THE STUDY ON ADDIS ABABA
FLOOD CONTROL PROJECT

CHAPTER 8

FRAMEWORK OF MASTER PLAN

THE STUDY

ON

ADDIS ABABA FLOOD CONTROL PROJECT

IN

THE FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

CHAPTER 8 FRAMEWORK OF MASTER PLAN

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8. FRAMEWORK OF MASTER PLAN

8.1 Target Year and Protection Area

The target year for the master plan is set at the year 2020. Protection area is the present densely populated area and under-developing area in the eastern part of the Study Area. Whereas, for new urban areas to be extended in the future, land use regulation in line with the Addis Ababa Master Plan, is recommended to avoid flooding problem which will be newly involved.

8.2 Objective Rivers

The following seven rivers in the Study Area are the objective rivers for flood control master plan.

1) Kurtume river
2) Kechene river
3) Bantyiketu river
4) Kebena river
5) Little Akaki river
6) West Akaki river
7) Hanku river

The total catchment area (the Study Area) is 310 km^2 covering the central and eastern part of Addis Ababa Administration and the western part of Oromia region. The catchment area covered with the urban area to be protected is around 140 km^2 as of 1997.

8.3 Socio-economy

8.3.1 Population

The population in the Study Area is estimated at 1.8 million in 1997 and 4.4 million in 2020, respectively.

8.3.2 Gross Regional Domestic Product (GRDP)

Gross Regional Domestic Product (GRDP) of Addis Ababa has not been officially announced yet. Region 14 Administration has just started to estimate the GRDP of Addis Ababa since a year ago. Official figures of production by sectors have not been available either. Therefore, GRDP of the Study Area has been estimated roughly from available information.

According to the results of the interview survey for riverine people, average household income is 250 Birr/month and this amount can probably be considered disposable income and savings of each household. The number of households in the Study Area in 1997 is estimated at 320,000 households from population and the average family size in the Study Area in 1997. Total household disposable income and savings in the Study Area are estimated as shown below.

250 Birr x 12 months x 320,000 households = 960 million Birr

The total household disposable income and savings are assumed to be 70 % of GRDP. Total of depleting assets, indirect taxes and subsidies, income other than households are assumed to be 30 % of GRDP from other countries' samples.

GRDP of the Study Area = 960 million Birr / 70 % = 1,370 million Birr

GRDP per capita is calculated to be 760 Birr (approximately US$ 110) and this is about 20 % higher than the national average.

The Five Year Program of the Federal Government aims average annual economic growth rate at 7 to 10 %. The rate has been set in order to achieve 4 to 5 % of economic growth for population. Based on this target, GRDP in 2020 has been estimated. The household income in 2020 is estimated at 610 Birr/month with annual growth rate of 4 % from 1997 to 2020. The number of households in the Study Area in 2020 is estimated at 780,000 households from projected population and average family size in the Study Area. Total household disposable income and savings in the Study Area are estimated as shown below.

610 Birr x 12 months x 780,000 households = 5,709.6 million Birr

Therefore, GRDP of the Study Area in 2020 has been estimated as shown below.

GRDP of the Study Area in 2020 = 5,709.6 million Birr / 70 %
= 8,156 million Birr

Average annual growth rate of GRDP is about 8 % as a result of calculation.

GRDP per capita is calculated to be 1,850 Birr (approximately US$ 270) as shown below.

Year	1997	2020
Number of households	320,000	780,000
GRDP of the Study Area (million Birr)	1,370	8,150

8.3.3 Future Land Use

The future land use is to be expanded to the south and west of the city of Addis Ababa. The urban area including industrial area and commercial area is going to exceed to the south out of the Study Area. The future land use in the Study Area is estimated as follows.

Land use categories	Area in 1997 (km^2)	Area in 2020 (km^2)
Industry	23	28
Commercial and Business	3	10
Residential	80	92
Other urban use	52	60
Green area	116	83
Wood land	27	27
Functional green	9	10
Total	310	310

8.4 Existing Development Plan

The flood control master plan is formulated in relation to the development plans and projects presented below.

1) Addis Ababa Master Plan
2) Addis Ababa Flood Control and Prevention Project
3) Reforestation
4) Addis Ababa Water Supply Project
5) Master Plan for Development of Wastewater Facilities for the City of Addis Ababa
6) Addis Ababa Ring Read Construction Project
7) Feasibility Study on Flood Protection and Storm Sewer System of Addis Ababa

8.5 Implementing Organization

The Steering Committee of Addis Ababa Flood Control and Prevention Project is entirely responsible as implementing organization and has strong ties with organizations concerned of the central government and the Region 14 Administration, making necessary consultations. Under the Steering Committee, the Addis Ababa Flood Control and Prevention Project is responsible for plan and implementation of flood protection measures on practical basis.

CHAPTER 9

FLOOD CONTROL PLAN

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CHAPTER 9 FLOOD CONTROL PLAN

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9.1 Basic Concept and Methodology

9.1.1 Protection Area and Objective Rivers

Protection area and objective river stretches of a flood control master plan, are decided with due considerations of the present situation of flood damage, land use and socio-economic development in the future in the target year of 2020 as described below.

- Flooding is a serious problem for the regional socio-economy under the present socio-economic and land use conditions in the river basin, and
- Flooding will have a serious impact on the regional socio-economy with the future socio-economic and land use conditions in the river basin.

The flood control plan covers 4 river systems consisting of 7 rivers in the present densely populated area and under-developing area in the Hanku river basin in the eastern part of the Study Area. These objective rivers are principal ones characterized by destructive flood flow coming directly from the mountain areas.

For new urban areas to be extended towards south in the future, a land use regulation scheme along river courses is to be applied to avoid flooding problem which will be newly brought, in line with the Addis Ababa Master Plan.

Figure 9.1.1 shows objective rivers and stretches of the master plan. They are as follows.

- Kurtume Rivers: Confluence with Bantyiketu - Dajazmach Yigezu bridge in the main channel which includes a basin of the mountain area (L= 5.5 km)
- Kechene River: Confluence with Bantyiketu - Kechene bridge (L= 5.4 km)
- Bantyiketu River: Confluence with Kebena - Confluence with Kechene (L= 4.5 km)
- Kebena River: Railway bridge - Testa Aseged bridge (L= 7.8 km)
- Little Akaki River: Confluence with West Akaki - Arveynoch Street (L= 15.6 km)
- Hanku River: around Fikre Maryam Aba Techan Street

Aside from the above, the following areas are taken up as a drainage improvement. These areas have been suffered from both the reasons of floods by over topping from river channel and by local rain due to no drainage facilities along roads. Therefore, even after improvement of river channel, inundation in the said areas still remains. Those remarkable areas are as follows.

- Left bank area around confluence of Bantyiketu and Kechene river and
- Right bank area around confluence of Bantyiketu and Kechene river.

9.1.2 Design Scale

The design scale (protection level) of the flood control master plan is justified based on a preliminary study for 3 alternative scales, which will be discussed in the section 9.3. Scales of the remarkable past floods in 1968, 1970, 1978 and 1995 as discussed in chapter 6, basin size, and balance of safety level between main channel and tributaries are also considered in the justification. The scale is defined as a probability of total rainfall volume of design rainfall for flood to be estimated.

9.1.3 Methodology

(1) Characteristics of Natural and Social Conditions of Floods and Rivers

1) Characteristics of Natural Condition

Rainfall in the questioned area is of remarkably torrential one. In addition, slopes of the objective river channels are considerably steep ones varying from 1/20 to 1/100. Therefore, flood has destructive flow with high velocities, and that duration of flood is quite short lasting from 3 to 5 hours.

2) Characteristics of Social Condition

According to site reconnaissance and study result, it can be said that the objective rivers had been originally wide and deep in size. In the recent decades, many people have moved into the river bank areas, which are easily submerged by flood, especially on the terraces in the incised valleys.

As the results, tremendous numbers of houses and buildings exist on the river bank areas, above all in the Kechene, Kurtume and the middle Little Akaki downstream of the confluence with the Fereja river. Therefore, daily life of the riverine people has close relation with a river.

In this regard, these natural and social characteristics of the floods and rivers are basic considerations in setting up the flood control measures. It is a key factor to retard flood flow in the mountainous areas and to divert flood flow to other rivers in order to minimize large scale of the resettlement in the riverine areas.

(2) Promising Structural Measures for Flood Control Plan

Figure 9.1.2 shows a concept of flood control measures. In mitigation of flood damage in the urban areas, a special attention must be paid to resettlement of riverine people to be involved. To cope such constraints, the flood control plan is proposed to formulate in combination with the Structural and Non-structural Measures in the basin and rivers, both of which intend to protect the questioned area from flooding. The following are major promising structural measures in the flood control plan.

1) Temporary Flood Detention in the Basin and Rivers

To retard and store rain water temporarily in the basin, is technically, economically and socially effective measure to decrease flood peak to downstream reaches, which means minimization of resettlement in view of natural and social situations of floods and rivers in Addis Ababa.

According to site reconnaissance conducted so far, there are, fortunately, several open areas along the river courses in the upper basins, to be utilized as the flood Regulating Pond. Figure 9.1.3 shows a concept of the regulating pond. In the mountainous areas, there also exist wide valleys, to be utilized as the flood detention facilities of Reservoir by Low Weir. Figure 9.1.4 shows a concept of the reservoir by low weir.

These open areas can be converted into the flood regulating pond or reservoir without resettlement or with negligible small number of resettlement. Time duration occupied by the stored water will be only around half a day in the heavy rain time, and in the ordinary time, to be used as public purposes for football game or others. Such temporary detention measures in the upper basin are taken up as much as possible.

2) Retarding Basins

There exist extensive wide natural Retarding Basins in the confluence of the Kebena and Bantyiketu rivers, and in the lower reaches of the Hanku river. The retarding basin plays a roll to retard river flow and results in decreasing a peak discharge of the flood to downstream. Those existing retarding basins are a valuable property in view of flood control for the future. In case big floods exceeding a design level, it is expected to act as a buffer in the neighboring areas. In this viewpoint, they are remained as they are at present condition.

3) Diversion Channel

The Little Akaki river channel, downstream of the confluence with the Fereja river, had been originally wide and deep. However, the present river width has been narrowed due to occupation of houses and buildings. Widening of river channel results in voluminous resettlement. Therefore, channel improvement of these reaches is not an effective measure from social, technical and economical aspects. In order to avoid such constraints, a Diversion Channel scheme of flood coming from the mountain area, is taken up as one of the promising measures. The diversion channel will be effective at the point of upstream of the confluence with the Fereja river and diverted into the West Akaki river which has enough channel capacity.

4) River Channel Improvement

Finally, the remaining run-off in the basin is to be discharged rapidly by means of a river channel improvement. The river channel improvement works consist of excavation, embankment (dike), construction of flood protection wall, bank protection, etc (Channel Improvement). To control velocity in the river channel is also inevitable measure. Drop structures will be constructed as needed. Further, it is desired that some bridges with small span which act as a velocity and flow control, be left as they are.

9.2 Flood Control Alternatives

Based on the said considerations, the following flood control alternatives are structurally conceived in the flood control master plan.

9.2.1 Bantyiketu River System including Kechene and Kurtume Rivers

(1) Kurtume River

A measure by only channel improvement is not socially accepted in view of present riverine area conditions. Open areas to retard run-off coming from the mountainous area are available in the middle basins. These areas are fully allocated to reduce flood peaks to downstream as the regulating pond. In this regard, the following alternative plans are taken up, as shown in Figure 9.2.1.

Alternative 1: Construction of 2 regulating ponds of Kurtume 1 (A=4,300 km^2) and 2 (A=9,200 km^2) and river channel improvement mainly by construction of flood wall

Alternative 2: Construction of 4 regulating ponds of Kurtume 1, 2, 3 (A=5,000 km^2) and 4 (A=2,500 km^2) and river channel improvement mainly by construction of flood wall

(2) Kechene River

The basic idea for the Kechene river is the same with those of the Kertume river. The following are taken up and its scheme are shown in Figure 9.2.2.

Alternative 1: Construction of Kechene reservoir by low weir (H= 20 m) and river channel improvement mainly by construction of flood wall

Alternative 2: Construction of Kechene reservoir by low weir (H= 20 m) and Kostre regulating pond (A=7,900 km^2), and river channel improvement mainly by construction of flood wall

(3) Bantyiketu River

The river bank areas of the Bantyiketu river except the most upstream areas are not so densely populated compared with those of the Kechene and Kurtume. However, surrounding areas of the river areas are the most important districts of Addis Ababa. Accordingly, a combined scheme of channel improvement and regulating pond is conceived. Further, the existing natural retarding basin in the lower reaches is fully taken into the plan. For each plan to be selected in the Kurtume and Kechene rivers, the following alternatives are taken up, as shown in Figure 9.2.3.

Alternative 1: River channel improvement

Alternative 2: Construction of Bantyiketu regulating pond (A=29,000 km^2) and minor river channel improvement

9.2.2 Kebena River System

(1) Upstream of the Confluence with the Bantyiketu

The upper basin has several promising sites of flood retention. In order to minimize resettlement in the riverine areas by reducing flood peaks to the downstream reaches, a reservoir scheme is taken up in the alternatives. The existing retarding basin is also taken into the plan. The following alternatives are taken up, as shown in Figure 9.2.4.

Alternative 1: Construction of 2 reservoirs by low weir of Kebena 1 (H= 25 m) and Abo (H= 24 m) and river channel improvement mainly by construction of flood wall

Alternative 2: Construction of 3 reservoirs by low weir of Kebena 1 (H= 25 m) and 2 (H= 14 m), and Abo (H= 24 m) and river channel improvement mainly by construction of flood wall

(2) From the Confluence with the Bantyiketu to Bole railway bridge

For each plan to be selected in the upper Kebena and Bantyiketu rivers, the lower Kebena from the confluence with Bantyiketu up to the Bole railway-bridge is to be improved by means of a channel improvement.

9.2.3 Little Akaki and West Akaki River System

The West Akaki, which is the main river of the Little Akak, is wide and deep channel having enough flow capacity. Land use in the river bank areas, as the whole, are open areas covered with grasses, trees and vegetable fields. On the other hand, the river bank areas in the middle reaches of the Little Akaki are presently occupied by the dense houses and buildings. In case a channel improvement only is applied, voluminous resettlement will be needed. Accordingly, under the condition that the present land use along the West Akaki river be maintained and regulated in the future, the following alternatives are conceived, as shown in Figure 9.2.5.

Alternative 1: Construction of Little Akaki diversion channel (L=900 m) and regulating pond (A=13,500 km^2), and river channel improvement mainly by construction of flood wall

Alternative 2: Construction of Little Akaki regulating pond (A=13,500 km^2) and river channel improvement mainly by construction of flood wall

9.2.4 Hanku River System

The existing flooding problem in the river basin has been locally limited. There is no pocket to retard run-off in the mountain areas. In the lower reaches of the Hanku river near the International Airport, there exist extensive wide natural retarding basins. Under the condition that such natural retarding basins remain and be maintained as they are at present condition, a widening of the existing culvert across under the Fikre Maryam Aba Techan Street in the middle reaches of the left tributary is taken up.

9.3 Selection of Optimum Design Scale

9.3.1 Condition of Study

The Bantyiketu, Kurtume and Kechene rivers are selected for the study on optimum design scale of the flood control master plan. These rivers are the typical ones in the Study Area in the viewpoints of natural conditions, and the regional socio-economy with the present socio- economic and land use conditions. Further, the said Alternative 2 are studied for selection of optimum design scale, respectively, from a viewpoint of minimization of resettlement due to flood control plan.

With due consideration of the estimated flood scales of the past events as discussed in chapter 6, the following alternative scales are taken up for the study.

Case	Main rivers of Bantyiketu, Kebena and Little Akaki	Tributaries and Hank river
Case-1	20 year return period	10 year return period
Case-2	30 year return period	20 year return period
Case-3	40 year return period	30 year return period

9.3.2 Selection of Optimum Design Scale

The design discharge distributions of each case are shown in Figure 6.3.1 to 6.3.13 in Chapter 6. Based on preliminary design of the respective alternative scales, construction cost and benefit accrued from implementation of the works are estimated and described in chapter 10 and 12. Further, economic internal rate of return (EIRR) is calculated. The results are as follows.

- Case 1 (1/20); EIRR = 11.2 %
- Case 2 (1/30); EIRR = 11.4 %
- Case 3 (1/40); EIRR = 9.9 %

From the above results, the Case 2 of 30 years return period for main channel and 20 years return period for tributary is selected as the design scales of the flood control master plan.

9.4 Evaluation of Alternatives

9.4.1 Criteria

Figure 6.3.1 to 6.3.13 in Chapter 6 shows design discharge distributions of flood control alternatives. Major structures of each alternative are preliminary designed. The result is shown in chapter 10. The estimated construction costs and evaluation of economic aspect for each alternative are described in chapter 10 and 12, respectively.

Evaluation of the alternatives is conducted in accordance with the following criteria.

- Technical aspect,
- Financial aspect,
- Economic aspect, and
- Social Impact.

9.4.2 Selection and Evaluation of Flood Control Plan

In consideration of the above criteria, evaluation of alternatives is conducted. Table 9.4.1 shows the overall evaluation results of flood control alternatives for the master plan.

Based on these results, the following each alternative is selected among 4 river systems consisting of 6 rivers.

(1) Bantyiketu River System

1) Kurtume River

As discussed in the section 9.2, the following alternatives are taken up for flood control plan.

Alternative 1: Construction of 2 regulating ponds of Kurtume 1 (A=4,300 km^2) and 2 (A=9,200 km^2) and river channel improvement mainly by construction of flood wall

Alternative 2: Construction of 4 regulating ponds of Kurtume 1, 2, 3 (A=5,000 km^2) and 4 (A=2,500 km^2) and river channel improvement mainly by construction of flood wall

From the above, Alternative 2 is selected as optimum plan of the flood control.

2) Kechene River

The proposed alternatives are as follows.

Alternative 1: Construction of Kechene reservoir by low weir (H= 20 m) and river channel improvement mainly by construction of flood wall

Alternative 2: Construction of Kechene reservoir by low weir (H= 20 m) and Kostre regulating pond (A=7,900 km^2), and river channel improvement mainly by construction of flood wall

In the Kechene river, Alternative 2 is selected.

3) Bantyiketu River System

For each plan selected in the Kurtume and Kechene rivers, the following are taken up.

Alternative 1: River channel improvement

Alternative 2: Construction of Bantyiketu regulating pond (A=29,000 km^2) and minor river channel improvement

From the above, Alternative 2 is selected. EIRR for the selected plan including the Kurtume and Kechene rivers is estimated at 11.4 %. Further, the Bantyiketu river improvement works involves urban drainage which will be explained in the subsequent section 9.5.

(2) Kebena River System

The proposed Alternatives are as follows.

Alternative 1: Construction of 2 reservoirs by low weir of Kebena 1 (H= 25 m) and Abo (H= 24 m) and river channel improvement mainly by construction of flood wall

Alternative 2: Construction of 3 reservoirs by low weir of Kebena 1 (H= 25 m) and 2 (H= 14 m), and Abo (H= 24 m) and river channel improvement mainly by construction of flood wall

Among the above alternatives, Alternative 1 is selected as the flood control plan in this river system. The estimated EIRR is 3.4 % for Alternative 1.

(3) Little Akaki River System

The following alternatives are taken up under the condition that the present land use conditions of river banks along the West Akaki river be kept as they are and maintained in the future.

Alternative 1: Construction of Little Akaki diversion channel (L=900 m) and regulating pond (A=13,500 km^2), and river channel improvement mainly by construction of flood wall

Alternative 2: Construction of Little Akaki regulating pond (A=13,500 km^2) and river channel improvement mainly by construction of flood wall

In this river system, Alternative 1 is selected. EIRR estimated is 10.7 % for Alternative 1.

(4) Hanku River System

In the lower reaches of the Hanku river near the International Airport, there exist extensive wide natural retarding basins. Under the condition that such natural retarding basins remain and be maintained as they are at present condition, two culverts across under the Fikre Mayam Aba Techan Street in the middle reach of the left tributary is proposed. The estimated EIRR is 8.5 %.

9.5 Uban Drainage

9.5.1 Basic Concept

Flood control measures will mitigate the damage due to the overflowing of flood from rivers, but it does not always mitigate the damage due to the inundation resulting from the insufficient facilities of drainage. But since the objective of this study is the preparation of flood control master plan and is not the preparation of drainage master plan, the drainage improvement is here proposed very locally just as the auxiliary measures for flood control plan in Addis Ababa to enhance the flood control benefit.

9.5.2 Objective Area

As mentioned in the previous section on the present situation of the Study Area, the local drainage area that drains to the Bantyiketu river in the reaches between the confluence of the Kurtume and the Kechene rivers and the Finfine bridge site on the Menelik II avenue has insufficient condition of drainage of local storm. This area is always suffering from inconvenience due to insufficient condition of drainage during rainy season every year. But this area is one of the most important areas in Addis Ababa from the view point of existence of important agencies of the central government of Ethiopia and the international agencies, and the place of importance of the road and railway transportation.

In due consideration of the above from the socio-economic view point, this area is selected for the objective area for drainage improvement. The drainage area is shown in Figure 9.5.1.

9.5.3 Drainage Improvement Plan

(1) Design Scale

In due consideration of the balance with the design scale of flood control in Addis Ababa and the rainfall intensity adopted in other cities in other countries, rainfall intensity of 30 mm/hour is adopted for the design scale of drainage improvement. This corresponds to the return period of between 1 and 2 years.

(2) Methodology

In consideration of low cost and easy maintenance in future, road side ditch is proposed as the structural measures for drainage improvement. In addition, the road side ditch is proposed just as the terminal drainage ways to the Bantyiketu river. It is considered that secondary and tertiary drainage ways would be prepared or improved after the drainage master plan is formulated in future.

(3) Basic Features

The basic features of the drainage improvement are as follows:

- drainage basin	: 2.48 km^2 consisting of 4 sub-basins
- length of drainage ditch	: 4,000 m
- design discharge	: 2.6 m^3/s for sub-basin 1
	: 3.1 m^3/s for sub-basin 2
	: 3.6 m^3/s for sub-basin 3
	: 3.1 m^3/s for sub-basin 4

In due consideration of the topography of the drainage basin and the drainage conditions, the alignments of the road side ditches for drainage improvement are proposed as shown in Figure 9.5.1.

9.6 Proposed Flood Control Master Plan

The proposed flood control master plan for the target year of 2020 consists of both the structural and non-structural measures. Outline of the proposed plan is explained below.

9.6.1 Structural Measures

Figures 9.6.1 to 9.6.3 show the features of the proposed flood control master plan and drainage improvement, respectively. Table 9.6.1 shows the major work items of the plan. The works involved in the proposed master plan are outlined below.

(1) Bantyiketu River System

1) Kurtume River

1) Four (4) regulating ponds (Kurtume 1 to Kurtume 4)

2) Channel improvement
   - Flood wall (total length 800m)
   - Bank protection for bridge (10 bridges)
   - Velocity control structures /drop structures (10 nos.)

2) Kechene River

1) One (1) small weir (Kechene weir)

2) One (1) regulating pond (Kostre regulating pond)

3) Channel improvement
   - Flood wall (total length 980 m)
   - Bank protection for bridge (7 bridges)
   - Repair of one (1) bridge (repair of abutment)
   - Velocity control structures/drop structures (10 nos.)

3) Bantyiketu River

1) One (1) regulating pond (Bantyiketu regulating pond)

2) Channel improvement
   - Excavation (33,500 m^3, standard cross sections are shown in Figure 9.6.4)
   - Flood wall (total length 1,950 m)
   - Intake weir (for vegetable irrigation)
   - Footpath with water supply pipe (length 20 m)
   - Bank protection (total length 300 m)

3) Drainage improvement (construction of road side ditches : 4,000m)

(2) Kebena River System

1) Two (2) small weirs (Kebena 1 and Abo)

2) Channel improvement
   - Flood wall (total length 3,100 m)
   - Bank protection for bridge (12 bridges)
   - Velocity control structures /drop structures (12 nos.)

(3) Little Akaki River System

1) One (1) regulating pond(Little Akaki regulating pond)
2) Diversion channel (total length 1,000 m)
3) Channel improvement
   - Flood wall (total length 1,050 m)
   - Bank protection for bridge (9 bridges)
   - Velocity control structures/drop structure (16 nos.)

(4) Hanku River System

1) Reconstruction of 2 culverts (Fikre Mayam Aba Techan street)

9.6.2 Non-structural Measures

Aside from the above structural measures, non-structural measures are quite effective ones to supplement the structural measures. For some non-structural measures, a legislation of municipal bylaw will be necessary. Non-structural measures to be proposed are as follows.

(1) River Management

Proposed facilities involved in the flood control master plan must be operated and maintained so as to discharge design flood safely and function properly in line with the respective purposes. In this viewpoint, the following measures are proposed.

1) Authorization of Administrative River Zone (Region 14 Administration Level)

Required river width has been delineated in the proposed flood control master plan. The said river width is needed for its administration and management of rivers and facilities as Administrative River Zone (as an administrative limit in a river section). Therefore, land use in the administrative river zone is strongly desired to be regulated.

In order to achieve this purpose, an authorization of the administrative river zone is required with a legislation of municipal bylaw. AFCPO, Steering Committee and concerned organizations in Region 14 Administration are in charge of such legislation.

This legislation is proposed to start as soon as possible. Delineation of administrative river zone is proposed as follows.

- River bank with flood wall : Outside of wall
- River bank without flood wall : 5 m outside from river bank line

In relation with the above legislation, it is desired to prohibit to construct private facilities and to pitch garbage and soil into the authorized administrative river zone or directly into the river channel, which are described below.

2) Public Information and Education, and Regulation of Illegal Activities (Region 14 Administration and Community Level)

It is one of important activities to enhance Public Awareness against Flooding and for Rivers which act as public facilities for drainage ways and open spaces with green area in the urban areas.

Firstly, it is desired to enlighten public awareness for rivers. It is proposed to hold forum and ceremony or concert to "Love River". Also campaigns through mass media of TV and radio are proposed to enlighten the public awareness. Secondly, it is proposed to prohibit disposal of solid waste and soil into the administrative river zone, with a legislation of municipal bylaw in connection with the said Authorization of Administrative River Zone.

AFCPO and the related communities are recommended to be in charge of such enlightenment under directions of Steering Committee. This activity is recommended to start as soon as possible.

3) Regulation of Land Use along West and East Akaki Rivers (Works and Urban Development Bureau)

It is expected that the existing urban areas expand towards south especially in the areas between the West Akaki river and Akaki river including lower reaches of the Hanku river that natural retarding basin extends. Due to acceleration of such urbanization, flooding problem might be brought into the newly developed areas. In this regard, land use on the riverine area along the said rivers are regulated in relation with the Addis Ababa Master Plan. Area or width to be regulated is recommended to be 50m to 100 m for one side that is observed in the present West Akaki river.

This is recommended to authorize in the existing Addis Ababa Master Plan under the leadership of Works and Urban Development Bureau. This activity is recommended to start as soon as possible for sound urban development in the future.

4) Guideline of Structural Design (AFCPO of Region 14 Administration)

The flood control facilities are desired to design and construct appropriately for their purposes. For this purpose, a guideline of design is prepared for major structures involved in the proposed flood control master plan. The details of the proposed guideline is described in chapter 10.

(2) Watershed Management (Bureau of Agriculture of Region 14 Administration)

Conservation of soil and flood retention function in the mountain areas is an essential part of the non-structural measures from the viewpoint of not only flood control to directly reduce runoff to downstream reaches but also environment. Accordingly, the following measures are proposed.

Reforestation of the deforested areas in the mountain areas and Planting of trees in the open spaces of urban areas are proposed to be taken up.

Existing organization of the Bureau of Agriculture in Region 14 Administration is recommended to be a main implementation body for this measure, by applying the existing available strategy, methodology and system explained in the section of 4.6.3 in chapter 4. Accordingly, this activity is proceeded by the Bureau of Agriculture independently. Therefore, it is proposed to continue reforestation for the areas where the arrangements are easy.

(3) Flood Risk Management

1) Flood Warning System (Region 14 Administration and Community Level)

The floods in the mountainous areas are brought to the urban areas in short time with from 1 to 2 hours, therefore, it is quite difficult to promptly forecast flood scale. In this regard, a Warning System by Siren is an actual tool of damage mitigation against flood and large scale bank erosion. The warning is made when the acm3ulated rainfall amount exceeds 15 mm per 10 minutes. This activity is proposed to proceed by AFCPO and the community level (Kebele) in line with the existing available National Disaster Prevention and Preparedness Management Policies.

In this system, 3 rainfall observatory stations and small towers for a siren and electrical lines are installed in the mountain areas of the Kebena, Kechene and Little Akaki rivers, and along 6 major river channels of the Bantyiketu, Kechene, Kurtume, Kebena, Little Akaki including a part of West Akaki and Hanku rivers with an approximate distance of 500 m, respectively.

The following are the required works.

- Rainfall observatory station with telephone : 3 places
- Total length of system : 60,000 m
- Small tower with siren : 120 nos.

Installation of the warning system is proposed to carry out by AFCPO and its implementation is proposed to start in the preparatory stage of the Priority Project.

2) Flood Fighting System (Community Level)

It is a valuable activity to carry out Flood Fighting, to minimize flood damage to be brought in the flooding time. This activity is proposed to proceed in the community level (Kebele) in line with the existing available National Disaster Prevention and Preparedness Management Policies. Further, it is necessary to train riverine people through periodical exercise.

AFCPO under directions of Steering Committee is proposed to take a leadership in the activity, in cooperation with the existing available organization of NCEW in the said National Disaster Prevention and Preparedness Management Policies. This activity is also proposed to be started from the coming rainy season and the exercise, as soon as possible before the coming rainy season.

The construction of storage houses with necessary materials and tools are required for this activity. The storage houses to be constructed are 2 each in the respective rivers of the Kurlume, Kechene, Bantyiketu, Kebena, Little Akaki and Hanku rivers.

3) Storage of Storm Water (Community Level)

It is also desired to temporarily store Storm Water at Gardens in the Private Houses, Open Spaces in the Government Facilities and Campuses of the University. Water thus kept is very useful for car washing, cloth washing, etc. Such devise has a surprising effect not only to decrease run-off into the rivers but also to save amounts of water consumption in domestic water supply aspect.

For this activity, a campaign of enlightenment for community level will be a main work. Works and Urban Development Bureau is desired to take a leadership as a main implementation body. This activity is also proposed to be started from the coming rainy season.

9.7 Selection of Priority Project(s)

9.7.1 Criteria

The following are the criteria to select priority project(s) which are to be taken up for the feasibility study.

1) Technically and socially, the project is viable and implementation of the project is easy.
2) Financially, size of construction works is within the moderate one.
3) Economically, IRR is high.
4) Socially, beneficiaries are many and
5) Environmentally, implementation of the project has no remarkable negative environment issues.

9.7.2 Priority of Rivers

Priority of rivers to be improved is studied for the four river systems. The priority order of rivers is evaluated as shown in Table 9.7.1, in which cost per beneficiary, beneficial population, resettlement are included in evaluation criteria. These three items are accounted for as follows, which are also common to Table 9.7.2 for selection of priority project(s).

As is seen in the Table 9.7.1, the flood control projects in the Bantyiketu river system including the Kurtume and Kechene rivers are taken up as objective river system for selection of the priority project(s).

Cost per beneficiary (C/B): 290 Birr is average cost per beneficiary for all the river systems, derived by rounding (122 + 138 + 130 + 1.4) x 10^6/((610 + 280 + 420 + 35) x 10^3). 190 Birr is defined as the average of cost per beneficiary for all the alternatives of the priority river system derived by rounding (200 + 198 + 211 + 185 + 179)/5.

Beneficial population: 350,000 is the average beneficial population of the four river systems (Bantyiketu, Kebena, Little Akaki, Hanku), derived by rounding (610,000 + 280,000 + 420,000 + 35,000)/4.

Resettlement: 30 is defined as a maximum number of houses resettled by a project undertaken by Addis Ababa Flood Control Project Office (AFCPO) until now.

9.7.3 Alternatives for Selection of Priority Project(s)

With due consideration of the evaluation result in Table 9.7.1, the following alternative cases are considered for selection of the priority project(s). The improvement of the urban drainage is included in the works of the Bantyiketu river system.

Case 1: Same with the master plan

Kurtume River
1) Four (4) regulating ponds
2) Channel improvement

Kechene River
3) Kechene weir and Kostre regulating pond
4) Channel improvement
5) Repair of bridge abutment

Bantyiiketu River
6) Bantyiketu regulating pond
7) Channel improvement
8) Road side ditch

Case 2 : Excludes the above items 1) and 2)
Case 3 : Excludes the above items 3), 4) and 5)
Case 4 : Excludes the above items 1), 2) and 4)
Case 5 : Excludes the above items 1), 2), 4) and 7)

9.7.4 Evaluation and Selection of Priority Project(s)

Table 9.7.2 shows the evaluation results of the priority project(s). According to the above table, the Case 4 is selected as the priority projects in the river system of the Bantyiketu and Kechene rivers which are technically viable, economically feasible, environmentally sound, and socially and urgently needed. The following are major components of the priority projects for the subsequent feasibility study. The outline of the priority projects is presented in Figure 9.7.1.

Kechene river

- Construction of Kechene weir (storage volume: 115,000 m^3)
- Construction of Kostre regulating pond (pond area: 7,900 km^2) and
- Repair of bridge abutment (1 bridge)

Bantyiketu river

- Construction of Bantyiketu regulating pond (pond area: 29,000 km^2) and
- River channel improvement from confluence with the Kebena to confluence with the Kechene (widening of river channel, bank protection, flood wall, bridge, aqueduct, intake weir, objective river channel length: 4,500 m)
- Urban drainage: construction of road side ditch (total length: 4,000m)

Table 9.4.1 Evaluation of Alternatives for Flood Control Plan

Evaluation Item	Kurtume River		Kechene River		Banteyiketu River System		Kebena River		Little Akaki River	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2	Alternative 1	Alternative 2	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Outline of the Project Improvement Works Improvement Length	Regulating pond (2nos) Channel improvement	Regulating pond(4nos) Channel improvement	Weir(1no) Channel improvement	Weir(1no) Regulating pond(1no) Channel improvement	Channel improvement	Regulating pond(1no) Channel improvement	Weir (2nos) Channel improvement	Weir(3nos) Channel improvement	Regulating pond(1no) Diversion channel Channel improvement	Regulating pond(1no) Channel improvement
Technical Aspects Difficulty Point	ordinary 5	ordinary 5	ordinary 5	ordinary 5	ordinary 5	ordinary 5	ordinary 5	ordinary 5	difficult 3	ordinary 5
Financial Aspects Project Cost Point	costly 31 million Birr 5	not costly 29 million Birr 7	costly 53 million Birr 5	not costly 42 million Birr 7	costly 119 million Birr 5	not costly 118 million Birr 7	not costly 136 million Birr 7	costly 156 million Birr 5	costly 128 million Birr 5	not costly 89 million Birr 7
Economic Aspects EIRR(%)	same		same		same		same		same	
Social Impact Resettlement Point	large 0	small 5	large 0	small 5	large 0	small 5	small 5	small 5	small 5	large 0
Overall Evaluation Overall point Selected Plan	10	17 Selected	10	17 Selected	10	17 Selected	17 Selected	15	13 Selected	12

Evaluation Criteria

For each item, point is set with the following criteria.

Note:

Channel improvement consists of construction of flood wall, bank protection works etc.

Difficulty	Construction Cost	Resettlement
5 points : ordinary	5 points: Cost is costly	5 points: No. of House is small
3 points : difficult	7 points: Cost is not costly	0 point: No. of House is large

Table 9.6.1 Work Items of the Proposed Flood Control Master Plan

Work Item	Kurtume River	Kechene River	Bantyiketu River	Remarks
Channel Excavation(cu.m)			33,500	
Flood Wall				
Right Bank(lin.m)	200	370	1,600	
Left Bank(lin.m)	600	610	350	
Bank Protection				
(sq.m)	6,480	4,540	1,620	
	(10 bridges)	(7 bridges)		
Foot Path(nos)			1	
Repair of Bridge(nos)		1		
Velocity Control Structures				
(nos)	10	10		
Regulating Pond(site)	4	1	1	
Small Flood Control Dam				
(site)		1		
Intake Weir(nos)			1	

Work Item	Kebena River	Little Akaki River	Hanku River	Remarks
Channel Excavation(cu.m)	0	0		
Flood Wall				
Right Bank(lin.m)	1,700	200		
Left Bank(lin.m)	1,400	850		
Bank Protection(sq.m)	7,780	5,840		
	(12 bridges)	(9 bridges)		
Velocity Control Structures				
(nos)	12	16		
Regulating Pond(site)		1		
Small Flood Control Dam				
(site)	2			
Diversion Channel(lin.m)		1,000		
Culvert			1	
Foot Path(nos)		1		

Note : Detail location of flood wall is presented in Table 9.6.2.

Kebena River

Location	Length(m)	Average Height(m)	Total Area(sq.m)
Right Bank			
L= 4300 - 4800	500	2.0	1,000
L= 5000 - 5700	700	3.5	2,450
L= 5700 - 5900	200	2.0	400
L= 6600 - 6900	300	2.0	600
Left Bank			
L= 4300 - 4800	500	3.5	1,750
L= 5000 - 5700	700	3.5	2,450
L= 5700- 5900	200	3.5	700
Total			9,350

Little Akaki River

Location	Length(m)	Average Height(m)	Total Area(sq.m)
Right Bank			
L= 4700 - 4900	200	2.0	400
Left Bank			
L= 2556 - 3000	450	2.0	900
L= 3500 - 3700	200	2.0	400
L= 4700- 4900	200	2.5	500
Total			2,200

Note : L= Horizontal distance on the profile

Table 9.6.2 Detail Location of Flood Wall

Kurtume River

Location	Length(m)	Average Height(m)	Total Area(sq.m)
Right Bank			
L=2200 - 2400	200	2.5	500
Left Bank			
L=1100 - 1400	300	2.0	600
L=2200 - 2500	300	2.5	750
Total			1,850

Kechene River

Location	Length(m)	Average Height(m)	Total Area(sq.m)
Right Bank			
L= 600 - 800	200	2.0	400
L= 1200 - 1370	170	2.0	340
Left Bank			
L= 600 - 800	200	2.0	400
L= 1200 - 1370	170	2.0	340
L= 3820 - 4060	240	2.0	480
Total			1,960

Bantyiketu River

Location	Length(m)	Average Height(m)	Total Area(sq.m)
Right Bank			
L= 600 - 1300	700	1.5	1,050
L= 2050 - 2400	350	2.5	875
L= 2600 - 2900	300	2.0	600
L= 3450 - 3700	250	2.0	500
Left Bank			
L= 2050 - 2400	350	1.5	525
Total			3,550

Note : L= Horizontal distance on the profile

Cont`ed

Table 9.7.1 Priority of Rivers in the Mater Plan

Item	1	2	3	4	5
	Bantyiketu River System	Kebena River System	Little Akaki River System	Hanku River System	Non Structural Measures
Outline of the Project					
Improvement Works	1 Weir 6 Regulating Ponds Channel Improvement	2 Weirs Channel Improvement	1 Diversion Tunnel 1 Regulating Pond Channel Improvement	2 Culverts	1. Authorization of river reservation area 2. Public information and education, and regulation of illegal activities
Financial Aspects					
Project Cost	122 million Birr	138 million Birr	130 million Birr	1.4 million Birr	3. Guideline of structural design
Project Cost per Beneficiary	200 Birr	493 Birr	310 Birr	40 Birr	
Point	7	3	5	10	
Economic Aspects					
EIRR(%)	11.7	3.5	10.6	7.2	5. Flood warning system
B/C(at discount rate:10%)	1.17	0.42	1.07	0.72	
NPV(Birr at discount rate : 10%)	11.4 million Birr	-38.9 million Birr	4.8 million Birr	-0.3 million Birr	
Point	7	3	7	5	
Social Impact					
Beneficial Population	610,000	280,000	420,000	35,000	7.Storage of storm water in the basin (private house & government complex)
Point	10	5	7	3	
Resettlement	Small	Small	Small	Small	
Point	10	10	10	10	
Charactristic of Land Use	Mainly governmental agencies and commercial areas	Mainly residential area	Mainly densely residential area	Mainly residential area	
Point	7	3	5	3	
Environmental Impact by IEE	Not significant	Not significant	Not significant	Not significant	
Point	10	10	10	10	
Overall Evaluation					
Overall Point	51	34	44	41	
Priority Project	Selected				

Note: Project does not include price contingency.

Evaluation Criteria

For each item, ranking point is set with the following criteria.

Project Cost per Beneficiary	EIRR	Beneficial Population	Resettlement	Characteristics of Land use	Initial Environmental Examination (IEE)
10 points: Cost <190 Birr	10 points: EIRR ≥ 13 %	10 points: Population ≥ 450,000	10 points: No. of House is small (<30)	10 points: Government Agencies only	10 pionts : Not Significant
7 points: 190 Birr≤Cost<290 Birr	7 points: 13% >EIRR ≥ 10 %	7 points: 450,000 >Population ≥ 350,000	0 point: No. of House is large(≥30)	7 points: Government Agencies, Residential and Commecial Areas	0 point : Significant
5 points: Cost ≥ 290 Birr	5 points: 10% >EIRR ≥ 5 %				
3 points: Cost ≥ 390 Birr	3 points: EIRR < 5 %	5 points: 350,000 >Population ≥ 250,000		5 points: Densely Residential Area	
				3 points: Residential Area	
		3 points: Population < 250,000			

Table 9.7.2 Priority Project(s) in the Master Plan

Item	1 Case 1	2 Case 2	3 Case 3	4 Case 4	5 Case 5
Outline of the Project	Same with Master Plan				
Improvement Works	1. Kurtume river 2. Kechene river 3. Bantyiketu river	1. Kechene river 2. Bantyiketu river	1. Kurtume river 2. Bantyiketu river	1. Kechene river (weir and regulating pond) 2. Bantyiketu river	1. Kechene river (weir and regulating pond) 2. Bantyiketu river (only regulating pond)
Financial Aspects					
Project Cost	122 Million Birr	93 Million Birr	80 Million Birr	87 Million Birr	75 Million Birr
Project Cost per Beneficiary	200 Birr	198 Birr	211 Birr	185 Birr	179 Birr
Point	7	7	7	10	10
Economic Aspects					
EIRR	11.7%	12.6%	12.1%	13.3%	11.9%
B/C(at discount rate:10%)	1.17	1.27	1.22	1.35	1.2
NPV(Birr at discount rate:10%)	11.4 million Birr	15.6 million Birr	11.0 million Birr	18.9 million Birr	12.5 million Birr
Point	7	7	7	10	7
Social Impact					
Beneficial Population	610,000	470,000	380,000	470,000	420,000
Point	10	10	7	10	7
Resettlement	Small	Small	Small	Small	Small
Point	10	10	10	10	10
Characteristic of Land Use	Mainly government agencies and commercial areas	(do)	(do)	(do)	(do)
Point	7	7	7	7	7
Environmental Impact by IEE	Not significant	(do)	(do)	(do)	(do)
Point	10	10	10	10	10
Overall Evaluation					
Overall Point	51	51	48	57	51
Priority Project				Selected	

Note: Project does not include price contingency.

Evaluation Criteria

For each item, ranking point is set with the following criteria.

Note:

Channel improvement consists of construction of flood wall, bank protection works etc.

Project Cost per Beneficiary	EIRR	Beneficial Population	Resettlement	Characteristics of Land use	Initial Environmental Examination (IEE)
10 points: Cost <190 Birr	10 points: EIRR > 13 %	10 points: Population > 450,000	10 points: No. of House is small (<30)	10 points: Government Agencies only	10 pionts : Not Significant
7 points: 190 Birr<Cost<290 Birr	7 points: 13% >EIRR > 10 %	7 points: 450,000 >Population ≥ 350,000	0 point: No. of House is large(>30)	7 points: Government Agencies, Residential and Commecial Areas	0 point : Significant
5 points: Cost > 290 Birr	5 points: 10% >EIRR > 5 %	5 points: 350,000 >Population ≥ 250,000		5 points: Densely Residential Area	
3 points: Cost > 390 Birr	3 points: EIRR < 5 %	3 points: Population < 250,000		3 points: Residential Area	

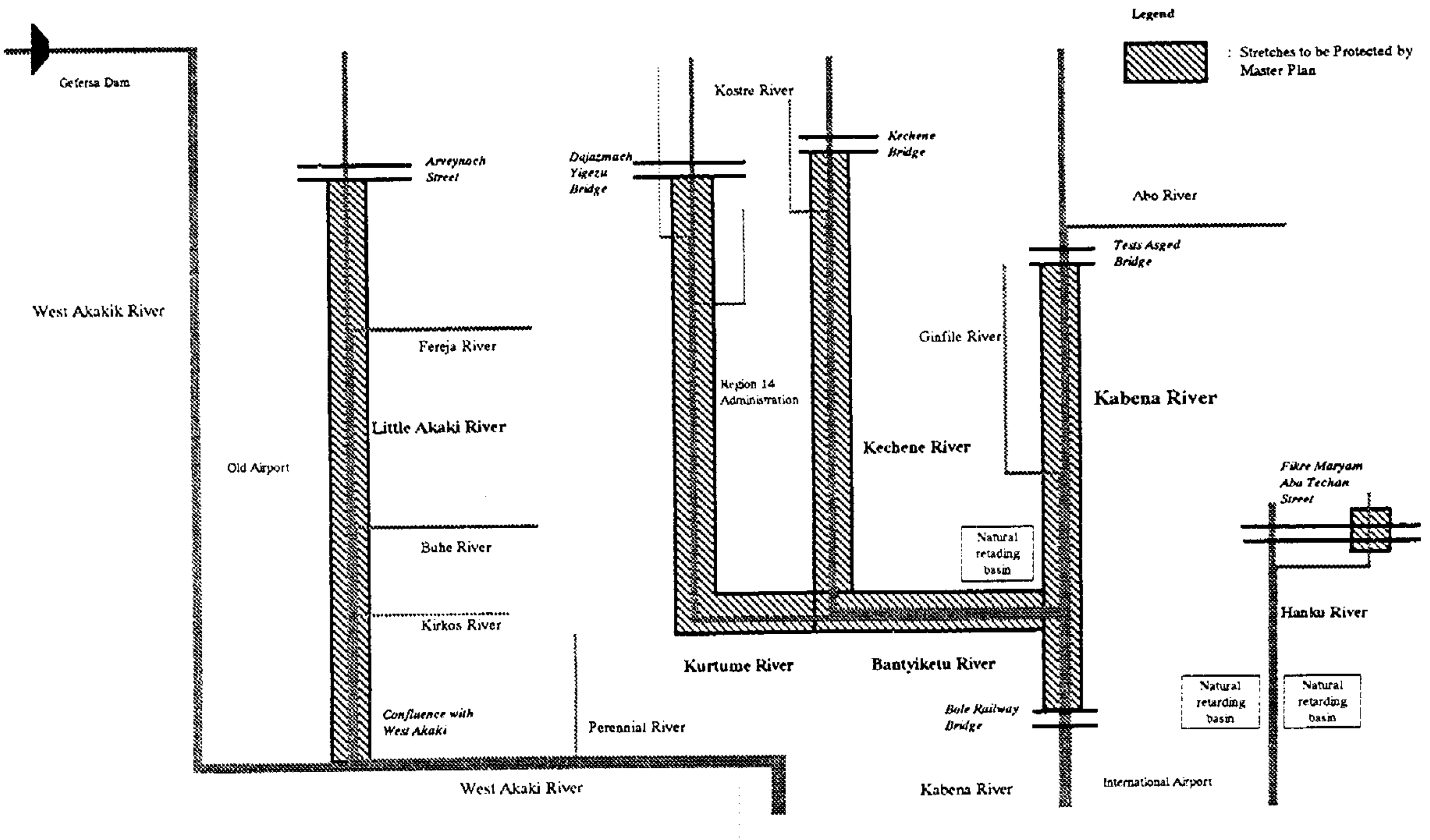


Figure 9.1.1 Objective Rivers and Stretches of Flood Control Master Plan

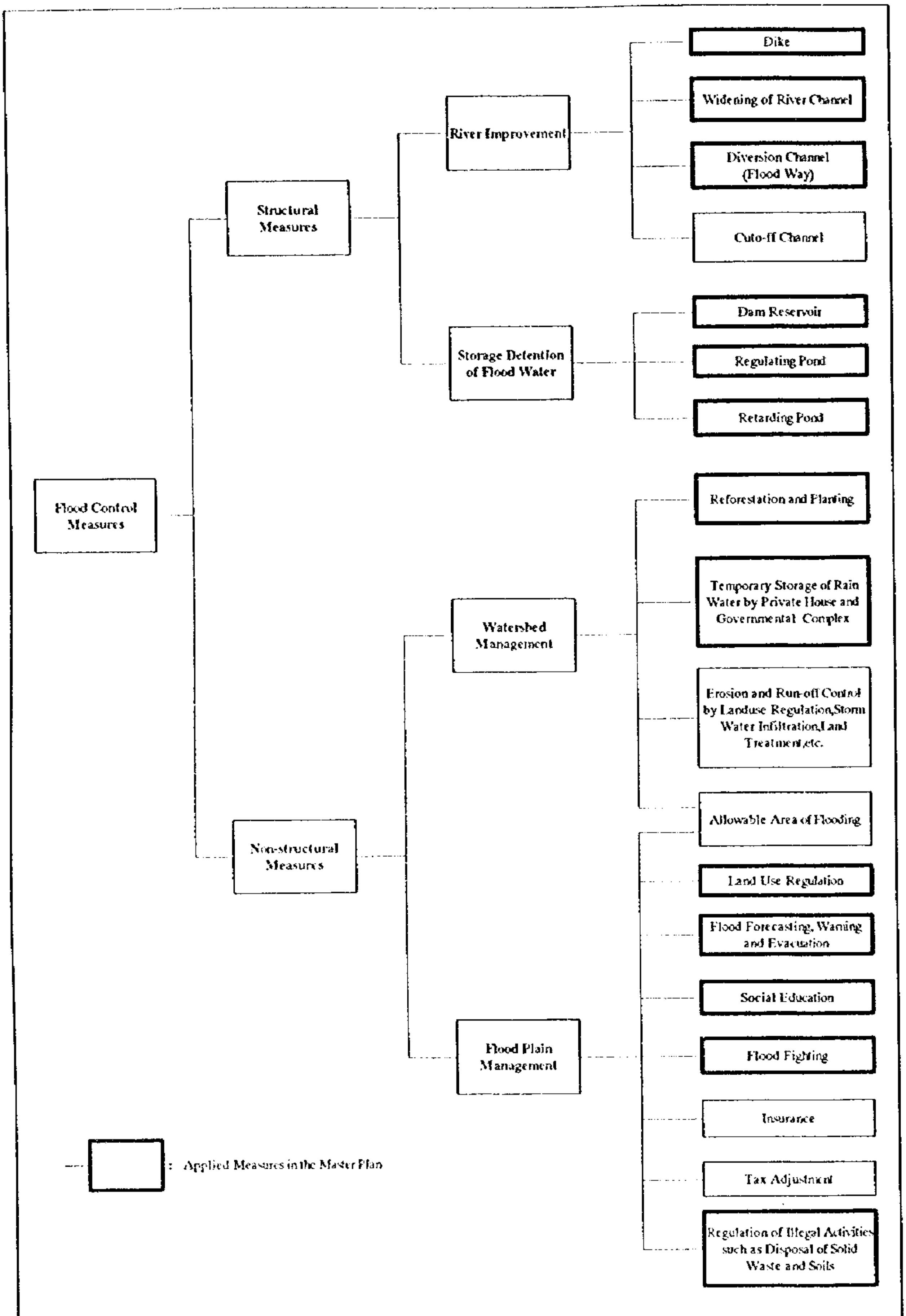
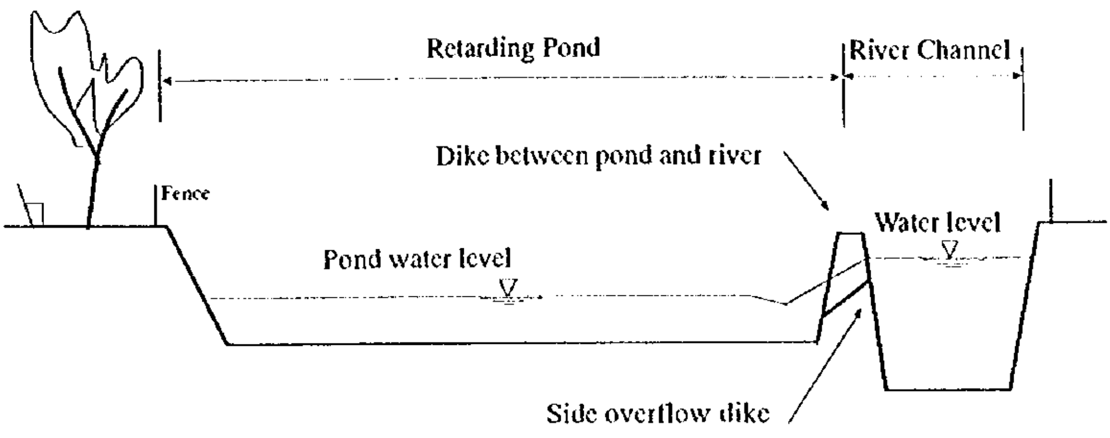
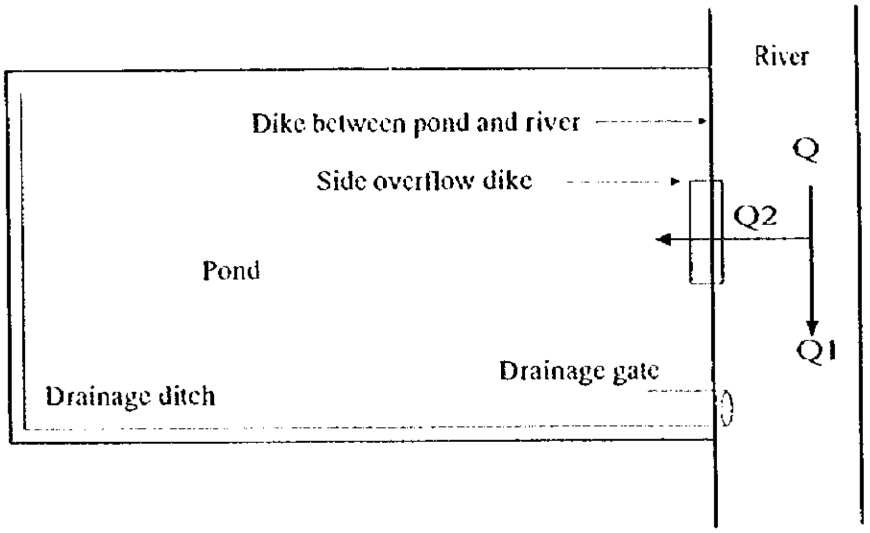


Figure 9.1.2 Concept of Flood Control Measures

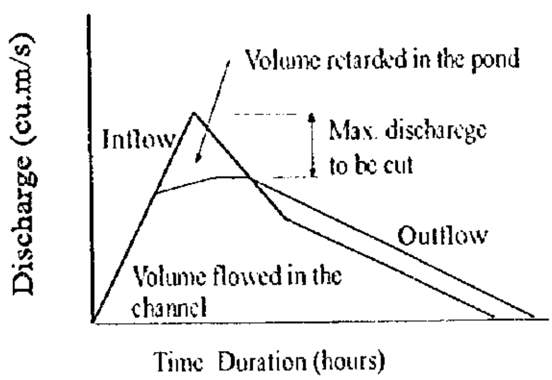
Cross Section of Regulating Pond and River



Plan of Regulating Pond and River



Discharge Hydrograph



$Q = Q_1$(into downstream)$+Q_2$(into pond)

Discharge into pond through overflow dike

$Q_2 = 0.667\ u\ (2g)^{(1/2)}\ L\ h^{(3/2)}$

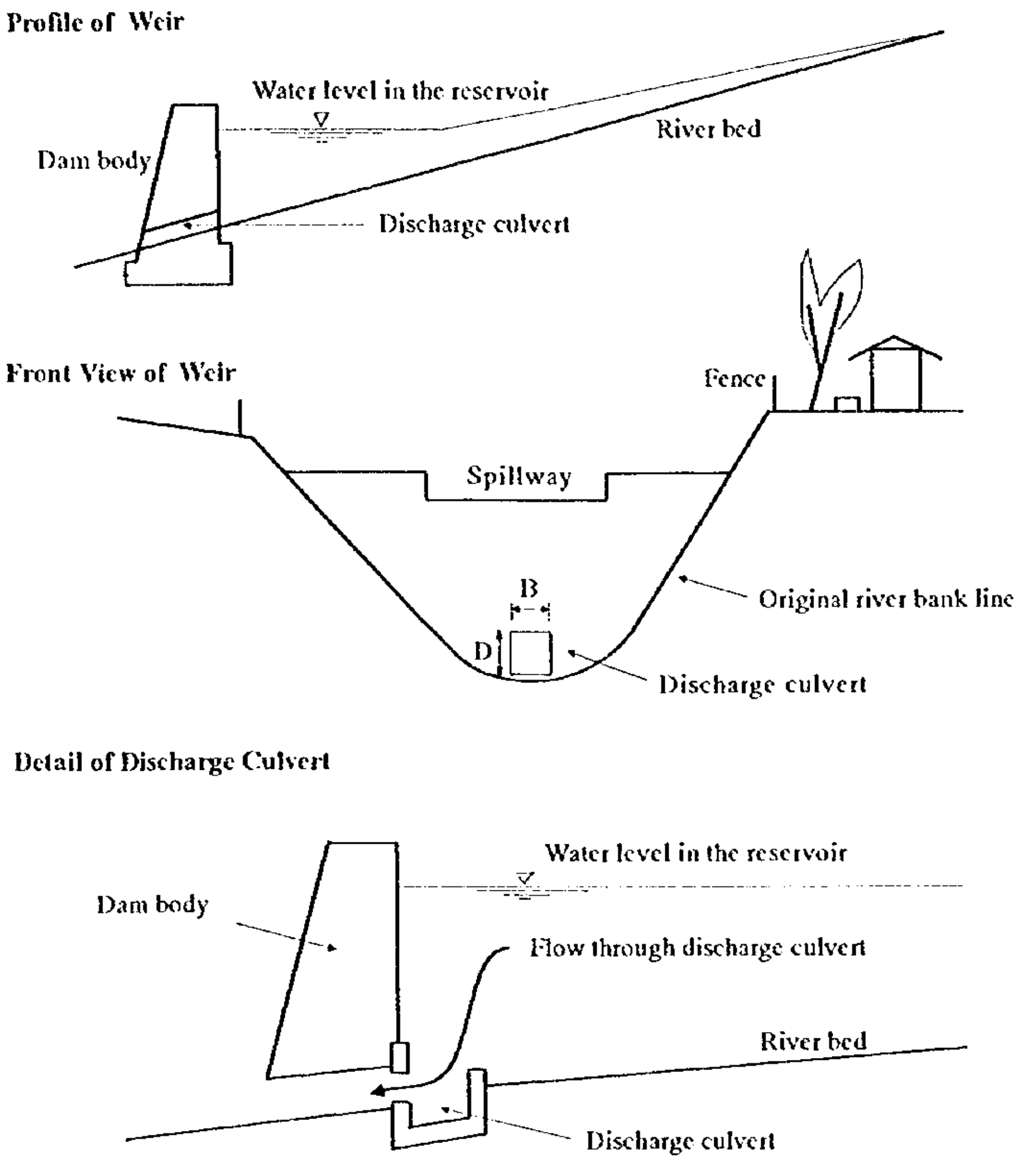
(in case perfect submergible flow)

Where, u: coefficient of over flow

g: acceleration of gravity

L: length of side overflow dike(m)

Figure 9.1.3 Outline of Proposed Regulating Pond



Discharge through dischage culvert

$Q = C*B*D*\{2g(H-D/2)\}^{1/2}$ (in case $H>1.8D$)

Where, Q: discharge(cu.m/s)

C: coefficient(0.6 without velmouth)

B: width(m) D: height(m) H: water depth(m)

Figure 9.1.4 Outline of Reservoir by Weir

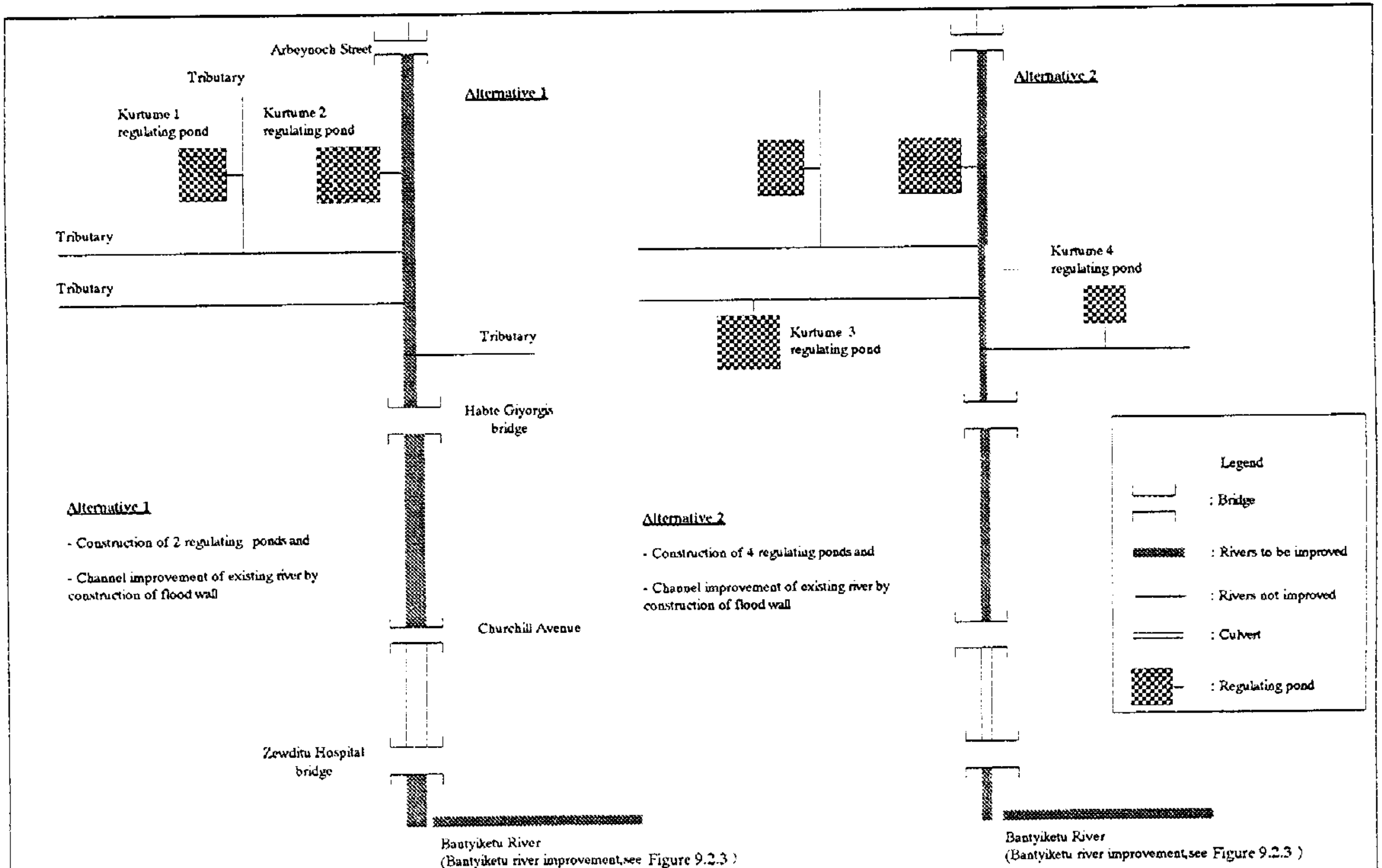


Figure 9.2.1 Alternative Plans of the Kurtume River

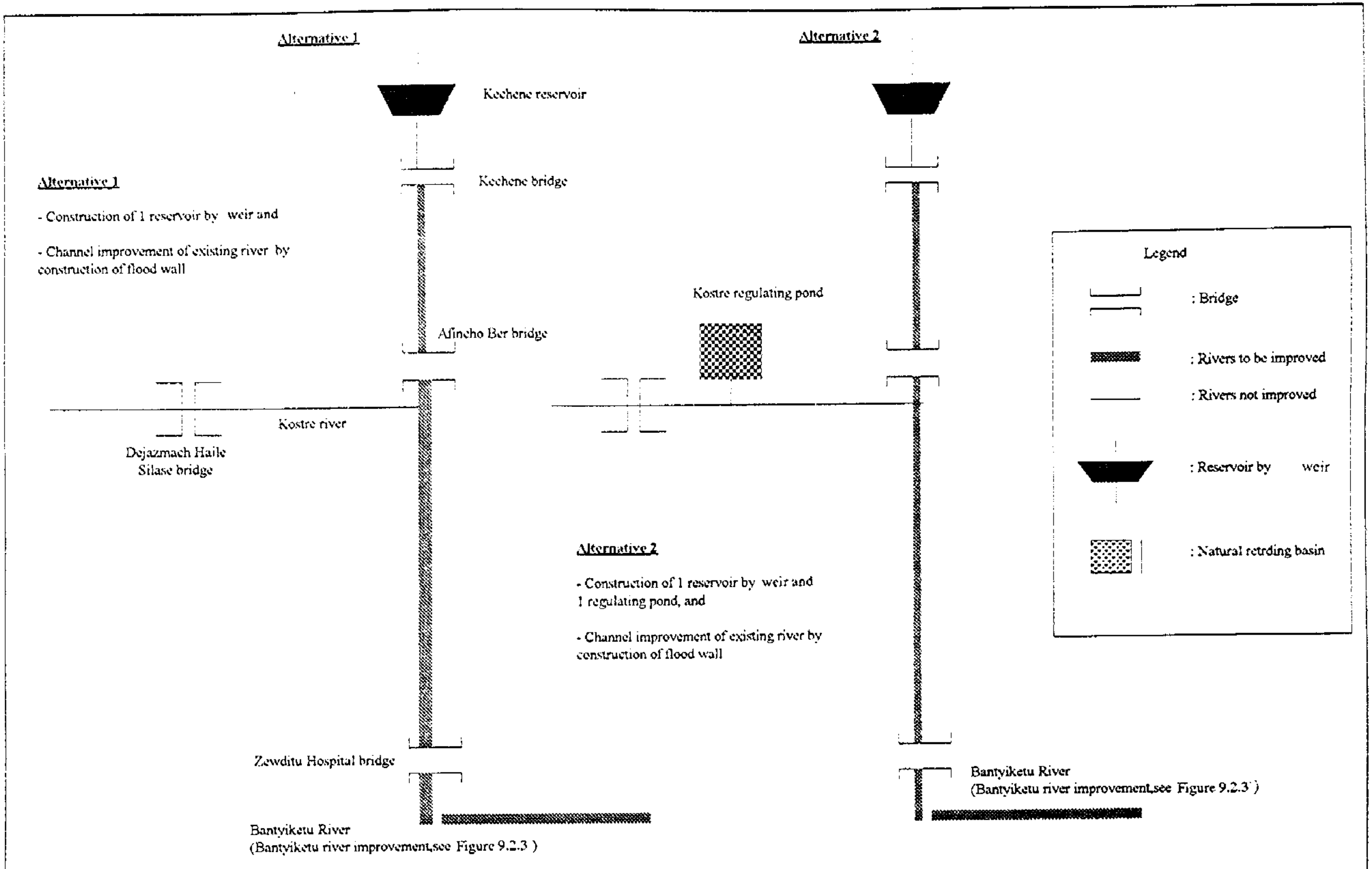


Figure 9.2.2 Alternative Plans of the Kechene River

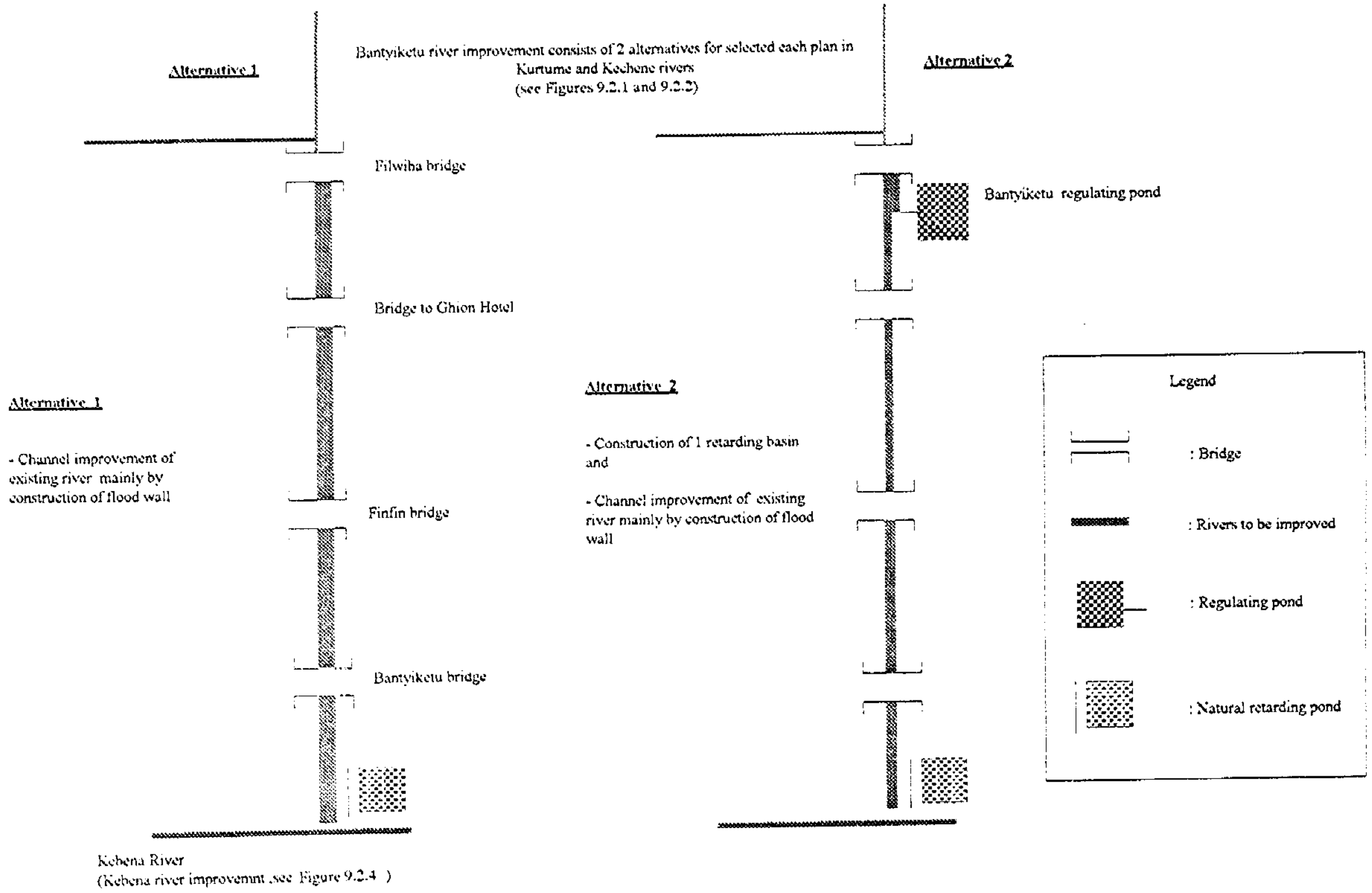


Figure 9.2.3 Alternative Plans of the Bantyiketu River

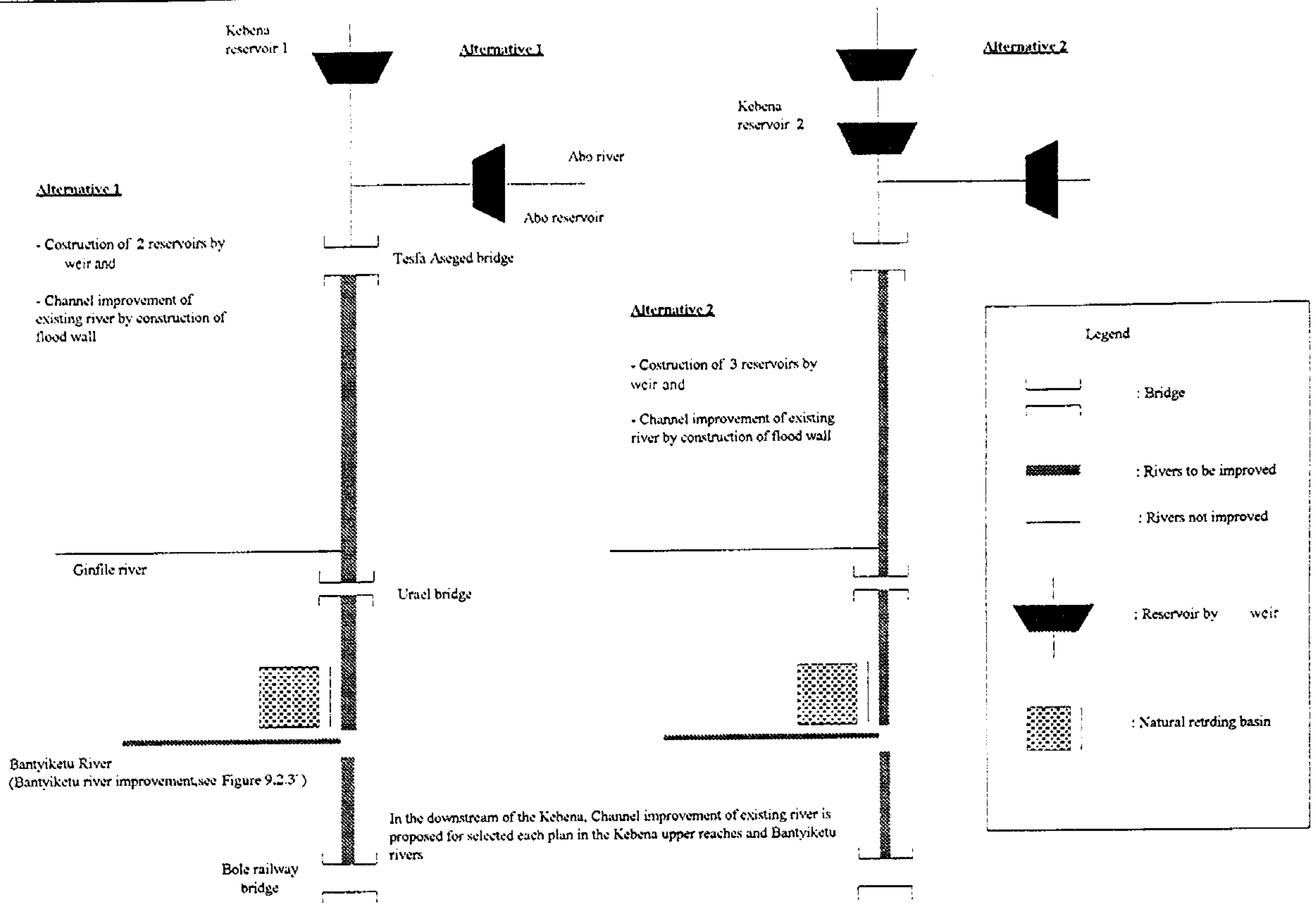


Figure 9.2.4 Alternative Plans of the Kebena River

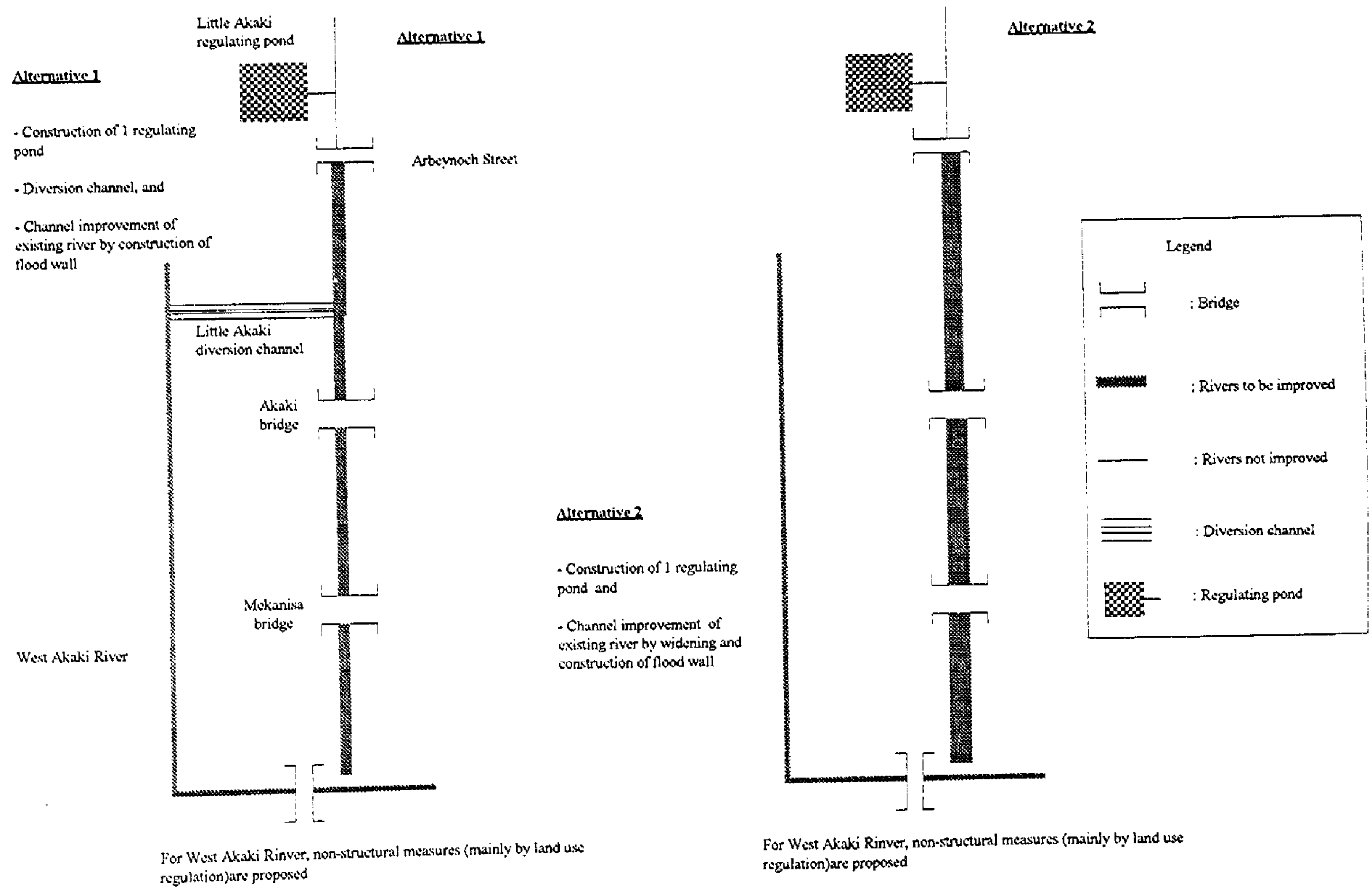


Figure 9.2.5 Alternative Plans of the Little Akaki River

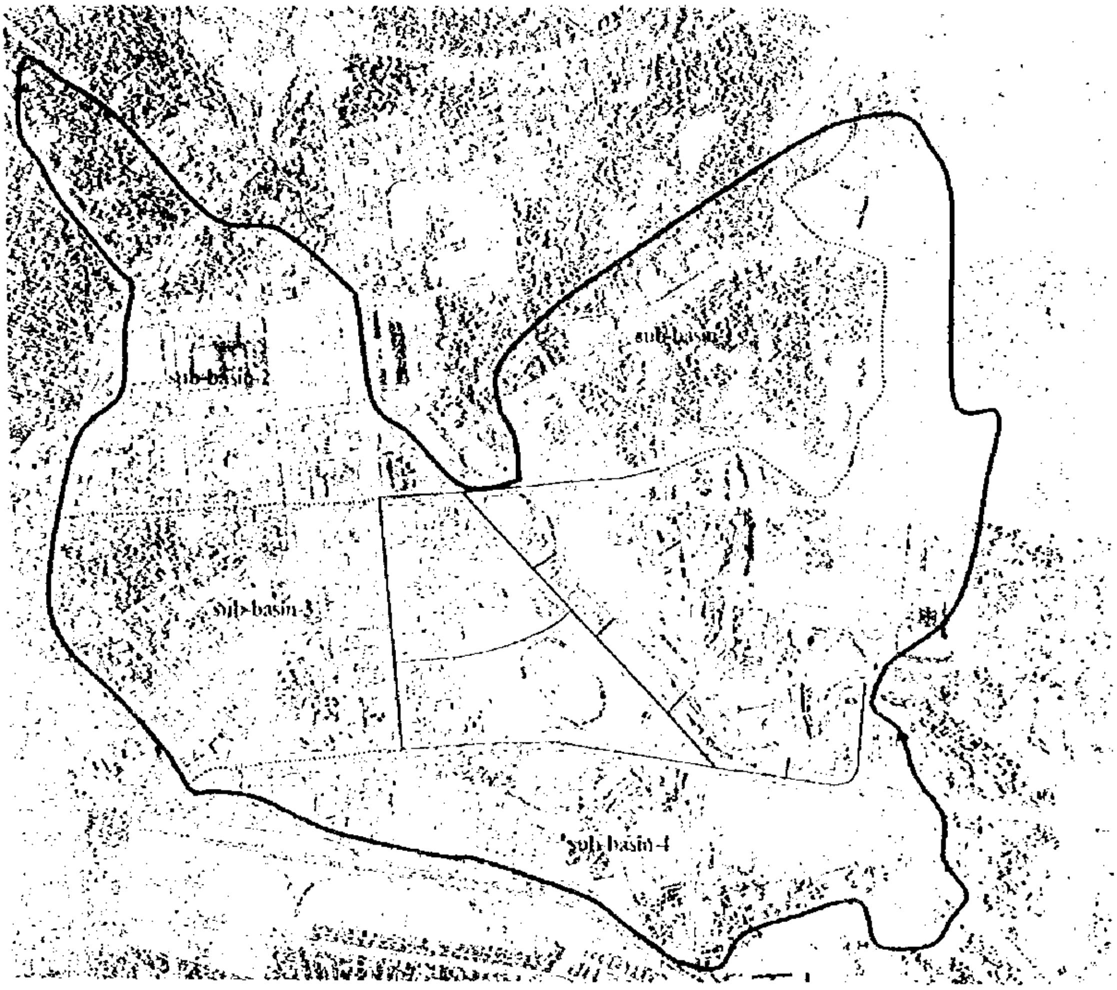


Figure 9.5.1 Drainage Basin for Drainage Improvement and Proposed Alignment of Drainage Ditch

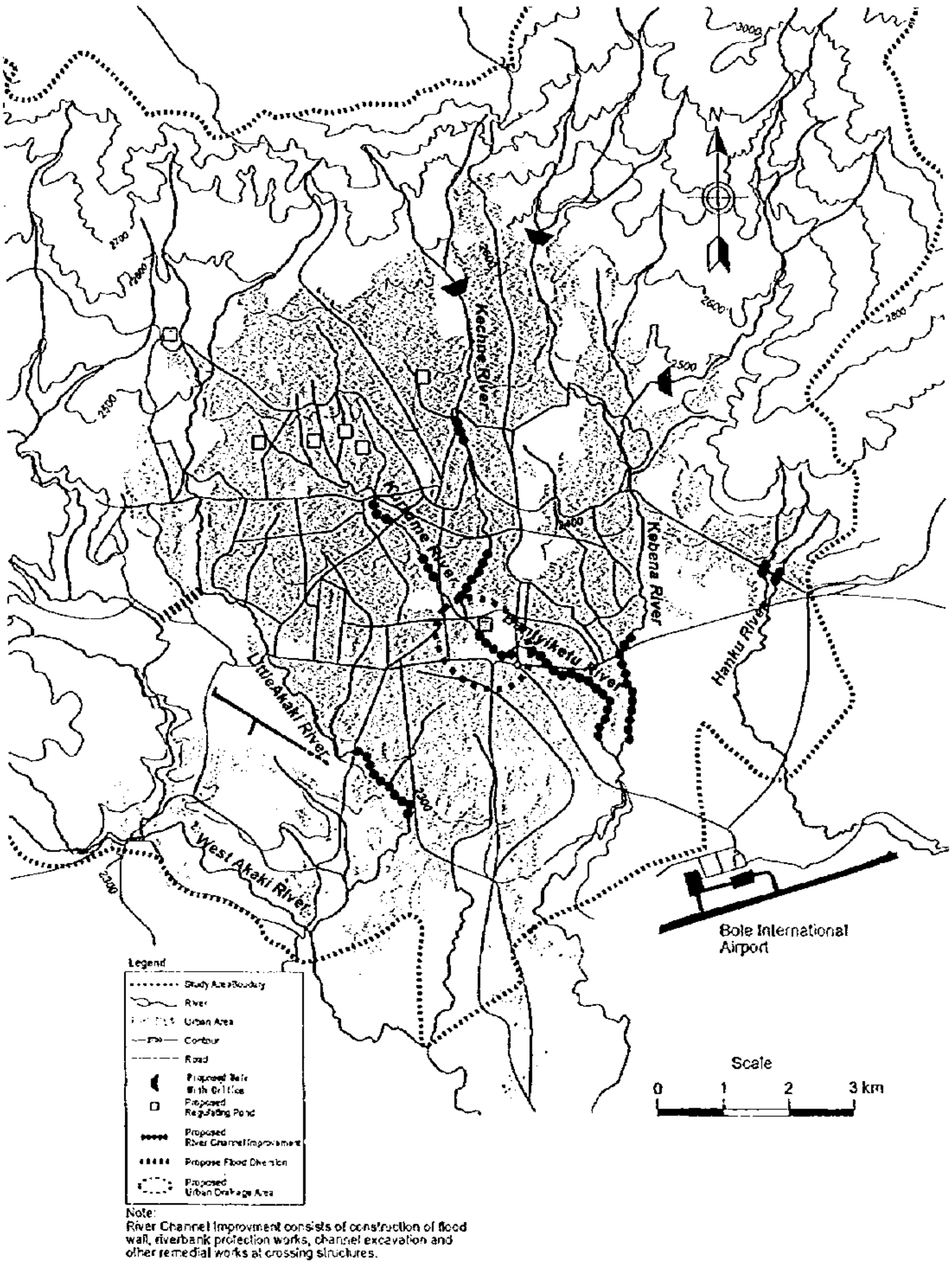


Figure 9.6.1 Location of Facilities Proposed by Master Plan

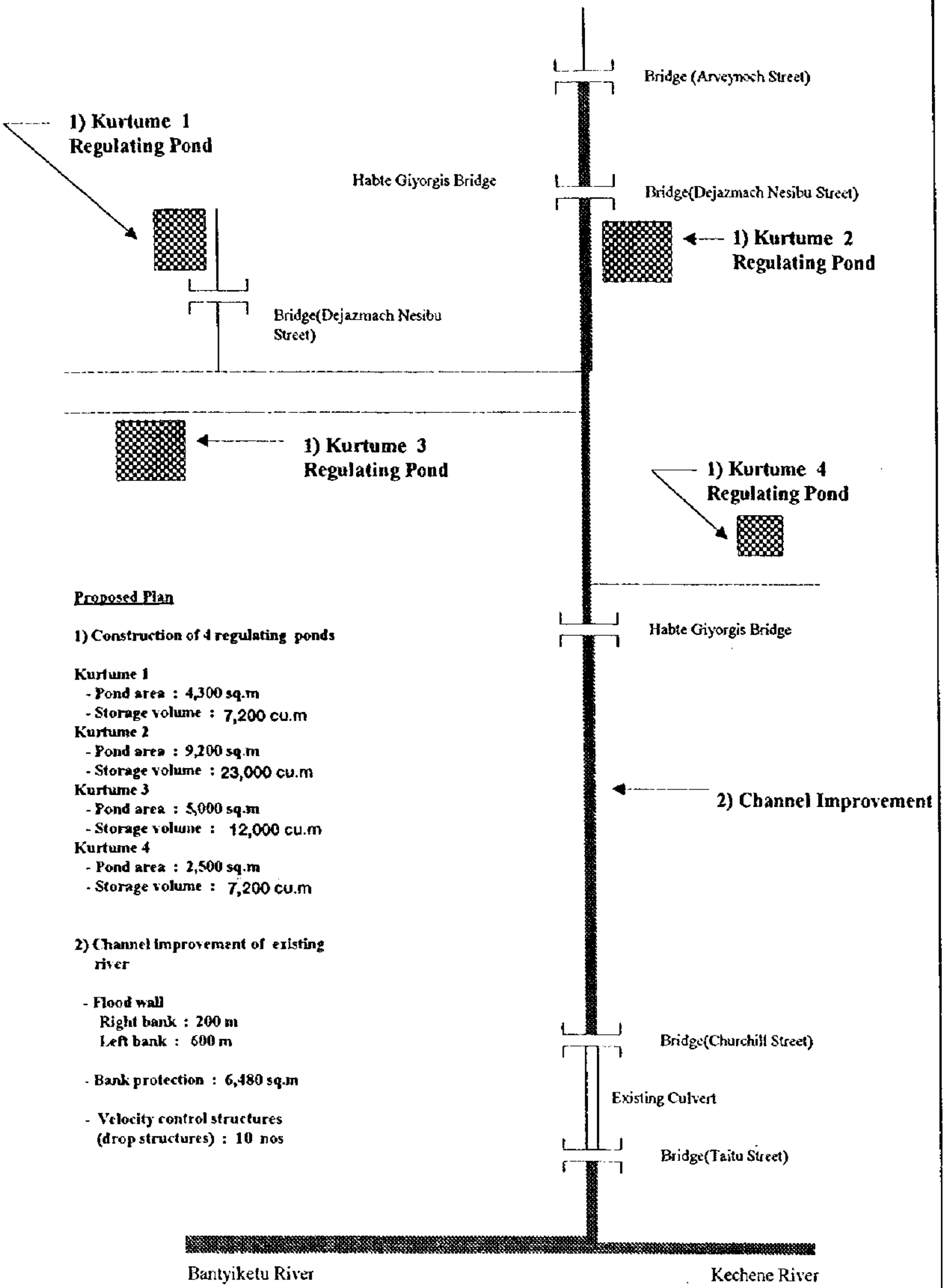


Figure 9.6.2 Proposed Plan of the Kurtume River(1/5)

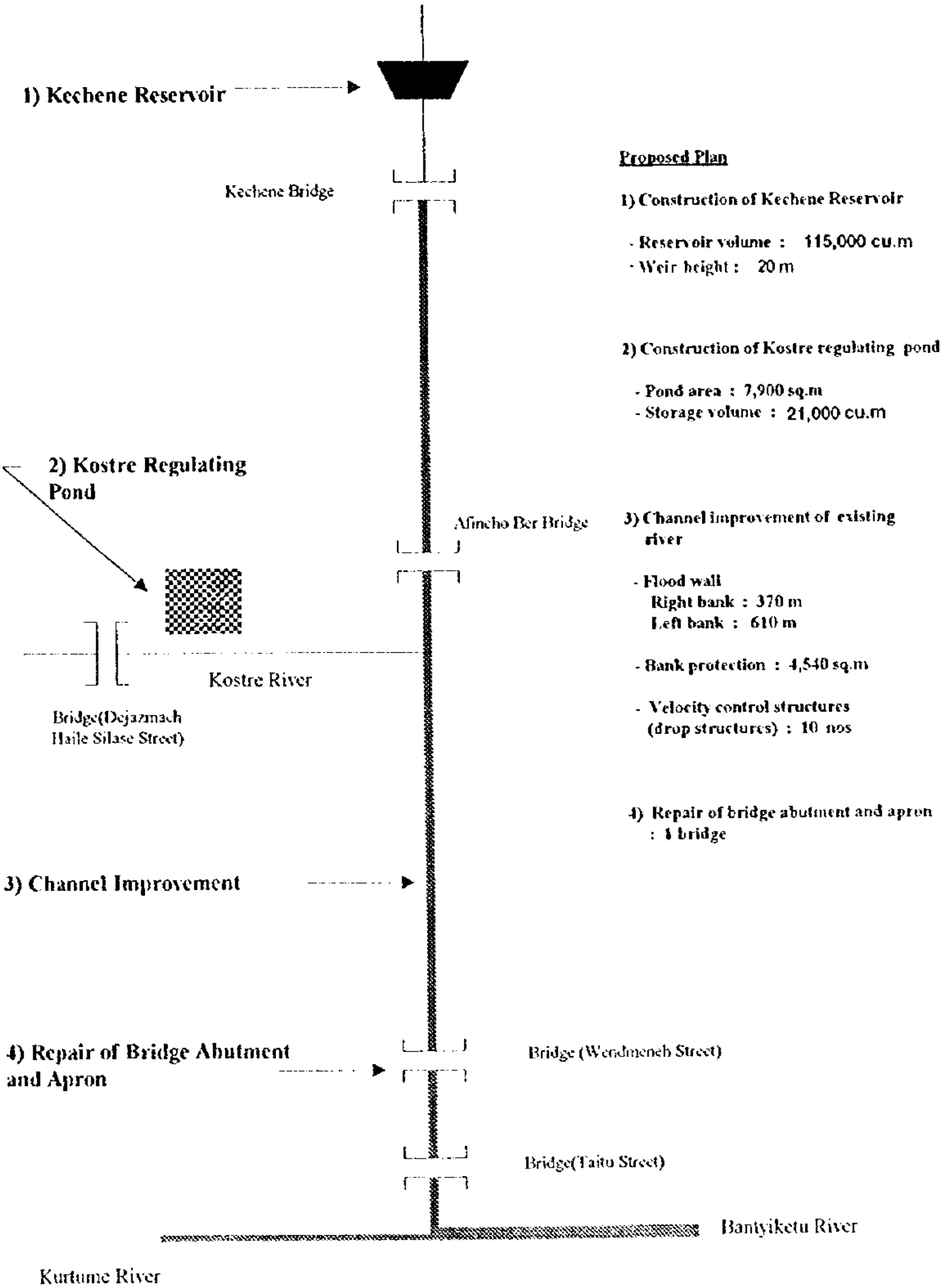


Figure 9.6.2 Proposed Plan of the Kechene River(2/5)

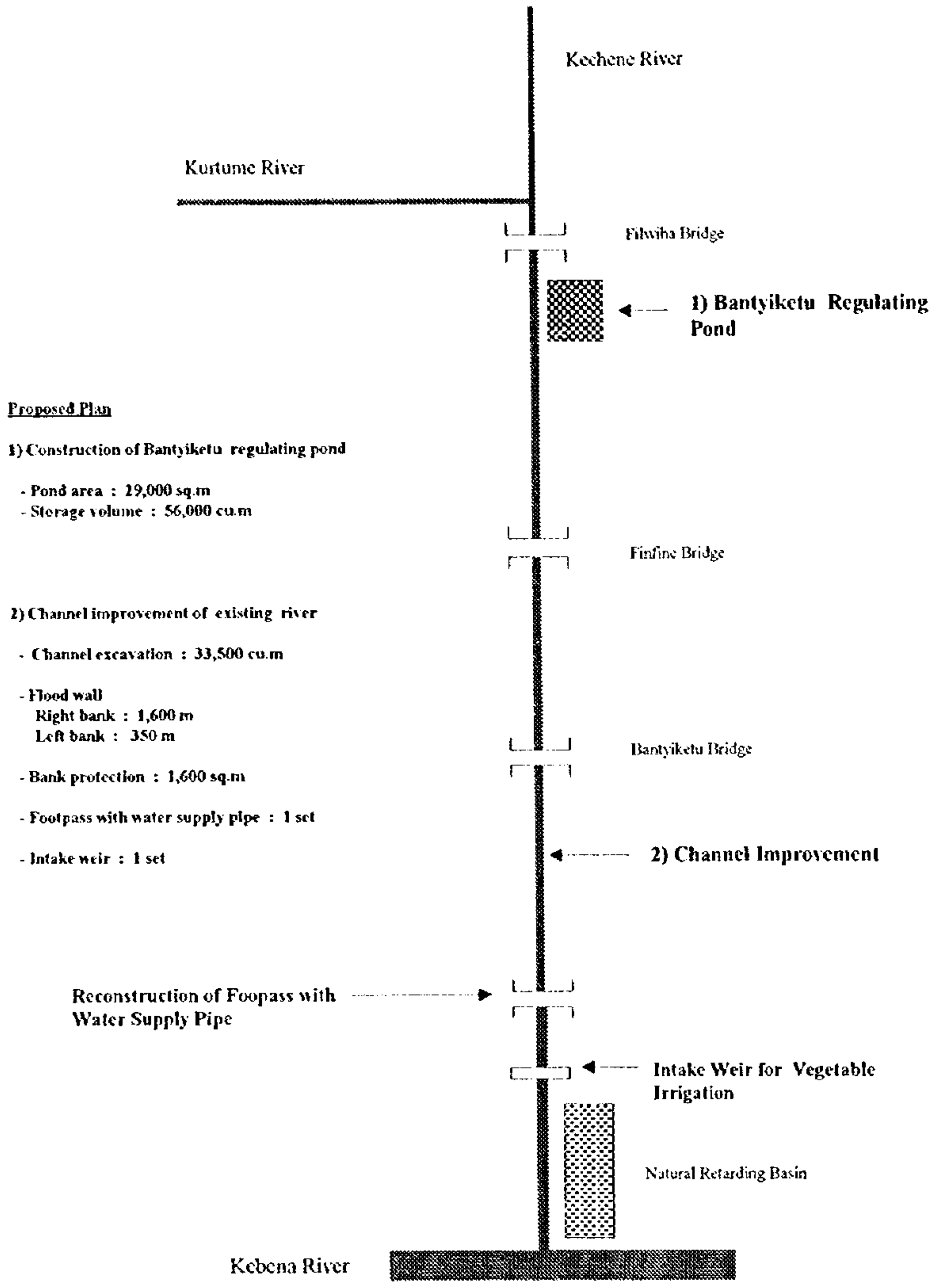


Figure 9.6.2 Proposed Plan of the Bantyiketu River(3/5)

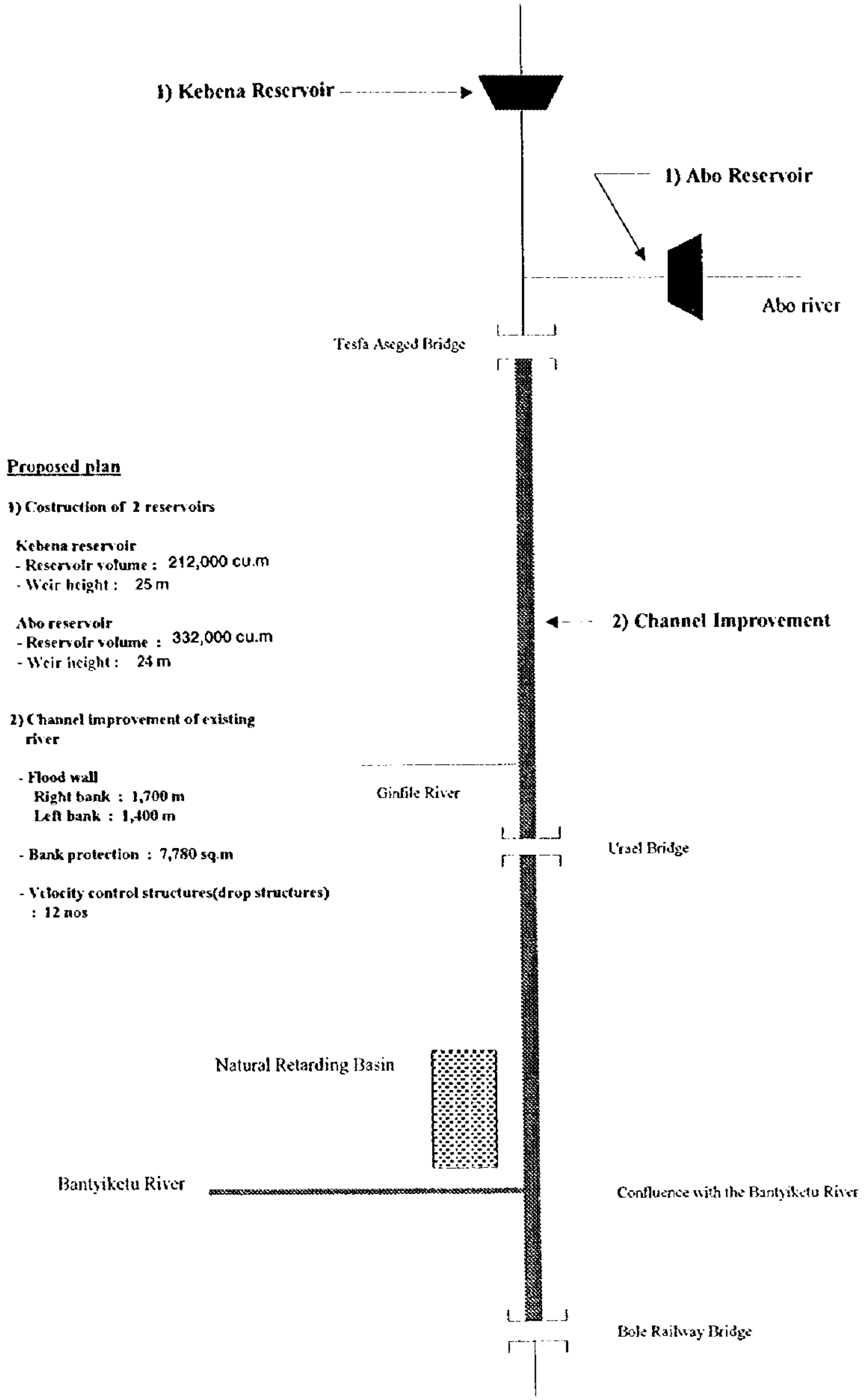
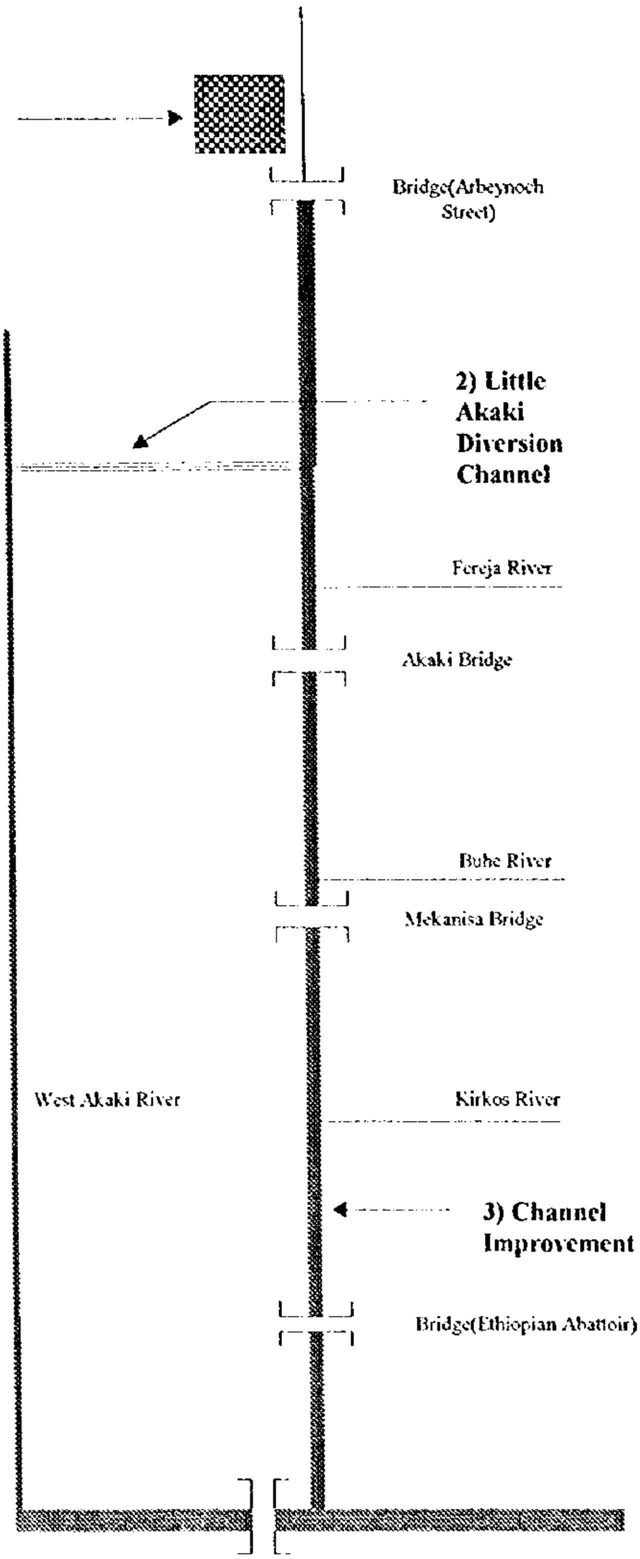


Figure 9.6.2 Proposed Plan of the Kebena River(4/5)



Proposed Plan

1) Construction of Little Akaki regulating pond

- Pond area : 13,500 sq.m
- Storage volume : 24,000 cu.m

2) Construction of Diversion Channel

- Design discharge : 160 cu.m/s
- Channel length : 1,000 m
- Tunnel(L=650 m) and open channel

3) Channel improvement of existing river

- Flood wall
  Right bank : 200 m
  Left bank : 850 m
- Bank protection : 5,840 sq.m
- Velocity control structures (drop structures) : 16 nos

For West Akaki Rinver, non-structural measures (by land use regulation)are proposed

Figure 9.6.2 Proposed Plan of the Little Akaki River(5/5)

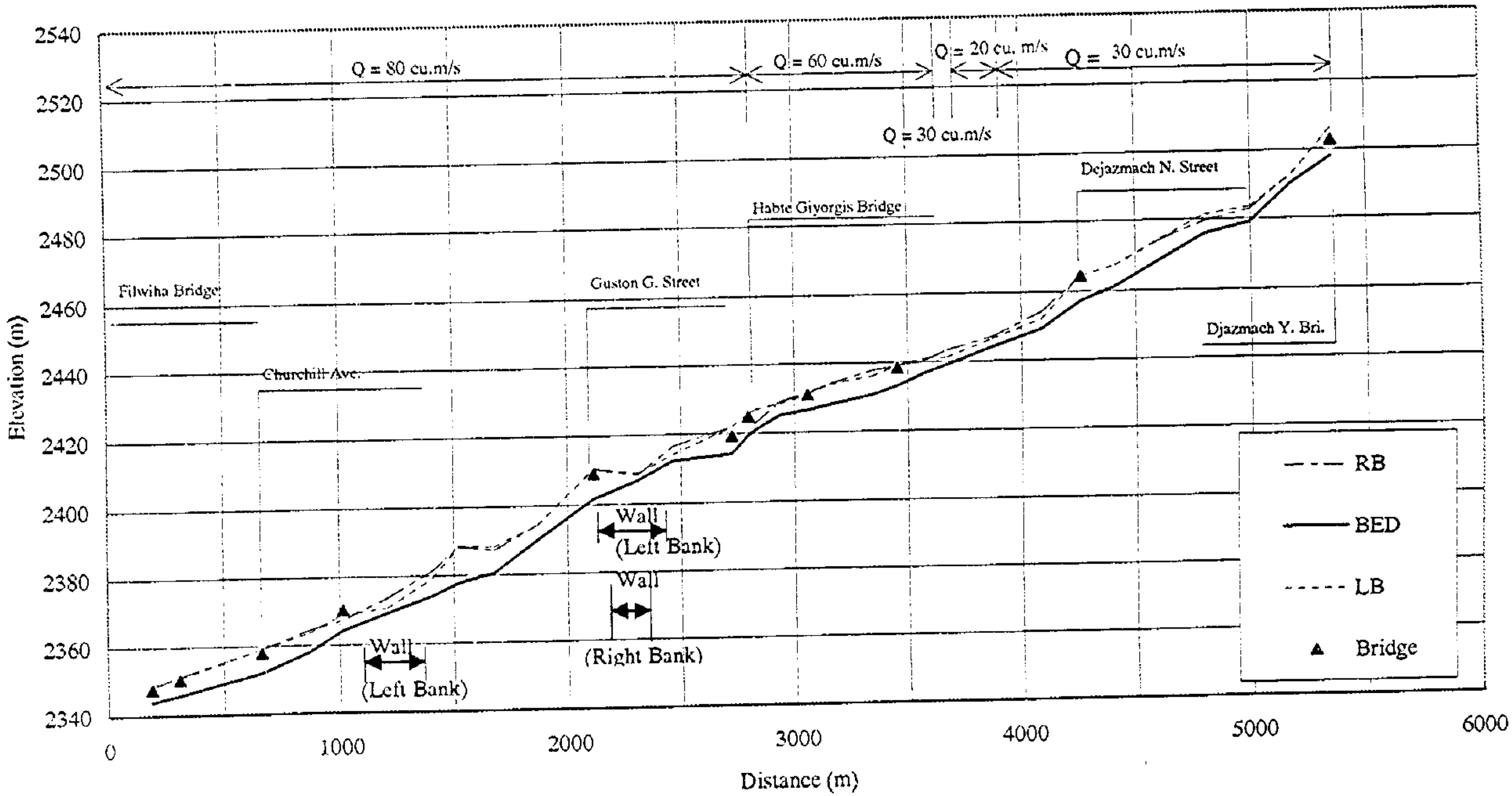


Figure 9.6.3 **Longitudinal Profile of the Kurtume River(1/5)**

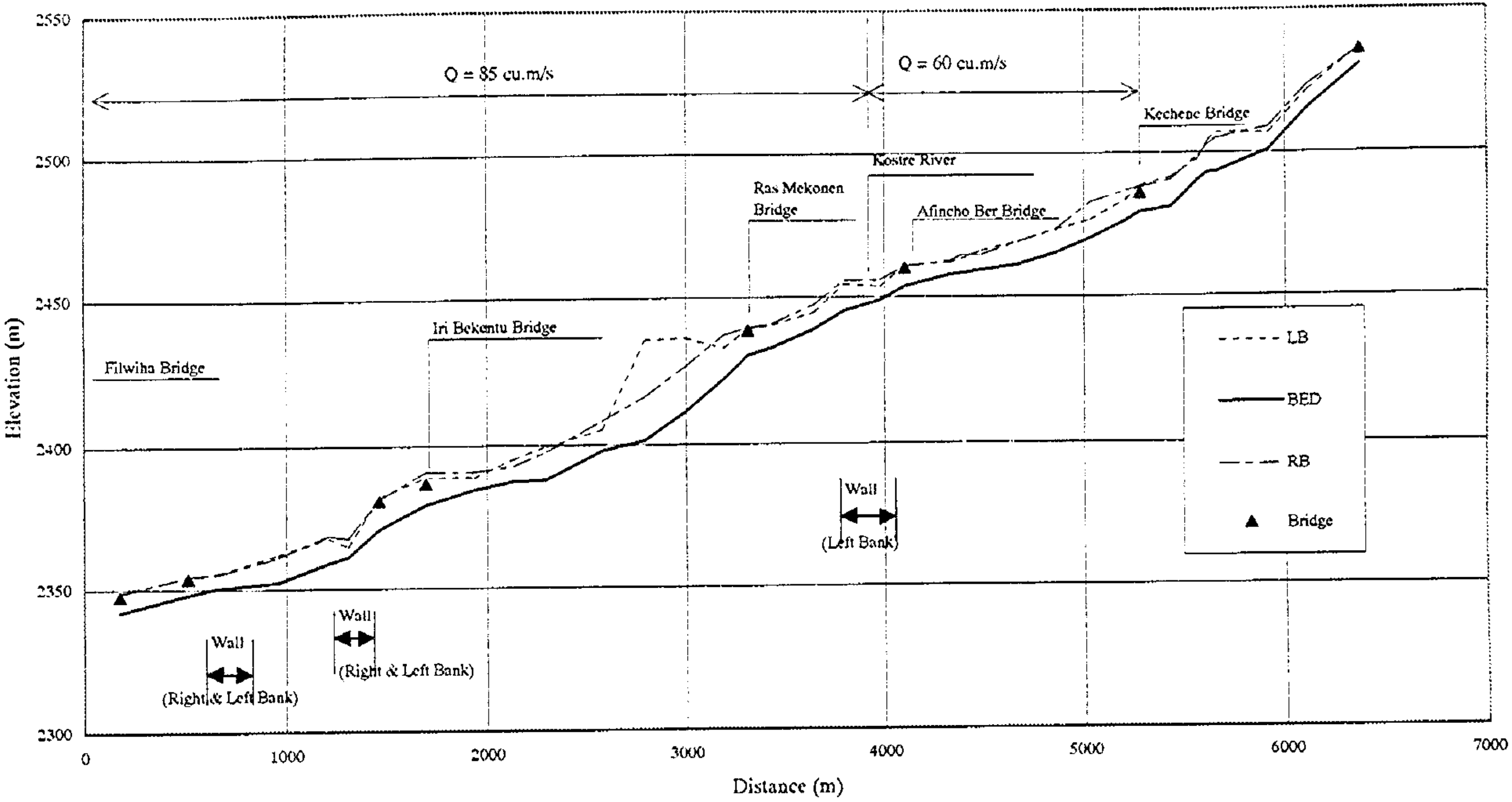


Figure 9.6.3 Londitudinal Profile of the Kechene River(2/5)

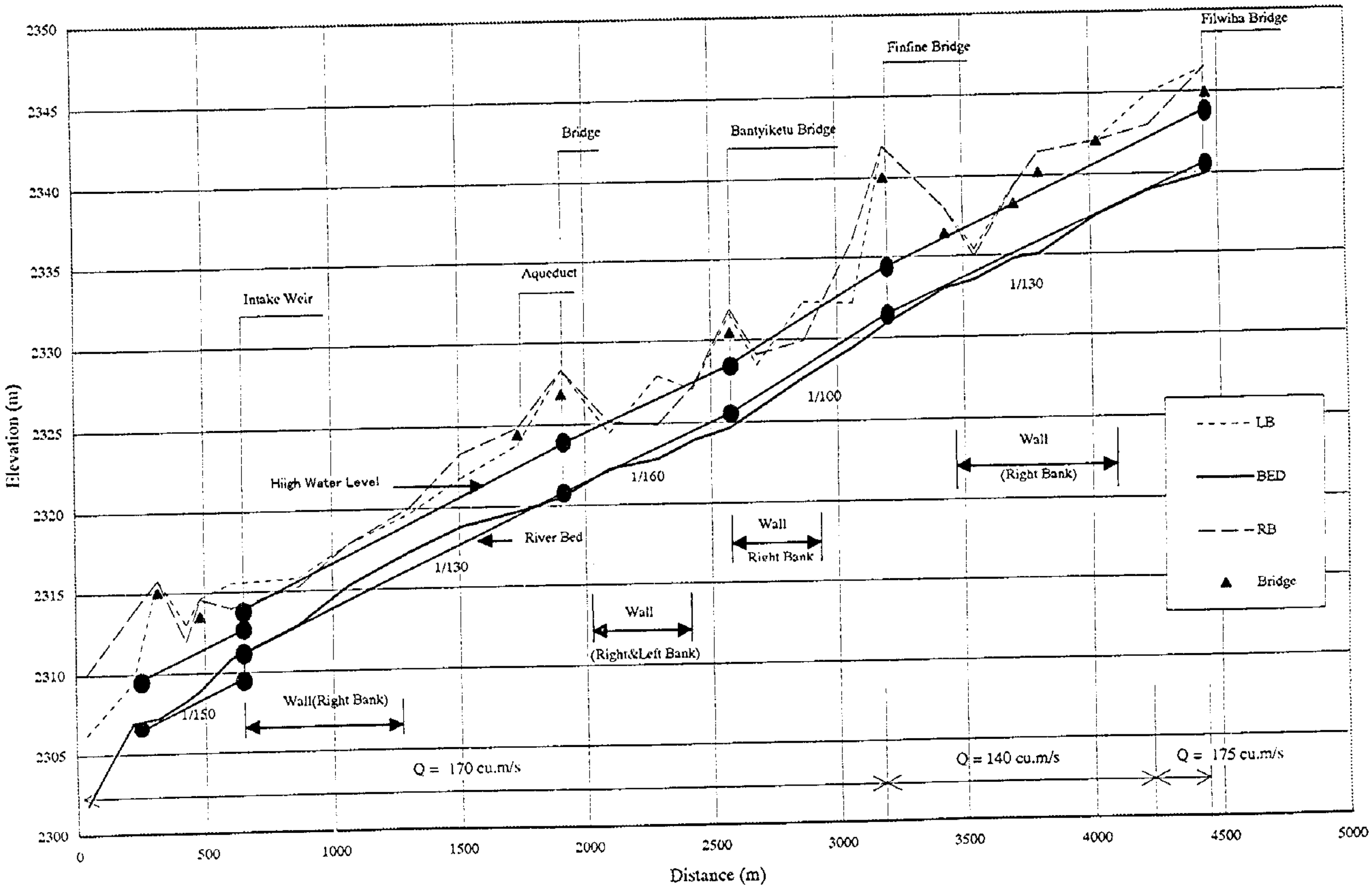


Figure 9.6.3 Longitudinal Profile of the Bantyiketu River(3/5)

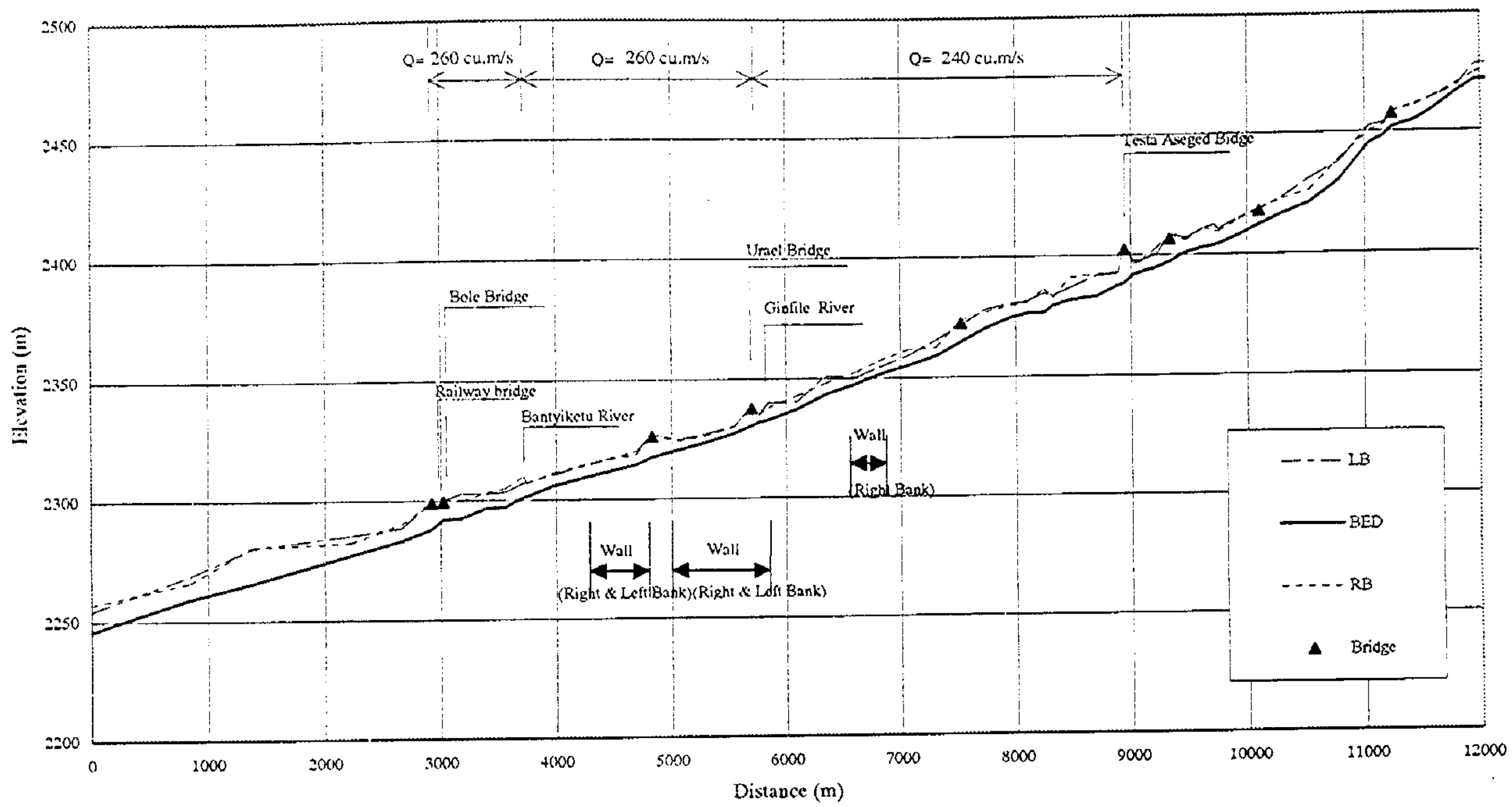


Figure 9.6.3 Longitudinal Profile of the Kebena River(4/5)

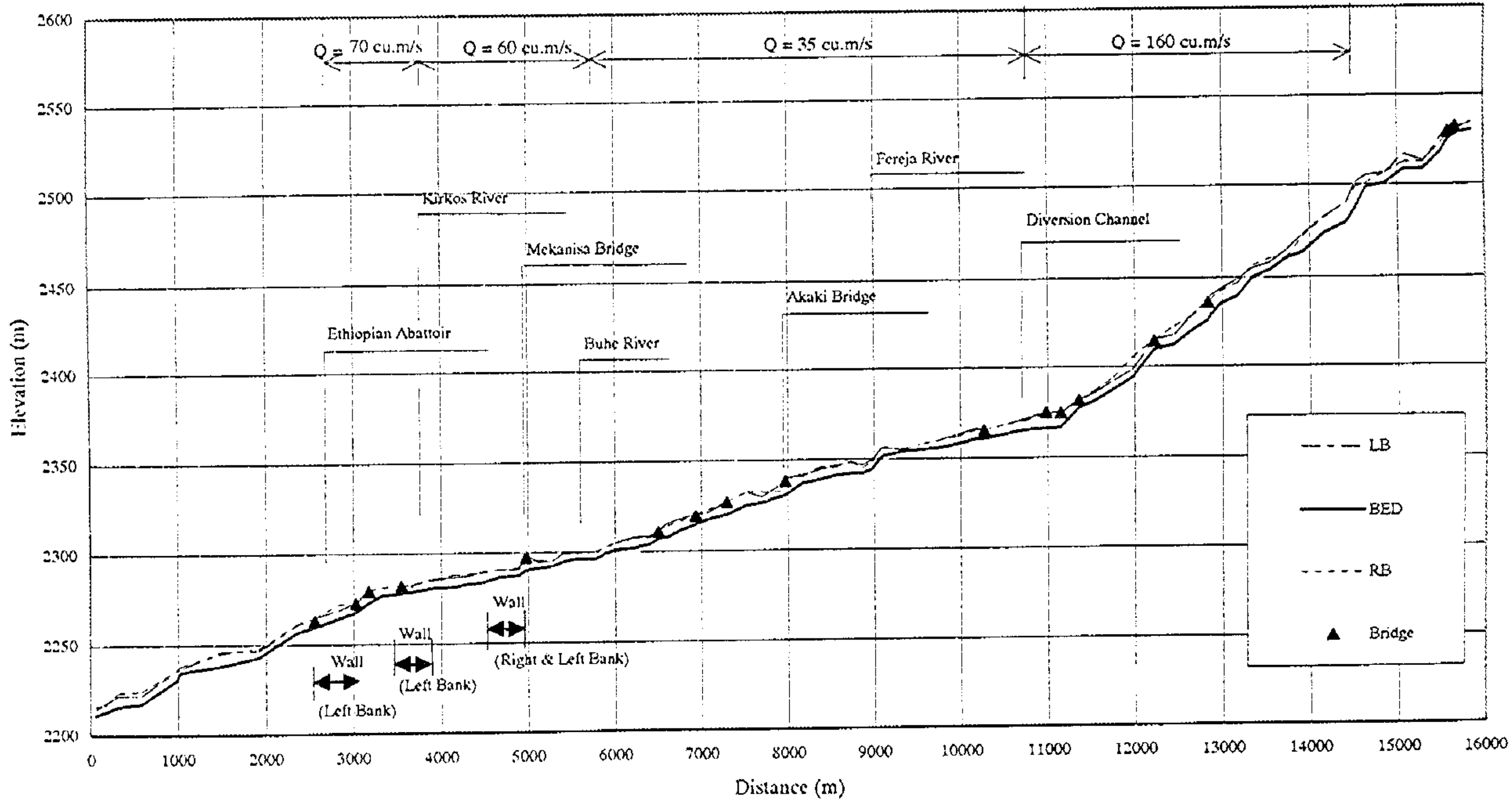


Figure 9.6.3 **Londitudinal Profile of the Little Akaki River(5/5)**

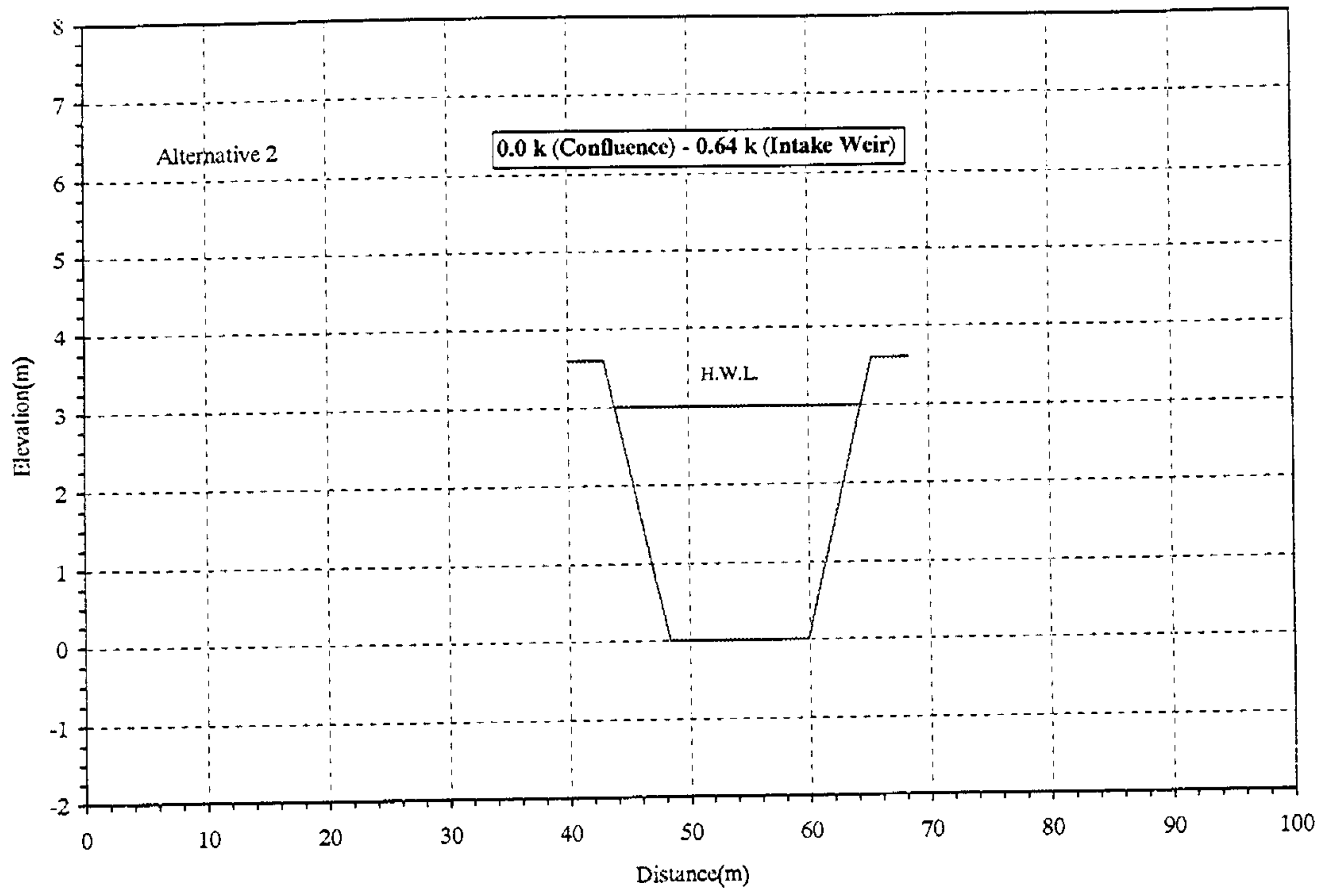


Figure 9.6.4 **Standard Cross Section of the Bantyiketu River (1/6)**

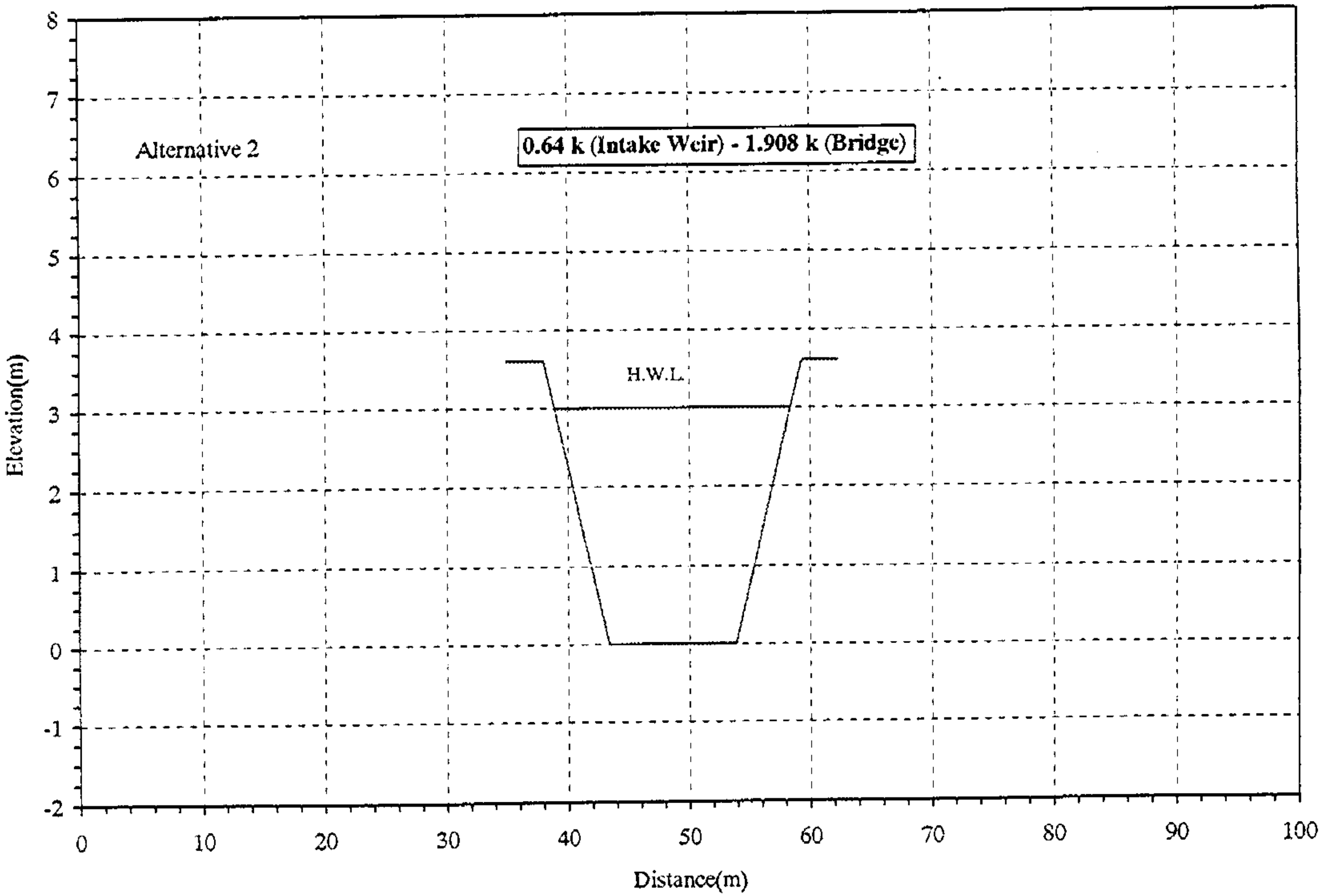


Figure 9.6.4 Standard Cross Section of the Bantyiketu River (2/6)

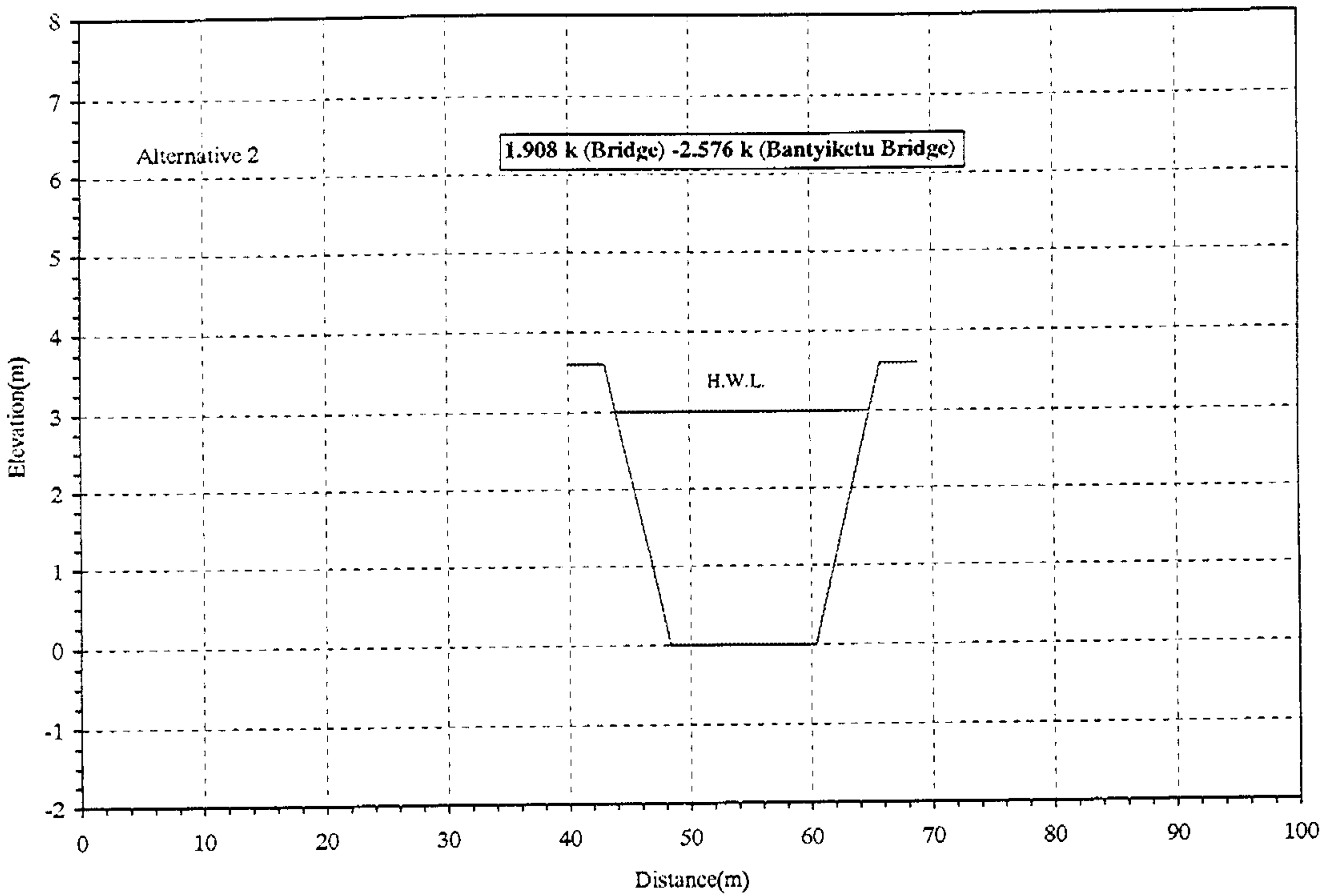


Figure 9.6.4 **Standard Cross Section of the Bantyiketu River(3/6)**

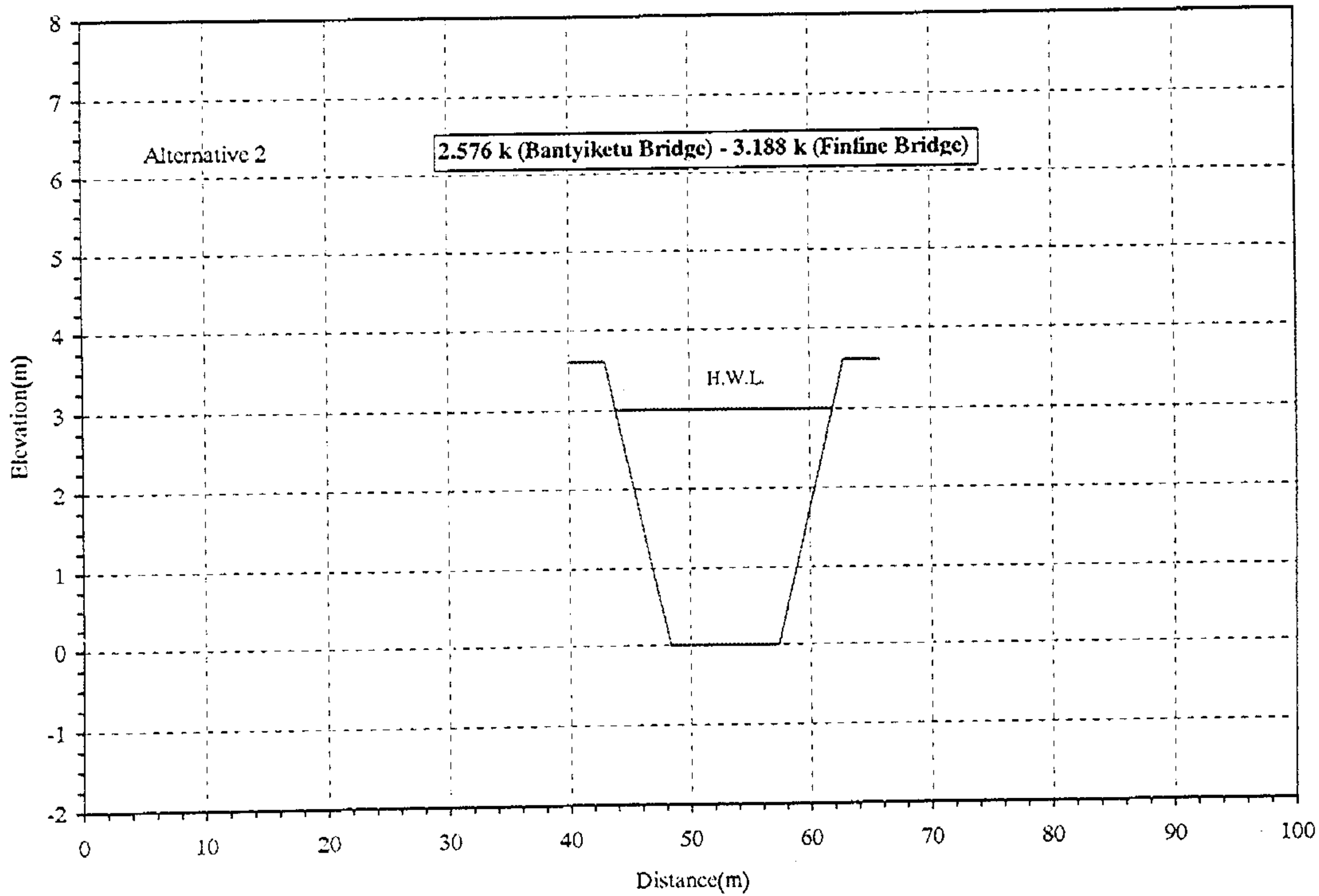


Figure 9.6.4 Standard Cross Section of the Bantyiketu River(4/6)

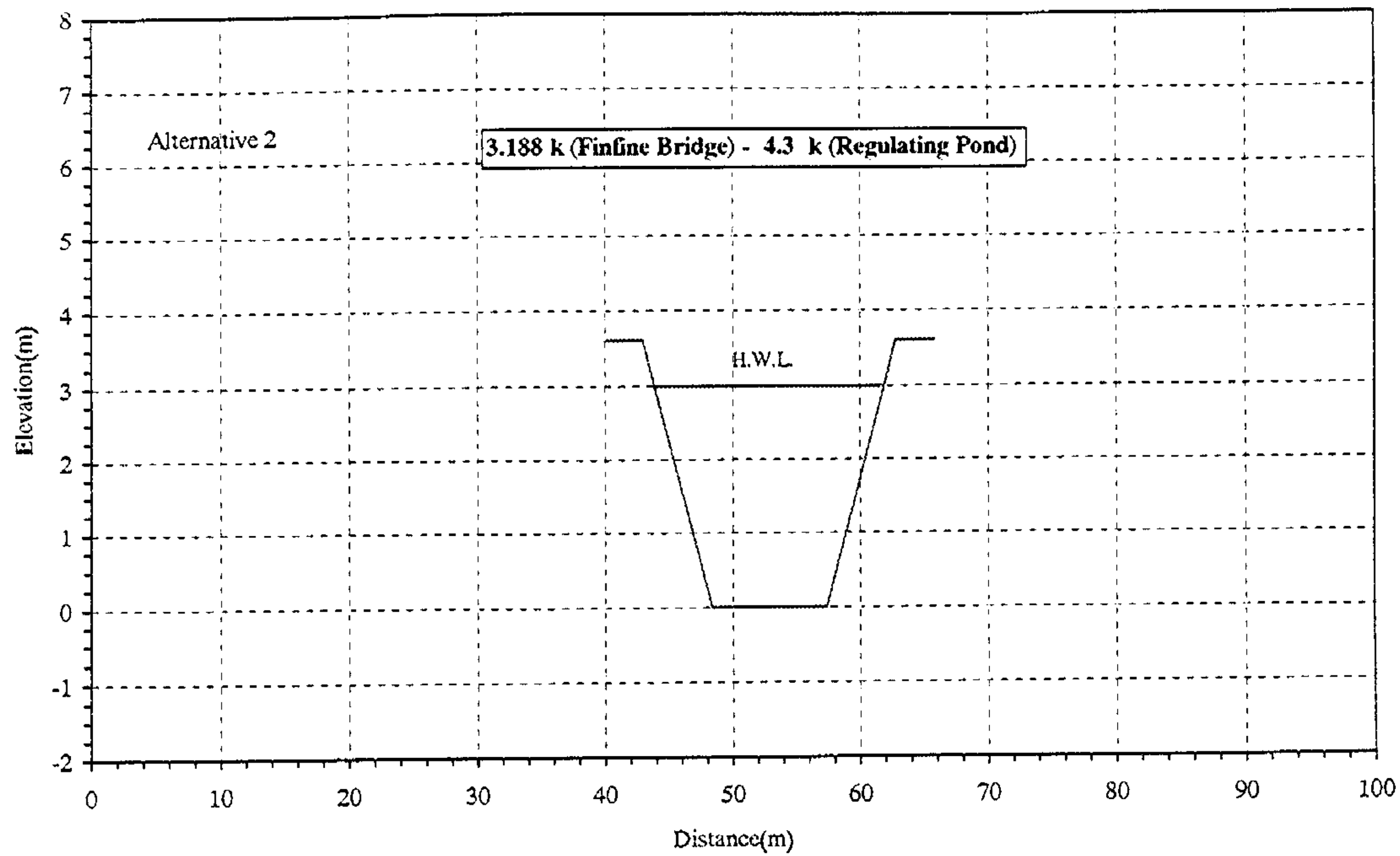


Figure 9.6.4 Standard Cross Section of the Bantyiketu River(5/6)

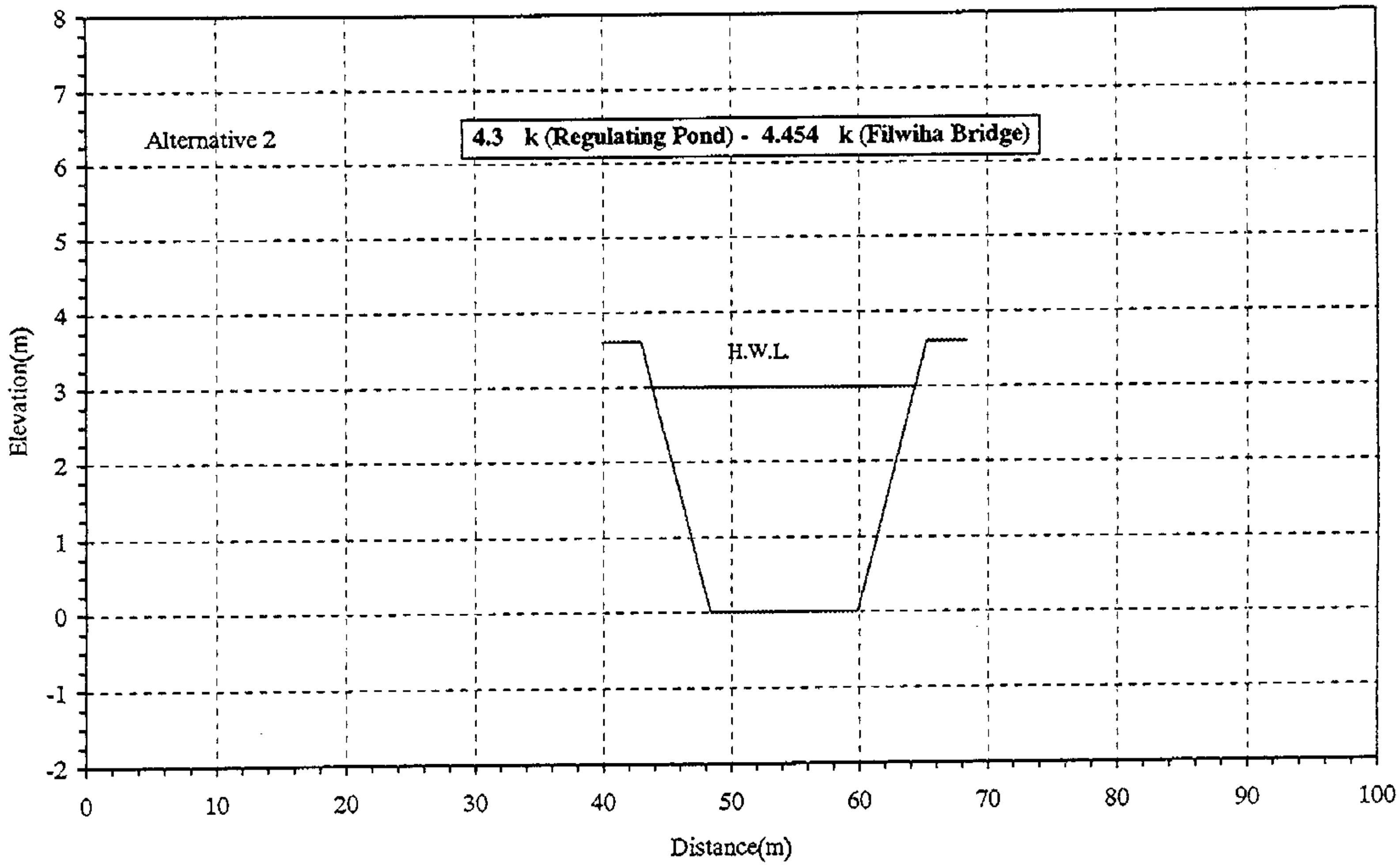


Figure 9.6.4 Standard Cross Section of the Bantyiketu River(6/6)

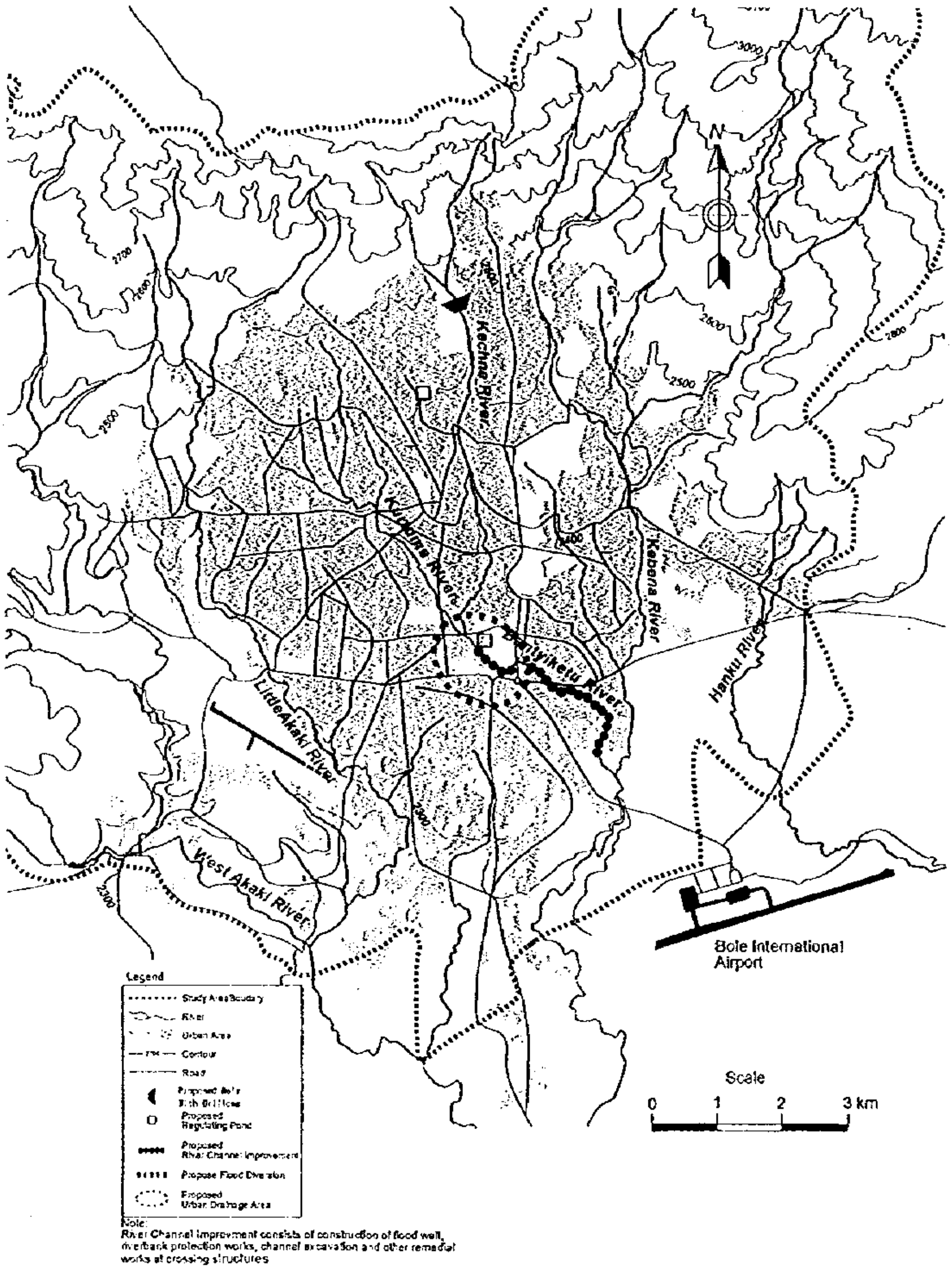


Figure 9.7.1 Priority Project

CHAPTER 10

DESIGN AND COST ESTIMATE

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

CHAPTER 10 DESIGN AND COST ESTIMATE

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10. DESIGN AND COST ESTIMATE

10.1 Design

10.1.1 Technical Guidelines

Hereafter, technical guidelines on design of flood regulating weirs and flood diversion tunnels are described, of which there are no design guidelines made or generally used by Ethiopian authorities. The guidelines for the two kinds of river structure are quoted from Design Standard of River and Sabo Structures edited by Ministry of Construction, Government of Japan. For other river structures like retaining wall and dyke, there is a design guideline in EBCS-7, Ethiopian Building Code Standard, Foundations, published by Ministry of Works and Urban Development in 1995.

(1) Flood Regulating Reservoir by Weir

1) Weir Type

The type of weir shall be determined from topography, geology, size of spillway, availability of construction materials. When the height of weir exceeds 30 m, earth fill weirs shall not be applied.

Major types of weir are as follows.

- Concrete Weir
  - Concrete Gravity Weir
  - Concrete Arch Weir
  - Concrete Buttress Weir
- Fill Weir
  - Earth Fill Weir
  - Rock Fill Weir

a) Viewpoints of Topography

Among concrete weirs, concrete gravity weirs are least influenced by topography. Where proposed sites form a U-shaped valley with a large width, the higher the weir height, the higher the feasibility of concrete buttress weirs. When the height of weir is 80 to 100 m, the weir volume of concrete buttress weirs is generally as much as 70 to 80 % of weir volume of concrete gravity weirs. The smaller the width between abutments at proposed sites, the more feasible the concrete arch weirs. Where the width between abutments the at weir crest are 3/2 times as large as the height of weir, the weir volume of concrete arch weirs is about 30 % of that of concrete gravity weirs. Where not only foundations but also abutments are geologically of hard rock and the width between abutments at the weir crest are within three times as large as the height of weir, concrete arch weirs are generally less costly than concrete gravity weirs.

As fill weirs are not allowed to have a spillway in their embankment and, instead, have to have it directly built on sound rock at abutments, their weir volume is much more than the weir volume of concrete weirs.

In addition, the narrower the mountain ridges where weir abutments are thrusted, the higher the possibility of the permeability and weathering at ridges.

b) Viewpoints of Geology

(A) Concrete gravity weir
For concrete gravity weirs, foundation rock is required to have sufficient shear strength and faults often become a critical factor.

(B) Concrete buttress weir
As concrete buttress weirs have a larger area at the bottom of weir, foundation rock is not expected to have as high shear strength as for concrete gravity weirs. However, where thick river deposits exist, concrete buttress weirs become more costly due to a large area at their bottom.

(C) Concrete arch weir
Concrete arch weirs require less shear strength of foundation rock than concrete gravity weirs. But both abutments have to be hard and sound rock to withstand arch thrusting force.

(D) Fill weir
Foundations at an impervious zone of fill weirs require a higher shear strength and imperviousness and foundations at a pervious zone require a higher shear strength and invulnerability against piping. However, because of a larger bottom area of fill weirs, they require less shear strength of foundations than concrete weirs. Soils foundations are not

suitable for high fill weirs due to their small shear strength and high susceptibility for sliding and settlement.

In this master plan study, four weirs are planned and the type of all weirs is concrete gravity. The reasons are:

- Topographically, the proposed sites do not form narrow gorges. This means that concrete arch weirs are inapplicable.
- Geologically, foundations are of hard and sound rock ,but both abutments are of weathered rock. This means that concrete arch weirs are inapplicable and that both fill weirs and concrete gravity weirs applicable. Further, the volume of concrete gravity weirs are much less than that of fill weirs, the former being less costly than the latter.
- Construction materials for fill weirs are not abundantly available in the vicinity of the proposed sites.

c) Size of Spillway

When the magnitude of a flood related to the design of a weir is large, it has a great influence on determination of the size of a spillway and hence the type of weir. A spillway shall be made of concrete because it has to pass a rapid flood flow safely. As a spillway of fill weirs shall be built separate from a weir body on hard rock at abutments, construction cost of a spillway at fill weirs tends to occupy a larger portion of total construction cost of a weir than concrete weirs.

2) Crest Elevation of Non-overflow Section of Weir

In case that the spillway is not equipped with gates, the crest elevation of non-overflow section shall be the highest elevation of the following three.

Hn + hw + he (If hw + he< 2, then Hn + 2)
Hs + hw + he/2 (If hw + he/2< 2, then Hs + 2)
Hd + hw (hw<1, then Hd + 1)

where,

Hn : Normal High Water Stage. This is defined as the highest water stage in non-flood seasons.

Hs : Surcharge Water Stage. This is defined as the highest water stage in flood seasons.

Hd : Weir Design Water Stage. This is defined as the highest water stage when the weir design flood flows down the spillway. Here, the weir design flood of concrete weirs is defined as a maximum flood among the following three.

① Probable 200-year flood at proposed weir sites

② Maximum previous flood at proposed weir sites

③ Maximum previous flood at sites similar to proposed weir sites with respect to hydrology and climate

hw : The height of wave caused by wind at Hd (Weir Design Water Stage)

he : The height of wave caused by an earthquake at Hn (Normal High Water Stage)

Beside the above-mentioned stipulation about concrete weir, there is another stipulation about the crest elevation of non-overflow section of sabo dams in Design Standard of River and Sabo Structures edited by Ministry of Construction, Government of Japan. According to Article 2.4.2 of the sabo dam's standard, the crest elevation of non-overflow section of sabo dams shall be a sum of the flow depth at the crest of spillway when a spillway design flood passes and a freeboard which magnitude is defined as follows.

Table 10.1.1 Freeboard of Non-overflow Section of Weir

Spillway Design Flood (m^3/s)	Freeboard (m)
$Q < 200$	0.6
$200 \leq Q < 500$	0.8
$500 \leq Q$	1.0

The spillway design flood shall be the largest among a discharge at a surcharge water stage, probable 100-year flood and a basic flood at a proposed weir site.

In this master plan study, the crest elevation of non-overflow section of a weir is derived, according to the sabo dam's standard, as a sum of the flow depth at the crest of spillway when a spillway design flood passes and a freeboard, using probable 100-year flood as a spillway design flood. This is simply for the sake of simplicity of design commanded by the master plan study, without estimation of the weir design water stage (Hd) and the parameters related to wave height (hw and he).

3) Design Requirement

Design requirements of weirs are tabulated as follows.

Table 10.1.2 Design Requirement of Weir

Type of Weir	Assumption of Weir Body as a Solid Model	Design Requirement
Concrete Gravity Weir Concrete Buttress Weir	Two dimensional elastic object	1) Middle Third Condition A composite force shall act within the middle third of the bottom of a weir in a direction perpendicular to the axis of a weir. 2) Safety against shear at the bottom of a weir Safety factor of shear at the bottom of a weir shall be at least four by using the Henny's formula. 3) Stress in a weir All stresses in a weir shall be below allowable limits.
Concrete Arch Weir	Three dimensional elastic object	1) Safety against shear at the bottom of a weir Safety factor of shear at the bottom of a weir shall be at least four by using the Henny's formula. 2) Stress in a weir All stresses in a weir shall be below allowable limits.
Fill Weir	Two dimensional non-elastic object	1) Safety against sliding Safety factor of sliding shall be at least 1.2 when the slice method is used.

4) Loading Conditions Required for Stability Analysis of Weir

Loading conditions required for stability analysis of weir are different by reservoir water stages and the type of weir as follows.

Table 10.1.3 Loading Conditions Required for Stability Analysis of Weir

Reservoir Water Stage \ Type of Weir	Concrete Gravity Weir Concrete Buttress Weir	Concrete Arch Weir	Fill Weir
Normal High Water Stage and Surcharge Water Stage	1)Weir's own weight 2)Static water pressure 3) Seismic water pressure due to reservoir water 4) Sediment force due to reservoir sedimentation 5) Seismic force due to weir's own weight 6) Uplift at the bottom of a weir due to reservoir water	1)Weir's own weight 2)Static water pressure 3) Seismic water pressure due to reservoir water 4) Sediment force due to reservoir sedimentation 5) Seismic force due to weir's own weight 6) Uplift at the bottom of a weir due to reservoir water 7) Thermal stress in a weir body	1)Weir's own weight 2)Static water pressure 3) Seismic force due to weir's own weight 4) Pore water pressure
Weir Design Water Stage	1)Weir's own weight 2)Static water pressure 3) Sediment force due to reservoir sedimentation 4) Uplift at the bottom of a weir due to reservoir water	1)Weir's own weight 2)Static water pressure 3) Sediment force due to reservoir sedimentation 4) Uplift at the bottom of a weir due to reservoir water 5) Thermal stress in a weir body	1)Weir's own weight 2)Static water pressure 3)Pore water pressure
Low Water Stage	1)Weir's own weight 2)Static water pressure 3) Seismic water pressure due to reservoir water 4)Seismic force due to weir's own weight 5) Uplift at the bottom of a weir due to reservoir water	1)Weir's own weight 2)Static water pressure 3) Seismic water pressure due to reservoir water 4)Seismic force due to weir's own weight 5) Uplift at the bottom of a weir due to reservoir water 6)Thermal stress in a weir body	
Abrupt Drawdown of Reservoir			1)Weir's own weight 2)Static water pressure 3) Seismic force due to weir's own weight 4)Pore water pressure
Middle Water Stage			1)Weir's own weight 2)Static water pressure 3) Seismic force due to weir's own weight 4) Pore water pressure
Without Impounded Water (Right after construction in case of fill weirs)	1)Weir's own weight 2)Seismic force due to weir's own weight	1)Weir's own weight 2)Seismic force due to weir's own weight 3)Thermal stress in a weir body	1)Weir's own weight 2)Seismic force due to weir's own weight 3)Pore water pressure

In this master plan study, the loading condition which corresponds to "Normal High Water Stage and Surcharge Water Stage" of "Concrete Gravity Weir/Concrete Buttress Weir" in the table above is used to determine the cross-sectional dimensions of concrete gravity weirs.

5) Estimation of Loads

Various kinds of load are estimated in manners as shown below.

a) Weir's Own Weight

Weir's own weight is calculated based on the unit weight of constructions materials. In this master plan study, the unit weight of concrete gravity weirs are obtained from EBCS-1, Ethiopian Building Code Standard, Basis of Design and Actions on Structures, published by Ministry of Works and Urban Development in 1995, which is 24 kN/m^3 or equivalent to 2.4 tf/m^3.

b) Static Water Pressure

Static water pressure acts upon both upstream and downstream faces of a weir. In the calculation of static water pressure on a weir's upstream face, the height of wave caused by wind and/or earthquake shall be added to corresponding water stages.

Static water pressure is estimated by the following equation.

$$P = W_o h$$

where,

P : Static water pressure (tf/m^2)

Wo : Unit weight of water (tf/m^3)

h : Water depth

According to the said EBCS-1, Ethiopian Building Code Standard, the unit weight of water is 10 kN/m^3 or equivalent to 1.0 tf/m^3.

c) Sediment Pressure due to Reservoir Sedimentation

Vertical pressure due to sediment in a reservoir shall equal to the submerged weight of sediment and horizontal sediment pressure at an arbitrary depth shall be calculated by the following equation.

$Pe = Ce\ W_1 d$

where,

Pe : Horizontal sediment pressure at an arbitrary depth (tf/m^2)

Ce : Coefficient of sediment pressure (0.4 - 0.6)

W_1 : Unit weight of submerged sediment (tf/m^3)

W_1 is derived from the following equation.

$W_1 = W - (1 - \nu)\ W_0$

where,

W : Wet unit weight of sediment (1.5 - 1.8 tf/m^3)

ν : Void ratio of sediment (0.4 - 0.6)

W_0 : Unit weight of water (1.0 tf/m^3)

d : Water depth (m)

d) Uplift at the Bottom of Weir due to Reservoir Water

For concrete weirs, uplift is to act vertically upward at the bottom of a weir and its magnitude is to be given as tabulated below, changing linearly between the upstream end of the bottom of a weir, drainage hole and the downstream end. Uplift shall not be influenced by the fluctuation of reservoir water stages with short duration such as caused by wave.

Table 10.1.4 Uplift at the Bottom of a Weir due to Reservoir Water

	Uplift at the upstream end	Uplift at a drainage hole	Uplift at the downstream end
When a drainage hole is furnished	Equal to static reservoir water pressure adjacent to the upstream end	(Uplift at the downstream end) + [(Uplift at the upstream end) - (Uplift at the downstream end)]/5	Equal to static water pressure adjacent to the downstream end
When a drainage hole is not furnished	(Uplift at the downstream end) + [(Uplift at the upstream end) - (Uplift at the downstream end)]/3	-	Equal to static water pressure adjacent to the downstream end

e) Seismic Force due to Weir's Own Weight

Seismic force due to weir's own weight shall act only horizontally and be given by the following equation.

$I = W k$

where,

I : Seismic force due to weir's own weight (tf)

W : Weir's own weight (tf)

k : Seismic Coefficient

Seismic coefficient applied shall be calculated by applying factors of seismic zone, subsoil condition and structural ductility, described in EBCS-8, Ethiopian Building Code Standard, Design of Structures for Earthquake Resistance, published by Ministry of Works and Urban Development in 1995.

f) Seismic Water Pressure due to Reservoir Water

Without relevant experiments, seismic water pressure horizontally acting on the upstream face of a weir is derived by using the Westergaard's formula which is applicable when more than a half height of the upstream face is vertical. When less than a half of the upstream face in height is vertical, the Zangar's formula is applied.

Seismic water pressure at an arbitrary depth is calculated by the following Westergaard's formula.

$$pd = 0.875\ W_0\ k\ \sqrt{H\ h}$$

where,

pd : Seismic water pressure at an arbitrary depth (tf/m^2)

W_0 : Unit weight of water (1.0 tf/m^3)

k : Seismic coefficient

H : Depth of the bottom of a weir below reservoir water surface (m)

h : Depth where seismic water pressure acts below reservoir water surface (m)

Total seismic water pressure is an integral of seismic water pressure at an arbitrary depth (Pd) over entire depth which is given by:

$$Pd = (7/12) W_0 k\ H^2$$

and Pd acts at a depth given by:

$$Hd = 0.4\ H$$

6) Design of Spillway

Design flood of overflow sections and a shootway of a spillway shall be the largest among a discharge at a surcharge water stage, probable 100-year flood and a basic flood at a proposed weir site. While, design flood of a stilling basin shall be such that which enables all of a discharge at a surcharge water stage, probable 100-year flood and a basic flood at a proposed weir site to be dissipated quickly.

If a catchment area of a weir is less than 20 km^2, a spillway shall not be furnished with gates.

The length of a stilling basin in a direction parallel to flow is obtained from the following formula described in the sabo dams standard in Design Standard of River and Sabo Structures edited by Ministry of Construction, Government of Japan.

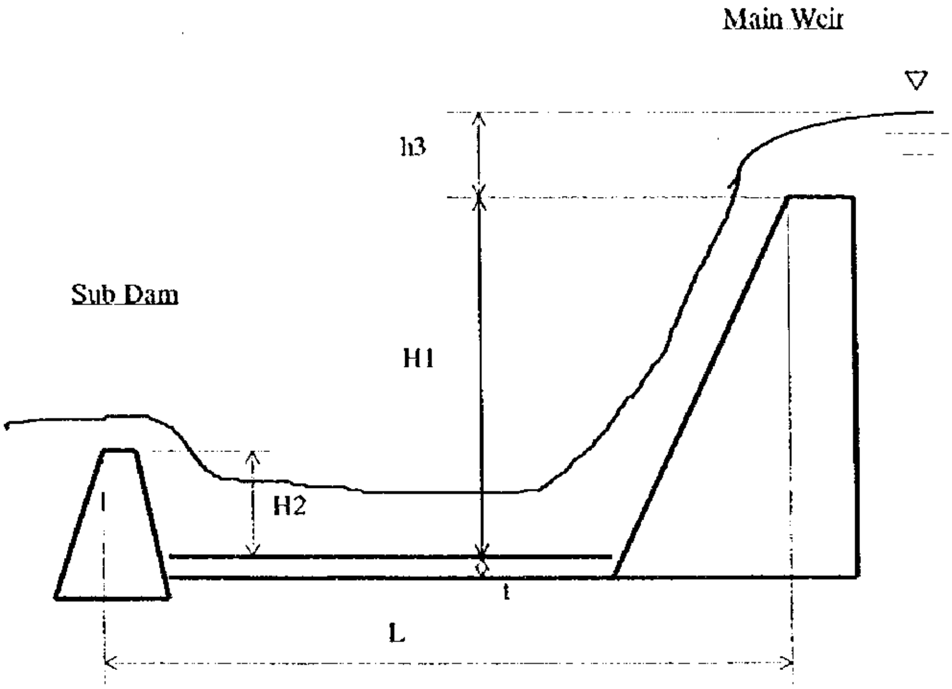
$$L = (1.5 \sim 2.0)(H_1 + h_3)$$

where,

L : Length of a stilling basin, or distance between the downstream end of the crest of a main weir and the downstream end of the crest of a sub weir (m)

H_1 : Height of the crest of main weir's overflow section above the top of floor slab of a stilling basin (m)

h_3 : Overflow depth at the crest of overflow section of a main weir (m)



The height of a sub weir is calculated by the following formula shown in the said sabo dam's standard.

$$H_2 = [(1/3) \sim (1/4)]\,H_1$$

where,

H_2 : Height of a sub weir (m)

H_1 : Height of the crest of main weir's overflow section above the top of floor slab of a stilling basin (m)

The thickness of floor slab of a stilling basin is calculated by the following formula shown in the said sabo dam's standard.

$t = 0.1(0.6H_1 + 3h_3 - 1.0)$

where,

H_1 : Height of the crest of main weir's overflow section above the top of floor slab of a stilling basin (m)

h_3 : Overflow depth at the crest of overflow section of a main weir (m)

(2) Flood Diversion Tunnel

Descriptions here are based on Design Standard of River and Sabo Structures edited by Ministry of Construction, Government of Japan.

1) Design Discharge

Design discharge of flood diversion tunnels shall be 1.3 times as much as design discharge of a river where the inlet of tunnels is proposed. This is because flood diversion tunnels are:

- liable for clogging by flowing objects,
- much less flexible for increased stream flow than open channels.

2) Design Velocity

Design velocity of flood diversion tunnels shall be 2 to 5 m/s. Manning's coefficient of roughness shall be 0.015 for the calculation of velocity and Froude number and 0.023 for the determination of cross-sectional area.

3) Tunnel Cross-section

Except siphons which are constantly subject to pressure flow, flood diversion tunnels shall take a form of free flow.

For supplying air to avoid low pressure inside tunnels, tunnel cross-section shall be furnished with extra space not occupied by water. This extra space shall be not less than 15 % as much as cross-sectional area for the design discharge of flood diversion tunnels.

Cross-sectional shape shall be of standard horse-shoe in principle. However, where geological conditions are excellent, vertical sides are applicable.

The inside of tunnels shall be wholly concrete-lined to prevent abrasion. Irrespective of geology, tunnel inverts shall be concrete-lined with minimum thickness of 35 cm.

Hydraulic jump shall occur nowhere inside tunnels.

4) Inlet and Outlet Portals

Inlet and outlet portals shall have such shape and dimensions for floods to flow in and out smoothly. Riverbeds and riparian banks adjacent to inlet and outlet portals shall be protected.

Inlet portals shall be furnished with facilities to protect its partial or total closure due to sediment, trees or other flowing matters.

Flow at outlet portals shall not be pressure flow, with the elevation of tunnel portal's threshold being sufficiently high above the high water stage of an adjacent river.

10.1.2 Design Conditions of Preliminary Design

(1) Unit Weight

Unit weights are quoted from EBCS-1, Ethiopian Building Code Standard, Basis of Design and Actions on Structures, published by Ministry of Works and Urban Development in 1995 as shown below.

Table 10.1.5 Unit Weight

Materials		Unit weight (kN/m^3)	Remarks
Concrete			
	Light weight	9 - 20	
	Normal weight	24	Density may be in the range 20 - 28 depending on local material
	Heavy weight	> 28	
	Reinforced and prestressed concrete	+ 1	
	Unhardened concrete	+ 1	
Masonry			
	Basalt	27	
	Limestone	25	
	Granite	27	
	Sandstone	23	
	Trachyte	26	
Water	Fresh	10	

In this master plan study, 2.4 tf/m^3 is used as the unit weight of concrete for concrete gravity weirs which is equivalent to 24 kN/m^3 as shown on the table above.

(2) Seismic Coefficient

The seismic coefficient used for the stability analysis of concrete gravity weirs are calculated on the basis of EBCS-8, Ethiopian Building Code Standard, Design of Structures for Earthquake Resistance, published by Ministry of Works and Urban Development in 1995.

According to EBCS-8, the Ethiopian Building Code Standard, the seismic coefficient is given by the following formula.

$Sd = \alpha \beta \gamma$

where,

Sd : Seismic coefficient against the acceleration of gravity

α : Ratio of the design bedrock acceleration to the acceleration of gravity given by:

$\alpha = \alpha_0 I$

where,

α_0 : Bedrock acceleration ratio for the site which depends on the seismic zone as given in Table 10.1.6 and Figure 10.1.1.

Table 10.1.6 Bedrock Acceleration Ratio (α_0)

Zone	4	3	2	1	0
α_0	0.10	0.07	0.05	0.03	0.00

As Addis Ababa belongs to Zone 2 from Figure 10.1.1, α_0 is equal to 0.05.

I : Importance factor given in Table 10.1.7

Table 10.1.7 Importance Categories and Importance Factors for Buildings

Importance Category	Buildings	Importance Factor I
I	Buildings whose integrity during earthquakes is of vital importance for civil protection ,e.g., hospitals, fire stations, power plants etc.	1.4
II	Buildings whose seismic resistance is of importance in view of the consequences associated with collapse, e.g., schools, assembly halls, cultural institutions, etc.	1.2
III	Ordinary buildings, not belonging to the other categories	1.0
IV	Buildings of minor importance for public safety, e.g., agricultural buildings etc.	0.8

Because the concrete gravity weirs planned in this study are considered to be quite important, I equal to 1.4 is used.

β : Design response factor given by the following formula.

$$\beta = 1.2\,S / T^{2/3}$$

where,

S : Site coefficient for soil characteristics given by the following table.

Table 10.1.8 Site Coefficient

Subsoil Class	Subsoil Conditions	Site Coefficient (S)
A	-Rock or other geological formation characterized by a shear wave velocity of at least 800 m/s -Stiff deposits of sand, gravel or over consolidated clay, at least several tens of meters thick, characterized by a shear wave velocity of at least 400 m/s at a depth of 10m	1.0
B	Deep deposits of medium dense, gravel or medium stiff clay with thickness from tens to hundreds meter, characterized by a shear wave velocity of at least 200 m/s at a depth of 10m and at least 350 m/s at a depth of 50 m	1.2
C	-Loose cohesionless soil deposits with or without some soft cohesive layers, characterized by a shear wave velocity below 200 m/s in the uppermost 20 m -Deposits with predominant soft-to-medium stiff cohesive soils, characterized by a shear wave velocity below 200 m/s in the uppermost 20 m	1.5

As the planned concrete gravity weirs are situated on hard rock, S is assumed 1.0.

T : Fundamental period of building in second given by the following formula.

$T = C H^{3/4}$

where,

C : Coefficient related to the resistance against moment given by:

0.085 for steel moment resisting frames

0.075 for reinforced concrete moment-resisting frames and eccentrically braced frames

0.050 for all other buildings

Because concrete gravity weirs are rigid with a large resistance against moment, C equal to 0.085 is used.

γ : Behavior factor which represents the energy dissipation capacity of structures given as a ratio against a completely elastic structure with viscous damping of 5 %.

As the behavior factor of mass concrete structures like concrete gravity weirs is not specified in the Ethiopian Building Code Standard or any other Ethiopian standard. However, the behavior factor of other structures are shown in EBCS-8, Ethiopian Building Code Standard, Design of Structures for Earthquake Resistance as follows:

For concrete buildings : $\gamma \leqq 0.70$

For unreinforced masonry buildings : $\gamma = 0.70$

As a conservative estimate, the behavior factor for concrete gravity weirs is assumed 0.70.

From the above, the seismic coefficient Sd is derived, assuming the weir height is 20 m, as follows.

$Sd = \alpha \beta \gamma$

where,

$\alpha = \alpha_0 I = 0.05 \times 1.4 = 0.07$

$\beta = 1.2\, S / T^{2/3} = 1.2\, S / (C\, H^{3/4})^{2/3}$

$= 1.2 \times 1.0/(0.085 \times 20^{3/4})$

$= 1.49$

$\gamma = 0.70$

therefore,

$Sd = 0.07 \times 1.49 \times 0.70 = 0.07$

In the stability analysis of concrete gravity weirs contemplated by the master plan study, Sd is made equal to 0.10 for the sake of conservativeness.

(3) Sediment

The reservoir sediment volume is used by the stability analysis of concrete gravity weirs, converting sediment volume into sediment depth. In the master plan study, the sediment volume is derived from an existing study report entitled "Addis Ababa Water Supply Project - Stage IIIA, Final Design and Tender Documents Preparation, Hydrology of Gerbi Dam, Final Report" undertaken by the Addis Ababa Water and Sewerage Authority, finalized in January 1997.

All concrete gravity weirs planned by this master plan study are designed to have outlet holes at the elevation almost as high as the existing riverbed for the purpose of discharging instream flows in downstream areas without manned operation. Therefore, almost no sediment is likely to deposit in reservoirs, being transported downstream by stream flows, as long as the outlet holes are not closed. In the stability analysis of concrete gravity weirs, reservoir sedimentation is assumed for the worst case in which the outlet holes are completely plugged.

Sediment volume applied to the stability analysis of concrete gravity weirs is estimated on the basis of suspended load measured at four sites during the said hydrological study of the Gerbi dam, assuming that (1) the bed load is equal to 10% of the suspended load, (2) the unit weight of deposited sediments in the reservoir water is equal to 0.91 tf/m^3, (3) the trap efficiency of reservoirs is 100%, and (4) 100-year sedimentation volume is applied as specified in Design Standard of River and Sabo Structures edited by Ministry of Construction, Government of Japan. The estimated sediment volume of the proposed weirs are shown on the following table.

Table 10.1.9 Reservoir Sediment Volume of Proposed Weirs

Sites of which Suspended Load Measurement was Conducted		Gerbi Dam	Chacha	Robi Gomoro	Berga	Average
Suspended Load	(ton/km^2/year)	60.9	101	102.7	64.5	82
Bed Load	(ton/km^2/year)	6.09	10.1	10.27	6.45	8
Total Sediment Load in Weight	(ton/km^2/year)	66.99	111.1	112.97	70.95	91
Unit Weight	(ton f /m^3)	0.91	0.91	0.91	0.91	0.91
Total Sediment Load in Volume	(m^3/km^2/year)	73.6	122.1	124.1	78.0	99
Trap Efficiency	(%)	100	100	100	100	100
100-year Sediment Volume	(m^3)					
Kechene Weir	(CA=5 km^2)	37,000	62,000	63,000	39,000	51,000
Kebena No.1 Weir	(CA=15 km^2)	111,000	184,000	187,000	117,000	150,000
Kebena No.2 Weir	(CA=20 km^2)	148,000	245,000	249,000	156,000	200,000
Abo Weir	(CA=15 km^2)	111,000	184,000	187,000	117,000	150,000

(4) Design Condition of River Channel

1) Calculation Method

Applying the uniform flow, discharge is calculated by the following formula:

$Q = A R^{2/3} I / n$

where,

Q : Discharge (m^3/s)

A : Flow area (m^2)

R : Hydraulic radius (m)

I : Slope of riverbed

n : Manning's coefficient of roughness

2) Manning's coefficient of roughness after river improvement

Considering existing river conditions, the Manning's coefficient of roughness after river improvement is assumed 0.040 for all rivers concerned.

3) Freeboard

As shown on the following table, taking into account a torrential flood flow in the study area, the freeboard used in this study is about 1.5 times as large as that stipulated by Design Standard of River and Sabo Structures edited by Ministry of Construction, Government of Japan.

Table 10.1.10 Freeboard

Design Discharge	Freeboard used in this study	Freeboard stipulated by the Japanese standard
$Q < 200\ m^3/s$	1.0 m	0.6 m
$200 m^3/s \leqq Q < 500 m^3/s$	1.2 m	0.8 m

10.1.3 Preliminary Design

(1) Weir

In the master plan study, total four weirs are contemplated, namely, one at the Kechene river, two at the Kebena river and one at the Abo river, a tributary of the Kebena river, locations of which are shown on Figure 10.1.2 through Figure 10.1.4. The weirs are designed based on design standards and design conditions described in the preceding sections. All weirs consist of a main weir, a subweir and a stilling basin. A subweir is situated at the downstream end of a stilling basin. The type of both the main weir and the subweir is concrete gravity weir. The stilling basin is made of reinforcing concrete. Downstream from the subweir, gabion mats are furnished on the riverbed to prevent scouring and erosion. Major features of the main weir are as follows.

Table 10.1.11 Major Features of Weirs

	Kechene	Kebena No.1	Kebena No.2	Abo
Type	Concrete Gravity	Concrete Gravity	Concrete Gravity	Concrete Gravity
Reservoir Storage Volume	115,000 m^3	212,000 m^3	22,000 m^3	332,000 m^3
Weir Height	20 m	25 m	14 m	24 m
Crest Length	154 m	189 m	106 m	191 m
Crest Width	2 m	2 m	2 m	2 m
Slope of Upstream Face	Vertical	Vertical	Vertical	Vertical
Slope of Downstream Face	1V to 0.7H	1V to 0.7H	1V to 0.7H	1V to 0.7H

To make weir operation unmanned, the main weir has an ungated spillway at weir crest and hollows as river outlet facility near the bottom of the weir. The spillway is designed for probable 100-year flood and spill out only when such a large flood takes place. The hollows near the bottom of the weir is to discharge floods of small to medium size as well as instream flow required in downstream areas.

The plan of weir and reservoir and the front view of weir are shown on Figure 10.1.5 through Figure 10.1.8. The reservoir storage volume curves are shown on Figure 10.1.9 through Figure 10.1.12. The plans and the reservoir storage volume curves are depicted on the 1/2,000-topographical maps published in 1995 for Addis Ababa Water Supply Project StageIIIA.

(2) Regulating Pond

In the master plan study, total seven regulating ponds are contemplated, that is, four at the Kurtume river, one at the Kostre river, a tributary of the Kechene river; one at the Bantyiketu river and;one at the Little Akaki river. The locations of the ponds are shown on Figure 10.1.13 through Figure 10.1.15.

All regulating ponds are constructed by excavation of the ground in riparian areas. Along the riverside of the pond, an inlet dyke and an outlet facility are built. The inlet dyke is made of soils embankment armored by wet masonry along its surface. The outlet facility is made of wet masonry, furnished with a flap gate. The flap gate is selected for fulfilling unmanned operation. Floods are designed to flow over the crest of the inlet dyke into the pond and is returned through the flap gate to the river when the water stage of the river becomes lower. The flap gate made of stainless steel is proposed from the aspect of maintenance-free policy. For the purpose of avoiding scouring, gabion mats are placed on the riverbed and the pond's bed next to the inlet dyke as well as the riverbed adjacent to the outlet facility.

Among the seven regulating ponds, two regulating ponds , namely, the Kostre and the Bantyiketu regulating ponds, are included in the priority projects which are forwarded to feasibility study. The proposed Kostre regulating pond is located at the Kostre river, a tributary of Kechene river and immediately downstream from the Dejazmach Haile Silase Street. The proposed site is currently used as a football ground for local people.

The proposed Bantyiketu regulating pond is located immediately downstream from the Filwiha bridge and is a vast grassland, unoccupied by houses and buildings, at present.

The major features of the two ponds are as follows:

Table 10.1.11 Major Features of Regulating Ponds

	Kostre pond	Bantyiketu pond
Reservoir storage volume	21,000 m^3	56,000 m^3
Surface Area	7,900 m^2	29,000 m^2
Depth of Pond Bottom Below Overflow Crest of Inlet Dyke	5 m	2 m

The plans of both the Kostre and the Bantyiketu regulating ponds are shown on Figure 10.1.16 and Figure 10.1.17.

(3) Flood Diversion Tunnel

In the master plan study, a flood diversion tunnel with design discharge of 160 m^3/s, inside diameter of 9m and length of 650m, is proposed to divert floods from the Little Akaki river to the West Akaki river. The location of the flood diversion tunnel is shown on Figure 10.1.18. Its alignment and dimensions are determined based on design policies and design conditions described in the preceding sections. Both upstream and downstream from the tunnel extends open channels, 320 m in total length. The floor and side slopes of the open channels are lined with wet masonry for protection. A minimum 10 m of overlaying soils thickness is attained above the crown of the tunnel. Gabion mats are furnished on the riverbed adjacent to the open channels both upstream and downstream to prevent scouring of riverbeds.

The longitudinal slope of the tunnel floor is 1/600, except the first 100-m-long portion adjacent to the inlet portal where the longitudinal slope of the tunnel is 1/3. If the slope of the tunnel is 1/600 in its entire length to constrain flow velocity inside the tunnel below 5m/s as stipulated in the aforementioned Japanese design standard, total length of tunnel is about 200m and the rest become an open channel. This causes a significant magnitude of resettlement of houses and relocation of roads, water supply pipes and power lines and other public utility facilities, which is socially unacceptable at all.

The plan and the longitudinal section of the Little Akaki flood diversion tunnel are shown on Figure 10.1.19. The plan is depicted on the 1/2,000-topographical maps published in 1995 for Addis Ababa Water Supply Project StageIII A

10.2 Cost Estimate

10.2.1 Construction Works

(1) Work Quantities

The following three work items will give major portion of work quantities and cost in the project construction.

- Excavation works, for river channel improvement and for regulating pond,
- Wet masonry works, for river channel improvement and for regulating pond and
- Concrete works, for weir construction

The work quantities of the above three items are given in Table 10.2.1.

(2) Construction Method

The excavation works will be undertaken with construction equipment of bulldozer and hydraulic excavator. Some of excavated earth material will be used for adjacent earthfilling works for embankment at the regulating pond work sites. And some of excavated rock material will be used for wet masonry works. Other surplus earth materials including stripped earth material will be conveyed by dump trucks and adequately filled at the disposal areas, which will be selected in the suburbs of Addis Ababa around 5 to 10km far from the work sites.

Wet masonry works are conventional and common methods to the structural works of walls, bridge pier and abutments and some house buildings in Addis Ababa. The material is usually produced at some quarries, which are controlled by the governmental agency, located in the suburbs of Addis Ababa.

Ready mixed concrete will be used for dam construction and for tunnel lining works. It is available at the Akaki Industrial Estate. Though it is not necessary to facilitate concrete production plant, it is required to procure enough number of agitator trucks to convey the ready mixed concrete from Akaki to the work sites. At the weir construction site, the conveyed ready mixed concrete will be placed into the structure body with concrete bucket and wheel crane.

10.2.2 Conditions and Assumptions for Cost Estimate

Project construction cost comprises 1) Construction cost, 2) Resettlement cost, 3) Engineering service cost, 4) Administration cost, 5) Physical contingency and 6) Price contingency. The following are the conditions and assumptions for the project cost estimate in the master plan.

1) Project cost is estimated at the price level as of June 1997.

2) Exchange rate used in the cost estimate is shown as follows:

   US$ 1.0 = Birr 6.8 = J.Yen 114.7-.

3) Construction works will be executed on contract basis through international competitive bidding. All the labor, materials and equipment required for the construction works will be provided by the contractors themselves. The construction cost is estimated as a construction contract price.

4) Resettlement cost does not include land acquisition cost, because the whole land belongs to the Government of Ethiopia.

5) Engineering services, such as design and supervision, will be executed by international contract basis. The engineering services cost is estimated at 15% of construction cost.

6) Administration cost is estimated at 10% of construction cost.

7) Cost is estimated in foreign currency and local currency portions. The foreign currency portion includes foreign labor wages, imported materials and equipment cost, international transportation cost and contractors' indirect cost. The local currency portion includes local labor wages, local materials cost, inland transportation cost, contractors' indirect cost, resettlement cost and administration cost.

8) Physical contingency is provided as 20% of the total of construction cost, resettlement cost engineering service cost and administration cost.

9) Price contingency is calculated based on the escalation rates of 3% per annum for foreign currency portion and of 6% for local currency portion.

10) Tax is included in the project cost.

10.2.3 Unit Prices

(1) Labor

Labor wage of common and skilled workers in Addis Ababa is given in Table 10.2.2.

(2) Construction Materials

Prices of some major construction materials are obtained through a simple market survey and from the report on average retail prices of goods and services published by the Central Statistical Authority. The prevailing purchasing prices of major construction materials at Addis Ababa is given in Table 10.2.3.

(3) Construction Equipment

Assuming that the construction equipment is imported by contractors, operation unit cost of such equipment is estimated as listed in Table 10.2.4.

(4) Unit Prices of Construction Works

Construction unit prices of major works are estimated through unit rate analysis and through comparison with some unit prices of past contract examples. Unit prices of construction works are listed in Table 10.2.5.

10.2.4 Cost Estimate

(1) Construction Cost of Structural Measures

The total costs, of master plan projects and of priority projects, including construction cost, resettlement cost, engineering services cost, administration cost and physical contingency are estimated in Table 10.2.6. The breakdown of the construction cost of master plan projects is given in Table 10.2.7. The breakdown of construction cost of priority projects is given in Table 10.2.8.

(2) Installation Cost of Non-structural Measures

Installation cost of non-structural measures is estimated in Table 10.2.9.

10.2.5 Implementation Plan

According to the schedule of the study, master plan study including feasibility study on priority project will be completed in May, 1998. The construction works of the flood control project is expected to be commenced in 2000. All the construction works of the project will be completed in the end of 2020. The construction period amounts to 21 years.

The non-structural measures are proposed to be implemented during the whole period up to the year of 2020. But authorization of river administrative zone and establishment of regulation to prohibit construction of structures in the river zone should be realized as soon as possible to avoid future problem for flood control activities.

The implementation plan is proposed as shown in Figure 10.2.1.

10.2.6 Project Cost

Project costs including price escalation for the structural measures and for the non-structural measures are estimated in Table 10.2.10 and in Table 10.2.11 respectively.

Project cost of priority projects is estimated in Table 10.2.12.

Annual operation and maintenance costs for the structural measures and for the non-structural measures are estimated in Table 10.2.13 and in Table 10.2.14 respectively.

Table 10.2.1 Major Work Quantities

Master Plan

Facility	Excavation (m3)	Concrete (m3)	Masonry (m3)
1. Bantyiketu river system			
(1) Kurtume No.1 regulating pond	4,000	0	2,000
(2) Kurtume No.2 regulating pond	51,000	0	3,000
(3) Kurtume No.3 regulating pond	18,000	0	2,000
(4) Kurtume No.4 regulating pond	18,000	0	1,000
(5) Channel improvement of Kurtume river	0	0	7,000
(6) Kechene weir	31,000	12,000	500
(7) Kostre regulating pond	31,000	0	2,500
(8) Channel improvement of Kechene river	0	0	6,000
(9) Bantyiketu regulating pond	166,000	0	3,500
(10) Channel improvement of Bantyiketu rive	42,000	0	6,000
(11) Urban development improvement	25,000	2,000	1,000
Sub-total of 1.	386,000	14,000	34,500
2. Kebena river system			
(1) Kebena weir	35,000	30,000	250
(2) Abo weir	20,000	27,000	250
(3) Channel improvement of Kebena river	0	0	20,000
Sub-total of 2.	55,000	57,000	20,500
3. Little Akaki river system			
(1) Little Akaki regulating pond	135,000	0	5,000
(2) Flood diversion tunnel	91,000	4,000	3,000
(3) Channel improvement of Little Akaki riv	0	0	7,000
Sub-total of 3.	226,000	4,000	15,000
4. Hanku river system			
(1) Channel improvement of Hanku river	3,000	0	0
Total of (1. - 4.)	**670,000**	**75,000**	**70,000**

Priority Project

Facility	Excavation (m3)	Concrete (m3)	Masonry (m3)
(1) Kechene weir	31,000	12,000	500
(2) Kostre regulating pond	31,000	0	2,500
(3) Bantyiketu regulating pond	166,000	0	3,500
(4) Channel improvement of Bantyiketu rive	42,000	0	6,000
(5) Urban development improvement	25,000	2,000	1,000
Total	**295,000**	**14,000**	**13,500**

Table 10.2.2 Labor Wage

No.	Particular	Unit	F.C. (Birr)	L.C. (Birr)
1.	Foreman	man-day	0	80
2.	Operator	man-day	0	60
3.	Assistant operator	man-day	0	45
4.	Driver	man-day	0	30
5.	Mechanic	man-day	0	80
6.	Electrician	man-day	0	70
7.	Rigger	man-day	0	60
8.	Welder	man-day	0	60
9.	Rebar worker	man-day	0	40
10.	Plumber	man-day	0	60
11.	Carpenter	man-day	0	40
12.	Plasterer	man-day	0	40
13.	Concrete worker	man-day	0	40
14.	Mason	man-day	0	45
15.	Pavement worker	man-day	0	55
16.	Boring worker	man-day	0	40
17.	Grout worker	man-day	0	40
18.	Tunnel worker	man-day	0	40
19.	Driller	man-day	0	40
20.	Blaster	man-day	0	60
21.	Skilled labor	man-day	0	30
22.	Common labor	man-day	0	10
23.	Engineer, senior	man-month	0	1,500
24.	Engineer, junior	man-month	0	710
25.	Surveyor	man-month	0	600
26.	Draftman	man-month	0	500
27.	Typist	man-month	0	600
28.	Office clerk	man-month	0	500
29.	Cook	man-month	0	300
30.	Maid	man-month	0	250
31.	Night keeper	man-month	0	250

Note: The value indicates the prevailing wage at Addis Ababa.
Price level; June 1997, US$ 1.0 = Birr 6.8 = J.Yen 114.7

Table 10.2.3 Construction Material Price

No.	Materials	Unit	F.C. portion (Birr)	L.C. portion (Birr)
1.	Gasoline	lit.	0	2.64
2.	Gas oil (=Light oil)	lit.	0	1.95
3.	Electric power	kWh	0	0.18
4.	Lubricant	lit.	0	9
5.	Grease	kg	0	34
6.	Portland cement	kg	0	0.50
7.	Reinforcing bar, deformed	kg	0	4
8.	Binding wire	kg	0	10
9.	Annealed iron wire	kg	0	10
10.	Nail	kg	0	10
11.	Steal plate	kg	0	10
12.	Channel steel	kg	0	10
13.	Angle steel	kg	0	10
14.	H-Shape steel	kg	0	10
15.	Steel sheet pile	kg	0	10
16.	Dynamite, in open	kg	137	0
17.	Dynamite, in tunnel	kg	137	0
18.	ANFO powder	kg	44	0
19.	Electric detonator	no.	30	0
20.	Timber, plank	m3	0	3,200
21.	Timber, square	m3	0	2,900
22.	Timber, log	m3	0	2,600
23.	Plywood	m3	0	4,500
24.	Form oil	lit.	0	8
25.	Brick	m3	0	400
26.	Galvanized iron pipe, 1/2in	m	0	8
27.	Galvanized iron pipe, 1in	m	0	16
28.	Galvanized iron pipe, 1+1/2in	m	0	25
29.	PVC pipe, 2in	m	0	8
30.	PVC pipe, 4in	m	0	25
31.	Aggregate, fine (= sand)	m3	0	84
32.	Aggregate, coarse	m3	0	100
33.	Crusher-run	m3	0	100
34.	Stone	m3	0	50
35.	Ready mixed concrete, 160kg	m3	0	548
36.	Ready mixed concrete, 240kg	m3	0	609
37.	Ready mixed concrete, 240kg, at seite	m3	0	703

Note: The value indicates purchasing price at Addis Ababa.
Price level; June 1997, US$ 1.0 = Birr 6.8 = J.Yen 114.7
Tax is included in the price.

Table 10.2.4 Unit Operation Cost of Construction Equipment

No.	Equipment	Class	Unit	Depreciation and maintenance cost F.C. (Birr)	L.C. (Birr)	Total (Birr)	Fuel comsumption cost L.C. (Birr)
1.	Bulldoser	11ton	Hour	145	19	164	27
2.	Bulldoser	15ton	Hour	193	25	218	38
3.	Bulldoser	21ton	Hour	320	41	361	56
4.	Bulldoser	32ton	Hour	426	61	487	76
5.	Bulldoser w/ripper	21ton	Hour	340	47	387	60
6.	Bulldoser w/ripper	32ton	Hour	420	60	480	86
7.	Backhoe	0.35m3	Hour	92	11	103	20
8.	Backhoe	0.60m3	Hour	133	16	149	34
9.	Backhoe	0.70m3	Hour	170	20	190	34
10.	Wheel loader	1.4m3	Hour	116	15	131	22
11.	Wheel loader	2.3m3	Hour	178	24	202	40
12.	Dump truck	8ton	Hour	70	11	81	19
13.	Dump truck	10ton	Hour	80	12	92	26
14.	Cargo truck	4ton	Hour	43	6	49	15
15.	Cargo truck	8ton	Hour	67	10	77	20
16.	Cargo truck, w/crane	4ton/2ton	Hour	52	7	59	14
17.	Truck crane, hyd.	15-16ton	Hour	167	23	190	17
18.	Wheel crane	25ton	Hour	256	33	289	30
19.	Giant breaker, hyd.	1300kg	Day	707	59	766	-
20.	Crawler drill, hyd.	150kg	Hour	516	63	579	-
21.	Motor grader	3.1m	Hour	143	19	162	18
22.	Macadum roller	10-12ton	Hour	84	12	96	15
23.	Tire roller	8-20ton	Hour	95	14	109	14
24.	Tamper	80kg	Hour	7	1	8	2
25.	Agitator truck	3.2m3	Hour	66	9	75	19
26.	Sprinkler truck	6kl	Hour	63	8	71	11
27.	Submersible pump	50mmx10m	Day	7	1	8	0.1
28.	Diesel generator	5kVA	Day	34	4	38	2
29.	Diesel generator	10kVA	Day	63	7	70	4
30.	Diesel generator	25kVA	Day	130	17	147	8
31.	Diesel generator	45kVA	Day	155	20	175	13
32.	Diesel generator	100kVA	Day	230	30	260	30
33.	Diesel generator	200kw	Day	436	60	496	64
34.	Diesel generator	250kw	Day	561	78	639	79
35.	Port. concrete mixer	0.2m3	Day	182	27	209	1
36.	Concrete backet, man.	1.0m3	Day	377	50	427	-
37.	Concrete vibrator	38mm	Day	15	2	17	0.1
38.	Engine welder	250A	Day	70	9	79	6

Note: The unit cost is estimated assuming that the equipment is imported and operated by contractors.
Price level; June 1997, US$ 1.0 = Birr 6.8 = J.Yen 114.7
Tax is included in the price.

Table 10.2.5 Unit Price of Construction Works

Work item	Description	Unit	F.C. (Birr)	L.C. (Birr)	Total (Birr)
1. Earthworks					
1.1 Clearing and stripping	cut.t=20cm, dozing, load., h.=7.5km, unload., spread.	m2	6	3	9
1.2 Excavation, common	excavation, load., haul.=7.5km, unload., spread.	m3	31	17	48
1.3 Excavation, river bed	excavation, load., haul.=7.5km, unload., spread.	m3	36	17	53
1.4 Excavation, rock	excavation, loading, haul.=5km, unloading	m3	84	24	108
1.5 Backfilling	spreading, compaction	m3	3	1	4
1.6 Embankment	spreading, compaction	m3	3	1	4
1.7 Sod facing	turfling, hauling, planting	m2	1	6	7
2. Concrete works					
2.1 Mass concrete, 160kg	ready mixed, haul., placing, crane, compact., curing	m3	147	832	979
2.2 Ordinary concrete, 240kg	ready mixed, haul., placing, crane, compact., curing	m3	147	919	1,066
2.3 Form, for concrete	plywood, setting, oil painting, removal	m2	23	109	132
2.4 Reinforcing bar, deform.	deformed, cutting, bending, assebling	kg	0	7	7
3. Masonry works					
3.1 Wet masonry	mortal 1:4, royalty, haul., unload., masonning	m3	0	423	423
3.2 Gabion mattress	incl. wire net, royalty, haul., unload., masonning	m3	54	230	284
3.3 Gravel bedding	crusher run, spreading, compaction	m3	2	167	169
4. Metal works					
4.1 Flap gate	stainless steel, install., paint., 1.5m x 1.5m class	kg	306	34	340
4.2 Structural steel works	section steel, process., assembl., weld., for bridge	kg	10	1	11
4.3 Iron pipe, dia.= 1,000mm	upto install., incl. piping upto valve	m	4,098	455	4,553
5. Tunnel works					
5.1 Tunneling, H= 9.0m	drilling, blasting, rock bolt, mucking, lining, form	m	40,098	18,585	58,683

Note: Price level; June 1997, US$ 1.0 = Birr 6.8 = J.Yen 114.7
Tax is included in the price.

Table 10.2.6 Total Cost of Each Project (1/4)

Master Plan (1/2) (Unit: 1,000 Birr)

Facility	F.C.	L.C.	Total
1. Bantyiketu river system			
(1) Construction cost			
1) Kurtume No.1 regulating pond	429	1,134	1,563
2) Kurtume No.2 regulating pond	3,673	2,647	6,320
3) Kurtume No.3 regulating pond	1,406	1,522	2,928
4) Kurtume No.4 regulating pond	1,353	1,106	2,459
5) Channel improvement of Kurtume river	0	3,390	3,390
6) Kechene weir	4,770	14,490	19,260
7) Kostre regulating pond	2,292	1,968	4,260
8) Channel improvement of Kechene river	0	2,841	2,841
9) Bantyiketu regulating pond	9,425	5,455	14,880
10) Channel improvement of Bantyiketu river	2,375	3,794	6,169
11) Urban development improvement	2,215	6,241	8,456
Sub-total of (1)	27,938	44,588	72,526
(2) Resettlement cost			
1) Kurtume No.1 regulating pond	0	638	638
2) Kurtume No.2 regulating pond	0	765	765
3) Kurtume No.3 regulating pond	0	332	332
4) Kurtume No.4 regulating pond	0	230	230
5) Channel improvement of Kurtume river	0	1,020	1,020
6) Kechene weir	0	638	638
7) Kostre regulating pond	0	0	0
8) Channel improvement of Kechene river	0	1,250	1,250
9) Bantyiketu regulating pond	0	0	0
10) Channel improvement of Bantyiketu river	0	2,486	2,486
11) Urban development improvement	0	0	0
Sub-total of (2)	0	7,359	7,359
(3) Engineering services	9,791	1,088	10,879
(4) Administration cost	0	7,253	7,253
Total of (1) - (4)	37,729	60,288	98,017
(5) Physical contingency	7,546	12,058	19,604
Total of (1) - (5)	**45,275**	**72,346**	**117,621**
2. Kebena river system			
(1) Construction cost			
1) Kebena weir	8,247	33,318	41,565
2) Abo weir	6,338	29,326	35,664
3) Channel improvement of Kebena river	0	9,981	9,981
Sub-total of (1)	14,585	72,625	87,210
(2) Resettlement cost			
1) Kebena weir	0	38	38
2) Abo weir	0	306	306
3) Channel improvement of Kebena river	0	3,953	3,953
Sub-total of (2)	0	4,297	4,297
(3) Engineering services	11,774	1,308	13,082
(4) Administration cost	0	8,721	8,721
Total of (1) - (4)	26,359	86,951	113,310
(5) Physical contingency	5,272	17,390	22,662
Total of (1) - (5)	**31,631**	**104,341**	**135,972**

Table 10.2.6 Total Cost of Each Project (2/4)

Master Plan (2/2) (Unit: 1,000 Birr)

Facility	F.C.	L.C.	Total
3. Little Akaki river system			
(1) Construction cost			
1) Little Akaki regulating pond	7,777	5,413	13,190
2) Flood diversion tunnel	39,217	27,381	66,598
3) Channel improvement of Little Akaki river	0	3,455	3,455
Sub-total of (1)	46,994	36,249	83,243
(2) Resettlement cost			
1) Little Akaki regulating pond	0	1,607	1,607
2) Flood diversion tunnel	0	0	0
3) Channel improvement of Little Akaki river	0	1,339	1,339
Sub-total of (2)	0	2,946	2,946
(3) Engineering services	11,237	1,249	12,486
(4) Administration cost	0	8,324	8,324
Total of (1) - (4)	58,231	48,768	106,999
(5) Physical contingency	11,646	9,754	21,400
Total of (1) - (5)	**69,877**	**58,522**	**128,399**
4. Hanku river system			
(1) Construction cost			
1) Channel improvement of Hanku river	217	583	800
(2) Resettlement cost			
1) Channel improvement of Hanku river	0	0	0
(3) Engineering services	108	12	120
(4) Administration cost	0	80	80
Total of (1) - (4)	325	675	1,000
(5) Physical contingency	65	135	200
Total of (1) - (5)	**390**	**810**	**1,200**
Total of (1. - 4.)	**147,173**	**236,019**	**383,192**

Table 10.2.6 Total Cost of Each Project (3/4)

Alternatives Study on Priority Projects (1/1) (Unit: 1,000 Birr)

	Facility	F.C.	L.C.	Total
Alt.-1	**Same as master plan, =Bantyiketu system, incl. side ditch**			
	(1) Construction cost	27,938	44,588	72,526
	(2) Resettlement cost	0	7,359	7,359
	(3) Engineering services	9,791	1,088	10,879
	(4) Administration cost	0	7,253	7,253
	Total of (1) - (4)	37,729	60,288	98,017
	(5) Physical contingency	7,546	12,058	19,604
	Total of (1) - (5)	**45,275**	**72,346**	**117,621**
Alt.-2	**Kechene system + Bantyiketu system, incl. side ditch**			
	(1) Construction cost	20,648	35,266	55,914
	(2) Resettlement cost	0	4,373	4,373
	(3) Engineering services	7,548	839	8,387
	(4) Administration cost	0	5,591	5,591
	Total of (1) - (4)	28,197	46,069	74,266
	(5) Physical contingency	5,639	9,214	14,853
	Total of (1) - (5)	**33,836**	**55,283**	**89,119**
Alt.-3	**Kurtume system + Bantyiketu system, incl. side ditch)**			
	(1) Construction cost	20,352	25,883	46,235
	(2) Resettlement cost	0	5,470	5,470
	(3) Engineering services	6,241	694	6,935
	(4) Administration cost	0	4,624	4,624
	Total of (1) - (4)	26,593	36,671	63,264
	(5) Physical contingency	5,319	7,334	12,653
	Total of (1) - (5)	**31,912**	**44,005**	**75,917**
Alt.-4	**Kechene weir & Kostre pond + Bantyiketu system, incl. side ditch)**			
	(1) Construction cost	21,077	31,973	53,050
	(2) Resettlement cost	0	3,124	3,124
	(3) Engineering services	7,162	796	7,958
	(4) Administration cost	0	5,305	5,305
	Total of (1) - (4)	28,239	41,198	69,437
	(5) Physical contingency	5,648	8,240	13,888
	Total of (1) - (5)	**33,887**	**49,438**	**83,325**
Alt.-5	**Kechene weir & Kostre pond + Bantyiketu pond + Bantyiketu road side ditch**			
	(1) Construction cost	18,822	28,077	46,899
	(2) Resettlement cost	0	638	638
	(3) Engineering services	6,332	703	7,035
	(4) Administration cost	0	4,690	4,690
	Total of (1) - (4)	25,153	34,108	59,261
	(5) Physical contingency	5,030	6,822	11,852
	Total of (1) - (5)	**30,183**	**40,930**	**71,113**

Table 10.2.6 Total Cost of Each Project (4/4)

Priority Projects (1/1) (Unit: 1,000 Birr)

Facility	F.C.	L.C.	Total
(1) Construction cost			
1) Kechene weir	4,770	14,490	19,260
2) Kostre regulating pond	2,292	1,968	4,260
3) Bantyiketu regulating pond	9,425	5,455	14,880
4) Channel improvement of Bantyiketu river (*)	2,375	3,819	6,194
5) Urban development improvement	2,215	6,241	8,456
Sub-total of (1)	21,077	31,973	53,050
(2) Resettlement cost			
1) Kechene weir	0	638	638
2) Kostre regulating pond	0	0	0
3) Bantyiketu regulating pond	0	0	0
4) Channel improvement of Bantyiketu river	0	2,486	2,486
5) Urban development improvement	0	0	0
Sub-total of (2)	0	3,124	3,124
(3) Engineering services	7,162	796	7,958
(4) Administration cost	0	5,305	5,305
Total of (1) - (4)	28,239	41,198	69,437
(5) Physical contingency	5,648	8,240	13,888
Total of (1) - (5)	**33,887**	**49,438**	**83,325**

Note: - Price level; June 1997, US$ 1.0 = Birr 6.8 = J.Yen 114.7-
- Tax is included in the cost.
- (*); Cost includes repair works of a bridge abutment of the Kechene river.

Table 10.2.7 Breakdown of Construction Cost for Master Plan (1/4)

Work item	Unit	Unit price (Birr)		Baniyiketu river system																			
				Kurtume No.1 regulating pond				Kurtume No.2 regulating pond				Kurtume No.3 regulating pond				Kurtume No.4 regulating pond				Kurtume channel improvement			
				Q'ty	Amount (1,000 Birr)			Q'ty	Amount (1,000 Birr)			Q'ty	Amount (1,000 Birr)			Q'ty	Amount (1,000 Birr)			Q'ty	Amount (1,000 Birr)		
		F.C.	L.C.		F.C.	L.C.	Total		F.C.	L.C.	Total		F.C.	L.C.	Total		F.C.	L.C.	Total		F.C.	L.C.	Total
1. Preparatory works	L.S.				39	103	142		334	241	575		128	138	266		123	101	224		0	308	308
2. Earthworks																							
2.1 Clearing and stripping	m2	6	3	6,094	37	18	55	11,286	68	34	102	8,852	53	27	80	5,165	31	15	46	0	0	0	0
2.2 Excavation, common	m3	31	17	1,388	43	24	67	24,440	758	415	1,173	8,401	260	143	403	8,272	256	141	397	0	0	0	0
2.3 Excavation, river bed	m3	36	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.4 Excavation, rock, open	m3	84	24	1,388	117	33	150	24,440	2,053	587	2,640	8,401	706	202	908	8,272	695	199	894	0	0	0	0
2.5 Exc., rock, culvert invert	m3	408	102	0				0				0				0				0			
2.6 Backfill	m3	3	1	750	2	1	3	750	2	1	3	540	2	1	3	375	1	0	1	0	0	0	0
2.7 Embankment	m3	3	1	5,250	16	5	21	4,875	15	5	20	3,597	11	4	15	1,585	5	2	7	0	0	0	0
2.8 Sod facing	m2	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.9 Other works	L.S.				22	8	30		290	104	394		103	38	141		99	36	135		0	0	0
Sub-total of 2.					237	89	326		3,186	1,146	4,332		1,135	415	1,550		1,087	393	1,480		0	0	0
3. Concrete works																							
3.1 Concrete, mass	m3	147	832	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.2 Concrete, reinforced	m3	147	919	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.3 Form work	m2	23	109	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.4 Reinforcing bar, deformed	kg	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 Other works	L.S.				0	0	0		0	0	0		0	0	0		0	0	0		0	0	0
Sub-total of 3.					0	0	0		0	0	0		0	0	0		0	0	0		0	0	0
4. Masonry works																							
4.1 Wet masonry	m3	0	423	1,836	0	777	777	2,512	0	1,063	1,063	1,978	0	837	837	1,214	0	514	514	6,625	0	2,802	2,802
4.2 Gabion mattress	m3	54	230	288	16	66	82	300	16	69	85	131	7	30	37	125	7	29	36	0	0	0	0
4.3 Gravel bedding	m3	2	167	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.4 Other works	L.S.				2	84	86		2	113	115		1	87	88		1	54	55		0	280	280
Sub-total of 4.					18	927	945		18	1,245	1,263		8	954	262		8	597	605		0	3,082	3,082
5. Metal works																							
5.1 Flap gate, stainless steel	kg	306	34	402	123	14	137	402	123	14	137	402	123	14	137	402	123	14	137	0	0	0	0
5.2 Structural steel for bridge	kg	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.3 Iron pipe, dia.=1,000mm	m	4,098	455	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.4 Other works	L.S.				12	1	13		12	1	13		12	1	13		12	1	13		0	0	0
Sub-total of 5.					135	15	150		135	15	150		135	15	150		135	15	150		0	0	0
6. Tunnel works																							
6.1 Tunnel excavation	m	40,098	18,585	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.2 Other works	L.S.				0	0	0		0	0	0		0	0	0		0	0	0		0	0	0
Sub-total of 6.					0	0	0		0	0	0		0	0	0		0	0	0		0	0	0
Total of (1. - 6.)					429	1,134	1,563		3,673	2,647	6,320		1,406	1,522	2,928		1,353	1,106	2,459		0	3,390	3,390

Note: - Price level: June 1997, US$ 1.0 = Birr 6.8 = J.Yen 114.7
- Preparatory works is estimated as 10% of total permanent works.
- Work items from 1. to 5. include other works of 10% of billing amount.
- Tax is included in the cost.

Table 10.2.7 Breakdown of Construction Cost for Master Plan (2/4)

Work item	Unit	Unit price (Birr) F.C.	Unit price (Birr) L.C.	Bantyiketu river system: Kechene weir Q'ty	Kechene weir Amount (1,000 Birr) F.C.	Kechene weir L.C.	Kechene weir Total	Kostre regulating pond Q'ty	Kostre regulating pond Amount (1,000 Birr) F.C.	Kostre regulating pond L.C.	Kostre regulating pond Total	Kechene channel improvement Q'ty	Kechene channel improvement Amount (1,000 Birr) F.C.	Kechene channel improvement L.C.	Kechene channel improvement Total	Bantyiketu regulating pond Q'ty	Bantyiketu regulating pond Amount (1,000 Birr) F.C.	Bantyiketu regulating pond L.C.	Bantyiketu regulating pond Total	Bantyiketu channel improvement Q'ty	Bantyiketu channel improvement Amount (1,000 Birr) F.C.	Bantyiketu channel improvement L.C.	Bantyiketu channel improvement Total
1. Preparatory works	L.S.				434	1,319	1,753		208	180	388		0	258	258		857	496	1,353		216	344	560
2. Earthworks																							
2.1 Clearing and stripping	m2	6	3	5,702	34	17	51	9,224	55	28	83	0	0	0	0	37,002	222	111	333	0	0	0	0
2.2 Excavation, common	m3	31	17	11,028	342	187	529	14,725	456	250	706	0	0	0	0	110,745	3,433	1,883	5,316	20	1	0	1
2.3 Excavation, river bed	m3	36	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41,875	1,508	712	2,220
2.4 Excavation, rock, open	m3	84	24	19,385	1,628	465	2,093	14,725	1,237	353	1,590	0	0	0	0	47,462	3,987	1,139	5,126	0	0	0	0
2.5 Exc., rock, culvert invert	m3	408	102									0											
2.6 Backfill	m3	3	1	1,976	6	2	8	1,090	3	1	4	0	0	0	0	392	1	0	1	10	0	0	0
2.7 Embankment	m3	3	1	0	0	0	0	2,432	7	2	9	0	0	0	0	0	0	0	0	0	0	0	0
2.8 Sod facing	m2	1	6	569	1	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.9 Other works	L.S.				201	67	268		176	63	239		0	0	0		764	313	1,077		151	71	222
Sub-total of 2.					2,212	741	2,953		1,934	697	2,631		0	0	0		8,407	3,446	11,853		1,660	783	2,443
3. Concrete works																							
3.1 Concrete, mass	m3	147	832	10,473	1,540	8,714	10,254	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.2 Concrete, reinforced	m3	147	919	1,890	278	1,737	2,015	0	0	0	0	0	0	0	0	0	0	0	0	20	3	18	21
3.3 Form work	m2	23	109	3,780	87	412	499	0	0	0	0	0	0	0	0	0	0	0	0	40	1	4	5
3.4 Reinforcing bar, deformed	kg	0	7	47,250	0	331	331	0	0	0	0	0	0	0	0	0	0	0	0	500	0	4	4
3.5 Other works	L.S.				191	1,119	1,310		0	0	0		0	0	0		0	0	0		0	3	3
Sub-total of 3.					2,096	12,313	14,409		0	0	0		0	0	0		0	0	0		4	29	33
4. Masonry works																							
4.1 Wet masonry	m3	0	423	0	0	0	0	2,144	0	907	907	5,550	0	2,348	2,348	3,050	0	1,290	1,290	5,550	0	2,348	2,348
4.2 Gabion mattress	m3	54	230	461	25	106	131	315	17	72	89	0	0	0	0	314	17	72	89	0	0	0	0
4.3 Gravel bedding	m3	2	167	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.4 Other works	L.S.				3	11	14		2	98	100		0	235	235		2	136	138		0	235	235
Sub-total of 4.					28	117	145		19	1,077	1,096		0	2,583	2,583		19	1,498	1,517		0	2,583	2,583
5. Metal works																							
5.1 Flap gate, stainless steel	kg	306	34	0	0	0	0	390	119	13	132	0	0	0	0	420	129	14	143	0	0	0	0
5.2 Structural steel for bridge	kg	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,000	40	4	44
5.3 Iron pipe, dia.=1,000mm	m	4,098	455	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	410	46	456
5.4 Other works	L.S.				0	0	0		12	1	13		0	0	0		13	1	14		45	5	50
Sub-total of 5.					0	0	0		131	14	145		0	0	0		142	15	157		495	55	550
6. Tunnel works																							
6.1 Tunnel excavation	m	40,098	18,585	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.2 Other works	L.S.				0	0	0		0	0	0		0	0	0		0	0	0		0	0	0
Sub-total of 6.					0	0	0		0	0	0		0	0	0		0	0	0		0	0	0
Total of (1. - 6.)					4,770	14,490	19,260		2,292	1,968	4,260		0	2,841	2,841		9,425	5,455	14,880		2,375	3,794	6,169

Note: - Price level: June 1997, US$ 1.0= Birr 6.8= J.Yen 114.7
- Preparatory works is estimated as 10% of total permanent works.
- Work items from 1. to 5. include other works of 10% of billing amount.
- Tax is included in the cost.

Table 10.2.7 Breakdown of Construction Cost for Master Plan (3/4)

Work item	Unit	Unit price (Birr)		Bantyiketu river system				Kebena river system												Little Akaki river system			
				Urban drainage improvement				Kebena No.1 weir				Abo weir				Channel improvement				Little Akaki regulating pond			
				Q'ty	Amount (1,000 Birr)			Q'ty	Amount (1,000 Birr)			Q'ty	Amount (1,000 Birr)			Q'ty	Amount (1,000 Birr)			Q'ty	Amount (1,000 Birr)		
		F.C.	L.C.		F.C.	L.C.	Total		F.C.	L.C.	Total		F.C.	L.C.	Total		F.C.	L.C.	Total		F.C.	L.C.	Total
1. Preparatory works	L.S.				201	569	770		250	3,029	3,779		576	2,666	3,242		0	907	907		707	492	1,199
2. Earthworks																							
2.1 Clearing and stripping	m2	6	3	20,500	123	62	185	7,028	42	21	63	5,470	33	16	49	0	0	0	0	24,023	144	72	216
2.2 Excavation, common	m3	31	17	16,500	512	281	793	13,260	411	225	636	9,607	298	163	461	0	0	0	0	90,962	2,820	1,546	4,366
2.3 Excavation, river bed	m3	36	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.4 Excavation, rock, open	m3	84	24	4,125	347	99	446	20,804	1,748	499	2,247	9,073	762	218	980	0	0	0	0	39,059	3,281	937	4,218
2.5 Exc., rock, culvert invert	m3	408	102					0				0				0				0			
2.6 Backfill	m3	3	1	20,625	62	21	83	10,423	31	10	41	3,202	10	3	13	0	0	0	0	750	2	1	3
2.7 Embankment	m3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13,500	41	14	55
2.8 Sod facing	m2	1	6	0	0	0	0	598	1	4	5	534	1	3	4	0	0	0	0	0	0	0	0
2.9 Other works	L.S.				104	46	150		223	76	299		110	40	150		0	0	0		629	257	886
Sub-total of 2.					1,148	509	1,657		2,456	835	3,291		1,214	443	1,657		0	0	0		6,917	2,827	9,744
3. Concrete works																							
3.1 Concrete, mass	m3	147	832	0	0	0	0	25,943	3,814	21,585	25,399	24,683	3,628	20,536	24,164	0	0	0	0	0	0	0	0
3.2 Concrete, reinforced	m3	147	919	2,250	331	2,068	2,399	3,912	575	3,595	4,170	2,268	333	2,084	2,417	0	0	0	0	0	0	0	0
3.3 Form work	m2	23	109	19,750	454	2,153	2,607	7,824	180	853	1,033	6,938	160	756	916	0	0	0	0	0	0	0	0
3.4 Reinforcing bar, deformed	kg	0	7	46,625	0	326	326	97,805	0	685	685	56,705	0	397	397	0	0	0	0	0	0	0	0
3.5 Other works	L.S.				79	455	534		457	2,672	3,129		412	2,377	2,789		0	0	0		0	0	0
Sub-total of 3.					864	5,002	5,866		5,026	29,390	34,416		4,533	26,150	30,683		0	0	0		0	0	0
4. Masonry works																							
4.1 Wet masonry	m3	0	423	0	0	0	0	0	0	0	0	0	0	0	0	19,500	0	8,249	8,249	4,304	0	1,821	1,821
4.2 Gabion mattress	m3	54	230	0	0	0	0	250	14	58	72	267	14	61	75	0	0	0	0	300	16	69	85
4.3 Gravel bedding	m3	2	167	875	2	146	148	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.4 Other works	L.S.				0	15	15		1	6	7		1	6	7		0	825	825		2	189	191
Sub-total of 4.					2	161	163		15	64	79		15	67	82		0	9,074	9,074		18	2,079	2,097
5. Metal works																							
5.1 Flap gate, stainless steel	kg	306	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	402	123	14	137
5.2 Structural steel for bridge	kg	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.3 Iron pipe, dia.=1,000mm	m	4,098	455	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.4 Other works	L.S.				0	0	0		0	0	0		0	0	0		0	0	0		12	1	13
Sub-total of 5.					0	0	0		0	0	0		0	0	0		0	0	0		135	15	150
6. Tunnel works																							
6.1 Tunnel excavation	m	40,098	18,585	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.2 Other works	L.S.				0	0	0		0	0	0		0	0	0		0	0	0		0	0	0
Sub-total of 6.					0	0	0		0	0	0		0	0	0		0	0	0		0	0	0
Total of (1. - 6.)					2,215	6,241	8,456		8,247	33,318	41,565		6,338	29,326	35,664		0	9,981	9,981		7,777	5,413	13,190

Note: - Price level: June 1997, US$ 1.0= Birr 6.8= J.Yen 114.7
- Preparatory works is estimated as 10% of total permanent works.
- Work items from 1. to 5. include other works of 10% of billing amount.
- Tax is included in the cost.

Table 10.2.7 Breakdown of Construction Cost for Master Plan (4/4)

Work item	Unit	Unit price (Birr)		Latti Akaki river system								Hank river sytem			
				Flood diversion tunnel				Channel improvement				Channel improvement			
				Q'ty	Amount (1,000 Birr)			Q'ty	Amount (1,000 Birr)			Q'ty	Amount (1,000 Birr)		
		F.C.	L.C.		F.C.	L.C.	Total		F.C.	L.C.	Total		F.C.	L.C.	Total
1. Preparatory works	L.S.				3,565	2,489	6,054		0	314	314		20	53	73
2. Earthworks															
2.1 Clearing and stripping	m2	6	3	17,000	102	51	153	0	0	0	0	875	5	3	8
2.2 Excavation, common	m3	31	17	43,750	1,356	744	2,100	0	0	0	0	2,000	62	34	96
2.3 Excavation, river bed	m3	36	17	0	0	0	0	0	0	0	0	0	0	0	0
2.4 Excavation, rock, open	m3	84	24	43,750	3,675	1,050	4,725	0	0	0	0	625	53	15	68
2.5 Exc., rock, culvert invert	m3	408	102	0				0				0			
2.6 Backfill	m3	3	1	0	0	0	0	0	0	0	0	1,750	5	2	7
2.7 Embankment	m3	3	1	0	0	0	0	0	0	0	0	0	0	0	0
2.8 Sod facing	m2	1	6	0	0	0	0	0	0	0	0	0	0	0	0
2.9 Other works	L.S.				513	185	698		0	0	0		13	5	18
Sub-total of 2.					5,646	2,030	7,676		0	0	0		138	59	197
3. Concrete works															
3.1 Concrete, mass	m3	147	832	0	0	0	0	0	0	0	0	0	0	0	0
3.2 Concrete, reinforced	m3	147	919	4,375	643	4,021	4,664	0	0	0	0	250	37	230	267
3.3 Form work	m2	23	109	24,500	564	2,671	3,235	0	0	0	0	750	17	82	99
3.4 Reinforcing bar, deformed	kg	0	7	109,375	0	766	766	0	0	0	0	16,625	0	116	116
3.5 Other works	L.S.				121	746	867		0	0	0		5	43	48
Sub-total of 3.					1,328	8,204	9,532		0	0	0		59	471	530
4. Masonry works															
4.1 Wet masonry	m3	0	423	2,875	0	1,216	1,216	6,750	0	2,855	2,855	0	0	0	0
4.2 Gabion mattress	m3	54	230	125	7	29	36	0	0	0	0	0	0	0	0
4.3 Gravel bedding	m3	2	167	0	0	0	0	0	0	0	0	0	0	0	0
4.4 Other works	L.S.				1	125	126		0	286	286		0	0	0
Sub-total of 4.					8	1,370	1,378		0	3,141	3,141		0	0	0
5. Metal works															
5.1 Flap gate, stainless steel	kg	306	34	0	0	0	0	0	0	0	0	0	0	0	0
5.2 Structural steel for bridge	kg	10	1	0	0	0	0	0	0	0	0	0	0	0	0
5.3 Iron pipe, dia.=1,000mm	m	4,098	455	0	0	0	0	0	0	0	0	0	0	0	0
5.4 Other works	L.S.				0	0	0		0	0	0		0	0	0
Sub-total of 5.					0	0	0		0	0	0		0	0	0
6. Tunnel works															
6.1 Tunnel excavation	m	40,098	18,585	650	26,064	12,080	38,144	0	0	0	0	0	0	0	0
6.2 Other works	L.S.				2,606	1,208	3,814		0	0	0		0	0	0
Sub-total of 6.					28,670	13,288	41,958		0	0	0		0	0	0
Total of (1. - 6.)					39,217	27,381	66,598		0	3,455	3,455		217	583	800

Note: - Price level: June 1997, US$ 1.0= Birr 6.8= J.Yen 114.7
- Preparatory works is estimated as 10% of total permanent works.
- Work items from 1. to 5. include other works of 10% of billing amount.
- Tax is included in the cost.

Table 10.2.8 Breakdown of Construction Cost of Priority Project

Work item	Unit	Unit price (Birr) F.C	Unit price (Birr) L.C	Kechene river: Kechene weir Q'ty	Amount (1,000 Birr) F.C	L.C	Total	Kechene river: Kostre regulating pond Q'ty	Amount (1,000 Birr) F.C	L.C	Total
1. Preparatory works	L.S.				434	1,319	1,753		208	180	388
2. Earthworks											
2.1 Clearing and stripping	m2	6	3	5,702	34	17	51	9,224	55	28	83
2.2 Excavation, common	m3	31	17	11,028	342	187	529	14,725	456	250	706
2.3 Excavation, river bed	m3	36	17	0	0	0	0	0	0	0	0
2.4 Excavation, rock	m3	84	24	19,385	1,628	465	2,093	14,725	1,237	353	1,590
2.5 Backfill	m3	3	1	1,976	6	2	8	1,090	3	1	4
2.6 Embankment	m3	3	1	0	0	0	0	2,432	7	2	9
2.7 Sod facing	m2	1	6	569	1	3	4	0	0	0	0
2.8 Other works	L.S.				201	67	268		176	63	239
Sub-total of 2.					2,212	741	2,953		1,934	697	2,631
3. Concrete works											
3.1 Concrete, mass	m3	147	832	10,473	1,540	8,714	10,254	0	0	0	0
3.2 Concrete, reinforced	m3	147	919	1,890	278	1,737	2,015	0	0	0	0
3.3 Form work	m2	23	109	3,780	87	412	499	0	0	0	0
3.4 Reinforcing bar	kg	0	7	47,250	0	331	331	0	0	0	0
3.5 Other works	L.S.				191	1,119	1,310		0	0	0
Sub-total of 3.					2,096	12,313	14,409		0	0	0
4. Masonry works											
4.1 Wet masonry	m3	0	423	0	0	0	0	2,144	0	907	907
4.2 Gabion mattress	m3	54	230	461	25	106	131	315	17	72	89
4.3 Gravel bedding	m3	2	167	0	0	0	0	0	0	0	0
4.4 Other works	L.S.				3	11	14		2	98	100
Sub-total of 4.					28	117	145		19	1,077	1,096
5. Metal works											
5.1 Flap gate, stainless steel	kg	306	34	0	0	0	0	390	119	13	132
5.2 Structural steel for bridge	kg	10	1	0	0	0	0	0	0	0	0
5.3 Iron pipe, dia.=1,000mm	m	4,098	455	0	0	0	0	0	0	0	0
5.4 Other works	L.S.				0	0	0		12	1	13
Sub-total of 5.					0	0	0		131	14	145
Total of (1. - 5.)					4,770	14,490	19,260		2,292	1,968	4,260

Work item	Bantyketu river: Bantyketu regulating pond Q'ty	Amount (1,000 Birr) F.C	L.C	Total	Bantyketu river: Channel improvement Q'ty	Amount (1,000 Birr) F.C	L.C	Total	Bantyketu river: Urban drainage improvement Q'ty	Amount (1,000 Birr) F.C	L.C	Total	Total: Amount (1,000 Birr) F.C	L.C	Total
1. Preparatory works		852	496	1,352		216	346	562		201	569	770	1,916	2,910	4,826
2. Earthworks															
2.1 Clearing and stripping	37,002	222	111	333	0	0	0	0	20,500	123	62	185	434	218	652
2.2 Excavation, common	110,745	3,433	1,883	5,316	20	1	0	1	16,500	512	281	793	4,744	2,601	7,345
2.3 Excavation, river bed	0	0	0	0	41,875	1,508	712	2,220	0	0	0	0	1,508	712	2,220
2.4 Excavation, rock	47,462	3,987	1,139	5,126	0	0	0	0	4,125	347	99	446	7,199	2,056	9,255
2.5 Backfill	392	1	0	1	10	0	0	0	20,625	62	21	83	72	24	96
2.6 Embankment	0	0	0	0	0	0	0	0	0	0	0	0	7	2	9
2.7 Sod facing	0	0	0	0	0	0	0	0	0	0	0	0	1	3	4
2.8 Other works		764	313	1,077		151	71	222		104	46	150	1,396	560	1,956
Sub-total of 2.		8,407	3,446	11,853		1,660	783	2,443		1,148	509	1,657	15,361	6,176	21,537
3. Concrete works															
3.1 Concrete, mass	0	0	0	0	0	0	0	0	0	0	0	0	1,540	8,714	10,254
3.2 Concrete, reinforced	0	0	0	0	20	3	18	21	2,250	331	2,068	2,399	612	3,823	4,435
3.3 Form work	0	0	0	0	40	1	4	5	19,750	454	2,153	2,607	542	2,569	3,111
3.4 Reinforcing bar	0	0	0	0	500	0	4	4	46,625	0	326	326	0	661	661
3.5 Other works		0	0	0		0	3	3		79	455	534	270	1,577	1,847
Sub-total of 3.		0	0	0		4	29	33		864	5,002	5,866	2,964	17,344	20,308
4. Masonry works															
4.1 Wet masonry	3,050	0	1,290	1,290	5,600	0	2,369	2,369	0	0	0	0	0	4,566	4,566
4.2 Gabion mattress	314	17	72	89	0	0	0	0	0	0	0	0	59	250	309
4.3 Gravel bedding	0	0	0	0	0	0	0	0	875	2	146	148	2	146	148
4.4 Other works		2	136	138		0	237	237		0	15	15	7	497	504
Sub-total of 4.		19	1,498	1,517		0	2,606	2,606		2	161	163	68	5,459	5,527
5. Metal works															
5.1 Flap gate, stainless steel	420	129	14	143	0	0	0	0	0	0	0	0	248	27	275
5.2 Structural steel for bridge	0	0	0	0	4,000	40	4	44	0	0	0	0	40	4	44
5.3 Iron pipe, dia.=1,000mm	0	0	0	0	100	410	46	456	0	0	0	0	410	46	456
5.4 Other works		13	1	14		45	5	50		0	0	0	70	7	77
Sub-total of 5.		142	15	157		495	55	550		0	0	0	768	84	852
Total of (1. - 5.)		9,425	5,455	14,880		2,375	3,819	6,194		2,215	6,241	8,456	21,077	31,973	53,050

Note:
- Price level: June 1997, US$ 1.0= Birr 6.8= J.Yen 114.7
- Preparatory works is estimated as 10% of total permanent works.
- Work items from 1. to 5. include other works of 10% of billing amount.

Table 10.2.9 Installation Cost of Non-structural Measures

Item	Unit	Unit price (Birr)	Bantyiketu river system Q'ty	Bantyiketu river system Amount (1,000 Birr)	Kebena river system Q'ty	Kebena river system Amount (1,000 Birr)	Little Akaki river system Q'ty	Little Akaki river system Amount (1,000 Birr)	Hanku river system Q'ty	Hanku river system Amount (1,000 Birr)	Total (1,000 Birr)
1. River management											
1) Public awareness and enhancement											
- Staking, @10m, both sides	m	30	3,200	96	1,200	36	1,600	48	0	0	180
2. Watershed management											
1) Forestation											
- Nursery preparation	m2	2	11,000	22	23,000	46	12,000	24	4,000	8	100
3. Flood risk management											
1) Flood warning system											
- Rainfall observatory station	no.	30,000	1	30	1	30	1	30	0	0	90
- Telephone	no.	600	1	1	1	1	1	1	0	0	3
- System line	m	8	19,000	152	9,000	72	11,000	88	1,500	12	324
- Support, @12m	no.	350	1,583	554	750	263	917	321	125	44	1,182
- Tower with siren	no.	65,000	32	2,080	12	780	16	1,040	0	0	3,900
Sub-total				2,817		1,146		1,480		56	5,499
2) Flood fighting system											
- Storage house, 100m2	no.	100,000	6	600	2	200	3	300	1	100	1,200
Total of 3.				3,417		1,346		1,780		156	6,699
Total of (1. - 3.)				**3,535**		**1,428**		**1,852**		**164**	**6,979**
4. Physical contingency				707		286		370		33	1,396
Total of (1. - 4.)				**4,242**		**1,714**		**2,222**		**197**	**8,375**

Note:
- All the cost is counted in local currency portion.
- Price level: June 1997, US$ 1.0 = Birr 6.8 = J.Yen 114.7-
- Tax is included in the cost.

Table 10.2.10 Project Cost of Structural Measures

(Unit: 1,000 Birr)

	F/C	L/C	Total
1. Bantyiketu river system			
(1) Construction cost	27,938	44,588	72,526
(2) Resettlement cost	0	7,359	7,359
(3) Engineering services	9,791	1,088	10,879
(4) Administration cost	0	7,253	7,253
Total of (1) - (4)	**37,729**	**60,288**	**98,017**
(5) Contingency	7,546	12,058	19,604
Total of (1) - (5)	**45,275**	**72,346**	**117,621**
(6) Price escalation	6,981	23,978	30,959
Total of (1) - (6)	**52,256**	**96,324**	**148,580**
2. Kebena river system			
(1) Construction cost	14,585	72,625	87,210
(2) Resettlement cost	0	4,297	4,297
(3) Engineering services	11,774	1,308	13,082
(4) Administration cost	0	8,721	8,721
Total of (1) - (4)	**26,359**	**86,951**	**113,310**
(5) Contingency	5,272	17,390	22,662
Total of (1) - (5)	**31,631**	**104,341**	**135,972**
(6) Price escalation	25,225	230,879	256,104
Total of (1) - (6)	**56,856**	**335,220**	**392,076**
3. Little Akaki river system			
(1) Construction cost	46,994	36,249	83,243
(2) Resettlement cost	0	2,946	2,946
(3) Engineering services	11,237	1,249	12,486
(4) Administration cost	0	8,324	8,324
Total of (1) - (4)	**58,231**	**48,768**	**106,999**
(5) Contingency	11,646	9,754	21,400
Total of (1) - (5)	**69,877**	**58,522**	**128,399**
(6) Price escalation	26,674	52,928	79,602
Total of (1) - (6)	**96,551**	**111,450**	**208,001**
4. Hanku river system			
(1) Construction cost	217	583	800
(2) Resettlement cost	0	0	0
(3) Engineering services	108	12	120
(4) Administration cost	0	80	80
Total of (1) - (4)	**325**	**675**	**1,000**
(5) Contingency	65	135	200
Total of (1) - (5)	**390**	**810**	**1,200**
(6) Price escalation	215	1,124	1,339
Total of (1) - (6)	**605**	**1,934**	**2,539**
5. Whole of master plan			
(1) Construction cost	89,734	154,045	243,779
(2) Resettlement cost	0	14,602	14,602
(3) Engineering services	32,910	3,657	36,567
(4) Administration cost	0	24,378	24,378
Total of (1) - (4)	**122,644**	**196,682**	**319,326**
(5) Contingency	24,529	39,337	63,866
Total of (1) - (5)	**147,173**	**236,019**	**383,192**
(6) Price escalation	59,095	308,909	368,004
Total of (1) - (6)	**206,268**	**544,928**	**751,196**

Note: - Price level; June 1997, US$ 1.0 = Birr 6.8 = J.Yen 114.7
- Tax is included in the cost.

Table 10.2.11 Project Cost of Non-structural Measures

(Unit: 1,000 Birr)

Item	Bantyitetu river system	Kebena river system	Little Akaki river system	Hanku river system	Total
1. River management	96	36	48	0	180
2. Watershed management	22	46	24	8	100
3. Flood risk management	3,417	1,346	1,780	156	6,699
Total of (1. - 3.)	**3,535**	**1,428**	**1,852**	**164**	**6,979**
4. Physical contingency	707	286	370	33	1,396
Total of (1. - 4.)	**4,242**	**1,714**	**2,222**	**197**	**8,375**
5. Price escalation	1,773	716	929	82	3,500
Total of (1. - 5.)	**6,015**	**2,430**	**3,151**	**279**	**11,875**

Note: - All the cost is counted in local currency portion.
- Price level; June 1997, US$ 1.0 = Birr 6.8 = J.Yen 114.7
- Tax is included in the cost.

Table 10.2.12 Project Cost of Priority Projects

(Unit: 1,000 Birr)

	F/C	L/C	Total
(1) Construction cost	21,077	31,973	53,050
(2) Resettlement cost	0	3,124	3,124
(3) Engineering services	7,162	796	7,958
(4) Administration cost	0	5.305	5,305
Total of (1) - (4)	**28,239**	**41,198**	**69,437**
(5) Contingency	5,648	8,240	13,888
Total of (1) - (5)	**33,887**	**49,438**	**83,325**
(6) Price escalation	3,922	12,236	16,158
Total of (1) - (6)	**37,809**	**61,674**	**99,483**

Note: - Price level; June 1997, US$ 1.0 = Birr 6.8 = J.Yen 114.7
- Price escalation is calculated with annual escalation ratio of 3% for foreign currency portion and of 6% for local currency portion.
- Tax is included in the cost.

Table 10.2.13 Annual O&M Cost for Structural Measures

	Unit	Q'ty	Unit price (Birr) F/C	Unit price (Birr) L/C	Amount (1,000 Birr) F/C	Amount (1,000 Birr) L/C	Amount (1,000 Birr) Total
1. Bantyiketu river system							
(1) Annual cost (0.5% of construction cost)	L.S.				0	363	363
(2) Annual reserve for replacement of gate	no.	6	6,800	700	41	4	45
(1 gate= Birr 150,000/20 years replacement cycle= Birr 7,500/year)							
Total of 1.					**41**	**367**	**408**
2. Kebena river system							
(1) Annual cost (0.5% of construction cost)	L.S.				0	437	437
(2) Annual reserve for replacement of gate	no.	0	6,800	700	0	0	0
(1 gate= Birr 150,000/20 years replacement cycle= Birr 7,500/year)							
Total of 2.					**0**	**437**	**437**
3. Little Akaki river system							
(1) Annual cost (0.5% of construction cost)	L.S.				0	416	416
(2) Annual reserve for replacement of gate	no.	1	6,800	700	7	1	8
(1 gate= Birr 150,000/20 years replacement cycle= Birr 7,500/year)							
Total of 3.					**7**	**417**	**424**
4. Hanku river system							
(1) Annual cost (0.5% of construction cost)	L.S.				0	4	4
(2) Annual reserve for replacement of gate	no.	0	6,800	700	0	0	0
(1 gate= Birr 150,000/20 years replacement cycle= Birr 7,500/year)							
Total of 4.					**0**	**4**	**4**
5. Whole of structural measures							
(1) Annual cost (0.5% of construction cost)	L.S.				0	1,220	1,220
(2) Annual reserve for replacement of gate	no.	7			48	5	53
Total of 5.					**48**	**1,225**	**1,273**

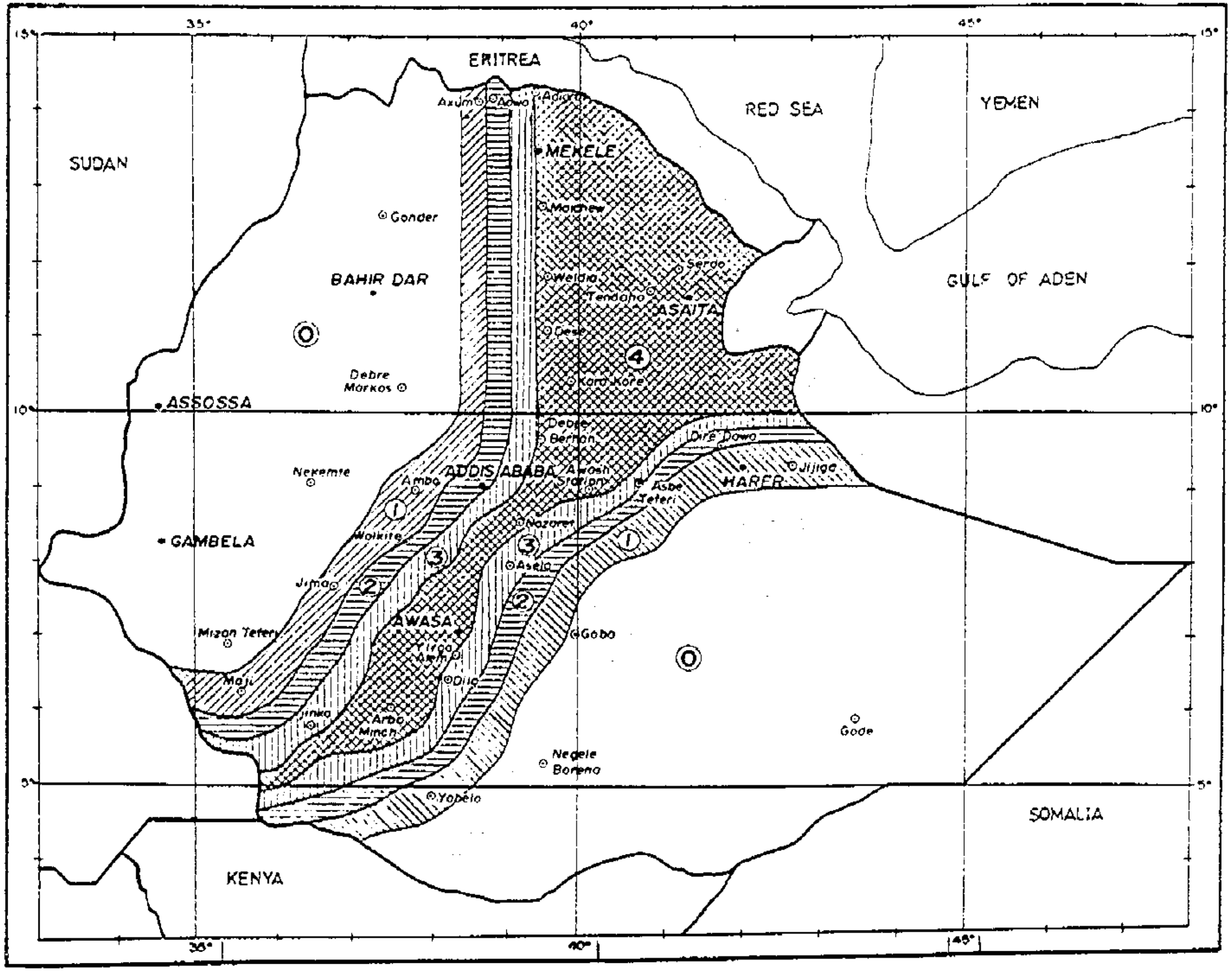
Note: Price level; June 1997, US$ 1.0 = Birr 6.8 = J.Yen 114.7
Tax is included in the cost.

Table 10.2.14 Annual O&M Cost for Non-structural Measures

(Unit: Birr)

	Unit	Q'ty	Unit price F/C	Unit price L/C	Amount F/C	Amount L/C	Amount Total
1. Bantyiketu river system							
(1) River management (Public awareness and enhancement)							
- Staking, @10m, both sides	m	32	0	30	0	960	960
(2) Watershed measures (Reforestation)							
- Nursery maintenance	ha	1.1	0	300	0	330	330
- Transplanting	ha	110	0	250	0	27,500	27,500
Sub-total of (2)					0	27,830	27,830
Total of 1.					**0**	**28,790**	**28,790**
2. Kebena river system							
(1) River management (Public awareness and enhancement)							
- Staking, @10m, both sides	m	12	0	30	0	360	360
(2) Watershed measures (Reforestation)							
- Nursery maintenance	ha	2.3	0	300	0	690	690
- Transplanting	ha	230	0	250	0	57,500	57,500
Sub-total of (2)					0	58,190	58,190
Total of 2.					**0**	**58,550**	**58,550**
3. Little Akaki river system							
(1) River management (Public awareness and enhancement)							
- Staking, @10m, both sides	m	16	0	30	0	480	480
(2) Watershed measures (Reforestation)							
- Nursery maintenance	ha	1.2	0	300	0	360	360
- Transplanting	ha	120	0	250	0	30,000	30,000
Sub-total of (2)					0	30,360	30,360
Total of 3.					**0**	**30,840**	**30,840**
4. Hanku river system							
(1) River management (Public awareness and enhancement)							
- Staking, @10m, both sides	m	0	0	30	0	0	0
(2) Watershed measures (Reforestation)							
- Nursery maintenance	ha	0.4	0	300	0	120	120
- Transplanting	ha	40	0	250	0	10,000	10,000
Sub-total of (2)					0	10,120	10,120
Total of 4.					**0**	**10,120**	**10,120**
5. Whole of structural measures							
(1) River management (Public awareness and enhancement)							
- Staking, @10m, both sides	m	60			0	1,800	1,800
- Publicity of bylaw (*)	no.	2000	0	10	0	20,000	20,000
- Poster of "Love Rivers" (*)	no.	30	0	100	0	3,000	3,000
Sub-total of (1)					0	24,800	24,800
(2) Watershed measures (Reforestation)							
- Nursery maintenance	ha	5.0			0	1,500	1,500
- Transplanting	ha	500			0	125,000	125,000
Sub-total of (2)					0	126,500	126,500
Total of 5.					**0**	**151,300**	**151,300**

Note:
- The two items marked (*) are common activities for the whole of river systems.
- Price level; June 1997, US$ 1.0 = Birr 6.8 = J.Yen 114.7
- Tax is included in the cost.



(Source : Ethiopian Building Code Standard. EBCS-8. DESIGN OF STRUCTURES FOR EARTHQUAKE RESISTANCE. Ministry of Works and Urban Development. Addis Ababa. Ethiopia. 1995)

Fig.10.1.1 Seismic Hazard Map of Ethiopia