(c) "Without" Case

In the "Without" case, the likely future scenario will be seen in case that the Project is not implemented, assuming that all other conditions will be the same as those in the "With" case.

i) The properties (buildings, roads, airport, shore protection structures, etc.) damaged by waves should be restored to their original condition.

ii) The existing damaged west breakwater in Avatiu Harbour will be rehabilitated with the same wave condition as the existing east breakwater in Avatiu Harbour.

(3) Benefits

Between the "With" and "Without" situations mentioned above, the following items are identified as major quantifiable benefits of the Project.

i) Increase in the protection of residential & public building and infrastructures (road, port, airport, etc.) against waves and consequent decrease in damage,

ii) Maintaining normal economic activities produced by the above Benefit Item i),

iii) Reduction in damage to shore protection structures produced by high waves and consequent reduction in rehabilitation costs.

(a) Protection of Residential & Public Buildings and Roads etc. against Wave Flood

The property damage suffered by Cyclone "Sally" was estimated in Table 4-5-1 based on the Ministry of Works report.

Table 4-5-1 Property Damage by Cyclone "Sally" (due to the wave flood)

Descriptions		Damage by Wave Flood (NZ$)
Public Sector		
a.	Government Buildings	1,151,000
b.	Church Buildings	16,000
c.	Clinic, Community Halls, etc.	25,500
d.	Water Supply	450,500
e.	Roads & Drains	2,201,500
f.	Bridges, Culverts, etc.	4,375,000
g.	Others	1,643,900
Private Sector		
h.	Houses	946,000
i.	Hotels, Motels	18,000
j.	Shops, Stores	38,000
k.	Others	200,400
Total		11,065,800

Among the damaged structures, some were situated in the commercial center of the island (Avarua) and others were scattered mainly along the northern coast of the island. The following factors (ratios) are used in calculating the benefits; that is, the ratios are assumed as the regional concentrating degrees of the properties and of the damages.

a ---------------------------------- 100 %

b, c, d, e, f, i ------------------- $L_p/L_s = 6.2/7.8 = 80$ %

where, L_p: Coast length to be protected against waves (6.2 km; from airport to a part of Pue)

L_s: Coast length to suffer heavy damage by northerly waves generated by cyclone/hurricane (7.8 km: from Pokinu to Pumataira)

h,j -------------------------------- $P_p/P_s = 186/228 = 82$ %

where, P_p: Number of houses in the area to be protected against waves

P_s: Number of houses in the area to suffer heavy damage by northerly waves generated by cyclone/hurricane

(Source: Table 4-1 and Table 4-2 of Master Plan of JICA Final Report, 1992)

Accordingly, total amount of properties to be protected against a cyclone with the strength of Sally (including the effect of wave flood) with the implementation of the Project will be NZ$9,103,000. The effect of the project during the project life (= thirty years) is estimated on the assumption that the damage is in proportion to the volume of wave over-topping caused by the waves of each return period. For this purpose, ratios of the damage over the one caused by Sally are computed at seven locations of the northern coast of Rarotonga as computed in Table 4-5-1A.

The damage ratio to Sally varies from 5.14 to 6.94 depending on the locations. Therefore, the damage ratio is fixed equivalent to 6.0 times of damage by the model cyclone if the project were not implemented. Therefore, annual benefit of this item can be estimated to be NZ$9,103,000 x 6.0/30 = NZ$1,821,000/year.

(b) Protection of the West End of the Runway in Rarotonga Airport against Erosion

In 1973, the runway of Rarotonga Airport was extended on both the east and west sides and is now 2,328 m long (Runway: 2,328 m x 45 m, Runway Strip: 2,368 m x 213 m). The west part of the extended runway was constructed on the reclaimed land over the lagoon. A circumvent national road runs around the west end of the airport. The part of the road rounding the west end of the airport has been repeatedly damaged by high waves (generated by Cyclones Sally, Val, for example). Direct damage to the localizer and the VOR (VHF Omnidirectional Radio Range) has not been reported.

During the collection of information and data in Rarotonga Island, the video movies showing the damages of the airport runway caused by "Sally" and "Val" were made available. It was noted that waves generated by "Sally" slightly eroded the runway bank while those by "Val" eroded the coastal road but the runway bank remained not eroded. Bearing in mind that waves of "Sally" are of about a 17-year-return-period, it is assumed that the runway embankment reclaimed onto the lagoon will be completely eroded by waves of 50-year-return-period. The higher waves of more than 50 years return period will carry away the localizer and the VOR (VHF Omnidirectional Radio Range). The price of the localizer and VOR including installation cost is estimated to be about NZ$10,000,000 in economic price. The avoided cost of reinstallation of the instruments due to the coastal protection of the Project can be estimated as follows:

NZ$10,000,000 x (30/50) x (1/30) = NZ$200,000 per year

Table 4-5-1A Scale of Damage by Wave Over-topping for Waves of Different Return Period (Damage Ratio to Cyclone Sally)

Airport Runway

Offshore Wave Height (m)	Return Period (year)	Probability of Exceedance	Probability of Distribution	Wave Over-Topping (m3)	Damage Indicator
2.34	2	0.5	0.214	0.000	0.000000
5.54	5	0.2	0.200	0.006	0.001200
7.37	10	0.1	0.076	0.026	0.001976
8.10	13	0.08	0.050	0.035	0.001750
9.40	25	0.04	0.030	0.061	0.001830
10.75	50	0.02	0.013	0.094	0.001222
11.98	100	0.01	0.013	0.116	0.001508
					0.009486
			Damage ratio to Sally		5.420571

Parliament Building

Offshore Wave Height (m)	Return Period (year)	Probability of Exceedance	Probability of Distribution	Wave Over-Topping (m3)	Damage Indicator
2.34	2	0.5	0.214	0.000	0.000000
5.54	5	0.2	0.200	0.000	0.000000
7.37	10	0.1	0.076	0.010	0.000760
8.10	13	0.08	0.050	0.020	0.001000
9.40	25	0.04	0.030	0.051	0.001530
10.75	50	0.02	0.013	0.112	0.001456
11.98	100	0.01	0.013	0.157	0.002041
					0.006787
			Damage Ratio to Sally		6.787000

TPP Fuel Depot

Offshore Wave Height (m)	Return Period (year)	Probability of Exceedance	Probability of Distribution	Wave Over-Topping (m3)	Damage Indicator
2.34	2	0.5	0.214	0.000	0.000000
5.54	5	0.2	0.200	0.016	0.003200
7.37	10	0.1	0.076	0.050	0.003800
8.10	13	0.08	0.050	0.064	0.003200
9.40	25	0.04	0.030	0.094	0.002820
10.75	50	0.02	0.013	0.150	0.001950
11.98	100	0.01	0.013	0.185	0.002405
					0.017375
			Damage Ratio to Sally		5.429688

Westpac Bank

Offshore Wave Height (m)	Return Period (year)	Probability of Exceedance	Probability of Distribution	Wave Over-Topping (m3)	Damage Indicator
2.34	2	0.5	0.214	0.000	0.000000
5.54	5	0.2	0.200	0.006	0.001200
7.37	10	0.1	0.076	0.018	0.001368
8.10	13	0.08	0.050	0.030	0.001500
9.40	25	0.04	0.030	0.076	0.002280
10.75	50	0.02	0.013	0.134	0.001742
11.98	100	0.01	0.013	0.178	0.002314
					0.010404
			Damage Ratio to Sally		6.936000

Banana Court

Offshore Wave Height (m)	Return Period (year)	Probability of Exceedance	Probability of Distribution	Wave Over-Topping (m3)	Damage Indicator
2.34	2	0.5	0.214	0.000	0.000000
5.54	5	0.2	0.200	0.039	0.007800
7.37	10	0.1	0.076	0.090	0.006840
8.10	13	0.08	0.050	0.124	0.006200
9.40	25	0.04	0.030	0.178	0.005340
10.75	50	0.02	0.013	0.267	0.003471
11.98	100	0.01	0.013	0.323	0.004199
					0.033850
			Damage Ratio to Sally		5.459677

Beachcomber

Offshore Wave Height (m)	Return Period (year)	Probability of Exceedance	Probability of Distribution	Wave Over-Topping (m3)	Damage Indicator
2.34	2	0.5	0.214	0.000	0.000000
5.54	5	0.2	0.200	0.011	0.002200
7.37	10	0.1	0.076	0.039	0.002964
8.10	13	0.08	0.050	0.052	0.002600
9.40	25	0.04	0.030	0.084	0.002520
10.75	50	0.02	0.013	0.121	0.001573
11.98	100	0.01	0.013	0.150	0.001950
					0.013807
			Damage Ratio to Sally		5.310385

Table 4-5-1A Continued

Health Department Offshore Wave Height (m)	Return Period (year)	Probability of Exceedance	Probability of Distribution	Wave Over-Topping (m3)	Damage Indicator
2.34	2	0.5	0.214	0.000	0.000000
5.54	5	0.2	0.200	0.001	0.000200
7.37	10	0.1	0.076	0.010	0.000760
8.10	13	0.08	0.050	0.016	0.000800
9.40	25	0.04	0.030	0.029	0.000870
10.75	50	0.02	0.013	0.050	0.000650
11.98	100	0.01	0.013	0.064	0.000832
					0.004112
			Damage Ratio to Sally		5.140000

Notes:

In the Additional Study, the economic analysis was made by taking into consideration the heights of offshore waves of various return periods, such as 100 years, 50 years, etc, during the project life of 30 years. In the analysis, it was assumed that the amount of damage was proportional to the volume of overtopping waves.

The volume of each return period's overtopping was multiplied by the distribution of the series of offshore waves and added up. In the same manner, the volume of overtopping caused by the offshore wave (8.1m) of Cyclone Sally was multiplied by its distribution. The ratio of the two final figures was calculated as the ratio of damage. That is to say that the magnitude of probabilistically analyzed damage by using wave heights of different return periods in comparison to the damage caused by Cyclone Sally was estimated. Using this calculation, the damage ratios of six different sites on the nortern coast of Rarotonga in comparison to Cyclone Sally during the 30 year period were estimated. And as the result, a typical damage ratio of 6.0 was adopted.

It is said that the reinstallation of ILS (Instrument Landing System) takes more than six months, during that period a visual landing system will have to be adopted which may adversely affect the flight schedule.

On visibility and low cloud, "The climate and weather of the Southern Cook Islands (New Zealand Meteorological Service, Wellington, New Zealand)" has reported as follows:

"Normally visibility is very good apart from the usual reduction during showers. The airport is seldom affected by low cloud, the main base of the predominant cumulus cloud being about 2,000 - 2,500 ft (600 - 760 m). Yearly frequency of poor flying weather in category A (i.e. cloud below 1,500 ft. and/or visibility less than 5,000 m) is 2.6 %."

It is impossible to quantify the benefit due to the avoided damage to ILS. However, it is essential to mention here that the benefit is large in view of safe landing of airplanes.

The effect of the above-mentioned damages on air flight service will be estimated later.

(c) Reduction in Damage to JUHI Fuel Storage

In the opposite direction to the airport terminal building, there is JUHI fuel storage which is the only facility in Rarotonga Island to provide airflight fuel for domestic flight service which is carried through Avatiu Harbour from overseas. The tank yard of JUHI seems partly built on the reclaimed land.

There are two more fuel tanks (Triad and Mobil) between Avatiu Harbour and Rarotonga Airport. According to the estimation on coastal erosion by high waves, the higher waves of more than 50 years return period will carry away all fuel tanks in the JUHI and Triad storages and damage Mobil storage by half. Total damage to the above three facilities is calculated to be NZ$9,131,000.

The avoided cost by the reinforced coastal protection per year is estimated as follows:

NZ$9,131,000 x (30/50) x (1/30) = NZ$183,000 per year

The effect of the above-mentioned damages on air flight service will be estimated later.

(d) Reduction in Damage to Port Facilities

According to JICA report in 1987, total amount of damage to port facilities was estimated at NZ$1,225,000 as shown in Table 4-5-2 below. Among that damage, items marked "*1" and "*2" will be avoided by implementation of the short term plan, of which item *1 will be estimated in f). Total amount of item *2 is NZ$175,000 which is the damage caused by cyclones with the strength of Sally. Therefore, the annual benefits from this item *2 can be counted as follows:

NZ$175,000 x 6.0/30 = NZ$35,000 per year

Table 4-5-2 Port Facilities' Damage by Cyclone "Sally" at Avatiu Harbour

Avatiu Hobour			
a.	Eastern Breakwater	220,000	*1
b.	West Breakwater	150,000	*1
c.	Apron	150,000	*2
d.	Reclamation	25,000	*2
e.	Dredging	510,000	
f.	Pontoon & Barges	50,000	
g.	Miscellaneous	120,000	
	Total	NZ$1,225,000	

The damage to the breakwaters is estimated statistically in Table 4-3-3 and the annual benefit related to the breakwaters is NZ$72,000 per year.

(e) Maintaining the International/Domestic Flight Service

The international flight services between Aukland and Rarotonga are provided by B-767 and those among Aukland - Rarotonga - Honolulu - Los Angels, by B-747. The present length of the runway of Rarotonga Airport is marginal for B-747s taking off with normal passengers number and baggage weight. The coastal erosion mentioned above makes the runway strip narrow, which shortens the effective length of the runway and brings the flight service between Rarotonga and Honolulu/Los Angeles to a stop. The current flight service by B-747 will be temporarily changed to direct flight between Aukland and Honolulu/Los Angeles.

The period of the reconstruction of the damaged runway and runway strip is estimated to be six months.

Referring to the previous Report, the averaged number of international tourists over the Project Life is assumed to be 75,000 per year by taking into account the increase rate of lodging facilities in the Cook Islands.

According to the Report "Cook Islands Visitor Survey, 1991, Survey Report No. 13" (Tourism Council of the South Pacific), tourists from USA and Canada accounted for 20 per cent of all international tourists. Averaged length of stay and average daily expenditure per person from the two countries are 10 nights and NZ$95 respectively.

Benefit by the avoided cancellation of tourists from the USA and Canada will be estimated as follows:

75,000*0.2*10*NZ$95*(6/12)*(1/50) = NZ$142,500 per year

Here, the affected period of the decrease is assumed to be six months considering an aftereffect of the disaster.

It is estimated to take six months to repair the JUHI fuel storage.

The inconvenience on the supply of fuel for domestic flight under repair work will bring the decrease of international tourists who want to visit other islands of Southern Group of Cook Islands (Aitutaki etc.) through Rarotonga Airport. There is no statistic data to estimate this effect; therefore it is assumed here that 10 % of international tourists cancel to visit the Cook Islands during the repair work. The benefit by the avoided cancellation of international tourists by the implementation of the project is estimated as follows:

75,000* 0.8*10%*10*NZ$95*(6/12)*(1/50) = NZ$57,000

Therefore, the total benefits from maintaining flight service is: NZ$142,500 + NZ$57,000 ÷NZ$200,000

(f) Maintaining Economic Activities

In general, when properties such as offices, shops/stores, utilities and so on have been damaged, economic activities are limited. Within the limited available data, GDP is used for the estimation of this item.

GDP in 1990	:	NZ$105,834,000
Population in 1990	:	approx. 18,300 persons
GDP per capita	:	NZ$5,800

The Cook Islands government predicted the GDP growth for 1991 through 1995 which revealed a very small growth rate. Thus, a constant GDP value over the evaluating period is applied.

It is also assumed that restoration work will continue for about two weeks after the damage by a cyclone with the strength of Sally and economic activities will be limited to half of the usual activities. The amount expected to be lost by the above mentioned case is calculated as follows:

NZ$5,800 x 10,000 x (1/2) x (2 weeks) / (52 weeks/year) = NZ$1,115,000
where, the figure 10,000 is the population of Rarotonga Island

Therefore the annual benefit can be calculated as follows:

NZ$1,115,000 x 6.0/30 = NZ$223,000 per year

(g) Reduction in Damage to Shore Protection Structure and Breakwaters, etc.

i) Damage to Shore Protection

The mean construction & maintenance cost per year in "Without case" is estimated as NZ$3,600,000 per year.

NZ$985,200 x 2.73 x 1.34 = NZ$3,600,000

where,	NZ$985,200:	JICA 1991 (Note 1)
	2.73:	5.70 km/2.09 km (Note 2)
	1.34:	due to Probability of Distribution. (Note 3)

Note 1: The Final Report of the previous study indicates the construction cost (rehabilitation cost) without facility as follows:

Construction Cost	NZ$956,500 per year
Maintenance Cost	NZ$ 28,500 per year
Total	NZ$985,200 per year

Note 2: According to the same report, the rehabilitation cost without facility is for the 2,090 m coastline. In the Additional Study, it is planned to construct a total of 5,700 m of coastal protection work. Thus, the construction cost (rehabilitation cost) without facility was increased in proportion to the length of the coastal protection work.

Note 3: In the previous study, a offshore wave height of 8.1 m was used for the damage analysis for the "without facility" case. However, in the Additional Study, the offshore wave heights that cause damage were probabilistically analyzed. Thus, even in the economic analysis for the "without facility" case, it was necessary to take into account the effect of wave height.

For the convenience of analysis, the effect was included as follows:

$$\frac{\Sigma\,(\text{Phi x Vhi})}{\Sigma\,(\text{Phi x V(hi} < 8.1\text{ m))}}$$

Where, Phi: Occurrence probability of wave height of hi
Vhi Volume of overtopping wave of height hi
V(hi < 8.1 m): Volume of overtopping wave of the height hi that should be 8.1 m if hi is higher than 8.1 m

The actual analysis was made as shown in the following table :

	Offshore Wave Height (m)	Return Period (year)	Probability of Exceedance	E Probability of Distribution	F Wave Over-Topping (m^3)
8	2.34	2	0.5	0.214	0
9	5.54	5	0.2	0.200	0.006
10	7.37	10	0.1	0.076	0.031
11	8.10	13	0.08	0.050	0.056
12	9.40	25	0.04	0.030	0.078
13	10.75	50	0.02	0.013	0.134
14	11.98	100	0.01	0.013	0.178

Equation : 1/(F8 * E8 + F9 * E9 + F10 * E10 + F11 * (E11 + E12 + E13 + E14)) * (F8 * E8 + F9 * E9 + F10 * E10 + F11 * E11 + F12 * E12 + F13 * E13 + F14 * E14) = 1.34344711

ii) Damage to the west end area of Rarotonga Airport

According to the simulation on coast erosion by high waves, the localizer and the VOR will be washed away and the reclaimed area for runway strip, etc. will be eroded by the waves of more than 50 years return period. The cost for the repair work is estimated in Table 4-3-4 to be NZ$41,511,000.

Therefore the annual benefit can be calculated as follows:

NZ$41,511,000/50 = NZ$830,200 per year

Damage to the road around the west end of the runway should not be included here (it's already included in Item i)).

(4) Economic Prices of Construction Costs

In the economic analysis, construction costs have to be divided into the foreign currency portion and the local currency portion. Moreover, the local currency portion can be divided into skilled labour, unskilled labour, and others. Since the foreign currency portion is shown in CIF prices, there is no need for conversion into economic prices. The labour costs should be converted into economic prices by using the respective conversion factors. Table 4-5-3 shows the economic prices of construction costs.

(5) Calculation of EIRR

Annual costs and benefits in economic prices are shown in Table 4-5-4. In the Table, it is assumed that coastal protection work started from west end part of the runway of Rarotonga Airport, followed by the protection work at Avarua Coast.

The economic internal rate of return (EIRR) based on a cost-benefit analysis is used to appraise feasibility of the project.

The EIRR is the discount ratio which makes the costs and benefits of a project during the project life equal. It is calculated by using the following formula:

$$\sum_{i=1}^{n} \frac{Bi - Ci}{(1+r)^{i-1}} = 0$$

where, n : Project life
B_i : Benefit in i th year
C_i : Cost in i th year
r : Discount rate

The result of EIRR calculation is shown in Table 4-5-5.

The EIRR of the Project is calculated as 1.11 % and is small and this project is considered unfeasible. Therefore, selective protection works are recommended in order to protect national and private assets.

Table 4-5-3 Economic Prices of the Construction Cost

Location	Construction (NZ$)	Foreign Portion (1.00)	Local Portion			Overall Conversion Factor	Economic Prices (NZ$)
			Non Trade Goods (0.86)	Skilled Labour (0.92)	Unskilled Labour (0.69)		
Health Department							
Sea Wall	928,920	0.600	0.225	0.035	0.140	0.922	856,464
Beachcomber							
Offshore Breakwater	21,198,000	0.750	0.075	0.035	0.140	0.943	19,989,714
Sea Wall	637,100	0.600	0.225	0.035	0.140	0.922	587,406
Banana Court							
Sea Wall	23,040	0.600	0.225	0.035	0.140	0.922	21,243
Yacht Basin	3,594,124	0.800	0.000	0.040	0.160	0.947	3,403,635
Westpac Bank							
Offshore Breakwater	30,816,000	0.750	0.075	0.035	0.140	0.943	29,059,488
Sea Wall	1,032,960	0.600	0.225	0.035	0.140	0.922	952,389
TPP Fuel Depot							
Offshore Breakwater	58,606,800	0.750	0.075	0.035	0.140	0.943	55,266,212
Sea Wall	1,813,840	0.600	0.225	0.035	0.140	0.922	1,672,360
Parliament Building							
Sea Wall	2,288,880	0.600	0.225	0.035	0.140	0.922	2,110,347
Airport Runway							
Offshore Breakwater	23,868,000	0.750	0.075	0.035	0.140	0.943	22,507,524
Sea Wall	3,075,000	0.600	0.225	0.035	0.140	0.922	2,835,150
Avatiu Breakwater							
East Breakwater	12,816,072	0.600	0.225	0.035	0.140	0.922	11,816,418
West Breakwater	12,695,208	0.600	0.225	0.035	0.140	0.922	11,704,982
A. Direct Cost Total	173,394,000	-	-	-	-	0.939	162,783,332
B. Indirect Cost	35,546,000	0.650	0.300	0.010	0.040	0.945	33,590,970
C. Grand Total Cost (A+B)	208,940,000	-	-	-	-	0.940	196,374,302

Table 4-5-4 Annual Cost and Benefits in Economic Prices

No.	Year	Costs		Benefits					
		With Case Construction	Total Costs	Costs-Without Construction & Maintenance	Protection of Buildings	Maintaing Flight Service	Economic Activity	Others	Total Benefits
1	1994	32,729,000	32,729,000	3,600,000					3,600,000
2	1995	32,729,000	32,729,000	3,600,000		143,000	37,167	1,030,000	4,810,167
3	1996	32,729,000	32,729,000	3,600,000	910,500	143,000	74,333	1,030,000	5,757,833
4	1997	32,729,000	32,729,000	3,600,000	1,821,000	143,000	111,500	1,030,000	6,705,500
5	1998	32,729,000	32,729,000	3,600,000	1,821,000	162,000	148,667	1,126,667	6,858,333
6	1999	32,729,000	32,729,000	3,600,000	1,821,000	181,000	185,833	1,223,333	7,011,167
7	2000			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
8	2001			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
9	2002			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
10	2003			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
11	2004			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
12	2005			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
13	2006			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
14	2007			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
15	2008			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
16	2009			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
17	2010			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
18	2011			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
19	2012			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
20	2013			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
21	2014			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
22	2015			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
23	2016			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
24	2017			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
25	2018			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
26	2019			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
27	2020			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
28	2021			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
29	2022			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
30	2023			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
31	2024			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
32	2025			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
33	2026			3,600,000	1,821,000	200,000	223,000	1,320,000	7,164,000
Total		196,374,000	196,374,000	118,800,000	55,540,500	6,172,000	6,578,500	41,080,000	228,171,000

Benefits Others :

1) Decrease in Damage of Runway			
41,511,000/50	=	830,000	NZ$/year
2) Avoidance of Damage to I.L.S.		200,000	"
3) Decrease in Fuel Tank Storage			
9,130,000/50	=	183,000	"
4) Decrease in Damage of Port Facilities		107,000	"
Breakwater 72,000 + Apron 35,000			"
		1,320,000	NZ$/year

Table 4-5-5 Calculation of EIRR

EIRR = 1.11%

(Unit:NZ$)

Year	Benefits Total	Costs Total	Benefits - Costs		Present Value Benefits	Present Value Costs	Present Value Difference
1994	3,600,000	32,729,000	-29,129,000	0	3,600,000	32,729,000	-29,129,000
1995	4,810,167	32,729,000	-27,918,833	1	4,757,319	32,369,416	-27,612,097
1996	5,757,833	32,729,000	-26,971,167	2	5,632,009	32,013,783	-26,381,774
1997	6,705,500	32,729,000	-26,023,500	3	6,486,905	31,662,057	-25,175,152
1998	6,858,333	32,729,000	-25,870,667	4	6,561,862	31,314,196	-24,752,333
1999	7,011,167	32,729,000	-25,717,833	5	6,634,389	30,970,156	-24,335,767
2000	7,164,000		7,164,000	6	6,704,530	0	6,704,530
2001	7,164,000		7,164,000	7	6,630,870	0	6,630,870
2002	7,164,000		7,164,000	8	6,558,018	0	6,558,018
2003	7,164,000		7,164,000	9	6,485,967	0	6,485,967
2004	7,164,000		7,164,000	10	6,414,708	0	6,414,708
2005	7,164,000		7,164,000	11	6,344,231	0	6,344,231
2006	7,164,000		7,164,000	12	6,274,529	0	6,274,529
2007	7,164,000		7,164,000	13	6,205,593	0	6,205,593
2008	7,164,000		7,164,000	14	6,137,414	0	6,137,414
2009	7,164,000		7,164,000	15	6,069,984	0	6,069,984
2010	7,164,000		7,164,000	16	6,003,295	0	6,003,295
2011	7,164,000		7,164,000	17	5,937,338	0	5,937,338
2012	7,164,000		7,164,000	18	5,872,107	0	5,872,107
2013	7,164,000		7,164,000	19	5,807,592	0	5,807,592
2014	7,164,000		7,164,000	20	5,743,785	0	5,743,785
2015	7,164,000		7,164,000	21	5,680,680	0	5,680,680
2016	7,164,000		7,164,000	22	5,618,268	0	5,618,268
2017	7,164,000		7,164,000	23	5,556,542	0	5,556,542
2018	7,164,000		7,164,000	24	5,495,494	0	5,495,494
2019	7,164,000		7,164,000	25	5,435,116	0	5,435,116
2020	7,164,000		7,164,000	26	5,375,402	0	5,375,402
2021	7,164,000		7,164,000	27	5,316,344	0	5,316,344
2022	7,164,000		7,164,000	28	5,257,935	0	5,257,935
2023	7,164,000		7,164,000	29	5,200,168	0	5,200,168
2024	7,164,000		7,164,000	30	5,143,035	0	5,143,035
2025	7,164,000		7,164,000	31	5,086,530	0	5,086,530
2026	7,164,000		7,164,000	32	5,030,646	0	5,030,646
Total	228,171,000	196,374,000	31,797,000		191,058,608	191,058,608	-0

5. CONCLUSIONS AND RECOMMENDATIONS

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Northern Coast of Rarotonga Island

Through the site reconnaissance of geography, photos and video movies, interview of the people, it is evident that the northern coast of Rarotonga Island has been attacked by hurricane sea state. One clear geographical evidence is the fact that the coastal road runs on the heap made of coral boulders, 4.8 m above the sea level between Avarua and Avatiu at highest, which have been thrown by strong wave actions in the past. Other is the fact that coral rock which seems heavier than 6 ton are studded on the lagoon.

Coastal Protection

Necessity

It is very vital for the Cook Islands Government to protect the assets on the northern coast from the hurricane sea state. The area is the commercial and political center of the country and many private and public assets are concentrated there. Particularly Avatiu Harbour and Rarotonga Airport are located on the northern coast and they are life line. The latter is the vital facility for the tourism industry which is the main resource of the country income.

Hurricane Sea State for a 100-Year Return Period

The sea state of a 100-year return period is used for the design purpose on the northern coast of Rarotonga Island according to the policy which the Cook Islands provided to the JICA Study Team in October 1993. The calculation results indicate that the sea state of a 100-year return period will bring serious damages to the northern coast. The sea state is summarized in Table 1-1.

Criterion for Preliminary Design

For the preliminary coastal protection works, the criterion for permissible wave over-topping volume is set forth to be 0.05 $m^3/m/sec$. In Japanese Standard Design Criteria of coastal protection works, the wave topping of this value will not destroy unpaved shore protection dike.

According to the technical knowledge at present, the combination of artificial wave dissipating concrete blocks, rocks and concrete sea wall seems to be only solution as to provide the protection against the hurricane sea state for 100-year return period.

Preliminary Layout and Cross Section of Coastal Protection

The preliminary coastal protection works are designed at 6-cross sections of the northern coast as summarized below:

Coast:	Protection Works:
Airport Runway:	Combination of offshore breakwater of 20 ton wave dissipating concrete blocks and on-shore revetment of 0.5 ton wave dissipating concrete blocks.
Parliament Bldg.	Concrete sea wall with rock armor in front.
TTP Fuel Depot:	Combination of offshore breakwater of 25 ton wave dissipating concrete blocks and on-shore concrete sea wall with rock armor rocks in front.
Westpac Bank:	Combination of offshore breakwater of 25 ton wave dissipating concrete blocks and on-shore concrete sea wall with armor rocks in front.
Beachcomber:	Combination of offshore breakwater of 25 ton wave dissipating concrete blocks and on-shore concrete sea wall with armor rocks in front.
Health Department:	On-shore concrete sea wall with armor rocks in front.

The hinterland of Avarua Harbor is very low, approximately +1.9 m MSL. Flood by waves around this area cannot be prevented by the coastal protection works. It can be prevented by elevating the coastal road, which will be costly and bring about huge impacts to the town planning at Avarua. While, because of the return currents induced at Avarua Harbor, it is foreseen that the energy of waves will be reduced when they are reaching to the shore across Avarua Harbor and they will not cause heavy damages to the assess at the hinterland.

In this regard, it is suggested that tide wall about 0.8 m high and equipped with a small gate be built to further reduce the wave energy. The tide wall is to be designed appropriate at a tourist spot.

The layout of the preliminary coastal protection works is shown in Figure 4-1-10 and the cross sections are shown in Figure 4-1-11 through Figure 4-1-18.

The construction cost of the above coastal protection works is very roughly estimated to be about NZ$174,000,000.

Environmental Issues

The preliminary coastal protection works against the hurricane sea state of 100-year return period fulfill not all the objectives of the policy of the Cook Islands Government; particularly they will suffer the scenic value of the natural shorelines.

The offshore breakwaters are likely to block the view of the ocean. Artificial wave dissipating concrete blocks look sore to eyes even though they are neatly placed according to the planned alignment.

Port Improvement

Avatiu Harbour:

As the forecast predicts that cargoes will not much increase, no expansion of the berths is necessary. However, as more cargoes will be containerized, the container stacking yard is to be developed. To this end, the relocation of the fuel depot located at present within the port area is required.

Despite the previous JICA Study in 1991, no fish landing quay is required to be developed because a fish market seem unnecessary in the island. Therefore, the layout of the breakwater is determined accordingly, i.e. the extension of the east breakwater which was previously proposed is shortened.

The breakwaters, however, are to be constructed to protect the harbour from the hurricane sea state. Especially, the west breakwater is to be constructed as soon as possible as it remains scattered by Cyclone Sally in 1987.

Against the hurricane sea state of 100-year return period, artificial wave dissipating concrete blocks of a nominal 40 ton weight at maximum as amours of the breakwater are required.

The construction cost of the breakwaters is very roughly estimated to be NZ$31,000,0000.

Avarua Harbour

As Avatiu Harbour is congested with cargo ships and leisure boats, Avarua Harbour is to be developed to have a yacht basin for accommodating leisure boats. This is also according to the town planning of the coastal zone between Avatiu and Avarua prepared by University of Auckland in 1992.

The yacht basin requires an water area of 200 m x 60 m with a depth of 3 m below mean sea level to accommodate 30 leisure boats. It can be constructed in leeward of the offshore breakwaters which will protect the coast from the hurricane sea state.

The quay wall of the yacht basin must be of vertical concrete block wall of a wave dissipating type for the sufficient calmness for leisure boat accommodation.

The construction cost of the yacht basin is very roughly estimated to be NZ$4,300,000.

Economic Feasibility of the Coastal Protection Works

Construction Cost

A very rough cost estimate shows that the protection works of the northern coast of Rarotonga Island, including the provision of the breakwaters of Avatiu Harbour and the yacht basin at Avarua Harbour will cost the Cook Islands Government about NZ$209,000,000.

Benefits by Coastal Protection Works

The implementation of the coastal protection works will have the following benefits:

- Reduction of probable damages to be caused by the hurricane sea state.
- Reduction of maintenance of the coast.
- Reduction of probable decrease of the tourism income due to the airport damages.
- Increase of the income by accommodating leisure boats.
- Increase GDP by quarrying of rocks for the construction works.
- Increase of the economic activities on the northern coast.

For estimating the reduction of probable damages in case no protection works are constructed, the sea state of 2, 5, 10, 25, 50 and 100-year return periods were respectively predicted and the corresponding damages were estimated in proportion to those experienced in Cyclone Sally.

Economic Internal Rate of Return

A very preliminary economic analysis, by converting the quantifiable benefits to monetary terms, indicates that the economic internal rate of return of the coastal protection works will be very low, i.e. about 1.11 %.

It is concluded, therefore, the coastal protection of its full scale development is not viable from the economical point of view.

The annual costs and benefits in economic prices are shown in Table 4-5-4 while the calculation of economic internal rate of return is shown in Table 4-5-5.

5.2 Recommendations

Selective Protection Works

As the full scale development of the coastal protection works seems not economically viable, selective protection is recommended; particularly Avatiu Harbour ,the airport runway and the fuel tanks must be properly protected since these facilities are vital for the Cook Islands' economy.

Relocation of Important Assets on the Northern Coast

As the coastal protection works are very expensive, it is recommendable for the Cook Islands Government to consider the relocation of important assets like fuel depots to inland.

For other private assets it is recommended for the government to financially assist the people in relocating or protecting them from the hurricane sea state.

Newly Innovated Coastal Protection Units

With regards to the newly innovated concrete units, which the Cook Islands Government considers to apply to the coastal protection of the northern coast of Rarotonga Island, no technical information is available during the study period.

It is recommended, therefore, that a scale model testing of the concrete units be carried out at first by means of a water tank and then, when the scale model testing shows successful results, a prototype model testing be carried out at the actual site in order to collect engineering date and establish the construction specifications therefor.

APPENDIX

POLICY PAPER

COASTAL PROTECTION - NORTHERN COAST

RAROTONGA - COOK ISLANDS

1. INTRODUCTION

The coastal zone endowed with various life-supporting ecosystems is a vital resource base to all island states of the Pacific region. The reefs and lagoons have been, for centuries, prime sources of food; in recent years, the coastal zone has increasingly assumed a significant economic role, especially for the smaller island states which must depend on tourism development to fuel economic growth. For most Pacific Islands, the coastal zone is also being subjected to increasing demands to support rapidly growing populations. However, the heavy concentration of population and subsistence/economic activities in this zone is often responsible for much of the plundering of coastal resources, the destruction of breeding grounds and beach areas, the pollution of lagoons and harbours, the loss of some marine species and ecosystems, and the fouling of nearshore waters and reefs. When arable land is extremely limited, as is the case in most smaller island states, the pressure to accommodate urban growth and expanded economic activities inevitably results in the construction of hotels, houses and infrastructure in areas close to the shoreline making them highly vulnerable to damages from cyclones and heavy seas. Thus, the coastal zone is not only a source of sustenance for the vast majority of island communities, it also contains within its boundaries a significant proportion of an island nation's investments in physical/infrastructural assets.

Viewed in this light, a comprehensive programme of coastal zone management to reduce and, ultimately, to eliminate pollution of coastal waters and plundering of coastal resources, and to protect and properly manage our shorelines is a must if we are to ensure the long-term livelihood of our people.

This policy paper is intended address the latter; that is, the coastal protection and shoreline management aspects of a coastal zone management programme.

2. CONVENTIONAL COASTAL PROTECTION SYSTEMS

The conventional response to Coastal Protection requirements is to construct hard structures such as concrete sea walls, rock boulder and concrete block revetments and sea walls. These structures are usually designed with sufficient bulk and height to withstand and overpower incoming waves and thus, 'hopefully', protect the land/properties behind them. Contrary to popular conceptions, however, such structures are expensive and require considerable efforts to construct, maintain and repair after cyclones and other tropical storms. It is also now recognised world-wide, that in terms of providing effective protection against coastal retreat and destruction, these solid structures perform poorly. Besides often being a detraction from the natural scenery, these solid shoreline defence structures frequently increase coastal damage by enhancing erosion, and destroying existing sandy beaches. Furthermore, wave heights over the structure (normally referred to as 'wave overtopping height') are increased, thereby intensifying back-shore scour and creating the necessity for ever bigger and higher structures. The latter phenomena, for example, was witnessed in Niue during Cyclone Ofa when waves hit the straight-faced cliff, ran up some 26 metres and demolished the hotel.

In short, solid wall defence structures can seriously degrade the environment, breakdown under increased pressure, and eventually help destroy the very areas they are designed to protect.

3. RAROTONGA

Like many of the smaller Pacific Island States, the Cook Island's vital commercial and national assets and essential infrastructure are mainly located within its coastal zone. In the case of Rarotonga most of these assets are situated on the low-lying Northern Coastline where the land levels range between 2 metres and 5 metres above mean sea level.

This Northern Coastline has recently seen an extensive program of foreshore development and beautification works along the urban sea front between the two harbours of Avatiu and Avarua and a major Town Planning exercise is underway for redevelopment of the Avarua Civic Centre which forms a focal point of the Urban area and its coast. This Urban coast is thus the Commercial and Government Centre of the Cook Islands as well as one of its principle showpieces.

Other vital infrastructure located on the Northern Coast includes the Rarotongan International Airport, J.U.H.I. - Triad - and Mobile bulk fuel depots, a coastal fringe road, underneath which run the main services of water mains, plus electric power and telephone cables. Also located on this Coastline are Parliament Buildings, an Airport bypass road and seawall, and oil and fuel pipelines servicing the bulk fuel depots.

While the Northern Coastline has over the past 25 years been adversely affected by Hurricane Sea States which have caused appreciable damage to roads, property, fuel supply lines, and other infrastructure, it is recognized that none of these Hurricanes were particularly large, nor were they an especially rare event. It is also recognized that during this period the Cook Islands had been extremely lucky with several near misses of Hurricanes which had devastated other Pacific Islands and it is only a matter of time before the Cook Islands is again struck by another such significant event.

A study analysis of past cyclone conditions suggested that if or when very extreme sea-conditions caused by an event of the "Val" type and magnitude were to hit Rarotonga the damage to all the North Coast infrastructure, Main Town Urban Area, and the Airport would be devastating. It is obvious that the Cook Islands could not afford a disaster of this magnitude, which is compounded by the fact that insurance is not available for sea-surge damage resulting from wave and water impact.

However, while it is obvious that we need Coastal Protection against these events it is known that traditional Coastal Protection Systems (such as those referred to in section 2. above) rarely provide satisfactory, long-lasting protection. They are also a detraction from the natural shoreline scenery and could conceivably negate efforts to promote our Tourism industry which is currently our leading economic sector.

4. COASTAL PROTECTION PLANNING

Taking into account all the fore-going, and taking special account of the major Town Planning and redevelopment of the Avarua Civic Centre, the tourist driven economy, and the recent main town foreshore development and beautification works, a coastal protection system that would fulfill most of our needs should be designed with the following objectives in mind.

A. It should provide effective protection for all vital infrastructure and domestic, commercial, and national assets on the designated area of the North Coast from hurricane - force seas, "from whatever direction they may arrive";

B. For engineering design purposes, design waves with return periods in the order of 100 years should be used. (I.E an event with a 1% risk of occurrence in a given year)

C. The system should assist our efforts to preserve our recreational beaches for the benefits of future generations and the tourist industry; and should not be of a Type which will erode and degrade these beaches and make them unusable.

D. It should not diminish the scenic value of our natural shorelines and should not degrade the coastal environment.

Meeting the above objectives means satisfying acceptable engineering requirements as well as complying with certain political, economic, and social considerations and should be based on the following criteria:

1. It should be cost effective long term, and as maintenance-free as possible.

2. It should be as low as possible in height, allow lagoon and ocean views while at the same time greatly reducing wave height and wave velocity;

3. The protection should enhance the environment, not degrade it;

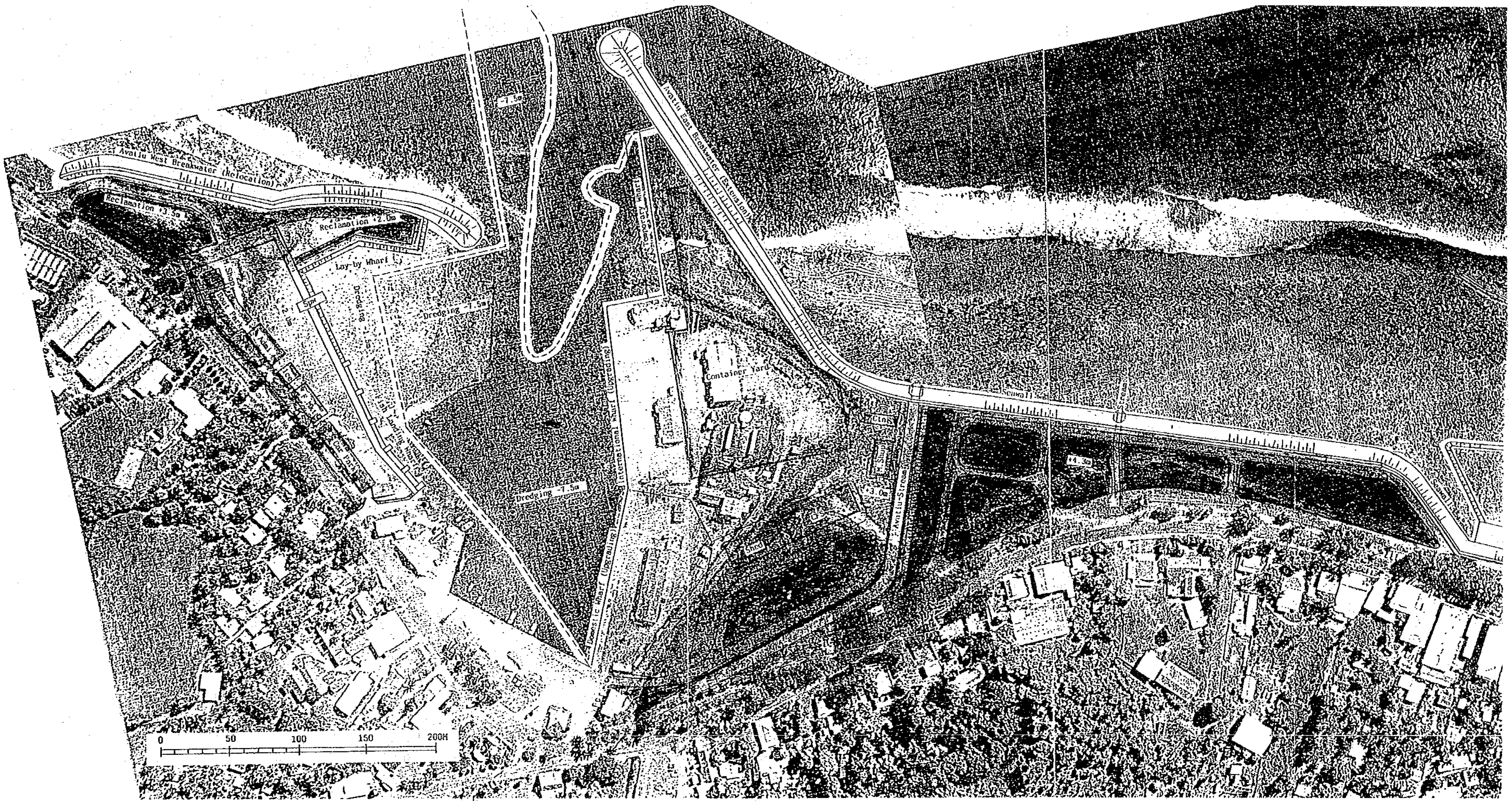
4. It should allow normal water flows to prevent lagoon degration and stagnation yet be capable of calming hurricane-force seas when necessary;

5. It should be aesthetic, not an 'eyesore';

6. Especially in the Main Town foreshore it should produce useable foreshore recreation areas and a Marine Promenade. It should not form an impassable barrier;

7. Where necessary, it should protect and help to rebuild existing beaches; and not be the cause of eroding and degrading them.

Appendix–B   Excerpt From the Final Report
of the Previous Study (Page 11–9)



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