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MINISTRY OF WATER DEVELOPMENT

THE STUDY

ON

THE NATIONAL WATER MASTER PLAN

SECTORAL REPORT
(G)

FLOOD CONTROL PLAN

JULY 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

Interpretation of Report

The original objective of this NWMP Study is to propose a nationwide framework for orderly planning and development of water resources in the country. The Study also deals with the formulation of individual development schemes. However, it should be noted that the plans formulated in this Study remain at a national level and do not provide complete details at local level. Further details should be examined in subsequent studies on each river basin, district, and project basis which are separately recommended in this Study.

Administrative Division of Districts

In this Study, the original 41 districts were considered and various statistical data, particularly socio-economic information, were collected for these districts. During the progress of the Study, six districts were detached from the original ones and established as new districts. In the report, the data on these new districts are grouped together with the corresponding original districts as shown below.

	Original Districts	New Districts	Data included in:
1.	Machakos	Makueni	Machakos/Makueni
2.	Kisii	Nyamira	Kisii/Nyamira
3.	Kakamega	Vihiga	Kakamega/Vihiga
4.	Meru	Tharaka-Nithi	Meru/Tharaka-Nithi
5.	Kericho	Bomet	Kericho/Bomet
6.	South Nyanza	Migori	South Nyanza/Migori

(Note: The last three Districts were established very recently.
The report refers only to the names of the original 41 districts.)

The administrative boundary map used in this Study is the latest complete map set covering the whole country (41 Districts, 233 Divisions and 976 Locations), prepared in 1986 by the Survey of Kenya, Ministry of Land, Housing and Physical Planning.

Data and Information

The data and information contained in the report represent those collected in the 1990-1991 period from various documents and reports made available mostly from central government offices in Nairobi and/or those analyzed in this Study based on the collected data. Some of them may be different from those kept in files at some agencies and regional offices. Such discrepancies if any should be collated and adjusted as required in further detailed studies of the relevant development projects.

Development Cost

The cost and benefit estimate was based on the 1991 price level, and expressed in US$ equivalent according to the exchange rate of US$1 = KShs25.2 prevailing at that time. The same exchange rate was used in calculating the development cost in K£/KShs currency.

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G1. INTRODUCTION

Rivers in Kenya, as a whole, are still in their natural state. They have not been intensively utilized by people. There are two major perennial rivers in the central-southeastern part; the Tana and Athi rivers, both flowing into Indian Ocean. A number of rivers pour into the Lake Victoria; while in the ASAL area sharing a greater part of the country, rivers are commonly seasonal.

The issue of floods has not been a serious problem in Kenya because of few human activities in flood-prone areas. However, to cope with the growing development of the country, a need for the establishment of an overall flood protection plan covering the whole territory has been recognized. In this context, this Sectoral Report G - Flood Protection Plan deals with problems on rivers, especially flood issues, and intends to formulate flood protection plans for areas/rivers in question. The contents of the report are as follows:

(1) Chapter G2 describes present conditions relevant to rivers such as the division of drainage areas, characteristics of rivers and major issues on rivers;

(2) Chapter G3 compiles and analyzes flood records as well as flood protection projects proposed to date;

(3) Chapter G4 describes flood protection plans for the selected target areas inclusive of cost estimates;

(4) Chapter G5 assesses flood damage reductions, namely benefits accrued from the flood protection projects;

(5) Chapter G6 evaluates each of the flood protection projects from the viewpoint of economy and social requirement;

(6) Chapter G7 proposes the other river related works needing the appropriation of budgetary resources,

(7) Chapter G8 proposes an implementation schedule of the flood protection projects to be realized under the scope of the proposed Master Plan; and

(8) Chapter G9 discusses some recommendations.

G2. PRESENT CONDITIONS

2.1 Drainage Areas

The territory of the Republic of Kenya is broadly divided into the following five major drainage areas (see Fig. G2.1):

(1) Lake Victoria Basin; No.1 Area (46,229 km^2)

This comprises the whole area west of the Rift Valley which mainly drains into the Lake Victoria by a number of rivers such as Nzoia, Yala, Nyando, Sondu and Kuja.

(2) Rift Valley Basin; No.2 Area (130,452 km^2)

This basin consists of a number of closed basins. Two major basins in terms of area are those discharging into Lake Turkana in the north through the Turkwel and Kerio rivers mainly, and into Lake Natron in the south through the Ewaso Ngiro South River. Within this area, there are also several river basins discharging into smaller lakes such as Baringo, Bogoria, Nakuru, Elementeita, Naivasha, and Magadi.

(3) Athi River Basin; No.3 Area (66,837 km^2)

This comprises the southern part of the country east of the Rift Valley, and drains the southern slopes of the Aberdare Range and the flanks of the Rift Valley, to form the Athi River finally flowing into the Indian Ocean.

(4) Tana River Basin; No.4 Area (126,026 km^2)

This drains the eastern slopes of the Aberdare Range, the southern slopes of Mt. Kenya and the Nyambeni Hills, and discharges through the Tana River into the Indian Ocean.

(5) Ewaso Ngiro North River Basin; No.5 Area (210,226 km^2)

This comprises the northern part of Kenya, and drains the northern slopes of the Aberdare Range and Mt. Kenya. Even during flood season the river flow of Ewaso Ngiro North is absorbed in Lorian Swamp, though in some years the flow continues to Juba River in Somalia where flooding occurs.

2.2 Rivers

Main features of 12 major rivers listed below are presented in Table G2.1. The information was derived from studies on topographic maps of 1:50,000 scale and relevant reports as well as interview surveys and field reconnaissance. The longitudinal profiles of the major rivers are also prepared based on 1:50,000 topographic maps as shown in Figure G2.2.

Lake Victoria Basin

(1) Nzoia River
(2) Yala River
(3) Nyando River
(4) Sondu River
(5) Kuja River
(6) Mara River

Rift Valley Basin

(7) Turkwel River
(8) Kerio River
(9) Ewaso Ngiro South River

Athi River Basin

(10) Athi River	- Upper reach	a) Upper Athi River
		b) Nairobi River
		c) Ndarugu River
	- Middle reach	a) Middle reach of Athi River
		b) Thwake River
	- Lower reach	a) Galana/Sabaki Rivers
		b) Tsavo River

Tana River Basin

(11) Tana River	- Upper reach	a) Mathioya/Sagana Rivers
		b) Chania River
		c) Thiba River
	- Middle reach	a) Mutonga River
		b) Kazita River
	- Lower reach	

Ewaso Ngiro North River Basin

(12) Ewaso Ngiro North River

Rivers in Kenya are broadly classified into two types. One is the perennial type of river mostly in the central-western part of the country. The other is the seasonal type in ASAL areas; so-called lagas, mostly in the northern part, whose river channels, at least in the lower reaches, contain flowing water only during flood time. Although the latter type of rivers also cause flooding in their riverine areas, it is still not a prominent problem because of less human activities in the ASAL areas. In this context, present conditions of rivers are discussed hereunder focusing mainly on the former type of rivers in the central-western part of the country.

Rivers in the central-western part flow mostly in mountainous or hilly areas (or highlands), with only small alluvium plains, sometimes fans, at their rivermouths. The Nzoia (together with Yala), Nyando and Tana rivers exceptionally form relatively large plains in the downmost reaches, named Yala Swamp Area, Kano Plain and Lower Tana Area, respectively. A steep gradient of riverbed is a characteristic of rivers in the central-western part. Gradient of less than 1/1,000 of is rarely found in most of the rivers, except in the lower reaches of Nzoia, Yala, Athi and Tana.

From the viewpoint of river morphology, most rivers in the central-western part are characterized by heavy meandering not only in the lower reaches but also on the valley bottoms in the upper reaches. Some river stretches, which appear to carry a lot of bed loads, are of braiding type; e.g., the middle stretches of Turkwel, Kerio and Tana, and the lower stretches of Athi. The widths of river channels are generally narrow compared to the catchment area, which may be attributed to less specific discharge even in flood time.

Owing to the topography surrounding rivers in the central-western part, flood-prone areas are limited in the downmost reaches and narrow riverine areas along the middle/upper reaches. Parts of the flood-prone areas are rather intensively cultivated; especially in Yala Swamp, Kano Plain and other rivermouth areas in the Lake Victoria Basin. On the contrary, only subsistence agriculture and grazing take place in other areas.

2.3 Major Issues on Rivers

There are several issues on rivers in Kenya as identified through interview surveys and field reconnaissance.

The issues can be grouped into two categories: namely, (i) issues on watersheds and (ii) issues on river channels and flood-prone areas, which are discussed below.

Issues on Watersheds

Watershed Erosion and Deforestation

Watershed erosion is broadly observed over the country in the form of gully, rill and sheet erosion. Erosion has certainly caused many serious problems for the country, namely,

(a) Decrease of fertile soils on agricultural lands, such as;
- soil degradation due to direct exposure, where gulleys run parallel to the contours
- change of soil strictures due to aggravation of stability and porosity
- decline of organic matters content causing decrease in nutrient storing capacity of soil due to percolation

(b) Deterioration of the water retaining and infiltration capacity of the ground;

(c) Siltation of reservoirs; and

(d) Turbidity of river water.

To reduce soil erosions, several countermeasures such as terracing, cutoff drains and check dams have been practiced in some places with reasonable success.

Extensive deforestation has been progressing in parts of mountainous areas due to encroachment of agricultural activities and logging. It tends to have a significant impact on the environment of watersheds.

Issues on Rivers and Flood-prone Areas

(1) Flood and Bank Erosion

There are a number of places where flooding and bank erosion constitute a serious problem.

The details are described in the succeeding chapters of this report.

(2) Urban Inundation

Inundation sometimes takes place in urban areas, especially in Nairobi and Mombasa. It usually lasts a couple of hours, causing traffic interruption and hampering the function of cities. This is due to poor storm drainage systems and insufficient maintenance thereof, which should be improved to enhance the economy and welfare of urban areas.

(3) Difficulty in River Water Utilization

From the standpoints of river water utilization, most rivers in Kenya are characterized by such negative features as:

(a) Large imbalance of discharge between the dry and rainy seasons which prevents steady water abstraction;

(b) Low water stage in the dry season which require pumping for water abstraction;

(c) Instability of river channels due to meandering or braiding which makes the construction of bridges, intake facilities and other river structures to be somewhat difficult;

(d) Steep riverbed gradients, except in the Lower Tana, which impedes navigation along rivers;

(e) Large amount of sediment causing devastation of river courses and siltation of reservoirs; and

(f) Turbid river water causes the maintenance of intake facilities and purification plants costly whereas brackish water intrusion is rarely observed in the rivers.

This report chiefly deals with flood issues together with bank erosion in view of its relative importance among problems related to the river.

G3. FLOOD RECORDS

3.1 Chronology of Flood Events

Flood records are sparsely documented in Kenya. Table G3.1 is a chronology of flood events obtained from relevant reports, interview survey and field reconnaissance as well as interpretation of water level records at gauging stations. According to the table, the 1961-flood was probably the biggest in the last 30 years. The flood, often called Uhuru Rains, caused serious damage over the country (whose features are described later). Other noteworthy events were floods in 1963/64, 1968, 1977/78, 1982, 1985, 1988 and 1990. These floods mainly hit the Lake Victoria Basin and the coastal area (Athi, Lumi, Tana river basins, etc.). However, the detailed features have not been well recorded.

The Grundy Report on the 1961 flood (Ref.G.1) is the only record reporting the actual condition/damage caused by a flood. The report is hence very helpful to show the general features of flood and damage in Kenya; a summary of which is quoted hereunder:

During the latter part of 1961, floods of unusual intensity and duration were experienced in most areas of the country. The channels of many rivers were inadequate to contain the flood waters, which spread over their valleys and inundated large areas of low-lying land. Many bridges were destroyed or submerged for periods of days, and numerous road and railway embankments were breached or washed away. Damages caused by the 1961 flood were as follows:

(1) The flood inundated the Kano Plain, Yala Swamp and other low-lying areas around Lake Victoria. The inundation area was approximated to be as large as 250 km^2, excluding permanently swampy areas. Serious damage took place along the Nzoia, Yala and Nyando rivers. The inundation was reportedly aggravated by the rising of water stage of Lake Victoria, which has been about 1.3 m higher since then.

(2) The flood also hit the Lower Tana reaches. About 500 km^2 of land near Garissa was inundated by flood waters. At Garsen, the plains were submerged under as much as 2 m of water and inundation was observed to be up to 13 km in width.

(3) The bridge spanning the Athi River north of Malindi was carried downstream by the flood. This bridge has been re-constructed so high as not to be submerged under any flood water.

3.2 Collection of Flood Data

There are, as mentioned before, few documents or reports on flood condition and damage as well as existing flood protection works in Kenya. In this study, the following data collection was attempted:

(1) Distribution of Questionnaires

To collect information on past flood damage and riparian structures either existing or planned; Questionnaires were distributed to ministries/ authorities concerned and their local offices. The answers to the questionnaires received from 28 district offices are compiled by district as Appendix G1 "RECORD ON PAST FLOOD DAMAGE" and Appendix G2 "RECORD ON RIPARIAN STRUCTURES".

The data is quite important to interpret the river conditions, especially on flood damage and riparian structures. It is recommended that the data files be updated annually by MOWD with additional information collected.

(2) Interview Survey and Field Reconnaissance

Interview survey as well as field reconnaissance was carried out not only to complete the above answers but to identify general situation of flood condition and damage in respective areas. The interview survey was performed at seven provincial water offices of MOWD, the headquarters of TARDA, KVDA and LBDA, and other site offices concerned. The results of the survey are included in Table G3.2.

3.3 Flood Condition and Damage

Based on the result of the interview survey summarized in Table G3.2, the flood condition and damage of respective areas were categorized as shown in Table G3.3, classifying into four relative damage-potential levels (based on damage experienced in the past) and four relative flood area classes. The former classification may represent an index of flood damage intensity under existing land use condition, while the latter the potential flood damage under future land use condition. According to Table G3.3, the following are concluded:

(1) Most serious damage takes place in Kano Plain, as reported in many previous reports, mainly due to flooding from the Nyando River. The flooding causes severe damages almost every year not only to farmlands and grazings but also to human settlements in the plain.

(2) The next severe area may be Yala Swamp, which is affected by the combination of floods from the Nzoia and Yala rivers. The damage potential is foreseen to increase in progress of the expansion of Yala Swamp farming.

(3) The rivermouth areas of Sondu, Kuja and Lumi rivers are also damaged by floods almost every year. Although the areas are smaller than the above two, the degree of damage is considerably greater.

(4) Intensive rains often hit Nairobi and Mombasa urban areas, causing not only flooding along riverine areas of small rivers but also traffic interruption even at

main roads. This is, as indicated in Ref. 2, due to not only insufficient flow capacities of bridges/culverts but also the lack of maintenance of drain and hence blocking of manhole. It is important to check the flow capacity of drain when it is properly maintained. Such flooding and traffic interruption are one of factors hampering economic activities of these two major cities.

(5) There are large flood area along the Lower Tana: as long as 650 km from the rivermouth up to Kora hills with approximately 5 km of width on an average. However, human settlements and farmlands are mostly situated on natural levees generally a couple of meters higher than the flood plain. Less human activity has developed in the plain so far. On the other hand, the Tana River is notorious for its heavy meandering, with bank erosion at concave portions and local deposition at convex portions, sometimes leaving oxbow lakes in the flood plain. Thus, damage recorded is mainly attributed to bank erosion, particularly near villages and at intake structures and bridges.

(6) The Middle/Lower Turkwel and Downmost Athi have flood areas along the river banks where minor farming and grazing are practiced.

(7) Small flood areas, with low damage, exist in the lower reaches of Malakisi, Sio, Awach Tende, Lambwe, Malewa, Molo and Daua rivers,and parts of Muranga, Nyandarua and Embu districts. Submergency, sometimes destruction, of bridges is a characteristic of the damage in this category.

(8) Flooding in the Middle/Lower Ewaso Ngiro North and the Lower Kerio occurs in considerably large areas. Nevertheless, the damages are usually of a minor extent due to less human activity thereat.

(9) Riverine areas and valley bottoms in the upper reaches of many rivers elsewhere suffer from flooding in limited areas. But no significant damage has been reported.

(10) Along small streams in mountain areas and lagas in the ASAL area, there exist almost no flood problems. The only damage caused is traffic interruption due to drifts in the lagas during heavy rainfalls. .

Major flood areas in the country are shown in Figure G3.1. Further, flood prone areas appearing on soil map (flood plains and sedimentary plains) are shown in Figure G3.2.

3.4 Flood Protection Projects Proposed to Date

There are several flood protection projects proposed to date, some of which have already been completed. The planning conditions and features of works are presented in Table G3.4. The majority of the flood protection projects is concentrated on rivers in the Lake Victoria Basin, such as Nzoia, Yala, Nyando and Kuja. Besides, some projects are conceived at Nairobi City and the Lower Tana.

G4. FLOOD PROTECTION PLAN

4.1 Target Areas and Rivers/Stretches

Judging from the magnitude of damage and the largeness of flooded area per place, the following nine areas are suggested as target areas where flood protection plan is to be examined in this Study. The features of each area, together with the target river/stretch to be improved, are shown in Table G4.1.

(1) Yala Swamp
(2) Kano Plain
(3) Sondu Rivermouth
(4) Kuja Rivermouth
(5) Middle Turkwel
(6) Downmost Athi
(7) Lumi Rivermouth
(8) Nairobi City
(9) Lower Tana

4.2 Principles for Flood Protection Plan

There is an advanced study on the flood protection of Nairobi City (Ref.G.2), which identifies flood issues in the city and also suggests protection level and measures together with the estimate of construction cost. With regard to the flood protection plan for Nairobi city, this Study assumes it appropriate to incorporate the results as per having been proposed in the previous study.

In the Lower Tana, as mentioned in Para. (5) of Subsection 3.3 "Flood Condition and Damage", flooding itself is a less serious problem in terms of present damage potential, compared with the bank erosion which is hazardous especially in the vicinities of villages, intakes and bridges. Then, bank protection works with groynes/riprap are proposed at the sites enumerated in Table G4.1.

For the other seven target areas, several alternative measures have been contemplated. Such measures are conceptionally composed of:

(1) Structural Measures

   (a) Continuous Dike/Polder
   (b) Channel Excavation/Dredging
   (c) Diversion Channel (Floodway)
   (d) Retarding Basin
   (e) Multipurpose Dam

(2) Non-structural Measures

(a) Restriction of Development
(b) Land Use Change/Resettlement Plan
(c) Flood Proofing
(d) Flood Forecasting and Warning System

The flood protection plan in this study was formulated giving focuses to the structural measure, in view of its certainty of the effect. As the first measure for introducing non-structural measures, it is recommended that district water offices managing the target areas be provided with three vehicles for routine patrol of rivers, early warning of floods and the flood fighting activity. Such cost is included in the operation and maintenance cost (O/M cost) mentioned in Subsection 6.1 "Economic Evaluation".

Among the structural measures, the method of continuous dike/polder has been applied to the plan, because:

(1) The flood regulation effect by multipurpose dams would be in most cases negligible and unsure since the catchments of the existing/envisaged damsites share only small parts of the catchments at which the flood protection plan is examined. Further, in such a case, precise dam operation for flood control is usually difficult. Nevertheless, some of flood control dam plans were examined in Sectoral Report H: Dam Development Plan, wherein however relatively low merit of the plans was identified.

(2) Retarding basin is usually provided upstream of the stretch in question where the enlarging improvement of downstream river channel is difficult due to urbanization, etc. and there is a low-lying area suitable for use as retarding basin. However, this planning concept was not applicable to the target areas/rivers under consideration. (NB: Conservation of existing natural retarding basin is a separate issue);

(3) Although a diversion channel plan was conceived near the rivermouth of Nzoia, all the target rivers including the Nzoia River at present take the shortest course to the sea or lakes, and thus the plan of diversion channel is therefore not appropriate; and

(4) The effect of the channel excavation/dredging is uncertain in view of future sedimentation on the deepened riverbed, and it is generally expensive than the dike construction.

Polder is applied to the Middle Turkwel in order to protect three irrigation schemes distant from each other. For the other six target areas, continuous dike is applied in consideration of wide spread distribution of the areas to be protected.

4.3 Protection Level and Design Discharge

Protection level (in terms of probability of design flood) for the flood protection plan was determined with two indices in consideration; protection method (embankment or non-embankment) and land use condition (urban area, rural area-A or rural area-B). The proposed criteria are given in Table G4.2. The table proposes the following three separate settings of protection level varying by implementation phase and type of structures:

(1) For river channel/dike planning in this study (initial phase protection);
(2) For river channel/dike planning in future (ultimate phase protection); and
(3) For weir/bridge

River channels/dikes for initial phase protection are planned for comparatively small design discharges of 10- and 20-year return period, which generally conform to those adopted for the projects proposed to date (see Table G3.4). Such protection levels are proposed to be upgraded almost 2 times (in terms of return period of design flood) in the future when economic enhancement in the flood areas will progress. Weirs/bridges, whose reconstruction/ expansion are usually difficult, are planned for the ultimate protection level. The design discharge in each target river/stretch was derived from a study result in Sectoral Report B - Hydrology (see Table G4.1).

4.4 Flood Protection Works and Project Costs

Based on the principles mentioned above, flood protection plans for each target area were worked out as shown in Figures G4.1 to G4.8. The following describe the design concepts of structures and works involved in the plans:

(1) Both dikes are aligned so as to envelope the existing river channel. The freeboard and crest width of dikes are as tabulated below:

Design discharge	Freeboard	Crest Width
More than or equal to 100 m^3/s	1.0 m	5 m
Less than 100 m^3/s	0.6 m	3 m

The side slopes of dikes are 1:2 (vertical : horizontal) with sod facing. The material for dike construction will be procured from the works of succeeding items (2) and (3).

(2) The existing river channels are to be realigned, in some cases by short-cut, in order to pass a flood flow smoothly.

(3) To solve the drainage problem in inner lands, drain channels will be provided alongside both dikes.

(4) Sluices for inland drainage and water intake are to be constructed at necessary points.

(5) Existing bridges will be reconstructed unless they have sufficient flow capacity to pass the design discharges.

(6) For the purpose of bank protection in the Lower Tana, concrete-pile groynes (3 m wide in the flow direction and 8 m long in the cross-sectional direction) will be provided at an interval of 50 m together with riprap.

Table G4.3 shows the project costs required for the flood protection works in the nine target areas. The project costs are estimated at the price level as at the beginning of 1992 (1 US Dollar equivalent to 25.2 Kenya Shilling).

G5. ESTIMATION OF FLOOD DAMAGE REDUCTIONS

5.1 Methodology of Estimation

(1) Flood Damages

The damages caused by flooding with various occurrence probabilities were estimated based on an empirical criterion that the damages are nil at the discharge of a probability corresponding to the bankful discharge of each target river stretch, and increase linearly in proportion to the probability on semi-log coordinates (see Fig. G5.1). Based on this criterion, the relation between damages and probability can be obtained when knowing the probability of bankful discharge (non-damage flood) and the probability and damages of an objective past flood for which the damage was estimated. Since there was little statistical data on past floods, the damages were estimated from the hydraulic conditions and assets in the flood area at the time of the flood event.

(2) Bank Erosion Damages

The damages caused by bank erosion are estimated for the target sites along the Lower Tana. Different from the case of flood damages, it is quite difficult to identify the non-damage flood discharge and the damages of a specific past flood. What we can know is only how wide, on average, banks are eroded annually. It is presumed that the bank erosion rate is approximately 5m per year as a result of interviews and reconnaissance on site. Annual average damage amount was estimated simply by multiplying the area eroded per annum by the assets value in the area.

(3) Currency of estimate

US$ equivalent (US$1=Kshs25.2) was used in view of fluctuation of exchange rate prevailing the study period.

5.2 Conditions of Damage Estimate

(1) Land Use/Assets

The damage amount was estimated on the following two land use/assets conditions in the target areas:

(a) 1990-Condition

This refers to the existing land use/assets condition.

(b) 2010-Condition

This represents the future land use/assets condition in the target areas, where the following are assumed: Firstly, the whole flood area, except swamps and the areas influenced by the lake water, would be fully developed due to the completion of flood protection works. Secondly, the value of assets in the flood area would increase from 1990 towards 2010 at an annual rate corresponding to a half of GDP growth of Kenya. This works out to 2.5% taking Kenya's GDP to be 5%.

(2) Composition of Damage

The damages due to either flooding or bank erosion consist of agricultural damage, housing damage, damage to public facilities and indirect damage.

(a) Agricultural Damage

Farmland is taken to be 80% of the utilized area, where maize is assumed to be planted since it is the major crop in low-lying lands in Kenya. This may not represent the actual land uses, but appears to be acceptable for estimating an average level of damage potential of agricultural lands. On each proposed project basis the damage should be assessed through land use surveys. The unit yield of maize is estimated at 2.8 ton/ha (Ref. 11), with a value of 120 US$/ton (1990) according to the National Cereals and Produce Board. On the other hand, maize is damaged by floods at the rate shown in Table G5.1 which was determined for various inundation depth-duration conditions.

(b) Housing Damage

The table below shows the interview results on the density and value of housing in the target areas:

Item	Urban Area (Nairobi)	Rural Area (Other areas)
Density of Housings (houses/ha)	20	1.2*
Value of Housings** (US$/house)	8,000	1,500
(Kshs/house)	201,600	37,800

* Investigation result in Ref. 11 also taken into account.
** Including furniture

The density and value of housings were derived from sampling interview in flood areas under this Study. No statistical data seems to be available. In the studies on each project basis, actual number of housings should be surveyed and average value assessed through sampling survey.

In the Study, the total number of housings in the flood area was obtained by multiplying the density of housing by the area of farmland for the rural areas and by the urbanized area for Nairobi City. The damage rate of housing by inundation depth is shown in Table G5.2.

(c) Damage to Public Facilities

This consists of the damages to roads, railways, irrigation channels, electricity and telecommunication facilities, water supply works, public buildings and so on. No definite criteria exist with regard to the ratios of estimating the damage to public facilities and the indirect damage. The 50% and 30% represent approximate figures derived from sample surveys in USA and Japan. In the Study, the amount of damage is usually as much as 50% of the housing damages.

(d) Indirect Damage

The indirect damage refers to the losses of wages, commercial trade, industrial products, transportation and utility services, and the costs for rescue and relief activity caused by floods. The amount is generally 30% of the total of agricultural, housing and public facilities damages.

(3) Hydraulic Conditions of Non-damage Floods and Objective Past Floods

Shown in Table G5.3 are the hydraulic conditions of the non-damage flood (bankful discharge) and the objective past flood in each target area. The objective past flood is selected among floods occurring for the last five years in consideration of latest information through interviews in the field. The areas flooded by the objective past floods are drawn on Figures G4.1 to G4.9, including the flood-prone area of the Lower Tana in Figure G4.8.

5.3 Damage Reductions

The damages in each target area caused by the objective past flood were calculated for conditions of both year 1990 and year 2010, as shown in Table G5.4. The relation between damages and probability was delineated from the probability of non-damage flood and the probability and damages of the objective past flood (see Figure G5.1). This relation gives the annual average flood damages by the floods of less than a certain probability; in other words, the damage reductions due to the flood protection works of the same probability. The results are presented in Table G5.5 for the 1990- condition and Table G5.6 for the 2010-condition. As a result, the damage reductions accrued from flood protection works for the target areas were estimated as follows:

Target Area	Protection Level (year)	Damage Reductions			
		1990-Condition		2010-Condition	
		(10^3US$)	(10^3Kshs)	(10^3US$)	(10^3Kshs)
Yala Swamp	25	572	14,414	3,448	87,898
Kano Plain	25	1,516	38,203	4,147	104,504
Sondu Rivermouth	25	61	1,537	328	8,266
Kuja Rivermouth	25	96	2,419	520	13,104
Middle Turkwel	10	30	756	163	4,108
Athi Downmost	10	19	479	214	5,393
Lumi Rivermouth	25	309	7,787	727	18,320
Nairobi City	50	718	18,094	1,683	42,412

On the other hand, Table G5.7 shows annual average damage due to bank erosion in the Lower Tana. The bank protection proposed will relieve the Lower Tana from damages amounting US$ 79,000 for the 1990-condition and US$ 182,000 for the 2010-condition annually.

G6. EVALUATION OF FLOOD PROTECTION PROJECTS

6.1 Economic Evaluation

Economic viability of the proposed flood protection works was evaluated in terms of Benefit-cost ratio (B/C) as well as B-C on both conditions of the years 1990 and 2010 for each target area. The results are given in Table G6.1, where the following are assumed:

(1) Project Life (n) : 50 years

(2) Discount Rate (i): A reduced opportunity cost of the capital of 8% was assumed for selection of the proposed projects taking account of the social welfare development need involved in this sector. The case of 10% was also assessed for reference.

(3) Annual cost (c) :

$$\text{Initial Cost (Project Cost)} \times \left(i + \frac{i}{(1+i)^n - 1}\right)$$

(4) Annual Benefit (B):
Annual Average Damage Reduction - Annual O/M Cost

where, Annual O/M cost = Initial Cost x 0.5%

As evaluated in Table G6.1, the B/Cs under the 1990-condition are less than 1.0 (which means flood protection works are less beneficial under the existing land use) in all areas, while under the 2010-condition the B/Cs are assessed to be higher.

		Benefit - Cost Ratio (B/C)			
	Target Area	2010-Condition		1990-Condition	
1	Kano Plain	2.40	(1.63)	0.84	(0.59)
2	Yala Swamp	2.33	(1.58)	0.34	(0.26)
3	Nairobi City	1.85	(1.26)	0.75	(0.54)
4	Kuja Rivermouth	1.20	(0.84)	0.17	(0.15)
5	Lumi Rivermouth	1.01	(0.71)	0.39	(0.30)
6	Sondu Rivermouth	0.76	(0.53)	0.09	(0.09)
7	Lower Tana	0.62	(0.45)	0.23	(0.20)
8	Middle Turkwel	0.24	(0.20)	0.00	(0.00)
9	Downmost Athi	0.20	(0.17)	0.00	(0.00)

Note: Discount rate of 8%. ( ) shows the case of 10%

In evaluating the proposed schemes, it should be considered that; (a) after the completion of flood protection works, the land use might be enhanced; and accordingly (b) the

value/amount of assets might increase through the project life with economic growth. These factors are taken into account in the B/C index evaluated for the year 2010-condition. Therefore, this study made the evaluation of the schemes based on this year 2010-index.

6.2 Overall Evaluation

Table G6.2 presents the overall evaluation of the proposed nine flood protection projects. Some aspects of social requirement are also described in the table. The results are summarized as follows.

Priority	Target Area (Province)	Description	Total Cost (mil. US$)	(mil.Kshs)
A	- Kano Plain (Nyanza) - Nairobi city (Nairobi)	Relatively high economic viability, even under 1990-condition, and high social requirement	31.4	791.3
B	- Yala Swamp (Western/Nyanza) - Kuja Rivermouth (Nyanza) - Lumi Rivermouth (Coast)	High-moderate economic viability (2000 condition), though low under 1990-condition, and high/mid social requirement	31.0	781.2
C	- Sondu Rivermouth (Nyanza) - Lower Tana (Coast/North Eastern) - Middle Turkwel (Rift Valley) - Downmost Athi (Coast)	Relatively low economic return and low social requirement	24.7	622.4
Total			87.1	2,194.9

6.3 Socio-environmental Aspect

(1) Kano Plain Flood Protection Project

The proposed project involves the rehabilitation and construction of dykes of 112 km in total (see Table G4.1 and Figure G4.2). Since the project is proposed in relatively dense-populated area, the work will require the resettlement of several

hundred families. This may be a major issue involved in the implementation of the project.

The construction of dykes will create many areas requiring measures for inland drainage; otherwise there may arise unhygeine standing water problem. Particularly in populated area like Kano plain, the provision of proper drainage system (sluices, dyke-toe drain canal) would be important.

The number of the beneficiaries will be about 110,000 people estimated on a very preliminary basis.

(2) Nairobi City flood Protection Project

The project proposed in the present study (Ref. G.2) consists of the enlargement of channels narrowed by existing bridges and culverts (see Table G4.1 and Figure G4.9). The project may be regarded as the first stage implementation of a long-term flood mitigation work which would be a continuous undertaking as the runoff characteristics change in future due to further development of the city.

Under the presently proposed works, not many families resettlement is foreseen and therefore sociological impact is minimal.

The number of the beneficiaries of the proposed project is estimated to be roughly 26,000 people.

(3) Yala Swamp flood Protection Project

This project consists of the improvement of two rivers; Nzoia River downstream from Luambwa and Yala river downstream from the existing pump station for Yala Swamp Farm-Area 1 (see Table G4.1 and Figure G4.1).

The improvement of the Nzoia River is virtually the rehabilitation of existing dyke (16 km) and hence the influences on socio-environmental aspects will be minimal.

The improvement of the Yala River involves increasing the height of existing 9 km dyke and the construction of a new dyke (14 km, along the right bank of the diverted new Yala river). The former will not involve any noteworthy socio-environmental issues, while the latter will require the resettlement of several families. No important influence on fauna and flora is likely due to the proposed improvement work.

An aspect to be noted is the possible change of hydrological environment of Lake Kanyaboli. The Lake has already been isolated from inflow of the Yala River by existing diversion of flows through a new channel into Lake Sare. Therefore, the proposed improvement work of existing dykes does not give further direct influence on to the environment of Lake Kanyaboli. Nevertheless, it is

recommended to continue the monitoring of the Lake water quality since there may be a case of water quality deterioration (eg. eutrophication) in the long term.

The number of beneficiaries of the proposed project is roughly 27,000 people.

(4) Kuja River Mouth Flood Protection Project

The proposed project envisages improving the Kuja river downmost reaches of 10 km in length by dyking. The present river course meanders heavily and the dyking may require a relatively wide land acquisition to envelope the existing channel or otherwise the shortcutting of channel at some places. In view of relatively sparse population in the area, the resettlement requirement may be in the order of several tens of housing (according to interpretation on map), but this should be subject to a further survey in the field.

It is not reported that there are important fauna and flora in the river reach. However, there will be access of many livestock and presumably animals to the river channel. The dyke should preferably be designed to have a flatter embankment slope or otherwise provide access paths for livestock watering.

The number of the beneficiaries is roughly estimated to be 12,000 people.

(5) Lumi River Mouth Flood Protection Project

The proposed project involves the construction of dyke of some 11 km in length downstream from Taveta town (see Table G4.1 and Figure G4.7). The main protection areas are the riverine areas on both banks in the stretch and also a wide flat land extending south from Kamleza village. A new water supply work was completed at Njoro spring, which is also exposed to fear of flooding.

No important socio-environmental issues are foreseen other than the resettlement of housings which will be roughly in the order of several tens.

The number of people to benefit from the project is roughly estimated to be 25,000.

G7. OTHER PROJECTS NEEDING SPECIFIC CONSIDERATION

Other than major flood protection projects proposed in Chapter G6, there are other river related works needing the appropriation of budgetary resources. In view of the type of works and also due to limited inputs allowed under the Study, the Study could not go into much detail with regards to the issues described below. Only the main points are presented.

7.1 Urban Drainage Projects

Urban drainage work is a network of main, secondary and tertiary drains for collecting and conveying drainage water from specific areas in the town. The work is the responsibility of local authorities (municipal, urban and area councils) under the present organizational set-up.

Issues relating to urban drainage are occurring in many cities and urban centres, causing stagnant waters sometimes in unhealthful condition and inundation in local areas. Problems in Nairobi and Mombasa in particular appear to be aggravating.

The Study presumes that the priorities of urban drainage works would be given to major urban centres which are listed in Table G7.1. The table also shows very preliminarily estimated cost of the drainage works composing of gravity drains. It is to be noted that drainage work involves in some cases major associated works such as pumping station, retarding basin, improvement of receiving river channels, etc., which should be planned in detail for each urban centre. (NB; Nairobi City Commission foresees to commence a drainage master plan study in 1992).

7.2 Minor Ad-hoc River Improvement Projects

Other than specific flood control projects proposed in Chapter G6, there will also be need for improvement of river channels on ad-hoc basis, such as the improvement associated with urban drainage works, local bank protection work, removal of excessively accumulated silt, channel clearing work, canalization, etc. particularly in urban areas.

The estimates of these works on an individual scheme basis are beyond the scope of this Study, and hence a rule-of-thumb estimate made herein that a budget resource of almost same amount appropriated for major flood control projects (US$90 million or KShs 2,610 million) should be reserved to cover the expenditures for these minor river improvement works.

It is recommended that MOWD should collect more accurate information of the cost requirements from their regional offices and the river basin authorities together with information or the plans of improvement work requirements contemplated by these offices.

7.3 Long-term Improvement of Lower Tana River

Studies in Chapters G4 to G6 showed that the proposed bank protection work in the Lower Tana river is not economically justified. Nevertheless, a point to be noted is that the Lower Tana area has a great development potential particularly for irrigated agriculture in terms of the availability of exploitable lands in the area and water resources in the river.

There are two major existing problems in the Lower Tana reaches. One is flood problem and the other the unstable river course. The former, though not an acute problem at present, can ultimately be solved possibly by constructing flood control dams in the upstream reaches (there are several potential damsites) and levee construction in the downstream reaches. The latter is already causing a lot of inconveniences to riverine people and also to some major irrigation schemes (Bura and Hola irrigation schemes). It is deemed that the stabilization of the river channel is a primary step toward the overall improvement of the Lower Tana river including flood protection objective, to be achieved in advance of the levee construction.

The work will involve sophisticated planning of river morphological aspects and step-wise works on a do-and-see basis, and hence require a long period until the channel is in a stable regime. This Study proposes that MOWD and TARDA launch step-wise experimental works to this objective; firstly with the protection of excessively eroded portions, groins for rectifying the meanders and shortcutting at appropriate sections. Observation of the river regimes by periodical profile and cross section surveys should also be included. The proposed work is considered as a follow-up of the Tana River Morphology Project, wherein the Research Division of MOWD should be actively involved.

The Study presumes that a budget of the order of KShs 150 million/year (US$5 million) will be made available for this task for the coming 10 years. Based on findings in experimental works, the subsequent work programme can be formulated.

G8. IMPLEMENTATION SCHEDULE

8.1 Flood Protection Project

The National Water Master Plan intends to formulate two plans: namely, the Master Action Plan towards year 2000 and the overall Master Plan towards year 2010. When viewing the evaluation results on flood protection projects, it is recommended that: (1) projects accorded Priority-A be implemented within the Master Action Plan period, (2) those accorded Priority-B within the Master Plan period.

(1) Master Action Plan

(a) Kano Plain
(b) Nairobi City

(2) Master Plan

(a) Yala Swamp
(b) Kuja Rivermouth
(c) Lumi Rivermouth

The budgetary and manpower schedules for the implementation of the flood protection projects are estimated in Tables G8.1 and G8.2 respectively.

8.2 Other River Improvement and Drainage Projects

For the three projects described in Chapter 7, the following approximate schedules are proposed:

(1) Urban drainage projects

Nairobi and Mombasa to have priorities in implementation. The works to start in 1995 after 3 years of pre-construction studies. For the other urban centres, it is preliminarily assumed that 30% of the total budget will be allocated between the years 1995 and 2000 and the remainder towards the year 2010.

(2) Minor ad-hoc river improvement projects

The studies and pre-construction preparations will require some 3 years. Same as for (1) above, 30% of the total budget to be disbursed during a period of 1995 through 2000 and the remainder 70% in the next 10 years.

(3) Long-term improvement of Lower Tana river

This project can start within a short period, say in 1993, since TARDA has already accumulated the knowledge to this undertaking. It is preliminarily assumed that a total budget of KShs 1,200 million (US$40 million) will be disbursed for 8 years towards 2000 for this experimental project.

A preliminary budgetary schedule is shown in Table G8.3.

G9. RECOMMENDATIONS

(1) Implementation of Flood Protection Projects

Presently, floods are not a serious problem in Kenya. However, the rapid increase of population, development of agricultural industries and economic advancement will soon necessitate flood protection works in several flood-prone areas as studied in Section G6. To cope with such a situation, it is proposed that the flood protection projects recommended herein be realized in line with the implementation schedule proposed in Chapter G7. The cost required for the projects is estimated at 62.4 million US dollars in total, consisting of 31.4 million US dollars in the Master Action Plan period (towards 2000) and 31.0 million US dollars in the Master Plan period (towards 2010). Taking into account the budgetary tightness in Kenya, a part of the cost may have to be financed by foreign aid agencies.

(2) Accumulation of Flood Records and Technical Data on Rivers

There are only limited flood records and other technical data on rivers accumulated so far. This makes it difficult to evaluate flood and river conditions including the formulation of flood protection plans. It is firstly recommended to collect actual information/data on floods and rivers as much as possible through interview survey and field reconnaissance on site. This will require only small efforts and expenses. The formats prepared for the questionnaire (see Appendixes 1 and 2) might be useful to compile such information/data concerning flood damage and riparian structures.

The collection of flood data will be managed by the River Management Division (proposed to be newly established. See Sectoral Report P) in liaison with Hydrology Section and possibly with District Flood Disaster Committee (also proposed to be newly established).

Secondly, the following efforts should be attempted to get more detailed and quantitative information/data, though they need certain expenditures:

(a) Preparation of topographic maps with a scale of 1:5,000 to 1:25,000 for the flood-prone areas in question;

(b) Preparation of topographic maps along the rivers in question with a scale of 1:1,000 to 1:2,500;

(c) Preparation of longitudinal profiles and cross sections along the rivers in question; and

(d) Rehabilitation/construction of water level gauging stations immediately upstream of the flood-prone areas in question.

(3) Institutional Set-up for River Management

The Ministry of Water Development is the responsible ministry dealing with water issues including surface water in streams and rivers, and the water area in the form of running water along rivers or retaining water in lakes. For this reason, dealing with water is necessarily accompanied by the management of rivers and lakes. Nevertheless, there is no division and/or section in the Ministry which is responsible for managing rivers or river channels together with various kinds of facilities such as dike, revetment, weir, sluice and bridges. To cope with the management requirements for increasing development activities in the rivers and land in flood-prone areas in future, it is recommended that a responsible division and/or section be set up in the headquarters of MOWD and possibly in provincial water offices. The main responsibilities to be assigned may be as follows:

(a) Management of rivers and riparian structures, including periodical patrol/inspection for problem identification, planning of remedied measures/maintenances, to keep them in proper functional orders;

(b) Compilation of flood records and other technical data relevant to river statistics and behaviours;

(c) Planning, designing and implementation of river improvement works, including flood protection works; and

(d) Direction of flood warning and fighting activities in extraordinary flood times.

REFERENCES

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Ref. G.4 MOWD; PRE-INVESTMENT STUDY FOR WATER MANAGEMENT AND DEVELOPMENT OF THE NYANDO AND NZOIA RIVER BASINS; Nzoia River Basin Pre-development Report: Oct. 1983; Italconsult

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Ref. G.7 LBDA; LAKE BASIN RIVER CATCHMENT DEVELOPMENT RIVER PROFILE STUDIES; Volume IV, Lower Kuja Irrigation Development Report; Oct. 1985; C.Lotti & Associati

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Ref. G.10 TARDA; TANA RIVER MORPHOLOGY STUDIES; Final Report, Volume I to IV; DHV Consulting Engineers

Ref. G.11 LBDA; THE STUDY OF INTERGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE LAKE BASIN DEVELOPMENT AREA; Final Report, Volume 3, Sector Report 1, Agriculture/Livestock/Fishery; Oct. 1987; JICA

TABLES

Table G2.1 Features of Major Rivers (1/4)

Name of River	Catchment Area (km2)	River Length (km)	Mean Annual Rainfall (mm)	Stretch (km)	Natural Condition: Geography/River Morphology	Natural Condition: Longitudinal Gradient	Natural Condition: Width of Channel (m)	Social Condition: Districts	Social Condition: Human Activities / Land Use
Nzoia	12,696	315	1,350	0 - 20	Meandering river on a flood plain including Yala Swamp, pouring into Lake Victoria. There exist 16km dikes downstream of Luambwa Bridge (1986 completed).	1/3,400	70 (400 - 600)*	Busia & Siaya	Rather intensive agriculture, especially at Bunyala Pilot Irrigation Scheme for rice, with livestock farming and fishery. A lot of human settlements along the river.
				20 - 135	Meandering river on a narrow valley bottom in a hilly land.	1/390	50	Siaya, Kakamega & Bungoma	Subsistence agriculture and grazing. A few human settlements on the velley bottom.
				135 - 257	Slightly meandering river, forming a V-shaped valley on a highland area.	1/240	40	Kakamega, Bungoma, T. Nzoia & U. Gishu	Grazing. Few human settlements on the valley bottom.
Yala	3,262	261	1,500	0 - 25	Original meandering river in Yala Swamp relocated along the hills south to the swamp, and pours into Lake Sare. Between 16km and 25km points provided a right dike (1971 completed).	1/2,700	40 (About 100)**	Siaya	Intensive agriculture in a part of Yala Swamp, Yala Swamp Farm - Area I. However, few human settlements in the swamp area.
				25 - 125	Meandering river on a narrow valley bottom in a hilly land.	1/250	30	Siaya & Kakamega	Subsistence agriculture and grazing. A few human settlements on the velley bottom.
				125 - 190	Slightly meandering river, forming a V-shaped valley on a highland area.	1/120	20	Nandi & Uasin Gishu	Grazing. Few human settlements on the valley bottom.
Nyando	3,450	153	1,400	0 - 45	Meandering river on a flood plain, named Kano Plain, including swampy area. Pours into Lake Victoria. There is 2km dikes completed by now downstream of Ahero Bridge.	1/700	50 (200 - 250)*	Kisumu	Intensive agriculture, especially at Ahero Pilot Scheme for rice and West kano Irrigation Scheme, with livestock farming and fishery. A lot of human settlements on the plain.
				45 - 75	Meandering river on a narrow valley bottom in a hilly land.	1/160	40	Kisumu & Kericho	Subsistence agriculture and grazing. A few human settlements on the velley bottom.
				75 - 109	Less meandering river, forming a deep V-shaped valley in a mountain area of Mt. Londiani.	1/45	20	Kericho	Subsistence agriculture and forestry. Few human settlements in the valley.

* Distance between both dikes

** Distance between the right dike and the left hills

Table G2.1 Features of Major Rivers (2/4)

Name of River	Catchment Area (km2)	River Length (km)	Mean Annual Rainfall (mm)	Stretch (km)	Natural Condition: Geography/River Morphology	Natural Condition: Longitudinal Gradient	Natural Condition: Width of Channel (m)	Social Condition: Districts	Social Condition: Human Activities / Land Use
Sondu	3,489	176	1,480	0 - 15	Meandering river, forming a remarkable fan towards Lake Victoria.	1/500	45	Kisumu & South Nyanza	Subsistence agriculture, grazing and fishery. A lot of human settlements on the fan.
				15 - 25	Straight river in a deep V-shaped valley running down the escarpment.	1/45	20	Kisumu & South Nyanza	Less human activities. Few human settlements in the valley.
				25 - 121	Slightly meandering river, forming a V-shaped valley on a hilly land.	1/190	30	Kisumu, South Nyanza, Kisii & Kericho	Subsistence agriculture and grazing. A few human settlements on the velley bottom.
Kuja	6,868	180	1,340	0 - 20	Meandering river on a fan with swampy area. Pours into Lake Victoria.	1/900	55	South Nzoia	Subsistence agriculture, grazing and fishery. A lot of human settlements on the fan.
				20 - 80	Slightly meandering river on a narrow valley bottom in a hilly land.	1/500	40	South Nzoia & Kisii	Subsistence agriculture and grazing. A few human settlements on the velley bottom.
				80 - 128	Slightly meandering river, forming a V-shaped valley on a highland area.	1/110	30	Kisii	Subsistence agriculture and grazing. A few human settlements on the velley bottom.
Mara	9,574	198	980	0 - 125	Meandering river on the ASAL plain, flowing into Tanzania.	1/360	50	Narok	Nomadic grazing. Few human settlements on the plain.
				125 - 138	Slightly meandering river, forming a V-shaped valley on a highland area.	1/85	30	Kericho	Less human activities. Few human settlements on the valley bottom.
Turkwel	20,283	390	530	0 - 158	Meandering river with limited riverine forests on the ASAL plain, pouring into Lake Turkana.	1/700	200	Turkana	Nomadic grazing. Few human settlements on the plain.
				158 - 212	Braiding river on a wide valley bottom between highlands.	1/570	150	Turkana	Grazing and limited farming at Katilo, Juluk & Nakwamoru irrigation schemes. Few human settlements on the valley bottom.
				212 - 338	Slightly meandering river, forming a deep V-shaped valley in a mountain area. Turkwel Dam for hydropower generation under construction.	1/160	50	Turkana & West Pokot	Less human activities except for the hydropower generation. A few human settlements on the valley bottom.

Table G2.1 Features of Major Rivers (3/4)

Name of River	Catchment Area (km2)	River Length (km)	Mean Annual Rainfall (mm)	Stretch (km)	Natural Condition: Geography/River Morphology	Natural Condition: Longitudinal Gradient	Natural Condition: Width of Channel (m)	Social Condition: Districts	Social Condition: Human Activities / Land Use
Kerio	14,172	403	450	0 - 130	Meandering river with limited riverine forests on the ASAL plain, pouring into Lake Turkana.	1/530	150	Turkana	Nomadic grazing. Few human settlements on the plain.
				130 - 354	Braiding river on a wide valley bottom between highlands.	1/430	80	West Pokot, Elgeyo Marakwet & Bariogo	Nomadic grazing. Few human settlements on the valley bottom.
Ewaso Ngiro South	8,534	213	760	0 - 60	Meandering river on the ASAL plain, flowing into Tanzania.	1/410	50	Kajiado	Nomadic grazing. Few human settlements on the plain.
				60 - 90	Straight river in a deep V-shaped valley running down the escarpment.	1/50	20	Kajiado	Less human activities. Few human settlements in the valley.
				90 - 180	Slightly meandering river, forming a V-shaped valley on a highland area.	1/160	30	Narok	Subsistence agriculture and grazing. A few human settlements on the valley bottom.
Athi	36,903	631	610	0 - 55	Braiding river on a narrow valley bottom in a hilly land, pouring into Indian Ocean. The river mouth slightly clogged by sand.	1/1,400	150	Kilifi	Grazing and limited farming. Few human settlements on the valley bottom.
				55 - 150	Slightly meandering river, forming a U-shaped valley on a highland area.	1/790	100	Kilifi	Nomadic grazing. Few human settlements on the valley bottom.
				150 - 598	Slightly meandering river, forming a V-shaped valley on a highland area. There are a number of falls.	1/340	70	Tana River, Taita-Taveta, Kitui, Machakos, Kiambu & Nirobi	Grazing. Few human settlements on the valley bottom.

Table G2.1 Features of Major Rivers (4/4)

Name of River	Catchment Area (km2)	River Length (km)	Mean Annual Rainfall (mm)	Stretch (km)	Natural Condition: Geography/River Morphology	Natural Condition: Longitudinal Gradient	Natural Condition: Width of Channel (m)	Social Condition: Districts	Social Condition: Human Activities / Land Use
Tana	95,430	1,050	600	0 - 150	Heavily meandering river on its swampy delta. Pours into Indian Ocean cutting a sand dune along the coastline.	1/6,000	80	Tana River	Grazing and limited farming. There exists Tana Delta Irrigation Scheme mainly for rice. Some human settlements on the delta.
				150 - 295	Heavily meandering river on the flood plain limited by ASAL highlands, leaving oxbow lakes. Bank erosion/local deposition also serious.	1/3,600	100	Tana River	Grazing and limited farming. A few human settlements on natural dikes in the flood plain.
				295 - 509	- do -	1/2,800	120	Tana River & Garrisa	Simular to the above, although there exist Hola & Bura irrigation projects.
				509 - 650	Braiding to meandering river on a wide valley bottom.	1/1,500	200	Tana River & Garrisa	Nomadic grazing. There exists ADC Farm. Few human settlements on the valley bottom.
				650 - 960	Slightly meandering river, forming V-shaped valley on the ASAL highland. There exist Kindaruma, Gitaru, Kamburu and Masinga dams mainly for hydropower generation.	1/300	70	Tana River, Isiolo, Kitui, Meru, Embu & Machakos	Less human activities except for the hydropower generation. Few human settlements in the valley.
				960 - 1015	Slightly meandering river, forming V-shaped valley in the mountain area between Mt. Kenya and Mt. Nyandarua	1/95	40	Muranga, Kirinyaga & Nyeri	Subsistence agriculture with small areas. Few human settlements in the valley.
Ewaso N'giro North	91,428	740	370	0 - 225	Swampy area in the ASAL area, called Lorian Swamp, with water only during rainy season.	1/2,100	-	Garissa & Wajir	Nomadic grazing. Few human settlements in the swampy area.
				225 - 350	Meandering river on the ASAL area with water only during rainy season.	1/1,100	100	Isiolo	Nomadic grazing. Few human settlements on the ASAL area.
				350 - 580	Slightly meandering river on a valley bottom in a hilly area.	1/300	70	Isiolo & Samburu	Subsistence agriculture and grazing. A Few human settlements in the valley.
				580 - 704	Slightly meandering river, forming a V-shaped valley in a mountain area.	1/230	40	Laikipia	Subsistence agriculture with small areas. Few human settlements in the valley.

Table G3.1 Chronology of Flood Events

Year	Lake Victoria Basin						Rift Valley Basin			Athi River Basin			Tana River	Ewaso Ngiro North River	Remarks
	Nzoia River	Yala River	Nyando River	Sondu River	Kuja River	Mara River	Turkwel River	Kerio River	Ewaso South Ngiro River	Athi River	Lumi River	Nairobi River			
1961	●	●	●	●	●	-	-	-	-	◎	○	◎	●	○	Uhuru Rains
1962	-	-	-	○	-	-	-	-	-	-	○	-	-	-	
1963	◎	○	○	○	○	-	-	-	-	-	-	-	◎	-	
1964	○	○	◎	◎	○	-	-	-	-	-	-	-	◎	-	
1965	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
1966	-	-	-	-	-	-	-	-	-	-	-	-	○	-	
1967	-	-	-	-	-	-	-	-	-	-	○	-	○	-	
1968	○	◎	○	◎	○	-	-	-	-	-	○	-	◎	○	
1969	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
1970	○	-	○	-	-	-	-	-	-	-	○	-	-	-	
1971	-	○	-	-	-	-	-	-	-	-	○	-	○	-	
1972	○	-	○	-	-	-	-	-	-	-	-	-	-	-	
1973	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
1974	-	-	○	-	○	-	-	-	-	-	-	-	-	-	
1975	◎	-	-	-	-	-	-	-	-	-	-	-	-	-	
1976	-	-	-	-	-	-	-	-	-	-	○	-	-	-	
1977	◎	○	○	○	○	-	-	-	-	◎	-	◎	○	-	
1978	○	◎	○	-	◎	-	-	-	-	○	○	-	○	-	
1979	-	◎	○	-	-	-	-	-	-	-	-	-	○	-	
1980	-	-	-	-	-	-	-	-	-	-	○	-	-	-	
1981	○	○	-	○	-	-	-	-	-	-	○	-	-	-	
1982	○	○	○	○	○	-	-	-	-	-	○	-	-	○	
1983	○	○	-	-	-	-	-	-	-	-	-	-	-	-	
1984	-	-	-	-	-	-	-	-	-	-	-	-	○	-	
1985	-	○	◎	-	○	-	-	-	-	-	○	-	-	-	
1986	-	-	-	-	-	-	-	-	-	○	-	◎	-	-	
1987	-	-	-	○	-	-	-	-	-	-	○	○	-	-	
1988	○	○	◎	○	○	-	○	-	-	-	-	○	○	○	
1989	-	-	-	-	-	-	-	-	-	-	○	-	○	○	
1990	-	○	○	◎	◎	-	-	-	-	-	-	-	○	-	

Notes :
- ● : Most serious flood between 1961 and 1990
- ◎ : Serious floods
- ○ : Floods causing a certain damage

Table G3.2 Flood Condition and Damage by District (1/10)

Area	Flood Condition			Flood Damage				Existing Counter-measures	Category *
	Flooding	Bank Erosion	Sedimentation	Housing	Farmland / Grazing	Intake Facilities	Road / Bridge		
WESTERN PROVINCE									
1. Bungoma District:	Upper Reaches of Nzoia, Sio and Malakisi								
a. Mountain Area of Mt. Elgon	Less	Less; rocky	Less	None	None	None	Less	None	N N
b. Foot Area of Mt. Elgon	- Riverine areas of small rivers, e.g., Bokoli & Mayanga - Almost every year (e.g., 1986) - Some 100m wide (some km2) - Less than 0.5m deep - Lasts a few hours	Slight	Slight	None; no human settlements existing in the riverine areas	Less; less cultivation and only seasonal grazing practiced in the riverine areas	Less; some intakes existing, but barely damaged	Less; A minor bridge washed away in 1986	None	N S
2. Kakamega District:	Middle Reaches of Nzoia and Yala								
a. Whole District; Hilly Land	- Valley bottoms of Nzoia, Yala & thier tributaries (e.g., Edzawa) - Some years (e.g., 1988) - Less than 100m wide (some km2) - Less than 0.5m deep - Lasts a few hours	Slight	Less	None; no human settlements existing in the valley bottoms	Less; less cultivation and only seasonal grazing practiced in the valley bottoms	Less; many intakes existing, but barely damaged	Less; A minor bridge washed away in 1988	None	N S
3. Busia District:	Lower Reaches of Malakisi and Sio, plus Downmost Reaches of Nzoia and Yala								
a. Lower Reaches of Malakisi River	- Riverine areas of Malaba & its tributaries (e.g., Malakisi) - Almost every year (e.g., 1987 & 89) - Some 100m wide (some km2) - Less than 0.5m deep - Lasts a day or more	Slight	Slight	Less; few human settlements existing in the riverine areas	Slight; limited farmlands damaged and gazing affected by floods in the riverine areas	Less; some intakes existing, but barely damaged	Less; A minor bridge washed away in 1987	None	L S
b. Lower Reaches of Sio River	- Riverine areas of Sio & its tributaries - Almost every year - Max. 3km wide (some km2) - Less than 0.5m deep - Lasts a day or more	Slight	Sometimes heavy causing Busia water supply intake	Less; few human settlements existing in the riverine areas	Slight; limited farmlands damaged and gazing affected by floods in the riverine areas	Less; some intakes existing, e.g., pump station for Busia Water Supply, but barely damaged	Less; minor bridges sometimes submerged during high flood	None	L S
c. Downmost Reaches of Nzoia & Yala rivers	- Yala swamp area affected by combination of floods from Nzoia & Yala rivers - Almost every year (e.g., 1982) - About 110km2 (incl. 4.a) - 0.5m to 1m deep - Lasts about a month	Slight; esp., along Nzoia	Slight; esp., at rivermouth of Nzoia & Yala Swamp	Serious; villages along both banks of Nzoia inundated/damaged by floods, causing human transfer to higher places, and sometimes life lost	Slight; farmlands along both banks of Nzoia damaged by floods (main crops damaged are rice and maize), and some livestocks lost	None; no intakes existing	Serious; many roads & bridges submerged and sometimes damaged, causing isolation of human settlements	16km dikes on both banks of Nzoia R. downstream of Luambwa Br.	M L

* Refer to Table 3.5.3

Table G3.2 Flood Condition and Damage by District (2/10)

Area	Flood Condition			Flood Damage				Existing Counter-measures	Category *
	Flooding	Bank Erosion	Sedimentation	Housing	Farmland / Grazing	Intake Facilities	Road / Bridge		
NYANZA PROVINCE									
4. Siaya District:	Lower Reaches of Nzoia and Yala, plus Small rivers in the South								
a. Lower Reaches of Nzoia & Yala rivers	- Yala swamp area affected by combination of floods from Nzoia & Yala rivers - Almost every year (e.g., 1982) - About 110km2 (incl. 3.c) - 0.5m to 1m deep - Lasts about a month	Slight; esp., along Nzoia	Slight; esp., at Yala Swamp	Slight; villages on left bank of Nzoia sometimes inundated by floods	Serious; farmlands in/ around Yala Swamp, esp., Yala Swamp Farm-Area 1, damaged by floods, and livestocks lost	Less; there are intakes of Bunyala Irr. Scheme on Nzoia and of Yala Swamp Farm on Yala, but barely damaged	Slight; farm roads submerged and sometimes damaged	A 9km dike on right bank of Yala River, a part of which was breached in 1988	M L
b. Hilly Land	- Valley bottoms of Nzoia, Yala & thier tributaries - Almost every year - Some 10m wide (less than km2) - Less than 0.5m deep - Lasts a few hours	Slight; esp., along Nzoia	Less	None; no human settlements existing in the valley bottoms	Less; limited farmlands in the valley bottoms sometimes damaged by floods	Less; intakes sometimes submerged	Less; minor bridges submerged and sometimes damaged	None	N S
5. Kisumu District:	Middle / Lower Reaches of Nyando and Sondu, plus small rivers in the Northeast								
a. Lower Reaches of Nyando River	- Kano Plain affected by the floods from Nyando as well as other small rivers: Kibos, Luanda, Ombeyi, Miriu, Nyaidho and Awach Kano - Almost every year (e.g., 1961, 82 & 88) - About 200km2 - 0.5m to 1m deep - Lasts about a week	Slight	Slight	Serious; towns/villages in Kano Plain, esp., Ahero Town, inundated/ damaged by floods, causing human transfer to higher places, and sometimes life lost	Serious; farmlands damaged and grazing affected by floods in Kano Plain (main crops damaged are rice, sugar-cane, maize & cotton)	Slight; intakes on Nyando submerged, but barely damaged (there are intakes of Ahero Pilot Sch. & S.W. Kano Irr. Project)	Serious; minor roads/bridges submerged and sometimes damaged (however truck roads are rarely affected)	2km dikes on both banks along Nyando downstream of Ahero Bridge	H L
b. Lower Reaches of Sondu River	- Rivermouth of Sondu on right bank (Lower Kadianga area) - Almost every year (esp.,1990) - About 10km2 (incl. 6.a) - 0.5m to 1m deep - Lasts about a week	Slight	Slight	Serious; villages/human settlements in Lower Kadianga area inundated/ damaged by floods, causing human transfer to higher places	Slight; limited farmlands in Lower Kadianga area damaged by floods, and livestocks lost	None; no intakes existing	Slight; community roads/bridges submerged and sometimes damaged (however the truck road to Kundu Bay is not affected)	None	M M
c. Mountain Slope Zone	Less	Serious	Slight	None	Less	Less	Less	None	N N
6. South Nyanza District:	Middle / Lower Reaches of Sondu, Awach Tende and Kuja, plus Lambwe River								
a. Lower Reaches of Sondu River	- Rivermouth of Sondu on left bank (Kobala area) - Almost every year (esp., 1990) - About 10km2 (incl. 5.b) - 0.5m to 1m deep - Lasts about a week	Slight	Slight	Serious; villages/human settlements in Kabola area inundated/damaged by floods, causing human transfer to higher places	Slight; limited farmlands in Kabola area damaged by floods, and livestocks lost	None; no intakes existing	Slight; community roads/bridges submerged and sometimes damaged (however the truck road to Kundu Bay is not affected)	None	M M

* Refer to Table 3.5.3

Table G3.2 Flood Condition and Damage by District (3/10)

Area	Flood Condition			Flood Damage				Existing Counter-measures	Category *
	Flooding	Bank Erosion	Sedimentation	Housing	Farmland / Grazing	Intake Facilities	Road / Bridge		
b. Lower Reaches of Awach Tende	- Rivermouth of Awach Tender - Almost every year (e.g., 1987 & 88) - Less than km2 - Less than 0.5m deep - Lasts about a week	Slight	Slight	Less; few human settlements existing in the rivermouth	Less; limited farmlands in the rivermouth sometimes damaged by floods	None; no intakes existing	Slight; the truck road to Homa Bay submerged/damaged	None	L S
c. Lower Reaches of Lambwe River	- Riverine area of Lambwe River - Almost every year - About some km2 - Less than 0.5m deep - Lasts about a week	Slight	Slight	None; no human settlements existing in the riverine area	Less; less cultivation and only seasonal grazing practiced in the riverine area	Less; few intakes existing	Slight; the truck road to Mbita submerged/damaged	None	L S
d. Lower Reaches of Kuja	- Rivermouth of Kuja (Central & South Kaden area) - Almost every year (esp., 1990) - About 25km2 - Less than 0.5m deep - Lasts about a month	Slight	Slight	Serious; human settlements in Central Kaden area inundated/ damaged by floods, causing human transfer to higher places and sometimes life lost	Slight; farmlands damaged and grazing affected by floods in Central Kaden area	Less; few intakes existing	Slight; main roads submerged and sometimes damaged	None	M M
e. Hilly Land	Less	Slight	Less	None	Less	Less	Less	None	N N
7. Kisii District:	Upper Reaches of Kuja and Awach Tende, plus small tributaries of Sondu								
a. Whole District; Hilly Land	- Valley bottoms of small rivers - Almost every year - Some 10m wide (less than km2) - Less than 0.5m deep - Lasts a few hours	Slight	Less	None; no human settlements existing in the valley bottoms	Less; limited farmlands in the valley bottoms sometimes damaged by floods	Less; intakes sometimes submerged, but barely damaged	Less; minor bridges submerged and sometimes damaged	None	N S
RIFT VALLEY PROVINCE									
8. Trans Nzoia District:	Upper Reaches of Nzoia								
a. Mountain Areas of Mt. Elgon & Cherangan Hill	Less	Less	Less	None	Less	None	Less	None	N N
b. Highland Area in between	- Riverine areas of small rivers, e.g., Nzoia & Koitobos rivers - Almost every year - Max. 1km wide (some km2) - Less than 0.5m deep - Lasts a few days	Slight	Slight	Less; few human settlements existing in the riverine areas	Less; limited farmlands in the riverine areas damaged by floods	Less; many intakes existing and Kitale Town Water Supply sometimes stopped by floods	Less; minor bridges submerged and sometimes damaged	None	N S

* Refer to Table 3.5.3

Table G3.2 Flood Condition and Damage by District (4/10)

Area	Flood Condition			Flood Damage				Existing Counter-measures	Category *
	Flooding	Bank Erosion	Sedimentation	Housing	Farmland / Grazing	Intake Facilities	Road / Bridge		
9. Uasin Gishu District:	Upper Reaches of Nzoia, and Upmost Reaches of Yala and Nyando								
a. Mountain Area of Mt. Londiani	Less	Less	Less	None	Less	None	Less	None	N N
b. Highland Area	- Riverine areas of small rivers, e.g., Sosiani River - Almost every year - Some 100m wide (some km2) - Less than 0.5m deep - Lasts a few days	Less	Less	None; no human settlements existing in the riverine areas	Less; less cultivation and only seasonal grazing practiced in the riverine areas	Less; many intakes existing, but barely damaged	Less; minor bridges sometimes submerged, but barely damaged	None	N S
10. Nandi District:	Upper Reaches of Nzoia, Yala and Nyando								
a. Whole District; Highland Area	- Riverine areas of small rivers, e.g., Kimondi River - Some years - Some 100m wide (some km2) - Less than 0.5m deep - Lasts a few days	Slight	Slight	None; no human settlements existing in the riverine areas	Less; less cultivation and only seasonal grazing practiced in the riverine areas	Less; many intakes existing and Nandi Hills & Lelemoko water supplies affected by floods	Less; minor bridges sometimes submerged, but barely damaged	None	N S
11. Kericho District:	Upper Reaches of Nyando, Sondu and Mara								
a. Whole District; Mountain Area	- Valley bottoms of small rivers, e.g., Nyando & Kipsonoi - Some years (e.g., 1988 & 90) - Some 10m wide (less than km2) - Less than 0.5m deep - Lasts a few hours	Less	Less; basin well covered with vegitation	None; no human settlements existing in the valley bottoms	Less; limited farmlands in the valley bottoms sometimes damaged by floods	Less; many intakes existing, but barely damaged	Less; minor bridges submerged and sometimes damaged (A minor bridge washed away in either 1988 or 90)	None	N S
12. Nakuru District:	Upper Reaches of Molo, and Lake Basins of Nakuru, Elmentaita and Naivasha, plus Upmost Reaches of Sondu								
a. Escarpment Zones on Both Sides of Rift Valley	Less	Slight	Less	None	Less	None	Less	None	N N
b. Bottom Plains of Rift Valley	- Rivermouth of Malewa flowing into Lake Naivasha - Some years (e.g., 1961) - About 5km2 - Less than 0.5m deep - Lasts a few days	Slight	Slight	None; no human settlements existing in the rivermouth	Slight; limited farmlands damaged and grazing affected by floods in the rivermouth	Less; some intakes existing, but barely damaged	Less; minor bridges sometimes submerged and drifts unpassable	None	L S

* Refer to Table 3.5.3

Table G3.2 Flood Condition and Damage by District (5/10)

Area	Flood Condition			Flood Damage				Existing Counter-measures	Category *
	Flooding	Bank Erosion	Sedimentation	Housing	Farmland / Grazing	Intake Facilities	Road / Bridge		
13. Baringo District:	Lower Reaches of Molo and Small Tributaries of Kerio, plus Lagas								
a. Whole District; Bottom Plains of Rift Valley	- Rivermouth of Molo flowing into Lake Baringo - Almost every year - Some km2 - Less than 0.5m deep - Lasts a few days	Slight	Slight; making tarbid the Baringo lake water	None; no human settlements existing in the rivermouth	Slight; limited farmlands in the rivermouth damaged by floods	Less; many intakes existing and Seretimini W.S. intake on Ndau R. swept away in 1988	Less; drifts unpassable	None	L S
14. Elgeyo-Marakwet District:	Small Tributaries of Kerio								
a. Whole District; Elgeyo Escarp. zone	Less	Slight	Serious	None	Less	Less	Less; drifts unpassable	None	N N
15. West Pokot District:	Upper Reaches of Turkwel and Small Tributaries of Kerio								
a. Whole District; Mountain Area	- Parts of riverine areas of Suam & Weiwei - Some years (e.g., 1984, 85 & 87) - Some 10m wide (Less than km2) - Less than 0.5m deep - Lasts a few hours	Slight	Less	Less; few human settlements existing in the riverine areas	Less; limited farmlands in the riverine areas sometimes damaged by floods	Less; few intakes existing	Less; drifts unpassable and a bridge washed away in 1985	None	N S
16. Turkana District:	Lower Reaches of Turkwel and Kerio, plus Some Lagas								
a. Midle/Lower Reaches of Turkwel River	- Riverine areas of Turkwel, esp. upstream of Katilo - Some years (e.g., 1988) - Some 100m wide on either bank (about 15km2) - Less than 0.5m deep - Lasts a few days	Slight	Slight	None; no human settlements existing in the riverine areas	Slight; limited farmlands in the riverine areas sometimes damaged by floods (there are irr. schemes at Katilo, Juluk & Nakwamoru)	Less; some intakes existing, but barely damaged	Less; drifts unpassable	None	L M
b. Lower Reaches of Kerio River	- Riverine areas of Kerio - Some years - Some 10m wide on either bank (some 10km2) - Less than 0.5m deep - Lasts about a week	Slight	Slight	None; no human settlements existing in the riverine areas	Less; less cultivation and only nomadic grazing practiced in the riverine areas	Less; few intakes existing	Less; drifts unpassable	None	N M
c. Other ASAL Area	Less	Less	Less	None	Less	None	Less; drifts unpassable	None	N N

* Refer to Table 3.5.3

Table G3.2 Flood Condition and Damage by District (6/10)

Area	Flood Condition			Flood Damage				Existing Counter-measures	Category *
	Flooding	Bank Erosion	Sedimentation	Housing	Farmland / Grazing	Intake Facilities	Road / Bridge		
17. Laikipia District:	Upper Reaches of Ewaso Ngiro North								
a. Whole District; Highland Area	Less	Slight	Slight	None	Less	Less	Less; drifts unpassable	None	N N
18. Samburu District:	Middle Reaches of Ewaso Ngiro North, and Lagas								
a. Whole District; Hilly Land	Less	Slight	Slight	None	Less	Less; some intakes damaged	Less; drifts unpassable	None	N N
19. Narok District:	Ewaso Ngiro South, Middle / Lower Reaches of Mara, and Upper Reaches of Kuja (Migori)								
a. Whole District; ASAL Area	Less	Slight	Slight	None	Less	Less	Less; drifts unpassable	None	N N
20. Kajiado District:	Lower Reaches of Ewaso Ngiro South, Lake Basins of Magadi and Amboseli, plus Upper Reached of Athi, Kiboko and Tsavo								
a. Whole District; ASAL Area	Less	Slight	Slight	None	Less	Less	Less; drifts unpassable	None	N N
CENTRAL PROVINCE									
21. Kiambu District:	Upper Reaches of Athi								
a. Mountain Area of Nyandarua Mountains	Less	Less; rocky	Less	None	Less	Less	Less	None	N N
b. Foot Area of Nyandarua Mountains	- Valley Bottoms of small rivers, e.g., Ruiru - Almost every year - Some 10m wide (Less than km2) - Less than 0.5m deep - Lasts a few hours	Slight	Slight	None; no human settlements existing in the valley bottoms	Less; limited farmlands in the valley bottoms sometimes damaged by floods	Less; many intakes existing, but barely damaged	Less; minor bridges sometimes submerged, but barely dameged	None	N S
22. Muranga District:	Upper Reaches of Tana								
a. Mountain Area of Nyandarua Mountains	Less	Less; rocky	Less	None	Less	Less	Less	None	N N
b. Foot Area of Nyandarua Mountains	- Valley Bottoms of small rivers, e.g., Saba Saba & Muragua - Almost every year (e.g., 1987 & 88) - Some 10m wide (less than km2) - Less than 0.5m deep - Lasts about a day	Slight	Slight	None; no human settlements existing in the valley bottoms	Less; limited farmlands in the valley bottoms damaged by floods	Slight; intake weirs damaged in 1988 & 90	Slight; minor bridges damaged in 1987 & 88	None	L S

* Refer to Table 3.5.3

Table G3.2 Flood Condition and Damage by District (7/10)

Area	Flood Condition			Flood Damage				Existing Counter-measures	Category *
	Flooding	Bank Erosion	Sedimentation	Housing	Farmland / Grazing	Intake Facilities	Road / Bridge		
23. Kirinyaga District:	Upper Reaches of Tana								
a. Mountain Area of Mt. Kenya	Less	Less; rocky	Less	None	Less	Less	Less	None	N N
b. Foot Area of Mt. Kenya	- Riverine areas of small rivers, e.g., Thiba & Ragati - Almost every year (e.g., 1987 & 88) - Some 10m wide (less than km2) - Less than 0.5m deep - Lasts about a day	Slight	Slight	None; no human settlements existing in the riverine areas	Less; limited farmlands in the riverine areas damaged by floods (there are Mwea Irr. Scheme)	Less; some intakes existing, but barely damaged (Sedimentation takes place)	Less; minor bridges sometimes submerged, but barely dameged	None	N S
24. Nyeri District:	Upper Reaches of Tana								
a. Whole District; Mountain Area	Less	Slight	Less	None	Less	Less; many intakes existing, but barely damaged	Less	None	N N
25. Nyandarua District:	Upper Reaches of Malewa and Upmost Reaches of Ewaso Ngiro North								
a. Whole District; Highland Area	- Swampy area of Lake Ol Bolossat - Some years (e.g., 1961 & 85) - Less than 10km2 - 0.5m to 1m deep - Lasts a few weeks	Less; rocky	Less	Slight; some human settlements forced to be relocated	Less; less cultivation and only seasonal grazing practiced in the swampy area	less; few intakes existing	Less; minor bridges sometimes submerged, but barely dameged	None	L S
26. NAIROBI:	Upper Reaches of Athi								
a. Whole Province; Highland Area	- Valley bottoms of small rivers: Nairobi & Ngong, due to narrow sections of bridges/culverts - Some years (esp., 1977, 86 & 88) - Some 10m wide (less than km2) - 0.5m to 1m deep - Lasts a few hours	Less	Less	Serious; some houses in the valley bottoms inundated/damaged, and sometimes life lost	Less; less cultivation practiced in the valley bottoms	less; few intakes existing	Serious; floodwaters restricted by bridges/culverts overflowing main roads, causing traffic interruption	Revetment in Nairobi & Ngong rivers, damaged in places by 1988-flood	M S
EASTERN PROVINCE									
27. Embu District:	Upper Reaches of Tana								
a. Mountain Area of Mt. Kenya	Less	Less; rocky	Less	None	Less	Less	Less	None	N N
b. Highland Area	- Riverine areas of small rivers, e.g., Thiba & Ena - Some years (e.g., 1988) - Some 10m wide (less than km2) - Less than 0.5m deep - Lasts a few hours	Slight	Slight	None; no human settlement existing in the riverine areas	Less; less cultivation and only seasonal grazing practiced in the riverine areas	Less; A part of intake weir for Ena Water Supply washed away	Slight; minor bridges washed away, and many submerged in 1988	None	L S

* Refer to Table 3.5.3

Table G3.2 Flood Condition and Damage by District (8/10)

Area	Flood Condition			Flood Damage				Existing Counter-measures	Category *
	Flooding	Bank Erosion	Sedimentation	Housing	Farmland / Grazing	Intake Facilities	Road / Bridge		
28. Meru District:	Upper Reaches of Tana and Ewaso Ngiro North								
a. Mountain Area of Mt. Kenya	Less	Less; rocky	Less	None	Less	Less	Less	None	N N
b. Highland Area	- Riverine areas of small rivers, e.g., Kazita & Mutonga, flowing into Tana - Almost every year (e.g., 1984, 88 & 89) - Some 10m wide (less than km2) - Less than 0.5m deep - Lasts a few hours	Slight	Less; Mt. Kenya well covered with forest	None; residents in Igarie sometimes forced to transfer to higher places	Less; limited farmlands, e.g., Kajuwa Irr. Scheme, sometimes damaged by floods	Less; an intake (under construction) damaged in 1989	Less; A minor bridge washed away in 1984	None	N S
29. Isiolo District:	Middle Reaches of Ewaso Ngiro North, and Upper Reaches of Tana								
a. Whole District; ASAL Area	- Riverine area of Ewaso Ngiro N. - Almost every year (e.g., 1983, 88 & 89) - About 10km wide - Less than 0.5m deep - Lasts about a month	Less	Slight	Less; few human settlement existing in the riverine area	Less; limited farmlands, e.g., Makadaka Irr. Scheme, sometimes damaged by floods	Less; few intakes existing	Less; bridges & culverts sometimes damaged	None	N L
30. Marsabit District:	Some Lagas								
a. Whole District; ASAL Area	Less	Less	Less	None	Less	Less	Less; Marsabit road unpassable at Sololo, Laisamis & Logo Logo	None	N N
31. Machakos District:	Middle Reaches of Athi								
a. Whole District; ASAL Area	Less	Slight	serious; at Thwake R.	None	Less	Less	Less; drifts unpassable	None	N N
32. Kitui District:	Middle Reaches of Tana								
a. Whole District; ASAL Area	Less	Slight	Slight; esp., in lagas	None	Less	Less	Less; drifts unpassable	None	N N
NORTH EASTERN PROVINCE									
33. Mandera District:	River Daua and Some Lagas								
a. Whole District; ASAL Area	- Parts of riverine area of Daua on right bank - Some years - Less than km2 - Less than 0.5m deep - Lasts about a week	Slight	Slight	Less; few human settlements existing in the riverine areas	Slight; limited farmlands in the riverine areas damaged by floods	Less; some intakes existing, but barely damaged	Less; drifts unpassable	Small/short dikes around three irr. schemes	L S

* Refer to Table 3.5.3

Table G3.2 Flood Condition and Damage by District (9/10)

Area	Flood Condition			Flood Damage				Existing Counter-measures	Category *
	Flooding	Bank Erosion	Sedimentation	Housing	Farmland / Grazing	Intake Facilities	Road / Bridge		
34. Wajir District:	Lower Reaches of Ewaso Ngiro North, and Some Lagas								
a. Whole District; ASAL Area	- Riverine area of Ewaso Ngiro North on left bank - Almost every year - About 5km wide on left bank - Less than 0.5m deep - Lasts about a month	Less	Slight	None; no human settlement existing in the riverine area	Less; less cultivation and only nomadic grazing practiced in the riverine area	Less; few intakes existing	Less; drifts unpassable	*None*	N L
35. Garissa District:	Lower Reaches of Ewaso Ngiro North and Tana, plus Lagas flowing into Indian Ocean								
a. Lower Reaches of Ewaso N'giro North and Small River Basins	- Riverine area of Ewaso Ngiro North on right bank - Almost every year - About 5km wide on right bank - Less than 0.5m deep - Lasts about a month	Less	Slight	None; no human settlement existing in the riverine area	Less; less cultivation and only nomadic grazing practiced in the riverine area	Less; few intakes existing	Less; drifts unpassable	*None*	N L
b. Middle Reaches of Tana River	- Riverine area of Tana River on left bank - Some years - About 100m wide on left bank (About 2,000km2 incl. 36.a) - Less than 0.5m deep - Lasts about a month	Serious; banks at concaved portions eroded annually 5m on average, leaving oxbow lakes	Serious; local deposition	Less; human settlements, generally located on natural dikes, barely inundated by floods	Slight; farmlands, e.g., in ADC Farm, eroded by floods	Slight; high cost maintenance due to bank erosion and sedimentation (turbidity of river water is also problem)	Slight; drifts unpassable, sometimes damaged, in lagas joining to Tana	Riprap works at Garissa	L L
COAST PROVINCE									
36. Tana River District:	Lower Reaches of Tana								
a. Whole District; ASAL Area	- Riverine areas of Tana - Some years (e.g., 1961, 88, 89 & 90) - About 5km wide on either bank (About 2,000km2 incl. 35.b) - Less than 0.5m deep - Lasts about a month	Serious; banks at concaved portions eroded annually 5m on average, leaving oxbow lakes	Serious; local deposition	Less; human settlements, generally located on natural dikes, barely inundated by floods (Garsen Village and other human settlements inundated only by 1961-flood)	Slight; limited farmlands inundated and eroded by floods	Slight; costly maintenance due to bank erosion, sedimentation and change of river course as observed at Hola and Bura irr. schemes	Slight; traffic interruption due to overflowing of lagas, and Bura new bridge threatened by change of river course	Dike around Lower Tana Irr. Scheme, and ripraps at Hola & Garissa	L L
37. Lamu District:	Lagas flowing into Indian Ocean								
a. Whole District; ASAL Area	Less; brackish water intrusion, however, observed in rivers	Less	Less	None	Less	Less	Less; drifts unpassable	None	N N

* Refer to Table 3.5.3

Table G3.2 Flood Condition and Damage by District (10/10)

Area	Flood Condition			Flood Damage				Existing Counter-measures	Category *
	Flooding	Bank Erosion	Sedimentation	Housing	Farmland / Grazing	Intake Facilities	Road / Bridge		
38. Taita-Taveta Dist.:	Middle Reaches of Athi, Upper Reaches of Voi, and Lower Reaches of Lumi								
a. Whole District; ASAL Area	- Rivermouth of Lumi near L. Jipe - Almost every year (e.g., 1987 & 89) - About 30km2 - 0.5m to 1m deep - Lasts about a week	Slight	Slight	Slight; some human settlements in the rivermouth damaged by floods	Serious; farmlands in the rivermouth, esp., at Kimorigo Irr. Scheme, damaged by floods	Slight; some intakes damaged by floods	Slight; minor roads/bridges damaged	Dikes on right bank of Lumi with short distances, damaged in places	M M
39. Kilifi District:	Lower Reaches of Athi, Voi (Rare) and Tana, plus Small Rivers, all flowing into Indian Ocean								
a. ASAL Area	Less	Less	Less	None	Less	Less	Less	None	N N
b. Coastal Area	- Riverine areas of Athi - Some years (e.g., 1961) - Some 100m wide (About 15km2) - Less than 0.5m deep - Lasts about a month	Slight	Serious; Athi riverbed gradually rising	Less; few human settlements existing in the riverine areas	Less; less cultivation and only seasonal grazing practiced in the riverine area	Slight; Baricho intake silted (turbidity of river water also problem)	Less; B-8 road br., however, washed away by 1961-flood	None	L M
40. Kwale District:	Small Rivers flowing into Indian Ocean								
a. ASAL Area	Less	Less	Less	None	Less	Less	Less	None	N N
b. Coastal Area	Less	Less	Slight; many dams filled with sand	None	Less	Less; intakes sometimes damaged	Less	None	N N
41. Mombasa Municipality:	No Particular Rivers								
a. Whole Municipality; Coastal Area	Less; Inundation, however, takes place due to poor drainage systems	Less	Less	None	Less	Less	Less	None	N N

Table G3.3 Categorization of Flood Areas

Damage	Flood Area per Place	Large (more than 50km2)	Medium (10km2 to 50km2)	Small (less than 10km2)	Nil
High		HL : 1 place - Kano Plain in Kisumu District	HM : None	HS : None	HN : None
Mid		ML : 1 place - Yala Swamp in Busia & Siaya districts (Yala and Nzoia river)	MM : 3 places - Sondu Rivermouth in Kisumu & South Nyanza districts - Kuja Rivermouth in South Nyanza District - Lumi Rivermouth in Taita-Taveta District	MS : 1 place - Nairobi City in Nairobi Province	MN : None
Low		LL : 1 place - Lower Tana in Tana River & Garissa districts	LM : 2 places - Middle/Lower Turkwel in Turukana District * - Downmost Athi in Kilifi District	LS : 10 places - Lower reaches of Malakisi, Sio, Awach Tende, Lambwe, Malewa, Molo & Daua rivers - Parts of Muranga, Nyandarua & Embu districts	LN : None
Negligible		NL : 1 place - Middle/Lower Ewaso Ngiro North in Garissa, Wajir & Isiolo districts	NM : 1 place - Lower Kerio in Turukana District	NS : 12 places - Riverine areas/valley bottoms in upper reaches	NN : 26 places - Small streams in mountain areas - Lagas in the ASAL area

* Damage only recorded at the katilo, Juluk and Nakwamoru irrigation schemes in the Middle Turkwel.

Note: HL, etc. are the abbreviations for categorizing flooded areas, which are also filled in the column "Category" of Table 3.5.2

Table G3.4 (1) Flood Protection Projects proposed to Date (1/2)

Name of Project	Objective River	Phase/ Stage	Planning Conditions				Features of Works		Information Source
			Protectin Level	Design Discharge	Catchment Area *	Specific Discharge	Planned	Completed	
Nzoia Flood Protection	Nzoia		25-year for left dike & 10-year for right dike	1,100m3/s (25-year)	11,849km2 (1EE1)	0.093m3/s/km2	18km dikes on the both banks from Lake Victoria up to Luambwa Bridge, and a diversion channel from 5km Point to Port Victoria with a length of 2km. (The latter only at a preliminary plan level.)	16 Km dikes on both banks downstream of Luambwa Bridge completed in 1986. (There are a number of depressions on the dikes due to poor maintenance, sometimes causing overflowing.)	Ref. 3 & 4
Yala Swamp Reclamation	Yala		100-year	300 m3/s	2,864km2 (1FG2)	0.105m3/s/km2	A 23km new channel with the right dike in Yala Swamp between 2km Point from Lake Sare and the vicinity of Bar Olwngo in the chain of Yala Swamp Reclamation Work	A 9km new channel with the right dike downstream of Bar Olengo completed in 1971. (The dike is of sufficient dimensions and well maintained althouth a part of the dike was breached in 1988 at a depression.)	Ref. 5
Nyando Flood Protection	Nyando	I - 1	25-year	425 m3/s	2,625km2 (1GD3)	0.162m3/s/km2	6 km dikes on both banks from the upmost of the swamp up to Ahero Bridge, and the re-construction of Abero Bridge.	4km dike on left bank and 3km dike on right bank downstream of Ahero Bridge completed to date. (There are a number of depressions on the dikes due to poor maintenance.)	Ref. 6
		I - 2	- do -	- do -	- do -	- do -	9.4 km dikes on both banks upstream of Ahero Bridge, and crossings and a drain.	None	
		I - 3	50-year				Hightening of the completed dikes.	None	
		II	- do -				Dredging of the Nyando rivermouth, and drainage channels on the inlands.	None	
		III					Three multipurpose dams; two in Nyando River and one in Kibos River.	None	
Lower Kuja Irrigation Development	Kuja		20-year	860m3/s	6,600km2 (1KB5)	0.130m3/s/km2	5km dikes on both banks downstream of Wath Ong'ar Bridge(11km Point). The distance between dikes is 300m to 700m.	None	Ref. 7

* At Control Point corresponding to the waterlevel guaging station immediately upstream of the target stretch, whose number is shown in the parenthesis.

Table G3.4 (2) Flood Protection Projects proposed to Date (2/2)

Name of Project	Objective River	Phase/ Stage	Planning Conditions				Features of Works		Information Source
			Protectin Level	Design Discharge	Catchment Area	Specific Discharge	Planned	Completed	
Nairobi City Drainage	Nairobi Ngong	I	50-year *	8 to 137 m3/s	Not specified	Not specified	Enlargement of existing bridges/culverts (13 sites).	None	Ref. 2
		II	- do -	- do -	- do -	- do -	Channel works immediately up and downstream of bridges/culverts (11 sites).	None	
Tana Delta Irrigation	Tana		50-year	2,400m3/s	95,430km2 (Rivermouth)	0.025m3/s/km2	Polders I, II & III for the protection of Tana Delta Irrigation Project, together with Sailoni weir.	A 32.64km dike in a part of Polder I completed in 1988.	Ref. 8
C112 Crossing of Tana **	Tana		50-year	2,000m3/s	95,430km2 (Rivermouth)	0.021m3/s/km2	About 13km road across Tana River near Garsen with the Idsowe, Mitapani and Lango la Simba bridges.	The construction works almost completed.	Ref. 9
Not specified	Tana		Not specified	Not specified	Not specified	Not specified	Bank protection works with groynes and gabions at the sites of: 1) ADC Farm pump station near Garissa 2) Bura new bridge 3) Hola Irrigation Project pump station 4) Hola Village 5) Mnazini Village	Relocation of Hola Irrigation Project pump station now under way.	Ref. 10

* For major bridges/culverts and channels.

** This is not actually a flood protection project, however its planning conditions will be referred to in this study.

Table G4.1 Features of Target Areas, Basic Methods and Protection Levels (1/2)

Target Area	Relevant Districts	Human Activities/Land Use in Flooded Area (Agricultural Potential)	Problem Identified	Target River/Stretch			Basic Method of Structural Measure	Protection Level	Design Discharge	Catchment Area	Specific Discharge
				River Name	Stretch(km) /Gradient	Length (km)		(year)	(m3/s)	(km2)	(m3/s/km2)
Yala Swamp	- Busia - Siaya	Rather intensive agriculture with livestock farming & fishery. There are Bunyala Pilot Irr. Scheme & Yala Swamp Farm - Area I. Considerable number of human settlements along Nzoia River. (High)	Flooding from Nzoia & Yala rivers	Nzoia	0 - 18 (1/3,400)	18	- Rehabilitation of existing dikes with construction of a drainage sluice (16km) - Construction of new dikes (2km)	25	1,070 (Control point : 1EE1)	11,849	0.090
				Yala	2 - 16 (1/2,700)	14	- Heightening of existing dike (9km) - Construction of a new dike on the right bank with a drainage sluice (14km) - Construction of a bridge	25	370 (Control point : 1FG2)	2,864	0.129
Kano Plain	- Kisumu	Intensive agriculture with livestock farming. There are Ahero Pilot and West Kano irrigation schemes. A lot of human settlements. (High)	Flooding from Nyando River together with Kibos, Luando, Ombeyi, Miriu, Nyaidho & Awach Kano rivers	Nyando	10 - 30 (1/700)	20	- Rehabilitation/heightening of existing dikes (2km) - Construction of new dikes (18km) - Re-construction of Ahero Bridge	25	590 (Control point : 1GD3)	2,625	0.225
				Kibos	0 - 10 (1/450)	10	- Construction of new dikes (10km) - Re-construction of two bridges	25	55 (Control point : Rivermouth)	274	0.201
				Luando	0 - 24 (1/700)	24	- Construction of new dikes with two closing sluices (24km) - Re-construction of four bridges	25	65 (Control point : Rivermouth)	440	0.148
				Ombeyi	-	-	- No measure. Only for usual drainage.	-	-	-	-
				Miriu	-	-	- No measure. Only for usual drainage.	-	-	-	-
				Nyaidho	0 - 12 (1/600)	12	- Construction of new dikes (12km) - Re-construction of a bridge	25	55 (Control point : Immediately upstream of confluence with Awach Kano River)	255	0.216
				Awach Kano	0 - 5 (1/400)	5	- Construction of new dikes (5km) - Re-construction of a bridge	25	60 (Control point : Immediately upstream of confluence with Nyaidho River)	364	0.165

Table G4.1 Features of Target Areas, Basic Methods and Protection Levels (2/2)

Target Area	Relevant Districts	Human Activities/Land Use in Flooded Area (Agricultural Potential)	Problem Identified	Target River/Stretch			Basic Method of Structural Measure	Protection Level	Design Discharge	Catchment Area	Specific Discharge
				River Name	Stretch(km) /Gradient	Length (km)		(year)	(m3/s)	(km2)	(m3/s/km2)
Sondu Rivermouth	- Kisumu - South Nyanza	Subsistence agriculture, grazing & fishery. Some human settlements. (Mid)	Flooding from Sondu River	Sondu	1 - 8 (1/500)	7	- Construction of new dikes (7km)	25	500 (Control point : 1JG1)	3,287	0.152
Kuja Rivermouth	- South Nyanza	Subsistence agriculture, grazing & fishery. Considerable number of human settlements. (Mid)	Flooding from Kuja River	Kuja	1 - 11 (1/900)	10	- Construction of new dikes (10km)	25	850 (Control point : 1KB5)	6,600	0.129
Middle Turkwel	- Turkana	Grazing and limited farming at Katilo, Juluk & Nakwamoru irr. schemes. Few human settlements. (Low)	Flooding from Turkwel River in parts	Turkwel	177 - 209 (1/570)	32	- Construction of three polders each with a intake sluice (11km for Katilo, 5km for Juluk and 7km for Nakwamoru irrigation schemes)	10	32 (Control point : Immediately downstream of confluence with Malmalte River)	7,014	0.046
Downmost Athi	- Kitifi	Grazing and limited farming. Few human settlemennts. (Mid)	Flooding from Athi River	Athi	9 - 29 (1/1,400)	20	- Construction of new dikes (20km)	10	1,590 (Control point : Rivermouth)	36,903	0.043
Lumi Rivermouth	- Taita-Taveta	Rather intensive agriculture with livestock farming. There is Kimorigo Irr. Scheme. Considerable number of human settlements. (High)	Flooding from Lumi River	Lumi	10 - 21 (1/400)	11	- Construction of new dikes with two intake sluices (11km) - Re-construction of a bridge	25	160 (Control point : 3J15C)	448	0.357
Nairobi City *	- Nairobi Province	A lot of housings with roads, bridges, culverts & service pipes. Less agriculture (urban area).	Flooding due to narrow sections of bridges/ culverts	(Nairobi River, Ngong River and their tributaries)			- Enlargement of existing bridges/culverts (13 sites) - Channel works immediately up/down-stream of bridges/culverts (11 sites)	50 (without dike, for bridge)	(Variable by location.)		
Lower Tana	- Tana River - Garissa	Grazing and limited farming. There are Tana Delta Irr. Scheme, Hola/Bura irr. projects & ADC Farm. A few human settlements located on natural dikes barely inundated. (Mid to Low)	Bank erosion at concave portions near villages, intakes & bridges	Tana	0 - 650 (1/6,000 to 1/1,500)	650	- Bank protection with groynes/riprap at Ngao, Garsen, Mnazini, Wenje, Hola, Hola Intake, Bura Bridge, Bura Intake, Garissa, ADC Farm Intake, Saka & Mbalambala (35km in total)	10	(Variable by location.)		

* See Ref.2.

Table G4.2 Criteria for Determination of Protection Level

Protection Method	Land Use Condition	Explanation	Target Area Applied	Project Scale		
				For River Channel/Dike		For Weir/ Bridge
				In this Study	In Future	
Embankment Method (HWL higher than ground height)	Uban Area	Population density high and social/economic activities vigorous. Floods seriously affect thereon and human life subject to loss.	None	50 - year	100 - year	100 - year
	Rural Area - A	A lot of human settlements in the flooed area. Floods probably cause comparatively serious damage to the society and economy. Human life also subject to loss.	- Yala Swamp - Kano Plain - Sondu Rivermouth - Kuja Rivermouth - Lumi Rivermouth	25 - year	50 - year	50 - year
	Rural Area - B	Less human settlements in the flooded area. Floods have limited influence on the social/ economic activities in the vicinity area. Human life barely endagered.	- Middle Turkwel - Downmost Athi - Lower Tana	10 - year	25 - year	25 - year
Non-embankment Method (HWL lower than ground height)	Uban Area	Land use condition is the same as above. But without provision of dikes, damage potential in the flooded area is lesser than the above. Further, loss of human life unlikely.	- Nairobi City	25 - year	50 - year	50 - year
	Rural Area - A		None	10 - year	25 - year	25 - year
	Rural Area - B		None	5 - year	10 - year	10 - year

Table G4.3 (1) Project Costs for Flood Protection Works (1/2)

Cost Item	Unit	Unit Price	Yala Swamp				Kano Plain									
			Nzoia River		Yala River		Nyando River		Kibos River		Luando River		Nyaidho River		Awach Kano River	
		(US $)	Quantity	Amount (US $)	Quantity	Amount (US $)	Quantity	Amount (US $)	Quantity	Amount (US $)	Quantity	Amount (US $)	Quantity	Amount (US $)	Quantity	Amount (US $)
1. Construction Cost				4,570,800		7,683,000		8,166,600		1,151,800		3,062,800		1,268,800		575,900
Channel Excavation	m3	3.4	590,000	2,006,000	950,000	3,230,000	900,000	3,060,000	130,000	442,000	320,000	1,088,000	160,000	544,000	65,000	221,000
Dike Embankment	m3	3.0	460,000	1,380,000	730,000	2,190,000	690,000	2,070,000	100,000	300,000	240,000	720,000	120,000	360,000	50,000	150,000
Sluice	pc	130,000.0	1	130,000	1	130,000	0	0	0	0	2	260,000	0	0	0	0
Bridge	m2	720.0	0	0	500	360,000	1,600	1,152,000	200	144,000	400	288,000	100	72,000	100	72,000
Groyne/Riprap	pc	2,500.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
General/Miscelaneous (30% of the above total)	L.S.			1,054,800		1,773,000		1,884,600		265,800		706,800		292,800		132,900
2. Land Acquisition Cost	ha	420.0	28	11,760	0	0	74	31,080	30	12,600	72	30,240	36	15,120	15	6,300
3. E/S Cost (15% of 1.)	L.S.			685,620		1,152,450		1,224,990		172,770		459,420		190,320		86,385
4. Administration Cost (5% of 1. & 2.)	L.S.			229,128		384,150		409,884		58,220		154,652		64,196		29,110
5. Physical Contingency (20% of 1. to 4.)	L.S.			1,099,462		1,843,920		1,966,511		279,078		741,422		307,687		139,539
6. Total				6,596,770		11,063,520		11,799,065		1,674,468		4,448,534		1,846,123		837,234
				(TOTAL OF YALA SWAMP :		17,660,290)								(TOTAL OF KANO PLAIN :		20,605,424)

Table G4.3 (2) Project Costs for Flood Protection Works (2/2)

Cost Item	Unit	Unit Price	Sondu Rivermouth		Kuja Rivermouth		Middle Turkwel		Downmost Athi		Lumi Rivermouth		Nairobi City		Lower Tana	
			Sondu River		Kuja River		Turkwel River		Athi River		Lumi River		Nairobi, Ngong, etc.		Tana River	
		(US $)	Quantity	Amount (US $)	Quantity	Amount (US $)	Quantity	Amount (US $)	Quantity	Amount (US $)	Quantity	Amount (US $)	Quantity	Amount (US $)	Quantity	Amount (US $)
1. Construction Cost				3,398,200		3,481,400		4,531,800		6,962,800		5,759,000		7,500,000 *		2,275,000
Channel Excavation	m3	3.4	460,000	1,564,000	470,000	1,598,000	540,000	1,836,000	940,000	3,196,000	720,000	2,448,000			0	0
Dike Embankment	m3	3.0	350,000	1,050,000	360,000	1,080,000	420,000	1,260,000	720,000	2,160,000	550,000	1,650,000			0	0
Sluice	pc	130,000.0	0	0	0	0	3	390,000	0	0	2	260,000			0	0
Bridge	m2	720.0	0	0	0	0	0	0	0	0	100	72,000			0	0
Groyne/Riprap	pc	2,500.0	0	0	0	0	0	0	0	0	0	0			700	1,750,000
General/Miscelaneous (30% of the above total)	L.S.			784,200		803,400		1,045,800		1,606,800		1,329,000				525,000
2. Land Acquisition Cost	ha	420.0	35	14,700	40	16,800	0	0	0	0	55	23,100	0	0	0	0
3. E/S Cost (15% of 1.)	L.S.			509,730		522,210		679,770		1,044,420		863,850		1,125,000		341,250
4. Administration Cost (5% of 1. & 2.)	L.S.			170,645		174,910		226,590		348,140		289,105		375,000		113,750
5. Physical Contingency (20% of 1. to 4.)	L.S.			818,655		839,064		1,087,632		1,671,072		1,387,011		1,800,000		546,000
6. Total				4,911,930		5,034,384		6,525,792		10,026,432		8,322,066		10,800,000		3,276,000

* Refer to Ref.2.

Table G5.1 Damage Rate of Maize

Inundation Depth * \ Duration of Flooding	Less than a Day	A Few Days	More than a Week
Less than 0.5m	0.3	0.5	0.7
0.5m to 1.0m	0.5	0.8	1.0
More than 1.0m	0.7	1.0	1.0

* The inundation depth in the table refers to average inundation depth in the flooded area at the flood peak.

Note: 1) Based on the interview with farmers.
2) Floods usually hit farmlands where maize has grown up 0.5m to 2.0m high since farmers are apt to plant maize immediatly after the starting of rainy seasons.

Table G5.2 Damage Rate of Housing

Inundation Depth (m) *	Damage Rate
Below Floor Level	0.03
0.5m above Floor Level	0.05
1.0m above Floor Level	0.07
2.0m above Floor Level	0.11
3.0m above Floor Level	0.15
More than 3.0m above Floor Level	0.22

* The inundation depth in the table refers to average inundation depth in the flooded area at the flood peak.

Note: 1) Quoted from the Technical Standerd for River and Sabo Works in Japan.
2) In Kenya, the floor level is usually slightly higher than the ground height near housing.

Table G5.3 Hydraulic Conditions of Non-damage Floods and Objective Past Floods

Target Area	Target River	Non-damage Flood			Objective Past Flood						
		Discharge (m3/s) *	Probability **	Integrated Probability	Month/ Year	Discharge (m3/s) ***	Probability **	Integrated Probability	Flooded Area (km2) ****	Inundation Depth (m)	Duration
Yala Swamp	Nzoia	270	1.5	1.4	Oct. 1988	680	7.7	6.1	128	0.5 to 1.0	More than a week
	Yala	80	1.3			200	4.5				
Kano Plain	Nyando *****	200	2.2	-	Apr. 1988	430	10.5	-	227	0.5 to 1.0	More than a week
Sondu Rivermouth	Sondu	210	2.7	-	May 1988	300	5.9	-	12	0.5 to 1.0	More than a week
Kuja Rivermouth	Kuja	410	2.4	-	Apr. 1988	570	5.9	-	27	Less than 0.5	More than a week
Middle Turkwel	Turkwel	150	2.4	-	Apr. 1988	300	8.9	-	24	Less than 0.5	A few days
Downmost Athi	Athi	500	1.6	-	Dec. 1986	1,500	9.1	-	16	Less than 0.5	More than a week
Lumi Rivermouth	Lumi	55	2.8	-	Dec. 1987	100	8.3	-	39	0.5 to 1.0	More than a week
Nairobi City ******	Nairobi, Ngong, etc.	-	2	-	-	-	50	-	4	0.5 to 1.0	A few hours

* The discharge of the non-damage flood was determined on the estimation of bankful discharge along the target stretch with reference to the flood discharge record observed at the control point immediately upstream of the stretch.

** Refer to Sectoral Report B - Hydrology.

*** The discharge of the objective past flood was determined based mainly on the flood water level given in the interview survey with reference to the flood discharge record observed at the control point immediately upstream of the stretch.

**** Refer to Fig. 04.1 to Fig. 04.7.

***** The flooding conditions in Kano Plain are dominated by the floods of Nyando River, although other small rivers may contribute to the conditions to some degree. Thus, the probabilities of the non-damaged flood and the objective past flood can be represented by those of Nyando River.

****** For all information in the table, refer to Ref.2.

Table GS.4 Damages by Objective Past Floods

a. Year 1990 Land Use/Assets Condition

Target Area	Agricultural Damage			Housing Damage			Damage to Public Facilities	Indirect Damage	Total
	Farmland (ha)	Damage Rate	Damage (US $) *	Number of Houses	Damage Rate	Damage (US $) **	(US $) ***	(US $) ****	(US $)
Yala Swamp	2,048	1.00	688,128	2,458	0.06	221,184	110,592	305,971	1,325,875
Kano Plain	10,896	1.00	3,661,056	13,075	0.06	1,176,768	588,384	1,627,862	7,054,070
Sondu Rivermouth	288	1.00	96,768	346	0.06	31,104	15,552	43,027	186,451
Kuja Rivermouth	648	0.70	152,410	778	0.04	46,656	23,328	66,718	289,112
Middle Turkwel	960	0.50	161,280	0	0.04	0	0	48,384	209,664
Downmost Athi	256	0.70	60,211	0	0.04	0	0	18,063	78,275
Lumi Rivermouth	2,184	1.00	733,824	2,621	0.06	235,872	117,936	326,290	1,413,922
Nairobi City	0	0.30	0	5,600	0.06	2,688,000	1,344,000	1,209,600	5,241,600

* 120 US$/ton x 2.8 ton/ha x Farmland (ha) x Damage Rate --- Maize assumed to be planted

** 1,500 US$/house x Number of Houses x Damage Rate ----- for rural area
8,000 US$/house x Number of Houses x Damage Rate ----- for urban area

*** 50% of Housing Damage

**** 30% of the total of Agricultural Damage, Housing Damage and Damage of Public Facilities

b. Year 2010 Land Use/Assets Condition

Target Area	Agricultural Damage			Housing Damage			Damage to Public Facilities	Indirect Damage	Total
	Farmland (ha)	Damage Rate	Damage (US $) *****	Number of Houses	Damage Rate	Damage (US $) *****	(US $) ***	(US $) ****	(US $)
Yala Swamp	10,240	1.00	5,642,650	2,458 ******	0.06	362,742	181,371	1,856,029	8,042,791
Kano Plain	18,160	1.00	10,006,886	21,792	0.06	3,216,499	1,608,250	4,449,491	19,281,126
Sondu Rivermouth	960	1.00	528,998	1,152	0.06	170,035	85,018	235,215	1,019,267
Kuja Rivermouth	2,160	0.70	833,172	2,592	0.04	255,053	127,526	364,726	1,580,477
Middle Turkwel	1,920	0.50	528,998	2,304	0.04	226,714	113,357	260,721	1,129,789
Downmost Athi	1,280	0.70	493,732	1,536	0.04	151,142	75,571	216,134	936,579
Lumi Rivermouth	3,120	1.00	1,719,245	3,744	0.06	552,614	276,307	764,450	3,312,616
Nairobi City	0	0.30	0	8,000	0.06	6,297,600	3,148,800	2,833,920	12,280,320

***** Increasing rate of production/assets value from 1990 to 2010; (half rate of per-capita GDP growth; 5%)^20; taken into account.

****** Yala Swamp will be used exclusively as farmland, so that number of houses may barely increase from the condition in 1990.

Table G5.5 (1) Annual Average Damages due to Flooding; 1990 - Condition (1/2)

a. Yala Swamp

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
1.4 - year	-	0	-	-	-
5 - year	0.5143	1,153,858	576,929	296,706	296,706
10 - year	0.1000	1,780,000	1,466,929	146,693	443,399
15 - year	0.0333	2,146,270	1,963,135	65,438	508,837
20 - year	0.0167	2,406,142	2,276,206	37,937	546,774
25 - year	0.0100	2,607,715	2,506,929	25,069	571,843
30 - year	0.0067	2,772,412	2,690,064	17,934	589,777
40 - year	0.0083	3,032,285	2,902,348	24,186	613,963
50 - year	0.0050	3,233,858	3,133,071	15,665	629,628
70 - year	0.0057	3,537,804	3,385,831	19,348	648,976
100 - year	0.0043	3,860,000	3,698,902	15,852	664,828

b. Kano Plain

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
2.2 - year	-	0	-	-	-
5 - year	0.2545	3,705,309	1,852,654	471,585	471,585
10 - year	0.1000	6,830,000	5,267,654	526,765	998,350
15 - year	0.0333	8,657,827	7,743,914	258,130	1,256,481
20 - year	0.0167	9,954,691	9,306,259	155,104	1,411,585
25 - year	0.0100	10,960,617	10,457,654	104,577	1,516,161
30 - year	0.0067	11,782,519	11,371,568	75,810	1,591,972
40 - year	0.0083	13,079,383	12,430,951	103,591	1,695,563
50 - year	0.0050	14,085,309	13,582,346	67,912	1,763,475
70 - year	0.0057	15,602,118	14,843,713	84,821	1,848,296
100 - year	0.0043	17,210,000	16,406,059	70,312	1,918,608

c. Sondu Rivermouth

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
2.7 - year	-	0	-	-	-
5 - year	0.1704	151,423	75,712	12,899	12,899
10 - year	0.1000	320,000	235,712	23,571	36,470
15 - year	0.0333	418,611	369,306	12,310	48,780
20 - year	0.0167	488,577	453,594	7,560	56,340
25 - year	0.0100	542,846	515,712	5,157	61,497
30 - year	0.0067	587,188	565,017	3,767	65,264
40 - year	0.0083	657,154	622,171	5,185	70,449
50 - year	0.0050	711,423	684,288	3,421	73,870
70 - year	0.0057	793,255	752,339	4,299	78,169
100 - year	0.0043	880,000	836,627	3,586	81,755

d. Kuja Rivermouth

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
2.4 - year	-	0	-	-	-
5 - year	0.2167	237,238	118,619	25,701	25,701
10 - year	0.1000	460,000	348,619	34,862	60,563
15 - year	0.0333	590,308	525,154	17,505	78,068
20 - year	0.0167	682,762	636,535	10,609	88,677
25 - year	0.0100	754,476	718,619	7,186	95,863
30 - year	0.0067	813,070	783,773	5,225	101,088
40 - year	0.0083	905,524	859,297	7,161	108,249
50 - year	0.0050	977,238	941,381	4,707	112,956
70 - year	0.0057	1,085,373	1,031,305	5,893	118,849
100 - year	0.0043	1,200,000	1,142,686	4,897	123,746

Table G5.5 (2) Annual Average Damages due to Flooding; 1990 - Condition (2/2)

e. Middle Turkwel

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
2.4 - year	-	0	-	-	-
5 - year	0.2167	118,619	59,309	12,850	12,850
10 - year	0.1000	230,000	174,309	17,431	30,281
15 - year	0.0333	295,154	262,577	8,753	39,034
20 - year	0.0167	341,381	318,267	5,304	44,338
25 - year	0.0100	377,238	359,309	3,593	47,931
30 - year	0.0067	406,535	391,886	2,613	50,544
40 - year	0.0083	452,762	429,649	3,580	54,124
50 - year	0.0050	488,619	470,691	2,353	56,478
70 - year	0.0057	542,686	515,653	2,947	59,424
100 - year	0.0043	600,000	571,343	2,449	61,873

f. Downmost Athi

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
1.6 - year	-	0	-	-	-
5 - year	0.4250	56,887	28,443	12,088	12,088
10 - year	0.1000	90,000	73,443	7,344	19,433
15 - year	0.0333	109,370	99,685	3,323	22,756
20 - year	0.0167	123,113	116,242	1,937	24,693
25 - year	0.0100	133,773	128,443	1,284	25,977
30 - year	0.0067	142,483	138,128	921	26,898
40 - year	0.0083	156,227	149,355	1,245	28,143
50 - year	0.0050	166,887	161,557	808	28,951
70 - year	0.0057	182,961	174,924	1,000	29,950
100 - year	0.0043	200,000	191,480	821	30,771

g. Lumi Rivermouth

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
2.8 - year	-	0	-	-	-
5 - year	0.1571	749,920	374,960	58,922	58,922
10 - year	0.1000	1,650,000	1,199,960	119,996	178,918
15 - year	0.0333	2,176,513	1,913,256	63,775	242,694
20 - year	0.0167	2,550,080	2,363,296	39,388	282,082
25 - year	0.0100	2,839,841	2,694,960	26,950	309,031
30 - year	0.0067	3,076,593	2,958,217	19,721	328,753
40 - year	0.0083	3,450,159	3,263,376	27,195	355,948
50 - year	0.0050	3,739,920	3,595,040	17,975	373,923
70 - year	0.0057	4,176,843	3,958,382	22,619	396,542
100 - year	0.0043	4,640,000	4,408,422	18,893	415,435

h. Nairobi City

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
2 - year	-	0	-	-	-
5 - year	0.3000	1,491,138	745,569	223,671	223,671
10 - year	0.1000	2,620,000	2,055,569	205,557	429,228
15 - year	0.0333	3,280,342	2,950,171	98,339	527,567
20 - year	0.0167	3,748,862	3,514,602	58,577	586,143
25 - year	0.0100	4,112,275	3,930,569	39,306	625,449
30 - year	0.0067	4,409,205	4,260,740	28,405	653,854
40 - year	0.0083	4,877,725	4,643,465	38,696	692,549
50 - year	0.0050	5,241,138	5,059,431	25,297	717,847
70 - year	0.0057	5,789,118	5,515,128	31,515	749,362
100 - year	0.0043	6,370,000	6,079,559	26,055	775,417

Table G5.6 (1) Annual Average Damages due to Flooding; 2010 - Condition (1/2)

a. Yala Swamp

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
1.4 - year	-	0	-	-	-
5 - year	0.5143	6,953,043	3,476,521	1,787,925	1,787,925
10 - year	0.1000	10,740,000	8,846,521	884,652	2,672,577
15 - year	0.0333	12,955,228	11,847,614	394,920	3,067,498
20 - year	0.0167	14,526,957	13,741,093	229,018	3,296,516
25 - year	0.0100	15,746,085	15,136,521	151,365	3,447,881
30 - year	0.0067	16,742,185	16,244,135	108,294	3,556,176
40 - year	0.0083	18,313,915	17,528,050	146,067	3,702,243
50 - year	0.0050	19,533,043	18,923,479	94,617	3,796,860
70 - year	0.0057	21,371,333	20,452,188	116,870	3,913,730
100 - year	0.0043	23,320,000	22,345,667	95,767	4,009,497

b. Kano Plain

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
2.2 - year	-	0	-	-	-
5 - year	0.2545	10,133,758	5,066,879	1,289,751	1,289,751
10 - year	0.1000	18,680,000	14,406,879	1,440,688	2,730,439
15 - year	0.0333	23,679,231	21,179,615	705,987	3,436,426
20 - year	0.0167	27,226,242	25,452,736	424,212	3,860,638
25 - year	0.0100	29,977,517	28,601,879	286,019	4,146,657
30 - year	0.0067	32,225,472	31,101,495	207,343	4,354,001
40 - year	0.0083	35,772,483	33,998,978	283,325	4,637,325
50 - year	0.0050	38,523,758	37,148,121	185,741	4,823,066
70 - year	0.0057	42,672,333	40,598,046	231,989	5,055,055
100 - year	0.0043	47,070,000	44,871,167	192,305	5,247,360

c. Sondu Rivermouth

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
2.7 - year	-	0	-	-	-
5 - year	0.1704	806,910	403,455	68,737	68,737
10 - year	0.1000	1,710,000	1,258,455	125,846	194,582
15 - year	0.0333	2,238,274	1,974,137	65,805	260,387
20 - year	0.0167	2,613,090	2,425,682	40,428	300,815
25 - year	0.0100	2,903,820	2,758,455	27,585	328,399
30 - year	0.0067	3,141,364	3,022,592	20,151	348,550
40 - year	0.0083	3,516,180	3,328,772	27,740	376,290
50 - year	0.0050	3,806,910	3,661,545	18,308	394,598
70 - year	0.0057	4,245,294	4,026,102	23,006	417,604
100 - year	0.0043	4,710,000	4,477,647	19,190	436,794

d. Kuja Rivermouth

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
2.4 - year	-	0	-	-	-
5 - year	0.2167	1,283,839	641,919	139,083	139,083
10 - year	0.1000	2,500,000	1,891,919	189,192	328,274
15 - year	0.0333	3,211,409	2,855,704	95,190	423,465
20 - year	0.0167	3,716,161	3,463,785	57,730	481,194
25 - year	0.0100	4,107,678	3,911,919	39,119	520,314
30 - year	0.0067	4,427,570	4,267,624	28,451	548,764
40 - year	0.0083	4,932,322	4,679,946	39,000	587,764
50 - year	0.0050	5,323,839	5,128,081	25,640	613,404
70 - year	0.0057	5,914,196	5,619,017	32,109	645,513
100 - year	0.0043	6,540,000	6,227,098	26,688	672,201

Table G5.6 (2) Annual Average Damages due to Flooding; 2010 - Condition (2/2)

e. Middle Turkwel

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
2.4 - year	-	0	-	-	-
5 - year	0.2167	640,950	320,475	69,436	69,436
10 - year	0.1000	1,240,000	940,475	94,048	163,484
15 - year	0.0333	1,590,422	1,415,211	47,174	210,657
20 - year	0.0167	1,839,050	1,714,736	28,579	239,236
25 - year	0.0100	2,031,901	1,935,475	19,355	258,591
30 - year	0.0067	2,189,471	2,110,686	14,071	272,662
40 - year	0.0083	2,438,099	2,313,785	19,282	291,944
50 - year	0.0050	2,630,950	2,534,525	12,673	304,617
70 - year	0.0057	2,921,745	2,776,348	15,865	320,481
100 - year	0.0043	3,230,000	3,075,873	13,182	333,664

f. Downmost Athi

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
1.6 - year	-	0	-	-	-
5 - year	0.4250	623,713	311,856	132,539	132,539
10 - year	0.1000	1,000,000	811,856	81,186	213,725
15 - year	0.0333	1,220,114	1,110,057	37,002	250,726
20 - year	0.0167	1,376,287	1,298,201	21,637	272,363
25 - year	0.0100	1,497,425	1,436,856	14,369	286,732
30 - year	0.0067	1,596,402	1,546,913	10,313	297,044
40 - year	0.0083	1,752,575	1,674,488	13,954	310,999
50 - year	0.0050	1,873,713	1,813,144	9,066	320,064
70 - year	0.0057	2,056,373	1,965,043	11,229	331,293
100 - year	0.0043	2,250,000	2,153,186	9,228	340,521

g. Lumi Rivermouth

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
2.8 - year	-	0	-	-	-
5 - year	0.1571	1,769,780	884,890	139,054	139,054
10 - year	0.1000	3,880,000	2,824,890	282,489	421,543
15 - year	0.0333	5,114,400	4,497,200	149,907	571,450
20 - year	0.0167	5,990,220	5,552,310	92,538	663,988
25 - year	0.0100	6,669,559	6,329,890	63,299	727,287
30 - year	0.0067	7,224,620	6,947,090	46,314	773,601
40 - year	0.0083	8,100,441	7,662,530	63,854	837,456
50 - year	0.0050	8,779,780	8,440,110	42,201	879,656
70 - year	0.0057	9,804,137	9,291,958	53,097	932,753
100 - year	0.0043	10,890,000	10,347,069	44,345	977,098

h. Nairobi City

Probability	(1) Balance of Probabilities	Flood Damage (US$)	(2) Average Flood Damage (US$)	(1) x (2) Annual Average Flood Damage (US$)	Accumulated Annual Average Flood Damage (US$)
2 - year	-	0	-	-	-
5 - year	0.3000	3,496,957	1,748,478	524,543	524,543
10 - year	0.1000	6,140,000	4,818,478	481,848	1,006,391
15 - year	0.0333	7,686,081	6,913,041	230,435	1,236,826
20 - year	0.0167	8,783,043	8,234,562	137,243	1,374,069
25 - year	0.0100	9,633,913	9,208,478	92,085	1,466,154
30 - year	0.0067	10,329,125	9,981,519	66,543	1,532,697
40 - year	0.0083	11,426,087	10,877,606	90,647	1,623,344
50 - year	0.0050	12,276,957	11,851,522	59,258	1,682,601
70 - year	0.0057	13,559,961	12,918,459	73,820	1,756,421
100 - year	0.0043	14,920,000	14,239,980	61,028	1,817,450

Table G5.7 Annual Average Damages due to Bank Erosion in Lower Tana

Site	Year 1990 Land Use/Assets Condition							Year 2010 Land Use/Assets Condition						
	Agricultural Damage		Housing Damage		Damage to Public Facilities	Indirect Damage	Total	Agricultural Damage		Housing Damage		Damage to Public Facilities	Indirect Damage	Total
	Farmland (ha)	Damage (US$) *	Number of Houses	Damage (US$) **	(US$) ***	(US$) ****	(US$)	Farmland (ha)	Damage (US$) *****	Number of Houses	Damage (US$) *****	(US$) ***	(US$) ****	(US$)
Ngao	0.75	504	1	1,350	675	759	3,288	2.50	2,755	3	7,380	3,690	4,148	17,973
Garsen	0.45	302	1	810	405	455	1,973	1.50	1,653	2	4,428	2,214	2,489	10,784
Mnazini	0.45	302	1	810	405	455	1,973	1.50	1,653	2	4,428	2,214	2,489	10,784
Wenje	0.30	202	0	540	270	303	1,315	1.00	1,102	1	2,952	1,476	1,659	7,189
Hola	0.60	403	1	1,080	540	607	2,630	2.00	2,204	2	5,904	2,952	3,318	14,378
Hola Intake	0.30	202	0	540	10,270	3,303	14,315	1.00	1,102	1	2,952	11,476	4,659	20,189
Bura Bridge	0.30	202	0	540	13,270	4,203	18,215	1.00	1,102	1	2,952	14,476	5,559	24,089
Bura Intake	0.30	202	0	540	10,270	3,303	14,315	1.00	1,102	1	2,952	11,476	4,659	20,189
Garissa	0.60	403	1	1,080	540	607	2,630	2.00	2,204	2	5,904	2,952	3,318	14,378
ADC Farm Intake	0.30	202	0	540	10,270	3,303	14,315	1.00	1,102	1	2,952	11,476	4,659	20,189
Saka	0.45	302	1	810	405	455	1,973	1.50	1,653	2	4,428	2,214	2,489	10,784
Mbalambala	0.45	302	1	810	405	455	1,973	1.50	1,653	2	4,428	2,214	2,489	10,784
Total	5.25	3,528	6	9,450	47,725	18,211	78,914	17.50	19,286	21	51,660	68,830	41,933	181,709

* 120 US$/ton x 2.8 ton/ha x 2 harvests/year x Farmland (ha) ----- Maize assumed to be planted

** 1,500 US$/house x Number of Houses

*** 50% of Housing Damage plus replacing cost of intake facilities and bridges.

**** 30% of the total of Agricultural Damage, Housing Damage & Damage of Public Facilities

***** Increasing rate of production/assets value from 1990 to 2010; (half rate of per-capita GDP growth; 5%)^20; taken into account.

Table G6.1 Annual Costs, Annual Benefits and B/Cs

Land Use/Assets Condition	Item	Yala Swamp	kano Plain	Sondu Rivermouth	Kuja Rivermouth	Middle Turkwel	Downmost Athi	Lumi Rivermouth	Nairobi City	Lower Tana
	Initial Cost (Project Cost)	17,660,000	20,650,000	4,912,000	5,034,000	6,526,000	10,026,000	8,322,000	10,800,000	3,276,000
	Annual Cost; C *	1,443,579	1,687,990	401,521	411,494	533,454	819,554	680,264	882,823	267,790
Year 1990	Annual Average Damage Reduction; D/R	572,000	1,516,000	61,000	96,000	30,000	19,000	309,000	718,000	79,000
	Annual O/M Cost; O/M **	88,300	103,250	24,560	25,170	32,630	50,130	41,610	54,000	16,380
	Annual Benefit; B (D/R - O/M)	483,700	1,412,750	36,440	70,830	(2,630)	(31,130)	267,390	664,000	62,620
	B - C	(959,879)	(275,240)	(365,081)	(340,664)	(536,084)	(850,684)	(412,874)	(218,823)	(205,170)
	B / C	0.34	0.84	0.09	0.17	0.00	0.00	0.39	0.75	0.23
Year 2010	Annual Average Damage Reduction; D/R	3,448,000	4,147,000	328,000	520,000	163,000	214,000	727,000	1,683,000	182,000
	Annual O/M Cost; O/M **	88,300	103,250	24,560	25,170	32,630	50,130	41,610	54,000	16,380
	Annual Benefit; B (D/R - O/M)	3,359,700	4,043,750	303,440	494,830	130,370	163,870	685,390	1,629,000	165,620
	B - C	1,916,121	2,355,760	(98,081)	83,336	(403,084)	(655,684)	5,126	746,177	(102,170)
	B / C	2.33	2.40	0.76	1.20	0.24	0.20	1.01	1.85	0.62
	Economic Priority	2	1	6	4	8	9	5	3	7

* Initial Cost x $\left(1 + \frac{i}{(1+i)^n - 1} \right)$ = Initial Cost x 0.0817

** Initial Cost x 0.5 %

where,

i : Discount rate (8 %)

n : Project life (50 years)

Table G6.2 Overall Evaluation of Proposed Flood Protection Projects

Target Area (Province)	Economy				Social Requirement				Overall Priority
	Project Cost (Mil.US$)	B/C 1990-cond.	B/C 2010-cond.	Economic Priority	Human Activities / Land Use at Present	Agriculture Project Proposed	Previous Study	Judgement	
Kano Plain (Nyanza)	20.6	0.84	2.40	1	- Intensive agriculture with livestock farming. - A lot of human settlements.	- Kano Plain (26,150 ha)	Exists (Ref. 6)	High	A
Yala Swamp (Western/Nyanza)	17.7	0.34	2.33	2	- Rather intensive agriculture with livestock farming & fishery. - Considerable number of human settlements along Nzoia River.	- Yala Swamp (7,000 ha) - Lower Nzoia / Bunyala Extension (10,480 ha)	Exists (Ref. 3, 4 & 5)	High	B
Nairobi City (Nairobi)	10.8	0.75	1.85	3	- Less agriculture. - A lot of housings with roads, bridges, culverts & service pipes.	(Some reclamation projects for housing.)	Exists (Ref. 2)	High	A
Kuja Rivermouth (Nyanza)	5.0	0.17	1.20	4	- Subsistence agriculture, grazing & fishery. - Considerable number of human settlements	- Lower Kuja (1,900 ha)	Exists (Ref. 7)	Mid	B
Lumi Rivermouth (Coast)	8.3	0.39	1.01	5	- Rather intensive agriculture with livestock farming. - Considerable number of human settlements	- Taita Taveta (3,780 ha)	Not exist	Mid	B
Sondu Rivermouth (Nyanza)	4.9	0.09	0.76	6	- Subsistence agriculture, grazing & fishery. - Some human settlements.	Not exist	Not exist	Low	C
Lower Tana (Coast/North Eastern)	3.3	0.23	0.62	7	- Grazing & limited farming. - A few human settlements.	- Tana Delta (12,000 ha)	Exists (Ref. 8 & 10)	Low	C
Middle Turkwel (Rift Valley)	6.5	0.00	0.24	8	- Grazing & limited farming. - Few human settlements.	- Turkwel (600 ha)	Not exist	Low	C
Downmost Athi (Coast)	10.0	0.00	0.20	9	- Grazing & limited farming. - Few human settlements.	- Sabaki Extension (3,000 ha)	Not exist	Low	C

Table G7.1 List of Proposed Urban Drainage Schemes

	Town Name	Location of Town Centre				Town Area (km2)	Estimated Const.Cost (1000 $)	Remark
			District		Location Name			
1	Nairobi	110	Nairobi			90.00	360,000	*1
2	Kiambu	210	Kiambu	211.4	Kiambu Municipality	1.62	12,920	
3	Thika	210	Kiambu	214.4	Thika Municipality	1.85	14,800	*1
4	Kerugoya	220	Kirinyaga	222.3	Inoi	0.96	7,680	
5	Murang'a	230	Murang'a	234.3	Mbiri	5.25	31,500	
6	OlKalou	240	Nyandarua	241.3	OlKalou	0.75	5,980	
7	Nyeri	250	Nyeri	257.0	Nyeri Municipality	1.64	13,120	*1
8	Kilifi	310	Kilifi	313.2	Tezo	0.62	4,940	
9	Malindi	310	Kilifi	314.4	Malindi	0.95	7,600	*1
10	Kwale	320	Kwale	321.1	Shimba North	0.90	7,200	
11	Lamu	330	Lamu	333.2	Lamu Town	0.88	7,000	
12	Mombasa	340	Mombasa	340.0	Mombasa	11.64	46,550	*1
13	Voi	350	Taita Taveta	352.4	Voi	1.15	9,200	
14	Wundanyi	350	Taita Taveta	353.2	Werugha	0.28	2,240	
15	Hola	360	Tana River	363.3	Zabaki	0.93	7,400	
16	Embu	410	Embu	413.7	Embu Municipality	0.95	7,600	
17	Isiolo	420	Isiolo	421.1	Central	0.45	3,600	
18	Kitui	430	Kitui	431.4	Changwithya	0.46	3,640	
19	Machakos	440	Machakos	441.1	Muvuti	2.76	22,080	*1
20	Mitaboni	440	Machakos	441.2	Mutituni	0.20	1,600	*1
21	Marsabit	450	Marsabit	454.1	Mountain	0.11	840	
22	Meru	460	Meru	461.4	Ntima	0.34	2,700	*1
23	Garissa	510	Garissa	519.1	Sankuri	0.80	6,400	*1
24	Mandera	520	Mandera	521.1	Mandera	0.06	500	
25	Wajir	530	Wajir	532.4	Wajir Township	0.19	1,540	
26	Kisii	610	Kisii	615.0	Kisii Municipality	2.64	21,080	*1
27	Kisumu	620	Kisumu	622.2	Central Kisumu	5.58	33,480	
28	Siaya	630	Siaya	634.1	East Alego	0.12	960	
29	Homa Bay	640	South Nyanza	641.1	Kanyada West	1.15	9,180	
30	Kajiado	710	Kajiado	713.1	Ildamat	1.16	9,240	
31	Kericho	720	Kericho	725.5	Kericho Township	1.17	9,360	*1
32	Nanyuki	730	Laikipia	731.5	Nanyuki	1.96	15,640	*1
33	Naivasha	740	Nakuru	744.1	Naivasha	0.90	7,200	*1
34	Nakuru	740	Nakuru	749.0	Nakuru Municpality	12.95	51,800	*1
35	Narok	750	Narok	752.1	Lower Melili	0.81	6,440	
36	Kitale	760	Trans Nzoia	762.3	Kitale	4.20	25,200	*1
37	Eldoret	770	Uasin Gishu	772.5	Eldoret Municipality	8.58	34,320	*1
38	Kabarnet	810	Baringo	812.5	Kabarnet Mosop	0.16	1,280	
39	Iten	820	Elgeyo-Marakwet	822.4	Kiptuilong	0.33	2,640	
40	Kapsabet+Baraton	830	Nandi	832.2	Chemundu	1.64	13,120	
41	Maralal	840	Samburu	841.4	Maralal Urban	0.70	5,600	
42	Lodwar	850	Turukana	853.5	Lodwar	0.22	1,760	
43	Kapenguria/Makutano	860	West Pokot	861.1	Kapenguria	0.35	2,800	
44	Bungoma	910	Bungoma	912.4	Kanduyi	1.87	14,960	*1
45	Webuye	910	Bungoma	914.2	Webuye	0.23	1,840	*1
46	Busia	920	Busia	921.5	South Teso	0.11	900	
47	Kakamega	930	Kakamega	935.4	Kakamega Municipality	2.07	16,560	*1
	Total cost						873,990	

Notes: Town area was obtained from the maps of 1: 50,000 scale.
*1 Projected population in 2010 is more than 100,000 people.

Construction cost of drainage works above was estimated based on the following assumption.

Civil works per km2 of drainage area:

Improvement and new construction of drainage channels without concrete/masonry slope protection works.

Type I :	bottom width=4 m, height= 2 m, slope 1:2.0	200 m long each
Type II :	bottom width=10 m, height= 2 m, slope 1:2.0	200 m long each
Closed channel (culvert):	3m wide and 2.5 m high	100 m long
Lateral (concrete pipe):	0.6 m dia.	1,000 m long

Unit Price:

Area = 1 km2 class	US $ 8,000,000
Area = 5 km2 class	US $ 6,000,000
Area = 10 km2 class	US $ 4,000,000

Table G8.1 Budgetary Schedule for Flood Protection Projects

Target Area	Item	Master Action Plan Period									Master Plan Period											Total	Reference
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010		
Kano Plain	Project Phase			+ F/S +		+ D/D +			Const.		+					O/M						+ -	
	Const. Cost (Mil.US$)			1.033		2.065	4.388	4.388	4.388	4.388												20.650	Table G4.3
	O/M Cost (Mil.US$)										0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	1.133	Table G6.1
	Sub-total (Mil.US$)	0.000	0.000	1.033	0.000	2.065	4.388	4.388	4.388	4.388	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	21.783	
Nairobi City	Project Phase					+ F/S +		+ D/D +		Const.	+					O/M						+ -	
	Const. Cost (Mil.US$)					0.540		1.080	3.060	3.060	3.060											10.800	Table G4.3
	O/M Cost (Mil.US$)											0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.540	Table G6.1
	Sub-total (Mil.US$)	0.000	0.000	0.000	0.000	0.540	0.000	1.080	3.060	3.060	3.060	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	11.340	
Yala Swamp	Project Phase								+ F/S +		+ D/D +		Const.		+			O/M				+ -	
	Const. Cost (Mil.US$)								0.883		1.766	3.753	3.753	3.753	3.753							17.660	Table G4.3
	O/M Cost (Mil.US$)															0.088	0.088	0.088	0.088	0.088	0.088	0.528	Table G6.1
	Sub-total (Mil.US$)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.883	0.000	1.766	3.753	3.753	3.753	3.753	0.088	0.088	0.088	0.088	0.088	0.088	18.188	
Kuja Rivermouth	Project Phase													+ F/S +		+ D/D +		Const. +		O/M		+ -	
	Const. Cost (Mil.US$)													0.252		0.503	2.139	2.139				5.034	Table G4.3
	O/M Cost (Mil.US$)																		0.025	0.025	0.025	0.075	Table G6.1
	Sub-total (Mil.US$)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.252	0.000	0.503	2.139	2.139	0.025	0.025	0.025	5.109	
Lumi Rivermouth	Project Phase															+ F/S +		+ D/D +		Const.	+ -		
	Const. Cost (Mil.US$)															0.416		0.832	2.358	2.358	2.358	8.322	Table G4.3
	O/M Cost (Mil.US$)																						Table G6.1
	Sub-total (Mil.US$)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.416	0.000	0.832	2.358	2.358	2.358	8.322	
Grand Total	Const. Cost (Mil.US$)	0.000	0.000	1.033	0.000	2.605	4.388	5.468	8.331	7.448	4.826	3.753	3.753	4.004	3.753	0.920	2.139	2.972	2.358	2.358	2.358	62.466	
	O/M Cost (Mil.US$)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.103	0.157	0.157	0.157	0.157	0.245	0.245	0.245	0.270	0.270	0.270	2.276	
	Total (Mil.US$)	0.000	0.000	1.033	0.000	2.605	4.388	5.468	8.331	7.448	4.929	3.910	3.910	4.161	3.910	1.165	2.384	3.217	2.628	2.628	2.628	64.742	

Note: F/S, D/D, Const. and O/M refer to the phases of feasibility study, detailed design, construction and operation/maintenance respectively.

Table G8.2 Manpower Schedule for Flood Protection Projects

Item	Master Action Plan Period										Master Plan Period										Total	Reference
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010		
Budgetary Schedule (Million US $)	0.000	0.000	1.033	0.000	2.605	4.388	5.468	8.331	7.448	4.929	3.910	3.910	4.161	3.910	1.165	2.384	3.217	2.628	2.628	2.628	64.743	Table G7.1
Engineer	0	0	1	0	3	5	7	10	9	6	5	5	5	5	1	3	4	3	3	3	78	
Assistant Engineer	0	0	1	0	3	5	7	10	9	6	5	5	5	5	1	3	4	3	3	3	78	
Technician	0	0	3	0	7	11	14	21	19	12	10	10	10	10	3	6	8	7	7	7	162	
Others	0	0	2	0	5	9	11	17	15	10	8	8	8	8	2	5	6	5	5	5	129	
Administration Staff	0	0	1	0	1	2	3	4	4	2	2	2	2	2	1	1	2	1	1	1	32	
Total	0	0	8	0	19	32	40	62	55	36	29	29	31	29	9	18	24	19	19	19	479	

Note: The number of manpower per 1 million US dollar of annual budget required for the project implementation was presumed as follows:

- Engineer : 1.2 people
- Assistant Engine : 1.2 people
- Technician : 2.5 people
- Others : 2.0 people
- Administration Staff : 0.3 people

Table G8.3 Budgetary Schedule for Other River Related Projects

(Unit : million US$)

Item	Description	Master Action Plan Period								Master Plan Period										Total
		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
1	Urban Drainage Projects																			
	1.1 Nairobi			90	90	90	90													360.0
	1.2 Mombasa				11.6	11.6	11.7	11.7												46.6
	1.3 Other urban cetres			23.4	23.4	23.4	23.4	23.4	23.4	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	467.4
	Total			113.4	125.0	125.0	125.1	35.1	23.4	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	874.0
2	Minor River Improvement Projects			4.5	4.5	4.5	4.5	4.5	4.5	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	90.0
3	Long-term Improvement of Lower Tana River	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	(New project to be proposed)										40.0
	TOTAL	5.0	5.0	122.9	134.5	134.5	134.6	44.6	32.9	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	1004.0