles)= 1,500 vehicle/day

If the hourly rate of peak traffic is to be 20%, 300 vehicle/hr may be considered as the standard capacity of road. As a result, the vehicular traffic may be absorbed by a two-lane road.

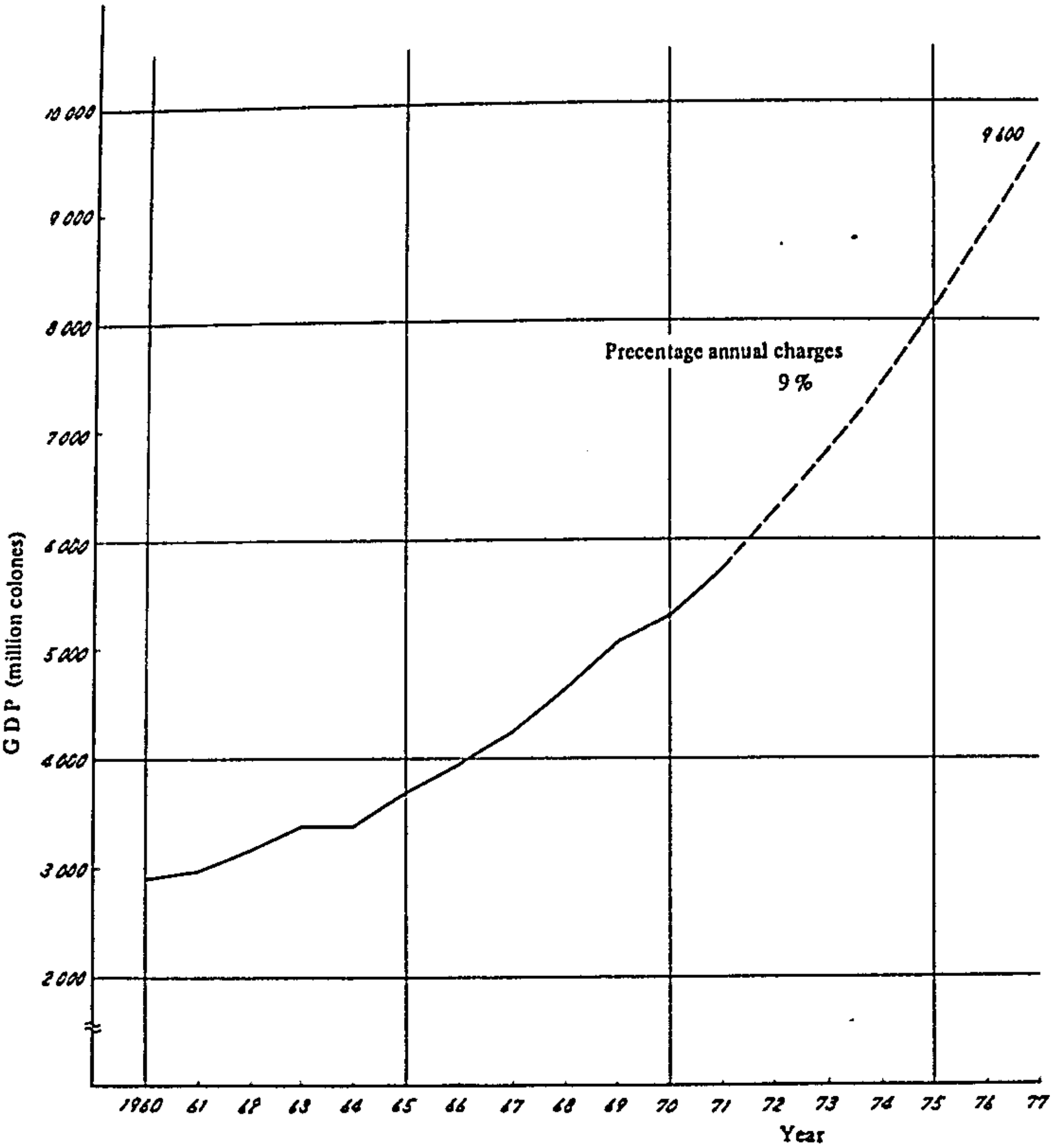
The size of city facilities to be provided along with the construction of a new port will be as follows. As for the number of workers required upon completion of the new port, a total of 12 gangs will be required since a total of 12 hatches will be opened when two ships are berthed at the same time. At present, a gang at the Port of Puntarenas is, composed of 24~12 men on the ship and 12 on the warf. Accordingly, a total of 288 longshoremen will be required. In the case of the Port of Puntarenas, more than 20% of the total port workers are port-related workers such as warehouseman, guard, clerk, pilot and foyboatman at present. The share of guard is relatively large and if the rate of related workers at the new port is 15%, the number of guards required will be 45 and a total of 330 workers will be required for the new port.

On the basis of the above, the population of the new port city is estimated at about 1,200, which comprises the following.

Port workers: 330	Single (50%)	- 165	About 1,200 in total
	Married (50%)	- 165	
	Family (wife and two children)	- 495	
Population of related services (20% of the total population)		- 200	

Assuming that one half of the total longshoremen and all of the related workers have families, the number of families living in the port area is estimated to be 200.

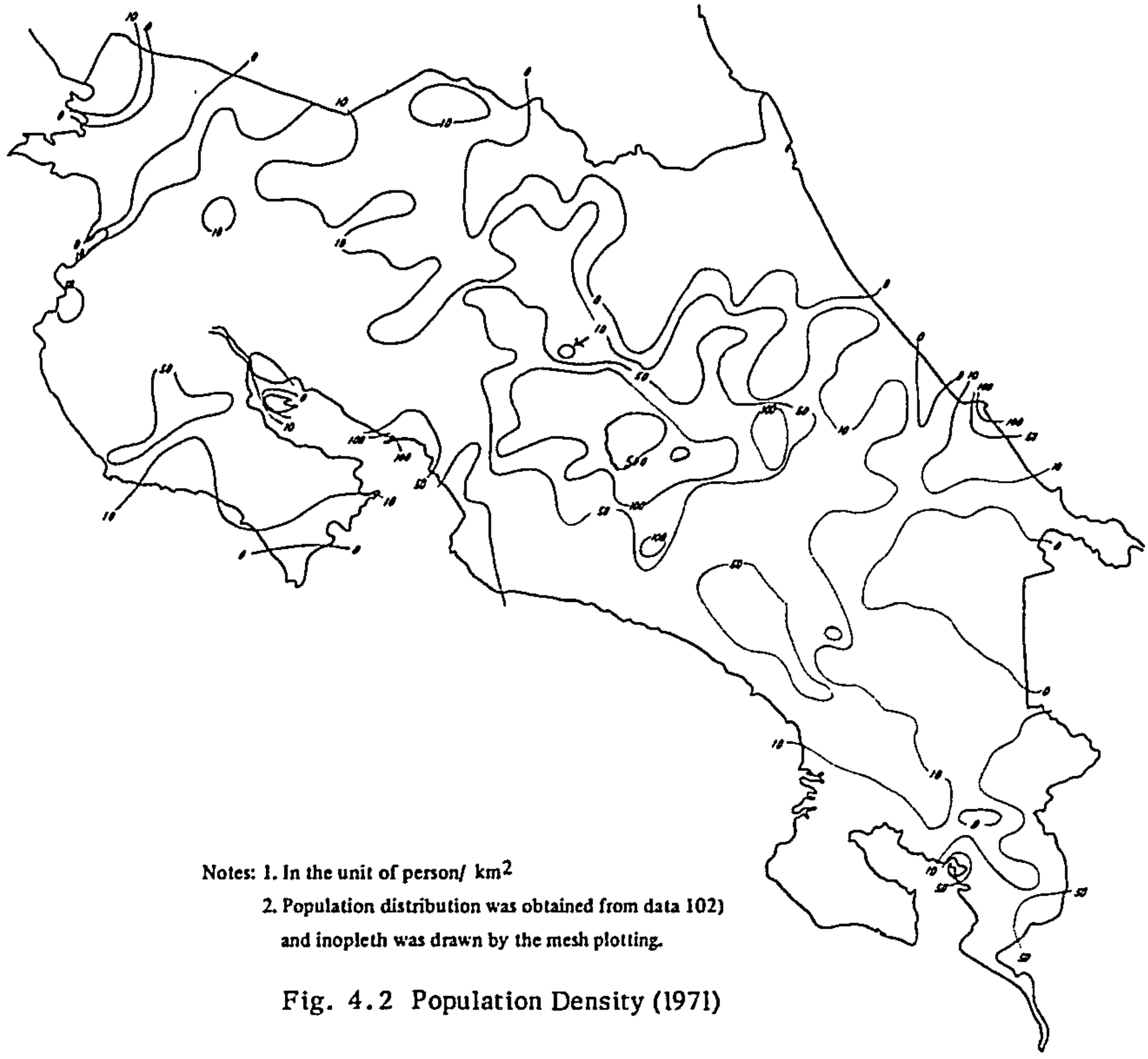
It is advisable that the size of main urban facilities be determined and land use plan be worked out by considering the above results.



Notes: 1. Thick line represents actual value and broken line represents estimated value

2. Actual value was derived from data 117).

Fig. 4.1 Actual and Estimated Value of G D P



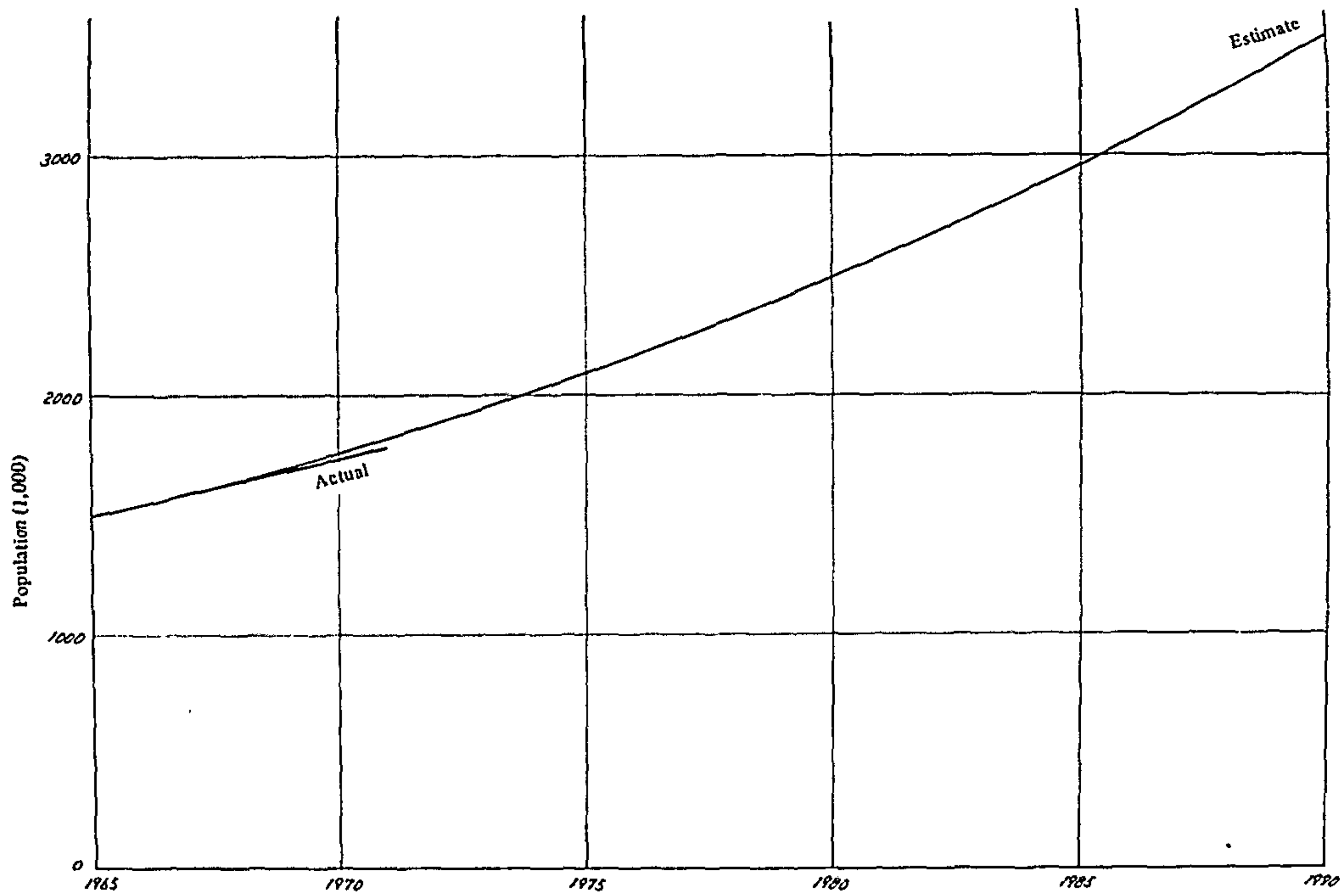
Notes: 1. In the unit of person/ km^2

2. Population distribution was obtained from data 102) and inopleth was drawn by the mesh plotting.

Fig. 4.2 Population Density (1971)

Source: 105)

Fig. 4.3 Surface Water Resources in Costa Rica



Source: 102) 103)

Fig. 4.4 Transition and Estimate of Population in Costa Rica

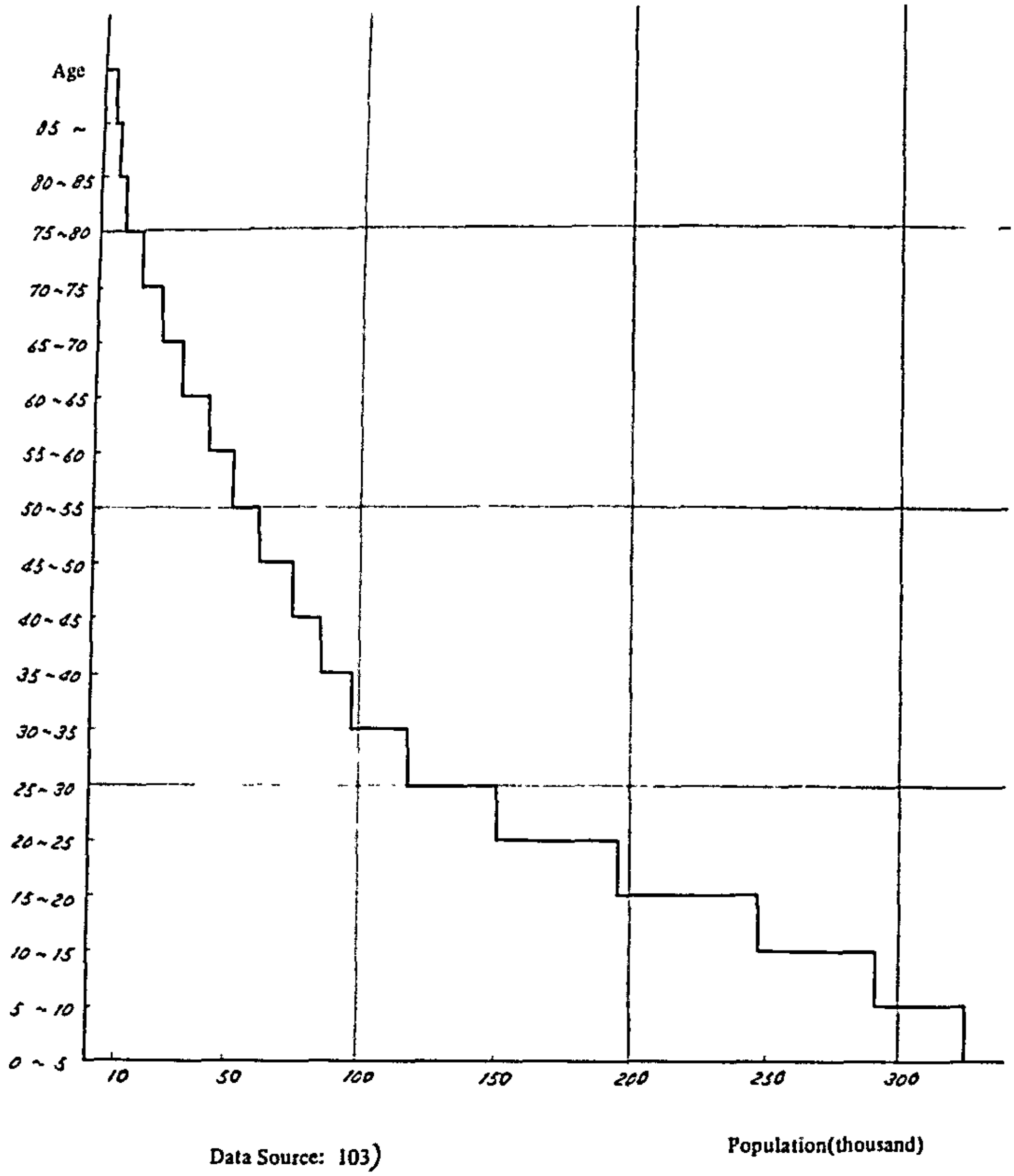
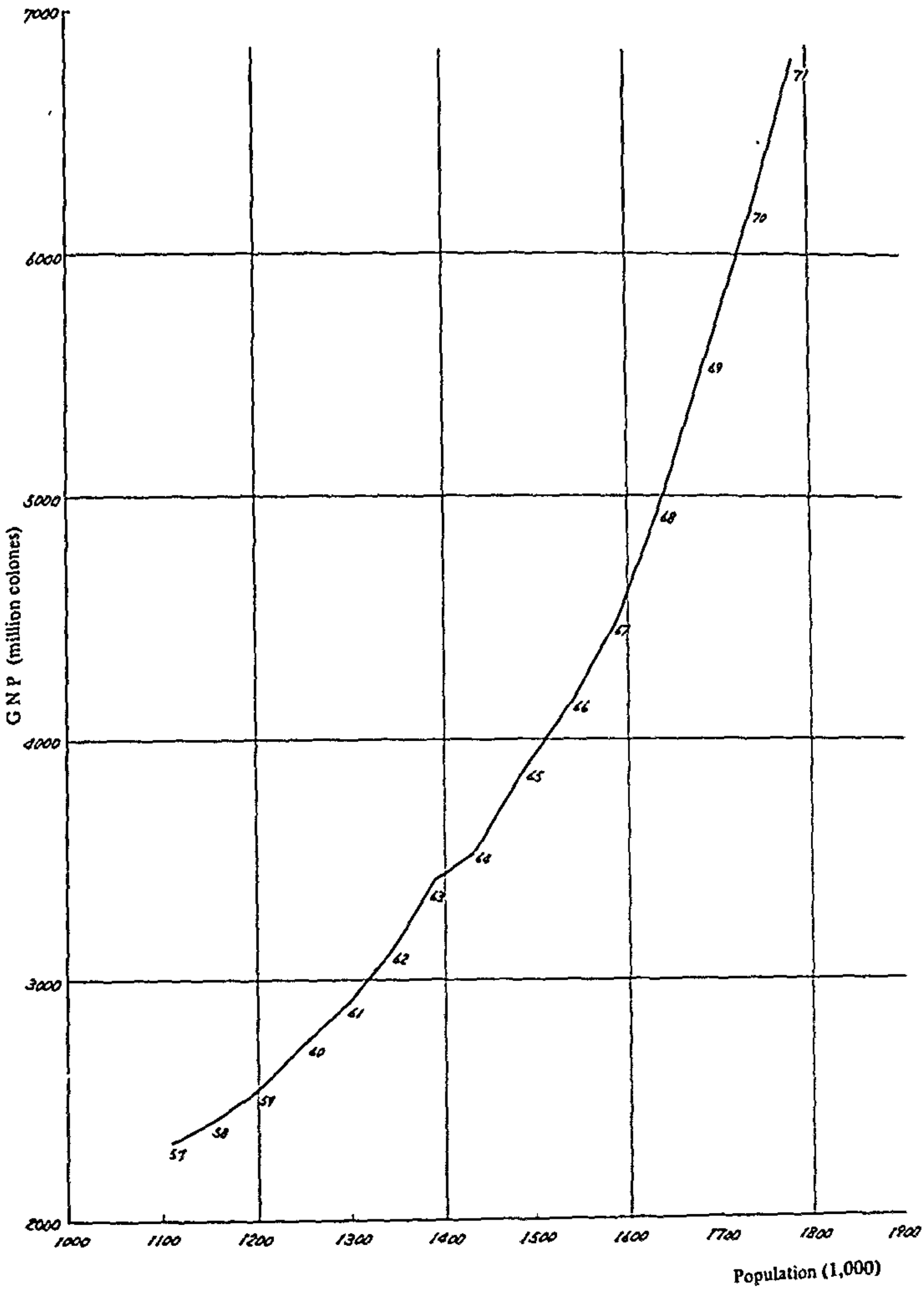
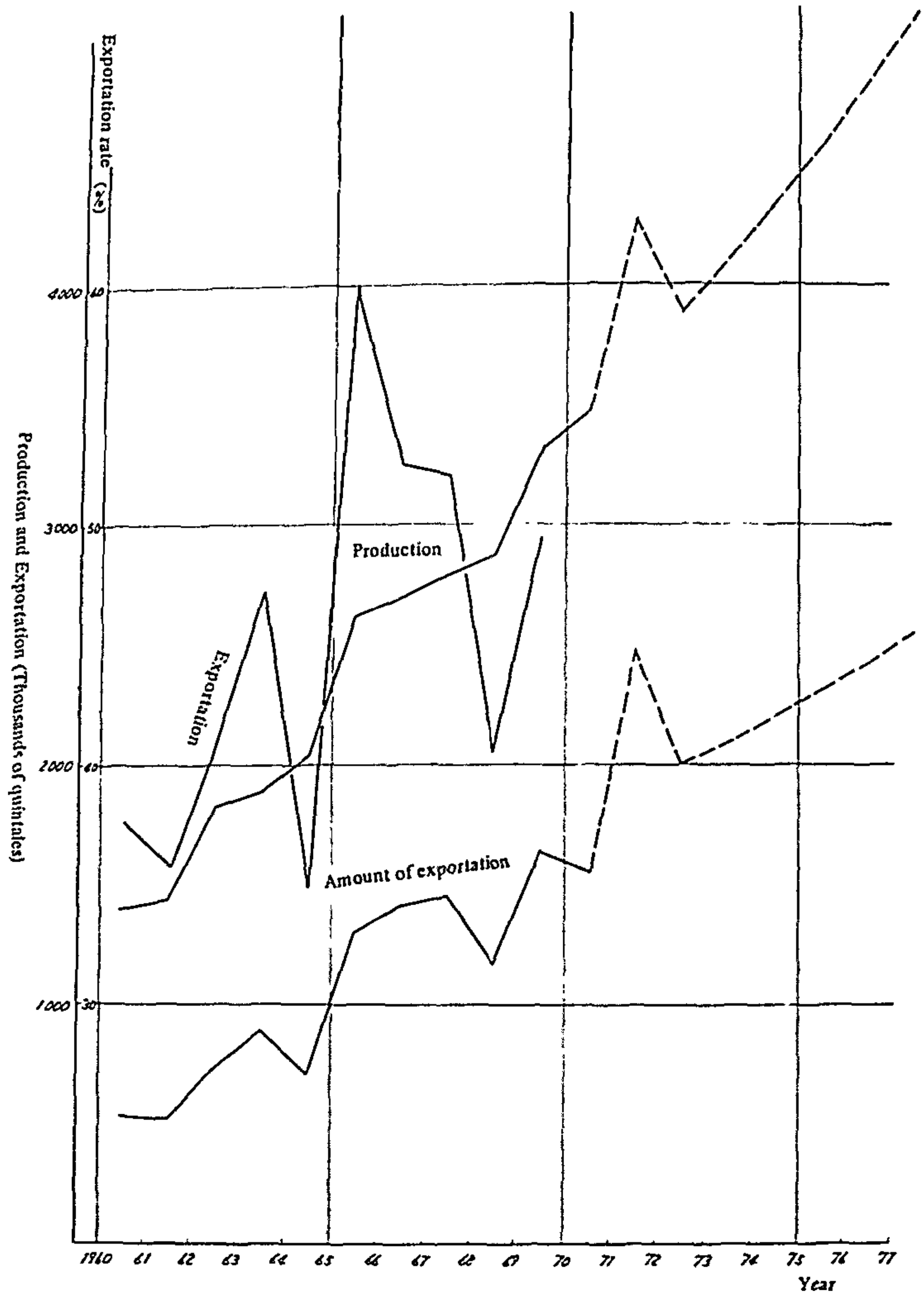


Fig. 4.5 Structure of Population in Order of Age



Source:102) 103) 117)

Fig. 4.6 Relation of G N P and Population in Costa Rica (1957-1971)

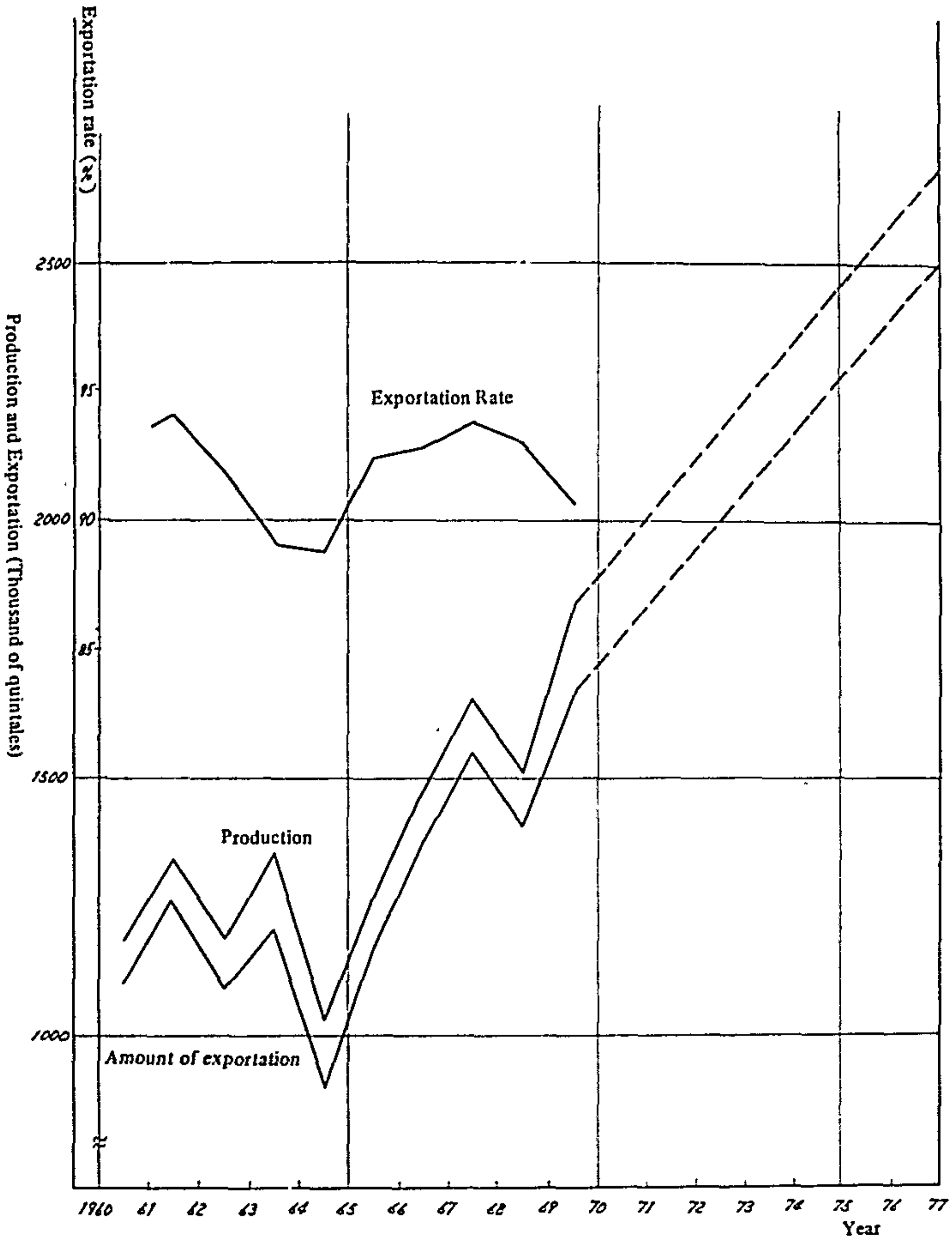


Notes:

1) Values in 1970-1971 1976-1977 are estimated by Banco Central

2) Actual Values are obtained from data 02)

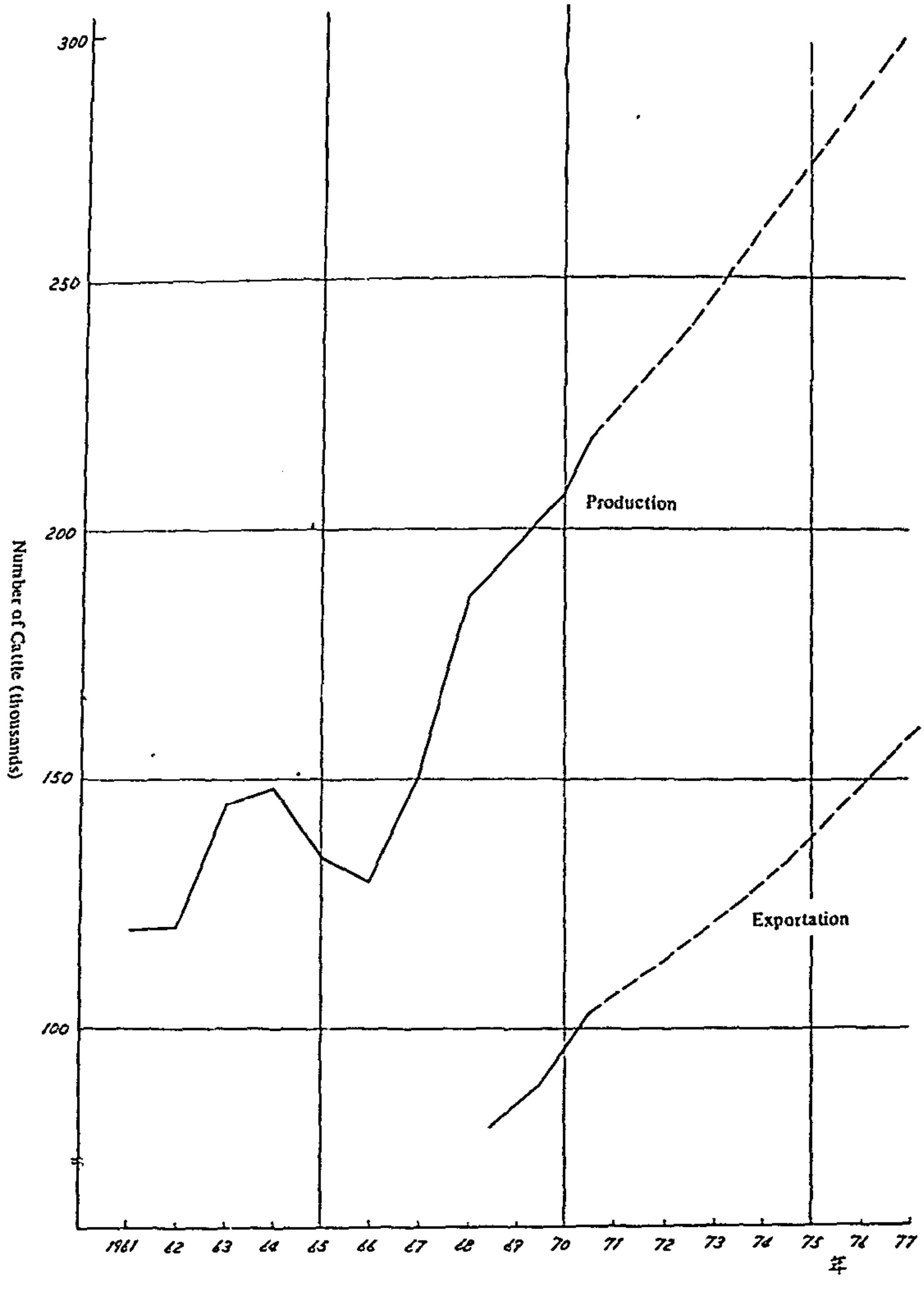
Fig. 4.7 Production and Exportation of Sugar in Costa Rica



Notes: 1) Values in 1969-70 1977 are estimated by Banco Central

2) Actual Values are obtained from data 102)

Fig. 4.8 Production and Exportation of Coffee in Costa Rica



Notes: 1) Values in 1969-1970 1977 are estimated by Banco Central

2) Actual values are obtained from data 102)

Fig. 4.9 Production and Exportation of Cattle in Costa Rica

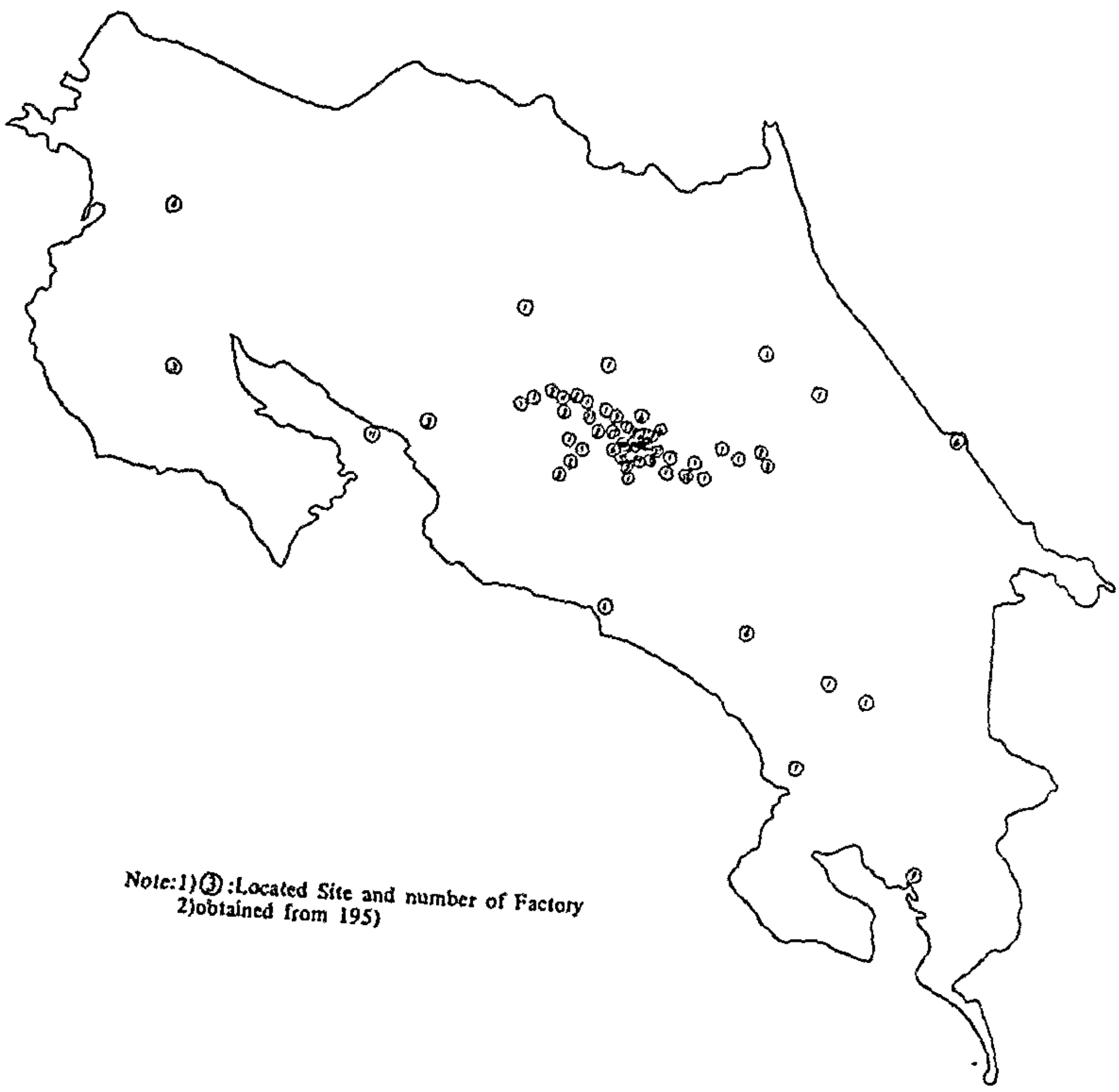
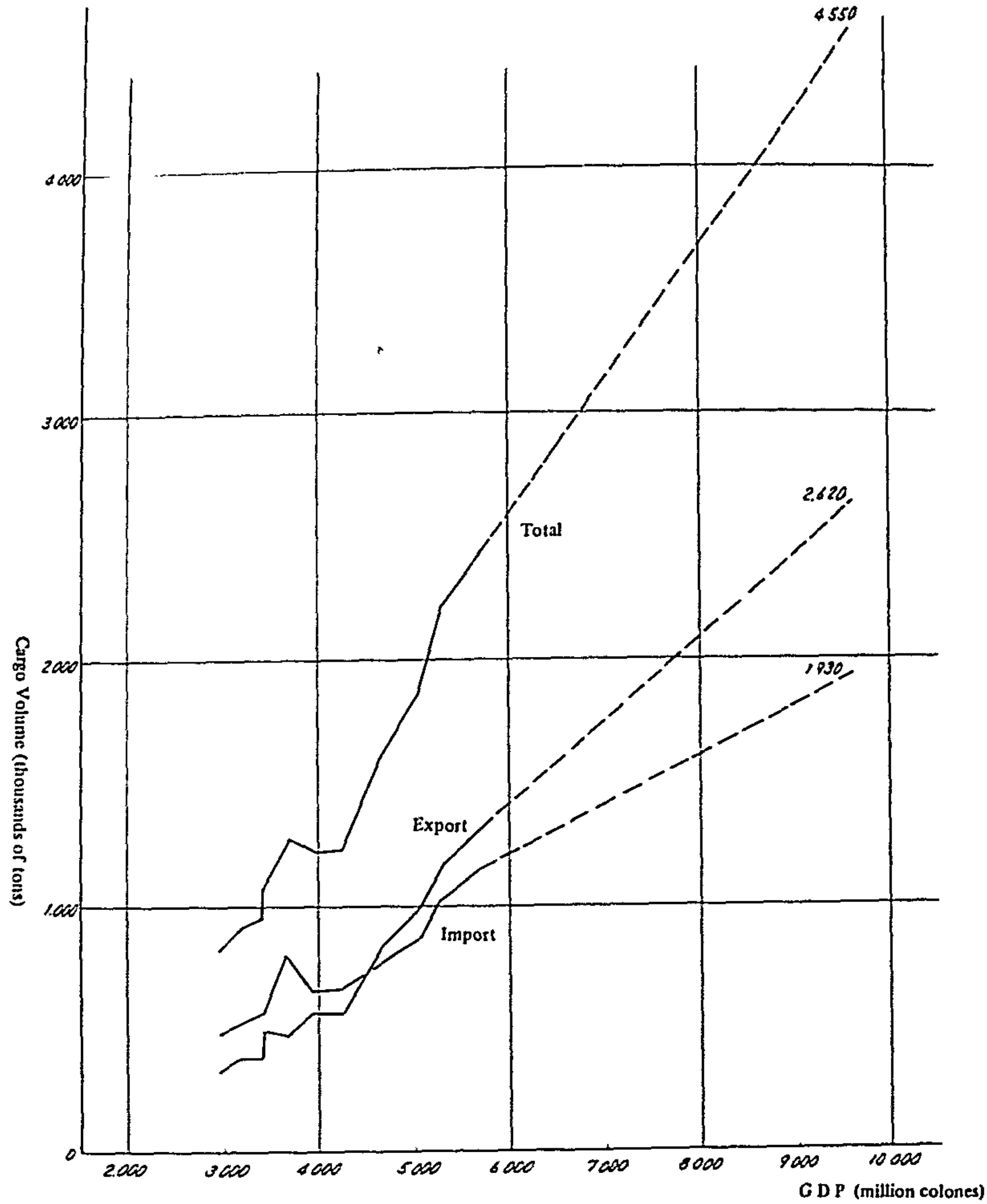


Fig. 4.10 Distribution of Factory in Costa Rica



Notes: 1. Thick line represents actual value and broken line indicates estimated value.
2. Actual value forthe volume of cargo handle derived from data 102) 103) and that for GDP was obtained from data 117).

Fig. 5.1 Estimated Cargo Volume Handled at Ports in Costa Rica

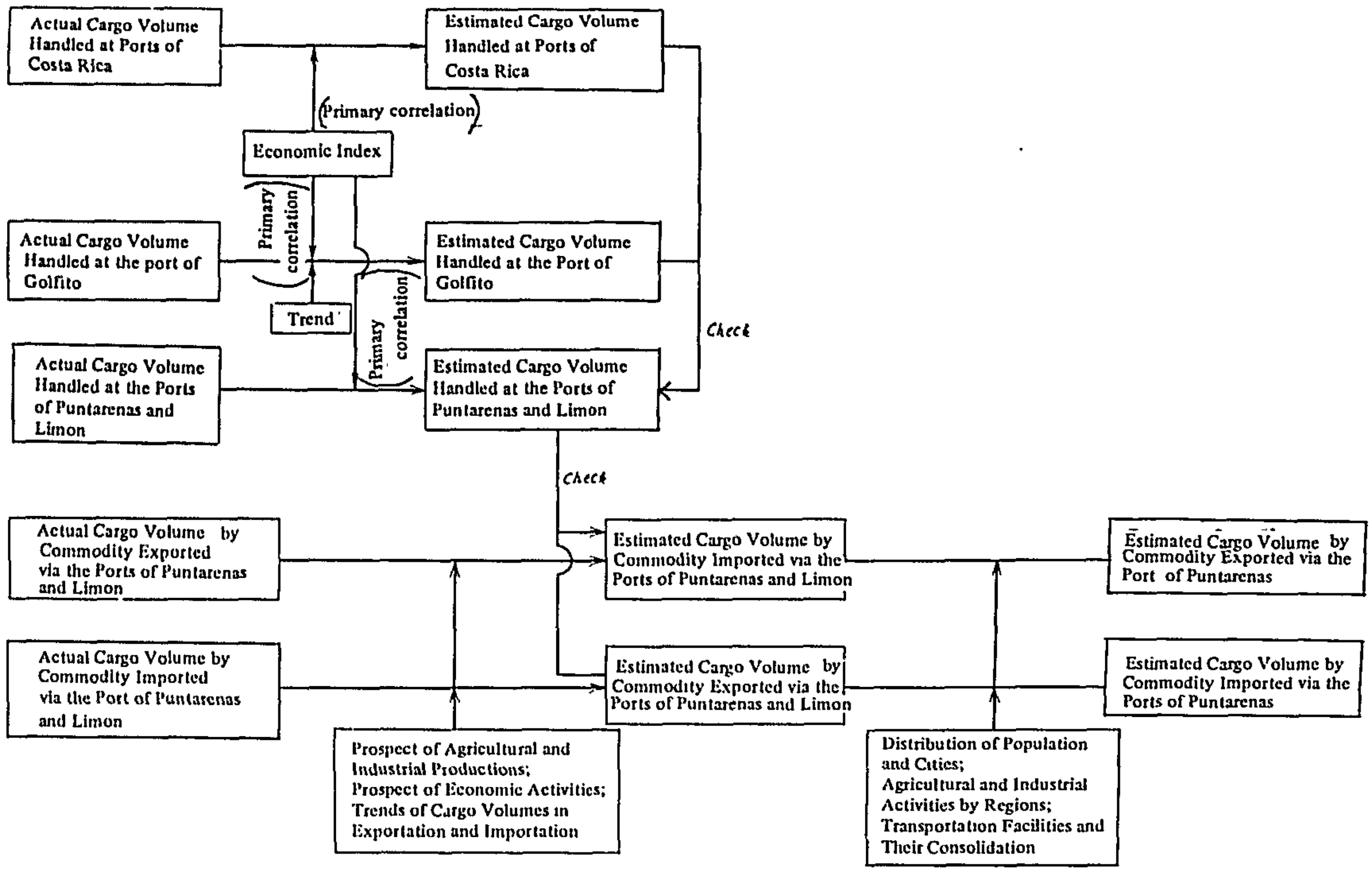
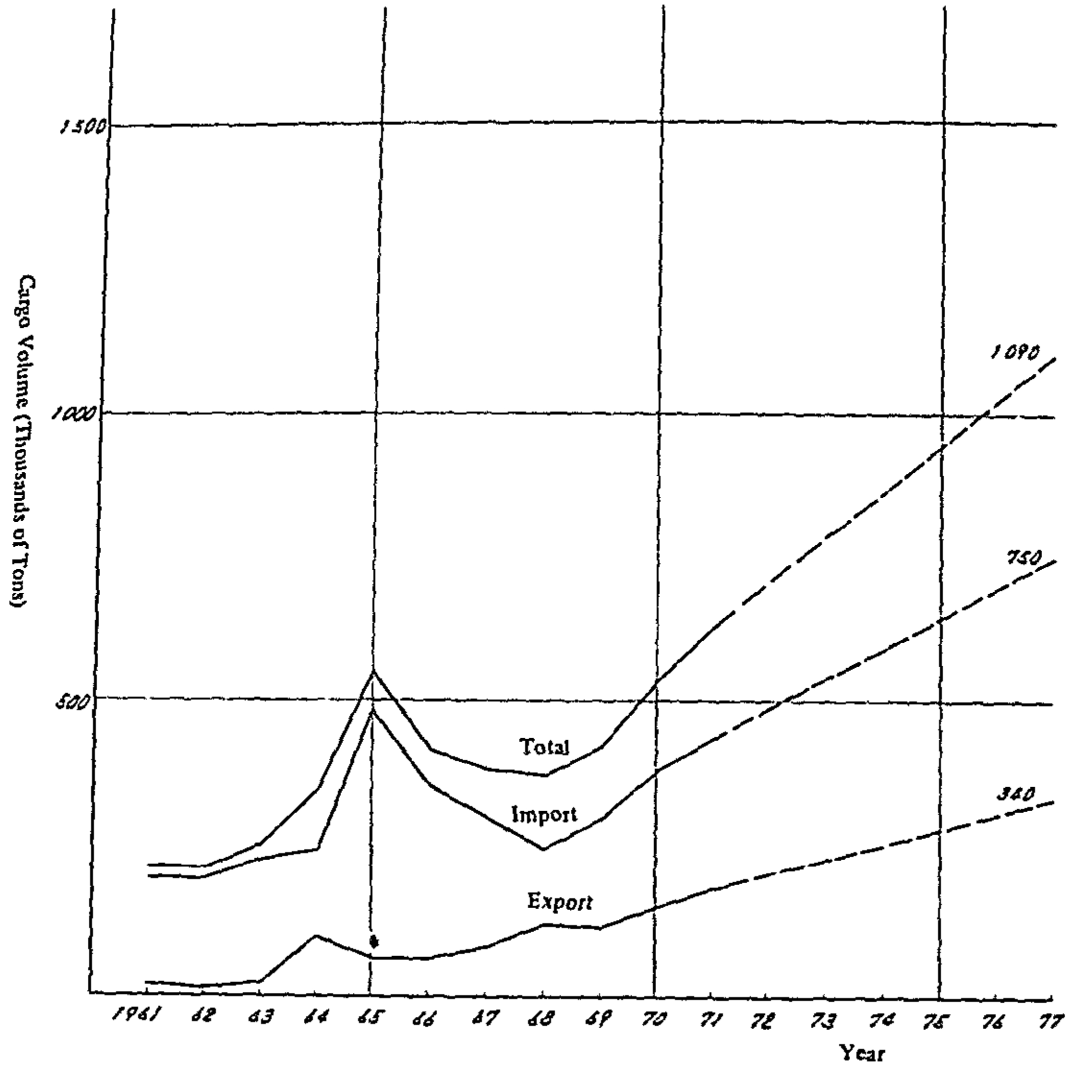
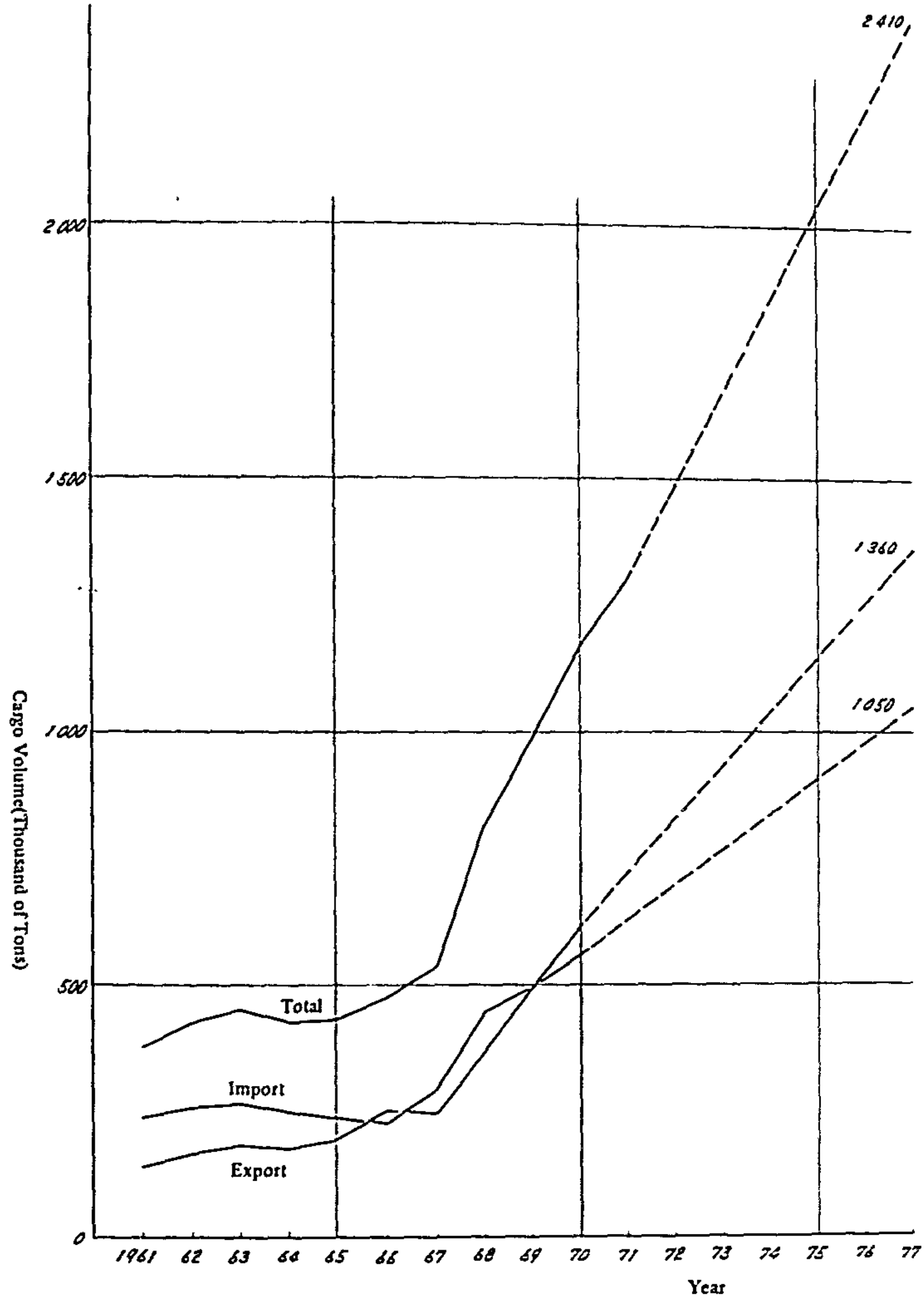


Fig. 5.2 Flow Chart of Estimation of Cargo Volume Handled at the Port of Puntarenas



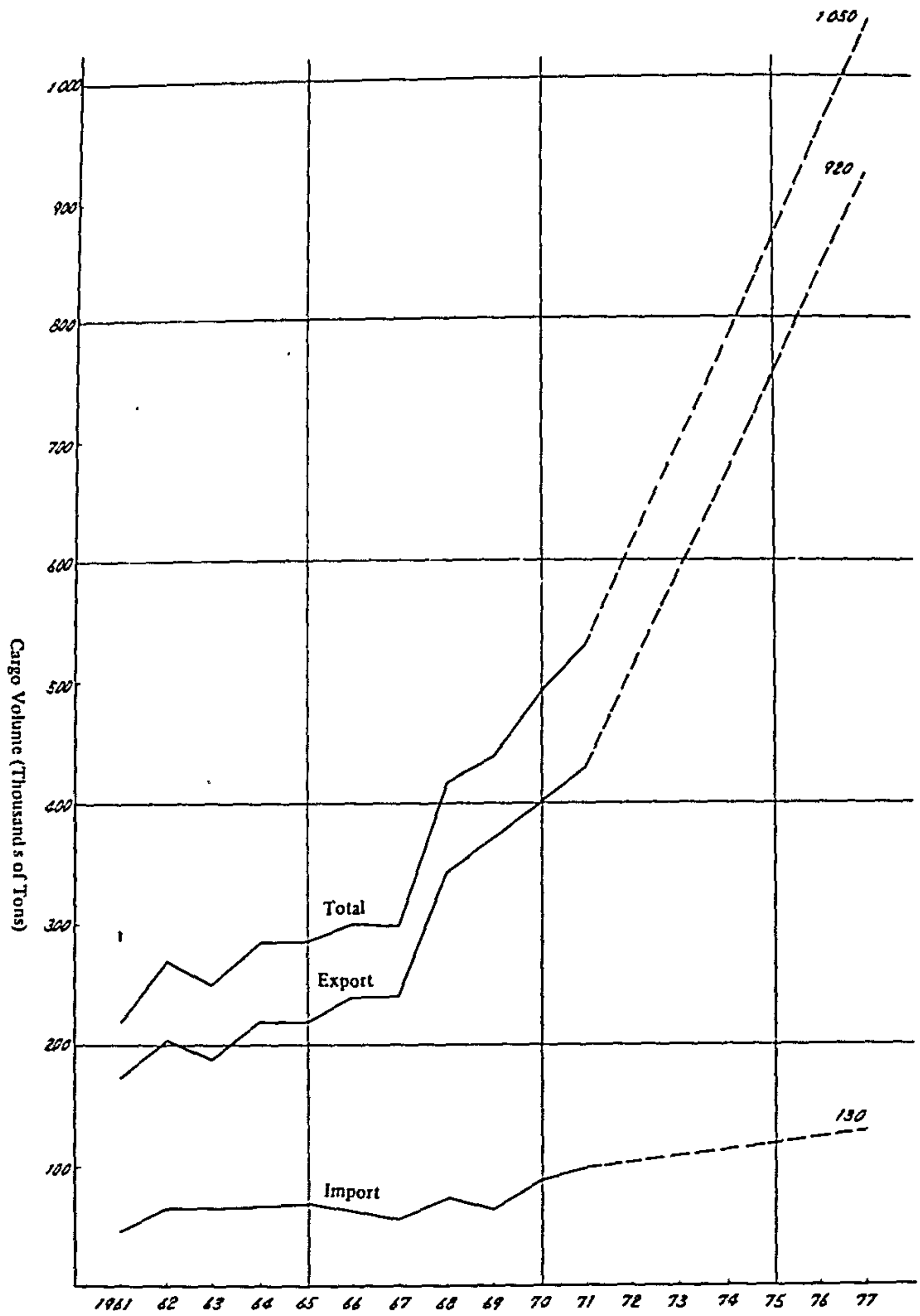
Notes: 1. Thick line represents actual value and broken line indicates estimated value.
2. Actual values was obtained from data 102) and 103).

Fig. 5.3 Estimated Cargo Volume Handled at the Port of Puntarenas



Notes: 1. Thick line represents actual value and broken line indicates estimated value.
2. Actual value was obtained from data 102) and 103).

Fig. 5.4 Estimated Cargo Volume Handled at the Port of Limon



Notes: 1. Thick line represents actual value and broken line indicates estimated value.

2. Actual value was obtained from data 102) and 103).

Fig. 5.5 Estimated Cargo Volume Handled at the Port of Golfito

Fig. 5.6 Fig. 5.19 Actual Value and Future Estimation of Cargo Volume by Commodity

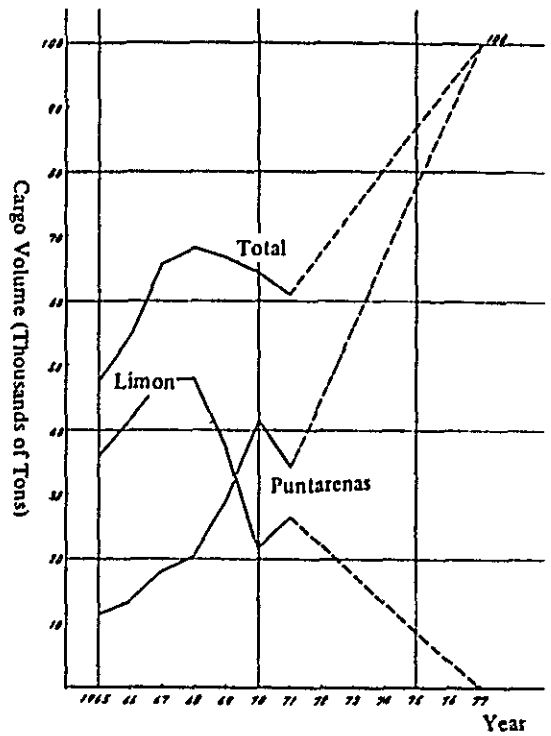


Fig. 5.6 Exportation of Coffee

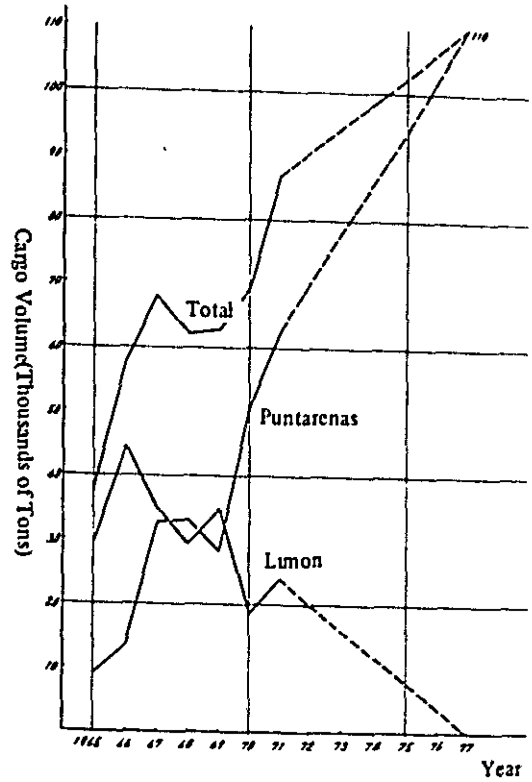


Fig. 5.7 Exportation of Sugar

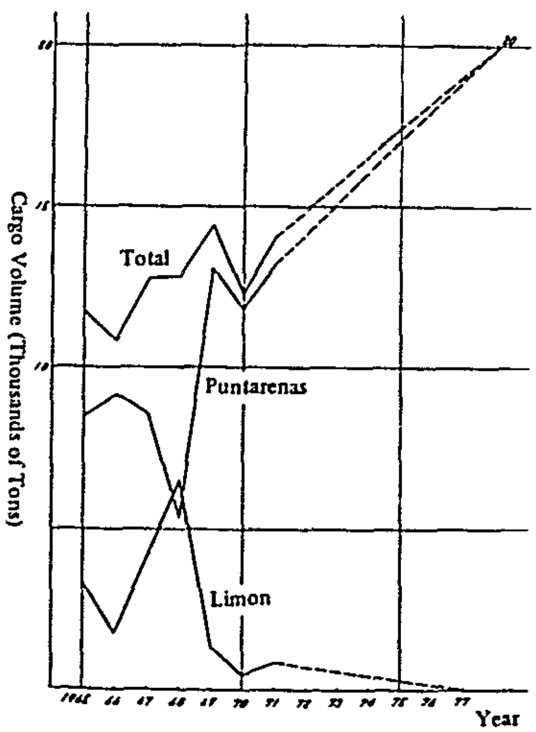


Fig. 5.8 Exportation of Beef and Live Beef Cattle

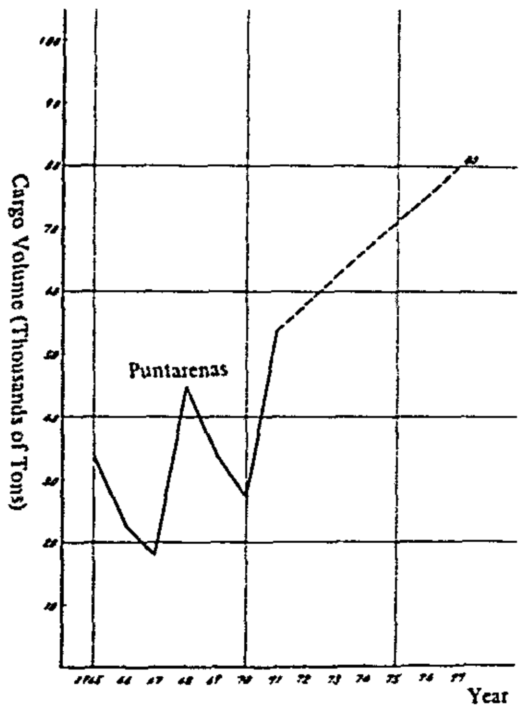


Fig. 5.9 Exportation of Manufactured Fertilizer

Notes: 1. Thick line represents actual value and broken line indicates estimated value.

2. Actual value was obtained from data 102) and 103).

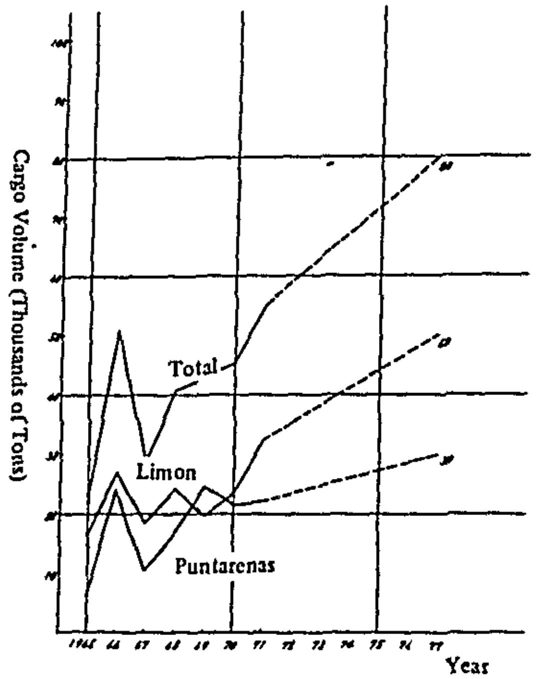


Fig. 5.10 Exportation of Other Cargos

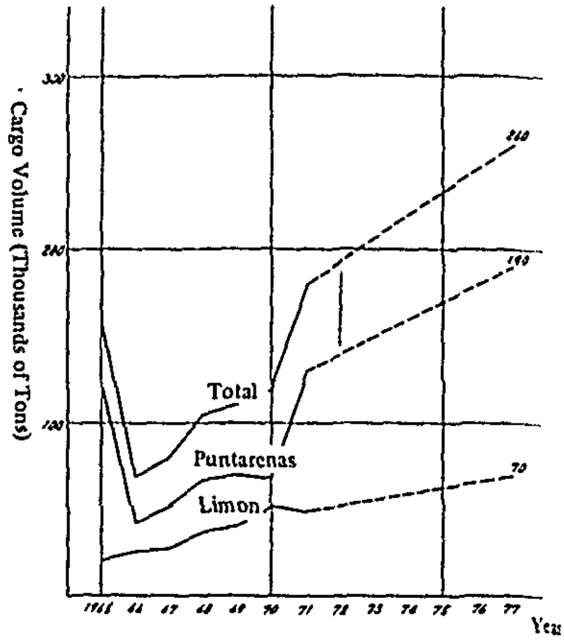


Fig. 5.11 Importation of Fertilizer and Fertilizer Materials

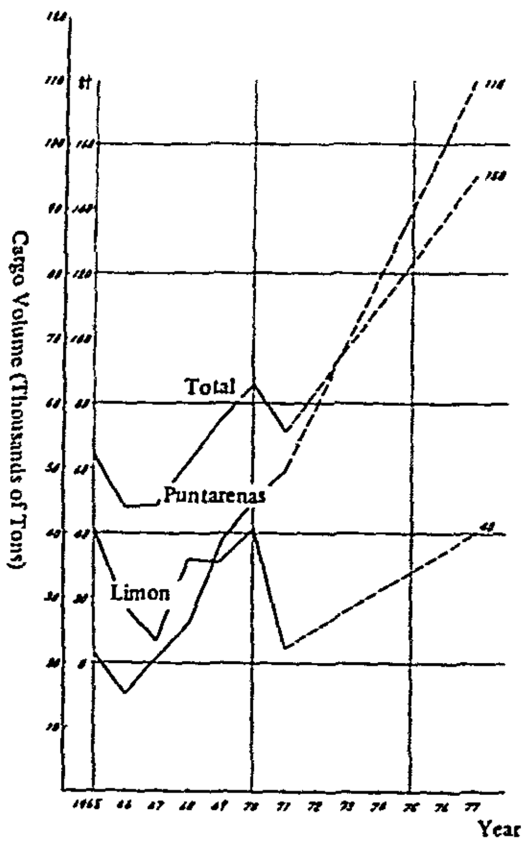


Fig. 5.12 Importation of Iron and Steel

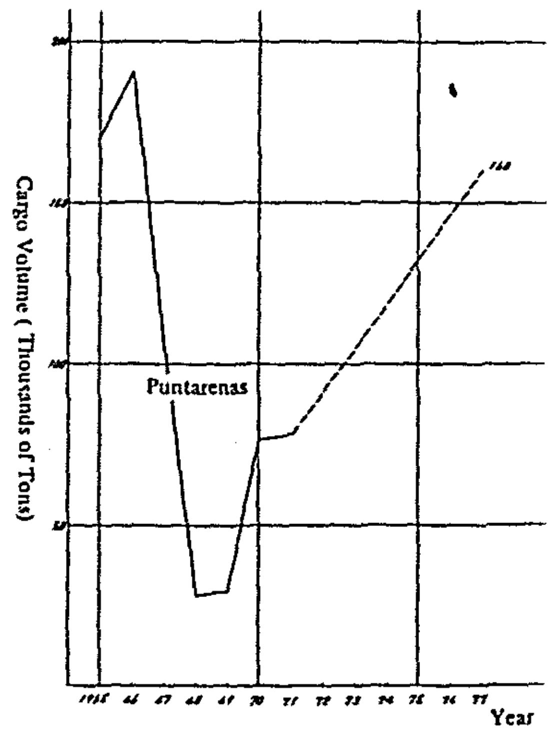
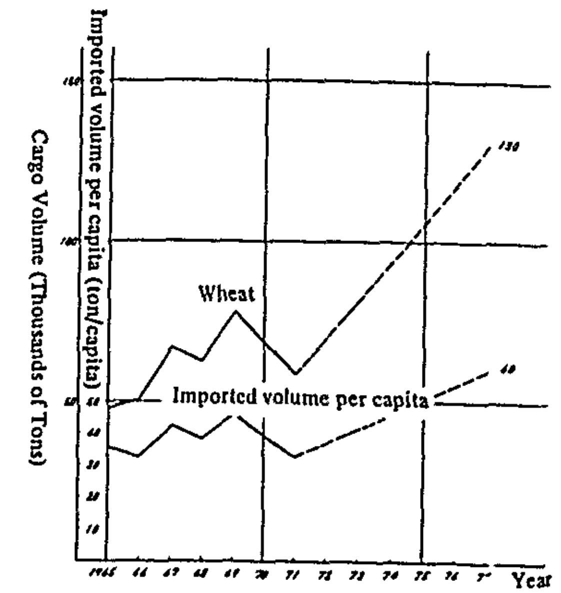


Fig. 5.13 Importation of Petroleum Product



Note: It includes the volume of flour converted into that of wheat by using 1/0.9 as the rate of conversion.

Fig. 5.14 Importation of Wheat

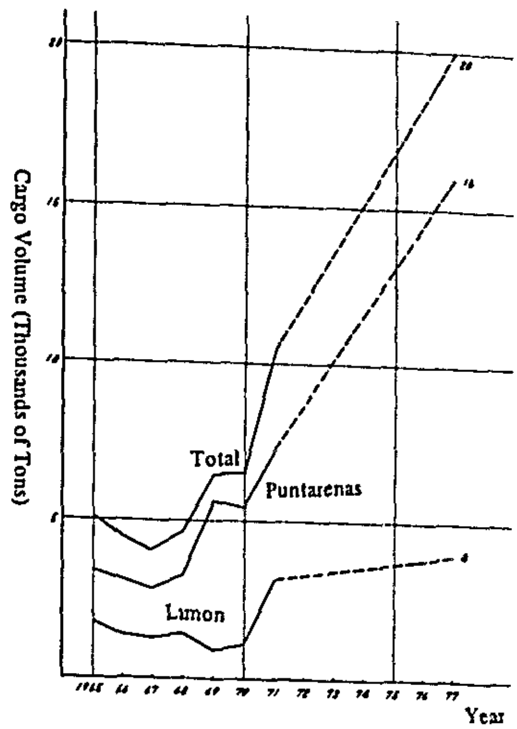


Fig. 5.15 Importation of Vehicles

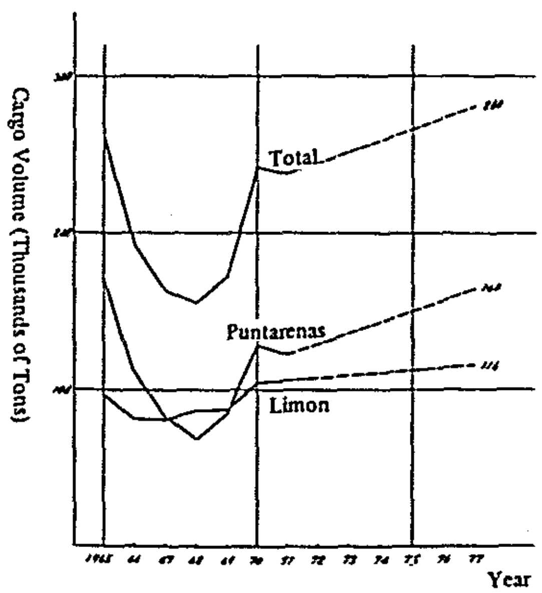


Fig. 5.16 Importation of Other Cargos

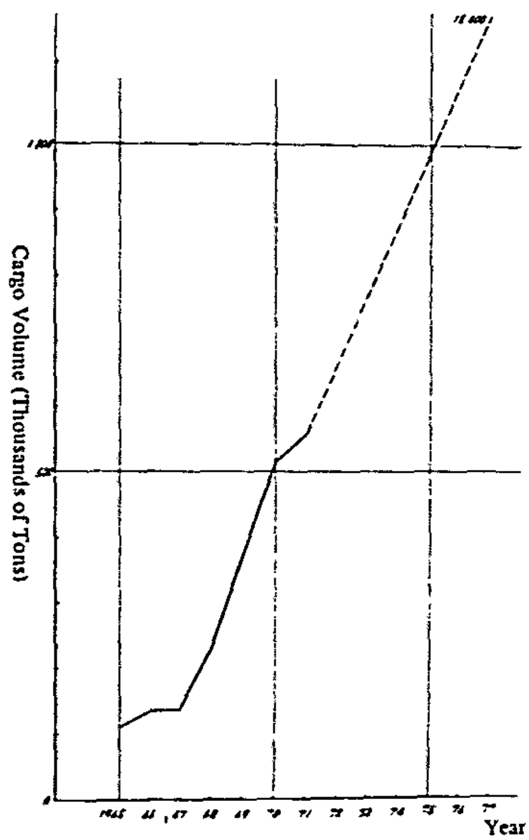
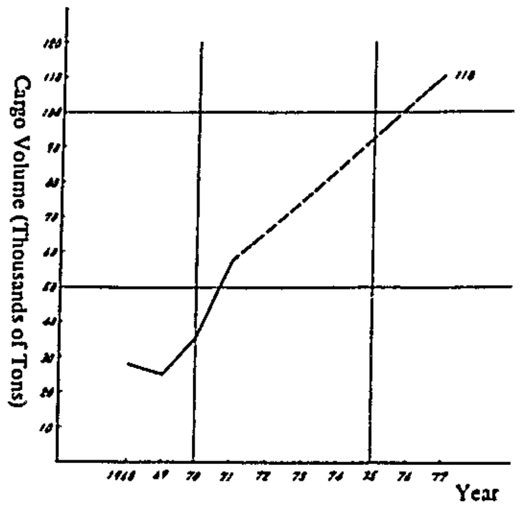


Fig. 5.17 Exportation of Banana



Note: Values for 1969 and 1970 are those estimated.

Fig. 5.18 Exportation of Petroleum Product

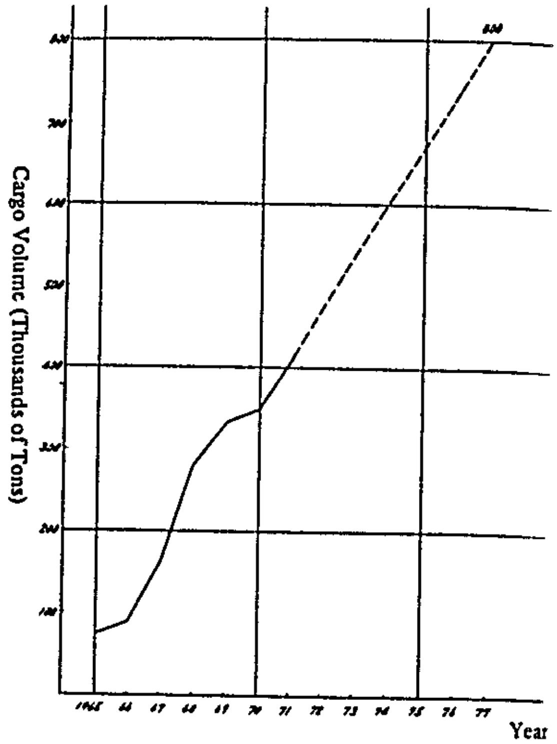
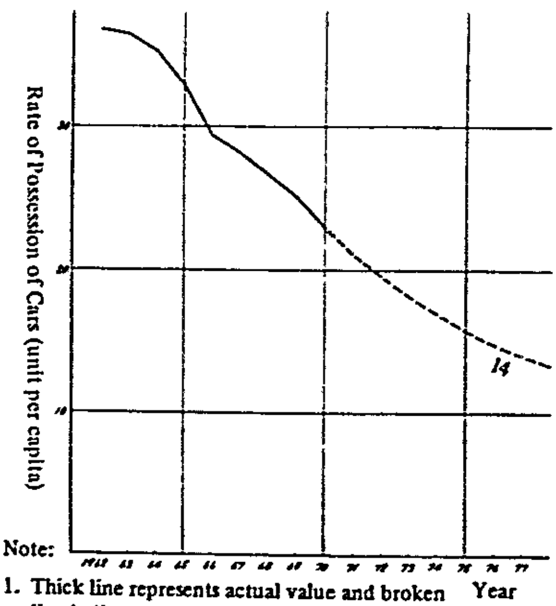
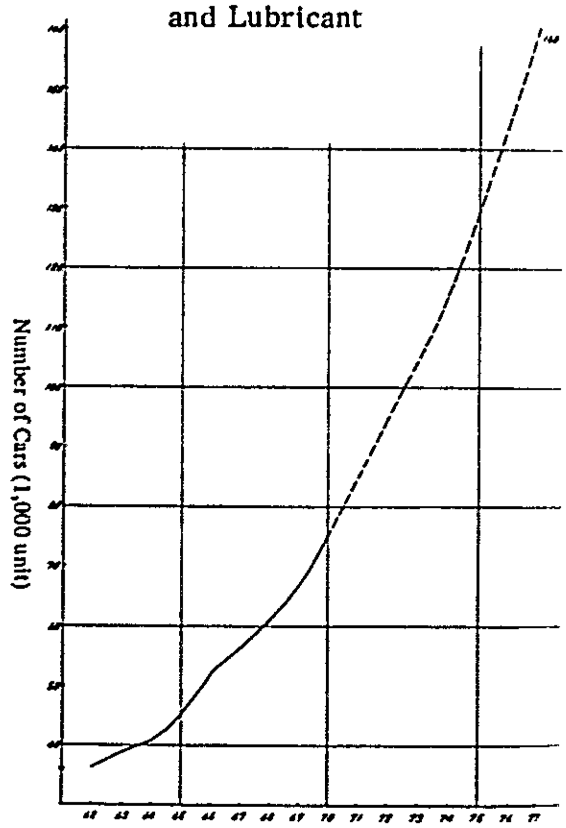


Fig. 5.19 Importation of Fuel and Lubricant



Note:
1. Thick line represents actual value and broken line indicates estimated value obtained from the trend.
2. Actual value was derived from data 102) and 103).

Fig. 5.20 Rate of Possesion of Cars



Notes: 1. Thick line represents actual value and broken line indicates estimated value
2. Actual value was obtained from data 102) and 103).

Fig. 5.21 Number of Cars

Table 4.1 National Account in Costa Rica

Year	G D P (million colones)			GDP per Capita (colon)	
	at Current Price	Real (1962 price)	Percentage annual changes	Real	Percentage annual changes
1960	2,767	2,914	%	2,324	%
61	2,920	2,971	2.0	2,289	- 1.5
62	3,174	3,174	6.8	2,363	3.2
63	3,464	3,384	6.6	2.433	3.0
64	3,600	3,380	0.0	2,349	- 3.5
65	3,950	3,697	9.4	2,481	5.6
66	4,243	3,947	6.8	2,561	3.2
67	4,595	4,252	7.7	2,674	4.4
68	5,060	4,639	9.1	2,839	6.2
69	5,654	5,051	8.9	2,998	5.6
70	6,269	5,304 2)	5.0	3,048	1.7
71	6,930 1)	5,737 2)	8.2	3,213	5.4
1965 - 69 Average			8.4	1965~69 Average	5.0

1) Preliminer
2) Estimated
3) Source: 117)

Table 4.2 GDP by Sector

unit: million colones

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Agriculture, Silviculture, Fishery.	672.6	764.0	806.5	875.3	879.0	971.2	998.6	1,092.3	1,204.2	1,388.7	1,447.7	1,524.5
Manufacture and exploration of mining	476.8	466.3	532.9	606.1	649.5	699.6	778.2	874.0	980.2	1,076.5	1,210.7	1,327.8
Construction	130.1	150.4	172.0	183.2	150.3	186.2	200.2	198.8	229.9	236.1	283.2	359.1
Electrity, Gas Water works Sanitary service	33.6	37.2	39.7	46.6	51.9	59.2	65.0	69.8	80.3	99.2	107.6	124.5
Transportation, Warehouse, Communication	105.2	110.5	118.2	130.2	143.5	155.9	159.1	184.0	204.1	237.5	252.1	282.0
Commercial	504.7	486.7	537.7	574.4	604.2	661.2	706.1	717.0	788.2	871.1	1,044.3	1,160.8
Bank, Insurance, Real estate	70.7	74.3	73.1	79.4	93.1	103.3	114.3	131.9	151.9	182.1	214.7	245.2
Dwelling	255.7	272.6	293.9	315.7	328.6	341.0	353.6	367.4	384.2	401.2	423.2	449.3
Public officials	253.0	274.3	292.3	319.9	338.4	379.9	442.8	491.6	557.7	612.4	681.9	797.6
Service	264.3	283.6	308.1	333.2	361.4	392.4	424.8	468.5	499.5	549.1	604.0	658.8
G.D.P	2,766.7	2,919.9	3,174.4	3,464.0	3,599.9	3,949.9	4,242.7	4,595.3	5,060.2	5,653.9	6,269.4	6,929.6

Remarks: * Preliminer
Source: 117)

Table 4.3 Structure of Occupational Population in Costa Rica

Agriculture and Mining	48.1 %
Industry and Construction	18.8
Electric and Transportation	4.9
Commerce .	10.2
Service and etc.	17.9

Data Source : 110)

Table 4.4 Population Change of Province in 1961~1971

	1961	1971	1971-1961	1971/1961
San Jose	430,344	630,348	200,004	146.5 %
Alajuela	232,002	317,738	95,736	136.8
Cartago	154,225	203,809	49,584	134.0
Heredia	77,296	108,274	30,978	140.2
Guanacaste	146,644	194,805	48,159	132.6
Puntarenas	148,058	217,091	69,033	146.6
Limon	62,828	90,397	27,569	143.8

Data Source : 102)

Table 5.1 Cargo Volume of Foreign Commerce in Costa Rica

unit: thousand of metric tons

	1961	62	63	64	65	66	67	68	69	70	71
Limon											
Exp.	139	163	181	178	195	251	243	367	491	616	704
Imp.	235	261	268	248	235	224	293	443	498	560	599
Total	374	424	449	426	429	475	536	810	989	1,176	1,303
Puntarenas											
Exp.	22	16	22	102	66	82	88	120	127	153	186
Imp.	204	203	238	255	495	361	308	256	307	390	447
Total	226	219	260	357	561	443	396	376	434	543	633
Golfito											
Exp.	174	204	187	219	218	239	241	344	372	402	430
Imp.	45	66	64	66	68	63	56	73	66	90	100
Total	219	270	251	285	286	302	297	417	438	492	530
Total											
Exp.	335	383	390	499	479	572	572	831	990	1,171	1,320
Imp.	484	530	570	569	797	648	657	772	871	1,040	1,146
Total	819	913	960	1,068	1,276	1,220	1,229	1,603	1,861	2,211	2,466

Data Source: 102), 103)

Table 5.2 Estimated Cargo Volume Handled at the Port of Puntarenas

	Cargo Volume (thousands of metric tons)	Share	1977/71
Exportation			
Coffee	100	29.4 %	2.91
Sugar	110	32.4	1.75
Fertilizer	80	23.5	1.49
Beef, Live Beef Cattle	20	5.9	1.52
Others	30	8.8	1.36
Total	340	100.0	1.83
Importation			
Fertilizer & Fertilizer Material	190	25.3 %	1.45
Wheat	110	14.7	1.88
Iron & Steel	110	14.7	2.22
Petroleum Products	160	21.3	2.05
Vehicles	16	2.1	2.20
Others	164	21.9	1.34
Total	750	100.0	1.68
Total	1,090	-	1.72

Table 5.3 Estimated Cargo Volume for Each Facility (1977)

unit : 1,ooo ton

	Commodity	Total	Existing Facility	Sea Berth (Caldera)	New Facility
Export	Coffee	100	64	-	36
	Sugar	110	-	-	110
	Fertilizer	80	80	-	-
	Beff, Live Beef Cattle	20	12	-	8
	Others	30	19	-	11
	Total	340	175		165
Import	Fertilizer & Fertilizer Materials	190	190	-	-
	Wheat	110	-	-	110
	Iron & Steel	110	70	-	40
	Petroleum	160	-	160	-
	Vehicles	16	10	-	6
	Others	164	108	-	56
	Total	750	378		212
Grand Total		1,090	553	160	377

Table 6.1 Estimated Number of Vessel (1977)

Commodity		Volume	Main Forland	Size of Vessel	Handling Cargo tonnage/vessel	Calling Numbers in a Year
Export	Sugar	110,000 ton	N. America	5,000 D/W	5,000 ton	22
	Coffee	30,000	"	5,000	2,000	15
	"	6,000	Europe, Asia	15,000	4,000	1.5
	Beef, Live Beef Cattles	8,000	N. America	5,000	2,000	4
	Other	8,000	N. America	5,000	2,000	4
	"	3,000	Europe, Asia	15,000	4,000	0.75
Import	Wheat	110,000	N. America	5,000	5,000	22
	Iron & Steel	40,000	Europe, Asia	15,000	4,000	10
	Vehicles	6,000	Europe, Asia	15,000	4,000	1.5
	Other	40,000	Europe, Asia	15,000	4,000	10
	"	124,000	N. America	5,000	2,000	62
Total		377,000	15,000 D/W	24 Vessels	5,000 D/W	118 Vessels

*A haltof salling bulk carriers which carry wheat and sugar will unload wheat and load sugar, and other half will carry each of them indivdually. Therefore, total number of calling bulk carrier will be obtained to 33.

Table 6.2 Analysis of Handling Time

Size of Vessel	Hatch	Kind of Cargo	Faculty of Gang	Faculty in a day	Unit Volume of Loading & Unloading	Handling days	Total Anchorage days
15,000 D/W	6	General Cargo	15 t/h	720 t/vessel	4,000 t	5.6	144
5,000 D/W	3	"	15 t/h	360 t/ "	2,000 t	5.6	510
		Bulk Cargo	50 t/h	1,200 t/ "	5,000 t	4.2	149

* Mooring days are calculated to be 6.6 and 4.5 days respectively for classification of vessels by adding several hours to handling days.

Table 6.3 Size of Berth

Size of Vessel	Length of Standard Vessel	Excessive Length	Length of Berth	Draft	Water Depth of Berth
15,000 D/W	165 m	15 m	180 m	9.5 m	10.0 m
5,000 D/W	109 m	21 m	130 m	6.7 m	7.5 m

Chapter III Natural Environments Around the East Coast of the Golf of Nicoya

7. General

As a result of the study made in the previous chapter, it became apparent that the center of population, industry and transport in Costa Rica is on the Pacific side at present and that construction of the proposed port on the Pacific side is not only advantageous but indispensable.

Since the development of agriculture and manufacturing industry in the Peninsula of Nicoya (Peninsula de Nicoya), the Valley of Tempisque (Valle de Tempisque) and the east coast of the Gulf of Nicoya (Golfo de Nicoya) is considered to be the basic factor for the future growth of the economy of Costa Rica, construction of a new port in this region will be of prime importance.

In view of the above fact, it is natural that attension is focused on several locations along the east coast of Gulf of Nicoya as proposed sites for construction of a new port,because the area is close to the present center of population, industry and transport and is considered to become the center of future economic growth. On the other hand, the north coast of Peninsula de Nicoya has shallow water and is not qualified for construction of a good port. The Pacific coast of the Peninsular and south of Conejo Head (Punta Conejo) on the Pacific coast have also disadvantages in inland transport. Therefore, it is extremely difficult to select an appropriate location for construction of a port in these areas.

In consideration of various conditions mentioned so far, it was concluded that the site of a new port should be chosen in the area between Punta Morales on the east coast of the Gulf of Nicoya and Herradura Bay (Bahia Herradura). Accordingly, the discussion which follows will be centered on the natural conditions in this area.

This area forms a relatively gently sloped highland extending from the southwest foot of the mountains of Cordillera (Cordillera de Tilaran) to the lower reaches of the great river of Tarcoles (Rio Grande de Tarcoles). This is mainly a grassland with an altitude of 10 to 1,000 m where many farmers are raising sugar cane and pasturage over an extended area. Geology of this highland consists mainly of tertiary sandstone and tertiary tuff, and partly of Mesozoic rock. The top soil is accumulated volcanic ash less than a few meters deep forming a loam layer. The surface of the loam forms a generally flat table and is divided by deep gorges.

Incidentally, such a topography and geology resemble those on the south coast of Tokyo Bay and are very familiar to Japanese engineers.

These tertiary sandstone or tertiary tuff is a suitable material for port construction. However, a careful test should be conducted to examine whether they are suited for use as construction materials of breakwaters and armor stone of quaywalls. If these materials are determined to be unsuitable for use as armor stone, hard igneous rock such as andesite distributed near Esparta and Orotina may be used instead.

The lowland less than 10 m in altitude except the portion in the Peninsula of Puntarenas is generally a marsh land thickly covered with palm trees and mangrove. While part of this area has been developed as salt-field and farm-land for production of sugar, the greatest part is left untouched for many years. Such a lowland generally has a thick deposit of soft clay or soft silty alluvial soils.

In such districts as Punta Morales, Çerro Playa Linda, Alto de Las Mesas, Punta Loros and Cerro Herradura, on the other hand, there are rocky mountains close to the sea forming headlands or peninsulas. The Peninsula of Puntarenas itself is a large sand spit. Between these peninsulars lie such beaches as Playa Tivives and Playa Bajamar between Puntarenas and Boca de Barranca and that between Bajamar and Tarcoles. In the area except the abovementioned peninsulas · the water is generally shallow to a considerable distance from the coastline. For this reason, it is difficult to find a site for construction of a new port in the area other than in and around these peninsulas.

This area together with Meseta Central, the central part of the country, enjoys most comfortable weather with its tropical wet and dry climate and annual rainfall of less than 2,000 mm. As this kind of climate is suitable for human life, future development of these areas can be expected.

Among these areas, Esparta and Orotina have already been developed as important cities with large populations and some industrial plants. The Inter American Highway (Carretera Interamericana) runs through the highland area about 100 m above the sea-level, and approximately 10 km distant from the coastline. In addition, a new highway called the South Coast Highway (Carretera Costanera Sur) is planned to be constructed, connecting Esparta and Palmar Norte. This highway will play an important role as the bypass of the Inter American Highway.

8. Meteorology

8.1 Temperature

The coastal area of the Gulf of Nicoya (Golfo de Nicoya) belongs to the tropical wet and dry zone. The temperature in the area is influenced by the position of the sun* and is closely related with rainfall and altitude, which will be discussed in detail in the following paragraph. The hottest month is April and the coolest period is from September through December. The difference of mean temperature between the hottest month and the coolest month is less than 5°C and mean temperature of the coolest month is above 18°C.[501, 502, 503)]

Monthly fluctuations of temperature actually observed in Puntarenas in 1970 are shown in Table 8.1[501)]. From the table, it is known that the monthly averaged maximum temperature is no lower than 30°C and that even the monthly averaged minimum temperature does not fall below 20°C. Meanwhile, the mean temperature of 23.8°C for September shown in Table 8.1 can be considered rather low in consideration of the average for a long period of time. This is because the monthly mean temperature in the area around Puntarenas are much higher than the above value: e.g. 26.6°C (November) at the highest and 29.1°C (April) at the lowest in Canas (45 m above the sea-level, for a period of observation of 10 years), 25.8°C (December) and 28.3°C (April in Nicoya (130m, 10 years) and 25.3°C (November) and 28.8°C (April) in Esparta (208m, 10 years) respectively, with a monthly average of 25°C in each case. At any rate, the coastal area of this bay has a temperature slightly higher than that in Meseta Central and is covered with various tropical plants grown wild or cultivated.

* Conformity of the declination of the sun with the latitude of Costa Rica is observed on April 16th and August 27th.

8.2 Precipitation and River Discharge

In the area around the Gulf of Nicoya the climate is distinctly divided into two seasons, the rainy and the dry, with the former generally lasting from April to November. According to the record of observations in Puntarenas for a period from 1969 through 1971, there is a periodic rainfall in almost every afternoon or evening during the rainy season. Specifically in July, September and October, there is a continuous heavy rainfall (over 60 mm/hr) for a duration of about four hours. In the dry season, on the other hand, there is at least one month in which the total monthly precipitation is less than 60 mm. Table 8.2 shows monthly precipitation and evaporation in Puntarenas in 1970. It is known from the table that precipitation is concentrated in the wet season and that evaporation is centered on the dry season. The average annual precipitation for the last decade is 1480 mm. This figure is close to that of Tokyo;i.e. 1560 mm (average of 1931 - 1960 period).

Distribution of precipitation in Costa Rica is shown in Fig. 8.1, from which it is known that the coastal area of the Gulf of Nicoya has the least rainfall in Costa Rica in respect of the total annual precipitation.

Data on river discharge in the drainage area within the watershed of the coastal area is shown in Table 8.3 and Fig. 8.2. For the drainage area adjacent to Herradura Bay, the Bay of Caldera and in the north and south of Punta Morales, the total area and average values of annual precipitation are shown in Table 8.4. Since the coefficient of discharge is 0.6 - 0.8, it is easily recognized that the direct discharge is smallest in the Bay of Caldera.

9. Wind

9.1 General

Knowledge of wind conditions is indispensable for the analysis of sea-surface conditions such as swells and wind waves. However, the basic meteorological data available for the Pacific Ocean in the west of Costa Rica is very limited. From this limited meteorological data, the mechanism of tropical wind in this area may be considered as follows.

The tropical wind system in the East Pacific may be divided largely into the following three types.

1. Trades
2. Local wind
3. Tropical cyclones (Hurricanes, tropical storms and tropical depressions).

Among the trades, the wind that blows into the tropical convergence zone (doldrum usually having a width of about 250 km) from the south is the source of swells that propagate directly to the Gulf of Nicoya. Local winds such as sea breeze and land breeze, etc., generate wind waves in and out of the bay. Winds due to harricanes and tropical storms sometimes generate big swells in the northeastern Pacific. Winds and waves will be discussed more in detail hereinafter.

9.2 Trades

The only synoptic weather charts for the tropics in the eastern Pacific available to the team for this survey were those prepared by the Global

Atmospheric Research Project in November 1969 and June 1970[510). Distribution of monthly mean winds in the Pacific Ocean, meanwhile, is shown in several meteorological texts and weather charts[512). The U.S. Air Force aeronautical charts show monthly mean stream lines at an altitude of 1,000 m, from which the monthly fluctuation of the distribution of the trades may be obtained[512).

The pattern of trades in the sea off the west coast of Central America is characterized as shown in Table 9. 1 and Fig. 9. 1. One of the typical patterns of trades is that which initiated in about 10 degrees of south latitude, moves toward the northwest, turns to the northeast near the Galapagos Islands to arrive at the west coast of Costa Rica. Trades of this pattern occur frequently in the months denoted by C and D in Table 9. 1. During these months about 60% of the winds observed seems to fall into this pattern.

According to the obseration made in November 1969, the maximum wind velocity along the path of wind travel attained as strong as 25 kt just after the turning point. The most frequent wind velocity were between 10 to 20 kt. The total distance of this wind travel from the equator (Galapagos) to Costa Rica is no less than 1400 km. In June 1970 the trades frequently showed complicated patterns under the activities of tropical cyclones and the shift of the doldrum. However, one of the most important patterns observed during this period was that the trades moved straight from the 10th degrees of south latitude to the sea off Costa Rica. Trades of this pattern account for nearly 20% of the total winds. The maximum wind velocity in this course was near 30 kt along a considerable distance of their path.

In general, a relatively low speed but highly stable trade wind blows in the winter season (in the northern hemisphere) in the southwestern sea of Costa Rica. In the summer time, meanwhile, the trade winds are somewhat unstable but the southwestern wind gets stronger. The fetch of this strong wind (over 15 kt) is considered to be about 700 km at the maximum.

9.3 Local winds

In the western region of Costa Rica there are six observatories where wind velocity is observed continuously; i. e., from west, Liberia, Nicoya, Puntarenas, F. Baudrit, San Jose and La Pinera. Among these locations complete data for 1970 was filed in Puntarenas, F. Baudrit and San Jose[501). For the study of waves in the Gulf of Nicoya due to local winds, observation records for Puntarenas and Nicoya are the most useful. For these two locations, some additional informations of unpublished records and results of analyses were available to the team[506, 507, 508). Fig. 9. 2[502) shows the percentage frequency and magnitude of winds observed in Puntarenas * in 1970 and 1971. The predominant direction of winds for the period from January to April is northeast (35%), followed by south (25%). Northeasterly wind (land breeze) blows mainly at night but in the dry season a strong northerly or northeasterly wind blows in the afternoon at times. This is due to the influence of anti-

* Location of Puntarenas Weather Station and other related data.

Location:	Long. 84°50'W, lat. 9°58'N
Elevation:	3 m
Height of cup anenometer:	5.75 m
Wind velocity observed:	Average hourly velocity (Distance of air movement km/hr)

cyclone (high pressure) over North America and is a phenomenon caused by the southward movement of the polar air mass to the south in winter. In the daytime during the winter, meanwhile, sea breezes prevail from the south. In other months land breeze and sea breeze repeat alternately in cycle every day. Maximum wind speeds for each direction observed in Puntarenas in 1970 are shown in Table 9.2.

9.4 Tropical Cyclones

Statistical data on Hurricanes (abbreviated to HU with a sustained wind speed of over 64 kt), Tropical Storms (T.S. with sustained wind of 34 ~ 63 kt) and Tropical Depressions (T.D. with sustained wind of less than 33 kt) are well known in the Atlantic Ocean, the Carribean Sea and the Gulf of Mexico. On the other hand, statistics on Tropical Cyclones in the eastern Pacific have become available in the post-war period, particularly since 1962 with the advent of operational satellites (and weather reconnaissance)[515~520].

Table 9.3 shows the number of Tropical Cyclones (T.S. and T.D. included) occured in the northeastern Pacific during the post-war period. The table shows that 10 to 20 Tropical Cyclones occur every year from May to October since 1966 when substantial observations were initiated. Some of their tracks are shown in Fig. 9.3 and Fig. 9.4[515,516]. These figures show that the western sea of Costa Rica (5°N ~ 20°N) is the area where the Tropical Depressions initiate. Since 1886 a total of four Hurricanes hit across Costa Rica or Nicaragua from the Carribean Sea. One of them is Hurricane Olivia (Fig. 9.4: Central Pressure P_c=990mb, sustained wind speed Um = 70 kt on the sea at 2122 GMT, September 21st 1971; and P_c=948mb, Um = 100 kt at 1800 GMT, September 26th). Of the Tropical Cyclones which occurred since 1968, the one which came closest to the Gulf of Nicoya was Hurricane Francesca (Fig. 9.3: P_c = 1002 mb, Um = 85 kt, easterly wind, wave height~45 ft* at 1800 GMT, July 3rd 1970 and P_c = 991 mb, Um = 70 kt at 1800 GMT, July 4th).

It is grossly estimated that, in general, hurricanes in this sea area have a sustained wind of about 100 kt, a distance of about 30 km from the eye of the hurricane to the point of maximum wind velocity and a minimum center pressure of about 950 mb.

In the eastern Pacific of the Southern hemisphere, meanwhile, no substantial hurricanes have ever been recorded because of the existance of cold water masses and scanty rainfall[520].

10. Waves

10.1 Guideline for Determination of Design Wave

For the determination of design wave for each alternative site chosen for construction of a new port, it is appropriate to select a design wave according to the general principle described below.

(a) Maximum wave in the past or

(b) Wave of appropriate recurrence intervals or wave of appropriate probability of occurrence

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* No explanation is given as to the altitude and location these winds and waves were observed.

among the waves determined (1) by actual observations for a considerably long period of time or (2) by modification of the values estimated on the basis of meteorological data for a considerably long period of time with data obtained from actual observations for a relatively long period of time.

However, it is quite improbable to be able to assume these conditions for the coastal area of the Gulf of Nicoya. This is because there is no observation data on waves and winds that satisfy statistical requirements of "a considerably long period of time". The only available informations are data on waves obtained by visual observations in a considerably wide area of the open sea for a period of eight years, rough data on hurricanes occurred in the postwar period mentioned in Section 9, weather charts for the last two months and wind observation data in Puntarenas for a period of three years. Of course, no regular wave observations with the use of a wave recorder have ever been made and no apparent records are available as to the example of damages caused by waves which might be useful for the estimation of maximum wave. As the last resort, adoption of the limiting wave height in relation to the water depth of each alternative site may be considered. However, this may provide unreasonably higher values.

In this report, therefore, wave conditions in the sea outside the bay will be comprehended through analysis of the foregoing visual observation data at first. Then the origin of waves and the maximum wave occurred during the period of meteorological observations will be estimated from the observed wind conditions of generating area which became obvious in the preceding Section 9. Finally, the design wave considered most appropriate at the present stage will be determined through analysis of the difference or the conformity of the estimated value and the value obtained by visual observations while taking into account the shortness of observation period.

10.2 Swells Approaching from the Outer Sea

Data on the waves in the sea off the west coast of Costa Rica are contained in two reports which summarize the results of visual observations by ships operating on the international routes[521, 522]. Wave data in these reports have once been directly applied to the feasibility study of the Ports at Puntarenas and Tivives. However, since these observed values involve major problems in respect of their absolute values and observation points, analysis of these observed values will first be attempted.

1) Analysis of Visual Observation Data

Of the visual observation data, those provided by the U.S. Navy Hydrographic Office[522] are useful for the analysis of the frequency of wave occurence from each direction but fail to clearly indicate absolute values of wave height. On the other hand, data provided by Hogben et al.[521] give the frequency of wave occurence by direction and season, wave height and wave period in the sea zone between long. 80°W and long. 90°W and between lat. 0°N and lat. 10°N. A summary of statistical data provided by the latter is shown in Table 10.1. Significant wave height $H_{1/3}$ and wave period $T_{1/3}$ shown in the table are values obtained through modification of wave height H_{obs} and wave period T_{obs} shown as visual observation data with the following correction equation.

$$H_{1/3} = 1.23 + 0.44\, H_{obs} \quad \text{.................} \quad (3.1)$$

$$T_{1/3} = T_m/0.9 = (4.7 + 0.32\ T_{obs})/0.9 \ldots\ldots.. \quad (3.2)$$

where T_m represents the modified mean wave period. Since the waves indicated as "wave period ~ 0 and 1" in the tables provided by Hogben have less reliability as pointed out by the author, these waves will be ignored and excluded from the analysis of Table 10. 1.

The most frequent wave direction is 150 ~ 210 degrees (clockwise from the north). The maximum wave height recorded during the period from 1953 to 1961 was 3.9 m with a wave period of 7.5 seconds. High waves with a wave height of 3 m or more have occurred on 13 occasions during the above-mentioned observation period. The longest wave period, meanwhile, was 12 seconds with a wave height of 2.8 m which was recorded during the period from September to November. As far as the frequency of wave occurrence is concerned, statistical data provided by Hogben et al. and data provided by the U.S. Navy Hydrographic Office conform fairly well with each other.

While individual data provided by Hogben et al. may be considered relatively reliable after modifications, they fail to clearly indicate where the above-mentioned waves were observed and whether all high waves were observed or not, which are important factors for the determination of waves at the entrance of the Gulf of Nicoya. Therefore, further attempts to make a statistical analysis will be meaningless. Then, attempts will be made to ascertain whether the waves with a large wave height provided by Hogben et al. will occure at the entrance of the bay at all or where they have occurred from available meteorological data in order to determine appropriate wave elements at the mouth of the bay.

2)Estimation of Waves at the Entrance of the Gulf of Nicoya

In view of the topography of the Gulf of Nicoya, the important wave direction for various points within the bay is 150~210 degrees at the mouth of the bay. This direction corresponds to the most frequent wave direction ascertained by the above visual observations. In the meantime, it will be appropriate to consider that the waves from this direction are swells generated by southwesterly trade winds. Then, these swells should be most conspicuous from July to October and this tendency is justified by the remarks of sailors and fishermen or the results of the above-mentioned visual observations.

Accordingly, swells at the entrance of the Gulf of Nicoya were estimated from the weather charts prepared in November 1969 and June 1970, using the Wilson method that considers variable wind field for the generation of wind waves, the Bretschneider method for attenuation of swells and the energy method for the superposition of swells and wind waves to obtain resultant wave height and wave period.

As a result, the maximum waves in these months was determined to be the one which occurred in November 1969 with a significant wave height of $H_{1/3}$ = 2.4 m and a wave period of $T_{1/3}$ = 7 sec. (the sum of velocity U = 20 kt, fetch F = 500 km, wind duration t = 24 hrs and the subsequent U = 25 kt, F = 300 km and t =6 hrs at a wind field; wave height of Hf = 3.1 m and Tf = 7 sec. at the front edge of the above fetch; subsequent decay distance of D = 400 km, swell at the entrance of the bay~H_D = 2.3 m, T_D = 8 sec; wind waves with H_W = 0.7 m and T_w = 4 sec. caused by local wind with U = 10 kt, F = 400 km and t > 48 hrs), and that occurred in June 1970 with a significant wave height of $H_{1/3}$ = 2.1 m and a wave period of $T_{1/3}$ = 6 sec (the sum of U = 30 kt, F = 400 km, t = 24 hrs, Hf = 4.0 m, Tf = 8 sec., D = 1,400 km, H_D = 1.3m, T_D = 11 sec. and wind waves with H_W = 1.7m, T_W = 5 sec. caused by a local wind with U = 20 kt, F = 400 km and t = 12 hrs). The former has the origin of swell in the sea north to the equator and the latter has its origin in the south to the equator, which varies each month with the shift of doldrum of the equator. Although the values of these assumed waves explain in considerable detail the values obtained by visual observations of waves approaching from south or southwest shown in Table 10.1, estimated wave height is smaller than that obtained by visual observations. This is probably due to the fact that the estimation period was limited to one month and that the value provided by visual observations was obtained at the point near the origin of swells.

Meanwhile, the waves at the entrance of the Gulf of Nicoya generated by a tropical cyclone were estimated under the most severe conditions imposed by a tropical cyclone and hurricane (Hurricane Francesca, 1970) occurred at the point closest to the entrance of the bay. (see Fig. 9.3 and 9.4).

As a result, the wave generated by the tropical cyclone at the entrance of the bay had a significant wave height of $H_{1/3}$ = 0.3 with a wave period of $T_{1/3}$ = 8 sec (U = 15 m/sec, F = 100 km, D = 500 km, Hf = 2.5 m, Tf = 6 sec) and the wave generated by the hurricane had a significant wave height of $H_{1/3}$ = 1.7 m with a wave period of $T_{1/3}$ = 13 sec. (U = 30 m/sec, F = 150 km, D = 1000 km, Hf = 7.2 m, Tf = 9.5 sec.). For the wave generated most frequently by hurricanes at the point 2000 km west of the entrance of the bay, the significant wave height was estimated as H = 1.2 m with a wave period of $T_{1/3}$ = 14 sec (U = 30 m/sec, F = 200 km, D = 2,000 km).

Judging from the statistical data on tropical cyclones shown in Table 9.3, waves obtained by the last estimate are considered to occur on 10 to 20 occasions annually. From the results of these estimates, it may be said that some of the high waves approaching from west confirmed by visual observations were probably obtained in the sea near the hurricane rather than at the entrance of the bay.

At any rate, waves propagated to the entrance of the Gulf of Nicoya from west or northwest by a hurricane are not appropriate for adoption for that location. This is because the waves approaching from west or northwest propagate along the Peninsular of Nicoya and do not bring invading waves directly into the bay and the wave of the above-mentioned intensity will have its height damped to less than 1% by diffraction resulting from the sheltering effect of the peninsular when the wave propagates to the inside of the bay.

On the basis of the above analysis, the optime wave elements required for the determination of design wave height for the proposed site in the Gulf of Nicoya were considered as follows. Waves to be considered are those generated by trades and the accompanying wind systems. In view of the fact that the estimated values are for a period of only two months and that there is a possibility of the occurrence of higher waves in a longer period of time, the significant wave height was determined to be about 3 m with a wave period of 7 seconds (swells generated in the vicinity) and 12 seconds (swells generated in the distance) approaching from the direction of 150 - 210 degrees. Of course, it is probable that these values will be modified in the future when more substantial meteorological data and wave observation data become available. However, a wave height of 3 m at the entrance of the bay corresponds to 1.5 m at the National Pier (Muelle Nacional) at the Port of Puntarenas as will be discussed later. This value is not so high as to conflict the fact that the pier has never been washed by waves or damaged by thrust of waves and is not so low as to conflict the fact that La Punta was once washed by swash around 1950 (runup is estimated to be about 30 to 40% of the height of deepwater wave).

3) Refraction and Diffraction of Swell and Design Wave

The above proposed wave at the entrance of the Gulf of Nicoya is propagated into the Gulf being considered refraction and diffraction under the influence of islands and the peninsular and shoaling under the effect of water depth. Fig. 10. 1 ~ 3 show refraction diagrams of the above swell prepared on the basis of calculation by the electronic computer (owned by the Port and Harbour Research Institute, Ministry of Transport, Japanese Government). The refraction coefficients obtained from the diagrams or the ratios of the height of invading waves at each alternative site (Tivives, Corralillo Head, Puntarenas and Punta Morales besides Herradura Bay shown by dark spots in Fig. 10. 1) and at the entrance of the bay are shown in Table 10. 2. These values include the effects of diffraction and shoaling. As far as swells are concerned (Height of waves generated by local winds is relatively small as will be described in Section 10. 3), therefore, the design wave height is largest in Tivives. In Punta Morales, meanwhile, swells are so insignificant that they can be ignored. In the Bay of Caldera a wave height of 3. 0 m including the diffraction effect at the point directly sheltered by Corralillo Head will be appropriate as the design wave height.

10. 3 Wind Waves Generated by Local Winds in the Bay

Wind waves generated in the Gulf of Nicoya were estimated for each alternative site shown in Table 10. 2 with the use of sustained wind speeds observed in Puntarenas in 1970 and 1971 (Fig. 8. 3 and Table 9. 2). Here, a speed of 10 m on the sea is used as wind velocity. For this reason, the measured value for wind was increased by 1.4 times (1. 11 times by modification of the elevation of observation station and 1. 25 times by modification of the position from land to sea). For fetch, the effective fetch[527] was used. For duration, the longest duration which can be expected from the measured value was adopted. These results are shown in Table 10. 3.

Attention must be paid to the fact that the highest southerly wind wave (H = 0. 8m, T = 3. 6 sec.) at Corralillo Head shown in the table will be damped considerably in Caldera Bay by diffraction. Therefore, the second ranked westerly wave (H = 0. 6m) has a probability of occurrence for a period of only one month through the year (only once in Fig. 9. 2). In Punta Morales, meanwhile, the highest southwesterly wave (H = 0. 7m) has a probability of occurrence for a period of three months during the year (5 occasions in Fig. 9. 2). When is considered the fact that the sustained wind speed will have a greater value than that used here if the meteorological observation period becomes longer than the above-mentioned two years, it will be appropriate to designate 1. 0 m and 1. 2 m as the design wave height of wind waves at Corralillo Head and Punta Morales respectively. However there is no definite coefficient to be used for modification of the estimated value at present and the completeness of the future observation data will have to be expected.

11 Tide and Tidal Current

11.1 Tide

According to the British chart and tide tables prepared by the Hydrographic Department in Japan, tidal constants in Puntarenas and Herradura are as shown in Tables 11.1 and 11.2.

11.2 Tidal Current

According to the Sailing Directions, a publication in USA, the flood current into the Gulf of Nicoya sets toward the mouth of Rio Barranca and then moves westward along the Penninsula of Puntarenas. Current speed is 1-1.5 kt in general Ebb current follows the reverse course.

Observations by SOGREAH Company in and around Puntarenas (Sep. - Nov. 1955, B. B. T. Neyrpic current meter used) also show about the same current speed. However, the speed of ebb current in El Estero attains 3 kt at times. Observations between Punta Morales and Islas Cortezas (May - June 1972, values obtained with a float at a depth of about 14 ft., estimated tide range of 2 - 2.5 m at the time of observations) also shows almost the same results.

Judging from the generating point, course and frequency of hurricanes described in Section 9, 4, there is little possibility that the outstanding high water will occur in the Gulf of Nicoya.

12. Littoral Drift

12.1 Description of Coastal Area

This section describes the coastal area between Punta Morales and Herradura on the east coast of the Gulf of Nicoya (see Fig. 12.1 - 12.6).

1) Punta Morales, situated about 15 km northwest of La Punta, is a kind of land-tied rock connected to Mt. Morales (elevation: 73 m). Part of the beach is covered with shell debris over the low water line and with sedimentary mud below that line. Both sides of land-tied portion are small mangrove woods. The north side of Mt. Morales consists of rocky coast covering mangrove woods, the Morales river run its east. Both sides of river mouth have wide mangrove woods.

In the sea west of Puntarenas about 700 - 1,000 m off the coast lie two islands called Islas Cortezas. The maximum depth of a channel between these two islands is more than 50 ft. Sea bed consists mainly of silty base rock.

2) In the coastal area between Puntarenas and the north coast at the base of the Penninsula of Puntarenas a vast mangrove wood extends through which several rivers flow into the sea.

The narrow estuary sandwiched between the southeastern portion of this beach and the Peninsula of Puntarenas is called El Estero. The water area in front of the river mouth on the north coast of this estuary has some troughs and the deepest part of the trough is about -5m according to the sounding chart (SOGREAH Company) prepared in 1955. Besides, there are two troughs with a depth of -7.5m and -6m respectively near the municipal pier. The beach west of the pier has a concave shape and several groynes protect the beach from errosion by littoral current. Bottom material of El Estero consists of fine sand or silty fine sand.

3) The beach at La Punta is protected by a group of groynes constructed after serious erosion in 1950. The 1885 chart (Fig. 12.3) and the 1891

sounding map show the tip of peninsular indented toward north. Afterwards, the action of southerly waves and littoral current entering and exiting from El Estero probably shifted the tip of peninsular to the present position.

An extensive shoal expands from the tip of peninsular toward south or southeast. A trough with a depth of about -6 fathom lies in parallel to the peninsular across this shoal. Between this shoal and San Lucas island a 10 fathom contour penetrates toward northwest and the maximum depth is 27 fathom (about 50 m).

4) The south coast of the Peninsula of Puntarenas is a sand beach extending 13 km to Boca de Barranca. The west end of this beach is thronged with people for bathing in the dry season. The present the National pier is about 2 km from the tip of the peninsula (La Punta). About 2 km to the east of the National pier there are a submarine pipeline and three mooring buoys owned by Gulf Oil Company. The pipeline is simply laid on the sea bottom but no accidents have ever been reported. Toward the east from this point the beach becomes narrower gradually. Since the shoreline comes close to the railroad bed in Angostura, slope protection is provided by rubble deposition. To the east the beach expands again and a considerable advancement of the shoreline is recognized near the new hospital in recent years. Rio Barranca flows along the north side of Punta Farallon and empties into the gulf and is accompanied by some river mouth bars containing some cobble.

Bottom materials of this beach are mainly fine sand and medium sand with a mean diameter of about 200 micron in the west and about 600 micron near Boca de Barranca.

5) To the south of Punta Farallon are several headlands including Punta Coralillo, Punta Loros, Punta Carrizal and Punta Mala. Behind (north side) these headlands are found river or lagoon mouths of Estero de Mata de Limon, Rio Jesus Maria, Laguna Carrizal and Rio Grande de Tarcoles. Between these mouths sandy littoral barriers run from northwest to southeast. In the rear of the barriers are mangrove woods.

6) Inside of the Bay of Caldera are mooring buoys and pipelines owned by Esso Oil Company.

Estero de Mata de Limon is surrounded by hills and has no rivers emptying into it. In the depth of Estero there is a salt-field which was in use until recently. Near the lake inlet and on the beach there are some resort houses. In the beach to the south of littoral barrier (toward the lake inlet) errosion is in progress and provisional protection is provided by wooden fences. The beach on the south coast protrudes sharply toward the shoal in front of the lake inlet. It seems that waves invade into the lake over the shoal at times and damages to the revetment in front of resort houses were observed.

During the survey period a sounding and a sampling of bottom material were conducted. Sounding chart is shown in Fig. 12. 5. Bottom material consists mainly of fine sand.

7) A sounding and a sampling of bottom material along the coast of Tivives were conducted by INCOP during a period from 1968 to 1970. The bottom material consists of medium sand near the river mouth and fine sand along the

littoral barrier. The constant swell along this beach is larger than that observed in the Bay of Caldera and other coast in the depth as a matter of course and some cusps were observed in the beach ridge.

8) Bahia Herradura is situated near the mouth of the Gulf of Nicoya and is sheltered by Herradura Island on the south and opens in WSW direction. There is a large deposit of cobble near the estuaries of a small river in the depth of the bay and reefs also exist besides cobble in the south. A chart shows a sunken rock near the center of the bay (Fig. 12.4).

12.2 Changes in Water Depth

Marine charts and sounding maps obtained during this survey are shown in Table 12.1. Small corrections to the chart are only those related to the change of magnetic north and there is no change in the indicated water depth shown in the table (See Fig. 12.1 ~ 12.6).

Changes in the water depth ascertained on the basis of these data will be described below.

1) Although an up-to-date sounding chart (Fig. 12.6) is available for Punta Morales and its surrounding area, a close comparison of it with the existing charts is not possible because of the difference in the sounding density between the two. Judging from the continuation of 50 ft contour, however, any marked shoaling does not seem to have occurred.

2) Changes in the water depth in El Estero can be examined from the charts prepared in 1885, 1891, in the 1930s, 1955 and 1970. A SOGREA's report shows a comparison of some profiles between 1925, 1948 and 1955. It shows no substantial changes in the existing location and depth of the previously mentioned troughs and bars. Sounding charts prepared in 1885 and 1891 do not necessarily show the existence of troughs. As previously mentioned, the tip of the peninsula (La Punta) was indented to the north then and a lateral profile of La Punta prepared in 1925 (contained in SOGREA's report) also shows this fact. It is assumed that the main guts then linked El Estero directly to a deep channel in front of San Lucas Island.

As mentioned above, the tip of the peninsula (La Punta) and its vicinity were showing marked changes in the past. The present stability is probably due to urban development and the construction of groynes.

3) Changes in the water depth in the south of the Peninsula of Puntarenas can be examined from charts of 1885, 1930's, 1955 and 1970. No substantial changes in the general characteristics of the configuration of seabed and in the water depth are recognized. Supply source of a vast shoal in this water area is considered to be sediment transport from various rivers in the north to the peninsular, but the amount of transport seems to be small. This is justified by the fact that no maintenance, dredging has been required for the anchorage and channel in front of the National pier. The 6 fathom trough extending in the east-west direction has been maintained for many years and the effect of converging tidal current from the sea to the east of the shoal is considered to be one of the factors contributing to the stability of the trough.

On the basis of these comparisons and the proviously mentioned various characteristics of the coast, littoral drift in the south coast of the Peninsula of Punterenas may be dealt with in three separate sections - east, west and central sections. In the shallow water area of the west section, littoral drift shows a movement according to the intensity of incoming waves and the discharge of the adjacent rivers. In the east section the littoral drift is under direct influence of the sediment transport from Barranca River. In the central section supply of sand is very scarce along the coast and the beach is subjected directly to the errosion by wave action. After all, changes in the sea bottom are limited to shallow water and there is very little littoral movement in the area deeper than several meters. The fact that the longshore-bar or trough, which is an indicative of the extent of littoral transport, does not exist in this area is considered to be due to a large tide range compared with wave height.

4) For Caldera Bay and Tivives coast, sounding charts of 1897 or 1896 are available. A comparison of these charts with the recent sounding chart shows the stability of shoreline features and general characteristics of seabed. Local changes near the lake inlet or river mouth or temporary changes following abnormal waves or flood can be expected as a matter of course, but the amount of littoral transport is considered very small.

5) For Herradura Bay, only one chart is available and a comparison of water depth is not possible. However, the effect of littoral transport is estimated quite small.

13 Earthquakes and Tsunami

13.1 Earthquakes

Table 13.1 and Table 13.2 show respectively the number of earthquakes which hit Costa Rica for the period from 1953 to 1961 and from 1930 to 1955 by revised Mercalli seismic intensity. Fig. 13.1 shows an isopleth of the frequency of earthquakes with a seismic coefficient of IV or over obtained on the basis of Table 13.1.

Judging from the data for Barranca and Esparta in Table 13.1 and the data for San Ramon in Table 13.2 using these districts as neighboring districts of Puntarenas, this area experienced no earthquakes with a seismic coefficient of VI or over, in other words, the earthquake having acceleration exceeding 44 gal, for a period of 30 years from 1931 to 1961. In view of the fact, however, that this area does not belong to the most frequent major earthquake zone but is close to it, that the above data are only for a short period of time, that Table 13.3 and Fig. 13.2 quoted by the final report by TAMS Company and DYPSA Company suggest the occurrence of earthquakes of magnitude 7 on Richtor scale on several occasions in the past and that a design seismic coefficient of 0.1 is used for construction of a bridge in Meseta Central, use of a design seismic coefficient of 0.1 for port and harbour structures in and around Puntarenas is considered appropriate.

13.2 Tsunamis

There are no informations about remarkable tsunamis due to submarine earthquakes in the vicinity of the Gulf of Nicoya. However, tsunamis caused by the Chile earthquake (May 22nd, 1960) and the Alaska earthquake (March 28th 1964) were recorded by the tide gauge (owned by Instituto Geografico) installed at the National pier.

In the case of the Chile tsunami of 1960, change of waterlevel with a period of 20 ~ 30 minutes continued for several days and the maximum rise of water level above astronomical tide was about 25 cm. In the case of the Alaska tsunami of 1964, the maximum rise of water level was about 60 cm with a period of 30 ~ 50 minutes. Tide records at Quepos also showed almost the same change in water level.

Occurrence of moderate tsunamis must be anticipated in the future as a matter of course but there will be no need to consider tsunami as special conditions in the planning of a new port.

14. Soil Conditions

14.1 General

The following soil explorations have been conducted in and around Puntarenas in the past.

(1) Borings in Punta Morales.

(2) Borings in the vicinity of the National pier in the Port of Puntarenas.

(3) Sampling of bottom materials in the area around the Penninsula of Puntarenas

(4) Sampling of bottom materials near the shoreline of Tivives.

Besides, a survey of bottom materials and borings were performed in the Bay of Caldera by Ministrio de Obras Publicas y Transportes during the survey by the team. The outline of soil conditions in each alternative site on the basis of survey data mentioned above will be as follows.

14.2 Punta Morales

Locations of borings performed in July 1972 are shown in Fig. 14.1. This boring test included a standard penetration test and a mechanical analysis. In the sea, however, the standard penetration test was conducted only at one location.

Soil profiles prepared on the basis of the findings are shown in Fig. 14.2 and Fig. 14.3. Profile shown in Fig. 14.2 is almost in parallel with the contour line at a depth of 13 m and that shown in Fig. 14.3 is almost perpendicular to the contour line. These data show that the seabed consists of a soft silt stratum having a thickness of about 6 m. Below the silt stratum is weathered sandstone about 60 cm thick and below that is dense sedimentary rock. N value of weathered sandstone is 100 for 23 cm in depth of penetration at Boring point No. 5. Base rock inclines toward the sea at a gradient of about 8/100.

The surface of the ground is a deposit of humus to a depth of 60 ~ 80 cm and below it is a silt stratum having about the same thickness. N value of the silt stratum is 4 ~ 46 for 15 cm in depth of penetration. On the top of sedimentary rock below the silt stratum having an N value of 50 (for 15 cm in depth of penetration) to a depth of 1 ~ 1.5 m.

14.3 Puntarenas

In the Port of Puntarenas borings were performed at the face line of the Nacional pier and on the land behind it as shown in Fig. 14.4. Soil profiles perpendicular to the coastline prepared by TAMS/DYPSA on the basis of the results of borings are shown in Fig. 14.5. Index property of soils at Boring No. A-4 is shown in Fig. 14.6.

According to these data, seabed in the vicinity of the existing pier consists of very loose silty sand or sandy silt having a thickness of about 10 m. Below it is a soft clayey silt stratum or silty clay stratum which becomes stiffer with the increase in depth. On the other hand, the density of sand stratum of the top soil increases on the land.

Since the boring test did not include in-situ test and unconfined compression test, shear strength parameters of soils could not be determined.

In addition to the above-mentioned borings, mechanical analysis of bottom materials at the point shown in Fig. 14.7 was conducted for the Peninsula of Puntarenas and the results are shown in Table 14.1. According to the table, the bottom materials at the north side of the Peninsula of Puntarenas or in El Estero have small grain size in general and consist of silty sand or silt, containing shells in part. Bottom materials sampled at the point near the middle of El Estero (Sample No. 9.14) contain organic matters.

Bottom materials at the south side of the peninsula consist of fine sand and contain crushed shells in part but do not contain organic matters.

Grain size of sand increases closer to Barranca River and materials at Stations No. 30 ~ No. 32 contain gravel in the ratio of 1 ~ 3%.

14.4 Caldera

Locations of jet borings and sampling of bottom materials conducted in Caldera Bay during the survey period are shown in Fig. 14.8. Soil profiles prepared on the basis of the results of boring tests and the results of mechanical analysis of bottom materials are shown in Fig. 14.9 and Table 14.2 respectively. According to the soil profiles, the top of seabed is a silt stratum having a thickness of 1.5 m ~ 5 m underlain by a sand stratum having a thickness of less than 3 m below which is a dense sand stratum. The existance of sand stratum at the bottom has not been fully confirmed and the existance of base rock is also probable. The thickness of silt stratum increases closer to the coastline. Dense sand stratum exists at a depth of -7.3 ~ 15.0 m and it appears at a smaller water depth as it comes nearer to the coast and Estero Mata de Limon. According to the results of mechanical analysis, the bottom materials consist fine sand and the content of silt is less than 20% except for a few locations. Judging from the results of mechanical analysis, the top soil which was determined to be silt as a result of borings is considered to contain a considerably large quantity of sand.

14.5 Tivives

Bottom materials in Plaja de Tivives extending from Punta to Penon de Bayamar were surveyed by Mr. A Gomez in the year 1969 ~ 1970. Sampling points of bottom materials are shown in Fig. 14.10. Results of mechanical analysis are also shown in Table 14.3. Samples were taken at elevation of +2 m on the land and at depths of -1 m and -3 m in the sea. Bottom materials near the shoreline in Plaja. Tivives are mostly fine sand and contain only a small amount of silt. The silt content increases to about 10% in the sea bottom at a depth of -3 m between Sosa, south eastern edge of the survey area, and Espinosa. The grain size increases to medium sand at an elevation of +2 m and at a depth of -1 m around the headlands on both banks of Estero las Flores and Estero los Loros, sand spit and on the coast east to the sand spit. In particular, bottom materials at a depth of -1 m in Flores and 500-0 (Sosa) contain almost no fine sand. In all sampling points, however, bottom materials at a depth of -3 m are fine sand and more than 80% have a grain size of less than 0.42 mm.

In the beach Cope in the northwest of the survey area, Cope and the beach Espinoza in the southeast, specific gravity of soil particle of sand on the land is as high as 3.5 and the content of iron sand is coceivable.

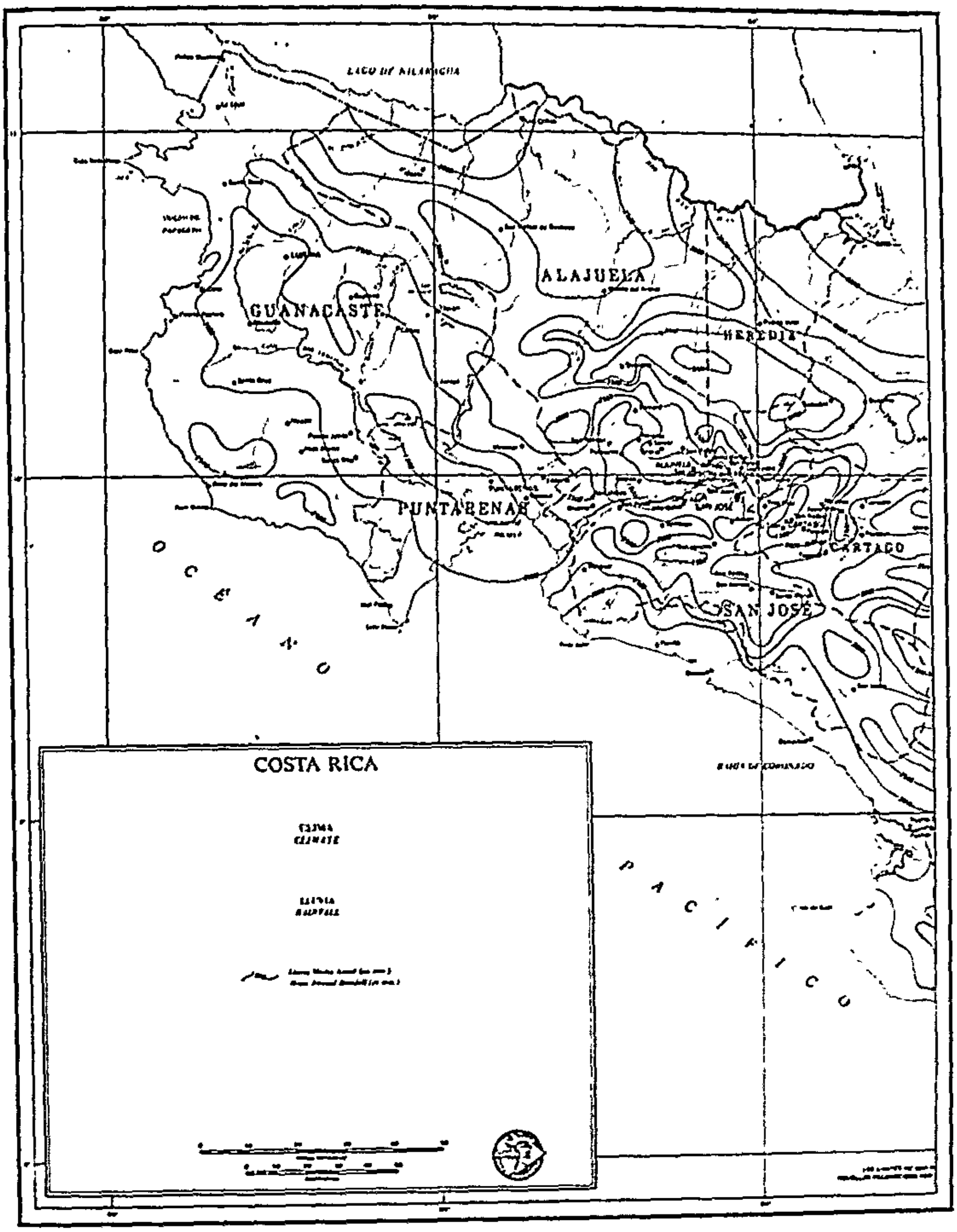


Fig. 8.1 Mean Annual Rainfalls in Costa Rica

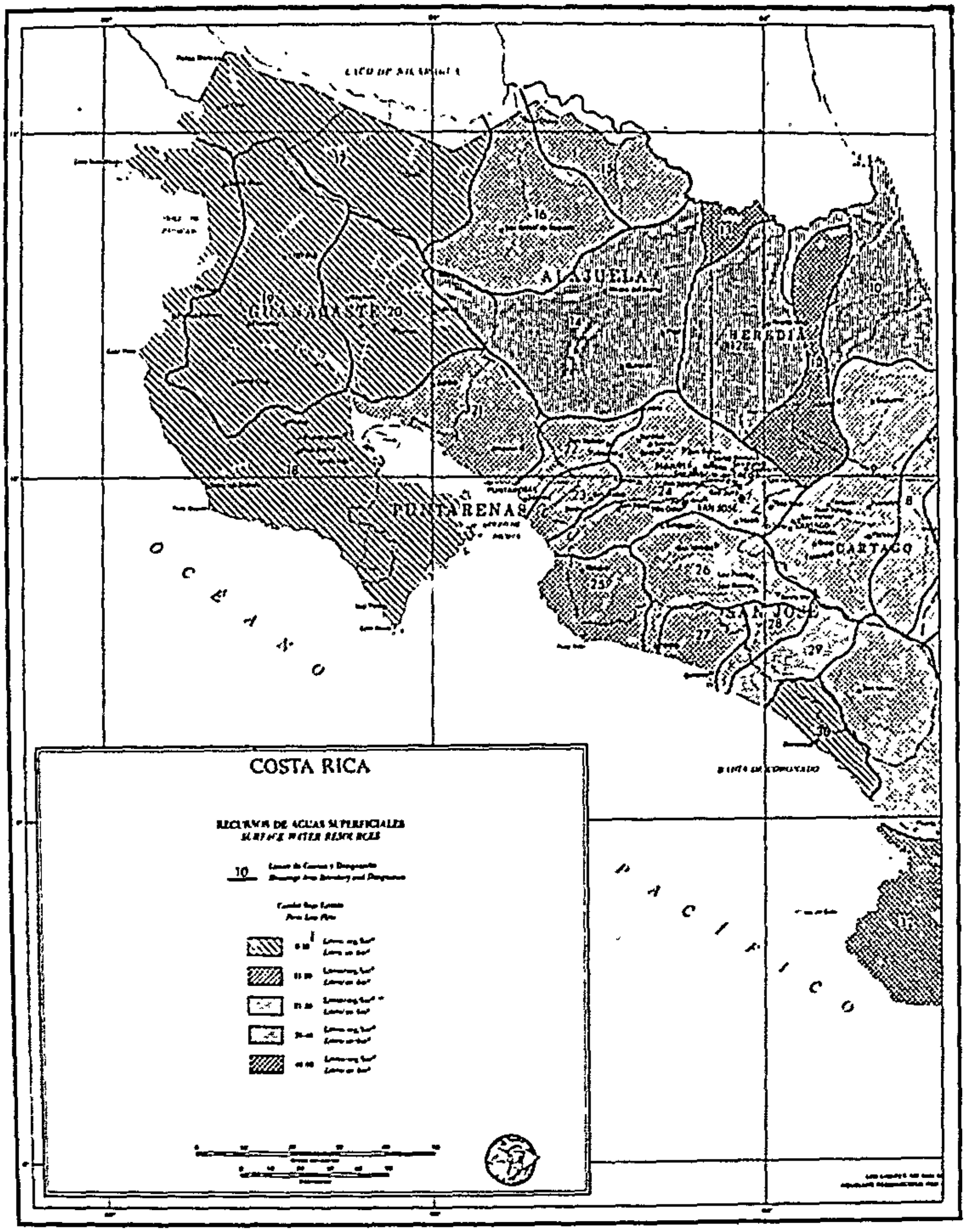
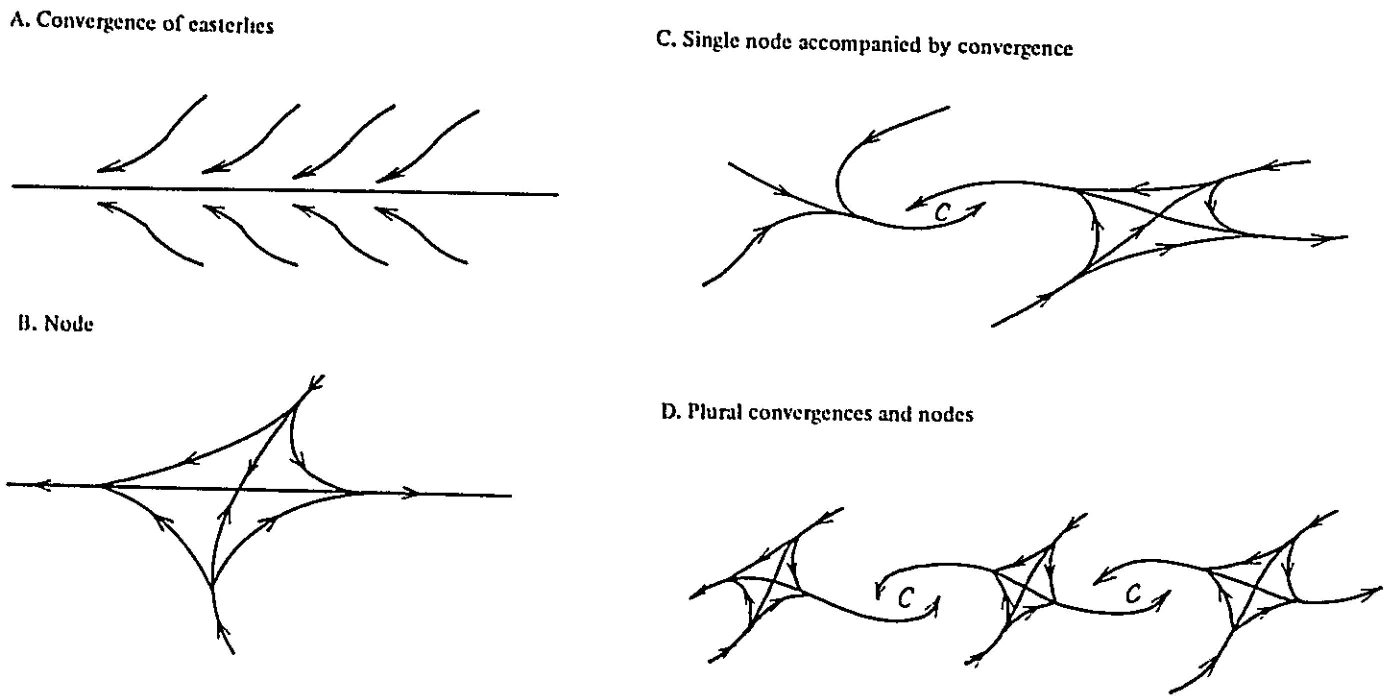


Fig. 8.2 Surface Water Resources in Costa Rica



Note: It is derived by analyzing and classifying the data 512).

Fig. 9.1 Pattern of Trade Winds

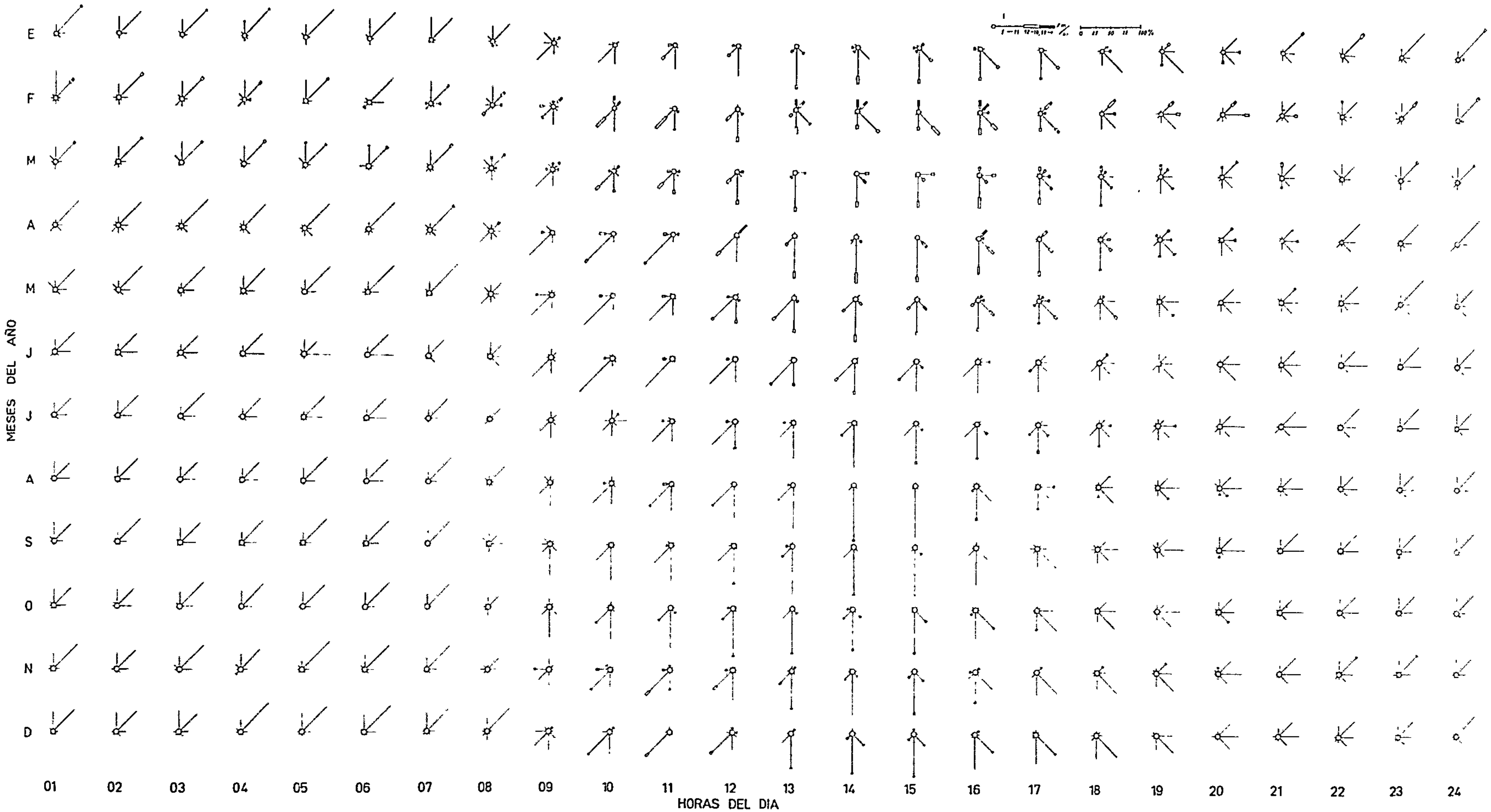


Fig. 9.2 Percentage frequency and magnitude of winds observed in Puntarenas (1970 - 1971)

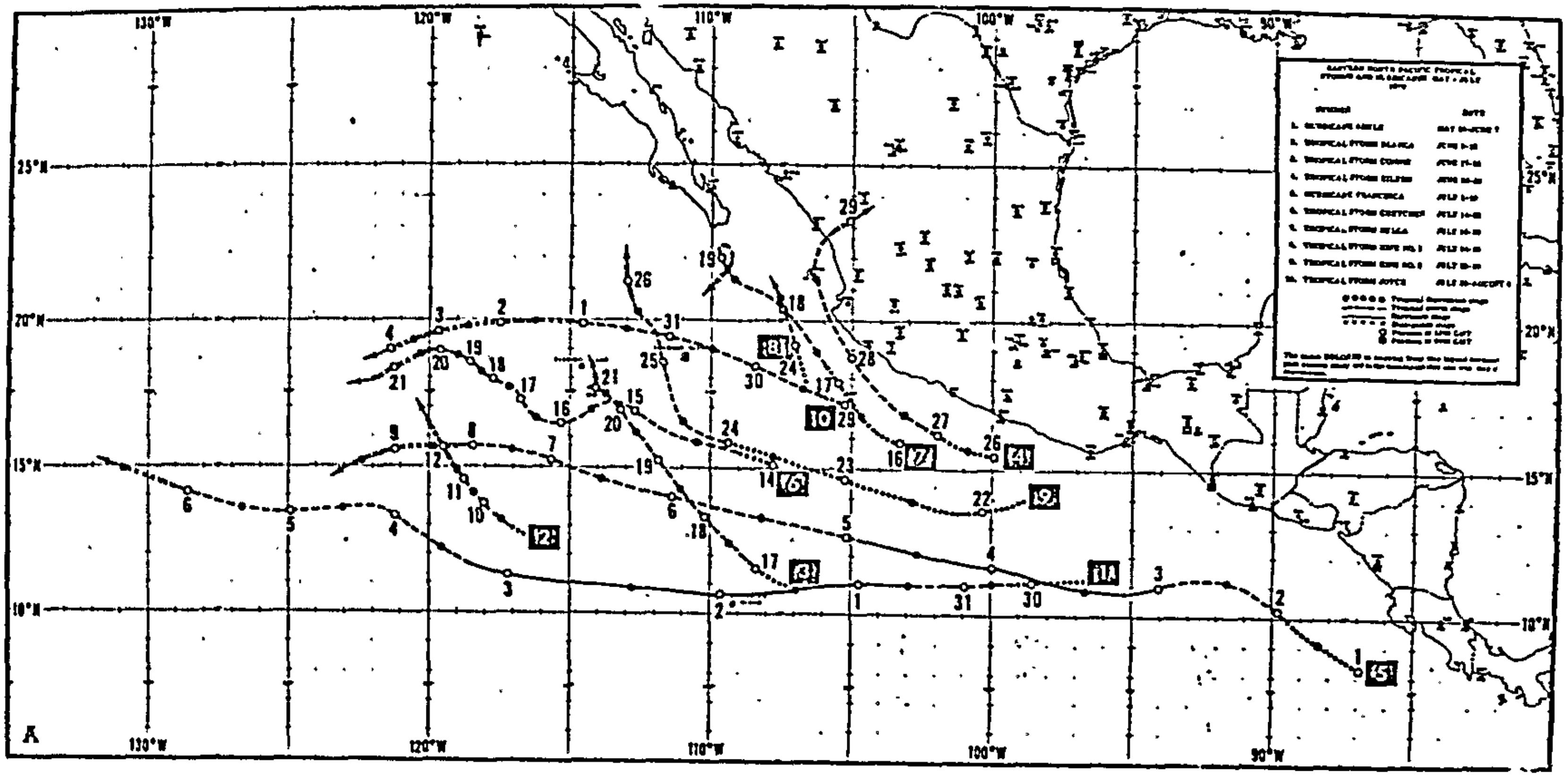


Fig. 9.3 Eastern North Pacific Tropical Storms and Hurricanes During May-July, 1970

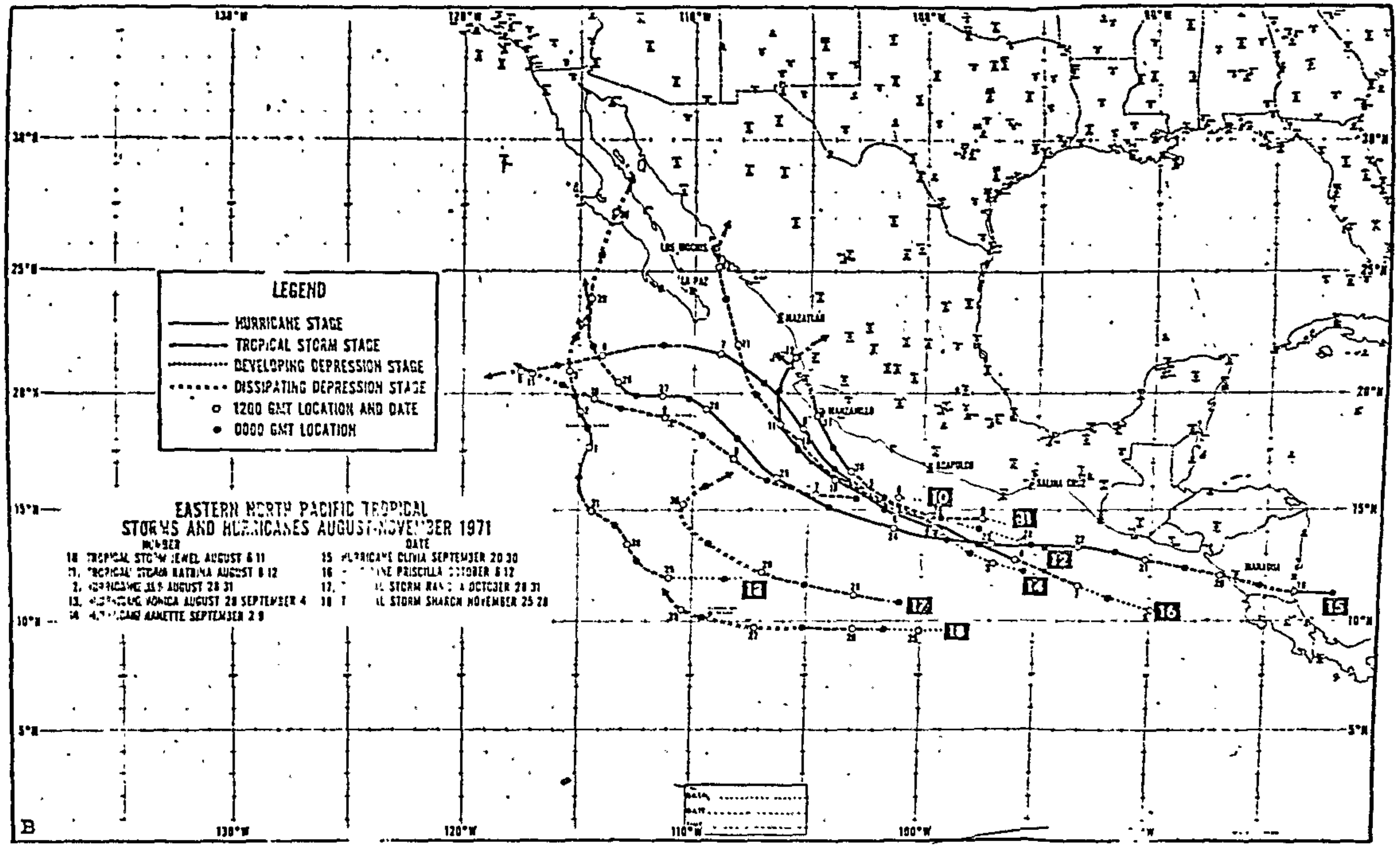
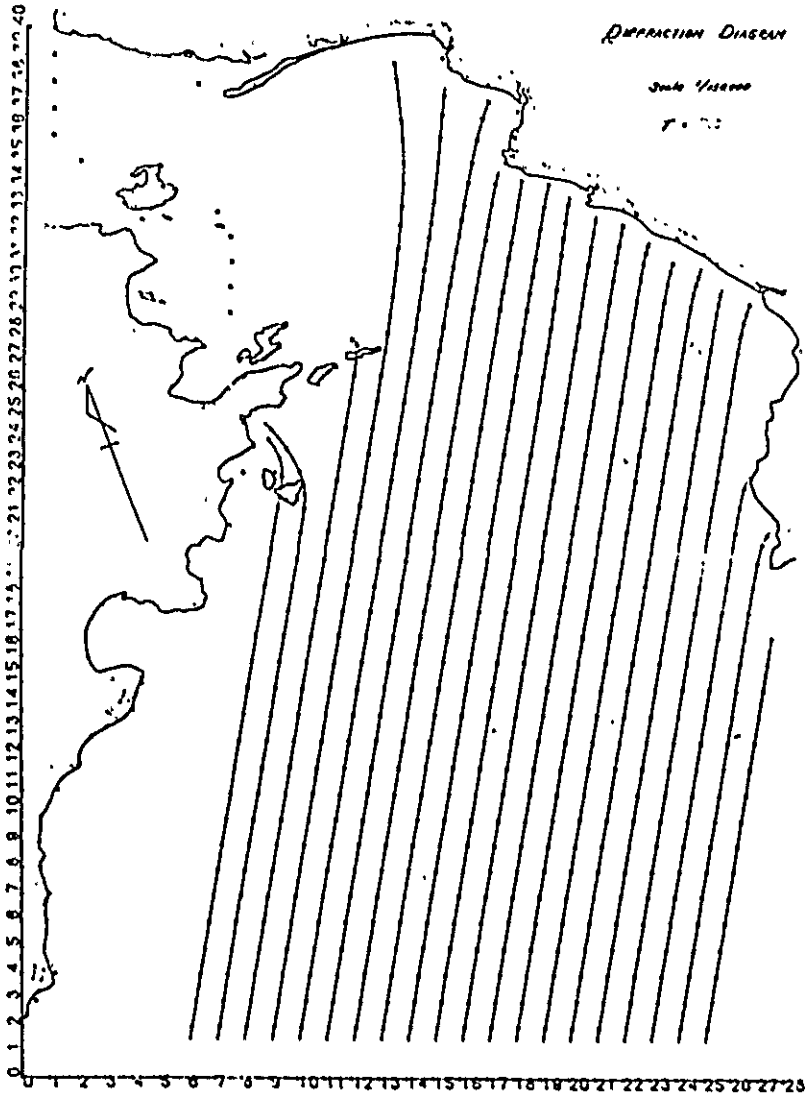


Fig. 9.4 Eastern North Pacific Tropical Storms and Hurricanes During August-November, 1971



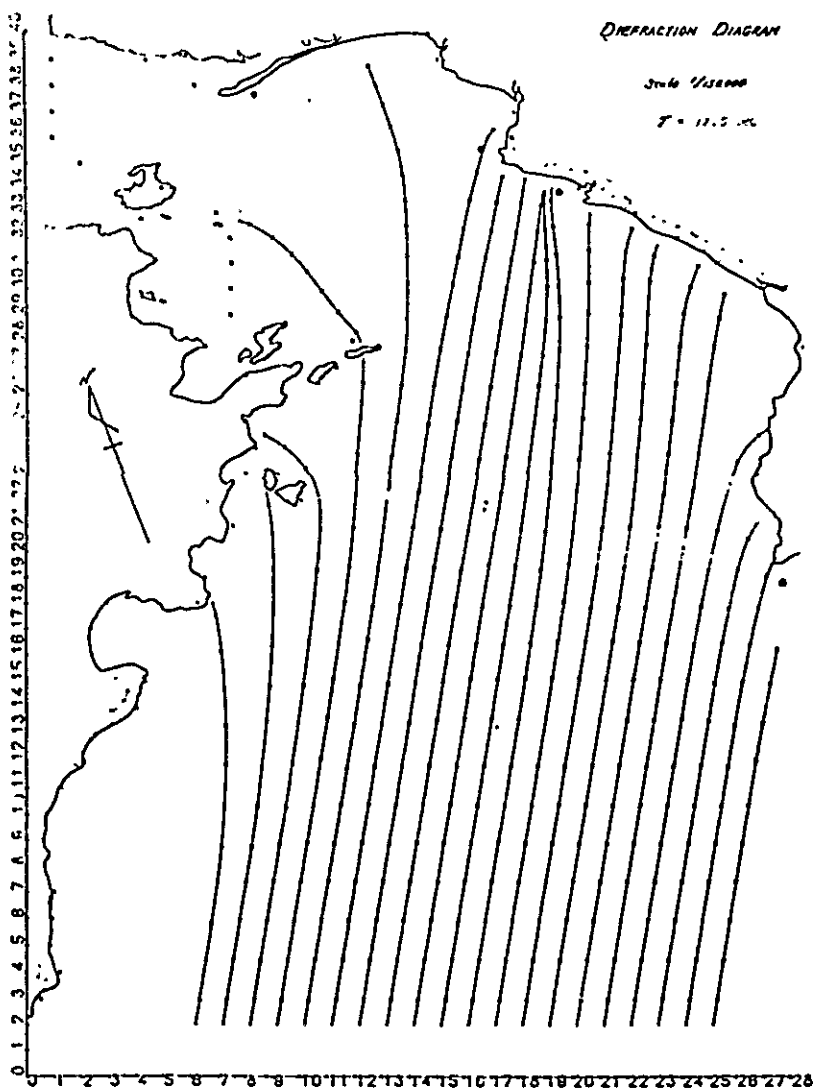


Fig. 10.1 Refraction Diagrams (Incident Waves from 210 degrees)

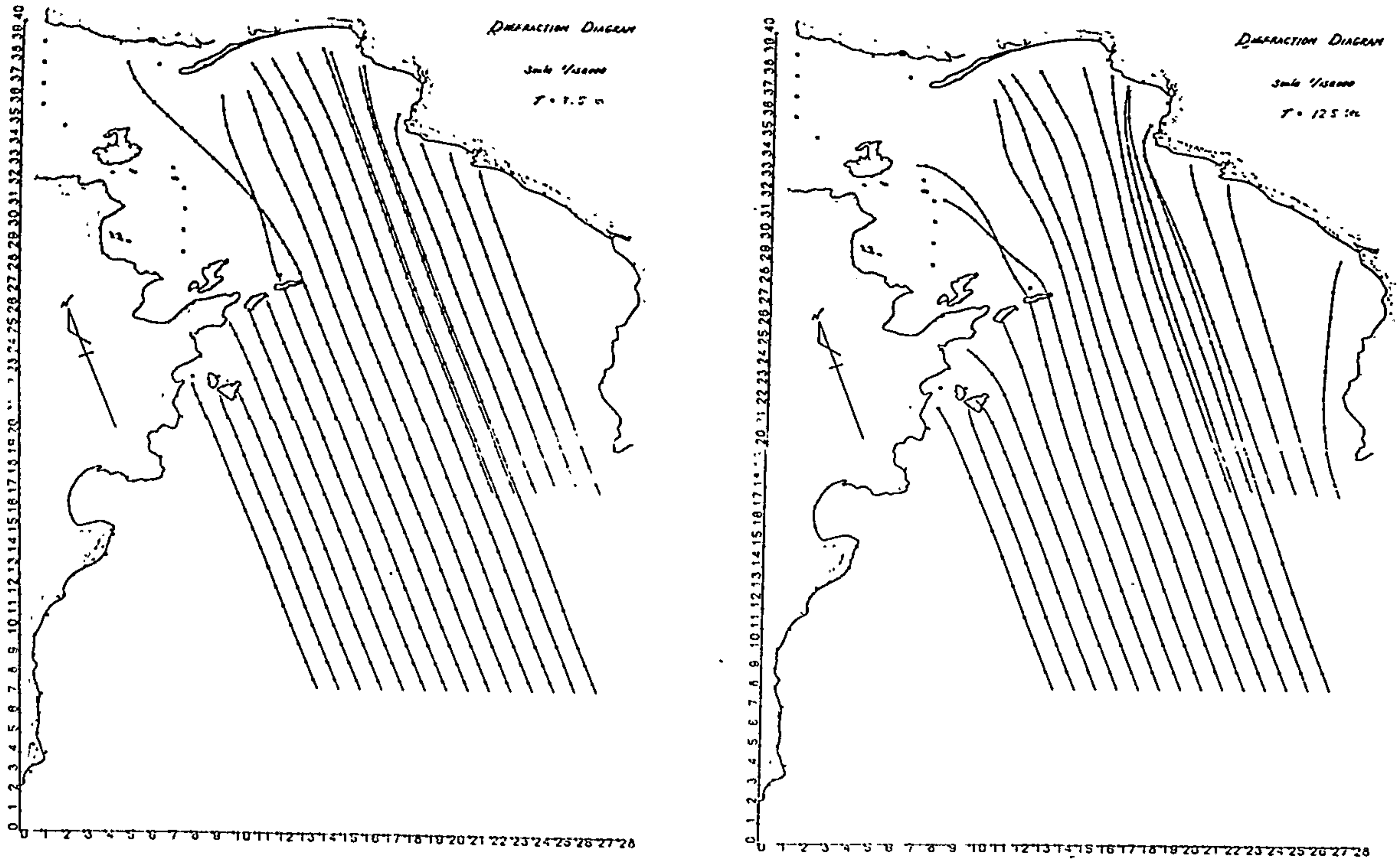


Fig. 10.2 Refraftion Diagrams (Incident Waves from 180 degrees)

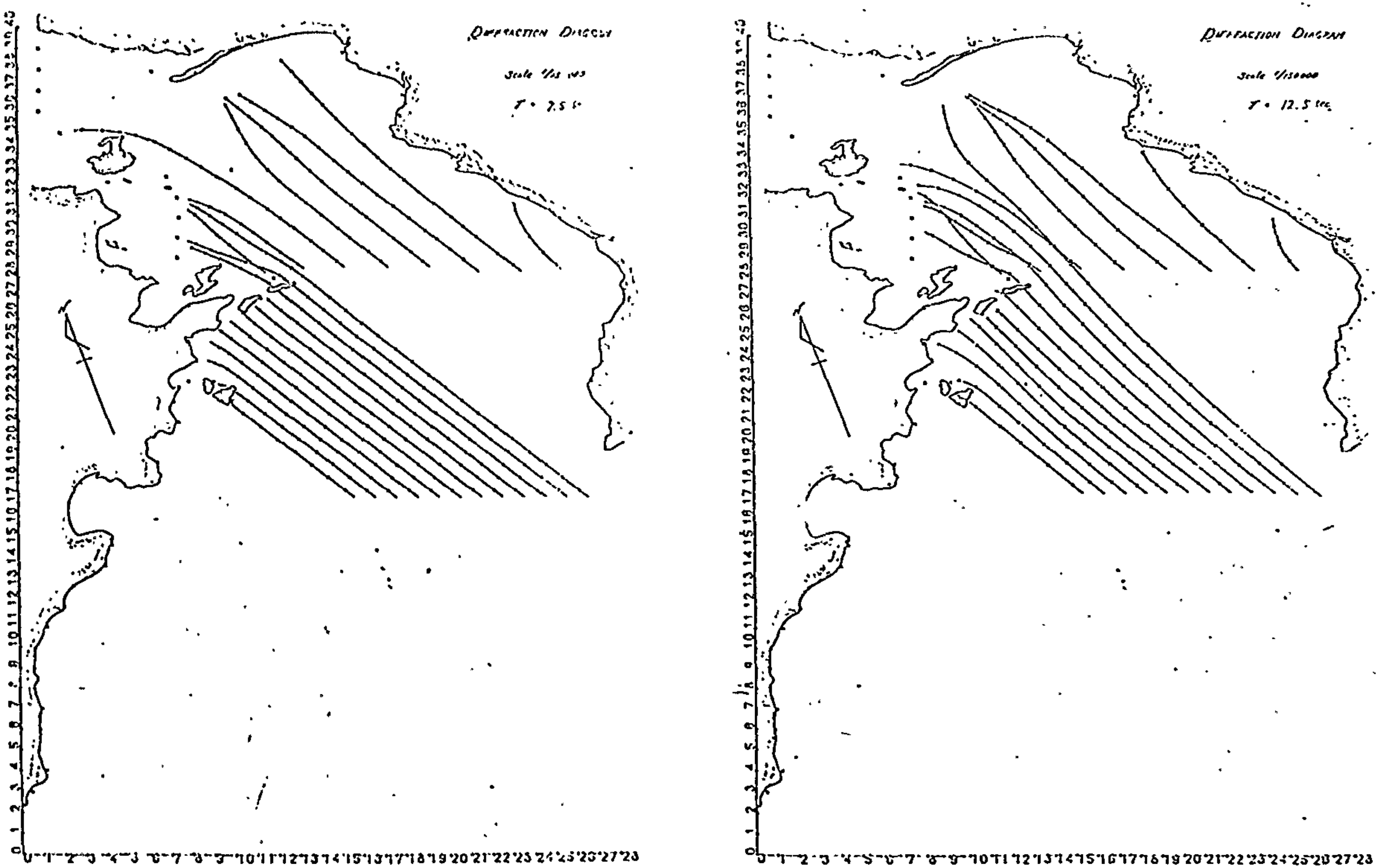


Fig. 10.3 Refraction Diagrams (Incident Waves from 150 degrees)

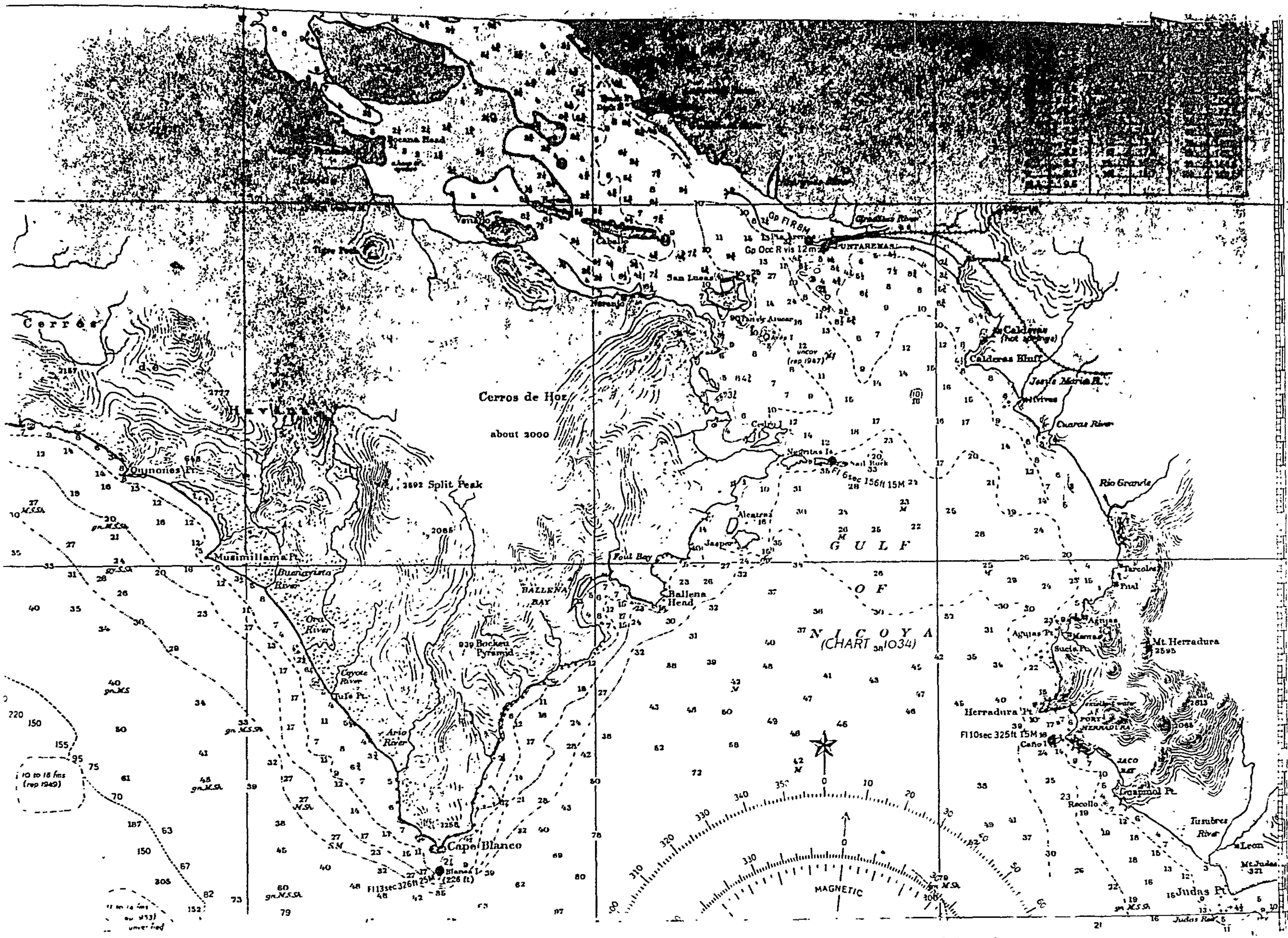


Fig. 12.1 General pattern of the depth contour of Golfo de Nicoya (depth of water in fathoms)
Scale 1/29,420

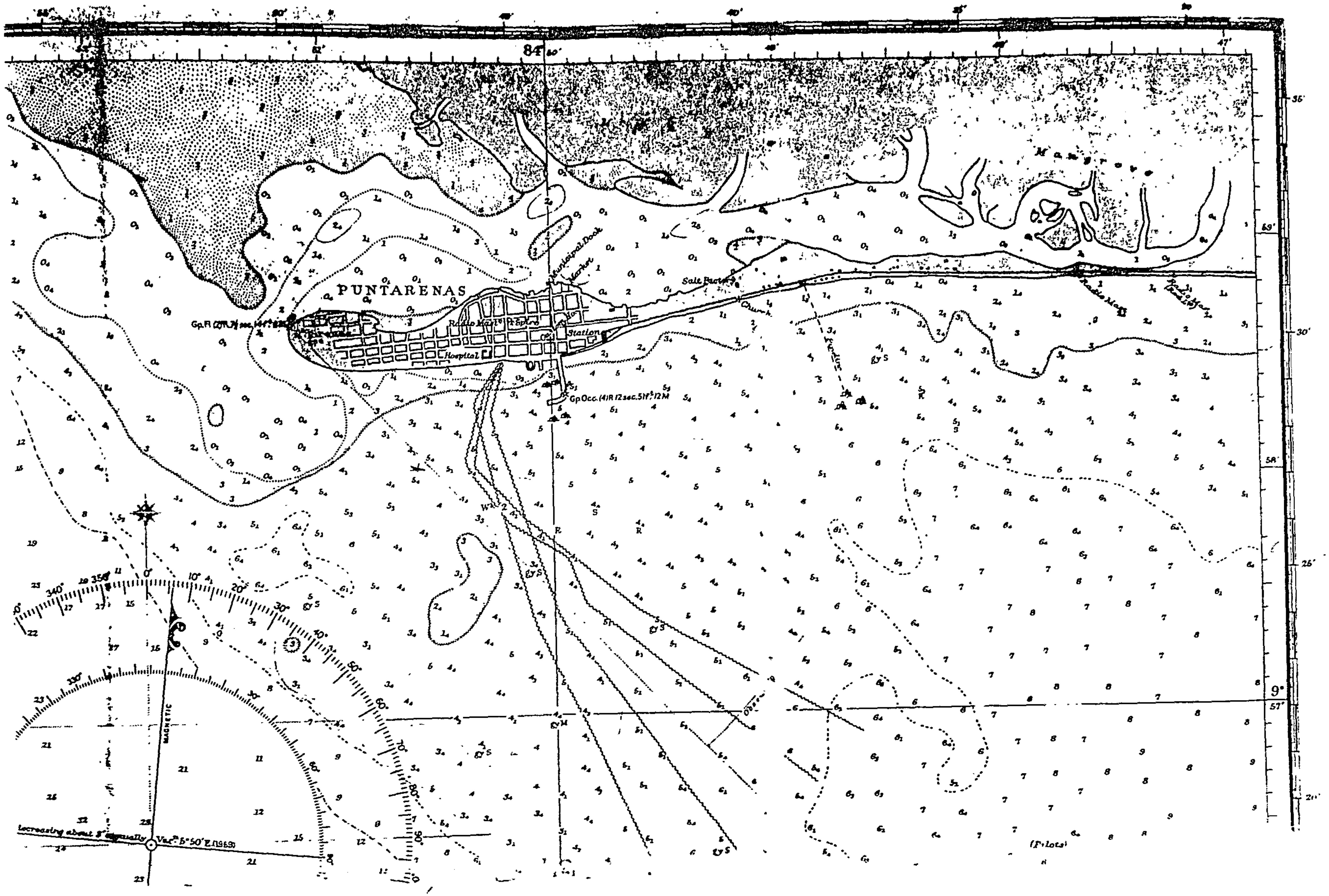
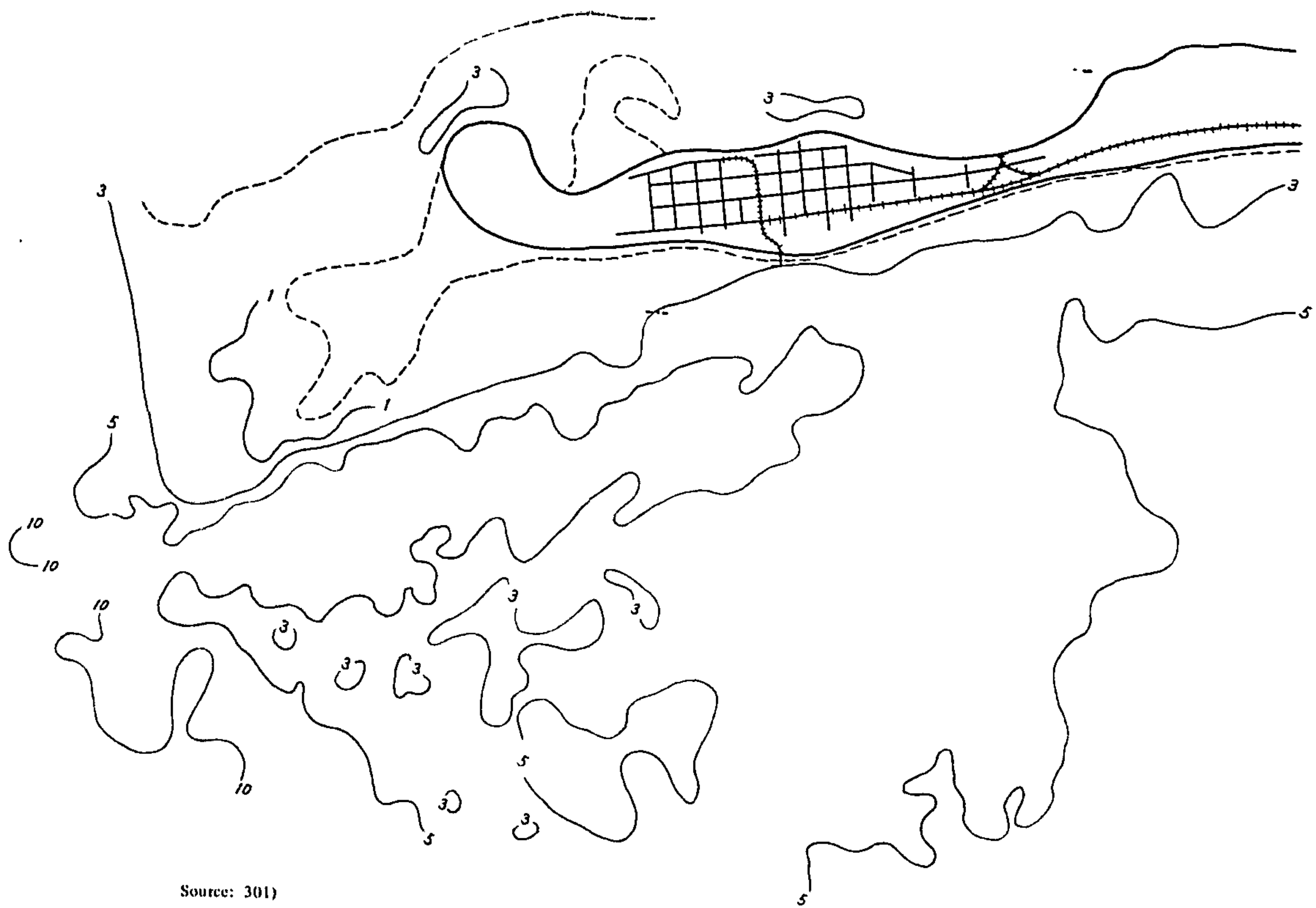


Fig. 12.2 Depth of water around the Peninsular of Puntarenas (in fathoms)
Scale 1/30,000



Source: 301)

Fig. 12.3 Puntarenas in 1885 (depth of water in fathom)

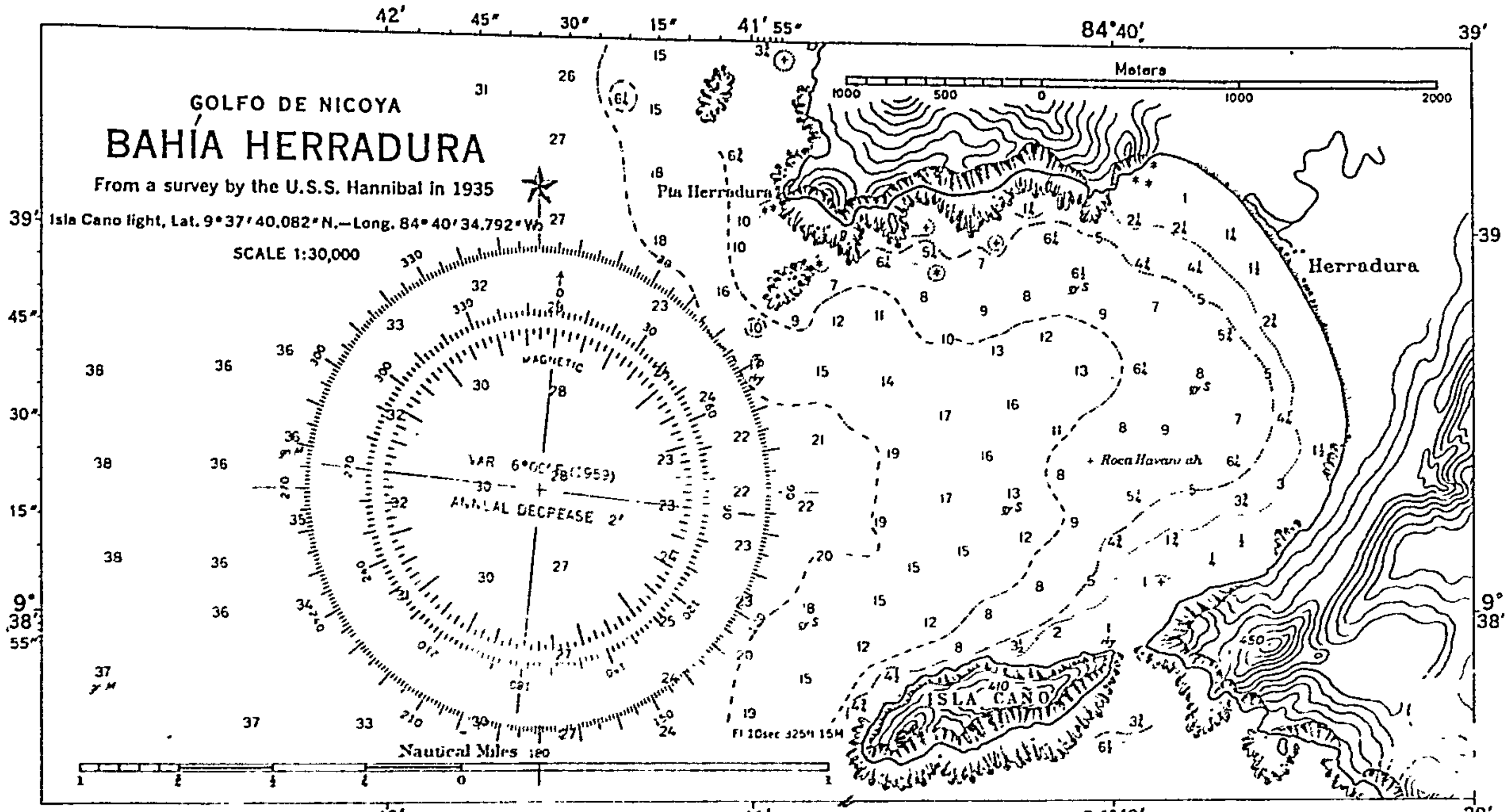


Fig. 12.4 Depth of water of Bahia de Herradura (in fathoms)
Scale 1/30,000

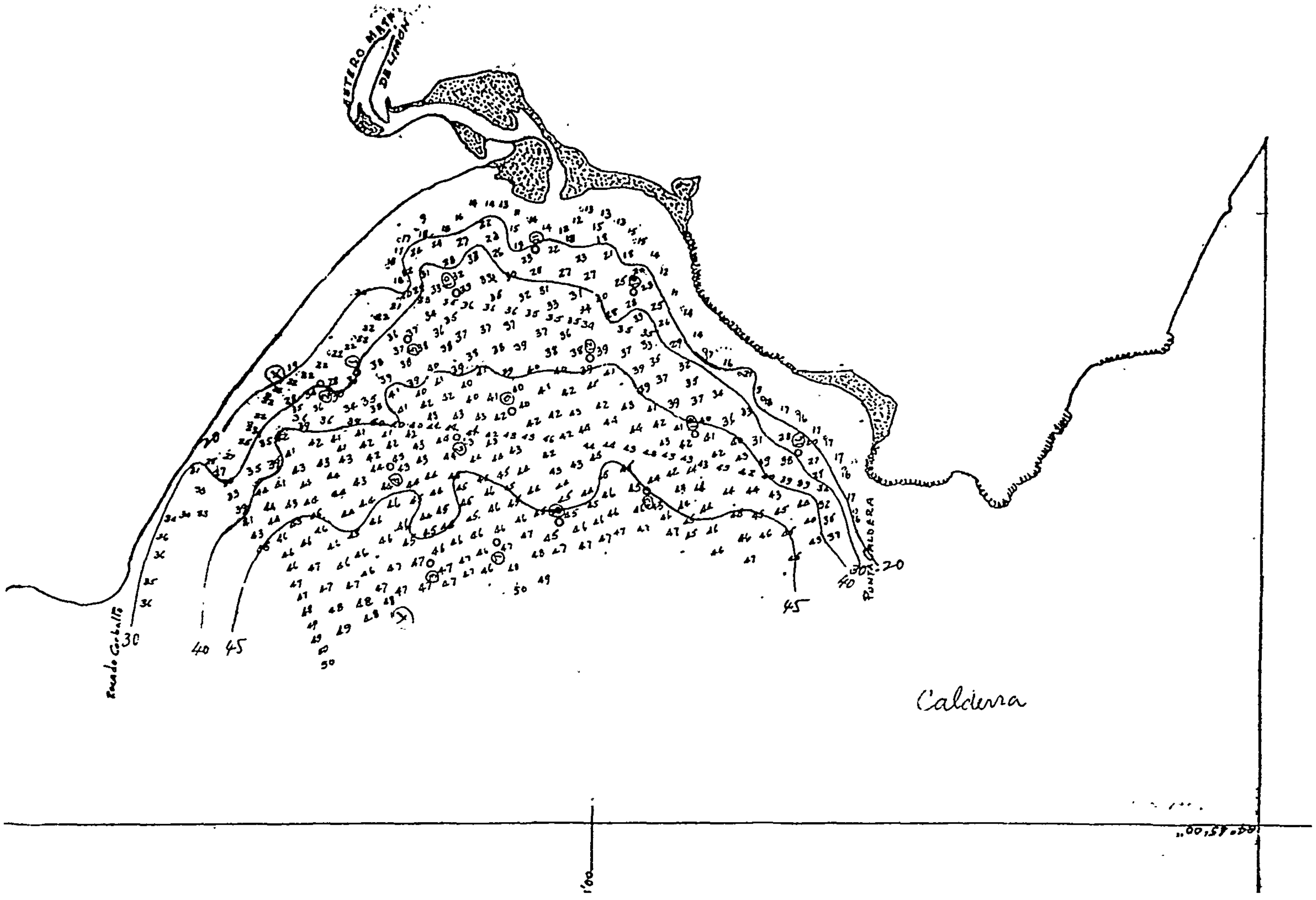


Fig. 12.5 Depth of water of Bahia de Caldera (in feet), 1972
Scale 1/25,000

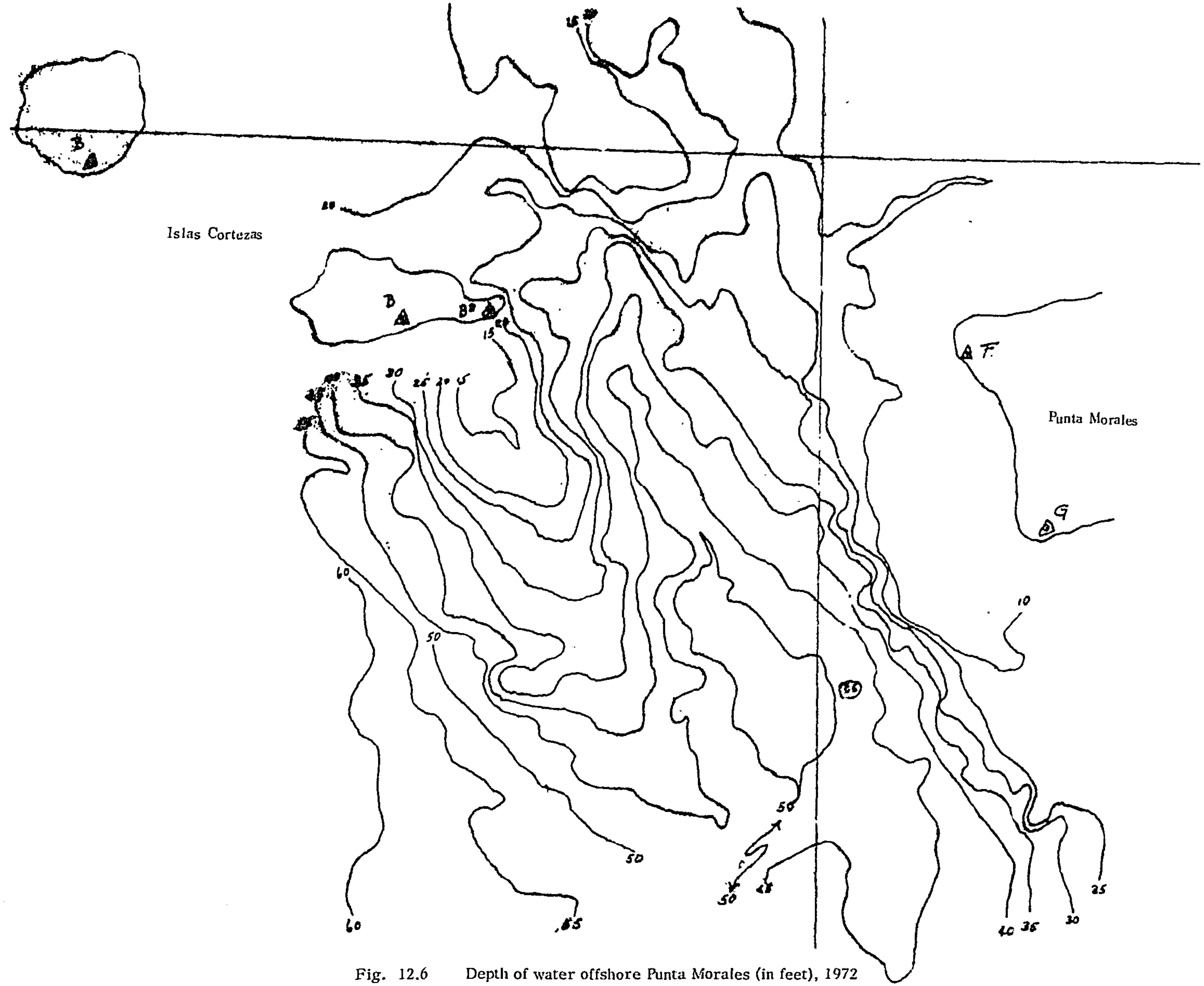


Fig. 12.6 Depth of water offshore Punta Morales (in feet), 1972
Scale 1/5,000

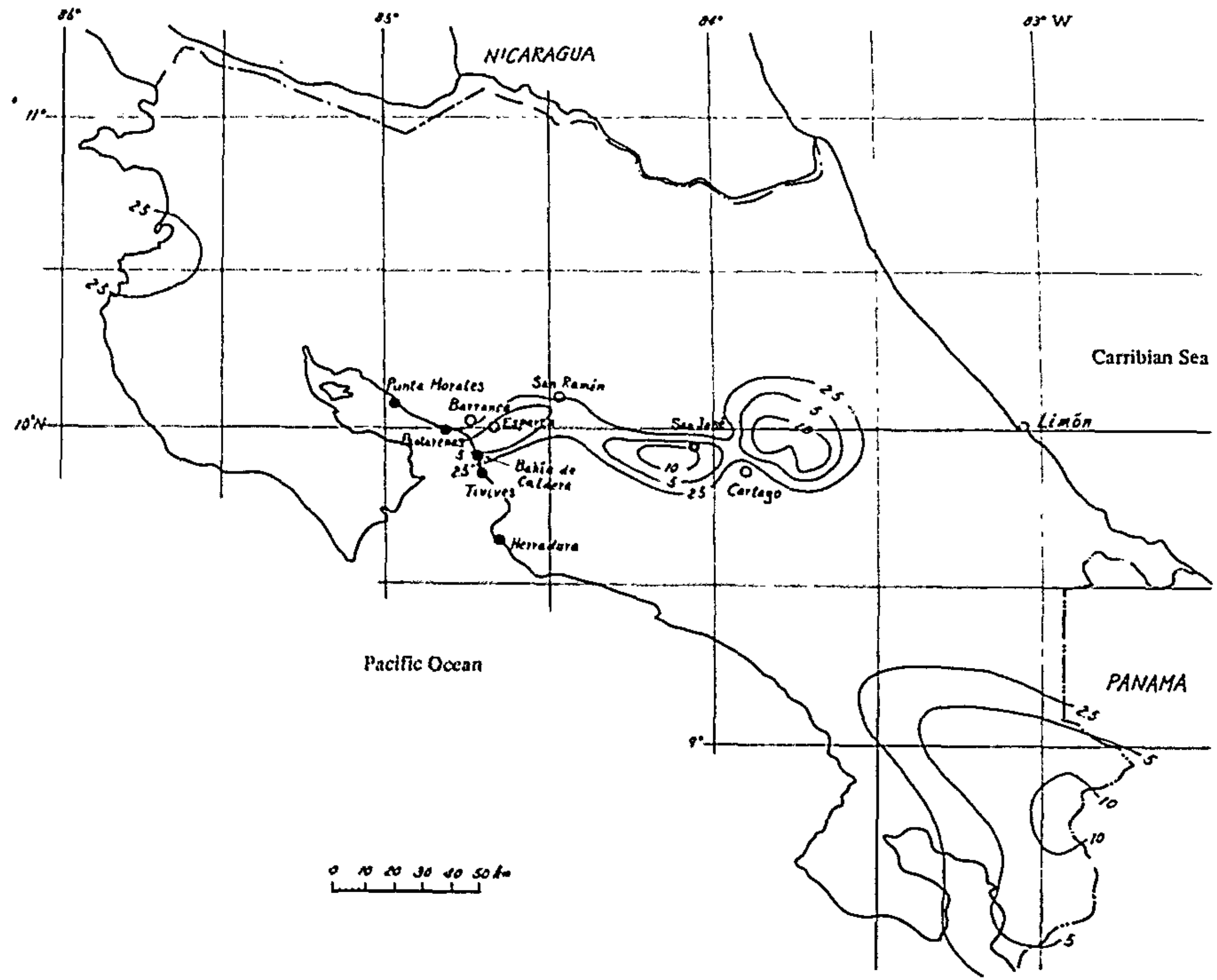


Fig. 13.1 Number of Earth-Quakes of Intensity IV or Bigger in the Scale of Modified Mercalli Cancanni, which happened during 1953 - 1961.

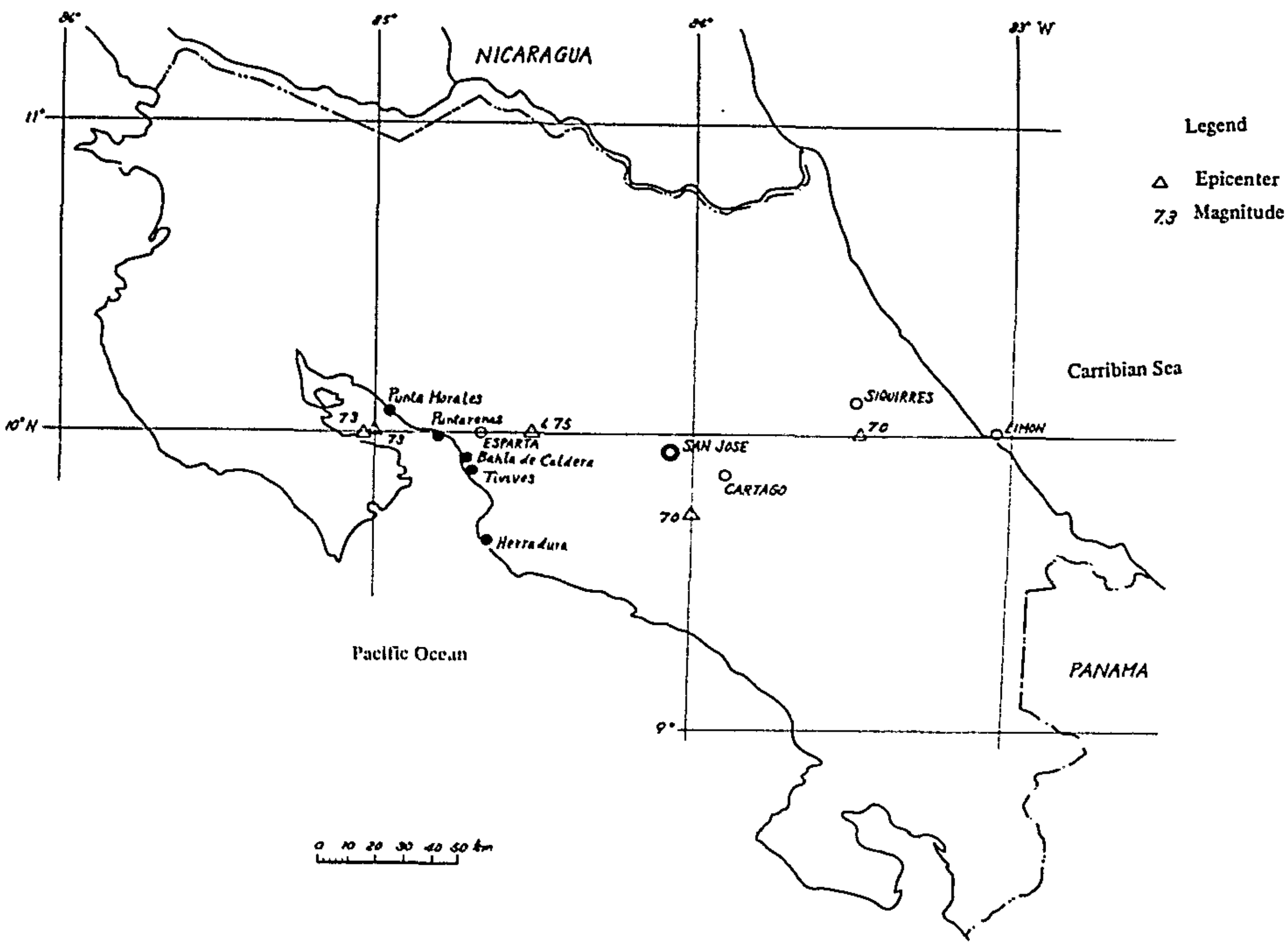
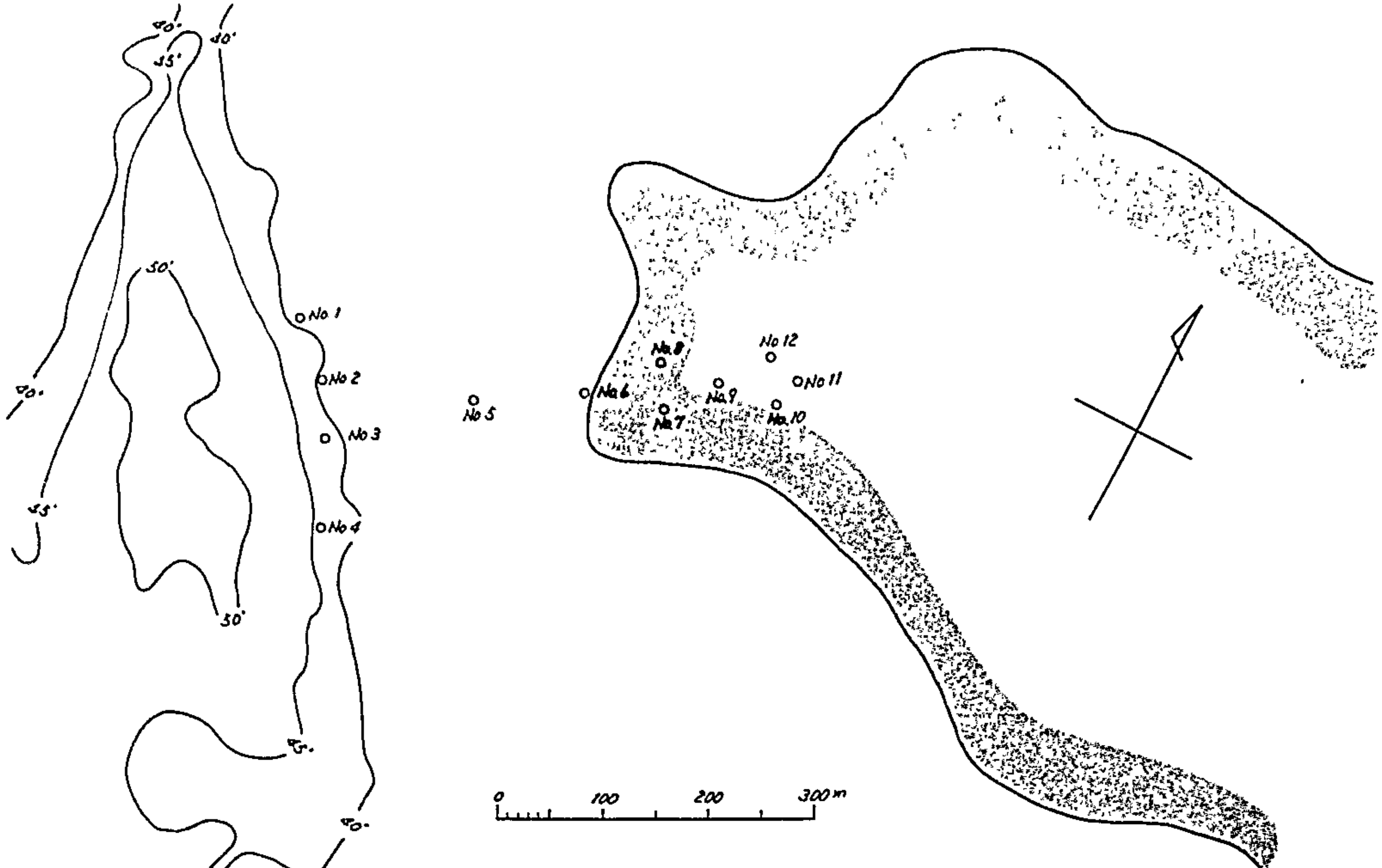
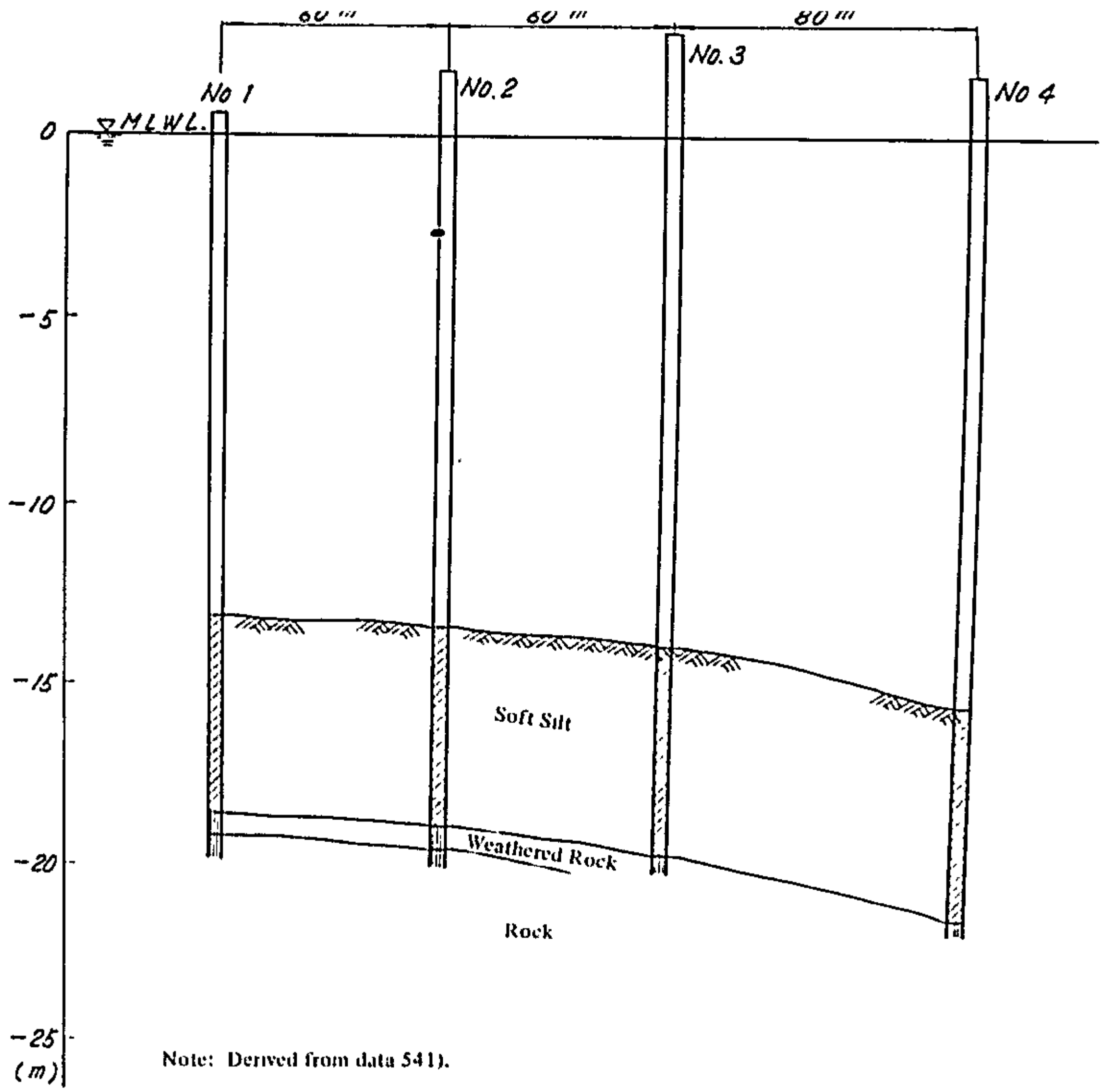


Fig. 13.2 Earth-Quake Activity in Costa Rica



Source: 622)

Fig. 14.1 Location of Boring at Punta Morales



Note: Derived from data 541).

Fig. 14.2 Soil Profile at Punta Morales (1)

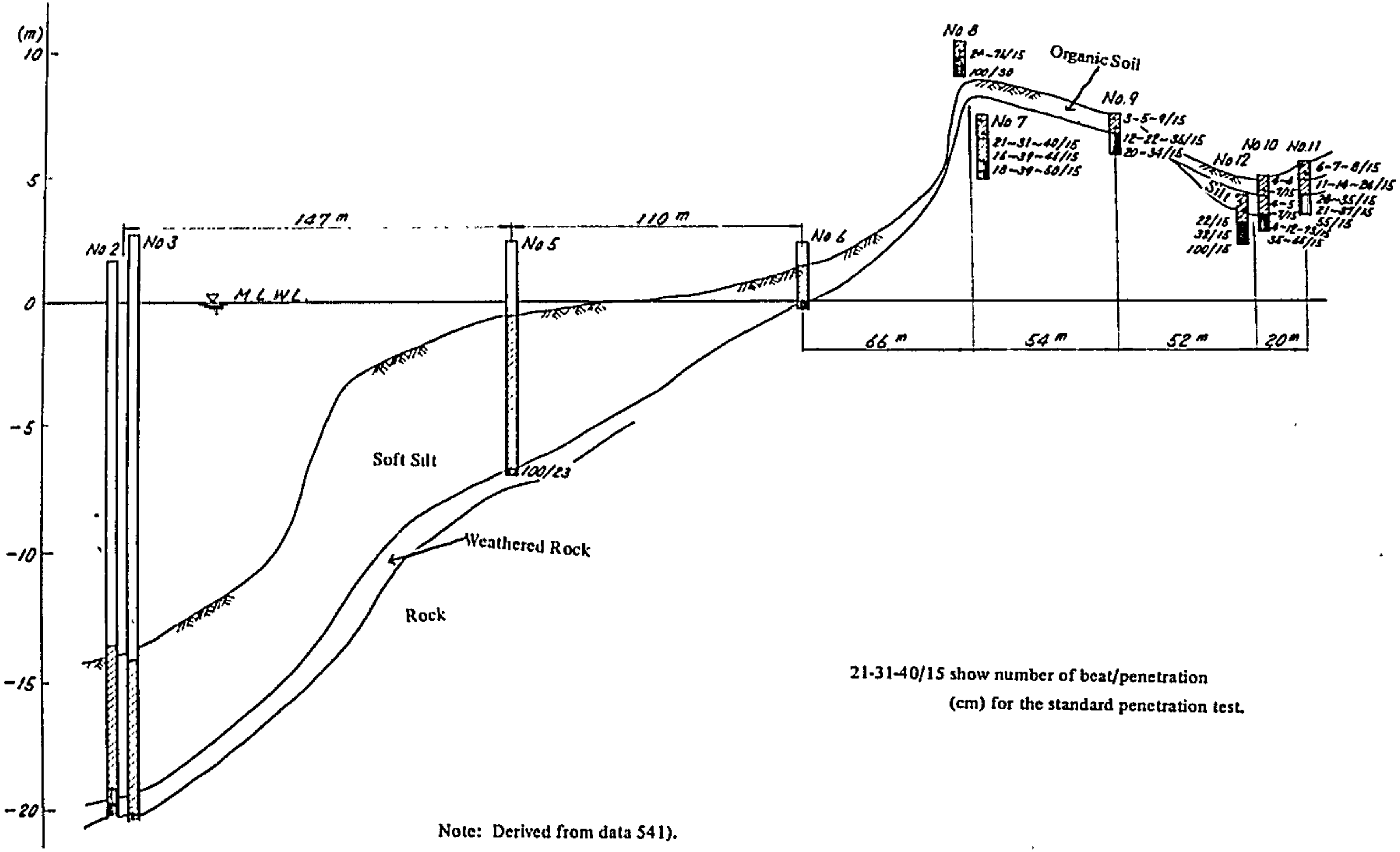
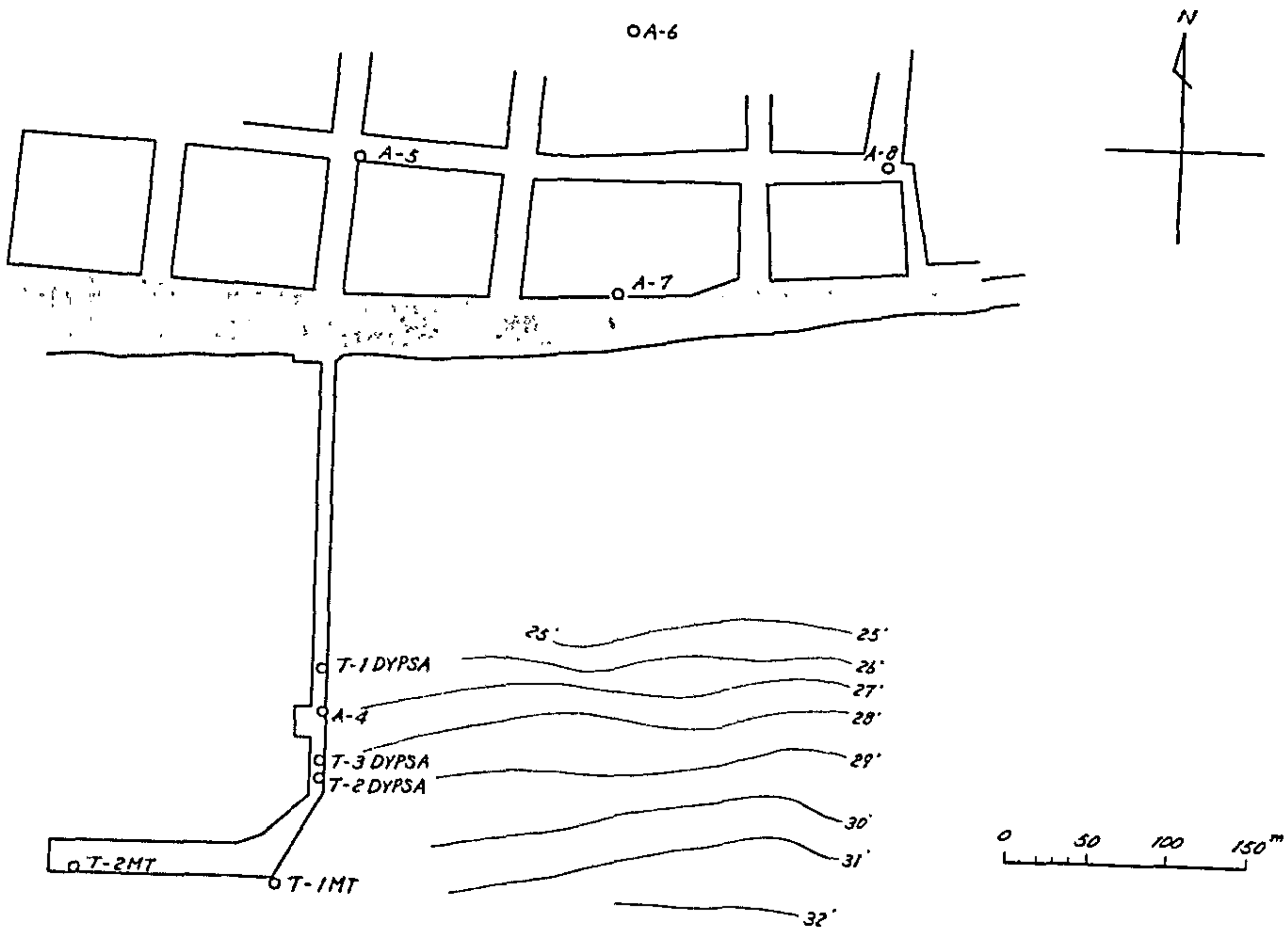
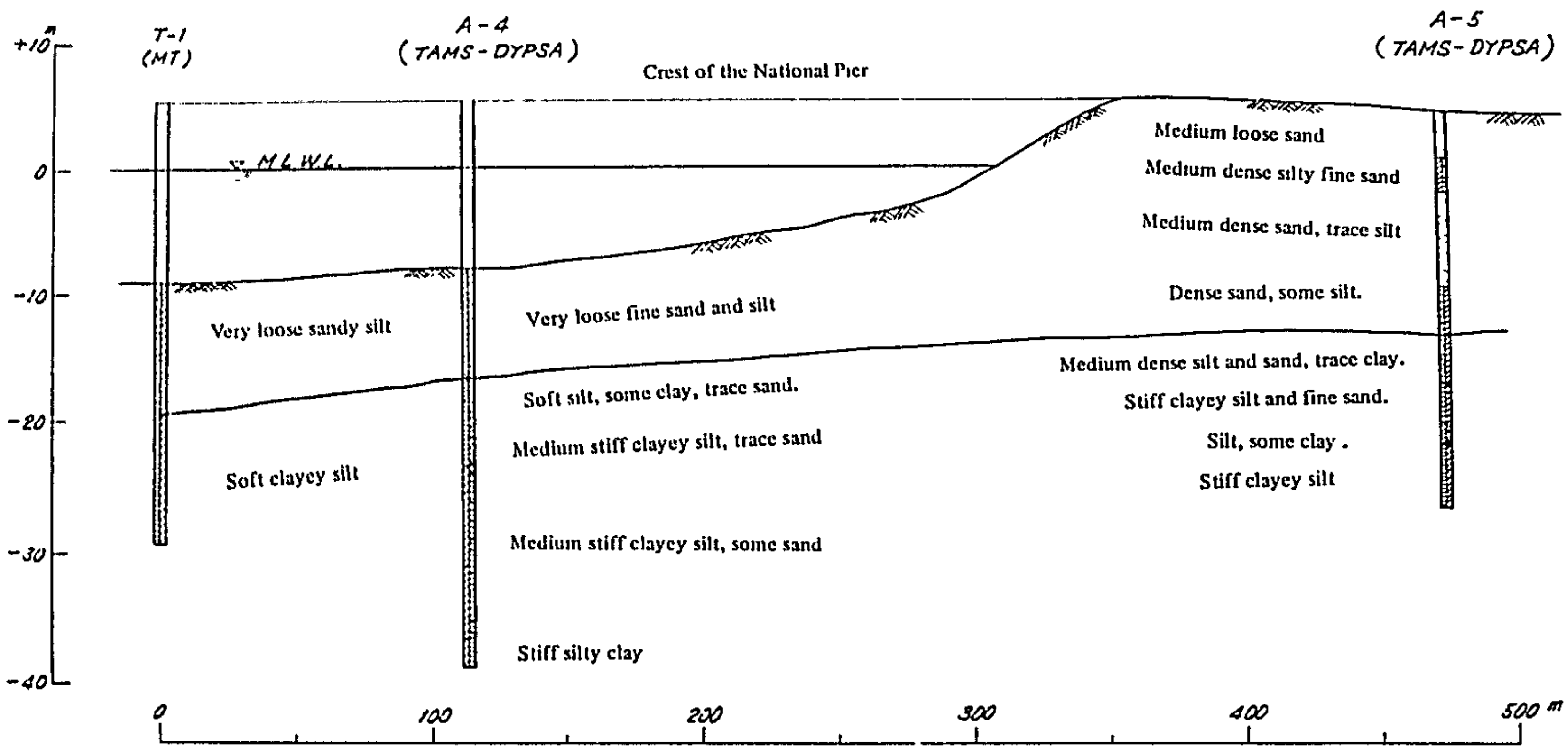


Fig. 14.3 Soil Profile at Punta Morales (2)



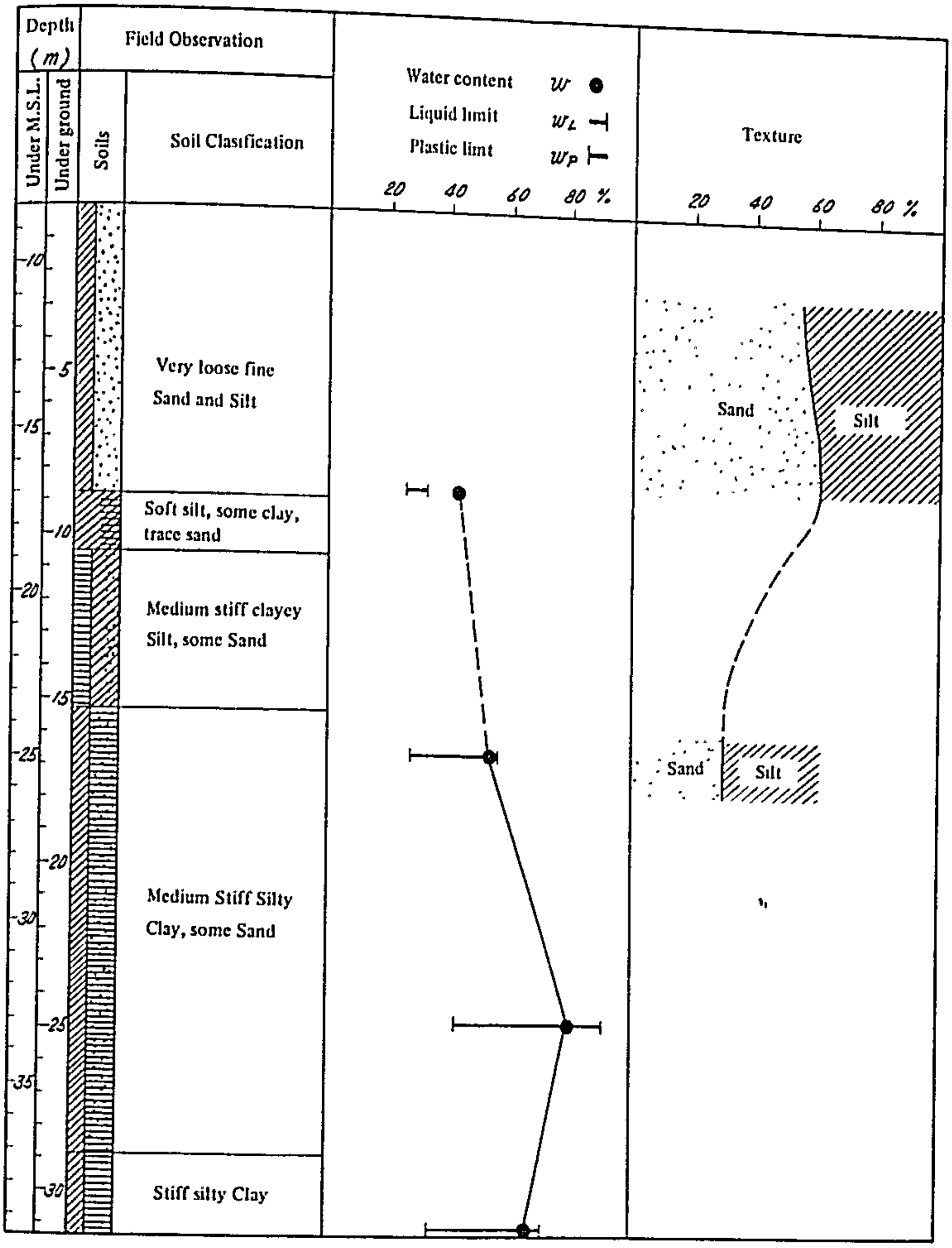
Source: 543)

Fig. 14.4 Location of Boring at the National Pier, Puntarenas



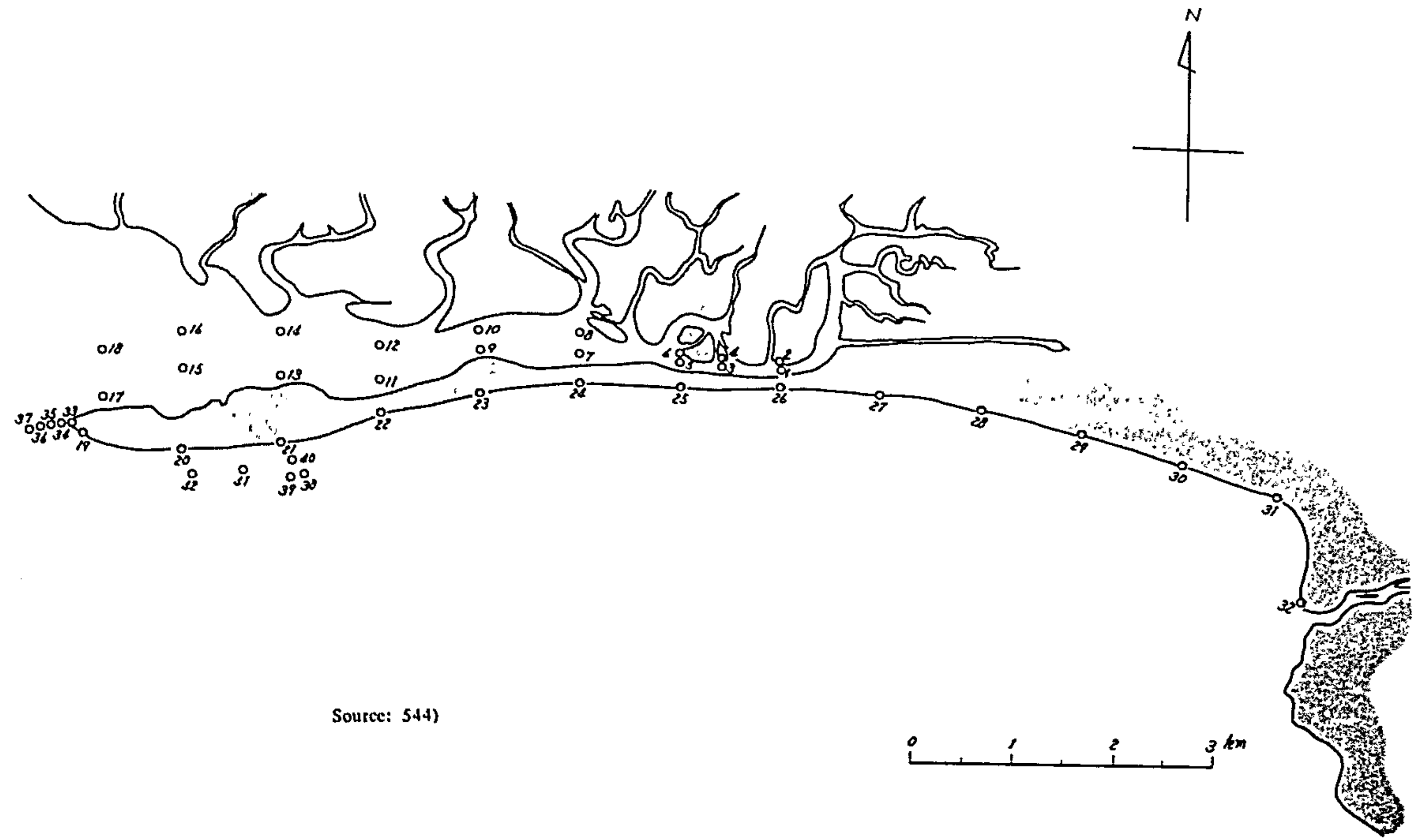
Source: 543)

Fig. 14.5 Soil Profile at Puntarenas



Note: It is derived from data 543).

Fig. 14.6 Index Properties of Soil of Puntarenas
(Boring No. A-4)



Source: 544)

Fig. 14.7 Location of Soil Sampling at Puntarenas

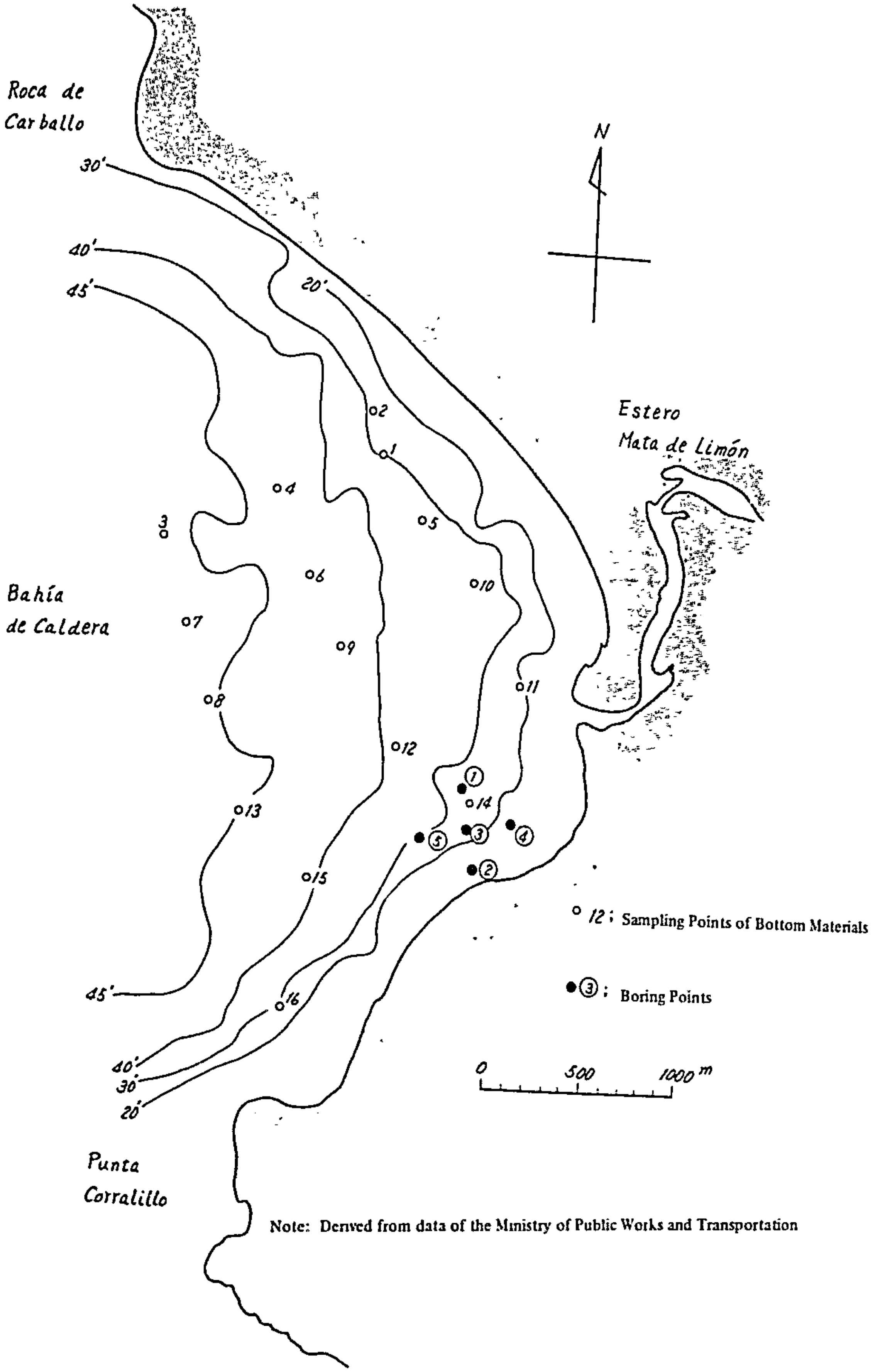
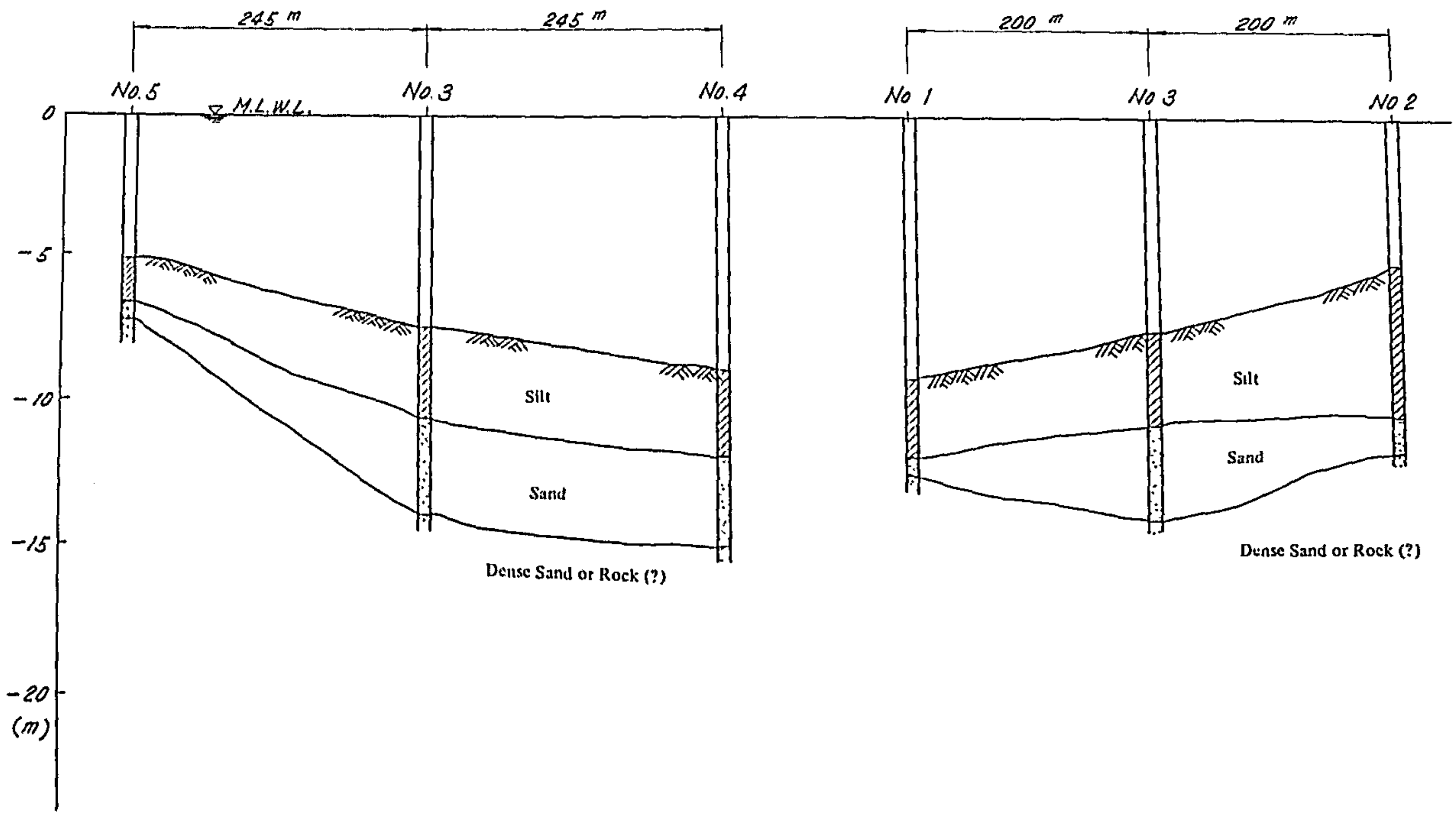


Fig. 14.8 Location of Soil Sampling and Boring (Caldera)



Note: It is derived from data of the Ministry of Public Works and Transportation.

Fig. 14.9 Soil Profiles at South Caldera

Fig. 14.10 Location of Soil Sampling (Tivives)

Table 8.1 Annual Variation of Temperature[501)]
(Puntarenas, 1970)

unit: °C

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average
Maximum	36.5	37.5	38.5	38.5	36.5	34.0	34.5	33.5	32.5	32.5	33.0	33.5	
Minimum	19.5	19.5	18.0	21.5	21.5	22.0	21.5	21.0	21.2	19.5	16.0	14.5	
Average of Maximum	33.2	35.3	35.0	35.0	33.1	33.0	32.0	32.0	31.3	30.7	30.6	31.2	32.7
Average of Minimum	21.8	22.0	22.4	23.5	23.2	23.4	22.9	22.5	22.5	22.0	20.9	20.3	22.3
Monthly Average	27 0	28.1	28.2	28.5	27.1	27.0	26.2	25.4	23.8	25.1	25.3	25.7	26.1

Table 8.2 Precipitation and Evaporation[501,504)]
(Puntarenas, 1970)

unit: mm

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Total Precipitation	13	3	30	44	168	148	417	321	270	419	39	61	1931
Maximum Precipitation*	7	3	16	20	49	59	134	66	74	157	13	14	
Monthly Average Precipitation**	1	12	6	30	125	233	197	187	276	280	107	23	1477
Potential Evaporation	96	185	131	112	68	46	41	40	41	39	65	61	
Evaporation under sunshine	118	203	189	176	120	101	94	101	97	115	102	119	

* Within 24 hours.

** "Period of average 1960 - 1969".

Table 8.3 River Discharges at each Drainage Area[509)]

River basin name	Mean annual rainfall (mm)	Drainage area (km^2)	Mean annual runoff coefficient	Mean* annual flow (m^3/sec) *
18. Peninsula Nicoya	2,200	4,124	0.49	140
19. Tempisque	2,022	3,412	0.41	87
20. Bebedero	2,167	2,078	0.46	66
21. Abangares	2,168	1,316	0.60	54
22. Barranca	2,451	380	-	28
23. Jesús Maria	2,229	448	0.79	29
24. Grande de Tároles	2,216	2,019	0.61	87
25. Tusubres	2,731	740	0.83	53

* Number of this colum is conformed with multiplying Drainage area to the original value in (liters/sec/km^2)

Table 8.4 Details of Drainage Areas and Mean Annual Railfall

unit: mm

Name		Drainage area (km^2)	Mean Annual rainfall
Bahia Herradura		30	3,000 - 3,500
Bahia de Caldera		19	2,000 - 2,500
Punta Morales	Northern	30	1,400 - 1,500
Punta Morales	Southern	250	1,500 - 3,000

Table 9.1 Variation of Trade Pattern

Month	1	2	3	4	5	6	7	8	9	10	11	12
Pattern*	B	A	A	A	B	C	D	D	C	C	B	B
Latitude of doldrums(°N)	4	5	5.6	5.7	7	7.5	10	11	8	8	6	5
Average wind spell at doldrums	8	5	7	7	5	4	4	4	5	5	7	5

* A: Westward convergence
B: Node
C: Single Node accompanied with a cyclone
D: Several Nodes and cyclones

Table 9.2 Maximum wind speed observed at Puntarenas (1970)

unit: km/hr

N	NE	E	SE	S	SW	W	NW
24	19	17	13	14	14	15	12

Table-9. 3 Hurricanes (HU) and Tropical Storms (TS) in the Eastern Pacific

(1) 1947 - 1961

Year	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Total
1947					2			2
1948						1		1
1949		2			4			6
1950		1	2			1		4
1951	1	2	1	2	2		1	9
1952	1	1	2		2	1		7
1953				1	2	1		4
1954		1	3		4	2		10
1955		2	1		1	2		6
1956	2	2	2	1	3	1		11
1957			1	2	3	3		9
1958		2	3	2	3	2		12
1959		2	3	3	2	2		12
1960		2	1	2	1	2		8
1961		1	4	1	1	2	2	11
Monthly total	4	18	23	14	30	20	3	112
Average of 15 years								7.5

(2) 1962 - 1965

Year	May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Total		
	HU	TS	HU	TS	HU	TS	HU	TS	HU	TS	HU	TS	HU	TS	HU	TS	
1962			1			1		2		3	1				2	6	8
1963			1		2					4	1				4	4	8
1964					2	1		2		1					2	4	6
1965				4			1	2		3					1	9	10
Monthly total			2	4	4	2	1	6		11	2				9	23	32
Average of 4 years															2.3	5.8	8.0

(3) 1966 - 1971

Year	May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Total		
	HU	TS	HU	TS	HU	TS	HU	TS	HU	TS	HU	TS	HU	TS	HU	TS	
1966			1				4		2	4		2			7	6	13
1967			1	2		4	2	2	1	2	2	1			6	11	17
1968				1		4	3	5	2	1	1	2			6	13	19
1969					1	2	1	1	1	3	1				4	6	10
1970	1			3	1	2	1	3		1	1	1		1	4	14	18
1971	1		1		5	5	2	2	2		1	1		1	12	6	18
total	2		3	6	7	17	13	13	8	11	6	7		2	39	56	95
6-yr average															6.5	9.3	15.8

Table 10.1 Wave Statistics Obtained by Visual Observation Off-West Coast of Costa Rica[521)]

Month	Wave direction (clockwise degree from the north)	% of Occurrence		Highest wave		Longest wave		Most frequent* wave height	
		Total	$H_{1/3}<1^m$ *	$H_{1/3}$ (m)	$T_{1/3}$ (sec)	$H_{1/3}$ (m)	$T_{1/3}$ (sec)	$H_{1/3}$ (m)	%
3~5	120	12		2.1	9.0	1.9	10.4		
	150	20		2.3	9.0	2.1	11.8		
	180	19	18	3.7	7.5	2.3	11.1	1.7	40
	210	8		2.3	10.4	2.3	11.8		
	240	4		1.9	9.0	1.0	10.4		
	270	2		1.7	6.8	2.1	7.5		
	300	1		2.3	9.0	2.3	9.0		
6~8	150	23		2.8	9.7	2.3	11.1		
	180	35		2.8	7.5	2.3	11.1		
	210	17	8	2.8	7.5	2.3	9.7	1.7	36
	240	7		2.8	8.2	2.6	10.4		
	270	2		2.8	7.5	1.9	8.2		
	300	1		2.3	7.5	1.9	9.0		
9~11	150	24		2.8	9.7	1.5	11.8		
	180	36		2.8	11.1	1.5	11.8		
	210	18	5	3.9	7.5	2.8	11.1	1.7	39
	240	8		2.8	6.8	2.1	10.4		
	270	2		2.6	9.0	2.6	9.0		
	300	1		2.1	7.5	1.9	9.7		
12~2	150	20		3.0	7.5	1.9	10.4		
	180	17		3.2	6.8	2.1	11.4		
	210	9		3.9	6.8	2.3	10.4		
	240	5	14	2.1	8.2	1.9	9.0	1.7	38
	270	3		1.9	7.5	1.0	10.4		
	300	3		2.1	8.2	2.1	9.7		

* Include all wave directions

Table 10.2 Ratios of Wave Height of Each Site and the Mouth of Golfo de Nicoya (Swell)

Wave direction of the baymouth		Bahia de Herradura	Tivives	Punta Carralillo	Puntarenas	Punta Morales
150°	T=12.5 sec	0.92	0.22	0.01	0.49	0.04 ~ 0.05
180°		0.92	0.84	1.08	0.44	
210°		0.92	1.36	0.81	0.35	
150°	7.5 sec	0.97	0.20	0.01	0.50	0.02 (150°–180°)
180°		0.97	0.88	0.88	0.42	
210°		0.97	0.98	0.93	0.09	0.01

Table 10.3 Maximum Wind Waves due to Local Winds

Upper numbers : $H_{1/3}$ (m)
Lower numbers in Parentheses : $T_{1/3}$ (sec)

Wind direction	Bahia de Herradura	Tivives	Punta Carralillo	Puntarenas	Punta Morales	*
N	0.9 (3.5)					2
NW	0.3 (2.0)	0.4 (2.3)	0.3 (2.0)		0.3 (2.2)	0
W	0.7 (3.3)	0.6 (2.8)	0.6 (2.8)	0.4 (2.2)	0.6 (2.8)	1
SW	0.8 (3.6)	0.8 (3.6)	0.5 (2.7)	0.4 (2.4)	0.4 (2.4)	2
S	0.8 (3.6)	0.8 (3.6)	0.8 (3.6)	0.5 (2.6)	0.4 (2.4)	1
				0.7 (3.1)	0.7 (3.0)	3

* Number of months when winds over 19 km/hr are observed at Puntarenas in 1970-1971 (Fig. 9.1)

Table 11.1 Description of Tide

Location	Height above datum of soundings (ft)			
	High Water		Low Water	
	Mean springs	Mean neaps	Mean springs	Mean neaps
Puntarenas	9.3	7.3	-0.1	1.9
Puerto Herradura	9.3	7.3	-0.1	1.9

Note: Chart datum (Mean Low Water Spring) is 1.42 m below datum of topographical surveying.
Source: British Chart 1931

Table 11.2 Correction Nonharmonic Constants
(Standard port: Panama Canal)

Location	Latitude	Longtude	Correction Constants		Mean high water interval	Mean low water interval	Spring rise	Neap rise	Mean sea level
			Time Difference of tide	Height Ratio					
Puntarenas	N 9°58'	W84°50'	-1 hr 5 min	0.60	2 hr 35 min	-	2.8m	2.3m	1.40m
Puerto Herradura	9°39'	84°40'	-1 10	0.60	-	-	-	-	1.37

Source: Tide Table Vol. 2 (Pacific Ocean and Indian Ocean), Hydrographic Department, Maritime Safety Agency, Japan, September 1971.

Table 12.1 List of Marine Charts and Sounding Maps Obtained

No.	Description	Scale	Year of Surveying	Small Correction	Remarks
H.O. 1016	West Coast of Central America	1:2590,420	1885	~1947	
H.O. 1016	West Coast of Central America	1:290,420	1885	~1970	(Fig. 12.1)
H.O. 1034	Colfo de Nicoya	1:120,000	1932~35	~1952	
NO. 21544	Colfo de Nicoya	1:120,000	1932~35	~1971	Revision of H.O. 1034
NO. 1060	Punta Arenas Anchorage	1: 25,000	1885	Unknown	(Fig. 12.3)
NO. 1060	Puntarenas and Approaches	1: 30,000	1932~35	~1951	Sub-chart (1:30,000) of Ballena and Herradura (Fig. 12.4) are included.
H.O. 1060	Puntarenas and Approaches	1: 30,000	1932~35	~1959	Revision of No. 1060
H.O. 1060	Puntarenas and Approaches	1: 30,000	1932~35	~1960	
1931	Golf of Nicoya	1:150,000	1938	~1970	Sub-chart (1:30,000) of Puntarenas included (Fig. 12.2)
-	Puntarenas Caldera Tivives	1: 25,000 1: 20,000 1: 13,000	1891 1897 1896		
-	Port of Puntarenas	1: 5,000	1914		
~	Puntarenas (South) Puntarenas (West) Puntarenas North (El Estero)	1: 5,000 1: 5,000 1: 5,000	1955 1955 1955		Contained in SOGREA's report
~	Puntarenas (North & South)	1: 5,000	1970		Only east of Muélle Nacional
~	Puntarenas (South)	1: 5,000	1972		Only a small area east of Muelle Nacional
~	Tivives	1: 5,000	1969		Contained in Tivives report on reduced scale.
~	Caldera	1: 25,000	1972		(Fig. 12.5)
~	Punta Morales	1: 1,000 1: 5,000	1972		(Fig. 12.6)

Table 13.1 Number of Earthquakes (1953~1961) in Costa Rica (1)

Location	Modified Mercalli Seismic Intensity						Total
	II	III	IV	V	VI	VII	
Avance	2						2
Bagaces	2						2
Barranca		1	1				2
Buena Vista S.C.	2	1	1				4
El Coco	4						4
El Guarco	5	3					8
Esparta		2	2	2	1		7
Filadelfia	2						2
Finca 47 Golf.	13	11	7				31
Golfito	19	11	4				34
Juan Viñas	14	14	6	5	2	1	42
La Suiza			1				1
Limón		3					3
Los Cartagos	1	5					6
Monte Verde	2		1				3
Naranjo				1	1		2
Nicoya		1					1
Orotina			1				1
Pacayas		3		2		1	6
Palmares	1		2		1		4
Potrero Grande	8	7	6				21
Puerto Armuelles			2				2
Puriscal			1				1
San Cristóbal			1				1
San Joaquin Fdr.		3	1				4
San José S. M.	8	17	4	4	1		34
San Vito Jaba	8	16	9	2			35
Sanatorio Duran	24	13	8	4	1		50
Santa Ana	24	19	7	2	2		54
Santa Cruz Gte.	2	2	1				5
Tapanti		3					3
Tilarán		3					3
Vuelta Jorco	1	3	2				6

Table 13.2 Number of Earthquakes (1930~1955) in Costa Rica (2)

Location	Modified Mercalli Seismic Intensity									Total
	II	III	IV	V	VI	VII	VIII	IX	X	
San José	48	38	9	3	1	2				101
Cartago		2		2		2				6
Heredia	1	3			1					5
Alajuela	1	1			2					4
San Ramón	1	3			1					5
Grecia	1	5	1							7
Limón	2	3			1			1		7
Golfito	8	3	1						1	13

Table 13.3 Seismic Activity in Costa Rica[1]

Year	Type Shock	Location of Epicenter[2]		Magnitude on Richter Scale
		Lat (N)	Lon (W)	
1916	Shallow[3]	10°	85°	7.3
1924	Shallow	9°45'	84°	7.0
1939	Shallow	10°	84°30'	6.75
1948	Intermediate[4]	10°	83°30'	7.0
1950	Shallow	11°	85°	7.7

Source : B. Gutenberg and C.F. Richter, "Seismicity of the Earth", Princeton University Press. (1954), Princeton, New Jersey.

(1) Data are available until 1952.
(2) Location of Limon: N 10° W 83.0°
Puntarenas: N 10° W 34.7°
(3) Shallow: Shocks occurring at depths less than 60 kilometers.
(4) Intermediate: Shcoks occurring at depths between 70 kilometers and 300 kilometers.

Table 14.1 Grain Size Distribution of Bottom Materials around Puntarenas

Sampling Point	Passing Weight Percentage — Mesh diameter: 1-1/2" (mm 33.1)	1" (25.4)	3/4" (19.1)	1/2" (12.7)	3/8" (9.52)	# 4 (4.76)	# 8 (2.38)	# 16 (1.19)	# 30 (0.58)	# 50 (0.297)	# 100 (0.149)	# 200 (0.074)	Remarks
1								100	99	96	25	14.8	with little shell particle
2								100	100	99	39	19.5	
3							100	96	87	70	37	20.6	with little black coat like particle
4							100	100	100	93	67	37.7	with small shell particle
5				100	98	95	93	90	82	65	46	38.1	containing large quantities of shell
6								100	100	96	61	35.9	containing small shell particle
7						100	98	96	91	70	47	39.9	with few shell particle
8						100	100	96	70	28	10	5.0	with light shells containing
9								100	98	97	79	65.6	much organic matter
10									100	98	91	82.2	with organic matter
11									100	98	65	35.5	with plenty refuse
12									100	99	53	42.6	dirty sand
13								100	100	98	93	84.8	with organic matter
14								100	99	98	63	32.2	with little organic matter
15						100	99	98	95	87	51	34.0	containing shells

Passing Weight Percentage

Sampling Point	Mesh diameter 1-1/2" (mm 33.1)	1" (25.4)	3/4" (19.1)	1/2" (12.7)	3/8" (9.52)	#4 (4.76)	#8 (2.38)	#16 (1.19)	#30 (0.58)	#50 (0.297)	#100 (0.149)	#200 (0.074)	Remarks
16								100	97	76	23	12.9	
17								100	96	33	7	5.4	with shell particle
18								100	98	82	41	29.6	containing shells
19									100	93	21	4.9	no organic matter
20								100	99	89	33	8.5	
21								100	99	94	30	6.1	
22								100	99	88	20	9.2	containing shell crushings
23								100	98	91	23	7.8	with shell crushing
24								100	96	90	30	10.0	"
25								100	96	89	36	6.3	"
26								100	97	92	33	5.8	"
27							100	98	90	85	33	8.7	"
28								100	96	90	32	12.9	
29						100	99	94	79	51	13	3.6	
30					100	99	98	94	83	57	22	13.2	

Passing Weight Percentage

Sampling Point	Mesh diameter 1-1/2" mm 33.1	1" 25.4	3/4" 19.1	1/2" 12.7	3/8" 9.52	#4 4.76	#8 2.38	#16 1.19	#30 0.58	#50 0.297	#100 0.149	#200 0.074	Remarks
31				100	99	98	96	94	91	86	32	9.4	containing shells
32			100	99	98	97	93	81	42	10	5	3.2	
33						100	98	93	76	35	11	9.4	containing shell crushings
34				100	99	99	97	91	71	32	5	1.0	"
35							100	98	81	32	9	6.0	
36	100	72	36	14	12	11	10	9	8	5	2	1.5	containing shell crushing
37	100	95	93	92	92	91	91	90	88	81	64	59.8	"
38						100	95	82	89	83	24	5.3	"
39					100	74	58	50	46	43	26	19.0	"
40								100	97	74	15	6.4	containing much organic matter
41								100	98	91	17	9.4	containing sticks and shells
42							100	94	83	69	22	3.8	with shells

Table 14.2 Grain Size Distribution of Bottom Materials at Bahia de Caldera

Passing Weight Percentage

Sample No.	Mesh diameter						
	#4	#8	#16	#30	#50	#100	#200
	mm 4.76	2.28	1.19	0.59	0.297	0.149	0.074
1	100	99	99	98	95	70	18.9
2	99	98	97	96	93	70	25.2
3	100	99	98	96	87	31	23.7
4	100	98	97	96	92	61	15.7
5	100	100	100	100	96	61	18.3
6	100	100	99	97	96	60	19.9
7	99	98	98	97	94	68	28.7
8	100	99	99	98	95	52	16.4
9	99	98	98	97	92	54	15.9
10	100	100	100	99	94	62	16.8
11	100	99	99	98	91	43	10.7
12	100	100	99	98	97	40	5.2
13	100	99	99	98	82	15	1.8
14	100	99	99	99	98	48	7.9
15	100	100	100	99	98	50	10.7
16	100	100	99	98	98	60	5.2

Table 14.3 Grain Size Distribution of Bottom Materials at Tivives

Sampling Point	Ground height (m)	3/4" 19.1	3/8" 9.52	4 4.76	10 2.00	40 0.42	200 0.074	Remarks
		Passing Weight Percentage						
		Mesh diameter (mm)						
Polo	+2			100	100	61.4	0.0	Gs = 2.51
	-1			100	100	96.4	0.2	Gs = 2.49
	-3			100	99.1	93.8	2.6	Gs = 2.50 Clay 0.2%
Cope +500	+2			100	100	93.8	0.1	Gs = 3.42
	-1			100	99.5	93.3	0.4	Gs = 2.79
	-3			100	97.7	82.0	1.9	Gs = 2.85 Clay 0.1%
Cope	+2			100	100	99.3	0.2	Gs = 3.68
	-1			100	99.7	92.3	0.5	Gs = 2.63
	-3		100	99.2	94.2	77.2	1.3	Gs = 2.82 Clay 0.1%
Flores +100	+2			100	100	88.9	0.1	Gs = 2.93
	-1		100	97.3	88.3	63.7	0.2	Gs = 2.77
	-3			100	99.0	92.8	1.3	Gs = 2.97 Clay 0.1%
Flores	+2			100	100	46.0	0.0	Gs = 2.88
	-1		100	95.4	68.1	0.1	0.0	Gs = 28.8
	-3			100	99.9	93.8	0.6	
Rudin	-1	100	94.9	88.7	76.9	29.4	0.0	Gs = 2.82
	-3			100	99.7	97.2	1.4	Gs = 2.78
Monge	-1			98.0	87.0	11.0	0.0	Gs = 2.80
Chacon	+2			100	100	32.0	0.0	Gs = 2.81
	-1	100	100	100	96.5	77.5	13.5	Gs = 2.72
500-D Sosa	+2			100	100	18.1	0.0	Gs = 3.04
	-1		100	99.5	94.9	2.4	0.0	Gs = 2.94
	-3			100	99.9	92.0	0.6	Gs = 2.92

Passing Weight Percentage

Sampling Point	Ground height (m)	3/4" mm 19.1	3/8" 9.52	4 4.76	10 2.00	40 0.42	200 0.074	Remarks
		Mesh diameter						
Sosa	+2			100	99.0	37.7	0.1	Gs = 2.76
	-1		100	98.0	86.1	22.8	0.0	Gs = 2.64
	-3			100	99.9	96.3	8.2	Gs = 2.58 Clay 0.5%
500M Oeste	+2			100	99.4	68.9	0.0	Gs = 2.99
	-1			100	99.8	90.6	0.2	Gs = 2.53
	-3			100	99.9	97.6	9.7	Gs = 2.50 Clay 0.9%
#34 Est. Por	+2			100	100	89.5	10.5	Gs = 3.12
	-1		100	94.8	93.6	88.0	0.5	Gs = 2.54
	-3			100	99.6	95.4	7.9	Clay 0.5%
Espinoza	+2			100	100	96.1	0.1	Gs = 3.65
	-1		100	90.7	83.2	71.0	0.4	Gs = 2.60
	-3			100	99.5	93.3	7.9	Gs = 2.58 Clay 1.1%

Chapter IV Selection of Site for the New Port Construction

15. General

As described previously, a construction site for the new port should be selected within the range between Punta Morales and the Bay of Herradura. The length of the shoreline is about 120 km. The following seven sites can be selected as the possible ones for the port construction.

1. Punta Morales
2. El Estero (on the north side of the Peninsula of Puntarenas)
3. Puntarenas (on the south side of the Peninsula of Puntarenas)
4. North Caldera
5. South Caldera
6. Tivives
7. Herradura

We collected all available data, review and analysis concerning these sites. Concurrently, land, sea and aerial surveys of respective sites were conducted to study from all aspects the adaptability of each site to the construction of a new port, which were carried out effectively with the cooperation of excellent engineers provided by the Government of the Republic of Costa Rica.

Further, under the arrangement by the Government of Costa Rica who did its best to cooperate with the survey team, sounding, sediment sampling and analysis and jet boring were conducted during a short stay in Costa Rica.

On the basis of the results obtained from this and the opinions of survey engineers of the Government of Costa Rica, as well as various reports prepared by the consultants so far, analyses were made from the view points by social and economic as well as technical conditions in each of the proposed sites for the construction of a new port as described in the following.

16. Analysis of Economic and Social Conditions.

16. 1 General

In order to make comparison of economic and social conditions between the proposed sites, analyses were made of hinter land transportation conditions, relation to urban activities and relationship with various industries or resources. The methodology in selecting respective evaluation factors is as outlined below.

The basic transportation facilities existing in the hinter land of the proposed sites for port construction include Inter-American Highway (Carretera Interamericana), Highways No. 11 and No. 143 and the railway of INCOP, with the South Coast Highway (Corretera Costanera Sur) which is being planned. The comparison of hinter-land transportation facilities for the suggested sites can be made by examining the connections of each site to these basic transportation facilities. In particular, the hinterland transportation of the new port seems to constitute a dominant factor for the linkage between the port and the industries such as agriculture and stock farming in this country. Outlines of main transportation facilities are illustrated in Table 16. 1. The connections between the proposed sites and primary transportation facilities are compared in Table 16. 1 in terms of distance in kilometers by road and railway. Table 16. 2 snows the transport facilities which need some additional construction or improvement in order to provide access to the proposed sites. Table 16. 3

shows the hauling distances to San Jose from respective sites after the required addition or improvement of the transport facilities shown in Table 16.2.

In order to assure smooth port activities, it is necessary that sufficient port functions are formed behind the port facilities. Especially for a port at which liners call frequently, many port functions including banking facilities, firms, agents and government offices concerned must be provided, to say nothing of the need for port facilities of good quality and skilled port laborers. Historically, the development of a great port has paralleled by that of a city, but the establishment of port functions need a long period of time in general.

In the case of a new port, a situation is that the establishment of city functions in the hinterland of port cannot keep pace with the tempo of port construction may be expected. Although it may be possible to arrange a settlement fairly quickly for port laborers to accommodate their families and other services for supporting their daily livings, it will be inevitable to rely on the existing city for highlevel functions for the time being.

Besides, some of the proposed sites are being developed as a health or recreation resort and the conflict with the tourist industry presents a serious problem in selecting a site.

Fisheries of Costa Rica are operated principally on the Pacific coast and a fishing area of shrimp has been established in the region in front of Puntarenas[113]. Of this fishing area, the zone toward the land from the line stretching from Puntarenas to Punta Gigante of the Peninsula of Nicoya designated as a marine reserve.

As regards the mineral resources around the proposed new port much is not known except the manganese deposit of the Peninsula of Nicoya, though there are some gold vein and sulfur near Meseta Central [105], [114]. Therefore, mineral resources do not seem to present any problem in relation to the location of a new port.

16.2 Punta Morales

The existing seasonal road extends halfway to Punta Morales. In order to link this road with the Inter-American Highway and construct a new port here it is necessary to improve the road for about 11 kilometers including one bridge. The nearest railway station is Barranca to which the distance from the proposed port is 30 kilometers including improved road.

The proposed site is at a distance of 9 kilometers from Chomes (having a population of 2,800) which is too far apart to commute for port laborers, and there is a need to create a new settlement for them. It will be unavoidable for the new port to rely on Puntarenas as the center of higher level port functions. Since Puntarenas is 46 kilometers away from the Puntarenas any close linkage cannot be expected with the port functions.

At preset, there is almost no conflict in interest with fisheries and the tourist industry.

16.3 El Estero

El Estero is on the north side of the urban district of Puntarenas.

The urban district of Puntarenas is served by highway No. 17 which is a complete two-lane road connecting with Inter-American Highway. As the road nears the city area, land is used intensively along the road and widening of road by more than two lanes will face considerable difficulties. If El Estero is selected as a site for the construction of a new port, it will be necessary to consider a supporting transportation by railway or to widen the road with readiness to deal with considerable difficulties.

In view of the relationship between the port and the city activities, the hinter-land of El Estero is equipped with accumulated port functions linked with the existing port facilities as already mentioned in article 3 which are adaptable to the port functions of the new port. It is also possible to secure a land for physical distribution center through reclamation of the sea to some extent.

However, more basic problem is that in view of the restriction on land use, it is difficult to make compatible the functions as tourist, fishery and local central city to which the urban district of Puntarenas is being directed with the function as port city. In El Estero more intensive use of water surface and water-side has already been made in the form of marina, fishery facilities and shipyard with a resulting fear for incompatibility with such use. Also many problems are presented in receiving into the urban district of Puntarenas the traffic of motor vehicles including large-sized truck and the population mainly of laborers increased with port activities becoming more active. The redevelopment of will be required in order to secure space for accepting a higher level of port functions.

16.4 Puntarenas

Puntarenas is on the south coast on the opposite side of El Estero with the urban district area of Puntarenas between them and its advantages and disadvantages are approximately the same as those of El Estero.

The point especially different from El Estero is that the urban district of Puntarenas and the beach to the south adjacent to it constitute an important resort area of the country with many tourist facilities such as tourist hotels, villas and those to let. Therefore the construction of new port will have more strong effect on the orientation of this city as a tourist town compared with the case of El Estero. In the city area on the south side the port functions are heterogeneous with those in the other part of the city and it is not preferable to intensify such hetereogenousness of functions by the construction of port facilities.

16.5 North Caldera

North Caldera is served by a seasonal road which connects to Inter-American Highway and the construction of new port necessitates to improve the road for 11 kilometers and build a new one of about 4 kilometers to reach Salinas. As the road to be improved runs through ridge not so rolling the use of it during a rainy season and its maintenance will be comparatively easy. Also, as this site is served by a railway which faces directly to the sea it has an advantage in that the railway is available immediately.

Creation of new community is required to accept the port laborers who can commute from Puntarenas for the time being.

For the present the high level of port functions can be found in the city of Puntarenas through the railway and in addition it is possible to utilize the accumulation of facilities in the urban district of Puntarenas after a shortcut to it having been completed in future. It is also possible to establish a new city using flat hills around the site. The site is the nearest to Meseta Central among the proposed site.

On the other hand, as a recreation resort is formed around Mata de Limon and the front sea region is a fishing area, some coordination will be necessary to take them into consideration.

Near to the railway station of Caldera there is the oil transfer base of the Esso Co. equipped with a sea berth and a group of oil tanks which may necessitate to coordinate with new port facilities to be provided.

16.6 South Caldera

South Caldera is nearly the same as North Caldera in its advantages and disadvantages. However they differ in that South Caldera has the railway running near to it without any need to constrct new one but it needs to construct a new road from Salinas, while North Caldera requires to extend the railway from Salinas with the existing road improved to some extent.

16.7 Tivives

A seasonal road extends from Tivives only half way to connect to the Inter-American Highway and no road serves the coast of Tivives. Therefore it is necessary to build a road of 21 kilometers if a new port is constructed here. It is possible to reach Salinas by the construction of road to connect to the railway and also possible to connect to the railway of INCOP at Jesus Maria by the construction of new railway 9 kilometers in length.

This site will require to create a new community for port laborers and also to form a center of port functions of its own.

As the site is utilized as a recreation and a fishing area is established in its front sea region some coordination will be necessary to take them into consideration.

16.8 Herradura

Herradura is isolated from the existing transport facilities and depends wholly on the realization of the South Coast Highway to which the construction of road of 3 kilometers is necessary. Even if the South Coast Highway completed the distance to Meseta Central from it is longer by about 40 kilometers than that from Caldera.

Herradura is at a distance of 38 kilometers to Orotina (having population of 5,800) and 77 kilometers to Puntarenas and it is necessary to create not only a community for port laborers but the center of port functions as in the case of Tivives. The development of this site also depends on the realization of South Coast Highway.

17. Analysis of Technical Conditions

17.1 General

The evaluation factors, which have been adopted to compare natural and construction conditions for respective proposed sites are as follows.

(1) Natural conditions

a) Swell and wind wave

Where the site is affected intensively by swell and wind wave a larger amount of investment is required for a breakwater to secure the calmness within port and insure the utilization conditions of land region.

b) Littoral drift discharged from estuary

When the effect of such drift sand or silt is great with a fear for the port being deposited with it, regular investments are required to maintain the water depth of fairway and anchorage. Any structure built on drift sand beach causes a fear for erosion of the shore adjacent to it constituting a problem especially in the area around a city.

c) Soil

The erection of structure on poor subsoil costs higher in general and in particular it costs remarkably high and takes longer construction period where any improvement is required to the foundation. A land reclaimed on poor subsoil continues to settle for a long time and it is necessary to provide some measure to deal with such settlement. Bedrock in the shallow sea has a great effect on the layout of facilities and selecting of structural type.

(2) Construction conditions

a) Calmness of sea for works at sea and easiness of refuge at the time of stormy weather

When the frequency is higher in swell or wind wave above a certain degree or the refuge of working craft is hard at the time of stormy weather the number of days unavoidable for works at sea increases causing the increase in working period as well as construction cost.

b) Transportation of construction materials

Imported construction materials are to be transported to the site from the Port of Puntarenas by sea or by road and rail, and domestic material carried to the site from inland points by road and rail. Therefore evaluations are made for the construction site on seaborne distance between it and the Port of Puntarenas, easiness of connecting it to existing road and railway, and distance between it and the material transport facilities.

c) Securing of construction labor

When the construction site is situated around the existing city the construction labor can be secured most advantageously. At least it is desirable that some community exists in the vicinity to which communication is kept conveniently.

17.2 Punta Morales

Although wind wave is foreseen to some extent the effect of swell is small. So rapid depositing is not likely to occur under the effect of tidal current in the water way in front of Punta Morales. However, if the shape of land to be reclaimed is not adequate the current characteristics will be changed so that some siltation may take place.

As submarine ground is composed of silt layer, about 6 meters in depth, deposited on sedimentary rock of Tertiary period any construction of structure will be impossible without improvement of the ground. Reclaimed land causes a fear for consolidation of long duration. Judging from the topography around it, the bed rock is supposed to have rugged surface and this fact has a great effect on the cost of ground improvement.

(2) Working conditions

In order to transport construction materials by land it is necessary to build a new construction road of about 2 meters wide - the distance to national Highway No. 1 is about 13 kilometers from the site and the use of railway is difficult. The transportation of materials by sea will be made from the port of Puntarenas and its distance is about 13 kilometers or the second shortest next to that from Caldera. As there is some distance to the existing accumulation the securing of labor for construction is somewhat difficult. Almost any effect is foreseen for the works at sea but wind wave is expected to occur to some extent.

17.3 El Estero

(1) Natural Conditions

The water within El Estero is very calm but some dredging is necessary in order to secure the anchorage and fairway for large-sized vessels. In order to maintain the water depth of 5 meters or more maintenance dredging is required, otherwise rapid siltation is inevitable at the inside of El Estero and fairway around the point of the peninsula.

The bottom material of this region is composed of silt partly comprising organic matters or of silty sand and it is supposed to be poor to a considerable extent. Therefore the improvement of ground is needed at least in order to construct deepwater wharf.

(2) Working conditions

As regards the transportation materials the site is favorably situated for carrying either by road, rail and sea although the over-crowded city area and congested road traffic may cause a bottleneck in the transportation. However the fact that the site is in the existing city makes it most advantageous in securing necessary labor. Almost any effect of swell and stormy weather is not foreseen in executing the works.

17.4 Puntarenas

(1) Natural conditions

Swell has a considerable effect on the vessels moored at the existing national pier and it needs to eliminate such effect by means of some facilities. However, to this end if a breakwater is provided 200 meters off the pier, for example, the necessary length of such breakwater is about 300 meters so that the reduction rate of wave height should be about 30% of the present height. Further, in constructing such breakwater the effect it will have on beach drift sand should be taken into consideration.

With regard to sea bottom material, the surface layer of about 10 meters thick is of loose silty sand or sandy silt and the layer beneath it is of poor silt or silty clay, thus it may necessitate to improve the ground depending on the type of structure.

(2) Working conditions

The conditions for transportation of materials and securing of construction labor are the same as those of El Estero. Constantly incoming swell seems to constitute a considerable obstruction to the works at sea but refuge at the time of stormy weather is comparatively easy as El Estero is in the vicinity.

17.5 Caldera North

(1) Natural conditions

Wave height at Caldera North in greater than that at Puntarenas and it needs to provide a breakwater to shelter the port from swell. The sea-bottom slope is steep and this constituter an disadvantage in constructing reclaimed land and breakwater. The effect of drift sand is small.

The sea-bottom soil has been inferred on the basis of the results of boring made at Caldera South and the survey of bottom material conducted at this region; that is, the surface layer of several meters are of silty sand with a layer of sand beneath it and thus it does not seem that any special problem is presented on the construction works.

(2) Working conditions

The provision of construction road of 4 kilometers is required to connect to the seasonal road for the transportation of construction materials and this enables to connect to National Highway No. 1 at a distance of about 16 kilometers. The railway can be used through the Caldera station and the length of material transportation from Meseta Central to the site is shorter than that to Puntarenas or El Estero. The seaborne distance to Puntarenas is about 15 kilometers, the third shortest next to those from Puntarenas and El Estero. With regard to the securing of labor it is also advantageous next to the above two points in terms of distance to Meseta Central or Puntarenas. Swell and wind wave have some effects on the works at sea.

17.6 Caldera South

(1) Natural conditions

The sheltering effect of Corralillo Head against swell constitutes an advantage especially at the initial stage of construction works. Sand bar at the river mouth which is comparatively narrow will gradually shift a little to the south with the decrease in wave height on the south coast resulting from the construction of new port.

The quantity of sand discharged from the estuary in considerably small compared with other rivers. With regard to wind wave generated in Nicoya Bay, Caldera is more favorably placed than Punta Morales. The frequency of wind waves from the most dangerous direction is smaller for Caldera than Punta Morales as mentioned article 10.3. According to the results of jet boring, silt layer lies from 1.5 to 5 meters beneath the sea bottom under which is compact sand (or it is possible to be bed rock). The surface layer of silt which is composed of fine sand at all point, within the bay as indicated by the survey of bottom material comprises much sand and this seems to present little problem on construction.

(2) Working conditions

Construction materials can be transported using the seasonal road for about 17 kilometers to reach National Highway No. 1. The distance to the railway station at Salinas is 4 kilometers by the seasonal road. If a railway is constructed parallel to the seasonal road the transportation condition is almost the same as that for Caldera North. The effects of swell and wind wave on the works at sea are already mentioned in the article of natural conditions.

17.7 Tivives

(1) Natural conditions

For Tivives, as it is supposed that a great quantity of sand is discharged from Rio Jesus Maria it is necessary to select the site apart from the estuary. Since littoral drift is not noticeable it is possible to construct new port by providing proper breakwaters near the center of sandy beach. Wind wave height is greater than that at Caldera and the sheltering during construction works becomes important.

According to the survey of bottom material near shore line the material of sea bottom is fine sand; which as there is a possibility for poor layer existing underneath it cannot be said that any improvement of ground is considered unnecessary.

(2) Working conditions

For transportation of construction materials it is necessary to construct an access road of 2 kilometers which connects to the seasonal road. National Highway No. 1 is at a distance of about 22 kilometers but railway cannot be used. Swell and wind wave have some effect on the construction works.

17.8 Herradura

(1) Natural conditions

In order to secure a sufficient calmness within port it seems that the construction of breakwater is required to some extent.

Bottom material is not unknown, but gravel are found on the beach judging from the topography there is a possibility for bed rock lying in comparatively shallow depth.

(2) Working conditions

The site can be linked with the seasonal road by the construction of access road of 3 kilometers but the distance to National Highway No. 1 is 53 kilometers, the longest among other sites. Railway cannot be used. Swell has a considerable effect on works at sea.

18. Determination of Construction Site

18.1 General

On the basis of various conditions examined in the above objective evaluations are made of the seven sites selected previously from all points of view. The prerequisites which constitute the bases of such evaluations are as follows.

(1) Port to be constructed on the east coast area of Nicoya Bay (Golfo de Nicoya) should be a modern port tailored to the tendency in physical distribution of the world. It must be a port with deep-sea berth, calm water and sufficient land to support port functions.

(2) At the same time, a close relationship must be maintained between the back land city which provides labor, energie and water to support the port and grows in concert with the development of that port. This city is destined to

become a social and economic center in the east coast of the Gulf of Nicoya and in its turn constitute a major strategic point for economic development of this company.

Starting of the first stage of construction must be easy in terms of cost and execution of works and at the same the needed least requirement should be met already at the initial stage of the accommodation of the part of facilities.

18.2 Method of Evaluation

Plans of port facilities are assumed from the above points of view to cover the seven sites and then the evaluations of respective sites are made basing on these plans.

(1) The first phase of evaluation - Presumed scale of port facilities includes 3 berths of quaywall for large-sized vessels, 10 meters of water depth at fairway and at least 300 meters in width of premise at the back of quaywall. The width of back premise planned far wider than that of existing port facilities in this country is intended to adapt it to the modern system of physical distribution. For example, at present many of container berths in the world require back premise of more than 300 meters in width in general and in some cases one of 500 meters in width; besides it is a common practice to provide storage area and truck terminal of the same width at farther back premise.

There may not be much possibility that containerization will be promoted so rapidly at the commercial ports in this country. However, handling of containers to some extent should be taken into consideration as a matter of course, and the essential factors as a modern port are to arrange adjacent to it such facilities as wharf, shed, warehouse and simple distribution processing plant to improve the efficiency of port activities. It is believed that all this requires a back ground of 300 meters at least in width.

After rough scale of facilities having been assumed as described above, a plan of port facilities including that of supporting transportation facilities are presumed basing on economic-social and technical conditions for each of seven proposed sites. Main harbor works which seems to be required for each of proposed sites are shown in Table 18. 1.

Even if such works are implemented the levels of port facilities are not same for all sites. This problem is dealt with by including it in the evaluation to be made in later phase.

(2) The second phase - Selection is made of evaluating factors which seems to produce some meaningful differences in selecting any one among seven proposed sites. For this, endeavor is made to adopt various factors which can be evaluated from the standpoints diversified as far as possible relating to transportation system, value as a depot of physical distribution, city, and port facilities and operation by combining the analysis of economic - social conditions with technical examination as outlined previously. There are twelve evaluating factors which are subdivided if necessary.

(3) The third phase - Three-grade evaluation that is, A, B, and C, is made in order of preferability by evaluating factors. The results of such evaluation are shown in Table 18. 2 of which explanation is made later (article 18. 3).

(4) The fourth phase - Preferable site is determined from the overall viewpoint. In deciding such site, it is not sufficient only to compare the total of marks for each of A, B and C. Also it is not possible to give marks respectively to A, B and C and assign weights to such marks to calculate the total for comparison purpose. One fatal defect of such total marks is that there is a possibility that all other superiorities may be denied by any inferiority. Also each of A, B and C expressed uniformly involves some differences. According to such way of thinking, the ultimate superiority is determined referring to the evaluations by proposed site prepared in the third phase.

18.3 Explanation on Evaluations of Sites made by Various Evaluating Factors

Evaluations made in three grades, A, B and C, are shown in Table 18.2 to which some explanations are added.

Supporting transportation condition can be evaluated by the distance to Meseta Central and situations of access roads to main arterial highway and railway. The Bay of Caldera (Bahia de Caldera) is at the shortest distance to Meseta Central by either of road and railway and requires to provide new transport facilities only to small extent, offering a good condition for construction of such facilities as well as easy maintenance of them.

For El Estero and Puntarenas, any increase of port size causes a bottleneck of road transportation but the existing road can be made to connect to the railway. The potential of Herradura depends entirely on the completion of South Coast Highway (Carretera Costanera Sur).

In respect of aptitude as the base of physical distribution in the region the Bay of Caldera is most advantageous as it is near to Barranca which constitutes a node of transportation and situated at the pivot of east coast area of the Bay of Nicoya of which development is progressing. Puntarenas and El Estero present many difficulties in terms of transportation and land for physical distribution facilities.

As regards aptitude as port city, an intensive utilization has already been made of the city area of Puntarenas; for El Estero and Puntarenas the merit is great in that the existing accumulation can be utilized but physically they need to be redeveloped. For the Bay of Caldera, as the connection with the city area of Puntarenas is possible only by rail it cannot be said to be the best site. However, it has an advantage that its back land include a hill suitable for constructing new city.

In respect of conflict with other activities, it is only natural that backward region presents the least problems. In relation to the conflict with tourism Puntarenas is most unpreferable. El Estero causes a fear of conflict with the activities in the bay. The Bay of Caldera and Tivives are developing as recreation resort and cannot be said most favorable. In addition, the Bay of Caldera is required to coordinate with the existing berth owned by the Esso Co.

In terms of construction costs the necessity of breakwater, dredging and improvement of foundation will have a great influence.

As far as the data mentioned in article 17 are concerned South Caldera represents the lowest construction costs with Punta Morales following next to it and El Estero, Puntarenas, North Caldera and Tivives represent higher costs.

As regards the execution of works, El Estero and Caldera is advantageous in the easiness of works at sea as it is possible to utilize natural shelter. El Estero and Puntarenas and North Caldera are favorable in view of working base as the existing road and railway can be used at once. As for moorage of working craft South Caldera is favorable. In respect of access road the above mentioned three sites are also advantageous and Herradura is most unfavorable.

Effect on the coast by the execution of harbor-construction works is most intensive at El Estero. Still important is the fact that there is a strong possibility that the point of sand spit is affected by the excavation of deep fairway near to it.

El Estero is most unfavorable in view of maintenance of fairway and other sites will have no question in this regard.

Construction period to be taken into consideration is either longer one of two periods, that is, period of harbor-construction works themselves and that of approach works to the back land facilities; South Caldera is advantageous in this respect. El Estero and Tivives requires a long time for dredging and Herradura depends on the opening of South Coast Highway for service.

As regards easiness of securing laborers, water and energie needed for the harbor-construction works and the port activities after the harbor having been opened for service, the more advantageous it will be the nearer it is to the existing community. El Estero, Puntarenas and the Bay of Caldera gain an advantage in this respect.

Easiness of port activities is assessed taking into consideration the number of days operated, safety of cargo handling, ship operation, and safety of vessel and fender beam.

In respect of ship operation, El Estero is inferior to other sites as it is affected by tidal current.

The space for extension of port is important. In this country of which economic growth is remarkable an important point is that the demand for port will increase more and more in future.

In view of the fact that a port in an infrastructure which ensures the economic growth there should be sufficient space reserved for the extension of port so as to be able to adapt to unforeseen trend of economy. In this sense, Caldera Bay is most advantageous and Tivives will provide a place for the extensive growth of the Bay of Caldera. For Puntarenas or El Estero, any extension of port should be restraines as it matters much to the city. For Punta Morales or Herradura any large scale development cannot be expected due to topographical restriction.

18.4 Determination of Construction Site

Based on the above consideration we determine the superiority of the seven proposed sites as follows.

Most advantageous	South Caldera
Next advantageous	Punta Morales North Caldera
Most disadvantageous	El Estero Puntarenas Tivives Herradura

Some comments are added in the below.

Although it is recognized that South Caldera is most suitable as a site for constructing port there still remains problems on conflicts with the facts that Esso's berth already exists and it is developing as health resort is one which should essentially be judged from the overall viewpoint of the country. However, as specialist in port we dare add that we can hardly find any other site more suitable than this site to construct a port which can be the infra-structure for economic development of the country, while there may be many spots appropriate to develop as health resorts in this country abundant in natural benefits.

Finally, our recommendation does not intend to reject the proposed sites other than South Caldera. As mentioned already, this country is continueing its economic growth and its demand for port will increase more and more in future. The space to accept such demand can be secured at South Caldera over a long period of time. In this respect a sign is already seen at the east coast area of the Gulf of Nicoya and with the progress of development in this area it is well foreseen that the construction of port will be demanded at more places. In this sense the two sites designated as next advantageous should be reserved positively as proposed sites for constructing new port in future and Tivives as place for extensive growth of South Caldera. Further, the same arrangement should be made for Herradura which will be able to be an important water-front base of development after South Coast Highway having been completed.

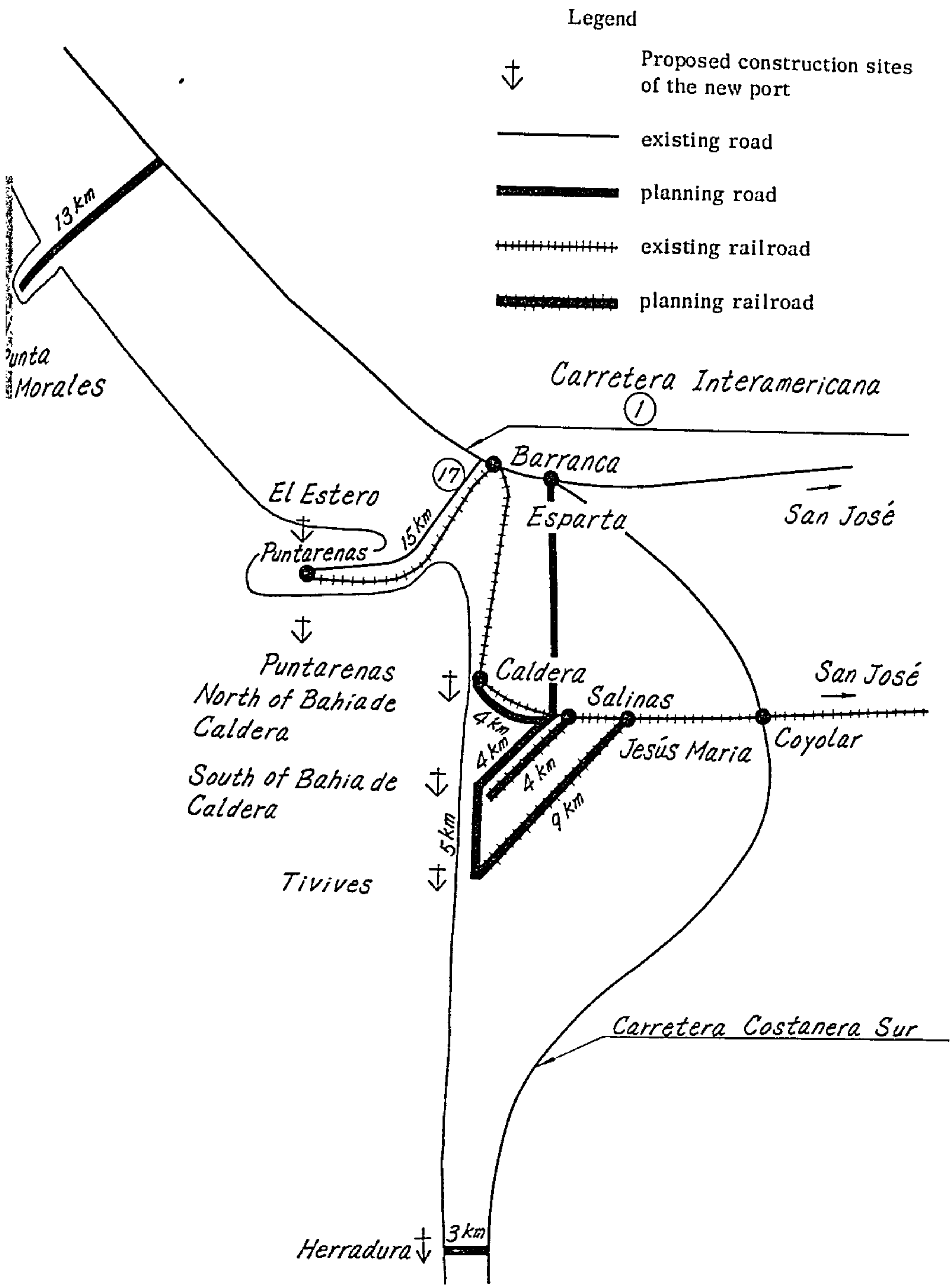


Fig. 16.1 Main facilities of transportation

Table-16. 1 Proposed Sites and Main Transport Facilities

Proposed Sites	Access to major roads	Access to Railway Station by Road	Access to Railway Station by Railway
Punta Morales	13 km to C. I.[2] (connected at San Gerard)	30km to Barranca	
El Estero	15 km to C. I. (connected at Barranca)	0 km to Puntarenas	0 km to Puntarenas
Puntarenas	15 km to C. I. (connected at Barranca)	0 km to Puntarenas	0 km to Puntarenas
North Caldera	16 km to C. I. (connected at Esparta)	0 km to Caldera	0 km to Caldera
South Caldera	17 km to C. I. (connected at Esparta)	4 km to Salinas	4 km to Salinas
Tivives	22 km to C. I. (connected at Esparta)	9 km to Salinas	9 km to Jesus Maria
Herradura	3 km to C. C. S.[3] (connected at Herradura)	33 km to Coyalar	-

Notes:(1) Prepared from 111)

(2) C. I. = Carretera Interamericana (Interamerican Highway)

(3) C. C. S. = Carretera Costanera Sur (plan)

Table-16.2 Roads, Railways and Bridges to be Improved or Newly Constructed

Proposed Site	Type of Work	Length (Quantity)	Remarks
Punta Morales	Improvement of road	11 km	To San Gerad along the
	Construction of bridge	1 each	seasonal road.
El Estero	-	-	
Puntarenas	-	-	
North Caldera	Construction of road	4 km	To Salinas.
	Improvement of road	11 km	To the outskirt of Esparta.
South Caldera	Improvement of road	16 km	To the outskirt of Esparta. along the seasonal road.
	Construction of railway	4 km	To Salinas.
Tivives	Construction of road	2 km	To the seasonal road along the coast.
	Improvement of road	19 km	To the outskirt of Esparta along the seasonal road.
	Construction of railway	9 km	To Jesús María.
Herradura	Construction of road	3 km	To Carretera Costanera Sur.

Notes: 1) Construction of roads: Construction of two-lane roads in the districts where no roads other than cart track are available.

2) Improvement of roads: Construction of two-lane roads in the districts where at least seasonal roads are available.

Table-16.3 Distance to San José

(Unit : km)

	By road only	By road and railway			
	Distance by road	Road	Railway	Total	Via station
Punta Morales	131	30	101	131	Barranca
El Estero	116	0	116	116	Puntarenas
Puntarenas	116	0	116	116	Puntarenas
North Caldera	111	0	93	93	Caldera
South Caldera	112	4	89	93	Salinas
		0	93 (4km of New Line)	93	New Station
Tivives	117	9	89	98	Salinas
		0	95 (9km of New Line)	95	New Station
Herradura	151	33	71	104	Coyolar

Note: Use of the new highway El Coco-San Ramon is considered in calculation of distance.

Table 18. 1 Assumed Construction Work

Kinds of Work	Punta Morales	El Estero	Punta-renas	North Caldera	South Caldera	Tivives	Herradura
Breakwater	×	×	O	O	O	O	O
Dredging	×	O	×	×	×	O	×
Foundation Improvement	O	O	×	×	×	?	×

O : the work is necessary

× : the work is not necessary

Table 18.2 Evaluation of Possible Project Sites

Kinds of Work	Punta Moralés	El Estero	Punta-renas	North Caldera	South Caldera	Tivives	Herradura
Transport Accessibility	C	B	B	A	A	C	C
- Accessibility to Meseta Central	(C)	(B)	(B)	(A)	(A)	(C)	(C)
- Accessibility to Highway	(B)	(C)	(C)	(B)	(B)	(C)	(C)
- Accessibility to Railway	(C)	(A)	(A)	(A)	(B)	(C)	(C)
Availability as a Regional Physical Distribution Base.	C	C	C	A	A	C	C
Conformity to Port City	C	C	C	A	A	C	C
- Relationship between Existing City and Site	(C)	(B)	(C)	(B)	(B)	(C)	(C)
- New Town Construction	(C)	(C)	(C)	(A)	(A)	(C)	(C)
Avoiding the Conflict with Other Activities	A	C	C	B	B	B	A
Economy of Construction Cost	B	C	C	C	A	C	B
Workability	B	A	B	B	A	C	C
- Sea Work	(B)	(A)	(C)	(C)	(A)	(C)	(B)
- Work Base	(C)	(A)	(A)	(A)	(B)	(C)	(C)
- Preparatory Road for Work	(B)	(A)	(A)	(A)	(A)	(B)	(C)
Influence upon Coast	A	C	B	B	B	B	A
Maintenance of Channel	A	C	A	A	A	A	A

Kinds of Work		Punta Morales	El Estero	Punta-renas	North Caldera	South Caldera	Tivives	Herradura
Construction Period		B	C	B	B	A	C	C
Supply of Labor Force, Water, Energy, etc.		C	A	A	A	A	C	C
Workability in Port		B	A	B	B	A	B	A
- Workable Days		(B)	(A)	(B)	(B)	(A)	(B)	(B)
- Safety of Handling		(B)	(A)	(B)	(B)	(A)	(B)	(B)
- Marshalling of Vessels		(B)*	(B)*	(B)*	(A)	(A)	(A)	(A)
- Safety of Vessels and Fenders		(A)	(A)	(B)	(B)	(A)	(B)	(A)
Capacity for Future Development		C	B	C	A	A	B	C
Total	A	3	3	2	6	10	1	4
	B	4	2	5	5	2	4	1
	C	5	7	5	1		7	7

Note: * By tidal current

Chapter V Planning of New Port

19. General

As a results of analysis and study made in the preceding chapter, South Caldera has been found to be the most preferable site for constructing new port, so we made an optimum plan of port construction at this site. The ground plan is shown in Fig. S-1, on which the new port is indicated in including one berth of quay for 15,000 D/W vessel, two berths of quay for 5,000 D/W vessel and facilities needed in relation to them which are the objectives of the present survey and foreseen to become necessary by 1977 in Chapter 6.

The plan of the new port has advantages as shown below, compared with other alternations expected in this site.

(1) Among other sites in the Gulf of Caldera, the selected site is affected least by waves from the open sea and the effect of wave on the ships mooring at quay can be eliminated by providing only a small scale of breakwater.

(2) By levelling the bluff of Tertiary system at the back of expected site, at ones for breakwater and revetment and earth for reclamation can be aquired easily, at low cost and in great quantities immediately from the commencement of works.

(3) As the quay is approximately in parallel with the present shoreline and the design water deapth is almost the same as the present one, its construction can be conducted most economically, and a sufficient land necessary for port functioning can be secured between the quay and the bluff of Tertiary system forming the present shcreline.

(4) As the end of seasonal road extends near to land to be reclaimed in the new port, construction or improvement of harbor road or road for use of construction work is easy, and railway leading from Salinas can be constructed easily along the road. Thus, the construction materials can be easily carried to the site to meet the requirement for starting the initial stage.

(5) Few conflicts are expected with the resort facilities dotting on both banks of Estero Mata de Limon or Esso's petroleum facilities at Caldera for the time being, and there is almost no other problem needing any coordination.

(6) In future, on condition that only social requirement is met, it will be very easy both physically and economically to extend this new port toward its both sides. Further if the utilization of whole region within the bay is taken into consideration together with the extension toward Tivives it will be possible for the new port to achieve the growth as far as conceivable.

For reference, extension plans conceivable subsequent to the completion of proposed new port are shown in Fig. S-1 as divided in two stages respectively in dash-dot line and dashed line. These tentative plans indicate that, even with plans of this size, it is possible to provide on the south side a petroleum port with petroleum depot of considerably large scale separated from the new port for the safety sake, and to construct on the north side a great port with more than 20 berths of quay for large-sized vessels. Of course it needs a considerable time until such great port is required; meanwhile various innovations, technically and operationally, will be effected on the port and natural conditions of this port investigated further in detail to collect sufficient data, after which new plans should be elaborated according to the results of examination in arrangement of breakwater and quay, sizes of ancillary facilities and area of reclaimed land.

The plan of new port located at South Caldera is considered best and most optimal, and a plan of port to be sited at Punta Morales has been also prepared as the second best policy by way of precaution against the impracticability of the first plan due to unexpected obstruction. The ground plan is shown in Fig. S-2, and it is unavoidable that this latter plan is inferior in many respects compared with that of South Caldera. What is specially noteworthy about this plan is as follows.

(1) New port consolidated by end of 1976 indicated in full line on the plan, may be equipped with facilities of the same size as those of South Caldera. However, any extension of this port in future is very difficult and, though it depends on further survey, such extension will be limited to the extent shown in dash-dot line on Fig. S-2 even if it is practicable. For example, it is conceivable to proceed reclamation toward Cortezas Islands (Islas Cortezas) and to construct quay to link these islands with Punta Morales, if this is done however, the tidal current will change its course greatly and some shoaling will take place at the sea-bottom around here where a good water depth is maintained at present. When the port is extended toward south a considerable quantity of dredging will be necessary to provide fairway and anchorage and yet it seems difficult to maintain the water depth.

(2) The new port is scarcely affected by swells from open sea but entirely unprotected from wind waves. Construction of breakwater against wind waves will be out of the economic question. Considerable tidal current exist around the site and though the plan has been prepared so as to minimize the effect on such current it is not perfect.

20. Arrangement of Quay and Breakwater

Quay of 440 meters (one berth of 10. 0 m of water depth and two berths of 7. 5 m of water depth) has been planned to situate at a distance of about 300 meters off the present shoreline. Reclamation at the back of faceline of the quay has been planned as that a sufficient area of land can be secured to provide such facilities as shed, warehouse, open freight storage and office etc. The west side of this reclaimed land has been planned to protected by seawall from the end of which breakwater of 200 meters in length starts toward the northwest. The coefficients of refraction and diffraction of swells has been calculated for 3 points on the faceline of the quay shown in Fig. 20. 1. The results of calculation are shown in Table 20. 1 and it is judged that sufficient calmness will be ensured at the front of quay. Local wind waves from the west and the northwest will seldom exceed 0. 5 meters. There is no fear of rapid shoaling of sand in the harbor area. It is safe and easy for ship entering into the port from the northwest to berth in the entering position.

21. Arrangement Plan of Facilities

Figs. 21. 1 and 21. 2 show the arrangements plan of facilities at the new port in order to deal with physical distribution smoothly. For example, an apron of 20 meters wide is provided in parallel with the quay wall so that cargo unloaded from ship can be carried into a shed by forklift truck. Cargo assorted in a shed is transported directly to the hinterland by rail or truck, otherwise it is kept in a warehouse for a while. Of course a part of cargoes unloaded from ship will be stored in a open freight storage.

Handling of freight for loading is carried out in the reverse order that of for unloading described above. The necessary dimensions of various facilities are as calculated in chapter 2, article 6.

22 Rough Design

22.1 Stractures to be Designed

For two proposed sites of South Caldera and Punta Morales, rough designs have been made of principal port facilities including quay walls fof vessels of 15,000 D/W and 5,000 D/W, breakwater, sea wall and revetment.

For Punta Morales, as the quay is planned at a place of deep water depth in order to secure the needed area of reclaimed land, its design water depth is 12 meters for vessel of 15,000 D/W and 10 meters for vessel of 5,000 D/W.

22.2 Quay Wall

Design conditions are as follows.

Kind of Vessels	1 berth for vessel of 15,000 D/W	
	2 berths for vessel of 5,000 D/W	
Water depth		
a. South Caldera	For vessel of 15,000 D/W	10.0 m
	" 5,000 D/W	7.5 m
b. Punta Morales	" 15,000 D/W	12.0 m
	" 5,000 D/W	10.0 m
Crown height (above the L.W.L.)		5.0 m
Length of berth	For vessel of 15,000 D/W	180 m/berth
	" 5,000 D/W	130 m/berth
Width of apron		20 m
Berthing velocity (Tugboat is not used)		15 cm/sec
Surcharge	Normal	3.0 t/m^2
	Seismic	1.5 t/m^2
Design seismic coefficient	Horizontal	0.1
	Vertical	0
Soil condition below sea-bottom surface		
	Angle of internal friction	30°
	Angle of wall friction	15°
	Submerged unit weight	1.0 t/m^3

Note: As the ground of South Caldera is presumed to be loose sand ground the above values have been adopted. At Punta Morales soft silt layer is lying on bed rock, and if a retaining wall is constructed with its back reclaimed there is a fear of base failure to occur. On the assumption that this silt layer shall be replaced with sand the above values have been adopted.

Soil condition of back-fill		
Angle of internal friction		30°
Angle of wall friction		15°
Unit weight		
above residual water level		1.8 t/m^3
below residual water level		1.0 t/m^3
Tidal level	H. W. L.	+3.0 m
	L. W. L.	±0 m
Residual water level		+2.0 m
Allowable stress of material		
Steel sheet pile		
SY30	- normal	1,800 kg/cm^2
	- seismic	2,700 kg/cm^2
SY40	- normal	2,400 kg/cm^2
	- seismic	3,600 kg/cm^2
Steel pipe pile		
STK41	- normal	1,300 kg/cm^2
	- seismic	1,950 kg/cm^2
Tie rod - of yield point of 45kg/mm^2 and tensile strength of 70kg/mm^2		
	- normal	1,800 kg/cm^2
	- seismic	2,700 kg/cm^2
Waling		
SS41	- normal	1,400 kg/cm^2
	- seismic	2,100 kg/cm^2

As regards the form of structure, anchored steel sheet pile wall has been adopted taking into consideration the factors such as fewer kinds of works involved, capability of expedited execution of works, no special working facilities needed and relatively low construction costs. In the similar way, steel pipe pile has been adopted for anchoring of sheet pile wall, as the kind of work is the same as that of sheet pile driving and the same construction equipment can be used. It is desirable that, in preparing detailed designs, comparative designings are made on various structural forms to achieve more economy.

Standard sections are shown in Figs. 22.1 - 22.4.

In this rough planning, any examinations on stability of foundation ground against base failure and on consolidation settlement of reclaimed land have not conducted due to the unavailability of shear strength parameter and various constants on consolidation of original ground. Therefore, in preparing the detailed designs it is necessary to carry out a detailed soil survey to make the above examinations based on the results of such survey. For Punta Morales in particular, the surface of bed rock beneath the silt layer at sea-bottom is expected to be of complex shape and in this connection further detailed survey is needed too.

22.3 Breakwater and Sea Wall

These structures are required only at South Caldera, of which design conditions are as follows.

Water height	$H_{1/3}$ =	3.0 m
Tidal level	H.W.L.	+3.0 m
	L.W.L.	±0 m
Rubble-mound		
Specific gravity		2.65
Submerged unit weight		1.0 t/m^3

Breakwater and sea wall are of inclined surface dyke with riprap, which does not need any special working facilities. The standard section of breakwater is shown in Fig. 22.5 and that of seawall in Fig. 22.6.

22.4 Revetment

Design conditions are as follows.

Water height $H_{1/3}$ = 1.2 m

Other conditions are the same as those of sea wall.

Standard sections of revetment are shown in Figs. 22.7 and 22.8.

For revetment at Punta Morales, the soft silt layer shall be replaced with sand by the same reason as that described relating to quay. As regard revetment, it is also necessary to examine the stability of foundation ground against base failure on the basis of more detailed soil survey.

23. Stage of Construction Work

The stages of construction works in South Caldera and Punta Morales are shown in Fig. 23.1 and 23.2 respectively. The present plan has been elaborated so that the berth for vessel of 15,000 D/W can be opened for service as early as possible.

24. Rough Estimates of Construction Costs

Rough estimates of construction costs in Caldera and Punta Morales areas are shown in Tables 24.1 and 24.2 respectively.

These costs estimated are more expensive than those of corresponding works in Japan due to higher unit cost of construction works in Costa Rica and thus it is necessary to endeavor to rationalize the execution of works and reduce unit cost in order to implement the project economically as far as possible.

The unit costs used for the present estimation are those as of November, 1972 when our survey was conducted and furnished by the Costa Rican engineers. However, in the case of unit costs of pile and sheet pile drivings and of reclamation with material dredged those in Japan and Mexico have been used because of presuming the introduction of construction equipment from abroad.

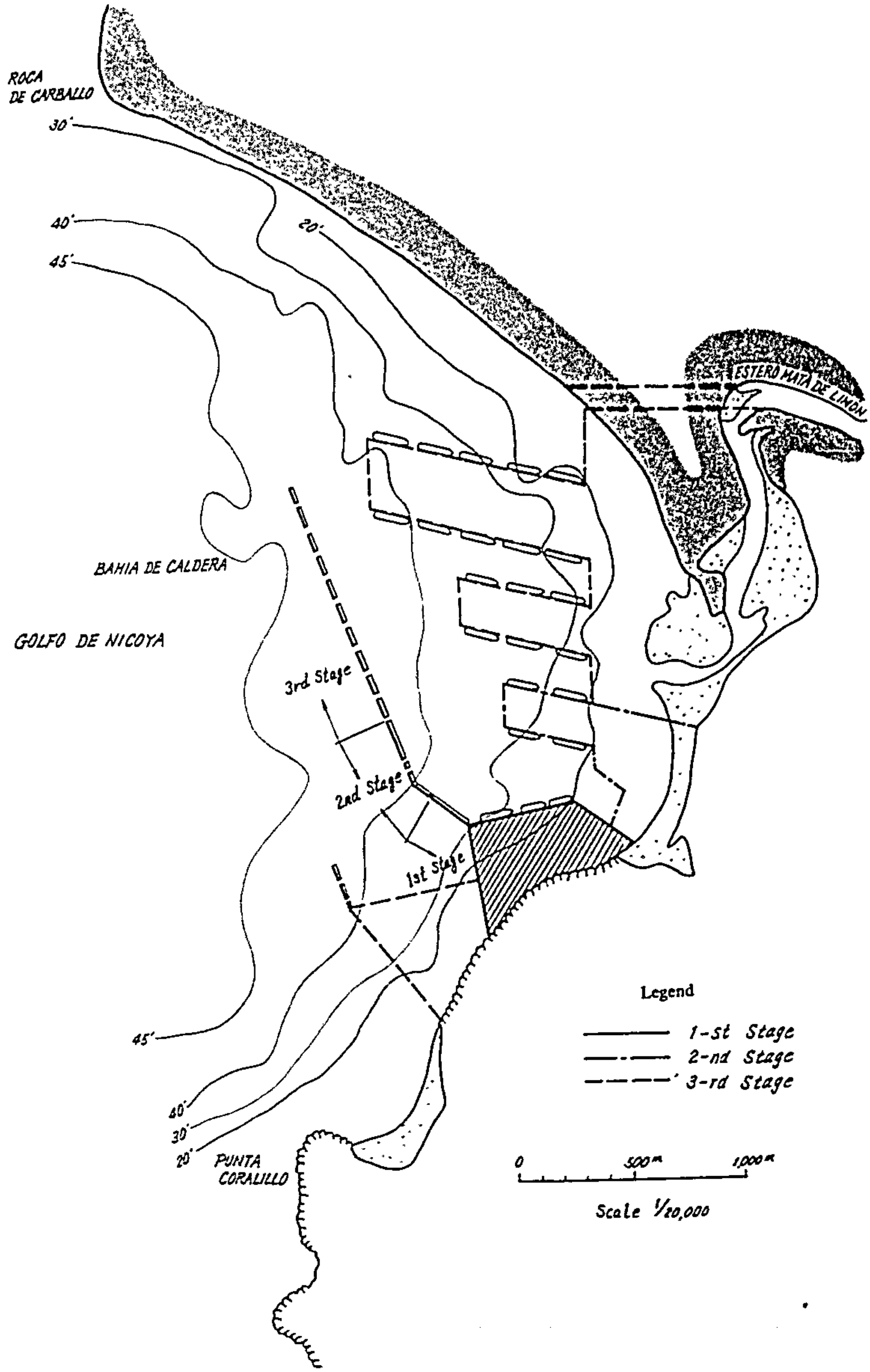
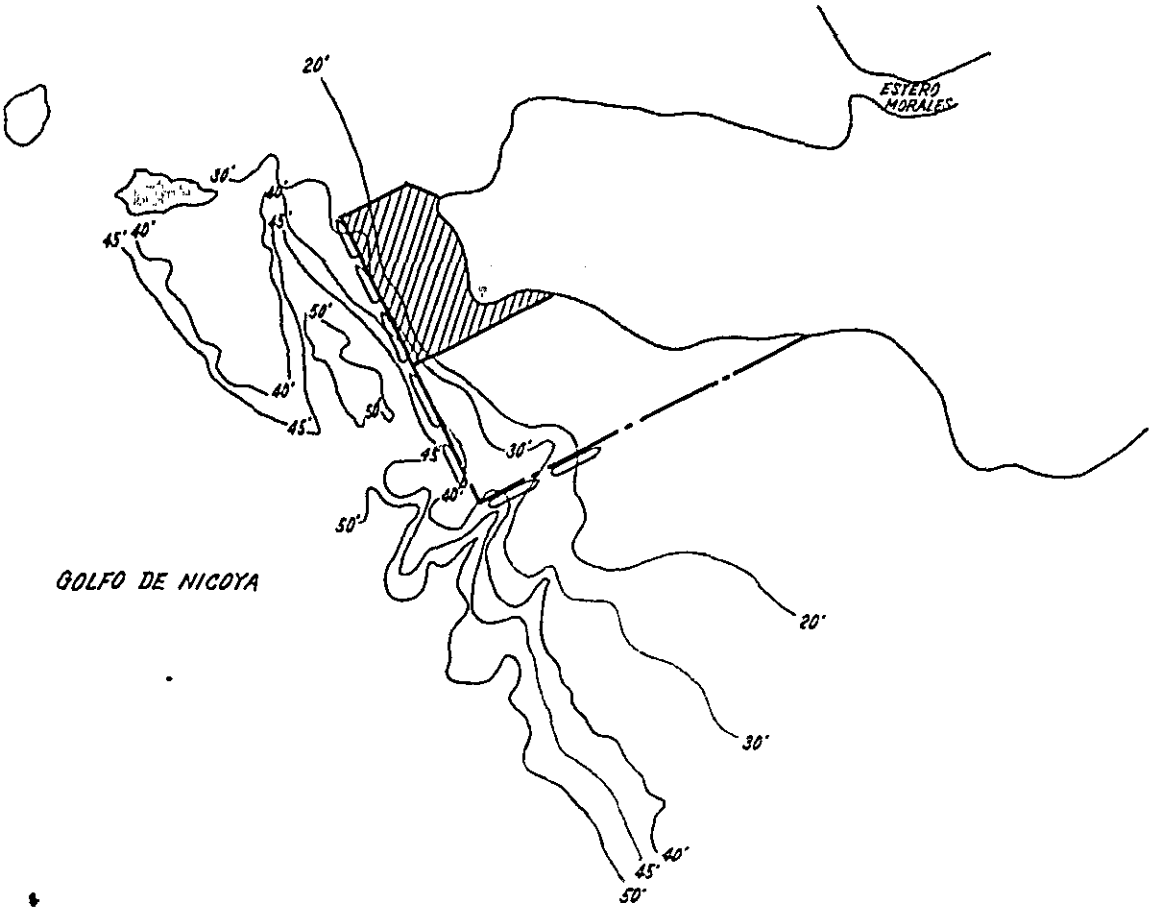


Fig. S-1 Ground Plan for South Caldera



Legend

Fig. S-2 Ground Plan for Punta Morales

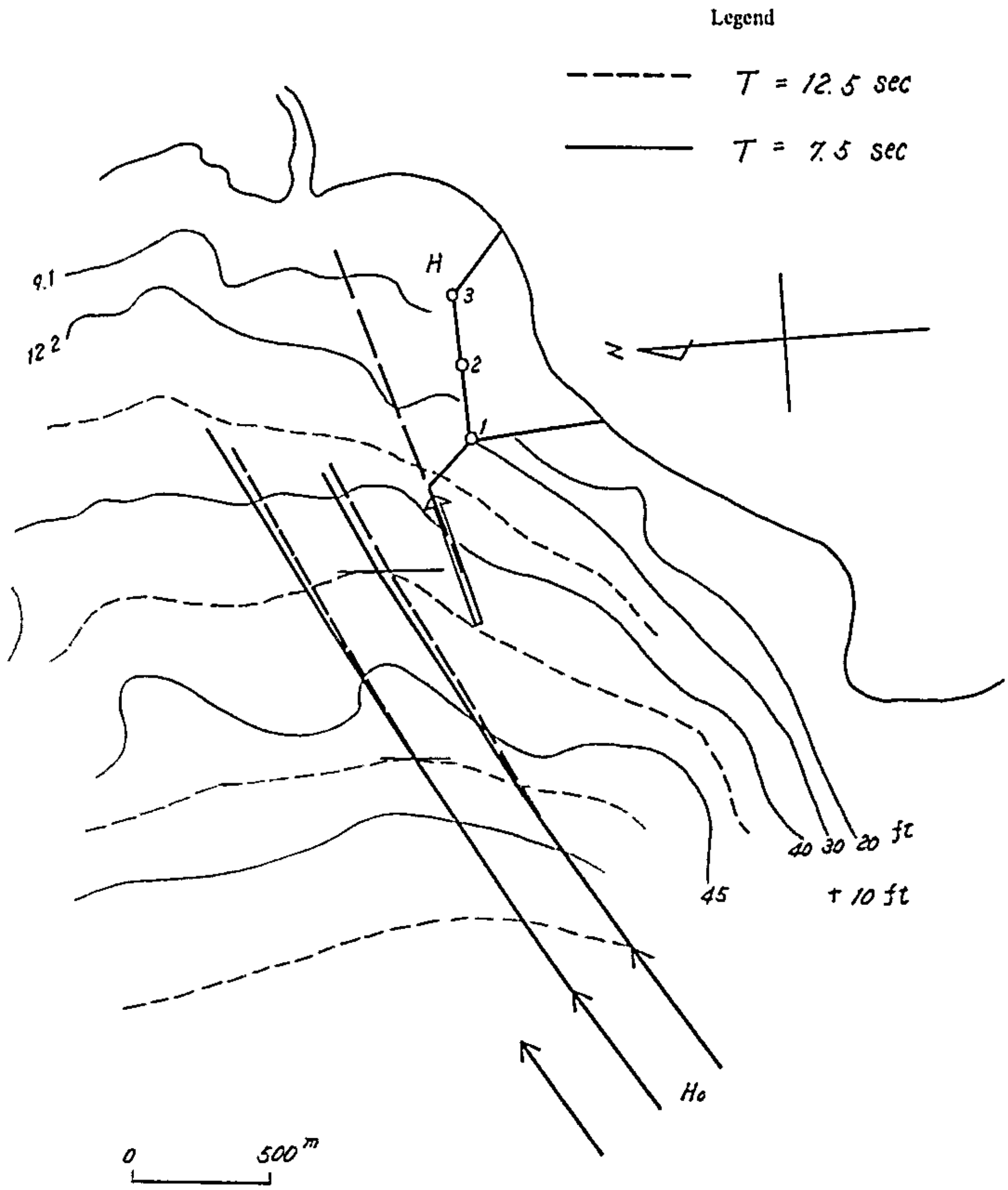
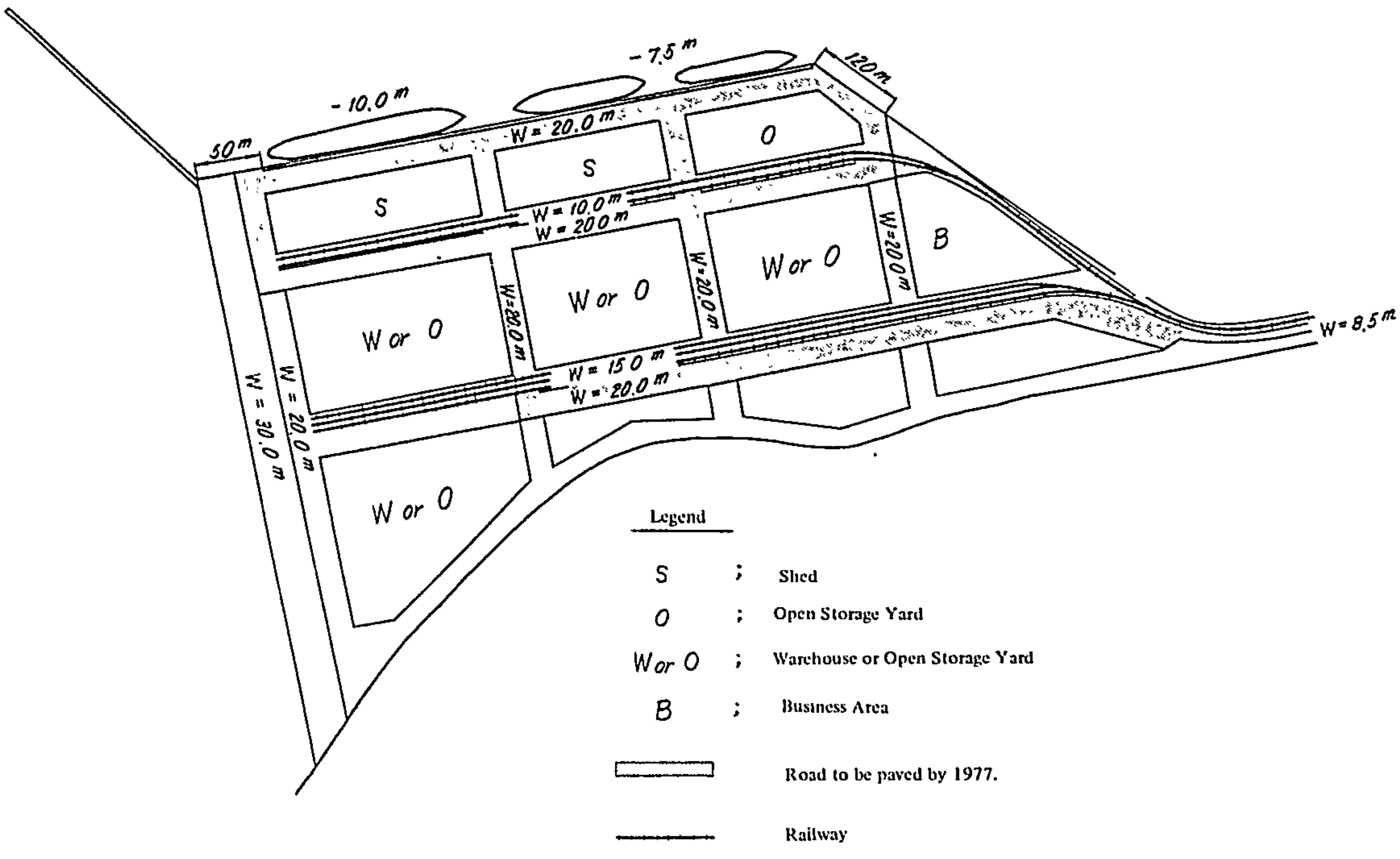
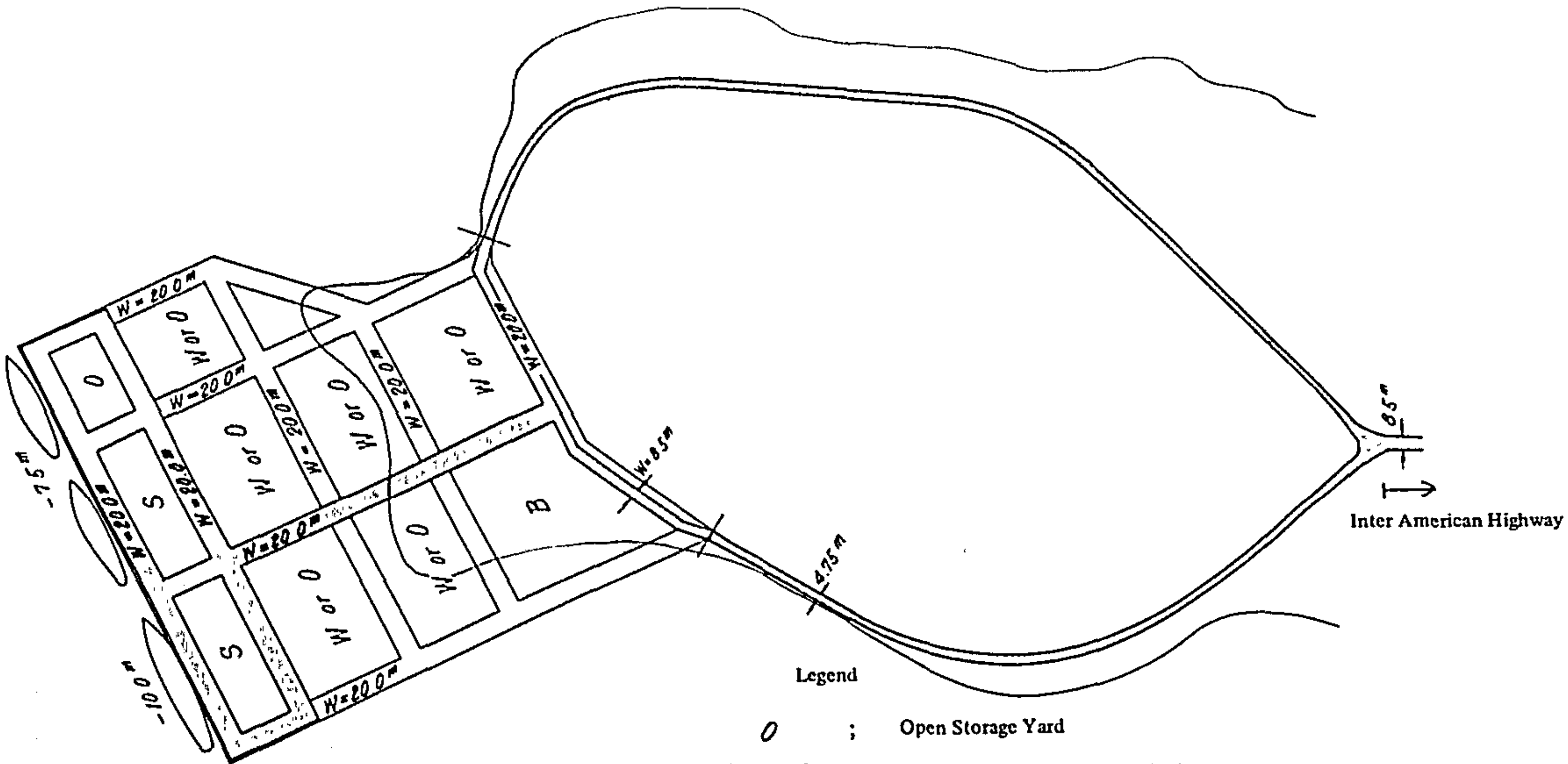


Fig. 20.1 Transformation of Waves in the Bay of Caldera



Note: Necessary port transportation facilities - Railway of 4 km to Salinas.
- Road of 16 km to Esparta (including 2 bridges en route)

Fig. 21.1 Facility Planning (South Caldera)



Legend

O	;	Open Storage Yard
W or O	;	Warehouse or Open Storage Yard
S	;	Shed
B	;	Business Area
(road symbol)	;	Road to be paved by 1977

Note: Neccessary port transportation facilities -Road of 13 km to connect to the Inter-American Highway, including 2 bridges en route.

Fig. 21.2 Facility Planning (Punta Morales)

unit: m

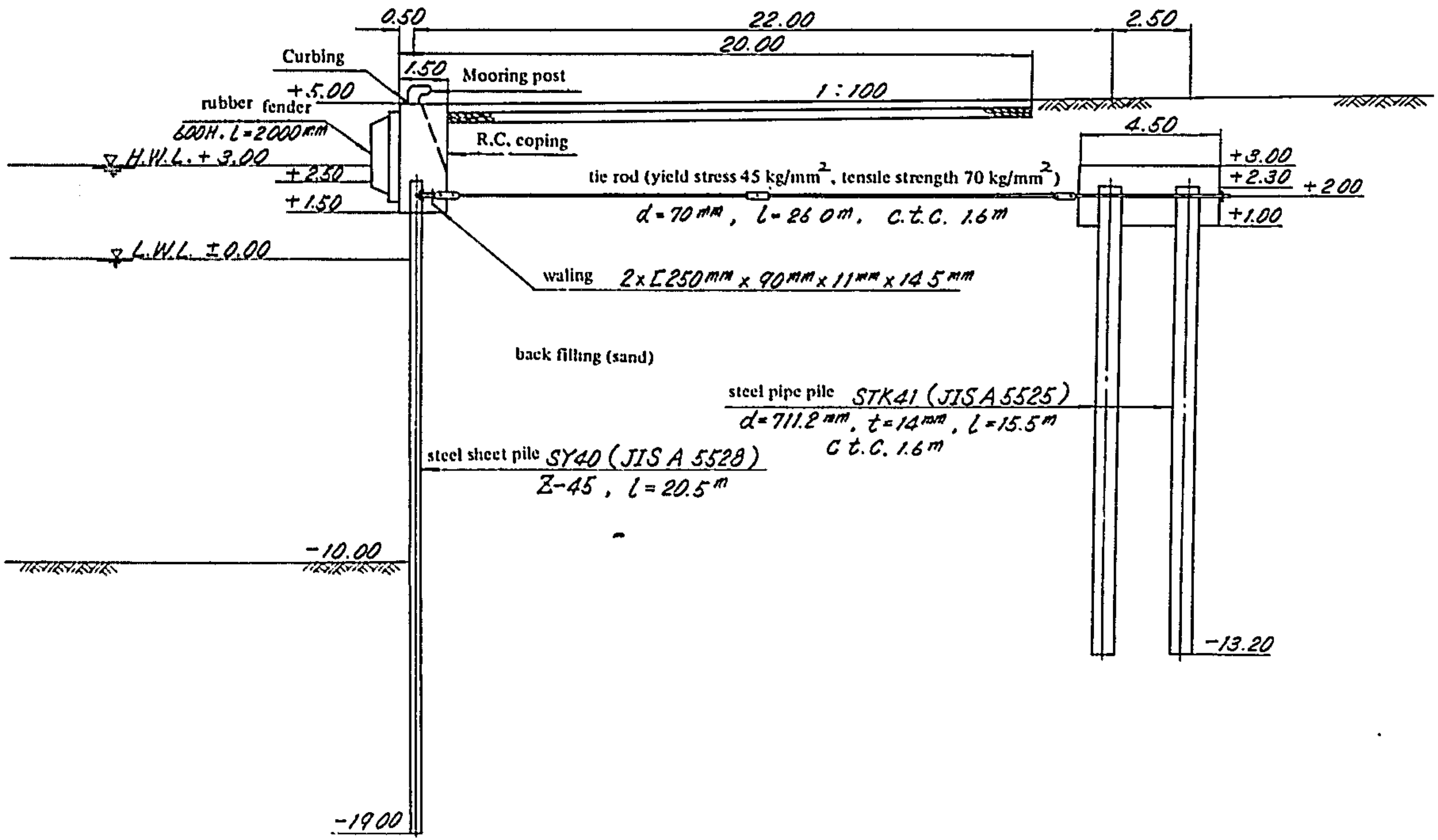


Fig. 22.1 Standard Cross Section of-10m Quay Wall (South Caldera)

unit: m

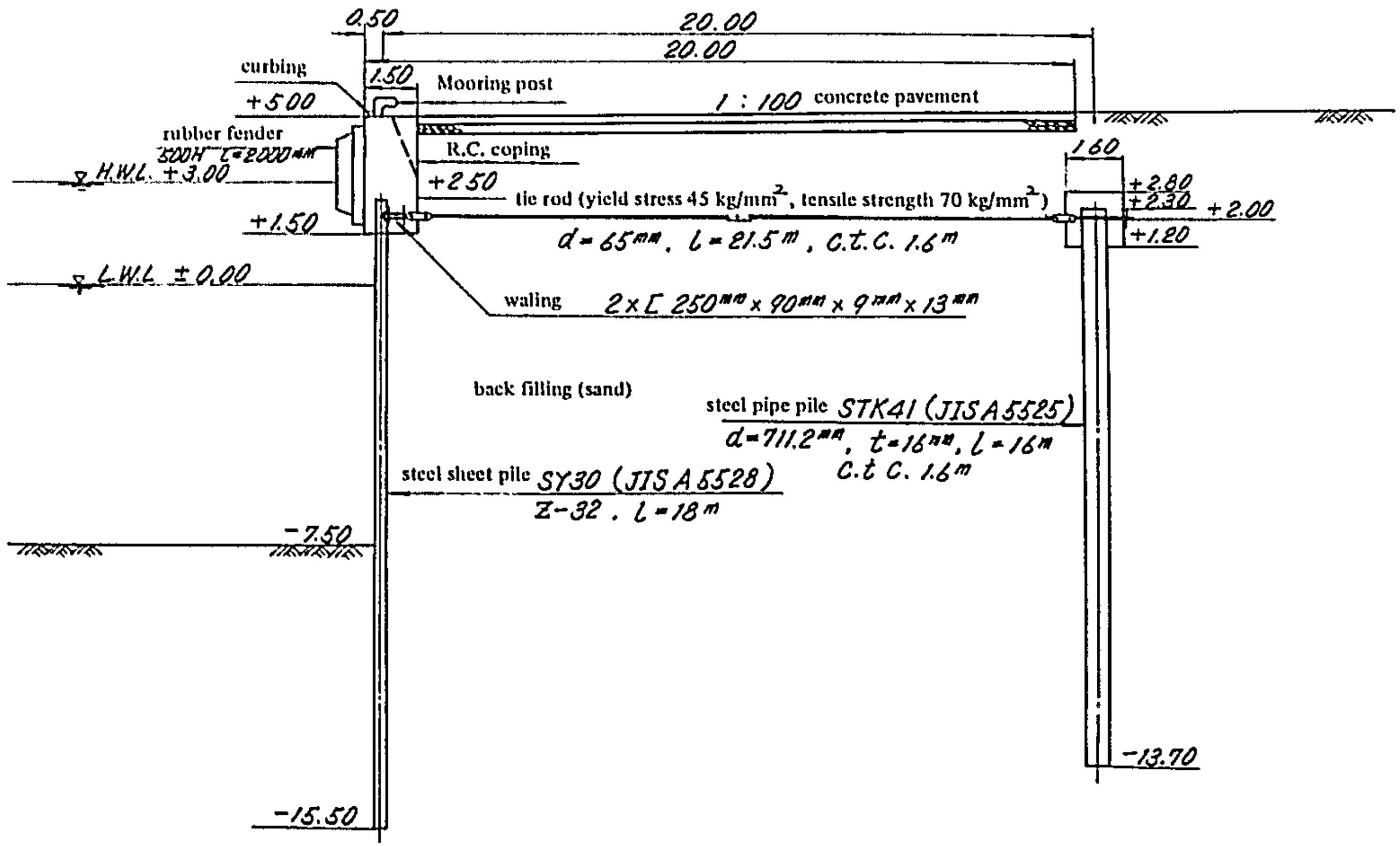


Fig. 22.2 Standard Cross Section of -7.5m Quay Wall (South Caldera)

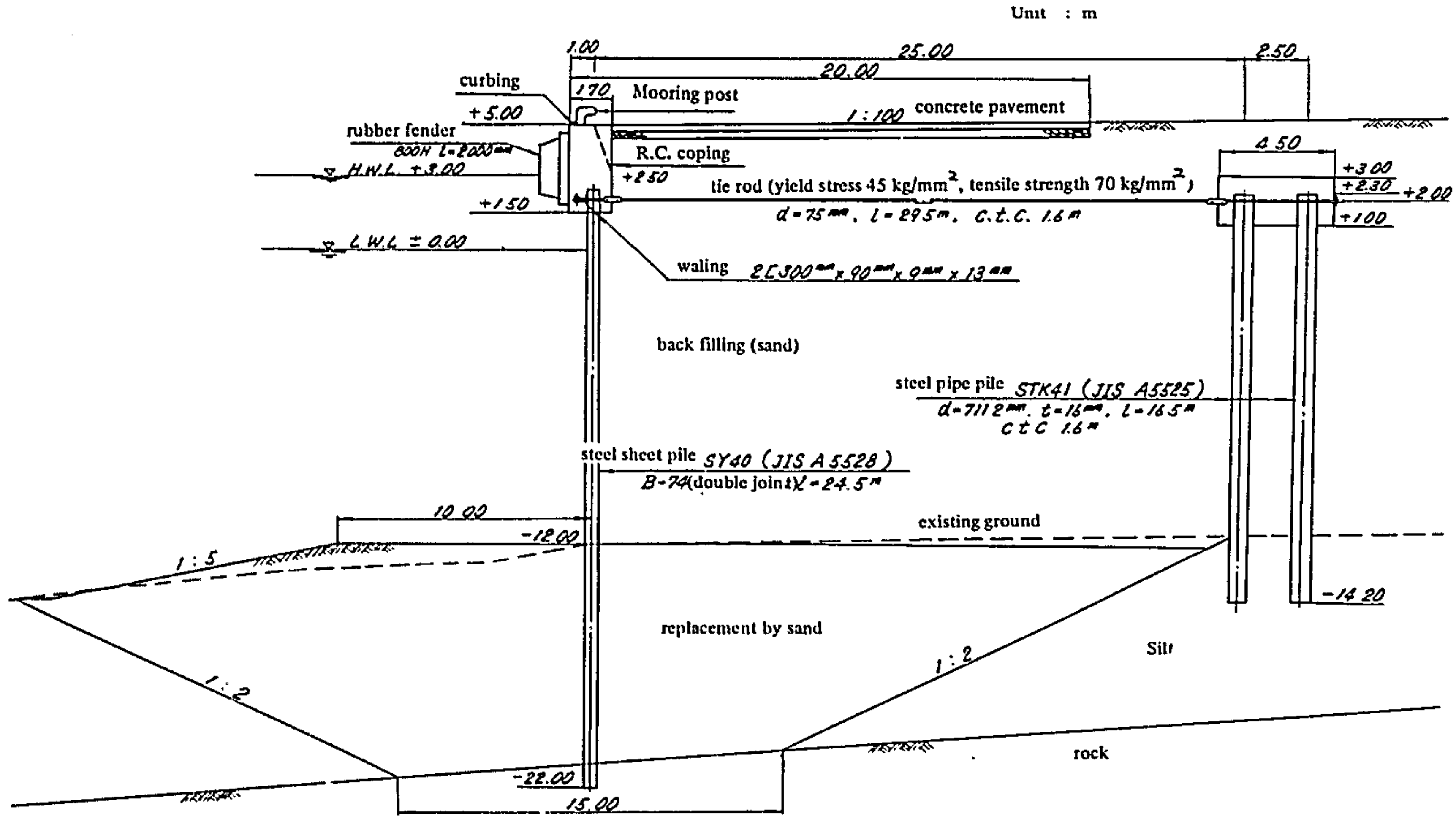


Fig. 22.3 Standard Cross Section of -12m Quay Wall (Punta Morales)

Unit : m

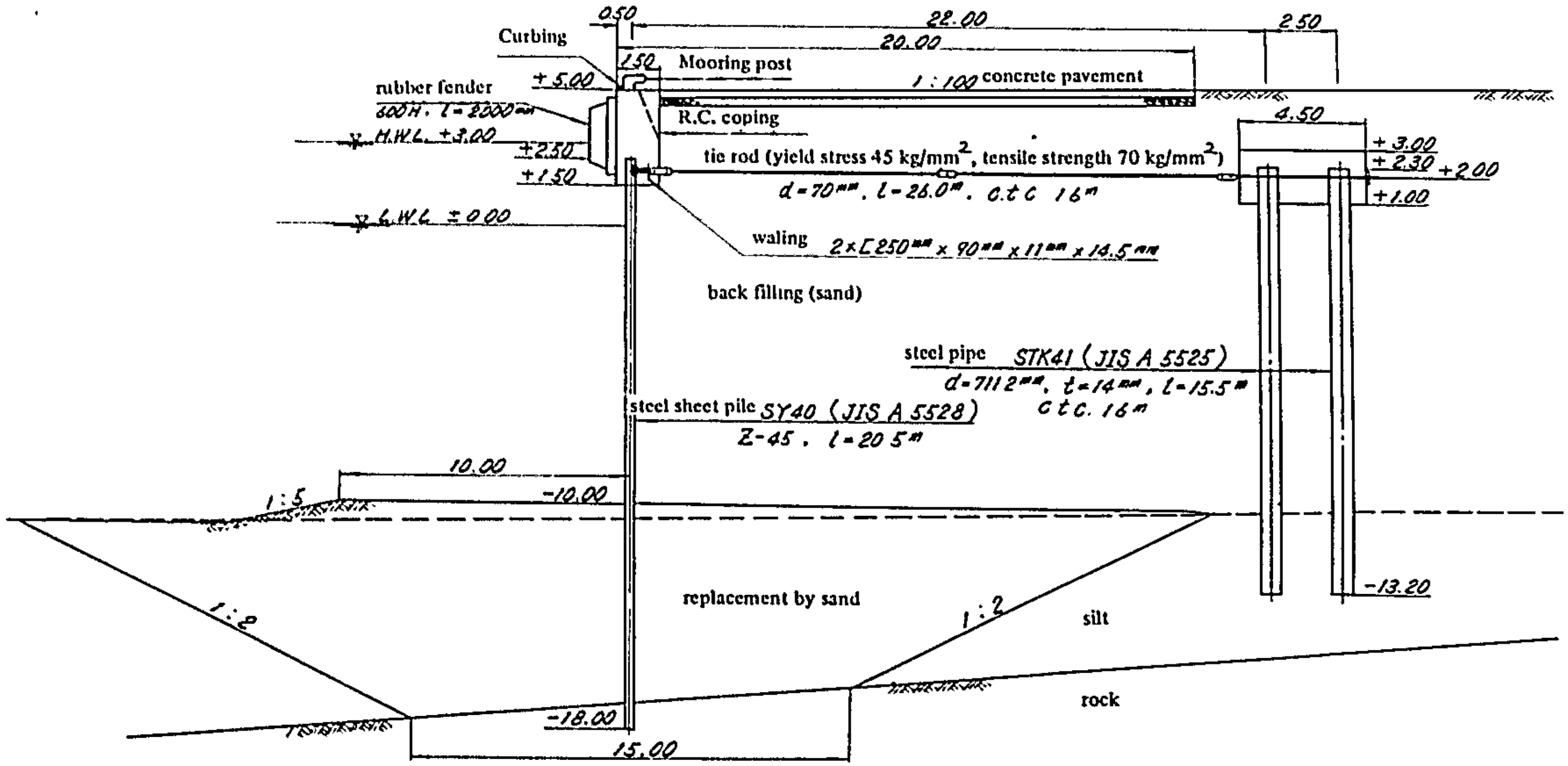


Fig. 22.4 Standard Cross Section of-10m Quay Wall (Punta Morales)

Unit: m

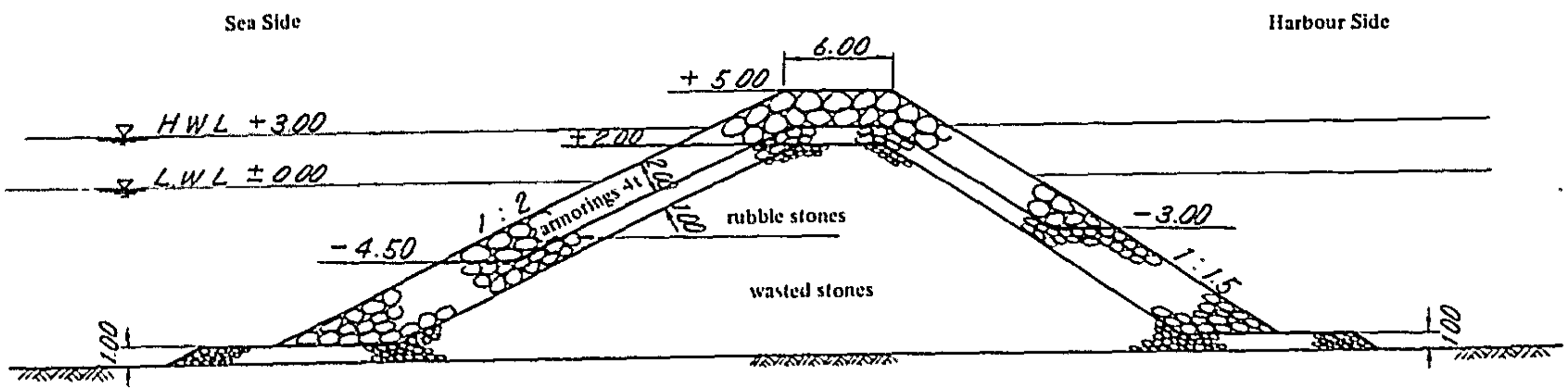


Fig. 22.5 Standard Cross Section of Breakwater (South Caldera)

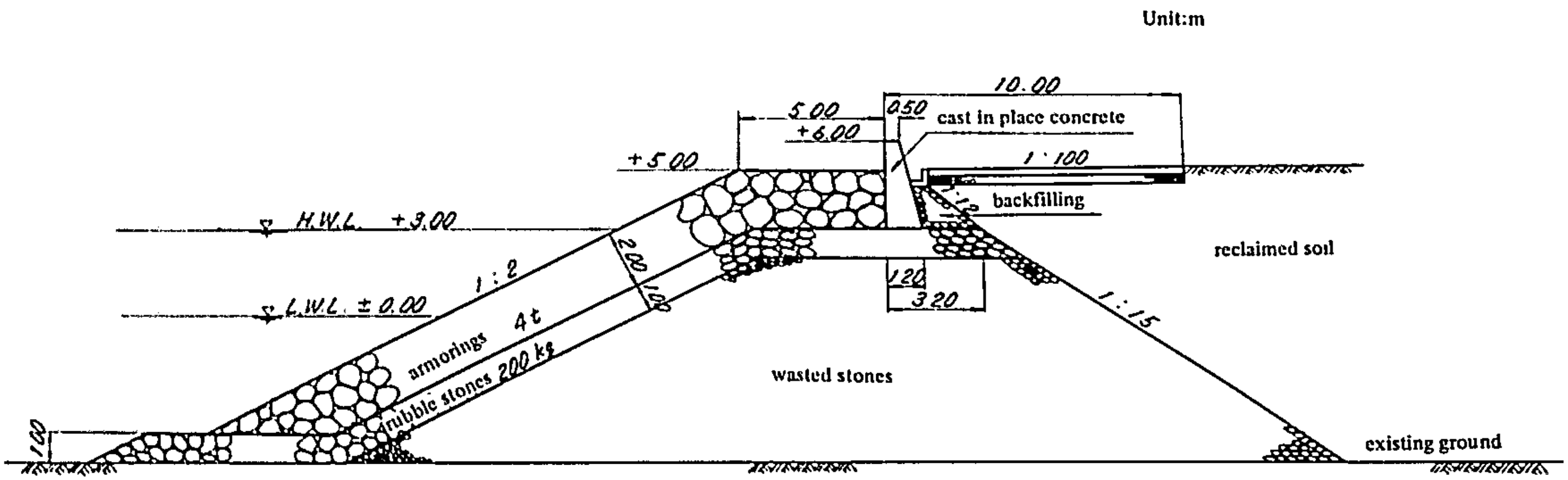


Fig. 22.6 Standard Cross Section of Seal Wall (South Caldera)

Unit : m

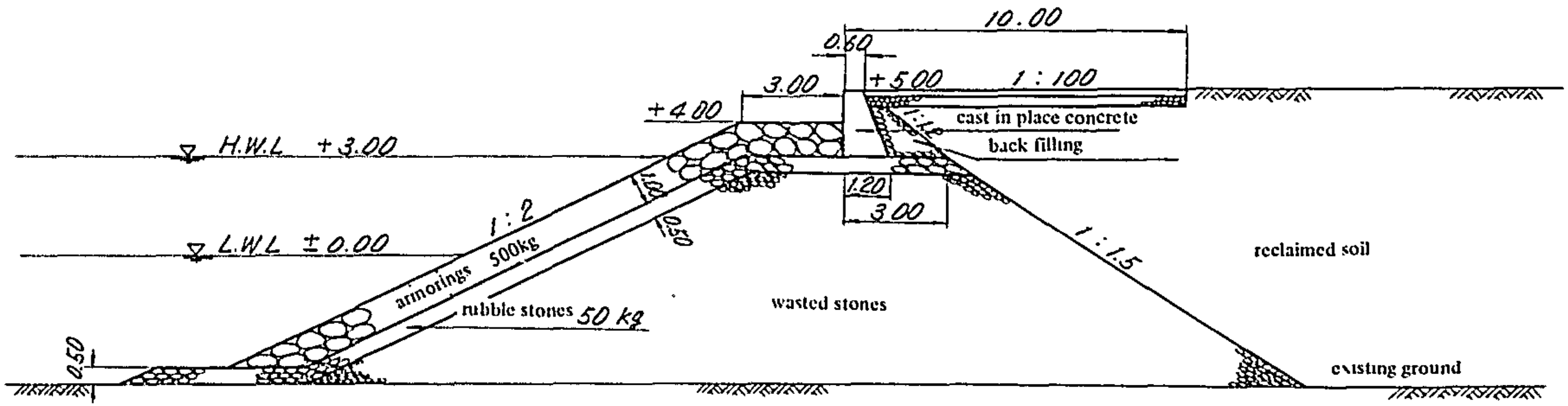


Fig. 22.7 Standard Cross Section of Revetment (South Caldera)

Unit : m

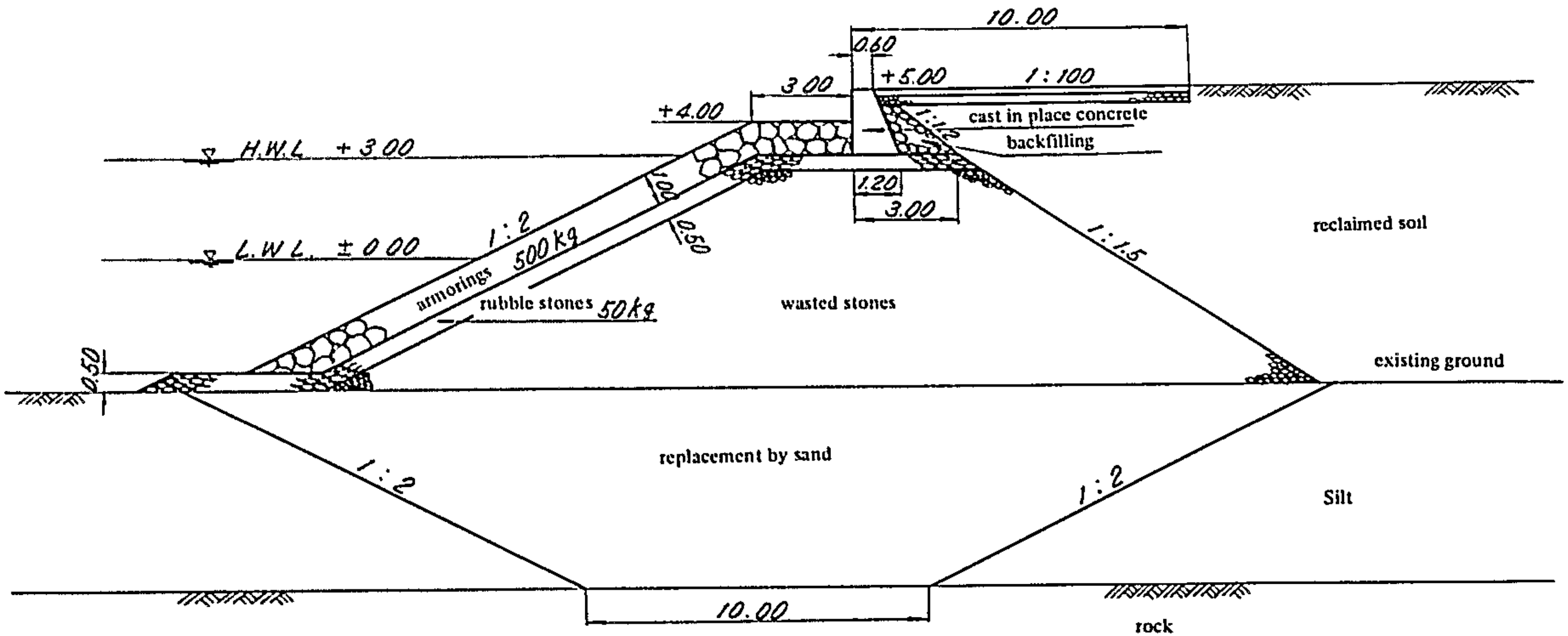


Fig. 22.8 Standard Cross Section of Revetment (South Caldera)

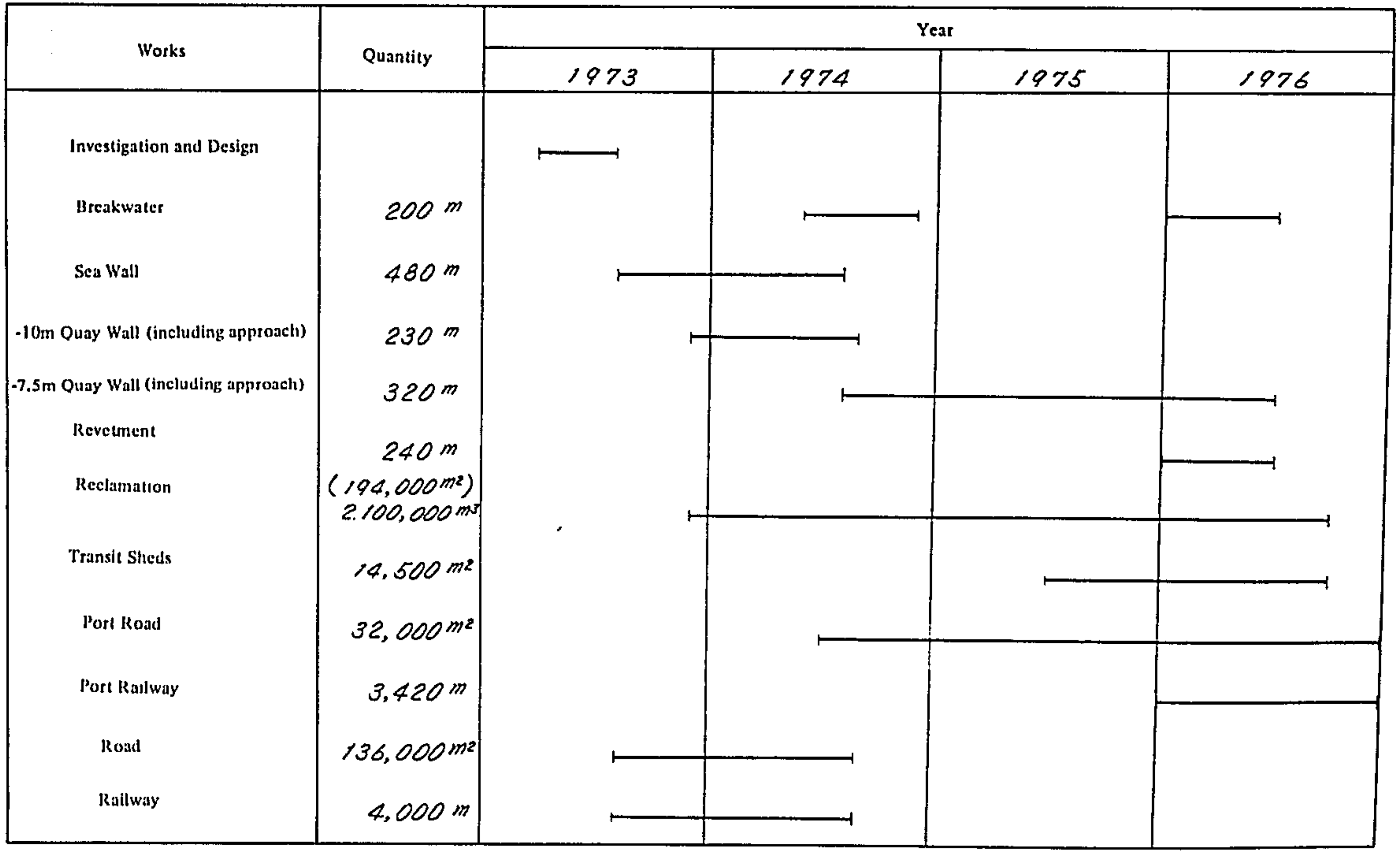


Fig. 23.1 Construction Schedule (South Caldera)

Works	Quantity	Year			
		1973	1974	1975	1976
Investigation and Design					
-12 m Quay Wall (including approach)	270 m				
-10m Quay Wall (including approach)	350 m				
Revetment	650 m				
Reclamation	(12,000 m^2) 1,370,000 m^2				
Transit Sheds	14,000 m^2				
Port Road	23,000 m^2				
Road	93,500 m^2				
Bridge	1 unit				

Fig. 23.2 Construction Schedule (Punta Morales)

Table-20.1 Ratios of Wave Height in and out of the New Port

Location	Period of Incident of Waves	
	7.5 sec	12.5 sec
①	0.2	<0.3
②	<0.2	<0.3
③	<0.2	<0.3

Table 24.1 Preliminary Estimate of Construction Costs
(South Caldera)

Item	Quantity	Unit Prices (colones) Foreign	Unit Prices (colones) Domestic	Estimated Costs (1,000 colones) Foreign	Estimated Costs (1,000 colones) Domestic	Estimated Costs (1,000 colones) Total
Breakwater	200 m		47,000		9,400	9,400
Sea Wall	480 m		40,000		19,200	19,200
-10 m Quay Wall	180 m	40,500	25,000	7,290	4,500	11,790
" Aproach	50 m	40,500	25,000	2,025	1,250	3,275
-7.5 m Quay wall	260 m	27,500	20,000	7,150	5,200	12,350
" Aproach	60 m	27,500	20,000	1,650	1,200	2,850
Revetment	240 m		11,400		2,736	2,736
Transit Sheds	14,500 m^2	460	340	6,670	4,930	11,600
Road (in port area)	32,000 m^2		60		1,920	1,920
Railway (in port area)	1,420 m	220	230	312	327	639
Reclamation	(194,000 m^2) 2,100,000 m^3	3	6.5	6,300	13,650	19,950
Road	136,000 m^2		100		13,600	13,600
Railway	4,000 m	220	280	880	1,120	2,000
Subtotal				32,277	79,033	111,310
Contingencies				4,800	11,800	16,600
Engineering & Supervision				3,423	7,667	11,090
Total				40,500	98,500	139,000

Table 24.2 Preliminary Estimate of Construction Costs (Punta Morales)

Item	Quantity	Unit Prices (colones)		Estimated Costs (1,000 colones)		
		Foreign	Domestic	Foreign	Domestic	Total
-12 m Quay wall	180 m	58,500	49,000	10,530	8,820	19,350
" Aproach	90 m	58,500	49,000	5,265	4,410	9,675
-10 m Quay wall	260 m	42,500	39,000	11,050	10,140	21,190
Aproach	90 m	42,500	39,000	3,825	3,510	7,335
Revetment	650 m	3,100	22,000	2,015	14,300	16,315
Transit Shed	14,000 m2	460	340	6,440	4,760	11,200
Road (in port area)	23,000 m2		60		1,380	1,380
Reclamation	(120,000 m2) 1,370,000 m3		25		34,250	34,250
Road	93,500 m2		100		9,350	9,350
Bridges	1 unit	1,000,000	500,000	1,000	500	1,500
Subtotal				40,125	91,640	131,765
Contingencies				6,300	13,700	20,000
Engineering & Supervision				4,075	9,160	13,235
Total				50,500	114,500	165,000

Chapter VI Cost-Benefit Analysis

25. Significance of Construction of New Port

The proposed new port has been planned as a modern wharf provided with calm water, mooring facilities adapted to demand and spacious land premise. The port should become one which merchant ship will most prefer to use among those on the Pacific coast. A port which is safe and has no trouble of detention is the most desired one in this region by shipping interests.

Release from rain, increased efficiency of port operations and eliminated retention of cargoes and ships, all these will result in reduction of physical distribution cost contributing greatly to reduce import costs of consumer goods, improve the nation's welfare and serve to promote foreign trade by reducing the physical distribution cost of export goods.

In the same way as all the adequately planned infrastructures, the new port will remain as a base to support economic development over a long period of time in the unforeseeable future.

With the increase of ships calling the port and the activation of harbor operations the employment as well as demands for materials and services will increase, and this will have multiplied effects on the national economy contributing to expand its framework.

The new port located nearest to Meseta Central will play the role as physical distributing depot in the Gulf of Nicoya area. This will results in that the new port becomes a nucleuse of reginal development and promote the exploitation of this area.

The construction works themselves will excite available demands accompanied by them.

As the location of new port is separated from the urban area of Puntareas, it will not constitute a factor to deteriorate the existing functions of that city. In addition, as the supporting city of economic development of this country to be achieved by the exploitation of east coast of Gulf of Nicoya, the new city to be established at the back of new port will march on to prosperity hand in hand with Puntarenas sharing city functions with each other.

26. Quantitative Measurement of Effects of New Port Construction

26.1 Cost-Benefit Analysis

Cost-benefit analysis is used to measure quantitatively the effects of new port construction.

The effects described in article 25 is divided into direct and indirect effects. In the measurement of indirect benefits it is needed as well to get a variety of high level data including input-output table etc., as to develop a technique capable to express pluralistic effects. Several techniques may be used for analysis of direct benefit,and here, taking into due consideration the data obtained, the method to calculate the internal rate of return is adopted, in which cost and effect are worked out by year over n years. This method which has a merit to be able to ignore the difference from method of depreciation or rate of interest is now used in general to judge the feasibility of a project.

It is presumed n = 20 because this value has been judged reasonable as project life for this country in which economic development is remarkable.

For the determination of benefits, being calculated those to be produced if the new port is completed as planned and those to have been expected without it, the balance of the former deducted by the latter is presumed as the benefits generated by the construction of new port. The details of benefits are described in article 27.

26.2 Cargo Volumes handled at New Facilities

In order to determine the cargo volume handled at new facilities, it is presumed that total capacity is 500,000 tons including 200,000 tons for berth of 10 m water depth and 150,000 tons for that of 7.5 m and that cargoes in excess of this capacity is handled at other port facilities. Therefore, the cargo volumes by year during the period until such capacity are forecasted referring to demand for cargoes and supply of facilities. Demand for cargoes is calculated by year by trend with the cargo volume handled in 1977 (estimated in chapter 2) set as target value; then, demand for cargoes of each year is divided by the ratio of quantities of import and export in 1977 to calculate such quantities of the year concerned. On the side of facilities, one berth of 10 m water depth is completed in the middle of 1974 as mentioned later, in which year it becomes possible to handle a part of demand for cargoes at new facilities. After then, other berths are open for service so as to adequately adapt to demand for cargoes and it becomes possible to handle the whole of presumed demand for cargoes. Demand for cargoes will reach the capacity of facilities in 1979, so after then, cargo volume handled at new facilities is assumed at 500,000 tons. Moreover, cargo volumes handled by commodity are calculated from total volume in each year by dividing it proportionally to that by commodity in 1977. The results of calculations are shown in Table 26.1.

Originating points of export goods and demand points of import goods by commodity respectively assumed in relation to cargoes handled at new facilities are as follows:

For coffee, Meseta Central where its producing centers concentrate is presumed as originating point of cargo.

For sugar, its quantities of export by district are presumed as shown in Fig. 26.1. It is based on the facts that its export is mainly directed to the Pacific region, while its producing centers are on the Pacific coast and moreover a room for expansion of production in future is open in and around Guanacaste Province (Provincia de Guanacaste).

For beef cattle, quantities of export by district are assumed as shown in Fig. 26.2. It is based on the facts that its destinations of export are distributed also in the Pacific region with producing centers distributed in the country wider than sugar and the possibility of expansion in production seems greater on the Pacific coast.

For other goods, Meseta Central which is the accumulation center of them is assumed as originating and demand point since such center is supposed to have a close relation with the distribution of cities and population.

26.3 Port Facilities

As stated in article 23, one berth of 10 m water depth will be opened for service in 1974 and each berth of 7.5 m water depth in 1975 and 1976 respectively. It is assumed that related facilities on the back land are consolidated so as not to obstruct the use of berthing facilities.

27. Costs

Construction cost and maintenance and repair cost are used as costs for analysis. The construction cost described in article 24 is adopted for construction works performed by 1977. Subsequently road and railway are constructed in 1979 when the berths are completed to capacity. Maintenance and repair costs include those on fenders and cathodic protection system. Fenders shall be replaced after 10 years of their installation. As cathodic protection is designed so as to be serviceable for 20 years no cost will be incurred on it during the project life of 20 years. Costs by year are shown in Table 27.1.

28 Benefits

28.1 Savings of Transportation Cost

(1) Savings of inland transportation cost

(a) Unit transportation cost

According to the information from INCOP, the average transportation costs for the use of railway between San Jose and Puntarenas are as follows.

Railway freight rate on import goods is 25.61 ¢/ton and that on export goods 14.57 ¢/ton, to either of which 15 ¢/ton is added as terminal charge.

Since the distance between San Jose and Puntarenas is 116 km, freight rate per ton kilometer is ¢0.221 for import goods and ¢0.126 for export goods.

These figures are consistent with the unit cost calculated from the operating revenue[115] of INCOP and transportation results on ton-kilometer basis. Thus, the above official rates are used for railway freight rate.

Freight rates for truck between San Jose and Puntarenas are 55 ¢/ton for general cargo and 66 ¢/ton for special cargo respectively, according to the information from the Ministry of Public Works and Transport.

The distance between these two points by road being 127 kilometers, freight rates per ton-kilometer are obtained to be 0.433 ¢/ton.km for general cargo and 0.520 ¢/ton.km for special cargo respectively. These figures are well consistent with those obtained from INCOP.

(b) Traffic Volume

Originated or demand volume by commodity described in article 26.2 is considered as traffic volume.

(c) Route of transportation

Route of transportation selected is such that produces the lowest transportation cost. The details are shown in Fig. 28. 1, in which also are shown distance of transportation, mode of traffic to be used, and transportation cost and time by section.

(d) Unit saving transportation cost

Unit saving transportation costs calculated by commodity according to Fig. 28. 1 are as follows:

Export:

Coffee	-	41.4 - 26.7 = 14.7 ¢/ton
Sugar	-	0.15 × (41.4 - 26.7) + 0.30 × (41.4 + 22.9 - 29.0) + 0.55 × (77.9 + 41.4 - 38.5) = 57.2 ¢/ton
Beef cattle	-	0.10 × (41.4 - 26.7) + 0.60 × (105.6 + 41.4 - 73.2) + 0.30 × 137.2 + 41.4 - 13.0) = 65.4 ¢/ton
Others	-	41.4 - 26.7 = 14.7 ¢/ton

Import: 52.6 - 35.6 = 17.0 ¢/ton

(e) Savings of transportation cost

Table 28. 1 shows savings of inland transportation costs which are obtained multiplying unit saving transportation cost as calculated in preceding (d) by traffic volume as mentioned in article 26. 2.

(2) Savings in time cost of inland transportation

(a) Presuming transportation time by route as shown in Fig. 28. 1, days reduced per ton are obtained as follows;

Export:

Coffee	-	10 × (2 - 2) = 0
Sugar	-	0.15 × (3-3) + 0.30 × (3-1) + 0.55 × (3-1) = 1.7 days/ton
Beef cattle	-	0.10 × (3 - 3) + 0.60 × (3-1) + 0.30 × (7-1) = 1.8 days/ton
Others	-	1.0 × (2-2) = 0

Import: 1.0 × (2-2) = 0

(b) Unit costs of cargo

Unit costs of cargoes are calculated as follows;[101]

Export:

Beef cattle	-	6,700 ¢/ton
Others	-	1,200 ¢/ton

Import: 1,700 ¢/ton

(c) Time cost per day

Obtained time cost per day with interest rate of 10% per year is as follows;

Export:

Beef cattle	-	6,700 × 0.1 ÷ 365 = 1.83 ¢/ton
Others	-	1,200 × 0.1 ÷ 365 = 0.32 ¢/ton

Import: 1,700 × 0.1 ÷ 365 = 0.46 ₡/ton

(d) Savings in time cost of inland transportation

Amounts of savings in time cost are obtained multiplying traffic volume saving by unit saving transportation cost, as shown in Table 28.2.

(3) Negative benefit on passage of the Panama Canal

It is assumed that of the cargoes handled at Puntarenas 60% in volume have their origin or destination in the Atlantic side and 40% in the Pacific side. If the same assumption is applies to cargoes handled at new port those of 20% will not need to pay the canal toll.

The seaborne rate of steel materials originated in Europe via the port of Limon (Puerto Limon) is lower by ₡25.2/ton than that via the port of Puntarenas (Puerto de Puntarenas)(according to the information from Centain Shipping Co.).

The price of steel materials is nearly the same as the average price of export and import goods in Costa Rica. It may be considered from overall viewpoint that the seaborn rate of export and import goods in Costa Rica is approximately the same as that of steel materials. Therefore, the seaborn rate via the port of Puntarenas is obtained higher than that via the port of Limon, in average, by:

25.2 × 0.2 = 5 ₡/ton

Increase in transportation cost via the Panama Canal is calculated multiplying 5 ₡/ton by annual volume of cargoes handled at new port as shown in Table 28.2, in which total amount of savings in transportation cost is shown too.

28.2 Benefit from elimination of ship congestion

Benefit from elimination of ship congestion is inferred as follows: If new facilities are not constructed, cargoes to be handled duely at new facilities are transfered to the Port of Limon where such cargoes are added to those proper to that port causing more congestion to generate congestion cost. This means in other words that a benefit of removing such congestion is produced by the construction of new facilities. Therefore, the benefits due to eliminated ship congestion can be expressed by congestion cost at the Port of Limon. It is assumed that such benefits are partly the savings in cost incurred by the ship transfered to the Port of Limon and partly the savings in cost concerning cargoes handled, which are expected to be equivallent with the rate of interest.

(1) Increase in time of ship congestion

Increased time of congestion due to transference of ship to the Port of Limon is calculated applying the queueing theory. For this, presumption and prerequisites are as follows;

a) Cargoes transfered from the Port of Puntarenas shall be handled by 5 berths among the existing facilities in the Port of Limon. Cargoes proper to the Port of Limon handled at these facilities are those other than banana and crude oil handled at the exclusive wharf. The quantity of those cargoes in 1971 is 330,000 tons and new facilities shall be constructed to handle any future increase in cargoes proper to the said port.

b) On the basis of presumption set out in Chapter 5, average size of vessels calling shall be 6,550 D/W, average volume of cargoes loaded and discharged per vessel 3,200 tons and average berthing time per vessel 5. 6 days.

c) Annual volume of cargoes transfered to the port of Limon from the port of Puntarenas are calculated based on the values set out in article 26.2, and number of vessels calling are obtained from that of 1977 using the ratio of volume of cargoes presumed in Chapter 5.

Based on the above presumptions and prerequisites, increase in average waiting time per vessel is calculated applying the queueing theory as shown in Table 28.3.

(2) Cost of eliminated ship congestion

Basing on the increased time of congestion calculated in the above, benefits derived from eliminated congestion are calculated in the following two ways;

First, cost of congestion incurred to ship is calculated by the following formula.

$$Cs = a \times \Delta T \times N$$

where Cs: cost of congestion incurred by ship
a : ship's cost per day
ΔT: increased time of congestion
N: number of vessel calling

Ship's cost per day include such expenses as labor cost, depreciation and interest etc. excluding navigation expense and estimated at 17,300 /day vessel of 6,500 D/W.

Next, cost incurred to cargoes is calculated by the following formula;

$$Cc = b \times \Delta T \times C$$

where Cc: cost of congestion incurred by cargo
b: time cost of cargo
ΔT: increased time of congestion
C: cargo volume handled

c is cargo volume handled

Time cost of cargo is presumed to be equivallent to the interest of cargo, i.e. 10% of price of cargo which has been calculated for export and import respectively based on data. It is 0.35 ₡/ton.day for import and 0.46 ₡/ton.day for export. Accordingly, benefits derived from eliminated congestion are calculated as shown in Table 28.4.

28.3 Saving in Longshore Cargo Handling Cost

The wharf of finger pier type and without shed is most general, of which "Pier 70" (Muelle 70) recently completed in the port of Limon is a good example in the port of this country. In the case of this system the distance between quay and shed is considerably long, on the contrary, that of new port is very short. Comparing each productivity of cargo handling facilities which are used at Pier 70 and wharf of new port, savings in longshore cargo handling cost are calculated needed for handling method in new port. If forklift truck is used on No. 7 and No. 8 berth of Pier 70 in the port of Limon it must run 420 m in one direction to reach the center of shed. Calculated necessary time for one cycle of operation for this distance is as follows:

Operation on apron	1 min.
Carrying 420 m	5 min.
	(at estimated speed of 5 km/hr.)
Operation in shed	1 min.
Returning 420 m	1.7 min.
	(at estimated speed of 15 km/hr.)
Total of one cycle	8.7 min/cycle

Thus, the turn-rounds of handling facility per hour is obtained as $60 \div 8.7 = 6.9$ cycles/hr. 2 tons of cargo in average being carried per cycle, quantity carried per hour results in $6.9 \times 2 = 13.8$ t/hr. The use of 5 ton forklift truck (according to the regulations of INCOP) costs 72 ₡/hour. Therefore, cost per ton is calculated as $72 \div 13.8 = 5.2$ ₡/t.

On the other hand, operation of one cycle at new port requires

Operation on apron	1 min.
Carrying 45 m	0.5 min.
	(at estimated speed of 5 km/hr.)
Operation in shed	1 min.
Returning 45 m	0.2 min.
	(at estimated speed of 15 km/hr.)
Total of one cycle	2.7 min.

Thus the turn-rounds per hour is calculated as 60   2.7 = 22.2 cycles/hr. 2 tons of cargo in average being carried per cycle, cost per ton results in $72 \div 22.2 \times 2 = 1.6$ ₡/t. Accordingly, the merit of handling system at new port compared with that at No. 7 and No. 8 berths of the Port of Limon gives at least.

$5.2 - 1.6 = 2.6$ ₡/t

Thus, the savings in longshore handling cost are obtained multiplying this by cargo volume handled at new port (Table - 28.5).

As Pier 70 is the newest among those of the port of Limon, if the above calculation is made with other pier instead of Pier 70 the greater amount of savings will be expected.

28.4 Net Profit derived from Use of Port

Port expenses of the present port of Puntarenas are worked out by comparing the operating revenue of the port department with the cargo volume handled as follows;

30 ₡/t for export;
75 ₡/t for import;

If these figures are applied to new port, revenue of the new port from cargo operation can be obtained from multiplying these unit cost by the cargo volume handled.

Moreover, INCOP made a profit of 12% of operating revenue in 1970, then the net profit from handling port cargo will be calculated with the above profit ratio, as shown in Table 28. 5.

28. 5 Rent of Land

A spacious land behind the quay of new port is planned to be used as site for business and physical distribution. It is reasonable to hire out the land to private concerns such as warehouse operater, business firm, bank etc.

Such rent is estimated at 10 ₡/m^2 taking into account the price of land in the city area of Puntarenas. Land allotted for hiring out is 90% of area (7. 1 ha.) after the needed area having been reserved for shed, open freight storage and transport facilities. Remaining 10% are to be reserved for public use. The area of land actually lent out will be increased with increase in quantity of cargo handled.

Annual proceeding from rent is shown in Table 28. 5.

29. Internal Rate of Return

Costs and benefits worked out by year in articles 28 and 29 are discounted to those in 1973 currency value applying discount rates respectively of 5%, 10%, 15%, 20% and 25% and the results are shown respectively in Table 29. 1 and 29. 2.

These values are dotted on the same graph, Fig. 29. 1, to calculate internal rate of return. Then internal rate of return of 16. 0% is obtained. On the basis of this value it is judged that this project is feasible.

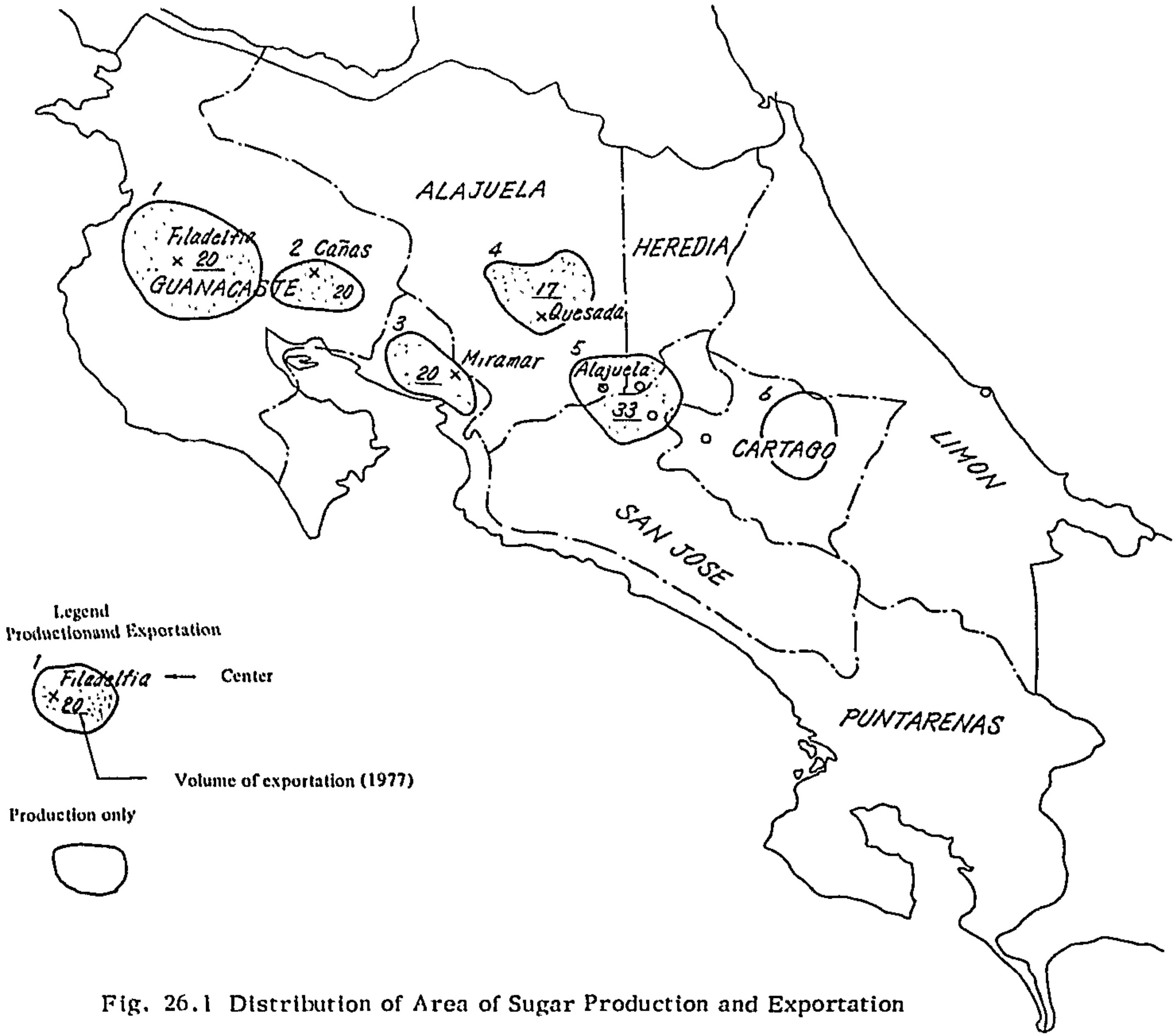


Fig. 26.1 Distribution of Area of Sugar Production and Exportation

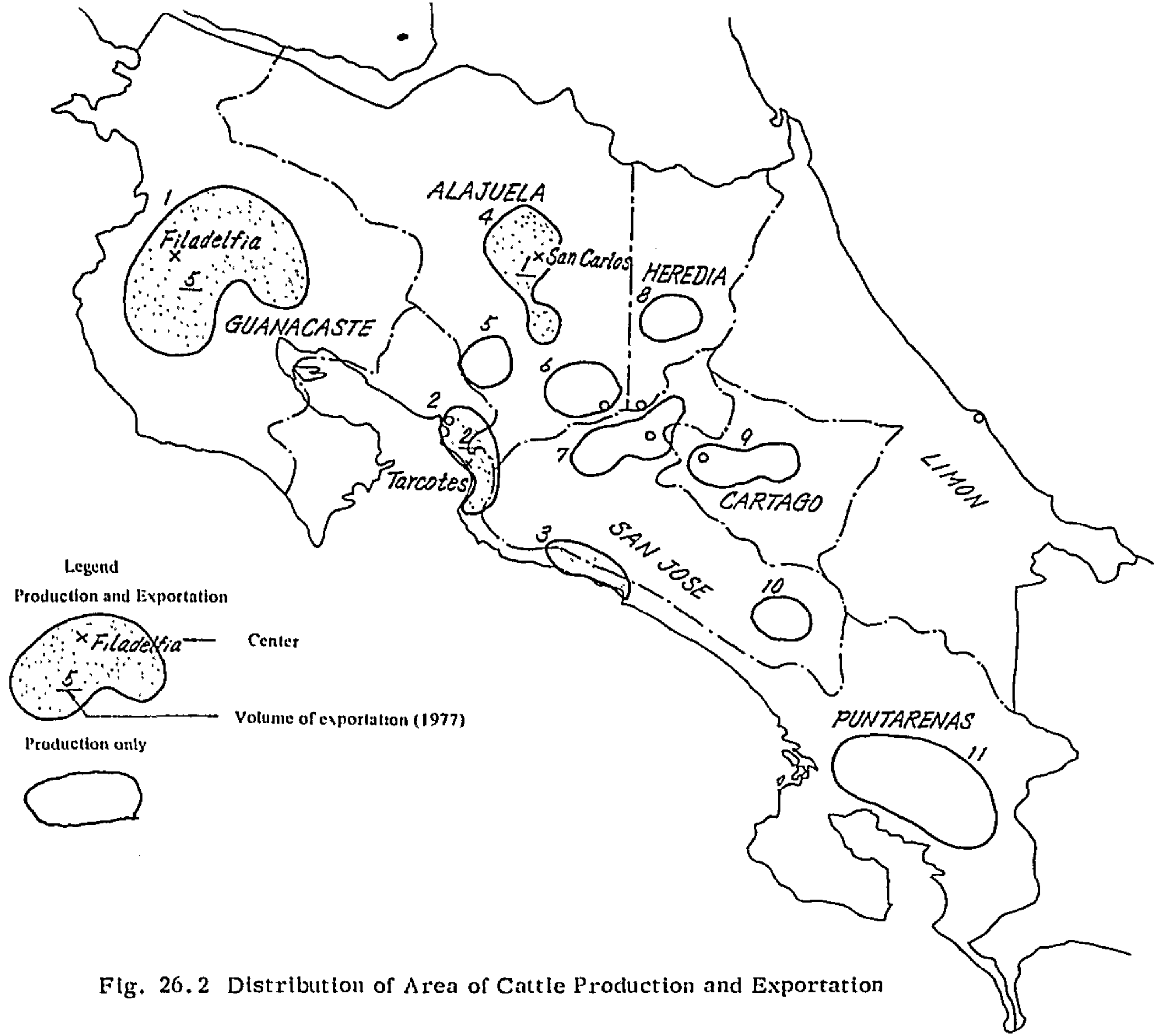


Fig. 26.2 Distribution of Area of Cattle Production and Exportation

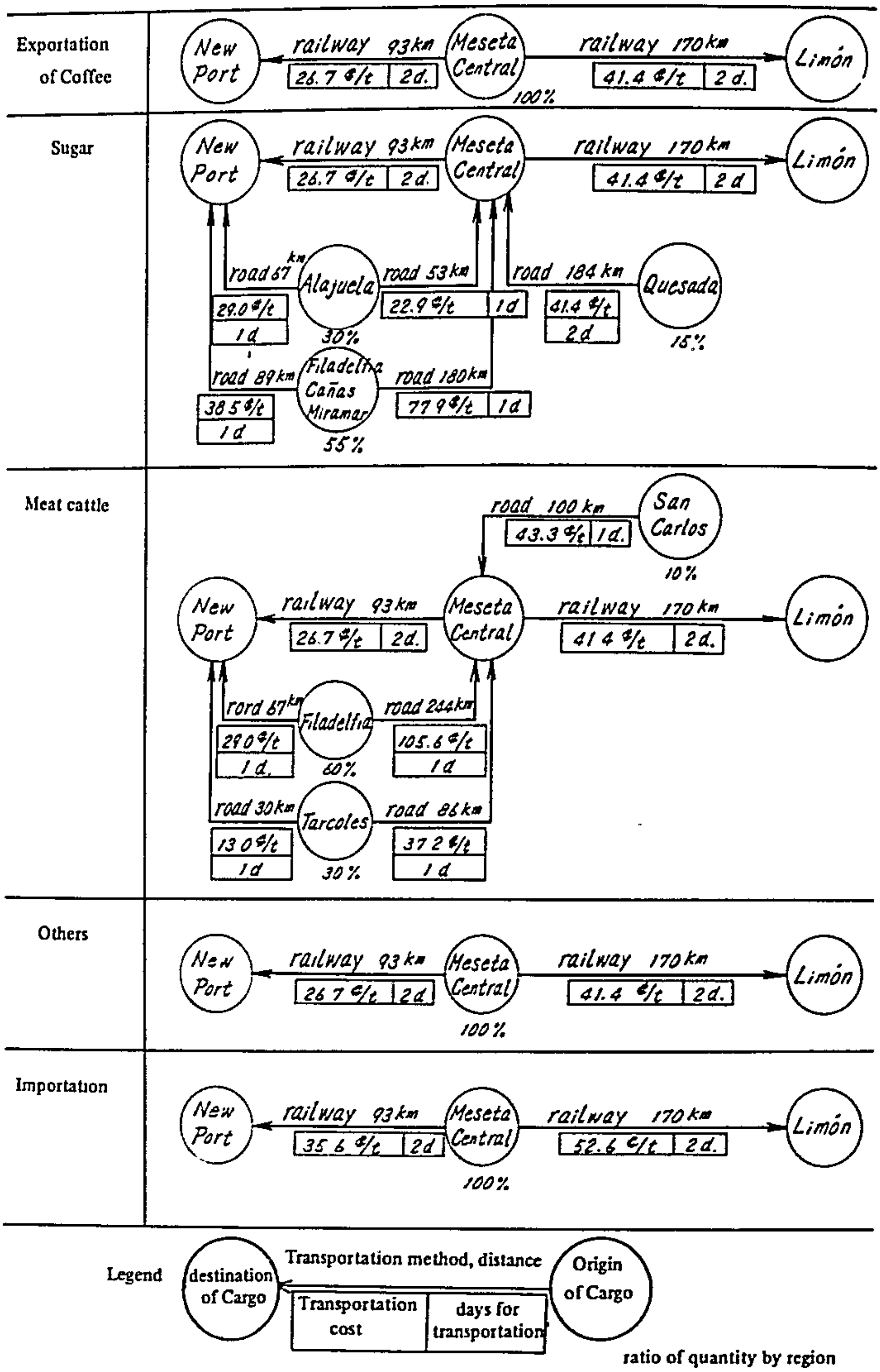


Fig. 28.1 Assumed Transportation Method to New Port and Limon

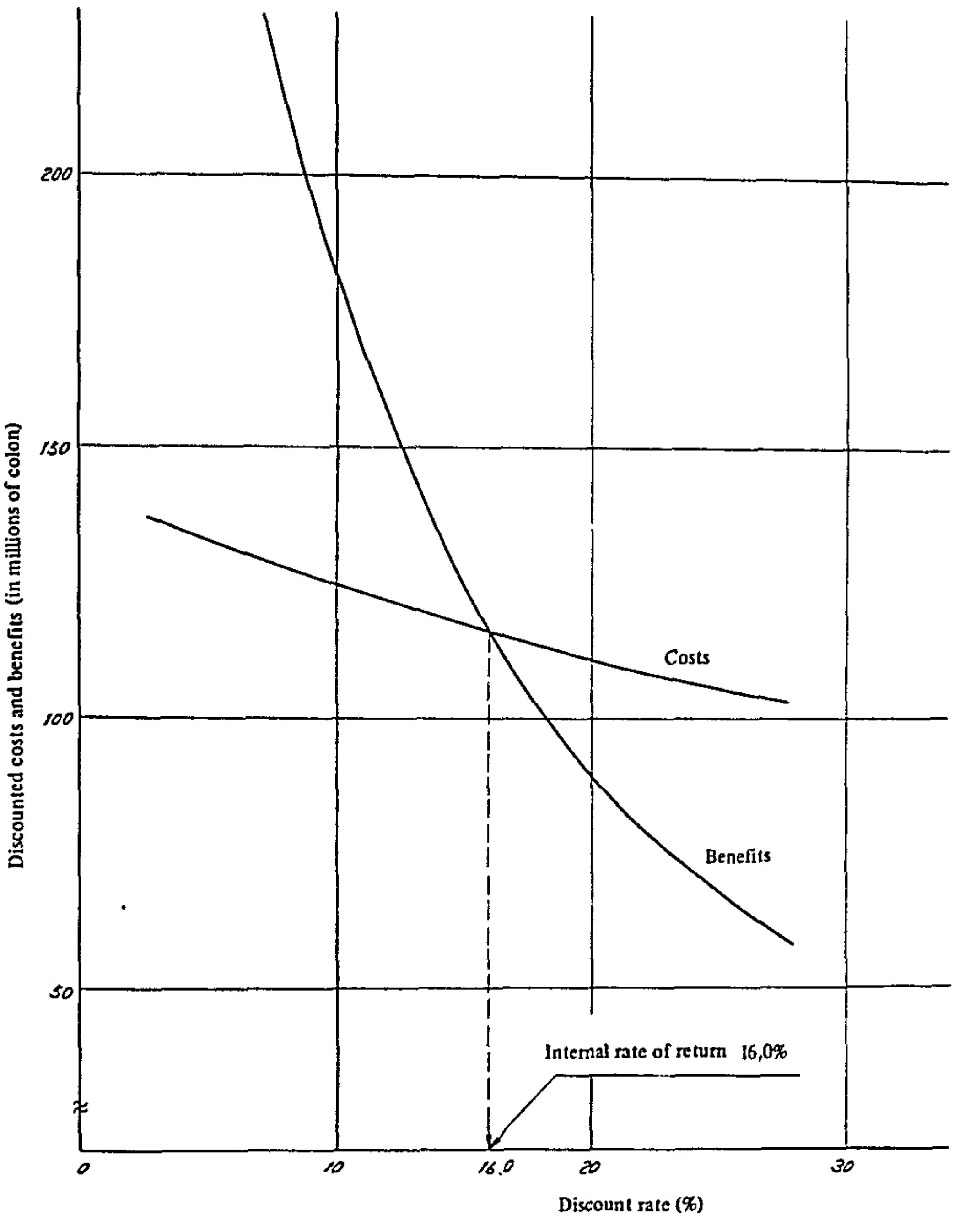


Fig. 29.1 Internal-Rate of Return

Table-26.1 Volume of Export and Import Cargo by Year and Commodity

(Unit: 1,000 ton)

Year	Export					Import	Total
	Coffee	Sugar	Beef	Others	Total		
1973							
74	6	20	1	2	29	37	66
75	24	74	5	7	110	141	251
76	30	92	7	9	138	176	314
77	36	110	8	11	165	212	377
78	42	129	9	13	193	247	440
79	48	145	11	15	219	281	500
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	same	same	same	same	same	same	same
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
1992	.	.	.	.	.	.	.

Table 27.1 Costs for Every Year

unit : 1,000 ₩

Year	Construction Cost	Maintenance Cost	Total
1973	25,940		25,940
74	64,280		64,280
75	21,550		21,550
76	27,230		27,230
77			
78			
79	3,270		3,270
1980			
81			
82			
83			
84		220	220
85		241	241
86			
87			
88			
89			
1990			
91			
92			

Table 28.1 Savings of Diversion Cost

unit : 1,000 ₡

	Export					
	Coffee	Sugar	Beef	Others	Import	Total
	$C_C \times 14.7$	$C_S \times 57.2$	$C_B \times 65.4$	$C_O \times 14.7$	$C_I \times 17.0$	
1973						
74	882	1,144	65	29	629	2,749
75	353	4,233	327	103	2,397	7,413
76	441	5,262	458	132	2,992	9,285
77	529	6,292	523	162	3,604	11,110
78	617	7,379	589	191	4,199	12,975
79	706	8,294	719	221	4,777	14,717
1980	·	·	·	·	·	·
81	·	·	·	·	·	·
82	·	·	·	·	·	·
83	·	·	·	·	·	·
84	·	·	·	·	·	·
85	·	·	·	·	·	·
86	same ·	same ·	same ·	same ·	same ·	same ·
87	·	·	·	·	·	·
88	·	·	·	·	·	·
89	·	·	·	·	·	·
1990	·	·	·	·	·	·
91	·	·	·	·	·	·
92	·	·	·	·	·	·

Table 28.2 Savings of Transportation Cost

Unit : 1,000 ₵

Year	Savings of Diversion Cost	Savings of Time Cost	Cost of Transit of Panama Canal	Total
1973				
74	2,749	14	- 330	2,433
75	7,413	56	-1,255	6,214
76	9,285	73	-1,570	7,788
77	11,110	86	-1,885	9,311
78	12,975	100	-2,200	10,875
79	14,714	113	-2,500	12,330
1980	.	.	.	.
81	.	.	.	.
82	.	.	.	.
83	.	.	.	.
84	Same	Same	Same	Same
85				
86	.	.	.	.
87	.	.	.	.
88	.	.	.	.
89	.	.	.	.
1990	.	.	.	.
91	.	.	.	.
92	.	.	.	.

Table 28.3 Increase of Congestion Time per Vessel

Year	Cargo Volume directed to Port of Limon (1,000 ton)	Number of Vessels	In Case that Cargo is diverted to Limon			Congestion time occured from Cargo of Limon own (day)	Increased Congestion Time (day)
			Cargo Volume (1,000 ton)	Occupation Ratio(ρ)	Waiting Time (day)		
1973	-	-	-				
74	66	26.7	396	0.380	0.10	0.04	0.06
75	251	101.7	581	0.557	0.50	"	0.46
76	314	127.2	644	0.618	0.84	"	0.80
77	377	152.8	707	0.678	1.23	"	1.19
78	440	178.3	770	0.738	2.13	"	2.09
79	500	202.6	830	0.796	3.08	"	3.04
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	same	same	same	same	same	same	same
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
1992	.	.	.	.	.	.	.

Remarks:

$$\rho = \frac{Q}{S \times 365 \times \xi_D} \times \frac{1}{\mu}$$

Q : Cargo Volume

S : Number of Berth

ξ_D : Loading or unloading Cargo Volume per Vessel

$1/\mu$: Mooring time per vessel

Table 28.4 Savings of Ship Congestion Cost

unit : 1,000 #

Year	Saving Cost of Ship	Saving Cost of Cargo			Total
		Export	Import	Total	
1973	-	-	-	-	-
74	28	1	1	2	30
75	808	23	23	41	854
76	1,758	51	49	100	1,858
77	3,141	90	88	178	3,319
78	6,439	186	181	367	6,806
79	10,643	306	299	605	11,248
.	.	.	.	.	.
.	Same	Same	Same	Same	Same
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
1992	.	.	.	.	.

Table 28.5 Benefits

unit : 1,000 ₩

Year	Savings of Transport Cost	Savings of Ship Congestion	Savings of Longshore Cargo Handling	Net Profit of Cargo Handling	Rent of Land	Total
1973						
74	2,433	30	237	437	90	3,227
75	6,214	854	903	1,665	360	9,996
76	7,788	1,858	1,130	2,081	450	13,307
77	9,311	3,319	1,357	2,502	540	17,029
78	10,875	6,806	1,584	2,918	620	22,803
79	12,330	11,248	1,800	3,317	710	29,405
1980	.	.	.	.	.	.
81	.	.	.	.	.	.
82	.	.	.	.	.	.
83	.	.	.	.	.	.
84	Same	Same	Same	Same	Same	Same
85						
86	.	.	.	.	.	.
87	.	.	.	.	.	.
88	.	.	.	.	.	.
89	.	.	.	.	.	.
1990	.	.	.	.	.	.
91	.	.	.	.	.	.
92	.	.	.	.	.	.

Table-29. 1 Discounted Cost for Each Discount Rate

(Unit: 1,000 ₩)

Year	5 %	10 %	15 %	20 %	25 %
1973	25,940	25,940	25,940	25,940	25,940
74	61,214	58,431	55,891	53,565	51,424
75	19,544	17,807	16,292	14,964	13,792
76	23,519	20,452	17,898	15,755	13,942
77					
78	2,439	1,885	1,413	1,094	857
79					
1980					
81					
82					
83					
84	129	77	47	30	19
85	134	77	45	27	17
86					
87					
88					
89					
1990					
91					
92					
Total	132,919	124,669	117,526	111,375	105,991

Table-29.2 Discounted Benefit for Each Discount Rate

(Unit: 1,000 ₱)

Year	5 %	10 %	15 %	20 %	25 %
1973					
74	3,073	2,933	2,806	2,689	2,582
75	9,065	8,260	7,557	6,941	6,397
76	11,493	9,995	8,747	7,699	6,813
77	14,006	11,627	9,732	8,210	6,975
78	17,866	14,154	11,331	9,160	7,470
79–1992	227,859	134,349	83,563	54,408	36,780
Total	283,362	181,318	123,736	89,107	67,017

APPENDIX

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205) " (" ,)

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208) " (" , 1/500,000)

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561) Numero de veces en que fueron reportados temblores de la intensidad respectiva de la escala mercalli cancanni modificada- durante el periodo de 1953-1961-

562) Temblores mayores de la escala de'modified and cancanni temblores ciudades en Costa Rica de 1930 a 1952

563) Numero de veces en que han occurrido temblores de intensidad IV o Mayor en la escala de mercalli cancanni-modificada, durante el periodo de 1953 a 1961

6. Constructions

601) Muelle grande de Puntarenas, dimensiones generales

602) Muelle de Puntarenas, esquena para control de reparacion

603) Piso de concreto prefablicado, puente del muelle Puntarenas

604) Losa de concreto para zona de transicion en el muelle de Puntarenas

605) Proyecto banda transportadora

606) Torre para carga y descarga combinada

621) Esquema preliminar para puerto nuevo de Puntarenas en Punta Morales

622) Esquena preliminar terminal azucarero en granel

623) Proyecto interamericana - Punta Morales

624) Proyecto interamericana - Punta Morales, Sectiones tipicas y cantidados

625) Proyecto interamericana - Punta Morales, pente sobre Rio Lagarto

641) Complejo portuario de Limon, plano general de instalaciones existentes

642) Complejo portuario de Limon, plano general de instalaciones existentes y proyectadas

661) Alternativa B. estacion terminal on Moin .

662) Presu puesto de inversion, terminal a granel en Punta Morales

663 Construction unit prices (TAMS)

664) Costo por kilometro via ferrea (INCOP)

665) Costo por 1,000 Mts (INCOP)

666) Costo por metro (INCOP)

APPENDIX 2 Cost-Benefit Analysis for Reduced Project

A2. 1 Outline

The project proposed by the Survey Team contemplates the construction of 3-berth quays in four years, of which initial construction cost has been estimated at 140 million colon. The initial construction cost is apparently very huge. In order to know the effect of any reduction of project itself to decrease such initial cost on the feasibility, internal rate of return has been calculated on the plan to reduce the entire project so as to provide 2-berth quay. It has been found that the reduced project with 2-berth quays is also feasible though somewhat inferior to that with 3 berth quays.

However, the 2-berth plan has not only physical difference that number of berths is fewer by one than the 3-berth plan but also certain fundamental problems as described below. It should be considered as a separate plan. In addition, there is a fear that this plan will constitute a serious obstacle to the development of the country as a whole as well as the east coast area of the Gulf of Nicoya which is expected through the construction of new port.

(1) Growth in port demand cannot be accommodated.

As stated in article 5, cargo volume handled at new port is estimated at 377,000 tons for 1977 and thereafter it will grow with the development of economy. As the handling capacity of cargo in the 2-berth plan is 350,000 tons, any growth in cargo after 1977 cannot be accommodated.

(2) There is a fear that port functions cannot be attracted to the hinterland.

An autonomous development of port activities requires accumulation of various economic and social port functions. Various organizations which form such functions will be located in the hinterland of new port on the basis on the judgement of their own interests. Should the construction of port facilities be confined to two berths for the time being, they may judge that they cannot foresee satisfactory activities profitable to them. As a result, even though port facilities have been completed, necessary organizations will not be attracted causing inactivity of the port. There is the possibility of appearing of, so to speak, ghost town on shoreline. The same applies to the formation of city in hinter land.

(3) Unit cost of construction of facilities is rather expensive

In constructing a port it needs to transport large-sized equipment to construction site over a long distance. Its transportation cost is the same regardless of quantity of works. Therefore, any.reduction in project will naturally increase the unit cost, of which effect is taken into account in dealing with the cost in article A2.4 below.

A2. 2 Construction Planning

A2. 2. 1 Facilities Planning

Overall project is reduced as follows;

quay of 10 m water depth	1 berth
quay of 7. 5 m water depth	1 berth

with the minimum faclities required to operate the above facilities.

It is planned to provide these facilities at South Caldera.

Fig. A2. 1 shows ground plan.

Table A2. 1 shows quantity of works and unit prices by kind of works and construction costs. Unit prices and construction costs are calculated by foreign and domestic currency. The cost covered by foreign currency is 31 million colon and that covered by domestic currency is 76 million colon, making 107 million colon in total.

A2. 2. 2 Stages of Construction

The facilities described in article A2. 2. 1 are completed in three years from 1973 to 1975. The stages of construction are as shown in Table A2. 2, in which construction costs by year calculated by kind of works are shown also. Such construction costs by year have been worked out by dividing total construction costs by kind of works proportionally to construction period by year.

A2. 3 Cargo Volume Handled

Cargo volume handled at new facilities is estimated at 350, 000 tons according to the reduction in size of project. Cargo volume by year is calculated on the basis of cargo estimated in Chapter 2, by considering demand of cargo and supply of capacity of facilities, in the same way as done in article 25. 2. With this volume taking as control total, such cargo volume are divided into commodity as shown in Table A2. 3.

Origin and destination of cargoes by commodity are presumed as in article 25. 2.

A2. 4 Costs

Initial construction cost and maintenance and repair cost are considered as costs.

Initial cost is shown in Table A2-2.

Maintenance and repair cost is the cost of fenders to be replaced 10 years after the construction of quay wall.

The details of costs by year are shown in Table A2. 4.

A2. 5 Benefits

A2. 5. 1 Savings in Transportation Cost

(1) Savings in inland transportation cost

Amounts of savings in transportation cost per ton by commodity calculated in article 28. 1 (1) are as follows:

Export	
Coffee	14. 7 ₡/ton
Sugar	57. 2 ₡/ton
Beef	65. 4 ₡/ton
Others	14. 7 ₡/ton
Import	17. 0 ₡/ton

By multipling these values by the volume of cargo by commodity by year described in article A2. 3, the amounts of savings in inland transportation costs by year are obtained, as shown in Table A2. 5.

(2) Savings in time value of inland transportation

Savings in time of inland transportation per ton by commodity calculated in article 28. 2 (2) are as follows:

Export		
	Coffee	0
	Sugar	1. 7 day/ton
	Beef	1. 8 day/ton
	Others	0
Import		0

Time values per ton per day calculated in article 28. 7 (2) are as follows:

Export		
	Sugar	0. 32 ₡/ton. day
	Beef	1. 83 ₡/ton. day

Therefore, the amounts of savings in time value of inland transportation can be calculated as follows:

Sugar for export

1. 7 × 0. 32 × tons of sugar exported

Beef for export

1. 8 × 1. 83 × tons of beef exported

The amounts of savings in time value of inland transportation by year are shown in Table A2. 6.

(3) Negative benefit on passage of the Panama Canal

As the cargoes handled at new port bear the toll for passing the Panama Canal as described in article 28. 1 (3), it costs higher by 5 ₡/ton in average than the use of the Port of Limon. Therefore, negative benefit on passage of the Panama Canal can be obtained from 5 ₡/ton multiplied by annual volume of cargoes handled.

In Table A2. 7 are listed the amounts of saving in transportation costs calculated in articles (1), (2) and (3) above.

A2. 5. 2 Benefit from Elimination of Ship Congestion

(1) Increase in congestion time of ship

The way of thinking and prerequisites shall follow those mentioned in article 28. 2. Accordingly, increase in congestion time of ship is calculated as shown in Table A2. 8.

(2) Cost on eliminated congestion

On the basis of increased time of congestion calculated in article (1), congestion cost incurred to ship and that incurred to cargo are calculated in the same way as in article 28. 2. The same unit costs as in that article are also applied.

Those are

Ship cost per day	17,300 ₡/day. vessel
Time cost of cargo per day -	
Export	0.46 ₡/ton. day
Import	0.35 ₡/ton. day

The benefits from eliminated congestion of ship can be calculated as shown in Table A2. 9.

A2. 5. 3 Amount of Saving in Longshore Cargo Handling Cost

Since the sheds in new port are provided adjacent to the face line of the quay wall, longshore cargo handling equipment can be used effectively. The savings per ton of longshore handling cost is estimated at 3. 6 ₡ /ton in article 28. 3. By multipling this value by cargo volume handled at new port the amount of savings in longshore cargo handling cost are obtained (Table 2. 10).

A2. 5. 4 Net Profit derived from Use of Port

As done in article 28. 4, cost of handling one ton of cargo is estimated as follows:

Export	30 ₡/ton
Import	75 ₡/ton

If the net profit from port cargo handling is put at 12% of port operating revenue as in article 28.4, such profit can be calculated as shown in Table A2. 10.

A2. 5. 5 Rent of Land

About 5 ha. of land which can be rented may be prepared at the back of two berths. It is assumed that the area of land rented will increase with the growth in cargo volume. Rent shall be set at 10 ₡/m^2 taking into account the price of land in the urban area of Puntarenas. Accordingly, annual revenue from renting of land is as shown in Table A2. 10.

A2. 6 Internal Rate of Return

Costs and benefits worked in articles A2. 3 and A2. 5 are discounted to those in 1973 currency value applying discount rate respectively of 5%, 10%, 15% and 20%, and the results of calculation are shown respectively in Figs. A2. 11 and A2. 12.

These values are dotted on the graph, Fig. A2. 2, to calculate internal rate of return. There internal rate of return of 12. 3% is obtained. On the basis of such internal rate of return it is judged that this project which is reduced to two berths is also feasible, although somewhat to a inferrior degree compared to the project with three berths.

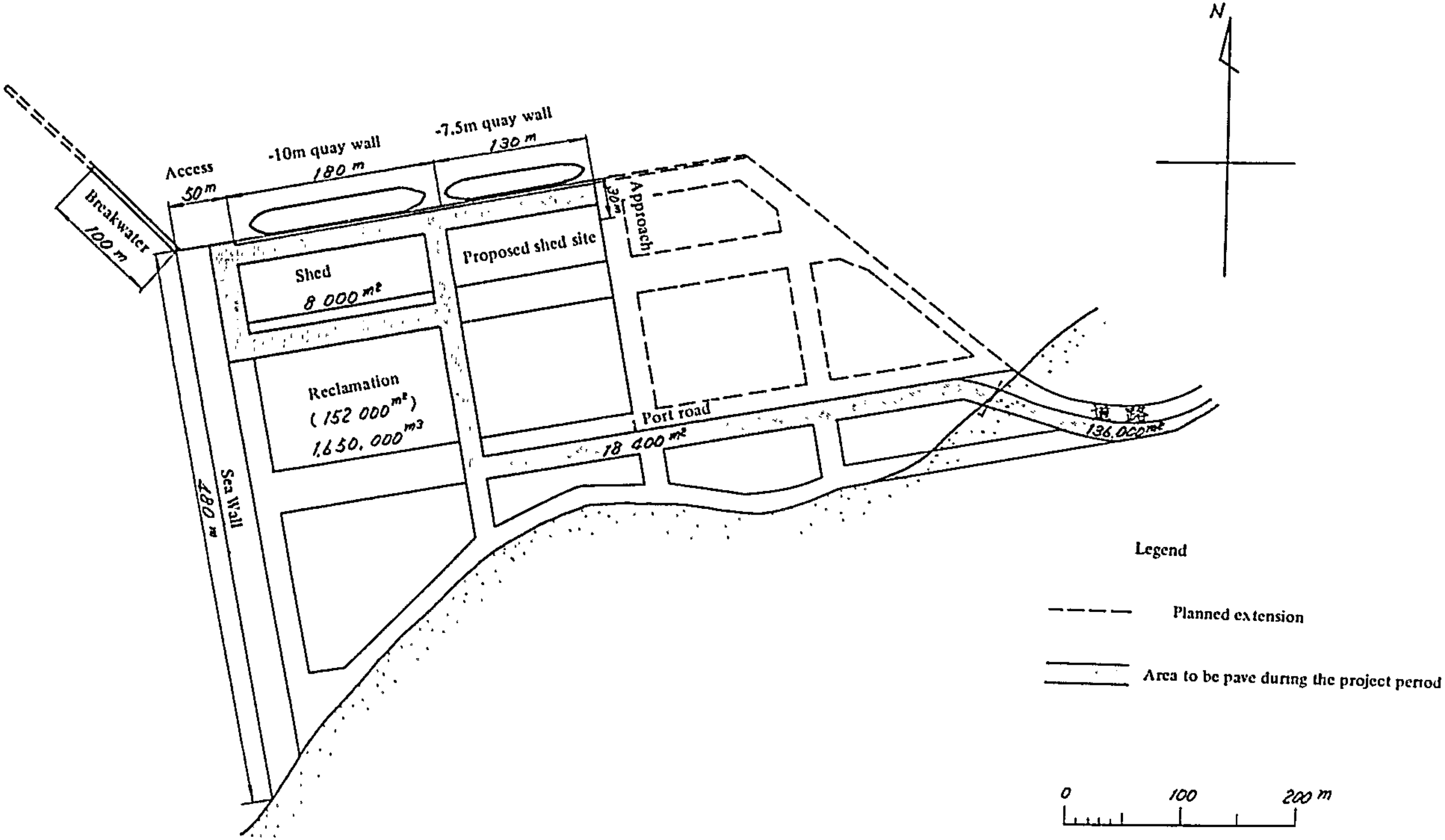

Fig. A 2.1 Ground Plan-for the Construction of 2 berths at South Caldera

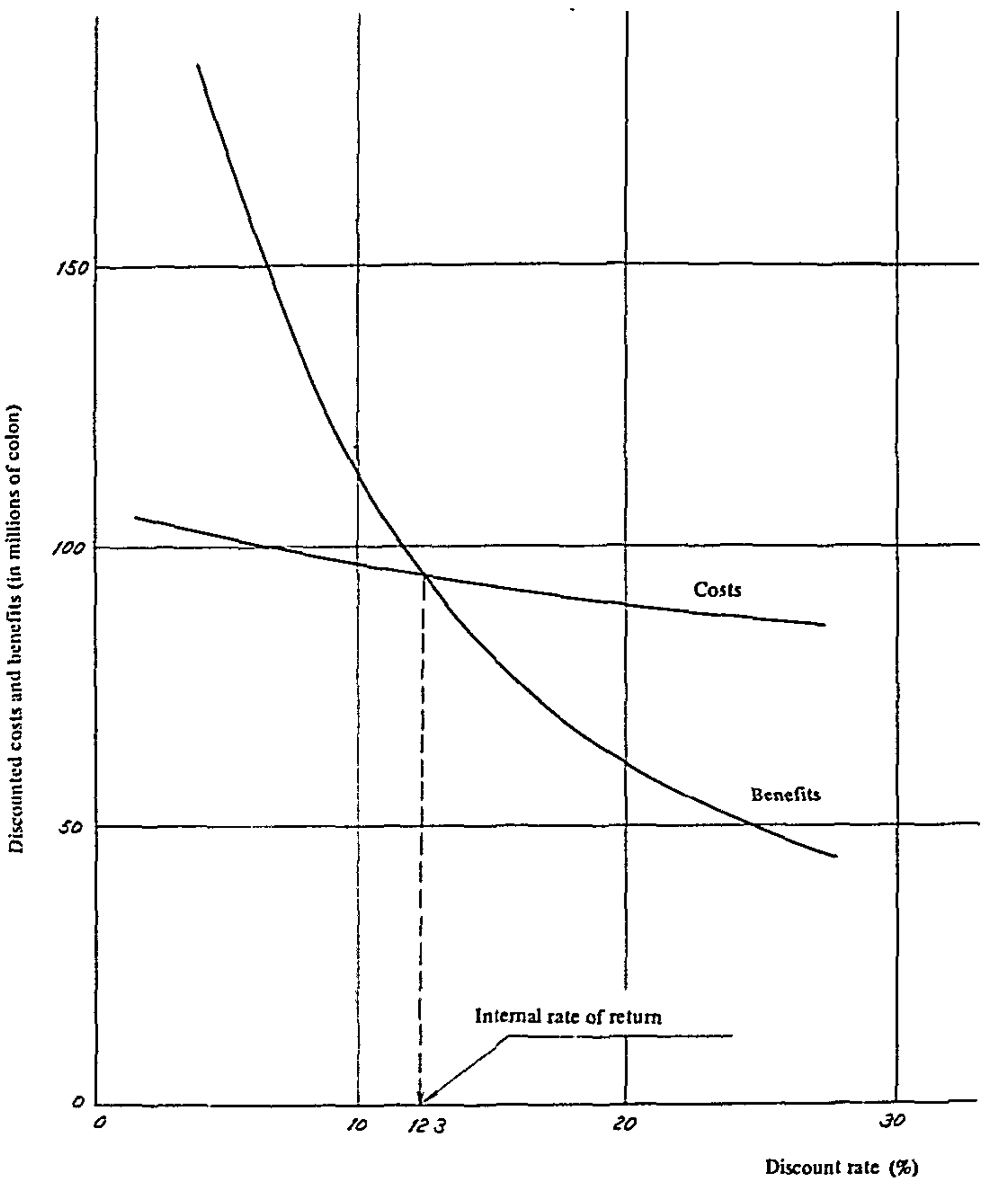

Fig. A 2.2 Internal Rate of Return

Table-A 2.1 Preliminary Estimate of Construction Costs

Item	Quantity	Amount (1,000 Colones)		
		Foreign	Domestic	Total
Breakwater	100^m		4,700	4,700
Seawall	480^m	9,600	9,600	19,200
-10^m Quaywal (including Approach)	230^m	9,315	5,750	15,065
-7.5^m Quaywall (including Approach)	160^m	4,800	3,200	8,000
Transit Sheds (in Port Area)	$8,000^{m^2}$	3,680	2,720	6,400
	$18,400^{m^2}$		1,100	1,100
Reclamation	$(152,000^{m^2})$			
	$1,650,000^{m^3}$	13,860	3,465	17,325
Road	$136,000^{m^2}$		13,600	13,600
Sub-total		41,255	44,135	85,390
Contingencies		6,345	6,765	13,110
Engineering & Supervision		4,100	4,400	8,500
Total		51,700	55,300	107,000

Table-A2.2 Construction Costs and Schedule

Item	Quantity	Amount	Construction Schedule 1973	1974	1975
			Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.	Jan. Feb. Mar. Apr. May Jun. Jul Aug. Sep. Oct. Nov Dec.	Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
		(1,000 ¢)			
Break-water	100^m	4,700		4,700	
Sea wall	480^m	19,200	8,000	11,200	
-10^m Quay wall (including Approach)	230^m	15,065	1,675	13,390	
-7.5^m Quay wall (including Approach)	160^m	8,000		4,440	3,560
Transit sheds	$8,000^{m2}$	6,400			6,400
Road(in port area)	$18,400^{m2}$	1,100		370	730
Reclamation	$16,500,000^{m3}$	17,325	785	9,450	7,090
Road	$136,000^{m2}$	13,600	5,230	8,370	
Sub-total		85,390	15,690	51,920	17,780
Contingencies		13,110			
Engineering & supervision		8,500	Survey 3,830	Supervision 12,770	4,320
Total		107,000	19,520	64,690	22,100

Table-A2.3 Volume of Export & Import Cargo by Year and Commodity

(Unit: 1,000 ton)

Year	Export					Import	Total
	Coffee	Sugar	Beef	Others	Total		
1973	-	-	-	-	-	-	-
74	6	19	1	2	28	35	63
75	24	74	5	7	110	141	251
76	30	92	7	9	138	176	314
77	34	103	7	10	154	196	350
.	.	.	.	.	.	.	.
.	same	same	same	same	same	same	same
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
1992	.	.	.	.	.	.	.

Table A2.4 Costs for Every Year

(Unit: 1,000 ₡)

Year	Construction Cost	Maintenance Cost	Total
1973	19,595		19,595
74	65,305		65,305
75	22,100		22,100
76			
77			
78			
79			
1980			
81			
82			
84		220	220
85		110	110
86			
87			
88			
89			
1990			
91			
92			

Table-A2.5 Savings of Diversion Cost

(Unit: 1,000₡)

Year	Export				Import	Total
	Coffee	Sugar	Beef	Others		
	$C_c \times 14.7$	$C_s \times 57.2$	$C_B \times 65.4$	$C_o \times 14.7$	$C_I \times 17.0$	
1973						
74	88	1,087	65	29	595	1,864
75	353	4,233	327	103	2,397	7,413
76	441	5,262	458	132	2,992	9,285
77	500	5,892	458	147	3,332	10,329
78	.	.	.	.	.	.
79	.	.	.	.	.	.
1980	.	.	.	.	.	.
81	.	.	.	.	.	.
82	.	.	.	.	.	.
83	.	.	.	.	.	.
84	same	same	same	same	same	same
85	.	.	.	.	.	.
86	.	.	.	.	.	.
87	.	.	.	.	.	.
88	.	.	.	.	.	.
89	.	.	.	.	.	.
1990	.	.	.	.	.	.
91	.	.	.	.	.	.
92	.	.	.	.	.	.

Table-A2.6 Savings of Time Cost in Diversion

(Unit: 1,000 ₱)

Year	Sugar 0.32 × 1.7 × Cs	Beef 1.83 × 1.8 × C_B	Total
1973			
74	10	3	13
75	40	16	56
76	50	23	73
77	56	23	79
78	·	·	·
79	·	·	·
1980	·	·	·
81	·	·	·
82	·	·	·
83	·	·	·
84	·	·	·
85	same	same	same
86	·	·	·
87	·	·	·
88	·	·	·
89	·	·	·
1990	·	·	·
91	·	·	·
92	·	·	·

Table-A2.7 Savings of Transportation Cost

(Unit: 1,000 ฿)

Year	Savings of diversion cost	Savings of time cost	Cost of transit of Panama Canal	Total
1973				
74	1,864	13	-315	1,562
75	7,413	56	-1,255	6,214
76	9,285	73	-1,570	7,788
77	10,329	79	-1,750	8,658
78	.	.	.	.
79	.	.	.	.
1980	.	.	.	.
81	.	.	.	.
82	.	.	.	.
83	.	.	.	.
84	same	same	same	same
85	.	.	.	.
86	.	.	.	.
87	.	.	.	.
88	.	.	.	.
89	.	.	.	.
1990	.	.	.	.
91	.	.	.	.
92	.	.	.	.

Table-A2.8 Increase of Congestion Time per Vessel

Year	Cargo volume diverted to Port of Limon (1,000 ton)	Number of Vessels	In case that cargo is diverted to Limon			Congestion time oc- cured from Cargo of Limon Own (day)	Increased congestion time (day)
			Cargo volume (1,000 ton)	Occupation Ratio (ρ)	Waiting time (day)		
1973	-	-	-	-	-	0.04	-
74	63	25.5	393	0.377	0.09	"	0.05
75	251	101.7	581	0.557	0.50	"	0.46
76	314	127.2	644	0.618	0.84	"	0.80
77	350	141.8	680	0.652	1.06	"	1.02
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
1992	.	.	.	.	.	.	.

Remarks: $$\rho = \frac{Q}{S \times 365 \times \xi_D} \times \frac{1}{\mu}$$

$$= \frac{Q}{5 \times 365 \times 3,200} \times 5.6$$

Table-A2.9 Saving of Ship Congestion Cost

(Unit: 1,000¢)

Year	Saving Cost of Ship	Saving Cost of Cost			Total
		Export	Import	Total	
1973	-	-	-	-	-
74	22	1	1	2	24
75	808	23	23	46	854
76	1,758	51	49	100	1,858
77	2,502	72	70	142	2,644
.	.	.	.	.	.
.	.	.	.	.	.
.	same	same	same	same	same
.	.	.	.	.	.
.	.	.	.	.	.
1992	.	.	.	.	.

(A) Cs = (Ship's cost per day) × (Increased time of congestion) × (Number of vessel calling)
   //
   17,300C/day vessel

Cc = (Cargo time value) × (Increased time of congestion) × (Cargo volume handled)
   //
   0.35 C/ton (import)
   0.46 C/ton (export)

Table-A2.10 Benefits

(Unit: 1,000₩)

Year	Savings of trans-port cost	Savings of decrease of conges-tion	Savings of longshore cargo handling	Net profit of cargo handling	Rent of land	Total
1973						
74	1,562	24	227	3,465	90	5,368
75	6,214	854	903	1,665	360	9,996
76	7,788	1,858	1,130	2,081	450	13,307
77	8,658	2,644	1,260	2,318	500	15,380
78	•	•	•	•	•	•
79	•	•	•	•	•	•
1980	•	•	•	•	•	•
81	•	•	•	•	•	•
82	•	•	•	•	•	•
83	•	•	•	•	•	•
84	•	•	•	•	•	•
85	same	same	same	same	same	same
86	•	•	•	•	•	•
87	•	•	•	•	•	•
88	•	•	•	•	•	•
89	•	•	•	•	•	•
1990	•	•	•	•	•	•
91	•	•	•	•	•	•
92	•	•	•	•	•	•

Table-A2. 11 Discount Cost for each Discount Ratio

(Unit: 1,000 ₩)

Year \ D.R.	5 %	10 %	15 %	20 %
1973	19,595	19,595	19,595	19,595
74	62,190	59,362	56,783	54,419
75	20,042	18,281	16,708	15,346
76				
77				
78				
79				
1980				
81				
82				
83				
84	129	77	47	30
85	61	35	21	12
86				
87				
88				
89				
1990				
91				
92				
Total	102,017	97,350	93,154	89,360

Table-A2. 12 Discounted Benefit for each Discount Ratio

(Unit: 1,000₩)

Year \ D.R.	5 %	10 %	15 %	20 %
1973				
74	5,112	4,880	4,667	4,473
75	9,065	8,260	7,557	6,941
76	11,493	9,995	8,747	7,699
77	•	•	•	•
78	•	•	•	•
79	•	•	•	•
1980	•	•	•	•
81	•	•	•	•
82	•	•	•	•
83	•	•	•	•
84	•	•	•	•
85	143,880	90,318	60,139	42,050
86	•	•	•	•
87	•	•	•	•
88	•	•	•	•
89	•	•	•	•
1990	•	•	•	•
91	•	•	•	•
92	•	•	•	•
Total	169,550	113,453	81,110	61,163