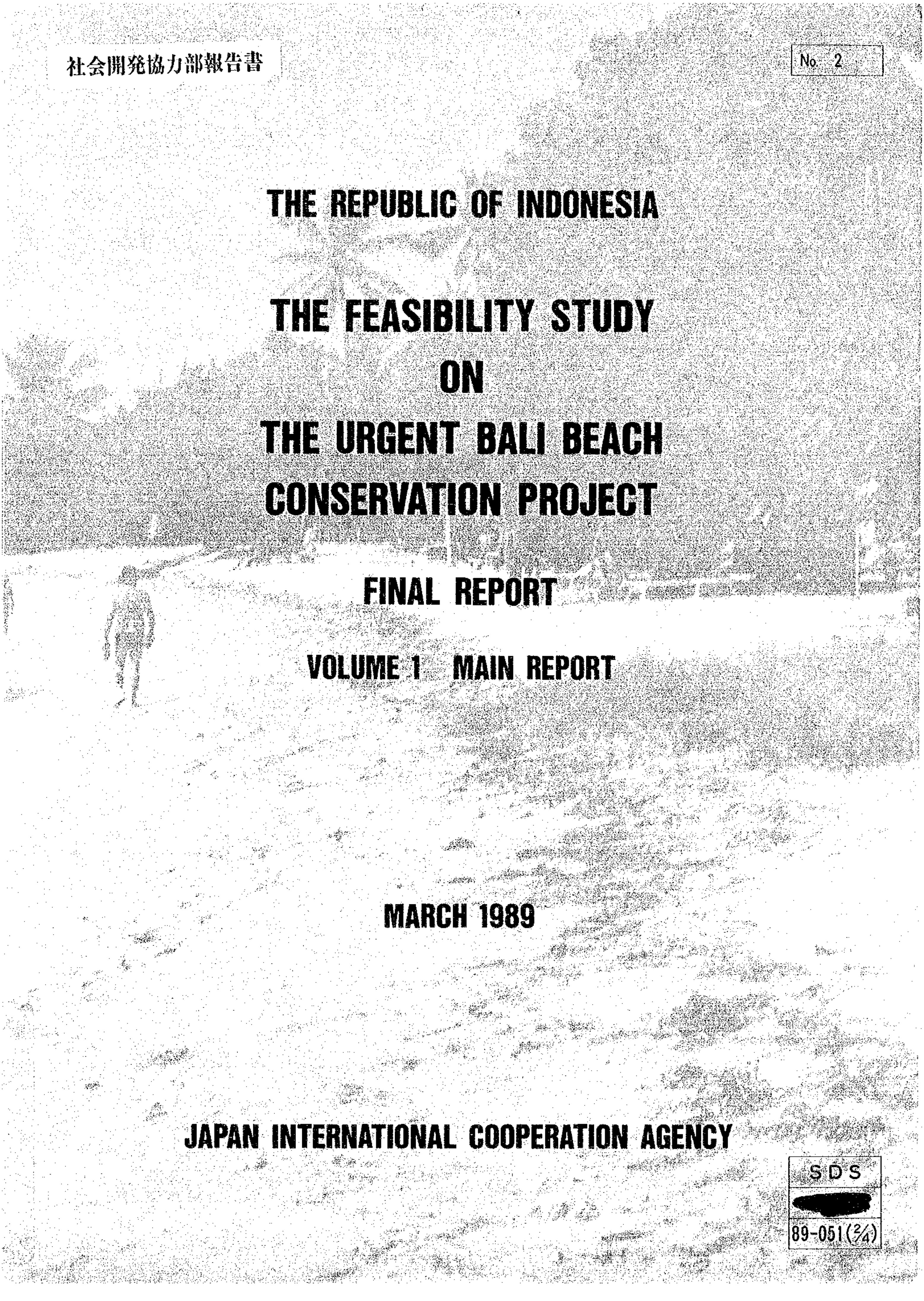


社会開発協力部報告書

No. 2

THE REPUBLIC OF INDONESIA

THE FEASIBILITY STUDY ON THE URGENT BALI BEACH CONSERVATION PROJECT

FINAL REPORT

VOLUME 1 MAIN REPORT

MARCH 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

THE REPUBLIC OF INDONESIA

THE FEASIBILITY STUDY
ON
THE URGENT BALI BEACH CONSERVATION PROJECT

FINAL REPORT

VOLUME 1 MAIN REPORT

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.

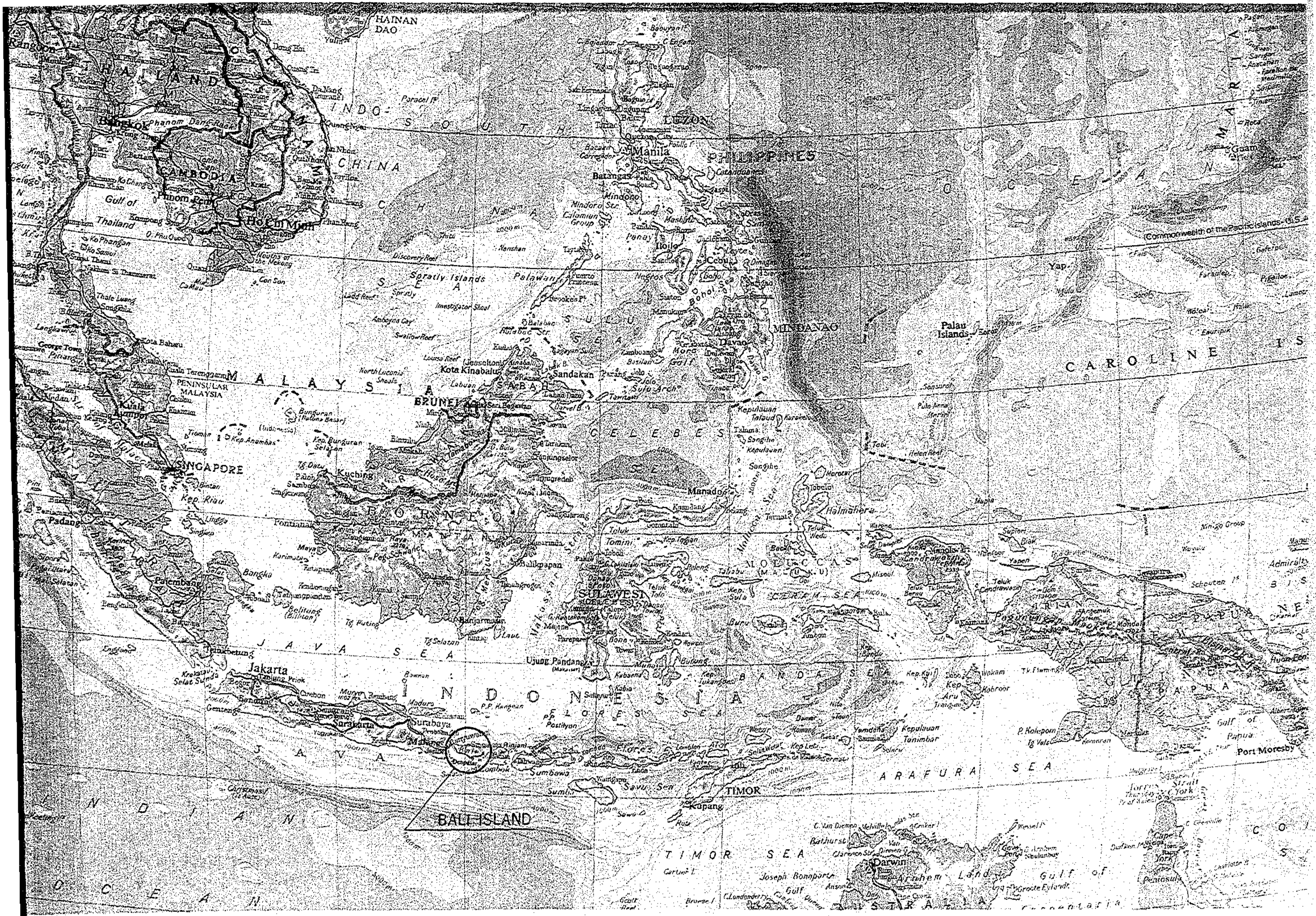
Regarding this project, the Study Team conducted three series of field surveys to collect a variety of data including data concerning natural conditions. The findings of these surveys were discussed to form the Urgent Conservation Plan and to study the feasibility of this Project, and were then compiled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



BALI ISLAND
INDONESIA
MALAYSIA
PHILIPPINES
THAILAND
CAMBODIA
SINGAPORE
BRUNEI
SULAWESI
BORNEO
MINDANAO
LUZON
TIMOR
Jakarta
Surabaya
Manila
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Ho Chi Minh
Phnom Penh
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Kota Kinabalu
Sandakan
Manado
Ujung Pandang
Palembang
Padang
Darwin
Port Moresby
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FLORES SEA
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TIMOR SEA
SULU SEA
MOLUCCAS
CAROLINE IS
Palau Islands
Yap
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Halmahera
HAINAN DAO
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Spratly Islands
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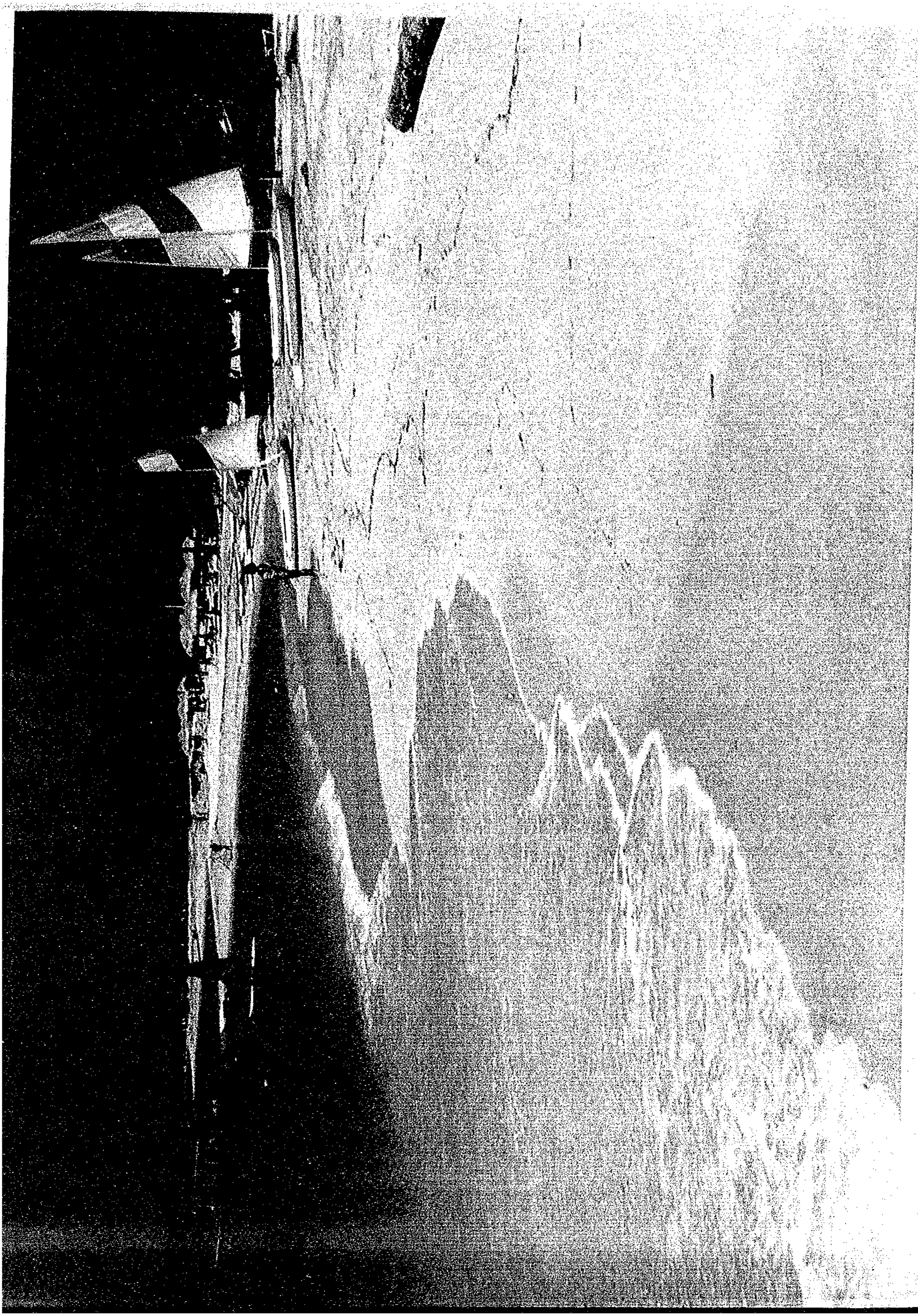

EXCHANGE RATE

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

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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.

CHAPTER 1

SOCIO-ECONOMIC BACKGROUND

CHAPTER 1 SOCIO-ECONOMIC BADKGROUND

1-1 General

Bali Island is located east of Java Island, from 8° 03'40" - 8° 50'48" South Latitude and 114 ° 25'53" - 115° 42'40" East Longitude. It is 140 km in length and has a maximum width of 50 km.

The population totals 2.7 million people in 1986. The population is mostly concentrated in the southern urban and tourist resort areas.

This tropical island has an area of about 5,632 km². Volcanoes are located in the center of the island, and the foot of the mountainous areas is covered with rice fields.

There are three beach resorts at the southern edge of the island, all of which are established as international resort areas, and as a centers of tourism in Indonesia.

1-2 *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 number of households has increased at an annual rate of 1.51% during the same period, showing a higher rate of growth than the population. This is due to the declinings size of the family unit from 5.1 members per household in 1984 to 5.0 in 1986. This tendency is apparent especially in urban areas such as Badung which includes the capital of the province, Denpasar. The average number of people per household differs by 0.8 persons between this urban area and the rural area of Buleleng.

The population is dispersed relatively densely along the east-west axis of Bali Island. Badung has a population of 550,000 and its population density reaches 1,015 persons per sq.km. It is followed by Buleleng, with a population of 517,000, Tabanan with 347,000 and Gianyar with 317,000. In terms of population density, the order is

Badung followed by Gianyar with 865 persons per sq.km Klungkung with 489, and Tabanan with 414.

The most sparsely inhabited regencies are Jembrama with 206,000 persons and a density of 244 persons per sq.km, followed by Bangli with 170,000 persons and 326 persons per sq.km, and Buleleng with 517,000 persons and 379 persons per sq.km. All of these regencies are located along the northern coast of the island.

The study areas are a part of the Badung regency which has the largest population and highest population density in 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. This 1.07 and 1.24 times as much as the population in 1986. The population density is expected to increase to 509 and 586 persons per sq.km in 1990 and 2000 respectively.

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

Regency	Area ('000 km²)	Population ('000 persons)	Density (persons per km²)	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)

1-3 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.

One more feature of the GRDP composition lies in the small share of the manufacturing industry.

Nationwide, manufacturing accounts for 1290 of the GDP, but in Bali manufacturing accounts for only 4,690 of the GRDP.

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

1-4 Tourism Industry

1-4-1 Tourism Industry in Bali

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.

Furthermore, there are a number of advantages to further development of tourism. Tourism is, after all, one sector that faces no quota threats or other protectionist moves.

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 paroblem at present is the beach erosion.

1-4-2 National Tourism Development

Indonesia records one of the lowest figures of foreign tourist arrivals among the ASEAN countries. The country is also suffering from sluggish oil prices which have aggravated its international balance of payments position. In these circumstance, the Indonesian Government has had to work out strategic measures of tourism promotion so as to gain foreign currency.

The Indonesian Government has set the following national tourism development guidelines:

- to create job opportunites in the tourism industry for the Indonesian people and to earn foreign currency
- to promote of domestic tourism
- to accelerate sales promotion and training

The government set up the following goals in Pelrita IV (1984-

1988) to attain a 14% annual increase in foreign tourist arrivals, and total arrivals shall reach 1.2 million in 1988.

- to increase job opportunities by development of the tourist areas
- to stimulate the nation's participation in tourism
- to increase the average length of stay in Indonesia to 12-14 days

The government efforts to stimulate tourism include:

- waiving visa requirements for tourists from 29 countries
- special discount airfare to foreign tourists entering at Jakarta- improvement of customs and immigration procedures
- increase of direct flights from the major market cities and encouragement of international joint operations in air transportation
- opening of new international gateways
- completion of tourism resorts in 10 priority destinations
- incentives for potential investors including a lower industrial tariff for electricity and decreasing the hotel development tax on hotels and restaurants from 10% to 5%.

1-4-3 Bali Tourism Development

A major thrust of the Indonesian tourism policy is embodied in the slogan "Bali & Nine". The slogan represents the aim of government to use Bali as a central attraction for Indonesia, and at the same time, to develop and spread tourism over its main islands.

Bali's tourism accommodation facilities are concentrated in Kuta, Sanur and Nusa Dua. Kuta and Sanur are located on the mainland of Bali where the spontaneous development of middle and low class hotels can be seen.

The government decided in 1972 to develop the Nusa Dua area as a high class international standard resort area and at the same time to limit the number of international 4 or 5 star class hotels in other areas until 1985.

Sanur will be developed and maintained as an area with a real Bali taste while Kuta will be an area for longer stay tourists.

The most significant policy lies in emphasizing measures to protect the Balinese way of life, the tourist attractions of the island and of course the natural beauty of Bali.

For this purpose, in the Nusa Dua area, the government hopes to provide a buffer between the potentially negative effects of tourism in terms of both cultural and social changes in the lives of the Balineses people and subsequent environmental deterioration. In all tourist areas, the government will follow a policy of "quality" rather than "quantity".

1-5 National Budget

The share of the national budget allocated to Bali is shown in Table 1-5-1. Funds for erosion protection total 700 million Rp. during the period 1985 to 1992, fluctuating +40% to -25% because of work implementation.

The allocation of the national budget among each beach in Bali Island is roughly decided according to criteria such as the progress of erosion, the size of the affected area, and the land use of the hinterland. The highest priority is given to the beaches of Sanur, Nusa Dua and Kuta. For these three beaches, the budget allocation is decided for Pelrita IV (1989/90 to 1993/1994).

Table 1-5-1 Allocation of National Budget for Erosion Protection by Region

(Unit: Million Rp.)

Fiscal Year	National Budget					Expenditure against C. Erosion
	Bali Province	Nusa Dua	Sanur	Kuta	Tanah Lot	
1980/81						-
1981/82	80	-	80	-	-	-
1982/83	-	-	-	-	-	-
1983/84	-	-	-	-	-	-
1984/85	50	15	-	35	-	-
1985/86	727	691	36	-	-	-
1986/87	794	694	100	-	-	-
1987/88	985	471	-	-	514	-
1988/89						
1989/90	525	50	100	20	n. a.	-
1990/91	650	50	50	15	n. a.	-
1991/92	755	50	50	150	n. a.	-
1992/93	890	-	-	350	n. a.	-
1993/94	1,180	-	-	500	n. a.	-

Note: n. a.; not available

Source; D.P.U.

CHAPTER 2

NATURAL CONDITIONS

CHAPTER 2 NATURAL CONDITIONS

2-1 General

Bali Island is located east of the Island of Java.

The Bali Strait between East Java and the western tip of Bali Island reaches a depth of only 60 meters. East of Bali Island, the Lombok Strait is one of the deepest waters in the Indonesian Archipelago. Bali Island is flanked by the Java sea to the north and the Indian Ocean to the south.

2-2 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.

The transitional periods between the two seasons are from April to May and from October to November.

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.

The winds blowing above the sea are usually heavier with velocities between 30-60 knots, compared with the average velocity of only around 5-10 knots. During the transitional periods (April-May and October-November), the flows of winds become irregular.

Indonesia consists of thousands of islands and mountains with different levels of temperature depending on the altitude. The temperature can be classified into three categories, i.e.:

- an average temperature of 27℃ for coastal areas.
- an average temperature of 25℃ for inland and mountain areas
- an average temperature of 22℃ for mountain areas (it depends on

the height of the mountains).

The conditions of the precipitation and wind frequency are shown in APP. Fig. 2-2-1, and 2-2-2.

2-3 Oceanography and Hydrography

Oceanographic and hydraulic survey were carried out, and the results of the surveys are as follows.

(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).

The tidal level figures in the Table show the range from MLWS at each place.

(2) Currents

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

The arrows on the chart indicate the prevailing direction, and the numerals show the mean current speed in knots.

These are based on data from Indian Ocean pilot charts in February 1986 and July 1986.

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.

In general, the offshore current of Bali Island tends to run slight slower in the rainy season (0.7 knots) than in the dry season (0.8 knots).

(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.

These data are used to determine the typical incoming wave characteristics at Kuta, Nusa Dua and Sanur respectively (Fig. 5-2-2-2 ～ Fig. 5-2-2-7).

(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. The locations of the field surveys are shown in Fig. 2-3-3～5.

1) Waves

Waves arriving at the shore are the primary cause of sediment transport in the littoral zone. Higher waves break further offshore, widening the surf zone and setting more sand in motion. Changes in period or height result in moving sand onshore or offshore. The angle between the crest of the breaking wave and the shoreline determines the direction of the longshore component of water motion in the surf zone. For these reasons knowledge about the wave motion is required for an adequate understanding of the littoral processes of any specific area.

The purpose of the wave measurement is to obtain the properties such as height and period of waves incident on the coast. To represent the east and west coasts of Bali Island, Nusa Dua and Kuta beaches were chosen as the sites where wave data was to be collected at a point about 10 ～20 m in depth off the coral reef. The data at Nusa Dua and Kuta are assumed to correlate with those at Sanur and Tanah Lot, respectively. In addition a wave-gauge was set at a point on the coral reef at Nusa Dua, Kuta and Sanur beaches. The data collected provides a comparison with those obtained off the reef, and shows such effects as dissipation due to breaking.

It is thus required that observation points be well away from man-made structures and areas where the depth changes rapidly such as submarine canyons. On the other hand the points should be as close as possible to the eroding areas. Accounting for the conflicting requirements, the observation points were selected as shown in the figures. Two observation points at each Nusa Dua and Kuta beaches were aligned in the wave direction. The duration was about three months.

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 (Kuta: Fig. 2-3-6, Nusa Dua: Fig. 2-3-7).

2) Nearshore Currents

Nearshore currents in the littoral zone are the steady component of wave-induced motions superimposed on the wave-induced oscillatory motion of the water. The net motions generally have low velocities, but because they transport whatever sand is set in motion by the wave-induced water motion they are important in determining littoral transport. Sometimes a strong stream falling into a nearshore submarine canyon on the ebb tide is responsible for the erosion.

A current meter was set at one or two points each at Kuta, Nusa Dua and Sanur beaches. The current data is expected to represent the typical current near the eroding area. 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. (Fig. 2-3-3)

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

A strong stream can be seen flowing into the deeper region (Fig. 5-1-1-3).

At Nusa Dua beach, a current meter was set on both sides of the canyon (Fig. 2-3-4).

Currents were observed flowing towards the canyon from both sides (Fig. 5-1-1-1).

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 (Fig. 2-3-5).

The current meter records are shown in Fig. 5-1-1-5.

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

3) Fluorescent Tracers

It is usually possible to obtain evidence on the direction of sediment movement and the origins of sediment deposits by the use of tracer materials which move with the sediment. Sand was collected on the said beach and dyed with a fluorescent substance. Fluorescent tracers were injected at a point 30 cm deep at the lowest ebb near each of the current meter site.

The sites of Kuta and Sanur had two tracer injection points respectively, and the two origins at each site were distinguished with the two colours of the tracers: green and red. At Nusa Dua beach, the tracer was injected at a third point near an eroding area (Fig. 2-3-9).

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.

4) Others

While the current and tracer tests were being executed at the sites, visual observation was done on the overall current distribution by tracing a float in the reef.

Fig. 2-3-8 and 2-3-10 show the observation results at Kuta and Sanur.

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.

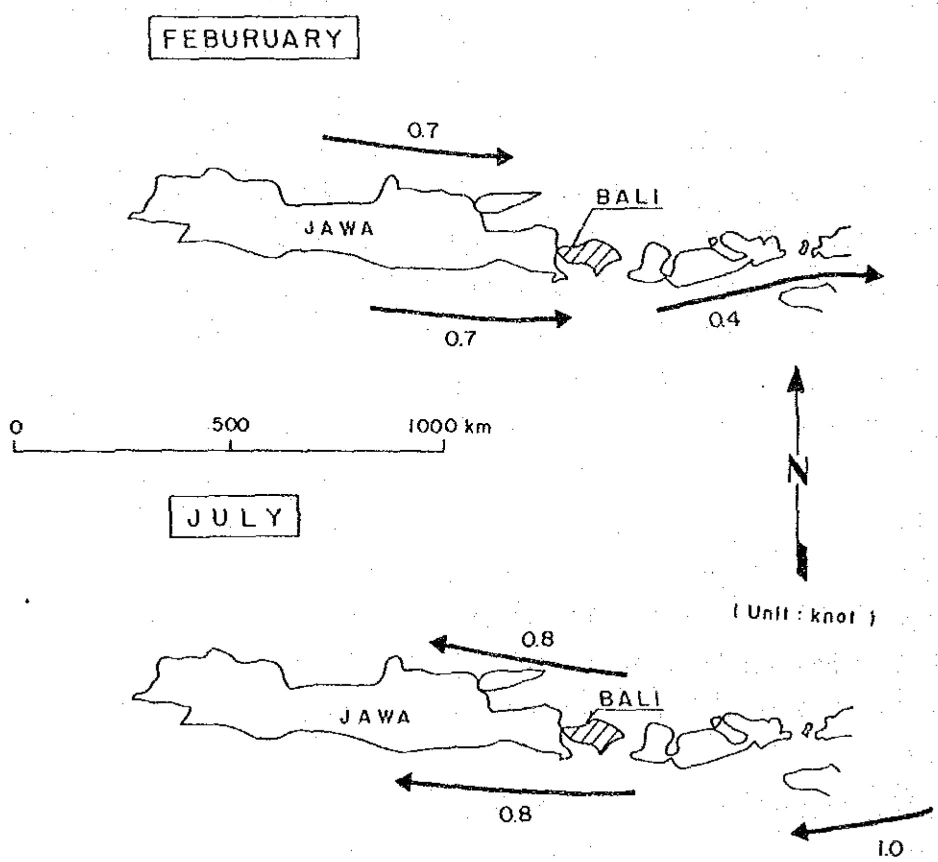


Fig. 2-3-1 Ocean Current

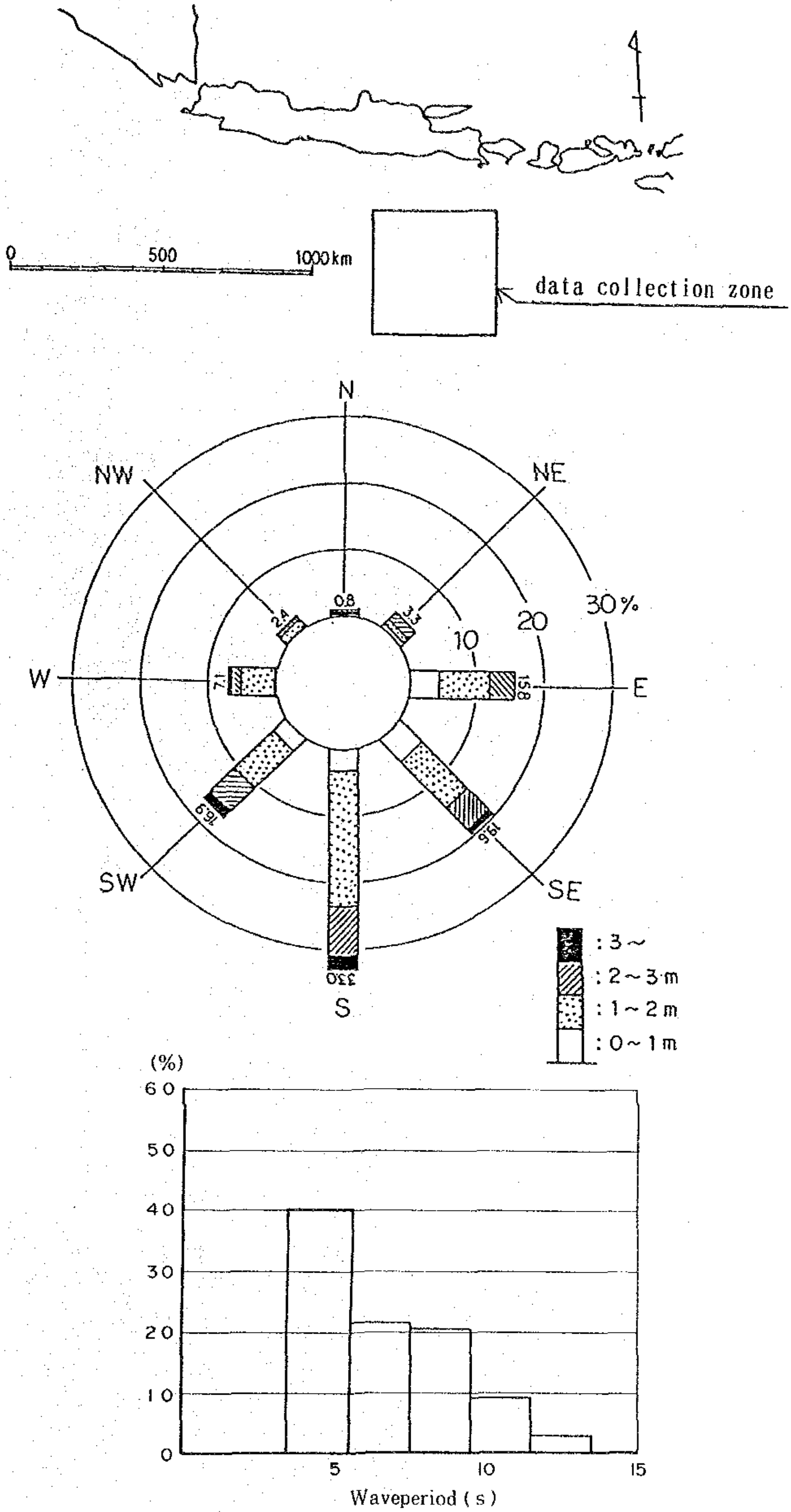


Fig. 2-3-2 Deep Water Waves

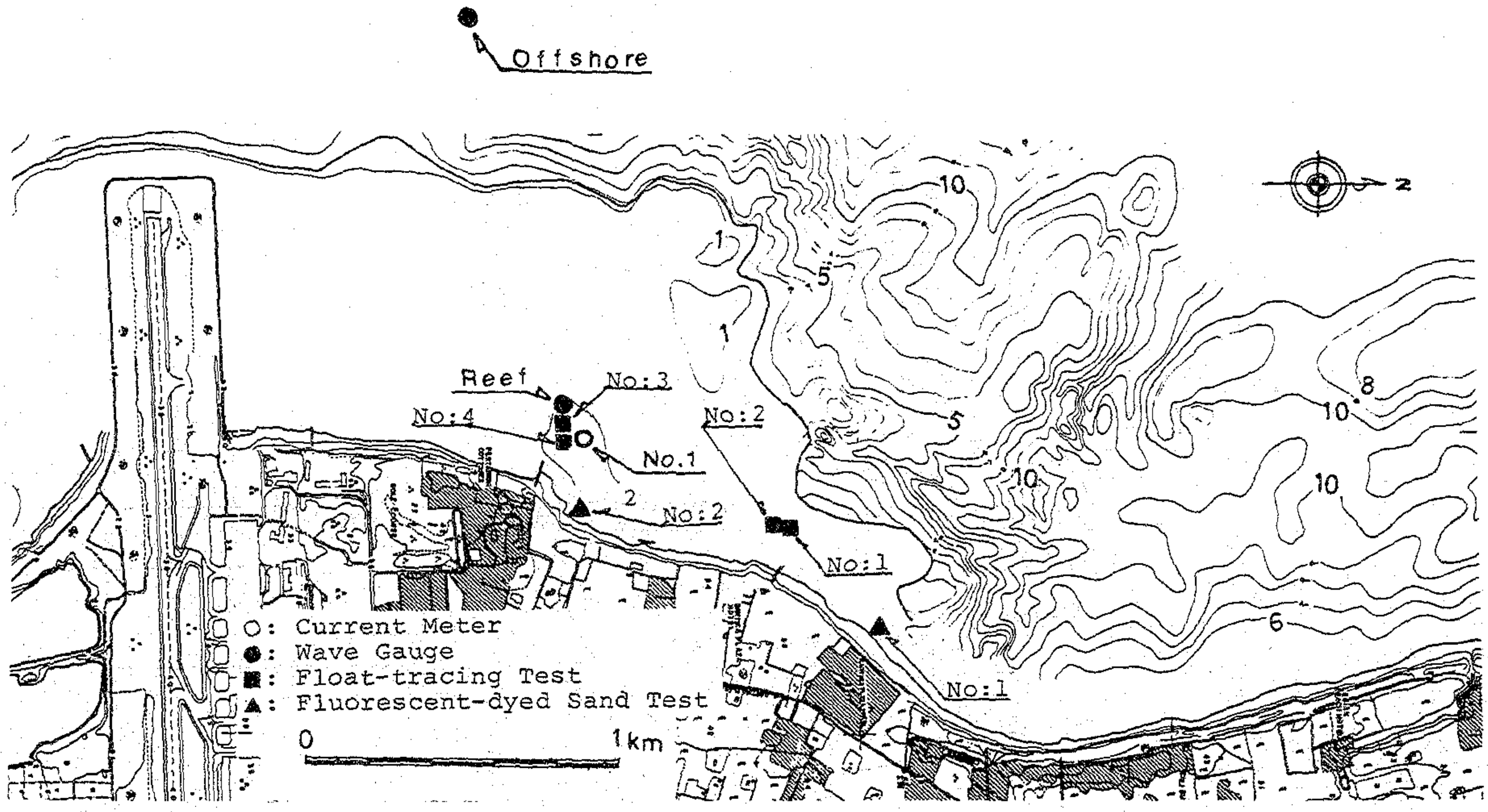


Fig. 2-3-3 Location of the Marine Observations (Kuta)

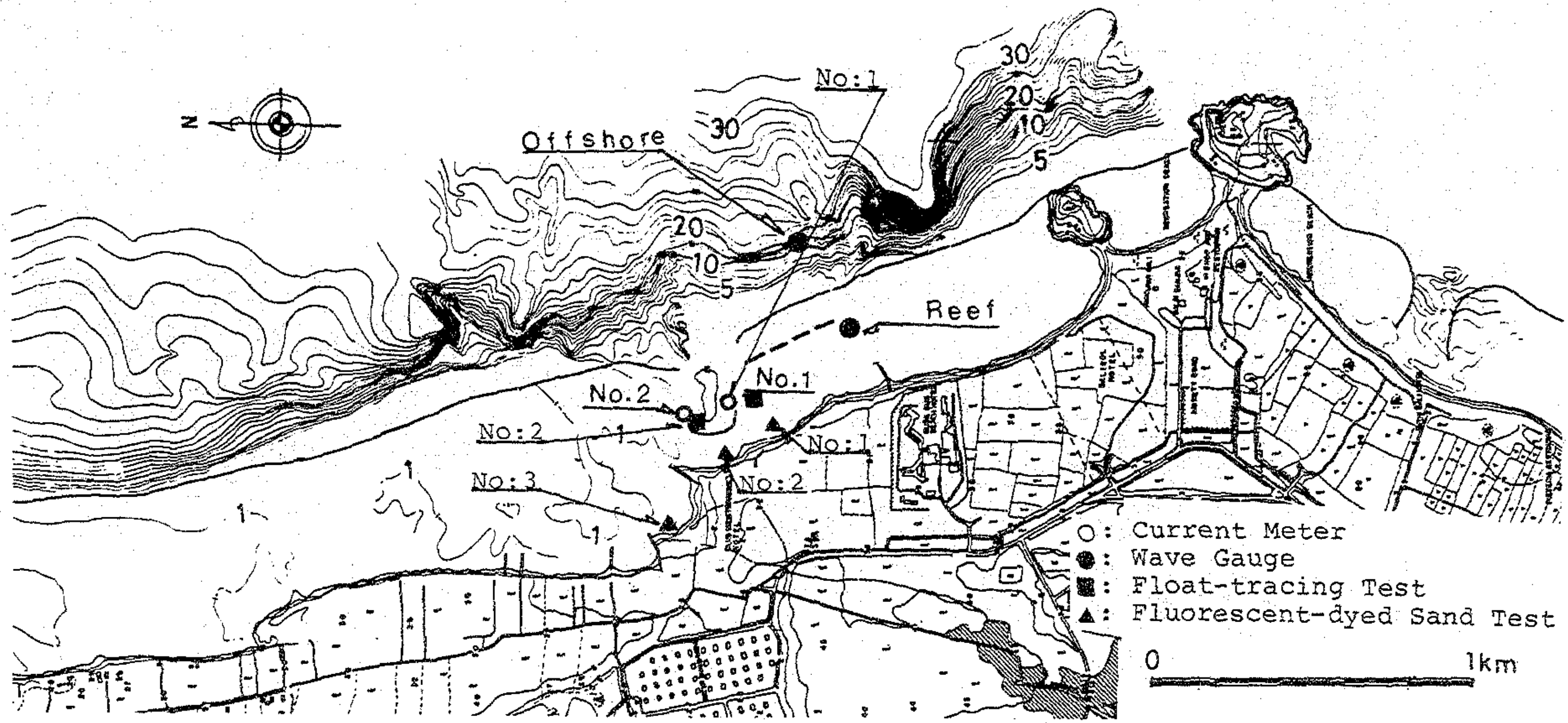


Fig. 2-3-4 Location of the Marine Observations (Nusa Dua)

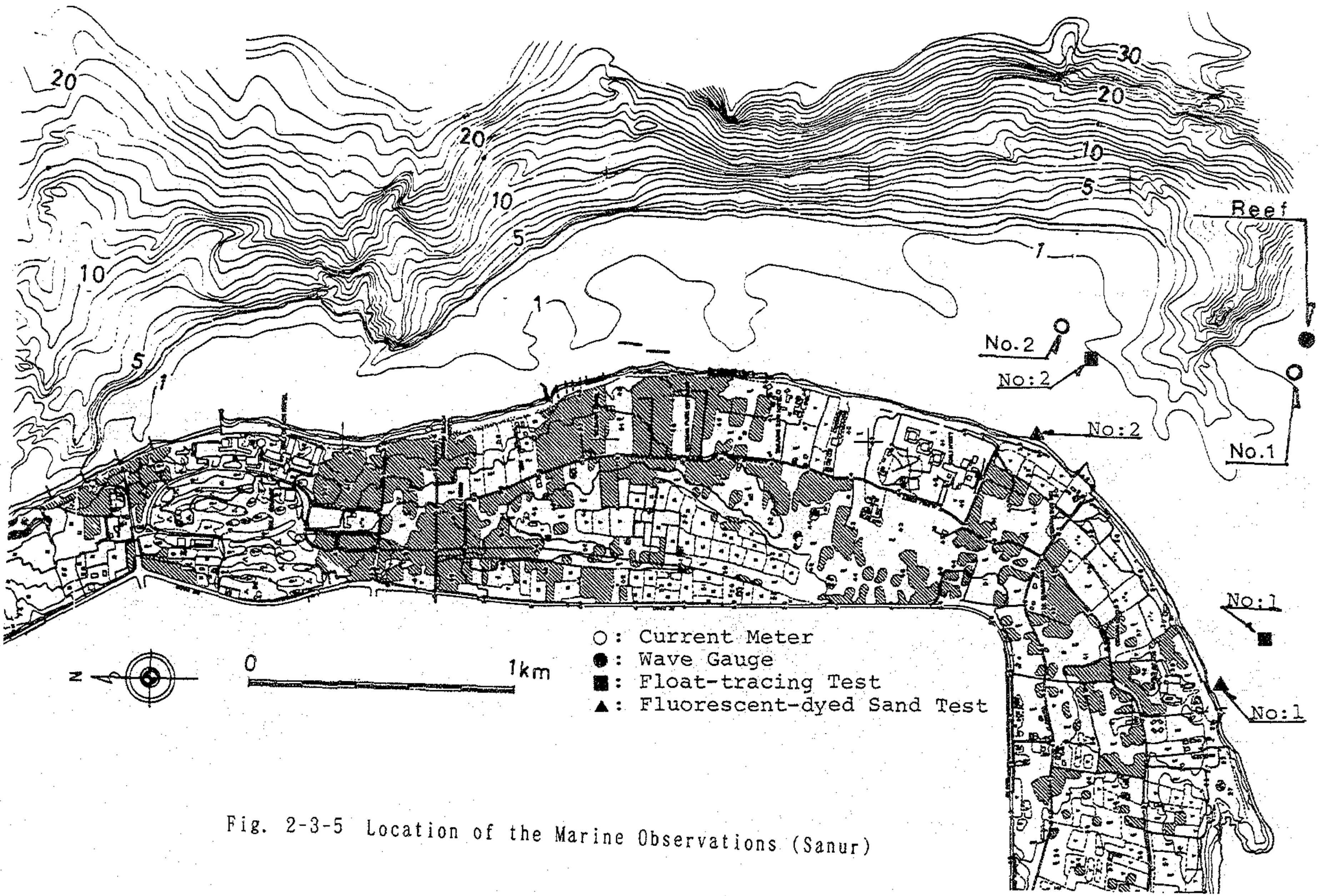
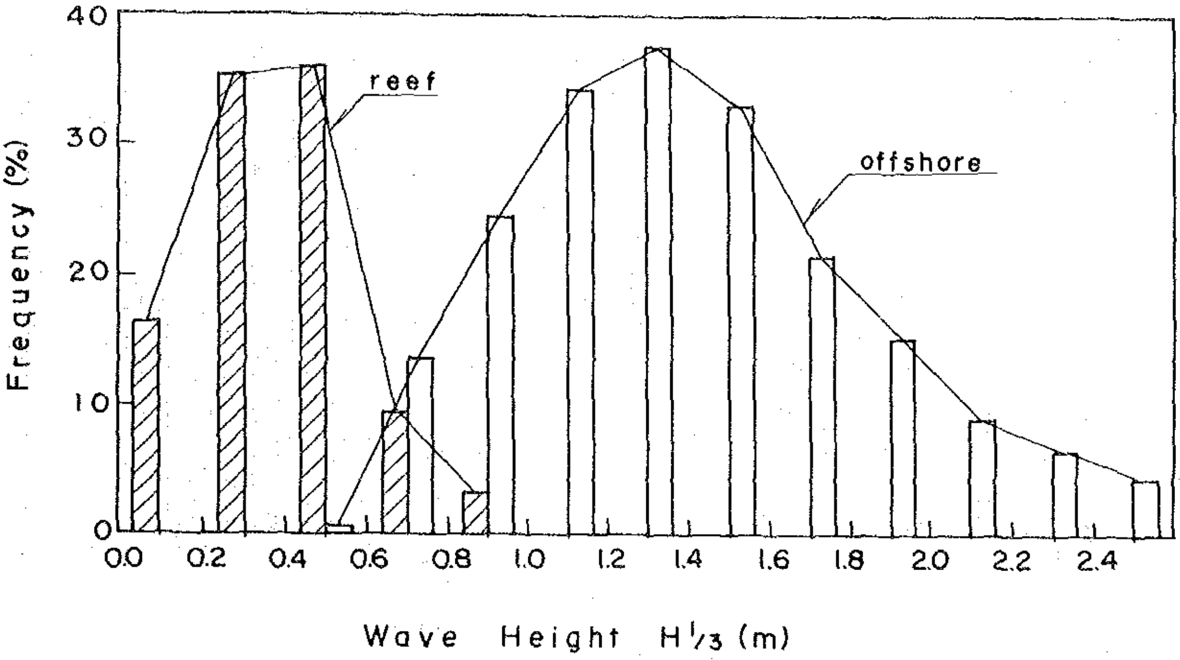


Fig. 2-3-5 Location of the Marine Observations (Sanur)

KUTA (MAY-JUNE : 1988)



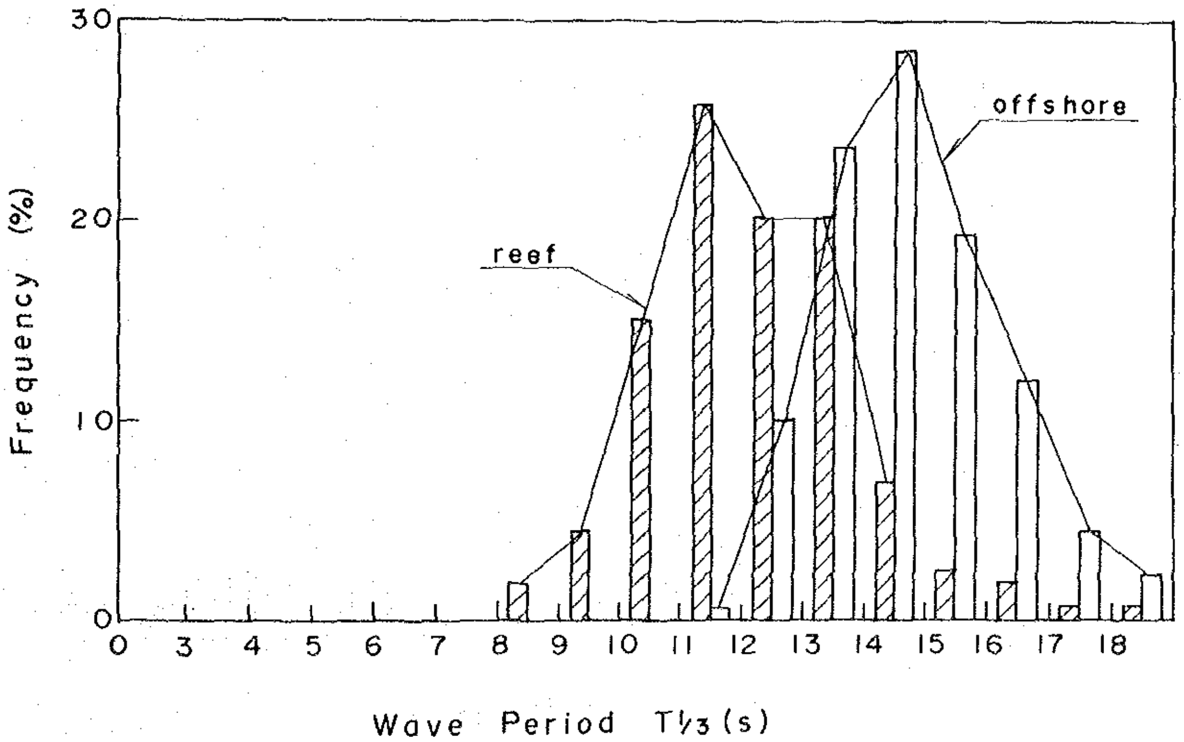
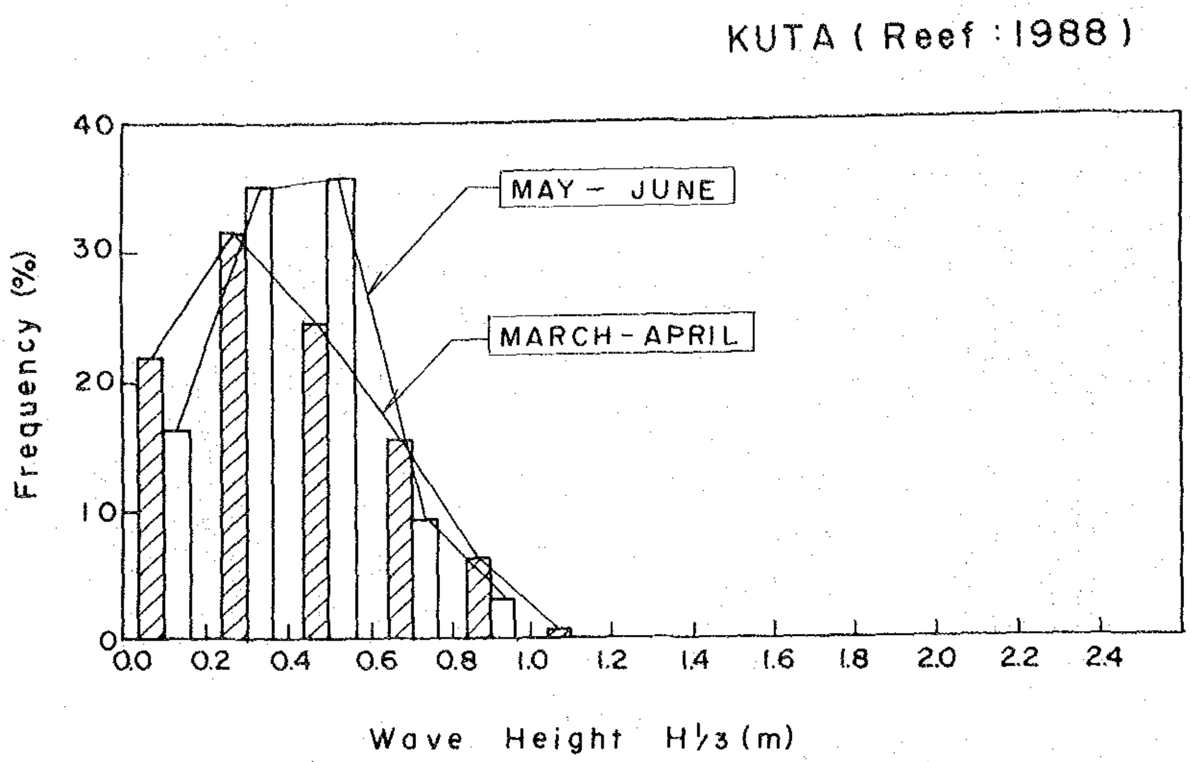


Fig. 2-3-6(1) Distributions of Wove Height and Period at Kuta



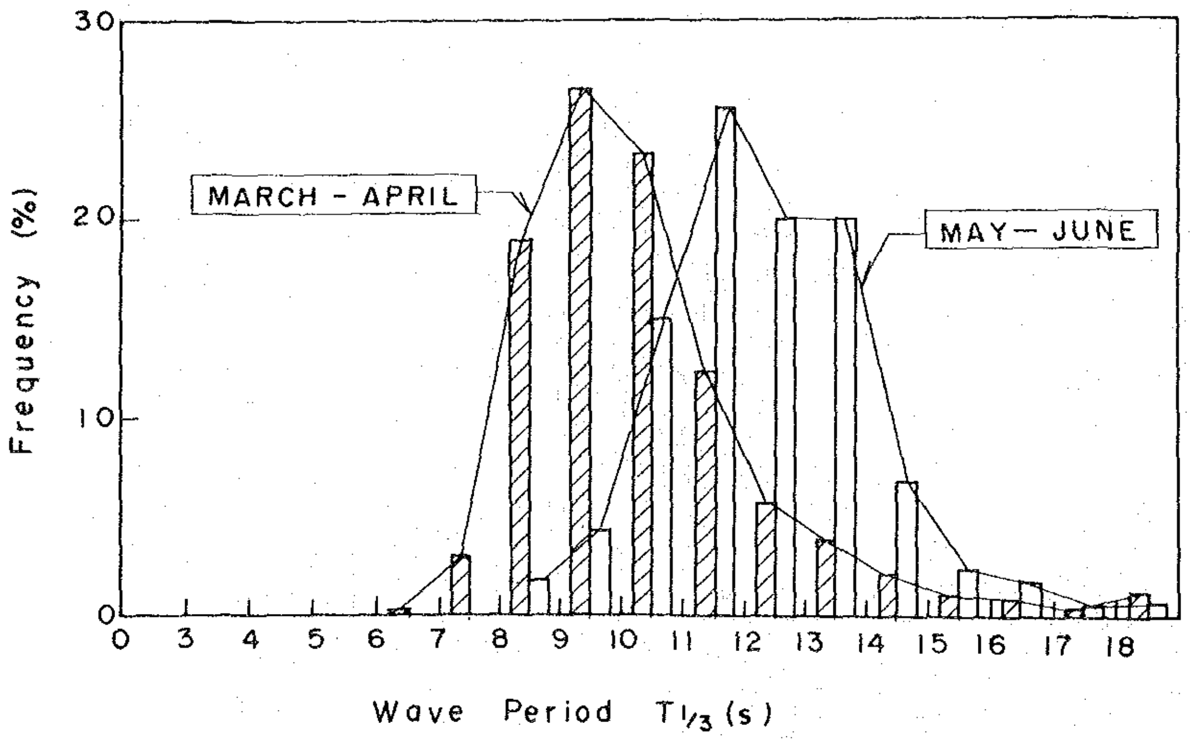


Fig. 2-3-6(2) Distributions of Wove Height and Period at Kuta

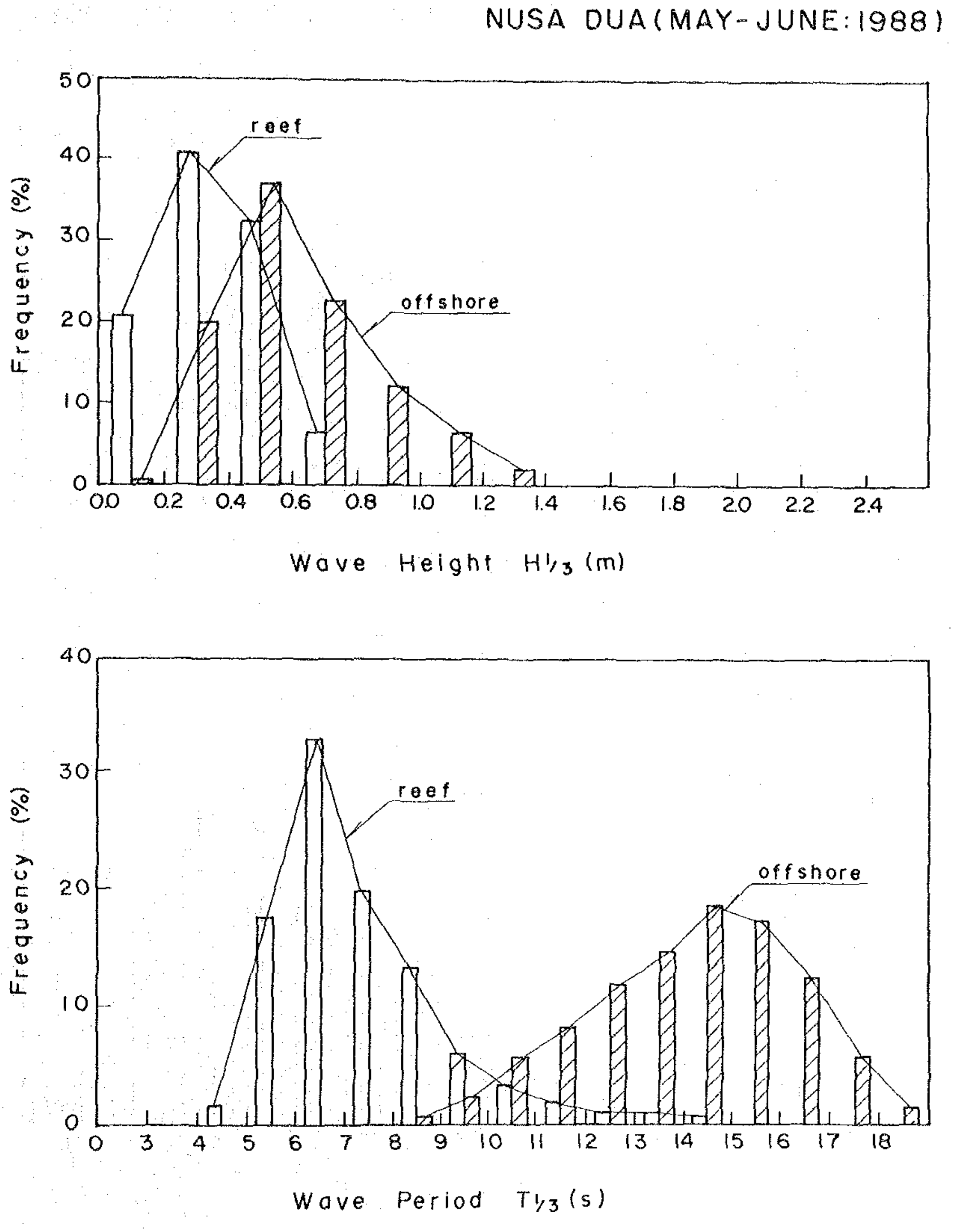
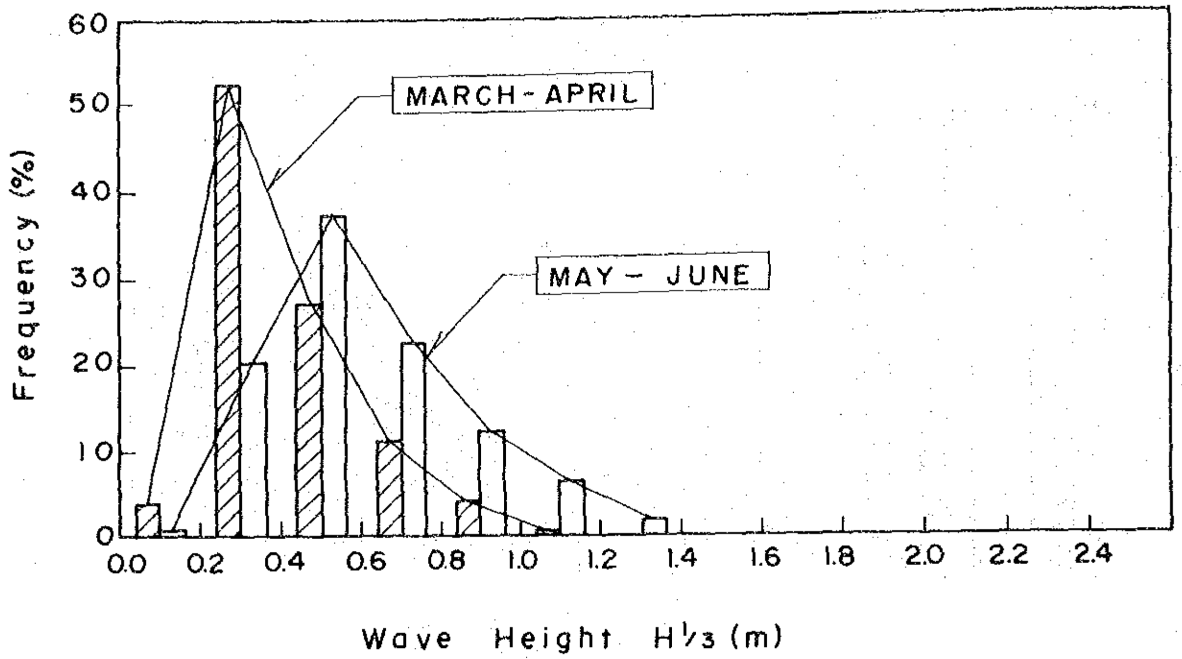


Fig. 2-3-7(1) Distributions of Wave Height and Period at Nusa Dua

NUSA DUA(OFFSHORE:1988)



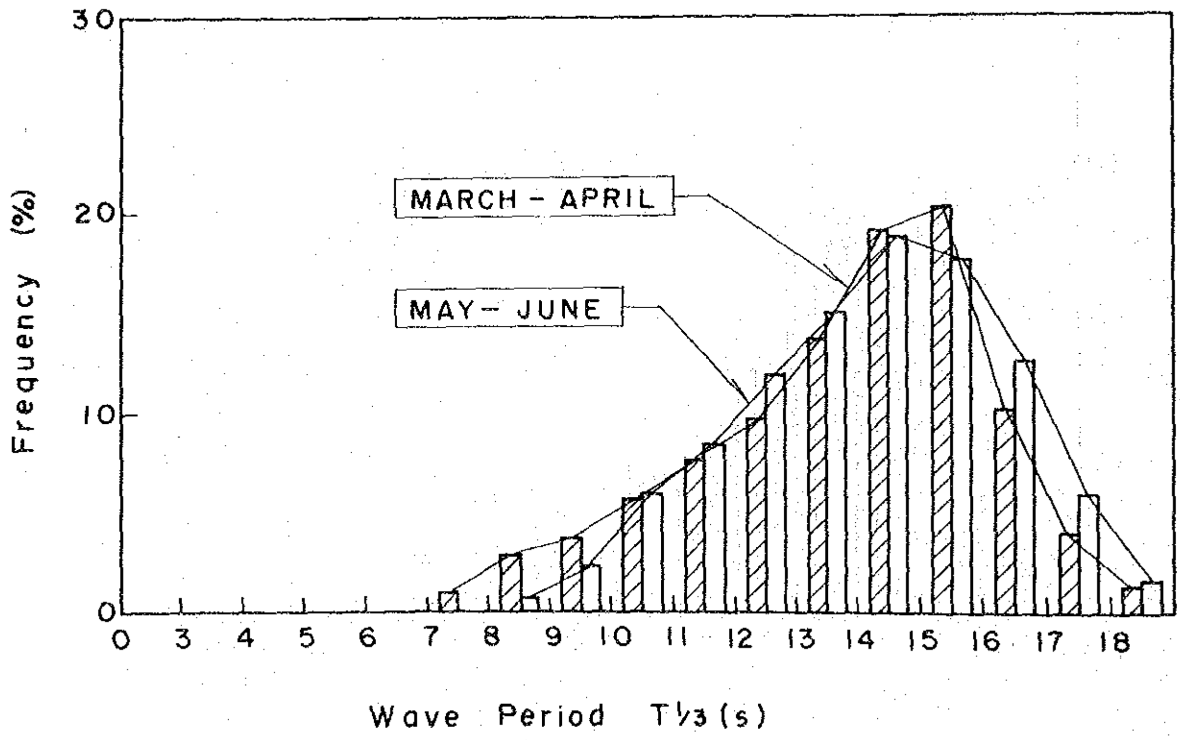


Fig. 2-3-7(2) Distributions of Wove Height and Period at Nusa Dua

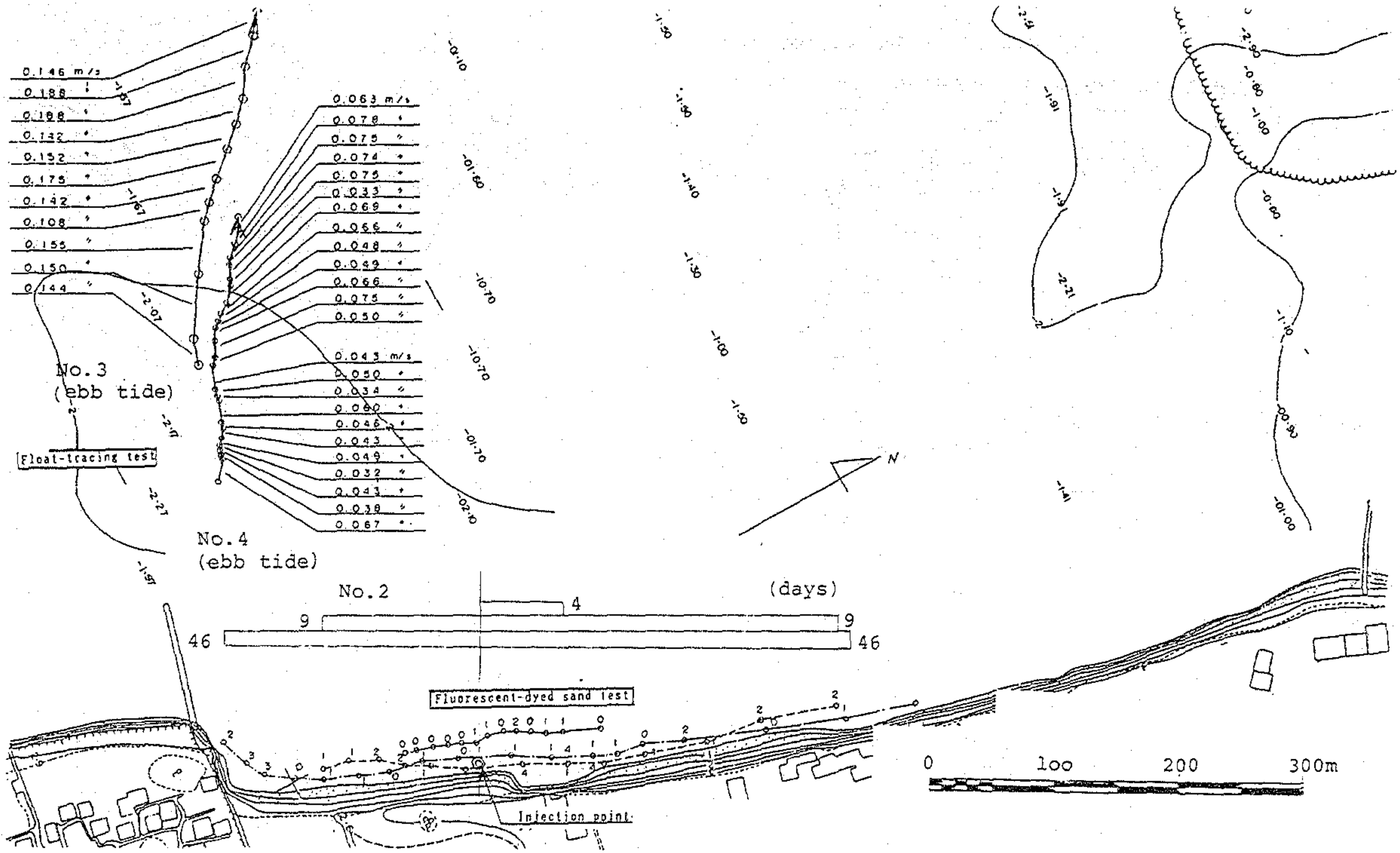


Fig. 2-3-8 (1) Results of Marine Obvservations (Kuta)

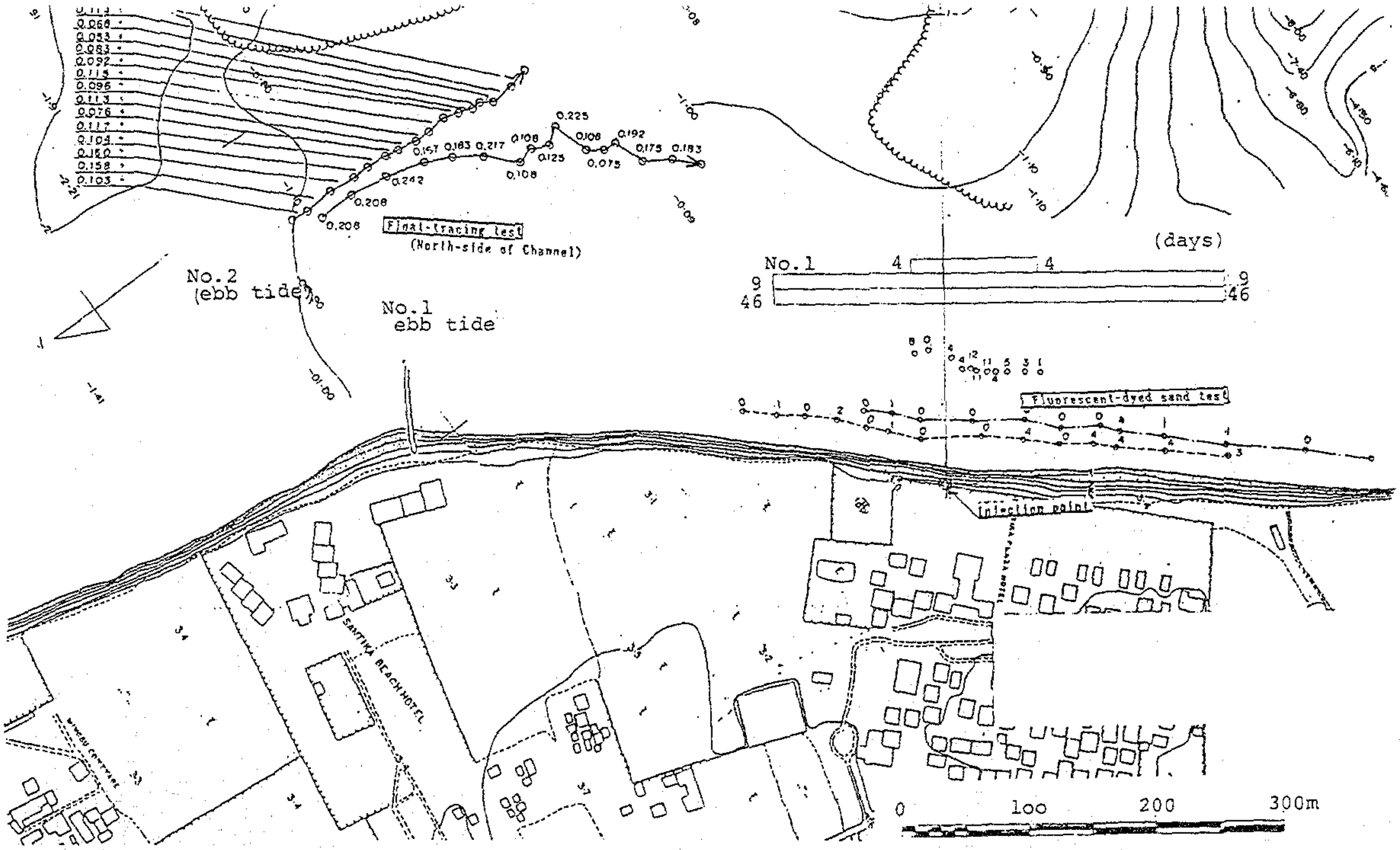


Fig. 2-3-8 (2) Results of Marine Obeservations (Kuta)

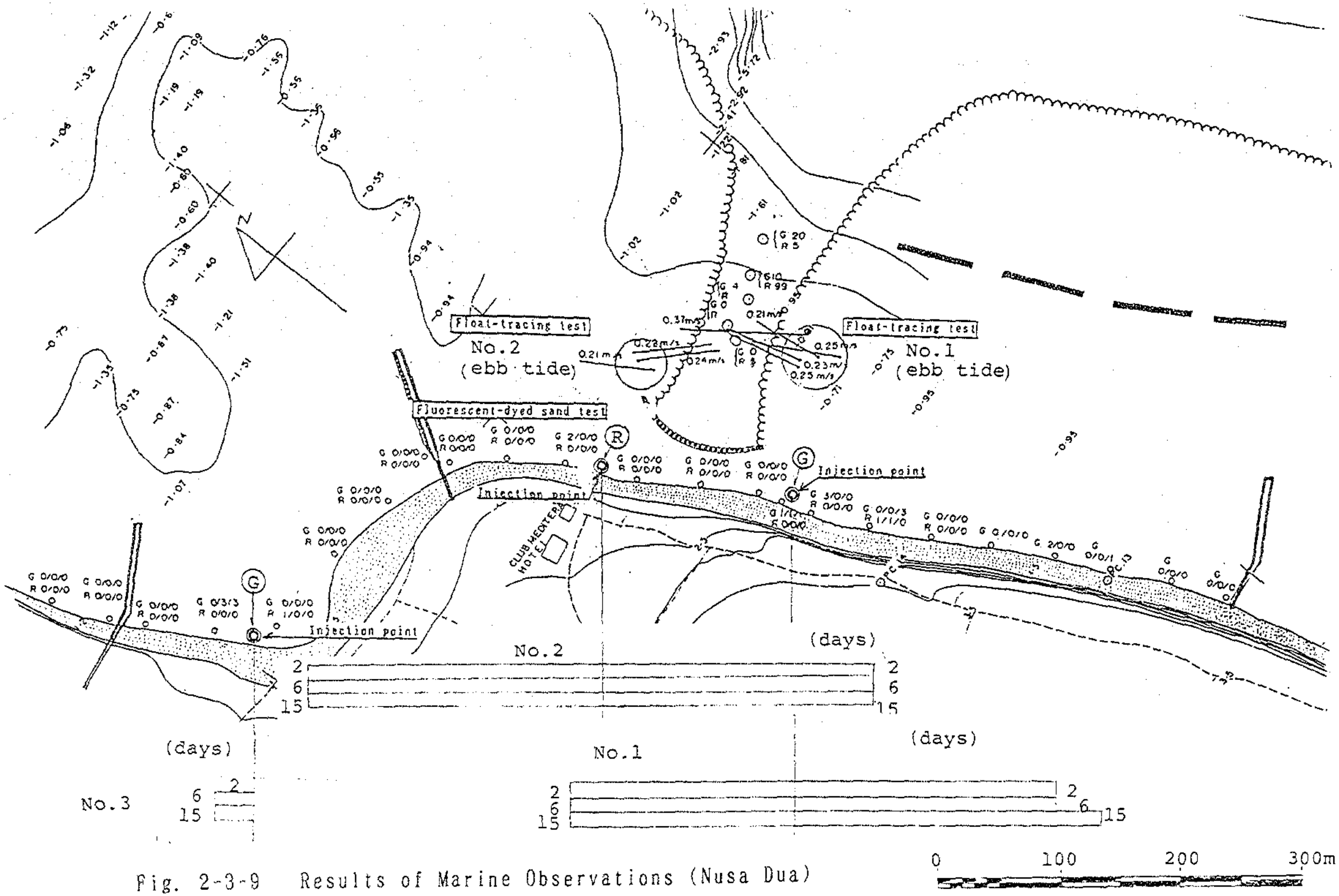


Fig. 2-3-9 Results of Marine Observations (Nusa Dua)

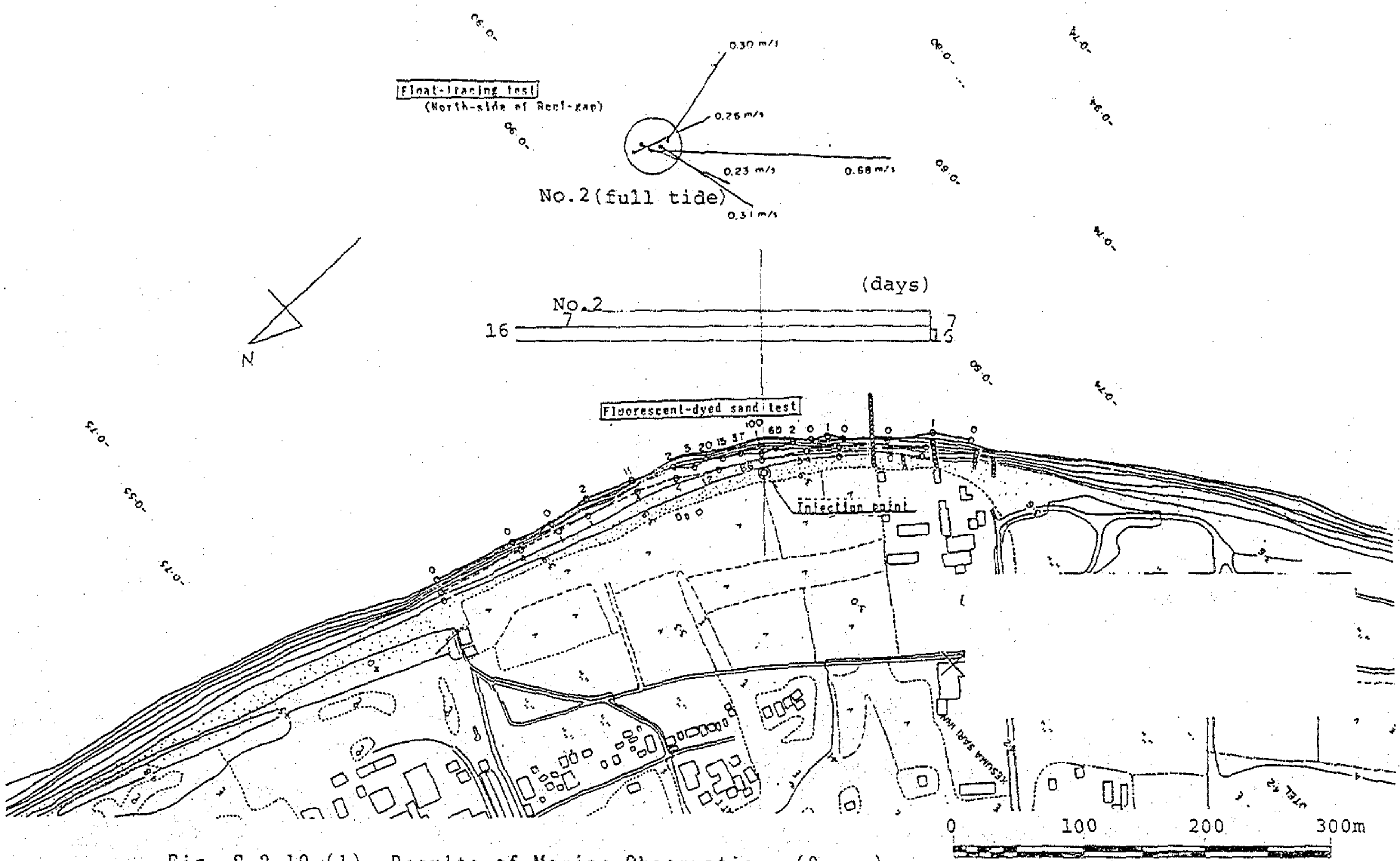


Fig. 2-3-10 (1) Results of Marine Observations (Sanur)

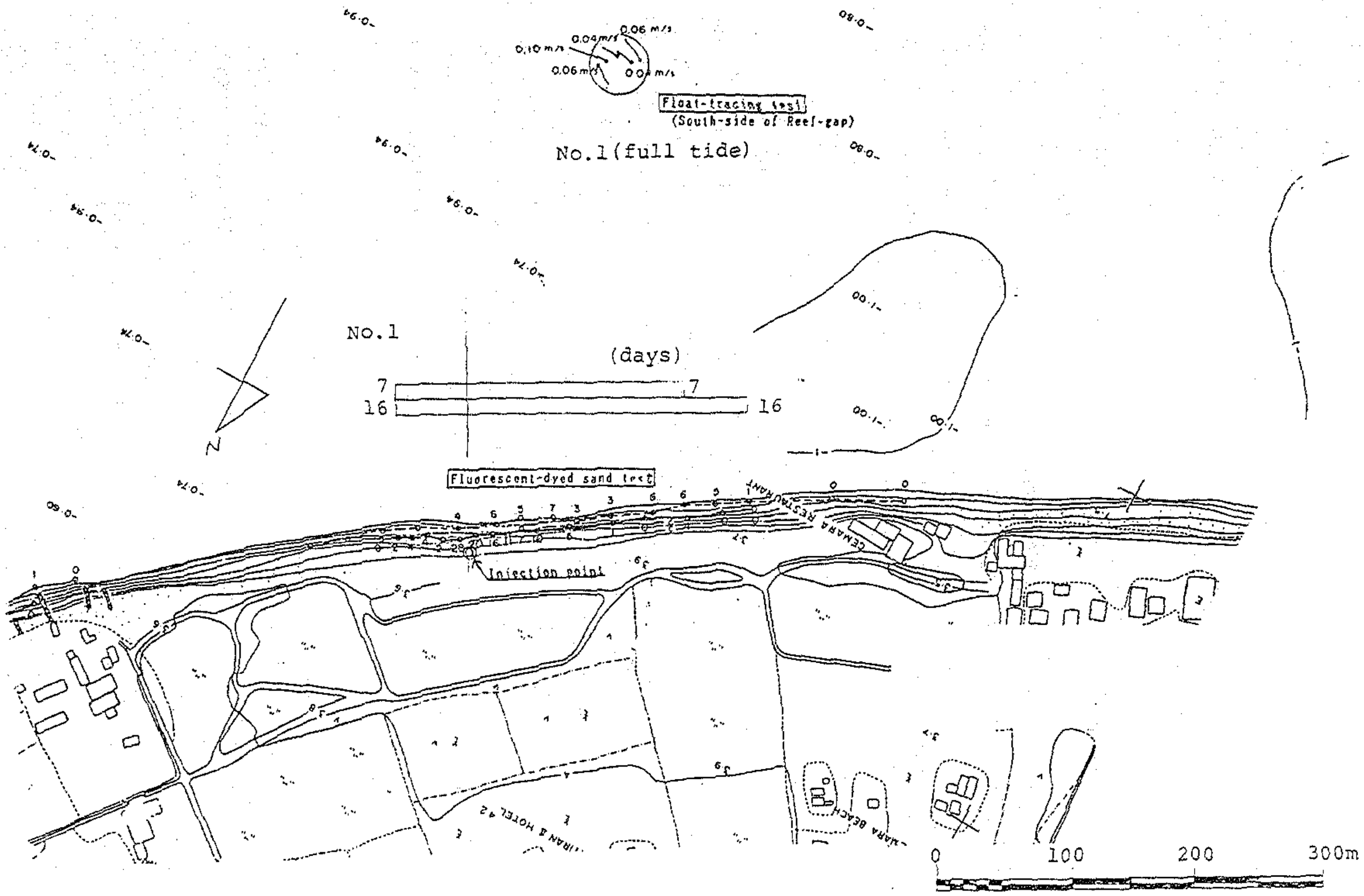


Fig. 2-3-10 (2) Results of Marine Observations (Sanur)

2-4 Topography and Geology

2-4-1 Topography

Bali Island is divided into four topographical units as follows (refer to Fig. 2-4-3-1).

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.

(1) Volcanic Range

The volcanic range consists of old volcanoes in the western part and new volcanoes in the eastern part of the island. The old volcanoes are broken down by erosion and have lost their original form. G. Kelatakan (698 m), G. Merbuk (1,388 m) and G. Patas (1,412 m) belong to this group of old volcanoes. The new volcanoes still maintain their original forms. G. Batukau (2,276 m), Buyan-Bratan Volcano (G. Pohen - G. Lesong - G. Catur), G. Batur (1,717 m) and G. Agung (3,142 m) belong to this group. Buyan-Bratan Volcano and G. Batur are double volcanos with Tamblingan, Buyan, Bratan and Batur caldera lakes. G. Agung is a simple stratovolcano and shows a beautiful conical form having a summit crater.

(2) Southern Slopes of the Volcanic Range

The southern slopes are fertile and have many rivers. The major streams are called He, Empass, Penet, Ayung, Wos, Petanu, Sangsang and Unda. These rivers run parallel to each other through the alluvial fan. Sea cliffs are found on the southwestern coast of the southern slopes, as at Tanah Lot. But, there are no cliffs on the southeastern coast.

(3) Low Land Area

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.

(4) Bukit Badung

Bukit Badung in the southern peninsula, is a land-tied island and is composed of flat hills of coral limestone. Coral limestone forms the karst landform, having dolines and caves. Beautiful steep sea cliffs are found on the southwestern coast of Bukit Badung. But, on the northeastern side, the flat hills show gentle sloping.

2-4-2 Stratigraphy

The Stratigraphy of Bali Island is summarized in Table 2-4-2-1, and the distribution of rock units is shown in Fig. 2-4-2-1, on the basis of "Geological Map, Bali" published by the Geological Survey of Indonesia.

The oldest rock in the area, the Ulakan Formation, consists of volcanic breccia, lava and tuff. This formation is distributed in the eastern part of Bali Island and is probably Lower to Upper Miocene. The Sorga Formation which is composed of tuff, marl and sandstone, is locally exposed in the western part of Bali Island. This formation is probably Middle to Upper Miocene.

The Selatan Formation is Miocene to Pliocene. It is younger rock than the above mentioned formations. This formation, which is mainly made up of coral limestone, is distributed in the southern peninsula and Nusa Penida. The age of this formation is confirmed by the fossils in the coral limestone. The above mentioned Ulakan, Sorga and Selatan Formations are relatively older rocks and form the foundations of Bali Island.

Pulaki Volcanics, Prapatagung Formation and Asah Formation, which are probably Pliocene age, are exposed along the northern coast area of Bali Island.

Djembrana Volcanics and Palasari Formation, which belong to the

Table 2-4-2-1 Stratigraphy of Bali Island

Age	Formation	Lithology
Quaternary (Pleistocene ∿ Holocene)	Alluvial Deposite	Gravel, sand, clay
	Volcanic Products of Subrecent	Volcanic products of present Buyan-Bratan Volcano
	Lava of G. Pawon	Parasitic cone of G. Agung
	Volcanic Products of G. Batukau	Volcanic products
	Volcanic Products of G. Agung	Volcanic products
	Volcanics of present G. Batur	Volcanic products
	Buyan-Bratan and Batur Tuff and Lahar Deposits	Tuff, lahar
Lower Quaternary (Pleistocene)	Palasari Formation	Conglomerate, sandstone, coral limestone
	Seraja Volcanics	Volcanic products
	Volcanics of Old Buyan-Bratan Volcano and Old Batur Volcano	Volcanic products
	Djembrana Volcanics	Lava, breccias, tuff of G. Kelatakan, G. Merbuk, G. Patas and associated rocks
Pliocene (?)	Asah Formation	Lava, breccia, pumiceous tuff with calcareous crack fillings
	Prapatagung Formation	Limestone, calcareous sandstone, marls
	Pulaki Volcanics	Lava, breccia
Miocene-Pliocene	Selatan Formation	Predominantly coral limestone
Middle (?) to Upper Miocene	Sorga Formation	Tuff, marl, sandstone
Lower (?) to Upper Miocene	Ulakan Formation	Volcanic breccia, lava, tuff with intercalations of calcareous material

Note: Quote from "Geological Map, Bali, 1971 (1 : 250,000)" published by the Geological Survey of Indonesia.

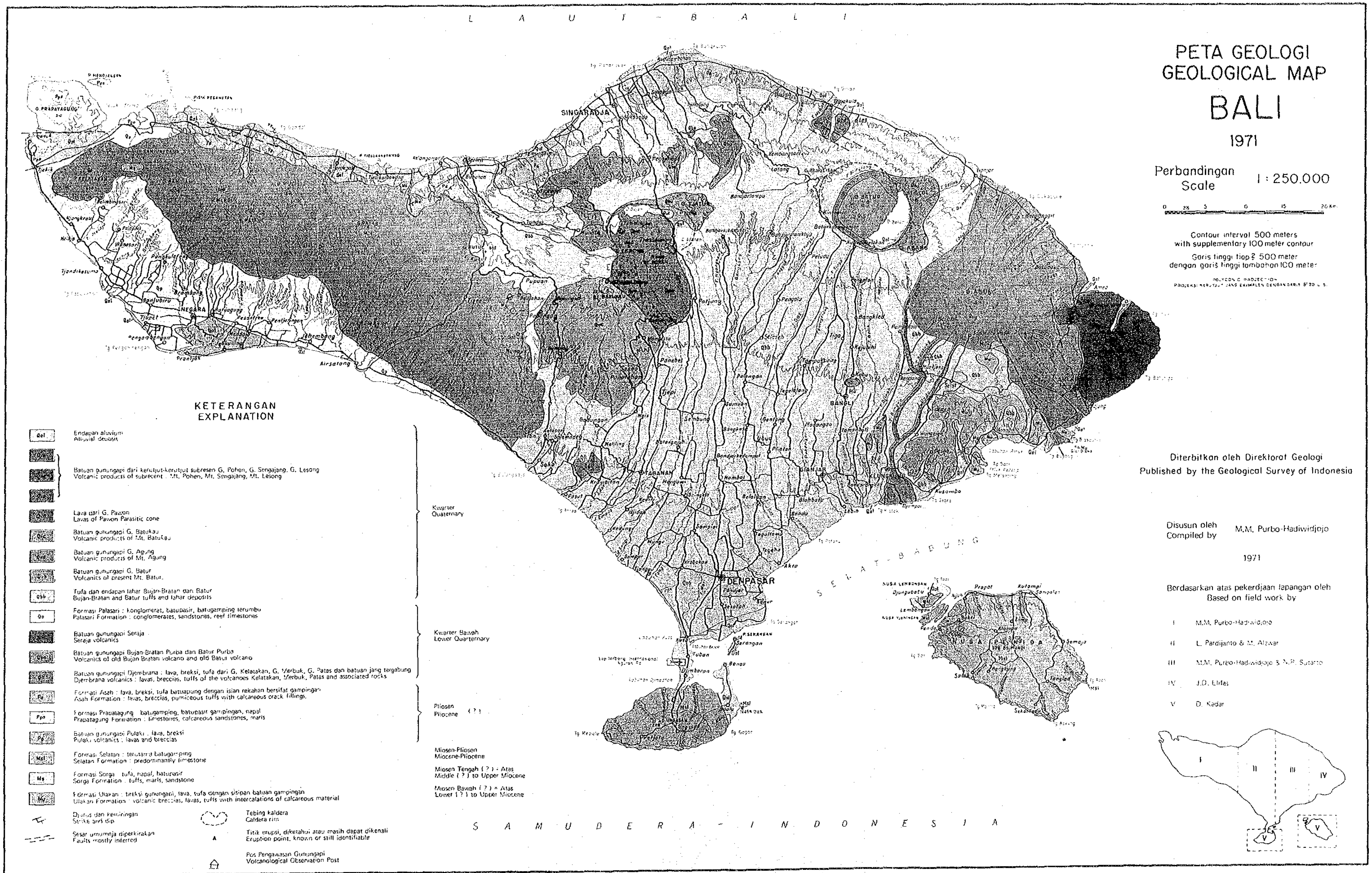


Fig. 2-4-2-1 Geological Map, Bali

Lower Quaternary (Pleistocene), are widely distributed in the western part of Bali Island. Djembrana Volcanics concerning old volcanoes (G. Kelatakan, G. Merbuk, G. Patas, etc.), consist of lava, breccia and tuff. Palasari Formation which is marine sediment, is composed of conglomerate, sandstone and coral limestone.

Other Lower Quaternary and Quaternary Volcanics, concerning new volcanos (G. Batukau, Buyan-Bratan Volcano, G. Batur, G. Agung and G. Seraja), are separately found in the central and the eastern part of Bali Island. Buyan-Bratan and Batur Tuff and Lahar Deposits which belong to Quaternary, are widely distributed in the central part of Bali Island.

Alluvial Deposits are found along river, coast and cardera lake, as river deposit, lake deposit, sand beach, sand dune, tombolos and spit. The alluvial deposits are composed of three kinds of clastics materials; volcanic rock origin, clastic rock origin and coral and coral limestone origin.

Much of Bali Island is covered by deposits of volcanic ash from the active volcanoes.

2-4-3 Structure

Bali Island is part of the island arc that links the Andaman Islands, Nicobar Islands, Sumatra, Java, Lesser Sunda Islands and to Banda Arcs. The volcanic front and earthquake belt run parallel to this island arc.

Gravity anomalies in the central part of Bali Island are shown in Fig. 2-4-3-1, which is provided on the basis of "Complete Bouguer Gravity Map" published by the Geological Survey of Indonesia. High gravity anomalies are found in the volcanic range and Bukit Badung. A low gravity anomaly is found on southern slopes. Therefore, it is estimated that the volcanic range and Bukit Badung have a tendency to uplift. The uplift movement generally produces mountain ranges and steep sea cliffs.

A drill hole[1] (201.35 m depth) which was bored by the Geological Survey of Indonesia at Ambengan village in the low land area (refer to Fig. 2-4-3-1), intersects directly fine-grained sandstone, coral limestone and silt to fine grained sandstone with interbeds of thin

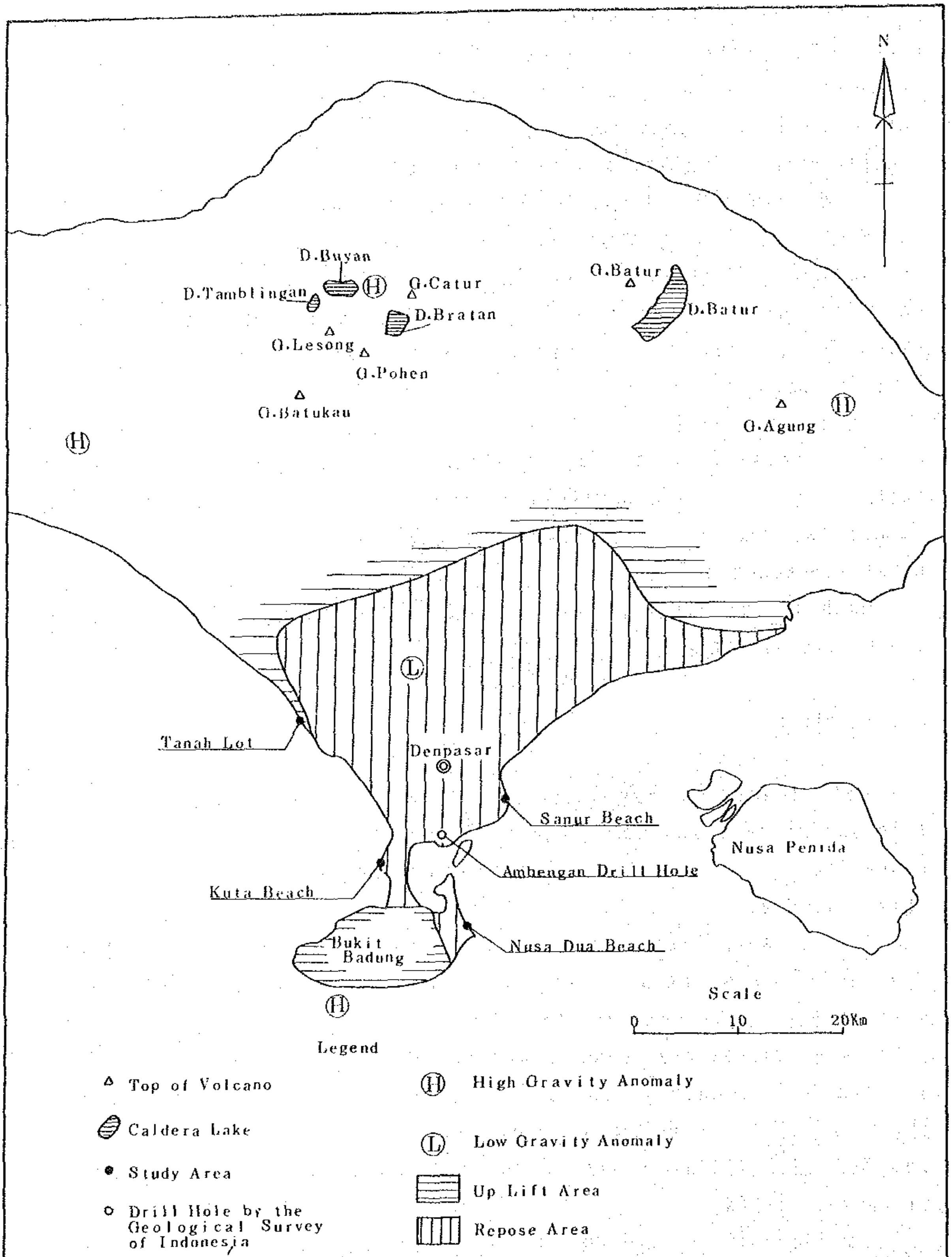


Fig. 2-4-3-1 Map showing the Gravity Anomaly and the Uplift Area in the Central Part of Bali Island (on the basis of "Complete Bouguer Gravity Map" published by the Geological Survey of Indonesia) clay. These rocks belong to the Parasari Formation (Pleistocene) in shallow depth and to the Propatagung Formation (Upper Pliocene to Pleistocene) in deeper depth, on the basis of literature by Kadar D. (1978) [(1)]. Because there is no remarkably thick alluvial deposit below the surface, there is no marked subsidence in the low land area.

Therefore, it is estimated that the alluvial deposits in Kuta and Sanur Beach are thin, and the foundation rocks are the above mentioned Parasari Formation and Prapatagung Formation.

Also, the foundation rocks in Nusa Dua Beach are probably coral limestone (Miocene to Pliocene) on the basis of geological evidence in the neighbouring area and at Nusa Dua.

2-4-4 Seismicity

Bali Island is covered by an earthquake belt along the island arc. But Bali Island is not a region of very high seismicity. The earthquakes of more than magnitude 6.0 MB from 1911 to 1984, within 300 km from Denpasar are listed up in Table 2-4-4-1.

The strongest earthquake in the table is magnitude 7.3 MB and 543 km depth at 300 km northeast from Denpasar. Also listed are four earthquakes with foci which lie inside Bali Island, with magnitudes of 6.4, 6.2, 6.1 and 6.0 MB at 80, 40, 25 and 38 km in depth.

The plane on which the foci lie inclines generally to north. The earthquakes do not appear to be directly related to volcanic activity, although some earthquakes are triggered by volcanic eruptions.

Note (1): Quote from "Kadar D.: Upper Pliocene and Pleistocene planktonic foraminiferal zonation of Ambengan drill hole, southern part of Bali Island. Geol. Res. Dev. Centre (Spec. Pub. 1) 1978.".

Table 2-4-4-1 Earthquakes more than Magnitude 6.0 MB within 300 km from Denpasar (1911 ～1984)

Date	Time			Location		Depth (km)	Magnitude		Remarks
	hr.	min.	sec.	Latitude	Longitude		MB	MS	
5, Jul. 1911	18	40	6	7.50 S	117.50 E	370	6.8	7.0	300 km NEE from Denpasar
11, Nov. 1916	6	30	36	9.00 S	113.00 E	100	6.9	7.2	200 km west from Denpasar
20, Jun. 1929	18	22	33	8.50 S	114.00 E	60	6.4	6.2	East part of Java
8, May 1930	12	47	18	8.00 S	117.20 E	-	6.2	-	250 km east from Denpasar
17, May 1932	12	56	30	8.50 S	115.00 E	80	6.4	6.2	South part of Bali Island
10, Apr. 1934	10	22	58	6.50 S	116.00 E	33	6.7	6.8	250 km NNE from Denpasar
11, Apr. 1934	21	56	2	7.00 S	116.25 E	33	6.3	6.0	200 km NNE from Denpasar
12, Feb. 1936	9	34	30	6.00 S	116.00 E	600	6.5	6.5	300 km NNE from Denpasar
11, Aug. 1937	0	55	52	6.50 S	116.50 E	543	7.3	7.8	300 km NE from Denpasar
29, Oct. 1938	22	53	0	9.00 S	116.00 E	90	6.5	6.5	Southern end of Lombok Island
17, Aug. 1953	3	14	36	6.80 S	115.10 E	33	6.3	6.0	200 km north from Denpasar
10, Jun. 1957	0	59	54	9.00 S	117.00 E	-	6.7	6.8	Southwestern end of Sumbawa Island
30, Mar. 1967	2	8	3	11.06 S	115.40 E	33	6.0	-	300 km south from Denpasar
30, Mar. 1967	2	28	2	11.00 S	115.50 E	33	6.0	-	Ditto
14, Jul. 1976	7	13	24	8.20 S	114.90 E	40	6.2	6.5	Northern part of Bali Island
30, May 1979	9	38	53	8.21 S	115.95 E	24	6.1	5.8	Eastern end of Bali Island
20, Oct. 1979	1	41	10	8.25 S	115.85 E	38	6.0	6.2	Ditto

2-5 Geological Survey and Bottom Material

2-5-1 Geological Survey

The geological survey was done in Tanah Lot. There are a holy temple island and beautiful steep sea cliffs with sea caves and a natural bridge in the area (refer to Fig. 2-5-1-1). Nine geological sections in the island and the sea cliffs were sketched and are shown in Fig. 2-5-1-2.

Volcaniclastic rocks which consist of volcanic breccia, tuff breccia, lapilli tuff and sandy tuff, are found in the island and the sea cliffs. Graded bedding, cross lamina and slumping are most commonly found in the rocks. The rocks are well layered with horizontal bedding planes several centimeters to several meters apart. Intervals of bedding plane in the lower part are thicker than in the upper part. It is estimated that the rocks are deposited in shallow sea by volcanic eruptions and belong to Djembrana Volcanics (Pleistocene), on the basis of its lithological characteristics and geological evidences.

The rebound numbers of rock were measured by Schmidt Rock Hammer. The measurement was done 15 strokes each time and 3-5 times each measured position along the geological sections. The rebound numbers of rock are shown following Table 2-5-1-1.

Table 2-5-1-1 Rebound Numbers of Rock by Schmidt Rock Hammer

Section	Volcanic breccia	Tuff breccia	Lapilli tuff	Sandy tuff	Average
A-A'	37 (3)	-	39 (2)	42 (1)	39 (6)
B-B'	38 (4)	37 (1)	38 (2)	37 (1)	38 (8)
C-C'	34 (3)	-	-	41 (2)	37 (5)
D-D'	26 (1)	-	35 (1)	41 (2)	36 (4)
E-E'	33 (5)	-	37 (2)	35 (2)	34 (9)
F-F'	30 (2)	-	-	40 (3)	36 (5)
G-G'	30 (2)	-	30 (1)	37 (1)	32 (4)
H-H'	32 (2)	-	-	31 (2)	31 (4)
I-I'	30 (2)	-	30 (1)	36 (1)	31 (4)
Average	33 (24)	37 (1)	36 (9)	38 (15)	35 (49)

( ); Number of measured position.

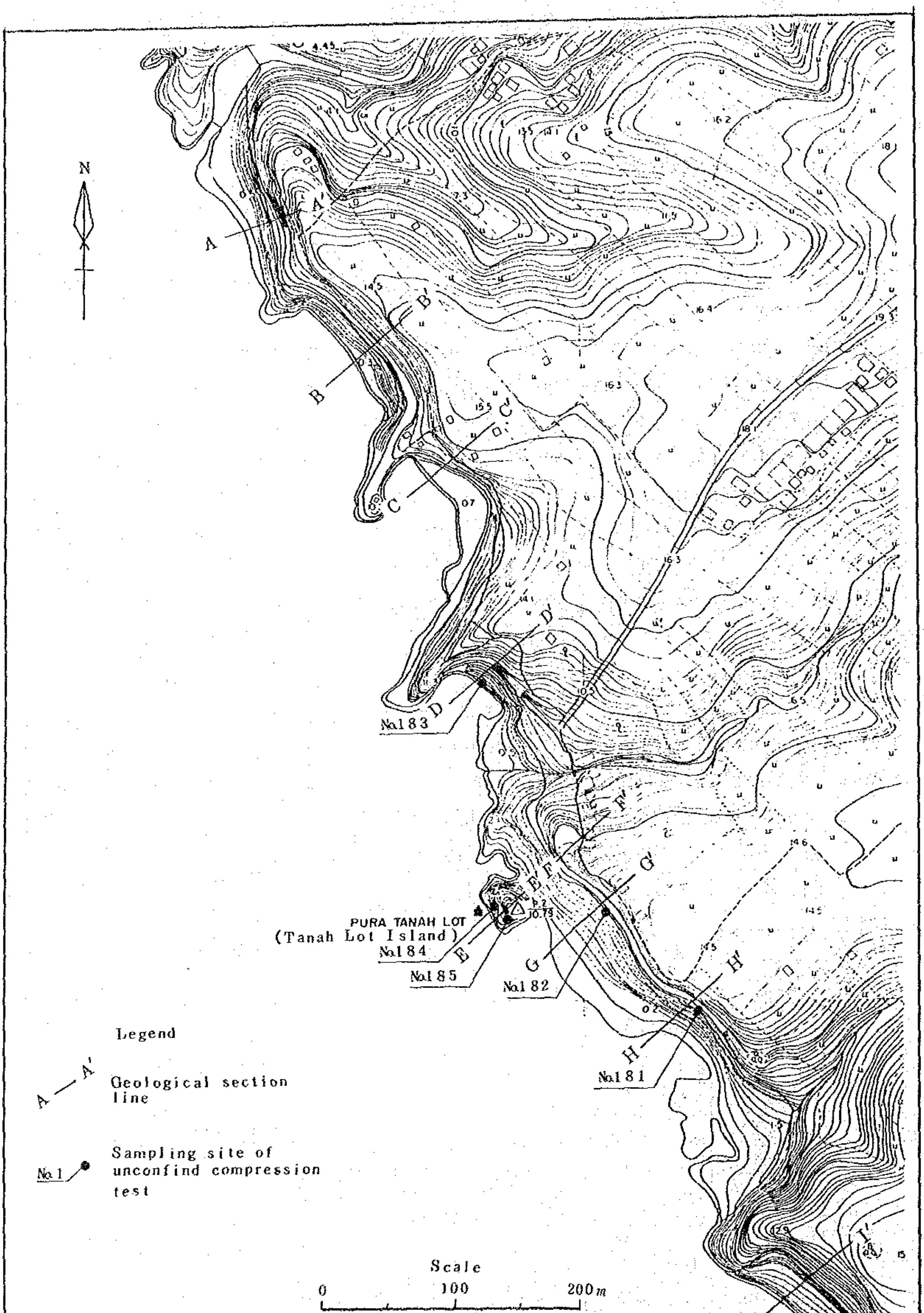


Fig. 2-5-1-1 Location Map Showing Geological Section Lines and Sampling Sites on Unconfined Compression Test, Tanah Lot

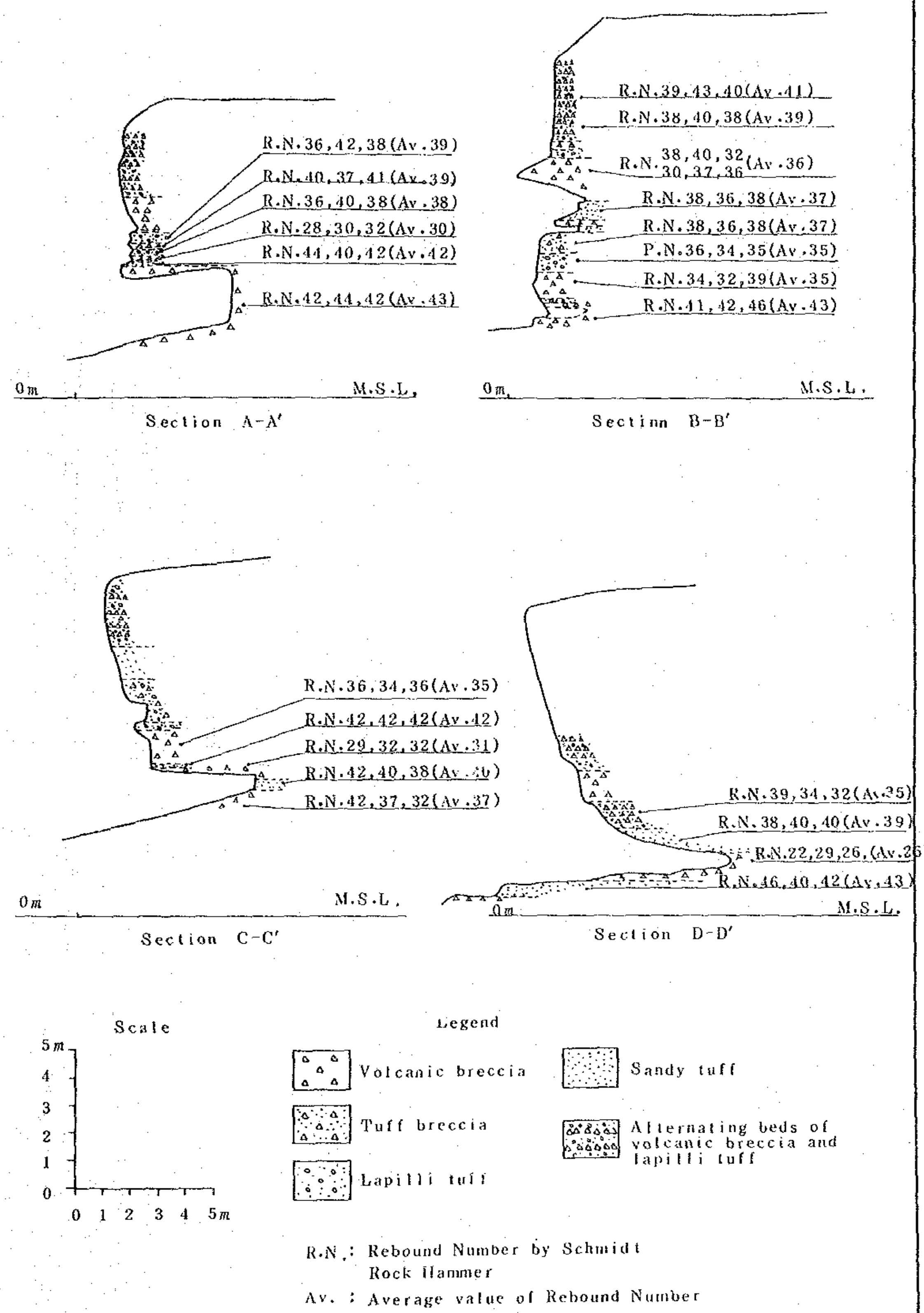


Fig. 2-5-1-2(1) Geological Section A-A', B-B', C-C', D-D', Tanah Lot

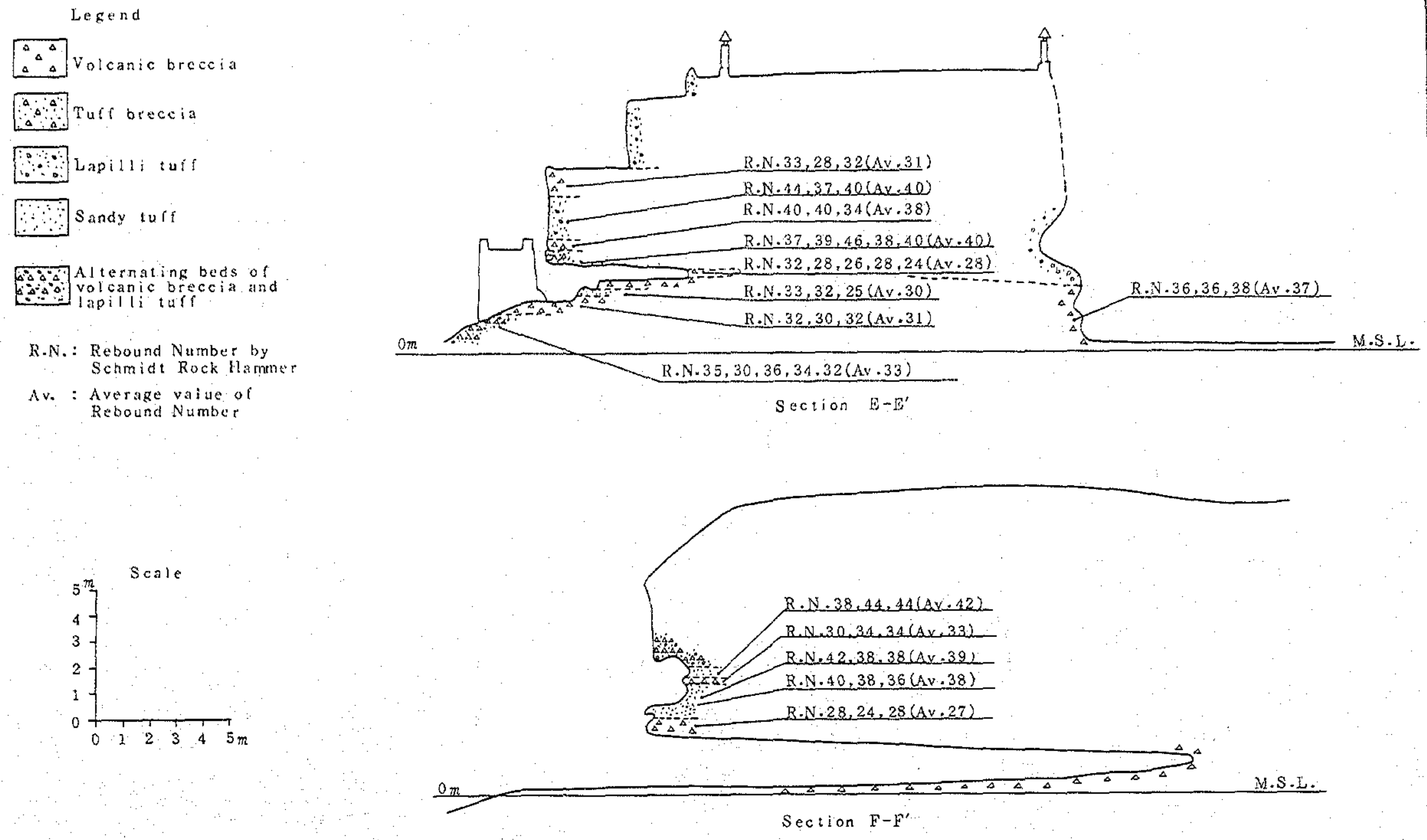


Fig. 2-5-1-2(2) Geological Section E-E', F-F', Tanah Lot

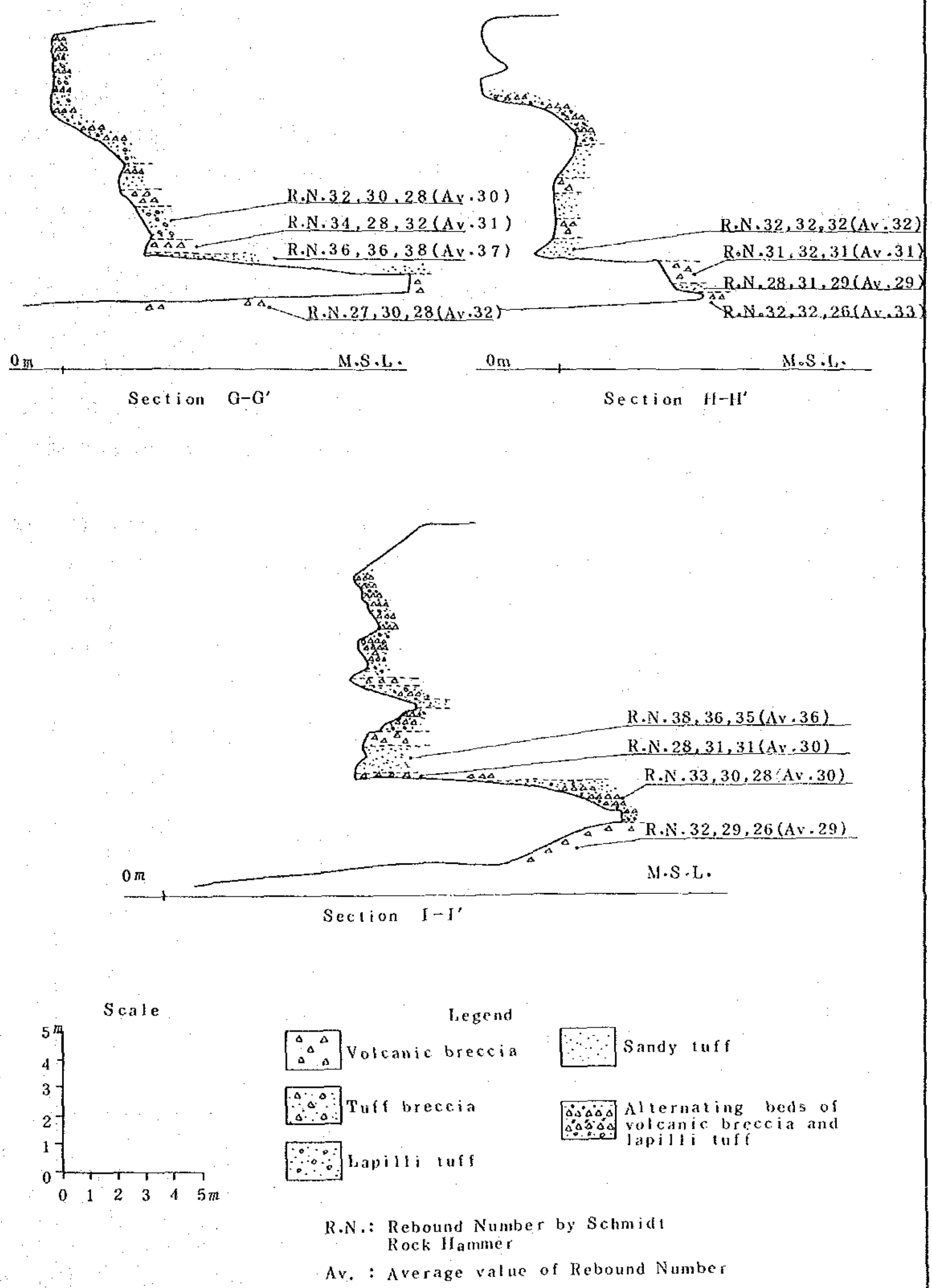


Fig. 2-5-1-2(3) Geological Section G-G', H-H', I-I', Tanah Lot

The rebound numbers of rock were generally higher in sandy tuff and lower in volcanic breccia. But, the differences are small and the values are sometimes inverse. In general, the volcanic breccia is regarded as weaker rock than the sandy tuff.

In Tanah Lot, notches 4 to 20 meters in depth and 5 to 30 meters wide are found on the island and the sea cliffs. These notches are often found at volcanic breccia in the lower part of volcaniclastic rocks. This fact shows that the lower part is located near sea level and consists of volcanic breccia having a thick interval.

Five volcanic breccia samples for unconfined compression test were collected in the lower part of volcaniclastic rocks (refer to Fig. 2-5-1-1). Unconfined compression tests were done under natural conditions and using "the method of unconfined compression test of soils (JIS A 1216)". The results of the unconfined compression test are shown in Table 2-5-1-2.

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. These unconfined compressive strength values are plotted in Fig. 2-5-1-5 [(2)] showing the relationship between the retreating speeds of beach in Japan and the compressive strength of rock.

Note (2) : Quote from "Sunamura T.: A review of recent studies of rock coast transformation due to waves, Geographical Review of Japan, 48-6, 395 ~411, 1975."

Table 2-5-1-2 Results of Unconfined Compression Test

Sample No.	Locality	Rock Name	Test Condition	Test Piece		Water Content (%)	Unit Weight (g/cm^3)	Compressive Strength (kg/cm^2)	Rebound Number of Rock
				Diameter (cm)	Length (cm)				
181	10 m SE from section H-H'	Volcanic breccia in the lower part	Natural	5.68	11.63	16.7	1.8	19.2	25
182 A	4 m SE from section G-G'	Ditto	Ditto	5.52	11.07	23.3	1.5	32.9	32
182 B			Ditto	5.58	9.07	29.3	1.5	19.3	
183 A	5 m SE from section D-D'	Ditto	Ditto	5.61	10.72	46.6	1.2	17.4	29
183 B			Ditto	5.55	9.32	5.8	1.4	16.0	
184	6 m NW from section E-E'	Ditto	Ditto	5.61	9.31	10.6	1.9	49.8	33
185 A	11 m SE from section E-E'	Ditto	Ditto	5.61	11.80	2.5	2.0	79.1	32
185 B			Ditto	5.61	11.63	14.9	1.9	60.0	
Average						18.7	1.7	36.7	

Note: Two tests, A and B were done about one sample.

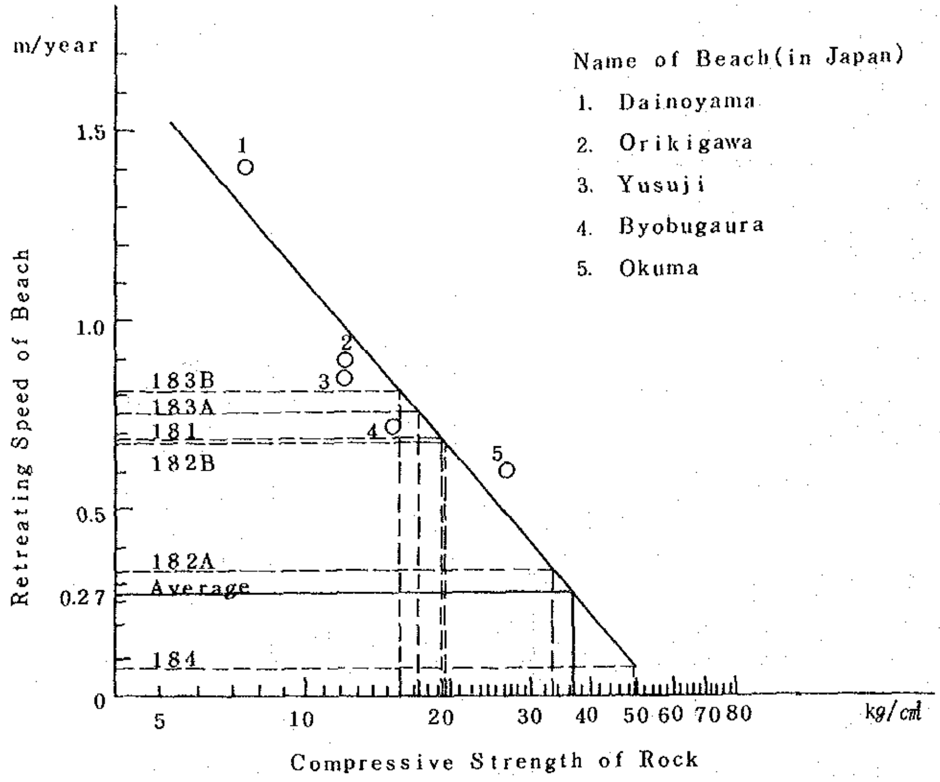


Fig. 2-5-1-3 Diagram showing the Relationship between Retreating Speed of Beach in Japan and the Compressive Strength of Rock(20 to 90 years term) ....

According to the above diagram, it is estimated that the retreating speed at Tanah Lot Beach is less than 80 cm/year and its average is 27 cm/year. However, the retreating is mainly advanced by collapses of sea caves, and is sudden and not continuous.

2-5-2 Bottom Material

Bottom material samples were collected from rivers and beaches in Kuta, Nusa Dua and Sanur Beach, and done grain size analysis, specific gravity and mineral composition tests were carried out.

Grain size analysis was done using "the method of grain size analysis of soils (JIS A 1204)" using 2.0 mm, 0.84 mm, 0.42 mm, 0.30 mm, 0.25 mm, 0.21 mm, 0.15 mm, 0.105 mm and 0.074 mm screen. Specific gravity was measured using "the method of specific gravity test of soil particles (JIS A 1202)". The mineral composition test consists of magnetic separation and a 2.4N−HCℓ soluble test. The procedures are shown in Fig. 2-5-2-1.

The results of the grain size analysis, specific gravity and mineral composition test are shown in Table 2-5-2-1. Also, the results of stereomicroscope observation on the bottom material are shown in Table 2-5-2-2.

(1) Bottom Material of the River

Bottom material samples were collected at 1 km intervals, along the river between Sawangan and Petangan village in Nusa Dua Beach, and along the Ayung River and the Loloan River in Sanur Beach. Also, several beach sand samples were collected near the mouths of these rivers to check the relationship between the river and the beach bottom materials. The sampling sites and sample numbers are shown in Fig. 2-5-2-2 and Fig. 2-5-2-3. Also, diagrams concerning the results of the tests are shown in Fig. 2-5-2-4 to Fig. 2-5-2-6.

1) River between Sawangan and Petangan Village

The river runs in flat hills consisting of coral limestone, and makes dolines. No river water usually runs in the river, except during heavy rains.

The median grain sizes of the bottom material in the river (river sand) range from 0.36 to 0.67 mm. Because the river is relatively steep, the median grain sizes are coarser than at the Ayung and the Loloan. Also, the median grain sizes are irregular and do not tend to become finer toward the lower stream because the river runs only during heavy rains.

The mineral composition of the bottom material in the river includes silicate and magnetic materials, from volcanic ash. The percentage of clastic fragments of coral limestone is small because river water does not usually run in the river.

The specific gravity of the bottom material in the river is 2.74.

2) Ayung River

The Ayung River, which is one of longest rivers on Bali Island, runs from the ridge between G. Batur and G. Catur to the north of Sanur Beach. The river flows in the Buyan-Bratan, Batur Tuff and Lahar Deposits, making deep gorges.

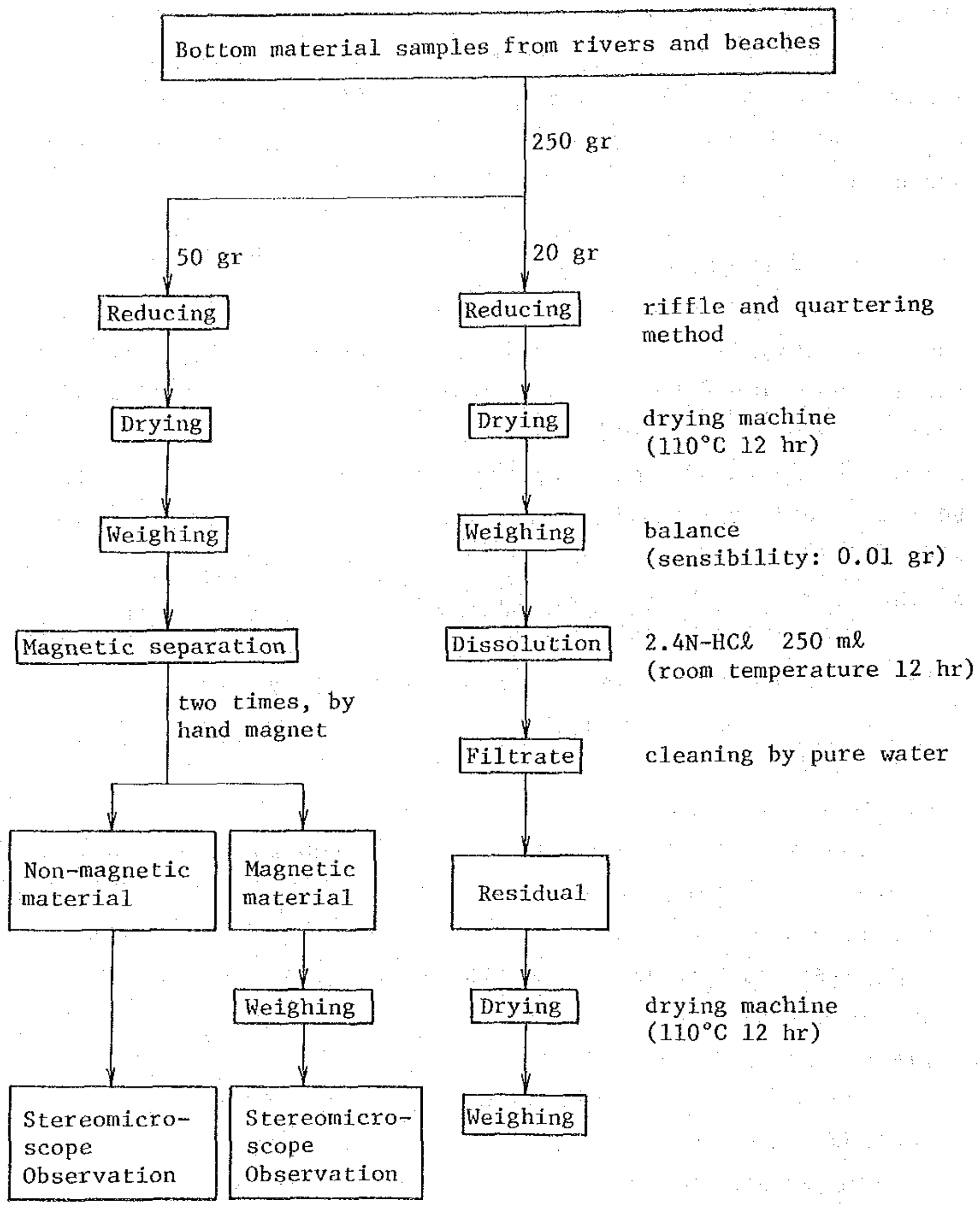


Fig. 2-5-2-1 Flow Sheet Showing the Procedures of Magnetic Separation and 2.4N-HCℓ Soluble Test

Table 2-5-2-1 Result of Grain Size Analysis, Specific Gravity and Mineral Composition Test

(1)

Sample No.	Sample Name (Sand)	Location	Laboratory Test Results					
			Median Grain Size	Grain Size Distribution		Specific Gravity	Min. Composition	
			D_{50} (mm)	Uc	Uc'		Magnetic Material (%)	Soluble Material (%)
1	Beach Sa	Nusa Dua	0.72	2.270	0.904	2.698	1.54	98.80
2	Beach Sa	Lebang	1.05	2.500	1.111	2.696	1.71	98.70
3	River Sa	Sawangan	0.67	5.649	1.135			
4	River Sa	Sawangan	0.57	3.463	0.992			
5	River Sa	Sawangan	0.42	2.941	1.205	2.744	5.71	22.70
6	River Sa	Sawangan	0.36	2.545	0.902			
7	River Sa	Sawangan	0.54	2.032	0.933			
8	Beach Sa	W. Sanur	0.63	3.737	1.508			
9	River Sa	Loloan	0.37	2.356	1.060			
10	River Sa	Loloan	0.31	3.214	0.849			
11	River Sa	Loloan	0.35	3.832	1.054	2.696	49.69	7.75
12	River Sa	Loloan	0.33	5.333	1.021			
13	River Sa	Loloan	0.23	4.091	0.991			
14	River Sa	Ayung	0.09	-	-			
15	River Sa	Ayung	0.14	0.237	0.100			
16	River Sa	Ayung	0.17	2.597	0.935			
17	River Sa	Ayung	0.22	2.755	0.967			
18	River Sa	Ayung	0.45	5.357	0.975			
19	River Sa	Ayung	0.12	-	-			
20	River Sa	Ayung	0.24	3.626	0.951	2.706	31.52	6.80
21 A	Beach Sa	Nusa Dua	0.97	7.929	0.701			
21 B	Beach Sa	Nusa Dua	0.90	6.993	0.665			
22 A	Beach Sa	Nusa Dua	0.38	1.955	1.082	2.700	2.32	93.55
22 B	Beach Sa	Nusa Dua	1.28	1.556	0.926			
23 A	Beach Sa	Nusa Dua	0.39	1.556	1.019			
23 B	Beach Sa	Nusa Dua	1.25	1.580	0.919			
24 A	Beach Sa	Nusa Dua	0.37	1.667	1.067	2.680	4.21	94.60
24 B	Beach Sa	Nusa Dua	0.73	2.844	0.759			
25 A	Beach Sa	Nusa Dua	0.41	1.610	0.870			
25 B	Beach Sa	Nusa Dua	1.18	2.289	1.239			
26 A	Beach Sa	Nusa Dua	0.37	1.538	1.047	2.681	3.55	94.80
26 B	Beach Sa	Nusa Dua	0.80	2.043	0.846			
27 A	Beach Sa	Nusa Dua	0.33	2.182	0.970			
27 B	Beach Sa	Nusa Dua	0.81	2.233	0.843			
28 A	Beach Sa	Nusa Dua	0.54	2.388	0.905	2.702	3.55	95.35
28 B	Beach Sa	Nusa Dua	1.22	1.811	1.008			
29 A	Beach Sa	Nusa Dua	0.52	1.970	0.830			
29 B	Beach Sa	Nusa Dua	1.22	1.929	1.079			
30 A	Beach Sa	Nusa Dua	0.31	1.422	1.006	2.741	3.87	96.00

(2)

Sample No.	Sample Name (Sand)	Location	Laboratory Test Results: Median Grain Size D_{50} (mm)	Grain Size Distribution: Uc	Grain Size Distribution: Uc'	Specific Gravity	Min. Composition: Magnetic Material (%)	Min. Composition: Soluble Material (%)
30 B	Beach Sa	Nusa Dua	1.15	2.612	1.291			
31 A	Beach Sa	Nusa Dua	0.53	1.788	0.928			
31 B	Beach Sa	Nusa Dua	1.03	2.682	1.055			
32 A	Beach Sa	Nusa Dua	0.53	2.577	0.744	2.725	1.90	97.25
32 B	Beach Sa	Nusa Dua	1.00	2.738	0.957			
33 A	Beach Sa	Nusa Du	0.41	1.607	0.972			
33 B	Beach Sa	Nusa Dua	1.05	2.674	1.120			
34 A	Beach Sa	Nusa Dua	0.29	1.180	0.950	2.731	3.31	95.60
34 B	Beach Sa	Nusa Dua	0.62	1.634	0.910			
35 A	Beach Sa	Nusa Dua	0.53	1.869	0.873			
35 B	Beach Sa	Nusa Dua	0.76	2.000	0.869			
36 A	Beach Sa	Nusa Dua	0.55	1.794	1.020	2.634	2.71	97.00
36 B	Beach Sa	Nusa Dua	0.78	2.022	0.850			
37 A	Beach Sa	Nusa Dua	0.42	1.690	0.862			
37 B	Beach Sa	Nusa Dua	0.65	1.816	0.921			
38 A	Beach Sa	Nusa Dua	0.60	1.833	0.970	2.769	2.26	99.25
38 B	Beach Sa	Nusa Dua	0.62	1.971	0.994			
39 A	Beach Sa	Nusa Dua	0.88	2.115	0.867			
39 B	Beach Sa	Nusa Dua	1.20	2.015	1.151			
40 A	Beach Sa	Nusa Dua	1.12	2.352	1.155	2.697	1.28	98.90
40 B	Beach Sa	Nusa Dua	0.95	2.558	0.949			
41 A	Beach Sa	Nusa Dua	0.54	1.765	0.949			
41 B	Beach Sa	Nusa Dua	0.84	2.106	0.853			
42 A	Beach Sa	Nusa Dua	0.85	3.125	0.661	2.656	1.49	98.95
42 B	Beach Sa	Nusa Dua	0.92	2.972	0.873			
43 A	Beach Sa	Nusa Dua	0.38	1.455	0.960	2.726	1.92	98.05
43 B	Beach Sa	Nusa Dua	0.66	1.800	0.939			
44 A	Beach Sa	Nusa Dua	0.60	2.290	0.764			
44 B	Beach Sa	Nusa Dua	1.10	2.510	1.227			
45 A	Beach Sa	Nusa Dua	0.44	1.790	0.843	2.759	0.95	91.80
45 B	Beach Sa	Nusa Dua	1.07	2.353	1.099			
46 A	Beach Sa	Nusa Dua	0.42	1.508	0.924			
46 B	Beach Sa	Nusa Dua	0.66	2.090	0.940			
47 A	Beach Sa	Nusa Dua	0.40	1.872	1.053	2.728	3.30	92.35
47 B	Beach Sa	Nusa Dua	1.07	2.860	1.334			
48 A	Beach Sa	Nusa Dua	0.35	1.854	1.315			
48 B	Beach Sa	Nusa Dua	0.70	2.189	0.902			
49 A	Beach Sa	Nusa Dua	0.28	1.318	1.101	2.764	3.63	92.75
49 B	Beach Sa	Nusa Dua	0.98	2.523	0.919			
50 A	Beach Sa	Nusa Dua	0.60	2.792	1.374			
50 B	Beach Sa	Nusa Dua	0.98	2.375	0.895			
51-1 A	Beach Sa	Kuta	0.22	1.656	0.887			
51-1 B	Beach Sa	Kuta	0.19	1.736	1.020			
51-2 A	Beach Sa	Kuta	0.22	1.731	1.095	2.729	3.19	81.95

(3)

Sample No.	Sample Name (Sand)	Location	Laboratory Test Results: Median Grain Size D50 (mm)	Grain Size Distribution Uc	Grain Size Distribution Uc'	Specific Gravity	Min. Composition: Magnetic Material (%)	Min. Composition: Soluble Material (%)
51-2 B	Beach Sa	Kuta	0.18	1.773	1.021			
52 A	Beach Sa	Kuta	0.14	1.620	1.195			
52 B	Beach Sa	Kuta	0.14	1.596	1.021			
53 A	Beach Sa	Kuta	0.13	1.614	1.040	2.739	5.94	80.35
53 B	Beach Sa	Kuta	0.16	1.830	0.951			
54 A	Beach Sa	Kuta	0.15	1.739	0.995			
54 B	Beach Sa	Kuta	0.16	1.650	0.965			
55 A	Beach Sa	Kuta	0.16	2.021	0.917	2.714	5.29	69.80
55 B	Beach Sa	Kuta	0.15	1.923	0.919			
56 A	Beach Sa	Kuta	0.13	1.726	0.993			
56 B	Beach Sa	Kuta	0.14	1.713	0.968			
57 A	Beach Sa	Kuta	0.42	8.352	0.244	2.716	5.13	86.75
57 B	Beach Sa	Kuta	0.56	7.685	0.238			
58 A	Beach Sa	Kuta	0.18	3.830	0.499			
58 B	Beach Sa	Kuta	0.15	1.848	0.936			
59 A	Beach Sa	Kuta	0.99	10.000	1.742	2.745	3.53	95.75
59 B	Beach Sa	Kuta	0.13	1.595	1.036			
60 A	Beach Sa	Kuta	0.25	3.897	0.425			
60 B	Beach Sa	Kuta	0.14	0.172	0.100			
61 A	Beach Sa	Kuta	0.24	6.040	0.318	2.725	2.46	80.90
61 B	Beach Sa	Kuta	0.13	1.667	1.029			
62 B	Beach Sa	Kuta	0.14	1.629	1.079			
64 B	Beach Sa	Kuta	0.20	2.207	0.883			
65 A	Beach Sa	Kuta	0.14	1.607	1.021	2.717	9.95	59.65
65 B	Beach Sa	Kuta	0.18	1.667	1.140			
66 A	Beach Sa	Kuta	0.15	1.700	0.934			
66 B	Beach Sa	Kuta	0.14	1.722	1.015			
67 A	Beach Sa	Kuta	0.18	1.776	0.978	2.744	6.49	75.30
67 B	Beach Sa	Kuta	0.20	3.727	0.435			
68 A	Beach Sa	Kuta	0.16	1.716	0.947			
68 B	Beach Sa	Kuta	0.75	2.903	1.007			
69 A	Beach Sa	Kuta	0.14	1.598	1.030			
69 B	Beach Sa	Kuta	0.15	1.732	0.990			
70 A	Beach Sa	Kuta	0.21	1.677	1.068	2.716	10.00	64.15
70 B	Beach Sa	Kuta	0.13	1.609	1.030			
71 A	Beach Sa	Kuta	0.14	1.728	0.984			
71 B	Beach Sa	Kuta	0.16	1.938	0.898			
72 A	Beach Sa	Kuta	0.15	1.691	0.963			
72 B	Beach Sa	Kuta	0.15	1.798	0.994			
73 A	Beach Sa	Kuta	0.19	1.641	1.013	2.708	15.00	71.75
73 B	Beach Sa	Kuta	0.16	1.786	0.878			

(4)

Sample No.	Sample Name (Sand)	Location	Laboratory Test Results: Median Grain Size D50 (mm)	Grain Size Distribution Uc	Uc'	Specific Gravity	Min. Composition: Magnetic Material (%)	Soluble Material (%)
74 A	Beach Sa	Kuta	0.17	1.990	0.800			
74 B	Beach Sa	Kuta	0.16	2.220	0.813			
75 A	Beach Sa	Kuta	0.15	1.734	0.971	2.739	14.06	64.75
75 B	Beach Sa	Kuta	0.18	1.835	0.836			
76 A	Beach Sa	Kuta	0.13	1.667	1.029	2.715	11.00	56.10
76 B	Beach Sa	Kuta	0.15	1.643	0.990			
77 A	Beach Sa	Kuta	0.14	1.648	1.020			
77 B	Beach Sa	Kuta	0.15	1.581	0.925			
78 A	Beach Sa	Kuta	0.15	1.649	0.959	2.755	10.03	55.25
78 B	Beach Sa	Kuta	0.17	1.682	0.946			
79 A	Beach Sa	Kuta	0.15	1.626	1.034			
79 B	Beach Sa	Kuta	0.13	1.296	0.952			
80-1 A	Beach Sa	Kuta	0.19	1.650	1.077	2.765	14.51	54.75
80-1 B	Beach Sa	Kuta	0.17	1.636	1.047			
80-2 A	Beach Sa	Kuta	0.21	1.958	1.025	2.755	7.15	77.55
80-2 B	Beach Sa	Kuta	0.19	1.842	1.069			
81 A	Beach Sa	Sanur	1.20	2.079	1.164	2.706	0.15	99.65
81 B	Beach Sa	Sanur	0.36	2.343	0.928			
82 A	Beach Sa	Sanur	0.41	2.085	1.004			
82 B	Beach Sa	Sanur	0.42	2.928	1.067			
83 A	Beach Sa	Sanur	0.83	3.175	0.892	2.691	0.30	99.10
83 B	Beach Sa	Sanur	0.49	2.791	0.950			
84 A	Beach Sa	Sanur	1.08	2.330	1.142			
84 B	Beach Sa	Sanur	1.15	2.667	1.318			
85 A	Beach Sa	Sanur	0.53	2.035	1.171	2.720	0.45	99.30
85 B	Beach Sa	Sanur	0.51	3.804	0.795			
86 A	Beach Sa	Sanur	1.12	2.864	1.429			
86 B	Beach Sa	Sanur	0.39	2.818	0.943			
87 A	Beach Sa	Sanur	0.67	2.294	0.905			
87 B	Beach Sa	Sanur	0.85	2.941	0.890			
88 A	Beach Sa	Sanur	0.46	2.208	1.019	2.764	1.17	97.75
88 B	Beach Sa	Sanur	0.90	3.453	0.998			
89 A	Beach Sa	Sanur	0.88	3.355	0.973			
89 B	Beach Sa	Sanur	0.64	4.050	0.845			
90 A	Beach Sa	Sanur	1.00	2.300	0.952			
90 B	Beach Sa	Sanur	0.60	2.536	0.974			
91 A	Beach Sa	Sanur	1.10	2.315	1.200	2.645	0.27	99.75
91 B	Beach Sa	Sanur	0.60	2.092	1.000			
92 A	Beach Sa	Sanur	1.16	2.167	1.133			
92 B	Beach Sa	Sanur	0.48	2.327	0.928			
93 A	Beach Sa	Sanur	1.30	1.522	0.939			
93 B	Beach Sa	Sanur	0.46	4.714	1.007			
94 A	Beach Sa	Sanur	1.30	1.538	0.916	2.685	0.06	99.55
94 B	Beach Sa	Sanur	1.20	2.062	1.125			

(5)

Sample No.	Sample Name (Sand)	Location	Median Grain Size D_{50} (mm)	Grain Size Distribution Uc	Grain Size Distribution Uc'	Specific Gravity	Min. Composition Magnetic Material (%)	Min. Composition Soluble Material (%)
95 A	Beach Sa	Sanur	0.70	1.951	0.889			
95 B	Beach Sa	Sanur	0.41	4.909	0.891			
96 A	Beach Sa	Sanur	1.17	2.600	1.339			
96 B	Beach Sa	Sanur	0.62	5.731	0.592			
97 A	Beach Sa	Sanur	1.00	2.714	1.023	2.678	0.74	98.20
97 B	Beach Sa	Sanur	0.70	3.000	0.839			
98 A	Beach Sa	Sanur	0.64	2.980	1.140			
98 B	Beach Sa	Sanur	1.05	3.077	1.267			
99 A	Beach Sa	Sanur	1.23	1.722	0.968			
99 B	Beach Sa	Sanur	1.08	2.727	1.273			
100 A	Beach Sa	Sanur	0.59	2.094	1.030	2.764	1.39	98.10
100 B	Beach Sa	Sanur	1.30	1.538	0.950			
101 A	Beach Sa	Sanur	0.41	2.087	1.047	2.788	2.36	97.05
101 B	Beach Sa	Sanur	1.15	2.612	1.320			
102 A	Beach Sa	Sanur	0.41	2.133	1.070	2.776	0.27	97.65
102 B	Beach Sa	Sanur	1.18	2.434	1.292			
103 A	Beach Sa	Sanur	1.28	1.562	0.908			
103 B	Beach Sa	Sanur	1.30	1.514	0.934			
104 A	Beach Sa	Sanur	0.87	2.525	0.891	2.774	20.56	72.00
104 B	Beach Sa	Sanur	1.16	2.955	1.496			
105 A	Beach Sa	Sanur	0.23	1.509	0.976	4.478	95.88	9.75
105 B	Beach Sa	Sanur	0.31	2.060	0.863			
106 A	Beach Sa	Sanur	0.22	1.655	0.973	3.949	81.37	8.30
106 B	Beach Sa	Sanur	0.27	2.105	0.898			
107 A	Beach Sa	Sanur	0.23	1.500	1.148			
107 B	Beach Sa	Sanur	0.25	2.319	0.817			
108 A	Beach Sa	Sanur	0.21	1.703	0.944	4.124	95.05	9.90
108 B	Beach Sa	Sanur	0.40	2.629	1.194			
109 A	Beach Sa	Sanur	0.25	1.906	0.861			
109 B	Beach Sa	Sanur	0.32	2.182	0.852			
110 A	Beach Sa	Sanur	0.27	2.481	1.172	4.659	97.48	6.05
110 B	Beach Sa	Sanur	0.33	2.118	0.864			

Note; Median Grain Size

D_{50} : 50% Grain size (mm)

Grain Size Distribution

$U_c = D_{60} \times D_{10}$

$U_c' = (D_{30})^2/(D_{10} \times D_{60})$

U_c : Coefficient of uniformity

U_c' : Coefficient of curvature

D_{10} : 10% of Grain size (mm)

D_{30} : 30% Grain size (mm)

D_{60} : 60% Grain size (mm)

Table 2-5-2-2 Result of Stereomicroscope Observation on the Bottom Material in River and Beach

(1)

Bottom Material		Magnetic Material	Non-magnetic Material
in River	River between Sawangan and Petangan Village	Magnetic material consists mainly of magnetite, and partly contains quartz, amphibole and brown iron-oxide material.	Non-magnetic material consists mainly of brown iron-oxide material including plagioclase, amorphous material and coral limestone fragment, and rarely contains amphibole and quartz.
	Ayung River	Magnetic material consists mainly of magnetite, and partly contains quartz, plagioclase, amphibole and andesite ∿ basalt fragment, including magnetite.	Non-magnetic material consists mainly of white unknown material (clay mineral?), andesite ∿ basalt, welded tuff (lahar) and obsidian fragment, and rarely contains quartz, amphibole and pyroxene.
	Loloan River	Magnetic material consists mainly of magnetite, and partly contains quartz, plagioclase, amphibole and andesite ∿ basalt fragment, including magnetite.	Non-magnetic material consists mainly of white unknown material (clay mineral?), andesite ∿ basalt and welded tuff (lahar) fragment, and rarely contains quartz, amphibole and pyroxene.

(2)

Bottom Material			Magnetic Material	Non-Magnetic Material
Beach	Kuta Beach		Magnetic material consists mainly of magnetite, and partly contains quartz, plagioclase, amphibole, pyroxene, andesite ∿ basalt, obsidian and coral fragment, including magnetite.	Non-magnetic material consists mainly of coral fragment (ball, dendritic shape etc.), and partly contains quartz, plagioclase, amphibole, pyroxene, andesite ∿ basalt, obsidian and coral limestone fragment.
	Nusa Dua Beach		Magnetic material consists mainly of magnetite, and partly contains quartz, amphibole, pyroxene, reddish brown unknown material and coral fragment, including magnetite.	Non-magnetic material consists mainly of coral fragment (ball, star, dendritic shape etc.), and rarely contains quartz, amphibole, reddish brown unknown material, obsidian and coral limestone fragment.
	Sanur Beach	The Southern side from the Groin	Magnetic material consists mainly of magnetite, and partly contains quartz, amphibole, pyroxene, andesite ∿ basalt, obsidian and coral fragment, including magnetite.	Non-magnetic material consists mainly of coral fragment (ball, dendritic shape etc.), and rarely contains quartz, plagioclase, amphibole, pyroxene, andesite ∿ basalt, obsidian and coral lime-stone fragment.

(3)

Bottom Material			Magnetic Material	Non-magnetic Material
Beach	Sanur Beach	Between the Groin and the Coral Reef Edge	Magnetic material consists mainly of magnetite, and partly contains quartz, amphibole, pyroxene, andesite ∿ basalt, welded tuff (lahar) and obsidian fragment, including magnetite.	Non-magnetic material consists mainly of coral fragment, and partly contains quatz, plagioclase, amphibole, pyroxene, andesite ∿ basalt, obsidian and coral limestone fragment.
		The Northern Side from the Coral Reef Edge	Magnetic material consists almost wholly of magnetite, and rarely contains quartz, plagioclase, amphibole, pyroxene and andesite ∿ basalt fragment, including magnetite.	Non-magnetic material consists of quartz, plagioclase, amphibole, pyroxene, andesite ∿ basalt fragment and carbonate material.

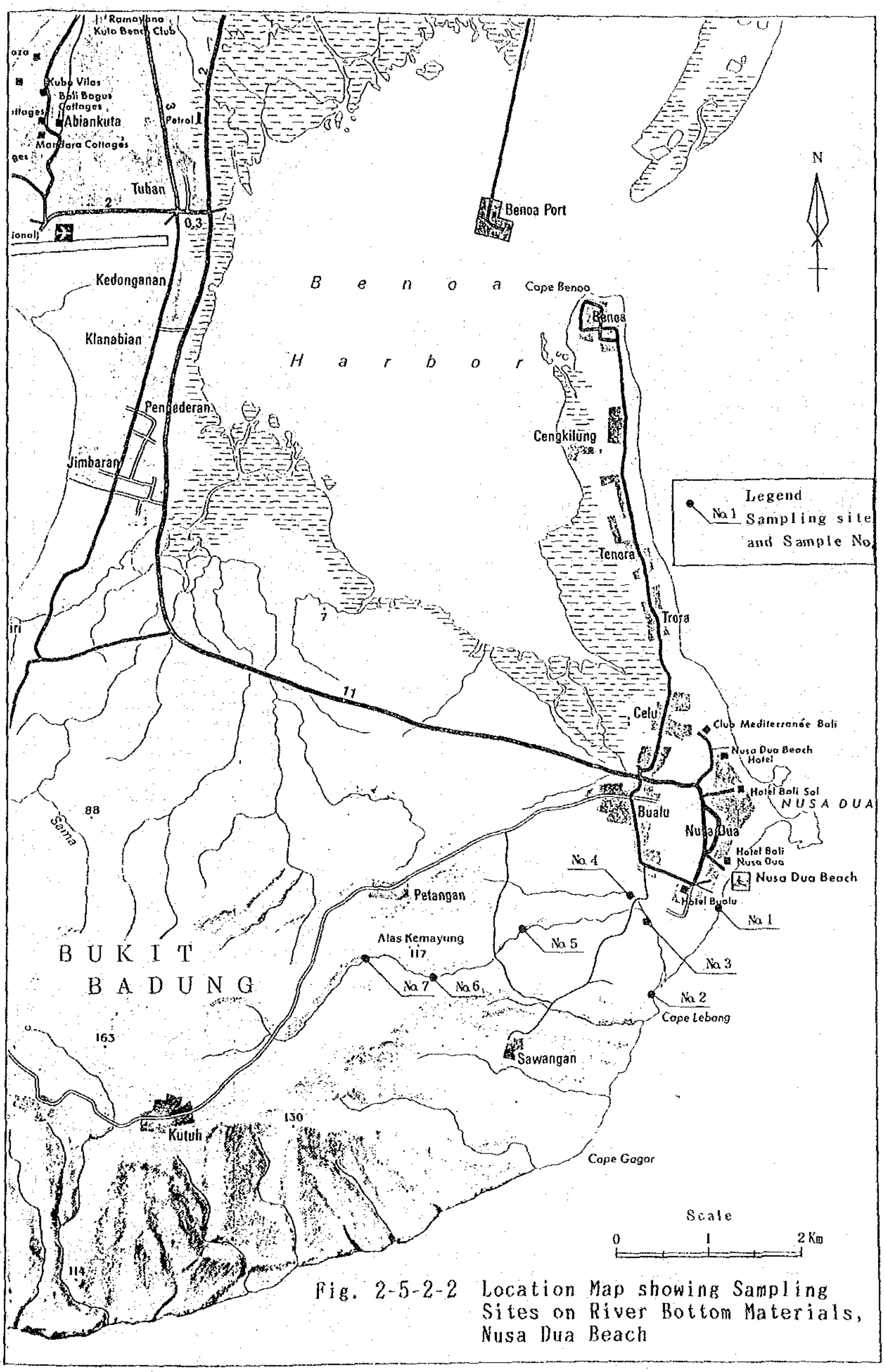


Fig. 2-5-2-2 Location Map showing Sampling Sites on River Bottom Materials, Nusa Dua Beach

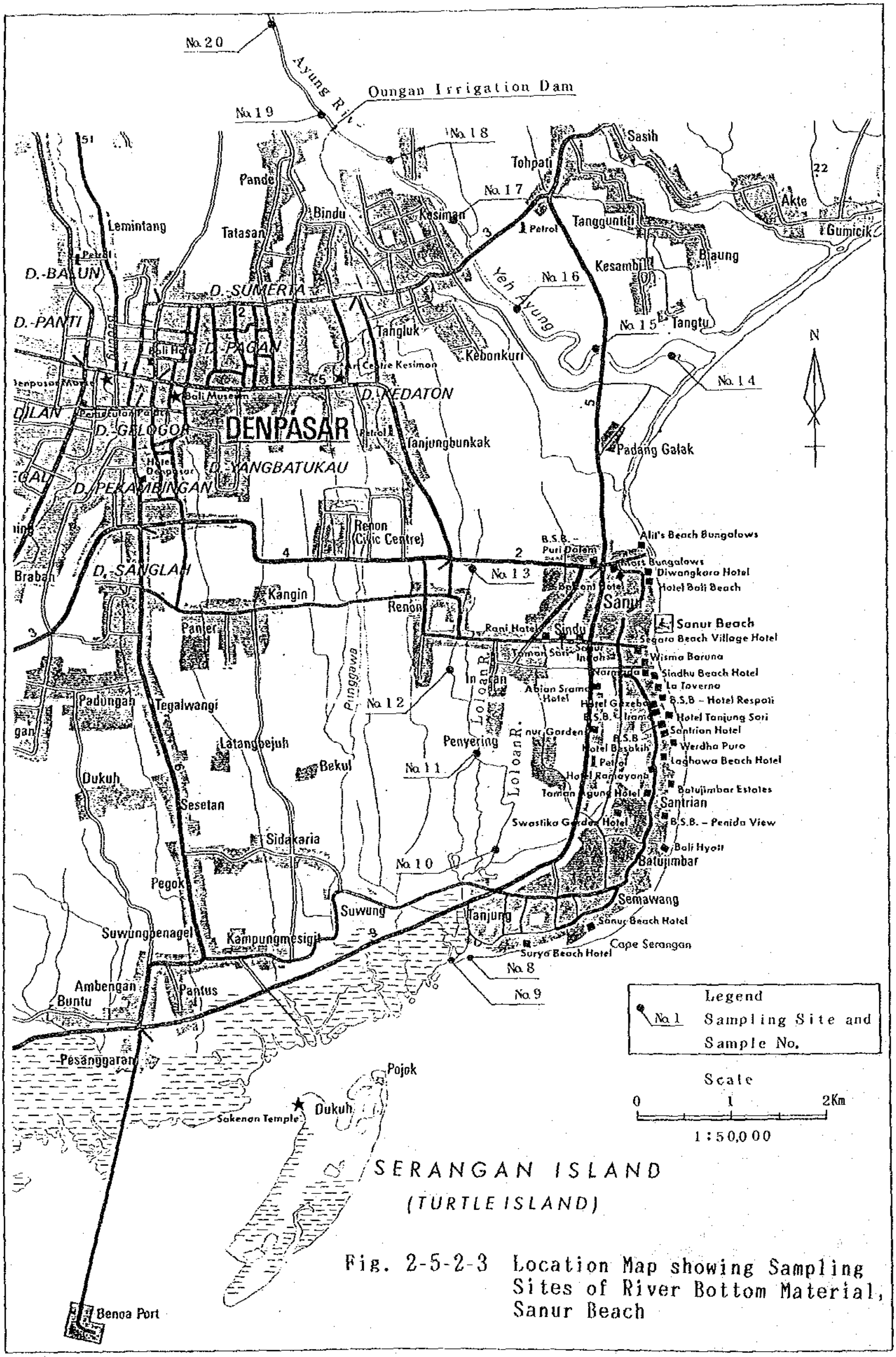


Fig. 2-5-2-3 Location Map showing Sampling Sites of River Bottom Material, Sanur Beach

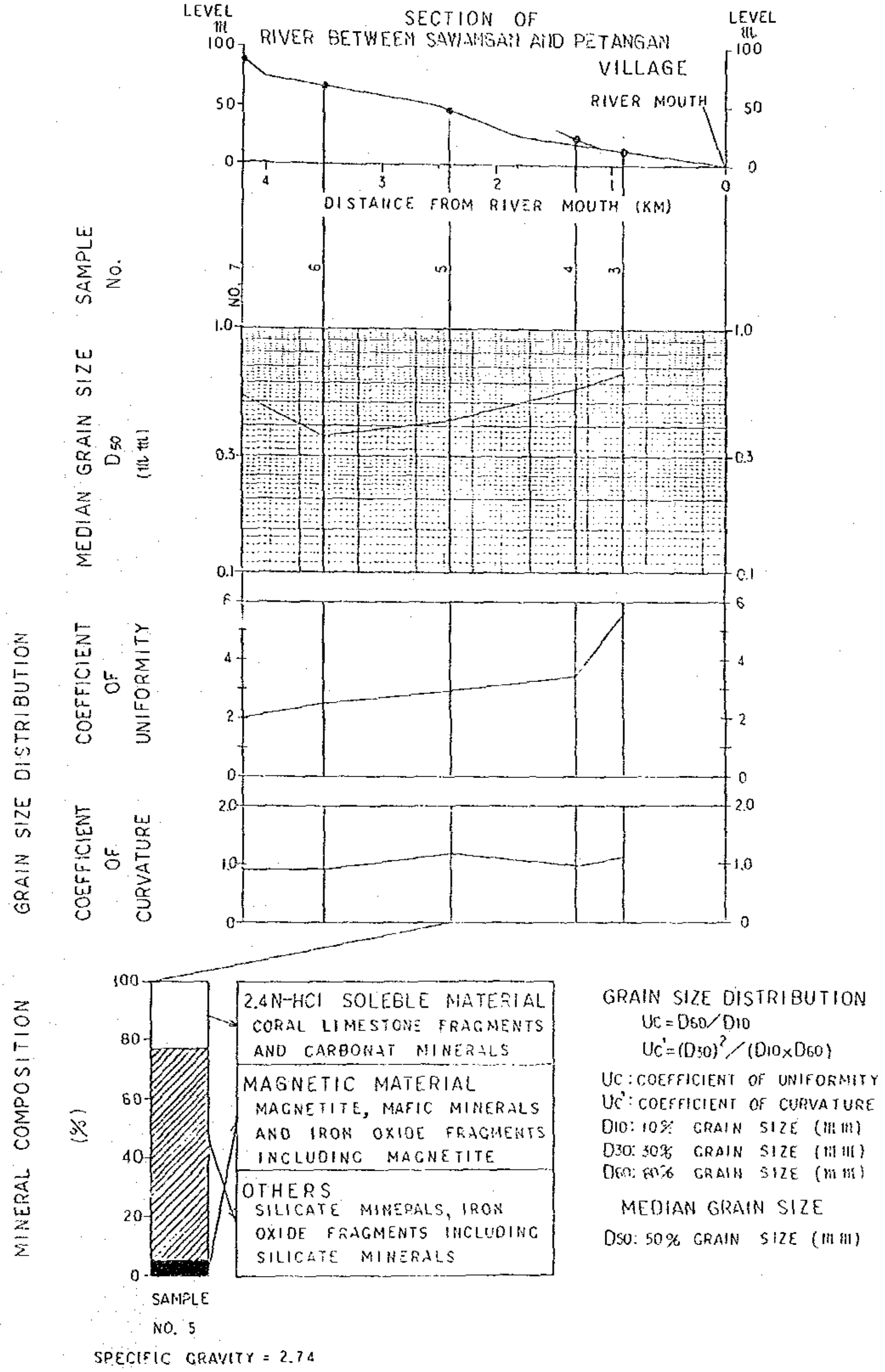


Fig. 2-5-2-4 Diagram Showing the Results of Grain Size Analysis, Specific Gravity and Mineral Composition Test, on River Bottom Materials between Sawangan and Petangan Village.

The median grain size of the bottom material in the river ranges from 0.09 to 0.45 mm. Because median grain sizes depend on river flow velocity, they become finer toward the lower stream, except at the upper stream from the Oungan irrigation dam.

The mineral composition of the bottom material in the river shows a high slicate material content, high magnetic material content and low 2.4N-HCℓ soluble material content. This means that the bottom material in the river is volcanic rock in origin.

The specific gravity of the bottom material in the river is 2.71.

3) Loloan River

The Loloan River is an irrigation waterway from Oungan dam in the Ayung River, and runs slowly to the west of Sanur Beach through paddy fields.

The median grain sizes of the bottom material in the river range from 0.23 to 0.37 mm. Because the river has a gentle inclination and similar flow velocities, the range of median grain sizes is smaller than at other rivers. And the median grain sizes are irregular and do not have a general tendency to become finer toward the lower stream.

The mineral composition of the bottom material shows high silicate material content, high magnetic material content and low 2.4N－HCℓ soluble material content. This means that the bottom material in the river is volcanic rock in origin, same os the Ayung River.

The specific gravity of the bottom material in the river is 2.70.

(2) Bottom Material of Beaches

The bottom material samples were collected (A and B) at 100 meters intervals at Nusa Dua beach and Kuta beach, and at 100 to 450 meter intervals at Sanur beach. The sampling positions are shown in the following Fig. 2-5-2-7.

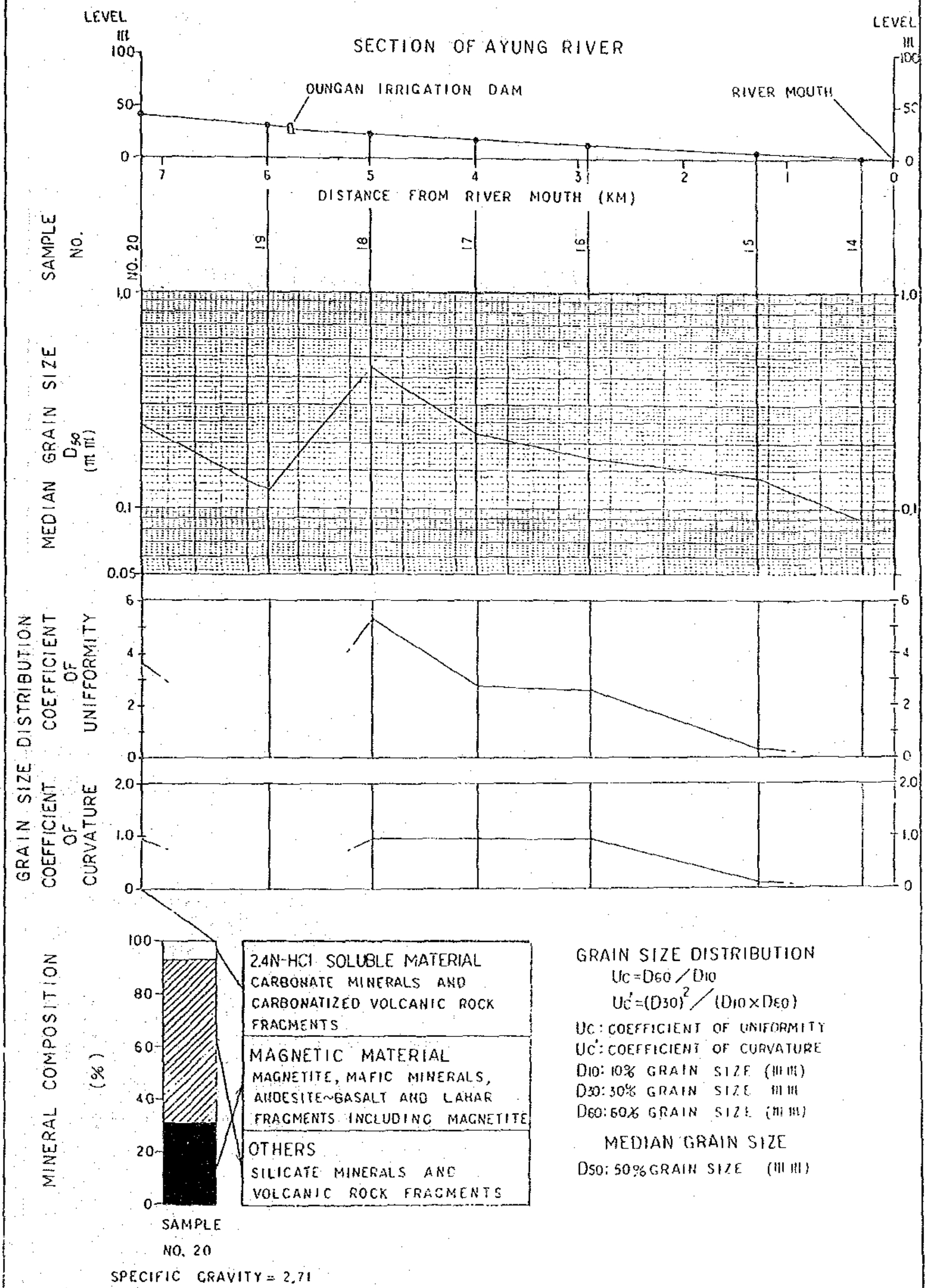


Fig. 2-5-2-5 Diagram Showing the Results of Grain Size Analysis, Specific Gravity and Mineral Composition Test on Bottom Materials in Ayung River.

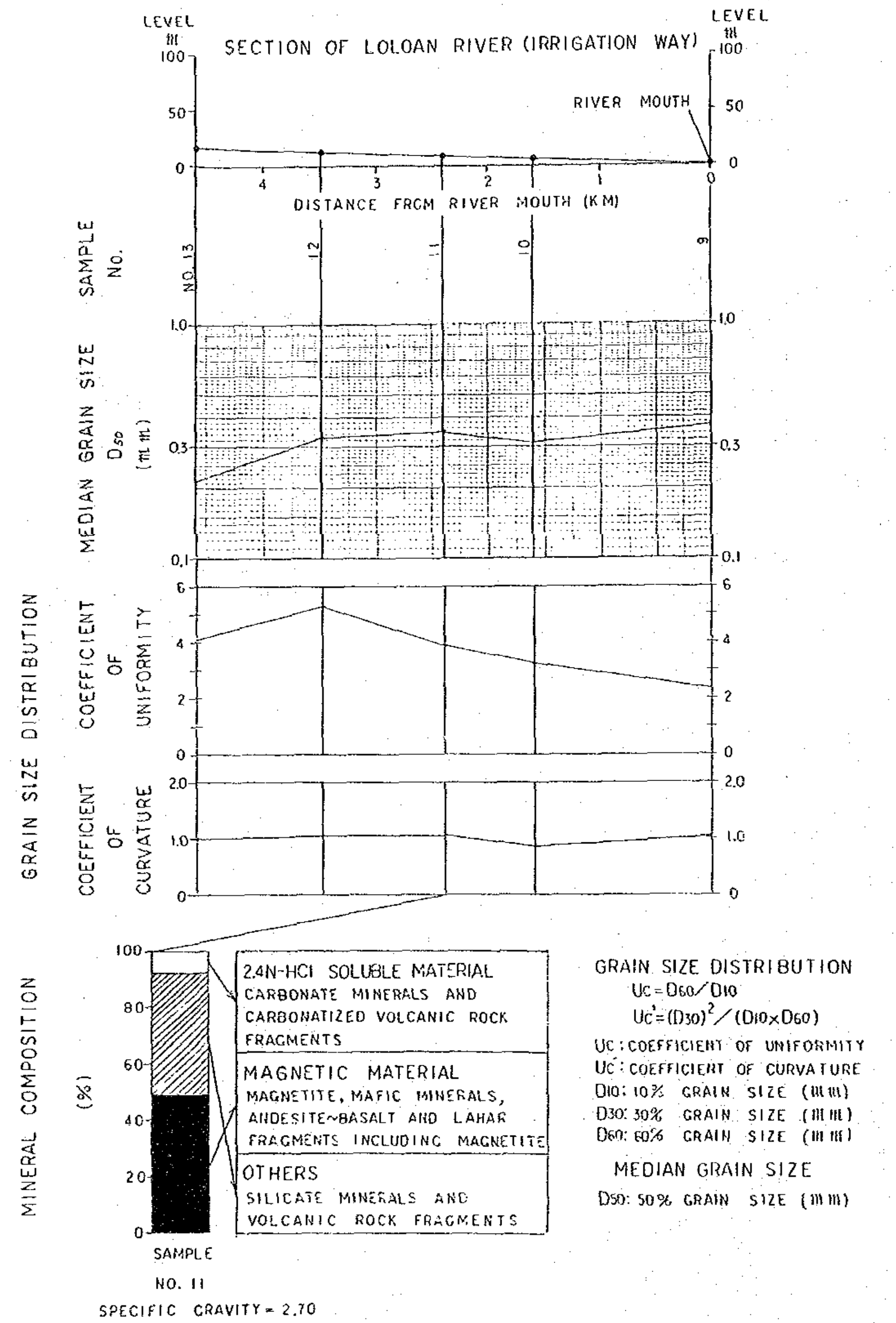


Fig. 2-5-2-6 Diagram Showing the Results of Grain Size Analysis, Specific Gravity and Mineral Composition Test on Bottom Materials in Loloan River.

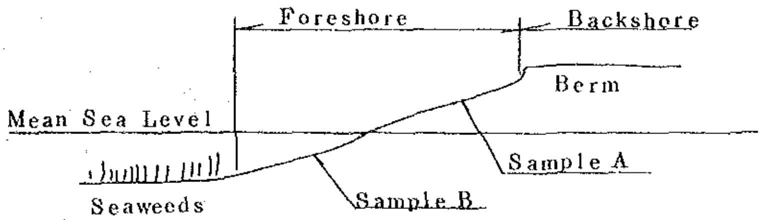


Fig. 2-5-2-7 Illustration showing Sampling Sites A and B on Bottom Material at Beaches

Sampling sites, sample numbers and diagrams concerning the results of the tests (grain size analysis, specific gravity and mineral compostion test), are shown in Fig. 2-5-2-8 to Fig. 2-5-2-13.

1) Kuta Beach

Kuta Beach a has gentle slope in comparison with Nusa Dua and Sanur 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 differences of median grain sizes between samples A and B are generally small. But, they become larger at the south of Pertamina Cottage and between Pertamina Cottage and the Santika Plaza Hotel. Also, at both places, the median grain sizes become coarser and the grain size distribution shows an abnormal pattern.

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. Because magnetic material and silicate material are volcanic rock in origin, they are supplied from the the southern slopes of the volcanic range. 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

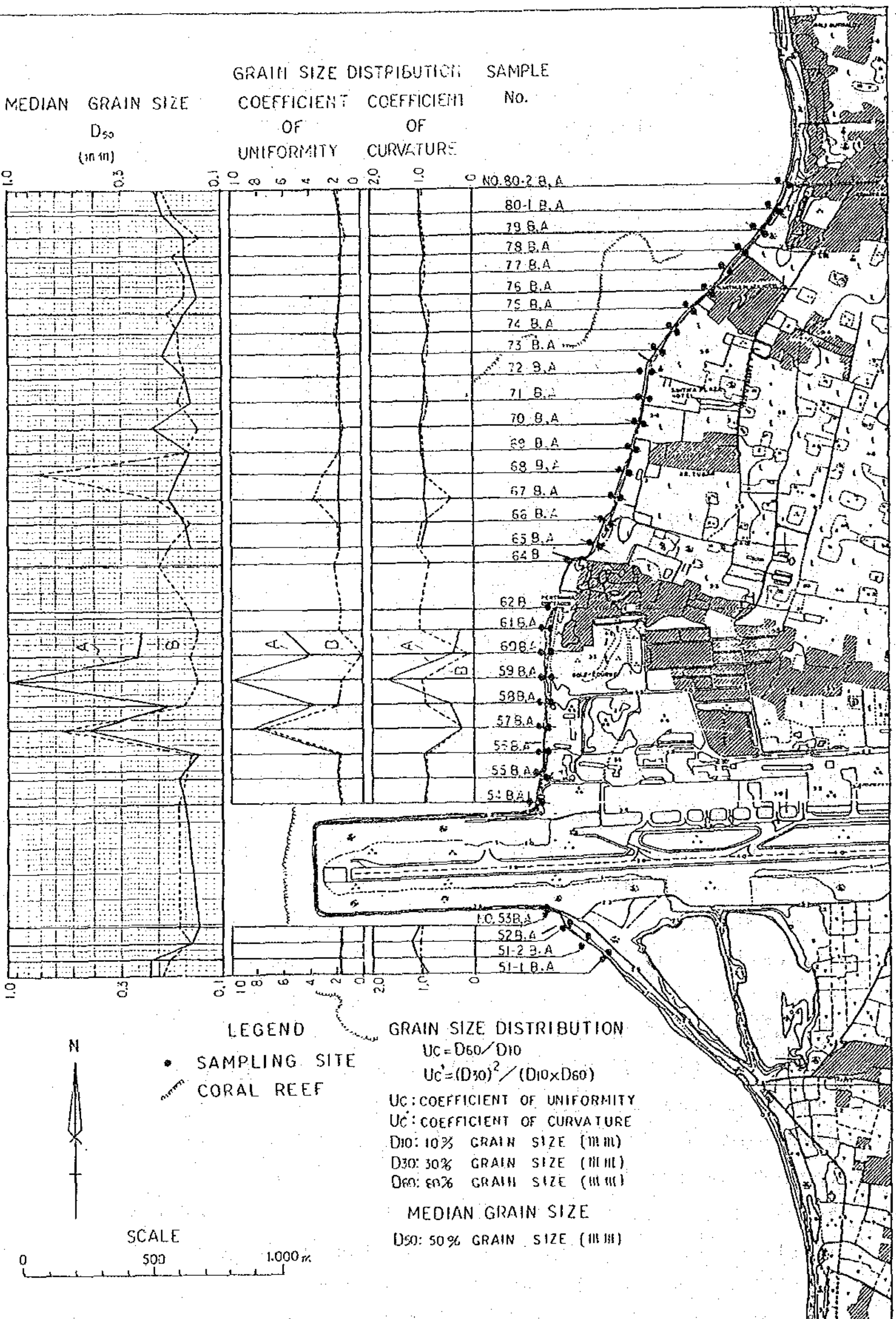


Fig. 2-5-2-8 Location Map Showing Sampling Sites and Diagram Showing the Results of Grain Size Analysis on Bottom Materials at Kuta Beach.

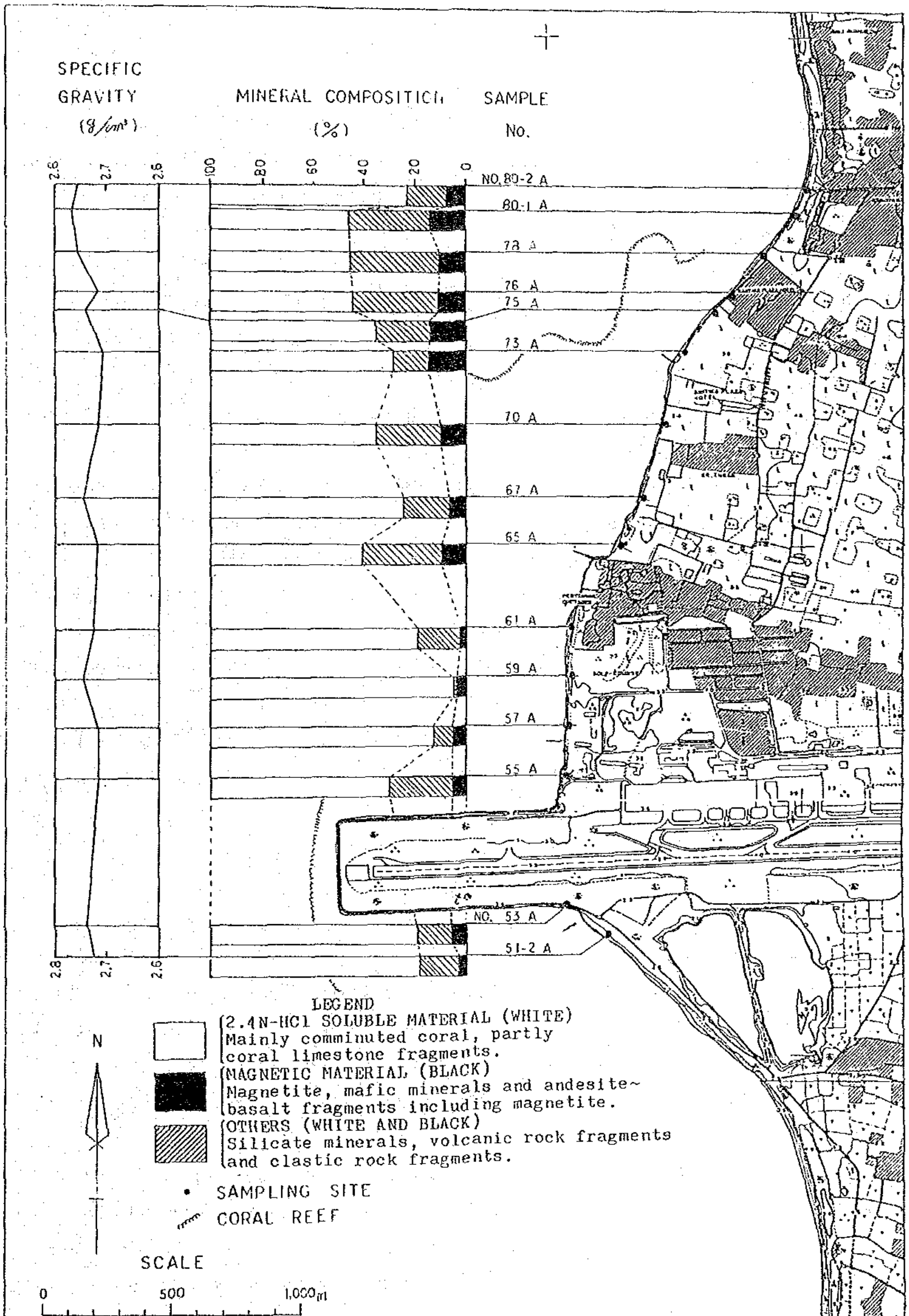


Fig. 2-5-2-9 Diagram Showing the Results of Specific Gravity and Mineral Composition Test on Bottom Materials at Kuta Beach.

increase slightly from 2.71 to 2.77 toward the north.

2) Nusa Dua Beach

Nusa Dua Beach has a steep slope in comparison with Kuta and Sanur 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), except near the Mediterranean Club. Because Nusa Dua beach has a steep beach slope, the median grain sizes are coarser than at Kuta Beach.

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-HCℓ soluble material content. The mineral composition is almost wholly 2.4N−HCℓ soluble material, which consists mainly of comminuted coral and partly contains coral limestone fragments. 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.

3) Sanur Beach

The beach slope at Sanur Beach is gentler than at Nusa Dua Beach and steeper than at Kuta 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 (between sampling sites No. 103 A and No. 104 A).

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 (betwen sampling sites No. 104 A and No. 105 A). The median grain sizes at the south side are obviously coarser than at the north side.

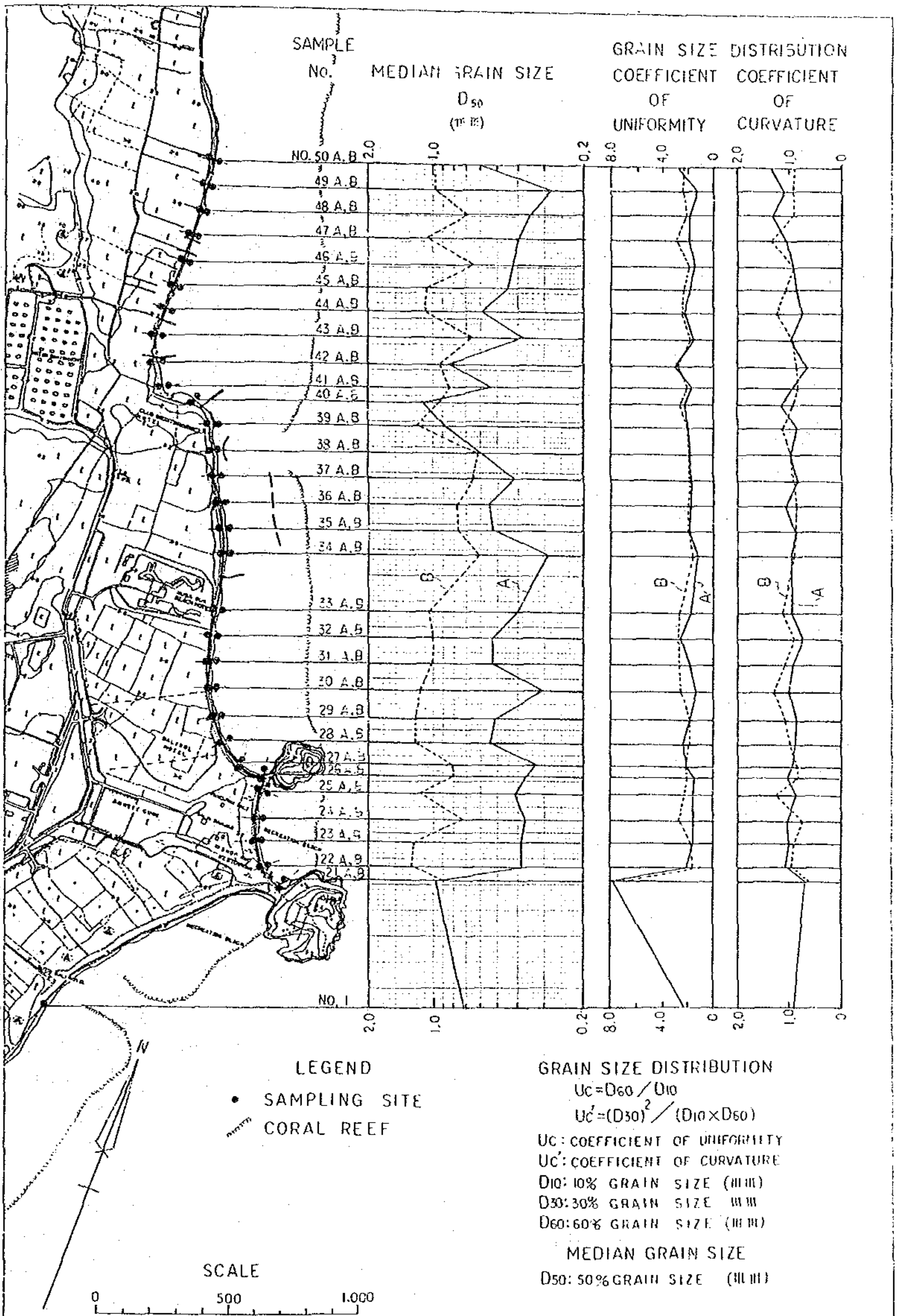


Fig. 2-5-2-10 Location Map Showing Sampling Sites and Diagram Showing the Results of Grain Size Analysis on Bottom Materials at Nusa Dua Beach.

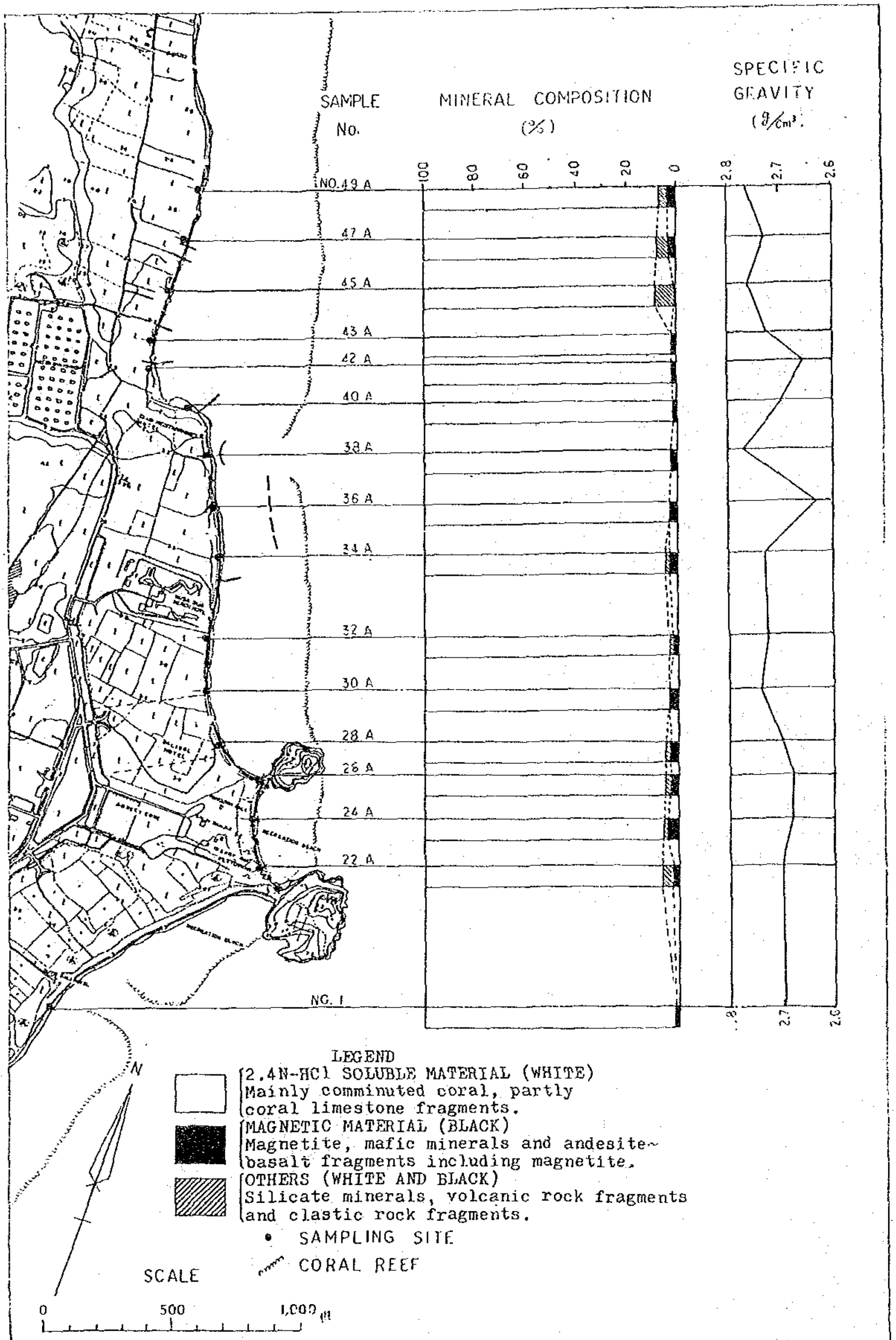


Fig. 2-5-2-11 Diagram Showing the Results of Specific Gravity and Mineral Compsotion Tests on Bottom Materials at Nusa Dua Beach.

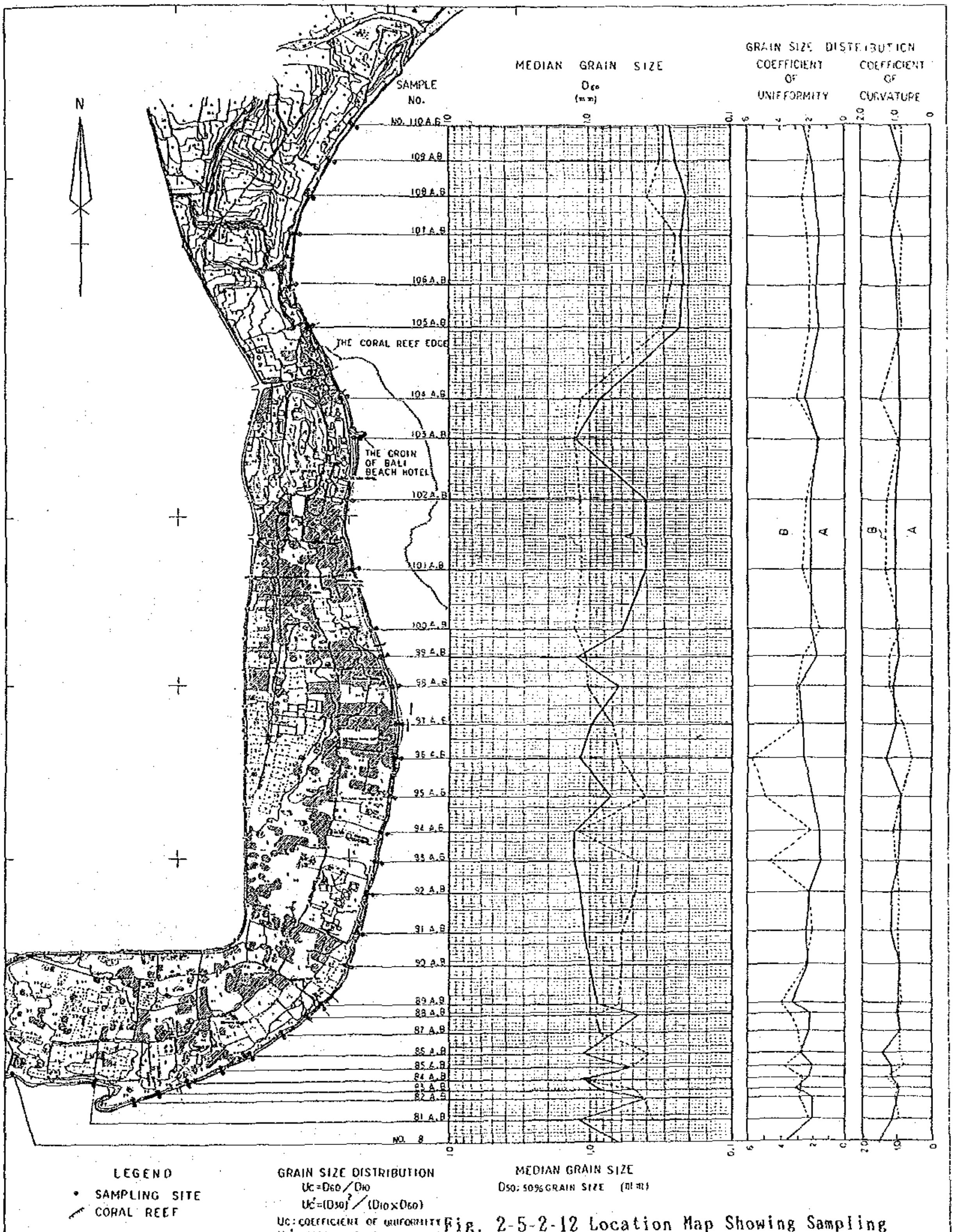


Fig. 2-5-2-12 Location Map Showing Sampling Sites and Diagram Showing the Results of Grain Size Analysis on Bottom Materials at Sanur Beach.

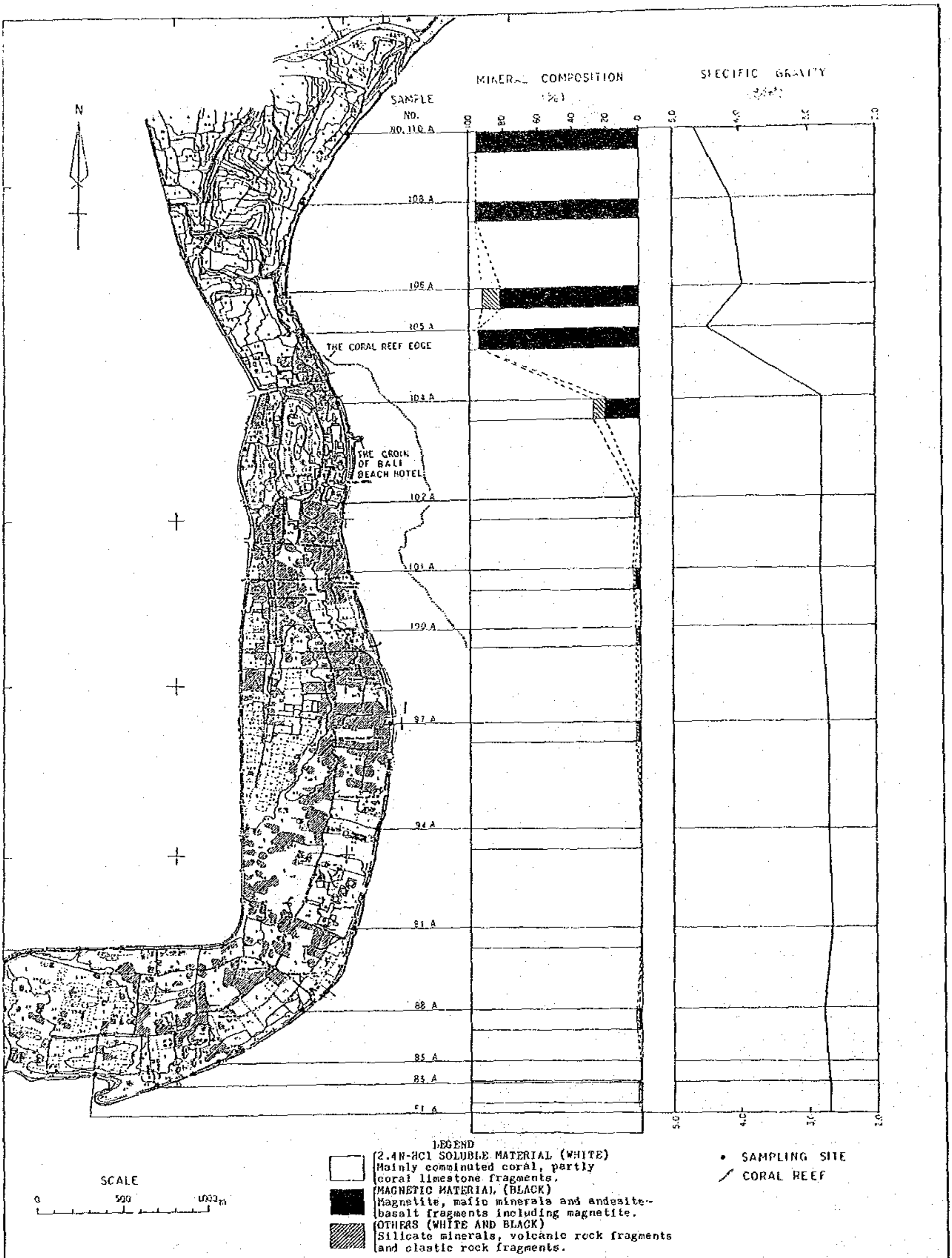


Fig. 2-5-2-13 Diagram Showing the Results of Specific Gravity and Mineral Composition Tests on Bottom Materials at Sanur Beach.

The median grain sizes of B samples (sea side) are coarser than those of A samples (land side) like Nusa Dua beach at the north side from the north of Besakih Hotel (Sampling site No. 100 A).

The mineral composition of the bottom material is divided into three types. The first type is similar to Nusa Dua Beach, and ranges from 0.1 to 2% in magnetic material content, 0 to 2% in silicate material content and 97 to 100% in 2.4N-HCℓ soluble material content, at the south side from the groin of the Bali Beach Hotel. The second type is heavy black sand, and ranges from 81 to 97% in magnetic material content, 0 to 10% in silicate material content and 6 to 10% in 2.4N-HCℓ soluble material content, at the north side from the coral reef edge. The third type is a mixture of the first and second type, with 21% in magnetic material content, 7% in silicate material content and 72% in 2.4N−HCℓ soluble material content, between the groin and the coral reef edge.

Magnetic material and silicate material are volcanic rock in origin, and they are supplied from the southern slopes of the volcanic range. 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. Therefore, the third type material is a mixture which is composed of 2.4N-HCℓ soluble material inside the coral reefs, and magnetic and silicate material from the north. 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.