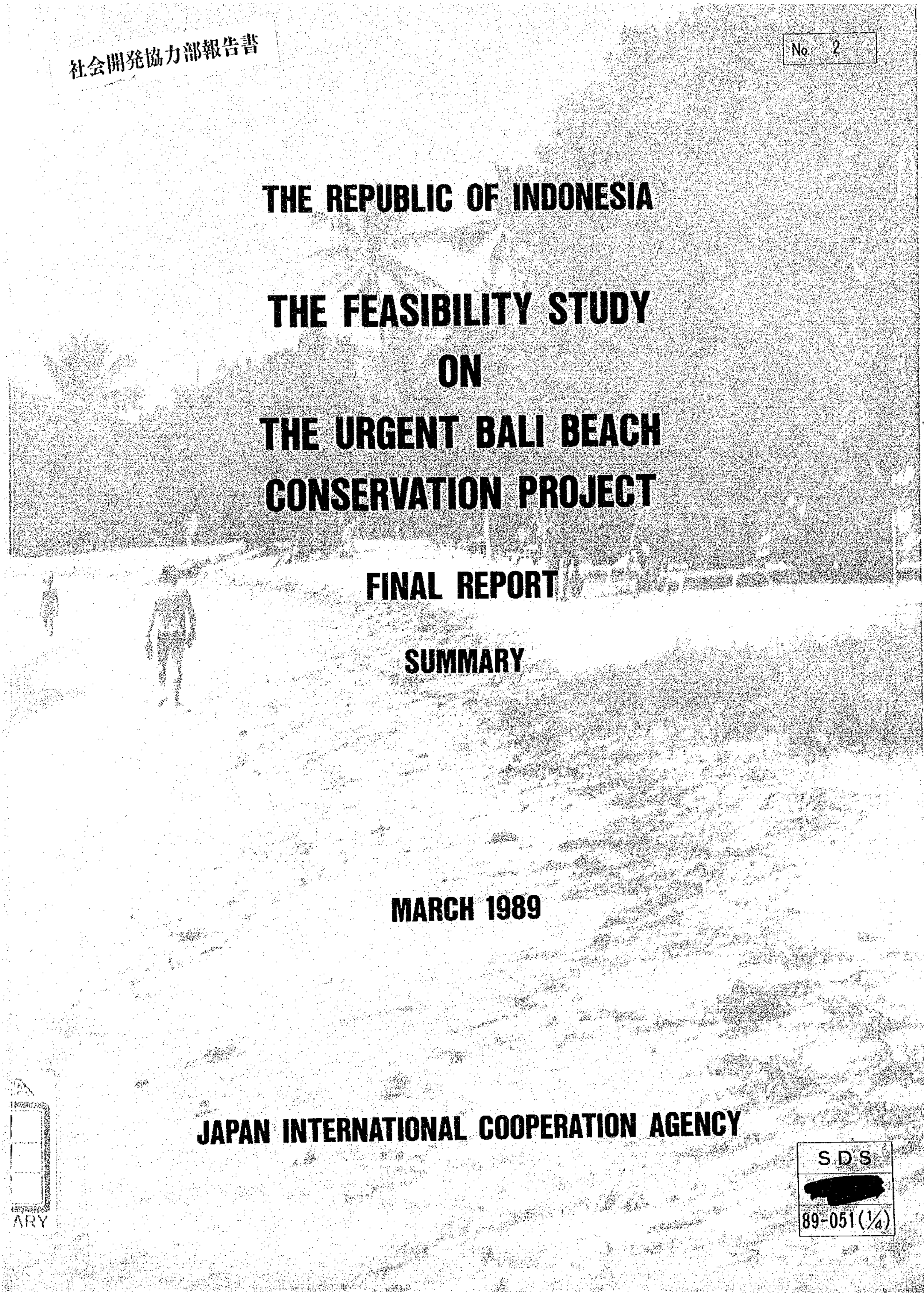


THE REPUBLIC OF INDONESIA

THE FEASIBILITY STUDY ON THE URGENT BALI BEACH CONSERVATION PROJECT

FINAL REPORT

SUMMARY

MARCH 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

THE REPUBLIC OF INDONESIA

THE FEASIBILITY STUDY
ON
THE URGENT BALI BEACH CONSERVATION PROJECT

FINAL REPORT

SUMMARY

MARCH 1989

PREFACE

In response to a request from the Government of the Republic of Indonesia, the Japanese Government decided to conduct a Feasibility Study on the Urgent Bali Beach Conservation Project in the Republic of Indonesia and has entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Indonesia a survey team headed by Mr. Fujio SAIGUSA of INA Civil Engineering Consultants Co.,Ltd., comprising members of INA Civil Engineering Consultants Co.,Ltd. and Pacific Consultants International, from February to July, 1988.

The team held discussions with concerned officials of the Government of Indonesia and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

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

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Indonesia for their close cooperation extended to the team.

March, 1988

Kensuke Yanagiya
President
Japan International Cooperation Agency

THE FEASIBILITY STUDY
ON
THE URGENT BALI BEACH CONSERVATION PROJECT

LETTER OF TRANSMITTAL

Mr. Kensuke YANAGIYA
President
Japan International
Cooperation Agency

March 1989

Dear Sir,

It is our great pleasure to submit herewith the Report for the Feasibility Study on the Urgent Bali Beach Conservation Project in the Republic of Indonesia. This report has been prepared by the study team in accordance with the contracts signed on 29 January 1988 and 6 March 1989 between the Japan International Cooperation Agency and the joint venture of INA Civil Engineering Consultants Co., Ltd. and Pacific Consultants International.

Regarding this project, the Study Team conducted three series of field surveys to collect a variety of data including data concerning natural conditions. The findings of these surveys were discussed to form the Urgent Conservation Plan and to study the feasibility of this Project, and were then compiled into this report.

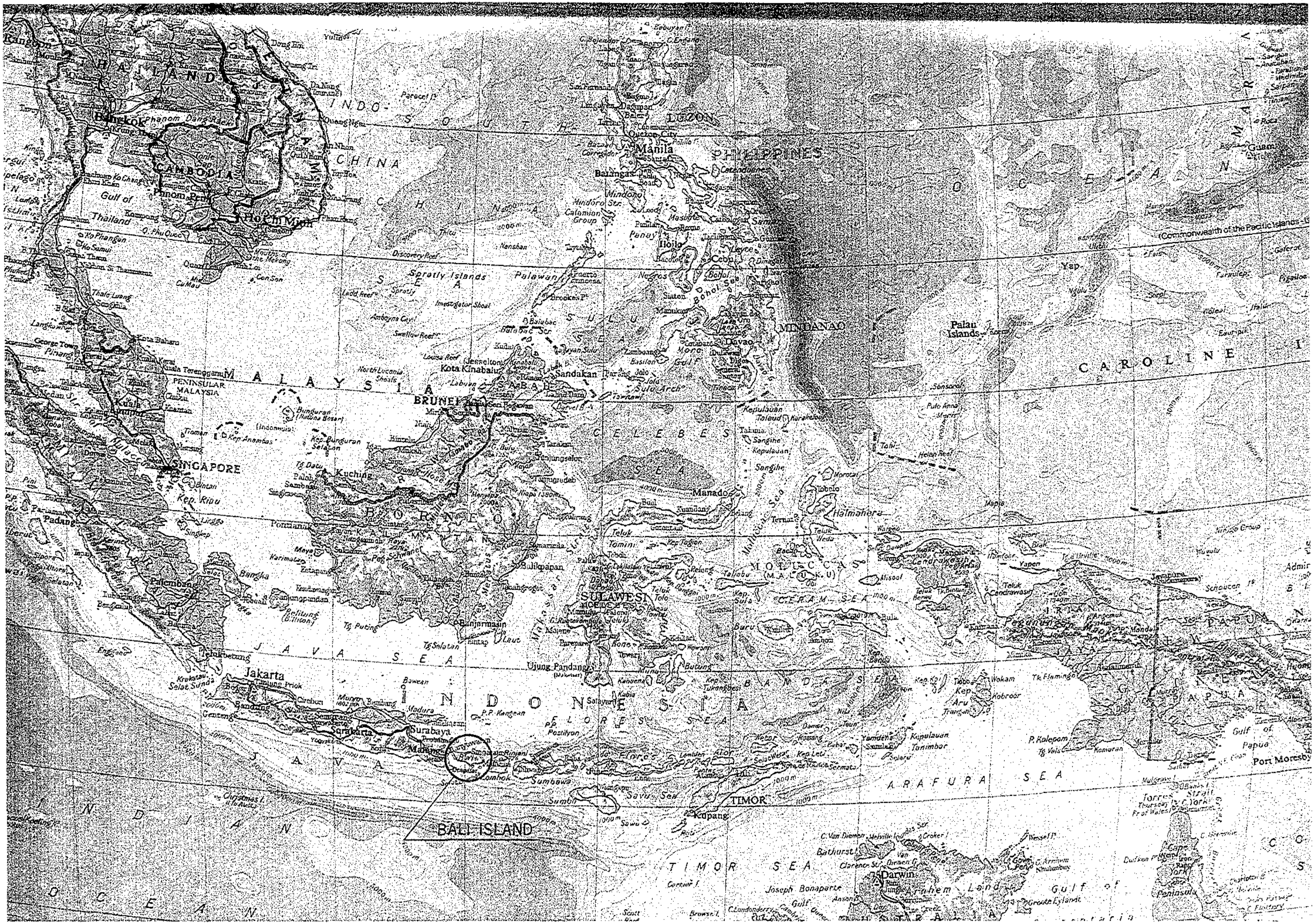
The report consists of the Summary Report, Main Report, Supporting Report and Data Book. The Main Report contains background conditions, results of hydrualic analysis, urgent beach conservation plan, implementation program, results of economic analysis, conclusions and recommendations. The Study shows that the beaches of the study areas are seriously eroded and this Project should be executed promptly.

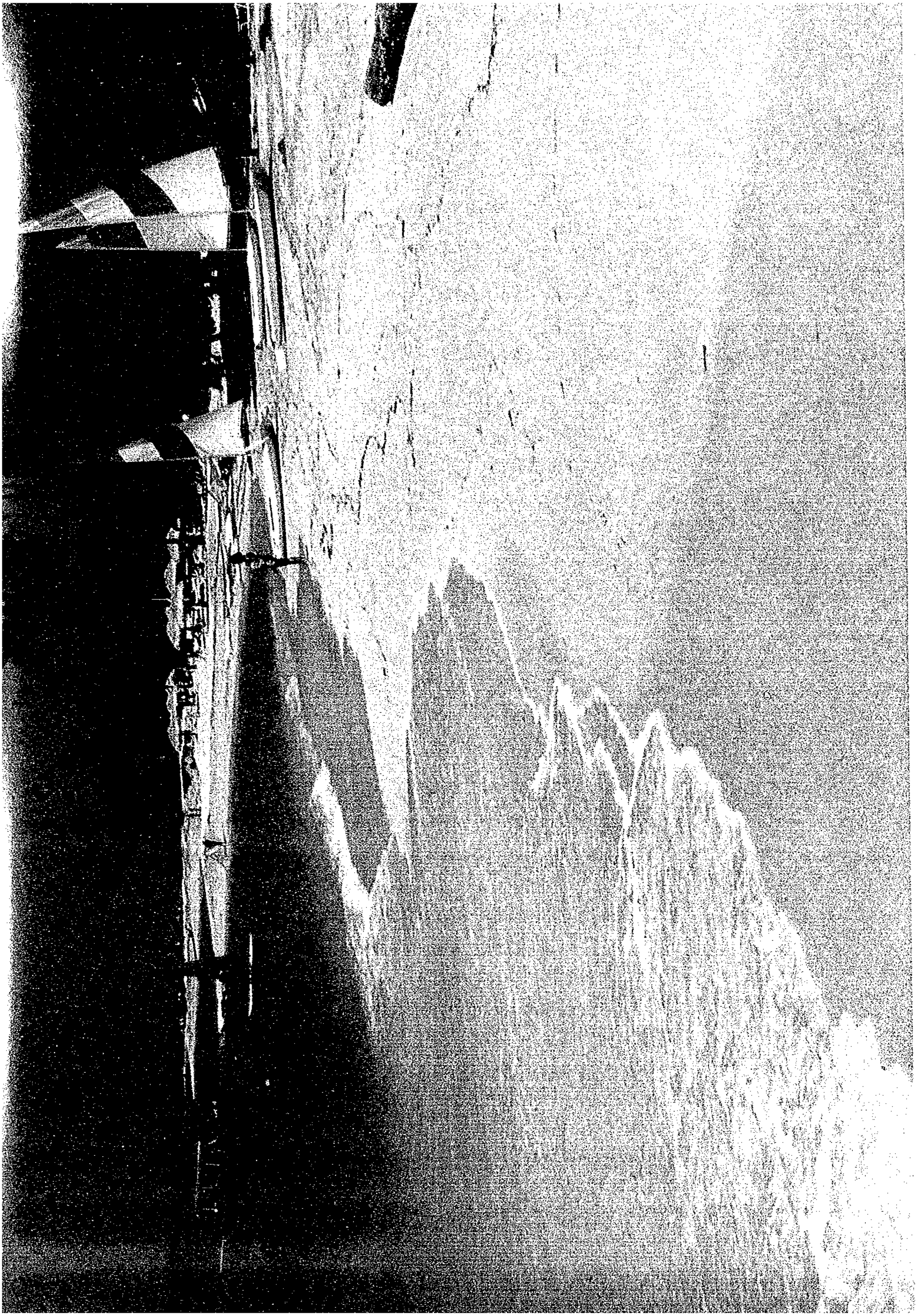
All the members of the Study Team wish to express their gratitude to the personnel of your Agency, the Adivisory Committee, the Ministry of Foreign Affairs, the Ministry of Construction, and the Embassy of Japan in Indonesia and also to the officials and individuals of the Government of Indonesia for their assistance. The Study Team sincerely hopes that the results of the Study will contribute to the socio-economic development of the Republic of Indonesia.

Yours faithfully,

Fujio Saigusa

Fujio SAIGUSA
Team Leader


BALI ISLAND
THAILAND
CAMBODIA
Bangkok
Ho Chi Minh
SINGAPORE
MALAYSIA
BRUNEI
BORNEO
SULAWESI
INDONESIA
JAVA SEA
JAVA
Jakarta
Surabaya
TIMOR
TIMOR SEA
ARAFURA SEA
FLORES SEA
BANDA SEA
CELEBES SEA
SULU SEA
SOUTH CHINA SEA
PHILIPPINES
LUZON
MINDANAO
Manila
MOLUCCAS
CAROLINE
Palau Islands
Yap
Guam
Darwin
PAPUA
Port Moresby
INDIAN OCEAN



EXCHANGE RATE

US$ 1 = Rp 1600

US$ 1 = ¥ 130

ABBREVIATIONS

B/C	Benefit-Cost Ratio
BTDC	Bali Tourism Development Corporation
CIF	Cost, Insurance and Freight
DL	Datum line
DGWRD	Directorate General of Water Resources Development
DOR	Directorate of Rivers
DPU	Ministry of Public Works
GDP	Gross Domestic Product
GRDP	Gross Regional Domestic Product
h	Water Depth
H	Wave Height
H_0	Offshore Wave Height
$H_{1/3}$	Significant Wave Height
IHE	Institute of Hydraulic Engineering
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
MHW	Mean High Water
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
ML	Mean Sea Level
MLW	Mean Low Water
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
NPV	Net Present Value
Rp	Rupiah
T	Wave Period
T_0	Offshore Wave Period
$T_{1/3}$	Significant Wave Period
VAT	Value Added Tax
$	US Dollar
¥	Japanese Yen

CONTENTS

INTRODUCTION

INTRODUCTION

1. *Background of the Study*

Indonesia is an island country consisting of about 13,700 islands, large and small, scattered over a vast sea area which extends approximately 2,000 km north and south from about 6 ° North Latitude through about 12 ° South Latitude crossing the equator and approximately 5,000 km west and east from about 95° East Longitude through about 140° East Longitude.

The land area of Indonesia is about 1.9 million km^2 with 216 main mountains, 221 large rivers and 18 large lakes. Administratively, Indonesia is divided into 27 provinces, 246 Kabupaten (regencies) and 54 Komamadya (municipalities).

More than half of the 13,700 islands are still unnamed while only 7% are inhabited. Bali island, one of the 27 provinces, is Indonesia's leading tourist destination.

Bali shares only 0.29% of the nation's total area but has a population of about 2% of the nation's total.

There are many sightseeing places in Bali Island and beaches are one of the most favored places. Every year, many tourists visit Bali from around the world. Tourism plays an important role in the economy of Bali and in the national economy. Tourism generates employment and is a leading earner of foreign exchange. The govenment is undertaking a policy to promote tourism.

On the other hand, the land of Indonesia is basically susceptible to erosion due to waves, and coastal erosion has advanced throughout the country recently.

There are dozens of main areas of coastal erosion in Indonesia at present. Especially in Bali Island, many eroded areas can be seen in the highly developed or inhabited areas along the coastal zone.

So, the Government of the Republic of Indonesia has requested the Government of Japan to provide technical cooperation in the implementation of the feasibility study on the Urgent Bali Beach Conservation Project which will become a base for the land protection policy and the economic development of the Republic of Indonesia.

In response to the request, the Government of Japan decided to undertake the study and dispatched the Japanese Preliminary Study Team to the Republic of Indonesia from October 18 to October 30, 1987. The Scope of Work for the Study was agreed upon on October 28, 1987 and signed by Mr. Tadashi Tanimoto, the leader of the Japanese Preliminary Study Team, and Mr. Putra Duarsa, Assistant Director General for River Development, Ministry of Public Works.

2. Objectives and Areas of the Study

The objectives of the study are;

(1) to prepare the shore protection plan of the study areas,
(2) to conduct a feasibility study based on the plan, and
(3) to transfer technology to the Indonesian counterpart personnel.

The study areas are located in the southern part of Bali island, and consist of the Sanur beach area, Nusa Dua beach area, Kuta beach area and Tanah Lot area, in the neighbourhood of Denpasar, the island's capital. From Denpasar, the Sanur beach area is 6 km southeast, the Nusa Dua beach area 16 km south, the Kuta beach area 9 km southwest, and the Tanah Lot area 15 km west. These study areas are connected by good paved roads from Denpasar.

At Sanur beach and Kuta beach where more than about 80% of the tourists visit and at Nusa Dua beach where more than about 40% of the tourists visit, there is serious erosion along several km of coastline.

The sea cliff on which the Tanah Lot temple, a Hindu cultural asset, is built is badly eroded, and is likely to flow away or collapse from erosion due to waves in the future.

3. Implementation of the Study

The Directorate General of Water Resources Development (DGWRD), Ministry of Public Works, was assigned as the counterpart executing agency of the Government of Indonesia while the Japan International Cooperation Agency (JICA) was assigned as the official agency responsible for the implementation of the technical cooperation programme of the Government of Japan.

The Study was carried out by the Japanese consultant team retained by JICA and the counterpart staff of DGWRD and the local engineers retained by DGWRD.

The Study was conducted from February, 1988 to March, 1989. The members involved in the Study are listed below.

(1) JICA Study Team

Mr. Fujio Saigusa	(INA)	:	Team Leader
Mr. Noboru Sakuma	(SMC)	:	Shore Protection Planning
Mr. Kazuhiro Goto	(PCI)	:	Facilities Planning
Mr. Kazuo Unoki	(INA)	:	Marine Investigations
Mr. Hiroshi Sakuramoto	(INA)	:	Hydraulic Model Test
Dr. Masakazu Shibata	(INA)	:	Coastal Analysis
Mr. Toshio Yamada	(PCI)	:	Facilities Design
Mr. Junji Ebihara	(INA)	:	Construction Planning, Cost Estimation
Mr. Yoji Terazu	(INA)	:	Geological Investigations
Mr. Shinji Okada	(COR)	:	Marine Survey
Mr. Akihisa Kojima	(PCI)	:	Economic Analysis
Mr. Osamu Isoda	(PCI)	:	Environmental Analysis
Mr. Kuniaki Takamatsu	(PASCO)	:	Topographical Survey/Sounding

(2) JICA Advisory Committee

Mr. Tadashi Tanimoto	(MOC)	:	Chairman
Dr. Takaaki Uda	(MOC)	:	Member
Mr. Yoshinori Ashida	(MOC)	:	Member

(3) Indonesian Government

Ir. Putra Duarsa	:	Inspector General, Ministry of Public Works (former Assistant Director General for River Development, Ministry of Public Works)
Ir. Soebandi Wirosumarto	:	Director General of Water Reosources Development
Ir. Kusdaryono	:	Assistant Director General of Water Resources Development

Ir. Hartono Pramudo	:	Director of Rivers, DGWRD
Ir. Amir Muryadi	:	General Manager of CIMANUK Project (former Chief of Sub Directorate of Planning & Design, DOR)
Ir. Siswoko	:	Chief of Sub Directorate of Planning & Design, DOR
Ir. Soetrisno	:	Chief of Sub Directorate of Erosion Control and Natural Disaster Prevention, DOR
Ir. Sarwono Sukardi	:	Chief of Erosion Control Planning & Design Section, DOR
Ir. C.L. Sumartono	:	Chief of Erosion Control Supervision on Section, DOR
Ir. M. Yahya	:	Institute of Hydraulic Engineering, Bandung
Ir. Soeroto Martomidjojo	:	Director, Bali Regional Office, Ministry of Public Works

(4) Counterparts

Ir. I Ketut Kaler, M. Eng	:	Overall Management
Ir. I Made Subagia	:	Overall Management
Ir. Kardana	:	Shore Protection Planning
Ir. Gde Adi Suarsajaya	:	Shore Protection Planning
Ir. Sarwono Sukardi	:	Facilities Planning
Ir. I Ketut Suwandi	:	Facilities Planning
I Wayan Mundra, BE	:	Marine Investigation
Ir. Syamsudin, Dipl. HE	:	Hydraulic Model Test
Ir. Tjokorda B. Budiana	:	Coastal Analysis
Ir. Titanata	:	Facilities Design
Ir. I Gst. Ngr. Anom Artawan	:	Facilities Design
Sobirin, BE	:	Construction Planning
I Ketut Netera, BE	:	Cost Estimation
Ir. C.L. Soemartono	:	Geological Investgation
Ir. Modesta Tandiayuk	:	Geological Investgation

Eddy Aristiyanto, BE : Geological Investgation
Subandi, BIE : Marine Survey
Endang, BE : Marine Survey
Drs. I Nyoman Padma : Economic Analysis

Special Abbreviations

MOC : Ministry of Construction, Government of Japan
INA : INA Civil Engineering Consultants Co., Ltd.
PCI : Pacific Consultants International
SMC : SHIN-NIPPON Meteocean Consultant Co., Ltd.
COR : Coast Ocean Research Co., Ltd.
PASCO: PASCO International Inc.

4. Composition of the Report

This report consists of four (4) volumes: Summary Report, Main Report, Supporting Report and Data Book.

The Summary Report presents the summarized results of all the studies. The Main Report contains background conditions, results of hydraulic analysis, urgent beach conservation plan, implementation program, results of economic analysis, conclusions and recommendations.

The Supporting Report includes the results of computer simulations on the hydraulic analysis and related oceanographic observation data.

The Data Baook consists of the following data.

I : Bottom Material Tests
II : Geological Survey and Unconfined Compression Tests
III : Construction Material Tests

5. Acknowledgement

The Study Team conducted three series of field surveys in Indonesia from February, 1988. During their stay, the Study Team carried out data collection and coastal surveys such as the topographical/sounding survey, oceanographic survey, geological survey and environmental survey.

The Study Team also tried to deepen the mutual understanding among

all the parties concerned through discussions with the counterpart personnel concerning various aspects of the actual situation.

On this occasion the Study Team wishes to express its deep appreciation for the cooperation and assistance rendered by the Ministry of Public Works and related organizations under the Government of Indonesia.

The Study Team would also like to express its heartfelt gratitude to the officials of the Embassy of Japan in Indonesia, the Ministry of Foreign Affairs and the Ministry of Construction of the Government of Japan who gave valuable advice and provided various support during the performance of the Study.

SUMMARY

CHAPTER 1 SOCIO-ECONOMIC BADKGROUND

1. Population

Population data is shown along with some household information in Table 1-2-1 The average annual growth rate of population in Bali Province is 1.08% since 1982, far lower than the national average. This is attributable to the net migration away from the province.

The population projection for Bali Island is shown in Table 1-2-2. This projection assumes that the annual growth rate will increase slightly from 1.40% during the period of 1980-1985 to 1.51% in the ensuring five years, and that it will again decline to 1.36% for the period of 1995-2000.

The forecast population is 2,866,000 persons in 1990 and 3,303,000 persons in 2000.

Table 1-2-1 Population, Density and Households in Bali, 1986

Regency	Area ('000 km^2)	Population ('000 persons)	Density (persons per km^2)	Number of Households	Average No. of Members of Household
1. Jembrama	842	205.7	244	43.2	4.8
2. Tabanan	389	347.4	414	70.7	4.9
3. Badung	543	550.6	1,015	99.9	5.5
4. Gianyar	368	317.3	865	59.6	5.3
5. Klungkung	315	157.9	489	28.9	5.3
6. Bangli	521	169.7	326	34.8	4.9
7. Karangasem	840	338.4	403	69.9	4.8
8. Buleleng	1,366	517.4	379	110.1	4.7
Total					
1986		2,660.4	462	517.1	5.0
1985		2,558.5	454	508.8	5.0
1984		2,528.6	449	495.5	5.1
1983		2,502.2	444	488.1	5.1
1982		2,491.0	442	487.0	5.1

Source: Statistical Year Book of Bali, 1986

Table 1-2-2 Population Projection of Bali, 1980 - 2000

('000 persons)

	1980	1985	1990	1995	2000
0 - 14	956.4	916.8	937.6	917.8	1,022.2
15 - 54	1,263.7	1,460.4	1,647.9	1,793.8	1,907.4
55 -	241.5	284.0	280.5	322.3	373.7
Total	2,479.4	2,658.5	2,866.0	3,087.9	3,303.3
Growth Rate (% per annum)	1.40%	1.51%	1.50%	1.36%	

Source: Statistical Year Book of Bali, 1986
(Statistical Office of Bali Province)

2. GRDP

GRDP is summarized in Table 1-3-1. Agriculture and Tourism dominate the province's gross regional production. Agriculture is the lealding sector. It accounts for 39.8% of the GRDP in 1986, and has shown a slight declining tendency since 1983. Almost all the piedmont areas are covered with paddy. Nationwide agriculture accounts for just 25% of the GDP of Indonesia in 1984.

The second largest sector in Bali is trade, hotels and restaurants. This sector occupies 14.1% of the GRDP in 1983. The share of this sector in the total regional production is growing, reaching 15.6% of the gross regional production in 1985. This is attributable to the increase in international tourist arrivals.

Furthermore some other industries such as transportation and communication, and services are closedly related with tourism. Therefore the real contribution of the tourist industry which is identified as trade, hotels and restaurants is actually larger than the figure in the table.

Table 1-3-1 Gross Regional Domestic Product of Bali Province

(in 1983 Constant Prices)

	GDP (Mil. Rp.)			Share (%)		
	1983	1984	1985	1983	1984	1985
1. Agriculture	390,268	427,110	423,440	43.3	43.2	39.8
2. Quarrying	5,907	4,497	4,227	0.7	0.5	0.4
3. Manufacturing	38,993	41,869	48,939	4.3	4.2	4.6
4. Electricity and Water Supply	6,748	7,239	10,160	0.8	0.7	1.0
5. Construction	61,714	62,374	64,196	6.9	6.3	6.0
6. Trade, Hotels and Restaurants	126,911	147,316	166,482	14.1	14.9	15.6
7. Transportation and Communication	83,716	93,397	101,329	9.3	9.5	9.5
8. Banking and Other Financial	18,956	21,549	21,989	2.1	2.2	2.1
9. Ownership of Dwellings	7,903	8,838	8,993	0.9	0.9	0.8
10. General Government and Defense	77,856	78,453	96,547	8.6	7.9	9.1
11. Services	82,225	95,533	118,453	9.1	9.7	11.1
Total	901,195	988,178	1,064,756	100.0	100.0	100.0

3. Tourism Industry

In 1986 and 1987, tourism record double-digit growth. Tourist earnings are Indonesia's sixth most important sector in terms of the country's total export earnings. Most of this stems from Bali Province, with at least 30% attributable to the Bali resorts according to the international tourist arrival data. In sluggish economic circumstances, this industry has to play a significant role in earning foreign currency.

In order to secure foreign currency and secure job opportunities for local people, tourism development must be guaranteed.

And any dangers which threaten this development and lessen the attraction of tourism resources on Bali Island should be overcome. The biggest parobIem at present is the beach erosion.

CHAPTER 2 NATURAL CONDITIONS

1. Meteorology

The climate of Bali Island changes every six months. The dry season (June to September) is influenced by the Australian continental air mass and the rainy season (December to March) is influenced by the Asian continental and the Pacific Ocean air masses passing over oceans.

In the rainy season, the winds are heavier and quicker. The winds blow from the west and northwest, so that the season is sometimes called the west season. During the dry season, the east winds blow from the Australian continent. The winds in this season may also be heavy and quick.

2. Oceanography and Hydrography

(1) Tides

The tidal ranges on the north coast are observed to be smaller than on the south coast. The tidal range is 2.0 m at Benoa near Nusa Dua Beach (Table 2-3-1).

(2) Currents

The offshore currents around the Indonesian archipelago, including the Pacific Ocean adjacent to Indonesia, are shown on Fig. 2-3-1.

Offshore currents can be seen along Java, Bali, Lombok, Sumbawa, P. Flores and P. Sumba.

In the dry season, the current flows from the east corresponding with the wind direction. And in the rainy season, the current through the Kaimata strait flows reversely from the west to the east.

(3) Deep Water Waves

As for the offshore wave climate in the Indian Ocean to the south of Bali, the U.S. Navy Marine Climatic Atlas of the World Vol. 3 Indian Ocean (1976) provides the statistics on the height, period and direction of the waves over 120 years. (Fig. 2-3-2)

These data show the characteristics of the deep water waves of the study areas.

The predominant direction of the waves is southeast to southwest.

(4) Field Surveys

Field surveys were carried out to collect data on waves, nearshore currents and sand drift at the sites of Kuta, Sanur and Nusa Dua.

1) Waves

Waves arriving at the shore are the primary cause of sediment transport in the littoral zone.

Fig. 2-3-6～7 show the distribution of wave height and period at Kuta and Nusa Dua.

In Bali, the reef functions as a natural breakwater, and the significant wave height at the reef is about 1/2 or 1/3 the height offshore.

2) Nearshore Currents

A current meter was set at one or two points each at Kuta, Nusa Dua and Sanur beaches.

The Kuta beach has an eroding area north of Purtamina Cottage. Whereas the reef is as wide as 1 km near the airport runway, it rapidly becomes narrow in front of the eroding area. A current meter was set at a point near the edge of the narrow reef.

At that point, the magnitude of velocity is large, and the directions is almost NNE.

On the Nusa Dua beach, a current meter was set on both sides of the canyon.

The currents towards the canyon from both sides is observed.

There is also a natural submarine canyon near the eroding area at Sanur beach. A current meter was set at two points which represent the north and south drifts, respectively.

The currents at both sides change direction around this area. And the megnitude of southward velocity is much higher than northward.

3) Fluorescent Tracers

The dispersions of the fluorescent-dyed sand are recognized at both sides of the injection points parallel to shoreline. But the predominant directions of the dispersion nearly correspond to the current directions at the injection points.

At Nusa Dua, the sediment falls into the canyon from both sides, but the amount of the falling sediment from the north side is much larger than from the south side.

Table 2-3-1 Tide Level

(In Meters)

Place	S. Lat.	E. Long	MHWS	MHWN	MLWN	MLWS	ML
Buleleng	8.06	115.05	+1.0	+0.6	+0.4	0	0.5
Teluk Padang	8.32	115.03	+1.2	+0.7	+0.5	0	0.6
Benoa	8.45	115.13	+2.0	+1.4	+0.6	0	1.0

MHWS : Mean High Water Springs
MHWN : Mean High Water Neaps
MLWN : Mean Low Water Neaps
ML : Mean Sea-levels
Source: Admiralty Tide Tables, Volume 3, 1988.

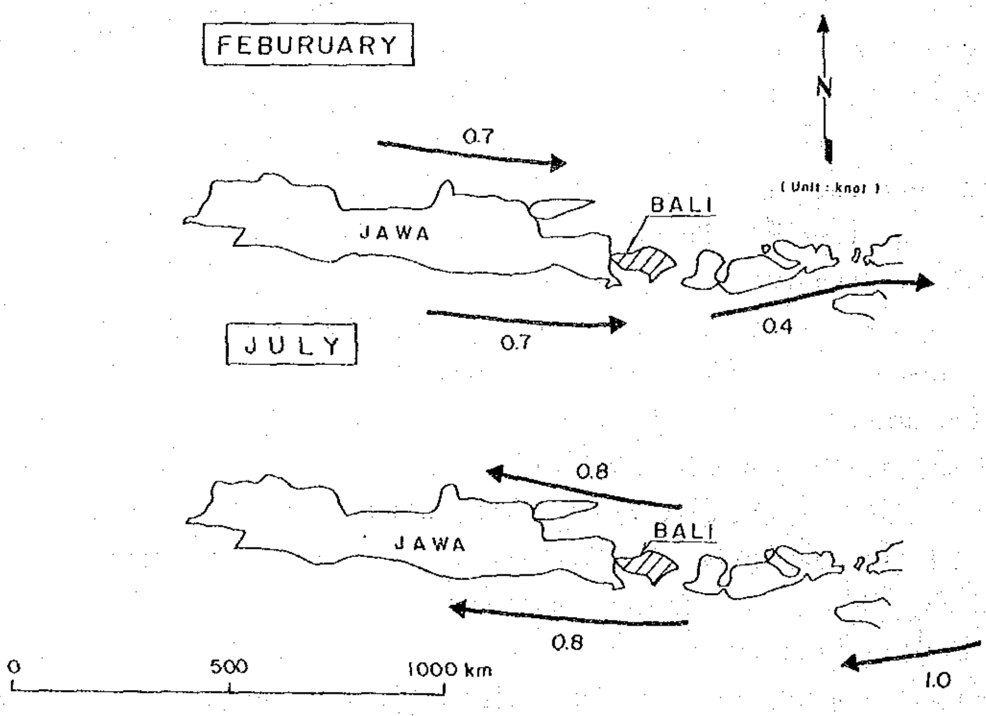


Fig. 2-3-1 Ocean Current

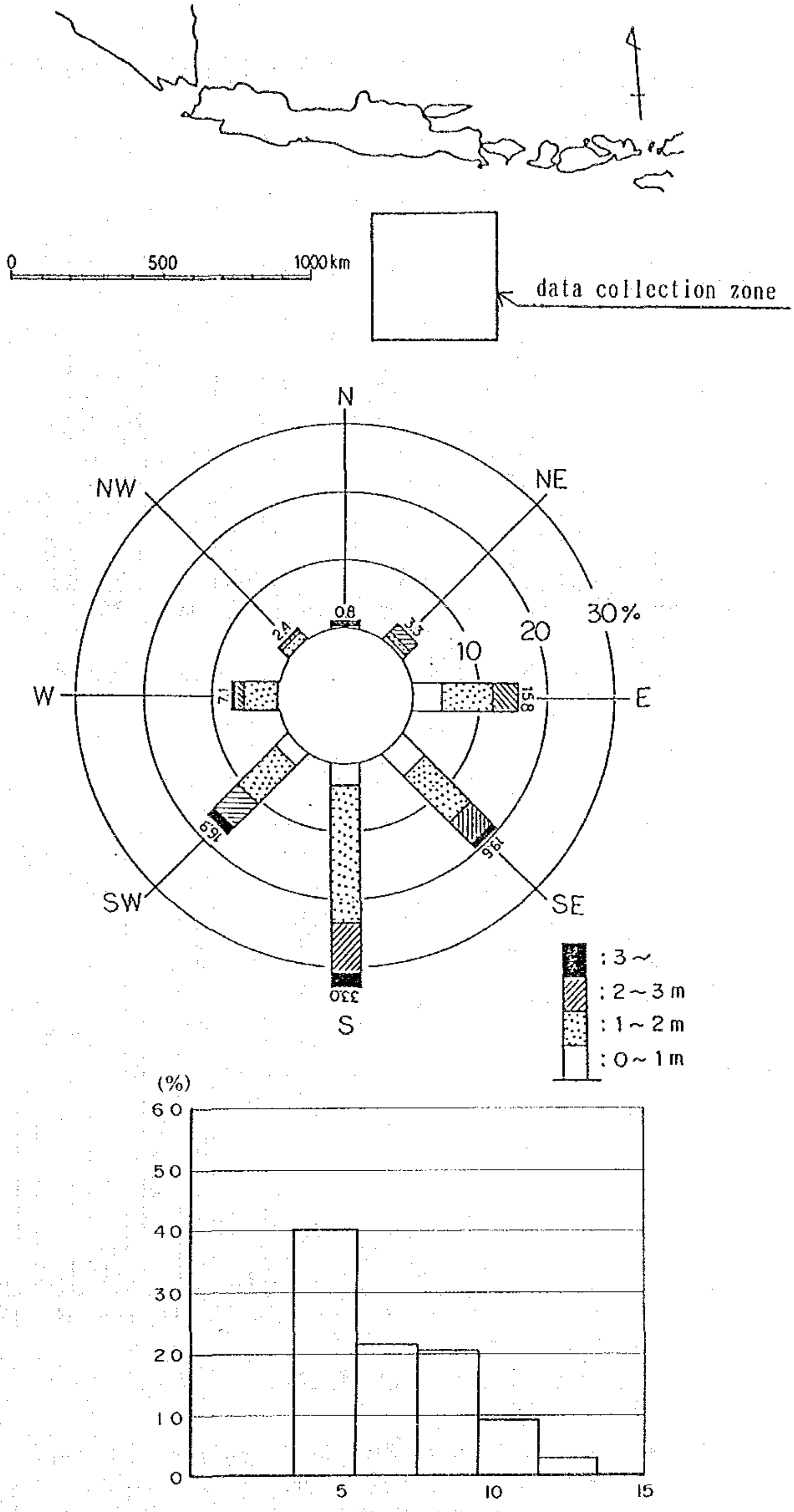
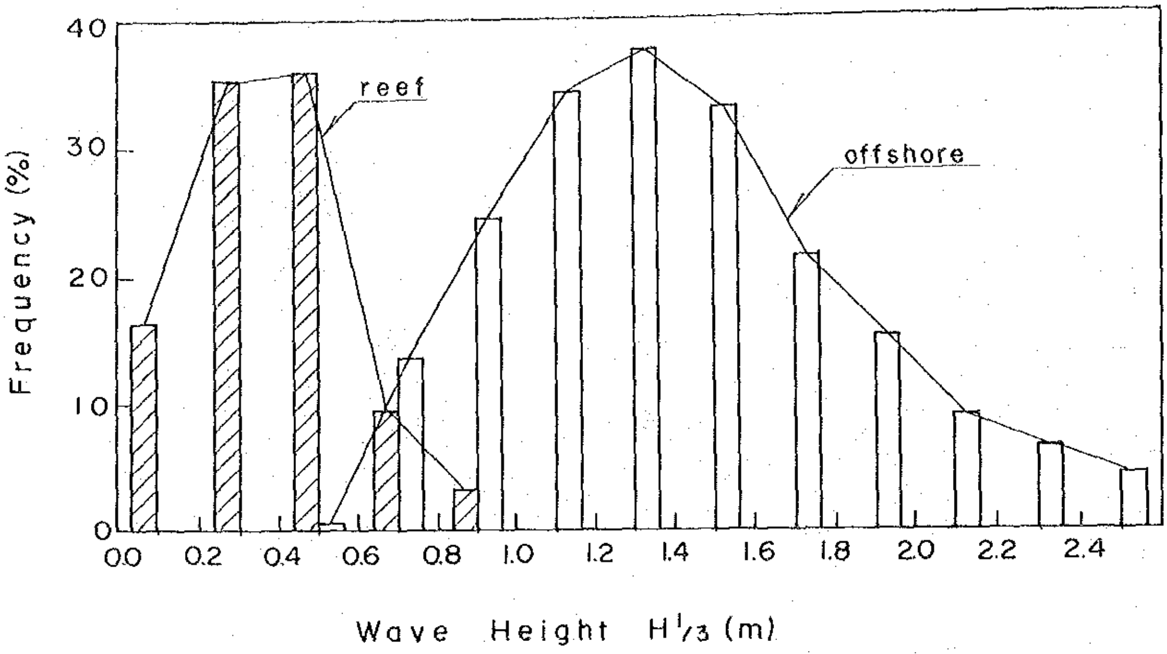


Fig. 2-3-2 Deep Water Waves

KUTA (MAY-JUNE:1988)



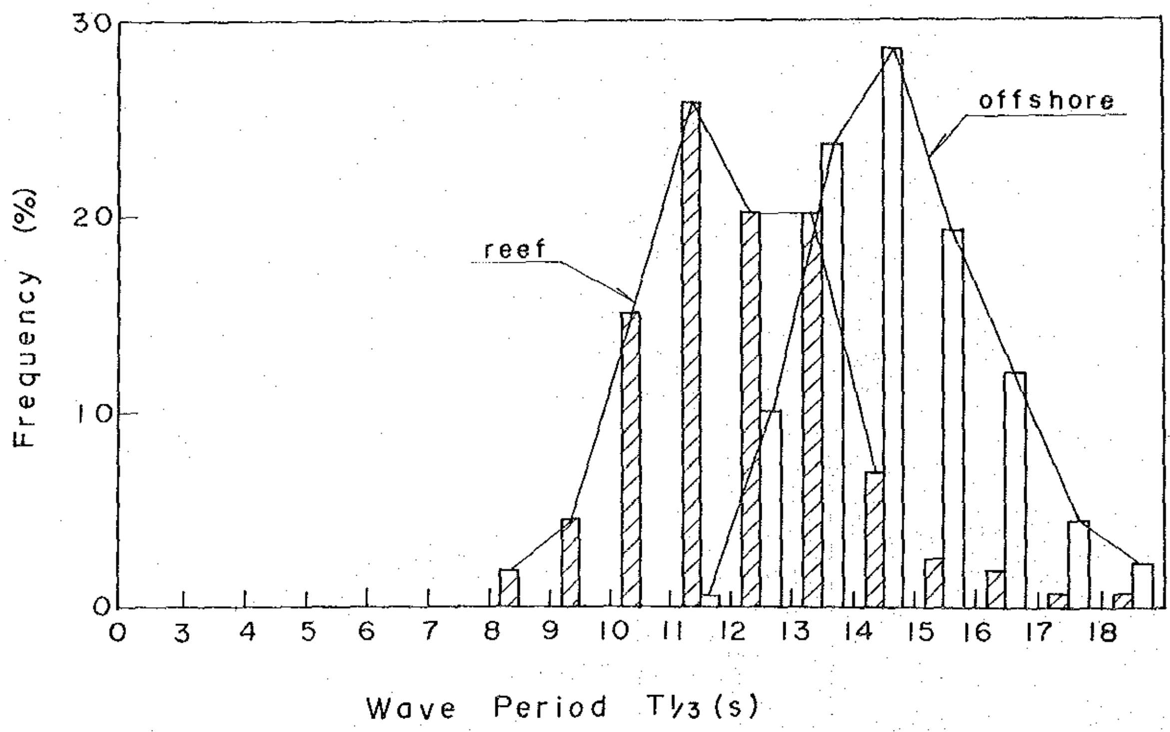


Fig. 2-3-6(1) Distributions of Wove Height and Period at Kuta

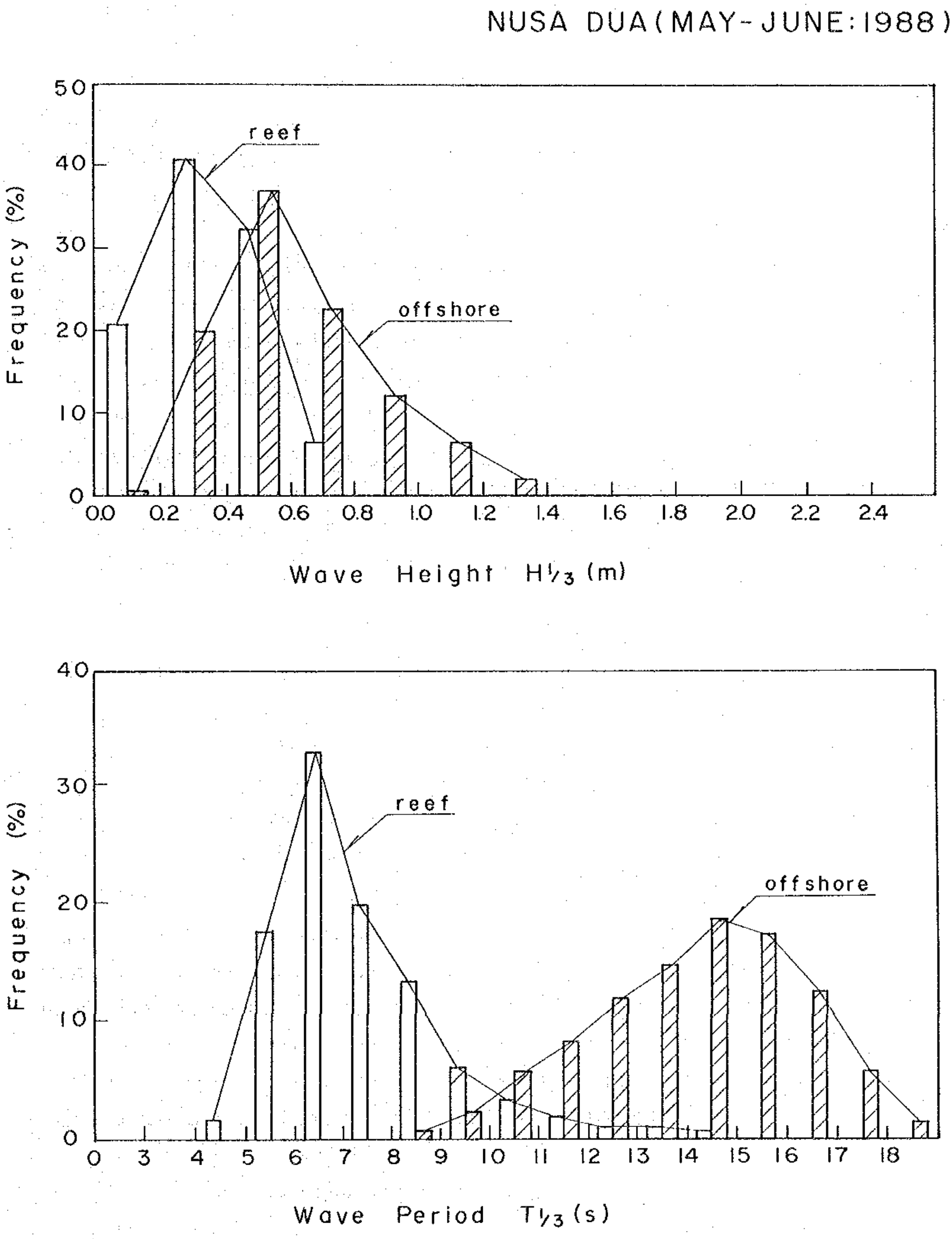


Fig. 2-3-7(1) Distributions of Wove Height and Period at Nusa Dua

3. Topography and Geology

(1) Topography

① Volcanic range, which runs east-west across the northern part of the island.

② Southern slopes of the volcanic range.

③ Low land area between the southern slopes of the volcanic range and Bukit Badung in the southern peninsula.

④ Bukit Badung is made up of flat hills, 100 to 200 meters high, running east to west across the southern peninsula.

The Low land area consists of alluvial plain, sand beach, sand dune, tombolos, lagoon and spit. The topography in this area is very variable due to beach erosion and sedimentation. The main study areas (Kuta Beach, Nusa Dua Beach and Sanur Beach) are included in this area.

(2) Seismicity

Bali Island is covered by an earthquake belt along the island arc. But Bali Island is not a region of very high seismicity.

4. Geological Survey and Bottom Material

(1) Geological Survey

The geological survey was done in Tanah Lot.

Five volcanic breccia samples for unconfined compression test were collected in the lower part of volcaniclastic rocks. Unconfined compression tests were done under natural conditions.

The results concerning the five volcanic breccia samples show 16.0 to 79.1 kg/cm^2 (average 36.7 kg/cm^2) in unconfined compression strength.

(2) Bottom Material of Beaches

i) Kuta Beach

The color of the beach sand gradually changes from white to black toward the north.

The median grain sizes of the bottom material at the beach range from 0.13 to 0.99 mm. Because of the gentle beach slope, the median grain sizes are finer than at Nusa Dua and Sanur Beach.

The magnetic material content and silicate material content gradually change from 2 and 15% to 1 and 35%, increasing toward the north. But the 2.4N−HCℓ soluble material content ranges from 55 to 96%, increasing toward the south. Such a distribution of magnetic material and silicate material increasing toward the north means that they are supplied from the northern beaches and rivers. The 2.4N−HCℓ soluble material is mainly supplied from coral reefs in the offing and is partly supplied from coral limestone in the southern peninsula.

The specific gravities of the bottom material in the beach increase slightly from 2.71 to 2.77 toward the north.

ii) Nusa Dua Beach

The color of the beach sand is white throughout the beach. Therefore, Nusa Dua Beach is very beautiful and still maintains its natural condition.

The median grain sizes of the bottom materials at the beach are 0.62 to 1.28 mm for B samples and 0.28 to 1.12 mm for A samples. Therefore, the median grain sizes are coarser for B samples (sea side) and finer for A samples (land side).

The mineral composition of the bottom material at the beach is not variable and ranges from 1 to 4% in magnetic material content, 0 to 7% in silicate material content and 92 to 99% in 2.4N-HC ℓ soluble material content. Therefore, it is estimated that the bottom material in Nusa Dua Beach is mainly supplied from coral reefs in the offing, and is partly supplied from coral limestone in Bukit Badung and volcanic ash in the surface.

The specific gravities of the bottom material range from 2.63 to 2.77, and show no special tendency.

iii) Sanur Beach

The color of the beach sand is clearly divided with white at the south side and black at the north side, from the groin of the Bali

Beach Hotel.

The median grain sizes of the bottom material are 0.36 to 1.30 mm at the south side and 0.21 to 0.40 mm at the north side, from the edge of the coral reef. The median grain sizes at the south side are obviously coarser than at the north side.

It seems that the coral reef and the groin of Bali Beach Hotel dam up the magnetic material and silicate material which are supplied from the north.

The specific gravities of the bottom material at the beach are very high (4.1 to 4.7) at the north side from the coral reef edge (between sampling site No. 104 A and No. 105 A), and are normal (2.6 to 2.8) at the south side.

CHAPTER 3 GENERAL DESCRIPTION OF THE STUDY AREAS

1. Environment and Landscape

(1) Marine Ecology and Birds

1) The marine life in Kuta is in a bad state. But in Nusa Dua and Sanur, the condition is considered as good, assuming that the level of disturbance is not increasing.

2) The main reason for beach erosion at the three sandy beaches is the destruction of the coral reefs. The destruction may be due to the collection of coral or high siltation. The condition of the seagrass beds which lie between the reefs and coast line depends on the condition of the coral reefs.

3) The observations clearly indicate that human population affects their activities.

4) It is suggested that the means of protecting the beach from erosion should take aesthetic factors and the conservation of marine and other associated animals into consideration. If erosion protection facitities are needed, they should be built in harmony with nature.

5) With regard to regulations concerning flora and fauna, no protected species are located in the study areas.

(2) Present Condition of Tourism

In order to grasp the present conditions of tourism, a questionnaire was distributed to ask each tourist in Kuta, Nusa Dua, Sanua Beaches and Tanah Lot.

Impressions of protection facilities against erosion damage (sewall, wave-absorbing blocks, groin, U-shaped breakwater, offshore breakwater) are in general good at every site because there are few negative answers to the questionnaires.

(3) Sea Water Quality

In general the sea water quality is good, but some parameters are not up to standard. This may be because waste water from residential areas in Denpasar is pouring into the sea.

2. Land Use

(1) Present Land Use

The three major areas were sparsely populated before the 1960s. There were a few small villages and most of the inhabitants were fishermen and small farmers.

During the mid-sixties, tourism in Bali experienced a rapid growth rate, along with hotel development. Tourist-related service activities were also induced by this development.

The major features of land use for each area are as follows:

1) Kuta (Fig. 3-2-1-1)

- This area is mainly composed of two categories; the hotel area and the rosmen area. Almost all the areas are occupied and thus no further construction of new hotels is expected.
- Many shops and restaurants are located along the main street, especially for the tourists. This area has the highest density of shops and restaurants in Bali
- Residential areas are concentrated at both sides of Ngurah Rai International Airport
- The hinterland is used for rice fields

2) Nusa Dua (Fig. 3-2-1-2)

The Nusa Dua Resort Area is developed and managed by Bali Tourism Development Corporation (BTDC) in the context of the Nusa Dua Master Plan, 1973.

- The BTDC area is designed to create a dominant Balinese atmosphere. It comprises nine hotel lots all of which have been leased to developers. All the construction is of low density with a maximum height limitation of 15 meters. This is called a garden resort in that more than half of the area consists of park land covered with velvety green grass and garnished with colourful flowers. Actually this is really an international standard resort.

- There are reserved hotel sites in the cape area. Developers plan to construct hotel facilaities at Yeh Kuwu Kaje, Terore Tengah, Terore Kaje, Desa Kampial and Desa Benoa.
- Traditional villages were moved to Bualu and form only one residential area in the Nusa Dua area. Land around the present residential area is reserved for a residential area in the future.

3) Sanur (Fig. 3-2-1-3)

This area shows the highest degree of various land use categories among the three resort areas.

- The hotel area spreads along Sanur Beach
- In the adjacent hinterland area behind the hotel zone there is a residential area
- Shops and restaurants are located along the main street, but they located rather densely around the Government offices
- The major features is the small number of rosmen. This area is composed of only three categories; hotel, residence and shops/restaurants

(2) Future Land Use

1) In Kuta and Sanur areas, no new hotels are expected because of land availability. Almost all the areas are already occupied by the existing hotels and rosmen.

2) Nusa Dua has a glorious prospect for the further development of new hotels and the further expansion of hotel and tourism facilities. In six out of the nine BTDC hotel lots, new hotel buildings and halls are planned by the year 2000. In addition, some hotel construction is planned outside the BTDC area, especially in Terore Tengah.

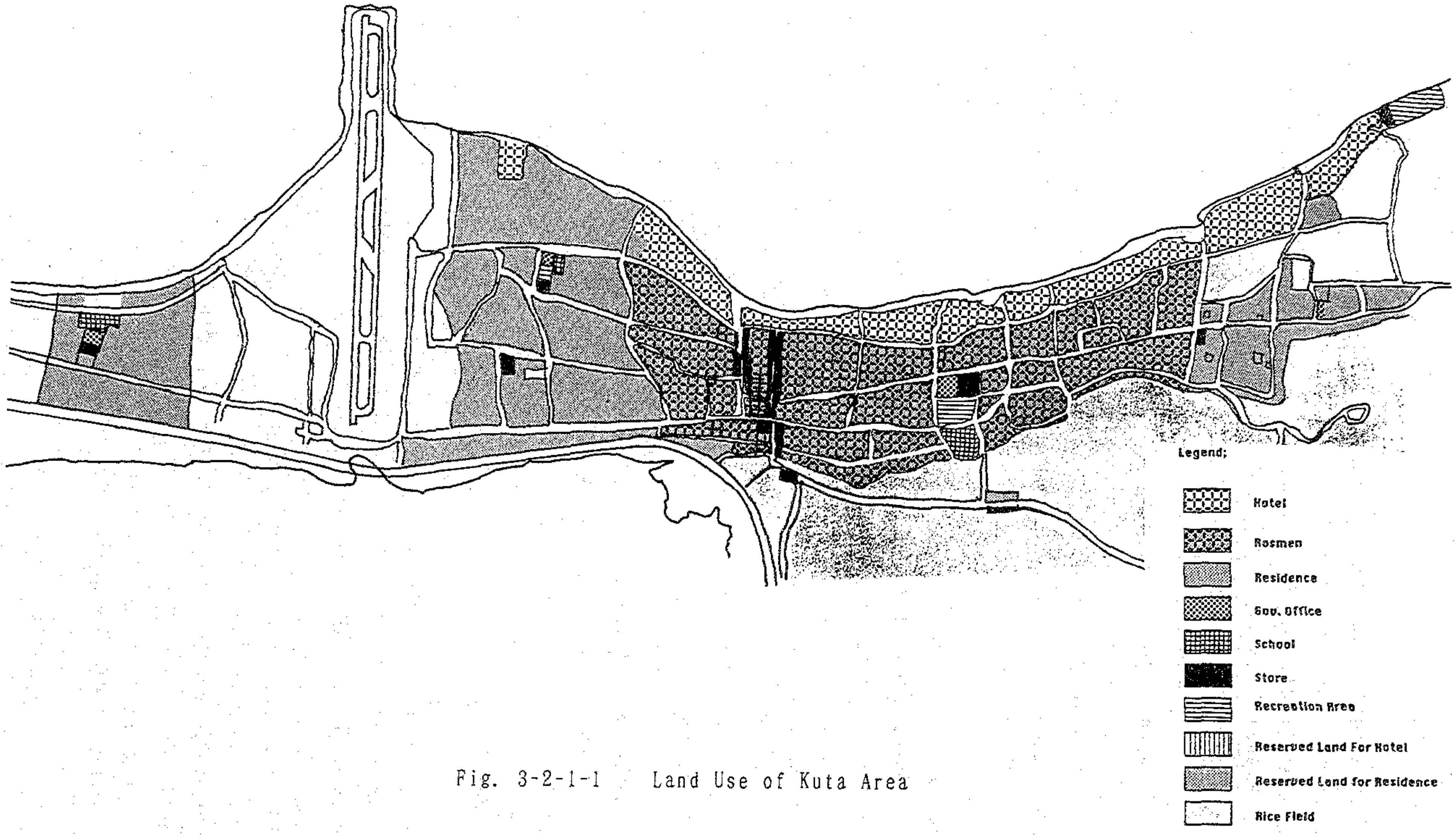


Fig. 3-2-1-1 Land Use of Kuta Area

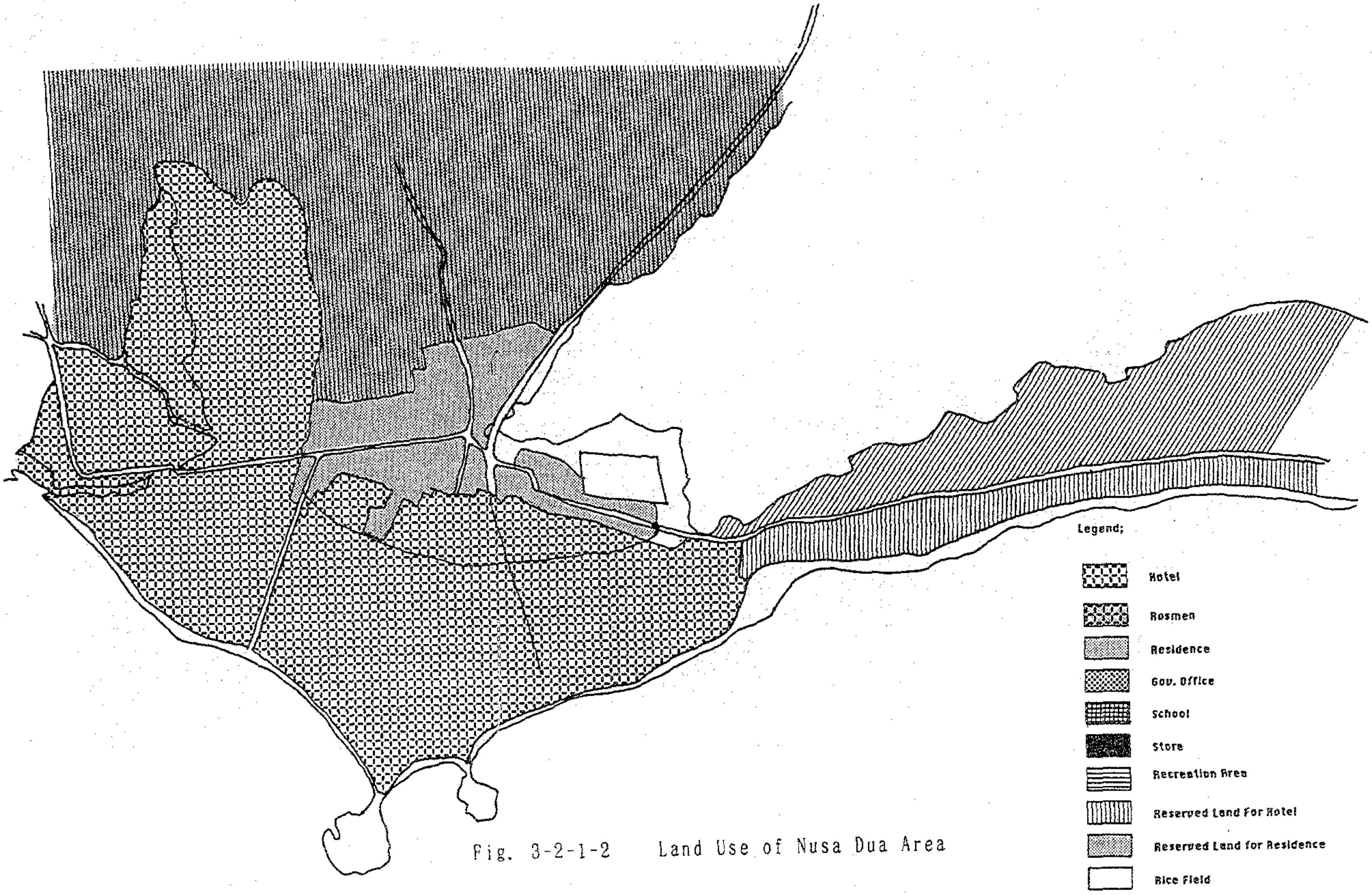


Fig. 3-2-1-2 Land Use of Nusa Dua Area

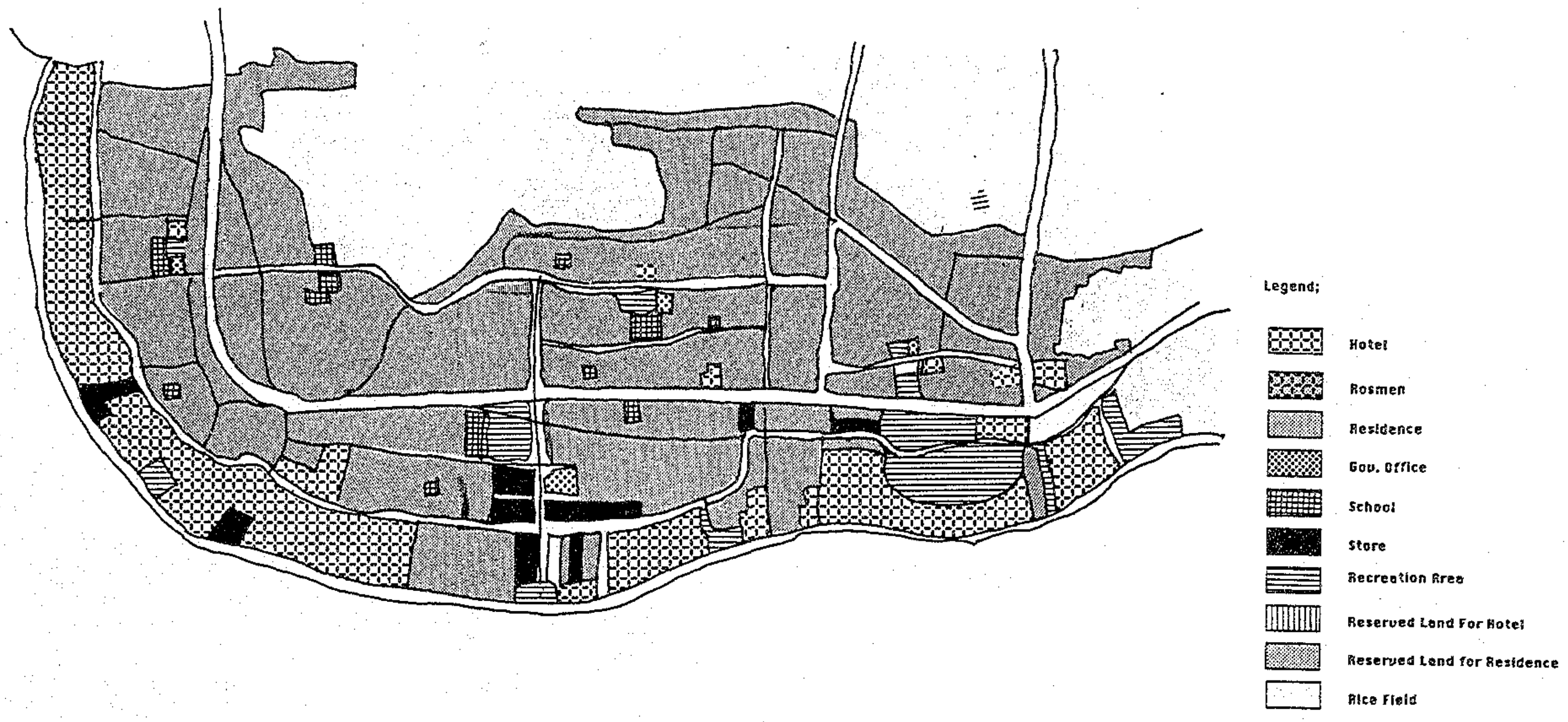


Fig. 3-2-1-3 Land Use of Sanur Area

3. Erosion

(1) Erosion in Bali Island

The coastline of Bali island is approximate 430 Km long. The erosion process depends on the waves, tides and currents, etc. which all influence the amount of energy that is transported to the coast.

The urgency of beach conservation works is classified into four levels as shown in Table 3-3-1-2.

Table 3-3-1-2 Classification of Urgency for Beach Conservation

No. of Priority	Evaluation of urgency	Location of beach
No. 1	Urgently required	Kuta, Nusa Dua, Sanur, Batu Madeg, Tanah Lot, Uluwatu.
No. 2	Required	Lebih, Siyut, Tegar Besar, Gumicik, Sangsit
No. 3	Protection of Roads	Pulaki, Gondol, Bukit, Gumrih
No. 4	Future Work	Sudimara, Candi Kesuma

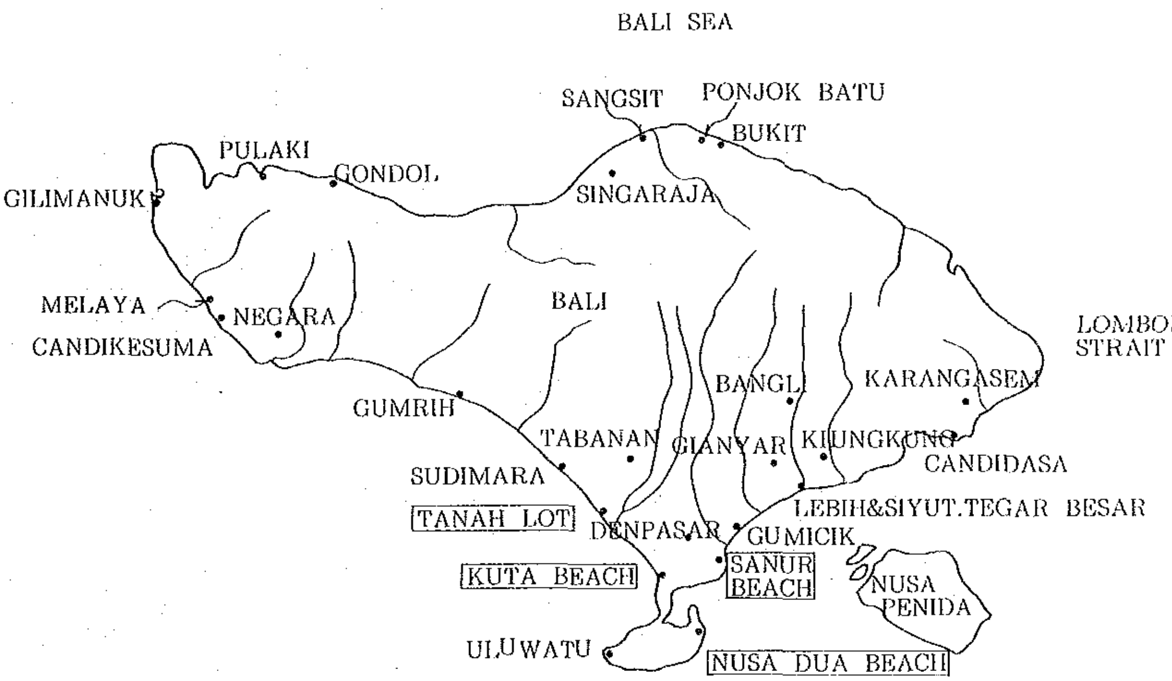


Fig. 3-3-1-1 Location of Beach Erosion in Bali Island

(2) Kuta

1) Change of shoreline (Kuta)

The length of the study area is about 3.0 kilometers, and the area is divided into seven divisions (A through G) based on the erosion condition (Fig. 3-3-2-1).

2) Change of beach profile (Kuta)

The change of beach profile between the years 1978 and 1988 is shown in Fig. 3-3-2-1～2.

3) Volume of eroded beach sand (Kuta)

Area	Volume of sand loss
600 ～ 1,000 m	42,800 m^3
1,000 ～ 1,900	94,240
1,900 ～ 2,400	24,200
Total area 1,800 m	161,240 m^3/10 years

The total loss of sand is about 16,000 m^3 per year.

(3) Nasa Dua

1) Change of shoreline (Nasa Dua)

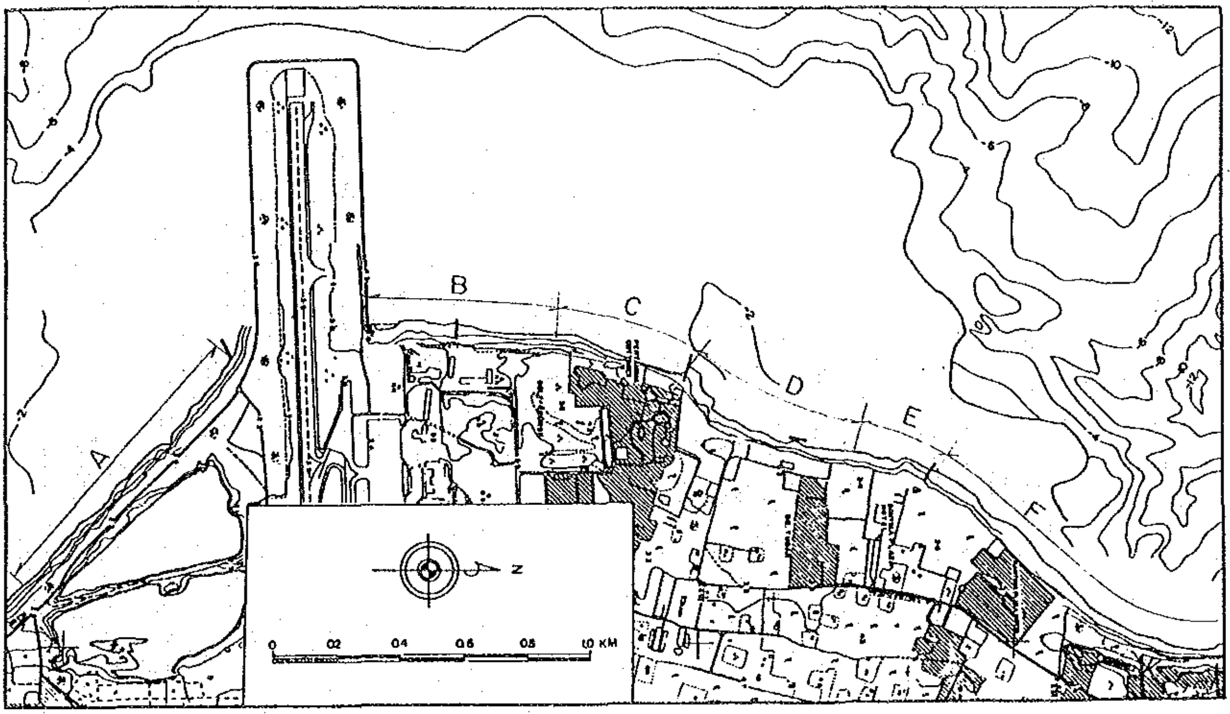
The study area is divided into eight divisions from A through H according to the erosion condition (Fig. 3-3-2-4).

2) Change of beach profile (Nusa Dua)

The change of the beach profile between 1983 and 1988 is shown in Fig. 3-3-2-4～5.

3) Volume of eroded beach sand (Nusa Dua)

Change of sand volume
within five years (1983-1988) 81,000 m^3



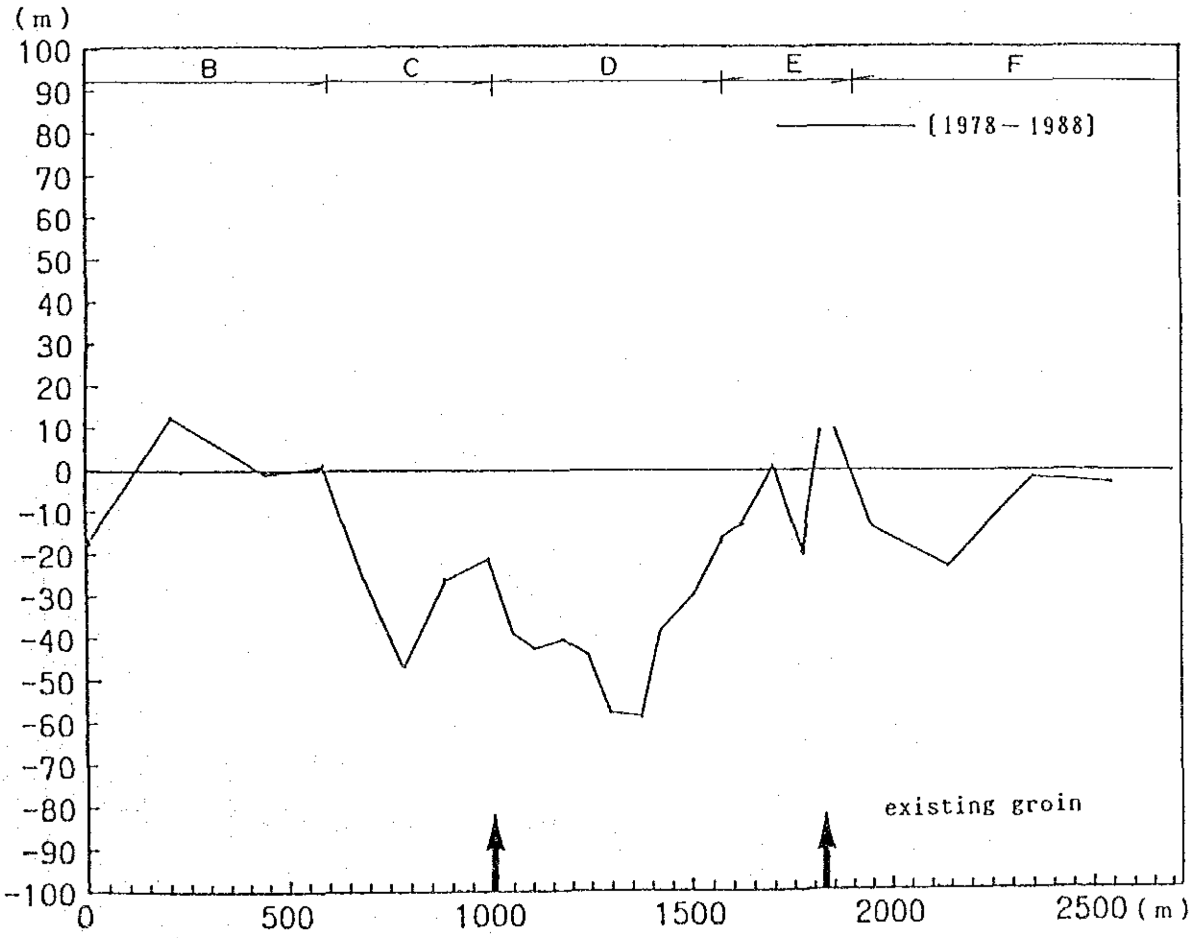


Fig. 3-3-2-1 Shoreline Change at Kuta

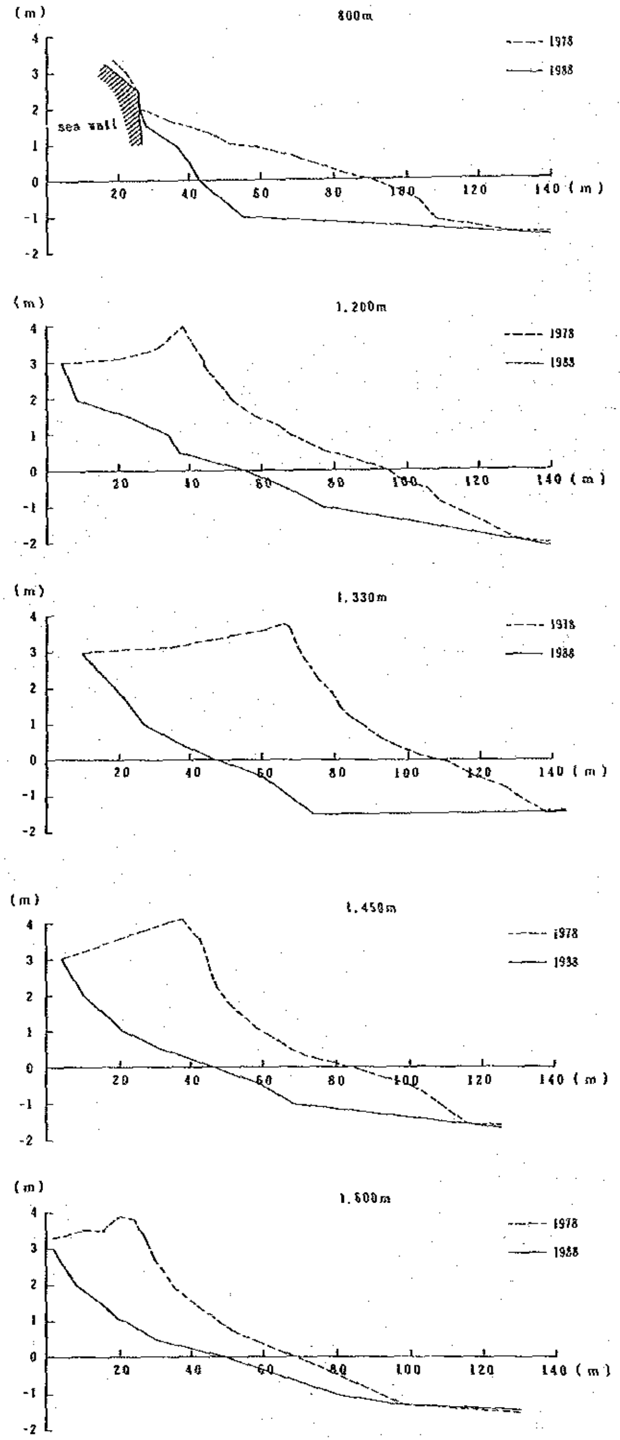


Fig. 3-3-2-2 Beach Profiles at Kuta

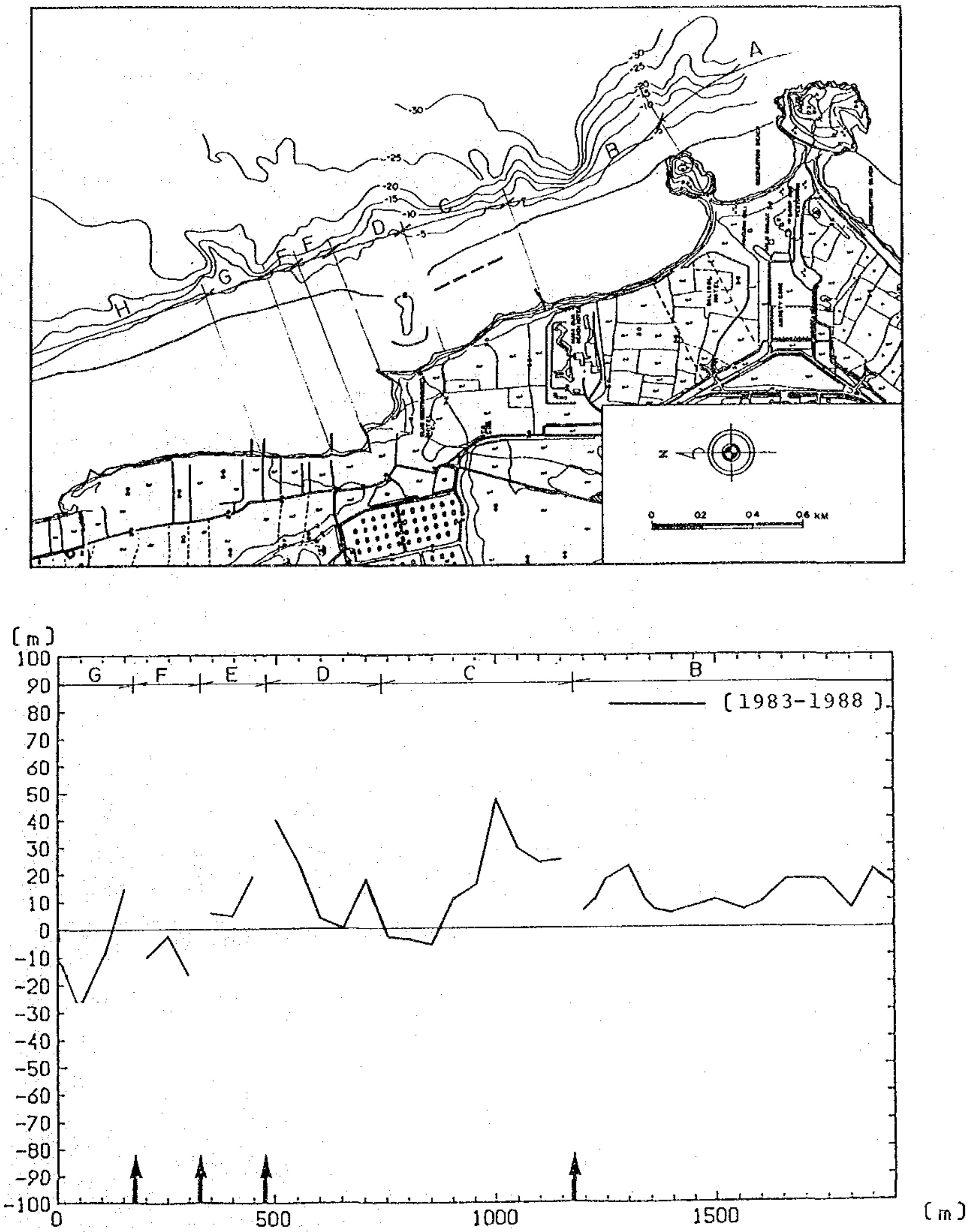


Fig. 3-3-2-4 Shoreline Change at Nusa Dua

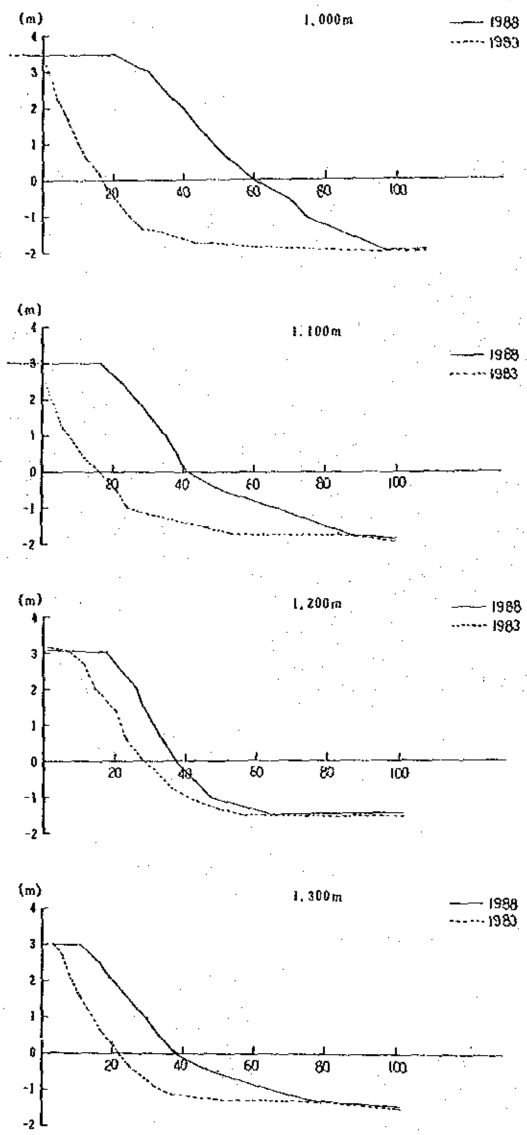


Fig. 3-3-2-5 Beach Profiles at Nusa Dua

Total volume of sand fill within the same period — -100,000

-18,900 m^3

The total loss of sand in five years is about 20,000 m^3; 4,000 m^3 per year.

(4) Sanur

1) Change of shore line (Sanur)

The area is divided into eight divisions from A to H, as shown in Fig. 3-3-2-7.

2) Change of beach profile (Sanur)

The beach profiles of the years 1978 and 1988 are shown in Fig. 3-3-2-7~8.

3) Volume of eroded beach sand (Sanur)

Area	Volume of sand loss
400- 500 m (South beach)	27,700 m^3
3,000-4,000 (Central beach)	31,300
4,000-5,000 (North beach)	31,600

The total loss of sand is about 9,000 m^3/year.

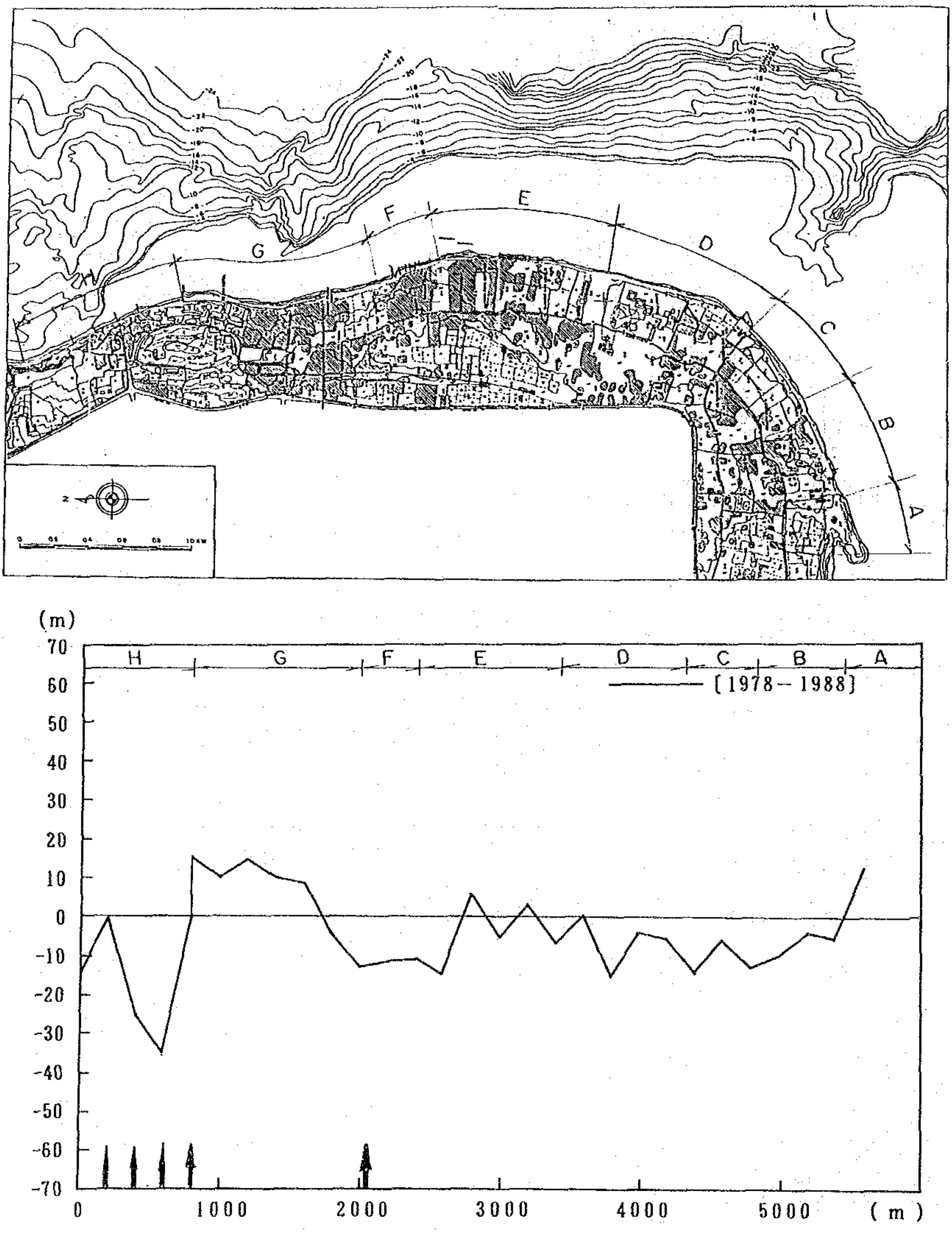


Fig. 3-3-2-7 Shoreline Change at Sanur

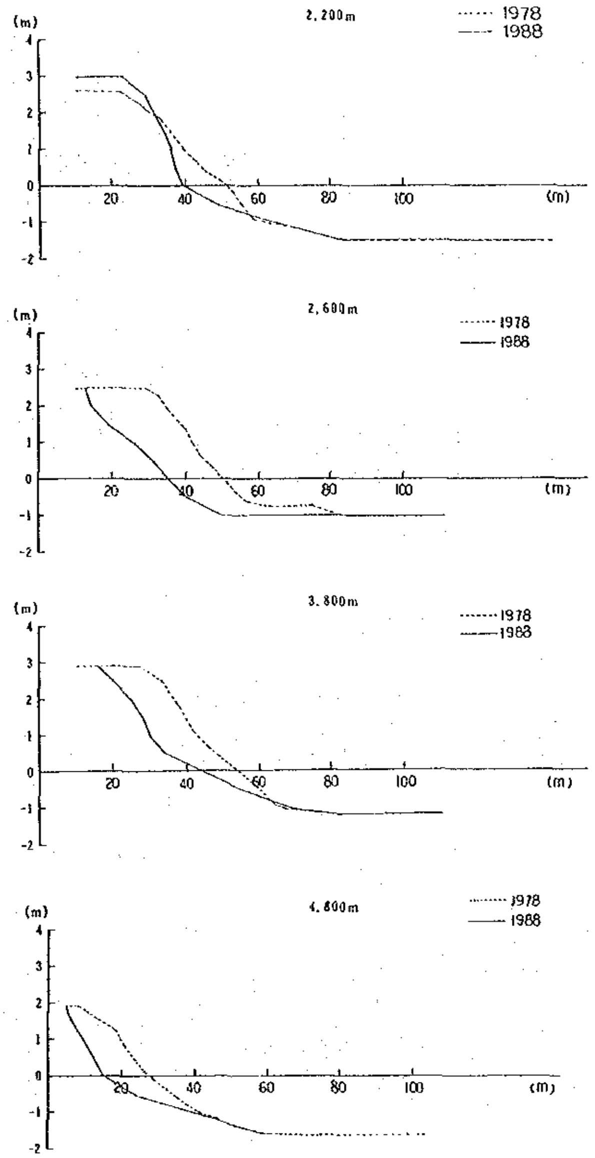


Fig. 3-3-2-8　　Beach Profiles at Sanur

(5) Tanah Lot

A small rocky island, where Tanah Lot temple is located, has been suffering from severe erosion by waves for a long period of time and shows many eroded holes or caves on the surface. Some of them are very deep and measure up to 10-20 meters in depth.

CHAPTER 4 CAUSES OF SHORELINE EROSION

(1) General

Natural causes of erosion are those which occur as a result of the response of the beach to the effects of nature. Man-induced erosion occurs when human endeavors impact on the natural system.

Natural Causes :

a. Sea Level Rise.
b. Variability in Sediment Supply to the Littoral Zone.
c. Storm Waves and Offshore Currents.
d. Wave and Surge Overwash.
e. Deflation.
f. Longshore Sediment Transport.
g. Sorting of Beach Sediment.

Man-Induced Causes :

a. Land Subsidence from Removal of Subsurface Resources.
b. Interruption of Material in Transport.
c. Reduction of Sediment Supply to the Littoral Zone.
d. Concentration of Wave Energy on Beaches.
e. Increase in Water Level Variation.
f. Change of Natural Coastal Protection.
g. Removal of Material from the Beach.

(2) Causes of Erosion at the Study Areas

It is evident that at Tanah Lot the vertical cliff on the island has been eroding due to the severe wave action. The rest of the sites (Kuta, Nusa Dua, and Sanur) consist of sandy beaches, and it is not straightforward to identify the causes of their erosion. A clue to the question is that until several decades ago the beaches had been fairly stable: neither eroding nor accreting. While we should have reservations about its arthenticity because the beach erosion may not have been as serious a concern in those days, it appears reasonable, with the limited data available on the nearshore topography and wave climate, to seek the causes from what has recently occurred or changed.

On Kuta beach an airport runway was constructed in 1969 virtually as a huge groin. On Kuta and Sanur beaches coral stones have been actively dredged so that arriving waves are greater than in the past. In the following, the areas are defined in Fig. 3-3-2-1, 4 and 7.

1) Kuta

Kuta beach especially in area D has been seriously eroding. The direct cause is apparently the wave and surge overwash (Natural Cause d). The tracer tests indicate the northward longshore drift in area D during the study period. The incident-wave direction, mostly southwest, also suggests the long-term longshore drift in the north direction. The runway appears to trap sediment material which would be transported from A to B, C, ... (Natural Cause f, Man-Induced Cause b), whereas in area A no permanent tendency of accretion is observed possibly because of the reflected wave by the runway. In area B the slope is armored with some revetments and no waves are incident from the southwest except through diffraction, thereby reducing the sediment supply to area D due to the longshore drift. (Man-Induced Cause c). The circulating current due to diffraction behind the runway results in accretion in area B. The coral dredging has allowed higher waves to reach the beach (Man-Induced Cause f). Another possibility cited is that some beach material may be permanently lost into the greater offshore depths from area F where the reef is very narrow (Natural Cause c).

2) Nasu Dua

On this beach except at area B the northward longshore drift is apparent from the fact that at the existing groins accretion is observed on the south side. The islands of Nusa Dua, whether or not connected with the beach, hinder the beach-material supply from the south (Natural Causes b and f) as a huge detached breakwater. Thanks to the beach fills conducted lately, the beach along its total stretch has rather accreted for these five years. However, the tracer tests and flow measurements show that some beach material is still lost into the canyon behind the U-shaped groin which does trap a significant amount of sediment which would fall into the canyon (Natural Cause c).

3) Sanur

The longshore drift is apparently southward in areas A and B and northward in D to H, judging from the accretion pattern on the groins and the results of the tracer tests and flow measurements. Areas C and D are eroding because of the negative sediment flow due to the longshore drift (Natural Cause f). During the study period a deposit of sand was observed along the boundary of areas C and D between the shoreline and the canyon mouth. This suggests some mechanism to induce a flow transporting the sediment material from somewhere else and make it settle down there. In conflict are the results of the flow measurements that show the flows away from the canyon. The results are also contrary to the results at Nusa Dua. At present it is not obvious whether each of these facts (deposition and flow directions) reflects the short-term or long-term tendency and further study is necessary. Area F is also eroding because the offshore breakwaters existing in area E trap the sediment which would be supplied into area F (Man-Induced Cause b). The same is the case for area H due to the heliport on the boundary between areas G and H (Man-Induced Cause b). The coral dredging has allowed higher waves to reach the beach (Man-Induced Cause f).

CHAPTER 5 HYDRAULIC EVALUATION OF THE URGENT PLAN

1. Hydraulic Model Test

Hydraulic model tests are aimed at examing the behavior of waves and currents which cause sand movement on the coral reef, and are also aimed at verifying the effects of preservation works against the present beach erosion.

The main results obtained in the 3-dimensional experiment are summarized in Figs. 5-1-3-21 and 22. Taking into account the wave height distribution at Kuta Beach, a calm wave condition will be generated behind the T type groin, sufficient to deposit beach sands even at the beach area without the coral reef as well as at the beach area surrounded by the reef. If a T type groin is set on the reef, the position near the narrow reef zone seems not to be suitable because it causes a strong current towards the offshore zone. Therefore, the arrangement of the T type groin apart from the narrow reef position is preferable at Kuta Beah as in c') as shown in Fig. 5-1-3-21.

Judging from the wave height distribution and the current field at Nusa Dua Beach, the proposed plan for the prevention work against beach erosion is thought to be effective in maintaining the beach sand on account of generating a wide calm wave field near the shoreline.

According to the wave flume tests, the dredging of bed material on the reef is not desirable because the wave height on the reef would increase much more than without dredging.

2. Computer Simulation

In view of the nature of the study and the available data, we use the so-called one-line model. The one-line model is one-dimensional and deals with the advancement and retreat of the shoreline along a sandy coast.

The first task is to find the wave and associated parameters that would best reproduce the shoreline evolution undergone from a previous time t_1 (say, 10 years ago) to a later time t_2 (say, the present).

The model wave thus found will in the forecast run bring about the shoreline change with the proposed countermeasure structures to be encountered from the time t_2 to a later time t_3 (say, 10 years from t_2).

Oceanographic data and sediment properties serve to find the model wave. In this study, however, such data available is far from sufficient, and we resort to the data on shoreline change. At Kuta and Sanur the shoreline data are available for the year of 1978 and at Nusa Dua for 1983. These data are used as the initial state for the shoreline evolution up to 1988 when the shoreline survey was done at each site in this study.

(1) Kuta

Fig. 5-2-4-2 plots the shoreline evolution with and without the planned measures. The bold and dotted curves represent the final shorelines after 10 years with and without the measures. Fig. 5-2-4-3 plots the accumulated longshore transport. This calculation tells that:

1) The erosion would progress without new countermeasure structures.

2) In order to trap the sediment that would leak alongshore, sufficiently long would be the groins except the rightmost one.

3) Sand trapped between a pair of groins tends to be distributed in the region so that the resultant shoreline parallels the incoming crests.

(2) Nusa Dua

Fig. 5-2-4-7 plots the shoreline evolution, and Fig. 5-2-4-8 the corresponding longshore transport. The following can be seen from the forecast run with new structures. It is seen that stable would be the region ($1,200 < x < 1,900$) between the island and the rightmost groin. Between the groin and the U-shaped groin the wave energy would be uniform with no detached breakwaters and a stable shoreline could be formed if oriented properly as shown in Fig. 5-2-4-7. Also in the region ($300 < x < 600$) between the U-shaped groin and the extended straight groin at $X = 300$, a significant amount of sand transport would take place.

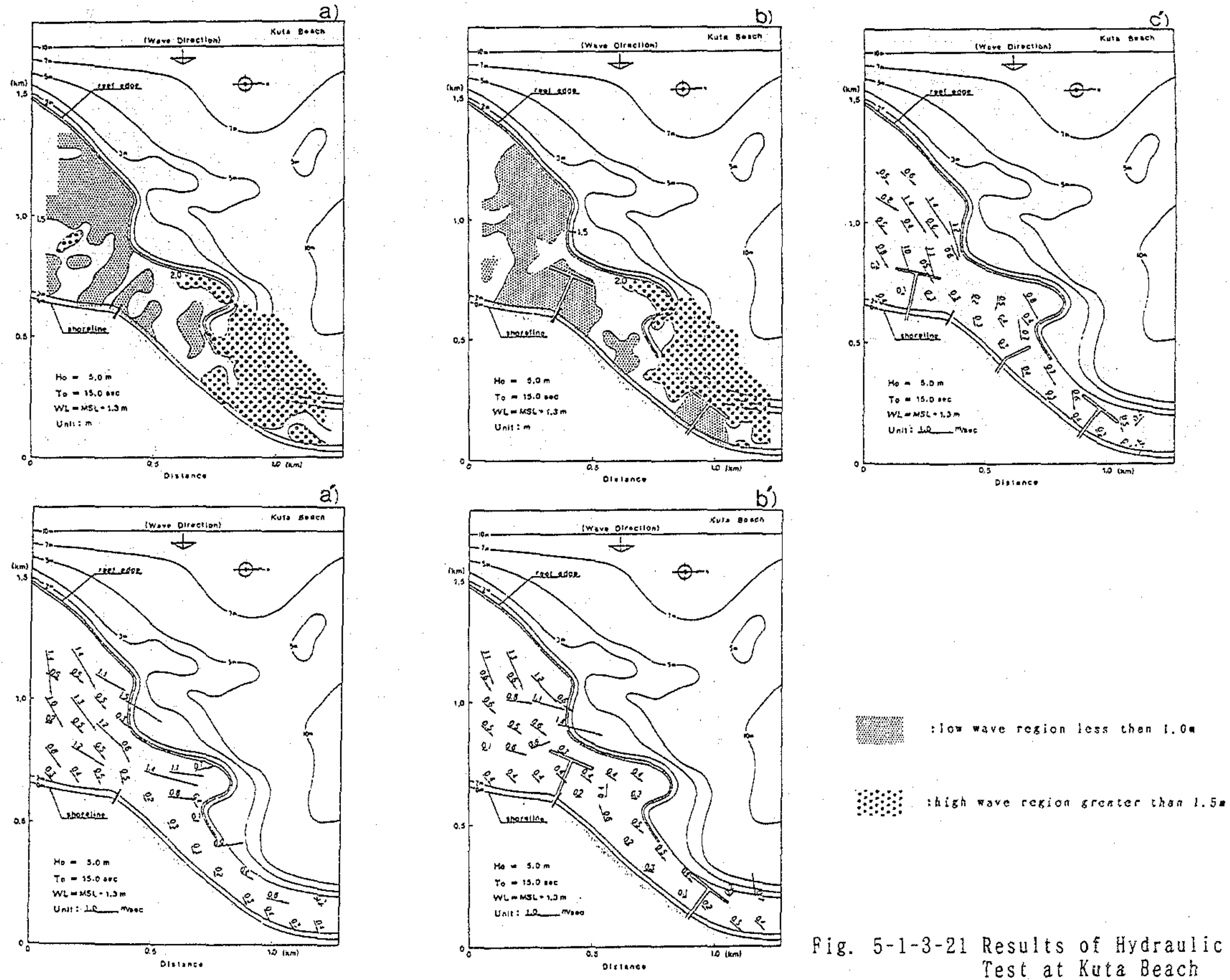


Fig. 5-1-3-21 Results of Hydraulic Model Test at Kuta Beach

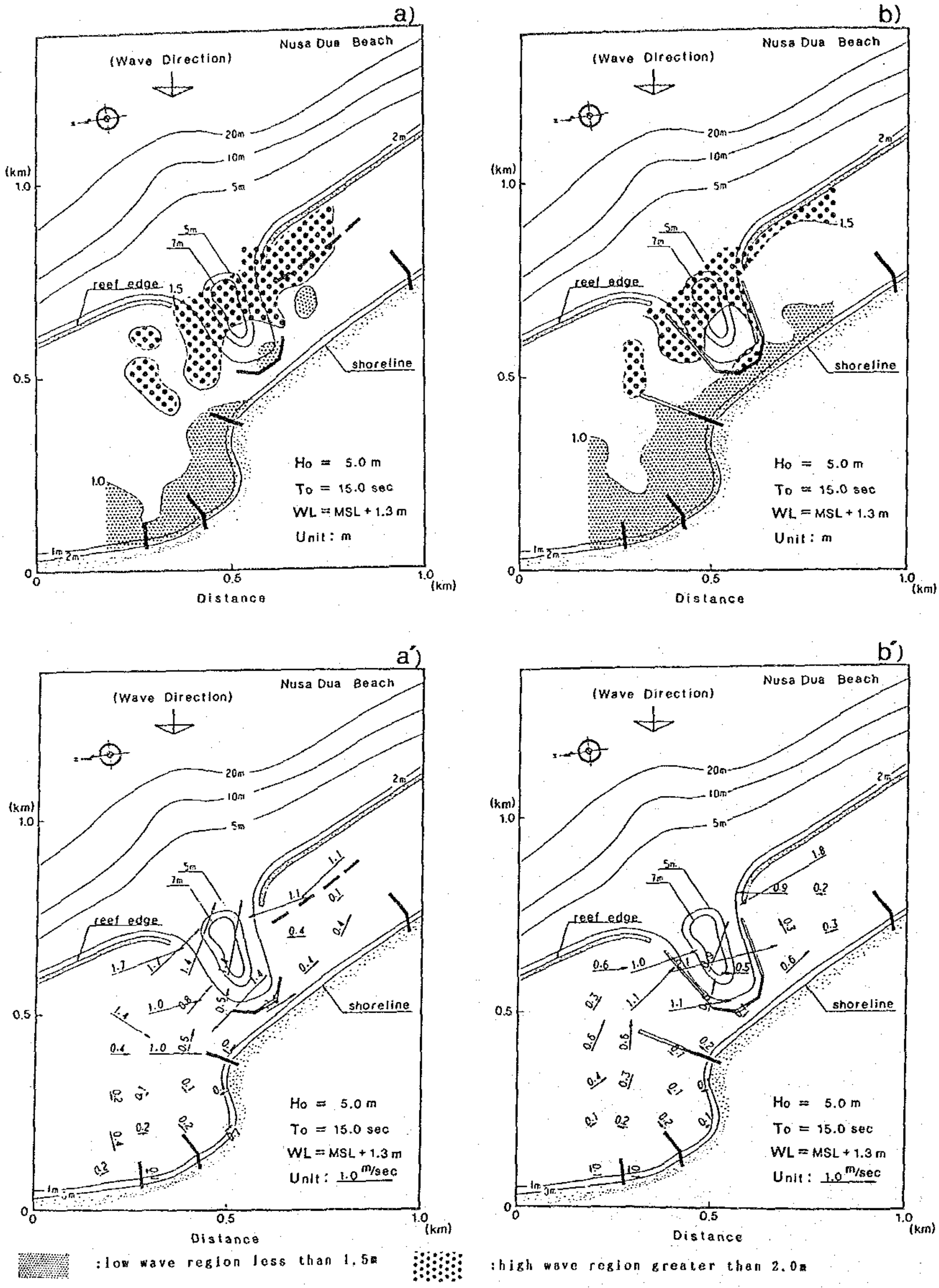


Fig. 5-1-3-22 Result of Hydraulic Model Test at Nusa Dua Beach

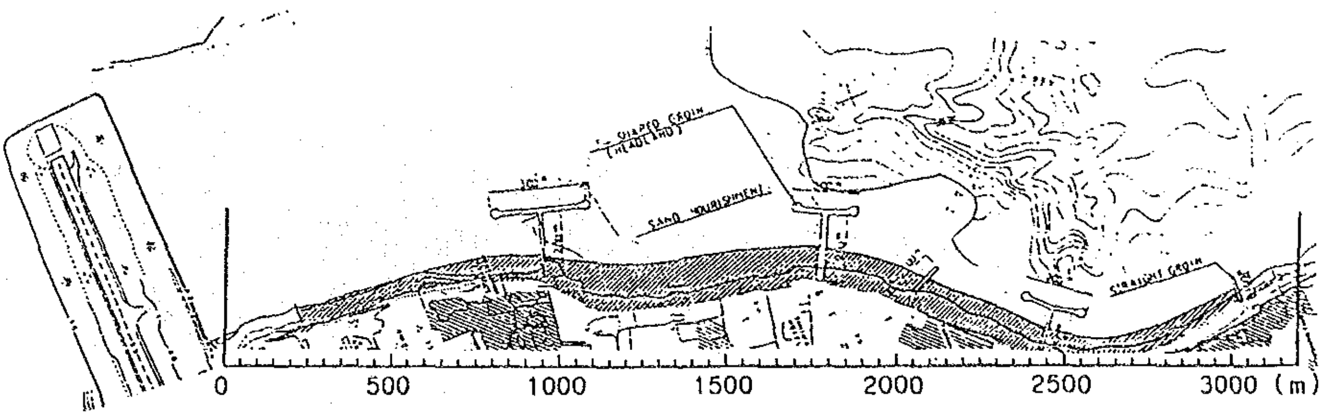


Fig. 5-2-4-1 Proposed Plan 1 (Kuta)

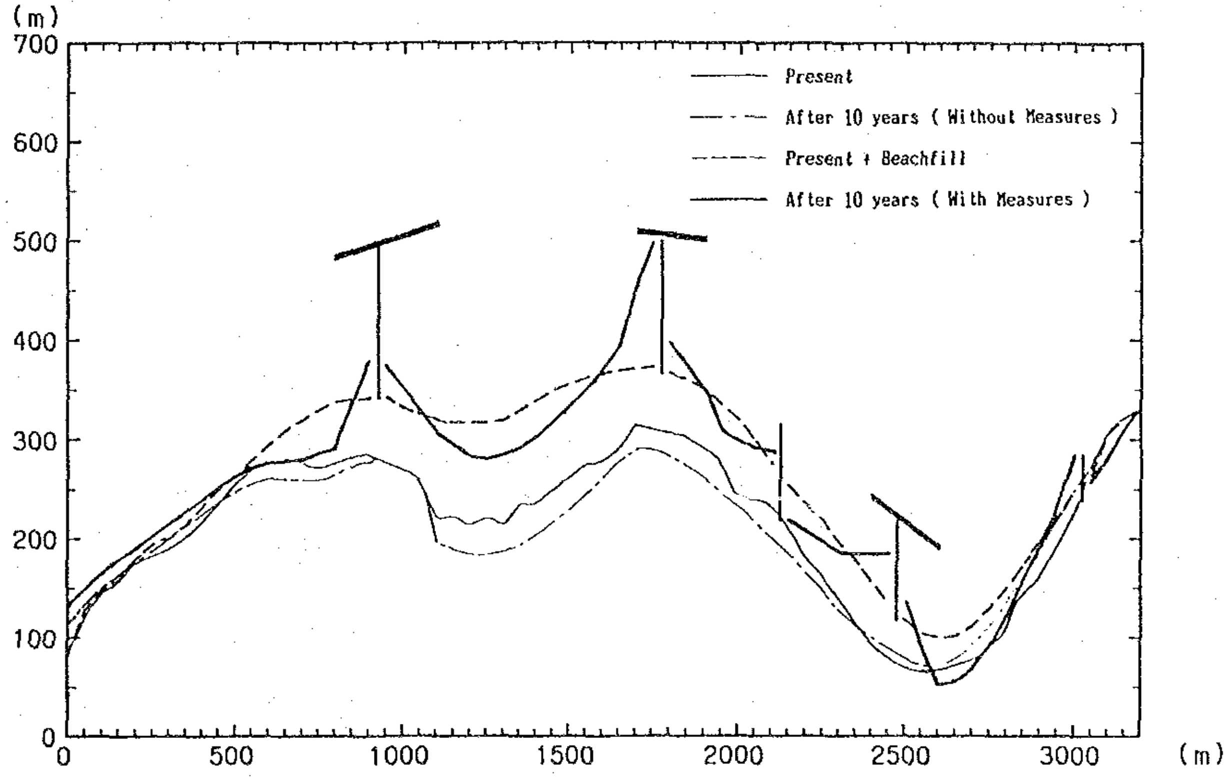


Fig. 5-2-4-2 Shoreline Evolution with Plan 1 (Kuta)

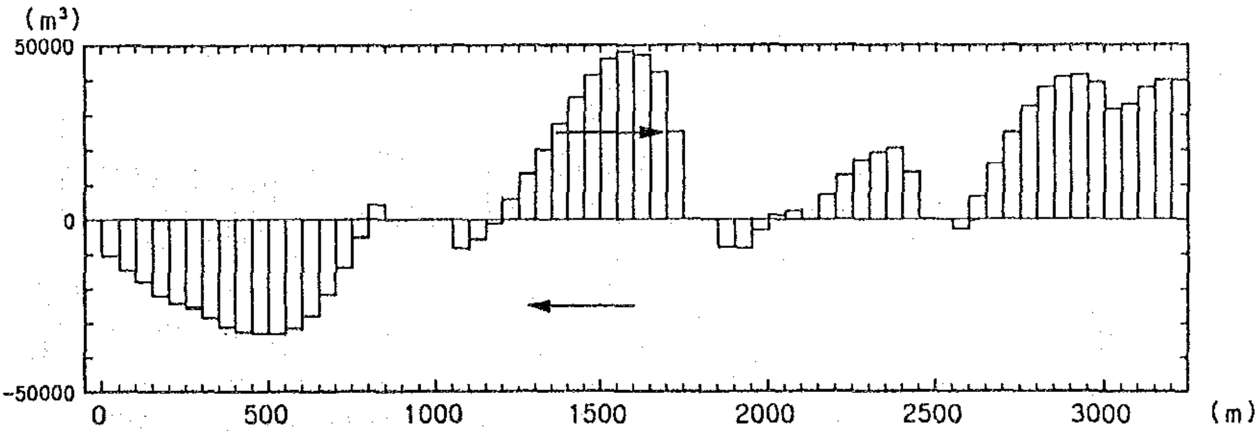


Fig. 5-2-4-3 Accmulated Longshore Transport(Kuta)

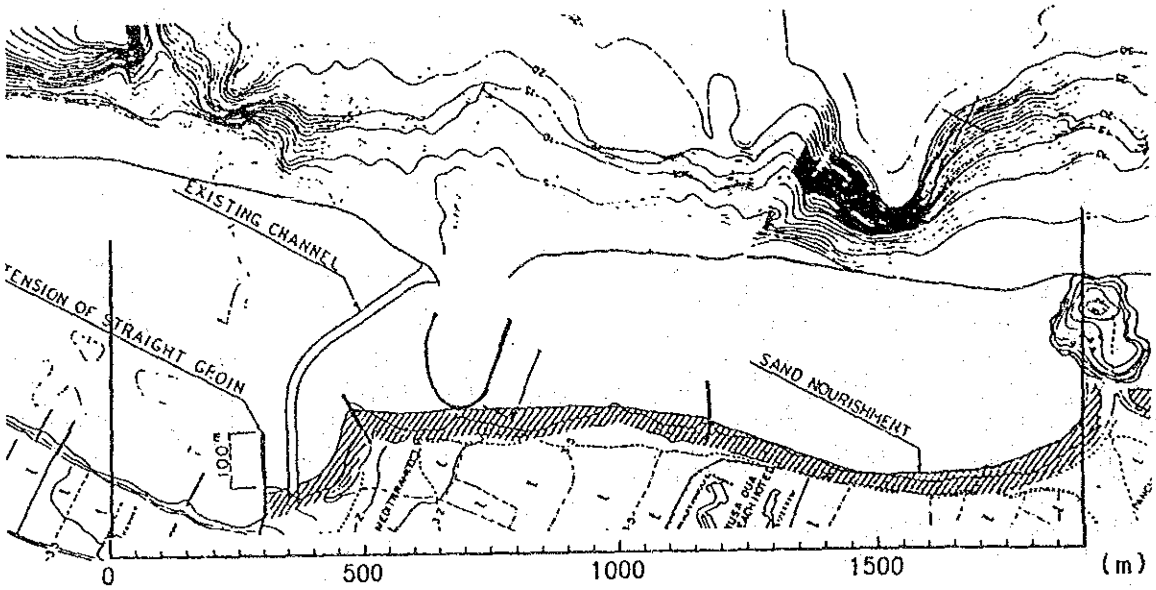


Fig. 5-2-4-6 Proposed Plan (Nusa Dua)

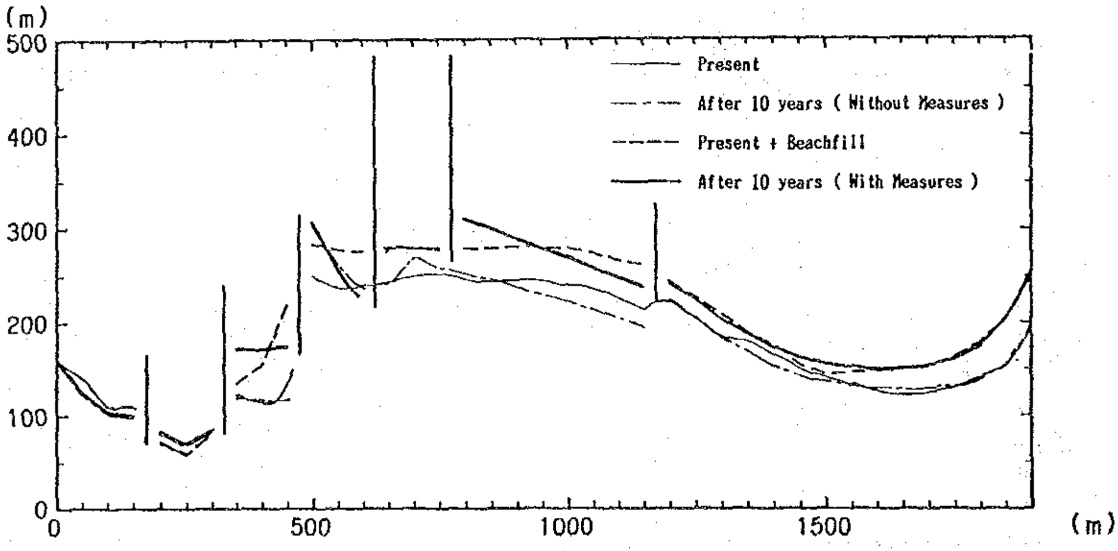


Fig. 5-2-4-7 Shoreline Evolution (Nusa Dua)

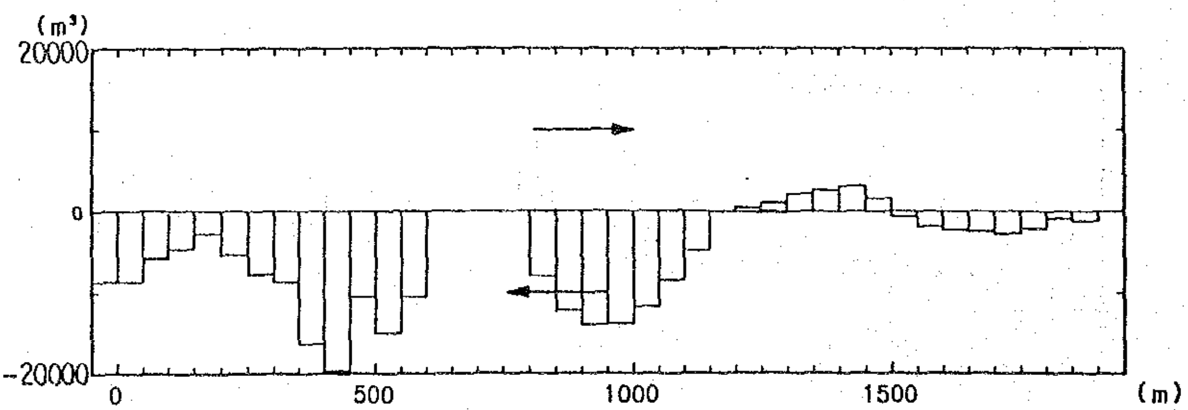


Fig. 5-2-4-8 Accumulated Longshore Sediment Transport (Nusa Dua)