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JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF ENERGY
THE REPUBLIC OF KENYA

FEASIBILITY STUDY
ON
MUTONGA/GRAND FALLS HYDROPOWER PROJECT

FINAL REPORT

VOLUME III
SUPPORTING REPORT (2)
(ENVIRONMENTAL ASSESSMENT)

MARCH 1998

NIPPON KOEI CO., LTD.
PASCO INTERNATIONAL INC.
TOKYO, JAPAN

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This Report consists of

Executive Summary

Executive Summary for Environmental Assessment

Volume I Main Report

Volume II Supporting Report (1)
(Engineering Study)

Volume III Supporting Report (2)
(Environmental Assessment)

Volume IV Supporting Report (3)
(Workshop Proceedings)

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FEASIBILITY STUDY
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DRAFT FINAL REPORT

SUPPORTING REPORT (2)

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INTRODUCTION & BACKGROUND

Chapter 1

INTRODUCTION

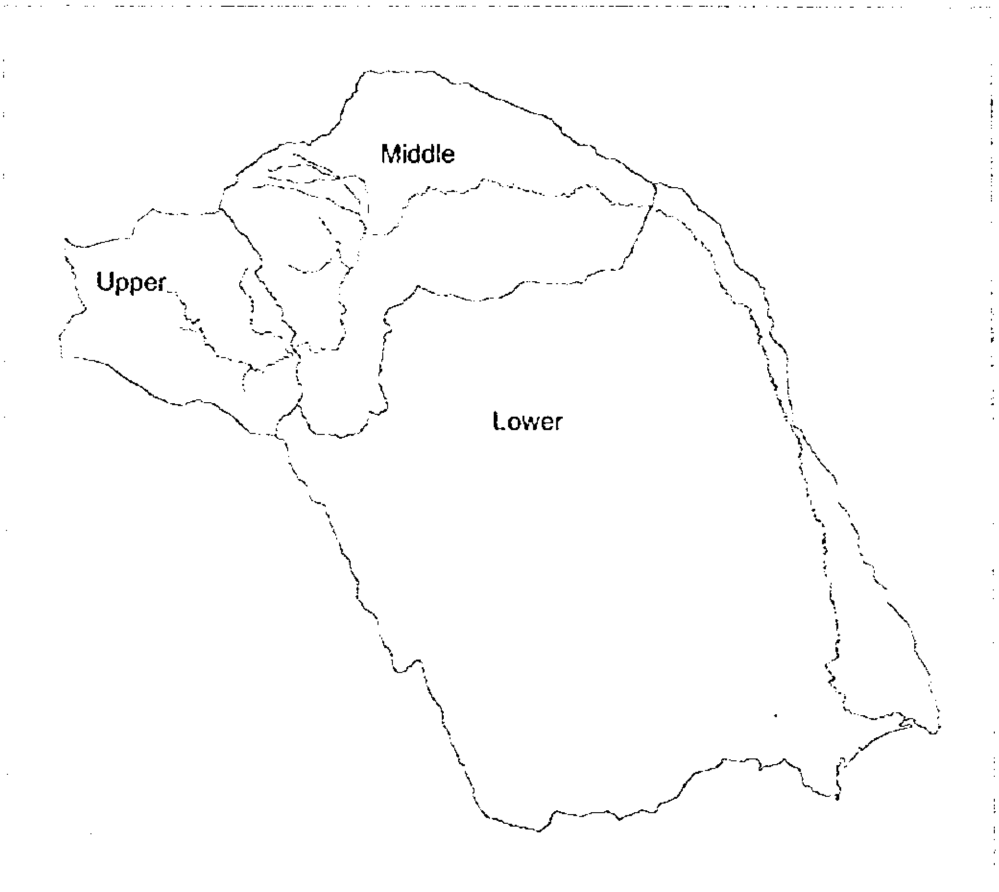
1. INTRODUCTION

1.1 THE TANA RIVER

The Tana river is the largest and most important river in Kenya. Its catchment covers some 95,950 km^2 (approximately 17% of the land area of Kenya) and stretches between the Kenya Highlands and the Indian Ocean). The total river length from source to the Indian Ocean is over 1,000 km. The river is fairly confined within its banks up to Kora Rapids. Downstream of Kora Rapids the river spreads out onto the floodplain during periods of high flow. The catchment area includes a wide range of climatic conditions and vegetation, including: alpine glaciers, afro-alpine moorland and high-altitude forest through to semi-arid and arid plains, and a humid coastal delta. The following physiographic regions can be defined in the river basin:

- An upper catchment (9,420 km^2) upstream of Kamburu with altitudes above 1,000 metres above sea level (masl);
- A middle catchment (21,370 km^2) between Kamburu and Kora Rapids, with altitudes between 1,000 and 200 masl;
- A lower catchment (65,160 km^2) downstream of Kora Rapids, with altitudes below 200 masl. The floodplain is included in this section.

Figure 1-1 Major catchments within the Tana River basin



Most of the rainfall occurs in the upper catchment and in the higher elevations of the middle catchment, and in this area tributaries are perennial. Downstream, rainfall decreases significantly and tributaries flow seasonally. By far the largest part of the annual runoff is derived from the perennial streams in the upper catchment and upper parts of the middle catchment, or about 20% of the catchment area. The rainfall pattern is bi-annual and during normal rainy seasons the natural situation (i.e. in the absence of regulation by reservoirs) is for regular flooding to occur in the floodplain of the Lower Tana.

The Tana river has already been regulated through construction of a number of storage reservoirs in the upper and middle catchments, with hydropower being the most important use to date. Construction of the proposed storage reservoirs near the Mutonga confluence and at Grand Falls would significantly increase total reservoir storage and regulation capacity in the Tana basin. However, Phase 2 studies found that whilst the proposed reservoirs capacity to regulate major, damaging floods was negligible, they would have a significant effect on the "normal" floods that constitute the Tana River's most important downstream economic and environmental benefits.

1.2 BACKGROUND TO PHASE 1 ENVIRONMENTAL ASSESSMENT

The Japan International Cooperation Agency (JICA) and the Tana and Athi Rivers Development Authority (TARDA) agreed in August 1993 to carry out a feasibility study of the next proposed phase of hydropower development in the Tana River basin. The feasibility study was managed by Nippon Koei Co. Ltd. Consulting Engineers reporting to the JICA Study Team, and responsible for presenting the overall conclusions and recommendations of the study.

The study examines the feasibility of development of a number of hydropower options based on three possible dam sites within the middle catchment of the Tana River. Proposed dam sites are: Mutonga Dam two kilometres downstream of the confluence of the Mutonga River; and at two Grand Falls Dam sites, respectively five and seven kilometres downstream from the confluence of the Tana and Kathita Rivers.

An Initial Environmental Assessment was carried out between February and August 1994, and was presented at a workshop held in Embu from 13 to 16 September 1994. The conclusions of this workshop were summarised in a report distributed to participants by Nippon Koei and TARDA. As a result of this workshop, a number of issues were identified for further study before an informed decision could be made on a preferred option for the construction and management of a dam, or, indeed, whether a hydropower scheme should be constructed at the proposed sites.

1.3 BACKGROUND TO PHASE 2 ENVIRONMENTAL ASSESSMENT

The results of the Phase 1 assessment were produced in draft format in August 1994 and presented at a workshop held in Embu between September 13 and 16 1994, to which representatives were invited from the districts which would be directly affected by the reservoir development. Invitations were also extended ministries (with representatives from the Forestry Department, the Ministry of Environment and

Natural Resources, Ministry of Energy, Department of Water Development) and to the Kenya Wildlife Service and to the National Museums of Kenya, as well as to the World Bank, IUCN and WWF.

Following the workshop, a final version of the report was produced and distributed to the major concerned institutions.

The Phase 1 study indicated that the affects of the dam on the river flow regime, could possibly be mitigated through the release of artificial floods from the reservoir, however the mechanism for this release had not been established. The need for these downstream floods was re-emphasised by the workshop attendees, in particular by the organisations with direct interests in wildlife conservation, including the Kenya Wildlife Service and the National Museums. The report indicated that there was a need for a clearer understanding of the downstream production systems, and that a substantial research and monitoring programme would be required. Specifically, the Pokomo irrigation and flood recession farming was identified as a system requiring further study, with particular reference to the requirements for the release of regulated flood discharges from the reservoir. The other downstream systems considered as requiring further study included the riverine forests, the pastoralist livestock management, the mangroves and the fisheries. The need for new institutional arrangements was referred to, in particular to support the rights of water users in the riverine corridor and to control levels of upstream abstraction.

Following the workshop and in response to queries raised by invited institutions and the phase 1 report, a second phase study was commissioned to run from mid September 1994 to March 1995. The Phase 1 Study had been considered as being an Initial Environmental Impact Study, the Phase 2 Study was referred to as being a Definitive Plan/Pre-feasibility Study.

1.4 BACKGROUND TO PHASE 3 ENVIRONMENTAL ASSESSMENT

The Phase 2 study was expected to indicate the optimal options for the dam design, linking both the engineering and the environmental aspects into a single overview. The main concern expressed in the environmental study was that there would need to be the capacity to manage the release of regular artificial floods of a size that would replicate the "normal" flooding pattern.

From the environmental point of view, the key aspect of the engineering study was that the option selected had to have the capacity to release these floods while at the same time minimising adverse impacts during the construction and particularly the impounding period. As a result, the conclusion was that if a reservoir was constructed which would regulate the last natural river flows into the Tana river system, the dam would have to be large enough to provide the excess storage capacity required to manage these flood releases, but not so large that the downstream system would suffer severe or irreversible damage during the impounding period.

The Phase 2 Study included field work in the downstream riverine corridor, covering both natural and human production systems. Water and sediment samples were collected at various points throughout the river system, to try to establish water quality and sediment transport parameters. The field work was carried out in November and December and coincided with the first major natural flood event for five years. Field work was also carried out in the reservoir area to try to quantify the number of people who would be displaced and to identify preferred sites for resettlement.

As part of the study process, a video was produced which was based on a series of interviews with farmers in and around the proposed reservoir site who would be directly affected by the dam construction, as well as with people in upstream areas who had been affected by the previous construction of reservoirs on the Tana river. Pastoralists, flood recession farmers and large and small scale irrigation farmers in the downstream areas were also interviewed.

The results of the study and the video were presented at a workshop held in Nairobi between March 20 and 22, 1995. The conclusions of the study team were that the best option appeared to be the combined development of a reservoir at Mutonga and the smaller option of Low Grand Falls. This option was considered as being the least environmentally damaging while still providing the capacity to release floods, and at the same time producing the highest firm power output.

The workshop was attended by representatives from all the organisations and institutions who had been at the previous workshop held in 1994, with additional representatives from the East African Wildlife Society, the Green Belt Movement, the NGO council, CARE and other environmental and social based NGOs.

The Phase 2 Study recognised that there were a number of aspects of the environmental systems that were still not clearly understood and would require further investigation before a final decision could be made as to the optimum design and management strategy for the dam.

The main aspects singled out for further study included:

- Resettlement - preparing a detailed plan of resettlement and buffer zone management; indicating mitigation measures and costs of compensation.

- Downstream Riverine Corridor - proposing a plan of reservoir operation to release downstream floods while minimising the loss of generation capacity; and further study on sediment transport and the implications for downstream nutrient supply.

- Hydrology - additional work to define "normal" floods; and further work on the effects of sediment trapping on downstream channel erosion and the potential for sediment release.

- Consultation - emphasis was placed on ensuring that the process included adequate consultation with communities and institutions affected by the proposed development, both in the reservoir area and in the downstream corridor.

The engineering component of the study would include preliminary design of the works, and estimates of the costs and a schedule for construction.

Draft terms of reference were drawn up and agreed in July. The study then commenced in September and included field work during the late dry season and again during the rains in November.

1.5 RESERVOIR AND DAM SITES

Pre-feasibility studies have been carried out on the three basic dam configurations - Mutonga, and the two alternatives at Grand Falls (for convenience called Low Grand Falls and High Grand Falls). The fourth possibility under consideration is to build both Mutonga and Low Grand Falls.

The reservoirs will directly impact populations within adjacent locations in Embu, Tharaka-Nithi and Mwingi Districts. The extent of the impact on these populations will depend on the selected reservoir options, on the selected buffer zone widths and on the selected management options for these buffer zones.

The reservoirs will also have extensive downstream impacts in Tharaka-Nithi, Mwingi, Isiolo, Garissa, and Tana River Districts. The extent of these impacts on downstream ecological, economic and production systems depends largely on the ability of the dams to release flood waters at the required times, following the natural biannual flooding cycle of the river.

1.6 POPULATION WITHIN THE TANA RIVER BASIN

This section provides a brief overview of settlements and population within the Tana River Basin. More detailed treatments of the reservoir area population are to be found in Section 2 of this report.

From the project area, the Tana River passes through Embu, Meru, Tharaka-Nithi (Nithi), Mwingi, Isiolo, Garissa, and Tana River Districts. The Tana River basin as a whole, at the time of the 1989 National census, had a population of 4.07 million (see Table 1-1, Figure 1-2), and a projected 1996 population estimated at about 4.99 million people (Table 1-2). Using the same projection, based on the 1979 to 1989 growth rates per district, by the year 2005 population of the Tana Basin would be 6.5 million people.

The basin provides water for major urban centres outside of the actual basin, in particular for Nairobi. Abstraction of water for Nairobi is projected to increase in line with the increase in population of the Nairobi area.

Population densities over the greater part of the basin are low (Figure 1-3), with the majority of the population being concentrated in the upper catchment where rainfall is higher and conditions suitable for agriculture. However, this map does not present a true picture due to the inherent area related bias with the relatively large sublocations in this area. The great majority of people in the Lower Tana basin live on or near the tana River floodplain. It is the floodplain that would be impacted by changes to the hydrological regime following construction of the proposed reservoirs.

Figure 1-2 Administrative Districts in the Tana River Basin

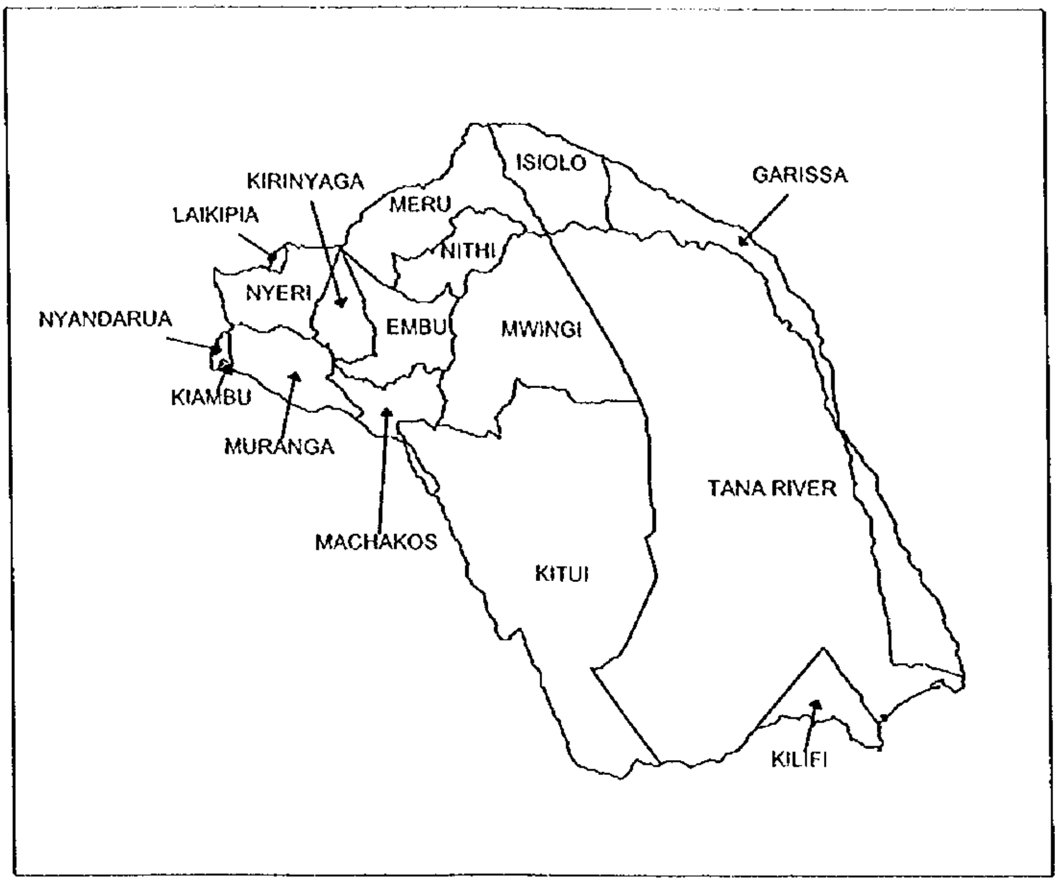


Table 1-1 Estimated Population within the Tana River Basin, 1989 National Census, Organised by District and Administrative Division.

Note: This table was produced by GIS analysis of population data at sub-location level. Populations within sublocations that were physically split by the Tana River basin boundary were split on an area-proportional basis.

District	Division	Population	Households	Area (km²)	Population Density
EMBU	Gachoka	114392	24261	1413	80.98
	Manyatta	99342	17068	190	522.94
	Mt. Kenya Forest	74	46	182	0.41
	Runyenjes	97454	17602	246	396.07
	Siakago	56932	11074	771	73.80
EMBU Total		368194	70051	2802	131.40
GARISSA	Bura	1158	199	681	1.70
	Central	21650	4705	1071	20.21
	Masalani	6701	1216	990	6.77
	Mbalambala	7416	1312	1968	3.77
GARISSA Total		36925	7432	4710	7.84
ISIOLO	Garba Tulla	6979	1528	3057	2.28
ISIOLO Total		6979	1528	3057	2.28
KIAMBU	Gatundu	4	2	2	2.47
	Lari	564	115	33	17.04
KIAMBU Total		568	117	35	16.36
KILIFI	Malindi	13608	1880	1722	7.90
KILIFI Total		13608	1880	1722	7.90
KIRINYAGA	Gichugu	111294	21691	231	481.77
	Mt. Kenya	190	45	345	0.55
	Mwea	107681	21988	545	197.41
	Ndia	178327	38993	366	486.73
KIRINYAGA Total		397492	82717	1488	267.12
KITUI	Central	147522	26259	1309	112.66
	Kwa-Vonza	73904	11470	1504	49.14
	Kyuso	103325	17222	6461	15.99
	Mutito	71162	12955	5392	13.20
	Mutomo	98228	16977	11906	8.25
	Mwingi	105553	17968	1812	58.25
KITUI Total		599694	102851	28385	21.13
LAIKIPIA	Central	10777	2234	105	102.34
LAIKIPIA Total		10777	2234	105	102.34
LAMU	Mpeketoni	3605	475	459	7.86
	Witu	3415	649	1258	2.71
LAMU Total		7020	1124	1717	4.09

MACHAKOS	Masinga	79091	13552	1424	55.54
	Yatta	53260	9456	480	110.90
MACHAKOS Total		132351	23008	1904	69.50
MERU	C.Imenti	94771	18045	437	216.90
	Igembe	108771	19981	352	309.23
	Meru National Park	322	137	873	0.37
	Mount Kenya Forest	55	19	930	0.06
	N.Imenti	143046	28659	374	382.88
	Ntonyiri	64889	11419	553	117.33
	S.Imenti	131276	24400	414	316.91
	Tigania	115826	20800	456	253.84
	Timau	8607	1720	2	4519.87
MERU Total		667563	125180	4391	152.04
MURANGA	Gatanga	68574	13245	217	315.94
	Kandara	153401	30957	237	646.53
	Kangema	178456	36322	530	337.00
	Kigumo	180083	36046	475	379.07
	Kiharu	175161	36394	412	425.35
	Makuyu	78076	17843	524	148.99
MURANGA Total		833751	170807	2395	348.15
NITHI	Nithi	175581	32438	736	238.61
	Tharaka	74929	13114	1546	48.46
NITHI Total		250510	45552	2282	109.77
NYANDARUA	Kinangop	32078	5943	189	169.88
	Ndaragwa	43	8	2	22.64
NYANDARUA Total		32121	5951	191	168.41
NYERI	Aberdare Forest/N.Park	161	41	183	0.88
	Kieni East	38878	8344	327	118.72
	Kieni West	31825	6940	438	72.64
	Mathira	145530	31463	324	449.11
	Mt.Kenya Forest/N.Park	0	0	360	0.00
	Mukurweini	95579	20566	180	530.93
	Municipality	88774	21527	171	520.36
	Othaya	85866	17600	263	326.33
	Tetu	90056	17795	286	314.85
NYERI Total		576669	124276	2532	227.77
TANA RIVER	Bura	25035	5140	5430	4.61
	Galole	46522	8556	9414	4.94
	Garsen	46915	8546	15121	3.10
	Madogo	19224	3652	8199	2.34
TANA RIVER Total		137696	25894	38163	3.61
TANA RIVER BASIN TOTAL		**4071918**	**790602**	**95878**	**42.47**

Figure 1-3 Population Densities over the Tana River Basin.

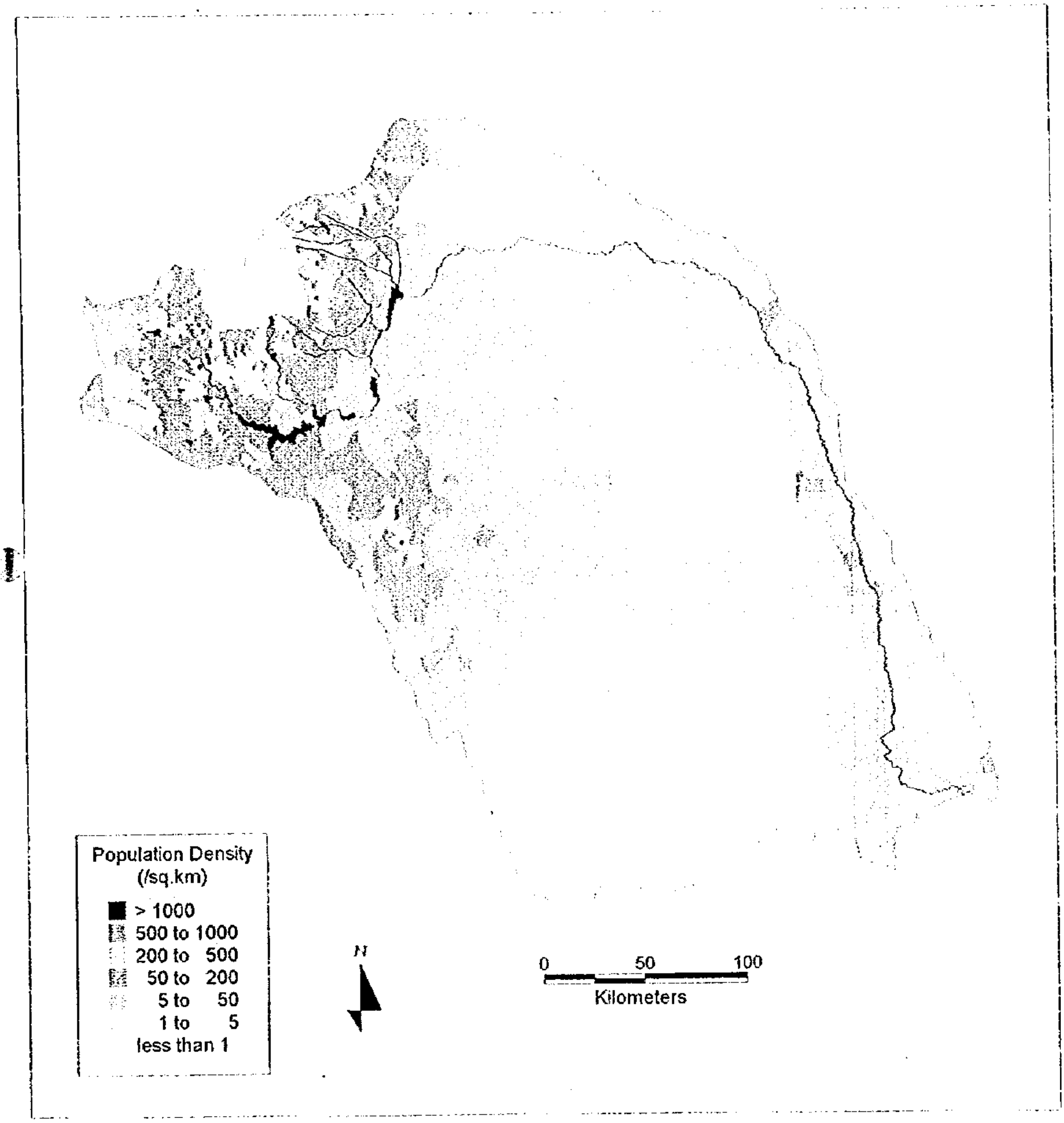


Table 1-2 Tana River Basin: Population Projections by District, 1989 - 2005

District	Rates used	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Embu	3.415	368194	380768	393771	407218	421125	435506	450379	465759	481665	498114	515124	532716	550908	569722	589178	609298	630106
Garissa	0.436	36925	37086	37248	37410	37573	37737	37902	38067	38233	38399	38567	38735	38904	39073	39244	39415	39587
Isiolo	4.624	6979	7302	7639	7993	8362	8749	9153	9577	10019	10483	10967	11475	12005	12560	13141	13749	14384
Kiambu	2.588	568	583	598	613	629	645	662	679	697	715	733	752	772	792	812	833	855
Kilifi	4.020	13608	14155	14724	15316	15931	16572	17238	17931	18652	19401	20181	20992	21836	22714	23627	24577	25565
Kirinyaga	3.152	397492	410022	422948	436281	450034	464221	478855	493950	509521	525584	542152	559243	576872	595057	613816	633166	653125
Kitui & Mwingi	2.971	599694	617512	635860	654753	674207	694239	714866	736106	757978	780499	803689	827568	852157	877477	903548	930395	958039
Laikipia	5.449	10777	11364	11984	12637	13325	14051	14817	15624	16476	17374	18320	19319	20371	21481	22652	23886	25188
Lamu	6.819	7020	7499	8010	8556	9140	9763	10428	11140	11899	12710	13577	14503	15492	16548	17677	18882	20169
Machakos	3.000	132351	136322	140411	144624	148962	153431	158034	162775	167658	172688	177869	183205	188701	194362	200193	206199	212385
Meru	2.901	667563	686929	706857	727363	748464	770177	792520	815511	839169	863513	888564	914341	940866	968161	996248	1025149	1054888
Muranga	2.849	833751	857506	881939	907067	932911	959492	986830	1014947	1043865	1073607	1104196	1135657	1168015	1201294	1235521	1270724	1306930
Nithi	2.901	250510	257777	265255	272950	280869	289017	297401	306029	314907	324042	333443	343116	353070	363312	373852	384697	395857
Nyandarua	4.213	32121	33474	34884	36354	37885	39481	41145	42878	44684	46567	48529	50573	52703	54924	57238	59649	62162
Nyeri	2.442	576669	590751	605177	619956	635095	650604	666492	682768	699441	716521	734019	751944	770306	789117	808387	828128	848351
Tana River	4.092	137696	143330	149195	155299	161654	168268	175153	182320	189780	197545	205628	214042	222800	231916	241406	251283	261565
Basin Total		4071918	4192381	4316500	4444389	4576167	4711954	4851875	4996061	5144644	5297762	5455559	5618180	5785779	5958511	6136538	6320029	6509155

Chapter 2

PHYSICAL & BIOLOGICAL ENVIRONMENT: RESERVOIR AREA

2. RESERVOIR AREA: PHYSICAL AND BIOLOGICAL ENVIRONMENT

2.1 INTRODUCTION

The Initial Environment Assessment Report and Phase 2 reports include description of conditions in the reservoir area. The following sections summarise this information and provide additional information for the Tana River basina as a whole where applicable.

2.2 TOPOGRAPHY

The project area is situated within the middle catchment of the Tana river at an altitude between 500 and 600 metres on the eastern footslope of Mt Kenya. The surrounding higher land to the North, South and West is drained by tributaries of the Tana. The landscape is dissected and hilly with several rocky hills rising to or above 1,500 metres. Landforms within the reservoir area and adjacent lands are shown by Figure 2-1.

2.3 GEOLOGY

The main land formation of the proposed reservoir area is an ancient erosion surface of Precambrian basement complex metamorphic rocks forming an extensive eastward-sloping plain with a rather broken topography punctuated by large hill masses formed by volcanic intrusions mainly of gneiss, as at Kijege and Kikingo. The most common rocks are gneisses, granite, granodiorite and migmatite. To the west and north these rocks are overlaid by Tertiary and Quaternary lava flows from Mount Kenya and the Nyambeni Hills which reach the Tana River in the vicinity of the confluence of the Mutonga and Tana Rivers. The area is dissected by a number of large perennial streams, including the Mutonga, Thanantu, Kathita and Thingithu, which join the Tana as it flows first North northeast and then, after Grand Falls, eastwards then northeast.

2.4 SOILS

The Tana Basin contains a complex range of soil types. Within most of the upper and middle parts of the Tana basin, soil drainage characters are relatively uniform and are classified as "somewhat excessively to well drained". However, soil depths vary considerably and the middle reaches of the Tana flow through areas with generally shallow soils (Figure 2-2).

Within the reservoir area, soils consist largely of ferric, orthic, rhodic or chromic Cambisols, Arenosols, Ferralsols and Luvisols. Soils are mostly derived from basement complex rocks except for some parts of the lower uplands to the west of the project area which are developed on intermediate igneous rocks. The basement derived soils are well-drained shallow to moderately deep, low in organic matter and plant nutrients and susceptible to erosion including soil loss and gulleying. In some areas the soil has been compacted and impermeable to rainfall. Soils developed on the

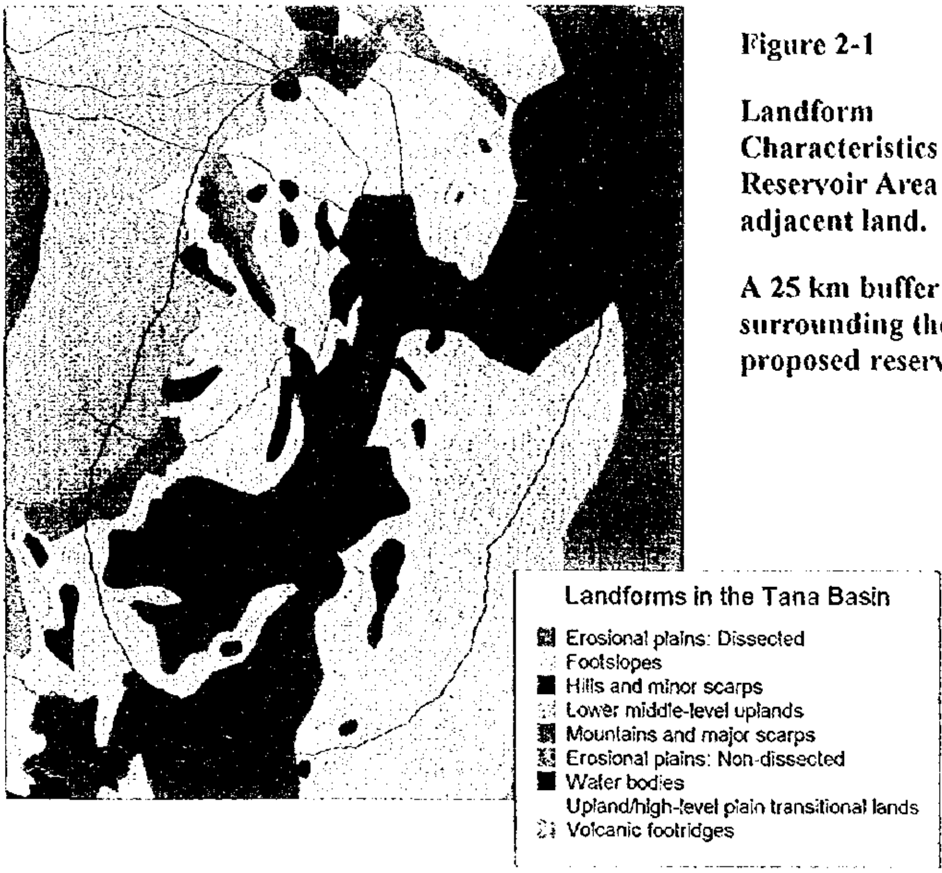


Figure 2-1

Landform Characteristics of the Reservoir Area and adjacent land.

A 25 km buffer is shown surrounding the proposed reservoirs.

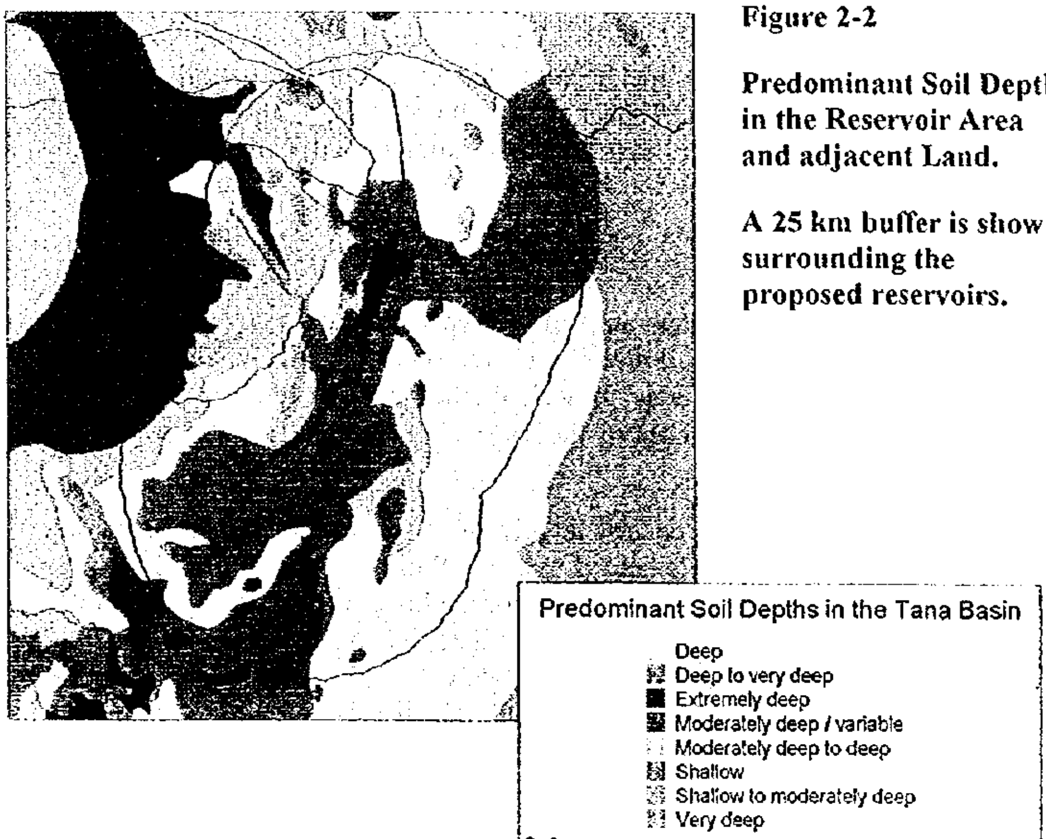


Figure 2-2

Predominant Soil Depths in the Reservoir Area and adjacent Land.

A 25 km buffer is shown surrounding the proposed reservoirs.

2.5 RAINFALL

Rainfall in the area is markedly bimodal and declines with altitude to the East and South East becoming erratic, with shorter and more unpredictable rainy seasons. Daily rainfall data from 37 raingauge stations within the Tana River catchment (CA) were made available in digital format through the courtesy of Kenya Meteorological Department, and data from some of these are summarised in Table 2-1 which indicates the wide variation within the catchment as a whole.

There is a strong rainfall gradient across the reservoir area, indicated by Table 2-2. At Ishiara, close to the reservoir area in Embu District, the onset of rains varies by as much as a month (October rains) or 55 days (March/April rains). The probability is that one of the two seasons will provide more than 300 mm while the other is usually inadequate for rainfed cropping. Much rainfall is lost through surface runoff. In East Central Kenya, on average 50% of each season's rainfall occurs in the first 22 days. Part of this rainfall infiltrates the soil to a depth below the roots of young crops, becoming unavailable to them. Uncertainty regarding onset of rains and the difficulty of ploughing dry ground leads farmers to delay planting until after rain has fallen.

Table 2-1 Climatological Summary Statistics of some Meteorological Stations in Tana Catchment

	Annual Evaporation and Wind Run		Annual Rainfall (mm)		
	Pan A (mm)	Miles	Max.	Min.	Mean
Thika Horticultural Res.	1,805	61.9	1,631	554	1,004
Sagana Fish Farm	1,776	54.9	1,933	771	1,340
Embu Met. Station	1,573	73.4	1,580	628	1,364
Kindaruma Fisheries	2,109	64.5	1,165	382	686
Marimanti, Tharaka-Nithi	2,287	73	1,201	545	847
Garissa Met. Station	2,712	116.4	757	69	352
Hola TRI Scheme	2,366	125.5	953	192	471
Kitui Dam W.D.D.	1,952	79.3	1,557	102	1,034
Lamu Met. Station	2,044	81.7	1,855	322	919
Malindi Gedde Cotton Research Station	2,038	114.9	2,481	676	1,173

Table 2-2 **Rainfall in the Vicinity of the Reservoir Areas**

Stations	No of years records	Average annual total (mm)
Mitunguu	29	1,365
Tunyai	12	1,110
Marimanti	21	847
Chiokariga	39	898
Gatunga	16	817
Grand Falls	6	790
Meru Nat. Pk HQ	12	724

2.6 LAND RESOURCE POTENTIAL

Much of the reservoir area is classified as Agro-Climatic Zone V: "*Arid areas characterised by Acacia Commiphora bushland where, given suitable soil depth and moisture-holding capacity, drought-tolerant cereals and legumes can be cultivated, although with significant risk of failure*".

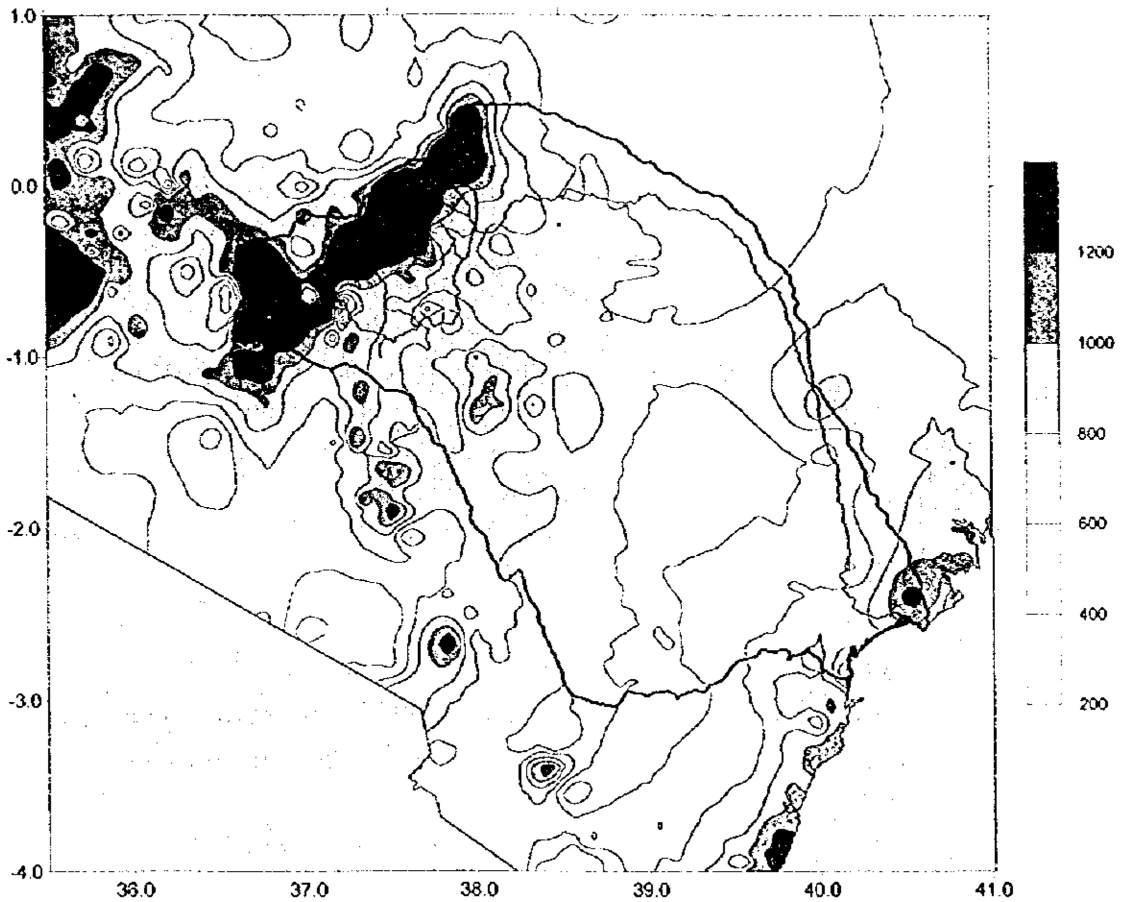
To the south-west patches of land in Marimanti and Chiakarika (formerly Kamanyaki) locations of Tharaka Nithi district and across the Mutonga river in Evurore location of Embu district are classified as Ecological zone IV: "*Semi-arid areas characterised by dryland acacias with some broad-leaved trees or shrubs where, despite relatively low and erratic rainfall, there is some potential for agriculture (e.g. sunflower, cotton, beans, or early-maturing cereals)*". These areas lie west of the Tana and will be directly affected by the project where some settlers may have to vacate better land than can be found in the rest of the project area.

A very small area of land in Tharaka Nithi, bordering the Tana river east of the Thangatha and adjoining the border of Meru National Park is classified in Zone VI: "*Arid areas, mostly low thorn bushland, shrub grassland or thicket, unsuitable for rainfed agriculture, although with moderate potential for extensive livestock production and wildlife*". Although quite distant from the reservoir, this land is part of the thinly populated area of Tharaka Nithi which has been depopulated as a result of insecurity over the last 30 years. It could potentially be used for extensive grazing in the absence of bandit activity.

The riverine corridor is semi-arid to very arid and passes through soils of marginal potential. The coastal zone is semi-humid. Irrigable potential in the corridor has in the past been over estimated.

Figure 2-3 Average annual rainfall (mm) over the Tana River basin and adjacent areas

This rainfall map was produced from a database of 1,203 point data sources (rainfall recording stations) representing average annual rainfall from available rainfall stations in Kenya, using Kriging techniques to generate the rainfall isohyets.



2.7 BIOLOGICAL RESOURCES

The following sections are intended to presnt an overview of the biological resources in the reservoir area. More detailed discussions, including the presentation of field survey adat, will be included in later sections of the report once these data are available.

2.7.1 Vegetation

2.7.1.1 General Description of Reservoir Area Vegetation

The dominant natural vegetation of the Grand Falls/Mutonga reservoir area is *Acacia/Commiphora* bushland, giving place to *Combretum* wooded grassland on the more acid volcanic soils at higher elevations. *Commiphora* tends to disappear in more alkaline areas leaving *Acacias* dominant. Vegetation density varies from thicket to open grassland. Removal of ground cover by grazing and cultivation has led to serious erosion in many areas with isolated bushes of limited palatability to stock left perched on islands of soil surrounded by lower eroded areas.

Within the locations of Tharaka Nithi, Embu and Mwingi directly affected by the reservoir and its buffer zone there are significant areas (around 10% of the land area of affected sublocations) of densely vegetated hills of which the more significant examples are gazetted as forest reserves. These areas are important for watershed protection and are closed to settlement, though they may be used for regulated dry season grazing and fuel wood collection. Recent satellite imagery shows that the vegetation of the main Forest Reserves (Kijegi and Mumoni) was in good condition with little or no evidence of encroachment or degradation.

A narrow band of evergreen riverine vegetation fringes the Tana and its tributaries and this habitat includes a majority of the larger trees within the reservoir area. These include *Acacia elatior, A. robusta, Mimusops fruticosa, Newtonia hildebrandtii, Ficus sur, F. sycomorus, Tamarindus indica, Sapium ellipticum, Hyphaene compressa and Phoenix reclinata.* Vegetation within this zone will be entirely destroyed by flooding of the reservoir but is currently especially important, providing significant benefits to local people, as:

- source of materials (construction and building materials, fencing, beehives)
- fuelwood, charcoal
- fodder (especially during drought)
- medicinal plants for both medical and veterinary use
- edible fruits, either consumed locally or sold in markets as a source of cash
- fibres and weaving materials, with products sold in local markets and beyond
- as well as having considerable shade, existence and aesthetic value

No detailed vegetation survey has been conducted in the proposed reservoir area. However, at least nine species which are known to be either rare or endangered in Kenya are considered likely to occur in the proposed reservoir area (Table 2-3). Additional details of vegetation in the reservoir area are listed in the Stage 1 Initial Environment Assessment report.

2.7.1.2 Endemic Species

Encephalartos powysorum is an endemic cycad restricted to one small hill in Kijege Forest, Meru District; this forest lies within the projected 3 km buffer zone around the reservoir which would form behind the High Grand Falls dam. Any increase in land pressure is likely to result in greater pressure on remaining forest resources. Cycad populations are rare and under threat throughout Kenya and in many other countries. Failure to investigate and protect the occurrence of an endemic species, one of only five cycad species found in Kenya, would be unacceptable.

The presence and ecological status this and any other rare or endangered plant species can be confirmed only through a detailed botanical survey. Such a survey would increase confidence that no already rare plant species will be endangered further by reservoir development, and also provide the opportunity for transplantation / *ex-situ* conservation or other mitigation measures of any rare or endangered species, as well as species of potential economic importance.

2.7.1.3 Economically Important Species

A preliminary survey of plant species in the reservoir area used by the Tharaks people was made during the Stage 1 Initial Environmental Assessment whilst a more detailed assessment was made during Phase 3. Many plants form a vital part of the resource base of the local community and a large proportion of material is derived from them. See Chapter 12 for further details.

2.7.2 Wildlife

No significant studies have been made of the fauna in the reservoir area, but from the density of settlement and managed / cultivated land in the area it is clear that the occurrence and relative abundance of many wild species has been greatly affected by increasing levels of human disturbance. Large mammals no longer occur in the area.

The area likely to be inundated by the reservoir does not contain significant populations of any animal species known to be either rare or endangered in Kenya with the exception of the pancake or flat tortoise (*Malacochersus tornieri*), listed as threatened by the World Conservation Union (IUCN) and the Leopard Tortoise (|*Geochelone pardalis*). Both of these species are declining in numbers throughout their range and significant populations in the reservoir area should be relocated.

2.7.3 Protected Areas: Forest Reserves

There are a number of protected forest reserves in the vicinity of the proposed reservoirs. These are indicated by Figure 2-4.

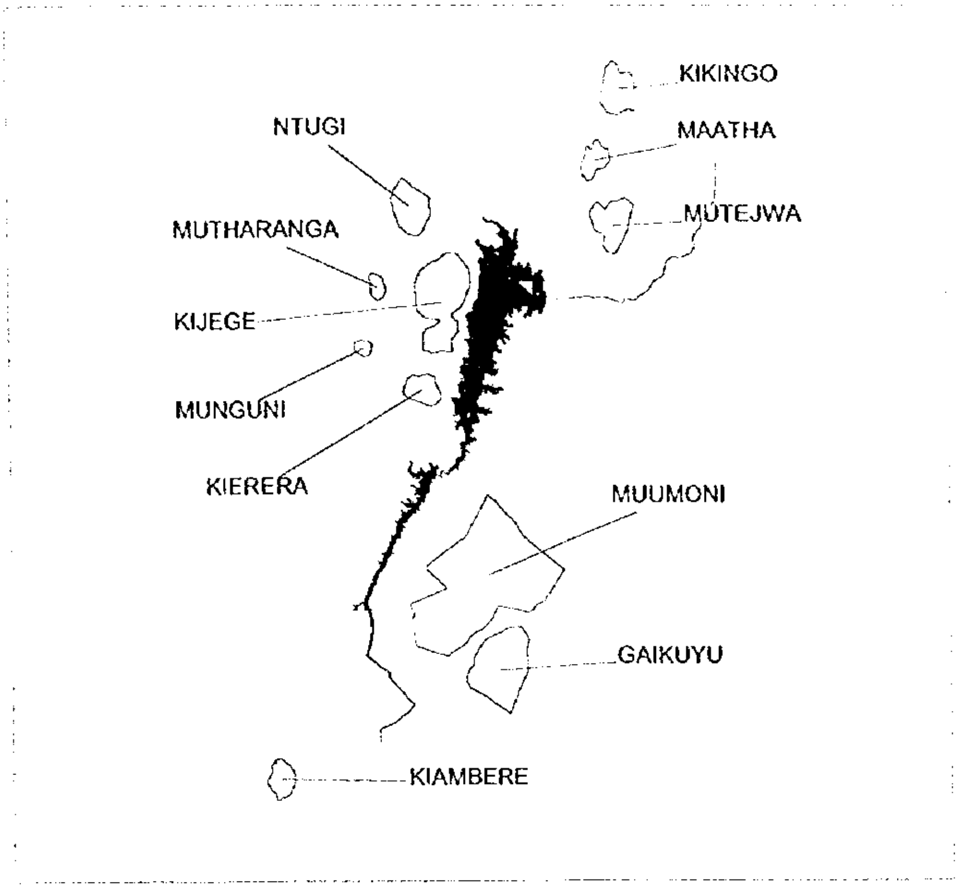
Table 2-3 Rare and Endangered Plant Species in the Reservoir Area

Species	Form	Status	Habitat
Albizia tanganyicensis sp. adamsoniorum	Tree	Rare; Endemic, (not recorded by the survey)	Rocky river banks
Baphia keniensis	Tree/shrub	Rare/Vulnerable (not recorded by the survey)	Riverine forest
Combretum tanaense	Shrub/liana	Vulnerable, Endemic, known only from 4 collections (not recorded by the survey)	Riverine forest
Encephalartos powysiorum	Cycad	Vulnerable, found only on one hill in reservoir area	Kijege Forest
Eriosema bogdanii	Herb	Rare (not recorded by the survey)	Grassland
Euphorbia cussonoides	Tree	Vulnerable; Endangered (not recorded by the survey)	Riverine
Euphorbia friesiorum	Shrub	Rare (not recorded by the survey)	Rocky sites & along rivers
Ficus exasperata	Tree	Rare	Riverine
Milletia tanaensis	Shrub	Rare/Vulnerable; Endemic	Rocky ground along rivers
Pandanus kajui	Tree	Rare/Vulnerable; Endemic (not recorded by the survey)	Riverine
Vernonia fischeri	Shrub	Rare, only three records (not recorded by the survey)	?

Note: Status based on IUCN classification, Habitat from Beentje (1994), Agnew (1974)[1]

[1] Beentje, H.J. (1994). *Kenya Trees Shrubs and Lianas*. National Museums of Kenya, Nairobi.
Agnew, A.D.Q. (1974). *Upland Kenya Wild Flowers*. Oxford University Press.

Figure 2-4 Forest Reserves in the vicinity of the proposed reservoirs.



Chapter 3

DOWNSTREAM PHYSICAL ENVIRONMENT

3. DOWNSTREAM PHYSICAL ENVIRONMENT

3.1 INTRODUCTION

Chapter 2 of this report includes a description of conditions in the reservoir area, whilst chapter 19 of this report describes the main downstream ecological systems. The following sections provide a brief summary of available information on downstream topography, geology and soils.

3.2 TOPOGRAPHY

The Tana basin has a wide range of landforms, ranging from the high peaks of Mt. Kenya to coastal plains, dunes and mangroves. Land above about 3,000 metres supports an afro-alpine flora and fauna. Below this, down to about 2,300 metres the occur important forest resources, which have a vital function in the maintenance of upper catchment river flows. Most of the rain falls over these highland areas. Below the highlands, the river flows through a substantial area of dissected erosion plains surrounding the middle reaches of the river before entering the Tana River floodplain stretching from Kora rapids downstream, finally merging with the delta.

The floodplain is an extensive and important feature. Including the Tana delta, this covers some 2,200 km^2 of land area and is responsible for supporting the livelihoods of a great majority of the human settlement and population over a very much larger area of the Tana basin. Maintenance of this floodplain is attained through the regular annual or biannual flooding of the Tana River. Figure 3-1 contains an overview of landforms within the Tana Basin.

3.3 GEOLOGY

Major features of the geology of the Tana River basin (Figure 3-2)include:

- volcanic and igneous rocks of the highlands which form an important part of the upper catchment as well as parts of the middle catchment;
- large areas of old basement system rocks that form an important part of the middle catchment and parts of the lower catchment;
- large areas of Plio-Pleistocene bay sediments which form the majority of the lower Tana basin.
- alluvial deposits which, together with the extensive Plio-Pleistocene bay sediments, form much of the Tana River floodplain

3.4 SOILS

The Tana Basin contains a complex range of soil types. Two major soil characteristics - soil depth and soil drainage characteristics - are shown by Figures 3-3 and 3-4. Within most of the upper and middle parts of the Tana basin, soil drainage characters are relatively uniform and at the scales of the information used (Kenya Soil Survey

1:1 million) are classified as "somewhat excessively to well drained". However, soil depths vary considerably and the middle reaches of the Tana flow through areas with generally shallow soils.

Above Kora rapids the soils are similar to those further upstream and are developed by weathering of the underlying parent material of mainly gneissic origin. Below Kora rapids and Mbalambala, soils are primarily formed from alluvial sediments and commonly have calcareous material and high salinity or alkalinity in the subsoil. Fluvisols are found in the immediate vicinity of the river. These are well drained and easily worked sandy loams or sandy clay loams and are usually neither saline nor sodic but often calcareous and are the soils usually preferred for cultivation.

The most important soils in the Tana delta are Fluvisols, Vertisols and Gleysols. These areas are commonly flooded up to twice a year to a depth of up to half a metre. Vertisols occur in lower lying basin lands adjacent to the river. These are dark, poorly drained, cracking clays, commonly have calcareous, saline or sodic subsoils and are generally difficult to manage although they have reasonable nutrient status. Gleysols are poorly drained dark grey clay soils and are suitable for irrigation development. Floodplain and delta soils are more fully described in the Stage 1 Initial Environment Assessment Report.

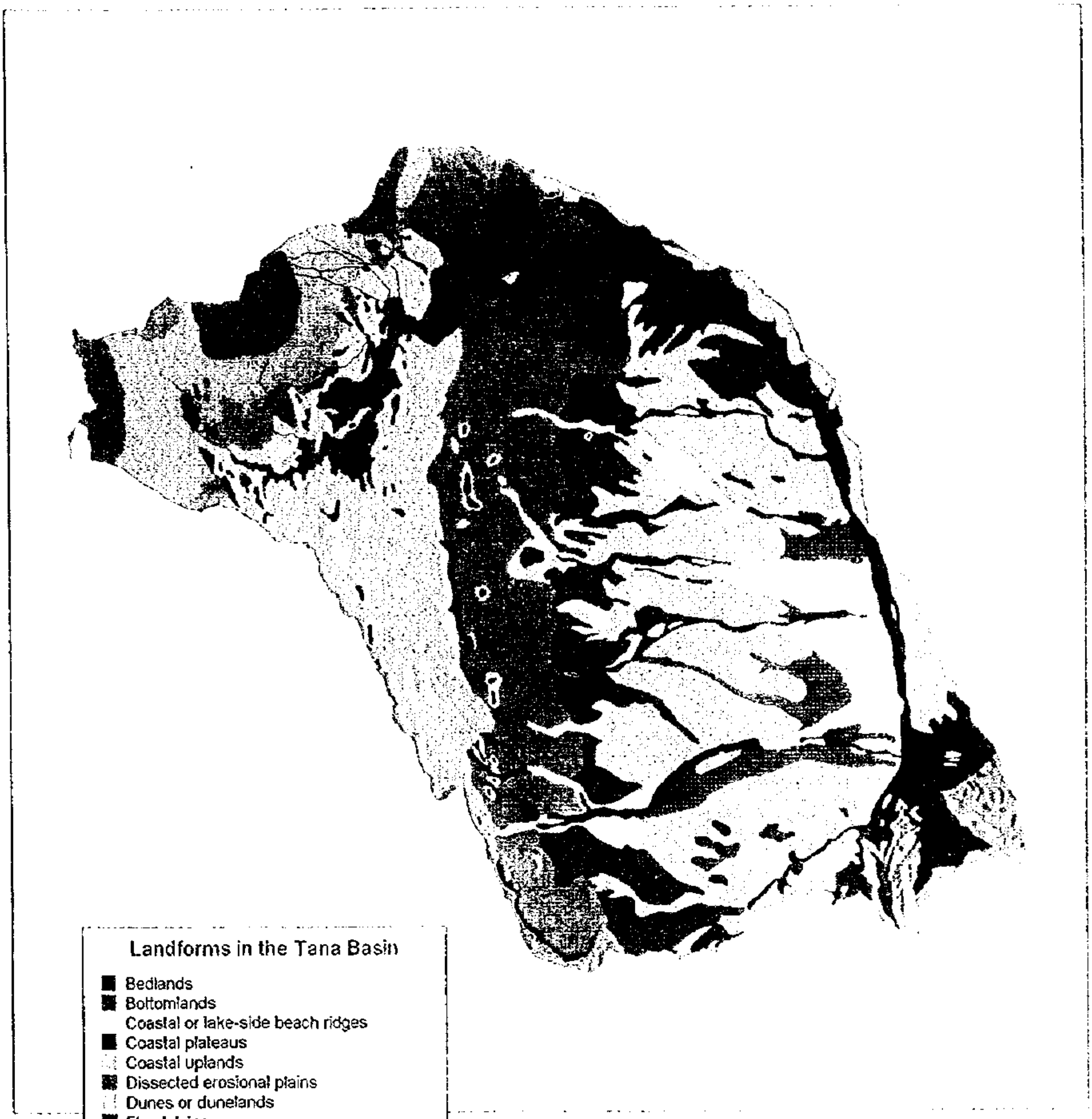


Figure 3-1 Landforms in the Tana Basin

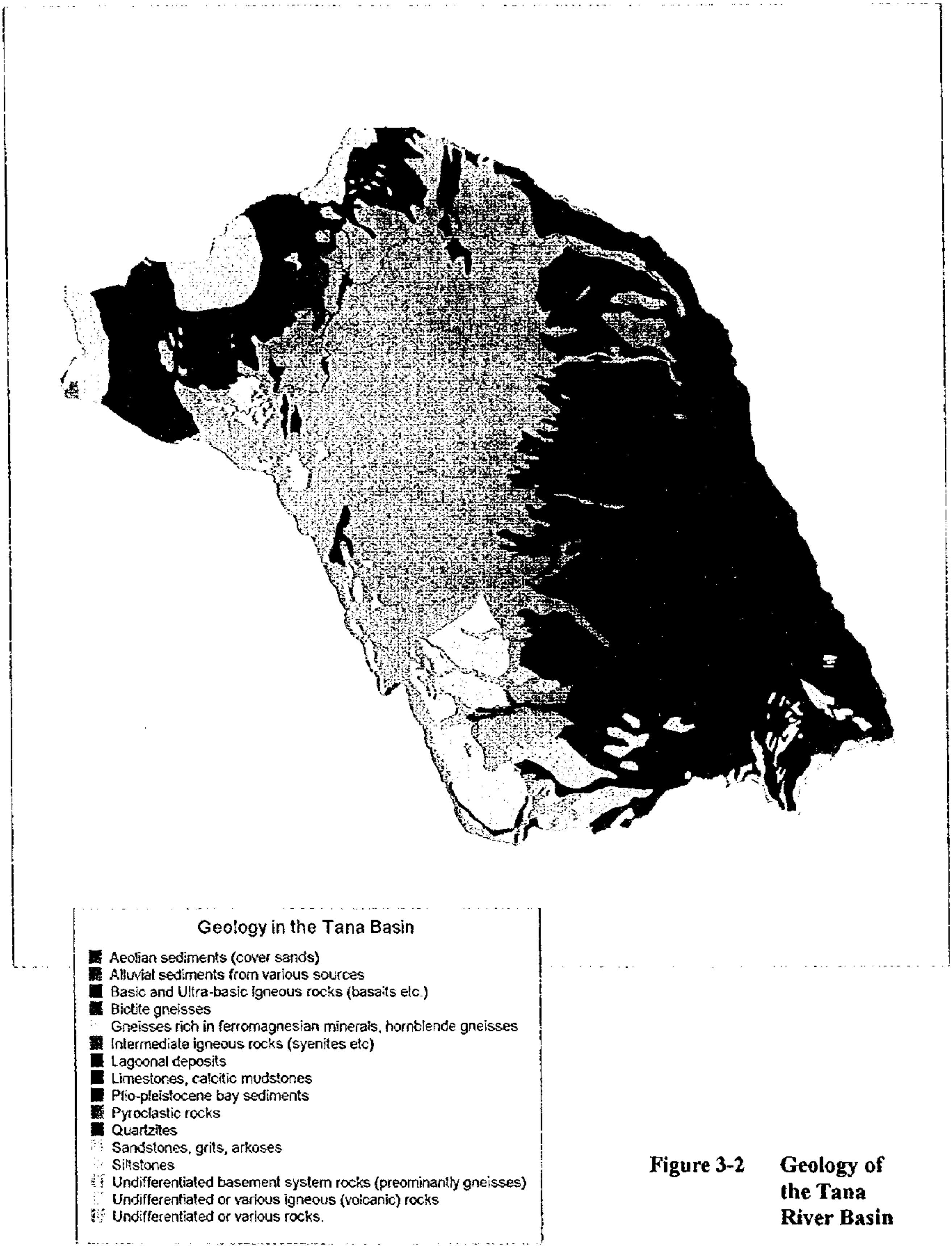


Figure 3-2 Geology of the Tana River Basin

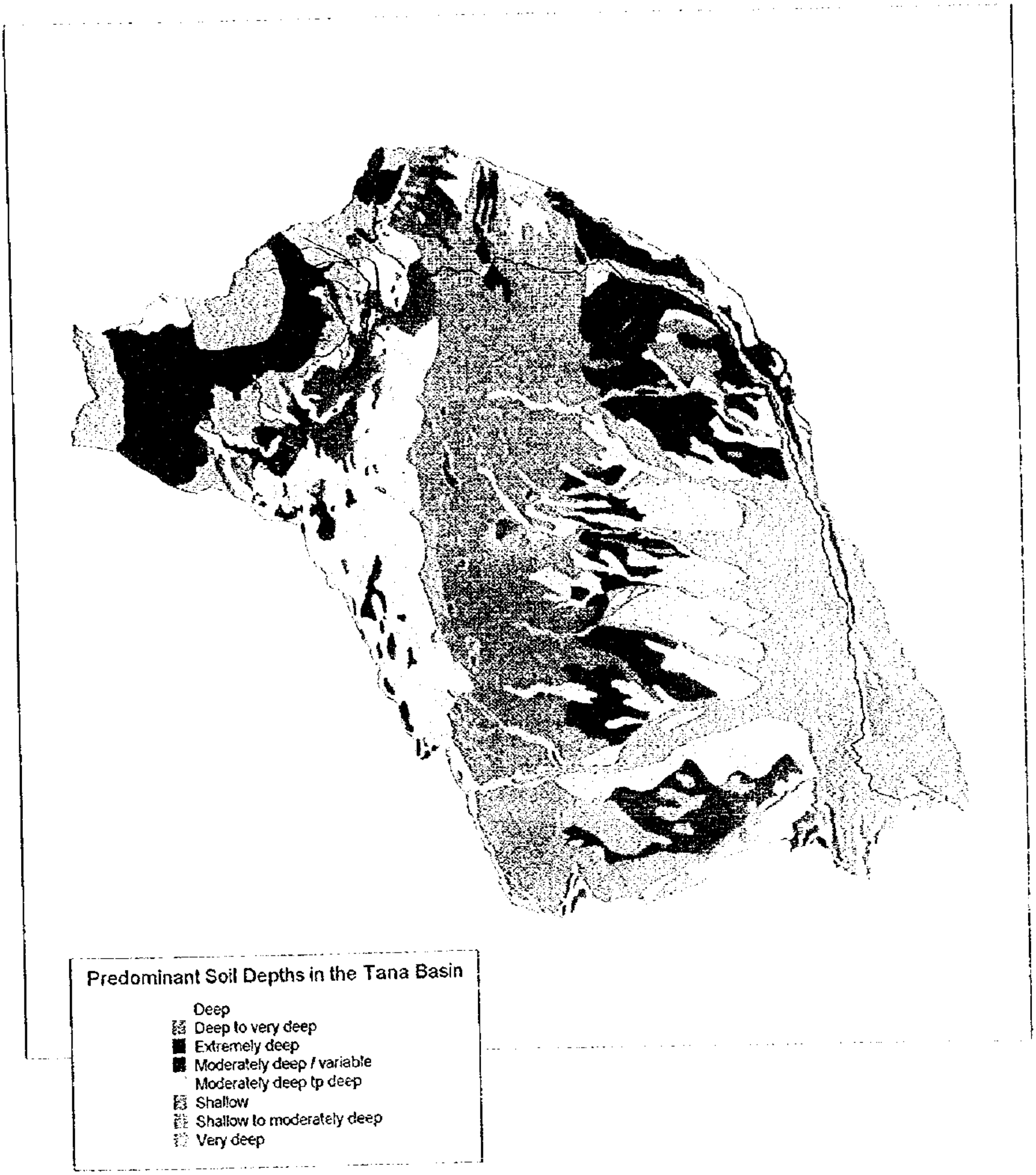


Figure 3-3 Predominant Soil Depths in the Tana Basin

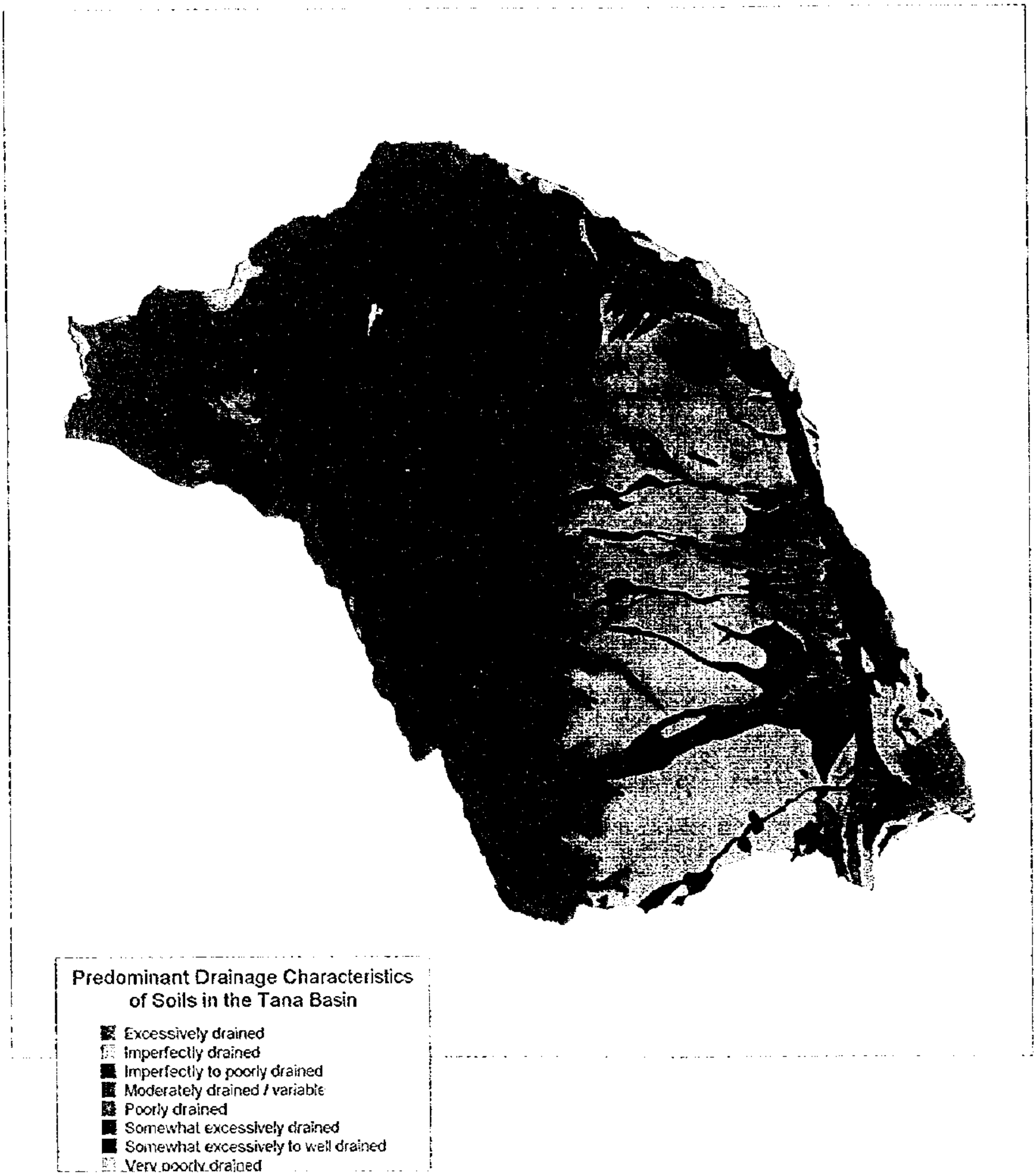


Figure 3-4 Predominant Drainage Characteristics of Soils in the Tana Basin

Chapter 4

SCOPE OF PHASE 1 & PHASE 2 STUDIES

4. SCOPE OF PHASE 1 AND PHASE 2 STUDIES

4.1 INTRODUCTION

The scope and conclusions of the previous two study phases[1] are reviewed within the context of the project requirements indicated in the Environmental Assessment Sourcebook (World Bank, 1991)[2].

It should be noted that there is no formalised environmental assessment procedure operating within Kenya (see also Chapter 25) although some have been proposed under the National Environmental Action Plan (MENR 1994). Consequently, unless otherwise stated, all references in the text to "required" or "recommended" assessments relate to the World Bank procedures as indicated in the World Bank's Environmental Assessment Sourcebook, and in particular to the Operation Directive OD 4.00 for the Environmental Assessment of investment lending operations.

4.2 PROJECT CATEGORY

All proposed options for development of hydropower at the Grand Falls Site would be classified as Category A Projects under standard screening procedures which would be carried out at the time of project identification. Category A Projects are defined as either having or as likely to have "adverse impacts that may be sensitive, irreversible and diverse". *A full environmental assessment is required as part of the pre-investment study of a Category A Project.*

CATEGORY A PROJECTS / COMPONENTS	CATEGORY B PROJECTS / COMPONENTS
Projects or components included in this list are likely to have adverse impacts that normally warrant classification in Category A	The following projects or components may have environmental impacts for which more limited analysis is appropriate
• dams and reservoirs • forestry and production projects • industrial plants large scale • irrigation, drainage & flood control large scale • land clearance and levelling • mineral development including oil and gas • port and harbour development • reclamation and new land development • resettlement and new land development • river basin development • thermal and hydropower development • manufacture, transportation, and use of pesticides and other hazardous and/or toxic materials	• agro industries • electrical transmission • aquaculture and mariculture • irrigation and drainage small scale • renewable energy • rural electrification • tourism • rural water supply and sanitation • watershed projects (management or rehabilitation) • rehabilitation, maintenance, and upgrading projects (small scale)

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1 Feasibility Study on Mutonga and Grand Falls Hydropower Project; Initial Environmental Assessment (August 1994) and Progress Report (1) Volume 1: Main Report; Volume 2: Environmental Assessment Report.

2 World Bank Technical Papers 139, 140 and 154 (1991); and Updates 1993 and 1994.

The assessment of Category A Projects includes the effect of other current and proposed development activities within the project area and activities that may be triggered by, but be independent of such project activities.

4.2.1 Issues Requiring Special Attention

In addition to the major impacts inherent in the development of a hydropower facility[1], there are a number of environmental and social issues that require special attention. The catchment, and in particular the downstream river basin, contains a number of protected areas of major conservation interest, as well as other environmentally sensitive areas - including significantly: the riverine floodplains, riverine forest, delta wetlands and mangrove ecosystems - as well as those economic and production systems depending on these ecosystems. The riverine forests are known to support endemic flora and fauna species, some with potential economic importance[2]. Forest and other habitats will be lost within the reservoir area, and downstream habitats will be affected by changed river flow patterns[3].

The proposed reservoir area includes populated land, held both under formal and usufructuary rights. The involuntary resettlement of these people will have major social and economic impacts on those resettled and, as significantly social, economic and environmental impacts on those areas to which they move.

4.3 SCOPE OF THE STUDY

As a result of the consultation process carried out during the first two phases of the feasibility study, the project is now considered to be multi-objective. The stated objectives of the project now incorporate the conventional output of power generation, and the environmental output of ***artificial release of floods*** and sediment to maintain, or improve, downstream natural and human production systems. The scope of the study has been extended to give more emphasis to the management of downstream systems, rather than solely mitigation through compensatory procedures.

However, as this change in emphasis was established at the end of the second phase of the study, the terms of reference of the environmental assessment for Phases 1 and 2 included an assessment of what would be the down stream impacts of ***controlling floods*** and what compensatory mechanisms would be required. The conclusions of the previous studies have therefore to some extent, been overtaken by the expanded objectives of the project.

There are a number of specific tasks which are considered as a minimum requirement of an integrated environmental assessment study[4]. Many of these tasks have been partially addressed in the first two phases, however in most cases continued study is

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1 World Bank. Environmental Assessment Sourcebook, Volume 3, p. 69: Table 10.8. Hydroelectric Projects.

2 For example, Wild Coffee, *Coffea sessiliflora*, a species with potentially very large economic benefits for plant breeding (disease resistance etc.).

3 Including variations within daily, seasonal and longer term periods.

4 World Bank: Environmental Assessment Sourcebook, Volume 3, Annex 10.1.

scheduled to be undertaken in Phase 3, or, as identified in the Workshop held at the end of Phase 2, will have to be included as ***a separate and parallel study*** as a precursor to the preparation of detailed engineering designs. In particular the development of a management and monitoring plan will not be completed at this stage of the study.

Tasks considered as a minimum requirement for integrated environmental assessment studies

- Assist in Inter-Agency Co-ordination and Public/NGO Participation
- Description of the Proposed Project, including the Project Objective.
- Description of the Environment
- Legislative and Regulatory Considerations
- Determination of the Potential Impacts of the Proposed Project
- Analysis of Alternatives to the Proposed Project
- Development of a Management Plan to Mitigate Negative Impacts
- Identification of Institutional Needs to Implement Environmental Assessment Recommendations
- Development of a Monitoring Plan

Table 4-1 Environmental Assessment Study Progress

TASKS	Phase 1/2	Phase 3	Parallel Study
Promotion of Interagency Co-ordination and Public/NGO Participation	⇨	⇨	➔
Strengthening Institutional Environmental Assessment Capacity	✗	✗	
Project and Project Objectives	⇨	✓	
Environment - Reservoir Habitat, Population and Dam Site	⇨	✓	
Environment - Downstream Hydrology and Production Systems	⇨	⇨	➔
National/International Legislative and Regulatory Considerations	⇨		➔
Potential Impacts - Reservoir Habitat and Displaced Population	⇨	✓	
Potential Impacts - Resettlement Area and Host Population	⇨	✓	
Potential Impact - Downstream Natural and Human Environments	⇨	⇨	➔
Alternative Power Sources, Site or Upgrading Existing Facilities	⇨		
Management and Monitoring Plan - Resettlement Area		⇨	➔
Management and Monitoring Plan - Reservoir Operation and Downstream Environment		⇨	➔
Institutional Needs to Implement Resettlement Proposals		✓	
Institutional Needs to Implement Reservoir and Downstream Management Proposals		⇨	➔
Institutional Development Prior to Implementation			➔

⇨ Included in Study, ✓ Completed/scheduled for completion ✗ Not Undertaken, ➔ Further Study Required

In addition, although an assessment of institutional needs will be included in Phase 3 of the study, it will be necessary to ***implement*** many of these institutional recommendations in order to develop the institutional capacity of both government departments, institutions and local groups ***prior*** to implementation of the project to ensure that the proposals for mitigation and final management can in fact be carried out.

4.4 INSTITUTIONAL ARRANGEMENTS

The environmental assessment, as an integral component of the feasibility study, would be expected to take as long as other components being studied. The environmental assessment process, if adequately linked to the engineering design study and other study areas, would not be expected to delay the programme, and in the long term through indicating possible future problems will reduce the true economic costs of the project[1]. In many cases the potential exists for the process of environmental assessment to strengthen local environmental institutions.

The success of environmental assessment as a means to ensure that the development proposal is environmentally and socially acceptable, largely depends on the existence of environmental management capacity within the institutions responsible for the development procedure[2]. The major institution directly involved in the project assessment process is TARDA, with responsibility for advising the government on the rational development of human and natural resources within the basin. The management board of TARDA includes representatives from various ministries concerned with agriculture, natural resources wildlife and water development; TARDA has already been the key agency responsible for developing two reservoirs within the Tana basin, Masinga and Kiambere, however their experience of environmental assessment is limited.

There is as yet no national environmental policy which can provide the overall context within which this project can be assessed nor any clearly defined institution on which the process can be built, which would in turn strengthen that institution[3].

4.4.1 Public Involvement

In view of the limited capacity for the direct involvement of TARDA in the process of environmental assessment, it is particularly important that the requirement for public

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1 Environmental assessment preparation costs as part of the feasibility study, rarely exceed one percent of capital costs of the project. In this particular case, with the sensitivity and complexity of the issues involved, costs should be at the higher end of the range.

2 Environmental Assessment Sourcebook, Volume I, Policies, Procedures, and Cross-Sectoral Issues. Chapter 5 Strengthening Local Capabilities and Institutions. Paragraph 1. "The success of environmental assessment... ...depends in large measure on the existence of environmental management capacity in the institutions of the borrowing country."

3 The National Environment Action Plan highlights the need for a national environmental policy to provide guidance for actions in all sectors. Institutional recommendations include the need to create a single institution with the legal authority to co-ordinate the management of environmental resources with responsibility for ensuring that adequate independent environmental assessments are implemented.

involvement is adequately met. The requirement states that affected groups and local NGOs are consulted in a meaningful way as part of the environmental assessment preparation, particularly where involuntary resettlement is involved

The process of public involvement is described as including:

- **Consultation** - with affected groups and local NGOs shortly after the identification of the need for an environmental assessment and secondly once a draft report has been prepared.
- **Participation** - specifically called for in projects involving involuntary resettlement; a voluntary process in which people, including marginal groups, together with project authorities share, negotiate and control the decision making process in project design and management.
- **Information Dissemination** - with information dissemination as a necessary precondition for consultation.

Furthermore, the results of the consultation process must be included in the final EA report. Information must be presented "in a timely manner and in a form that is meaningful for, and accessible to, the groups being consulted".

The results of the first phase of the study were presented at a workshop at which ***invited representatives*** from the affected districts were present, as well as representatives from ministries, the National Museums and Kenya Wildlife Service, and international NGOs. It was at this first workshop that the concept of deliberate release of floods and sediment as part of the operating rules of the dam was first raised, as an issue of particular concern to the Kenya Wildlife Services.

A major component of the second study phase was the incorporation of the opinions of a sample of the population who would be affected by involuntary resettlement, covering details of preferred resettlement locations and mechanisms for compensation. Meetings were held with farming and pastoral groups and with NGOs and other organisations operating in the downstream areas.

As a part of the information dissemination process, a video was produced covering the environment and populations that would be affected both in the immediate vicinity of the reservoir and in the downstream riverine corridor and the delta. The video was based around a series of un-structured interviews with local farmers, pastoralists and fishermen.

The results of the second phase, including the video, were presented at an ***open workshop*** at which there were representatives from local environmental and social development based NGOs, and MPs from areas which would be affected by the proposed developments.

The procedures that have so far been undertaken would be regarded as an adequate process of consultation and information dissemination and should be continued, including participation in any further planning process following the completion of the feasibility study[1]. The results of the completed study would be expected to be made publicly available[2], before a final decision is made.

4.5 BACKGROUND INFORMATION

4.5.1 The Project

The area directly affected by the proposed works has been identified, although specific site information will only be defined as part a further detailed design study, which will only take place if the findings of the feasibility study confirm that the proposed project should be undertaken.

Plans have been provided for each of the three dam sites at Mutonga Low Grand Falls and High Grand Falls. These plans indicate the general layout of facilities, including the dam crest, diversion tunnel, intake, penstock tunnel, power house, tailrace, spillway and plunge pool, and switchyard area and access road. Outline schedules have been produced, again for the three options, indicating the expected time requirements for the general construction stages and including the impounding period. The routing of the power transmission is described, and the proposed connection to the Kiambere Embakasi line.

The reservoir area and a small part of the surrounding land has been mapped at a scale of 1:5,000, based on aerial photography contracted as part of the study. Contours were mapped at two metre intervals, other locational information included stream lines, roads, tracks, buildings, forest, bushland, farmland and field boundaries where identifiable from hedges.

4.5.2 The Environment

4.5.2.1 Construction Parameters

The physical environment of the reservoir site has been described in detail, with particular attention given to those aspects affecting the design parameters.

Rainfall patterns have been analysed for the entire upper catchment, based on data from 30 rain-gauging stations with records of ten or more years, and these were used to predict the probable maximum daily precipitation.

Daily river flow data was obtained for a number of stations, both above and below the proposed reservoir. Based on this flow data, with some infilling to cover the periods

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1 The requirements are described in Environmental Assessment Sourcebook Update October 1993 Number 5, replacing the EA Sourcebook's Chapter 7.

2 Reference as above. "For IDA projects, if the government objects to the release of an EA report, the project will not be appraised.", and therefore by implication, could not be funded under the donor project.

when gauging stations were inoperative[1], a continuous series of daily data was produced covering the period of 25 years from 1966 to 1990. This data has been used to predict the annual mean discharges to the Mutonga and Grand Falls Reservoir sites, and from the mean monthly discharges a flow depth-duration curve has been derived. The representative flood season has been characterised from the daily data. The 1 in 10,000 year estimated maximum flood has been calculated, as being 7,933 m^3/sec. However for the design of the spillway the *probable maximum flood* has been calculated based on the *probable maximum precipitation* and the catchment area, giving a design value of 9,060 m^3/sec.

Sediment load has been assessed to give an indication of the reservoir life. The analysis is based on the sediment catchment for Masinga, which has been derived from actual measurements, and estimated trap efficiencies. The results indicate that sedimentation will not affect the performance of the reservoirs within the 50 year economic life of the project.

Geological studies have been carried out and sites for quarries and borrow pits have been identified. Both Dam sites are in the same seismic zone as Kiambere, and therefore the same earthquake coefficient is assumed to apply.

4.5.2.2 The Reservoir and Adjacent Areas

Studies have been carried out within the area that would be inundated and in adjacent areas that might be used as buffer zones and for resettlement. Much of the reservoir area is classified as Agro-Climatic Zone V, characterised by *Acacia Commiphora* bushland and suitable for livestock production as well as drought tolerant cereals and legumes. The general land use pattern is a matrix of small cleared farms and bushland, a narrow and patchy riverine forest along the Tana and isolated and densely forested steep hills, mainly gazetted as forest reserves. Vegetation density varies from thicket to open grassland. Removal of ground cover has led to serious erosion in many areas. The reservoir area and in particular the riverine forests are thought to contain a number of rare and endemic species, as well as species of particular local economic significance.

The reservoir area crosses three districts, Embu, Tharaka Nithi (previously part of Meru) and Mwingi (previously part of Kitui). The population around the reservoir area on the Mwingi side is almost exclusively Tharaka, although there are some Kamba in Katse location; in Tharaka Nithi and Embu, the population is predominantly Tharaka and Mbere. Part of the area has been adjudicated and formal land tenure rights granted to households, however in about half of Tharaka Nithi and throughout Mwingi, land is held under customary tenure as trust land under the county councils.

Population densities in the divisions covered by and adjacent to the reservoir are estimated to vary from around 20 to as high as 88 people/km^2 (CBS, 1994). There is a

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[1] The data is being reworked for Phase 3, based on changed/updated rating curves for part of the time series. Infilling of missing data has accounted for an estimated 25 to 30% of the time series.

clear change from the higher potential higher population densities to the west of the project area to the drier lower populated areas to the east. The staple food crops include maize and millet and the most common cash crops are cotton, millet and green grams. Livestock forms a major component of all farming systems in the area, with typical holdings of 30 head of cattle and 80 sheep and goats. Farm incomes are supplemented by other on-farm but non-agricultural incomes, mainly food preparation (baking and brewing) and handicrafts (tailoring, weaving and furniture making). Off farm incomes include charcoal burning, fuelwood marketing and fishing. The main energy source is fuelwood, with paraffin for lighting.

4.5.2.3 The Downstream Environment

In addition to, and built on, the flow data and flood analysis carried out to determine the design criteria for the dam structures, a separate assessment was made of the flow data to determine the natural flooding patterns that affect the downstream areas. The present discharge levels at Grand Falls and Garissa, were analysed from the 25 year daily flow data. A computer simulation, including the management of the existing reservoirs was prepared. The model was then run to remove the impact of the management of the five existing dams to establish the natural flooding cycle. Downstream flooding of the riverine floodplain, and hence the delta is triggered by overbank flow; overbank flow at Garissa starts at approximately 500 m^3/sec. The flooding pattern, following the bi-annual flow cycle generated floods in 29 seasons out of a theoretical possible 50. Floods would therefore be ***expected*** to occur more frequently than once a year.

4.5.2.4 Downstream Environment and Populations

Immediately below Grand Falls the river continues to form the boundary between Tharaka Nithi and Mwingi districts and is populated by Meru and Tharaka practising mixed farming. Further down past Isiolo there is a mixed population of Boran and Somali pastoralists. The population in this upper part of the basin is estimated as 180 000 in Tharaka Nithi, 125 000 in Mwingi and 27 000 in Garbatulla Division, Isiolo.

Between Grand Falls and Kora the river remains largely confined, dropping 250 metres in a distance of 100 kilometres.

Beyond Kora the river develops a floodplain between 3 and 15 kilometres wide until it spreads into the delta. The river passes through Garissa and Tana River districts, and again acts as the administrative boundary between the districts[1]. Virtually all of the population within these districts is dependent to some extent on the flooding pattern of the river.

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[1] Theoretically Tana River District crosses the river covering both banks and a three kilometre strip on the Garissa side including most of the flood plain; however this appears to be ignored and there has been considerable development on the Garissa side supported by the local administration

Tana River has a population of 152,000, largely Orma and Wardei pastoralists and Pokomo flood recession farmers. The rural population of Garissa, estimated at 127,000, is almost entirely Somali pastoralists. Both arable and pastoral farming systems have evolved to make use of and depend on the natural flooding pattern of the river. The Pokomo flood recession farming uses the natural irrigation mechanism of the floods for their staple crops, and the levees for bananas ad mangoes. The Orma and the Wardei have evolved a transhumant system that links dry season grazing in the floodplains with wet season grazing in the hinterland, during drought years up to 40,000 cattle graze in the delta grasslands. The Somali pastoralist system, though to a higher degree truly nomadic, still depends on the river for watering stock for up to six months of the year.

Table 4-2 Downstream Population Dependence

District / Division	Main Ethnic Group	Economic System	Estimated % Dependant on Tana River	Estimated Dependant Population, 1995
Tharaka Nithi / Tharaka	Meru / Tharaka	Mixed Farming	50%	91,000
Mwingi / Kyuso	Kamba	Mixed Farming	20%	125,000
Isiolo / Garbatulla	Boran	Semi sedentary Pastoralist	50%	27,000
Garissa	Somali	Nomadic Pastoralist	100%	126,000
Tana River	Pokomo / Orma	Flood Recession Farming / Transhumant Pastoralist	100%	152,000
Lamu	Orma	Transhumant Pastoralist	100%	4,000
Total				525,000

A number of irrigation schemes have been established adjacent to and dependent on the Tana river; all the existing large schemes have collapsed, although the most recent scheme, the Tana Delta Irrigation Project, is still under development. The Lower Tana

Village Irrigation Programme, which introduced the use of pumped irrigation to village level schemes, has not been much more successful, with only two out of six still operating. The recent development move has been towards even smaller pumped schemes for specific identified groups of farmers. These schemes are largely supported by NGOs.

4.5.2.5 Downstream Environment and Natural Production Systems

The natural production systems dependent on the flooding cycle include floodplain grassland, riverine forests and, further down, the delta grasslands and forests, and the mangrove forests.

- **Grasslands** occur in areas subject to longer flooding periods, the period of flooding limits the competition from bush and tree species, whilst at the same time enhancing the value of the grazing resource. This category occupies the greatest proportion of the floodplain and delta.
- **Riverine forests** occur in patches associated with river channel changes and movements. Low intensity/high frequency floods are needed for seedling germination; groundwater is required during the dry season; sediment deposition provides high nutrient levels for primary production; whilst high intensity/low frequency floods create new oxbow and river channels with point bar structures for the development of new forest areas.
- **Mangroves** occur in the intertidal zone between the mean neap tide and exceptional spring tide levels. Different species are adapted to very different conditions of flooding and salinity, determined by the present pattern of river flooding and flushing.

The riverine and delta pasture is the main dry season grazing resource for the pastoralists. The delta becomes particularly critical during drought years. The natural pattern of flooding has an additional management benefit, in that cattle are forced to move out during actual flood periods relieving grazing pressure and allowing for pasture recovery.

As a result of clearing, and in particular for the Bura and Hola irrigation schemes, the forests are now largely limited to the area between Wema and Garsen They are now further threatened by the development of the Tana Delta Irrigation Project (TDIP). The forests contain a number of rare and endemic plants and two endemic and critically endangered primates. Studies of bypassed oxbow forests show rapid changes from riverine forest to savannah species. A small area including both floodplain grassland and riverine forest has been gazetted as the Tana River National Primate Reserve, and as such has attracted considerable international conservation attention as well as funding for development both within the forest area and with adjacent communities.

The delta has three areas of mangroves, the present outlet at Kipini and in the former outlets at Mto Tana and Mto Kilifi. The present outlet of the river is characterised by estuarine mangrove vegetation and provides the only habitat in Kenya where there are significant areas of *Heritiera litoralis*. Mto Tana again provides a unique habitat, with mangroves running into floodplain and extensive marshland. Mto Kilifi is characterised by a more saline environment. However, even these two previous outlets are dependent for freshwater inputs on flooding within the delta. The mangroves support a wide range of flora and fauna and in particular fisheries. The mangroves provide the nursery grounds for a number of commercial species, as well as the spawning grounds for resident and shoreline species.

4.5.2.6 Protected Areas

In addition to the Tana River National Primate Reserve and the proposed Tana Delta National Wetlands Reserve, there are a number of other protected areas that might be affected directly or indirectly by changes to the river flow system. These include Meru National Park and the similar environment of the Bisanadi National Reserve and to the south the North Kitui National Reserve, with a thin fringe of riverine vegetation dependent upon persistent groundwater seepage.

Although the main river floodplain does not start until below the Kora National Park, some areas of major significance to wildlife and for stock grazing are related to seasonal river flow. In the north west of Kora the general narrow fringe of riverine vegetation extends into an alluvial plain up to two kilometres from the river and supporting dense vegetation At the other end of the park the forested Hameye swamp is a result of the flooding patterns, and in turn is thought to be responsible for loss of flow volume and moderation of flood events between Grand Falls and Garissa.

To the north of Kora is the Rahole National Reserve, this area is away from the river and would not be directly affected by any changes. The reserve is not actively managed.

4.5.3 Legislative and Regulatory Considerations

There is no comprehensive environmental policy, or legislative mechanism against which the project or the impacts of the project can be reviewed[1]. The present environmental legislation that applies to the development of the project is covered by a number of sectoral acts and statutes under different line ministries. TARDA, formerly the Tana River Development Authority which was established in 1974, effectively has the mandate for advising the government on all development within the Tana and Athi river basins. The emphasis is however on water development and there is provision for TARDA to have direct involvement in development projects. TARDA as an autonomous corporation, is obliged to work within the legislative mechanisms and take specified actions to prevent undue effects on the environment.

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[1] If the recommendations of the National Environmental Action Plan are accepted, there may be a new institution and legal framework in place before construction work is started. The present study might then have to be reassessed to comply with new procedures.

The following list include some of the main sectoral acts governing the development of the project.

- The Water Act - applies both to the reservoir and to any public water supplies that may be developed from it.
- The Land Acquisition Act - development must be shown to be for the public benefit and compensation must be provided to affected land owners.
- The Electric Supply Lines Act - again dealing with rights of way and compensation.
- The Forest Act - refers to defined "Forest Areas" and "Central Forests" and controls access to and use of these forests. The act covers specified forest within the area in which resettlement is likely to take place.
- The Agriculture Act - has the power to impose land conservation orders to control cultivation, grazing and clearing.
- The Wildlife (Management and Conservation) Act - applies to the management of national parks and reserves.

4.6 POTENTIAL IMPACTS

Effectively five reservoir options have been studied, these include the development of 1) High Grand Falls, 2) Low Grand Falls alone, 3) Mutonga alone and 4) Low Grand Falls and Mutonga, and 5) No Development - the base line situation. The main differences between these options in conventional terms is the total and firm energy output and the costs of development. In terms of direct negative and/or positive environmental and social impacts, the construction of Mutonga alone will have the least impact, both locally and downstream, and conversely the least capacity for managing flood releases for the benefit of the downstream environment. The greatest local and downstream disturbance would come from the construction of High Grand Falls, and in particular with the much greater storage volume, the management of the impounding period becomes problematic.

It should be noted that there has not been an overall economic assessment of the projects that included environmental considerations as well as conventional power output parameters.

4.6.1 River Basin Development

The development of hydropower will have direct impact on the adjacent and downstream environments, and will in itself be affected by future upstream developments. The project must therefore be considered within the overall development of the river basin. Although TARDA have responsibility for the co-ordination of development projects throughout the basin, there is no overall regional (basin wide) development plan within which to assess the relative benefits and/or costs of different sectoral proposals[1]. Development proposals are therefore almost invariably sectoral and in addition very often decentralised to district level.

Table 4-3 Summary of Environmental Impacts for Reservoir Options With and Without Flood Release.

	Reservoir Area		Downstream		
	Destruction of Habitat	Scale of Resettlement	Impounding: Flood Dependent Systems	Operating: Flood Dependent Systems	Irrigation
No Action	≈	≈	≈	≈	≈
Mutonga	×	×	≈	≈	≈
Low Grand Falls	××	××	×	××	≈
Low Grand Falls with Flood Release	××	××	×	✓	≈
Low Grand Falls and Mutonga	×××	×××	×	××	≈
Low Grand Falls and Mutonga with Flood Release	×××	×××	×	✓	≈
High Grand Falls	×××	××××	×××	×××	≈
High Grand Falls with Flood Release	×××	××××	×××	✓	≈

≈ Neutral ✓ Positive Impact × Negative Impact

The study has assessed the present and increased water demands within the basin, looking at both domestic and industrial water demands and irrigation requirements. The projections are based on the conclusions of the water master plan[2]. Despite limited data available there are indications of future conflicts over water resources.

- The projected public water supply demand, above the proposed reservoir options, is expected to increase by a factor of three by the year 2020. Shortfalls can be expected to occur in all years following 2005.
- Irrigation demand is expected to similarly increase, both above and below the reservoir. The conflict is compounded by the seasonal variations in water demand. Irrigation shortages are especially large in the Thiba and

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[1] CAP 443 of the Laws of Kenya: according to section 2 of the TARDA has responsibility for ".. the area drained by and bounded by the watersheds of the Tana and Athi Rivers .." and the authority was set up to "..advise on the institution and co-ordination of development projects in the area..".

[2] National Water Master Plan. Ministry of Water Development / JICA Nairobi 1992.

Kathita catchments, where demand is projected to be *double* the available water supply by the year 2020[1].

Clearly the future development of both irrigation and urban and rural water supplies needs to be reviewed, both in terms of the potential for meeting projected requirements and in terms of the implications for future hydropower development.

4.6.2 Resettlement and the Reservoir Area

The immediate result of the construction of the reservoir will be the displacement of the farming communities from within the area of inundation and the buffer zone, the larger the option the more people will be displaced. The estimated 1995 number of households within the inundated area and a minimum 100 metre buffer zone ranges from 190 for Mutonga to 1 500 households for High Grand Falls. The numbers of households displaced increases with increasing buffer zone size, and obviously is most significant with the larger reservoir options. The total number of households affected by High Grand Falls with a 3 kilometre buffer increases to 4 500. It should be noted that, given the number of people to be resettled, the programme should comprehensive and part of a wider or regional development strategy[2].

The reservoir and adjacent area is already settled, and both the only real option and also the preferred option for most of the residents is settlement within neighbouring communities. The implication is that the resettlement programme will have to deal with the impact on the host population as well as the direct costs of compensation both in kind and through financial compensation to displaced families. The indirectly affected population can be taken as being the entire population of the locations affected by the reservoir. Again the numbers increase with reservoir option.

Within the resettlement area, the impact of additional population will be an increase in overall land pressure, the greatest impact is likely to be in the communal areas used for grazing and fuelwood collection. There will also be a significant and immediate requirement for timber for replacing hut structures when opening up new farm sites. The implication is that settlement will accelerate the process of land degradation, and that erosion will become an increasing problem, which in itself could affect the reservoir life. The settlement programme will have to address this problem of increased land pressure through an extension programme promoting conservation farming.

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1. It is clear that this will require a major restructuring of irrigation, to include low volume irrigation and water harvesting techniques. However, in the event of water shortages, much of this change can be expected to be industry driven amongst commercial growers - probably accounting for the largest proportion of irrigation demand.
2. The EAS suggests that a comprehensive settlement plan is not necessary for relatively small displacements of a few hundred people, but that where it directly affects thousands of people it must be comprehensive.

Table 4-4 Phase 2 Estimates of Households directly affected by the Reservoirs and a 100m Buffer Zone, with additional households affected by resettlement in adjacent areas.

Option	Households 1995
Reservoir area:	
High Grand Falls	1,540
Low Grand Falls	530
Mutonga	190
Low Grand Falls and Mutonga	710
Adjacent Sub-Location Populations	10,640

(1995 estimates on the basis of the 1989 census analysed at sub-location level)

There will also be increased pressure on the infrastructure in the settlement area, as schools, markets, churches and other community structures are lost. The settlement programme will have to address the problem of either extension of existing facilities or provision of new structures.

The need for extended health facilities may be exacerbated by an increased incidence of water related diseases associated with the creation of the reservoir[1].

The resettlement plan must provide the additional following information:

- Organisational Capacity for Resettlement and Development - including departmental responsibilities, assisting line agencies and plans for organisational development and training.
- Participation of Affected People - including strategies for involvement in decision making, operation and implementation.

These and other aspects will have to be dealt with as part of the parallel study.

4.6.3 Reservoir Water Quality and Fisheries

The reservoir water quality will be determined by both the upstream inputs of pollutants and by processes within the reservoir body. Increasing population within the upper catchment, accompanied by increasing urbanisation will lead to increased levels of pollutants. The larger the reservoir the greater trap effect on pollutants. Nutrient levels within the reservoir are likely to be high; this not only has the potential to support an active fisheries, but stimulates the growth of aquatic weeds.

Initial assessments of possible fisheries benefits have been based on the output from the upstream reservoir, although with potentially over twice the surface area of

[1] There are indications that there has been an increase in water related diseases as a result of the previous reservoir construction programmes.

Masinga, and with higher temperatures and nutrient load, productivity is likely to be greater.

4.6.4 Downstream Systems

The fundamental parameter which dominates both natural and human production systems is the natural flooding pattern. Construction of any reservoir options without the inclusion of provisions for flood release will damage downstream systems, and the seriousness of these impacts will increase in relation to the reservoir volumes. Conversely, any management of reservoirs that can increase and assure regular low intensity floods will maintain and improve downstream systems.

The construction of either Low Grand Falls or High Grand Falls would provide a structure which could be designed to incorporate adequate storage for flood release; however the period of impounding required for High Grand Falls could result in irreversible damage during filling. The period of impounding will be determined by the minimum acceptable flow release, and as critically by the rainfall occurring during the impounding period. The period of impounding is as variable as the upstream climate, and will be significantly longer during drought years.

It should be noted that the construction of a dam with adequate storage and flood release structures does not in itself ensure that the ***management*** will take account of this in future operating procedures.

The second aspect of the changed flow regime is the reduction in sediment load. The release of sediments is clearly of benefit to the management and longevity of the reservoir system, and will minimise downstream impacts. Management and design will attempt to minimise sediment trapping, and in terms of downstream environments, this will be most important during flood periods.

The possible effect of decreased sediment load in terms of fertility and primary productivity has not been ascertained.

4.6.4.1 Changes in River Channels

The loss of sediment to the downstream system will result in morphological changes in the river channel directly below the dam site. The major impact would occur during flood periods when the decrease in sediment would significantly increase the erosivity of flows. The initial assessment indicated significant bed degradation downstream of Kora rapids starting within ten years, a lowering of the bed by two metres would effectively preclude flooding and would effect a stretch of 25 kilometres by the year 2020 and 50 kilometres by the year 2045.

4.6.4.2 Changes in Human Production Systems

Reservoirs without Flood Release

Any decreases in the frequency or regularity of low level floods will effect the two major production systems, flood recession farming and pastoralism.

The impact of decreased regular flooding will be to reduce the viability of the Pokomo flood recession farming, taking an existing high risk farming system already under pressure from reduced land resources, to the point at which it ceases to function. The potential for changing the farming system to adapt to lower frequency floods is negligible, the most obvious alternative is the introduction of small scale irrigation which in itself has been shown to be highly problematic. If no alternative can be found then the impact will effectively be the equivalent of a continued artificial drought, with all the associated requirements for food aid

The effects of decreased flooding on pastoralists is primarily the loss of floodplain pasture, although the trigger for the move to the pasture is generally shortage of water supplies in the hinterland. Decreased flooding in the delta will both reduce the total availability of pasture and the natural mechanism for ensuring against overgrazing, and decrease the quality of grazing through bush encroachment. In addition the change in flooding regime would increase the potential for competition between marginal rainfed arable farming and pastoralism. The impact of the loss of floodplain grazing can be reduced but not negated through the development of large numbers of small water harvesting structures in the hinterland, extending the period of hinterland grazing.

The result of increasing pressure on the pastoralist systems will again be similar to continued and extended drought, eventually leading to a permanent and decreased carrying capacity. It has been noted that the effects of drought on the pastoralist systems has been an increase in tension between different pastoralist groups, with attendant security problems.

Irrigation systems will be largely unaffected by changes in low level floods; this applies to both existing and proposed small scale and large scale schemes. The destructive effects of the larger floods, which will continue to occur with any reservoir option, will not be reduced.

Reservoirs With Managed Flood Release

The release of low level regular floods would improve the viability of downstream production systems. The effects of this improvement would be enhanced through an active monitoring programme that would provide advance warning of flood events, both the timing of regular floods and prediction of the major uncontrolled flood events. This would apply to all systems, including irrigation, and would not preclude external improvements to the systems such as extension of hinterland grazing.

The management of impounding would have to ensure that the systems are not adversely affected, this would be most problematic with High Grand Falls. Food aid and other drought relief programmes may be needed during the impounding period.

4.6.4.3 Changes in Natural Production Systems

Reservoirs Without Flood Release

The impact of changes to the floodplain grassland will be a decrease in total area and bush encroachment. Grasslands would be eventually be replaced by savannah vegetation in the upper areas and bushland in the delta. The impact of this changing habitat would be reflected in wildlife species supported and would lead to a loss of biodiversity.

The riverine forest system has evolved to exist in a changing flood environment, the loss of regular low intensity flooding will decrease the potential for seedling germination and survival. The increased regularity of stream flow is likely to enhance ground water recharge in the area immediately adjacent to rivers, may reduce stress on mature trees, however new potential environments created by the irregular large floods will not be colonised. The overall effect will be the creation of an increasingly imbalanced forest system gradually replaced by savannah species. The loss of habitat will in turn lead to the loss of endemic species and a decrease in biodiversity. *In situ* management of floods and sediment control to preserve habitat is unlikely to be practical in the immediate future. *Ex situ* conservation of species is an expensive last resort and is rarely successful.

The impact on the mangroves will largely result from changes in the salinity levels. The general trend would be for a decreased daily salinity in the narrow band of mangroves directly associated with the active river channel. However there would also be a loss of flushing mechanism which would affect both the active river channel and the creek systems that are inundated during flooding periods. The overall effect would be a change in the species composition, with a loss of species and a reduction in total area with increasing hinterland salinisation. The impact would clearly affect the secondary dependent species, including major commercial marine fish species. There would be an overall loss of biodiversity. Again, *in situ* flood management is unlikely to be practical, and *ex situ* conservation an expensive and incomplete last resort.

The floodplain fisheries, which form an important component of local diet as well as a commercial resource, depend on the floodplain environment for spawning and growth. Any loss of floodplain area will lead to a direct loss of productivity. Further towards the delta, the oxbows form a major component of the system. The formation of oxbows results from the major flood events, these will still occur; however, the regular filling of the oxbows relies on the frequent low flood events. The potential for replacement of the natural fisheries systems through aquaculture is extremely limited. An additional impact will result from changes in water quality discharged from the reservoir. Careful management of discharge water will be required, including possible multi-level release.

Reservoirs With Managed Flood Release

The release of regular low level floods would maintain the present natural downstream production systems, and might, over time, reverse some of the recent trends in decreasing productivity. In particular, the regular floods could increase the incidence of refilling of oxbow lakes, improving both fisheries and the viability of adjacent riverine forest areas.

There are indications that communities have recently increased the offlake of timber and non-timber products from natural forest areas, partly as an economic compensation for the decrease in viability of traditional farming systems. Improvements to the human production systems could result in a reduction of pressure on forest resources.

The impact of possible changes in nutrient levels to primary productivity has not been established.

4.7 ANALYSIS OF ALTERNATIVES

The potential for the development of hydropower facilities at Mutonga and Grand Falls has been identified in a number of previous documents, in particular the National Power Development Plan 1987 and 1992 and the National Water Master Plan 1992[1]. As the proposed projects are included in the National Development Plan there has been no real assessment of alternative means of meeting the predicted energy requirements, nor of the potential for upgrading existing facilities.

However, a brief description of the potential impacts alternative power generation systems has been included, noting the adverse impacts of oil-based and coal based thermal power plants and the renewable energy options of geothermal, wind and solar facilities. Effectively the assumption is that all alternatives will be pursued in addition to the Grand Falls/Mutonga development.

The study of the "No Action" option has not been within the context of the main conventional project objective of power output, as it did not propose alternatives to meeting that objective.

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[1] It should be noted that despite the recent publication of these documents, much of the information is derived from previous reports and should be treated with caution.

Table 4-5 Direct Impacts: Reservoir Area

Potential Impact	Study Conclusions	Further Information Requirement
Environmental Effects of Construction	Significant negative impacts will occur, increasing with the scale of the construction activities, including air and water pollution from construction, soil erosion and destruction of vegetation, and sanitation and health problems from the construction camp.	Detailed plans will need to be drawn up to minimise effects through careful selection of sites, implementation of conservation structures as part of site and access management and careful management of camps. Costs of health services need to be included. Provision of fuelwood and/or alternative energy sources should be investigated
Loss of Land through Inundation **(Further Studies during Phase 3)**	Significant negative impacts will occur. Loss of pasture and arable land will increase land pressure in adjacent areas. Loss of forest and bushland will increase pressure on adjacent forest areas, including forest reserves. Loss of riverine forest habitat is largely irreversible, active protection of alternative riverine forest areas should be pursued. Loss of riverine forest will lead to a decrease in biodiversity. The new reservoir environment may provide a significant habitat for migratory water bird species. Management of draw-down could improve habitat.	Further studies may be required, following the assessment of the results of the Phase 3 study of riverine forests and associated flora and fauna.
Loss of Historic, Cultural and Aesthetic Sites	A number of archaeological have been identified within and adjacent to the area to be inundated.; the importance of these sites is unknown. A survey and salvage operation is required.	Further survey work needs to be supported.

(continued)

Potential Impact	Study Conclusions	Further Information Requirement
Dislocation of People within the Reservoir and Buffer Area (Further Studies during Phase 3)	Significant negative impacts will occur, increasing with size of reservoir and buffer zone option. Estimates of displaced populations range from 710 households in Low Grand Falls and Mutonga with a minimum 100 metre buffer zone to 4,450 households in a 3 km Buffer Zone. Minimum disturbance and maximum potential for intensive management will come with a narrow buffer zone, surrounded by a special management zone in which conservation and improved farming practices are promoted. Affected communities indicated that resettlement would be preferred within adjacent local communities, and compensation should be both in provision of land and in cash.	A full registration programme will have to be implemented including an assessment of all household and farm resources. This will need to be carried out during the detailed design phase of the study.
Transmission Lines (Further Studies during Phase 3)	The impact of the transmission system will add to the affects of the inundation through increased displacement of population, increased land clearance, and road construction. Alternative routes may be selected following further studies.	Further studies will be required, following detailed engineering proposals covering right of way, switchyards and substations and access and maintenance requirements.

(continued)

Potential Impact	Study Conclusions	Further Information Requirement
Affects on Adjacent Populations (Further Studies during Phase 3)	Increased pressure on land resources and infrastructure will affect both resettled and host populations. The present population of affected and adjacent sublocations is estimated as 10,000 households. Affected populations will increase over the detailed design and construction periods by an estimated minimum of 20%. Increased land pressure will contribute to the decline in the viability of the present farming systems and to a loss of forest resources and hence higher levels of erosion. The project will have to include the provision of improved extension services and the development of sustainable farming systems aimed at improved management and marketing of crops and livestock. On-farm and community tree planting will need to be promoted. The buffer zone could be managed for intensive tree production. Increased pressure on infrastructure will need to be addressed through expansion of existing, and provision of new facilities. This includes schools, health facilities, water points and markets. The management capacity of responsible institutions will have to be supplemented through provision of additional resources and training.	Further work carried out as part of Phase 3 of the feasibility study will need to be supported by an additional, detailed land use and social development plan that will lead into a programme of implementation. This may include details of proposed additional services provided by the reservoir, including irrigation, water supplies and electrification.
Improved Access to Reservoir Area	Development of improved infrastructure, in particular road access, may result in in-migration increasing land pressure problems. The problem may be exacerbated by the permanent settlement of construction crews within the area at completion of the construction period.	Further studies required following detailed designs for the construction and operation phases.

(continued)

Potential Impact	Study Conclusions	Further Information Requirement
Increase of Water Related Diseases	Significant negative impacts are likely to occur. Increased incidence of malaria, persistent leishmaniasis and schistosomiasis is reported to have followed the construction of up-stream reservoirs. A health management programme will have to be built on the improved health infrastructure in adjacent areas.	Further studies are needed to define the health programme requirements, covering both treatment and prophylaxis and vector control. Disease incidence should be considered for any monitoring programme.
Deterioration of Water Quality and Proliferation of Aquatic Weeds (Further Studies during Phase 3)	Initial studies of pollutants from the upper catchment indicate potential problems of deteriorating water quality, largely from agro-industrial processes and urban and peri-urban settlements. Increasing nutrient load in the water may lead to eutrophication. High nutrient load may lead to high weed growth, potentially impairing the functioning of the reservoir. Problems associated with deteriorating water quality are likely to increase with larger reservoir options, due to longer retention time.	The results of the present studies will give an indication of the level of the problem, and suggest possible management strategies. These are likely to include clearance of vegetation prior to inundation, control of land use and waste water discharges within the upper catchment, and provision of multi-level releases. Further studies and specific monitoring of pollutant levels will be required, leading to a catchment management strategy.
Disruption of Riverine Fisheries (Further Studies during Phase 3)	It is expected that the present fish communities will change dramatically within the area of inundation, and this will affect migratory species passing to the Mutonga and Kathita rivers. The loss of the riverine environment will to a large extent be compensated for through the development of a reservoir fisheries resource; the value and sustainability of this resource will depend on the management of water quality within the reservoir. Extension programmes will have to be aimed at promoting fishing as a locally owned economic activity.	The present study is aimed at establishing the presence and significance of migratory fish species within and above the reservoir area. Further studies will be required, forming a component of the monitoring procedures needed to assess changes in water quality.

(continued)

Potential Impact	Study Conclusions	Further Information Requirement
Sedimentation and Loss of Storage Capacity (Further Studies during Phase 3)	Initial assessment indicates that present sediment loads do not decrease the economic life of the proposed reservoir options. In the area immediately adjacent to the reservoir, increased land pressure resulting from resettlement is likely to lead to increased erosion. Impacts will be reduced through active management of the buffer zone and direct and indirect interventions through the extension service to promote conservation farming systems. More generally, management of sediment load may be possible through sediment release or diversion structures, although the critical factor remains control of land use in the upper catchment.	The present studies, including further sampling of dry season and rainy season sediment loads will give a better indication of total and seasonal variations. For a complete seasonal picture and for indications of trends in sediment load, further studies and a full monitoring programme are likely to be necessary.

Table 4-6 Direct Impacts Downstream Area

Potential Negative Impact	Study Conclusions	Further Information Requirements
Changed Hydraulic Flow Regime (Further Studies during Phase 3)	The major potential negative downstream impacts are all related to the changes that could occur as a result of changed flow patterns, associated with storage reservoirs. The natural river flow pattern includes bi-annual high flow or flood periods, associated with the rains in the upper catchment. The effect has been the creation of a flood plain in which the natural and socio-economic environments have adapted to and rely on flooding for their existence. The only potential mitigation is the deliberate release of water, partially replicating the natural flooding conditions. The proposed reservoir designs will be adapted to include the potential for high flow release, or for diversion of river flow past the reservoir. It should be noted that none of the proposed reservoir options have the storage capacity to significantly reduce the infrequent major catastrophic flood events, that result in damage to downstream systems.	The Phase 3 Studies establish more clearly the "natural" flood conditions, and the release volumes and periods that can replicate them. Further studies will be required to establish the downstream flood dynamics, including hydraulic modelling of the floodplain. Monitoring of rainfall and flow levels will be needed to ensure optimum management of the system, balancing flood requirements with maximised power output.
Decrease Flow during Impounding (Further Studies during Phase 3)	Total river flow is decreased during the impounding period; the greater the decrease in flow, the greater the impact. Mitigation of impact is only possible through a guaranteed minimum flow and, if the total period covers a number of flood seasons, flood release adequate to create a minimum level of flooding in the floodplain and the delta.	Phase 3 studies provide a clearer indication of minimum required flow levels and flood requirements. Further studies and negotiations with downstream communities will be needed to define management options during impounding.

(continued)

Potential Impact	Study Conclusions	Further Information Requirement
Loss of Sediment and Scouring of Riverbed below Dam (Further Studies during Phase 3)	Serious negative impacts are expected; loss of sediment through deposition within the reservoir body will increase erosivity of downstream flow. Initial assessment suggests that bed degradation will take place, resulting in changes to water tables. Changes in sediment quality, as a result of decreasing levels of nutrient rich upper catchment sediments may affect flood plain fertility levels. Some potential for reduction of negative impacts exists through sediment release and/or diversion.	The Phase 3 Study includes the development of a simple dynamic model based on available topographic and geological data, including new sediment load data collected during this season. Further studies will be required to improve on the basic model, and should be combined with the sediment monitoring programme. The present studies should clarify the issue of nutrient transfer, but for the complete picture a full study will be needed.
Loss of Wildlife Habitat	Serious negative impacts are expected on the riverine forests, adapted to low volume-high frequency floods. Associated loss of endemic and rare species, particularly the Crested Mangabey and red Colobus. Decrease in nutrient rich sediments may lead to a decrease in overall primary productivity. Similar loss of delta wetlands and associated wildlife species, including increasing salinity and changes from floodplain grassland to bush. Within the mangroves there are indications that there would be significant changes as a result of loss of flushing mechanisms and changed patterns of sediment deposition; again loss of habitat and decreasing biodiversity are expected. Mitigation mechanisms rely on a replication of the low volume high frequency flood events.	Further studies will be required to establish more specific links between habitats and flow/flood regimes. These should be linked to the dynamic modelling of hydraulic flow within the floodplain. Monitoring of these habitats will provide input into the optimisation of management of flood release.

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Potential Impact	Study Conclusions	Further Information Requirement
Decrease in Flood Plain Farming (Further Studies during Phase 3)	An estimated 150,000 farmers are dependent to some degree on flood recession farming. Recent drought years have resulted in a high degree of dependence on relief food, indicating the likely impact of loss/decrease in regular seasonal flooding. Mitigation measures rely on the provision of regular low level floods. Monitoring will be necessary to optimise the flood patterns and avoid the risk of triggering catastrophic flood events. Increased regularity of low flood events, leading to improved cropping reliability may compensate for loss of fertility inputs through changes in sediment quality.	Phase 3 studies are limited to an assessment of the perceptions and dependency of downstream farming communities on seasonal river flow. Further studies will be required to develop mechanisms that will ensure that downstream communities are involved in decision making processes related to the management of the reservoir. Monitoring systems will be needed that can provide information to management in real time, to ensure maximum benefits from water storage capacity.
Loss of Pastoralist Grazing Areas (Further Studies during Phase 3)	An estimated 1,000,000 cattle, 1,300,000 shoats and 85,000 camels rely on natural flooding patterns for seasonal grazing water supplies. Loss of flood plain grazing, including any decrease in the delta grasslands will irreversibly damage the pastoralist system, which relies on the seasonal move between hinterland grazing and floodplains. Provision of regular flood events should improve the reliability of the present system, allowing improved management of flood plain grazing. This should be accompanied by improved management of hinterland grazing and water supplies.	Phase 3 studies are limited to an assessment of the perceptions and dependency of downstream pastoralist communities on seasonal river flow. Further studies will be required to develop mechanisms that will ensure that pastoralist communities are involved in decision making processes related to the management of the reservoir. Monitoring systems developed to assess the management of the riverine forests and delta wetlands can be used to assist management..

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Potential Impact	Study Conclusions	Further Information Requirement
Changes in Water Quality (Further Studies during Phase 3)	The reservoir water quality is expected to decline as a result of nutrient and other pollutant inputs. The quality of released water will also be affected. Clearer indications of levels and possible mitigation measures will result from the present studies. Potential impacts will affect riverine fisheries and water quality for human and livestock consumption.	Further studies leading to detailed management and monitoring requirements may be necessary following the present phase.
Disruption of Riverine Fisheries	Possible negative impacts will result from changes in water quality and changes in flooding patterns. Reduced flooding intensity will reduce floodplain spawning and growth areas. Reduced areas or loss of oxbow lakes will reduce commercial fisheries. Decreased sediment release will reduce primary productivity of marine and estuarine fisheries. Mitigation relies on regulated flood release replicating natural flood events.	Detailed studies should be included both as an integral part of monitoring water quality as an indicator of habitat impacts.