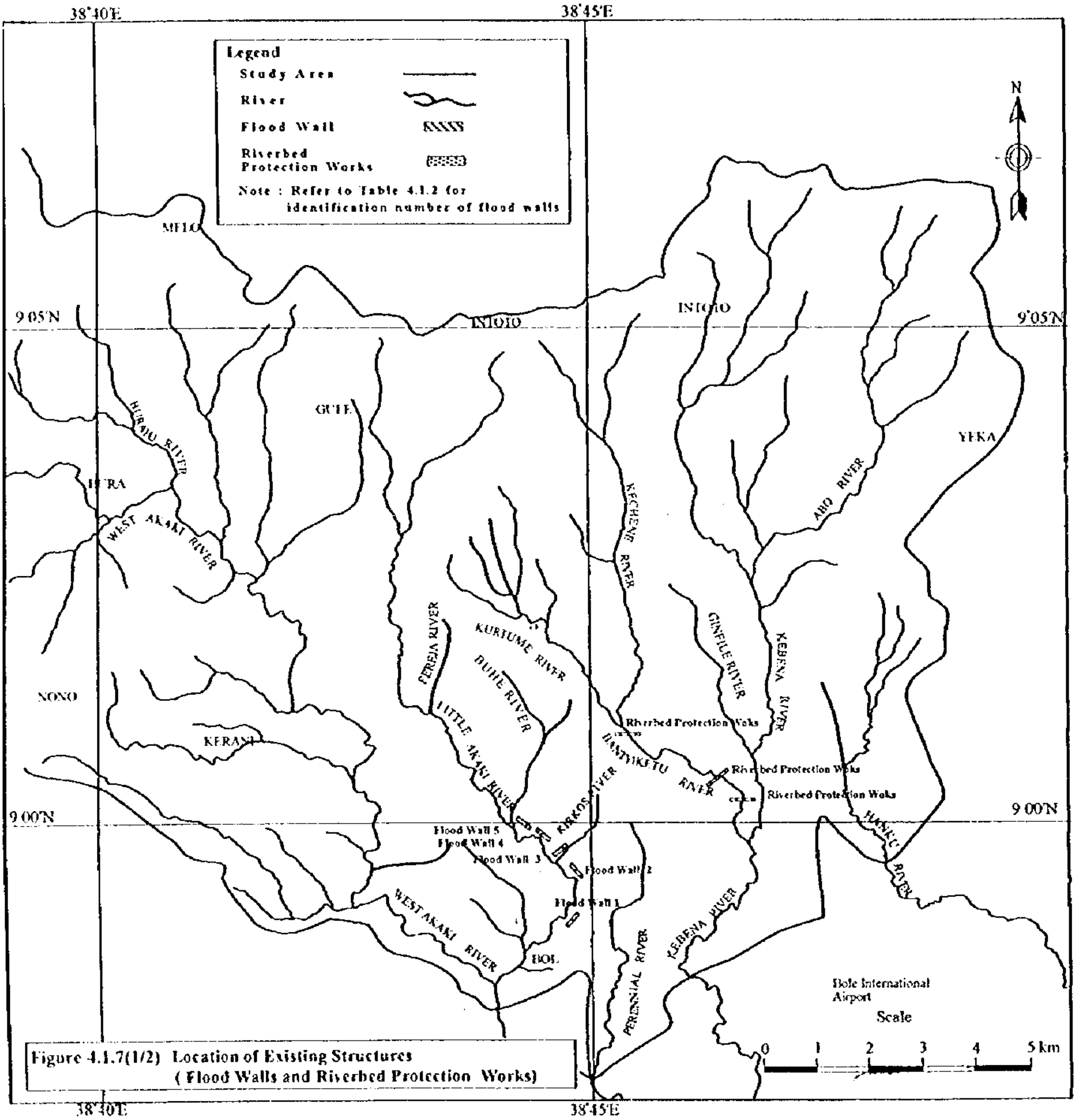


Figure 4.1.7(1/2) Location of Existing Structures
(Flood Walls and Riverbed Protection Works)

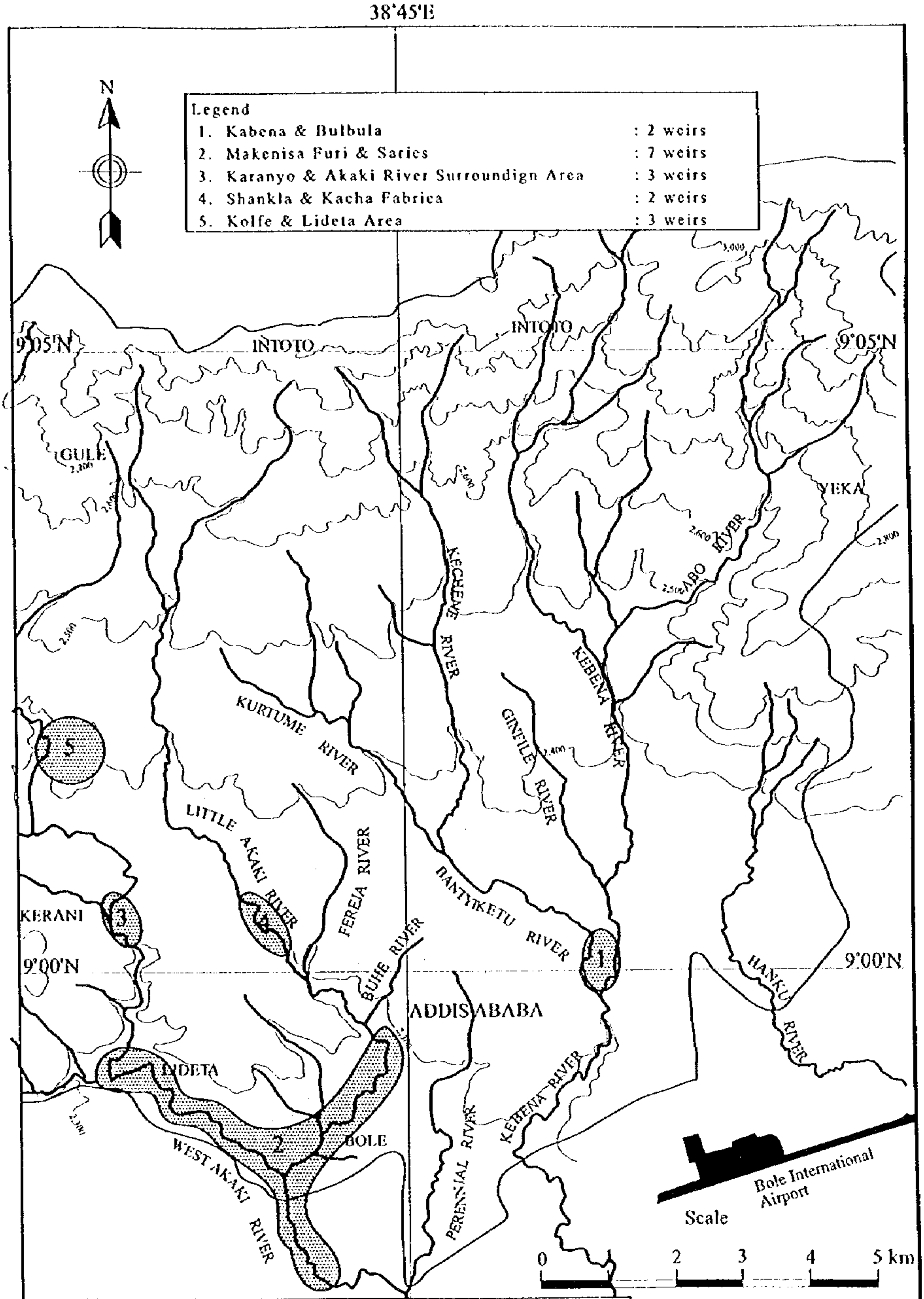


Figure 4.1.7(2/2) Location of Existing Structures (Weirs of Vegetable Grower Association)

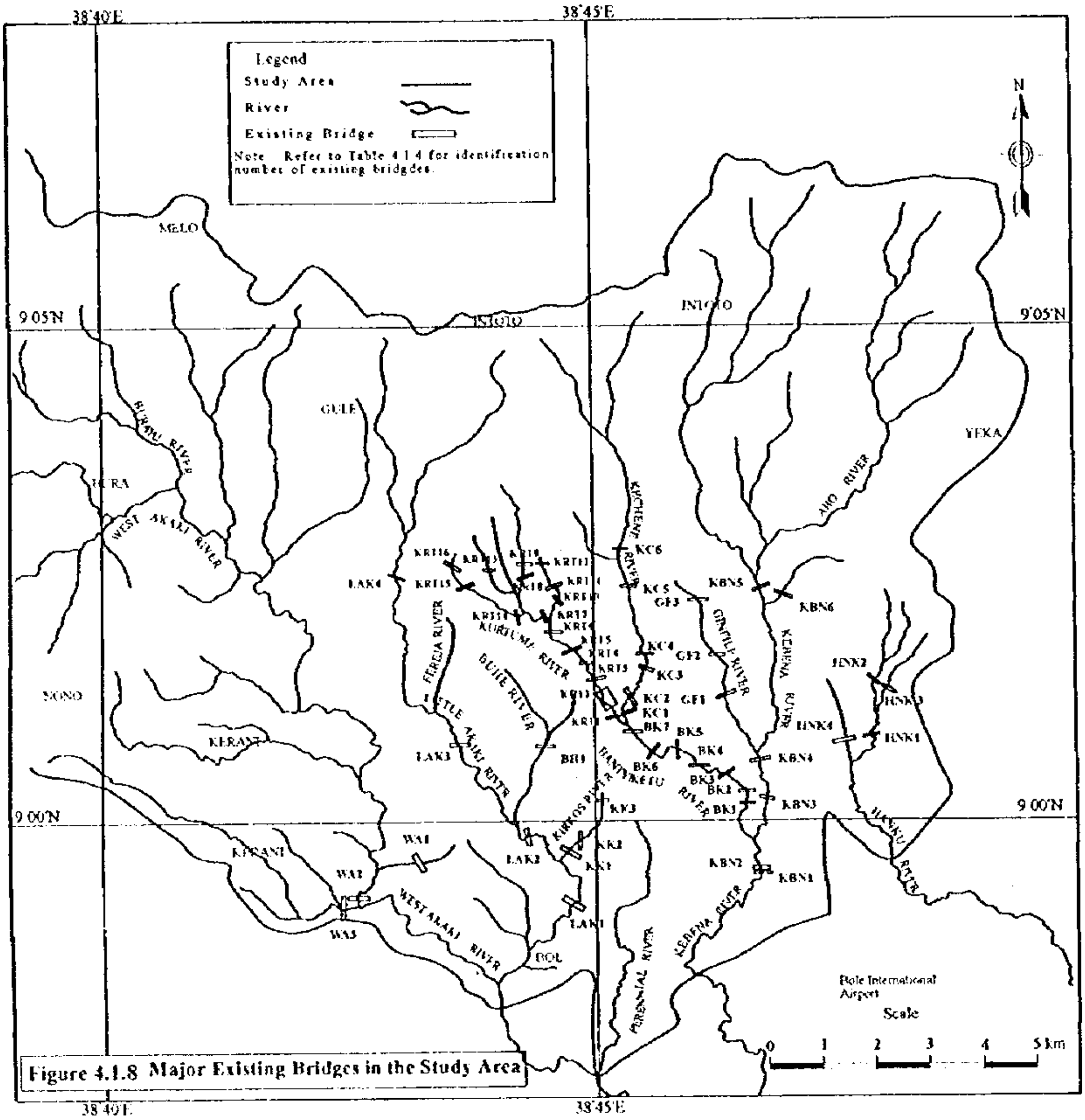


Figure 4.1.8 Major Existing Bridges in the Study Area

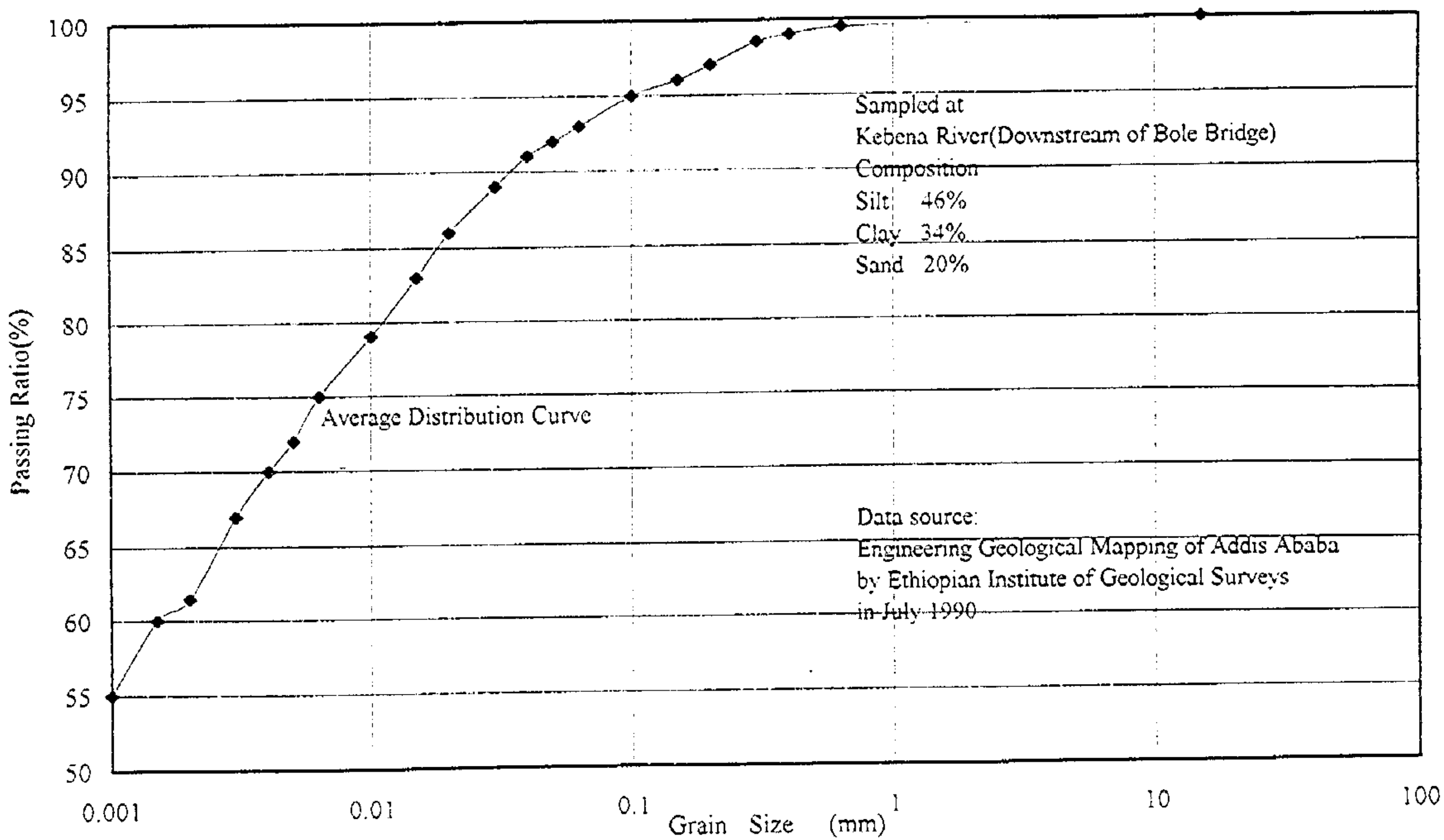


Figure 4.1.9 Grain Size Distribution

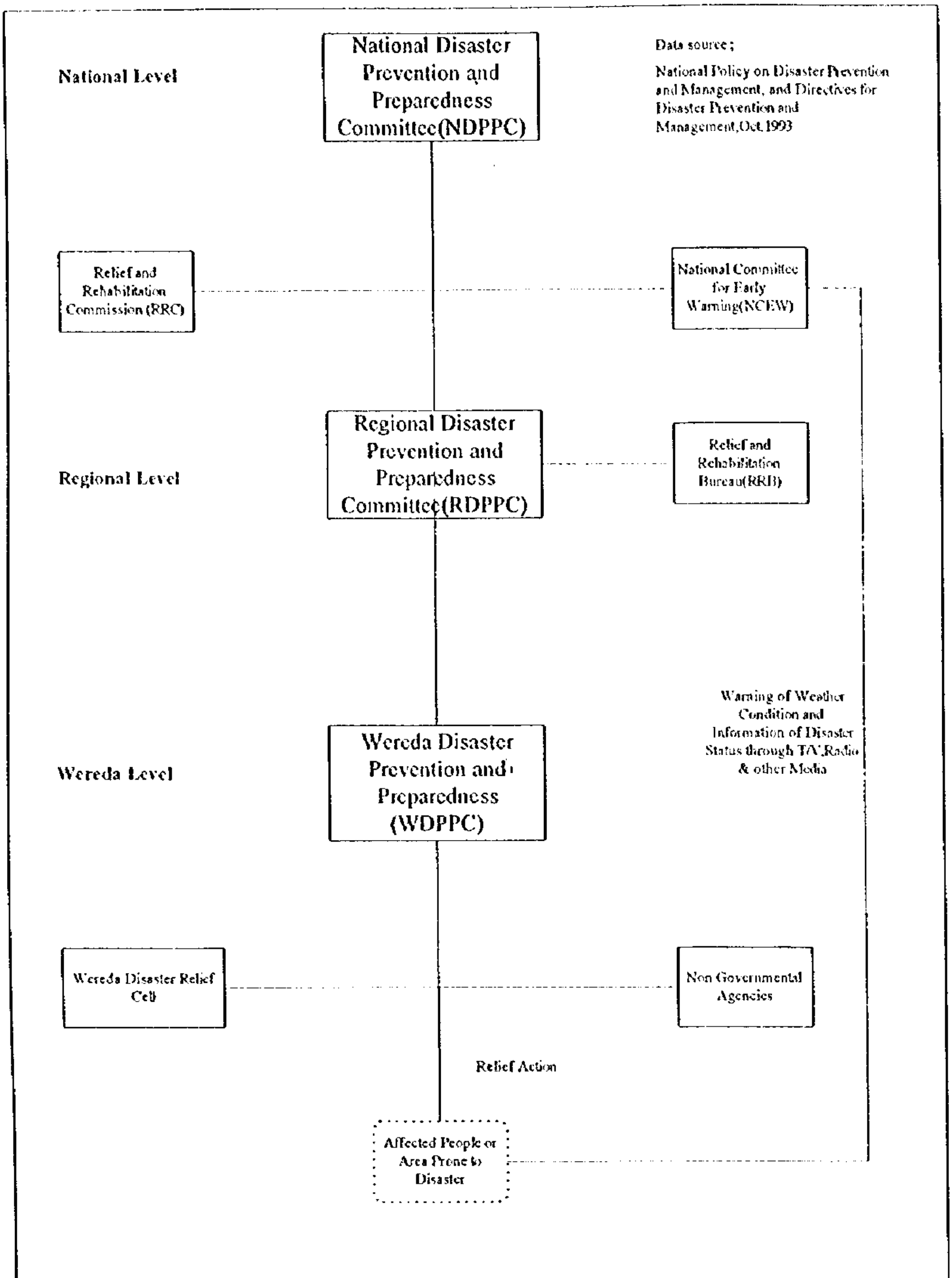


Figure 4.1.10 Organization Chart of Disaster Prevention and Preparedness Management

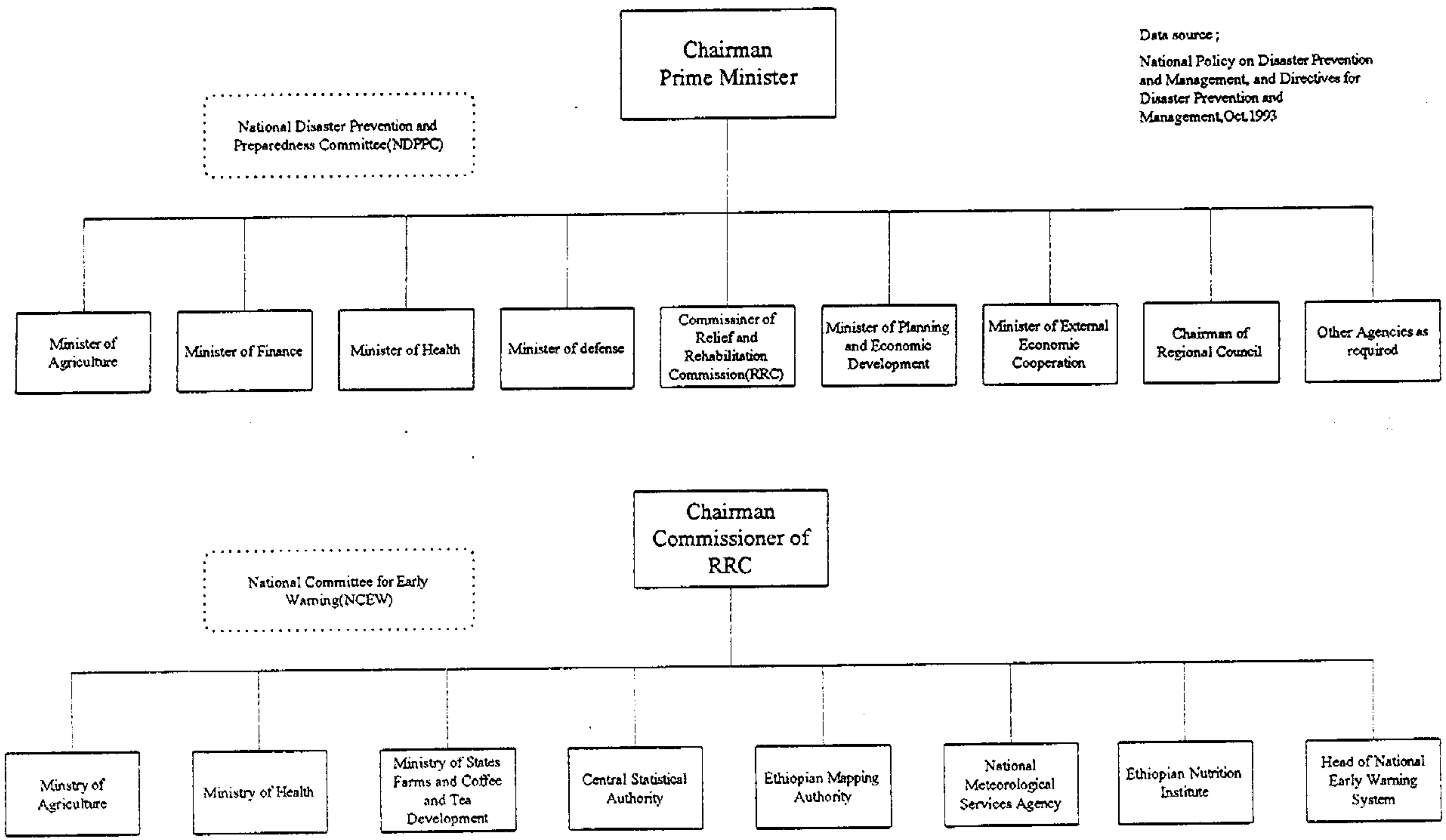
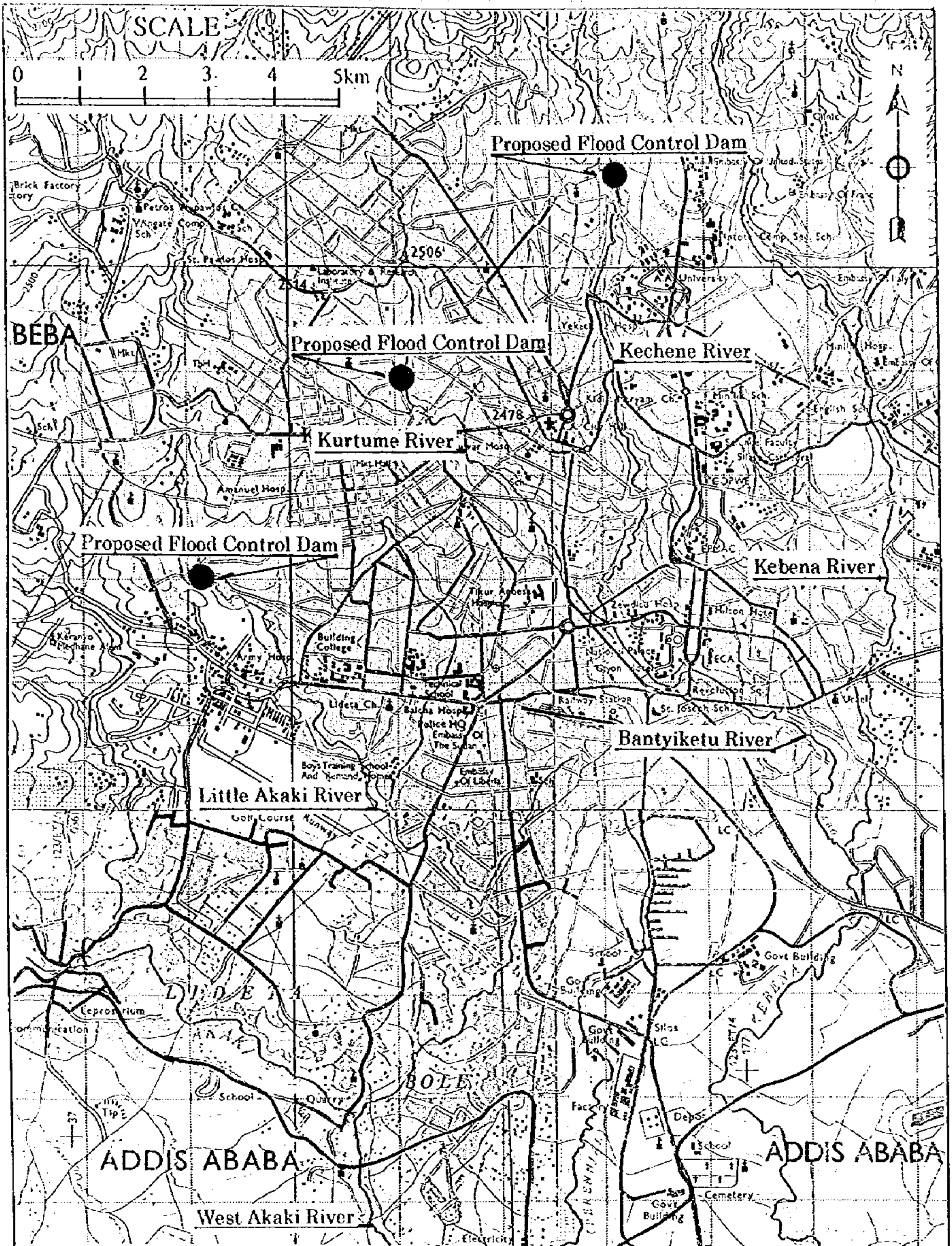


Figure 4.1.11 Organization Chart of NDPPC and NCEW



Data Source: Feasibility Study Report(Volume I General Report), Nov. 1982 by BCEOM

Figure 4.1.12 Proposed Dam Sites by Feasibility Study on Flood Protection and Storm Sewer System

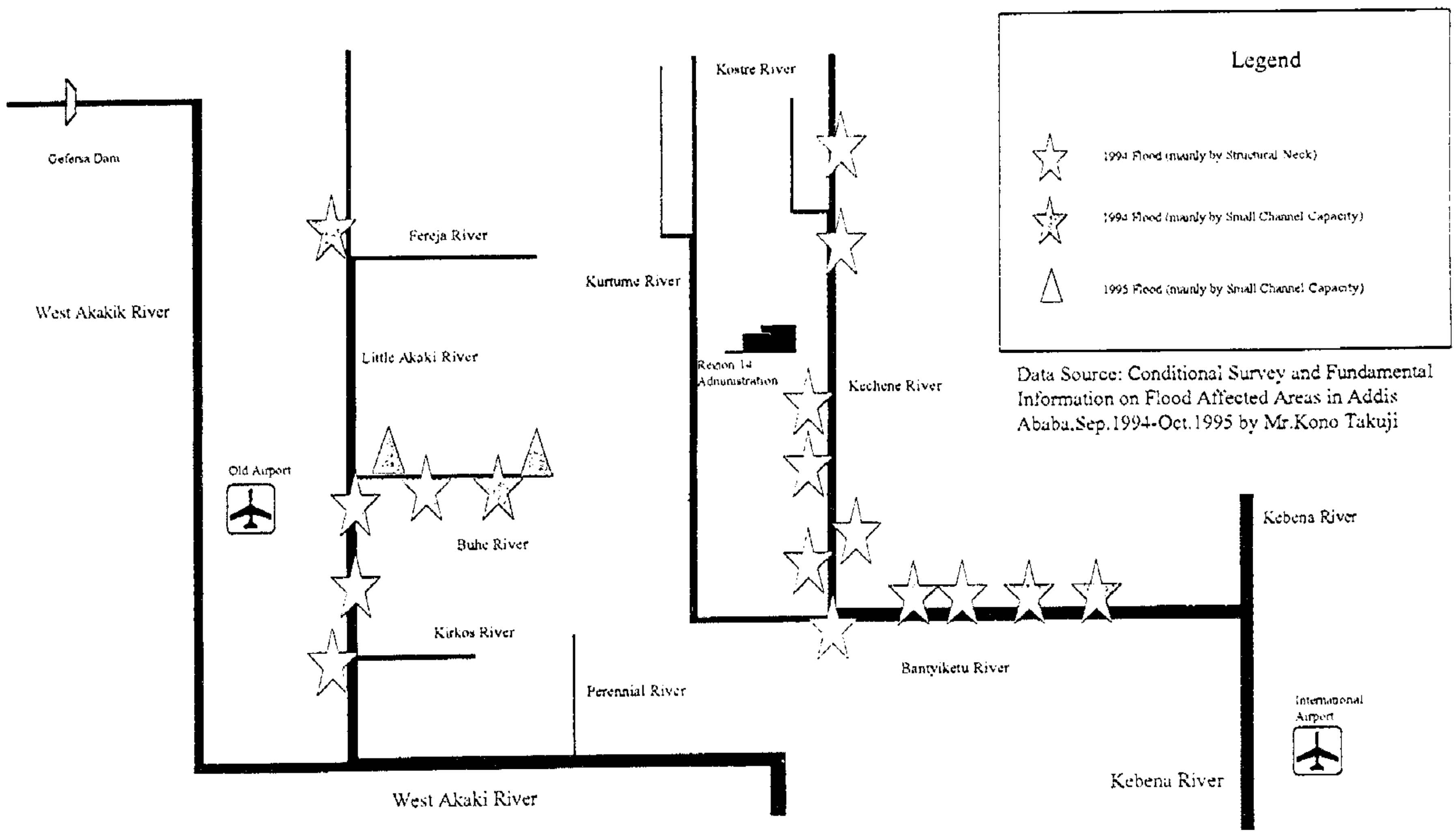


Figure 4.1.13 Locations of Major Flood Damages and Their Reasons

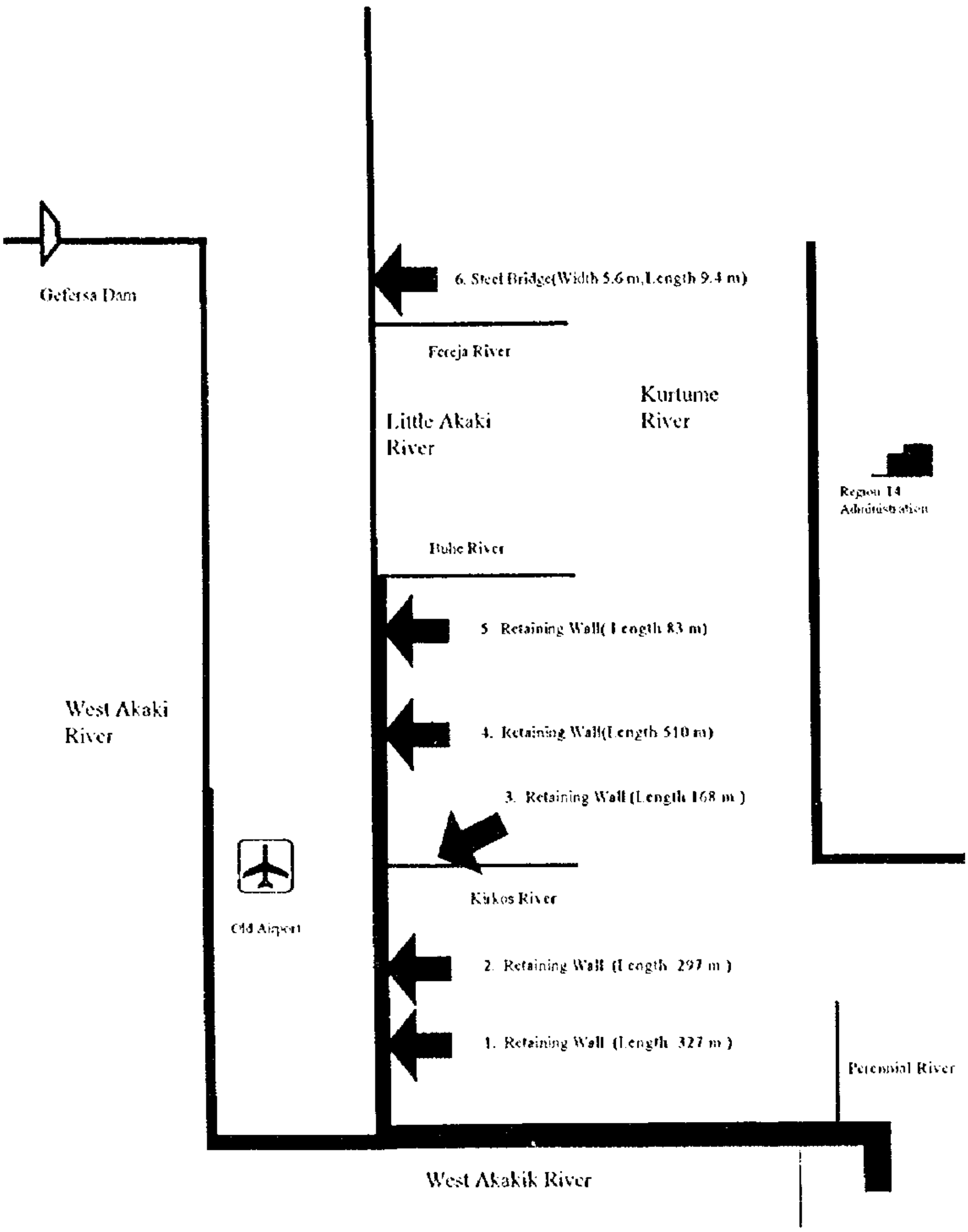


Figure 4.1.14 Locations of Completed Works by AFCPO

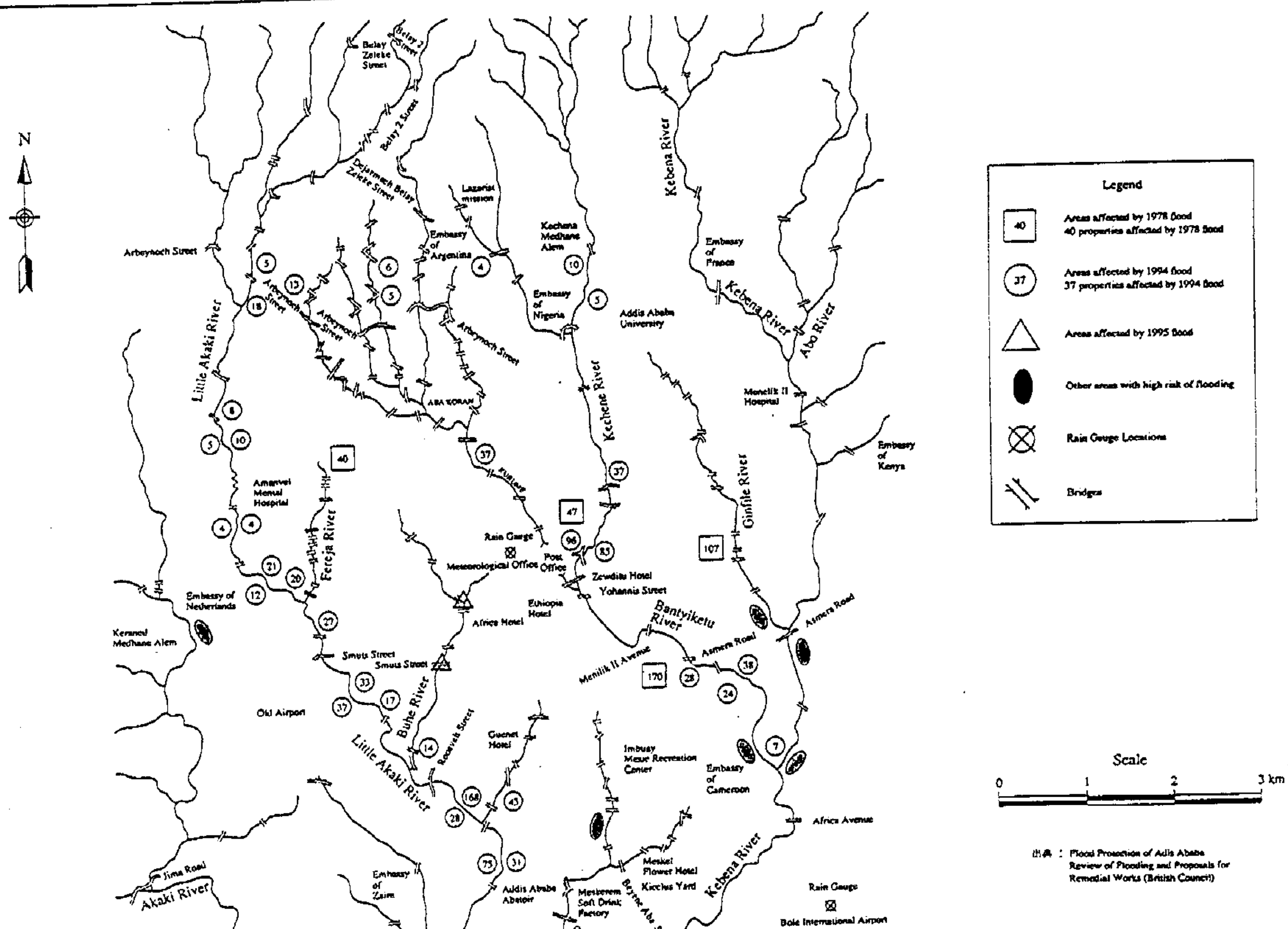


Figure 4.3.1 Flood Affected Areas in Addis Ababa

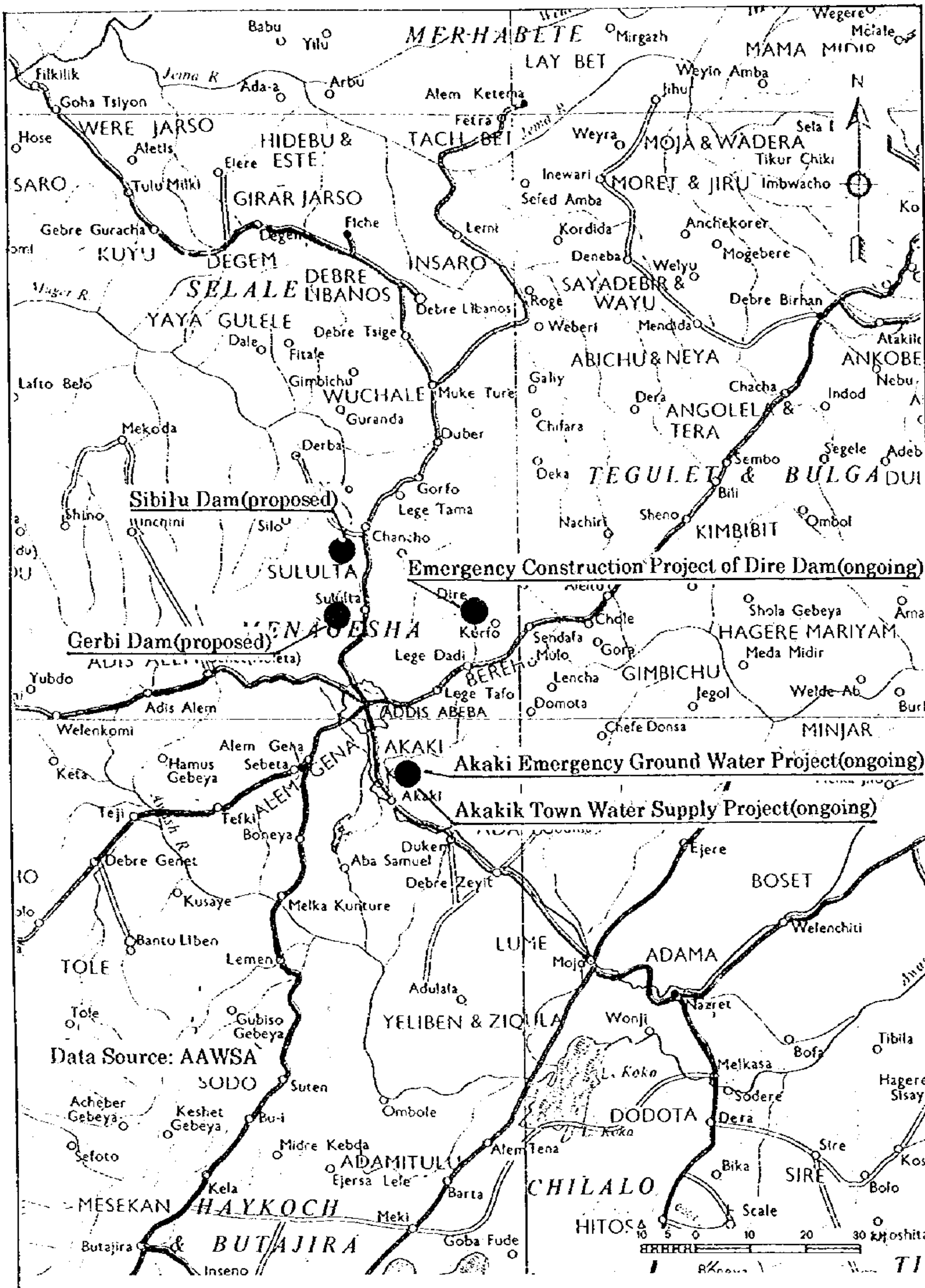


Figure 4.4.1 Project Sites of Ongoing and Proposed by AAWSA

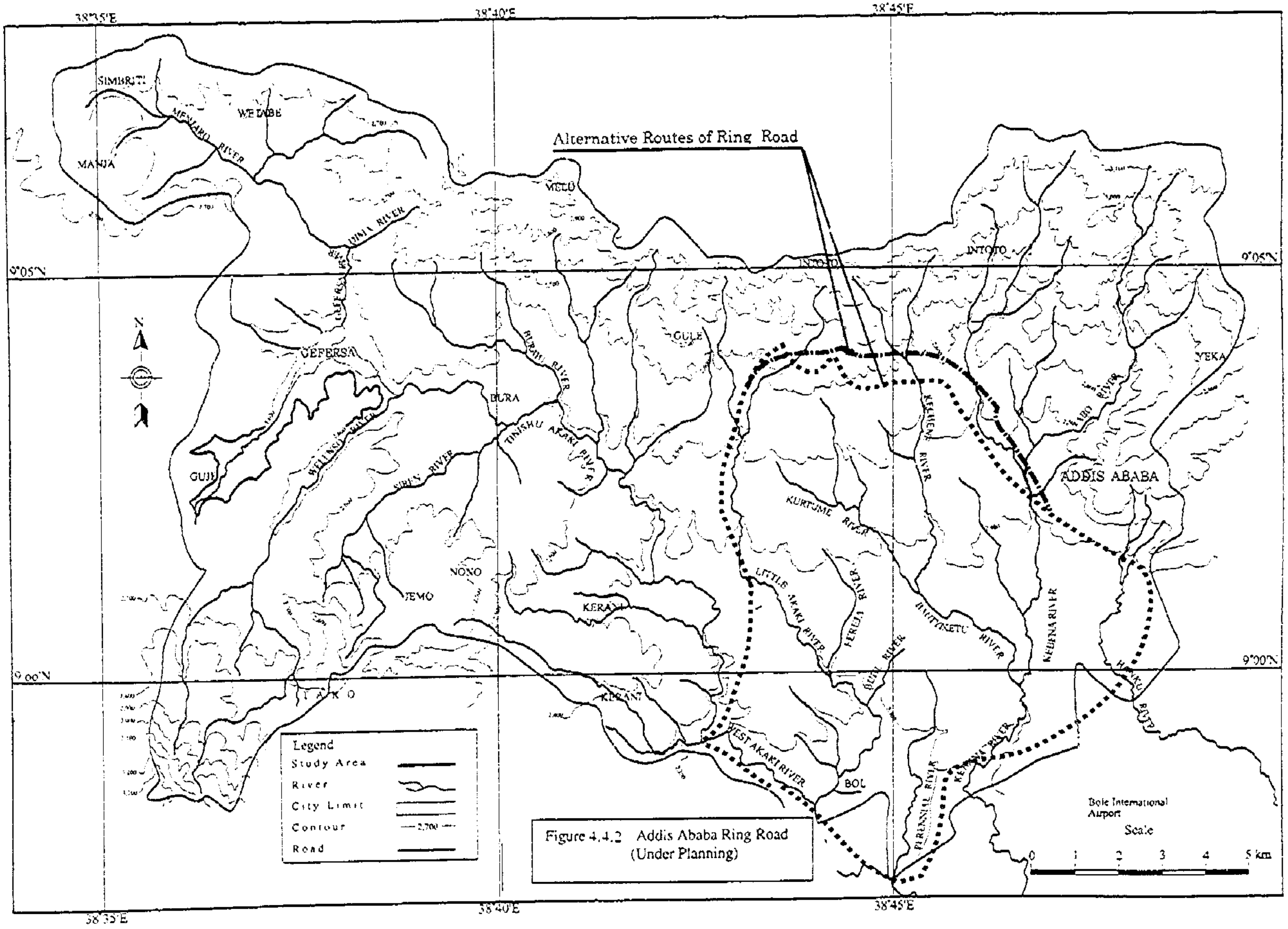


Figure 4.4.2 Addis Ababa Ring Road (Under Planning)

CHAPTER 5

FIELD SURVEY AND INVESTIGATION

THE STUDY

ON

ADDIS ABABA FLOOD CONTROL PROJECT

IN

THE FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

CHAPTER 5 FIELD SURVEY AND INVESTIGATION

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5. FIELD SURVEY AND INVESTIGATION

5.1 River Survey

5.1.1 Outline of Survey Work

(1) Contract and Work Items

The river survey consisting of leveling and cross-section survey was conducted to check flow capacities and characteristics of the present river channels. The river survey was started 3 May 1997, immediately after signing the contract and issuance of the order to the local contractor, and was completed as scheduled until 25 July 1997. The local contractor carried out under instruction and supervision by the Study Team. The main work items and quantities are as follows:

- Leveling survey and establishment of bench marks:	Approximate 70 km in length with 76 points of bench marks
- Cross-section survey:	450 sections with an average interval of 200 m. Width to be surveyed are each river width and plus approximate 20 m each at both river banks
- Drawing work:	Location maps of the surveyed cross-sections using the urban planning maps with a scale of 1:2,000, cross sections and longitudinal profiles

(2) Survey Area and Work Volume

The objective river stretches are shown in Figure 5.1.1. The total river length surveyed was estimated at approximate 70km. Table 5.1.1 shows work volume and details of river stretches surveyed.

(3) Reference Bench Marks

The existing bench marks and the polygonal points confirmed for reference to leveling survey are shown in Figure 5.1.2 and Table 5.1.2, and summarized below.

Confirmed points	Project
3 points (bench marks)	Blue Nile Geodetic Control Project in 1957/60
8 points (bench marks)	Mapping Project for the Urban Planning in Addis Ababa in 1972/73
14 points (polygonal points)	-do-

5.1.2 Survey Result

(1) Leveling Survey

Leveling survey by third order was carried out in order to measure the elevations of bench marks additionally established, cross-section posts and existing structures along river. The measured heights were tied to the elevations of the reference bench marks or polygonal points, which were surveyed for the Blue Nile Geodetic Control Project and the Mapping Project for urban planning in Addis Ababa. The additional bench marks were installed with an interval of 1 km approximately along the river bank and the planned leveling routes.

Locations of the bench marks was plotted on the topographic maps with a scale of 1:10,000 which were prepared for New Cartography for the Expansion Areas of Addis Ababa in 1987. A list of the bench marks are shown in Table 5.1.3.

(2) Cross-section Survey

Measurements of cross-sections were carried out with a interval of 200 m approximately. Supplemental cross-sections at the bridges, other related structures and narrow portions of river were also measured. Locations of cross-sections were identified on the existing topographic maps with a scale of 1:2,000, which were prepared for the urban planning in Addis Ababa.

Applied methods of measurement were either by direct leveling using auto-level or indirect leveling using theodolite depending on the terrain features at the respective cross-sections.

Longitudinal profile along each river was prepared based on the elevations of river bed and both river bank obtained from results of cross-section survey and leveling survey as well as locations of cross-sections indicated on the existing topographic maps with a scale of 1:2,000.

Data processing of survey results was carried out using a CAD system compatible with IBM computers.

Drawing scale of cross-sections and longitudinal profiles are as follows:

- Cross-sections:	Horizontal	1:200
	Vertical	1:200
- Location map of cross-sections:	1:2,000	
- Longitudinal profiles:	Horizontal	1:10,000 or 1:20,000
	Vertical	1:500 or 1:1,000

5.2 Installation of Staff Gauge and Water Level Observation

5.2.1 Installation of Staff Gauge

In order to obtain supplement hydrological data for runoff analysis, the three (3) staff gauges were installed by the Study Team. The locations of the installed staff gauges are as follows:

- downstream of the Urael bridge in the Kebena river,
- downstream of the Filwiha bridge in the Bantyiketu river, and
- downstream of the Mekanisa bridge in the Little Akaki river.

5.2.2 Water Level and Discharge Observation

The observation of water levels and velocities to check relationship (H-Q curve) between water level and discharge were conducted by the Study Team in cooperation with the counterpart personnel. The observations were made three times at each gauging station up to now. The observatory dates were July 9, July 16 and July 27 (except Urael bridge measured on July 29), 1997.

The water levels were observed at an interval of 5 minutes considering characteristics of flood concentrating in a few hours. The duration of observation varies from 1 hour or more, depending on flood condition. The flow velocities were stimulatory checked by using float having a total length of 65 cm and 50 cm draft. The flow velocities were checked twice at a time of water level observation.

The results of observations are arranged as shown in Figure 5.2.1.

5.3 Interview Survey for Riverine People

5.3.1 Outline of Survey

Interview survey for riverine people has been carried out to get information regarding their living condition, past flood damages and their opinions on flood control plan. The survey has been conducted for riverine communities in the five river basins which suffered from damages by past floods.

5.3.2 Method of the Survey

Random sample survey was conducted by assistants employed for the survey under the supervision of the Study Team's project economist on 115 riverine residents in the Study Area during the first and the second field works. Selection of the samples to be interviewed was made in the following manners.

The river basins in the Study Area have been divided into the following five river basins:

a) Little Akaki River Basin,
b) Kechene and Kurtume River Basin,
c) Bantyiketu River Basin,
d) Kebena River Basin, and
e) Hanku River Basin.

Prior to the interview survey, the Study Team discussed with AFCPO about interview sites. Based on the discussion, interview sites were decided considering the seriousness of the past flood damages as shown in Figure 5.3.1 and Table 5.3.1.

Total number of samples selected was 115 as summarized below.

River Basin	No. of Samples
Little Akaki	41
Kurtume and Kechene	33
Bantyiketu	20
Kebena	15
Hanku	6
Total	115

5.3.3 Items of the Interview Survey

Questionnaire for the interview includes the following items:

General Information

- Family structure
- Ethnic group
- Religion
- Major source of revenue of the family and household income
- Education level
- Health condition of family
- Size of house and its type

Flood Damages

- Frequency of flood, cause of flood
- Flood conditions such as time, depth, duration
- Damages to properties due to flood

Idea on Flood Control Project

- Idea on flood control works
- Idea on resettlement to be necessary for flood control works

Community

- Community structure
- Availability of community cooperation
- Communication method within a community
- Decision making procedure in a community

5.3.4 Results of the Interview Survey

Results of the interview survey were compiled and summarized in each river basin so that the characteristics of the river basin would become clear. Though the number of samples is limited compared to the number of households in the Study Area, the results of the survey are to be considered as indicative figures representing some average households.

(1) General Information

1) Duration of Dwelling at Present Location

Duration of dwelling	Percentage
3 years or less	8 %
3 - 5 years	5 %
6 - 10 years	10 %
11 - 20 years	29 %
21 - 30 years	39 %
More than 30 years	10 %
Total	100 %

Average duration of dwelling at the present location is about 19 years. 78 % of the households live at their present address for more than 10 years. More than 49 % of the households live there for more than 20 years.

2) Family Size

River Basin	Average Family Size (persons)
Little Akaki	8.8
Kurtume and Kechene	6.4
Bantyiketu	6.9
Kebena	6.8
Hanku	6.8
Total	7.5

Average family size is 7.5 persons and this is more than average family size of 5.5 persons in whole Addis Ababa. Especially in the Little Akaki River Basin, the average family size is large at 8.8 persons.

3) Major Source of Revenue of Family

Occupation	Percentage					
	Little Akaki	Bantyiketu	Kechene & Kurtume	Kebena	Hanku	Total
Pension	41 %	32 %	12 %	30 %	17 %	29 %
Employee	22 %	24 %	30 %	50 %	33 %	28 %
Daily labor	15 %	12 %	30 %	10 %	17 %	18 %
Merchant	7 %	20 %	15 %	0 %	33 %	13 %
Tailor	5 %	0 %	0 %	0 %	0 %	2 %
Guard	0 %	0 %	6 %	0 %	0 %	2 %
Rent	2 %	8 %	0 %	0 %	0 %	3 %
Other	6 %	4 %	6 %	10 %	0 %	6 %
Total	100 %	100 %	100 %	100 %	100 %	100 %

29 % of the households answered that the major source of income is pension, while 28 % answered employee, 18 % answered daily labor and 13 % answered merchant. Especially the households answered that their major income is pension is high at 41 % at the Little Akaki river basin.

4) Monthly Household Income

Monthly Household Income	Percentage
100 Birr or less	39 %
101 - 200 Birr	22 %
201 - 300 Birr	18 %
301 - 700 Birr	13 %
701 - 1,000 Birr	5 %
More than 1,000 Birr	3 %
Total	100 %

Distribution of income per households is as presented above. 79 % of the interviewed households get monthly income of 300 Birr or less, while 39 % of the household get 100 Birr or less. Average monthly income of family is about 250 Birr. Since most people are not willing to answer their true income to the interviewer, this result is to be carefully evaluated.

5) Type of House

Type of House	Percentage
Temporary type	3 %
Chika type	87 %
Concrete block type	6 %
Brick masonry type	4 %
Total	100 %

87 percent of the households live in a typical local house made by wood and mud plaster locally called "Chika" type house. 6 % live in concrete block houses and 4 percent live in brick masonry houses, while 3 percent live in temporary shanties. According to information obtained during the interview survey, new houses built with concrete blocks are increasing recent years.

6) Size of House

Type of House	Average Floor Area
Temporary type	22 m^2
Chika type	44 m^2
Concrete block type	44 m^2
Brick masonry type	67 m^2

The average floor area of Chika type house, which is dominant in the Study Area is 44 m^2 and it is almost same as that of the concrete block type house. The brick masonry type house is rather larger than those two types.

(2) Flood Damages

1) Frequency of Flood Occurrence

Frequency of Floods	Percentage
Once in the past	17 %
Twice in the past	36 %
3 times in the past	12 %
4 times in the past	5 %
5 times in the past	6 %
Almost every year	23 %
Total	100 %

With regard to frequency of flood occurrence, the households suffered twice in the past were 36 %, once were 17 %, three times were 12 %, while who answered every year were 23 %.

2) Cause of Flood

Cause of Flood	Percentage
Overflow of river water	30 %
Poor local drainage	3 %
River water + local drainage	68 %
Total	100 %

Overflow of river water plus poor local drainage was stated as major causes of flood by 68 % of the households. This shows both river and drainage improvement is considered to be the key for solving the flood problem in the Study Area.

3) Flood Damages

Major flood damage was damage to house, household equipment, and clothes. 3 % of the respondents answered that their land and corrugate fence were taken away by floods.

Flood Damages	Percentage
House only	22 %
House, household equip., and cloths	75 %
Merchandise	1 %
Fence and land	3 %
Total	100 %

4) Flood Condition

Inundation depth varies by landform condition of the residence. 80 % of respondents answered that the inundation depth was 1 m or more.

Inundation Depth	Percentage
Less than 50 cm	9 %
50 - 99 cm	11 %
100 - 199 cm	50 %
200 - 299 cm	23 %
300 cm or more	4 %
Not sure	3 %
Total	100 %

About 70 % of the respondents answered that the flood in August 1995 was most serious. Probably this is because the flood is still fresh in their memories. About 70 % of the respondents answered that the flood lasted more than one day. About 40 % of the respondents answered that the road traffic nearby their house was affected by the flood. Many people who suffered flood damage consider that damage due to floods amount to 300 to 5,000 Birr.

5) Importance of Flood Control Works

Almost all household interviewed recognized the importance of flood control works, especially construction of retaining walls and improvement of drainage facilities in the riverine community. This means that the flood control facility is poor and not sufficient for their daily life, the needs of urgent improvement for which are dully recognized.

6) Acceptance of Resettlement

Resettlement	Percentage					
	Little Akaki	Bantyiketu	Kechene & Kurtume	Kebena	Hanku	Total
Accept to move	29 %	44 %	55 %	60 %	50 %	43 %
If better place, willing to move	22 %	20 %	15 %	20 %	0 %	18 %
Not accept to move	49 %	36 %	30 %	20 %	50 %	38 %

About 61 percent of households answered that they will accept resettlement in case it is necessary for flood control works with reasonable compensation. However, about half households in the Little Akaki and Hanku river basins are not willing to accept the resettlement. With the above situation, special attention should be paid for formulation of flood control plan applying measures to mitigate the number of resettlement be minimized.

(3) Community

1) Structure of Community

About 85 % of respondents answered that local community is Kebele. Existence of smaller community than Kebele was not recognized by this interview survey. On the other hand, 17 % of the respondents answered no community exists or no idea on community.

2) Availability of Community Cooperation

Though the interview survey tried to clarify the cooperation system within the communities, almost all respondents explained the assistance made by Kebeles during and after flood disaster. Many respondents answered that the Kebeles provided shelters, foods and blankets during and after floods.

3) Method of Information Transmission in Community

Almost all respondents answered that any information is transmitted by Kebeles.

4) Method of Decision Making in Community

Almost all respondents answered that any decision making is made through Kebele. With the above circumstances, it will be important that Kebeles will play a key role to organize flood-fighting system in the communities.

The summery of the results of the interview survey is presented in Table 5.3.2.

Table 5.1.1 Work Volume and River Code of Cross-section

River	Name of Stretch	Code	Length (km)	No. of Cross-section
Hanku	Hanku	HAN		17
	(tributary)	HANR		4
	(tributary)	HANL		4
	sub-total		*5.2*	*25*
Kebena	Kebena	KEB		66
	(tributary)	KEBL		4
	Ginfile	GIN		19
	Abo	ABO		11
	(tributary)	ABOR		4
	sub-total		*16.8*	*104*
Banktyiketu	Banktyiketu	BAN		27
	sub-total		*3.8*	*27*
Kechene	Kechene	KEC		36
	(tributary)	KECR		9
	sub-total		*6.2*	*45*
Kurtume	Kurtume	KUR		32
	(tributary)	KURL		7
	(tributary)	KURR1		10
	(tributary)	KURR2		10
	(tributary)	KURR3		14
	sub-total		*7.4*	*73*
Perennial	Perennial	PER		9
	sub-total		*4.0*	*9*
Little Akaki	Little Akaki	LAK		87
	(tributary)	LAKR1		7
	(tributary)	LAKR2		3
	(tributary)	LAKL1		5
	(tributary)	LAKL2		5
	Buhe	BUH		12
	Fereja	FER		8
	sub-total		*17.8*	*127*
West Akaki	West Akaki	WAK		34
	sub-total		*8.8*	*34*
Staff Gauge Site	Urael Bridge			2
	Filwiha Bridge			2
	Mekanisa Bridge			2
	sub-total			*6*
Total			*70.0*	*450*

Table 5.1.2 Reference Bench Marks

Bench Mark No.	Elevation (m)	Remarks
Q 25	2355.425	Blue Nile Geodetic Control Project in 1959
BM 1 (UCAA)	2442.775	-do-
B 26	2538.771	-do-
LBM 1	2453.073	Addis Ababa Mapping Project in 1972
LBM 2	2440.077	-do-
LBM 3	2479.734	-do-
LBM 4	2422.700	-do-
LBM 5	2423.339	-do-
LBM 16	2538.372	-do-
LBM 18	2408.011	-do-
LBM 19	2459.252	-do-
129	2301.788*	(2301.704**) -do-
139	2345.985	-do-
162	2410.544	-do-
259	2341.898	-do-
266	2396.148*	(2396.245**) -do-
296	2376.900*	(2376.996**) -do-
318	2349.463	-do-
382	2300.099	-do-
430	2333.023*	(2333.404**) -do-
506	2333.504	-do-
624	2362.873	-do-
724	2286.972	-do-
1243	2481.796*	(2481.832**) -do-
1244	2481.906	-do-

Note: * New elevation data of River Survey for the Addis Ababa Flood Control Project.
** Unused elevation data for subsidence or movement points.

Table 5.1.3 (1/2) Established Bench Marks

Bench Mark No.	Elevation (m)	Remarks
BM 01	2460.662	
BM 02	2458.957	
BM 03	2485.731	
BM 04	2507.111	
BM 05	2488.063	
BM 06	2525.566	
BM 07	2389.108	
BM 08	2339.180	
BM 09	2331.828	
BM 10	2319.240	
BM 11	2319.591	
BM 12	2360.372	
BM 13	2387.906	
BM 14	2410.152	
BM 15	2425.774	
BM 16	2458.313	
BM 17	2446.148	
BM 18	2464.243	
BM 19	2482.788	
BM 20	2505.345	
BM 21	2458.440	
BM 22	2477.118	
BM 23	2479.908	
BM 24	2477.066	
BM 25	2309.529	
BM 26	2308.201	
BM 27-1	2293.371	
BM 27-2	2294.447	
BM 28	2278.381	(Marked bench mark on the bridge)
BM 29	2247.069	
BM 30	2239.613	
BM 31	2200.553	
BM 32	2211.988	
BM 33	2214.659	
BM 34	2240.568	
BM 35	2283.362	
BM 36	2280.099	
BM 37	2288.166	
BM 38	2300.213	
BM 39	2301.069	

Table 5.1.3 (2/2) Establised Bench Marks

Bench Mark No.	Elevation (m)	Remarks
BM 40	2307.478	
BM 41	2256.825	
BM 42	2258.893	
BM 43	2273.975	
BM 44	2289.949	
BM 45	2329.980	
BM 46	2447.332	
BM 47	2495.907	
BM 48	2530.851	
BM 49	2339.375	
BM 50	2351.166	
BM 51	2356.192	
BM 52	2334.445	
BM 53	2313.685	
BM 54	2330.171	(Marked bench mark on the stone)
BM 55	2354.630	
BM 56	2370.694	
BM 57	2410.743	
BM 58	2379.266	
BM 59	2319.502	
BM 60	---------	(Canceling number)
BM 61	---------	(Canceling number)
BM 62	2341.096	
BM 63	2355.280	
BM 64	2369.365	
BM 65	2397.284	
BM 66	2356.636	
BM 67	2373.330	
BM 68	2387.365	
BM 69	2338.056	
BM 70	2351.991	
BM 71	2363.021	
BM 72	2391.045	
BM 73	2407.368	
BM 74	2429.763	
BM 75	2458.592	
BM 76	2506.500	
BM 77	2441.708	

Table 5.3.1 Location of Interview Survey on Socio Economy and Flood Damage

River Basins	Interview Location			The Number of Respondents	Location on map
	Zone	Wereda	Kebele		
Little Akaki	1	6	24	5	J
	1	4	35	8	H
	2	22	2	5	B
	2	22	1	6	A
	2	21	19	3	F
	2	21	20	2	G
	2	20	28	2	E
	1	6	14	2	I
	2	22	4	4	C
	2	20	45	4	D
Kurtume & Kechene	5	8	11	5	W
	4	9	7	2	V
	4	2	11	3	P
	4	11	16	7	O
	4	13	1	3	S
	5	14	17	1	N
	5	2	17	12	Q
Bantyiketu	3	18	7	4	K
	3	18	18	4	L
	4	15	34	6	M
	4	15	35	6	Z
	4	15	36	5	R
Kebena	4	12	20	8	Y
	4	13	11	2	X
Hanku	3	17	16	3	T
	3	17	24	3	U
Total				115	

Note: Interview locations are shown on Figure 5.3.1

Table 5.3.2 Result of Interview Survey for Riverine People (1/3)

	Little Akaki		Bantyiketu		Kechene & Kurtume		Kebena		Hanku		Total	
	nos.	distr.	nos.	distr.	nos.	distr.	nos.	distr.	nos.	distr.	nos.	distr.
(1) Respondent												
Male	20	49%	5	20%	11	33%	2	20%	1	17%	39	34%
Female	21	51%	20	80%	22	67%	8	80%	5	83%	76	66%
Total	41		25		33		10		6		115	
(2) Duration of dwelling at present location												
3 years or less	2	5%	2	8%	4	12%	-	0%	1	17%	9	8%
4 – 5 years	1	2%	1	4%	2	6%	-	0%	2	33%	6	5%
6 – 10 years	4	10%	4	16%	2	6%	-	0%	1	17%	11	10%
11 – 20 years	12	29%	7	28%	10	30%	3	30%	1	17%	33	29%
21 – 30 years	16	39%	10	40%	11	33%	7	70%	1	17%	45	39%
More than 30 years	6	15%	1	4%	4	12%	-	0%	-	0%	11	10%
(3) Number of families live in house												
1 family	36	88%	24	96%	33	100%	10	100%	6	100%	109	95%
More than 1 family	5	12%	1	4%	-	0%	-	0%	-	0%	6	5%
(4) Family size												
2 persons	1	2%	1	4%	1	3%	-	0%	-	0%	3	3%
3 persons	2	5%	0	0%	2	6%	1	10%	-	0%	5	4%
4 persons	3	7%	4	16%	6	18%	-	0%	-	0%	13	11%
5 persons	2	5%	8	32%	5	15%	1	10%	4	67%	20	17%
6 persons	4	10%	1	4%	6	18%	1	10%	-	0%	12	10%
7 persons	2	5%	3	12%	4	12%	5	50%	-	0%	14	12%
8 persons	4	10%	2	8%	-	0%	-	0%	-	0%	6	5%
9 persons	5	12%	2	8%	1	3%	1	10%	1	17%	10	9%
10 persons	4	10%	3	12%	2	6%	1	10%	-	0%	10	9%
More than 10 persons	14	34%	1	4%	6	18%	-	0%	1	17%	22	19%
Average family size	8.8	pers.	6.4	pers.	6.9	pers.	6.8	pers.	6.8	pers.	7.5	pers.
(5) Ethnic group												
Amhara	15	37%	11	44%	20	61%	6	60%	4	67%	56	49%
Gurage	9	22%	5	20%	7	21%	1	10%	1	17%	23	20%
Oromo	14	34%	4	16%	2	6%	1	10%	1	17%	22	19%
Tigre	1	2%	1	4%	4	12%	2	20%	-	0%	8	7%
Eritreans	2	5%	2	8%	-	0%	-	0%	-	0%	4	3%
Hadere	-	0%	1	4%	-	0%	-	0%	-	0%	1	1%
Kembata	-	0%	1	4%	-	0%	-	0%	-	0%	1	1%
(6) Religion												
Orthodox	34	83%	17	68%	29	88%	10	100%	5	83%	95	83%
Muslim	4	10%	6	24%	4	12%	-	0%	-	0%	14	12%
Protestant	2	5%	2	8%	-	0%	-	0%	1	17%	5	4%
Catholic	-	0%	-	0%	-	0%	-	0%	-	0%	0	0%
Other	1	2%	-	0%	-	0%	-	0%	-	0%	1	1%
(7) Major source of revenue of family												
Pension	17	41%	8	32%	4	12%	3	30%	1	17%	33	29%
Employee	9	22%	6	24%	10	30%	5	50%	2	33%	32	28%
Daily labor	6	15%	3	12%	10	30%	1	10%	1	17%	21	18%
Merchant	3	7%	5	20%	5	15%	-	0%	2	33%	15	13%
Tailor	2	5%	-	0%	-	0%	-	0%	-	0%	2	2%
Guard	-	0%	-	0%	2	6%	-	0%	-	0%	2	2%
Rent	1	2%	2	8%	-	0%	-	0%	-	0%	3	3%
Teacher	1	2%	-	0%	-	0%	-	0%	-	0%	1	1%
Carpenter	1	2%	-	0%	-	0%	-	0%	-	0%	1	1%
Other	1	2%	1	4%	2	6%	1	10%	-	0%	5	4%
(8) Monthly income of family												
100 Birr or less	13	32%	8	32%	16	48%	6	60%	2	33%	45	39%
101 – 200 Birr	10	24%	4	16%	9	27%	2	20%	-	0%	25	22%
201 – 300 Birr	10	24%	6	24%	4	12%	1	10%	-	0%	21	18%
301 – 700 Birr	4	10%	3	12%	4	12%	-	0%	4	67%	15	13%
701 – 1,000 Birr	3	7%	3	12%	-	0%	-	0%	-	0%	6	5%
More than 1000 Birr	1	2%	1	4%	-	0%	1	10%	-	0%	3	3%
(9) Educational level												
Total persons	361	-	160	-	228	-	68	-	41	-	858	-
Elementary school	52	14%	23	14%	44	19%	19	28%	5	12%	143	17%
Junior secondary	25	7%	15	9%	22	10%	9	13%	5	12%	76	9%

Table 5.3.2 Result of Interview Survey for Riverine People (2/3)

	Little Akaki		Bantyiketu		Kechene & Kurtume		Kebena		Hanku		Total	
	nos.	distr.	nos.	distr.	nos.	distr.	nos.	distr.	nos.	distr.	nos.	distr.
Senior secondary	113	31%	40	25%	37	16%	14	21%	6	15%	210	24%
University	8	2%	5	3%	4	2%	5	7%	-	0%	22	3%
Graduate school	-	0%	-	0%	-	0%	-	0%	-	0%	0	0%
(10) Health condition of family												
All family is good	30	73%	23	92%	27	82%	8	80%	6	100%	94	82%
Sick person is in family	11	27%	2	8%	6	18%	2	20%	-	0%	21	18%
(11) Type of house												
Temporary type	1	2%	-	0%	2	6%	-	0%	-	0%	3	3%
Chika type	38	93%	18	72%	31	94%	8	80%	5	83%	100	87%
Concrete block type	2	5%	3	12%	-	0%	2	20%	-	0%	7	6%
Brick masonry type	-	0%	4	16%	-	0%	-	0%	1	17%	5	4%
(12) Average size of house by type												
Temporary type	21m2	-	-	-	22m2	-	-	-	-	-	22m2	-
Chika type	50m2	-	49m2	-	37m2	-	33m2	-	38m2	-	44m2	-
Concrete block type	50m2	-	43m2	-	-	-	38m2	-	-	-	44m2	-
Brick masonry type	-	-	67m2	-	-	-	-	-	40m2	-	67m2	-
(13) Frequency of flood												
Once in the past	10	24%	2	8%	5	15%	1	10%	2	33%	20	17%
Twice in the past	11	27%	7	28%	20	61%	2	20%	1	17%	41	36%
3 times in the past	5	12%	3	12%	6	18%	-	0%	-	0%	14	12%
4 times in the past	4	10%	1	4%	1	3%	-	0%	-	0%	6	5%
5 times or more in the past	5	12%	1	4%	-	0%	-	0%	1	17%	7	6%
Every year (often)	6	15%	11	44%	1	3%	7	70%	2	33%	27	23%
(14) Cause of flood												
River water	11	27%	15	60%	2	6%	5	50%	1	17%	34	30%
River water + poor drainage	28	68%	9	36%	31	94%	5	50%	5	83%	78	68%
Poor drainage	2	5%	1	4%	-	0%	-	0%	-	0%	3	3%
(15) Properties suffer flood damage												
House only	5	12%	8	32%	6	18%	4	40%	2	33%	25	22%
House, equipment, clothes	36	88%	16	64%	26	79%	4	40%	4	67%	86	75%
Merchandise	-	0%	-	0%	1	3%	-	0%	-	0%	1	1%
Fence and land	-	0%	1	4%	-	0%	2	20%	-	0%	3	3%
No damage	-	0%	-	0%	-	0%	-	0%	-	0%	0	0%
(16) Inundation depth												
Less than 50 cm	1	2%	3	12%	5	15%	1	10%	-	0%	10	9%
50 – 99 cm	4	10%	-	0%	4	12%	-	0%	5	83%	13	11%
100 – 199 cm	27	66%	15	60%	10	30%	5	50%	1	17%	58	50%
200 – 299 cm	5	12%	5	20%	13	39%	3	30%	-	0%	26	23%
300 cm or more	4	10%	-	0%	1	3%	-	0%	-	0%	5	4%
Not sure	-	0%	2	8%	-	0%	1	10%	-	0%	3	3%
(17) When you suffered serious flood damage												
Aug-95	41	85%	13	48%	33	70%	7	70%	3	50%	97	70%
Aug-96	6	13%	4	15%	14	30%	-	0%	3	50%	27	20%
July 1989	1	2%	-	0%	-	0%	-	0%	-	0%	1	1%
Every year	-	0%	1	4%	-	0%	1	10%	-	0%	2	1%
Not sure	-	0%	9	33%	-	0%	2	20%	-	0%	11	8%
(18) Duration of flood												
1 hour	1	2%	1	4%	1	3%	-	0%	1	17%	4	3%
2 hours	-	0%	6	24%	3	9%	4	40%	2	33%	15	13%
3 hours	-	0%	3	12%	2	6%	-	0%	1	17%	6	5%
5 hours	-	0%	-	0%	2	6%	2	20%	-	0%	4	3%
1 day	11	27%	6	24%	4	12%	-	0%	1	17%	22	19%
2 days	1	2%	-	0%	2	6%	-	0%	1	17%	4	3%
3 days	9	22%	-	0%	7	21%	-	0%	-	0%	16	14%
4 days – 7 days	12	29%	2	8%	9	27%	-	0%	-	0%	23	20%
8 days – 14 days	1	2%	-	0%	1	3%	-	0%	-	0%	2	2%
More than 2 weeks	6	15%	3	12%	1	3%	-	0%	-	0%	10	9%
Not sure	-	0%	4	16%	1	3%	4	40%	-	0%	9	8%
(19) Duration of traffic blockage on the street in front of house												

Table 5.3.2 Result of Interview Survey for Riverine People (3/3)

	Little Akaki		Bardyiketu		Kechene & Kurtume		Kebena		Hanku		Total	
	nos.	distr.	nos.	distr.	nos.	distr.	nos.	distr.	nos.	distr.	nos.	distr.
6 hours or less	3	7%	1	4%	5	15%	2	20%	1	17%	12	10%
7 hours - 1day	18	44%	5	20%	1	3%	-	0%	-	0%	24	21%
More than 1 day	4	10%	1	4%	5	15%	1	10%	-	0%	11	10%
Not sure	16	39%	18	72%	22	67%	7	70%	5	83%	65	59%
(20) Duration of suspension of economic activities due to flood												
Half a day or less	39	95%	21	84%	24	73%	8	80%	6	100%	98	85%
1 day	-	0%	-	0%	1	3%	-	0%	-	0%	1	1%
2 days - 3 days	-	0%	1	4%	3	9%	2	20%	-	0%	6	5%
4 days - 7 days	1	2%	3	12%	1	3%	-	0%	-	0%	5	4%
More than a week	1	2%	0	0%	4	12%	-	0%	-	0%	5	4%
(21) Estimated loss due to flood												
Not sure	1	2%	4	16%	5	15%	2	20%	2	33%	14	12%
100 Birr or less	-	0%	1	4%	1	3%	-	0%	1	17%	3	3%
101 - 200 Birr	-	0%	-	0%	2	6%	1	10%	-	0%	3	3%
201 - 300 Birr	1	2%	-	0%	-	0%	-	0%	-	0%	1	1%
301 - 700 Birr	5	12%	7	28%	4	12%	6	60%	3	50%	25	22%
701 - 1,000 Birr	5	12%	2	8%	4	12%	-	0%	-	0%	11	10%
1,001 - 2,000 Birr	7	17%	2	8%	5	15%	1	10%	-	0%	15	13%
2,001 - 5,000 Birr	10	24%	3	12%	10	30%	-	0%	-	0%	23	20%
More than 5,000 Birr	12	29%	6	24%	2	6%	-	0%	-	0%	20	17%
(22) Any other trouble due to flood												
Lost livestock	2	-	0	-	-	-	-	-	-	-	2	-
Lost food	41	-	15	-	33	-	6	-	3	-	98	-
Sick and injured	10	-	2	-	3	-	1	-	-	-	16	-
Could not attend school	1	-	0	-	-	-	-	-	-	-	1	-
(23) Idea on flood and flood control works (past and future)												
Needs retaining walls	34	68%	15	60%	26	70%	9	90%	6	100%	90	70%
Needs drainage facilities	12	24%	1	4%	5	14%	-	0%	-	0%	18	14%
Needs wider bridge	2	4%	-	0%	2	5%	-	0%	-	0%	4	3%
Hope to change river courses	-	0%	2	8%	1	3%	-	0%	-	0%	3	2%
Hope to build a new bridge to across river	-	0%	-	0%	-	0%	-	0%	-	0%	0	0%
Need the Government's help during flood	-	0%	-	0%	1	3%	-	0%	-	0%	1	1%
No idea	2	4%	7	28%	2	5%	1	10%	-	0%	12	9%
(24) Idea on resettlement to be needed for flood control works												
Accept to move	12	29%	11	44%	18	55%	6	60%	3	50%	50	43%
If there is better place, willing to move	9	22%	5	20%	5	15%	2	20%	-	0%	21	18%
Don't want to leave the present place	20	49%	9	36%	10	30%	2	20%	3	50%	44	38%
(25) Structure of community												
Development committee under kebele	37	90%	19	76%	29	88%	7	70%	5	83%	97	84%
Neighbors	1	2%	-	0%	-	0%	-	0%	-	0%	1	1%
Not sure	3	7%	6	24%	4	12%	3	30%	1	17%	17	15%
(26) Availability of community cooperation during or after flood												
Shelter was provided	-	0%	3	11%	8	22%	1	10%	3	50%	15	12%
Food and blankets were provided	4	10%	4	15%	6	16%	1	10%	-	0%	15	12%
Cooperation was available	7	17%	4	15%	4	11%	1	10%	-	0%	16	13%
Security services were available	-	0%	-	0%	-	0%	-	0%	-	0%	0	0%
Not functioning well	22	54%	10	37%	15	41%	3	30%	3	50%	53	44%
Not necessary	2	5%	-	0%	-	0%	1	10%	-	0%	3	2%
Not sure	6	15%	6	22%	4	11%	3	30%	-	0%	19	16%
(27) Method of information transmission in community												
Through kebele	41	100%	20	80%	33	100%	9	90%	5	83%	108	94%
Not sure	-	0%	5	20%	-	0%	1	10%	1	17%	7	6%
(28) Method of decision making in community												
Through kebele	41	100%	20	80%	33	100%	9	90%	5	83%	108	94%
Not sure	-	0%	5	20%	-	0%	1	10%	1	17%	7	6%

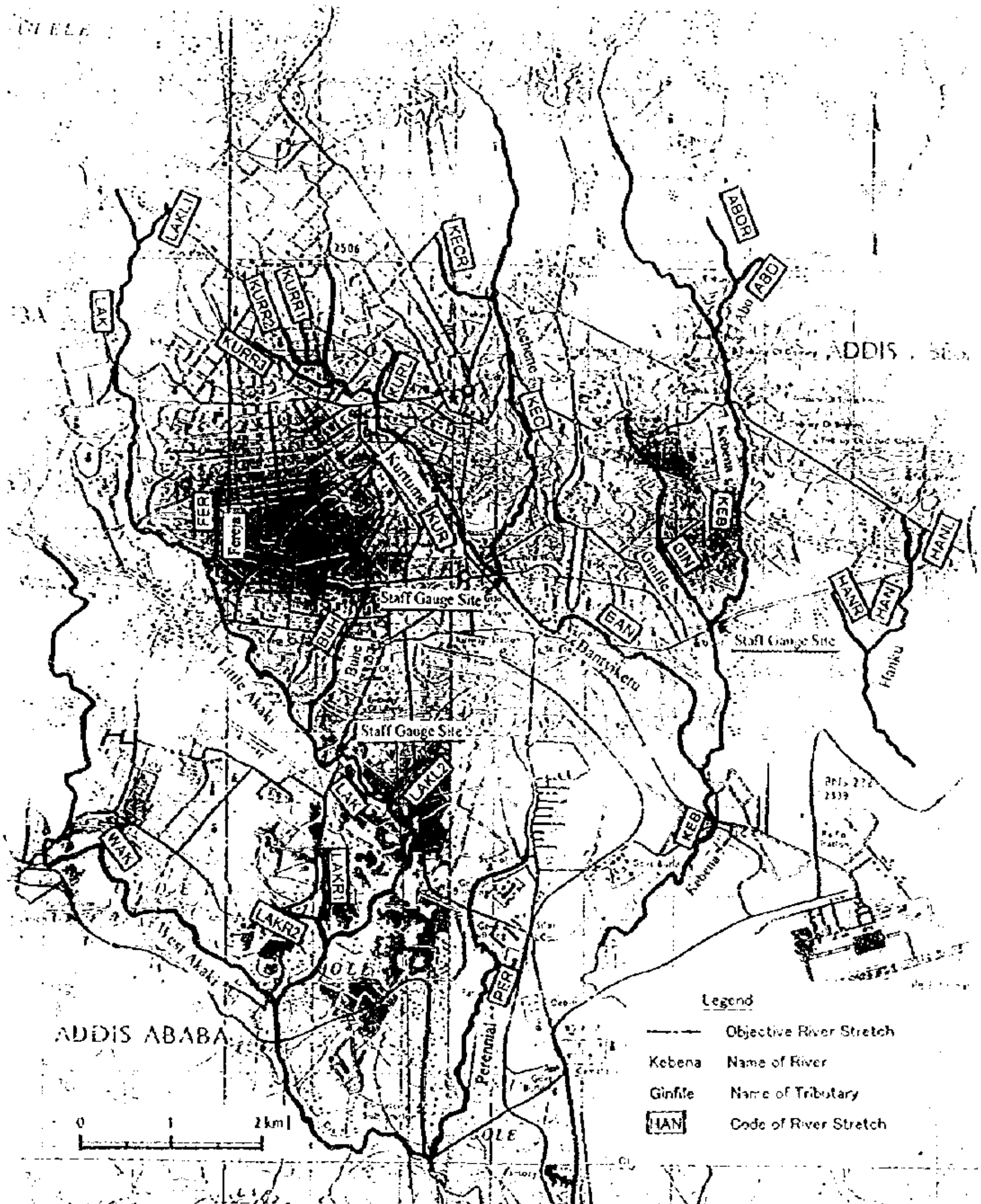


Figure 5.1.1 Objective River Stretches for the River Cross-section Survey

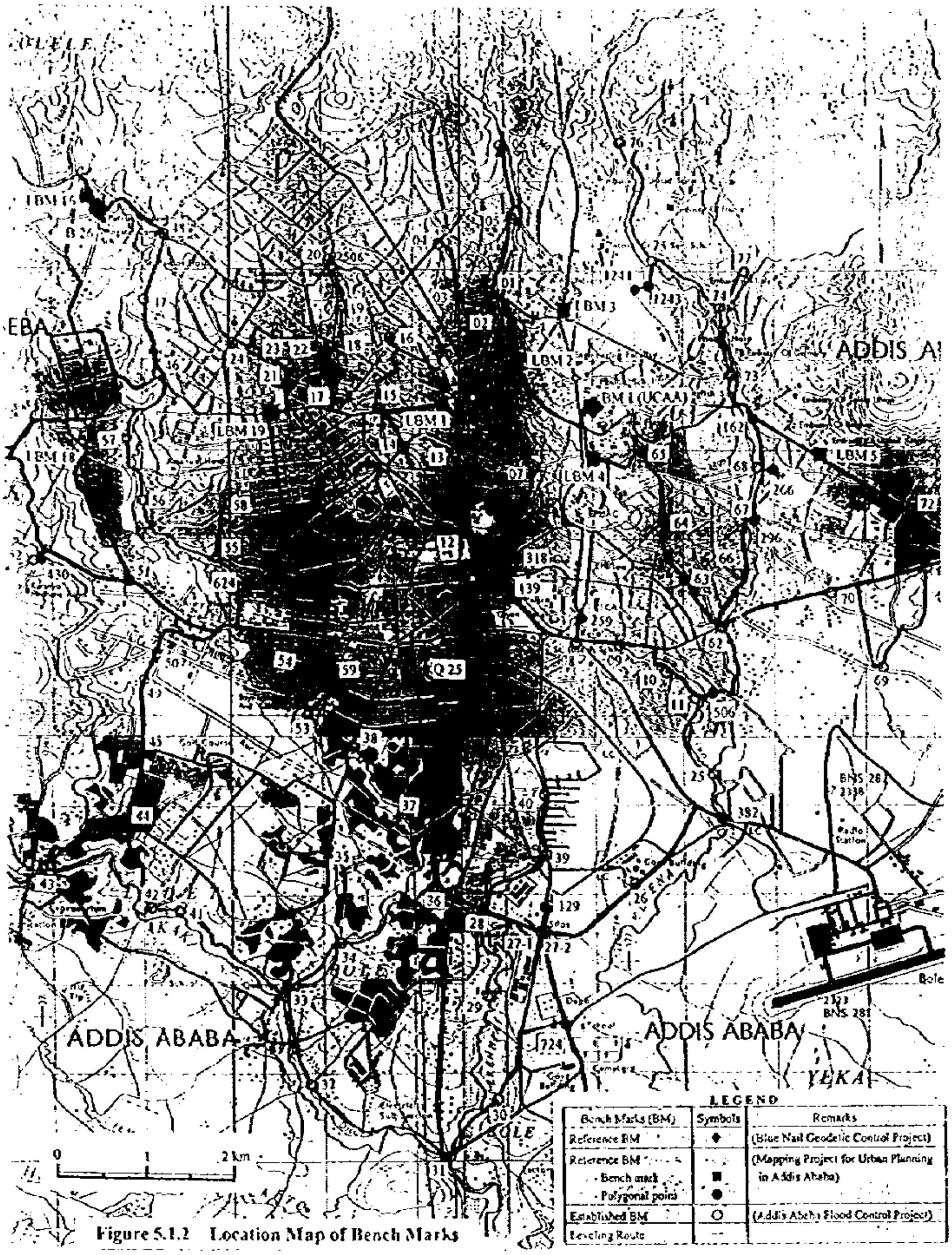
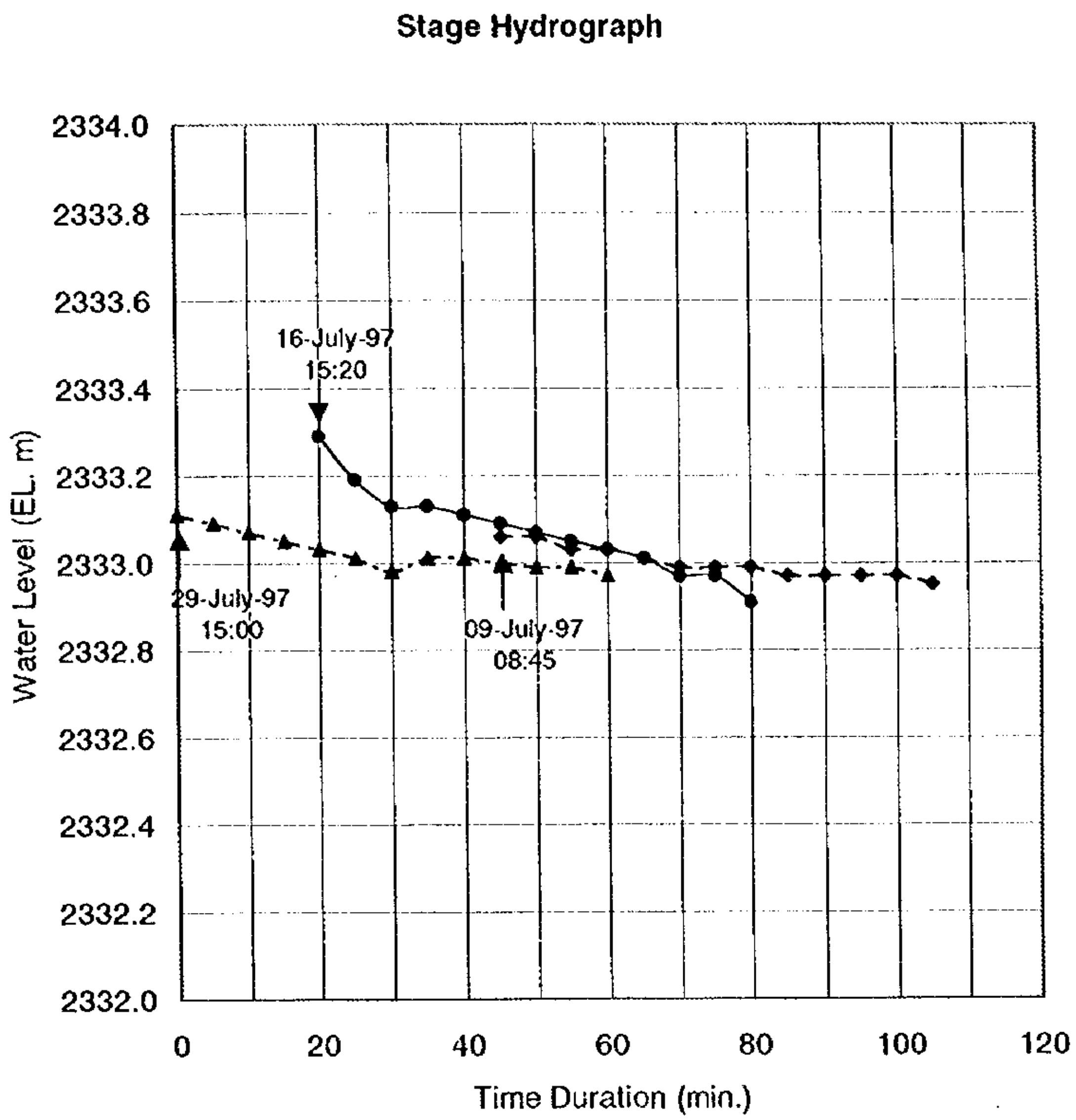


Figure 5.1.2 Location Map of Bench Marks



Note : Elevation of lowest river bed is EL. 2329.7.

Figure 5.2.1 Measured Water Levels at Urael Bridge in the Kebena River

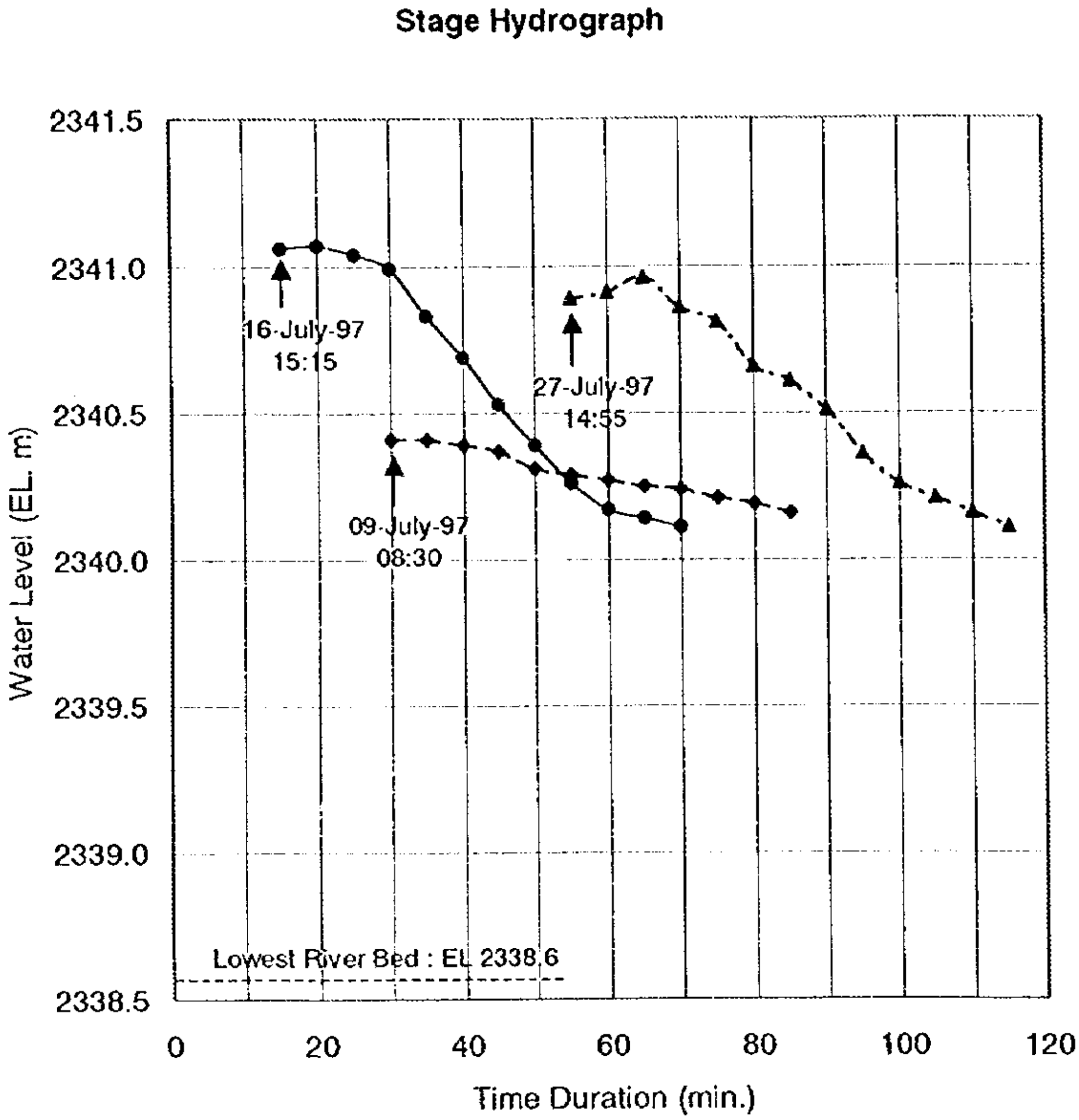


Figure 5.2.2 Measured Water Levels at Filwiha Bridge in the Bantyiketu River

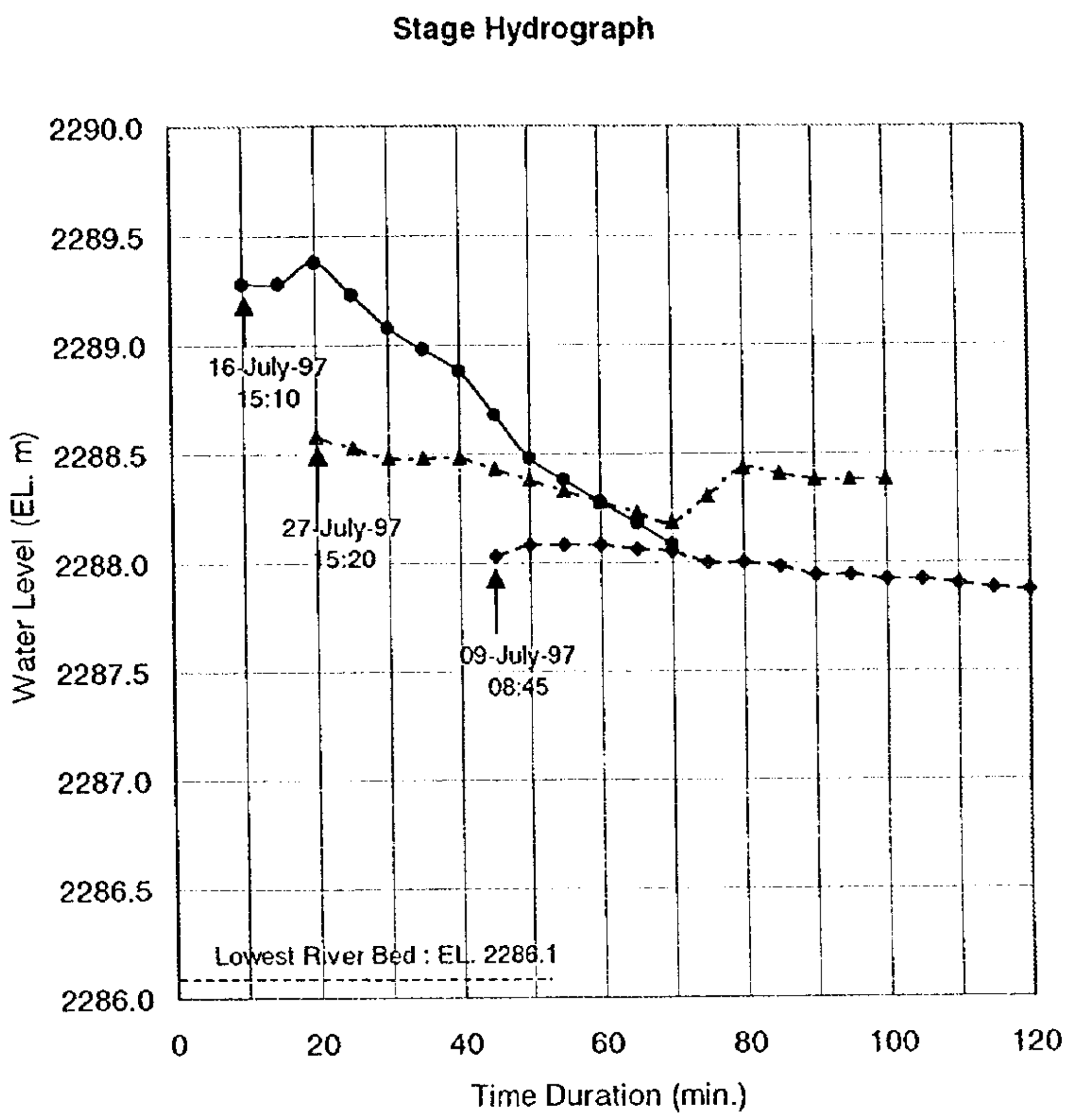


Figure 5.2.3 Measured Water Levels at Mekanisa Bridge in the Little Akaki River

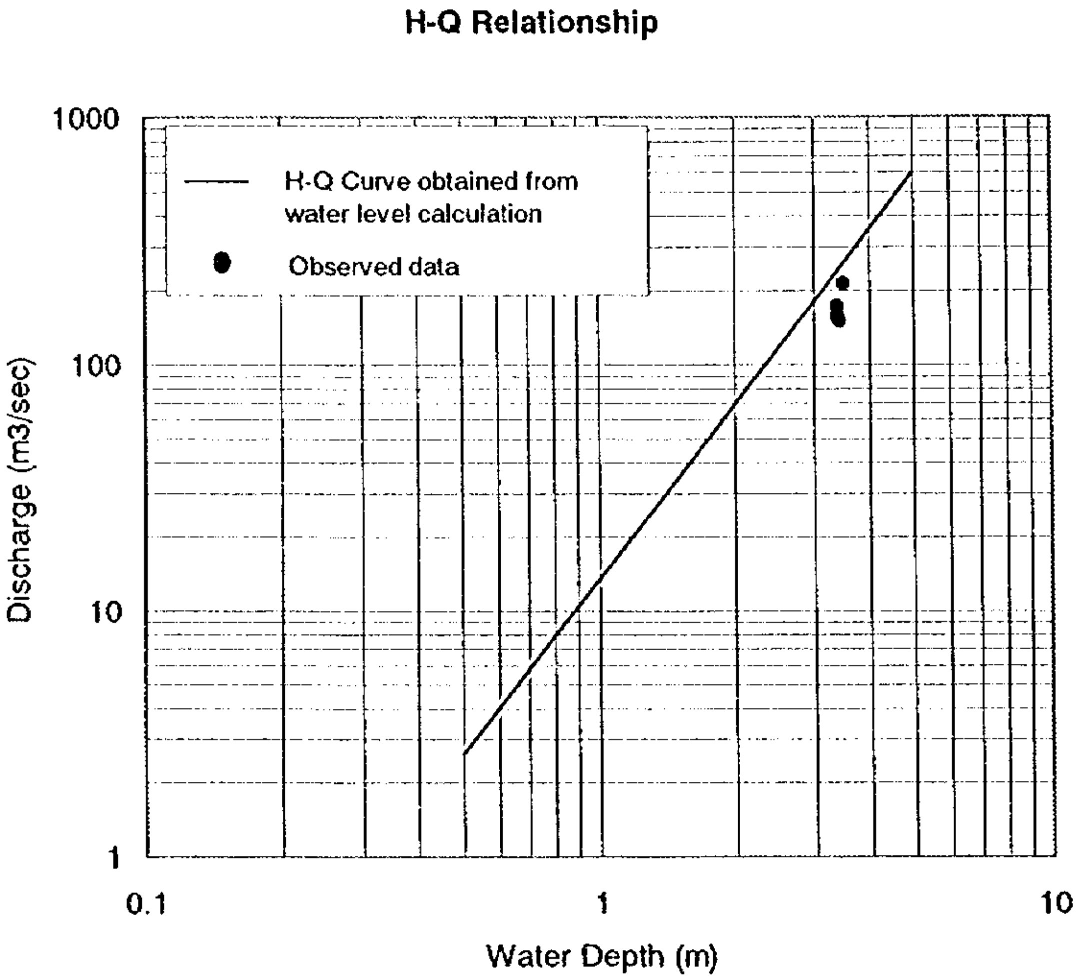


Figure 5.2.4 Stage-Discharge Relationship at Urael Bridge Gauging Site

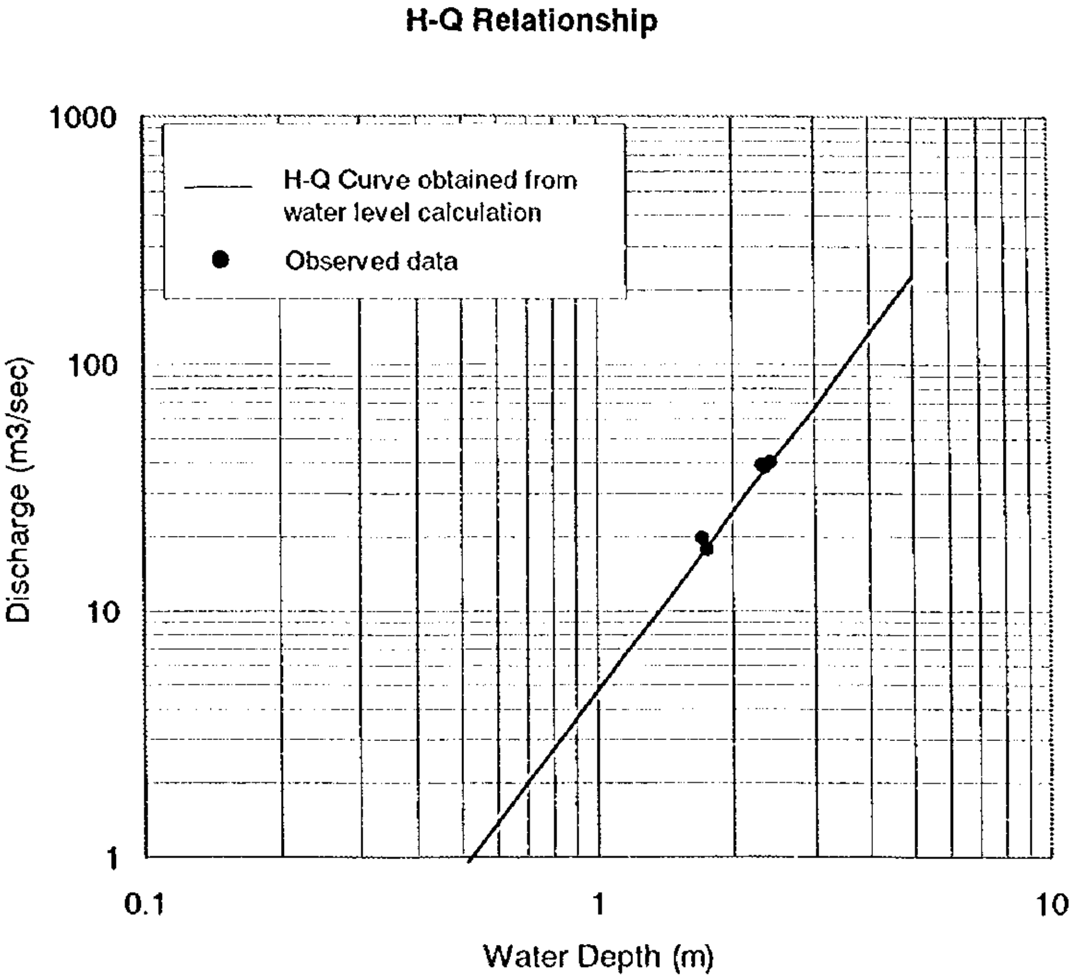


Figure 5.2.5 Stage-Discharge Relationship at Filwiha Bridge Gauging Site

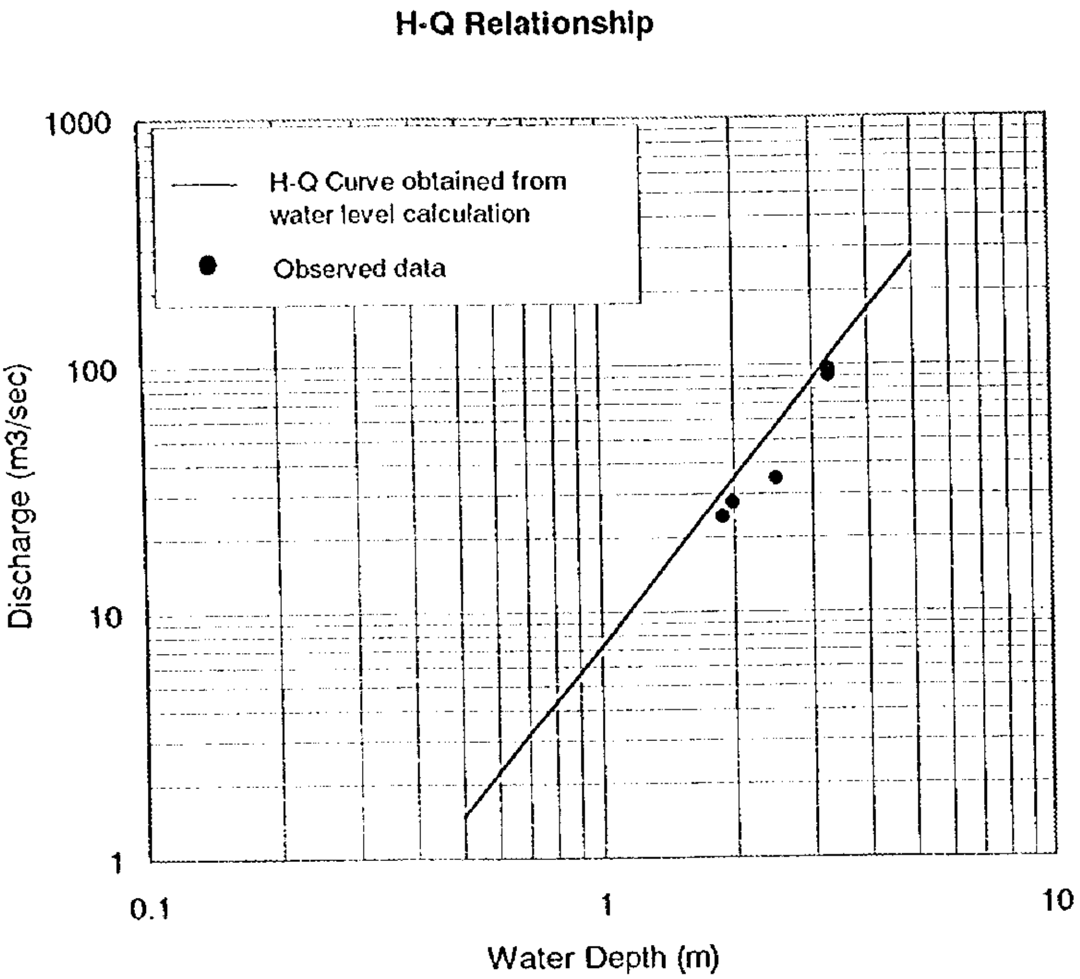


Figure 5.2.6 Stage-Discharge Relationship at Mekanisa Bridge Gauging Site

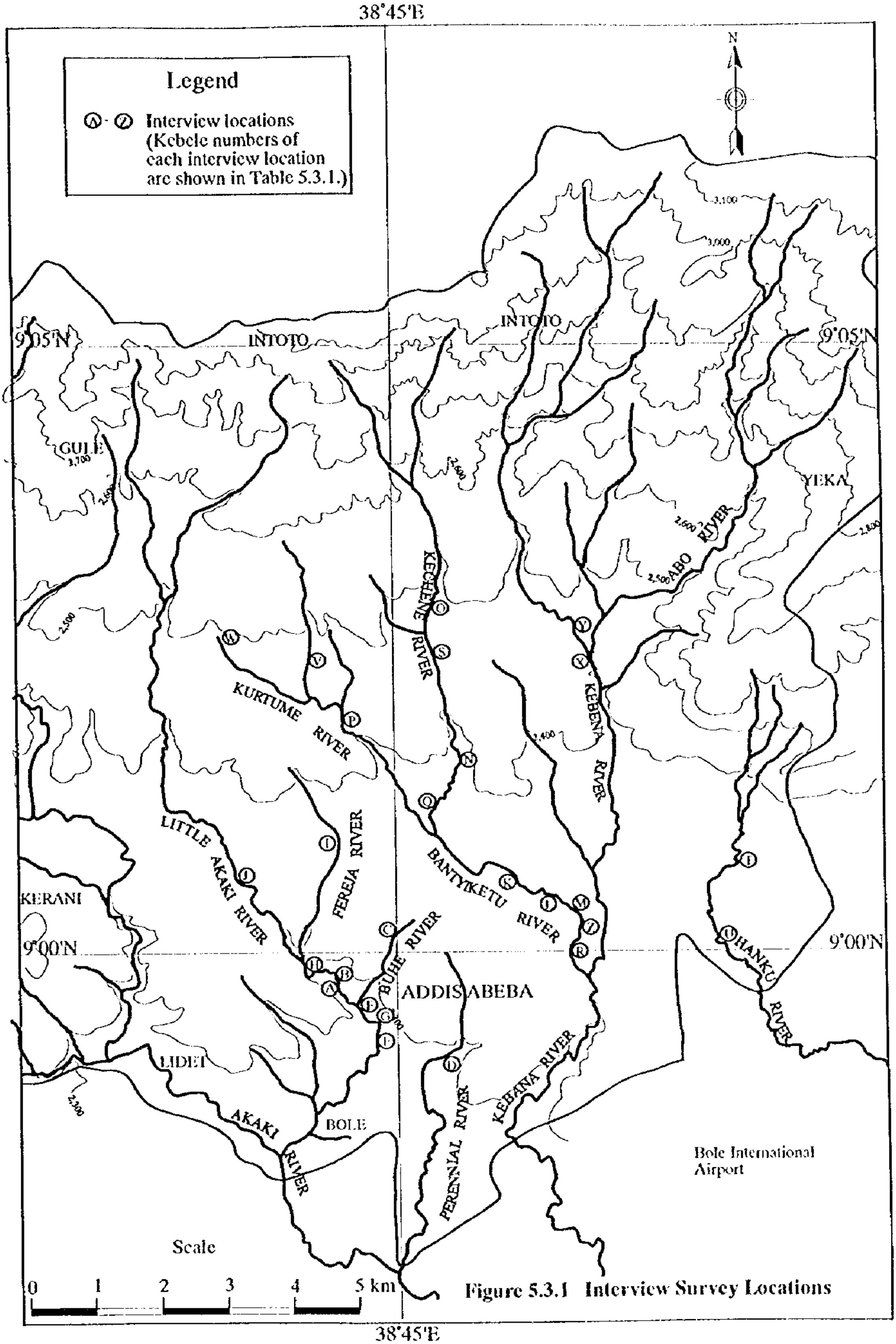


Figure 5.3.1 Interview Survey Locations

THE STUDY ON ADDIS ABABA
FLOOD CONTROL PROJECT

CHAPTER 6

RAINFALL AND RUNOFF ANALYSIS

THE STUDY
ON
ADDIS ABABA FLOOD CONTROL PROJECT
IN
THE FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

CHAPTER 6 RAINFALL AND RUNOFF ANALYSIS

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6. RAINFALL AND RUNOFF ANALYSIS

6.1 Rainfall Analysis

6.1.1 Characteristics of Storm Rainfall

Flood in Addis Ababa is subject to very intense rainfall coupled with steep terrain of river basins which result in rapid rise of river runoff. Heavy rainstorm in the Study Area is generally caused by small atmospheric disturbance which brings local thunderstorms with very high intensity of rainfall in a short duration. Figure 6.1.1 shows the rainfall graphs at Addis Ababa Observatory in NMSA and Bole International Airport in the flood event on August 1978. As seen in the graphs, a heavy rainstorm continues within a few hours and there is a time difference of the peak rainfall between these two locations, suggesting a movement of local rainstorm. The recorded daily rainfall is 93.5 mm at Addis Ababa Observatory and 51.6 mm at Bole International Airport, and the maximum rainfall in 1-hour duration is 63.1 mm and 23.9 mm, respectively.

Such characteristics of local rainstorm is also suggested by the flood event on 8 August 1994. According to the report on flood damage, the severe flood happened mainly in the Little Akaki river which flows down the western part of the urban area. However, the rainfall recorded in the central and west is not much for causing such a severe flood. The recorded daily rainfall is 23.8 mm at Addis Ababa Observatory and 11.0 mm at Bole International Airport. Although rainfall records are not available, the flood event in 1994 must be caused by a heavy rainstorm occurring locally in the upper basin of the Little Akaki river.

6.1.2 Rainfall Intensity, Duration and Frequency (IDF)

The analysis is carried out using the rainfall records at Addis Ababa Observatory. The annual maximum series of rainfall with 10 minutes, 60 minutes and 1-day are collected as listed in Table 6.1.1. Frequency analysis of storm rainfall depth for different duration is made employing the Gumbel's probability distribution as shown in Figures 6.1.2 to 6.1.4. As a result of the frequency analysis, the storm rainfall depths for different return periods are estimated as follows.

Return Period (years)	Storm Rainfall Depth (mm)		
	10 minutes	60 minutes	1-day
50	26.6	75.6	98.2
40	25.7	72.8	95.2
30	24.7	69.2	91.2
20	23.1	64.1	85.6
10	20.5	55.2	75.9
5	17.7	45.9	65.8
2	13.5	32.0	50.5

Equations for rainfall intensity, duration and frequency (IDF) are established based on the results of the frequency analysis. IDF equations are expressed as the following manner.

$$I = a / (t^{n} + b)$$

where,

I : *rainfall intensity (mm/hour)*

t : *duration (minutes)*

a, b, n : *constants*

The constants *a*, *b*, and *n* can be obtained from storm rainfall depth for different duration. In this analysis, IDF equations are established for short duration (within 60 minutes) and for long duration (over 60 minutes). The estimated constants for IDF equations are listed below. IDF curves for the respective return periods are illustrated in Figure 6.1.5

Return Period (years)	Short Duration (< 60 min.)			Long Duration (> 60 min.)		
	a	b	n	a	b	n
50	7182	35.07	1.00	5972	19.04	1.00
40	6882	34.59	1.00	5788	19.54	1.00
30	6497	33.93	1.00	5551	20.25	1.00
20	5952	32.90	1.00	5215	21.40	1.00
10	5013	30.83	1.00	4630	23.89	1.00
5	4050	28.15	1.00	4022	27.54	1.00
2	2640	22.57	1.00	3105	31.72	1.00

6.1.3 Design Storm Rainfall

Design storm rainfall for flood estimation is established in compliance with the available data of the past major rainstorms. To establish design storm rainfall, the following items need to be analyzed.

- duration
- time distribution
- rainfall depth and its frequency

The analyses is carried out using the records at Addis Ababa Observatory for the major rainstorm events in 1970, 1974, 1978, 1987 and 1995.

Figure 6.1.6 shows the rainfall graphs at Addis Ababa Observatory in the past major rainstorm events. As seen in the figure, duration of a series of rainstorm ranges from 2 to 6 hours. Whereas the high intense rainfall causing flood occurs within a shorter duration. The relationship between accumulated rainfall depth and duration shows that a great increase of accumulated rainfall appears within 60 minutes as seen in Figure 6.1.7. Percentage of accumulated rainfall to total rainfall is tabulated below.

Year	Duration (minutes)				
	30	60	120	180	240
1970	32%	81%	94%	96%	99%
1974	33%	90%	100%	100%	100%
1978	47%	73%	80%	85%	95%
1987	66%	87%	100%	100%	100%
1995	54%	95%	97%	100%	100%
Average	51%	88%	94%	96%	99%

From the table above, accumulated rainfall reaches 51% of total rainfall within 30 minutes, 88% within 60 minutes and 94% within 120 minutes on average. It suggests that the magnitude of flood peak discharge in the rivers in the Study Area be subject to heavy rainstorm with a duration of 60 to 120 minutes.

In addition, flood traveling time is taken into account to evaluate duration of design storm rainfall. Flood traveling time of the rivers in the Study Area is estimated using the empirical equations as described in the subsequent section 6.2. As a result, estimated flood traveling time from uppermost catchment to objective flooding areas is found to be not more than 120 minutes.

As a conclusion of rainfall depth-duration analysis and flood traveling time in the rivers in the Study Area, the duration of design storm rainfall is decided to be 120 minutes.

Time distribution of design storm rainfall is established applying the averaged curve for percentage of accumulated rainfall depth of the past major rainstorms. From the averaged curve, percentages of storm rainfall depth are obtained by 10 minutes interval as seen in Figure 6.1.8.

Depth of design storm rainfall and its frequency is known by IDF equations. The rainfall depths in 120 minutes duration for different return periods are derived from IDF equations as given below.

Return Period (years)	Rainfall Depth in 120 Minutes Duration (mm)
50	85.9
40	83.0
30	79.2
20	73.8
10	64.4
5	54.5
2	39.5

Rainfall depth in each 10 minutes interval can be computed multiplying the corresponding percentage to total rainfall depth in 120 minutes duration.

The resultant of the design storm rainfall is examined in view of coverage of the past major rainstorms. Figure 6.1.9 shows the comparison of accumulated rainfall depths for the design storm rainfalls and the rainstorm events in 1970, 1978 and 1995. The curves of the major rainstorms are almost covered by that of the design storm rainfall with 30-year return period. In other words, the frequency of the recorded heaviest rainstorm in 1970 is approximately equivalent to the return period of 30-year.

6.2 Runoff Analysis

6.2.1 General

For the purpose of flood control plan, it is necessary to estimate the magnitude of flood as design value, which is indicated by flood peak discharge and hydrograph. In general, carrying capacity of river channel is designed on the basis of flood peak discharge. Whereas design of flood retention facility for reduction of flood peak discharge requires flood runoff hydrograph in order to examine a retention capacity against runoff volume.

The analysis is therefore carried out for estimation of flood peak discharge as well as flood hydrograph for each objective river. The magnitude of flood is evaluated by runoff calculation on the basis of the design storm rainfall discussed in the sub-section 6.1 above due to the absence of runoff data in the Study Area. In consideration of the scale and hydrological characteristics of the river basins, the rational formula as given below is applied for runoff calculation.

$$Q = 1/3.6\ C\ I\ A$$

where,

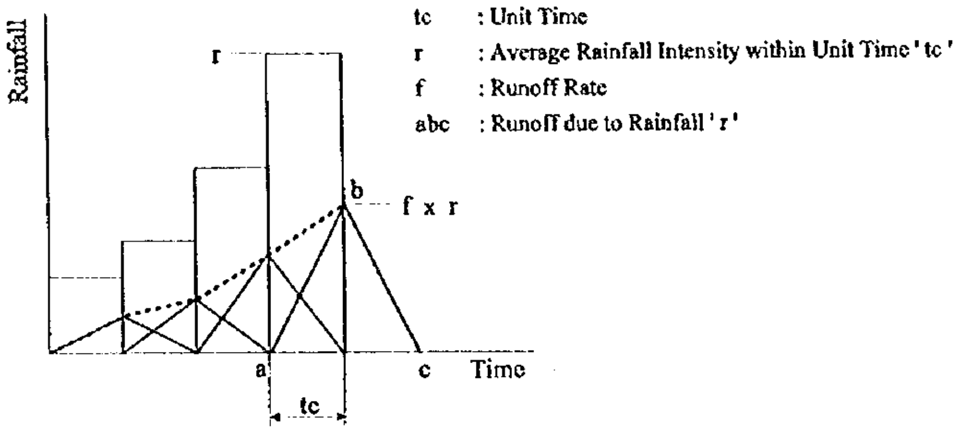
Q : *peak discharge* (m^3/sec)

C : *runoff rate*

I : *rainfall intensity (mm/hour)*

A : *catchment area* (km^2)

Flood runoff hydrograph is obtained by the rational formula in combination with unit hydrograph. It is assumed that rainfall within a unit time causes runoff indicating triangular hydrograph. This triangular hydrograph is considered as unit hydrograph . The sum of unit hydrograph for rainfall in each unit time results in flood runoff hydrograph. The computation of flood runoff hydrograph is explained as follows.



6.2.2 Flood Routing Model

In the flood runoff analysis, flood routing model is constructed in order to evaluate the magnitude of flood by location. The river system is divided into a number of sub-basins and stretches, taking the followings into consideration.

- hydrological characteristics (topography, riverbed gradient, land use, etc.)
- confluence
- base points for flood control (locations of existing or planned structures)

The schematic diagrams of flood routing model for the objective rivers are shown in Figures 6.2.1 to 6.2.5. Using the flood routing model, flood runoff is computed successively from upstream to downstream.

For computation of runoff by the flood routing model, the following data are prepared. Details are described in the succeeding sub-section 6.2.3.

- catchment area
- overland flow time
- channel flow time
- basin rainfall
- runoff rate
- base flow

6.2.3 Model Preparation

(1) Catchment Area

Catchment areas of sub-basins are obtained from the available topographic maps with a scale of 1:10,000 or 1:50,000. Other necessary information including topography, length and gradient of river, and land use are also derived from these maps.

(2) Overland Flow Time

Overland flow time is a time of runoff traveling from the remotest point to the downstream end of sub-basin and estimated by the following equation.

$$T_1 = 0.01947\, L^{0.77} / S^{0.385}$$

where,

T_1 : *overland flow time (minutes)*

L : *stream length (km)*

S : *gradient of stream*

(3) Channel Flow Time

Channel flow time is a time of runoff traveling from the upstream end to the downstream end of sub-basin and estimated by the following equation.

$$W = 20\,(H / L)^{0.6}$$

$$T_2 = 1 / 60\,(L / W)$$

where,

W : *flow velocity (m/sec)*

H : *height difference between upstream and downstream ends (m)*

L : *channel length (m)*

T_2 : *channel flow time (minutes)*

(4) Basin Rainfall

The analysis of rainfall intensity and duration at Addis Ababa Observatory are discussed in the sub-section 6.1 above. In addition, rainfall depth-area analysis is generally required for evaluating basin rainfall for flood estimation. However, storm rainfall data is not sufficiently available for evaluating depth-area relationship of rainfall in the Study Area.

Concerning with rainfall depth-area analysis, a similar analysis was elaborated on PMP isohyets for Gerbi Dam. The following equation was established for the depth-area relationship on the basis of storm rainfall at Addis Ababa Observatory.

(Rainfall Point-Area Ratio, %) = 111 - 3.85 x (Storm Radius, km)

Referring to the resultant of the PMP isohyetes analysis, a ratio of point rainfall at Addis Ababa Observatory to basin rainfall for each objective river is estimated in the case of the design storm rainfall with 120 minutes duration.

River System	Rainfall Point-Area Ratio
Kebena	87 %
Bantyiketu + Kechene + Kurtume	91 %
Little Akaki	88 %
West Akaki	77 %
Hanku	95 %

(5) Runoff Rate

Runoff rates are given to the sub-basins in compliance with the present land use in the Study Area. The following values are adopted in general.

Land Use	Runoff Rate
densely build-up area	0.7
moderately build-up area	0.6
cultivated land / grassland	0.5
mountain	0.6

(6) Base Flow

The average monthly runoff in August is 43.8 m^3/sec at Akaki gauging station, which is equivalent to 0.05 m^3/sec/km^2. This specific runoff is given to the sub-basins as base flow during flood season.

6.2.4 Estimation of Probable Flood Runoff

The probable flood runoff for each river in the Study Area is estimated on the basis of the conditions discussed above. For the purpose of flood control plan, probable flood runoff is firstly estimated in case of flood with the magnitude equivalent to the past maximum flood as far as recorded. Assuming that frequency of flood event corresponds with that of rainstorm, probability of such a flood event is evaluated at once in 30 years. The probable flood runoff is therefore estimated by runoff analysis using the design storm rainfall with the return period of 30 years. The estimated flood peak discharges are presented below.

River	Catchment Area (km^2)	Flood Peak Discharge (m^3/sec)
Kebena	89.1	578
Kechene	13.6	131
Kurtume	10.3	102
Bantyiketu	29.3	229
Little Akaki	30.8	212
West Akaki	172.2	561
Hanku	11.1	108

The estimated flood peak discharges are compared with the maximum discharges recorded or estimated in the neighboring river basins in the Study Area, namely, the upper Aish and the upper Blue Nile basins. The comparison is made on the basis of specific discharge (flood peak discharge per km^2). Although the available records are limited, an envelope curve of specific discharge is obtained as seen in Figure 6.2.6. This envelope curve suggests a regional characteristic of flood peak discharge in relation to catchment area.

The estimated flood peak discharges in the Study Area are seen above the envelope curve. It means that the estimated values are higher than those suggested by the available data. These higher values in the Study Area may result from the particular catchment characteristics in the Study Area. The rivers in the Study Area have relatively small catchment area (less than 200 km^2) and flow down the very steep mountains and the urbanized areas. Whereas the most of the available data were recorded further downstream of the Study Area. Their catchment areas are relatively wide (100 to 10,000 km^2) and dominated by moderately sloping topography. Taking such difference of catchment into account, the flood peak discharges resulting from runoff analysis are generally acceptable.

6.3 Design Discharge Distribution

6.3.1 Basic Flood Discharge

(1) General

Basic flood discharge is a fundamental design value for flood control plan and determined under the following assumptions.

- River basin is in future condition as of the target year for flood control plan.
- Flood discharge can be confined in river channel. Namely, carrying capacity of river is sufficiently improved against the magnitude of flood runoff designated for flood control plan.
- No flood retention facility exists in river basin.

(2) Future Runoff Rate

Basic flood discharge in the Study Area should be estimated under future river basin conditions in the year 2020 which is the target year of flood control master plan. Thus, the runoff rate in the objective river basins should be evaluated on the basis of future land use in the year 2020.

Future land use in the Study Area is proposed by Addis Ababa Master Plan and analyzed by the study on the socio-economic framework for this flood control plan as discussed in Chapter 7. In compliance with the future land use, significant change of runoff rate in the Study Area is not expected until the year 2020 from the following viewpoints.

- Future urban area will mainly expand to the south. The expanding urban area is located further downstream of the objective rivers in the Study Area.

- Upstream basins of the objective rivers will be preserved as forest area. Reforestation activities are also being proceeded in these areas.

- Green areas in the city will be preserved or improved.

The same runoff rate as present condition is therefore applied for estimation of basic flood discharge.

(3) Distribution of Basic Flood Discharge

The basic flood discharge for each river is estimated on stretch or tributary basis in order to know the different magnitude of flood discharge by location. Distribution of stretch with basic flood discharge for different return period is compiled in Table 6.3.1.

6.3.2 Flood Control Alternatives

(1) Provision of Alternatives

As discussed in Chapter 9, the basic concept of flood control master plan is that flood discharge should be regulated by temporary storage as much as possible in upstream reaches and remaining discharge to downstream reaches should be discharged safely by river channel improvement. This concept aims at minimizing negative social impact, namely resettlement by implementing river channel improvement with due consideration to the present condition that most of riverine areas to be protected has already been built up densely. The alternatives of structural measures therefore consist of limited extent of river channel improvement in combination with flood retention facilities including flood control weir and regulating pond, and diversion tunnel.

On the basis of the basic concept, the following alternatives are prepared.

Kechene River

Alternative 1	1 Flood Control Weir, Channel Improvement
Alternative 2	1 Flood Control Weir, 1 Regulating Pond and Channel Improvement

Kurtume River

Alternative 1	2 Regulating Ponds and Channel Improvement
Alternative 2	4 Regulating Ponds and Channel Improvement

Bantyiketu River

Alternative 1	River Channel Improvement
Alternative 2	1 Regulating Pond and River Channel Improvement

Kebena River

Alternative 1	2 Flood Control Weirs and River Channel Improvement
Alternative 2	3 Flood Control Weirs and River Channel Improvement

Little Akaki River

Alternative 1	1 Regulating Pond, Diversion Tunnel and River Channel Improvement
Alternative 2	1 Regulating Pond and River Channel Improvement

Provision of structural measures for the Hanku river is limited to the improvement of the existing culverts in the upstream reaches. The downstream reaches will be maintained to be the natural retarding basin as in the present condition.

The West Akaki river indicates sufficient carrying capacity against flood and intensive land use is not found at present in the riverine areas. Therefore, structural measures are not provided and regulation of future land use is proposed to maintain the present condition along the river.

(2) Selection of Optimum Design Scale

To select an optimum design scale, the study is carried out comparing the alternative design scales with different flood protection levels as discussed in Chapter 9. The Bantyiketu system including the Kechene and the Kurtume is selected to conduct this alternative study. The alternative design scales are provided as follows.

River	Flood Protection Level / Design Scale (return period of probable flood, years)		
	Case 1	Case 2	Case 3
Kechene (Tributary)	10	20	30
Kurtume (Tributary)	10	20	30
Bantyiketu (Main River Channel)	20	30	40

For comparison of the cases above, the study is conducted on the basis of the Alternative 2 for each river. The distributions of design flood discharge for the respective cases are shown in Figure 6.3.1 to 6.3.3.

As a result of this study, the design scale is selected against probable 30-year flood for the main river channels and probable 20-year flood for tributaries.

(3) Comparison of Alternatives

Distribution of design flood discharge for each flood control alternative is elaborated in line with assessment of individual scales of flood control structures. A scale of each structure is assessed on the basis of design flood discharge as well as topographic configuration, minimizing resettlement and siting/combination of structures for flood control effectiveness. The distribution of design flood discharge for each alternative is shown in Figure 6.3.4 to 6.3.13.

After the comparison of the alternatives, the followings are selected as the flood control plan for the respective rivers.

Kechene River	1 Flood Control Weir, 1 Regulating Pond and Channel Improvement
Kurtume River	4 Regulating Ponds and Channel Improvement
Bantyiketu River	1 Regulating Pond and River Channel Improvement
Kebena River	2 Flood Control Weirs and River Channel Improvement
Little Akaki River	1 Regulating Pond, Diversion Tunnel and River Channel Improvement

Finally, prioritization of the flood control plan is carried out in order to formulate the master plan in the whole Study Area. The result gives that the flood control plan for the Bantyiketu system including the Kechene and the Kurtume indicates the highest viability.

Details of the studies above are described in Chapter 9.

6.3.3 Priority Project

The flood control plan for the Bantyiketu river system is evaluated with the highest viability among the flood control master plan in the Study Area. The earliest implementation of this plan is therefore proposed. Whereas it is important that a scale of investment for flood control project and its effectiveness should be carefully assessed in order to prepare an appropriate implementation plan from financial viewpoints. For this purpose, the evaluation study is carried out to select a priority project which needs to be implemented in the earliest stage of the flood control plan for the Bantyiketu system. In compliance with the primary evaluation of the project components, the following alternative cases are selected for the evaluation study.

River	Case 1	Case 2	Case 3	Case 4	Case 5
Kurtume river					
- regulating pond	O	-	O	-	-
- channel improvement	O	-	O	-	-
Kechene river					
- weir	O	O	-	O	O
- regulating pond	O	O	-	O	O
- channel improvement	O	O	-	-	-
Bantyiketu river					
- regulating pond	O	O	O	O	O
- channel improvement	O	O	O	O	-

In the selection of priority project, the alternatives of Case 2 to 5 are provided on the condition that the flood control project of the whole Bantyiketu river system (same as Case 1) should be realized finally by further implementation. Therefore, these cases have different flood protection levels before completion of the whole project which has the flood protection level against probable 20-year flood for the Kechene and the Kurtume and 30-year for the Bantyiketu, respectively. As a result of distribution of design flood discharge, the flood protection levels for the alternative cases are evaluated as follows.

Flood Protection Level (Return Period of Design Flood for Bantyiketu River System, years)

River	Case 1	Case 2	Case 3	Case 4	Case 5
Kurtume river	20	5	20	5	5
Kechene river	20	20	5	15	20
Bantyiketu river	30	20	15	20	10

Flood control benefits for each case are estimated using the flood protection levels tabulated above. The selection of priority project is carried out on the basis of cost/benefit analysis as well as the other evaluation items such as technical soundness, social impact, initial environmental examination (IEE) and financial status. Details are discussed in Chapter 12.

6.4 Flooding Analysis

6.4.1 Present Carrying Capacity

Present carrying capacity of the objective rivers is evaluated by hydraulic analysis using the results of the river cross section survey conducted from May to July 1997. The survey results are compiled into longitudinal profile, river width diagram and carrying capacity diagram as seen in Figure 6.4.1 to 6.4.7. From these figures, the channel characteristics of the rivers are summarized as follows.

River	Average Slope	Channel Width(m)		Carrying Capacity (m^3/sec)
		Minimum	Average	
West Akaki	1/100	15	40	400 - 800
Little Akaki	1/50	5	20	50 - 300
Kebena	1/50	5	25	150 - 800
Kechene	1/30	8	15	50 - 250
Kurtume	1/35	8	10	30 - 150
Bantyiketu	1/120	10	20	30 - 300
Hanku	1/60	5	10	20 - 150

From the carrying capacity diagrams, major problematic areas due to flooding are identified.

In the Bantyiketu, the cross sections around the distance of 0.8 km, 2.3 km and 3.6 km show quite low carrying capacity less than 50 m^3/sec. Almost 50% length of the surveyed stretch has carrying capacity less than 150 m^3/sec or probable 5-year flood.

The Kechene and the Kurtume show sufficient carrying capacity for probable 10-year flood in general but the cross sections with lower carrying capacity exist at a few locations.

The stretch of the Little Akaki in the distance between 3 km to 9 km has a several number of cross sections with low carrying capacity ranging from 40 to 100 m^3/sec, which is less than probable 2-year flood.

The middle reaches of the Kebena in the distance between 4 to 7 km, shows the minimum carrying capacity of 120 m^3/sec. The most of this stretch has carrying capacity less than 300 m^3/sec or probable 7-year flood.

The stretch of the Hanku in the distance between 1.5 km to 2.5 km indicates quite low carrying capacity of 20 m^3/sec or less. This stretch is a part of the natural retarding basin expanding over the lower reaches. Low carrying capacity is also seen around the distance of 4 km where the small culvert exists.

The West Akaki indicates sufficient carrying capacity against 500 m^3/sec or probable 20-year flood in the most of the surveyed reaches.

6.4.2 Flooding Area

For the purpose to evaluate potential flood damage, flooding area due to probable flood is estimated in compliance with review of existing damage reports of 1978, 1994 and 1995 flood events, interview survey for riverine people and hydraulic analysis.

Extent of estimated flooding areas generally corresponds with the river stretches with low carrying capacity as described in the section 6.4.1 above. The results of flooding analysis are compiled into the relationship between flooding area and the magnitude of flood. The summary of flooding analysis is tabulated below.

Flooding Area (ha)

River	Return Period (years)			
	5	10	20	30
Bantyiketu	36	43	56	66
Kebena	7	10	17	21
Little Akaki	16	21	30	36
Hanku	4	14	27	30

Table 6.1.1 Annual Maximum Rainfall at Addis Ababa OBS

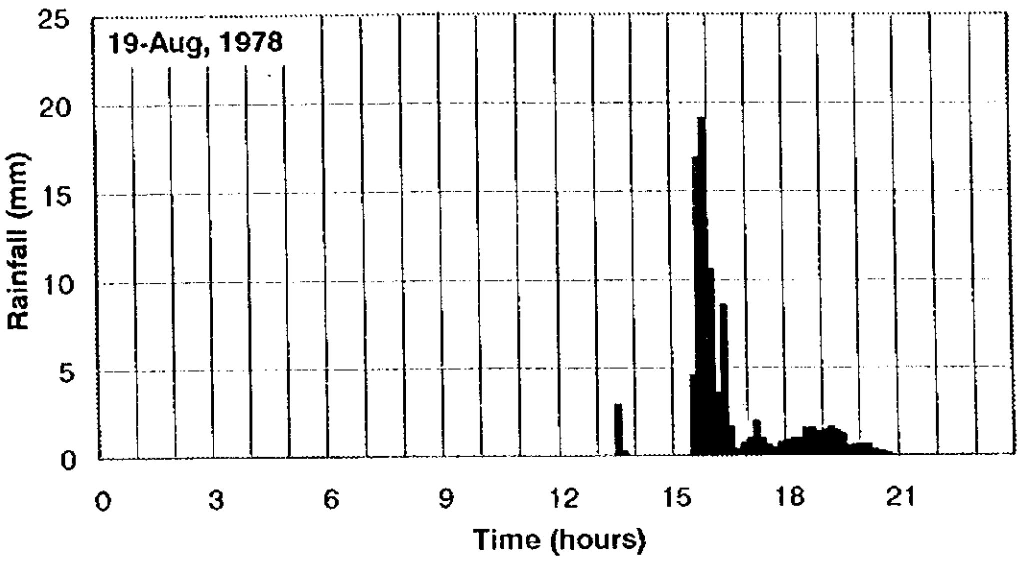
Year	10 min.	60 mim.	1-day
1951			32.7
1952			39.5
1953			50.6
1954			54.9
1955			42.5
1956			72.6
1957			59.8
1958			55.2
1959			43.2
1960			32.9
1961			38.1
1962			53.0
1963			56.2
1964			51.0
1965			58.6
1966			57.8
1967			39.0
1968			88.0
1969	19.0	32.5	51.0
1970	23.0	73.2	87.7
1971	11.6	39.1	42.1
1972	14.3	22.8	25.1
1973	14.3	28.8	47.1
1974	17.5	45.3	62.5
1975	11.2	20.6	28.9
1976	11.7	21.6	48.6
1977	14.0	44.3	59.4
1978	19.0	63.1	93.5
1979	12.0	23.0	50.6
1980	16.1	31.3	36.3
1981	10.0	23.8	58.0
1982	-	31.9	41.4
1983	10.4	24.8	50.1
1984	10.6	44.3	55.4
1985	10.3	26.8	43.2
1986	-	32.0	83.8
1987	19.5	48.2	56.8
1988	14.0	24.4	35.5
1989	23.3	34.9	49.2
1990	9.6	18.8	39.6
1991	13.3	20.3	47.3
1992	11.3	20.5	51.4
1993	9.7	38.8	53.5
1994	9.4	35.0	57.0
1995	18.2	58.0	85.3
1996	13.8	25.0	67.0

Table 6.3.1 Basic Flood Discharge

(Unit : m3/sec)

River	Location	Return Period (years)				
		2	5	10	20	30
Kechene	Proposed Kechene Weir Site	45	65	75	85	90
	Ras Mekonen Bridge	70	90	105	115	130
Kurtume	D. Yigezu Bridge	15	20	25	30	35
	H. Giyorgis Bridge	50	70	85	95	100
Bantyiketu	Filwiha Bridge	115	155	185	210	225
	Upstream Conf. Kebena	120	160	190	215	230
Little Akaki	Proposed Regulating Pond Site	30	40	50	55	60
	Akaki Bridge	90	120	145	165	175
	Mekanisa Bridge	95	130	155	180	195
	Upstream Conf. West Akaki	110	145	170	195	215
West Akaki	Jema Road Bridge	280	380	450	510	550
	Downstream Conf. Little Akaki	300	410	480	550	600
Kebena	Proposed Kebena No.1 Weir Site	80	110	130	150	160
	Proposed Abo No1. Weir Site	80	110	130	150	160
	T. Aseged Bridge	190	270	310	360	390
	Urael Bridge	200	280	320	370	400
	Bole Bridge	290	400	470	540	580
Hanku	Bridge, Asmera Road	25	30	35	40	45
	Bridge, Road to Bole Airport	50	65	75	90	95

Addis Ababa OBS



Bole

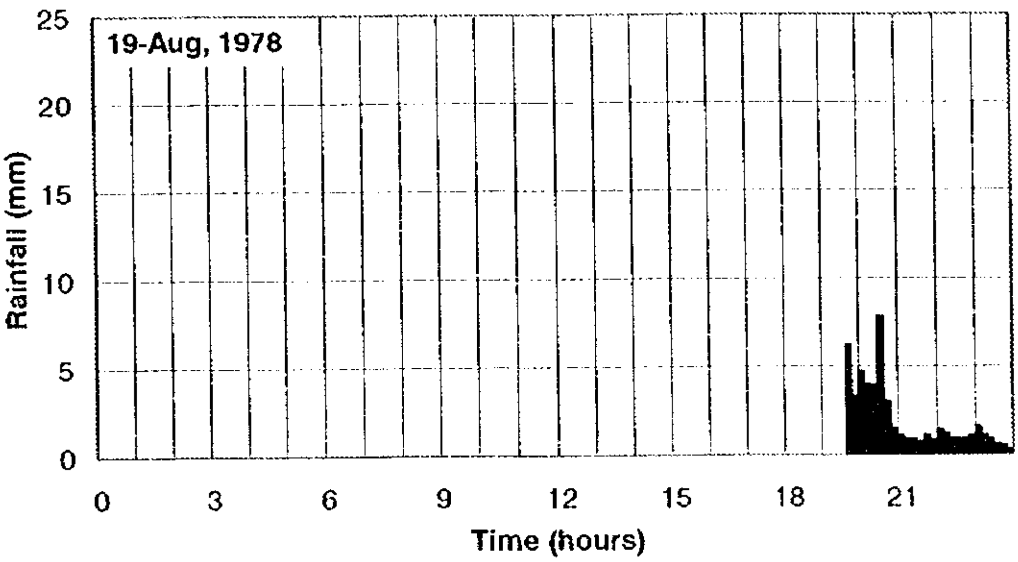


Figure 6.1.1 Rainstorm in 1978

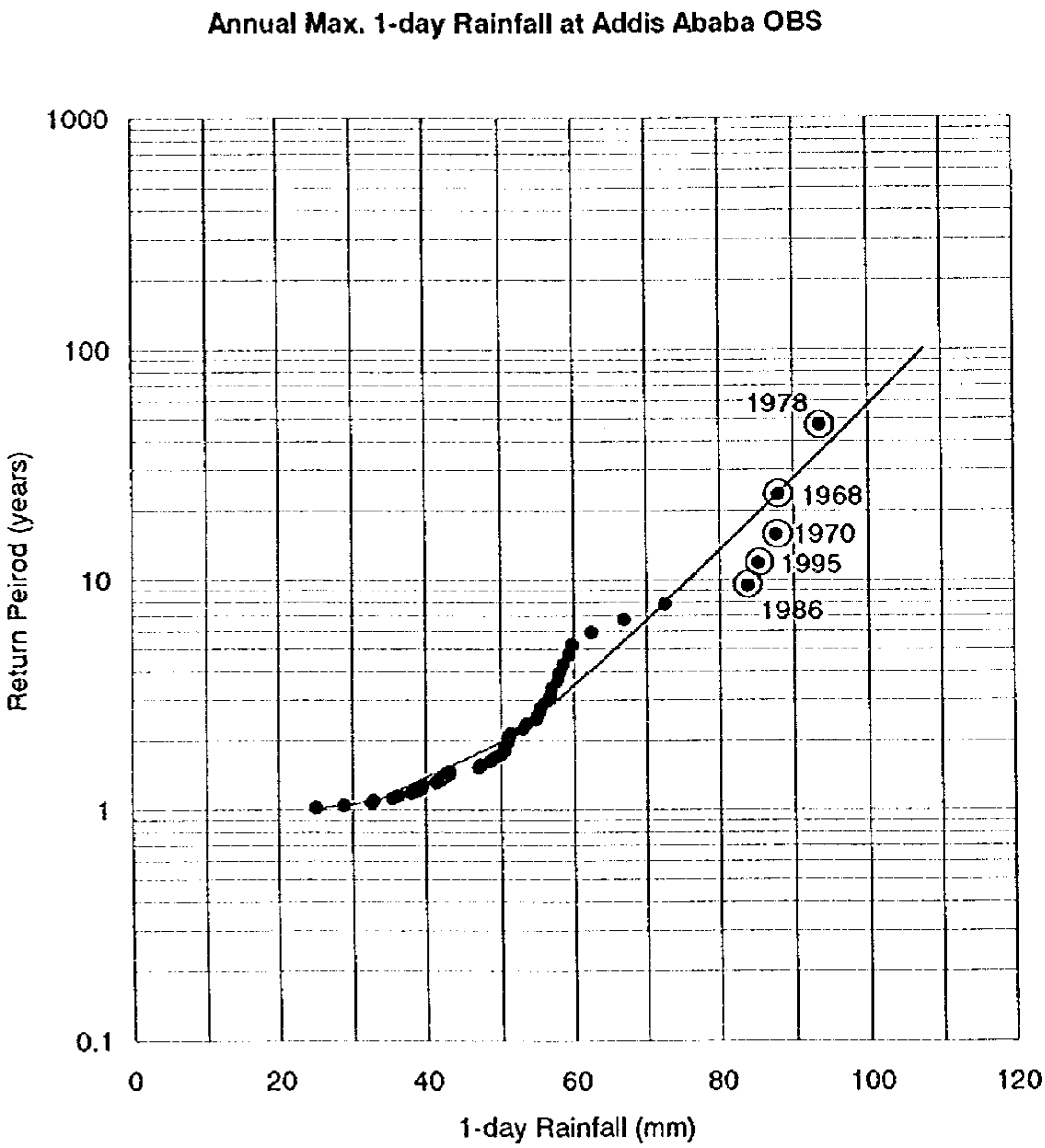


Figure 6.1.2 Frequency Analysis for 1-day Rainfall

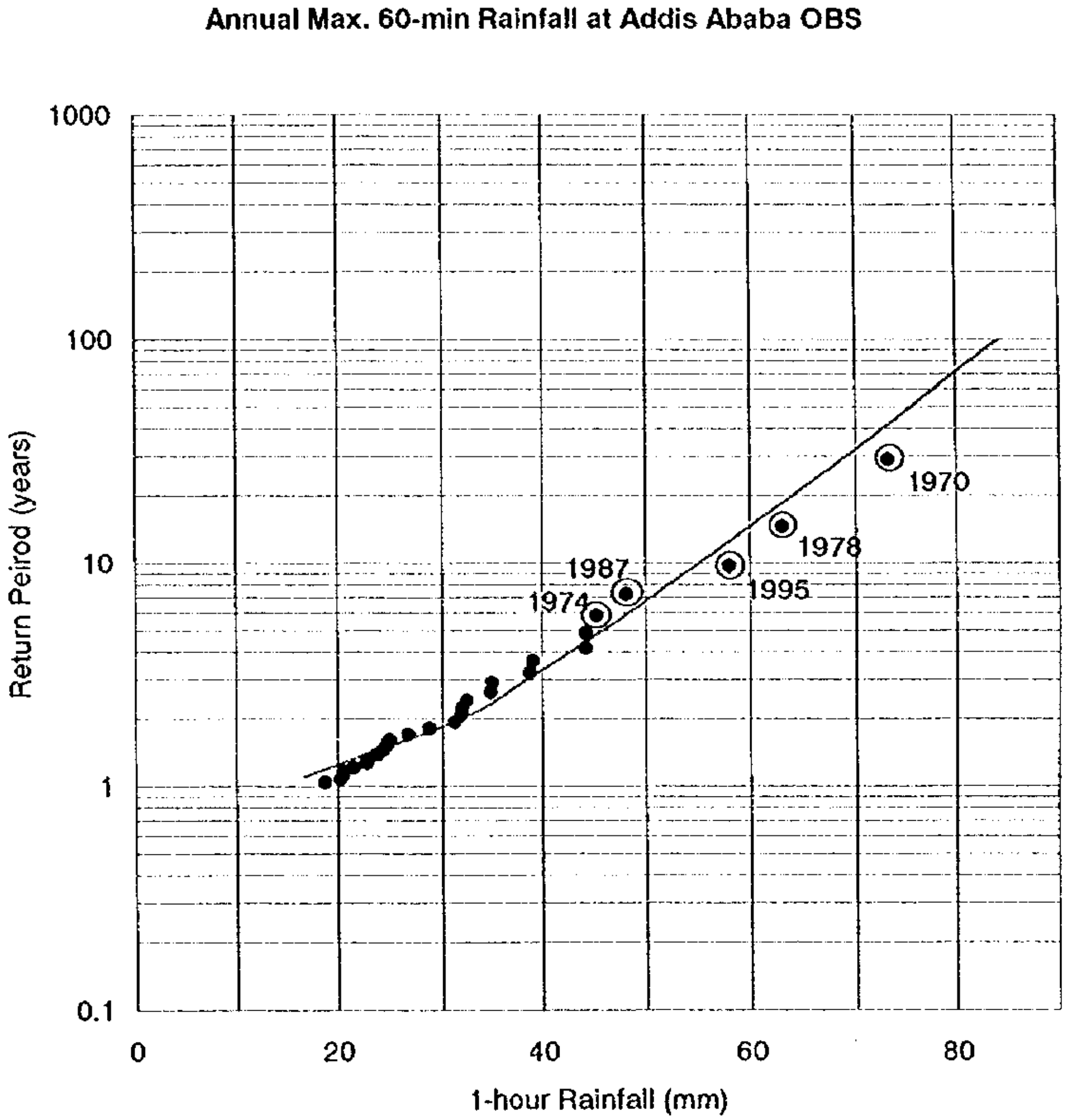


Figure 6.1.3 Frequency Analysis for 60-min. Rainfall

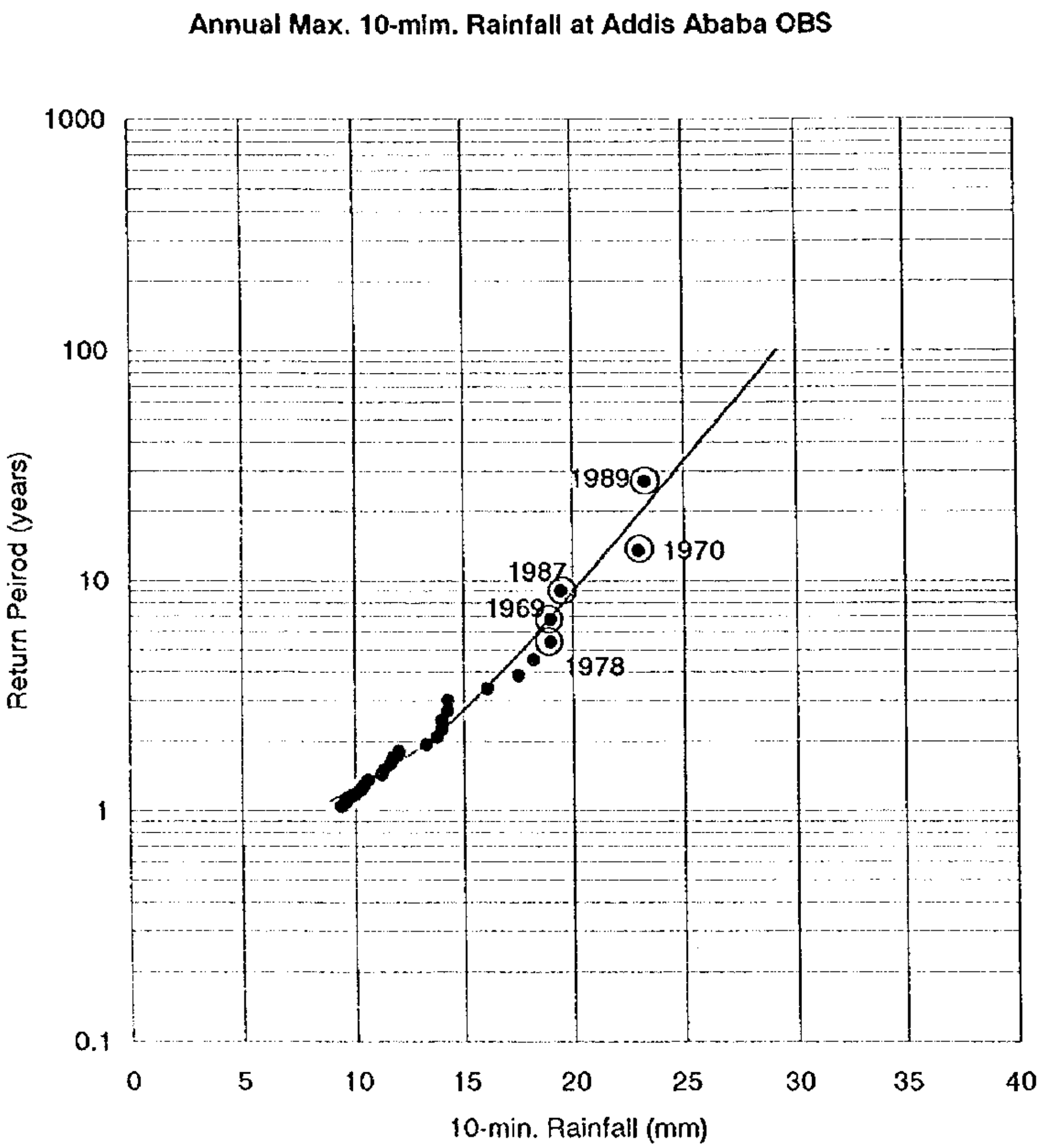


Figure 6.1.4 Frequency Analysis for 10-min. Rainfall

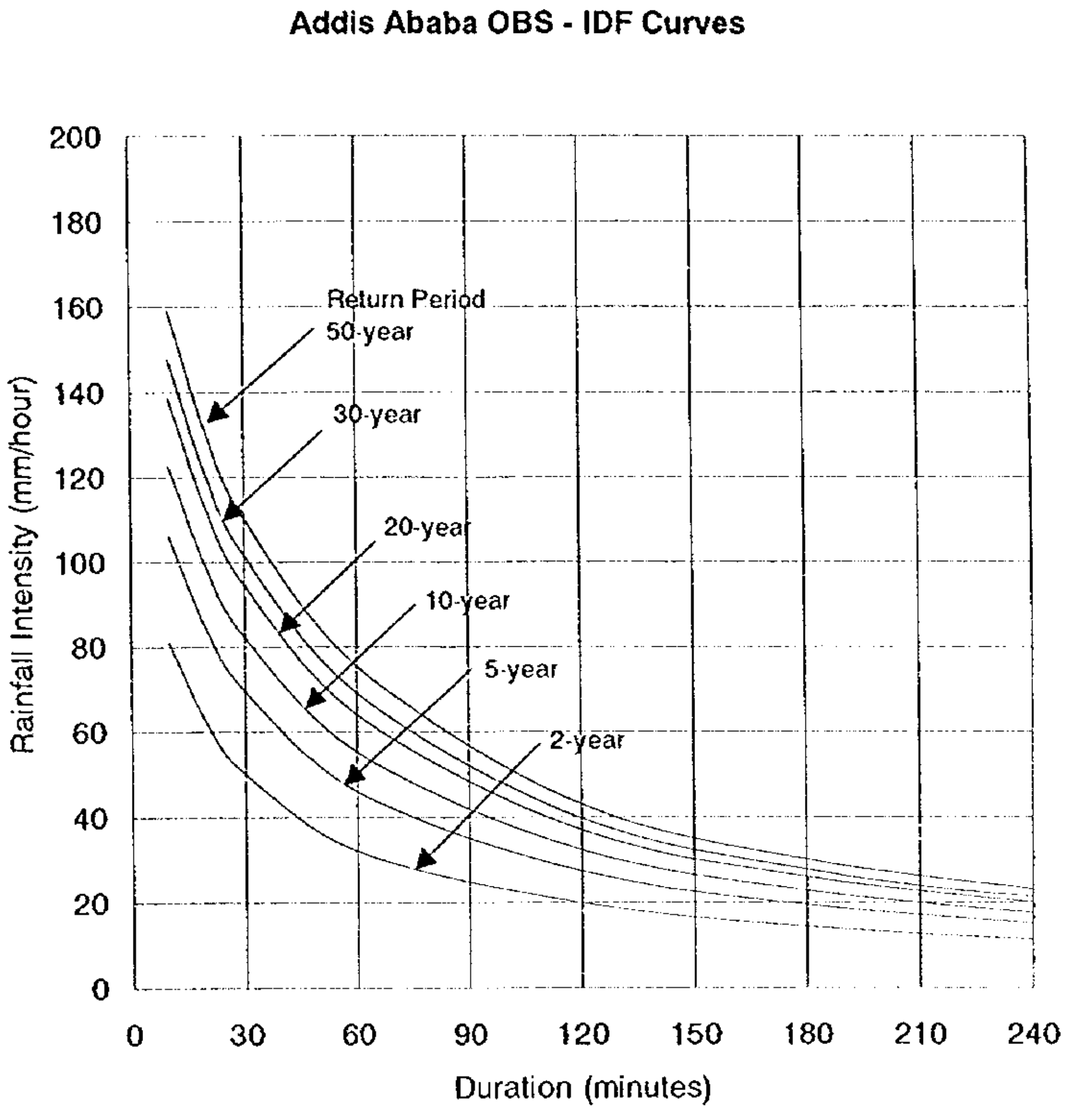


Figure 6.1.5 Rainfall Intensity, Duration and Frequency Curvers

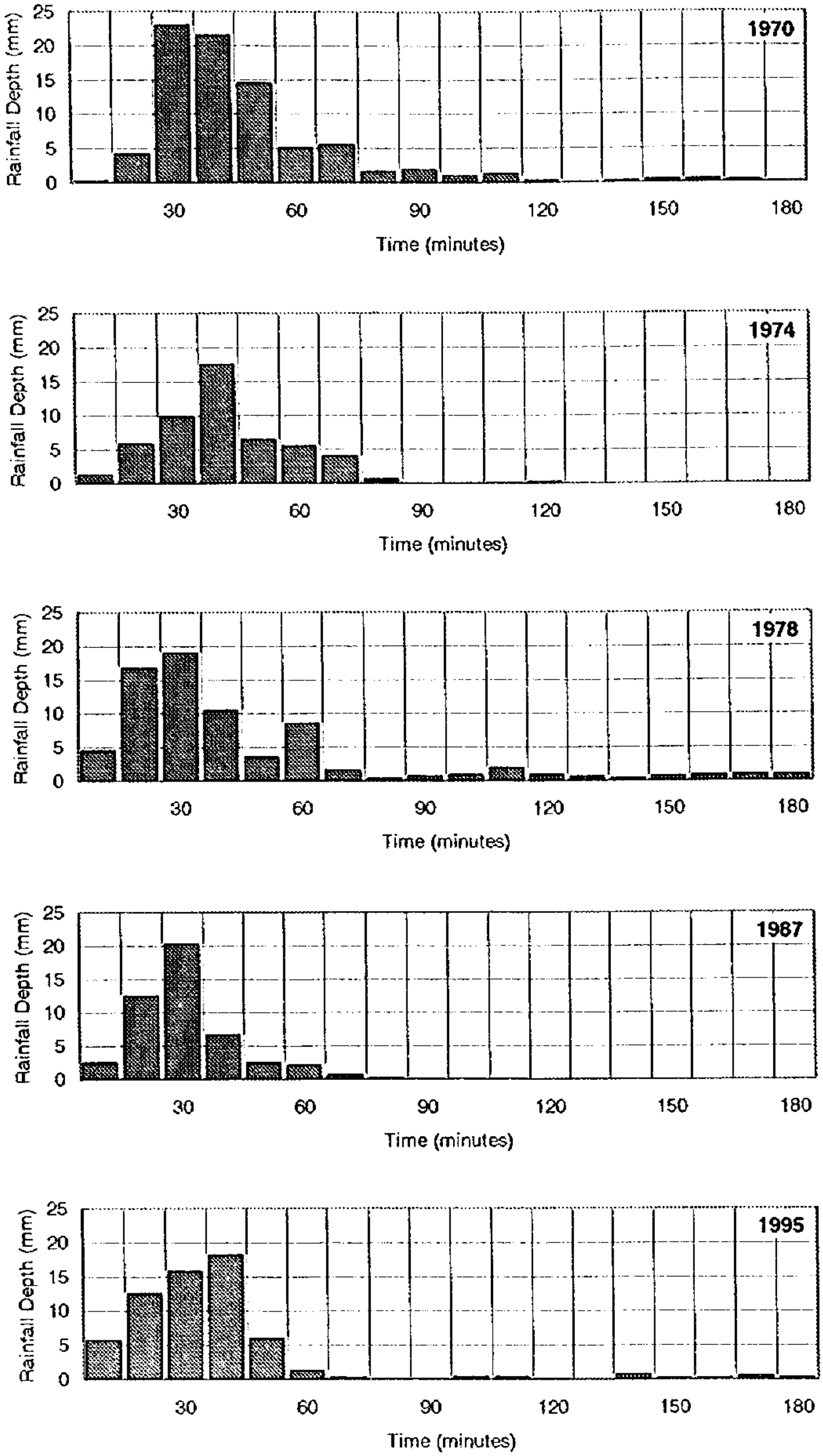
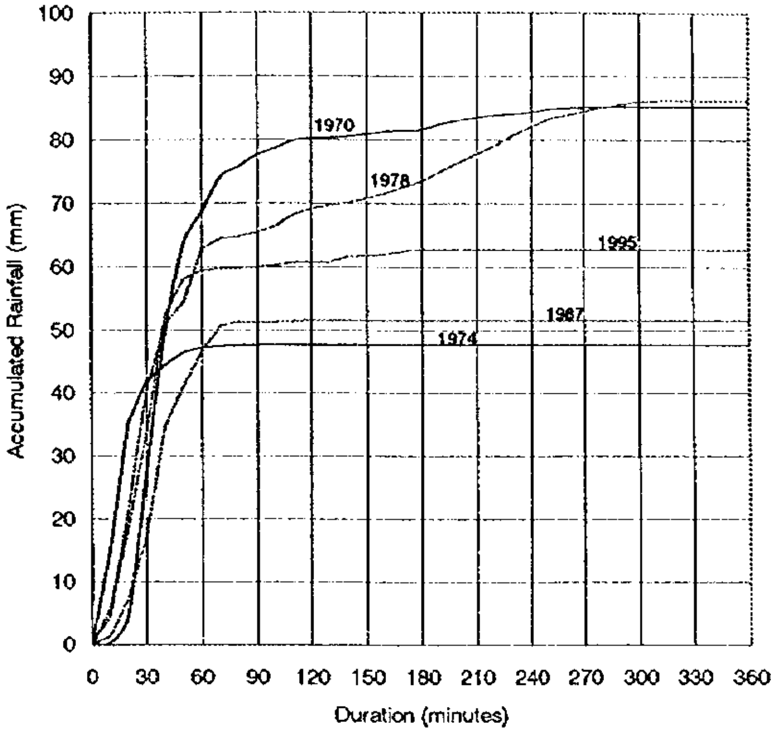


Figure 6.1.6 Rainfall Hyetograph in Major Rainstorm

Accumulated Rainfall - Duration



Percentage of Accumulated Rainfall - Duration

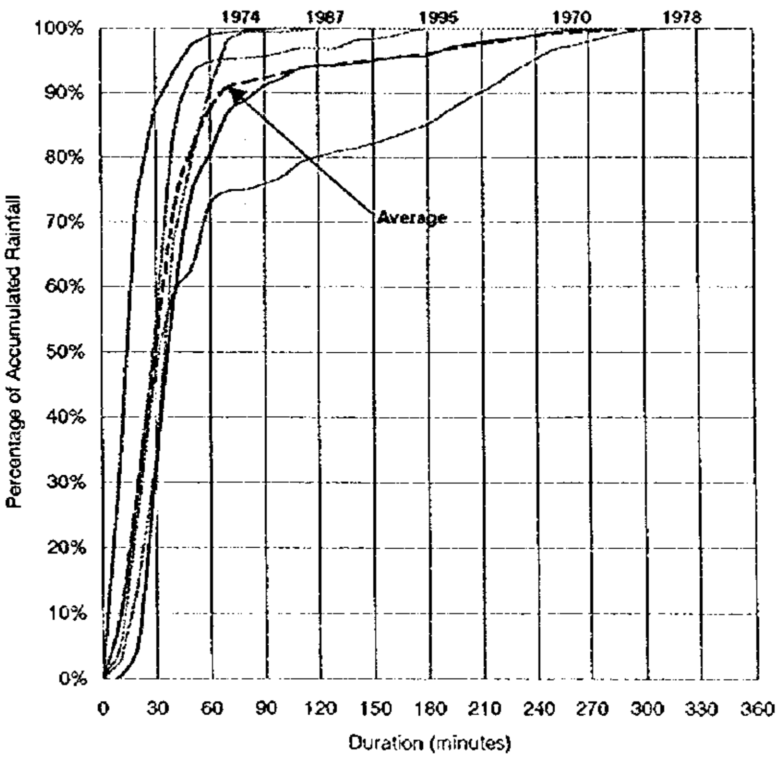
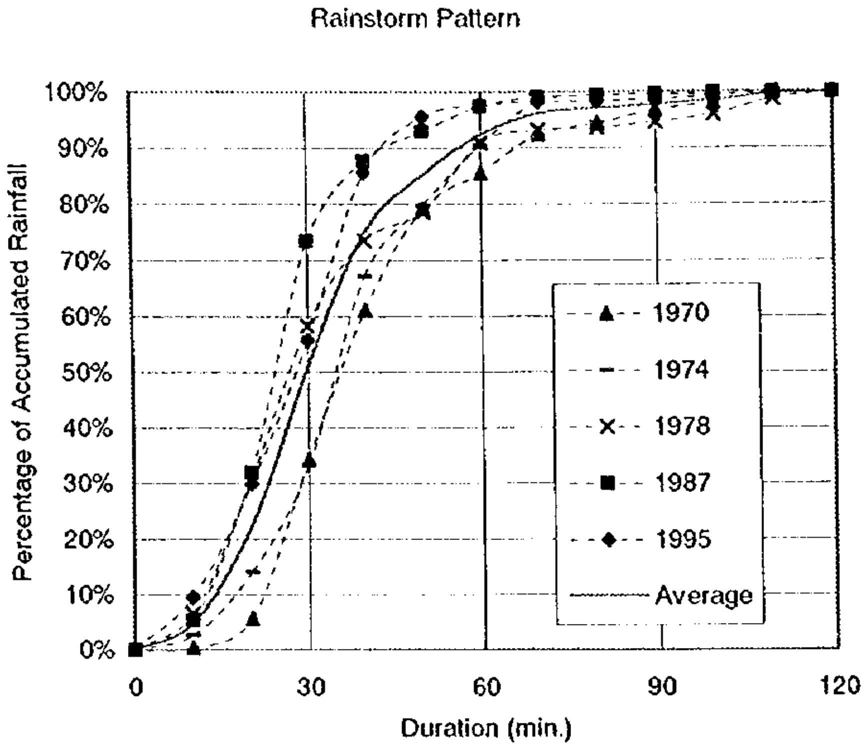


Figure 6.1.7 Accumulated Rainfall and Duration



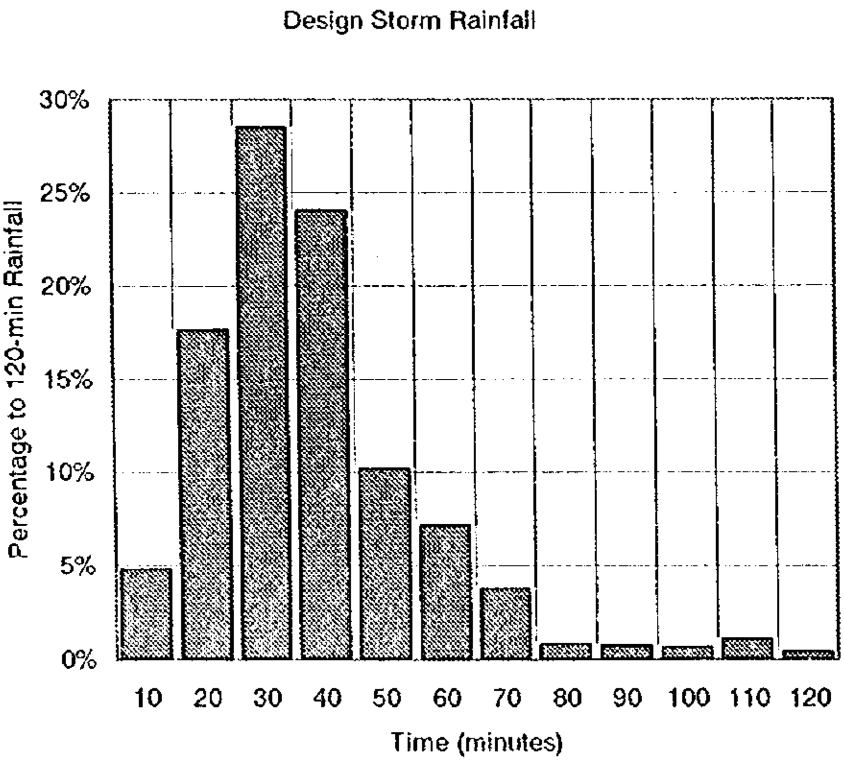


Figure 6.1.8 Time Distribution of Design Storm Rainfall

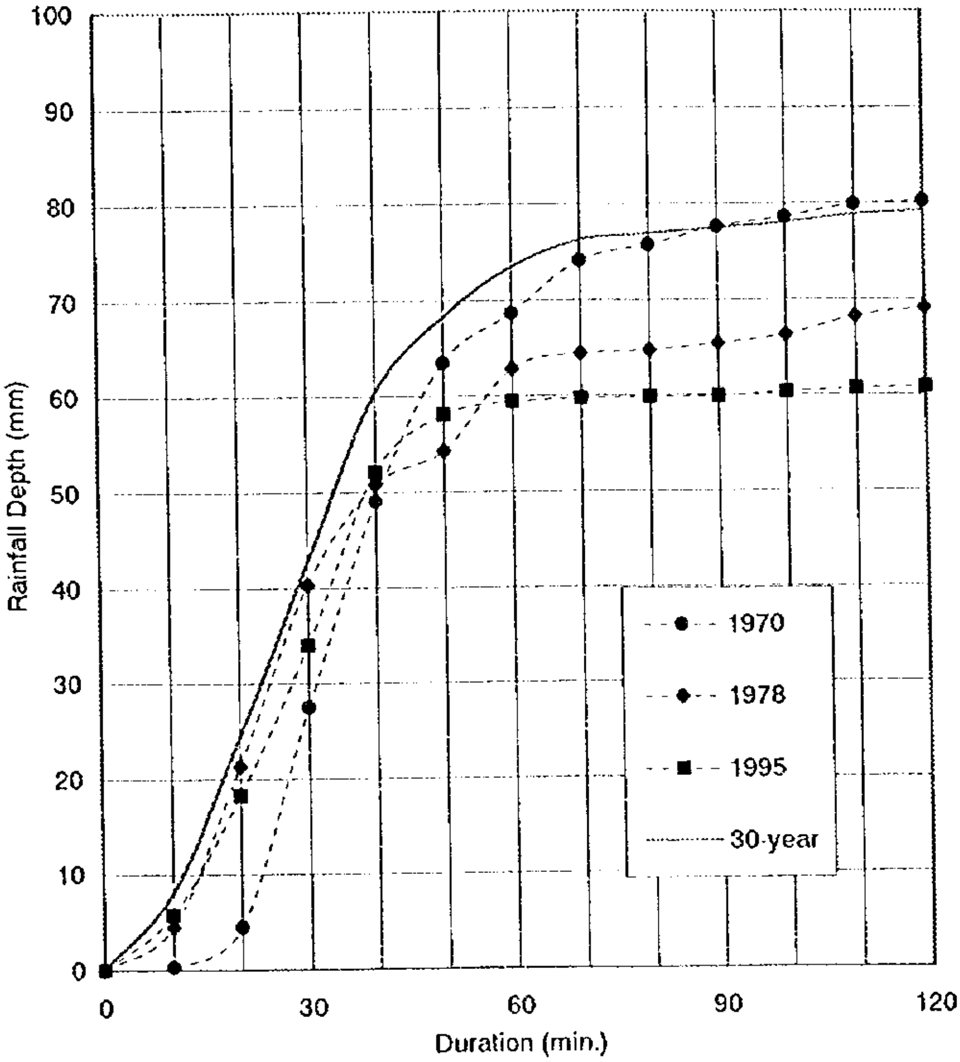


Figure 6.1.9 Comparison of Design Storm Rainfall and Major Rainstorm Events

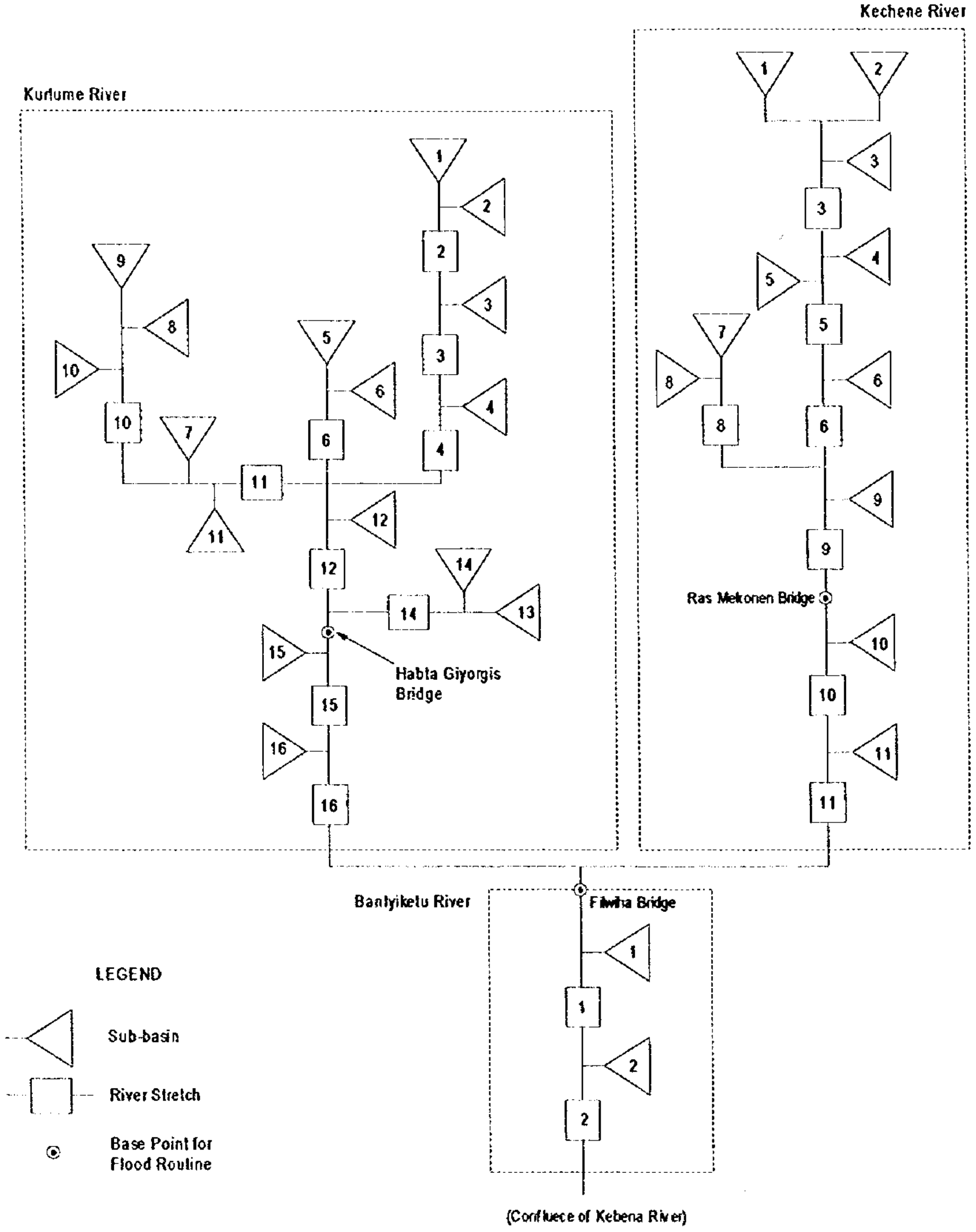


Figure 6.2.1

Schematic Diagram of Flood Routine Model
Kechene, Kurtume and Bantyiketu River

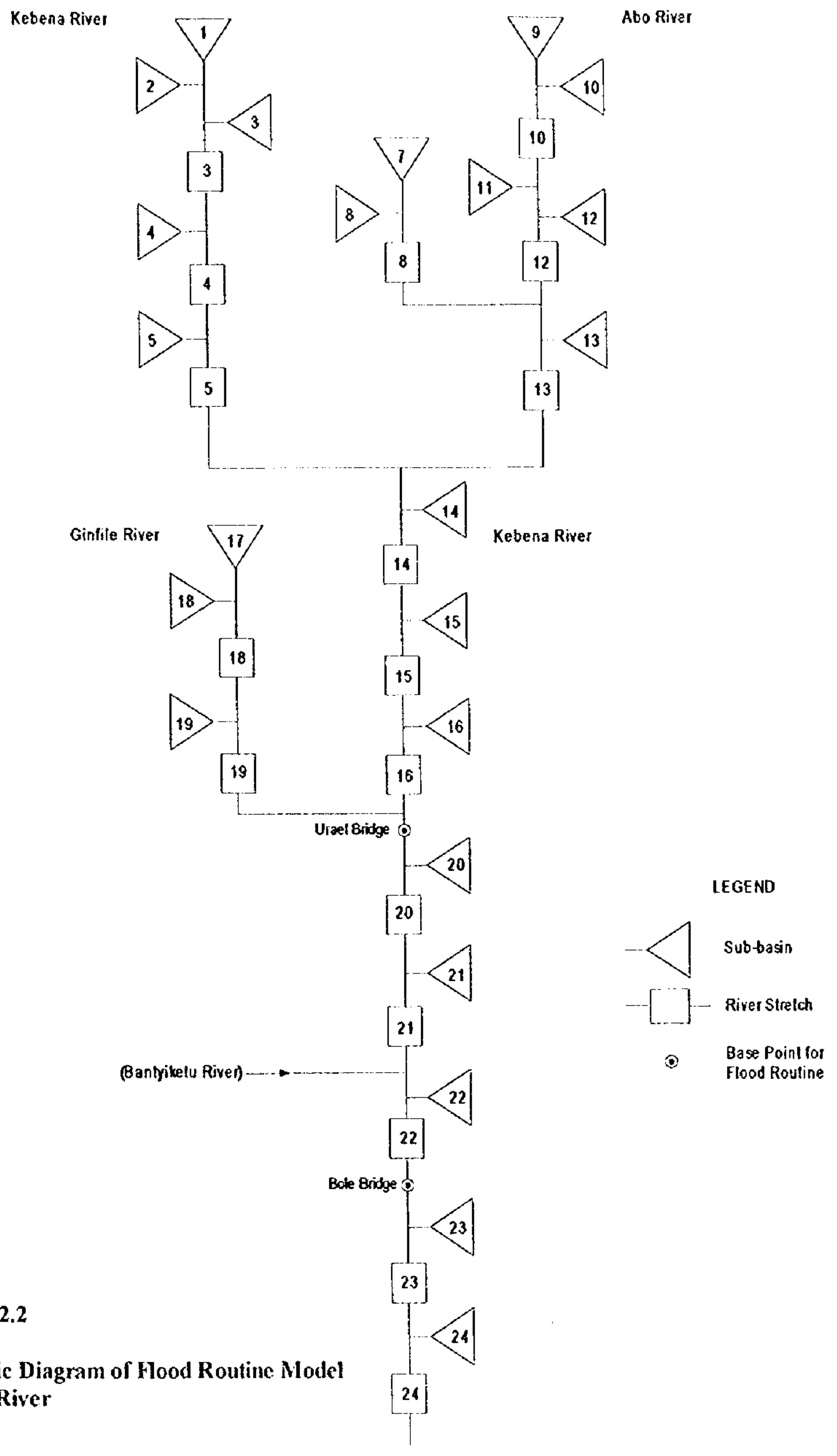


Figure 6.2.2

Schematic Diagram of Flood Routine Model Kebena River

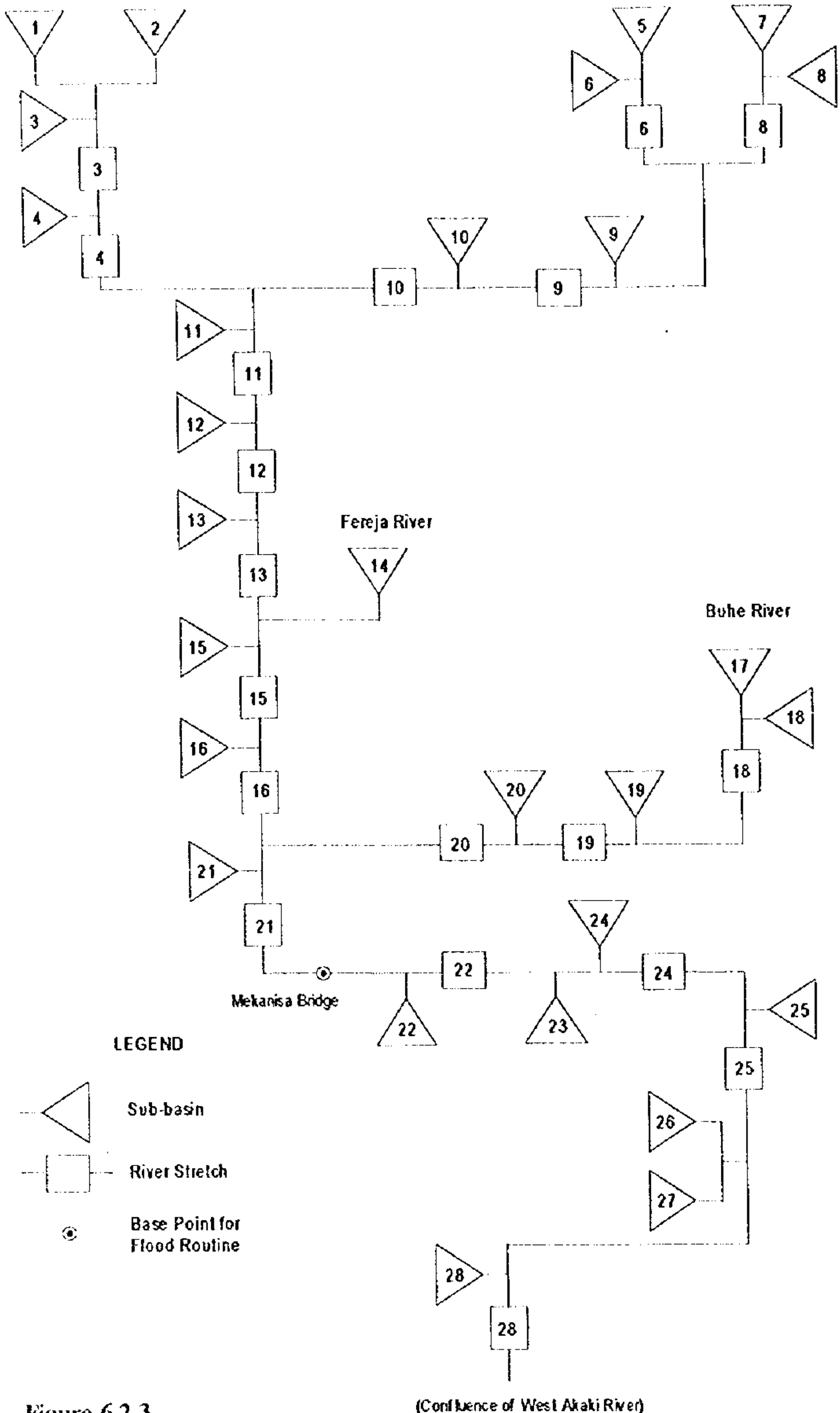


Figure 6.2.3

Schematic Diagram of Flood Routine Model Little Akaki River

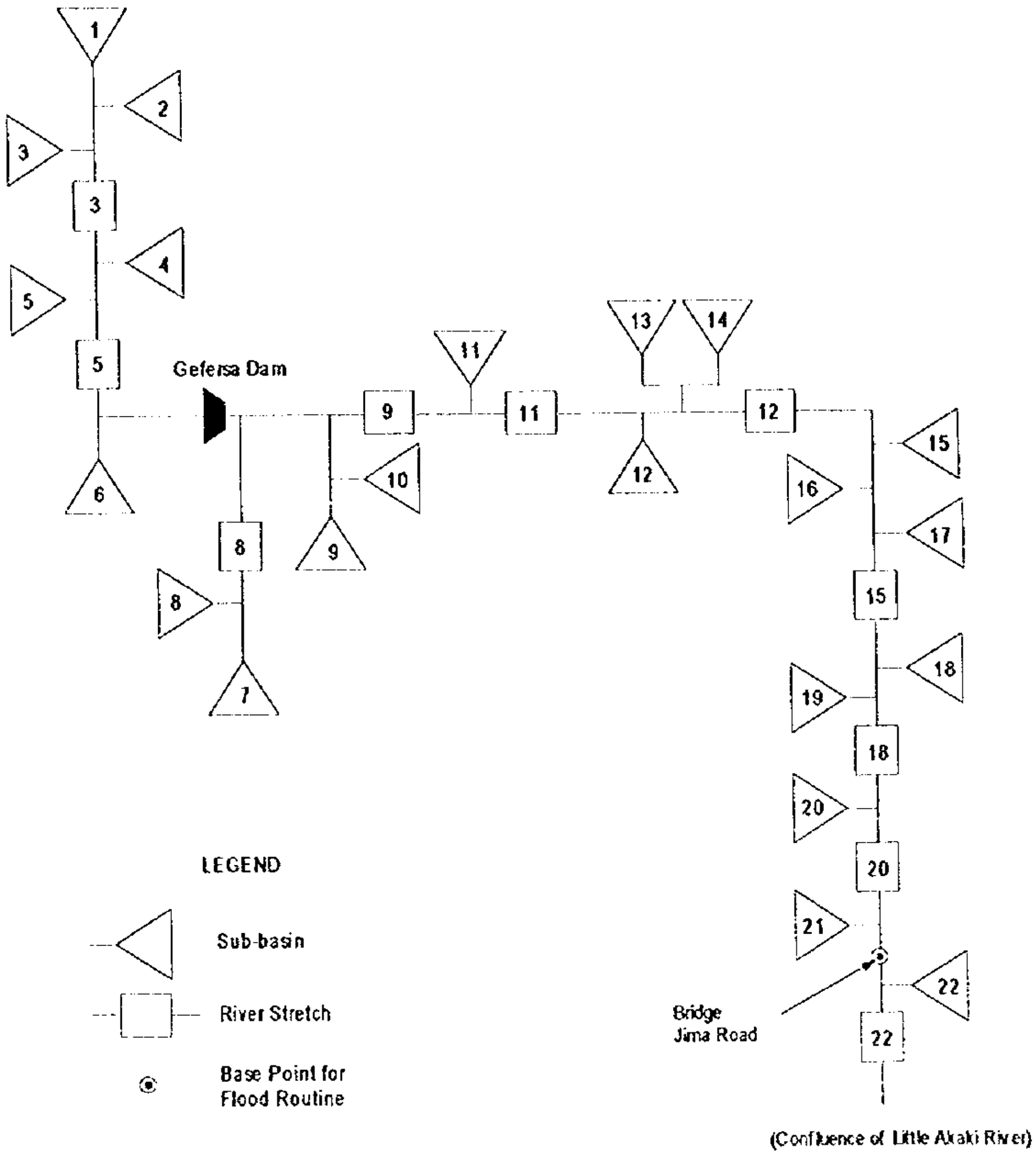


Figure 6.2.4

Schematic Diagram of Flood Routine Model
West Akaki River

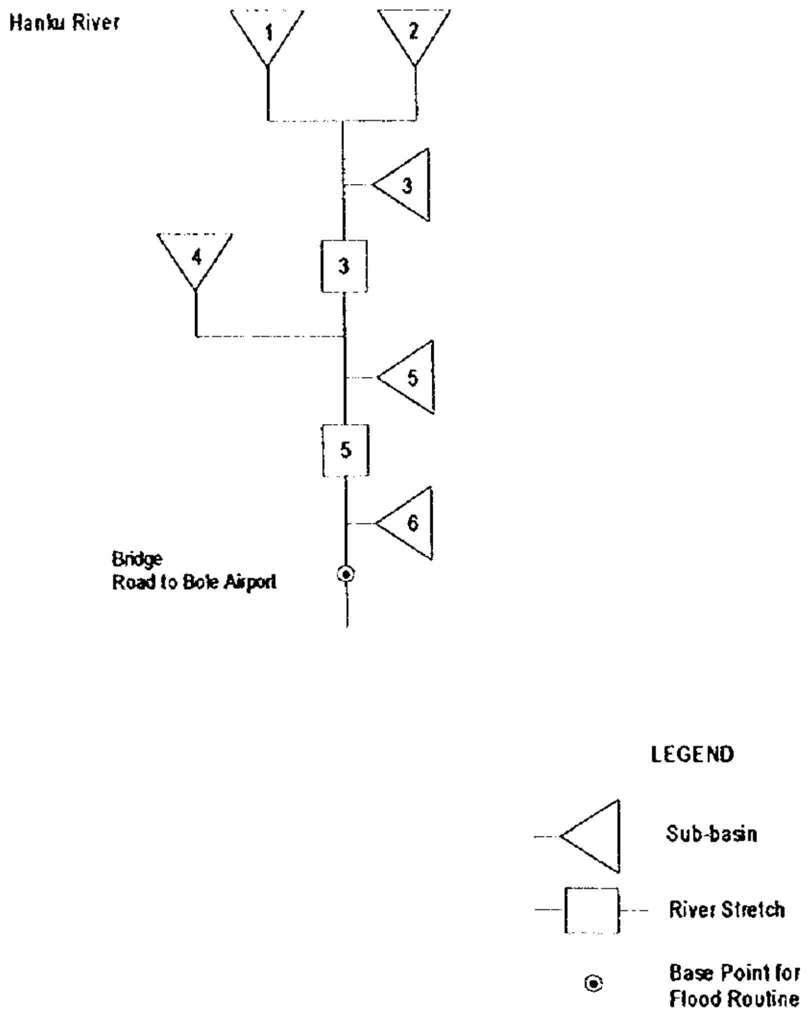


Figure 6.2.5

Schematic Diagram of Flood Routine Model
Hanku River

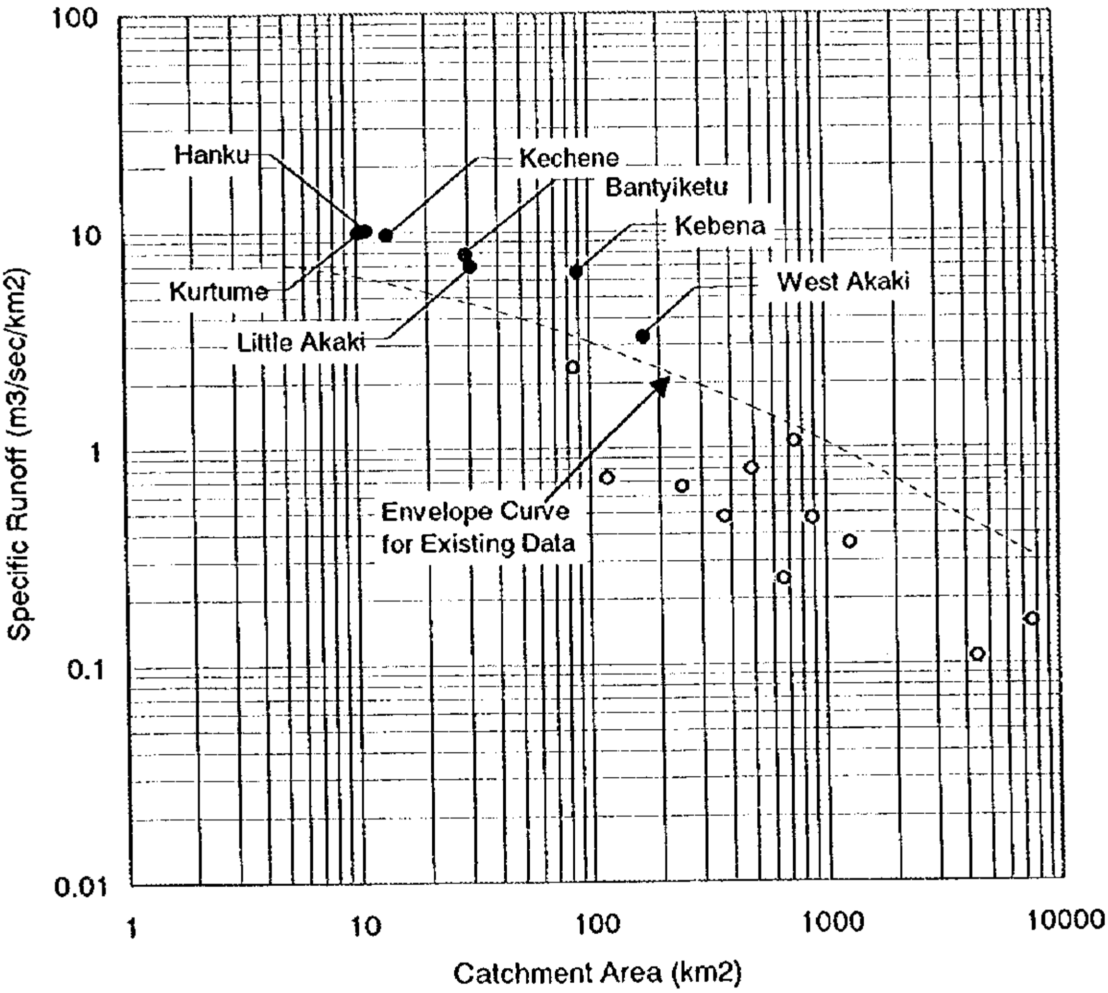
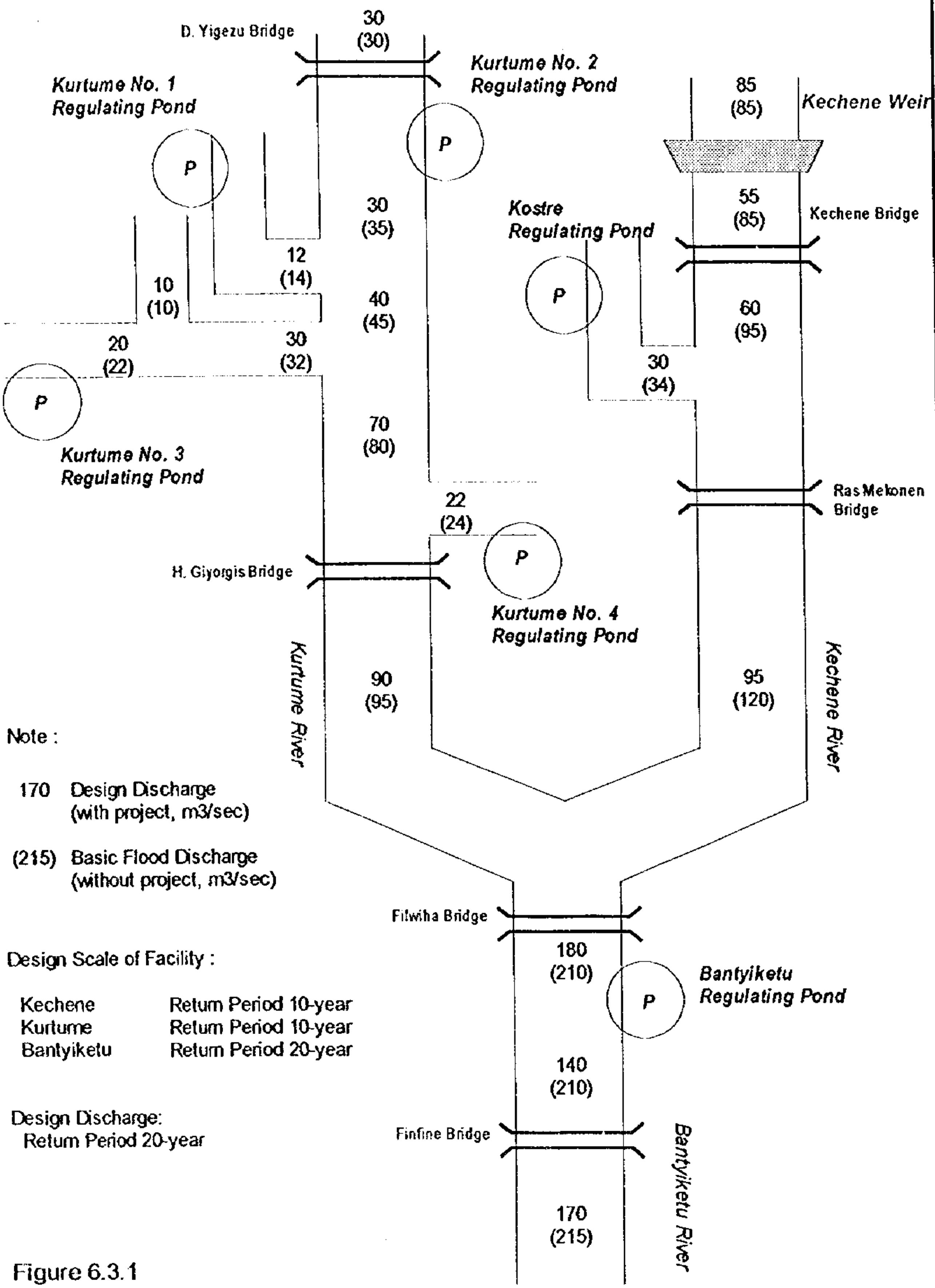


Figure 6.2.6 Specific Flood Peak Discharge



Note :

170 Design Discharge (with project, m3/sec)

(215) Basic Flood Discharge (without project, m3/sec)

Design Scale of Facility :

Kechene	Return Period 10-year
Kurtume	Return Period 10-year
Bantyiketu	Return Period 20-year

Design Discharge:
Return Period 20-year

Figure 6.3.1

Design Discharge Distribution for Bantyiketu River System
(Return Period 20-year)

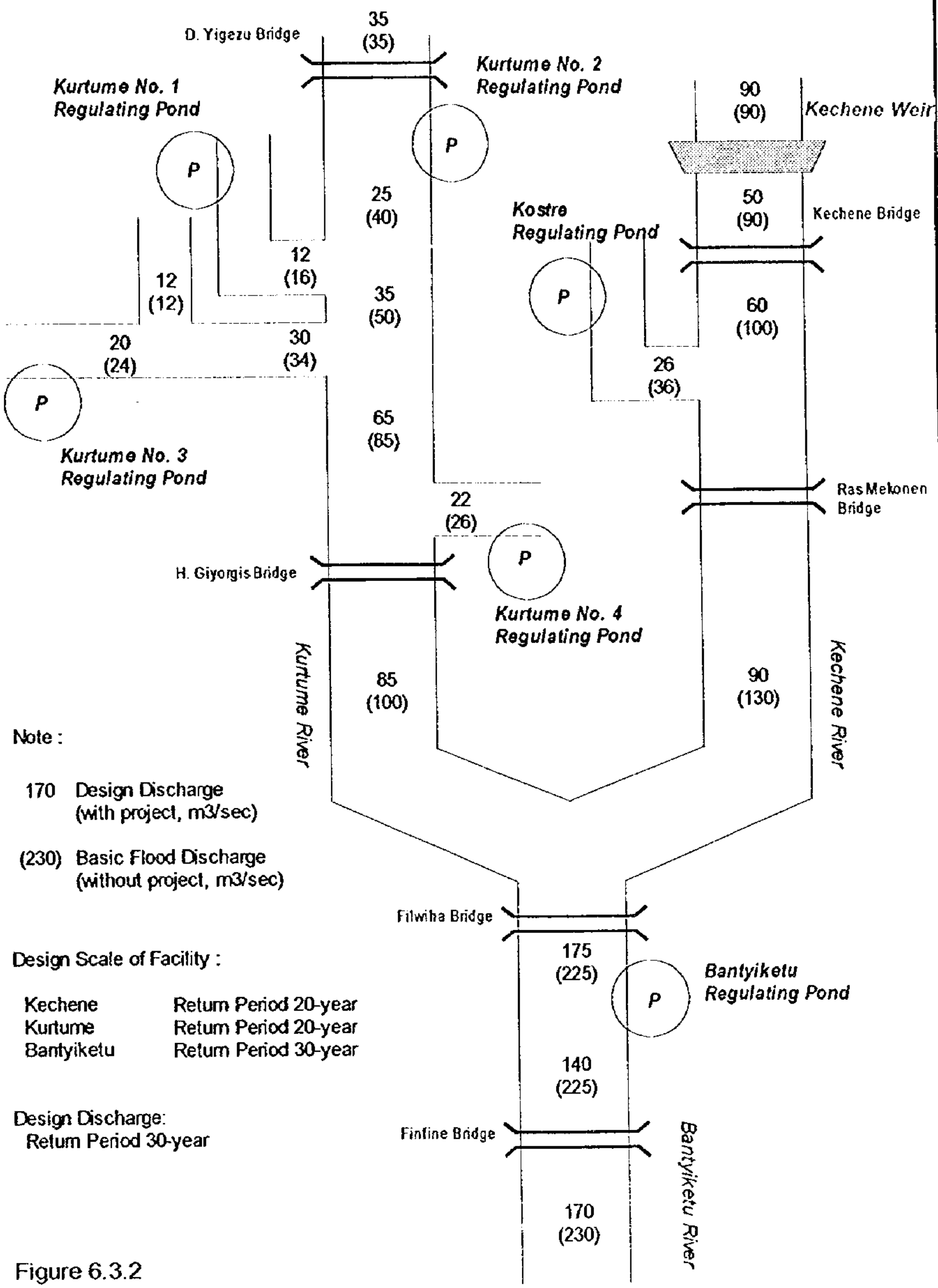
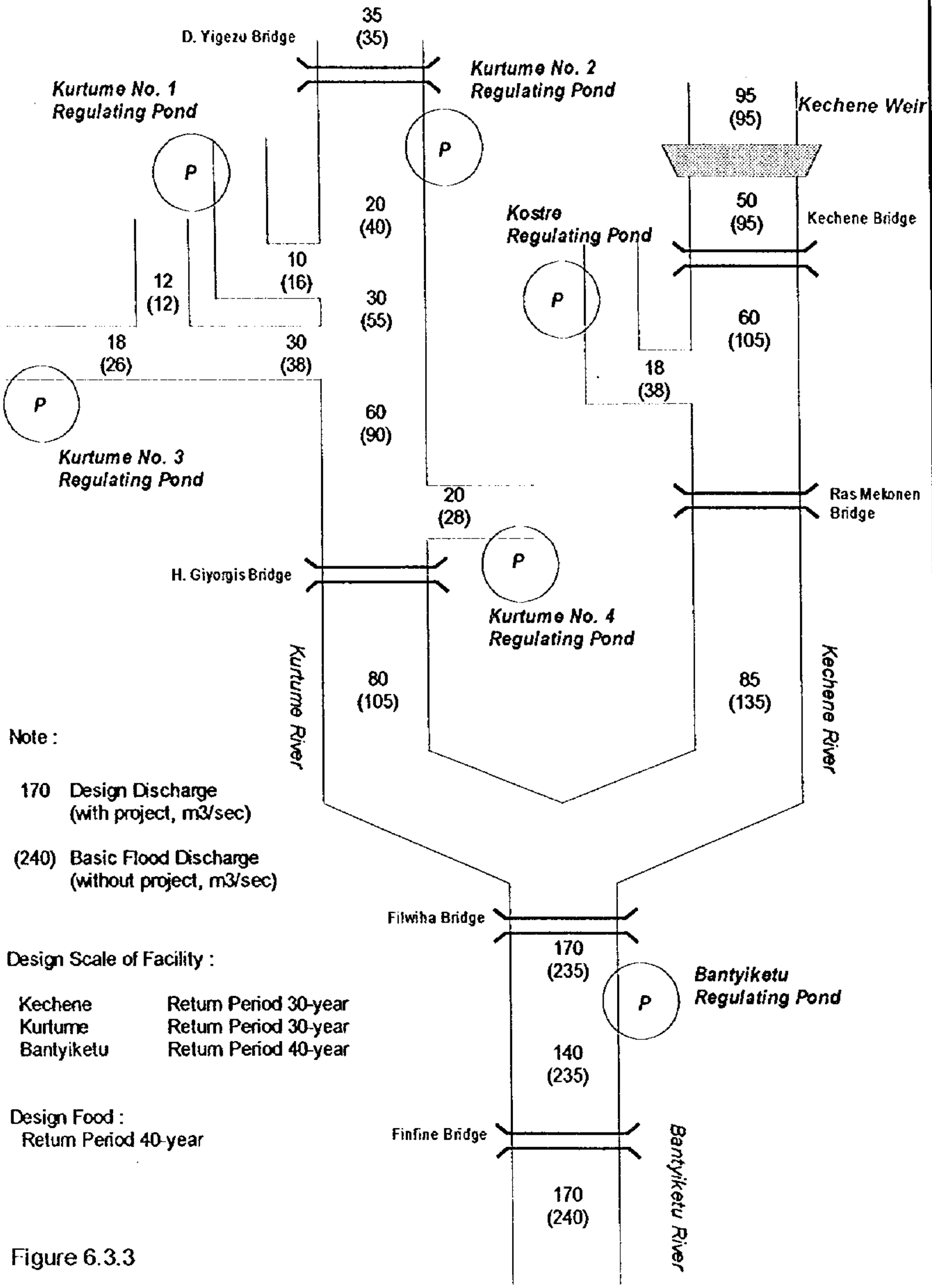


Figure 6.3.2

Design Discharge Distribution for Bantyiketu River System
(Return Period 30-year)



Note :

170 Design Discharge (with project, m3/sec)

(240) Basic Flood Discharge (without project, m3/sec)

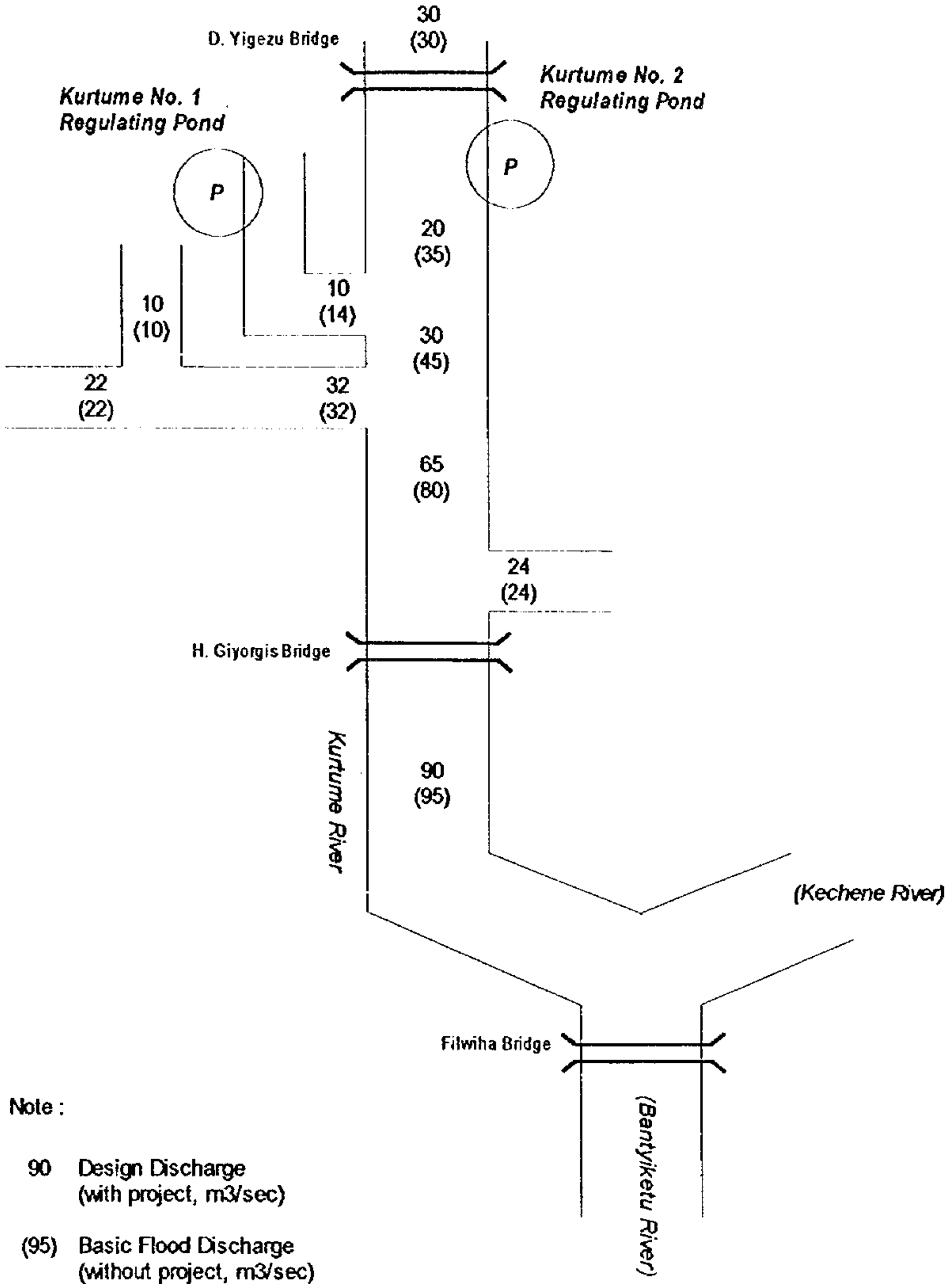
Design Scale of Facility :

Kechene	Return Period 30-year
Kurtume	Return Period 30-year
Bantyiketu	Return Period 40-year

Design Food :
Return Period 40-year

Figure 6.3.3

Design Discharge Distribution for Bantyiketu River System
(Return Period 40-year)



Note :

90 Design Discharge (with project, m3/sec)

(95) Basic Flood Discharge (without project, m3/sec)

Figure 6.3.4

Design Discharge for Kurtume River
(Return Period 20-year, Alternative 1)

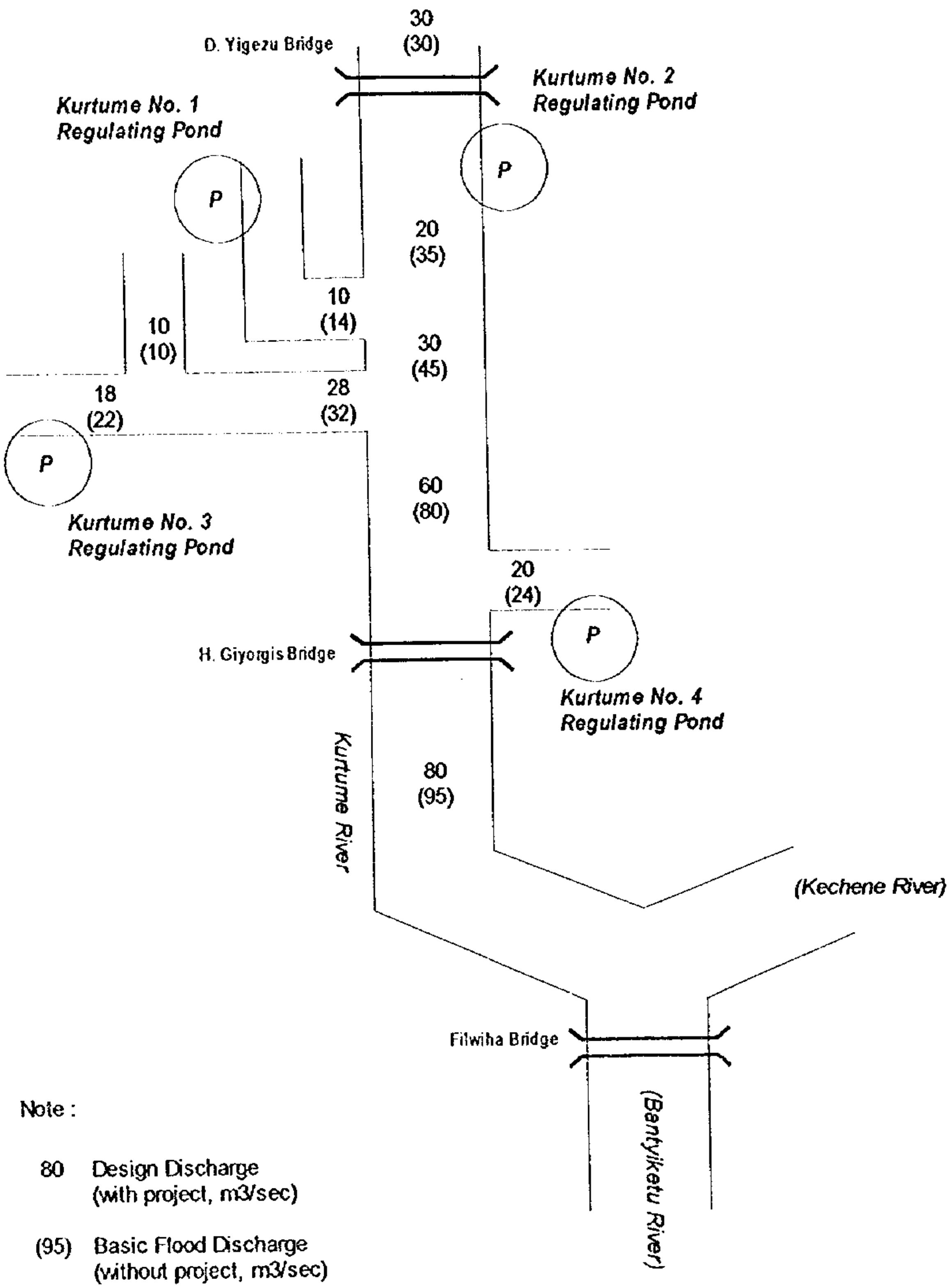
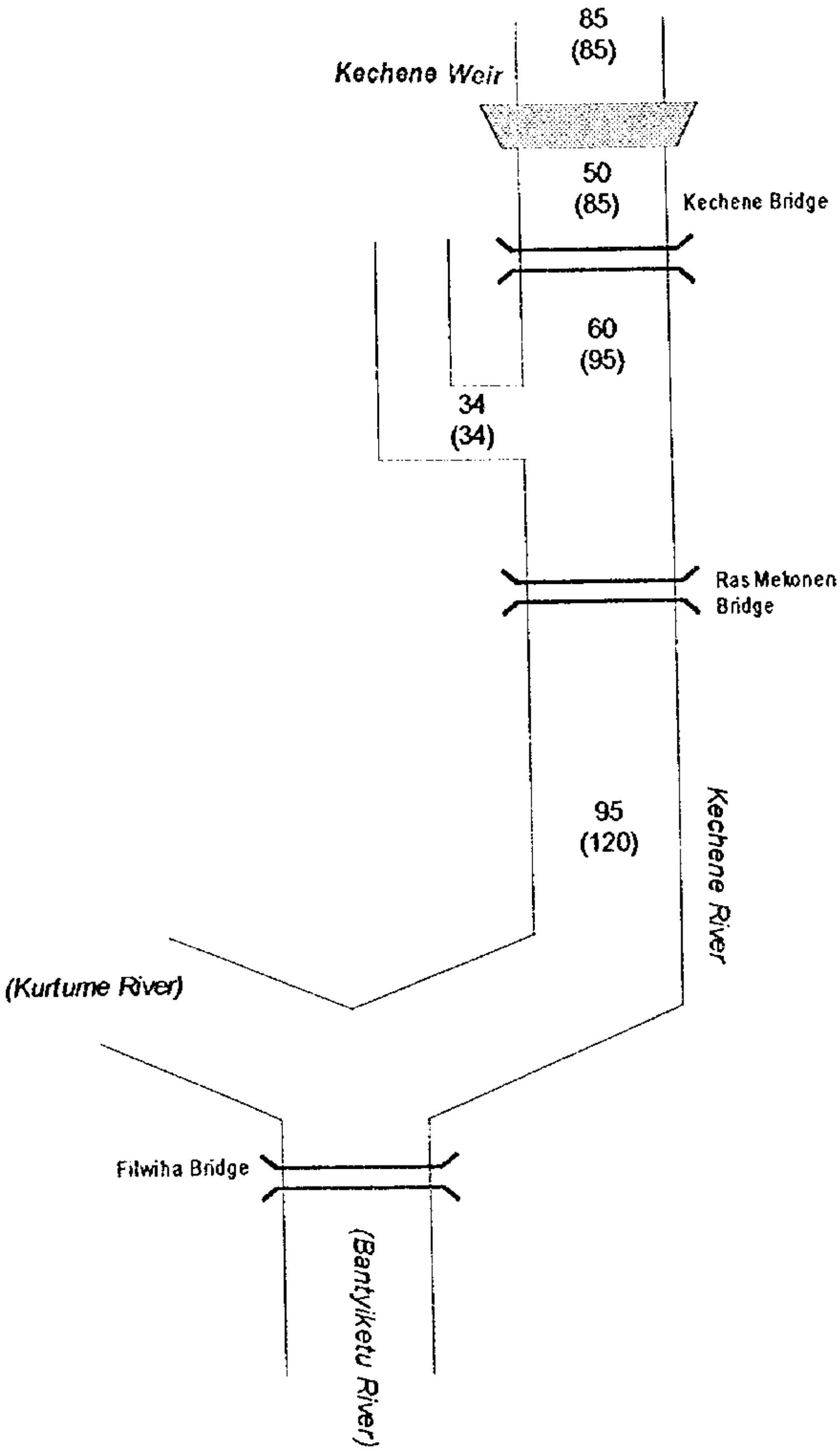


Figure 6.3.5

Design Discharge Distribution for Kurtume River
(Return Period 20-year, Alternative 2)



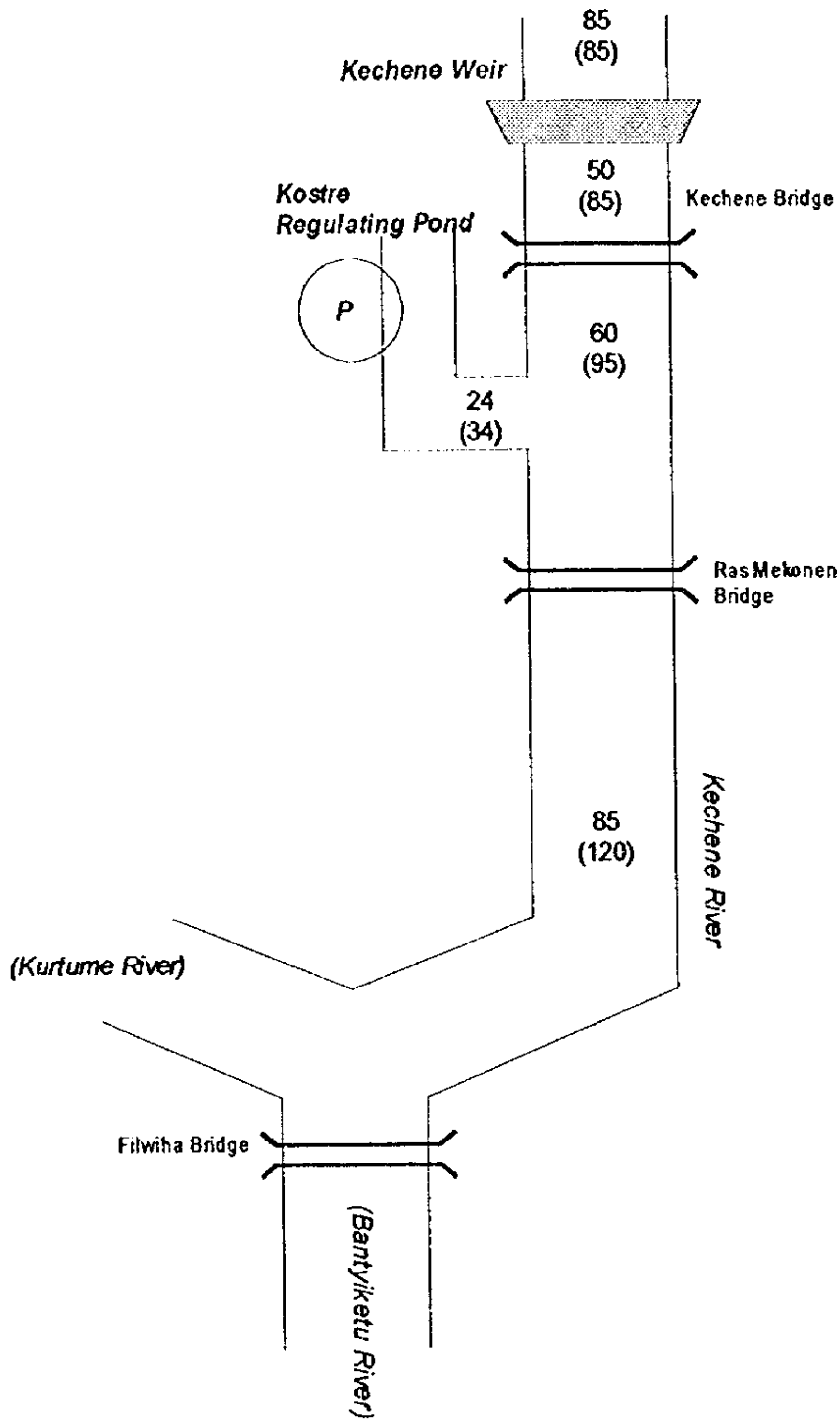
Note :

95 Design Discharge (with project, m3/sec)

(120) Basic Flood Discharge (without project, m3/sec)

Figure 6.3.6

Design Discharge Distribution for Kechene River
(Return Period 20-year, Alternative 1)



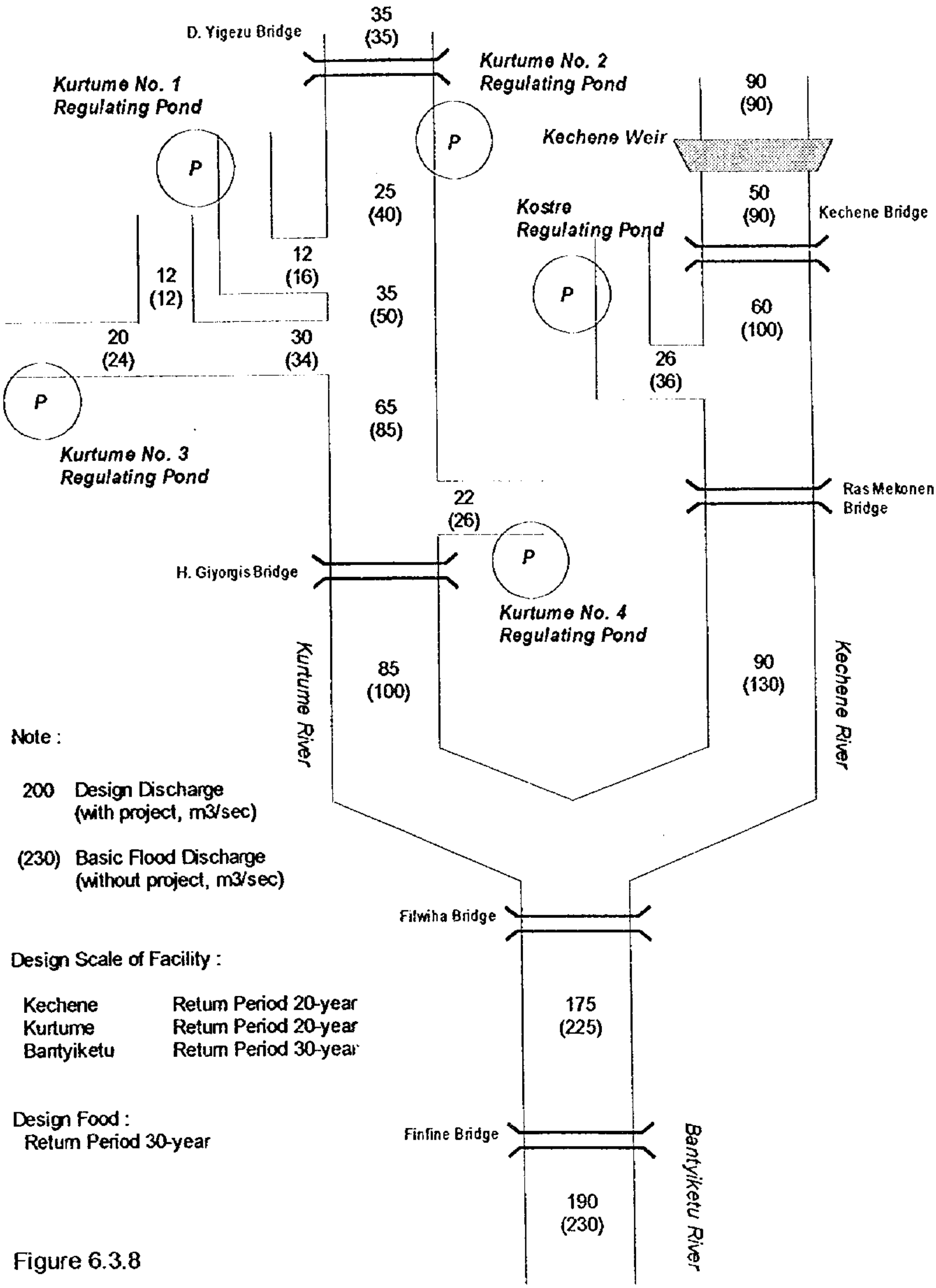
Note :

85 Design Discharge
(with project, m3/sec)

(120) Basic Flood Discharge
(without project, m3/sec)

Figure 6.3.7

Design Discharge Distribution for Kechene River
(Return Period 20-year, Alternative 2)



Note :

200 Design Discharge (with project, m3/sec)

(230) Basic Flood Discharge (without project, m3/sec)

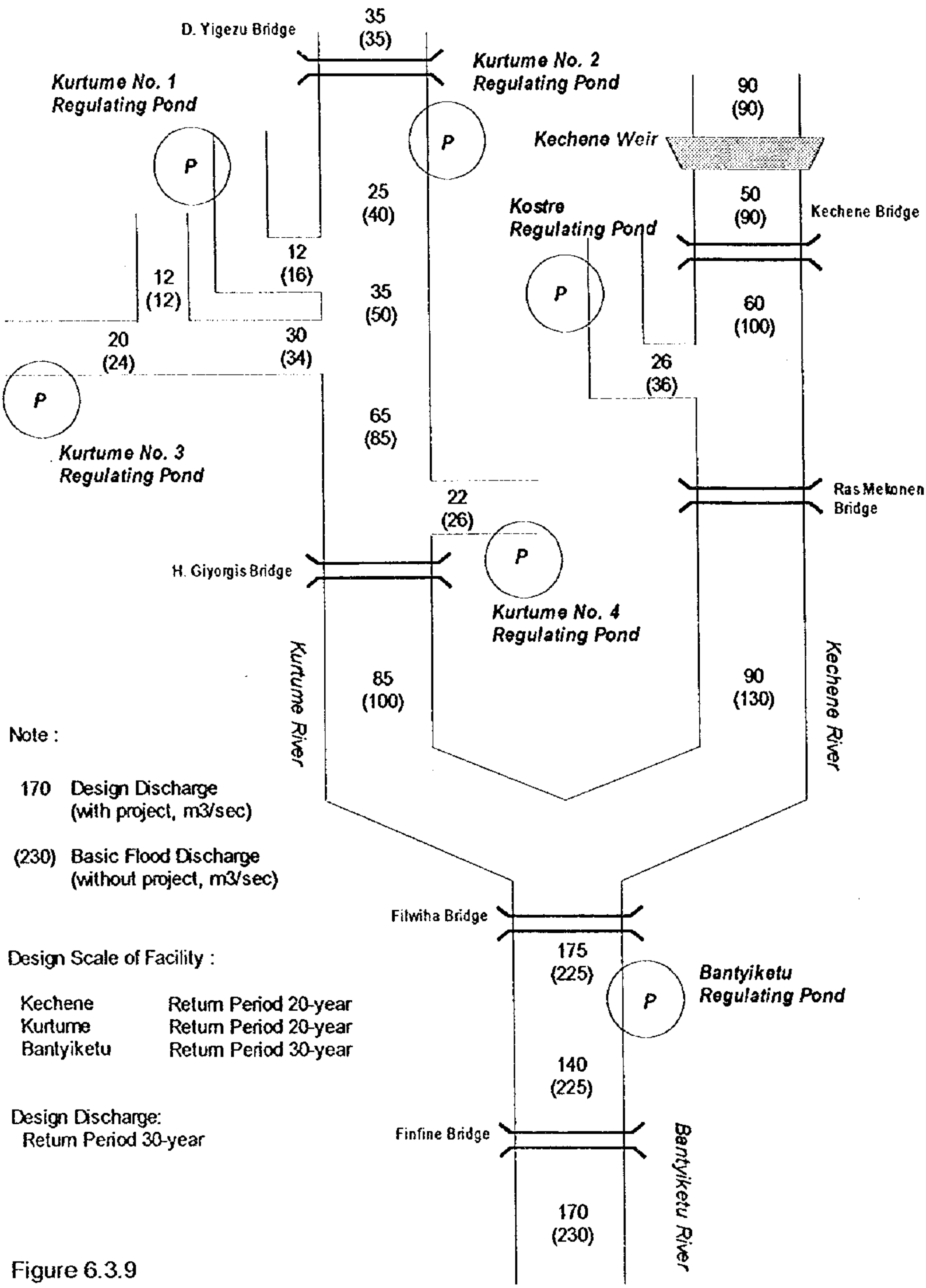
Design Scale of Facility :

Kechene	Return Period 20-year
Kurtume	Return Period 20-year
Bantyiketu	Return Period 30-year

Design Food :
Return Period 30-year

Figure 6.3.8

Design Discharge Distribution for Bantyiketu River System
(Return Period 30-years, Alternative 1)



Note :

170 Design Discharge (with project, m3/sec)

(230) Basic Flood Discharge (without project, m3/sec)

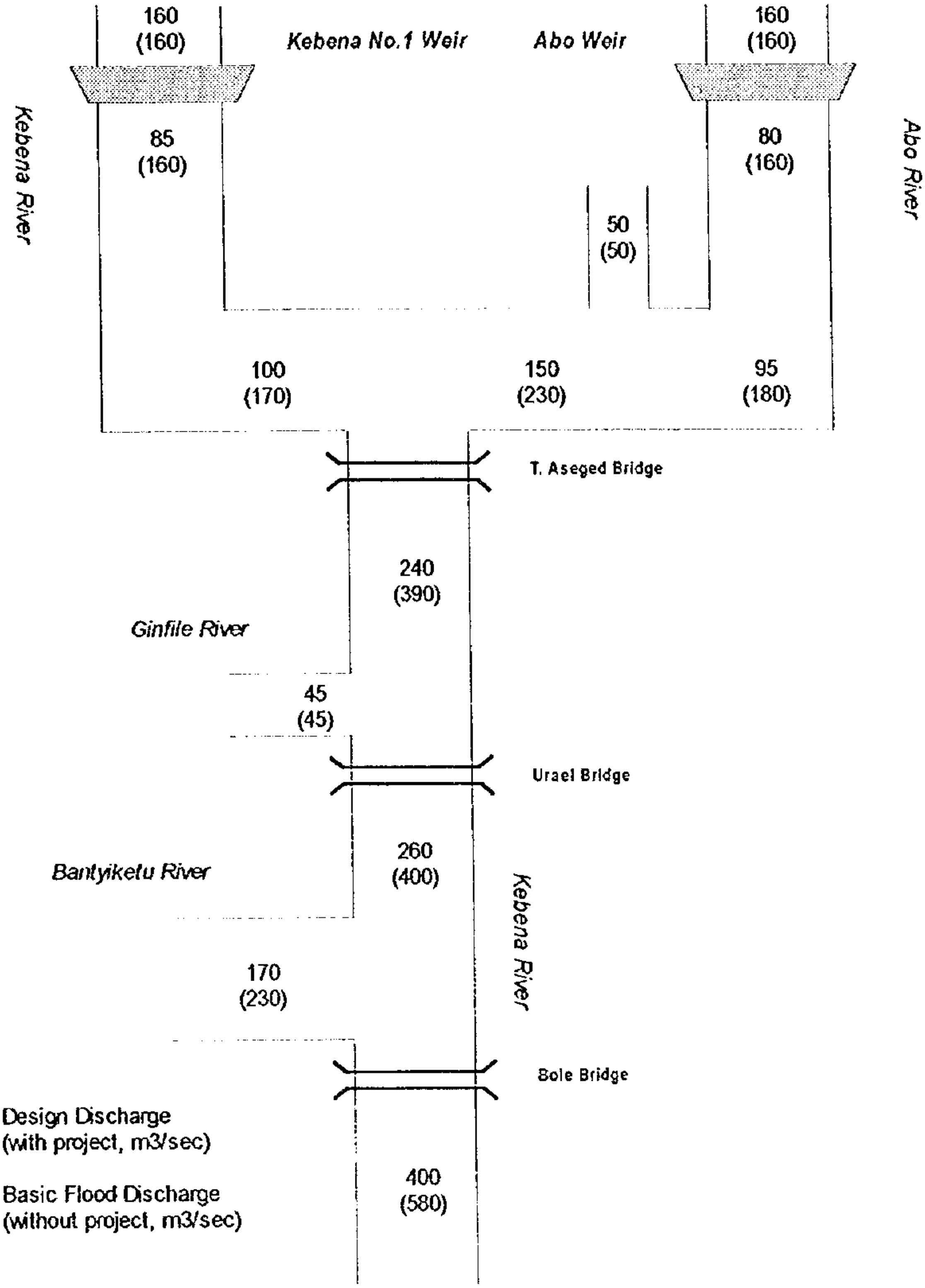
Design Scale of Facility :

Kechene	Return Period 20-year
Kurtume	Return Period 20-year
Bantyiketu	Return Period 30-year

Design Discharge:
Return Period 30-year

Figure 6.3.9

Design Discharge Distribution for Bantyiketu River System
(Return Period 30-year, Alternative 2)



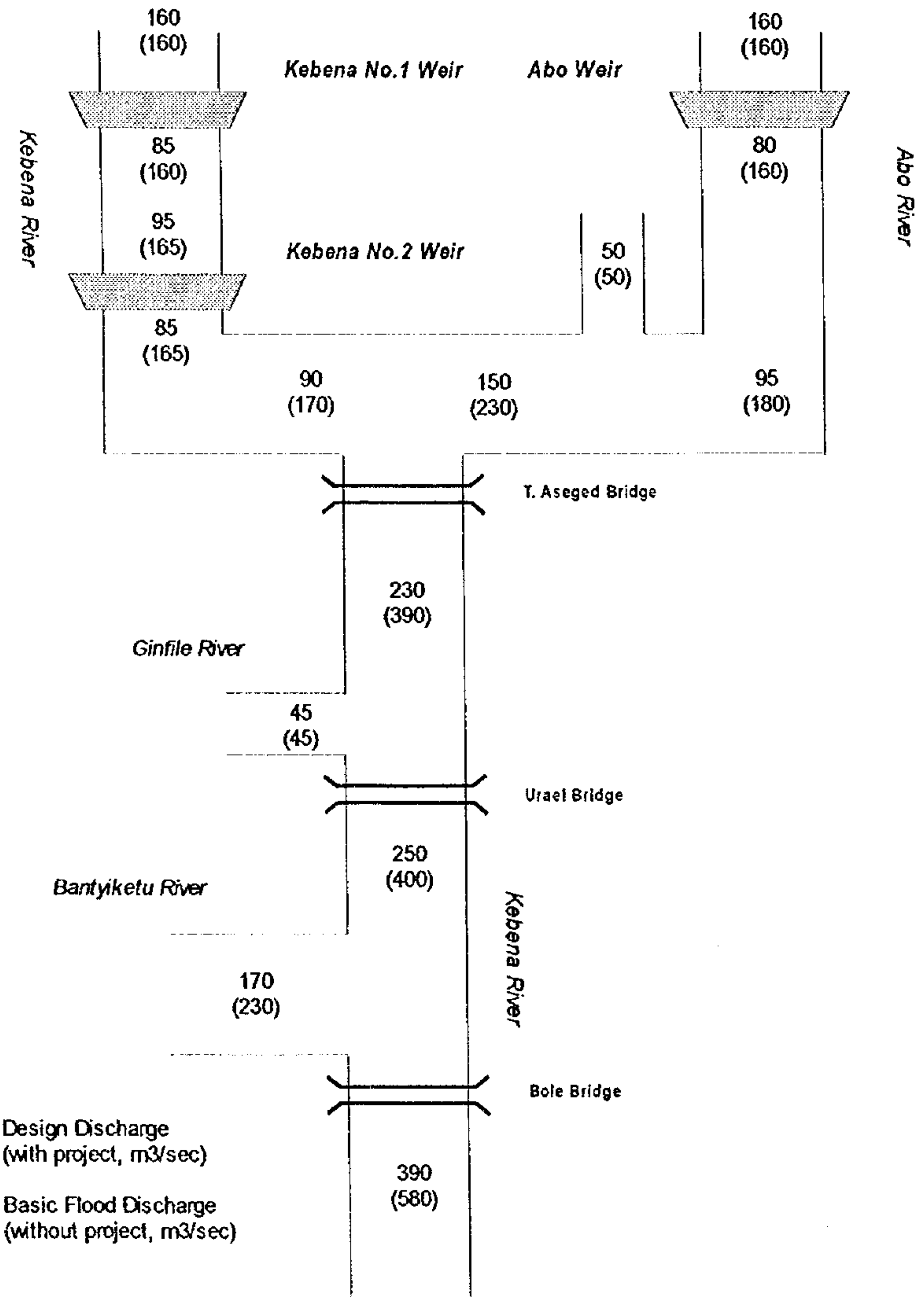
Note :

400 Design Discharge (with project, m3/sec)

(580) Basic Flood Discharge (without project, m3/sec)

Figure 6.3.10

Design Discharge Distribution for Kebena River System
(Return Period 30-year, Alternative 1)



Note :

390 Design Discharge (with project, m3/sec)

(580) Basic Flood Discharge (without project, m3/sec)

Figure 6.3.11

Design Discharge Distribution for Kebena River System
(Return Period 30-year, Alternatve 2)

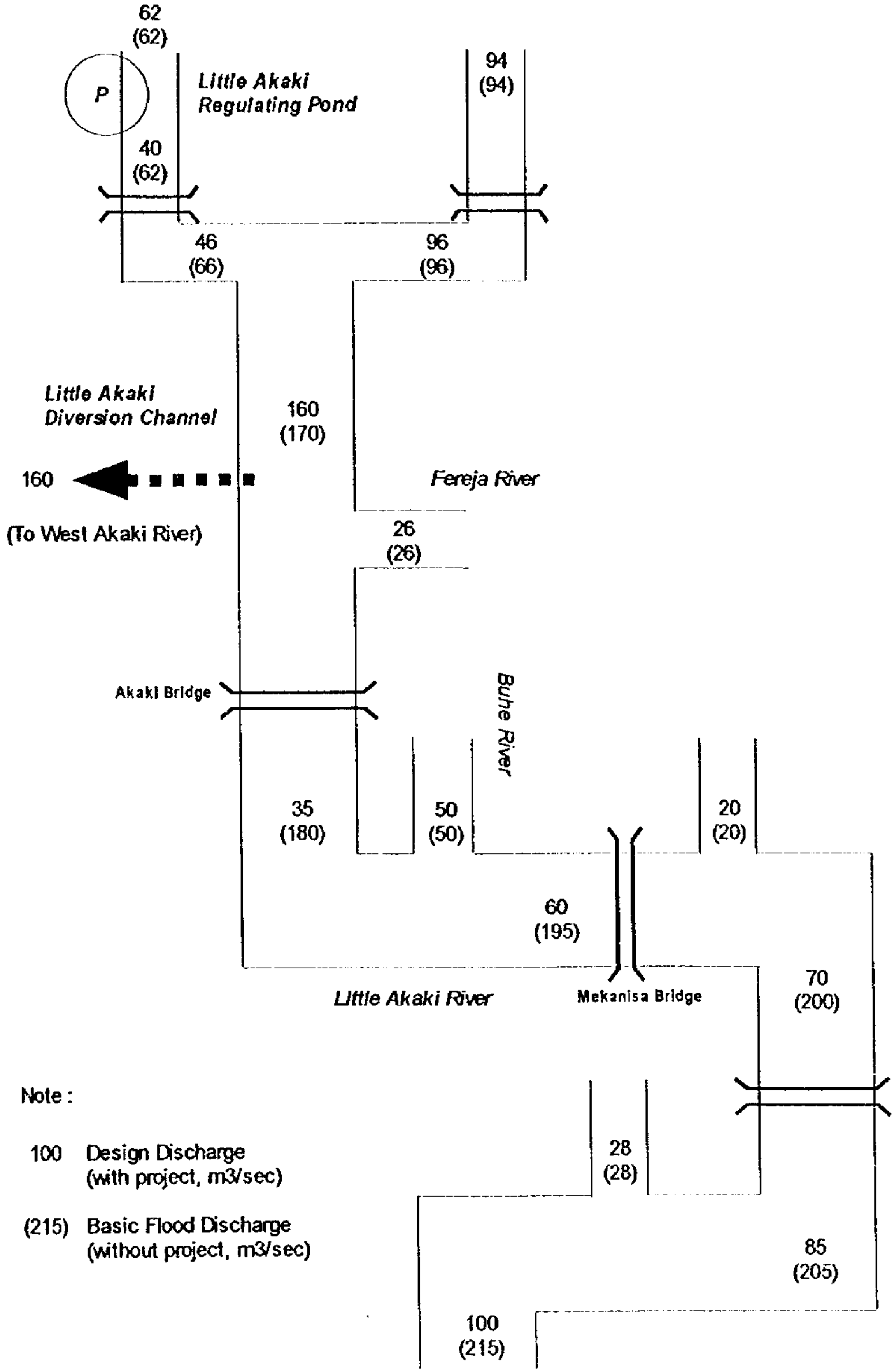
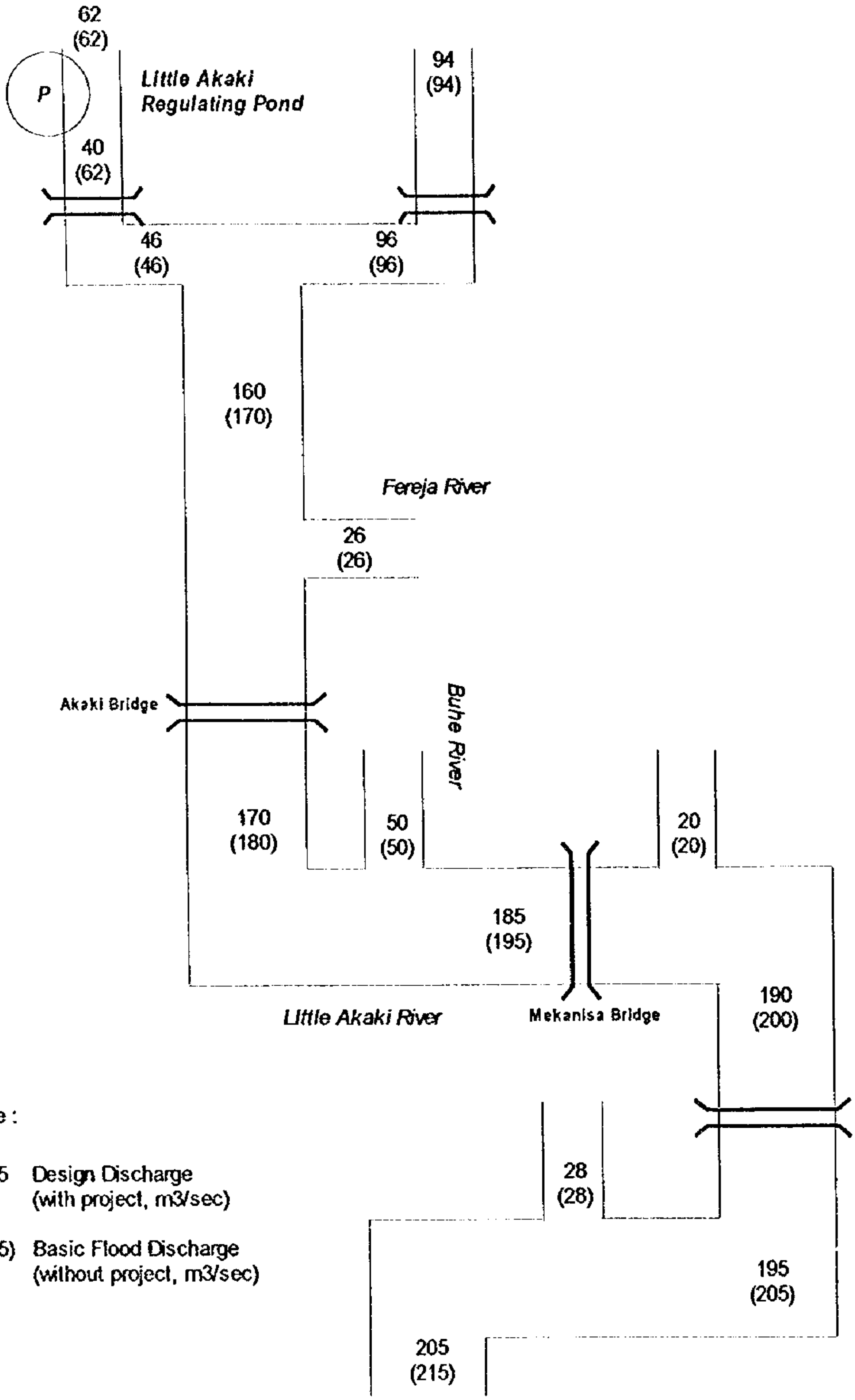


Figure 6.3.12

Design Discharge Distribution for Little Akaki River System
(Return Period 30-year, Alternative 1)



Note :

205 Design Discharge
(with project, m3/sec)

(215) Basic Flood Discharge
(without project, m3/sec)

Figure 6.3.13

Design Discharge Distribution for Little Akaki River
(Return Period 30-year, Alternative 2)

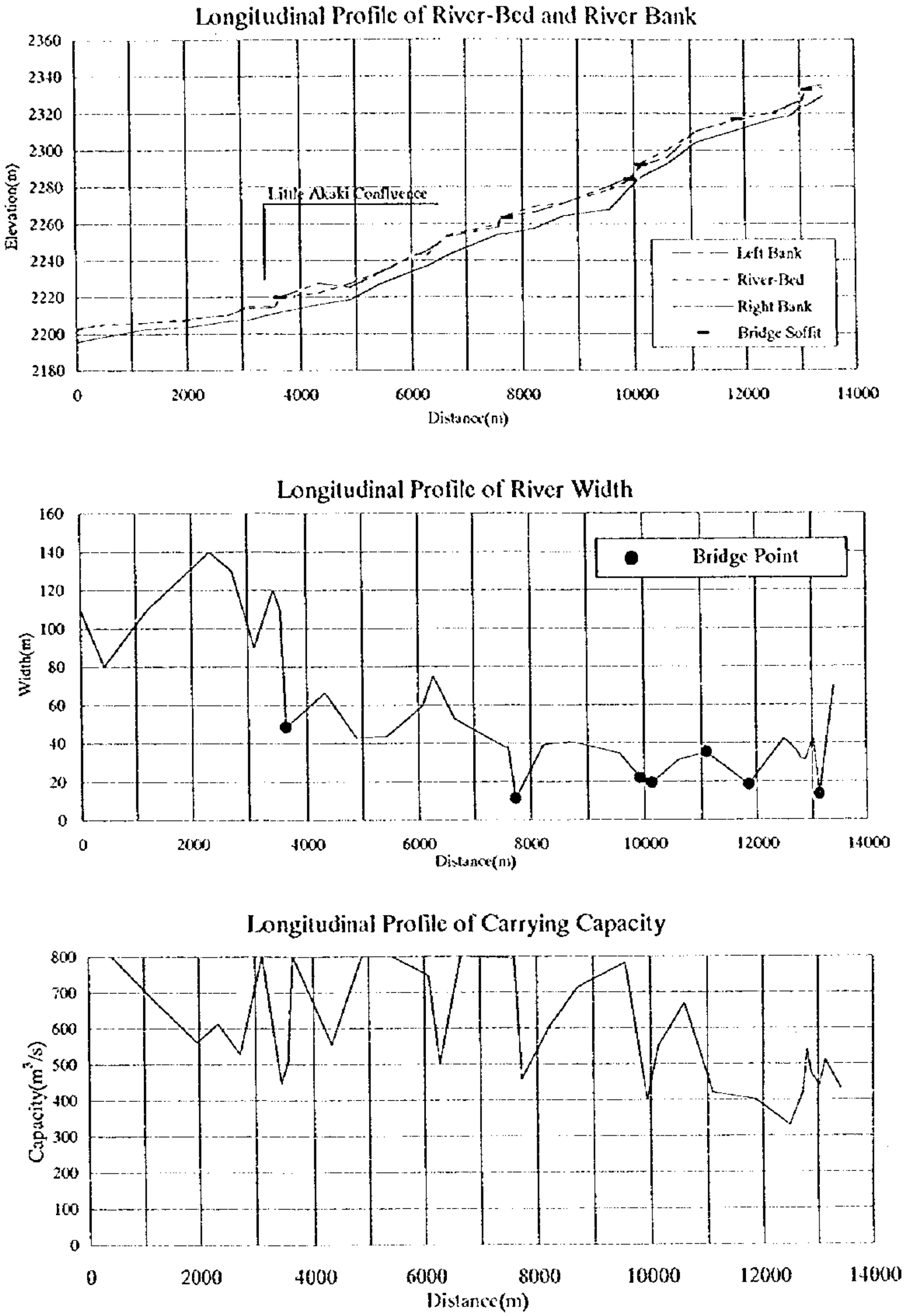


Figure 6.4.1 Longitudinal Profile of West Akaki River

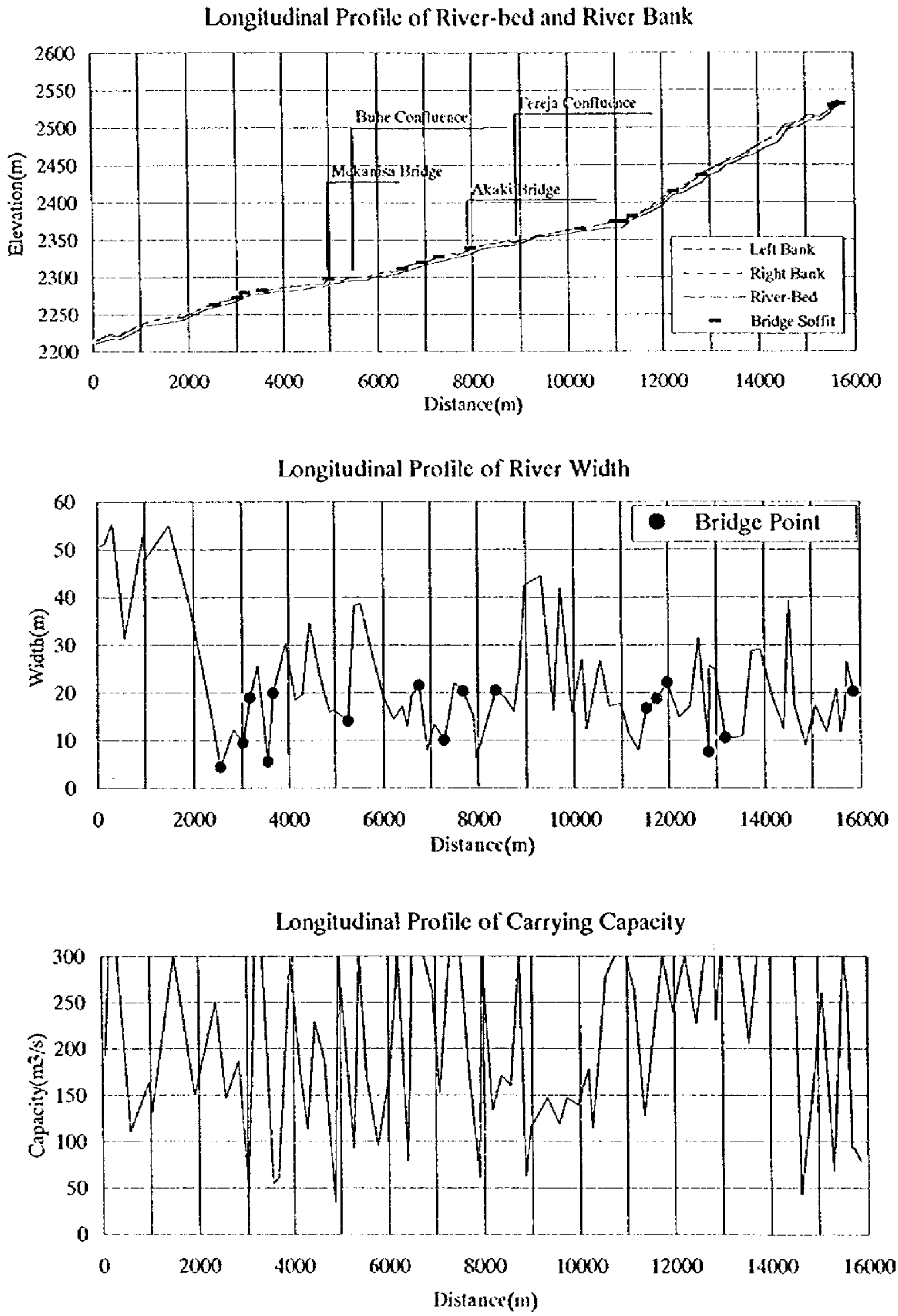


Figure 6.4.2 Longitudinal Profile of Little Akaki River

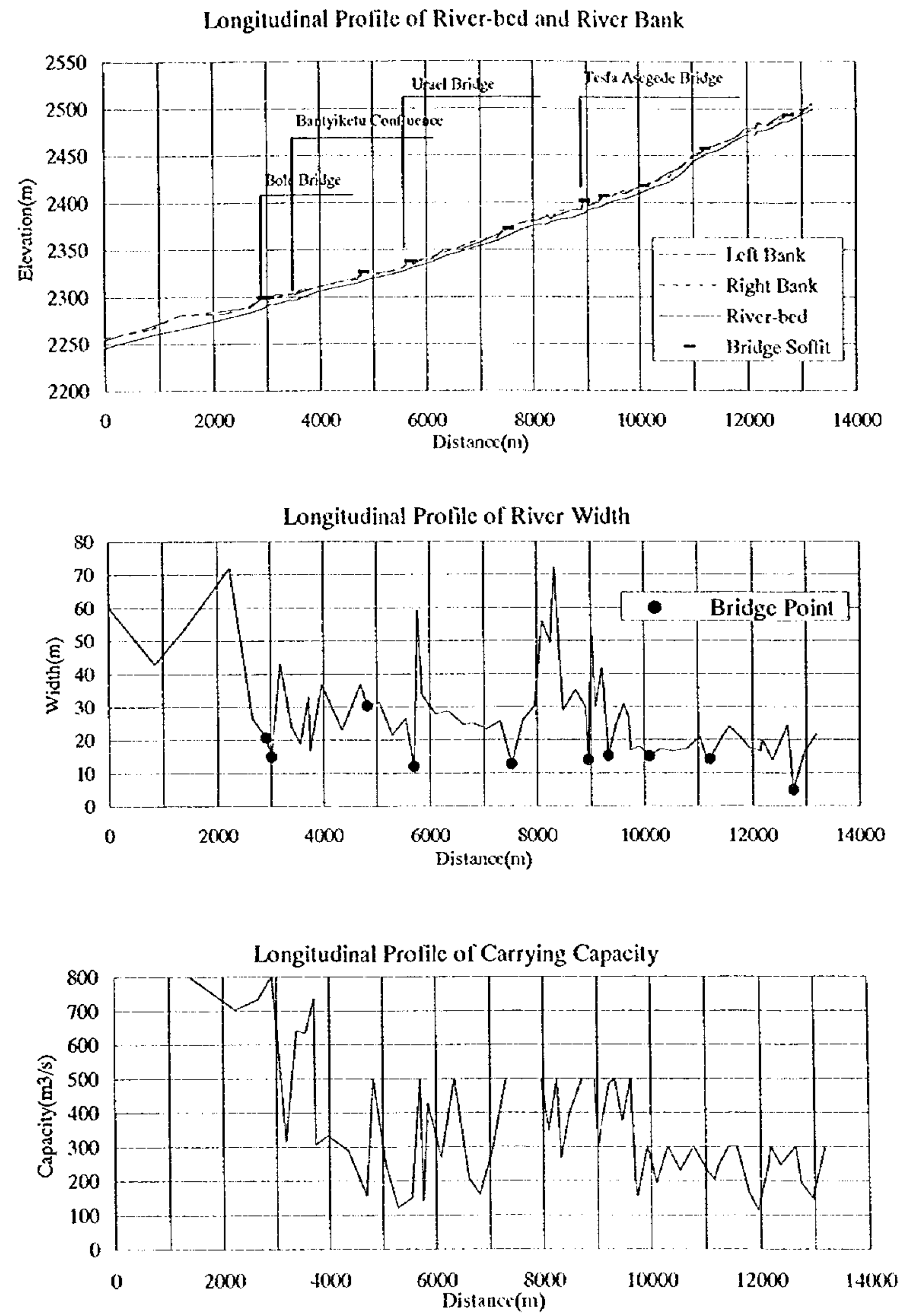
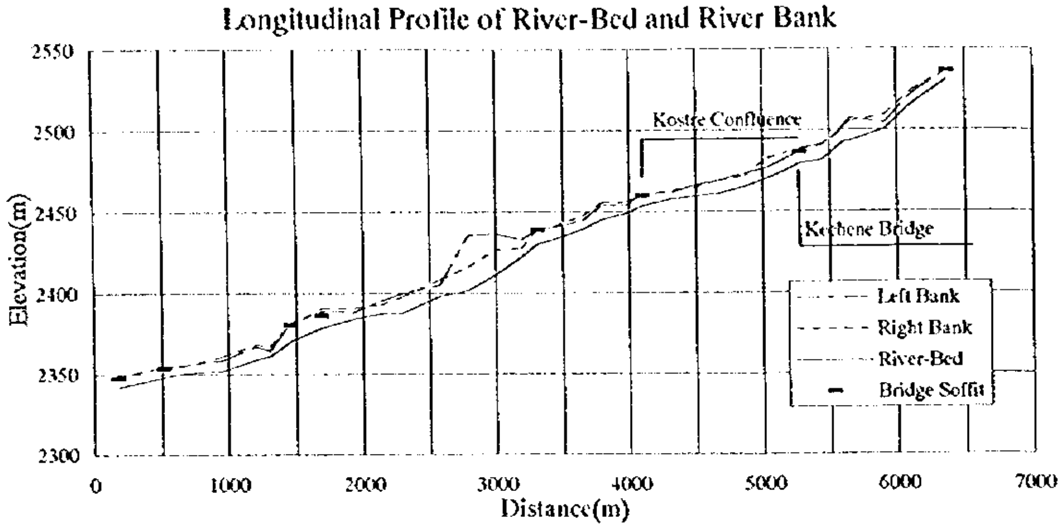
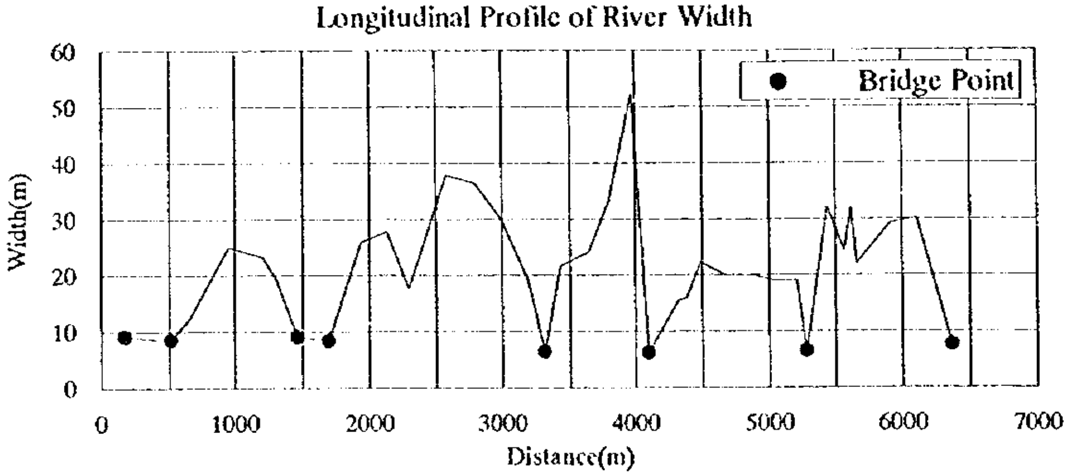


Figure 6.4.3 Longitudinal Profile of Kebena River





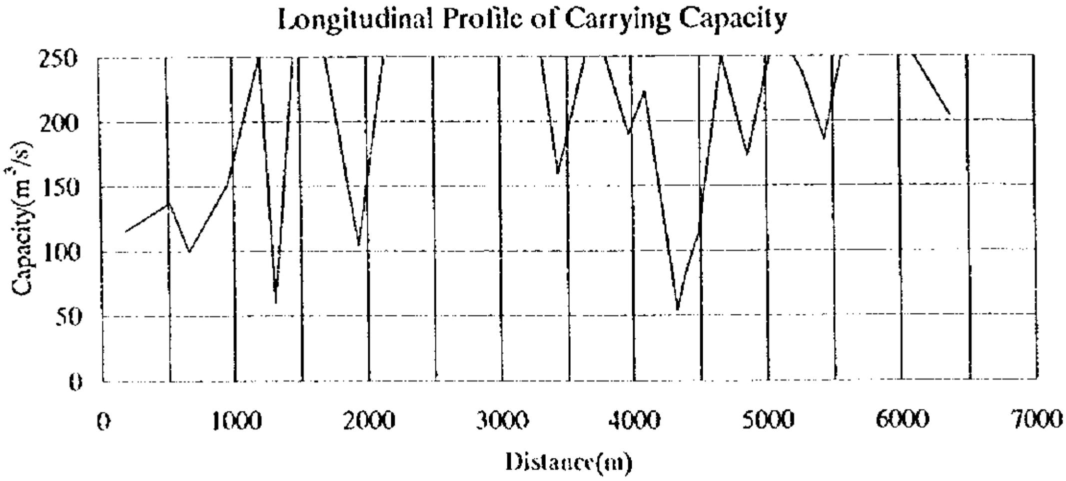


Figure 6.4.4 Longitudinal Profile of Kechene River

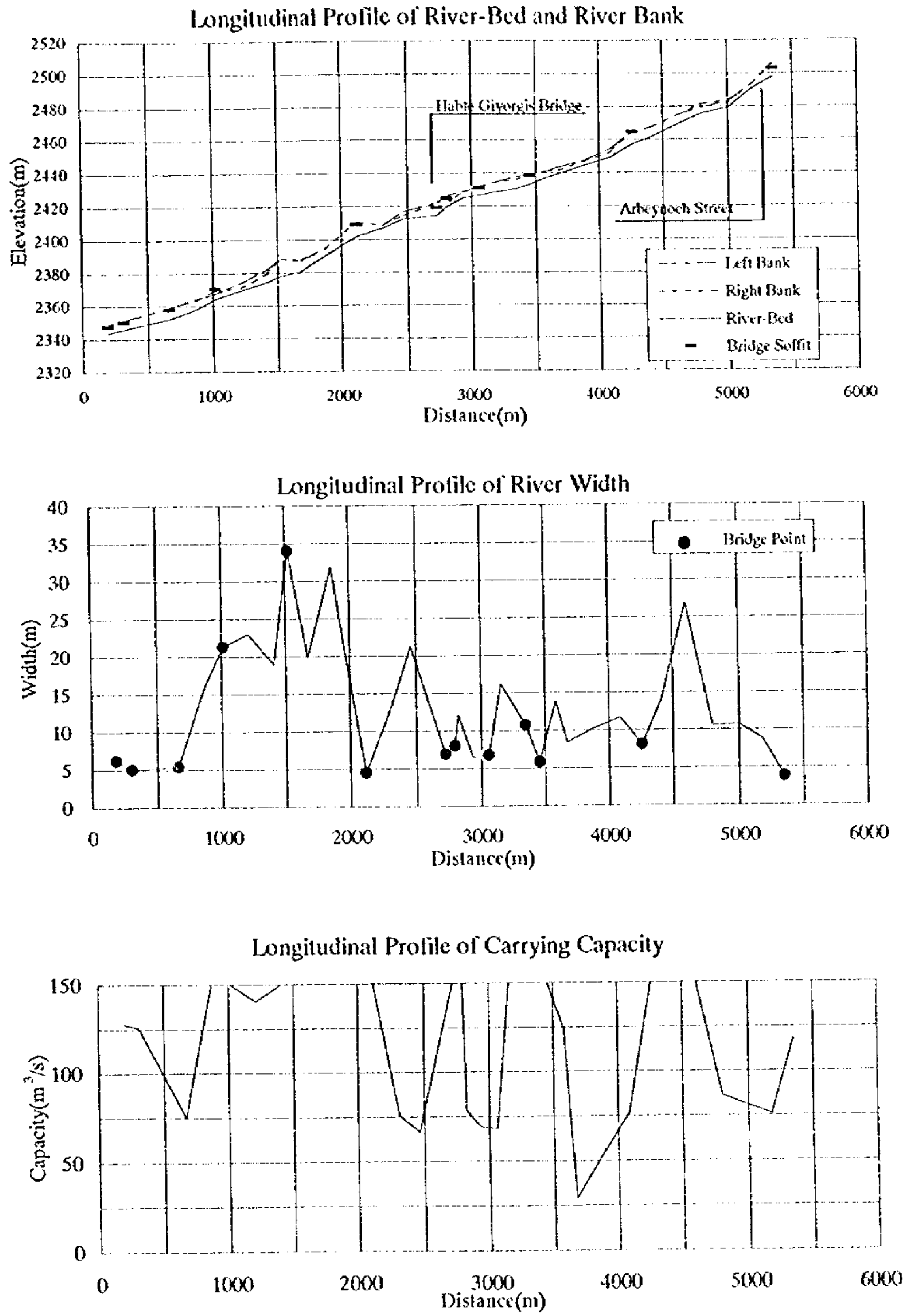
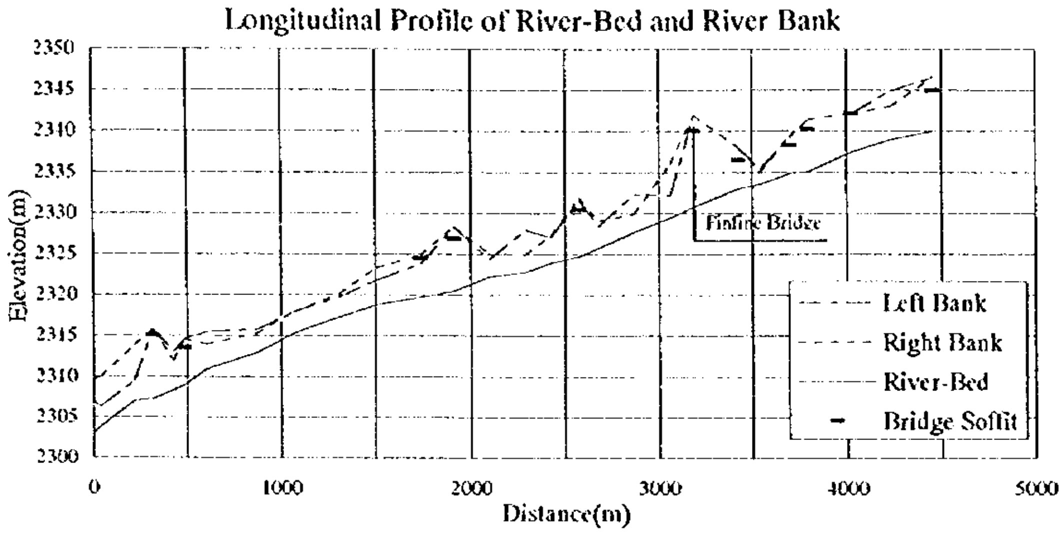
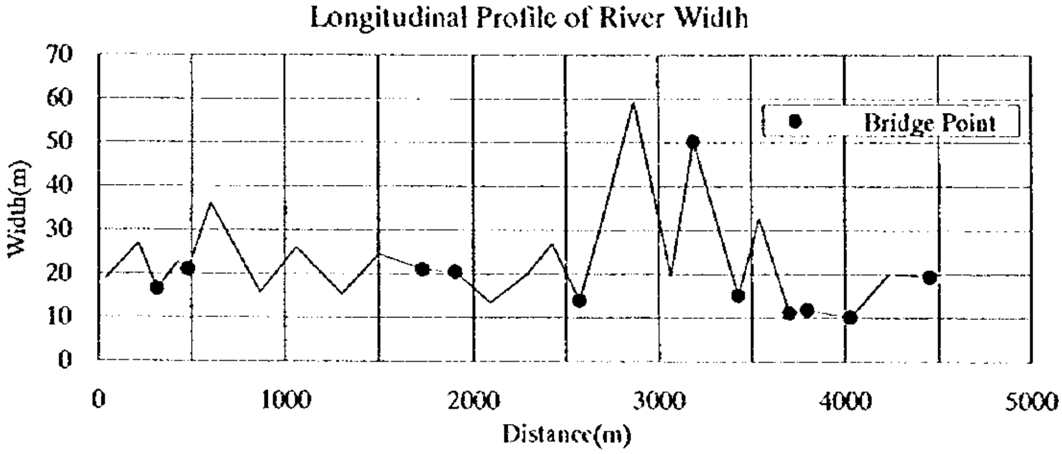


Figure 6.4.5 Longitudinal Profile of Kurtume River





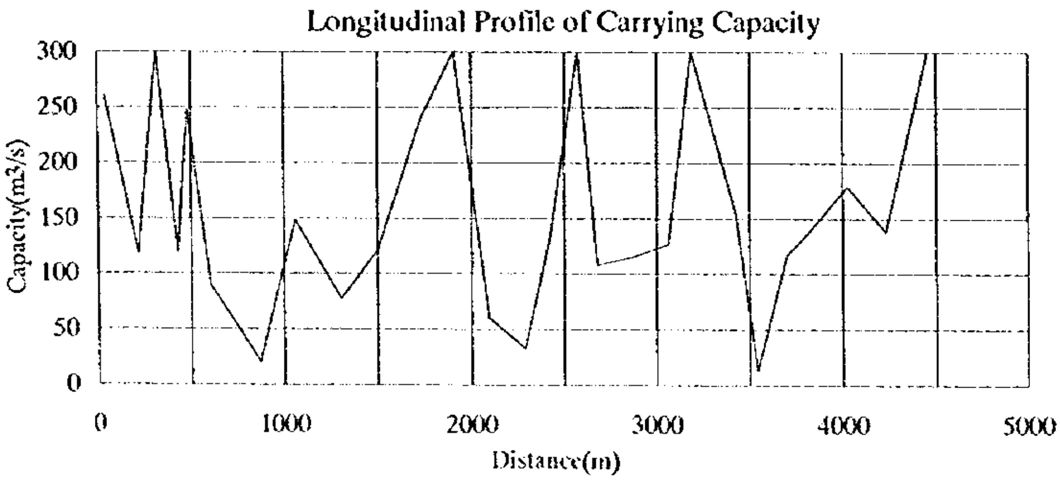


Figure 6.4.6 Longitudinal Profile of Bantyiketu River

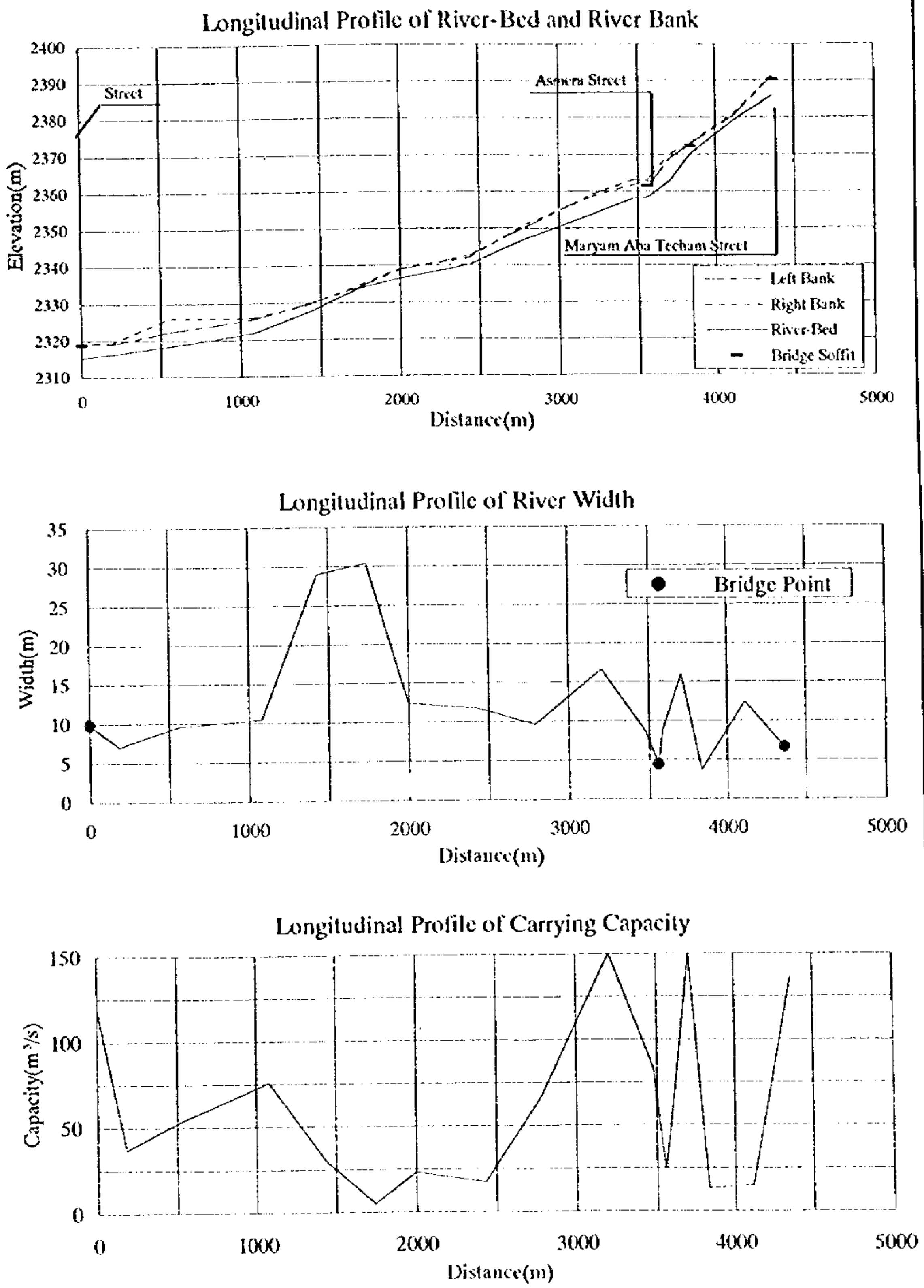


Figure 6.4.7 Longitudinal Profile of Hanku River