11.3 Investment Scale and Implementation Plan

As mentioned in Chapter 15, the initial investment of the project is shown in the following table. Fig. 11-1 shows the construction schedule.

Table 11-1 Initial Investment Cost

(Units: NZ$)

Site	No.	Area	:	Description of Work	Q'ty	Unit	Costs
1	1	Health Dept.	:	Seawall	300	m	747,000
2	2	Avarua East Coast	:	Seawall/Reclam.	125	m	833,000
	P3	Avarua Harbour	:	East Breakwater	90	m	535,000
	P4		:	West Breakwater	30	m	414,000
	P5		:	East Marina Wharf	155	m	474,000
	P6		:	Repair work of existing wharf	155	m	495,000
	P7		:	Temp. Quay/Jetty		L/S	371,000
	P8		:	Dredging	9,938	m^3	350,000
	9	Avarua Central Coast	:	Add. Works to MOW seawall	130	m	392,000
	10		:	Seawall/Reclam (middle)	220	m	1,703,000
	11		:	Seawall/Reclam (west)	195	m	1,084,000
	P12	Avatiu Harbour	:	East Breakwater	280	m	3,250,000
	P13		:	Inner Breakwater	100	m	57,000
	P14		:	Relamation	13,000	m^3	154,000
	P15		:	Repair of Existing Quay	130	m	218,000
	P16		:	Slipway (TLT)	30	m	51,000
	P17		:	Fisheries Quay	145	m	437,000
	P18		:	Fishery Market Shed	300	m^2	150,000
	P19		:	West Breakwater	290	m	637,000
	P20		:	Utilities		L/S	350,000
	P21		:	Dredging	30,000	m^3	1,400,000
	P22		:	Tugboat & Cargo Handling Equipment		L/S	1,280,000
	23	Airport East	:	Tank yard (Seawall, West)	130	m	433,000
	24		:	Tank yard (Seawall, Mid.)	90	m	322,000
	25		:	Tank yard (Seawall, East)	80	m	305,000
	26		:	Auxiliary side dike	120	m	97,000

27 Airport West	:	Seawall near MET	80	m	308,000
28	:	Detached Breakwater	150	m	304,000
29	:	Seawall at Nikao	115	m	490,000
Summary	:	Direct Costs Total------------------			17,641,000
		Coastal Protection			7,018,000
		Port Improvement			10,623,000
With Contingency	:	x 1.205 Total------------------			21,257,000
		Coastal Protection			8,457,000
		Port Improvement			12,800,000

Notes 1. Mark "P" means work item for port improvement sector.

2. Contingency means physical contingency and other allowance.

The total initial investment cost is about NZ$ 21.26 million. Total costs for the coastal protection works amount of about NZ$ 8.46 million and the total costs for the port improvement is about NZ$ 12.8 million. The total cost will be paid out over the first three years.

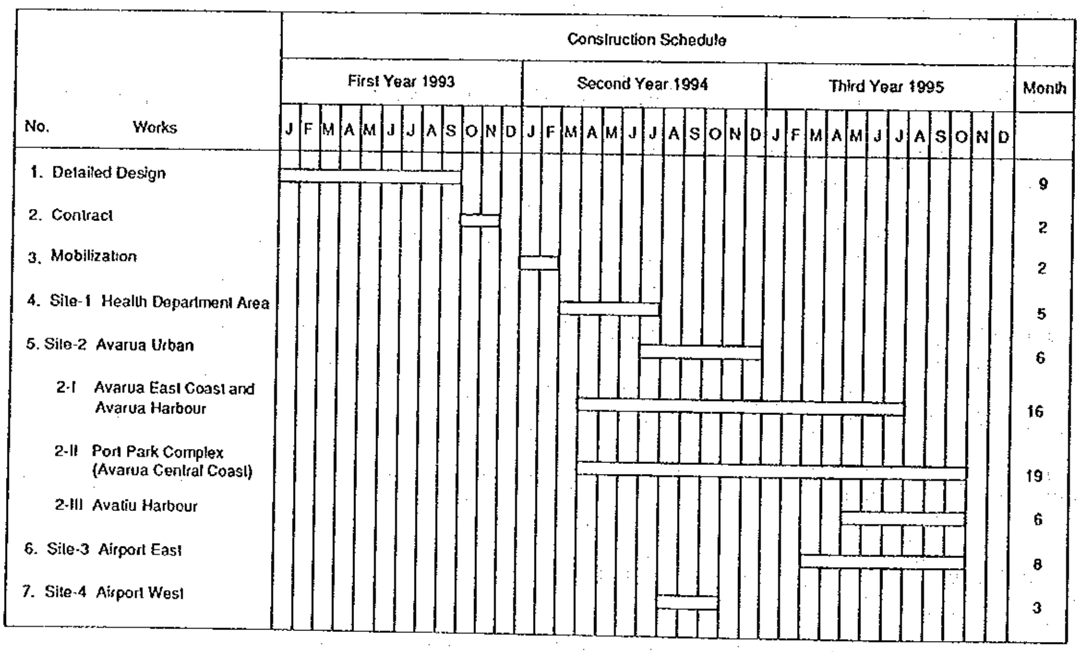
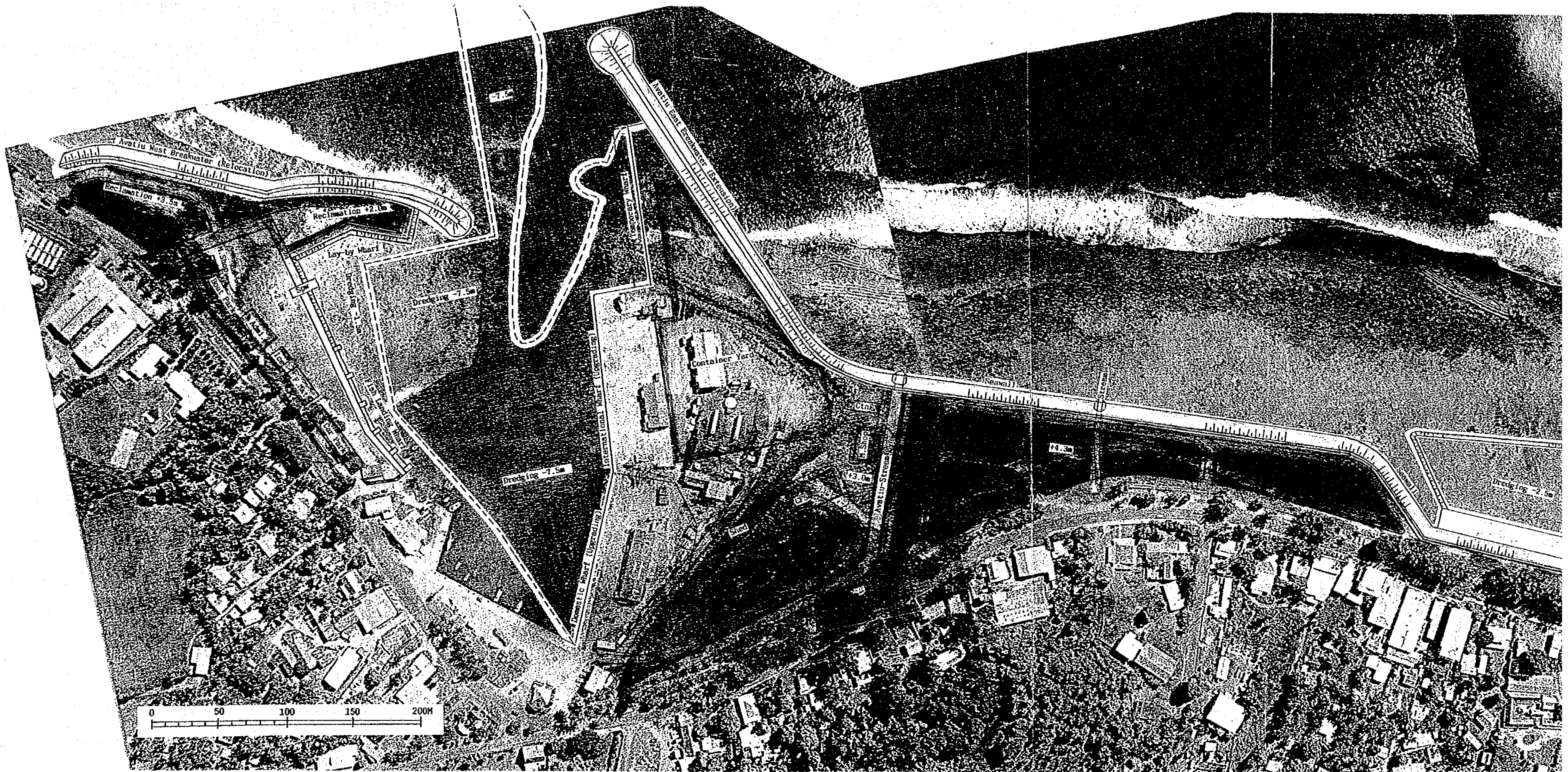


Fig. 11-1 Construction Schedule, Coastal Protection and Port Improvement Cook Islands


Avatiu West Breakwater (Relocation)
Reclamation +3.5m
Reclamation +2.0m
Lay-by Wharf
Dredging -7.5m
Boat Park
Container Yard
Avatiu East Breakwater (Extension)
Dredging -7.5m
Seawall
0
50
100
150
200M

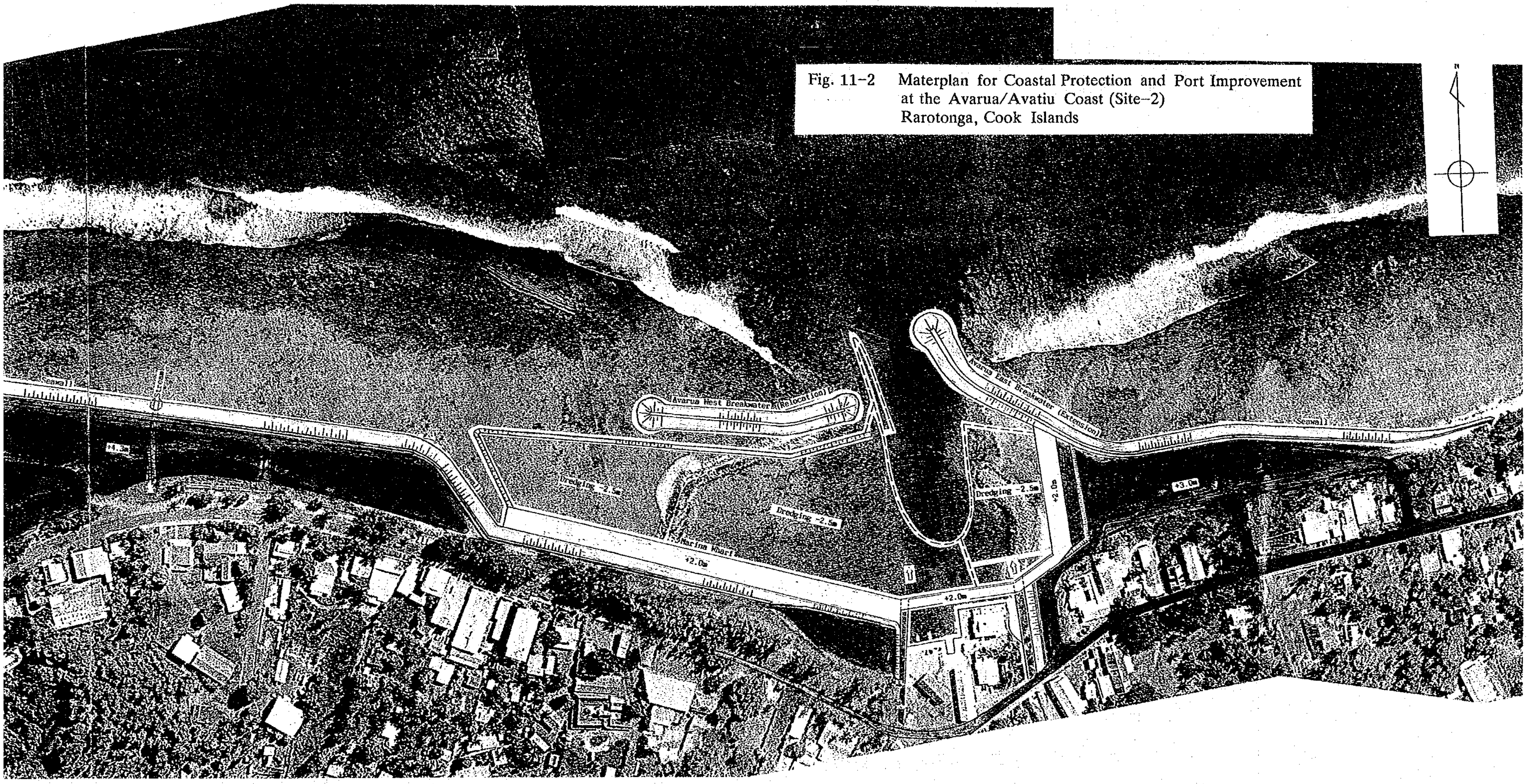
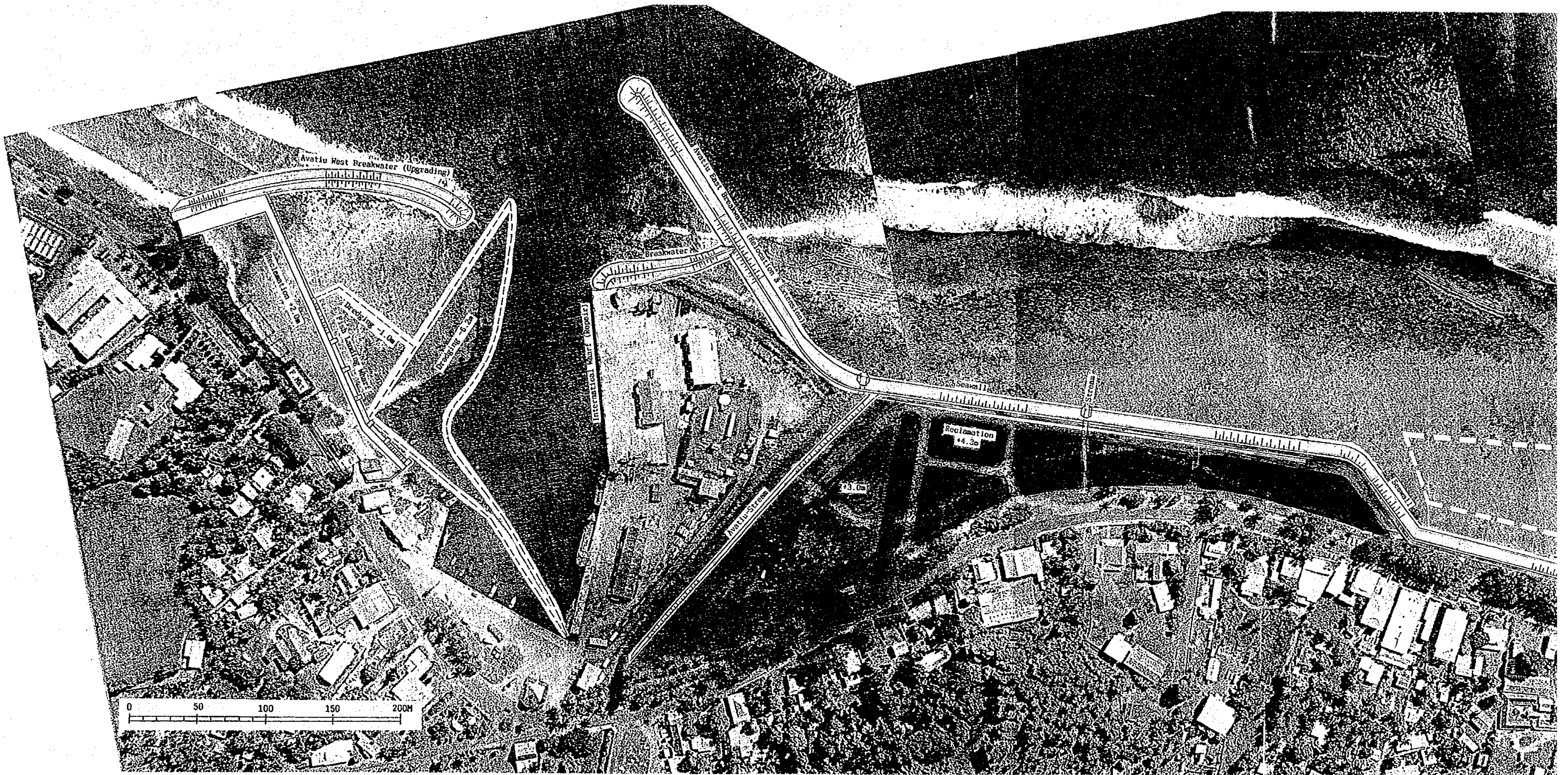


Fig. 11-2 Materplan for Coastal Protection and Port Improvement at the Avarua/Avatiu Coast (Site-2) Rarotonga, Cook Islands



Avatiu West Breakwater (Upgrading)
Avatiu East Breakwater (Relocation & Extension)
Breakwater
Reclamation +2.0m
Dredging -1.0m
Fish Landing Wharf
Dredging -6.2m
International Wharf (Repair)
Seawall
Stream
Reclamation
+4.3m
+3.0m
Avatiu Stream
Seawall
0
50
100
150
200M

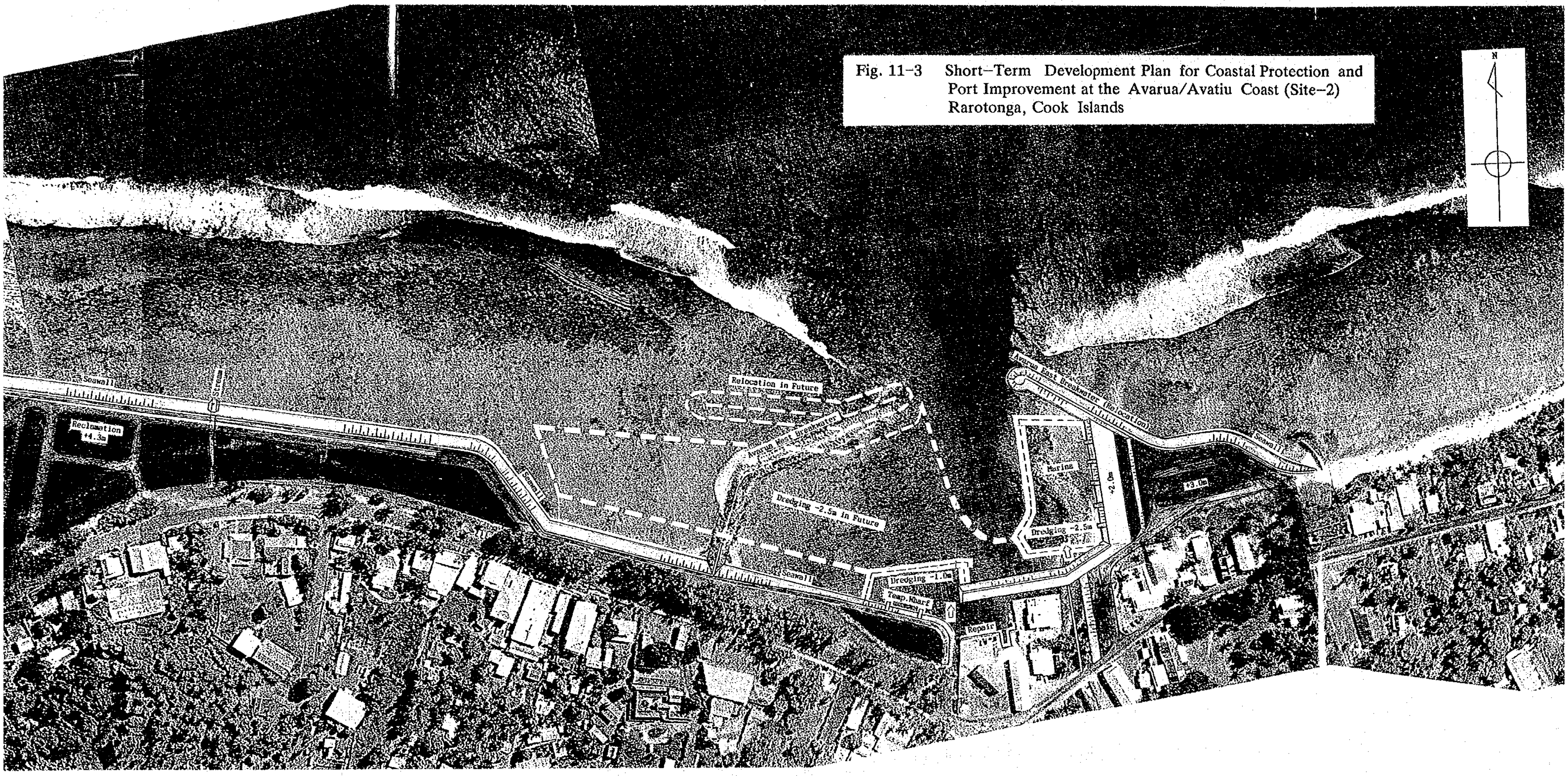
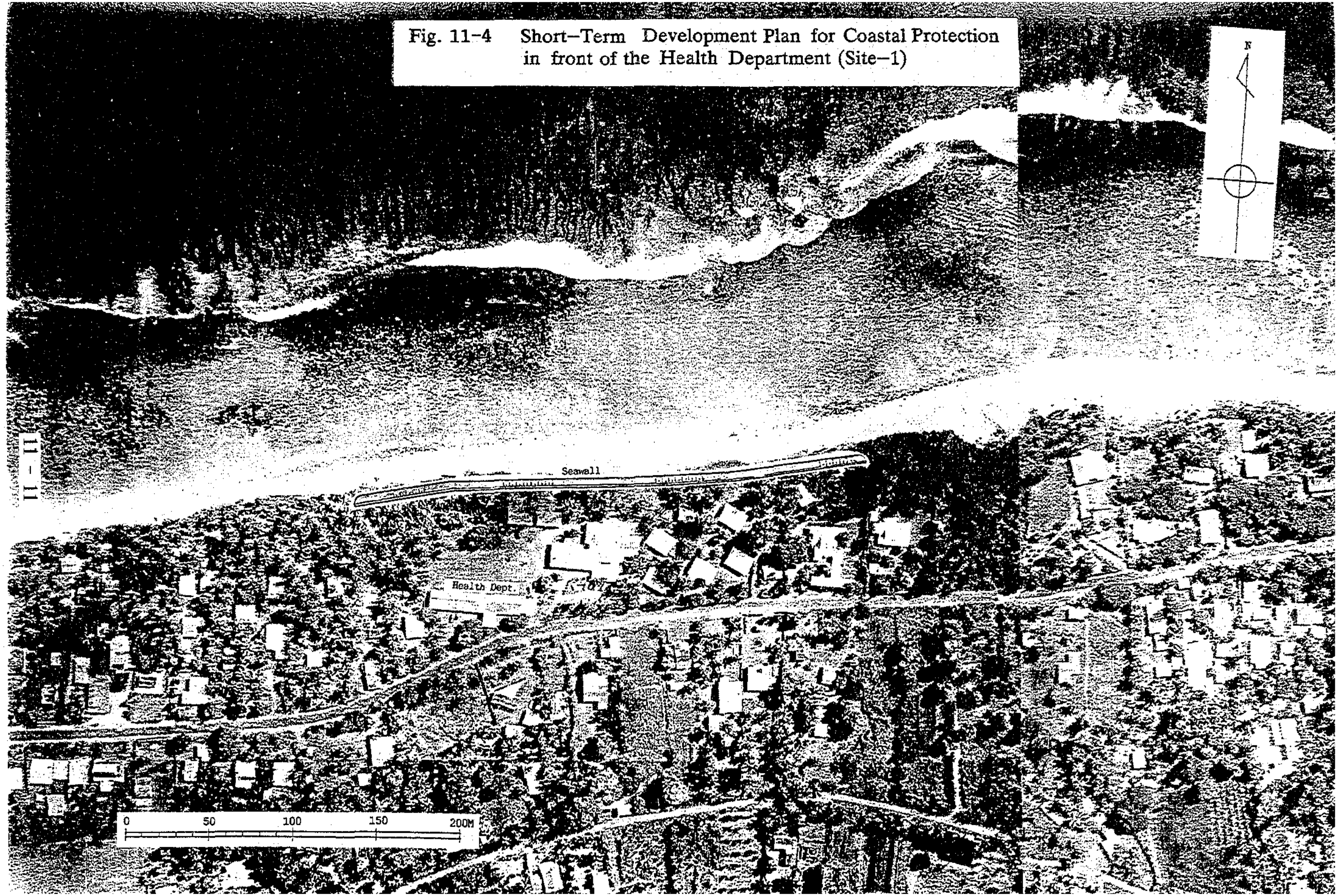


Fig. 11-3 Short-Term Development Plan for Coastal Protection and Port Improvement at the Avarua/Avatiu Coast (Site-2) Rarotonga, Cook Islands

Fig. 11-4 Short-Term Development Plan for Coastal Protection in front of the Health Department (Site-1)



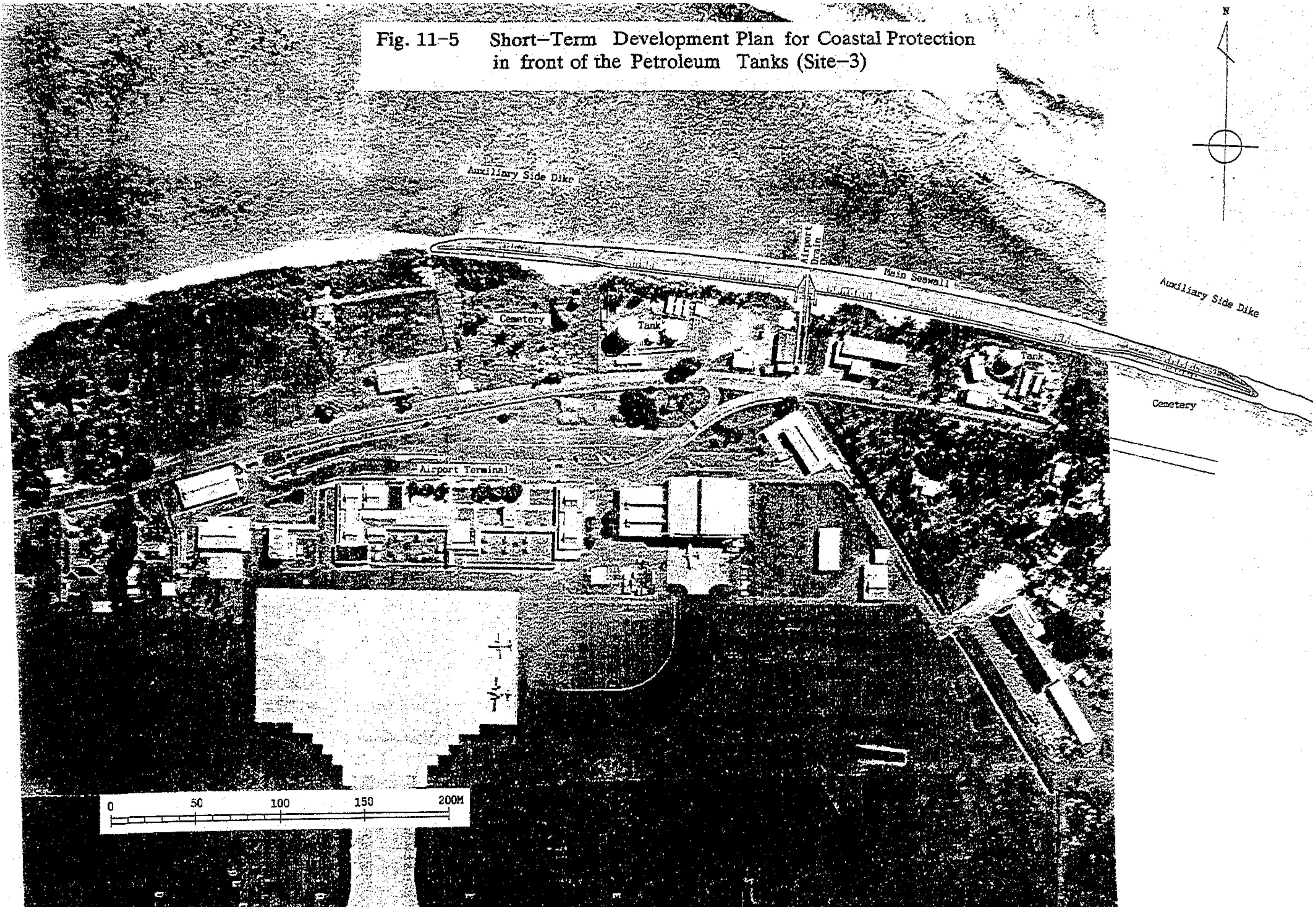
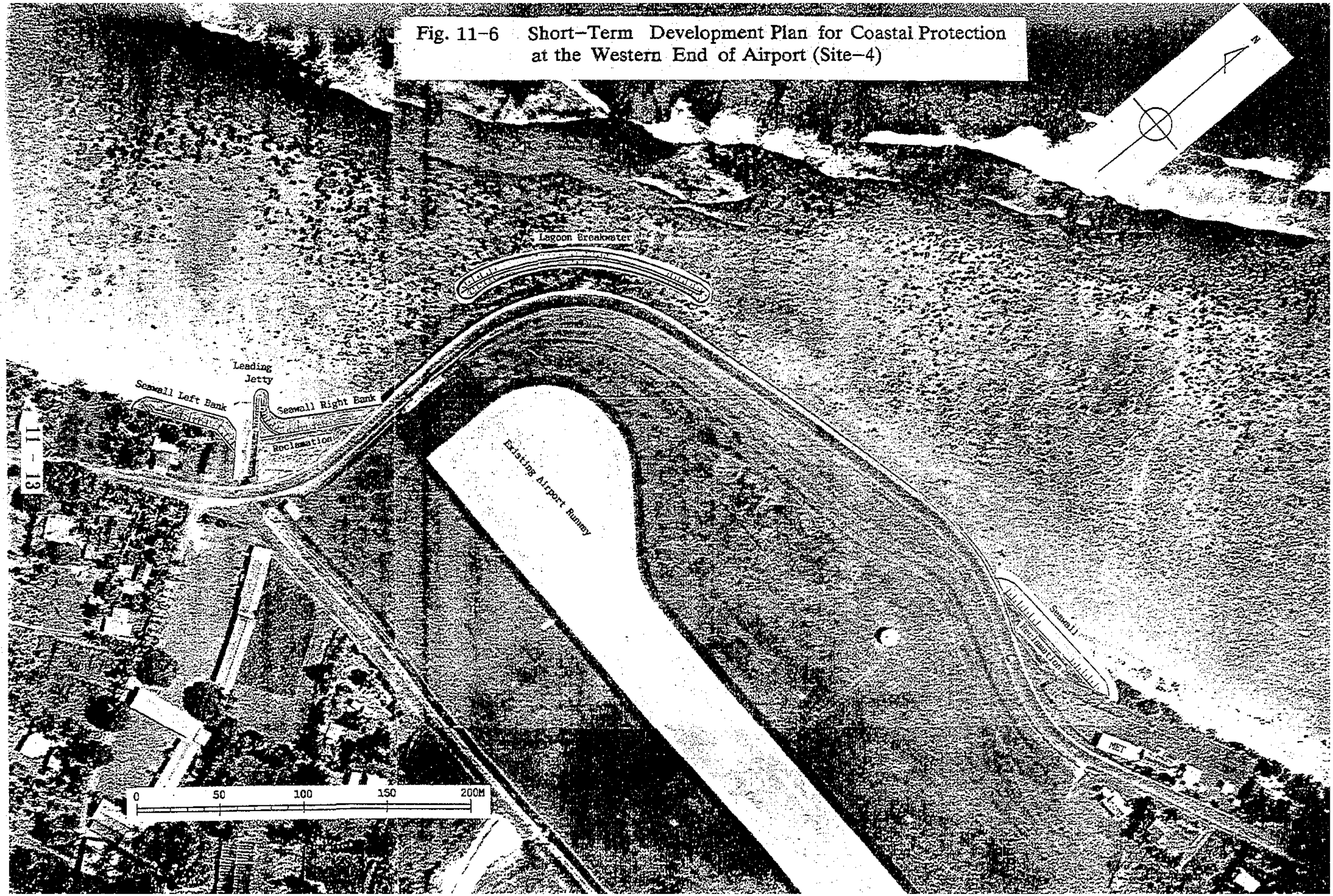


Fig. 11-5 Short-Term Development Plan for Coastal Protection in front of the Petroleum Tanks (Site-3)

Fig. 11-6 Short-Term Development Plan for Coastal Protection at the Western End of Airport (Site-4)



Chapter 12: Short-term Development Plan: Coastal Protection

Chapter 12 Short-term Development Plan : Coastal Protection

This chapter deals with the preliminary design of coastal protection together with the refinement of the general layout and design criteria. The description will commence from the general layout.

12.1 Formulation of the Short-term Development Plan

In Chapter 7, the Master Plan of Coastal Protection was presented together with its background information. This plan was developed for year 2010 requirements. The Phased Development Plan was presented in Chapter 10. This plan is a tentative short-term development plan to meet year 1997 requirements.

This section deals with the necessary arrangements for finalizing the Short-term Development Plan for project implementation.

12.1.1 Phased Development Plan Discussions

On the second visit of the JICA study team to the island, phased development plan discussions were conducted between the related government agencies and the team. The proposed phased development plan was basically accepted by the Cook Government as the tentative Short-term Development Plan.

Discussion made by the two parties relating to the Plan are summarized as follows:

1) The plan should include countermeasures based on the damage caused by the latest cyclones, Val and Wasa, in December 1991.

The study team collected necessary climatic data through MET and MOW. Both agencies were kind enough to provide to the team with the information, including photographs during the cyclone attack at Avarua Harbour and damaged asphalt concrete pavement at the causeway along the runway west end of existing airport.

Cyclone records in the South Pacific Ocean was provided to the team by MET. Refer to subsection 12.2.5.

2) Section of Coastal Protection as Avarua Coast

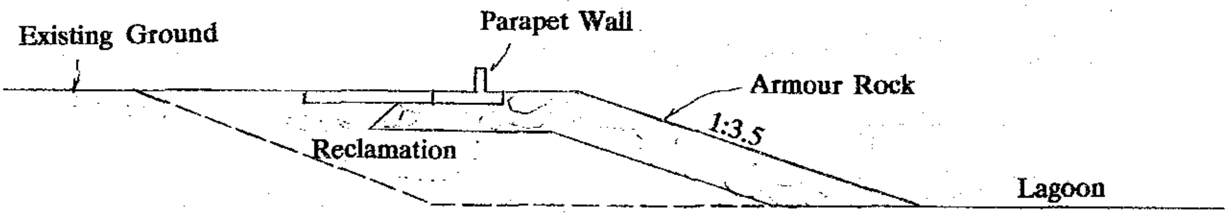
During the discussions, the study team presented the standard section of coastal protection at Avarua Coast. Proposed seawall sections are shown in Table 12-1 and Fig. 12-1.

Table 12-1 Seawall Formation Estimated, Feb. 1992

Section		Existing Ground	Proposed Scheme	
			Reclamation	Top of Wall
a.	Avarua East	MSL+ 3.0M	MSL+ 3.5M	MSL+ 5.0M
b.	Avarua Harbour	+ 2.5	+ 2.5	+ 3.7
c.	Avarua/Avatiu Coast (1)	+ 4.3	+ 4.3	+ 5.5
d.	Avarua/Avatiu Coast (2)	+ 4.8	+ 4.3	+ 5.5
e.	Avarua/Avatiu Coast (2)	+ 4.1	+ 4.3	+ 5.5

Note: Elevation is above MSL.

Fig. 12-1 Seawall Standard Section : Coastal Protection at Avarua Coast



3) Artificial Channel in Avarua Harbour

The team explained why the artificial channel was insufficient for wave set-up reduction. (For further information concerning the artificial channel see Section 7.2)

Although, the entire development of Avarua Harbour is not included in the Short-term Plan, this is one of the topics to be recorded.

4) Coastal Protection Work Conducted by MOW in 1991/1992

MOW is successfully executing Avarua Coast protection work. Eighty percent of the schedule work was completed by the beginning of 1992. The Government requested that this work be incorporated in the Short-Team Plan. The layout plan prepared by MOW was collected by the study team.

Fig. 12-2A shows the general layout of MOW Avarua Protection Work.

Standard sections of this work were mailed by MOW to the team in Tokyo the latter part of February 1992. The proposed Short-term Development Plan here is fully incorporated with this work.

5) LPG Facility in the port area

In the Master Plan, the relocation of the port area LPG storage to a different site was discussed. However, no conclusion has been reached. It is assumed that the relocation site will not be in the Port Park Complex.

12.1.2 Refinement of Plan

Coastal protection work in the proposed Short-term Development Plan is basically the same arrangement as described in the proposed Phased Development Plan. However, the necessary realignment was conducted based on the latest information including the requirements of the Cook Government and the preliminary design of system. The following four sites are to be protected:

Site - 1	Health Department and its Surroundings
Site - 2	Avarua/Avatiu Urbanized Area
Site - 3	Airport East
Site - 4	Airport West

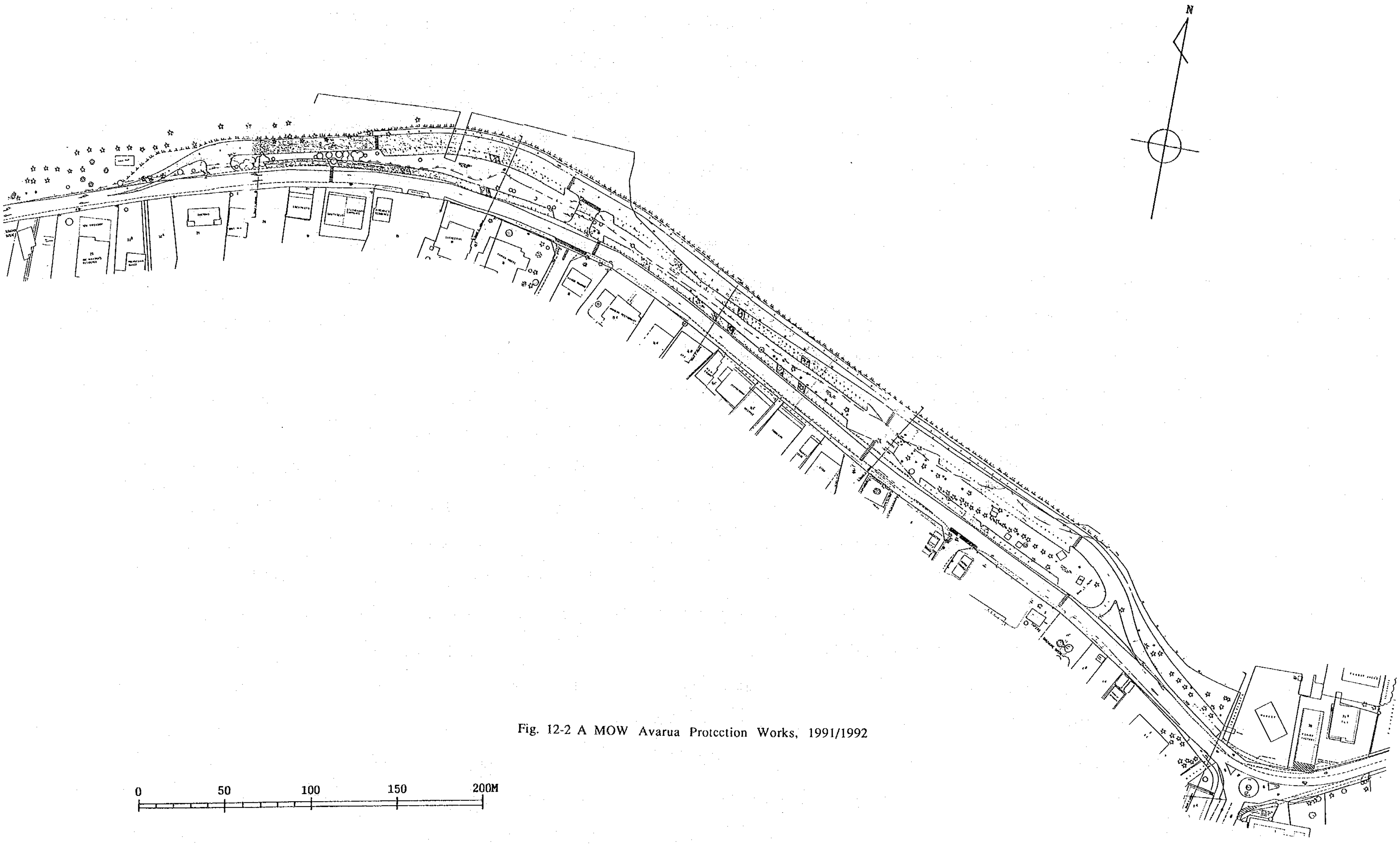


Fig. 12-2 A MOW Avarua Protection Works, 1991/1992

1) Site - 1 Health Department and its Surroundings

The proposed length of the coastal protection here is 300 meters. This is 100 meters longer than the original layout in Chapter 10. The new arrangement can cover the government offices and public facilities including the Health Department, Department of Education, the Office of Secretary and the Conservation Department. To prevent this site from such damage as caused by Cyclone Val/Wasa in late 1991 and Cyclone Gene in March 1992 makes this extension necessary.

The proposed defense line is about two meters behind the existing concrete seawall that is located near the beach top. Thus, the existing wide sandy beach will remain as it is for use by local swimmers.

The backfilling work on the existing moderate slope using excavated coral fragments will be made behind the proposed seawall for the creation of elevated flat land. The foreshore area should continue to be accessible by local swimmers.

2) Site - 2 Avarua/Avatiu Urbanized Area, Avarua Harbour East

The investment scale for protection work here will be made for a limited area for cost reduction purposes. The proposed coastal protection work beyond the existing East Breakwater will cover 160 meters of the coastal area. This is one half the coverage shown in the original layout in Chapter 10.

Proposed defense line is in advancing area about 50 m seawards in order to create new buffer zone.

Along the western faceline, a 160 meter long dike wall will be constructed for retaining reclaimed earth. The outlet of Takuvaine (Avarua) stream will be located at the southern end of this dike.

Among this dike, northern 85 m wall will be marina wharf together with five berthing jetties.

3) Site - 2 Avarua/Avatiu Urbanized Area, Avarua Harbour

The necessary coastal protection work should be conducted. However, the fundamental renewal of the port will not be performed during the Short-term Development Stage. While, the proposed alignment of major facilities is based on the Port Improvement Master Plan preventing work from double investment. As shown in Chapter 13, the East breakwater will be replaced to the new location of the Master Plan. However, the West breakwater will remain as it is until the Master Plan Stage to save costs.

The coastal protection work proposed here includes the realignment of the existing seawall line. Immediately westward of the existing Vaikapuangi Stream outlet, new reclamation work retained by a rock reprapping wall will be constructed. The proposed 120 meter long retaining wall will be constructed on the same faceline as the protection work at the West breakwater by MOW.

4) Site - 2 Avarua/Avatiu Urbanized Area, Port Park Complex

The coastal protection work proposed here has the same alignment as the original layout in Chapter 10.

Proposed faceline within 130 m Avarua West breakwater westwards is same alignment with the existing seawall executed by MOW in 1991. While remaining 350 m seawall to the Avatiu East breakwater will advance seawards in 40 m to 130 m in order to create cyclone buffer zone. This zone will be constructed by land reclamation and aims at mitigating cyclone disaster to Avarua urbanized area where the most concentrated investments in the island are made by both private sector and public sector.

Under normal climatic condition, this new land will provide space for public use such as car parking area, bus terminal, green park, etc. About 40 % of this land faced to Avatiu Harbour will be the future port expansion site in the Master Plan stage. Construction cost of seawall will be minimal due to reuse of the existing seawall armour rock.

5) Site - 3 Airport East

The proposed coastal protection length is 350 meters. This is 150 meters longer than the original layout. The new arrangement will cover the two existing Fuel Storage Facilities, JUHI and TRIAD, the laundry factory located between them and cemeteries.

The proposed seawall faceline is located about five meters seaward of the existing fuel storage seawall.

6) Site - 4 Airport West

The proposed coastal protection length is 360 meters. This is 160 meters longer than the original layout. The new arrangement will cover not only the existing northwest corner of the runway, it will take in the airport west-end seawall and the seawall near MET.

12.2 Design Criteria

This section deals with the basic conditions of the preliminary design for coastal protection work. The design criteria includes natural conditions, structural conditions and wave over-topping conditions.

12.2.1 Natural Conditions

1) Tides

The 1986 Admiralty Tide Tables lists the following tidal predictions for Rarotonga:

HAT	+ 0.7 m
MHWS	+ 0.4 m
MHWN	+ 0.2 m
MSL (= DL)	± 0.0 m
MLWN	- 0.2 m
MLWS	- 0.4 m
LAT	- 0.5 m

All levels provided generally are related to a datum of mean sea level (MSL). The datum of this study is also MSL.

2) Wave

a) Deepwater Wave : Significant Wave Ho

Design wave heights and periods for the Short-term Development areas (northern coast of Rarotonga) were predicted based on Cyclone Sally. The Sally climatic data used here for wave prediction was collected during the visit of the JICA S/W Mission in April 1991.

Deepwater waves created by Cyclone Sally have been hindcasted by using the Wilson Method which can be applied to wave hindcasting in a moving wind field such as a cyclone.

The result of wave hindcasting is as follows:

Direction------- N 6° W (at Sally)
Wave height--- $H_o = 8.1$ m (Significant wave)
Period---------- $T = 12.5$ sec
Length--------- $L_o = 1.56\ T^2 = 244$ m

Note: Deepwater Wave:

Waves can be categorized into two types, namely deepwater wave and shallow water wave. The former is wave in the deep water where seabed friction does not affect to wave characteristics. Deepwater is defined as deeper than a half of wave length.

As the deepwater wave (Ho) approaches the island's reef, the wave is affected by the refraction effect. Equivalent deepwater wave (Ho') at reef front is calculated by the following formula:

$$Ho' = Ho \cdot Kr$$

where Ho : Deepwater wave height (m)

Ho' : Equivalent deepwater wave height (m)

Kr : Refraction coefficient

b) Wave Deformation at Avarua Coast

As the deepwater wave progresses in a shallow water area, the shoaling deformation shall be taken into account.

Equivalent deepwater waves at three coastal sections are calculated based on the configuration of existing reef edge line. Refer to Fig. 12-2B.

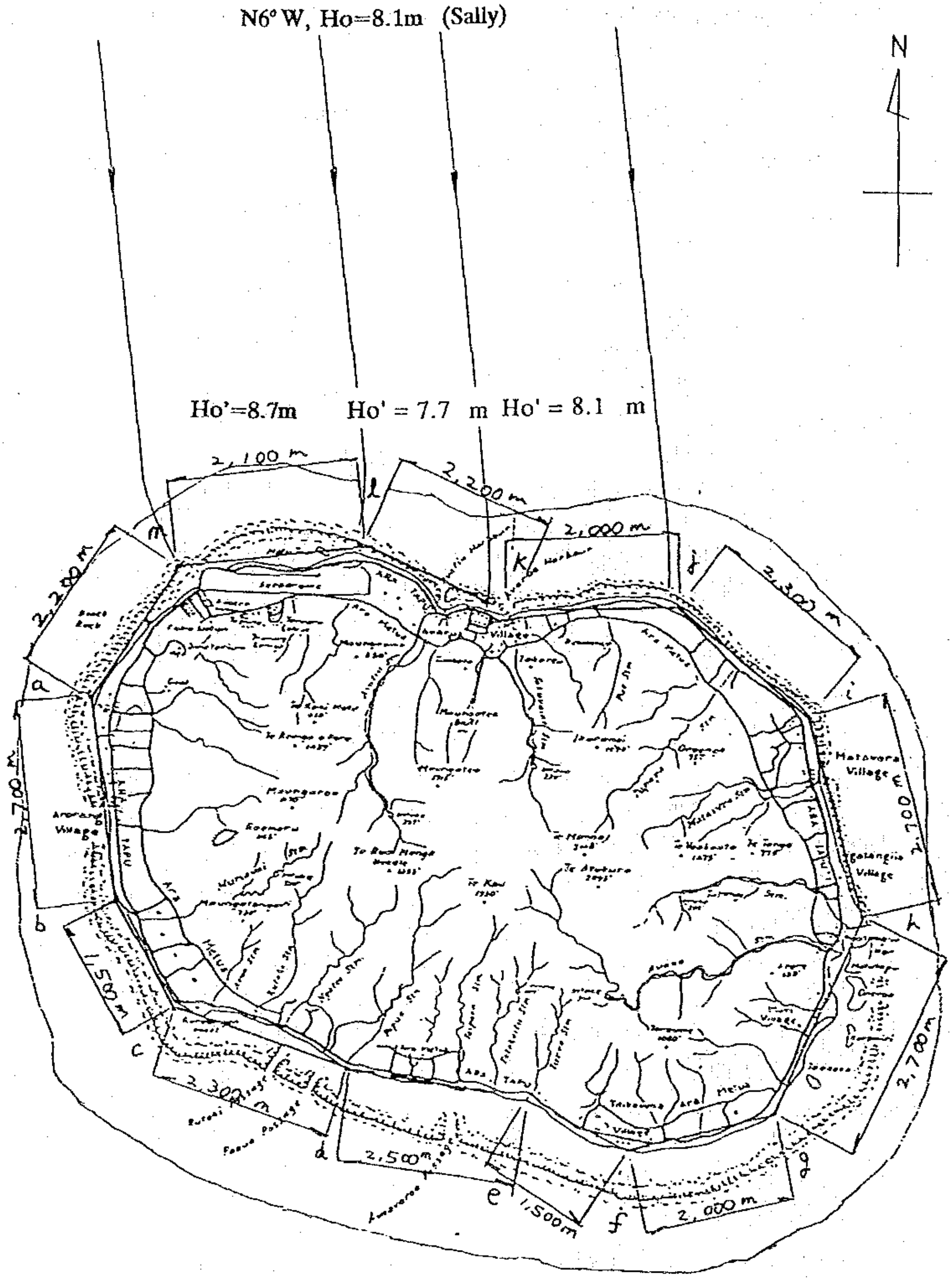
- Village Punataia to Avarua East Breakwater, Ho' = 8.1 m
- Avarua West Breakwater to Motutoa Island, Ho' = 7.7 m
- Motutoa Island to the West end of existing airport, Ho' = 8.7 m

These equivalent wave heights will be utilized for wave run-up study.

Detailed study on shoaling effect has been conducted at the Avarua coastal area since this area has complicated topography and covers the most valuable areas in the nation. There are three methods as follows.

- Computer simulation (Subsection 7.6.1)
- Detailed wave refraction study at the passage (Subsection 8.6.1)
- Conventional method using the empirical equation (Subsection 5.3.8)

Fig. 12-2B Deepwater Wave and Equivalent Deepwater Wave along the Northern Coast of Rarotonga



Ho' : Offsore Wave Height
Ho" : Equivalent Offshore Wave Height
(After Refraction)

Design wave heights for obtaining wave pressure and force on such structures as breakwaters or seawalls should be largest one among these study results. Wave shoaling deformation here are simulated by computer as shown in the Fig. 12-3 and 12-4.

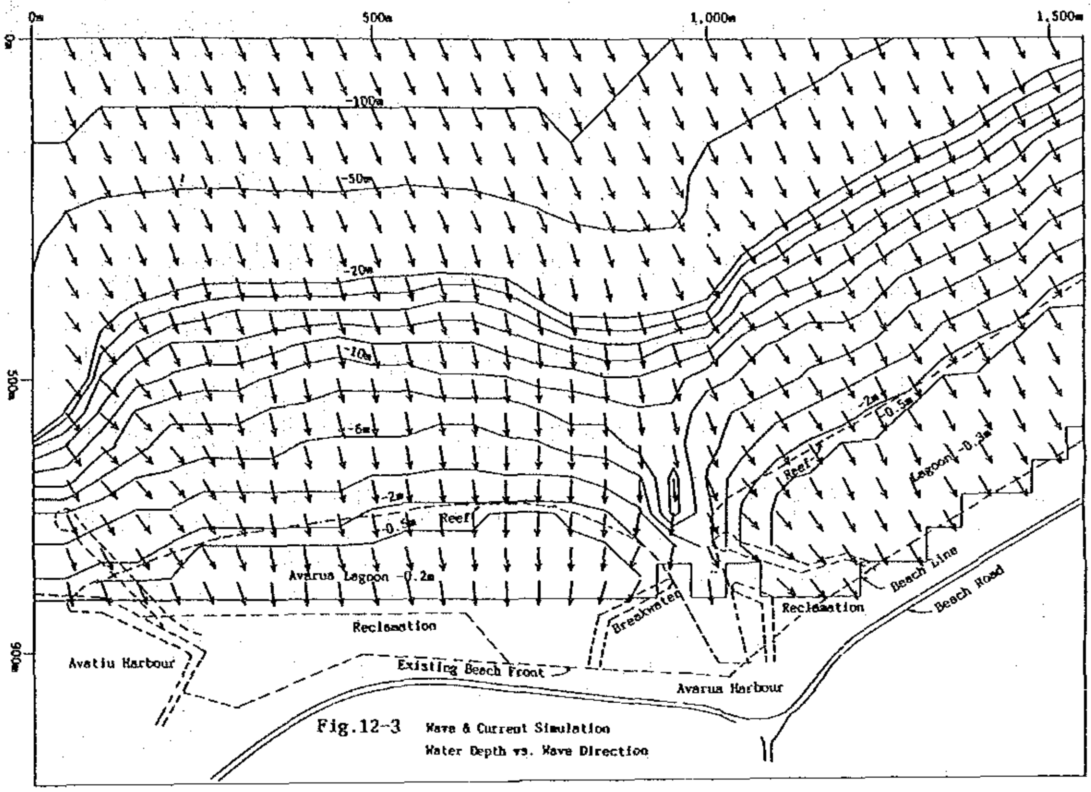


Fig.12-3 Wave & Current Simulation
Water Depth vs. Wave Direction

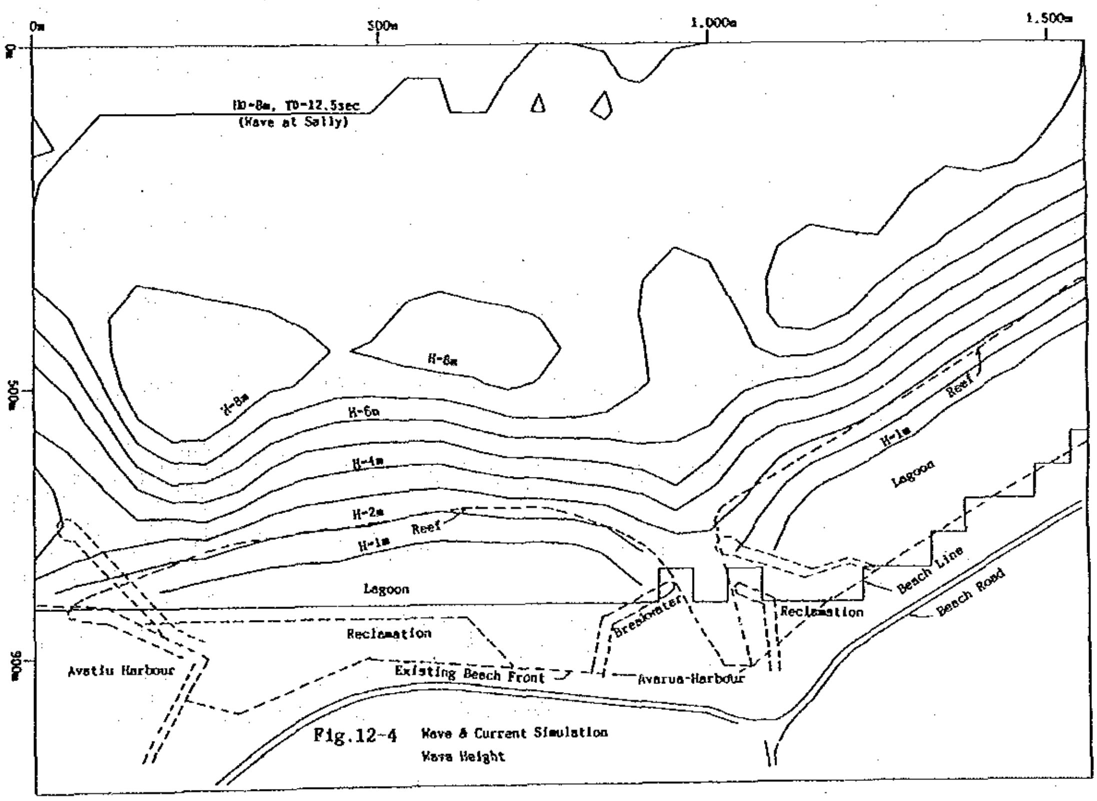


Fig.12-4 Wave & Current Simulation
Wave Height

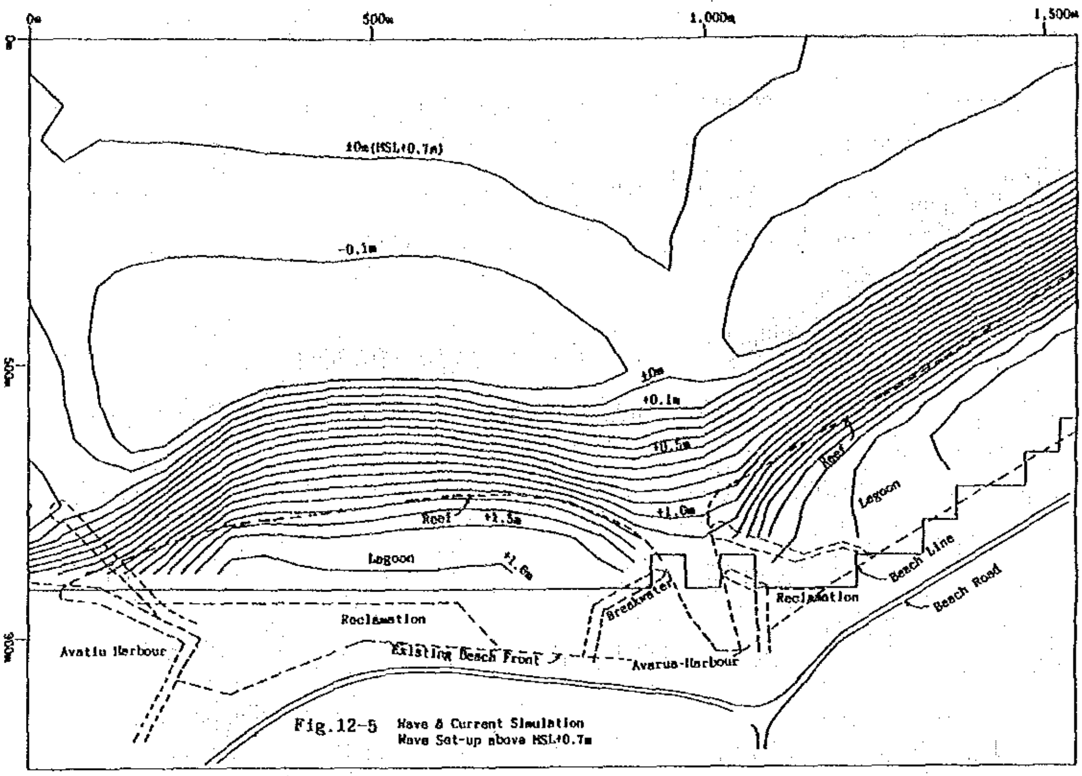


Fig. 12-5 Wave & Current Simulation
Wave Set-up above MSL+0.7 m

c) Random Wave Group

As seen wave arrivals at shoreline, wave height is not same but combination of various sizes. This shows that wave is one of natural wave characteristic of which is random.

For the engineering practice, one of wave in this group is selected as a representing one among them. On of those selection is a significant wave which is generally used for technical calculation.

This wave will be chosen by a rule. The significant wave at most dangerous moment of Cyclone Sally is as follows.

Wave Observation for ten minutes (or 600 sec.)

↓

Recording 48 waves (600 sec/12.5 sec = 48 waves)

↓

Tabulating 48 waves by height (No. 1---- No. 48)

↓

Calculating an average of largest one third

↓

Significant Wave

Thus, a significant wave is not overall average. Generally about 90 % waves in group are smaller ones than significant one. In the Sally case, the sixth wave is the significant one, thus there are five larger waves than significant one.

Table 12-2A shows an assumed wave group during the most hardest time of Sally. There are 48 waves showing by wave height. There are five representative waves such as:

Classification	Mark	by Sally	Correlation
(i) Average wave	($\bar{H}$)	5.1 m	$\bar{H}$ = 0.63 H1/3
(ii) 1/3 Significant wave	(H1/3)	8.1 m	
(iii) 1/10 Significant wave	(H1/10)	10.3 m	H1/10 = 1.27H1/3
(iv) Maximum wave	(Hmax)	12.2 m	Hmax = 1.50H1/3
(v) Minimum wave	(Hmin)	3.6 m	Hmin = 0.44H1/3

As shown in the table, these waves are defined as follows:

(i) Average wave

An average one in overall (Not a wave in 24th in order)

(ii) 1/3 Significant wave

An average of largest one third. As seen in the table, larger waves than this count five waves. Significant wave means this one otherwise noted.

(iii) 1/10 Significant wave

An average of largest one tenth. As shown in the table, larger waves than this count only two.

(iv) Maximum wave

The largest one in 48 waves.

(v) Minimum wave

The smallest one in 48 waves.

For the design of marine structure, one of items (ii), (iii) or (iv) will be chosen considering importance of structure to be designed and other factors. Calculation of seawall design, breakwater and wave run-up in this study will be conducted with a 1/3 significant wave.

Correlation between the significant wave and the maximum wave is as follows.

Number of Observed Wave	20	50	100	200	500
$H_{max}/H_{1/3}$	1.32	1.50	1.61	1.72	1.84

d) Design Wave

In this study, propagating waves in surf zone were calculated by following methods.

(i) Computer Simulation, (Three Dimensional)
(ii) Conventional method by refraction diagram, (Two Dimensional)

Design Wave after the reef edge

Comparison study of the Northern coast was conducted as shown in subsection 5.3.8. According to this, it was found that waves by the conventional method are larger than simulated ones. In this study, conventional ones were selected as the design waves taking structural stability into consideration.

Design Wave in the Passage

Comparison study was also conducted as shown in subsection 13.5.1. As seen in it, waves by conventional method are larger than simulated ones. With same reason shown above, conventional ones were selected as the design waves.

3) Water Level

The seawater level can be estimated by adding astronomical high tide, air depression and wave setup figures.

These three elements are individually independent physical phenomena. Astronomical tide is change due to gravity combination between Moon and Sun. Air depression makes water level high by means of suction. While, wave set-up comes in existence when wave broke in shoal area. After breaking, kinetic wave energy changes partly with statical one, thus higher water level. Water level at Avarua coast will be as follows.

(Astronomical tide MHWS)		(by Air depression rise)		(Wave Set-up)
MSL + 0.40 m	+	0.30 m	+	(as shown in Fig. 12-5) m

Wave setup at a certain point in Avarua coast can be found in the simulation result, as shown above. Water level in this formula indicates the maximum figure during high tide. This water level will be used for design of breakwater and seawall, since deeper water may contain large wave. While, more moderate water level than the maximum one will be used for wave run-up calculation. Refer to subsection 12.2.4.

4) Sub-soil Conditions

The result of soil investigations in respect to the beaches and lagoon show that the sub-soil along the coastline is composed of coral rubble and/or coral sand and base rock. Flat hard base consisting of hardened and set coral fragment in the swash zone appears at about ± 0.5 m MSL.

These coral fragments are generally deposited on the hard base. Average grain size of coral rubble and sand is 5 to 20 cm and 0.5 mm respectively. Hard base in the lagoon is generally exposed and occasionally covered by thin coral fragments layers. According to observation of excavated area immediate 30 meters behind the existing coastal line, composition of soil is same as discussed above and base rock appeared about MSL +0.5 m.

Coastal bank behind wider lagoon has low ground level about MSL +3 m and consists of sand content is larger than coral rubble, while coral rubble content in narrow lagoon coast is prevailing and its bank height is about MSL +6 m.

Table 12-2A Assumed Sally Wave Group
(at the most dangerous moment)

No.	H (m)	
1	12.2	8.1×1.50 H_{max}
2	11.1	10.3 8.1×1.27 $H_{1/10}$
3	10.1	
4	9.3	
5	8.7	
6	8.1	
7	7.8	
8	7.5	
9	7.3	8.1×1.00 $H_{1/3}$
10	7.1	
11	7.0	
12	6.9	
13	6.8	
14	6.7	
15	6.7	
16	6.6	
17	6.5	
18	6.4	
19	6.3	
20	6.2	
21	6.1	
22	6.0	8.1×0.63 $\bar{H}=5.1$
23	5.9	
24	5.8	
25	5.7	
26	5.7	
27	5.6	
28	5.5	
29	5.4	
30	5.3	
31	5.2	
32	5.1	
33	5.0	
34	4.9	
35	4.8	
36	4.7	
37	4.7	
38	4.6	
39	4.5	
40	4.4	
41	4.3	
42	4.2	
43	4.1	
44	4.0	
45	3.9	
46	3.8	
47	3.7	
48	3.6	
Average	5.1	