CHAPTER 2 DETERMINATION OF DESIGN FLOOD

2.1 Scale of Design Flood

The scale of design flood is determined by safety degree against flood which each inundated area requires. For example, no flood control measures may be required if an inundated area is located in bushes or mountainous area where there is no residents. However, a flood in the residential area, such as Nadi, Nausori and Ba, causes not only the damage to man and economy but also the damage to traffic and infrastructure resulting the nation wide damage to society and economy. Safety degree against flood varies depending on the social and economic importance of a particular area. High safety degree has to be allocated in the urban area and its vicinity where social and economic infrastructures are located densely.

In practice, the scale of design flood is determined by the return period of rainfall considering the social and economic importance of target area, area of watershed, flood discharge, flood damage expected and so on. An objective river is examined by watershed indices, such as area of watershed, population and properties in inundated area, in order to assess the necessary safety degree against flood. In Japan, there is a following relation between watershed index and design flood as shown in Table-E2.1.

Table-E2.1 Relation between Watershed Index and Design Flood in Japan

Return Period of Design Flood		1/30	1/50	1/70	1/100
Catchment Area (km²)		less than 50	50 ~ 300	300 ~ 600	more than 600
Area of Inundation (ha)		less than 1,000	1,000 ~ 3,000	3,000 ~ 5,000	more than 5,000
Inundated Area	Residential Area (ha)	less than 100	100 ~ 800	800 ~ 2,000	more than 2,000
	Population (1,000 persons)	less than 30	30 ~ 100	100 ~ 200	more than 200
	*Property (10³)	less than 12	12 ~ 120	120 ~ 400	more than 400
	*Industrial Product (10³)	less than 4	4 ~ 40	40 ~ 80	more than 80

*Value divided by GDP per Capita

Based on Table-E2.1, the objective 4 rivers were examined by watershed indices and the result is shown in Table-E2.2. Design flood of 4 watersheds in terms of areas of watershed and inundation ranges at 1/50 ~ 1/100, while design flood in terms of conditions of inundated area ranges at 1/30 ~ 1/50. Therefore, the flood of 50 year return period is considered appropriate as the design flood of 4 watersheds.

Table-E2.2 Design Flood of 4 Watersheds by Watershed Index

Water Index		Rewa		Sigatoka		Nadi		Ba	
		Index Value	Return Period	Index Value	Return Period	Index Value	Return Period	Index Value	Return Period
Catchment Area (km²)		3,092	1/100	1,453	1/100	516	1/70	937	1/100
Area of Inundation (ha)		14,000	1/100	2,700	1/50	3,050	1/70	1,920	1/50
Inundated Area	Residential Area (ha)	60	1/30	60	1/30	120	1/50	80	1/30
	Population (1,000 persons)	15.1	1/30	7.4	1/30	11.1	1/30	10.6	1/30
	*Property (10³)	50	1/50	12	1/50	59	1/50	30	1/50
	*Industrial Product (10³)	4.0	1/50	0.3	1/30	3.5	1/30	9.3	1/50
Design Flood Determined		1/50		1/50		1/50		1/50	

*Value divided by GDP per capita

Design flood discharge (50 year return period flood) and current flow capacity at river mouth were compared as shown in Table-E2.3.

As discussed in Supporting Report Part D, Runoff Analysis, flow capacity of Rewa river is the lowest at 35 km from river mouth and its converted discharge at river mouth is 4,800 m^3/sec. This lowest flow capacity at 35 km is concluded as current flow capacity of Rewa based on runoff analysis. However, for flood control plan, capacity of Rewa river around Nausori town was adopted as current flow capacity, because areas where population and properties are located densely is main concern for flood control rather than remote areas. Therefore, current flow capacity of 5,900 m^3/sec (converted discharge at river mouth) is used to formulate a flood control master plan.

Table-E2.3 Flood Discharge of 50 Year Return Period and Current Flow Capacity

River		Rewa	Sigatoka	Nadi	Ba
① Flood Discharge of 50 year return period (m^3/sec)		11,500	4,200	3,100	5,200
② Current Flow Capacity	Discharge (m^3/sec) at river mouth	5,900	2,600	300	2,000
	Return Period	1/7	1/16	1/1	1/5
③ Insufficient Capacity	①-② (m^3/sec)	5,600	1,600	2,800	3,200
	①/②	1.9	1.6	10.3	2.6

As shown in Table-E2.3, the flow capacity of Rewa, Sigatoka and Ba rivers has to be improved approximately twice as much as the current capacity, while one of Nadi has to be improved 10 times more. When the difference between the current flow capacity and design flood discharge is very large, the flood control plans may encounter the difficulty of implementation due to the large investment and works to be required. Under the circumstances, the stepwise plans are recommended and are effective to flood control.

The first step is to improve the current flow capacity by 50 % of insufficient capacity above and at the second step the river is improved to drain the design flood discharge (50 year return period flood). After implementation of the first step, the flow capacity of river would be improved as follows.

- Rewa: 8,700 m^3/sec (1/25 probability)
- Sigatoka: 3,400 m^3/sec (1/30 probability)
- Nadi: 1,700 m^3/sec (1/14 probability)
- Ba: 3,600 m^3/sec (1/16 probability)

2.2 Design Flood Discharge

Flood probability varies with watershed. If the different scales of design flood were determined for each watershed, the safety degree against flood would be different depending on watershed. The different safety degrees are not preferable from an administrative point of view. After improvement of 50 % of insufficient flow capacity, each river would be able to flow almost 1/20 probability flood. Therefore, the flood of 20 year return period was set as a goal of the first step.

In this Study, the Master Plan of flood control was formulated for the Step 1 (1/20 probability). Design flood discharge at river mouth and distribution of design flood discharge in watershed are shown in Table-E2.4 and Figure-E2.1, respectively.

Table-E2.4 Design Flood Discharge at River Mouth

River	Step 1 1/20 Probability (m^3/sec)	Step 2 1/50 Probability (m^3/sec)	Current Flow Capacity (m^3/sec)
Rewa	7,800	11,500	5,900
Sigatoka	2,900	4,200	2,600
Nadi	2,100	3,100	300
Ba	3,900	5,200	2,000

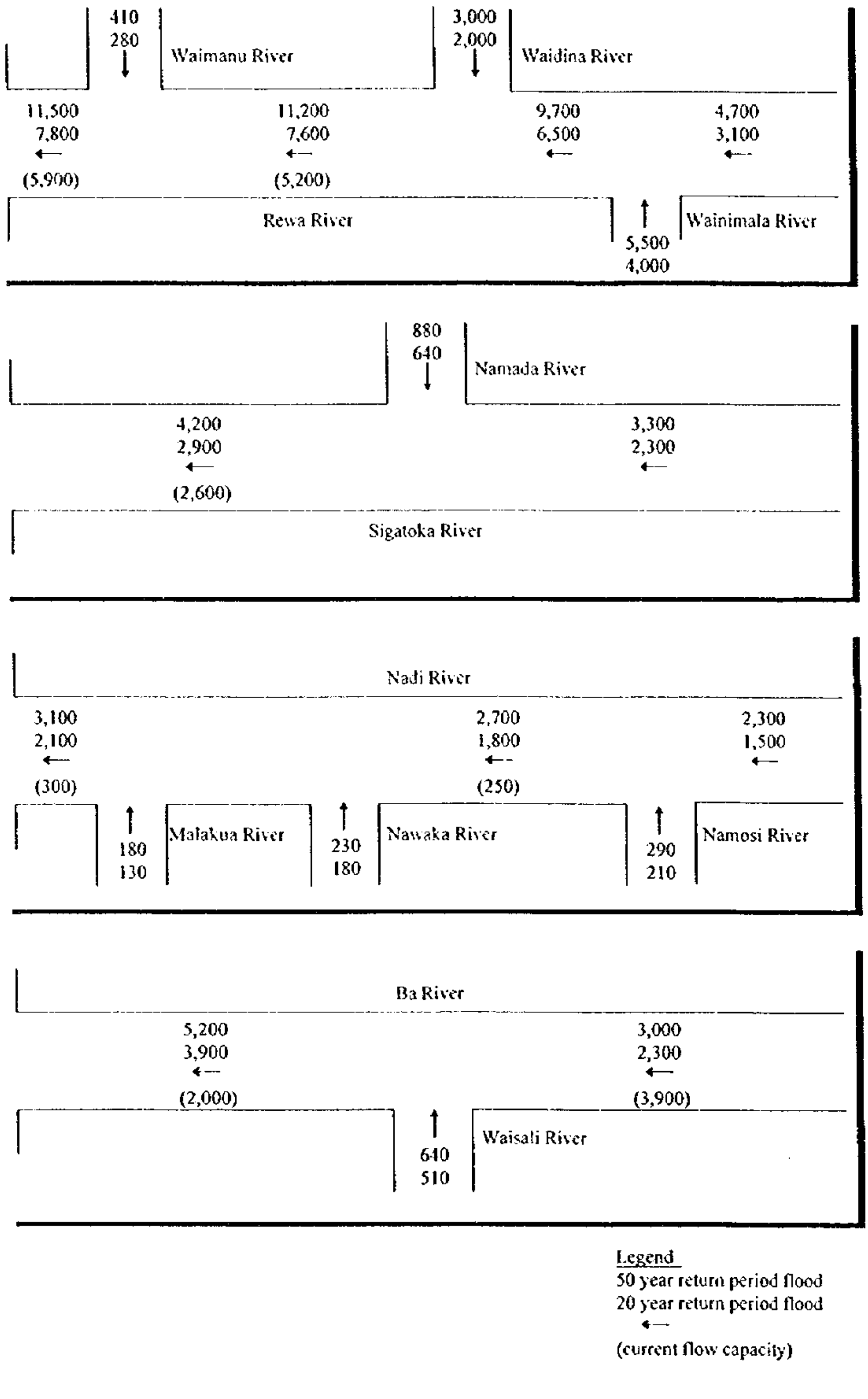


Figure-E2.1 Distribution of Design Flood Discharge

CHAPTER 3 FLOOD DAMAGE ANALYSIS

3.1 Flood Damage by Cyclone Kina

The study of flood damage was conducted by the JICA Study Team through the contract with a local consultant as described in Chapter 1. Based on the study results, the flood damage estimate of the cyclone Kina was carried out as shown below.

(1) Objects of Flood Damage Estimate

The major economic benefit of the flood control project can be presented as expected reduction in flood damage by implementing the project. The major flood damage to be reduced is composed of the damage to assets and damage to economic activities.

In this study, the assets are presented by buildings, household effects, agricultural field crops and public facilities. The building and household effects are called "general assets" herein. Components of each asset are described as follows.

1) The general assets are represented by residences, factories, commercial units and institutions. And each household in rural residence is assumed to keep some livestock as household effects.
2) The public facilities contains facilities of transport, agriculture, electricity, water supply, drainage, etc.
3) Agricultural field crops are limited to major crops represented by sugarcane, rice, root crops, vegetables and grazing.
4) Economic activities are represented by household income and profits of business activity, such as of factories, shops, restaurants, etc.

(2) General Formula of Flood Damage Estimate

The flood damages to general assets were estimated by 1) number of the assets inundated, 2) appraisal value of the assets, and 3) damage rate of the assets inundated. It can be expressed by an equation as follows;

$$D_i = N_i \cdot A_i \cdot R_i$$

where i : Kind of buildings

D_i: Flood damage to general asset for i-kind of building

N_i: Number of i-kind of building

A_i: Average appraisal value per general asset for i-kind of building

R_i: Average damage rate for i-building

Meanwhile, the damages to agricultural field crops were estimated by 1) inundation areas in the agricultural crop field, 2) price amount of the product per unit area, and 3) the damage rate of agricultural field crops inundated. It can be expressed by the following equation:

$D_j = A_j \cdot V_j \cdot R_j$

where j : Kind of agricultural field crops

D_j: Flood damage to j-crop

A_j: Planted area of j-crop

V_j: Average price per ha of j-crop

R_j: Average damage rate for j-crop

Damage to public facilities in each inundated area could not be obtained during the flood damage study, while Department of Regional Development (1993) estimated damage to public facilities in the whole Fiji caused by the cyclone Kina. Therefore, total damages to public facilities in 4 watersheds were estimated on the basis of the figures from Department of Regional Development (1993) as shown in Table-E3.1. The damages to public facilities in 4 watersheds caused by the cyclone Kina amount to F$ 32,758,000. Successively, the ratio of public facility damage to general asset damage was determined in order to assess the public facility damage in each inundated area. As a result, the flood damage to public facilities can be assumed to be 40 % of flood damage to general assets.

$$\text{about } 40\% = \frac{\text{F\$ 32,758,000 (flood damage to the public facilites)}}{\text{F\$ 73,660,000 (flood damage to the general assets)}}$$

Note: Estimate of flood damage to general assets is discussed below.

(3) Number of General Assets and Agricultural Field Crops

The population and the number of household suffered from the cyclone Kina were estimated by each inundated area and are totally 44,149 and 7,970, respectively. Locations of inundated areas are shown in Figure-E1.1 ~ E1.5 And the inundated area of scattered forest, agriculture and town were also estimated and the total area is 3,530 ha, 17,820 ha and 320 ha, respectively as shown in Table-E3.2.

The number of the assets and the area of respective agricultural field crops in each inundation area were estimated under the following conditions and assumptions. The results are shown in Table-E3.3 and Table-E3.4.

- Number of residential houses are assumed to be nearly equal to the number of household.
- Number of factory, commercial unit, and institutional unit were collected first from each district office and converted to the number of the average size of the respective unit, which is set based on the flood damage survey.
- Number of Nadi commercial units are assumed to be half of the total buildings because many of them are two-storied houses and only ground floor was inundated.
- Areas of respective agricultural field crops in each inundation area were estimated, based on the land use map and information collected from relative government authorities and district offices.

Table-E3.1 (1/4) Flood Damage to Public Facilities by Cyclone Kina

Item	Whole FIJI Cost (F$)		4 Watersheds by Flood ratio	4 Watersheds by Flood Cost (F$)		Remarks
1. Costs pertaining to the operation of Disaster Management Council(DISMAC)		936,201			640,839	
①Administrative and Miscellaneous	323,423		1.0	323,423		
②Police Logistic Support	34,681		1.0	34,681		
③FMF Service(includes FMF Air Wing)	257,039		1.0	257,039		
④Naval Squadron	85,362		-	0		
⑤Marine Department	200,000		-	0		
⑥Ministry of Health	15,696		1.0	15,696		
⑦Ministry of Infrastructure	20,000		0.5	10,000		
⑧Public Works and Maritime	-		-	0		
2. Economic production rehabilitation costs		17,849,140			3,122,501	
(1)Agriculture by government		4,949,821			3,087,001	
①Dredging and Irrigation	3,087,001		1.0	3,087,001		
②Extension	629,982		-	0		
③Livestock	572,831		-	0		
④Research	362,456		-	0		
⑤Market Survey	3,057		-	0		
⑥Administration	114,494		-	0		
⑦others	180,000		-	0		
(2)Agriculture(sugarcane) by private sector		11,700,000	-		0	
(3)Fisheries by government		221,579	-	0	0	
(4)Forestry by government		359,740			35,500	
①Uprighting and Propping Up	230,000		-	0		
②Road Clearing	71,000		0.5	35,500		
③Building Maintenance	58,740		-	0		
(5)Forestry by private sector		618,000	-		0	
3. Infrastructural rehabilitation costs		17,694,021			4,833,013	
(1)Bridge and crossing		2,231,782			1,304,469	
①Sigatoka Causeway	196,949		1.0	196,949		
②Sigatoka Bridge Decking	225,964		1.0	225,964		
③Ba Footbridge	120,087		1.0	120,087		
④Naboutolu Irish Crossing	176,862		-	0		
⑤Ba Bailey Bridge	761,469		1.0	761,469		
⑥Korovou Bailey Bridge, Naqali Sawani and Waisomo bridge	291,748		-	0		
⑦Benau Bridge	30,000		-	0		
⑧Store Purchase & Incidentals	428,703		-	0		

Table-E3.1 (2/4) Flood Damage to Public Facilities by Cyclone Kina

Item	Whole FIJI Cost (F$)		4 Watersheds by Flood ratio	4 Watersheds by Flood Cost (F$)		Remarks
(2)Roads		6,495,538			1,672,953	
1)Central/Eastern Division	5,592,688			1,495,303		
①Suva	681,933		-	0		
②Taunovo(Navua)	834,381		1.0	834,381		
③Rewa	578,000		-	0		
④Korovou(eastern coast)	660,922		1.0	660,922		
⑤Naqali(Rewa)	1,290,975		-	0		
⑥Eastern	493,243		-	0		
⑦R.C.U	1,038,234		-	0		
⑧Nasinu Quarry-Environmental Protection	15,000		-	0		
2)Western Division	355,299			177,650		
⑨Miscellaneous Roadworks	355,299		0.5	177,650		
3)Northern Division	547,551		-	0		
⑩Labasa East	22,473					
⑪Labasa West	28,579					
⑫Natua	39,706					
⑬Nabouwalu	103,151					
⑭Savusavu	178,117					
⑮Taveuni	37,930					
⑯Rabi	5,524					
⑰Saqani	100,480					
⑱Sealing	18,922					
⑲Building	12,669					
(3)Island jetties		76,195	-		0	
①Gau and Moala	36,570					
②Nabouwalu, Savusavu and Taveuni	39,625					
(4)Lighthouse and beacon		277,770	-		0	
(5)Water and sewerage		1,086,250			589,765	
1)DECE/E - Suva Water Supply	545,709			214,846		
①Maintenance/Main Office	152,325		0.5	76,163		
②Kinoya STP and Office(Suva)	174,188		-	0		
③Rewa Water Supply	95,880		1.0	95,880		
④Deuba Water Supply(nearby Navua)	25,043		-	0		
⑤Navua Water Supply	55,470		-	0		
⑥Hydrology	6,603		1.0	6,603		
⑦Master Plan	36,200		1.0	36,200		
2)Western Division	524,202			374,920		
⑧Miscellaneous Water Works	234,065		0.5	117,033		
⑨Vunisamaloa(Ba)	73,137		1.0	73,137		
⑩Vaqia(Ba)	110,000		1.0	110,000		
⑪Waiwai Treatment Plant	16,000		1.0	16,000		
⑫Water Main Across Sigatoka River	11,500		1.0	11,500		
⑬Miscellaneous Sewerage Works	64,500		0.5	32,250		
⑭Sewer Main Across Sigatoka River	15,000		1.0	15,000		

Table-E3.1 (3/4)　Flood Damage to Public Facilities by Cyclone Kina

Item	Whole FIJI Cost (F$)		4 Watersheds by Flood ratio	4 Watersheds by Flood Cost (F$)		Remarks
3)Northern Division	16,339		-		0	
⑮Miscellaneous Water Works	10,638					
⑯Nabouwalu	1,757					
⑰Savusavu	3,944					
(7)Government buildings		578,830			266,091	
①Central/Eastern Division	447,081		0.5	223,541		
②Western Division	85,100		0.5	42,550		
③Northern Division	46,649		-	0		
(8)Telecommunication		2,830,000			71,000	
1)Network Infrastructure	160,000			71,000		
①Antennas, Towers, Mast	18,000		-	0		
②Repair of access road	50,000		0.5	25,000		
③Transport(Air, Road and Sea)	25,000		0.5	12,500		
④Manpower	31,000		0.5	15,500		
⑤Fitting and Furniture(including postal)	28,000		0.5	14,000		
⑥others	8,000		0.5	4,000		
2)Customer Services	2,471,000		-	0		
⑦Central/Eastern Division	1,349,000					
⑧Western Division	1,082,000					
⑨Northern Division	40,000					
3)VHF, Telephone and HF Radiotelephones	199,000		-	0		
(9)Energy		4,117,656			928,736	
①Diesel Generation Cost	444,925		-	0		
②11KV Distribution Network	1,747,351		0.5	873,676		
③Monasavu Rehabilitation	1,136,820		-	0		
④132KV Tower Relocation	678,440		-	0		
⑤Perished Stock Materials	57,829		0.5	28,915		
⑥Buildings & Stations	52,291		0.5	26,146		
4. Proposed infrastructural development		23,100,000			20,000,000	
①New Sigatoka Bridge	10,000,000		1.0	10,000,000		
②New Ba bridge	10,000,000		1.0	10,000,000		
③New Korovou Bridge(eastern coast)	1,200,000		-	0		
④Reducing of Vunidawa Bridge(middlestream of Rewa)	650,000		-	0		
⑤Matainasau Bridge(upstream of Rewa)	1,250,000		-	0		

Table-E3.1 (4/4) Flood Damage to Public Facilities by Cyclone Kina

Item		Whole FIJI Cost (F$)		4 Watersheds by Flood ratio	4 Watersheds by Flood Cost (F$)	Remarks
5. Social services rehabilitation costs			29,029,439		4,161,403	
(1)Health			1,500,617	-	0	
(2)Rations	Population		13,756,817	-	0	
①Naitasiri	20,000					
②Rewa	10,000					
③Tailevu	25,000					
④Namosi	10,000					
⑤Serua	10,000					
⑥Bua	17,064					
⑦Western	20,000					
⑧Eastern	28,811					
(3)Schools			8,322,805	0.5	4,161,403	
①Schools Reconstructed by FMF		1,932,000				
②Schools Reconstructed by Rural Housing Unit(RHU)		2,639,876				
③Schools Reconstructed in Urban Areas by School Committees		3,750,929				
(4)Housings			5,449,200	-	0	
1)Central Division		2,304,000				
①Nausori		535,200				
②Suva		129,600				
③Navua		229,200				
④Vunidawa		877,200				
⑤Korovou		532,800				
2)Western Division		1,942,800				
⑥Lautoka/Yasawa		423,600				
⑦Nadi		80,400				
⑧Sigatoka		207,600				
⑨Ba		70,800				
⑩Tavua		135,600				
⑪Ra		1,024,800				
3)Northern Division		458,400				
⑫Bua		458,400				
4)Eastern Division		744,000				
Total			88,608,801		32,757,755	

Source: Department of Regional Development (1993)

Table-E3.2 Population and Areas Suffered from Cyclone Kina

	Urban		Rural		Total		Area (ha)			
	Population	Household	Population	Household	Population	Household	Scattered Forest	Agriculture	Town	Total
Rewa (1)	5,542	942	5,268	806	10,810	1,748	2,730	6,910	60	9,700
Rewa (2)	0	0	2,110	386	2,110	386	220	2,080	0	2,300
Rewa (3)	0	0	2,173	381	2,173	381	580	1,420	0	2,000
Sigatoka	2,217	416	5,191	902	7,408	1,318	0	2,640	60	2,700
Nadi	8,151	1,707	2,912	491	11,063	2,198	0	2,930	120	3,050
Ba	6,889	1,314	3,696	625	10,585	1,939	0	1,840	80	1,920
Total	22,799	4,379	21,350	3,591	44,149	7,970	3,530	17,820	320	21,670

Table-E3.3 Unit Number of General Assets

	Factory Unit	Commercial Unit	Institutional Unit
Rewa (1)	16	177	75
Rewa (2)	0	2	9
Rewa (3)	0	1	3
Sigatoka	1	8	11
Nadi	14	394	5
Ba	37	125	38
Total	68	707	141

Table-E3.4 Harvested Area by Crops

Unit: ha

	Sugarcane	%	Rice	%	Root Crop	%	Vegetable	%	Grazing	%	Total	%
Rewa (1)	0		1,382	20	2,073	30	2,073	30	1,382	20	6,910	100
Rewa (2)	0		0		728	35	728	35	624	30	2,080	100
Rewa (3)	0		0		497	35	497	35	426	30	1,420	100
Sigatoka	528	20	0		528	20	1,320	50	264	10	2,640	100
Nadi	2,490	85	0		147	5	147	5	147	5	2,931	100
Ba	1,564	85	0		92	5	92	5	92	5	1,840	100
Total	4,582	27	1,382	8	4,065	22	4,857	27	2,935	16	17,821	100

(4) Appraisal Value of General Assets and Agricultural Field Crops

The questionnaire survey was carried out as a part of flood damage study to obtain the present appraisal value of buildings, household effects and livestock for rural residences, factories, commercial units and institutional units in the inundated areas. Since available data samples in each inundated area were limited, the average appraisal values of whole areas are set as shown in Table-E3.5.

Regarding the agricultural field crops, the price at the farm gate were estimated on the basis of agricultural statistics, the result of questionnaire survey, and information from the relative government authorities and district offices.

Table-E3.5 Average Appraisal Value

Unit: F$

Asset	Item	Appraisal
General Assets	Residential Building	11,962
	Household Effects	5,669
	Livestock	1,134
	Factory Building	537,500
	Factory Assets	322,750
	Commercial Building	204,500
	Commercial Assets	112,629
	Institutional Building	301,000
	Institutional Assets	72,167
Agriculture	Sugarcane	2,970 /ha
	Rice	950 /ha
	Root Crop	4,500 /ha
	Vegetable	3,500 /ha
	Grazing	1,500 /ha
Economic Activities	Household Income	4,122 /year
	Factory Profit	150,000 /year
	Commercial Profit	50,000 /year

(5) Rates of Flood Damage

The rates of flood damages in the inundated areas were estimated under the following conditions;

- The flood damage rates of general assets, factories, commercial units, institutions and agricultural field crops were set as the average damage rate of the whole inundation areas, due to the limited amount of samples in each area.
- The damage rate to public facilities is assumed to be 40 % of general assets as discussed before.
- The economic losses of business activities are caused by suspensions of business activities. Actually, inhabitants, factory and commercial units in and around the inundation area have been obliged to suspend all or a part of their business and productive activities during some period in and after the flooding. Those losses are assumed to be 6 days based on the result of flood damage study. Therefore, the annual household income, annual sales profit of factory and annual commercial profit were multiplied by 0.016 (= 6 days/365 days) to assess the flood damage to economic activities.

Table-E3.6 Average Damage Rate

Asset	Item	Appraisal
General Assets	Residential Building	0.095
	Household Effects	0.388
	Livestock	0.470
	Factory Building	0.098
	Factory Assets	0.277
	Commercial Building	0.059
	Commercial Assets	0.285
	Institutional Building	0.116
	Institutional Assets	0.260
Agriculture	Sugarcane	0.412
	Rice	0.936
	Root Crop	0.983
	Vegetable	1.000
	Grazing	0.500
Economic Activities	Household Income	0.016
	Factory Profit	0.016
	Commercial Profit	0.016

(6) Estimate of Flood Damage by Cyclone Kina

The flood damage caused by the cyclone Kina was estimated based on conditions described above. The results are shown in Table-E3.7.

Table-E3.7 Flood Damage by Cyclone Kina

Unit: F$ 1,000

Asset	Rewa (1)	Rewa (2)	Rewa (3)	Sigatoka	Nadi	Ba	Total
General Assets	28,536	2,891	2,351	6,560	16,602	16,720	73,660
Agricultural Crops	26,167	8,731	5,960	8,580	1,727	2,983	54,148
Business activities	413	37	36	105	300	260	1,151
Public Facilities	11,414	1,156	940	2,624	6,641	6,688	29,464
Total	66,530	12,815	9,287	17,869	25,270	26,651	158,423

3.2 Annual Average Damage Reduction

Annual average damage reduction by the implementation of flood control plans was estimated in accordance with the flow chart shown in Figure-E3.1.

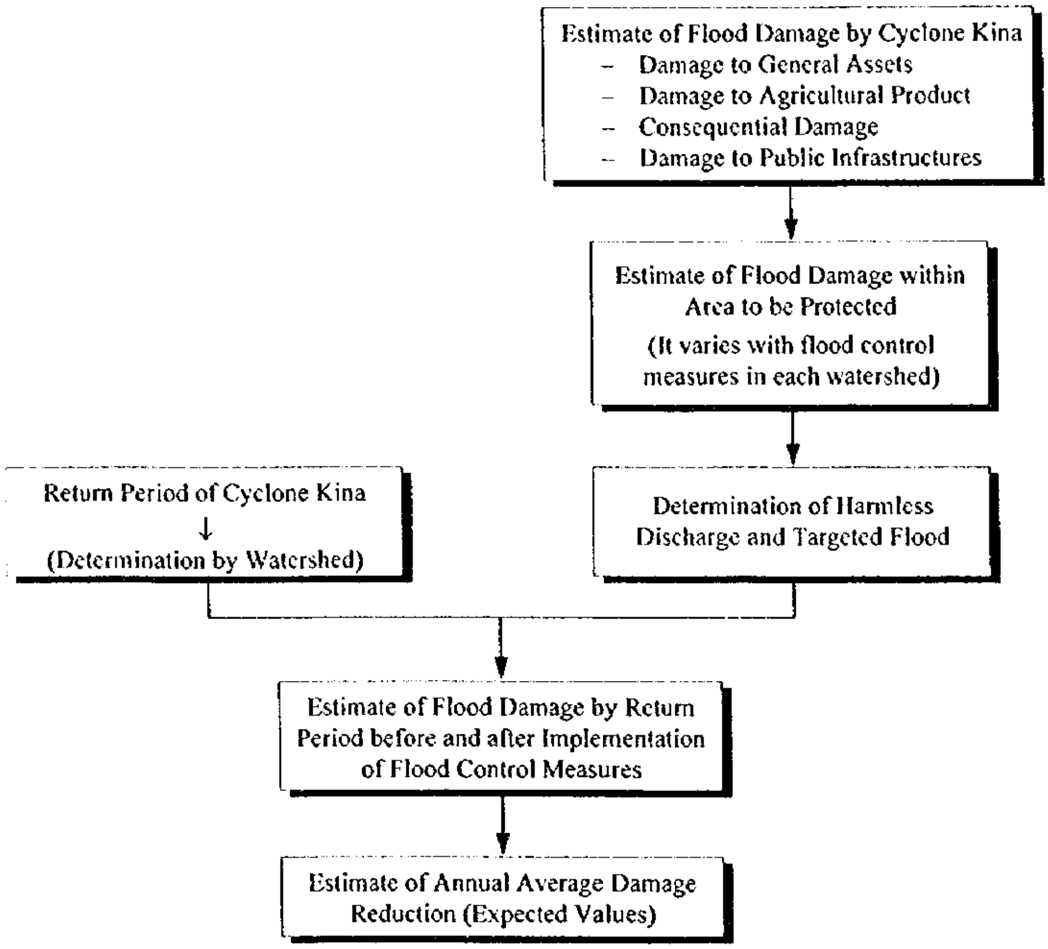


Figure-E3.1 Flow Chart to Estimate Annual Average Damage Reduction

Structural measures for flood control are discussed and proposed in Chapter 4. Proposed measures are summarized in Table-E3.8. Since stepwise implementation of structural measures is proposed for the Rewa watershed as a result of economic evaluation, there are two flood control plans as shown in Table-E3.8. Their effects on flood damage (annual average damage reductions) were estimated in the following sections.

Table-E3.8 Structural Measures Proposed

River		Structural Measures
Rewa	Case 1	Diversion Channel + Dike Construction on Left & Right Banks
	Case 2	Dike Construction on Left Bank
Sigatoka		Dredging
Nadi		Diversion Channel + Short Cut Channel
Ba		Dike Construction

(1) Estimate of Flood Damage by Cyclone Kina

As a result of the flood damage study, the flood damage by the cyclone Kina was estimated as follows.

- Rewa Watershed (total of 3 inundated areas): F$ 88,632,000
- Sigatoka Watershed: F$ 17,869,000
- Nadi Watershed: F$ 25,270,000
- Ba Watershed: F$ 26,651,000

(2) Flood Damage within Area to be Protected

Based on the flood damage by the cyclone Kina, its damage within the area to be protected by flood control measures was estimated. For the estimate of damage associated with building, household effects, livestock and agriculture, the ratio between the inundated area during the cyclone Kina and area to be protected was simply applied. Since factory, institution and commercial area are located in the target area of flood control, all their damage was included in the damage within the area to be protected.

1) Rewa Watershed

The flood control measures are effective to only Rewa (1) but not Rewa (2) and (3). Therefore, the flood damage in the area to be protected is equal to the damage in Rewa (1), F$ 66,530,000. The locations of Rewa (1), (2) and (3) are shown in Figure-E1.1.

2) Sigatoka Watershed

The effect of flood control measures covers the area from the river mouth to 30 km upstream of Sigatoka river. The area ratio is 0.718 (= 24.2 km^2/33.7 km^2) and the flood damage within the area to be protected is F$ 12,829,000.

3) Nadi Watershed

The effect of flood control measures covers the area from the river mouth to 18 km upstream of Nadi river. The area ratio is 0.819 (= 23.5 km^2/28.7 km^2) and the flood damage within the area to be protected is F$ 20,696,000.

4) Ba Watershed

The effect of flood control measures covers the area from the river mouth to 20 km upstream of Ba river. The area ratio is 0.732 (= 18.0 km^2/24.6 km^2) and the flood damage within the area to be protected is F$ 19,509,000.

(3) Estimate of Annual Average Damage Reduction

The annual average damage reduction was estimated with the following assumptions and conditions.

1) Return Period of Cyclone Kina

The flood damage within area to be protected was estimated based on the analysis of flood damage by the cyclone Kina. The damage within the aforesaid area is assumed to occur with the same return period of the cyclone Kina. The return period of the cyclone Kina in each watershed is shown in Table-E3.9.

2) Harmless Discharge

The harmless discharge, discharge which dose not cause any flood damage, is assumed to be the flow capacity of river in the town or its vicinity. The harmless discharge of each watershed is shown in Table-E3.9.

3) Effect of Flood Control Measures

The effect of flood control measures is the improved flow capacity of river after implementation of the measures for 20 year return period flood. Discharges discussed below are discharges at river mouth.

Rewa: (Case1) The flood discharge of 7,800 m^3/sec (20 year return period flood) would be reduced to 5,900 m^3/sec by implementation of diversion channel. Besides, the currently inundated area with a flood of 3,800 m^3/sec would be protected against a flood of 5,900 m^3/sec by dike construction. Therefore, the effect is;

$$7{,}800 - 3{,}800 = 4{,}000 \text{ m}^3/\text{sec}$$

Rewa: (Case 2) Nausori town and its vicinity are currently inundated with a flood more than 3,800 m^3/sec. Dike would protected those areas against 11 year return period flood (5,900 m^3/sec). Therefore, the effect is;

$$5{,}900 - 3{,}800 = 2{,}100 \text{ m}^3/\text{sec}$$

Sigatoka: The currently inundated area with a flood of 2,300 m^3/sec would be protected against a flood of 2,900 m^3/sec (20 year return period flood) by dredging. Therefore, the effect is;

$$2{,}900 - 2{,}300 = 600 \text{ m}^3/\text{sec}$$

Nadi: Out of 2,100 m^3/sec (20 year return period flood), 1,500 m^3/sec would be drained by diversion channel and the discharge of the Nadi river would be reduced to 600 m^3/sec. Beside, its flow capacity of 50 m^3/sec would be improved by a short cut channel. Therefore, the effect is;

$$2{,}100 - (600 - 50) = 1{,}550 \text{ m}^3/\text{sec}$$

Ba: The inundated area with a flood of 2,000 m^3/sec would be protected against a flood of 3,900 m^3/sec (20 year return period flood). Therefore, the effect is;

$$3{,}900 - 2{,}000 = 1{,}900 \text{ m}^3/\text{sec}$$

Table-E3.9 Estimate Conditions of Annual Flood Damage Reduction

Item		Rewa River	Sigatoka River	Nadi River	Ba River
Whole Watershed Area (km^2)		3,092	1,453	516	937
Harmless Discharge	Point from River Mouth (km)	11.5	3.0	11.0	15.5
	Watershed Area (km^2)	2,930	1,439	330	890
	Water Level (EL.m)	4.44	2.40	5.20	5.00
	Discharge at Point (m^3/sec)	3,600	1,300	350	1,900
	Converted Discharge at River Mouth (m^3/sec)	3,800	1,310	550	2,000
	Return period	1/5.0	1/4.0	1/2.5	1/4.5
Cyclone Kina	Discharge (m^3/sec)	11,500	3,500	960	3,900
	Return Period	1/50	1/30	1/5	1/20
	Flood Damage (thousand F$)	66,530	12,829	20,696	19,509

The annual average damage reduction was estimated with the following procedures.

- To determine the relation between discharge and flood damage based on the flood damage estimated (cyclone Kina) and harmless discharge (damage = 0)
- To estimate the flood damage before and after the implementation of flood control measures based on the above relation
- To estimate the annual average damage reduction based on the flood damage reduction at a certain return period

The relation between discharge and flood damage varies depending on the watershed characteristics. Since there is no general relation, as many data as possible should be plotted to determine the relation; however, in Viti Levu this relation is available only for the cyclone Kina. Therefore, the straight line was assumed to express the relation as shown in Figure-E3.2 ~ Figure-E3.5.

Flood damage at a certain return period was read by from those figures. The maximum return period to estimate the flood damage corresponds with the Step 1 target (20 year return period flood) proposed in Chapter 2.

Annual average flood damage reduction for each watershed was estimated based on Figure-E3.2 ~ Figure-E3.5. The result of estimate is shown in Table-E3.10. With the structure measures proposed in Chapter 4, the annual average damage reduction of each watershed is F$ 1,966,000 for Rewa (Case 1), F$ 798,000 for Rewa (Case 2), F$ 381,000 for Sigatoka, F$ 8,278,000 for Nadi and F$ 1,446,000 for Ba.

Rewa River, Case 1: Diversion Channel + Dike Construction on Left & Right Banks
Case 2: Dike Construction on Left Bank

Damage by Cyclone KINA

Watershed	Rewa	Remark
(1) General Assets	28,536,000	
(2) Agricultural Crops	26,167,000	
(3) Business Activities	413,000	
(4) Public Facilities	11,414,000	(1) x 40%
Total	66,530,000	

[66,530 10^3 F$]

Whole Catchment Area (km^2)		3,092	
Harmless Discharge	Point (km)	11.5	
	Catchment Area (km^2)	2,930	
	Ground Height (EL m)	4.44	
	Clearance (m)	0.00	
	Water Level (EL m)	4.44	
	Q (m^3/s)	3,600	
	Q at River Mouth (m^3/s)	3,800	1/5*
Discharge of Cyclone KINA (1/50)		11,500	

Damage (10^3 F$)	Q (m^3/s)
0	3,800
66,530	11,500

*: Return Period of Harmless Discharge
Q: Discharge
Point: Distance from River Mouth

Q=aD+b : a= 0.116 b= 3,800
D=cQ+d : c= 8.640 d= -32,833

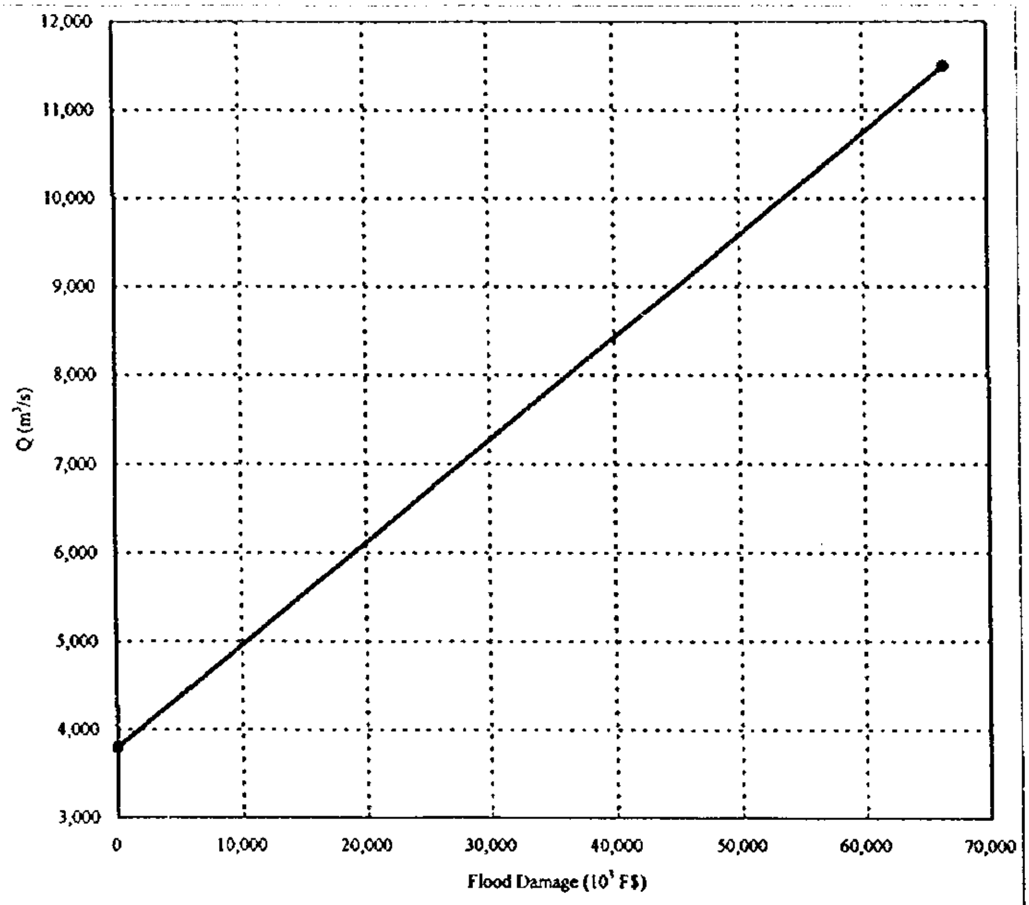


Figure-E3.2 Relation between Discharge and Flood Damage (Rewa, Case 1 & Case 2)

Sigatoka River: Dredging

Damage by Cyclone KINA

Watershed	Sigatoka	Remark	
(1) General Assets	4,710,000	Effective Ratio of Measures	0.718
(2) Agricultural Crops	6,160,000		
(3) Business Activities	75,000		
(4) Public Facilities	1,884,000	(1) x 40%	
Total	12,829,000		

12,829 10^3 FS

Sigatoka River

Whole Catchment Area(km^2)		1,450	
Harmless Discharge	Point (km)	3.0	
	Catchment Area (km^2)	1,439	
	Ground Height (EL m)	2.40	
	Clearance (m)	0.00	
	Water Level (EL m)	2.40	
	Q (m^3/s)	1,300	
	Q at River Mouth (m^3/s)	1,310	1/4*
Discharge of Cyclone KINA (1/30)		3,500	

Damage(10^3 FS)	Q(m^3/s)
0	1,310
12,829	3,500

* : Return Period of Harmless Discharge
Q: Discharge
Point: Distance from River Mouth

Q=aD+b : a= 0.171 b= 1,310
D=cQ+d : c= 5.858 d= -7,674

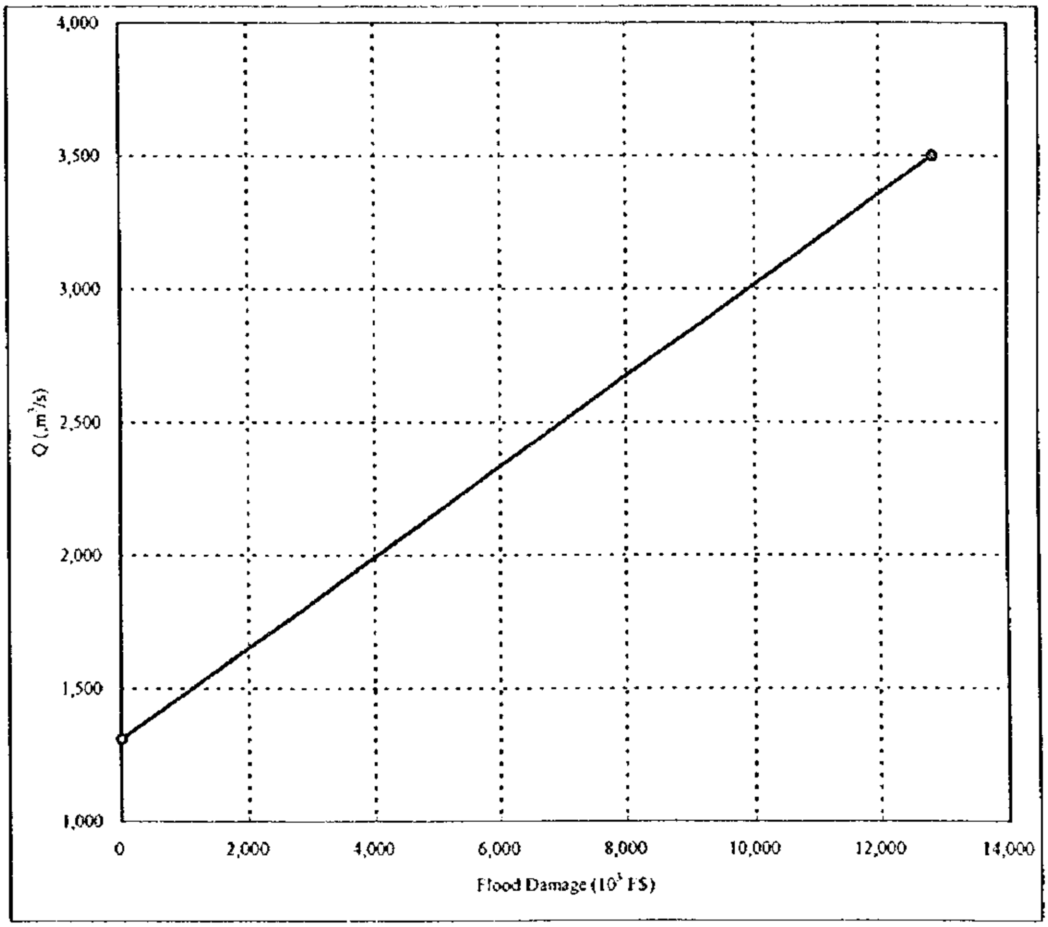


Figure-E3.3 Relation between Discharge and Flood Damage (Sigatoka)

Nadi River: Diversion Channel + Short Cut Channel

Damage by Cyclone KINA

Watershed	Nadi	Remark	
(1) General Assets	13,597,000	Effective Ratio of Measures	0.819
(2) Agricultural Crops	1,414,000		
(3) Business Activities	246,000		
(4) Public Facilities	5,439,000	(1) x 40%	
Total	20,696,000		

20,696 10^3 F$

Nadi River

Whole Catchment Area(km^2)		515	
Harmless Discharge	Point (km)	11.0	
	Catchment Area (km^2)	330	
	Ground Height (EL m)	5.20	
	Clearance (m)	0.00	
	Water Level (EL m)	5.20	
	Q (m^3/s)	350	
	Q at River Mouth (m^3/s)	550	1/2.5*
Discharge of Cyclone KINA (1/5)		960	

Damage(10^3 F$)	Q(m^3/s)	
0	550	
20,696	960	
78,241	2,100	1/20

* : Return Period of Harmless Discharge
Q: Discharge
Point: Distance from River Mouth

Q=aD+b : a= 0.020 b= 550
D=cQ+d : c= 50.48 d= -27,763

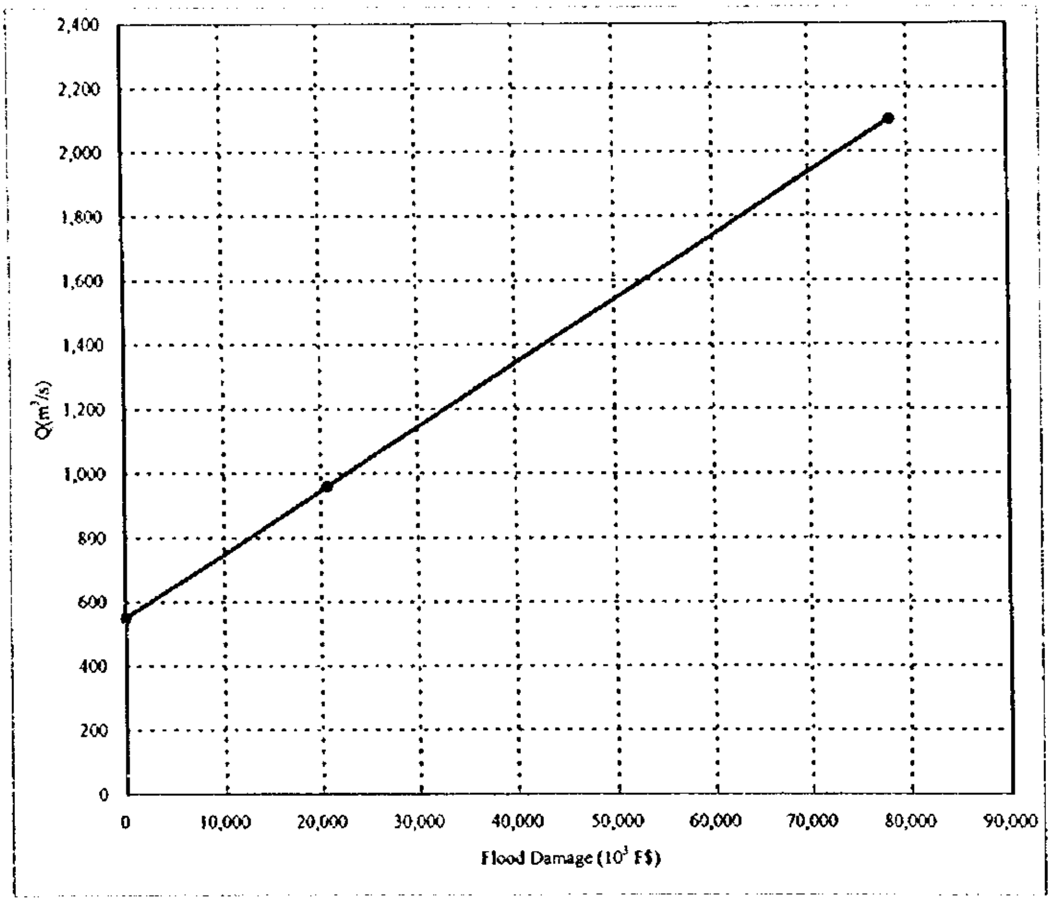


Figure-E3.4 Relation between Discharge and Flood Damage (Nadi)

Ba River: Dike Construction

Damage by Cyclone KINA

Watershed	Ba	Remark	
(1) General Assets	12,239,000	Effective Ratio of Measures	0.732
(2) Agricultural Crops	2,184,000		
(3) Business Activities	190,000		
(4) Public Facilities	4,896,000	(1) x 40%	
Total	19,509,000		

19,509 10^3 F$

Ba River

Whole Catchment Area(km^2)		936	
Harmless Discharge	Point (km)	15.5	
	Catchment Area (km^2)	890	
	Ground Height (EL m)	5.00	
	Clearance (m)	0.00	
	Water Level (EL m)	5.00	
	Q (m^3/s)	1,900	
	Q at River Mouth (m^3/s)	2,000	1/4.5*
Discharge of Cyclone KINA (1/20)		3,900	

Damage(10^3 F$)	Q(m^3/s)
0	2,000
19,509	3,900

* : Return Period of Harmless Discharge

Q: Discharge

Point: Distance from River Mouth

Q=aD+b : a= 0.097 b= 2,000

D=cQ+d : c= 10.268 d= -20,536

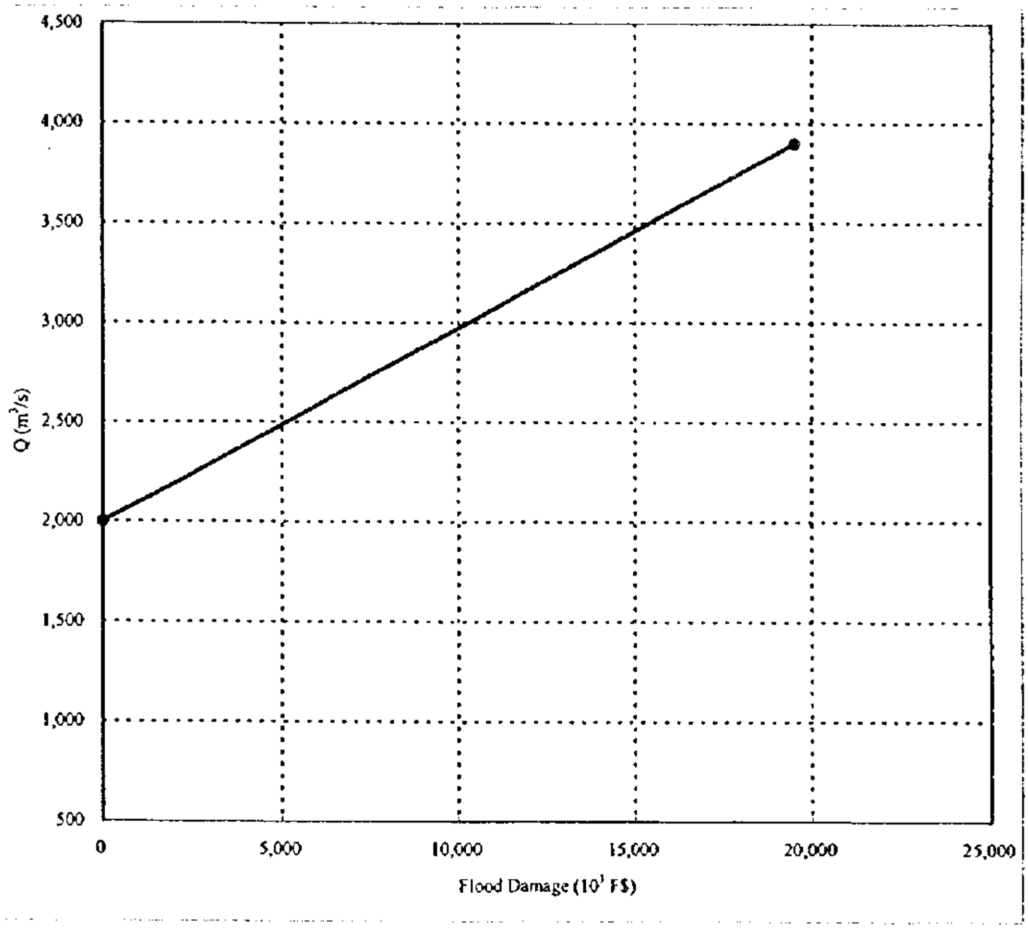


Figure-E3.5 Relation between Discharge and Flood Damage (Ba)

Table-E3.10 Estimate Result of Annual Average Damage Reduction

River	Return Period		Annual Average Return Periods	Discharge			Flood Damage		Flood Damage Reduction	Average Flood Damage Reduction	Annual Average Flood Damage Reduction
				Current	After Imple-mentation	Effect	Current	After Imple-mentation			
			①	②	③	④=②-③	⑤	⑥	⑦=⑤-⑥	⑧=(⑦n+⑦n-1)/2⑦	⑨=①x⑧
				m^3/sec	m^3/sec	m^3/sec	10^3F$	10^3F$	10^3F$	10^3F$	10^3F$
Rewa (Case 1)	1/20	0.050	-	7,800	3,800	4,000	34,561	0	34,561	-	-
	1/10	0.100	0.050	5,500	2,680	2,820	14,688	0	14,688	24,625	1,231
	1/5	0.200	0.100	3,800	1,850	1,950	0	0	0	7,344	734
Total											1,966
Rewa (Case 2)	1/11	0.091	-	5,900	3,800	2,100	16,385	0	16,385	-	-
	1/10	0.100	0.009	5,500	3,540	1,960	13,264	0	13,264	14,824	135
	1/5	0.200	0.100	3,800	2,450	1,350	0	0	0	6,632	663
Total											798
Sigatoka	1/20	0.050	-	2,900	2,300	600	9,314	5,799	3,515	-	-
	1/10	0.100	0.050	2,200	1,740	460	5,214	2,519	2,695	3,105	155
	1/6	0.167	0.067	1,650	1,310	340	1,992	0	1,992	2,343	156
	1/5	0.200	0.033	1,460	1,160	300	879	0	879	1,435	48
	1/4	0.250	0.050	1,310	1,040	270	0	0	0	439	22
Total											381
Nadi	1/20	0.050	-	2,100	550	1,550	78,241	0	78,241	-	-
	1/10	0.100	0.050	1,400	370	1,030	42,906	0	42,906	60,574	3,029
	1/5	0.200	0.100	960	250	710	20,696	0	20,696	31,801	3,180
	1/2.5	0.400	0.200	550	140	410	0	0	0	10,348	2,070
Total											8,278
Ba	1/20	0.050	-	3,900	2,000	1,900	19,509	0	19,509	-	-
	1/10	0.100	0.050	3,000	1,540	1,460	10,268	0	10,268	14,888	744
	1/5	0.200	0.100	2,300	1,180	1,120	3,080	0	3,080	6,674	667
	1/4.5	0.222	0.022	2,000	1,030	970	0	0	0	1,540	34
Total											1,446

CHAPTER 4 STRUCTURAL MEASURES

4.1 Comparison of Flood Control Measures

In this section, possible structural measures for flood control are proposed on the basis of discussions of the characteristics of each watershed. Possible structural measures were initially proposed considering topography, catchment area, storage volume and geology which are obtainable from the topographical map, geological map and aerial photo. The location and structural measures proposed are shown in Figure-E4.1. After evaluation of suitability of each measure, feasible measures were determined and their effects were examined. Finally flood control measures were proposed for each watershed.

(1) Main Components of Flood Control Plan

1) Rewa River

For Rewa river, its downstream part has an almost constant flow capacity for a length of 35 km toward river mouth. Within this section of the river, there is almost no any 'critical point' where river flow is hindered. The main stream of the river meanders all the way. At a place about 20 km from river mouth, the river channel is adjacent to some small rivers which flow directly to the sea. From the condition of the river channel and the topography in the watershed area, the following measures can be proposed as the main components of the flood control plan.

a) Diversion channel

b) Weir and retarding basin

c) Cut-off channel and retarding basin

d) Flood control dam

e) River improvement

- River channel widening
- River dike construction
- River bed excavation

2) Sigatoka River

Since the flow capacity of Sigatoka river is smaller at its downstream part, it is considered to be effective to discharge flood directly to the sea by a diversion channel. However, construction of the diversion channel seems to be difficult from the topographic conditions in the watershed. In addition, since the river flows through a narrow valley, it is difficult to find a suitable place to construct retarding basins with a significant storage volume. Therefore, only the following measures are considered to be suitable for the flood control plan.

a) Flood control dam

b) River improvement

- River channel widening
- River dike construction
- River bed excavation
- Dike construction surrounding urban area

3) Nadi River

Of the four rivers in the study area, Nadi river has the smallest flow capacity. In addition, there exists a 'critical point' at the downstream part 7.5-9.0 km from river mouth, where the flow capacity is relatively small. Under such a condition, construction of a diversion channel at the upstream side of the 'critical point' is considered to be effective. A route starting at a point of 14 km from river mouth and going through the side of Nadi airport may be the most favorable. Therefore, the flood control plan for Nadi river may consist of the following measures.

a) Diversion channel

b) Improvement of confluence point

c) Flood control dam

d) River improvement

- River channel widening
- River dike construction
- River bed excavation

4) Ba River

Of the four rivers in the study area, Ba river has the largest flow capacity. There are some points where flow capacity becomes smaller, but all of them are at the downstream part of the river. No potential site can be found for the construction of a diversion channel or retarding basin from the topographic conditions. Therefore, the following measures can be proposed for the flood control plan.

a) Flood control dam

b) River improvement

- River channel widening
- River dike construction
- River bed excavation

(2) Evaluation of Flood Control Measures

The flood control measures proposed above were compared and the suitability of each measure to watershed was evaluated. The results are shown in Table-E4.1.

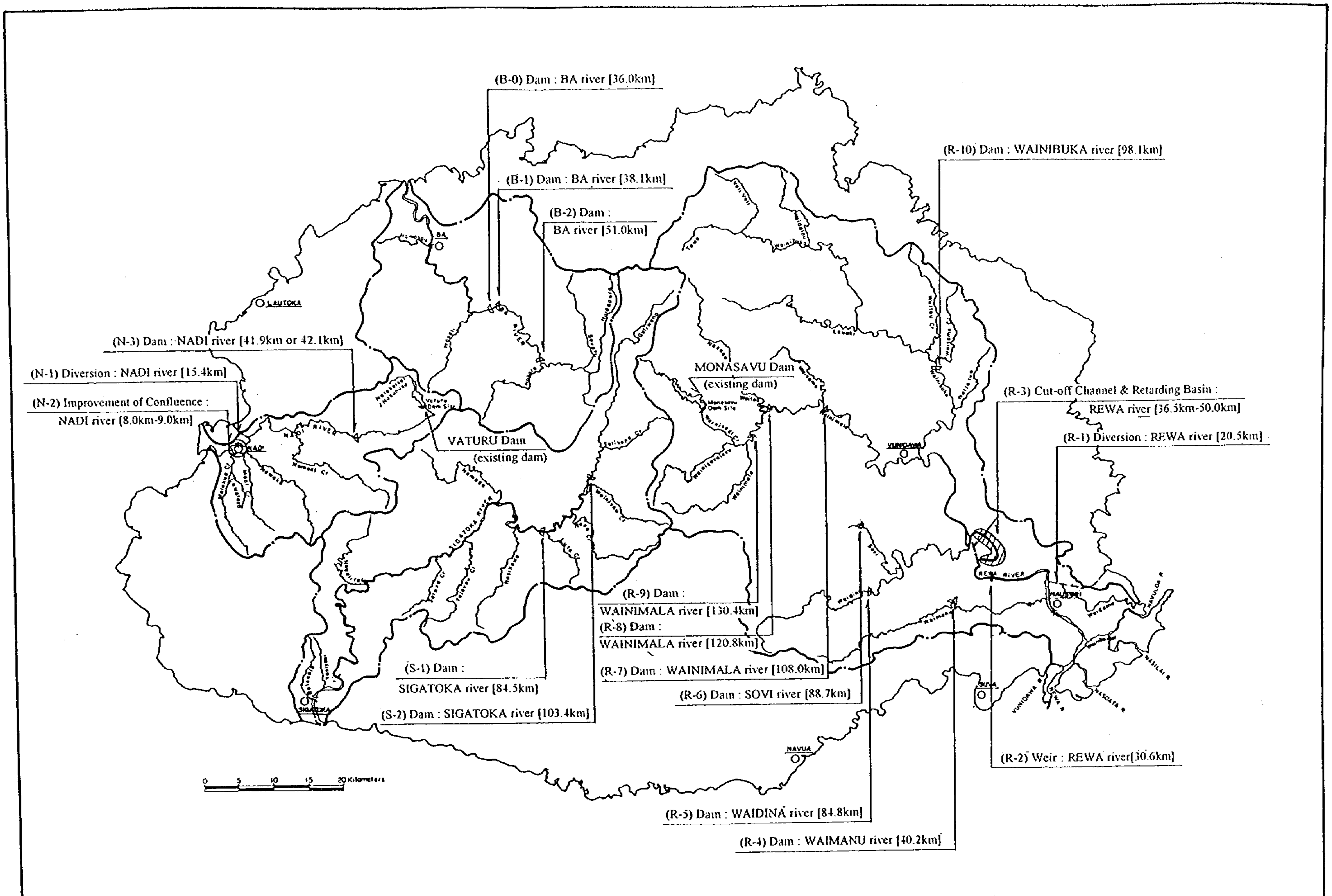


Figure-E4.1 Proposed Sites for Flood Control Structural Measures

Table-E4.1 (1/2) Comparison of Flood Control Measures

Flood control measures		Rewa River	Sigatoka River	Nadi River	Ba River
a. Diversion Channel	Merit	At 20 km from the river mouth, there is a river passing by and flowing directly to the sea. It is possible to construct a diversion channel by making use of this river.	Since the flow capacity of the river is small at its downstream part, construction of a diversion channel should be effective for flood control.	Since there exists a 'critical point' at the downstream of the river, construction of a diversion channel from its upstream side should be effective for flood control. A route from the point of 15.4 km through the side of Nadi airport is suitable.	Since the flow capacity of the river is small at its downstream part, construction of a diversion channel should be effective for flood control.
	Shortcoming	Land acquisition is needed	Topographically there is no potential candidate site for diversion channel construction.	Land acquisition is required.	Topographically there is no potential candidate site for diversion channel construction.
	Evaluation	O Very effective for flood control, although there may be a problem of land acquisition. If the sludge and soils excavated can be used for banking of the diversion channel, the efficiency will become higher.	× Impossible for topographic reason.	O Very effective for flood control, although there may be a problem of land acquisition. If the sludge and soils excavated can be used for banking of the diversion channel, the efficiency will become higher.	× Impossible for topographic reason.
b. Weir and retarding basin	Merit	By constructing a weir at about 30 km from the river mouth, its upstream area can be used as a retarding basin.	-	-	-
	Shortcoming	Provision of a large area as the retarding basin is required. The effectiveness of flood control depends on the retarding capacity; however there is a possibility that necessary storage capacity can not be obtained.	There is no area large enough as a retarding basin.	There is no area large enough as a retarding basin.	There is no area large enough as a retarding basin.
	Evaluation	△ Possible measure for regulating flood.	× Impossible for topographic reason.	× Impossible for topographic reason.	× Impossible for topographic reason.
c. Short-cut channel and retarding basin	Merit	By a short-cut channel between 36 km to 50 km, flood can flow straight forward downstream and the old river course can be used as a retarding basin.	-	-	-
	Shortcoming	Land acquisition is required for short-cut channel construction. There is a possibility that necessary storage capacity can not be obtained.	-	-	-
	Evaluation	△ Possible measure for regulating flood.	× Not suitable for this river from the condition of the river course.	× Not suitable for this river from the condition of the river course.	× Not suitable for this river from the condition of the river course.
d. Tributary improvement	Merit	-	-	The flow capacity of the river is the smallest near the confluence of the Nawaka creek to the Nadi river. Improvement of the Nawaka creek at this point is an effective measure.	-
	Shortcoming	-	-	Not only an improvement on the shape of the river course but also other works for increasing the flow capacity are required.	-
	Evaluation	× Not applicable from the condition of the tributaries.	× Not applicable from the condition of the tributaries.	O Effective for increasing the flow capacity of the Nadi river.	× Not applicable from the condition of the tributaries.
e. Flood control dam	Merit	Since the candidate site for dam construction lies in the devastate mountain area, there will be less problem in land acquisition. If the dam can be used for multi-purpose such as water supply and hydro power, the benefits will be high.	Since the candidate site for dam construction lies in the devastate mountain area, there will be no problem in land acquisition. If the dam can be used for multi-purpose such as water supply and hydro power, the benefits will be high.	Since the candidate site for dam construction lies in the devastate mountain area, there will be no problem in land acquisition. If the dam can be used for multi-purpose such as water supply and hydro power, the benefits will be high.	Since the candidate site for dam construction lies in the devastate mountain area, there will be no problem in land acquisition. If the dam can be used for multi-purpose such as water supply and hydro power, the benefits will be high.
	Shortcoming	Construction cost may be high. Since the current flow capacity is low, at least two dams are necessary for 50 year return period flood.	Construction cost may be high.	Construction cost may be high.	Construction cost may be high.
	Evaluation	△ Considering the demand of electricity and water, it is a favorable measure when the dam is constructed for multi-purpose, which can decrease the cost for flood control.	× Water demand will not increase in future and there is no site of dam to have a large effect on flood control.	△ Considering the demand of electricity and water in the Nadi area, it is a favorable measure when the dam is constructed for multi-purpose,. It is an advantage that the storage capacity required is small, unlike other rivers.	△ A feasible measure combining flood control and water supply when water resources development is required due to increase in water demand.

Table-E4.1 (2/2) Comparison of Flood Control Measures

Flood control measures		Rewa River	Sigatoka River	Nadi River	Ba River
f. River improvement - River course widening	Merit	When there exist only several 'critical points' where the flow capacity becomes low, river widening at these locations will be effective for flood control. River widening for the whole river will surely increase the river's capacity of flood discharge.	When there exist only several 'critical points' where the flow capacity becomes low, river widening at these locations will be effective for flood control. River widening for the whole river will surely increase the river's capacity of flood discharge.	When there exist only several 'critical points' where the flow capacity becomes low, river widening at these locations will be effective for flood control. River widening for the whole river will surely increase the river's capacity of flood discharge.	When there exist only several 'critical points' where the flow capacity becomes low, river widening at these locations will be effective for flood control. River widening for the whole river will surely increase the river's capacity of flood discharge.
	Shortcoming	Land acquisition is required especially when a long section of the river needs to be widened.	Land acquisition is required especially when a long section of the river needs to be widened.	Land acquisition is required especially when a long section of the river needs to be widened.	Land acquisition is required especially when a long section of the river needs to be widened.
	Evaluation	△ Possible measure for an improvement of the flow capacity of the river at the locations of 'critical points'.	△ Possible measure for an improvement of the flow capacity of the river at the locations of 'critical points'.	△ Possible measure for an improvement of the flow capacity of the river at the locations of 'critical points'.	△ Possible measure for an improvement of the flow capacity of the river at the locations of 'critical points'.
- Dike construction	Merit	The flow capacity of the river can be ensured by dike construction over a long distance.	The flow capacity of the river can be ensured by dike construction over a long distance.	The flow capacity of the river can be ensured by dike construction over a long distance.	The flow capacity of the river can be ensured by dike construction over a long distance.
	Shortcoming	Land acquisition is required, however it will encounter the difficulty due to the concentration of assets along the river. Therefore, the dike will be located within the river course, resulting in reduction of the current river width. Since the stage of river will become higher than the inland ground surface outside the dike, the potential of flood damage will still be high.	Land acquisition is required, however it will encounter the difficulty due to concentration of assets and Native Villages extending along the river. Therefore, the dike will be located within the river course, resulting in reduction of the current river width and higher flood stage of river than the current one. As a result, the potential of flood damage will be higher.	Land acquisition is required, however it will encounter the difficulty due to the concentration of assets along the river. Therefore, the dike will be located within the river course, resulting in reduction of the current river width and higher flood stage of river than the current one. As a result, the potential of flood damage will be higher.	Land acquisition is required. Since it is possible that the stage of river becomes higher than the inland ground surface outside the dike, the potential of flood damage will still be high.
	Evaluation	△ It may not be effective in Nausori and its vicinity, where assets are concentrated, due to the high potential of flood damage and problem to drain land side water during flood. It is effective in downstream from Nausori to increase the flow capacity of river.	× Dike construction is only applicable within the current river course reducing the river width and increasing the flood stage. As a result, the potential of flood damage will be higher. Therefore, its effect on flood control is not expected.	× Since the current flow capacity is too small compared to the design flood, the scale of dike would be very large. Besides, the dike within the current river course results in higher potential of flood damage and problem to drain land side water during flood. Therefore, it is not applicable.	O Since there is no asset located along the river, except the sugar mill, the land acquisition is not difficult. Therefore, the dike can be located without reducing the river width. As long as its scale is not too large, the potential of flood damage will not increase. Therefore, it is a feasible measure.
- River bed dredging	Merit	The flow capacity of the river can be increased without any influence on the inland side.	The flow capacity of the river can be increased without any influence on the inland side.	The flow capacity of the river can be increased without any influence on the inland side.	The flow capacity of the river can be increased without any influence on the inland side.
	Shortcoming	The large volume of dredging is required to suppress the flood at the required level. Effectiveness can only expected as dredging is carried out over a long length of the river. Periodic dredging is necessary since sedimentation may happen continuously.	The large volume of dredging is required to suppress the flood at the required level. Effectiveness can only expected as dredging is carried out over a long length of the river. Periodic dredging is necessary since sedimentation may happen continuously.	The large volume of dredging is required to suppress the flood at the required level. Effectiveness can only expected as dredging is carried out over a long length of the river. Periodic dredging is necessary since sedimentation may happen continuously.	The large volume of dredging is required to suppress the flood at the required level. Effectiveness can only expected as dredging is carried out over a long length of the river. Periodic dredging is necessary since sedimentation may happen continuously.
	Evaluation	△ Since its effect on flood control is small, it is only effective to maintain the cross section of river.	△ For the Step 1 target, it is effective because flood discharge to be controlled is small; however, it is not effective for the Step 2 target.	× Since the scale of the river is too small to introduce a large dredger, it is not possible to conduct a large scale dredging which is required for the Step1 target.	△ Since its effect on flood control is small, it is only effective to maintain the cross section of river.
- Dike construction surrounding urban area	Merit		It is effective on suppression of flood in the urban area surrounding only the target area.		
	Shortcoming		Land acquisition is required. Since it is possible that the stage of river becomes higher than the inland ground surface surrounded by dike, the potential of flood damage will still be high. The difficulty of its application depends on topographic features.		
	Evaluation		△ A possible measure if topographic features are favorable and inland flood is allowed.		

Note: O: Favorable △: Possible ×: Not Applicable

Based on the comparison and evaluation of flood control measures, the most effective and possible flood control measures for each watershed are as follows.

1) Rewa watershed: diversion channel and dike construction
2) Sigatoka watershed: river improvement (river bed excavation)
3) Nadi watershed: diversion channel and improvement of confluence
4) Ba watershed: river improvement (dike construction)

4.2 Structural Measures for Rewa Watershed

The diversion channel for the Rewa watershed drains the flood to the east coast after diverting flood at 20.5 km upstream from river mouth, approximately 3.0 km downstream from the bend. The dike on the left and right banks of Rewa river supplements to mitigate the flood damage.

(1) Design Discharge of Diversion Channel

If the design discharge of the diversion channel was determined to drain all objective flood, the dike construction of the Rewa would not be necessary; however, its scale would be too large to be realized. Therefore, the combination of the diversion channel and dike is proposed as the flood control plan for the Step 1 target, 1/20 probability flood.

The current flow capacity at Nausori, where the most of properties are located, would be maintained by the main stream and the excess flood (difference between 1/20 probability flood and current flow capacity at Nausori) which is 1,900 m^3/sec would be drained by the diversion channel. With this flood control plan, the discharge of the Rewa main stream would be reduced to 5,900 m^3/sec at river mouth, which is equivalent to the current flow capacity at Nausori.

(2) Route of Diversion Channel

There are two possible alignments of the diversion channel as shown in Figure-E4.2. Alignment No.1 will drain flood to Namata river, while alignment No.2 will use Waidamau river by widening its cross section. Hydraulic examination of both alignments was conducted to determine their specifications. Uniform flow computation was applied to determine required widths of the diversion channel, varying bed elevation at outlet from EL. -3.0 m to -6.0 m. Water level at inlet (diverting point) is equal to water level of Rewa river at downstream of diverting point determined by non-uniform flow computation for the case that discharge is decreased by application of the diversion channel. The results of uniform flow computation are shown in Table-E4.2 and summarized in Table-E4.3 with description of each alignment. Although the design discharge is 20 year return period flood, necessary bed width was also examined for 50 year return period to understand the scale of final target.

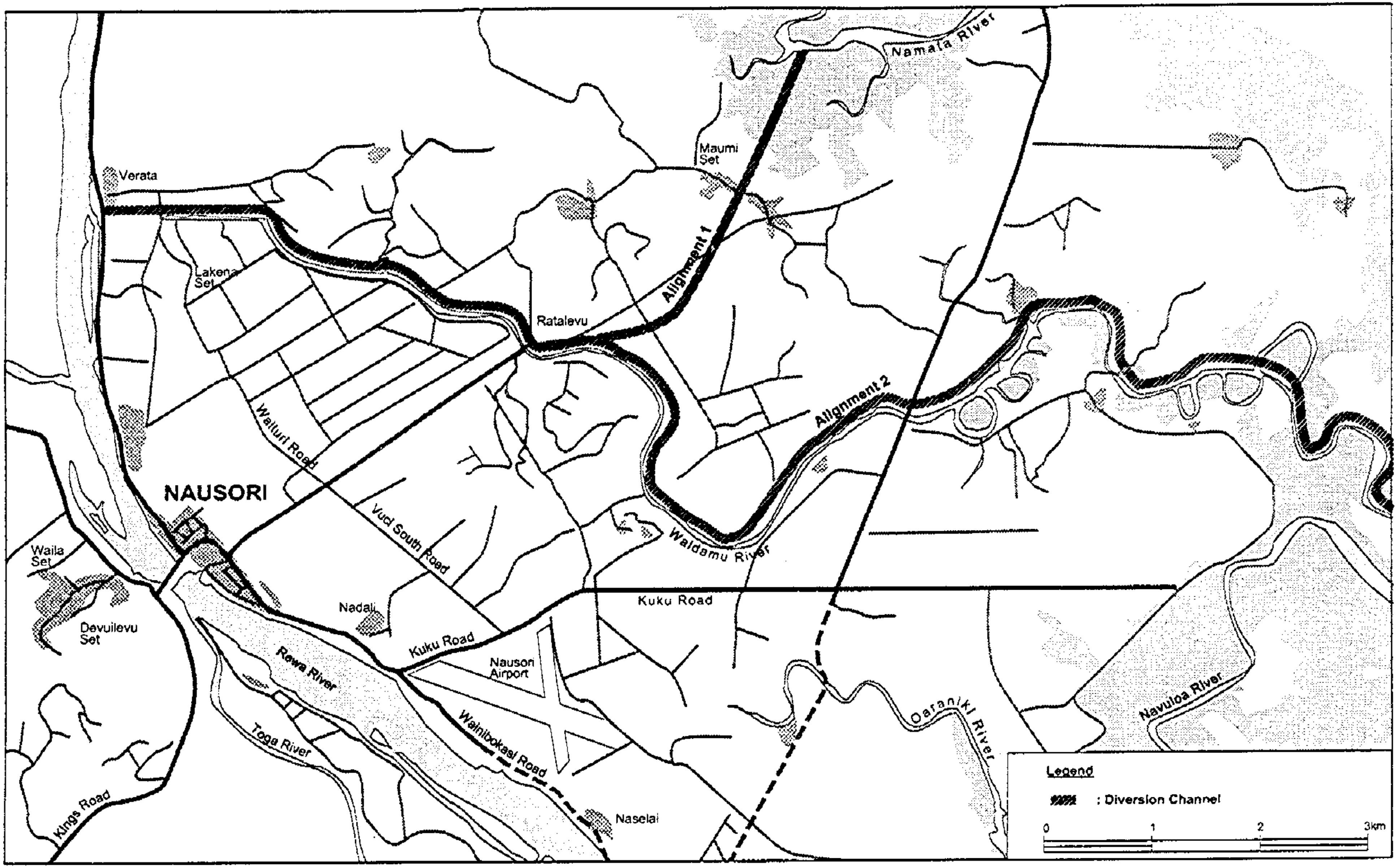


Figure-E4.2 Possible Alignment of Diversion Channel (Rewa)

Table-E4.2 Hydraulic Examination of Rewa Diversion Channel

Hydraulic Design for 20 Year Return Period Flood

	Q	Hc	Hb	h	L	Hm	Hmb	I	n	1:m	A	R	b	B
Alignment No.1	1,907	7.0	3.0	4.0	8,900	1.0	-3.0	1/1483	0.030	1:2.0	900.0	3.83	217.0	233.0
	1,901	7.0	2.0	5.0	8,900	1.0	-4.0	1/1483	0.030	1:2.0	790.0	4.64	148.0	168.0
	1,904	7.0	1.0	6.0	8,900	1.0	-5.0	1/1483	0.030	1:2.0	720.0	5.34	108.0	132.0
	1,906	7.0	0.0	7.0	8,900	1.0	-6.0	1/1483	0.030	1:2.0	672.0	5.93	82.0	110.0
Alignment No.2	1,901	7.0	3.0	4.0	16,600	1.0	-3.0	1/2767	0.030	1:2.0	1216.0	3.87	296.0	312.0
	1,901	7.0	2.0	5.0	16,600	1.0	-4.0	1/2767	0.030	1:2.0	1065.0	4.73	203.0	223.0
	1,906	7.0	1.0	6.0	16,600	1.0	-5.0	1/2767	0.030	1:2.0	966.0	5.49	149.0	173.0
	1,909	7.0	0.0	7.0	16,600	1.0	-6.0	1/2767	0.030	1:2.0	896.0	6.17	114.0	142.0

Hydraulic Design for 50 Year Return Period Flood

	Q	Hc	Hb	h	L	Hm	Hmb	I	n	1:m	A	R	b	B
Alignment No.1	2,404	7.0	3.0	4.0	8,900	1.0	-3.0	1/1483	0.030	1:2.0	1128.0	3.86	274.0	290.0
	2,406	7.0	2.0	5.0	8,900	1.0	-4.0	1/1483	0.030	1:2.0	990.0	4.71	188.0	208.0
	2,415	7.0	1.0	6.0	8,900	1.0	-5.0	1/1483	0.030	1:2.0	900.0	5.46	138.0	162.0
	2,410	7.0	0.0	7.0	8,900	1.0	-6.0	1/1483	0.030	1:2.0	833.0	6.11	105.0	133.0
Alignment No.2	2,405	7.0	3.0	4.0	16,600	1.0	-3.0	1/2767	0.030	1:2.0	1532.0	3.90	375.0	391.0
	2,400	7.0	2.0	5.0	16,600	1.0	-4.0	1/2767	0.030	1:2.0	1335.0	4.78	257.0	277.0
	2,407	7.0	1.0	6.0	16,600	1.0	-5.0	1/2767	0.030	1:2.0	1206.0	5.59	189.0	213.0
	2,409	7.0	0.0	7.0	16,600	1.0	-6.0	1/2767	0.030	1:2.0	1113.0	6.31	145.0	173.0

Q	: discharge	I	: bed slope
Hc	: water level at diverting point	n	: Manning roughness coefficient
Hb	: bed elevation at diverting point	1:m	: bank slope
h	: water depth	A	: discharge area
L	: length of diversion channel	R	: hydraulic radius
Hm	: water level at outlet	b	: bed width
Hmb	: bed elevation at outlet	B	: width of water surface

Table-E4.3 Specifications of Possible Alignments of Rewa Diversion Channel

Route	Inlet & Outlet	Design Discharge	Total Length	Specifications of Diversion Channel				Description
Alignment No. 1 to cross in the western side of Maumi Settlement	Rewa river at 20.5 km from river mouth ↓ Namata River at 3.0 km from river mouth	1,900 m^3/s	8,900 m	Hc = EL. 7.0 m Hm = EL. 1.0 m I = 1/1,483 Hmb = EL. -3.0 m Hmb = EL. -4.0 Hmb = EL. -5.0 Hmb = EL. -6.0	 h = 4.0 m h = 5.0 h = 6.0 h = 7.0	 b = 217 m b = 148 b = 108 b = 82	 B = 233 m B = 168 B = 132 B = 110	1) It would cross the hill in the western side of Maumi settlement. 2) Bed elevation at river mouth of Namata river is about E.L. -2.0 m and the river channel cross near Bau island. 3) When low tide, sea between Viti Levu and Bau islands, is dried up and electric poles are located in the sea. To examine effect of the diversion channel on that area, hydraulic experiments with models is necessary.
Alignment No. 2 to widen Waidamu River	Rewa river at 20.5 km from river mouth ↓ Waidamu river mouth	1,900 m^3/s	16,600 m	Hc = EL. 7.0 m Hm = EL. 1.0 m I = 1/2,767 Hmb = EL. -3.0 m Hmb = EL. -4.0 m Hmb = EL. -5.0 m Hmb = EL. -6.0 m	 h = 4.0 m h = 5.0 h = 6.0 h = 7.0	 b = 296 m b = 203 b = 149 b = 114	 B = 312 m B = 223 B = 173 B = 142	1) Since the total length is long resulting in very gentle bed slope, width of the diversion channel becomes wide. 2) Since bed elevation at river mouth of Waidamu river is lower than that of Namata river, dredging at outlet of the diversion channel will be a small scale. 3) There is no effect on Bau island.

Hc : water level at diverting point   I : bed slope   B : width of water surface
Hm : water level at outlet   h : water depth
Hmb: bed elevation at outlet   b : bed width

Since length of alignment No.2 is longer than that of alignment No.1, its bed slope is more gentle resulting in large bed width, approximately 40 % more, compared to No.1. As far as construction is concerned, depth of the diversion channel at outlet should be shallow; however, its width becomes large requiring more lands. Therefore, bed elevation at outlet should be as low as possible but within the depth which does not affect the construction works much. Considering the elevation of sea bed around the outlet, limit to lower the bed elevation is EL. -5.0 m and bed width of alignment No.1 in this case is 108 m for the design discharge (20 year return period flood).

As a result of the hydraulic examination, the bed elevation at outlet was determined as EL. -5.0 m for both alignments. Therefore, bed widths of alignment No.1 and No.2 are 108 m and 149 m, respectively. Rough cost estimate for two alignments was conducted as shown in Table-E4.4 and E4.5. Since objective of the cost estimate is comparison of two alignment, cost for land acquisition was excluded.

Table-E4.4 Rough Cost Estimate of Alignment No. 1

Description			Unit Cost	Quantity	Amount (F$)	Remarks
Main Work	Excavation	Sand & Soil	2.1 F$/m^3	5,970,000 m^3	12,537,000	Transportation Distance 20 m
		Rock	5.6 F$/m^3	450,000 m^3	2,520,000	
	Dike Construction	Loading & Transportation	4.0 F$/m^3	6,420,000 m^3	25,680,000	Transportation Distance 0.5 km
		Compaction	0.9 F$/m^3	6,420,000 m^3	5,778,000	
	Sub Total				46,515,000	
Compensation Work	Bridge		35,000.0 F$/m	960 m	33,600,000	6 bridges x 160 m
	Road		350.0 F$/m	2,000 m	700,000	
	Sub Total				34,300,000	
Construction Cost = Main Work + Compensation Work					80,815,000	

Table-E4.5 Rough Cost Estimate of Alignment No. 2

Description			Unit Cost	Quantity	Amount (F$)	Remarks
Main Work	Excavation	Sand & Soil	2.1 F$/m^3	13,200,000 m^3	27,720,000	Transportation Distance 20 m
		Rock	5.6 F$/m^3	m^3	0	
	Dike Construction	Loading & Transportation	3.5 F$/m^3	13,200,000 m^3	46,200,000	Transportation Distance 0.3 km
		Compaction	0.9 F$/m^3	13,200,000 m^3	11,880,000	
	Sub Total				85,800,000	
Compensation Work	Bridge		35,000.0 F$/m	960 m	33,600,000	6 bridges x 160 m
	Road		350.0 F$/m	2,000 m	700,000	
	Sub Total				34,300,000	
Construction Cost = Main Work + Compensation Work					120,100,000	

Based on the examination of two possible alignment above, No.1 alignment has been selected because of its cheapest cost. Construction costs of two alignment are as follows.

Alignment No. 1: F$ 81 x 10^6 (total length: 8,900 m)

Alignment No. 2: F$ 120 x 10^6 (total length: 16,600 m)

Excavated soil of the diversion channel is assumed to be used for dike construction and embankment whose width is large enough for the other uses, such as road, housing and so on, as shown in Figure-E4.3.

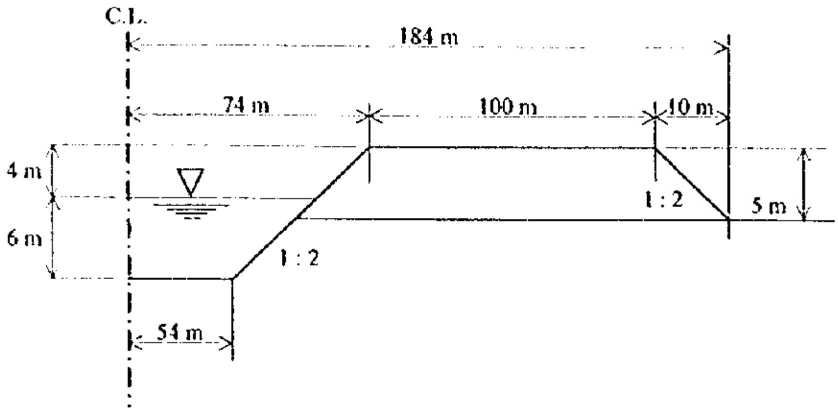


Figure-E4.3 Standard Cross Section of Rewa Diversion Channel (3,000 m from River Mouth)

(3) Dike Construction

The dike construction is employed against the excess flood which is not covered by the diversion channel. Areas to be covered by dikes are as follows and there is over flow of approximately 1.5 m depth in those areas when discharge is 5,900 m^3/sec with the implementation of diversion channel only. Location of dike construction are shown in Figure-E4.4.

Left Bank of Rewa River

- between 12.0 km and 16.0 km from river mouth
- between 20.0 km and 20.5 km from river mouth

Right Bank of Rewa River

- between 12.0 km and 16.0 km from river mouth

To determine the scale of the dikes, the following Japanese standard were applied. The results are shown in Table-E4.6.

- Levee crown width: 6.0 m (5,000 m^3/sec $\leq$ discharge < 10,000 m^3 /sec)
- Levee free board: 1.5 m (5,000 m^3/sec $\leq$ discharge < 10,000 m^3 /sec)

The average height of dike is approximately 3.0 m to mitigate the flood damage by 20 year return period flood in combination with the diversion channel.

Although dikes in both bank sides are proposed it is recommendable to implement those in the left bank side first if there are budgetary constraints. Properties in the Rewa delta are mostly located in the left bank side of Rewa river and the right bank side is less developed.

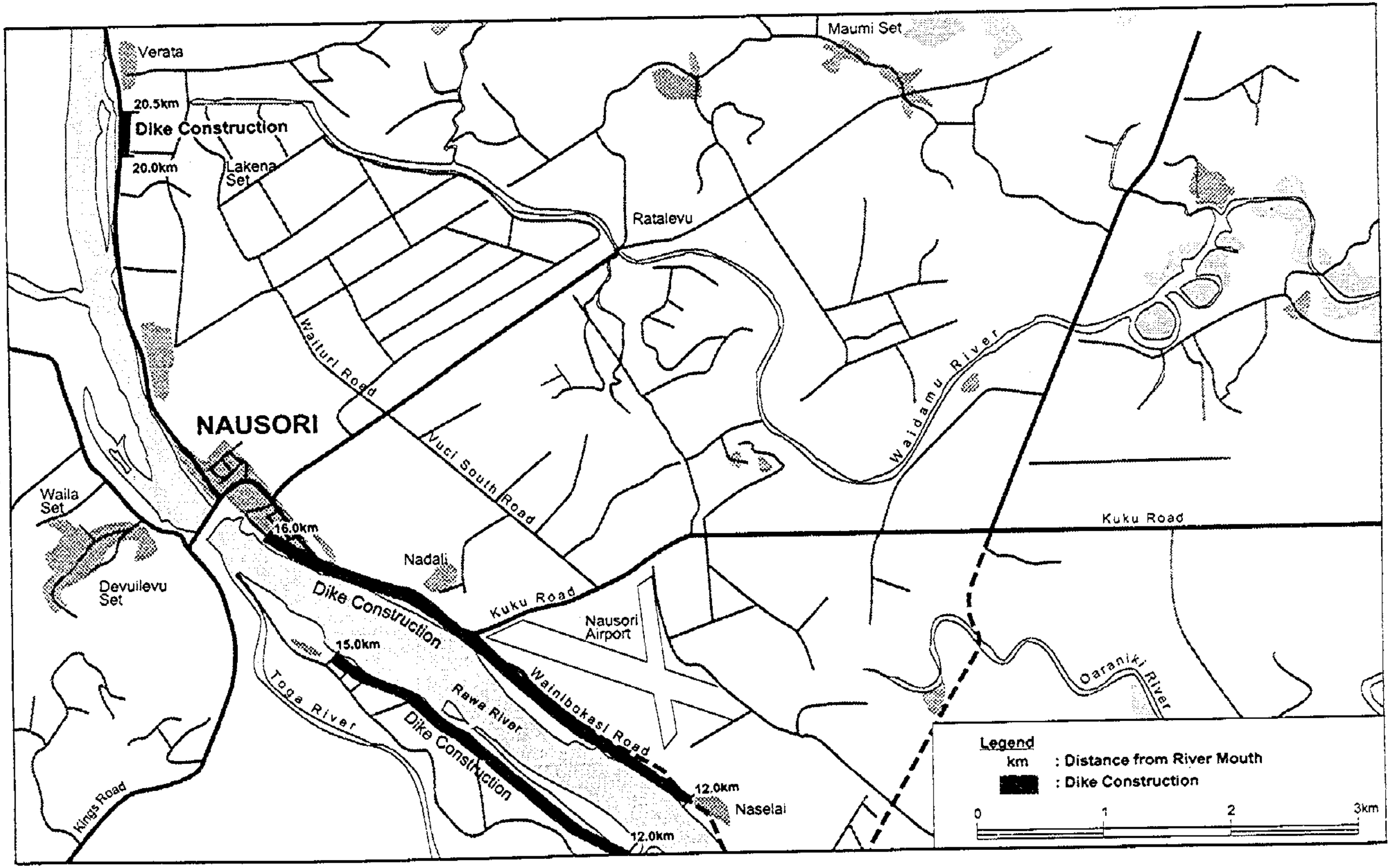


Figure-E4.4 Proposed River Section for Dike (Rewa)

Table-E4.6 Specifications of Dike (Rewa)

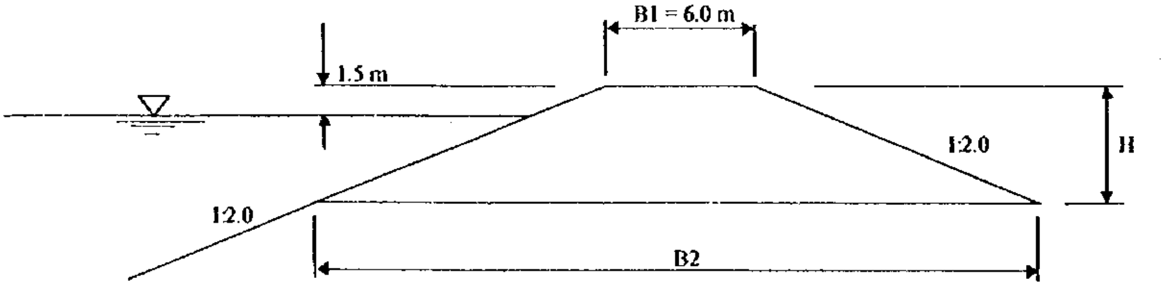
Volume of Embankment (Left Bank of Rewa River for 20 year Return Period Flood)

Section No.	delt X	Left Bank					
		H	B1	B2	A	A_{ave}	Volume
	(m)	(m)	(m)	(m)	(m^2)	(m^2)	(m^3)
REWA 11500	0	0.0	0.0	0.0	0.0	0.0	0
REWA 12000	500	2.6	6.0	16.4	29.1	14.6	7,280
REWA 12500	500	2.5	6.0	16.0	27.5	28.3	21,435
REWA 13000	500	2.1	6.0	14.4	21.4	24.5	33,665
REWA 13500	500	5.6	6.0	28.4	96.3	58.9	63,100
REWA 14000	500	0.0	0.0	0.0	0.0	48.2	87,180
REWA 14500	500	3.6	6.0	20.4	47.5	23.8	99,060
REWA 15000	500	3.5	6.0	20.0	45.5	46.5	122,315
REWA 15500	500	3.1	6.0	18.4	37.8	41.7	143,145
REWA 16000	500	1.8	6.0	13.2	17.3	27.6	156,920
REWA 16500	500	0.0	0.0	0.0	0.0	8.6	161,240
REWA 19500	0	0.0	0.0	0.0	0.0	0.0	0
REWA 20000	500	4.9	6.0	25.6	77.4	38.7	19,355
REWA 20500	500	0.0	0.0	0.0	0.0	38.7	38,710
Total							**199,950**
	H_{ave}	2.97					

Volume of Embankment (Right Bank of Rewa River for 20 year Return Period Flood)

Section No.	delt X	Right Bank					
		H	B1	B2	A	A_{ave}	Volume
	(m)	(m)	(m)	(m)	(m^2)	(m^2)	(m^3)
REWA 11500	0	0.0	0.0	0.0	0.0	0.0	0
REWA 12000	500	3.4	6.0	19.6	43.5	21.8	10,880
REWA 12500	500	3.2	6.0	18.8	39.7	41.6	31,680
REWA 13000	500	3.2	6.0	18.8	39.7	39.7	51,520
REWA 13500	500	3.0	6.0	18.0	36.0	37.8	70,440
REWA 14000	500	3.0	6.0	18.0	36.0	36.0	88,440
REWA 14500	500	2.8	6.0	17.2	32.5	34.2	105,560
REWA 15000	500	2.5	6.0	16.0	27.5	30.0	120,555
REWA 15500	500	0.0	0.0	0.0	0.0	13.8	127,430
Total							**127,430**
	H_{ave}	3.01					

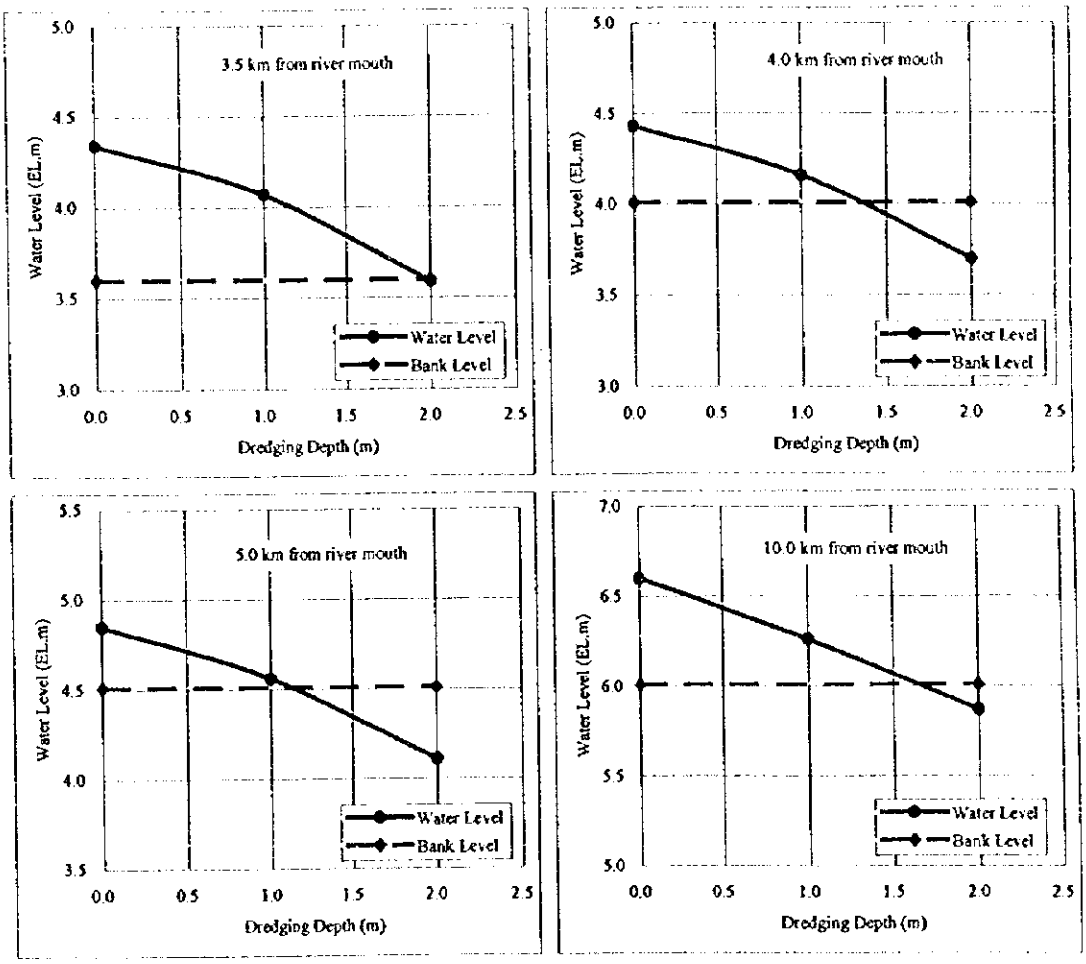
Note A_{ave}: Average Area of Dike
H_{ave}: Average Height of Dike



4.3 Structural Measures for Sigatoka Watershed

Since the current flow capacity of Sigatoka river is 2,600 m^3/sec, 1/16 probability flood, the safety degree against flood is the highest among the objective 4 watersheds. It requires the flood control measures to drain only 300 m^3/sec to achieve the Step 1 target, (2,900 m^3/sec). Therefore, the large scale measures are not necessary and the river course widening by means of the river bed excavation (dredging) is considered as the most effective. Regarding the dike construction, land acquisition is difficult because the Native Villages are located along the river.

Effect of dredging on water level of 1/20 probability flood was examined and the results are shown in Figure-E4.5. A section between 3.5 km and 5.0 km, and 10 km point from river mouth are critical points in Sigatoka river in terms of flow capacity. As shown in Figure-E4.5, it is necessary to dredge the river by 2.0 m depth at 3.5 km, 1.4 m depth at 4.0 km point, 1.1 m depth at 5.0 km and 1.7 m depth at 10 km to lower the water level until the bank level. Required depth of dredging varies with the river section; however, it should be constant at least at 2.0 m to satisfy the water level at 10 km point. If dredging depth at some sections downstream from 10 km point is less than 2.0, water level at 10 km point could not be lowered sufficiently due to backwater.



Water Level: 1/20 Probability Flood

Figure-E4.5 Effect of Dredging on Water Level

As shown in Table-E4.7, total volume of dredging was calculated for two cases, one for 1 m depth and another for 2 m depth. And then, a relation between dredging depth and its total volume was plotted. Since dredging of 2 m depth is required, the total volume of dredging is approximately 1,817,000 m^3.

Table-E4.7 Volume of Dredging

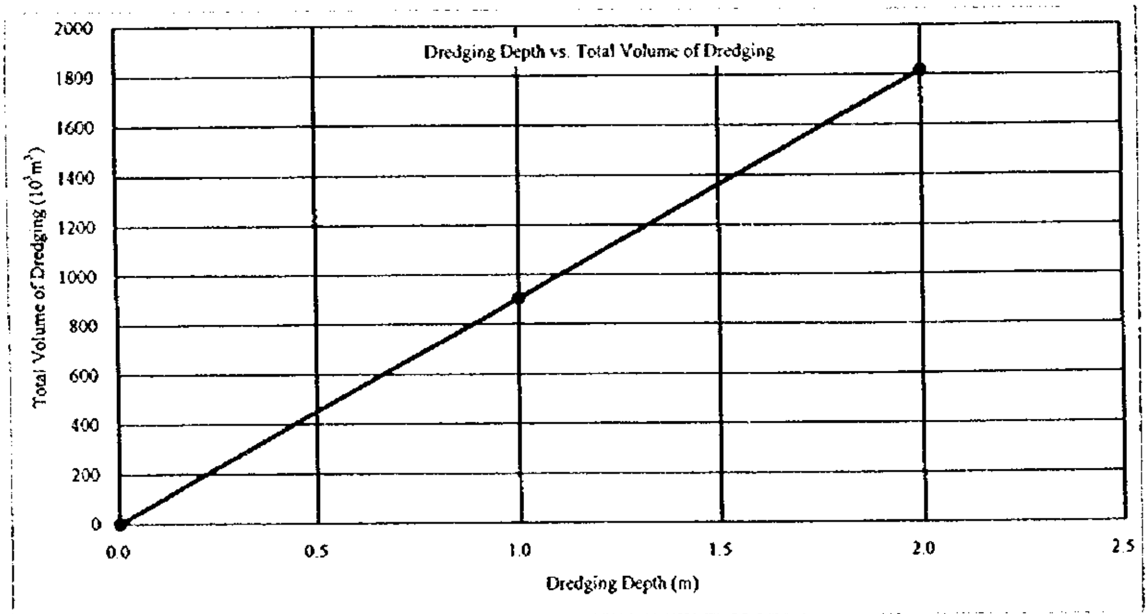
Dredging Volume (Sigatoka River : 20 year return period flood)

Section No.	delt X (m)	$_{ave}$A1 (m^2)	Volume-1 (10^3m^3)	$_{ave}$A2 (m^2)	Volume-2 (10^3m^3)
SIGA 0	0	0.0	0.0	0.0	0.0
SIGA 600	600	41.6	24.9	82.9	49.7
SIGA 1000	400	97.6	64.0	188.9	125.3
SIGA 1185	185	61.8	75.4	116.8	146.9
SIGA 1500	315	52.1	91.8	107.1	180.7
SIGA 2000	500	91.4	137.5	191.4	276.4
SIGA 2500	500	102.5	188.8	203.0	377.9
SIGA 3000	500	109.6	243.6	210.8	483.3
SIGA 3500	500	104.9	296.1	205.2	585.9
SIGA 4000	500	99.9	346.0	199.1	685.4
SIGA 4500	500	98.1	395.1	192.1	781.5
SIGA 5000	500	104.0	447.1	196.8	879.9
SIGA 5500	500	96.1	495.1	195.5	977.6
SIGA 6000	500	88.4	539.3	193.5	1,074.3
SIGA 6500	500	102.6	590.6	207.8	1,178.3
SIGA 7000	500	104.9	643.1	206.7	1,281.6
SIGA 7500	500	92.5	689.3	193.4	1,378.3
SIGA 8000	500	94.7	736.7	193.4	1,475.0
SIGA 8500	500	49.8	761.6	98.3	1,524.2
SIGA 9000	500	59.1	791.1	109.5	1,578.9
SIGA 9500	500	96.0	839.1	194.3	1,676.1
SIGA 10000	500	83.8	881.0	182.8	1,767.5
SIGA 10500	500	46.9	904.5	98.0	1,816.5

delt X: distance

$_{ave}$A1: average area of dredging by 1 m depth, Volume-1: volume of dredging by 1 m depth

$_{ave}$A2: average area of dredging by 2 m depth, Volume-2: volume of dredging by 2 m depth



The scale of river bed excavation (dredging) is as follows:

- Length: 10 km, from river mouth to 10 km upstream
- Excavation width: 100 m
- Average excavation depth: 2.0 m
- Total volume to be excavated: 1,817,000 m^3

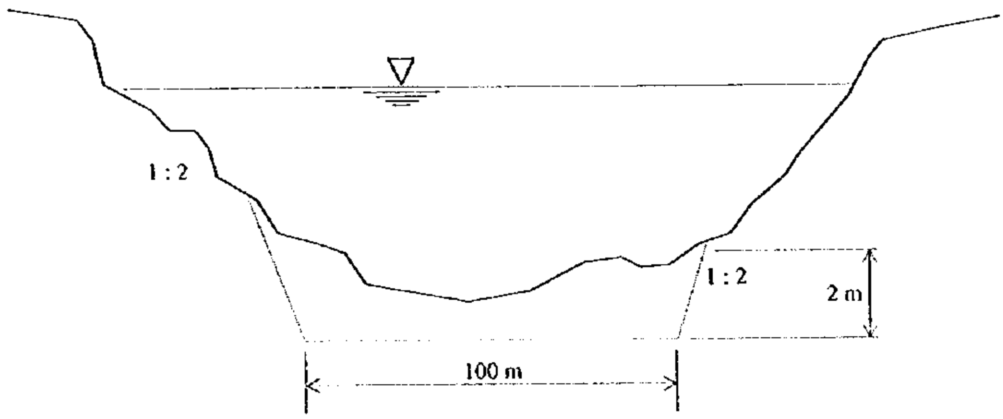


Figure-E4.6 Standard Cross Section of Dredging (Sigatoka)

4.4 Structural Measures for Nadi Watershed

The current flow capacity of Nadi river is the smallest, 1/1 probability, among 4 watersheds. Therefore, the large scale measures are required to achieve the Step 1 target, 1/20 probability. Since the town extends along the river, the river course widening is difficult. Therefore, the flood control measure for the Nadi watershed is the diversion channel, in combination with the short cut channel around the confluence with Nawaka river (8.0 km upstream from Nadi river mouth) where there is a critical point in terms of the current flow capacity.

(1) Design Discharge of Diversion Channel

After implementation of the short cut channel, the flow capacity of Nadi river at Nadi town, between 9.0 km and 12.0 km from river mouth, would increase from 250 m^3/sec to 300 m^3/sec. Maintaining this flow capacity, the design discharge of the diversion channel was determined as 1,500 m^3/sec, the difference between the flow capacity improved and 1/20 probability flood at the diverting point.

(2) Alignment of Diversion Channel

There are 4 possible alignments of the diversion channel based on topographical features, current and future land use, land classification and so on. Their locations are shown in Figure-E4.7.

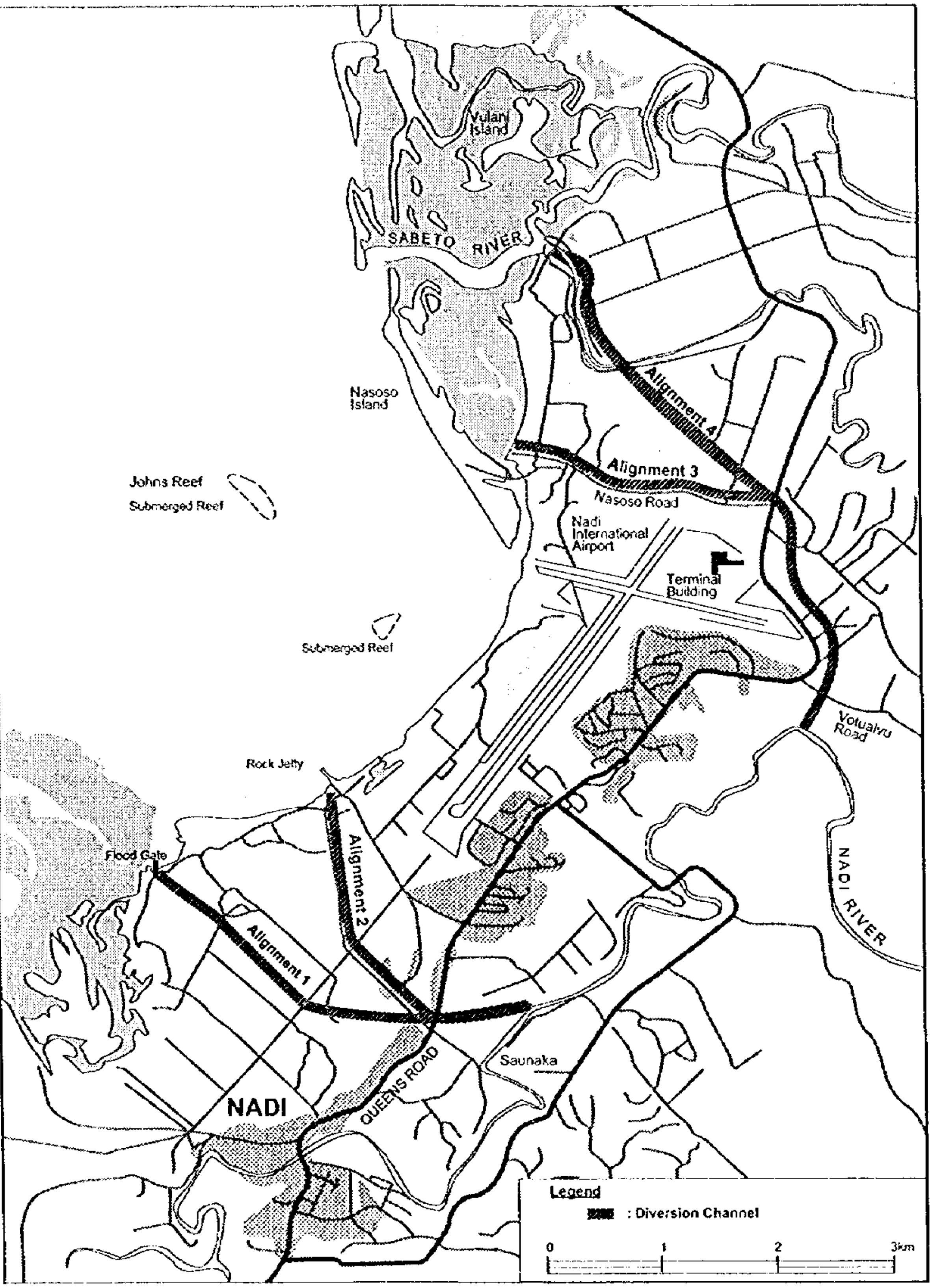


Figure-E4.7 Possible Alignment of Diversion Channel (Nadi)

Hydraulic examination of the 4 alignments was conducted to determine their specifications. Uniform flow computation was applied to determine required widths of the diversion channel, varying bed elevation at outlet from EL. -3.0 m to -6.0 m. Water level at inlet (diverting point) is equal to water level of Nadi river at downstream of diverting point determined by non-uniform flow computation for the case that discharge is decreased by application of the diversion channel. The results of uniform flow computation are shown in Table-E4.8 and summarized in Table-E4.9 with description of each alignment.

Bed width of alignment No.2 is the smallest because of the steepest bed slope. Since length and width of alignment No.2 are the smallest, alignment No.2 is preferable among the 4 alignments from a hydraulic point of view.

As far as construction is concerned, depth of the diversion channel at outlet should be shallow; however, its width becomes large requiring more lands. Therefore, bed elevation at outlet should be as low as possible but within the depth which does not affect the construction works much. Considering the elevation of sea bed around the outlet, limit to lower the bed elevation is EL. -5.0 m and bed width of alignment No.2 in this case is 52 m for the design discharge (20 year return period flood).

Uniform flow computation was applied to examine the hydraulic specifications of the 4 alignments because objective at the Master Plan Study is an approximate design. At the Feasibility Study, hydraulic examination was conducted in detail as discussed in Chapter 11.

Table-E4.8 Hydraulic Examination of Nadi Diversion Channel

Hydraulic Design for 20 year Return Period Flood

	Q	Hc	Hb	h	L	Hm	Hmb	I	n	1:m	A	R	b	B
Alignment No.1	1,504	6.0	2.0	4.0	3,700	1.0	-3.0	1/740	0.030	1:2.0	512.0	3.71	120.0	136.0
	1,499	6.0	-1.0	7.0	3,700	1.0	-6.0	1/740	0.030	1:2.0	399.0	5.37	43.0	71.0
Alignment No.2	1,507	6.0	2.0	4.0	3,000	1.0	-3.0	1/600	0.030	1:2.0	464.0	3.69	108.0	124.0
	1,505	6.0	1.0	5.0	3,000	1.0	-4.0	1/600	0.030	1:2.0	415.0	4.35	73.0	93.0
	1,502	6.0	0.0	6.0	3,000	1.0	-5.0	1/600	0.030	1:2.0	384.0	4.87	52.0	76.0
	1,497	6.0	-1.0	7.0	3,000	1.0	-6.0	1/600	0.030	1:2.0	364.0	5.25	38.0	66.0
Alignment No.3	1,503	7.6	3.6	4.0	4,500	1.0	-3.0	1/682	0.030	1:2.0	492.0	3.70	115.0	131.0
	1,499	7.6	0.6	7.0	4,500	1.0	-6.0	1/682	0.030	1:2.0	385.0	5.32	41.0	69.0
Alignment No.4	1,507	7.6	3.6	4.0	6,500	1.0	-3.0	1/985	0.030	1:2.0	588.0	3.75	139.0	155.0
	1,499	7.6	2.6	5.0	6,500	1.0	-4.0	1/985	0.030	1:2.0	520.0	4.47	94.0	114.0
	1,503	7.6	1.6	6.0	6,500	1.0	-5.0	1/985	0.030	1:2.0	480.0	5.06	68.0	92.0
	1,511	7.6	0.6	7.0	6,500	1.0	-6.0	1/985	0.030	1:2.0	455.0	5.53	51.0	79.0

Q : discharge
Hc : water level at diverting point
Hb : bed elevation at diverting point
h : water depth
L : length of diversion channel
Hm : water level at outlet
Hmb : bed elevation at outlet
I : bed slope
n : Manning roughness coefficient
1:m : bank slope
A : discharge area
R : hydraulic radius
b : bed width
B : width of water surface

Table-E4.9 (1/2) Specifications of Possible Alignments of Nadi Diversion Channel

Route	Inlet & Outlet	Design Discharge	Total Length	Specifications of Diversion Channel				Description
Alignment No. 1 to use the existing canal which runs in the south of the airport	Nadi river at 14.0 km from river mouth ↓ Nadi bay near rubbish dump	1,500 m^3/s	3,700 m	Hc = EL. 6.0 m Hm = EL. 1.0 m I = 1/740 Hmb = EL. -3.0 m Hmb = EL. -6.0	h = 4.0 m h = 7.0	b = 120 m b = 43	B = 136 m B = 71	1) Since the diversion channel would cross a high grade residential area located near Queen's road, cost of land acquisition and compensation would be high. 2) The diversion would cross the area for transmitter (45 ha). It is difficult to find another location for transmitter. 3) Hotel resort is under construction at the outlet of the diversion channel. 4) Flood gate may be necessary because of sugarcane fields around the outlet.
Alignment No. 2 to run along the Enamanu road in the south of the airport	Nadi river at 14.0 km from river mouth ↓ Nadi bay at the end of Enamanu road	1,500 m^3/s	3,000 m	Hc = EL. 6.0 m Hm = EL. 1.0 m I = 1/600 Hmb = EL. -3.0 m Hmb = EL. -4.0 Hmb = EL. -5.0 Hmb = EL. -6.0	h = 4.0 m h = 5.0 h = 6.0 h = 7.0	b = 108 m b = 73 b = 52 b = 43	B = 124 m B = 93 B = 66 B = 71	1) It is critical weather the airport authority can allocate some part of the airport extension area to the diversion channel. 2) Guide lights for airplanes would be installed in the cross section of the diversion channel. 3) There are areas for hotel and residential development along Enamanu road in the north of the airport extension site. 4) Since the sea is shallow at the outlet of the diversion channel, sedimentation occur easily. 5) To maintain the water level of the diversion channel, a large scale longitudinal dike will be required. It may have negative impact to environment. 6) It is the shortest route. 7) Flood gate may be necessary because of sugarcane filed around the outlet.

Table-E4.9 (2/2) Specifications of Possible Alignments of Nadi Diversion Channel

Route	Inlet & Outlet	Design Discharge	Total Length	Specifications of Diversion Channel				Description
Alignment No. 3 to run along the Nasoso road in the north of the airport	Nadi river at 19.5 km from river mouth ↓ Nadi bay at the end of Nasoso road	1,500 m^3/s	4,500 m	Hc = EL. 7.6 m Hm = EL. .0 m I = 1/740 Hmb = EL. -3.0 m Hmb = EL. -6.0	 h = 4.0 m h = 7.0	 b = 115 m b = 41	 B = 316 m B = 69	1) A tunnel through the hill (20 m high) which hotels (Fiji Mocambo and Tanoa International) are located is required just after diverting point. 2) Since the width between the airport and the hotel hill is only 100 m, it is not possible to conduct to diversion channel in that area avoiding the hill. 3) There is a high grade residential area at the outlet. Land acquisition would be difficult.
Alignment No. 4 to use the existing canal which runs in the north of the airport	Nadi river at 19.5 km from river mouth ↓ river mouth of Sabeto river	1,500 m^3/s	6,500 m	Hc = EL. 6.0 m Hm = EL. 1.0 m I = 1/985 Hmb = EL. -3.0 m Hmb = EL. -4.0 Hmb = EL. -5.0 Hmb = EL. -6.0	 h = 4.0 m h = 5.0 h = 6.0 h = 7.0	 b = 139 m b = 94 b = 68 b = 51	 B = 155 m B = 114 B = 92 B = 79	1) A tunnel thorough the hill (20 m high) which hotels (Fiji Mocambo and Tanoa International) are located is required just after diverting point 2) Since the width between the airport and the hotel hill is only 100 m, it is not possible to conduct to diversion channel in that area avoiding the hill. 3) There is no obstacles for the diversion channel between Queen's road and the existing canal. 4) The sea is not shallow at the outlet. Conditions at the outlet is the best compared to other alignments. 5) Flood gate may be required at the outlet because of sugarcane filed.

Hc: water level at diverting point
Hm: water level at outlet
Hmb: bed elevation at outlet
I: bed slope

h: water depth
b: bed width
B: width of water surface

Regarding land acquisition, the alignments in the north of Airport (No.3 and 4) are considered as difficult to be implemented because the land acquisition is not feasible due to the resort hotels on the hill at the diverting point and no space available for detour to avoid the hill. For the alignment No.1, there are two obstacles in terms of land use. One is the area of transmitters for the airport (approximately 45 ha) located in the south of the airport and another is the large development of the resort at the outlet of the diversion channel. Considering the above conditions, alignment No.2 is the most feasible because of the less problems in the land acquisition.

- Alignment No. 1: Land acquisition is difficult. (total length = 3,700 m)
- Alignment No. 2: Land acquisition is relatively less problems. (total length = 3,000 m)
- Alignment No. 3: Land acquisition is difficult. (total length = 4,500 m)
- Alignment No. 4: Land acquisition is difficult. (total length = 6,500 m)

Assuming that excavated soil of the diversion channel is used for the embankment whose width is large enough for the other uses, such as road, housing and so on, the standard cross section of Nadi diversion channel is shown in Figure-4.8.

As a result of examinations of hydraulic specifications and land acquisition, alignment No. 2 was selected for the Nadi diversion channel. Since elevation of the sea bed at outlet of alignment No. 2 is approximately EL. -5.0 m, bed elevation at outlet was determined as EL. -5.0 m.

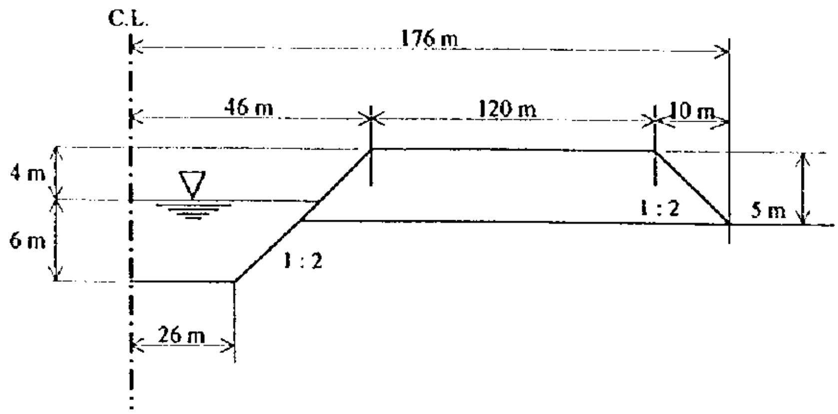


Figure-E4.8 Standard Cross Section of Nadi Diversion Channel (1,000 m from Outlet)

(3) Short Cut Channel

Nawaka river, a tributary of Nadi river in the left bank side, flows into Nadi river at about 8.0 km upstream from river mouth as shown in Figure-E4.9. Around this confluence, Nadi river meander remarkably inducing the large bank erosion and sedimentation which reduce the cross section area of river. By implementation of the short cut channel connecting between 7.5 km and 9.0 km points from river mouth, the stable flow and bed slope would be maintained. The length of the short cut channel is approximately 250 m. The effect of the short cut channel on flood is to increase the flow capacity. Its increment is 0.3 m in terms of stage and 50 m^3/sec in terms of discharge.

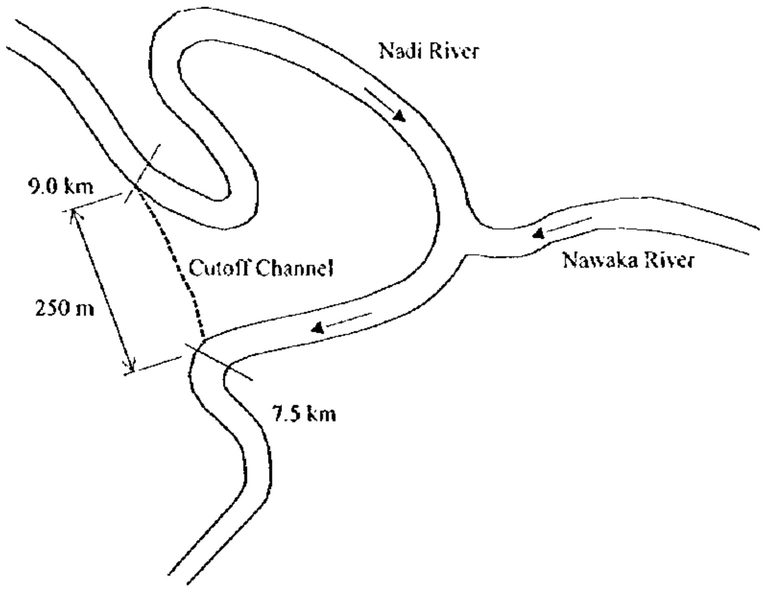


Figure-E4.9 Confluence of Nadi River and Nawaka River

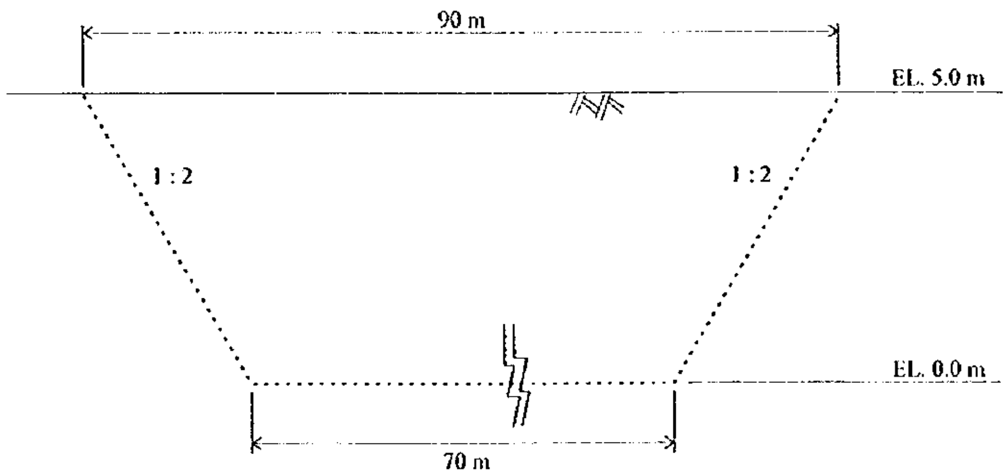


Figure-E4.10 Standard Cross Section of Short Cut Channel (Nadi)

4.5 Structural Measures for Ba Watershed

According to the topographical features in the Ba watershed, the diversion channel is not applicable and river bed excavation is not effective on flood control because the design flood level is 2 ~ 4 m higher than the ground level. Since land use along the river in the Ba delta is mainly crop land and housing is not located close to the river, except a sugar mill, dike construction is considered as the most applicable measure. Their locations are shown in Figure-E4.11.

(1) Dike Construction Area

- left bank side: 11.0 km - 16.0 km from river mouth
- right bank side: 10.0 km - 18.0 km from river mouth

(2) Scale of Dike

To determine the scale of the dike, following Japanese standard was applied.

- Levee crown width: 5.0 m (2,000 m^3/sec ≤ discharge < 5,000 m^3 /sec)
- Levee free board: 1.2 m (2,000 m^3/sec ≤ discharge < 5,000 m^3 /sec)

The result is shown in Table-E4.10 with cross section of dike. The average height of dike is 4.1 m to mitigate the flood damage by 1/20 probability flood.

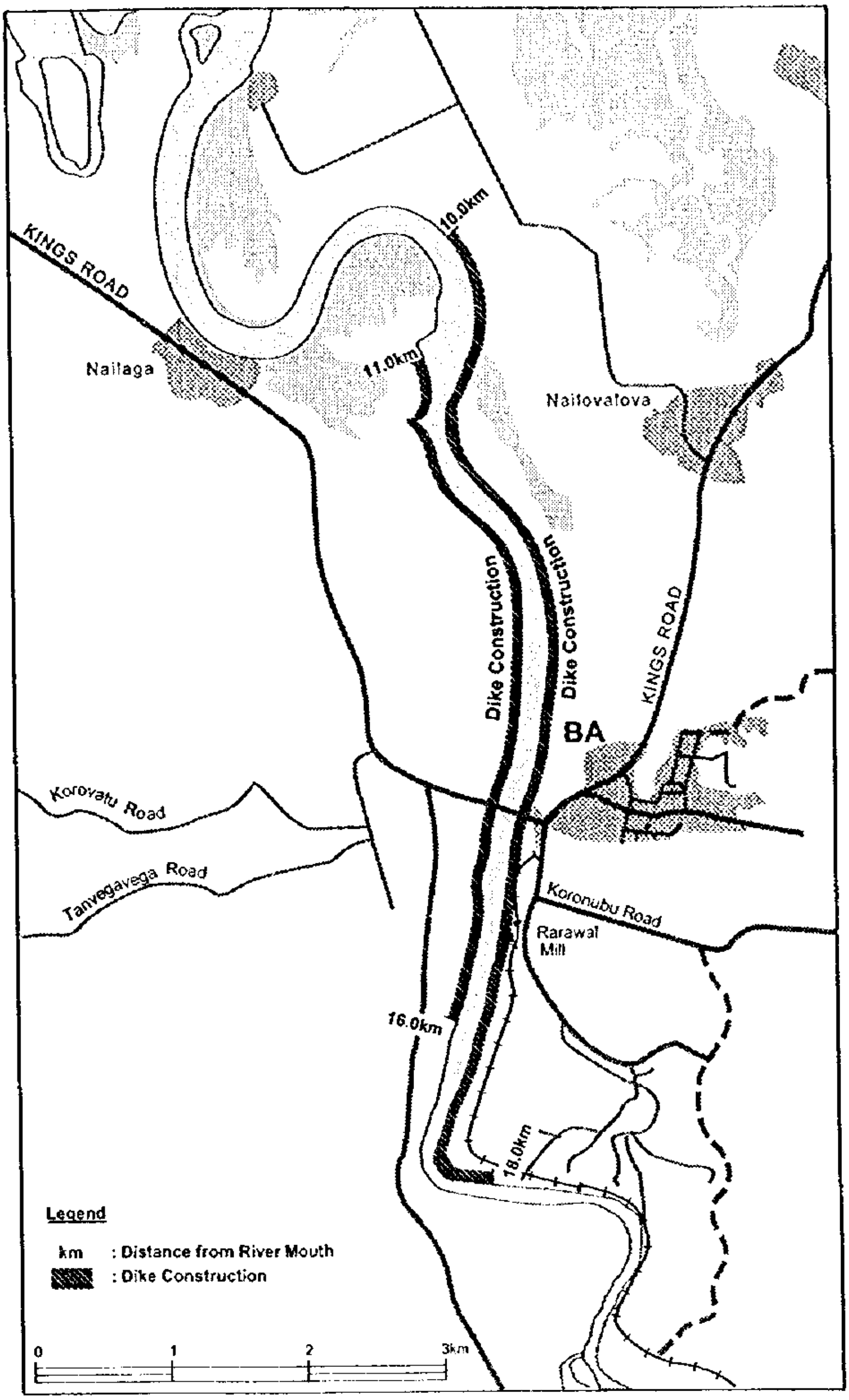


Figure-E4.11 Proposed River Section for Dike (Ba)

Table-E4.10 Specifications of Dike (Ba)

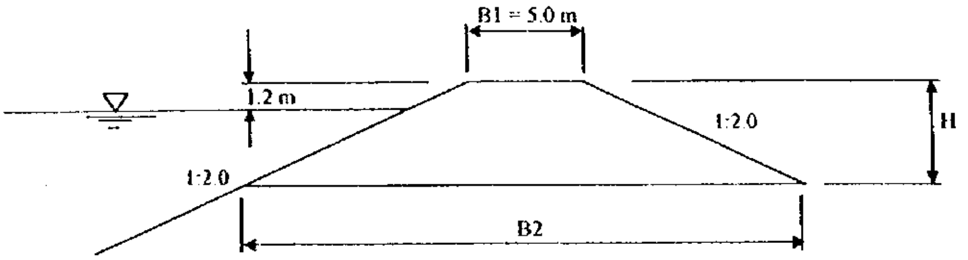
Volume of Embankment for 20 Year Return Period Flood

Section No.	delt X	Left Bank						Right Bank					
		H	B1	B2	A	A_{ave}	Volume	H	B1	B2	A	A_{ave}	Volume
	(m)	(m)	(m)	(m)	(m^2)	(m^2)	(m^3)	(m)	(m)	(m)	(m^2)	(m^2)	(m^3)
BA 9500	0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0
BA 10000	500	0.0	0.0	0.0	0.0	0.0	0	4.9	5.0	24.6	72.5	36.3	18,130
BA 10500	500	0.0	0.0	0.0	0.0	0.0	0	4.7	5.0	23.8	67.7	70.1	53,180
BA 11000	500	4.8	5.0	24.2	70.1	35.0	17,520	4.7	5.0	23.8	67.7	67.7	87,020
BA 11500	500	4.3	5.0	22.2	58.5	64.3	49,660	5.8	5.0	28.2	96.3	82.0	128,010
BA 12000	500	4.8	5.0	24.2	70.1	64.3	81,800	5.1	5.0	25.4	77.5	86.9	171,460
BA 12500	500	5.4	5.0	26.6	85.3	77.7	120,650	4.7	5.0	23.8	67.7	72.6	207,760
BA 13000	500	5.1	5.0	25.4	77.5	81.4	161,360	4.1	5.0	21.4	54.1	60.9	238,210
BA 13500	500	5.4	5.0	26.6	85.3	81.4	202,070	4.1	5.0	21.4	54.1	54.1	265,270
BA 14000	500	5.6	5.0	27.4	90.7	88.0	246,080	3.8	5.0	20.2	47.9	51.0	290,770
BA 14500	500	0.0	0.0	0.0	0.0	45.4	268,760	0.0	0.0	0.0	0.0	23.9	302,740
BA 15000	500	4.1	5.0	21.4	54.1	27.1	282,290	2.7	5.0	15.8	28.1	14.0	309,760
BA 15500	500	5.3	5.0	26.2	82.7	68.4	316,490	3.2	5.0	17.8	36.5	32.3	325,900
BA 16000	500	4.8	5.0	24.2	70.1	76.4	354,680	2.8	5.0	16.2	29.7	33.1	342,440
BA 16500	500	0.0	0.0	0.0	0.0	35.0	372,200	2.0	5.0	13.0	18.0	23.8	354,360
BA 17000	500	0.0	0.0	0.0	0.0	0.0	372,200	3.7	5.0	19.8	45.9	31.9	370,330
BA 17500	500	0.0	0.0	0.0	0.0	0.0	372,200	4.7	5.0	23.8	67.7	56.8	398,720
BA 18000	500	0.0	0.0	0.0	0.0	0.0	372,200	5.1	5.0	25.4	77.5	72.6	435,020
BA 18500	500	0.0	0.0	0.0	0.0	0.0	372,200	0.0	0.0	0.0	0.0	38.8	454,400

Left bank + Right bank = **826,600**

	Left	Right	Both
H_{ave}	3.59	3.52	3.55

Note
A_{ave} Average Area of Dike
H_{ave} Average Hight of Dike



4.6 Distribution of Design Flood Discharge

Design flood discharge with flood control measures described above would flow in the main stream and tributaries as shown in Figure-E4.12. In the figure, the areas to be protected against 1/20 probability flood are also shown.

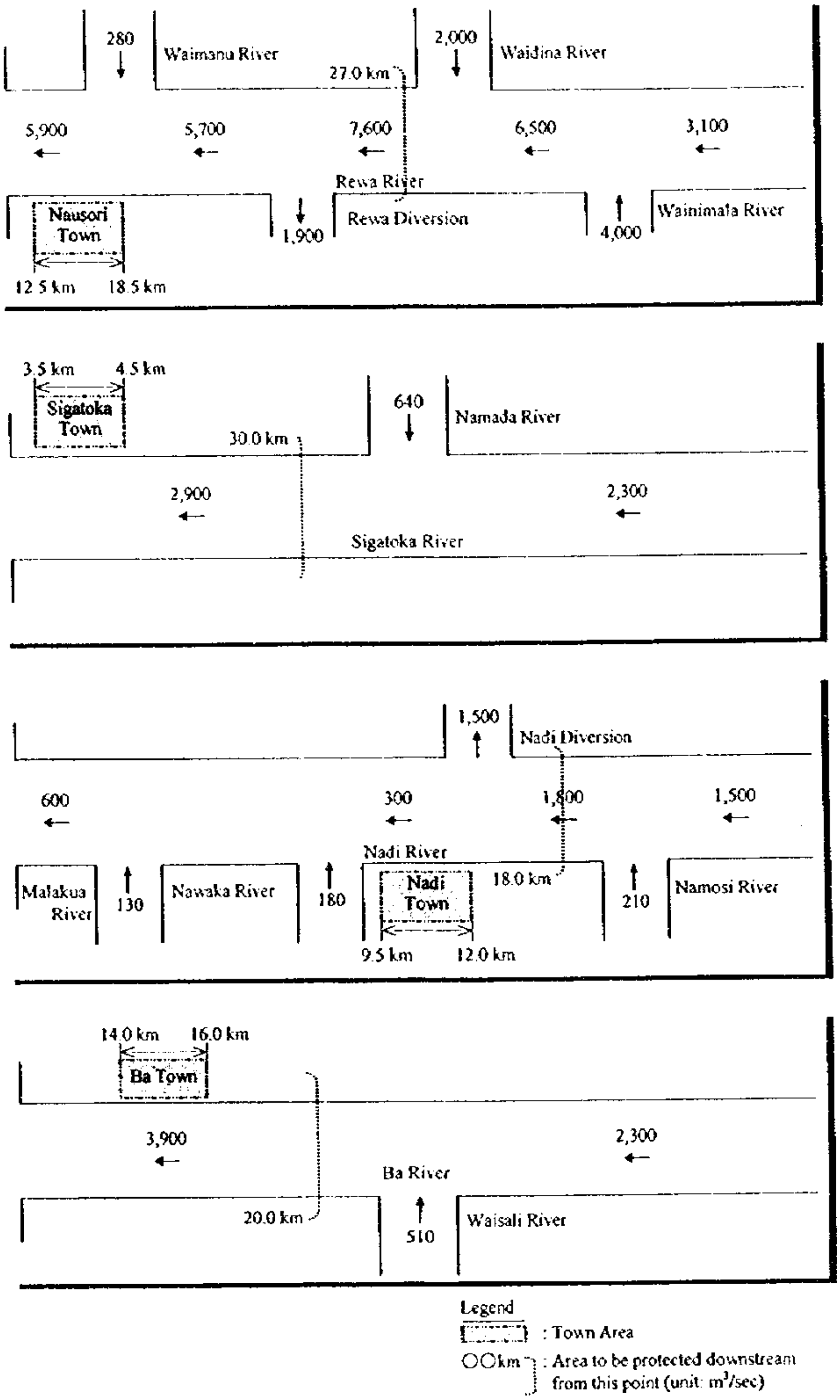


Figure-E4.12 Distribution of Design Flood Discharge for 20 Year Return Period Flood

4.7 Cost Estimate

(1) Estimate of Quantities

The structural measures for cost estimate are shown below:

Rewa watershed	Diversion channel + Dike construction (both banks)
Sigatoka watershed	Dredging
Nadi watershed	Diversion channel + Short cut channel
Ba watershed	Dike construction

By construction work of the diversion channels, the existing infrastructure, such as roads, wiring, piping etc. which is crossing the proposed sites will be cut in the Rewa and Nadi watershed. Therefore, the compensation work of the infrastructure with construction of bridges over the channels and road was added up in order to secure the traffic and the services. Near the outlet of the planned Nadi diversion channel, there is a flood gate at the end of the existing drainage to prevent the salt water intrusion. In this estimate, the flood gate was accounted at the outlet of the channel, although the necessity of the flood gate will be determined during the Feasibility Study based on the land use plan and so on.

The estimated quantities of the major construction works are shown below based on the above consideration.

Table-E4.11 Quantities of Main Work and Compensation Work

Description		River	Rewa	Sigatoka	Nadi	Ba
			Diversion Channel + Dike Construction	Dredging	Diversion Channel + Short Cut Channel	Dike Construction
Main Work	Excavation (m^3)	Sand and Soil	5,970,000	-	1,645,000[2]	826,600
		Rock	450,000	-	-	-
		Sub Total	6,420,000	-	1,645,000[2]	826,600
	Dike Construction (m^3)	loading & transportation	6,420,000[1]	-	1,645,000[2]	413,300
		Grading	6,420,000[1]	-	1,645,000[2]	826,600
		Compaction	6,420,000[1]	--	1,645,000[2]	826,600
	Dredging (m^3)		-	1,816,500	-	-
Compensation Work	Bridge (m)		960 (160 x 6)	-	300 (100 x 3)	-
	Road (m)		2,000		1,000	
	Flood Gate (m)		-	-	76 (x 1)	-

1): including 330,000 m^3 of dike construction
2): including 100,000 m^3 of the short cut channel construction

(2) Composition of Project Cost

The composition of the project cost is shown below. The ratios of the administration cost, the engineering cost and the contingency are estimated based on comparison of the similar projects in the world.

1) Construction cost

2) Land acquisition

3) Administration: 5 % of 1)

4) Engineering: 15 % of 1)

5) Physical contingency of construction quantities: 10 % of the sum of 1) ~ 4)

6) Price contingency: based on annual inflation rate of 5% for local cost and 3% for foreign cost, and construction period of 4 years

7) Taxes and duties: 10 % of the sum of 1) ~ 6)

(3) Estimate of Construction Cost

1) Condition of Unit Cost

a) In Fiji, the standard price per unit work is not available for the cost estimate. Therefore, the unit price of each work item was estimated based on the costs of previous works similar to the projects in the Master Plan, except for dredging. The unit price for the earth work in Fiji is approximately 80 % of that in Japan.

b) The unit price of the previous works available in D&I was adopted for dredging and the flood gate construction work.

c) The unit price of the construction work for the bridges and roads in compensation work was estimated based on data collection and interview study to the contractors in Fiji.

2) Estimate of Construction Cost

The construction cost in each watershed was estimated as shown in Table-E4.12 to E4.15, using the above unit cost.

Table-E4.12 Construction Cost of Rewa Diversion Channel and Dike Construction

Description			Unit Price	Quantity	Amount (F$)	Remarks
Main Work	Excavation	Sand and Soil	2.1 F$/m³	5,970,000 m³	12,537,000	Transportation Distance 20 m
		Rock	5.6 F$/m³	450,000 m³	2,520,000	
	Dike Construction[1]	loading & transportation	4.0 F$/m³	6,420,000 m³	25,680,000	Transportation Distance 500 m
		Grading	2.5 F$/m³	6,420,000 m³	16,050,000	
		Compaction	0.9 F$/m³	6,420,000 m³	5,778,000	
	Sub-Total				62,565,000	
Compensation Work	Bridge		32,500.0 F$/m	960 m	31,200,000	6 bridges x 160 m
	Road		1,000.0 F$/m	2,000 m	2,000,000	
	Sub-Total				33,200,000	
Construction Cost = Main Work + Compensation Work					95,765,000	

1): including 330,000 m³ of dike construction

Table-E4.13 Sigatoka Dredging Cost

Description	Unit Price	Quantity	Amount (F$)	Remarks
Dredging	4.4 F$/m³	1,816,500 m³	7,992,600	

Table-E4.14 Construction Cost of Nadi Diversion Channel and Short Cut Channel

Description			Unit Price	Quantity	Amount (F$)	Remarks
Main Work	Excavation	Sand and Soil	2.1 F$/m³	1,645,000 m³	3,454,500	Transportation Distance 20 m
		Rock	5.6 F$/m³	0 m³	0	
	Dike Construction[1]	loading & transportation	5.2 F$/m³	1,645,000 m³	8,554,000	Transportation Distance 1,500 m
		Grading	2.5 F$/m³	1,645,000 m³	4,112,500	
		Compaction	0.9 F$/m³	1,645,000 m³	1,480,500	
	Sub-Total				17,601,500	
Compensation Work	Bridge		32,500.0 F$/m	300 m	9,750,000	3 bridges x 100 m
	Road		1,000.0 F$/m	1,000 m	1,000,000	
	Flood Gate		70,000.0 F$/Unit	19 Units	1,330,000	1 gate = 4 m
	Sub-Total				12,080,000	
Construction Cost = Main Work + Compensation Work					29,681,500	

1): including 100,000 m³ of the short cut channel construction

Table-E4.15 Construction Cost of Ba Dike

Description			Unit Price	Quantity	Amount (F$)	Remarks
Main Work	Excavation	Sand and Soil	3.3 F$/m³	826,600 m³	2,727,780	Transportation Distance 50 m
		Rock	5.6 F$/m³	0 m³	0	
	Dike Construction	loading & transportation[1)]	5.2 F$/m³	413,300 m³	2,149,160	Transportation Distance 1,500 m
		Grading	2.5 F$/m³	826,600 m³	2,066,500	
		Compaction	0.9 F$/m³	826,600 m³	743,940	
	Sub-Total				7,687,380	

1): The half of the material for the dike will be obtained from the area near the project site. The other half will be transported in the average distance of 1.5 km.

(4) Estimate of Land Acquisition and Compensation

Among the land tenure system of Native Land, State Land and Free-hold Land in Fiji, land acquisition cost was counted for Free-hold Land and 99-year lease cost was counted for Native Land. State Land does not require either acquisition or lease but requires only compensation for the present land use.

The area by land tenure and the number of houses within the project site was estimated overlapping the project plan to the aerial photography (1994) and the cadastral map available from the Department of Land and Survey. The unit price of the land, 99-year lease and the unit compensation cost by preset land use, such as houses, sugarcane field, grazing, public facilities, etc. was set through discussion with the Department of Land and Survey. The dredging project for Sigatoka watershed does not require land acquisition and compensation cost.

(5) Estimate of Project Cost

The project cost (1996 price base) was estimated based on the conditions below.

- The ratio between local cost and foreign cost was set as shown in Table-E4.16 based on the construction works in Fiji.
- The ratio of material and equipment cost to labor cost is set as 7:3.
- Taxes and duties are included in the cost except the price contingency.
- The price contingency was taken into consideration with annual inflation rate of 5 % for the local currency portion and 3 % for the foreign currency portion.

Table-E4.16 Ratio of Local Currency and Foreign Currency

Item	Local Currency	Foreign Currency
1. Construction Cost		
1) Material & Equipment	20 %	80 %
2) Labor	80 %	20 %
2. Land Acquisition	100 %	0 %
3. Administration	100 %	0 %
4. Engineering	20 %	80 %
5. Physical Contingency	40 %	60 %

The result of project cost estimate is shown in Table-E4.17.

Table-E4.17 Project Cost

Unit: F$ 1,000

Project	Item	Project Cost	Local Currency	Foreign Currency
Rewa Diversion Channel and Dike Construction	1. Construction Cost	95,800	36,400	59,400
	1) Material & Equipment	67,100	13,400	53,700
	2) Labor	28,700	23,000	5,700
	2. Land Acquisition	5,000	5,000	–
	3. Administration	4,800	4,800	–
	4. Engineering	14,400	2,900	11,500
	5. Physical Contingency	12,000	4,800	7,200
	Sub Total	132,000	54,000	78,000
	6. Price Contingency	7,800	4,200	3,600
	7. Tax	14,000	14,000	0
	Grand Total	153,800	72,200	81,600
Sigatoka Dredging	1. Construction Cost	8,000	3,040	4,960
	1) Material & Equipment	5,600	1,120	4,480
	2) Labor	2,400	1,920	480
	2. Land Acquisition	–	–	–
	3. Administration	400	400	–
	4. Engineering	1,200	240	960
	5. Physical Contingency	1,000	400	600
	Sub Total	10,600	4,080	6,520
	6. Price Contingency	620	320	300
	7. Tax	1,120	1,120	0
	Grand Total	12,340	5,520	6,820
Nadi Diversion Channel and Short Cut Channel	1. Construction Cost	29,700	11,280	18,420
	1) Material & Equipment	20,800	4,160	16,640
	2) Labor	8,900	7,120	1,780
	2. Land Acquisition	4,000	4,000	–
	3. Administration	1,500	1,500	–
	4. Engineering	4,500	900	3,600
	5. Physical Contingency	4,000	1,600	2,400
	Sub Total	43,700	19,280	24,420
	6. Price Contingency	2,620	1,500	1,120
	7. Tax	4,630	4,630	0
	Grand Total	50,950	25,410	25,540
Ba Dike Construction	1. Construction Cost	7,700	2,920	4,780
	1) Material & Equipment	5,400	1,080	4,320
	2) Labor	2,300	1,840	460
	2. Land Acquisition	1,000	1,000	–
	3. Administration	400	400	–
	4. Engineering	1,200	240	960
	5. Physical Contingency	1,000	400	600
	Sub Total	11,300	4,960	6,340
	6. Price Contingency	670	380	290
	7. Tax	1,200	1,200	0
	Grand Total	13,170	6,540	6,630

Note: 1) Tax: Value Added Tax (VAT)
2) Material & Equipment = Construction Cost x 70 %
3) Labor = Construction Cost x 30 %

4.8 Economic Evaluation

(1) Conditions of Economic Evaluation

The economic evaluation of the flood control projects (structural measures proposed in this chapter and afforestation in the Sigatoka watershed proposed in Chapter 9) was made by comparing the two present values, economic benefit and cost of the project. The major economic benefit of the flood control project is presented as an expected reduction in flood damage by implementing the project, that is an economic difference between "with-project" and "without-project" situations. The comparison on economic benefit and cost was carried out using Economic Internal Rate of Return (EIRR), together with Benefit-Cost Ratio (B/C) and Net Present Value (NPV).

The economic cost and benefit were estimated using the economic prices under the conditions and assumptions as shown below;

- Transfer payments such as value added tax of 10 % are not included in the economic cost and benefit.
- Standard conversion rate (SCR) applied to equipment and materials procured locally is assumed to be 94.0 %, taking the export and import situations of Fiji in recent years into consideration.
- Opportunity cost of wages for unskilled laborers is assumed to be 94 % of existing cost, taking unemployment situations in recent years into consideration.
- Opportunity cost of land to be acquired for the project is assumed to be 90 % of the financial cost.
- Inflation factor is not taken into account in economic evaluation.
- Economic life of the project (hereinafter referred to as the "project life") is taken as 50 years after the completion of construction works for structural measures and 100 years for afforestation.
- Construction period is assumed to be 4 years.
- The benefit and the OM cost (operating and maintenance cost) for the project are expected to accrue every year during the period of the project life after completion of the construction works.
- Opportunity cost of capital is assumed to be 10 % and used as the discount rate, as indicated by the Central Planning Office.

(2) Annual Average Damage Reduction

The expected annual average damage reduction is described in Chapter 3 and the result is summarized in Table-E4.18.

Table-E4.18 Annual Damage Reduction

Unit: F$ 1,000

Flood Control Measures	Rewa	Sigatoka	Nadi	Ba
Structural Measures	1,966	381	8,278	1,446
Afforestation	–	186	–	--

The annual average damage reduction is equivalent to an expected Annual Average Benefit. This benefit is expected to accrue every year during the project life (50 years for structural measures and 100 years for afforestation).

(3) Economic Cost

The economic cost is a converted value from the project costs under the conditions and assumptions described in (1). As a result of the conversion, the economic costs and OM cost per annum were estimated. Meanwhile, the land lease charge of F$ 1.0 /year was included in OM cost for afforestation. The result is shown in Table-E4.19.

Table-E4.19 Economic Cost of Project

Unit: F$ 1,000

Flood Control Measures	Economic Cost	Rewa	Sigatoka	Nadi	Ba
Structural Measures	Project Cost	134,467	10,854	43,794	11,358
	Annual OM Cost	98	8	31	8
Afforestation	Project Cost	–	17,551	–	–
	Annual OM Cost	–	34	–	–

(4) Economic Evaluation

The economic evaluation of projects was conducted using the annual average economic benefit and cost in Table-E4.18 and Table-E4.19. The results of the evaluation are summarized in Table-E4.20.

Table-E4.20 Economic Evaluation of Project

Flood Control Measures	Item	Rewa	Sigatoka	Nadi	Ba
Structural Measures	Economic Benefit (F$ 1,000/year)	1,966	381	8,278	1,446
	Economic Project Cost (F$ 1,000)	134,467	10,854	43,794	11,358
	Economic Annual Maintenance Cost (F$ 1,000/year)	98	8	31	8
	EIRR (%)	negative	2.00	15.06	10.73
	B/C (Ratio)	0.12	0.30	1.61	1.08
	NPV (F$ 1,000)	-93,911	-6,075	21,143	737
Afforestation	Economic Benefit (F$ 1,000/year)	–	186	–	–
	Economic Project Cost (F$ 1,000)	–	17,551	–	–
	Economic Annual Maintenance Cost (F$ 1,000/year)	–	39	–	–
	EIRR (%)	–	negative	–	–
	B/C (Ratio)	–	0.09	–	–
	NPV (F$ 1,000)	–	-10,593	–	–

Discount Rate: 10 %

As a result, the EIRR of the structural measures indicates "negative" for the Rewa, 2.00 % for the Sigatoka, 15.06 % for the Nadi, 10.73 % for the Ba. Those percentages indicate that the structural measures for the Nadi is the most feasible, in view of the opportunity cost of capital (10 %) in Fiji. In addition, B/C of 1.61 at discount rate of 10 % supports the feasibility of the structural measures in the Nadi. EIRR of the Ba shows 10.73 % which is slightly higher than the opportunity cost of capital and B/C is 1.08 at discount rate of 10 %. This means that the structural measures in the Ba are at the threshold for implementation. Meanwhile, the negative results and low percentage of EIRR for the Rewa and Sigatoka indicate that the projects (structural measures and afforestation) are not economically feasible. In addition, B/C of 0.12 and 0.30 for structural measures, and 0.09 for afforestation at discount rate of 10 % show low economic viability.

In conclusion, it is expected that the flood control project (structural measures) in the Nadi watershed would make the high contribution to not only the flood mitigation, but also the promotion of economic development in the region.

4.9 Economic Evaluation of Nausori Dike Construction (Left Bank)

Proposed structural measures for the Rewa watershed, combination of the diversion channel and dikes, are not feasible as a result of economic evaluation. This is due to too large investment compared to properties to be protected. Properties in the Rewa delta are densely located on the left bank of Rewa river (Nausori town and international airport), while other areas are mainly crop and grazing land. Considering the current landuse, the flood control plan should be implemented in accordance with development of the Rewa delta. Therefore, step wise implementation of the flood control plan is proposed.

Since most of properties in the Rewa delta are currently located on the left bank of Rewa river, a first priority of flood control should be allocated to the left bank. The structural measures for the Rewa consist of the diversion channel, dike on the left bank and dike on the right bank of Rewa river. To protect the left bank from flood damage, the dike on the left bank was selected as the first step.

Since the diversion channel would drain 1,900 m^3/sec when 20 year return period flood (7,800 m^3/sec) occurs, discharge of Rewa river at river mouth would be reduced to 5,900 m3/sec. Dike construction is proposed against excess flood which is not drained by the diversion channel as discussed in the section 4.2. Therefore, the dike in combination with the diversion channel is designed for flood of 5,900 m^3/sec which is equivalent to 11 year return period flood. The same design flood (11 year return period flood) was adopted for the first step plan because the diversion channel and dike on the right bank will be implemented as development in the Rewa delta expands.

Cost of dike construction on the left bank was estimated assuming that bank material is available near the site (average transportation distance : 1.5 km) and no compensation work is required. Since cross sections of the dike are same as the proposal in Table-E4.6, only difference between cost estimate of the combination plan (diversion channel and dikes on both banks) and the dike on the left bank is the unit cost of loading and transportation of bank material. Construction cost of the dike on the left bank is approximately F$ 2.14 million as shown in Table-E4.21.

Table-E4.21 Construction Cost of Dike (Left Bank of Rewa River)

Description			Unit Price	Quantity	Amount (F$)	Remarks
Main Work	Excavation	Sand & Soil	2.1 F$/$m^3$	200,000 m^3	420,000	Transportation Distance 20 m
		Rock	5.6 F$/$m^3$	m^3	0	
	Dike Construction	Loading & Transportation	5.2 F$/$m^3$	200,000 m^3	1,040,000	Transportation Distance 1.5 km
		Grading	2.5 F$/$m^3$	200,000 m^3	500,000	
		Compaction	0.9 F$/$m^3$	200,000 m^3	180,000	
	Construction Cost				2,140,000	

Project cost was estimated and successively economic evaluation of the dike construction was conducted with same conditions in the section 4.7 and 4.8. The results are shown in Table-E4.22 and Table-E4.23, respectively.

Table-E4.22 Project Cost of Dike (Left Bank of Rewa River)

Unit: F$ 1,000

	Project Cost	Local Currency	Foreign Currency
1. Construction Cost	2,140	810	1,330
1) Material & Equipment	1,500	300	1,200
2) Labor	640	510	130
2. Land Acquisition	3,500	3,500	0
3. Administration	110	110	0
4. Engineering	320	60	260
5. Physical Contingency	610	240	370
Sub Total	6,680	4,720	1,960
6. Price Contingency	0	0	0
7. Tax	670	670	0
Total	7,350	5,390	1,960

Price Contingency: Since the construction can be completed in one year considering work quantity, there is no price contingency.

Table-E4.23 Economic Evaluation of Dike (Left Bank of Rewa River)

Item		Dike on Left Bank
Economic Benefit	(F$ 1,000/year)	798
Economic Cost of Project	(F$ 1,000)	6,039
Economic Annual Maintenance Cost	(F$ 1,000/year)	2
EIRR	(%)	13.15
B/C	(Ratio)	1.31
NPV	(F$ 1,000)	1,685

Discount Rate : 10 %

As shown in Table-E4.23, indices of economic evaluation show that the dike construction is feasible to be implemented. Therefore, the dike construction on the left bank of Rewa river is proposed as the Master Plan by the year of 2015. Other structural measures for the Rewa should be implemented as development in the Rewa delta expands.

CHAPTER 5 NON STRUCTURAL MEASURES

Flood control plans consist of structural measures, such as improvement of river (dike, river course widening, dredging) and storage facilities (dam, retarding basin), and non structural measures without any involvement of construction. Structural measures for each watershed were examined and proposed in Chapter 4. In the following section, non structural measures are discussed.

The following items are considered as non structural measures for flood control.

- Mitigation of flood discharge from watershed
- Reduction of flood damage potential
- Reinforcement of flood management

5.1 Mitigation of Flood Discharge from Watershed

In Fiji, population and assets are located in the lower reach of river and the flood damage in those areas is caused by overspill from a river channel. To suppress the overspill without structural measures, both water retention function and water storage function of watershed have to be improved in order to mitigate flood discharge into a river channel.

Water retention and storage functions of watershed is improved by the following non structural measures.

(1) To increase the area of forest

The area of forest varies with watershed. It covers 40 ~ 50 % of watershed in the Sigatoka, Nadi and Ba watershed, which are located in the western Viti Levu, while it covers 70 % of the Rewa watershed in the eastern Viti Levu. According to the case study in the Sigatoka watershed described in Chapter 9, 10 % of the peak discharge is reduced by afforestation. Therefore, afforestation should be promoted.

(2) To regulate the land use so as not to damage the water retention function of watershed

There has been no large scale development in Fiji so far; however, tourist developments and housing developments have been planned in the Nadi watershed and some of them are already under the construction. The development is expected to expand to other watersheds in future. Without regulation, the land which has a water retention function, such as agricultural land, bushes, forest and so on, would be reduced. Therefore, it is necessary to regulate the land use in order to keep the areas for water retention. For example, regulation ponds and parks which retain and store the water, should be promoted in the large scale development by enforcement of law.

(3) To promote the land use which has a retarding function of flow

The land which has a retarding function of flow, such as swamp, should be maintained and promoted as natural reserves.

(4) To maintain the flow capacity of river

At least, current flow capacity of river should be maintained by suppressing inflow of soil into river channel because sedimentation reduces the cross section area of flow. The inflow of soil can be controlled at the source and at the river. The former is the soil conservation, such as terracing and afforestation, while a green belt on river banks is effective for the latter.

5.2 Reduction of Flood Damage Potential

The flood prone area should be designated based on the past records of flood and be publicized. To reduce the current flood damage potential, housing in the flood prone area should be limited by law; however, if it is not avoidable, a raised house which is proof against flood should be promoted.

5.3 Reinforcement of Flood Management

Mitigation of flood discharge from watershed and reduction of flood damage potential are non structural measures before a flood occurs. When a flood is expected, communication system, evacuation system and flood prevention are essential. In Fiji, National Disaster Management Plan has been formulated. When any disaster is expected or occurred, National Disaster Management Council will be formed by relative government authorities to conduct alarming, relief assistance, rehabilitation and so on. However, it still need reinforcement.

The flood management mainly consists of the followings and is conducted by interactive cooperation among the relative government authorities.

- Analysis of flood conditions
- Flood forecasting
- Communication system of flood (flood alarming)
- Evacuation system
- Flood prevention activities

Fiji Meteorological Service provides the flood information, such as route of cyclone and area of rainfall, based on the satellite and radar analysis, while Public Works Department conducts the hydrological analysis, such as rainfall and discharge. Based on those information and data, scale and route of cyclone can be related to rainfall and discharge. Once the relation was determined, it would be possible to forecast a flood and successively flood alarming, evacuation and flood prevention would be conducted effectively.

To establish the flood management, the followings are necessary to be employed in Fiji.

1) Reinforcement of Hydrological Observation

The hydrological data is a base of the flood management. Considering the current conditions, the following improvement of raingauge and gauging stations is necessary.

- Since there is a large spatial variation of rainfall in Fiji, raingauge stations should be located with at least 20 km interval referring to the raingauge network in Japan.
- The rating curve should be revised by observation during flood and non-uniform flow calculation.

To cover the lack of raingauge and gauging stations, new stations should be located as shown in Table-E5.1.

Table-E5.1 Necessary Number of New Hydrological Station

Hydrological Station	River	Necessary Total Number	Number of New Station	Remarks
Raingauge Station	Rewa	12	5	middle to low reach
	Sigatoka	7	2	middle and low reach
	Nadi	3	–	
	Ba	3	1	middle reach
	Total	25	8	
Gauging Station	Rewa	9	1	along the Rewa river downstream from the confluence with the Wailoa river
	Sigatoka	4	1	at Nakuilau
	Nadi	4	–	
	Ba	4	–	
	Total	21	2	

2) Publicity of Flood Information and Establishment of Flood Forecasting System
   - Publicity of hydrological data
   - Analysis of relation between cyclone and rainfall/discharge during flood
   - Establishment of flood forecasting system in each watershed

3) Establishment of Communication System (Flood Alarming System)
   - Establishment of flood management system
   - Establishment of communication system which provides accurate information immediately to relative authorities
   - Establishment of evacuation system
   - Establishment of refuge places
   - Formulation of flood management manual

The conceptual diagram of flood management system is shown in Figure-E5.1 and that of flood forecasting and alarming system is shown in Figure-E5.2.

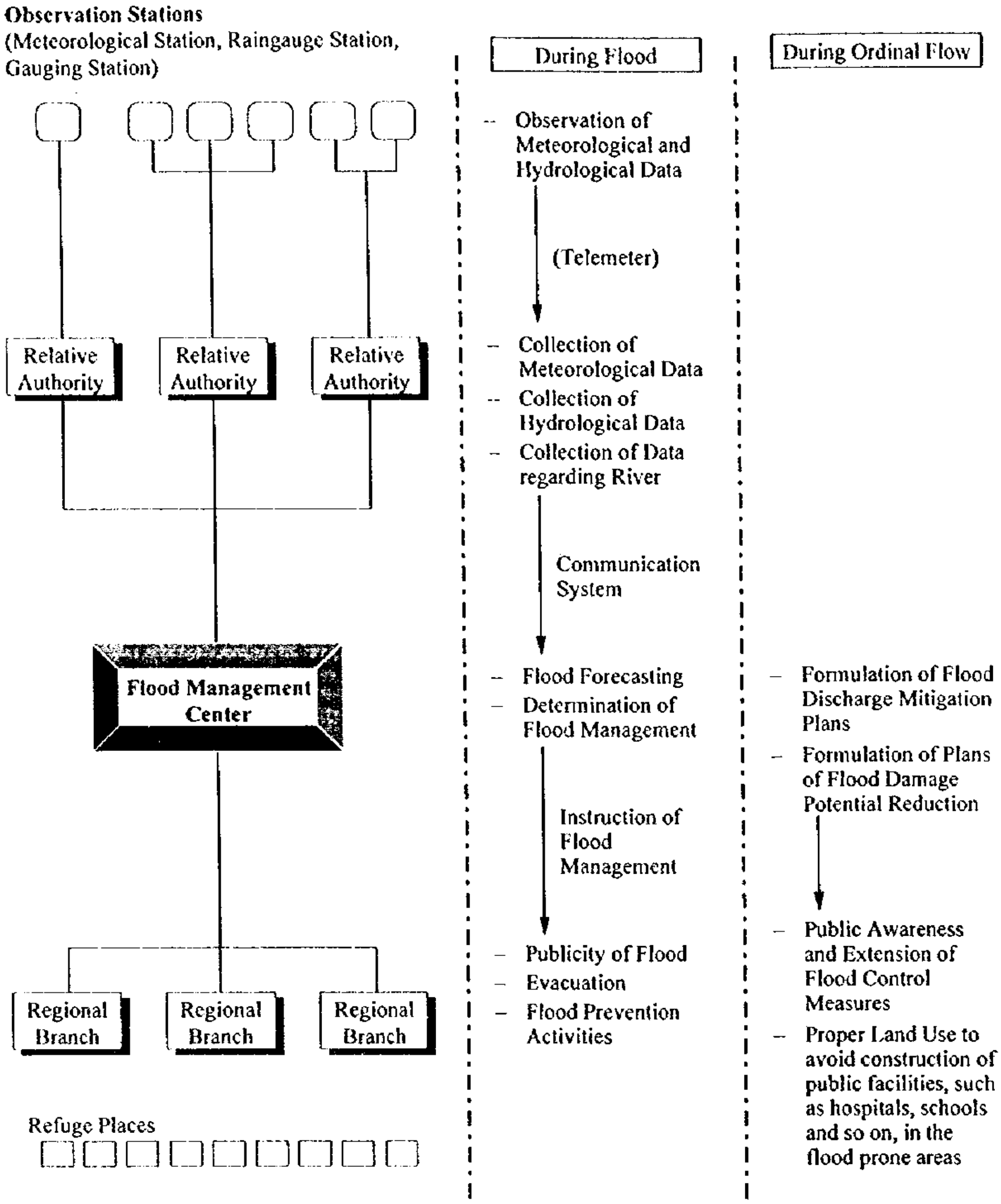


Figure-E5.1 Conceptual Diagram of Flood Management

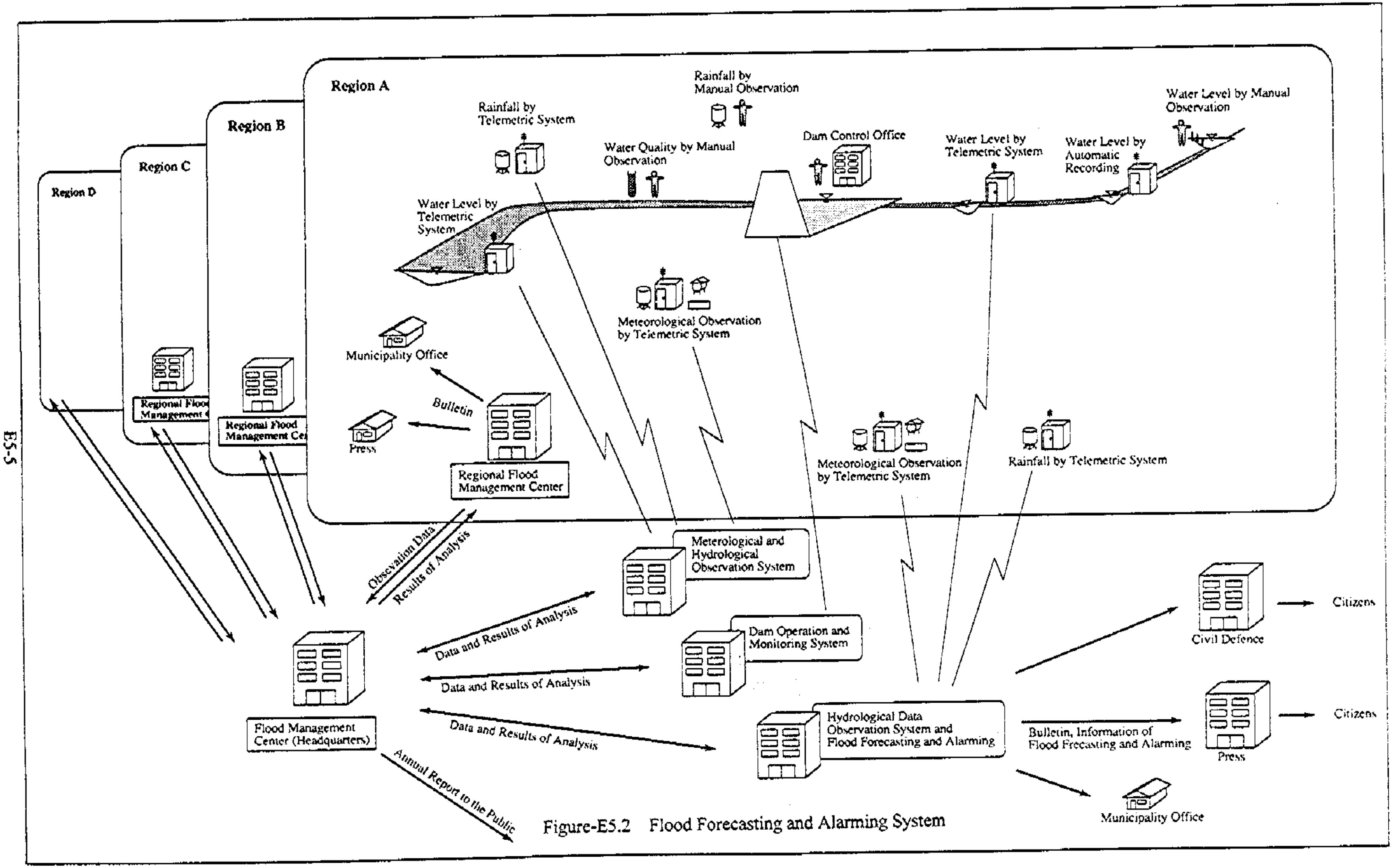


Figure-E5.2 Flood Forecasting and Alarming System

5.4 Case Study of Flood Forecasting & Alarming System in Rewa Watershed

The facilities to be required for the flood forecasting and alarming system in the Rewa watershed, which is the largest watershed in Viti Levu, are examined. Those for other watersheds can be determined by the same considerations.

Flood forecasting would be enabled by the proposals in the section 5.3. Traveling time of flood in the Rewa delta around Nausori is approximately 12 hours. Assuming that it takes 3 hours to inform the public of flood, forecasting future rainfall in 3hours is necessary so that flood alarming can be conducted 12 hours before flood occurs.

In general, media of flood alarming are radio, TV, speaker facilities and vehicles with speaker. Since inundated areas in the Rewa is very large, lots of speaker facilities would be required. Therefore, realistic media are radio, TV and vehicles with speaker. One vehicle can cover 5 km^2/hour with speed of 10 ~ 20 km/hour. To conduct flood alarming in flood prone areas of 50 km^2, 10 vehicles are necessary.

Evacuation is conducted by residents themselves; however, refuge places have to be informed to them during the ordinal time. Schools and public halls located on hill are suitable for refuge places.

The following authorities should be involved in flood forecasting and alarming system considering the present task of those authorities.

Table-E5.2 Authorities for Flood Forecasting & Alarming

Item	Authority	Necessary Equipment
Collection of Rainfall Data	FMS PWD	Raingauge Stations
Collection of Discharge Data	PWD	Gauging Stations
Projection of Rainfall	FMS PWD	Computers
Application of Runoff Model	PWD	Computers
Flood Forecasting	PWD	Computers
Communication	Flood Management Center Civil Defense Mass Media	Communication Equipment
Flood Alarming	Flood Management Center Mass Media	TV & Radio Vehicles

Facilities to be required for flood forecasting and alarming system in the Rewa watershed are shown in Table-E5.3 and their costs were also estimated.

Table-E5.3 Necessary Facilities and Cost for Flood Forecasting and Alarming System (Rewa)

Item	Necessary Total Number	Required Number to be established	Unit	Unit Price F$ 10^3	Cost F$ 10^3
Raingauge Station	12	5	station	5	25
Gauging Station	9	1	station	10	10
Telemeter Facility	1	1	lump sum	1,000	1,000
Computer	10	10	unit	10	100
Office	8	8	building	To use existing government buildings (Headquarters = 1, Regional office =7)	
Vehicle for Alarming	10	10	car	40	400
System Development	1	1	lump sum	100	100
Reserved Fund	1	1	lump sum	165	165
Total					1,800

5.5 Radar Application to Flood Forecasting

Applicability of radar to flood forecasting was examined to overcome insufficient network of raingauge stations. Fiji Meteorological Service (FMS) has two sites for meteorological radar in Viti Levu so that rainfall intensity of cloud with a scale of 5 km x 5 km in the whole Viti Levu can be measured. Sites for radar are Nausori airport and Nadi airport and the radar system at Nadi was recently improved by JICA (Japan International Cooperation Agency). Although rainfall intensity of cloud is different from actual rainfall at land surface, once calibration was conducted to link rainfall intensity of cloud and rainfall at land surface, it would overcome difficulties to install raingauge in remote areas where there is no access and improve data availability.

To determine the relation between rainfall intensity of cloud and rainfall at land surface, it is necessary to observe rainfall continuously and recommendable to have a raingauge network with 20 km distance to understand spatial variation of rainfall. As recommended in the section 5.3, 5 new raingauge stations are required for the Rewa watershed, 2 for the Sigatoka watershed and 1 for the Ba watershed to satisfy the minimum requirement of the raingauge network.

After calibrating the rainfall intensity of cloud, runoff model which converts rainfall to discharge is applied and also analysis to understand a relation between rainfall distribution and route of cyclones is conducted. The runoff model is calibrated by comparing discharge simulated with discharge observed. As a result, discharge and stage can be forecast by analyzing future movement of cloud and change of rainfall distribution.

Radar is applicable to flood forecasting; however, it still requires lots of works and analyses. Fiji Meteorological Service is in charge of collection and processing of radar data, while Hydrological Section, PWD is in charge of hydrological analysis. Therefore, their cooperation is essential to achieve this task.

CHAPTER 6 CASE STUDY OF MULTI-PURPOSE DAM IN NADI WATERSHED

Although a dam was excluded from the Master Plan, the case study was conducted for a dam in the Nadi watershed in order to assess its feasibility compared to the Master Plan. The site for dam considered is the most possible site (N-3 in Figure-E4.1), which was examined in Chapter 4.

6.1 Flood Control

The effect of dam on flood control should aim at the same effect as the Master Plan for the Nadi proposed in Chapter 4, which consists of a diversion channel and a short cut channel. The Master Plan controls the following amount of flood (20 year return period flood).

– Discharge at river mouth before implementation of measures:	2,100 m^3/sec
– Discharge at river mouth after implementation of measures:	600 m^3/sec
– Effect:	1,500 m^3/sec

However, since the inflow at dam site (N-3) is limited to 1,060 m^3/sec, it is not possible to have the same effect as the Master Plan even if the dam controls all inflow. Therefore, it was assumed that the dam has the flood control capacity at maximum, 1,000 m^3/sec.

Relation between water level and storage volume (H-V curve) of N-3 dam was calculated as shown in Figre-E6.1. Based on the H-V curve, the storage function model was employed to examine flood control capacity of N-3 dam and its effect in terms of discharge at river mouth. For runoff analysis by the storage function model, rainfall of 20 year return period transformed to hyetograph of the cyclone Kina was used and the model calculation is shown in Table-E6.1.

In Table-E6.1, discharges of Nadi river with an application of N-3 dam are shown at downstream from Namosi river confluence, upstream from Nawaka river confluence and river mouth. In addition, dam inflow and outflow, water level of reservoir and storage volume of flood are shown.

For flood control of N-3 dam, a natural method which does not require man operation was adopted. The natural method is to install dewatering facility at same height as water level when the reservoir stores full volume of water for water supply, and to store the difference between inflow by flood and outflow by dewatering facility, such as orifice. Since water level of N-3 dam at full volume for water supply (10,000,000 m^3) is EL. 77.4 m, dewatering facility would be installed at EL. 77.4 m.

Runoff analysis by the storage function model was conducted varying size of dewatering facility to examine the flood control capacity of N-3 dam. As a result, N-3 dam would have the maximum storage volume of flood based on topographical and geological features at site in the case that the dewatering facility is an orifice with height 2.8 m x width 2.8 m. Applying N-3 dam, discharge of 2,100 m^3/sec at river mouth (without any measures) would be reduced to 1,100 m^3/sec and required flood control capacity of N-3 dam would be 32,347,010 m^3.

According to Japanese standards of dam engineering, flood control capacity of dam is determined by multiplying calculated flood control capacity by 1.2. 1.2 is an empirical factor to consider clogging of dewatering facility by driftwood etc., reduction of storage volume by sedimentation in reservoir and so on. Adopting Japanese standard as safety factor, calculated flood control capacity (32,347,010 m^3)was multiplied by 1.2. As a result, flood control capacity of N-3 dam is 38,800,000 m^3.

The results of runoff analysis are summarized below.

– Discharge at river mouth before implementation of dam:	2,100 m^3/sec
– Discharge at river mouth after implementation of dam:	1,100 m^3/sec
– Effect:	1,000 m^3/sec
– Flood control capacity:	38,800,000 m^3
– Annual average damage reduction:	F$ 8,428,000/year

Dam H-V Curve

Nadi Watershed N3-Dam (C.A.=109.0km²)

Water Level EL.m	Area m²	Area(Ave.) m²	Volume m³
31	0	0	0
40	521,212	260,606	2,345
60	1,461,056	991,134	22,168
80	2,876,035	2,168,546	65,539
100	4,667,760	3,771,898	140,977
120	6,543,867	5,605,814	253,093

C.A: Catchment Area

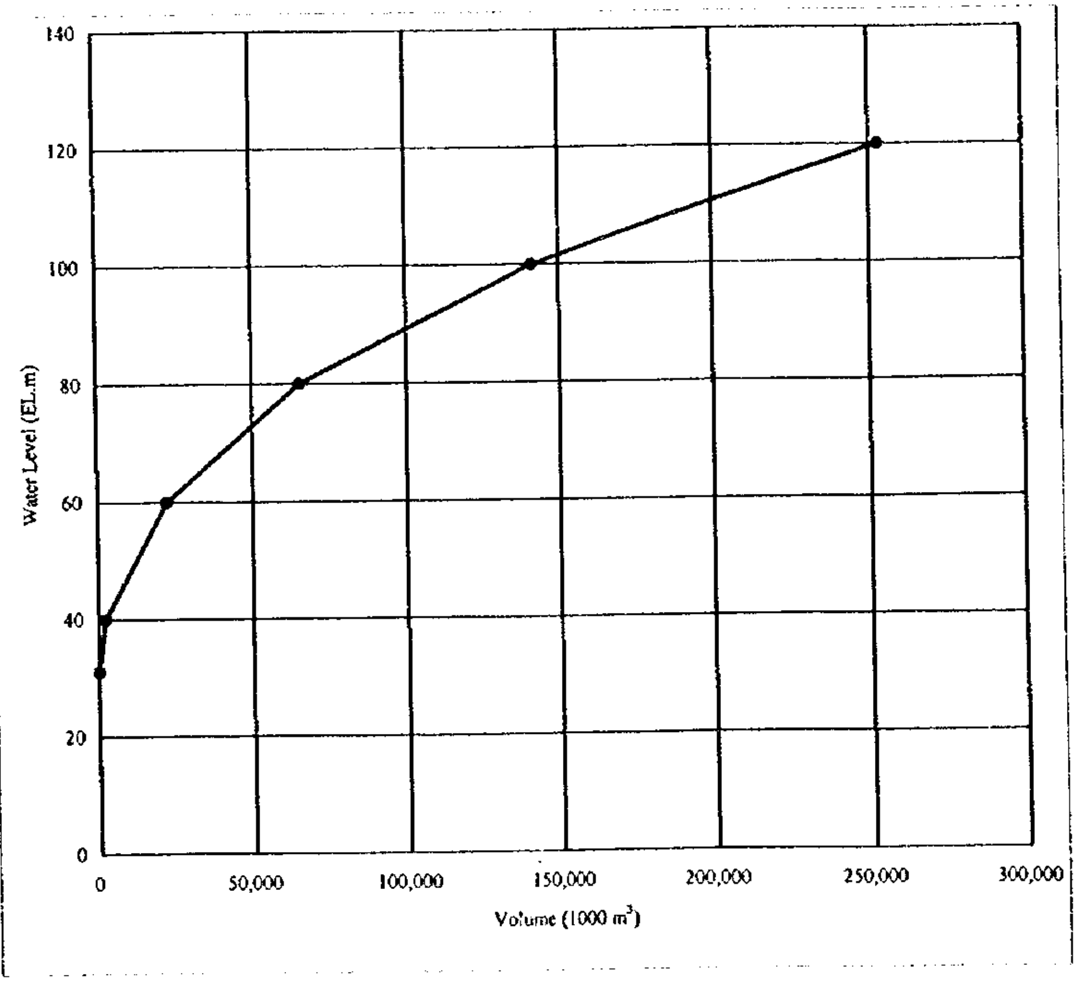


Figure-E6.1 Relation between Water Level and Storage Volume of N-3 Dam

Table-E6.1 (1/2) Runoff Analysis for N-3 Dam Effect on Flood Control

date	hr.	min	Discharge: after Namosi river m³/s	Discharge: before Nawaka river m³/s	Discharge: river mouth m³/s	Discharge: Dam inflow m³/s	Discharge: Dam outflow m³/s	Reservoir: Water Level EL m	Reservoir: Volume m³
1	0	0	16.6	21.9	40.8	10.9	0.0	77.40	0
1	0	30	16.6	21.9	40.8	10.9	0.0	77.41	23,950
1	1	0	16.6	21.9	40.8	10.9	0.0	77.42	47,990
1	1	30	16.6	21.9	40.8	10.9	0.0	77.43	72,030
1	2	0	16.6	21.9	40.8	10.9	0.0	77.44	96,070
1	2	30	16.6	21.9	40.8	10.9	0.0	77.45	120,100
1	3	0	16.7	21.9	40.8	10.9	0.1	77.46	144,140
1	3	30	16.7	21.9	40.8	10.9	0.1	77.47	168,180
1	4	0	16.7	21.9	40.8	10.9	0.1	77.48	192,220
1	4	30	16.7	21.9	40.8	10.9	0.1	77.49	216,260
1	5	0	16.7	21.9	40.8	10.9	0.1	77.50	240,300
1	5	30	16.8	21.9	40.8	10.9	0.2	77.51	264,340
1	6	0	16.8	21.9	40.8	10.9	0.2	77.52	288,380
1	6	30	16.8	21.9	40.8	10.9	0.2	77.53	312,420
1	7	0	16.8	21.9	40.8	10.9	0.2	77.53	336,460
1	7	30	16.8	21.9	40.8	10.9	0.2	77.54	360,500
1	8	0	16.9	21.9	40.8	10.9	0.3	77.55	384,540
1	8	30	16.9	21.9	40.8	10.9	0.3	77.56	408,580
1	9	0	16.9	21.9	40.8	10.9	0.3	77.57	432,620
1	9	30	16.9	21.9	40.8	10.9	0.3	77.58	456,660
1	10	0	17.0	21.9	40.8	10.9	0.4	77.59	480,700
1	10	30	17.0	21.9	40.8	10.9	0.4	77.60	504,740
1	11	0	17.0	21.9	40.8	10.9	0.4	77.61	528,780
1	11	30	17.1	21.9	40.8	10.9	0.5	77.62	552,820
1	12	0	17.1	21.9	40.8	10.9	0.5	77.63	576,860
1	12	30	17.1	22.0	40.9	10.9	0.5	77.64	600,900
1	13	0	17.2	22.0	40.9	10.9	0.6	77.65	624,940
1	13	30	17.2	22.1	41.0	10.9	0.6	77.66	648,970
1	14	0	17.2	22.1	41.0	10.9	0.6	77.67	673,010
1	14	30	17.3	22.1	41.0	10.9	0.7	77.68	697,050
1	15	0	17.3	22.2	41.1	10.9	0.7	77.69	721,090
1	15	30	17.3	22.2	41.1	10.9	0.7	77.70	745,130
1	16	0	17.4	22.2	41.1	10.9	0.8	77.71	769,170
1	16	30	17.4	22.2	41.1	10.9	0.8	77.72	793,210
1	17	0	17.5	22.3	41.2	11.0	0.8	77.73	817,250
1	17	30	17.5	22.3	41.2	11.0	0.9	77.74	841,290
1	18	0	17.5	22.4	41.3	11.0	0.9	77.75	865,330
1	18	30	17.6	22.4	41.3	11.0	0.9	77.76	889,370
1	19	0	17.6	22.4	41.3	11.0	1.0	77.77	913,410
1	19	30	17.7	22.5	41.4	11.0	1.0	77.78	937,450
1	20	0	17.7	22.5	41.4	11.0	1.1	77.79	961,490
1	20	30	17.8	22.6	41.5	11.1	1.1	77.80	985,530
1	21	0	18.1	22.6	41.5	11.2	1.1	77.80	1,009,560
1	21	30	19.2	22.6	41.5	12.2	1.2	77.81	1,033,600
1	22	0	21.8	22.7	41.6	14.6	1.2	77.82	1,057,640
1	22	30	28.9	22.8	41.7	21.2	1.3	77.83	1,081,680
1	23	0	41.2	23.0	41.9	32.9	1.3	77.85	1,129,760
1	23	30	58.4	23.6	42.6	49.4	1.5	77.88	1,201,880
2	0	0	79.5	25.2	44.4	70.9	1.7	77.92	1,298,040
2	0	30	101.1	30.4	50.4	95.1	1.9	77.98	1,442,280
2	1	0	122.8	40.3	62.8	122.0	2.3	78.06	1,634,590
2	1	30	117.1	43.0	70.8	125.0	2.8	78.14	1,850,950
2	2	0	110.7	48.1	79.6	125.9	3.3	78.23	2,067,300
2	2	30	146.4	60.7	92.3	166.5	4.0	78.34	2,331,740
2	3	0	190.0	77.0	110.7	211.0	4.9	78.47	2,668,290
2	3	30	211.3	98.4	137.0	228.2	6.0	78.62	3,052,920
2	4	0	227.1	118.5	164.8	244.1	7.2	78.79	3,461,590
2	4	30	216.0	132.4	189.7	245.3	8.6	78.96	3,894,300
2	5	0	207.7	152.8	219.4	248.5	10.1	79.14	4,327,010
2	5	30	206.2	182.9	255.6	253.0	11.6	79.31	4,759,720
2	6	0	207.0	213.7	295.2	250.5	13.2	79.48	5,192,430
2	6	30	214.9	235.9	329.2	244.7	14.8	79.65	5,601,100
2	7	0	224.0	250.1	353.7	237.7	16.5	79.81	6,009,770

Table-E6.1 (2/2) Runoff Analysis for N-3 Dam Effect on Flood Control

date	hr.	min	Discharge: after Namosi river m³/s	before Nawaka river m³/s	river mouth m³/s	Dam inflow m³/s	Dam outflow m³/s	Reservoir: Water Level EL.m	Volume m³
2	7	30	247.2	259.9	371.6	245.3	18.2	79.97	6,418,440
2	8	0	269.5	267.0	387.5	255.2	19.6	80.11	6,830,450
2	8	30	298.9	275.0	405.2	273.0	21.1	80.24	7,259,780
2	9	0	325.5	283.7	424.6	292.7	22.7	80.39	7,719,780
2	9	30	444.8	294.9	447.5	402.0	24.9	80.57	8,302,440
2	10	0	560.9	310.4	474.3	511.7	27.8	80.81	9,069,100
2	10	30	649.2	342.4	517.6	591.4	31.5	81.11	10,019,770
2	11	0	754.9	377.2	573.2	729.5	36.1	81.47	11,154,430
2	11	30	722.7	418.0	644.2	827.4	40.6	81.88	12,473,090
2	12	0	713.5	492.9	739.9	977.6	45.3	82.37	14,006,420
2	12	30	675.3	588.9	846.8	1,052.5	50.9	82.92	15,754,400
2	13	0	647.8	696.2	963.6	986.2	55.6	83.47	17,502,390
2	13	30	665.2	778.4	1,054.1	881.0	59.3	83.96	19,066,380
2	14	0	686.0	807.7	1,093.5	808.4	62.5	84.40	20,477,050
2	14	30	698.8	802.1	1,099.1	744.2	65.3	84.81	21,765,040
2	15	0	708.7	779.7	1,082.4	713.5	67.7	85.16	22,948,700
2	15	30	680.8	760.4	1,063.9	679.0	69.8	85.49	24,089,930
2	16	0	656.0	759.7	1,059.3	656.2	71.7	85.80	25,164,020
2	16	30	603.7	765.1	1,057.0	614.4	73.4	86.09	26,170,980
2	17	0	561.1	772.0	1,054.5	572.2	75.0	86.36	27,110,810
2	17	30	511.7	764.9	1,036.9	516.7	76.4	86.60	27,949,940
2	18	0	472.2	744.5	1,003.0	461.9	77.6	86.81	28,688,380
2	18	30	430.5	711.0	954.0	402.7	78.7	87.00	29,326,120
2	19	0	396.4	668.5	896.6	351.9	79.5	87.15	29,863,170
2	19	30	369.3	623.6	837.6	310.9	80.2	87.27	30,299,520
2	20	0	347.3	579.0	781.1	276.9	80.8	87.38	30,668,740
2	20	30	324.7	535.4	727.2	243.3	81.3	87.48	31,004,390
2	21	0	305.4	494.7	675.6	215.5	81.7	87.55	31,272,910
2	21	30	289.1	459.2	629.2	194.7	82.1	87.62	31,507,870
2	22	0	275.3	428.9	590.0	177.5	82.4	87.68	31,709,260
2	22	30	263.5	401.8	555.5	161.7	82.6	87.73	31,877,090
2	23	0	253.4	377.4	523.7	148.2	82.9	87.77	32,011,350
2	23	30	242.0	355.4	494.5	135.2	83.0	87.80	32,112,050
3	0	0	231.8	336.2	468.4	123.9	83.1	87.82	32,179,180
3	0	30	222.3	319.4	445.2	114.3	83.2	87.83	32,246,310
3	1	0	213.9	304.7	424.6	105.9	83.3	87.84	32,279,870
3	1	30	206.8	291.4	406.1	98.4	83.3	87.85	32,313,440
3	2	0	200.4	279.0	388.7	91.7	83.4	87.86	32,347,010
3	2	30	194.8	267.4	372.7	85.7	83.4	87.86	32,347,010
3	3	0	189.6	256.7	357.9	80.4	83.4	87.86	32,347,010
3	3	30	185.2	246.9	344.3	75.9	83.4	87.86	32,347,010
3	4	0	181.2	238.1	332.0	71.9	83.3	87.85	32,313,440
3	4	30	177.3	230.1	320.8	68.1	83.3	87.84	32,279,870
3	5	0	173.8	222.9	310.6	64.8	83.2	87.83	32,246,310
3	5	30	170.5	216.5	301.3	61.8	83.2	87.82	32,212,740
3	6	0	167.4	210.7	292.9	59.2	83.1	87.82	32,179,180
3	6	30	165.5	205.3	285.1	57.5	83.1	87.81	32,145,620
3	7	0	163.8	200.5	278.0	56.2	83.0	87.80	32,112,050
3	7	30	161.9	196.0	271.3	54.5	83.0	87.79	32,078,480
3	8	0	160.0	191.8	265.1	53.0	82.9	87.77	32,011,350
3	8	30	157.6	188.1	259.5	51.3	82.8	87.75	31,944,220
3	9	0	155.3	184.9	254.5	49.8	82.6	87.73	31,877,090
3	9	30	153.0	182.1	250.0	48.3	82.5	87.71	31,809,960
3	10	0	150.9	179.4	245.7	46.9	82.4	87.69	31,742,820
3	10	30	149.1	176.9	241.7	45.8	82.3	87.67	31,675,700
3	11	0	147.6	174.3	237.7	44.7	82.2	87.65	31,608,570
Peak Value			754.9	807.7	1,099.1	1,052.5	83.4	87.86	32,347,910
C.A [km²]			274.6	327.3	515.9	109.0			Peak x 1.2 = 38,817,490

6.2 Water Supply

The necessity of domestic water supply was examined in Chapter 5 of Main Report. Based on the examination of water demand, the storage capacity of dam as water resource and the benefit was determined. The benefit of dam is considered as revenue born from water supply charge and was computed with applying the revenue rate of F$ 85.5/year/(m^3/day) adopted from "Nadi - Lautoka Regional Water Supply Master Plan", PWD. The results are as follows.

- Water demand: 20,000 m^3/day
- Storage of dam required: 10,000,000 m^3
- Annual benefit: F$ 1,710,000/year

6.3 Specifications of Multi-Purpose Dam and Economic Evaluation

Considering the flood control and domestic water supply, the specifications of dam was determined and the result is shown in Tble-E6.2 with its construction cost.

Table-E6.2 Specifications and Cost of Dam

Specification	Quantity
1) Dam	N-3 Dam
2) Catchment Area	109 km^2
3) Sediment Storage	49.0 x 10^6 m^3
Sediment Storage per Unit Area	4,500 m^3/km^2/year
Design Sedimentation Year	100 years
4) Capacity of Water Utilization	10.0 x 10^6 m^3
5) Flood Control Capacity	38.8 x 10^6 m^3
6) Reservoir Capacity	97.8 x 10^6 m^3
7) Base Level	EL. 30.0 m
8) Normal Water Level	EL. 77.4 m
9) Surcharge Water Level	EL. 89.7 m
10) Top of the Dam	EL. 94.7 m
11) Height of Dam	64.7 m
12) Volume Content of Dam	2.175 x 10^6 m^3
Construction Cost	F$ 217.5 x 10^6

* Unit Cost = F$ 100/m^3 (per unit volume content of dam excluding tax)

Relation between flood damage and discharge for N-3 dam was determined as shown in Figure-E6.2. Based on that relation, annual average damage reduction by N-3 dam was estimated and the result is shown in Table-E6.3. Since the benefit of N-3 dam is the sum of revenue born from water supply and annual damage reduction, it will be F$ 10,138,000/year (F$ 1,710,000/year + F$ 8,428,000/year).

Damage by Cyclone KINA

Watershed	Nadi	Remark	
(1)General Assets	16,602,000	Effective Ratio of Measures	1.0
(2)Agricultural Crops	1,727,000		
(3)Business Activities	300,000		
(4)Public Structure	6,641,000	(1) x 40%	
Total	25,270,000		

25,270 10^3 F$

Nadi River

Whole Catchment Area(km²)		515	
Harmless Discharge	Point (km)	11.0	
	Catchment Area (km²)	330	
	Ground Height (EL m)	5.20	
	Clearance (m)	0.00	
	Water Level (EL m)	5.20	
	Q (m³/s)	350	
	Q at River Mouth (m³/s)	550	1/2.5*
Discharge of Cyclone KINA (1/5)		960	

*: Return Period of Harmless Discharge
Q: Discharge
Point: Distance from River Mouth

Damage(10^3 F$)	Q(m³/s)	
0	550	
25,270	960	
95,533	2,100	1/20

Q=aD+b : a= 0.016 b= 550
D=cQ+d : c= 61.63 d= -33,899

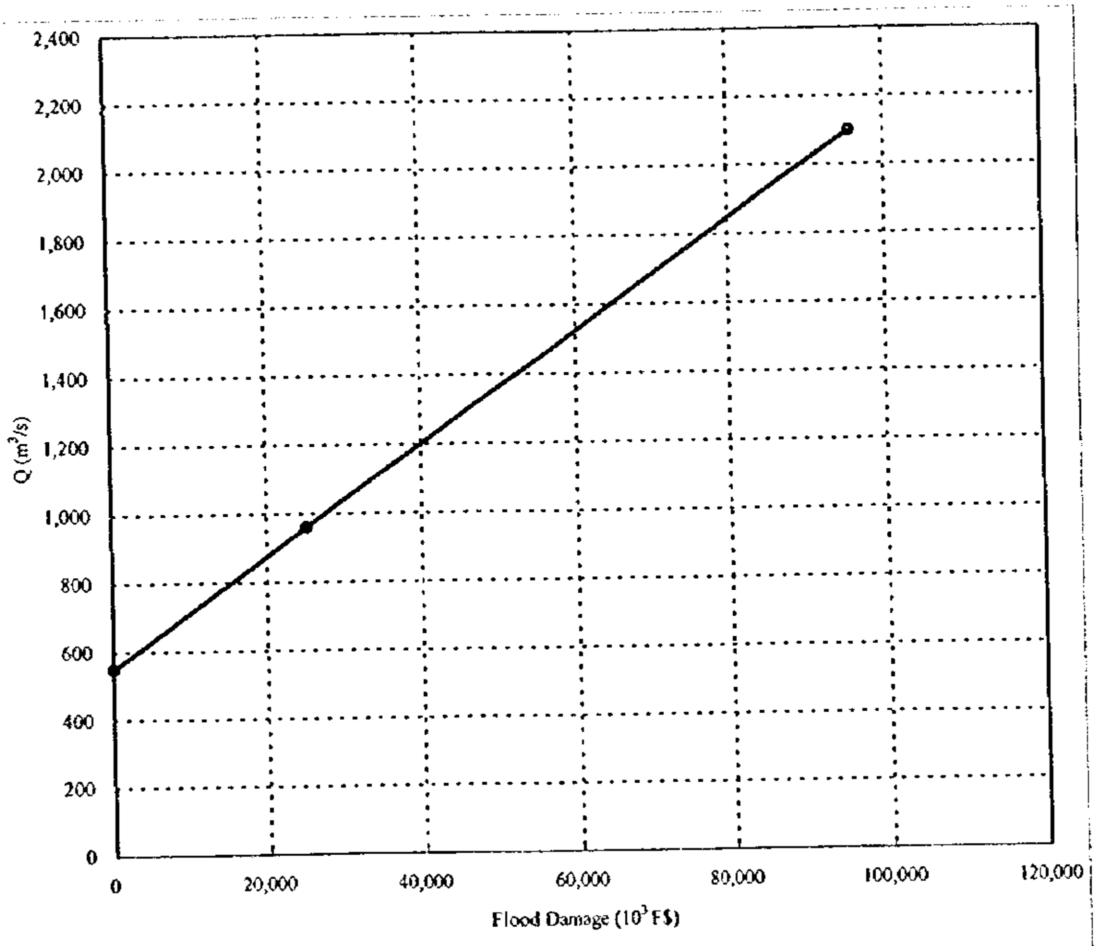


Figure-E6.2 Relation between Flood Damage and Discharge for N-3 Dam

Table-E6.3 Annual Average Damage Reduction by N-3 Dam

River	Return Period		Annual Average Return Periods	Discharge			Flood Damage		Flood Damage Reduction	Average Flood Damage Reduction	Annual Average Flood Damage Reduction
				Current	After Imple-mentation	Effect	Current	After Imple-mentation			
			①	②	③	④=②-③	⑤	⑥	⑦=⑤-⑥	⑧=(⑦n+⑦n-1)/2⑦	⑨=①x⑧
				m^3/sec	m^3/sec	m^3/sec	10^3F$	10^3F$	10^3F$	10^3F$	10^3F$
Nadi	1/20	0.050	-	2,100	1,100	1,000	95,533	33,899	61,634	-	-
	1/10	0.100	0.050	1,400	730	670	52,389	11,094	41,295	51,465	2,573
	1/5	0.200	0.100	960	500	460	25,270	0	25,270	33,282	3,328
	1/2.5	0.400	0.200	550	290	260	0	0	0	12,635	2,527
Total											8,428

The economic evaluation of the multi-purpose dam (N-3) was conducted based on the economic benefit and cost. The benefit consists of the annual damage reduction by flood control and revenue by water supply. The cost here does not include the land acquisition cost. As shown in Table-E6.4, EIRR of the dam project is "negative" and B/C of 0.29 at the discount rate of 10 % implies that the project is not feasible. Since the economic evaluation of the Master Plan which consists of a diversion channel and a short cut channel shows EIRR of 15.06 and B/C of 1.61, the Master Plan is much more feasible and effective compared to the multi-purpose dam.

Table-E6.4 Economic Evaluation of Dam

	Nadi Multi-Purpose Dam
Economic Benefit (10^3 F$/year)	*10,138
Economic Cost of Project (10^3 F$)	295,143
Annual Maintenance Cost (10^3 F$)	223
EIRR (%)	negative
B/C (Ratio) (Discount Rate: 10 %)	0.29
NPV (Discount Rate: 10 %)	-166,747

Note: a) The project life of the Multi-Purpose Dam is assumed to be 80 years.
b) *: Total of F$ 8,428,000 (benefit of flood control) and F$ 1,710,000 (benefit of water supply)
c) Project cost does not include the land acquisition cost.

CHAPTER 7 CASE STUDY OF DREDGING IN REWA RIVER

Dredging has been conducted in Rewa river, and Table-E7.1 shows its work in the last 5 years, from 1992 to 1996.

Table-E7.1 Dredging in Rewa River

Year	Dredging Section (distance from river mouth, km)			Total Length (km)	Cost (F$)
	13.0 ~ 15.5	16.5 ~ 17.5	19.0 ~ 20.0		
1992	402,000 m^3	–	–	2.0	1,085,229
1993	256,000 m^3	–	–	2.0	1,090,560
1994	*160,000 m^3	*80,000 m^3	–	2.0	756,171
1995	*142,795 m^3	–	* 90,000 m^3	2.0	1,033,389
1996	292,109 m^3	–	–	2.5	914,682
Total	1,252,904 m^3	80,000 m^3	90,000 m^3	10.5	4,880,031

*: The data is available only for total volume and river section dredged. Therefore, the total volume (240,000 m^3 and 232,795 m^3) was divided by a ratio of section length to obtain the volume of each section for 1994 and 1995.

Source: Drainage and Irrigation, MAFFA

The current flow capacity of river was compared with the flow capacity after dredging to assess the effect of dredging on flood control. Since only volume of dredging and river section are available, the cross section of dredging was assumed to be as follows.

1) 13.0 ~ 15.5 km: 300 m (width) x 1.67 m (depth) x 2,500 m (length) = 1,252,500 m^3
2) 16.5 ~ 17.5 km: 80 m (width) x 1.00 m (depth) x 1,000 m (length) = 800,000 m^3
3) 19.0 ~ 20.0 km: 90 m (width) x 1.00 m (depth) x 1,000 m (length) = 900,000 m^3

Non uniform flow was applied to calculate the flow capacity before and after dredging based on results of cross section survey. Stages at discharge of 5,000 m^3/sec, which flows without overspill from a river channel, were also calculated by non-uniform flow to examine the effect of dredging as shown in Table-E7.2 and longitudinal profit of stages is shown in Figure-E7.1.

Table-E7.2 (1/2) Water Level Calculation (5,000 m^3/sec)

Cross Section	delta X	X	Q	H	
				Present	After Dredging
	(m)	(m)	(m^3/s)	(m)	(m)
REWA 0	0	0	5,000	1.000	1.000
REWA 500	500	500			
REWA 1000	500	1,000	5,000	1.512	1.512
REWA 1500	500	1,500	5,000	1.774	1.774
REWA 2000	500	2,000	5,000	1.983	1.983
REWA 2500	500	2,500	5,000	2.241	2.241
REWA 3000	500	3,000	5,000	2.442	2.442
REWA 3500	500	3,500	5,000	2.581	2.581
REWA 4000	500	4,000	5,000	2.518	2.518
REWA 4500	500	4,500	5,000	2.750	2.750
REWA 5000	500	5,000	5,000	3.157	3.157
REWA 5500	500	5,500	5,000	3.487	3.487
REWA 6000	500	6,000	5,000	3.578	3.578
REWA 6500	500	6,500	5,000	3.634	3.634
REWA 7000	500	7,000	5,000	3.813	3.813
REWA 7500	500	7,500	5,000	3.943	3.943
REWA 8000	500	8,000	5,000	4.078	4.078
REWA 8500	500	8,500	5,000	4.162	4.162
REWA 9000	500	9,000	5,000	4.247	4.247
REWA 9500	500	9,500	5,000	4.279	4.279
REWA 10000	500	10,000	5,000	4.344	4.344
REWA 10500	500	10,500	5,000	4.362	4.362
REWA 11000	500	11,000	5,000	4.403	4.403
REWA 11500	500	11,500	5,000	4.464	4.464
REWA 12000	500	12,000	5,000	4.638	4.638
REWA 12500	500	12,500	5,000	4.735	4.735
REWA 13000	500	13,000	5,000	4.825	4.839
REWA 13500	500	13,500	5,000	4.821	4.830
REWA 14000	500	14,000	5,000	4.966	4.923
REWA 14500	500	14,500	5,000	5.036	4.971
REWA 15000	500	15,000	5,000	5.088	5.008
REWA 15500	500	15,500	5,000	5.206	5.079
REWA 16000	500	16,000	5,000	5.279	5.099
REWA 16500	500	16,500	5,000	5.370	5.204
REWA 17000	500	17,000	5,000	5.568	5.399
REWA 17500	500	17,500	5,000	5.487	5.324
REWA 18000	500	18,000	5,000	5.677	5.491
REWA 18500	500	18,500	5,000	5.913	5.743
REWA 19000	500	19,000	4,670	6.048	5.891
REWA 19500	500	19,500	4,670	6.180	6.021
REWA 20000	500	20,000	4,670	6.244	6.083
REWA 20500	500	20,500	4,670	6.335	6.164
REWA 21000	500	21,000	4,670	6.437	6.275
REWA 21500	500	21,500	4,670	6.595	6.445
REWA 22000	500	22,000	4,670	6.690	6.546
REWA 22500	500	22,500	4,670	6.736	6.597
REWA 23000	500	23,000	4,670	6.912	6.780
REWA 23500	500	23,500	4,670	6.889	6.756
REWA 24000	500	24,000	4,670	6.866	6.735
REWA 24500	500	24,500	4,670	7.049	6.927
REWA 25000	500	25,000	4,670	7.362	7.251
REWA 25500	500	25,500	4,670	7.393	7.284
REWA 26000	500	26,000	4,670	7.501	7.398
REWA 26500	500	26,500	4,670	7.756	7.661
REWA 27000	500	27,000	4,670	7.760	7.668
REWA 27500	500	27,500	4,670	7.973	7.887
REWA 28000	500	28,000	4,670	8.071	7.988
REWA 28500	500	28,500	4,670	8.156	8.076
REWA 29000	500	29,000	4,670	8.237	8.160
REWA 29500	500	29,500	4,670	8.271	8.195
REWA 30000	500	30,000	4,670	8.468	8.396

Table-E7.2 (2/2) Water Level Calculation (5,000 m^3/sec)

Cross Section	delta X	X	Q	H	
				Present	After Dredging
	(m)	(m)	(m^3/s)	(m)	(m)
REWA 30500	500	30,500	4,670	8.552	8.484
REWA 31000	500	31,000	4,670	8.617	8.550
REWA 31500	500	31,500	4,670	8.773	8.709
REWA 32000	500	32,000	4,670	8.787	8.723
REWA 32500	500	32,500	4,670	8.846	8.784
REWA 33000	500	33,000	4,670	8.913	8.852
REWA 33500	500	33,500	4,670	8.923	8.864
REWA 34000	500	34,000	4,670	9.311	9.259
REWA 34500	500	34,500	4,670	9.246	9.193
REWA 35000	500	35,000	4,670	9.665	9.618
REWA 35500	500	35,500	4,670	9.454	9.406
REWA 36000	500	36,000	4,670	10.043	10.002
REWA 36500	500	36,500	4,670	9.869	9.828
REWA 37000	500	37,000	4,670	10.269	10.233
REWA 37500	500	37,500	4,670	10.446	10.411
REWA 38000	500	38,000	4,670	10.565	10.531
REWA 38500	500	38,500	4,670	10.597	10.565
REWA 39000	500	39,000	4,670	10.648	10.616
REWA 39500	500	39,500	4,670	10.813	10.783
REWA 40000	500	40,000	4,670	10.773	10.742
REWA 40500	500	40,500	4,670	11.143	11.116
REWA 41000	500	41,000	4,670	11.230	11.203
REWA 41500	500	41,500	4,670	11.279	11.253
REWA 42000	500	42,000	4,670	11.345	11.319
REWA 42500	500	42,500	4,670	11.467	11.442
REWA 43000	500	43,000	4,670	11.568	11.544
REWA 43500	500	43,500	4,670	11.660	11.636
REWA 44000	500	44,000	4,670	11.757	11.734
REWA 44500	500	44,500	4,670	11.837	11.815
REWA 45000	500	45,000	4,670	11.816	11.794
REWA 45500	500	45,500	4,670	11.981	11.960
REWA 46000	500	46,000	4,670	12.040	12.019
REWA 46500	500	46,500	4,670	12.139	12.119
REWA 47000	500	47,000	4,670	12.262	12.243
REWA 47500	500	47,500	4,670	12.289	12.269
REWA 48000	500	48,000	3,800	12.437	12.418
REWA 48500	500	48,500	3,800	12.618	12.600
REWA 49000	500	49,000	3,800	12.704	12.686
REWA 49500	500	49,500	3,800	12.765	12.748
REWA 50000	500	50,000	3,800	12.850	12.833

delta X: distance
X: accumulated distance
Q: discharge
H: stage

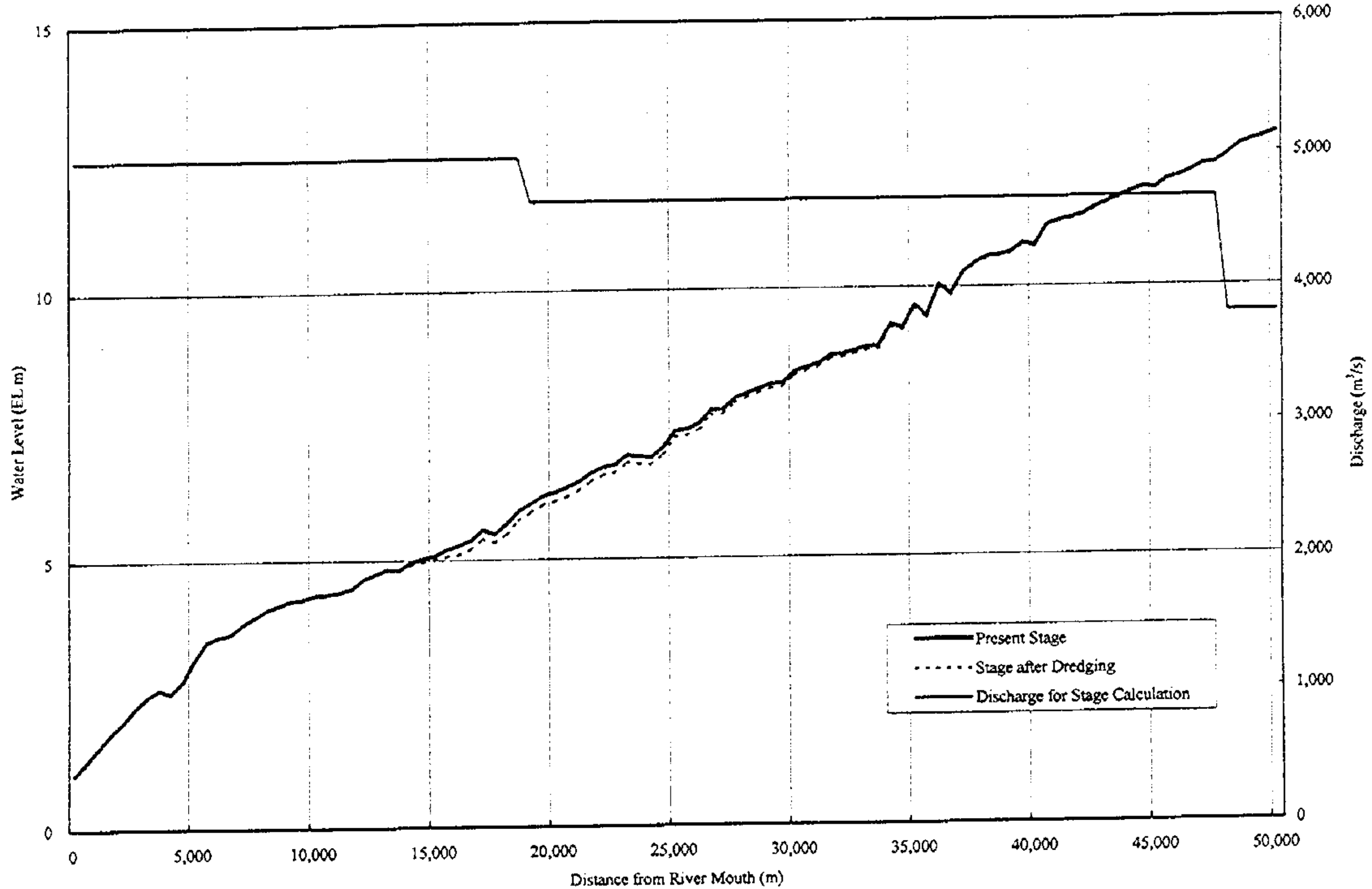


Figure-E7.1 Effect of Dredging on Stage (5,000 m^3/sec)

As shown in Table-E7.3, the maximum effect of dredging is an increase in flow capacity of 280 m^3/sec, approximately 4.5 %, and an increase in stage of about 17 cm. This result is based on the assumption that there is no sedimentation after dredging and dredged bed material is dumped outside of river channel. If dredged material was dumped along the river bank within the channel, dredging would be effective only to maintain water course but not effective on increase in flow capacity. As a result, the dredging is not effective in a large scale flood control but effective to maintain the current cross section of river.

Table-E7.3 Effect of Dredging in Rewa River

Section (Distance from River Mouth)	Flow Capacity				Stage at 5,000 m^3/sec		
	①	②	③	④	⑤	⑥	⑦
	before dredging	after dredging	②-①	③/①	before dredging	after dredging	⑤-⑥
	m^3/sec	m^3/sec	m^3/sec	%	EL. m	EL. m	m
15.0	5,710	5,850	140	2.5	5.088	5.008	0.080
18.5	6,700	6,980	280	4.2	5.913	5.743	0.170
19.0	5,160	5,380	220	4.3	6.048	5.891	0.157
20.0	5,740	5,970	230	4.0	6.244	6.083	0.161
25.0	5,480	5,620	140	2.6	7.362	7.251	0.111