JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF ENERGY
THE REPUBLIC OF KENYA

FEASIBILITY STUDY
ON
MUTONGA/GRAND FALLS HYDROPOWER PROJECT

FINAL REPORT

EXECUTIVE SUMMARY

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

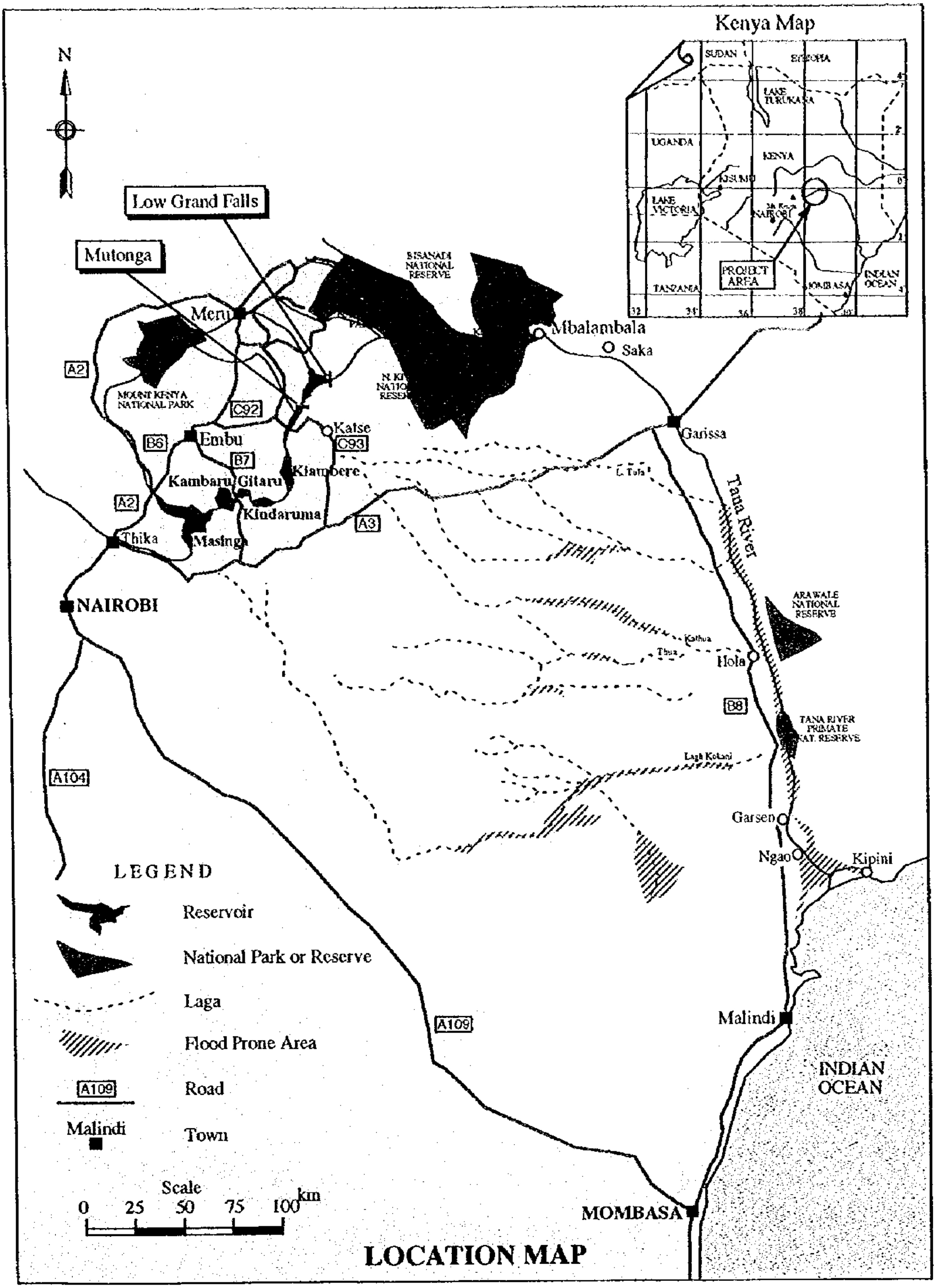
Volume II Supporting Report (1)
(Engineering Study)

Volume III Supporting Report (2)
(Environmental Assessment)

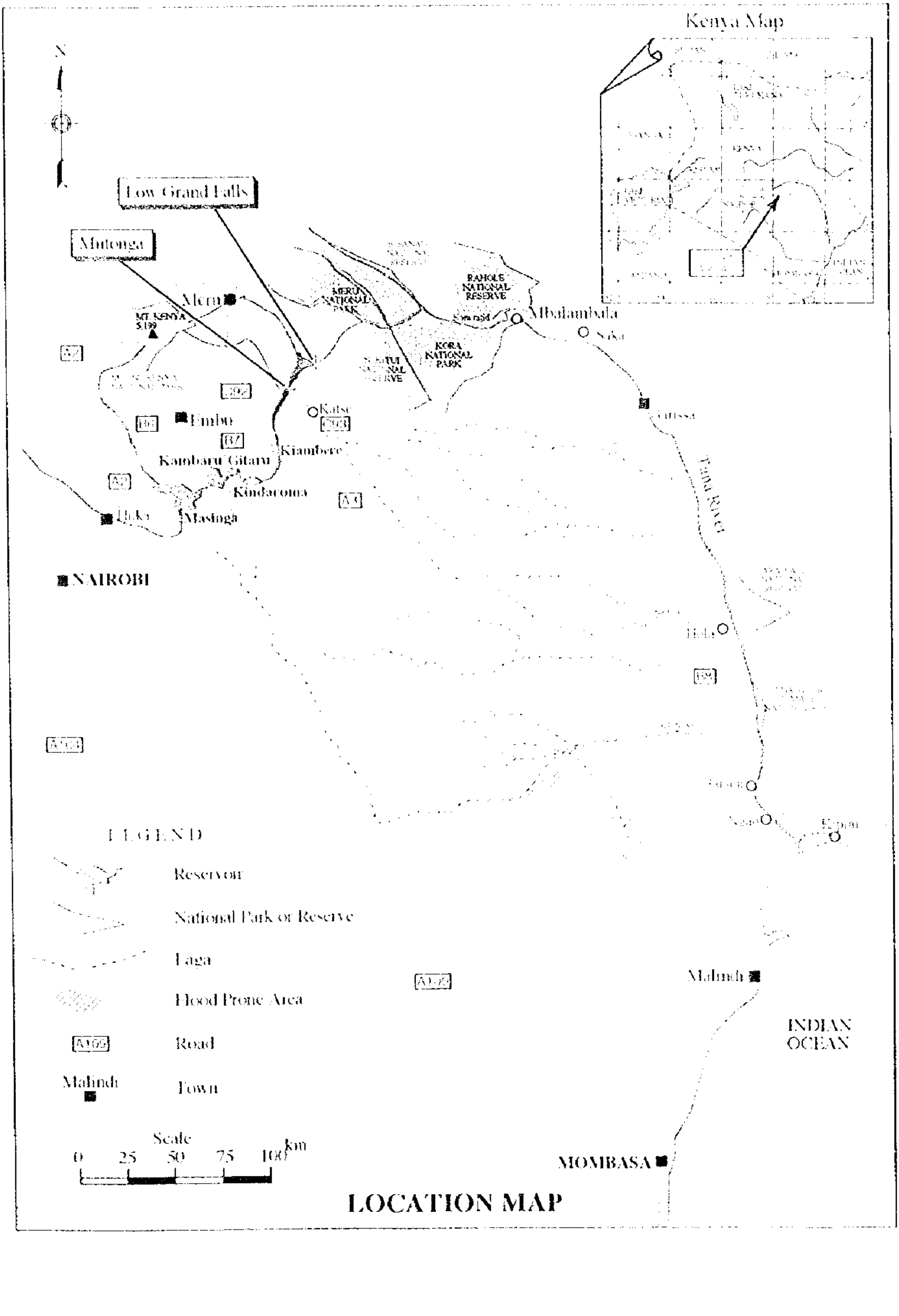
Volume IV Supporting Report (3)
(Workshop Proceedings)

The cost estimate is based on the price level of June 1997 and the monthly mean exchange rates in June 1997. The monthly mean exchange rates in June 1997 are:

US$ 1.00 = KShs. 54.0 = J. Yen 120



LOCATION MAP



LOCATION MAP

JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Waterfall of 4km Upstream from Grand Falls Dam Site	Photo 1

PRINCIPAL FEATURE OF THE PROJECT

		Low Grand Falls	Mutonga
1.	**Hydrology and Reservoir**		
	- Catchment area	17,234 km^2	15,365 km^2
	- Annual mean discharge	173 m^3/sec	157 m^3/sec
	- Full supply level (FSL)	EL. 512.0 m	EL. 550.0 m
	- Minimum operation level (MOL)	EL. 491.4 m	EL. 538.5 m
	- Gross storage capacity	1,261 MCM	132 MCM
	- Effective storage capacity	955 MCM	85 MCM
	- Design flood of dam	5,400 m^3/sec	4,000 m^3/sec
	Extreme flood of dam	12,800 m^3/sec	10,900 m^3/sec
	- Design flood of river diversion	2,800 m^3/sec	1,600 m^3/sec
2.	**Power Output**		
	- Installed capacity	140 MW (70 MW x 2 units)	60 MW (30 MW x 2 units)
	- Maximum plant discharge	227.6 m^3/sec	175.0 m^3/sec
	- Rated head	69 m	39 m
	- Firm output	134 MW	58 MW
	- Annual average energy	715 GWh/year	337 GWh/year
3.	**Main Structures**		
(1)	River diversion		
	- Diversion tunnel	2 lanes x 10.5 m (D) x 630m and 760 m (L)	11.0 m (D) x 660 m (L)
(2)	Main dam		
	- Type	Combined type with concrete and rockfill dam	Concrete dam type
	- Dam crest elevation	EL. 516.5 m	EL. 555.0 m
	- Dam height	90 m	60 m
	- Dam volume		
	Concrete	1,200,000 m^3	420,000 m^3
	Rockfill	2,900,000 m^3	-
(3)	Spillway		
	- Type	Gated type	Gated type
	- Number of gate	6 x15.0 m (W)x 15.5m (H)	4 x 17.5 m (W) x 16.0 m(H)
	- Energy dissipation	Roller bucket type	Stilling basin type

	Low Grand Falls	Mutonga
(4) Artificial flood and sediment release facility		
- Type	2 lanes x steel conduit with gates, 5m (W) x 5 m H)	2 lanes x steel conduit with gates, 5m (W) x 5 m H)
- Gates	A high pressure roller gate with a stoplog gate for one lane	A high pressure roller gate with a stoplog gate and a radial gate
(5) Waterway		
- Type of intake gate	Selected water intake gates	Sluice gate
- Penstock	5.4 m (D) x 90 m (L)	4.7 m (D) x 59 m (L)
(6) Powerhouse		
- Type	Open-air type	Open-air type
- Dimensions	32m(W) x 60m(L) x 50m(H)	30m(W) x 49m (L) x 44m(H)
(7) Generating equipment		
- Maximum plant discharge	227.6 m^3/sec	175.0 m^3/sec
- Rated head	69.0 m	39 m
- Type of turbine	Francis type	Francis type
- Type of generator	3-phase synchronous alternator of Vertical shaft with brushless excitor	3-phase synchronous alternator of Vertical shaft with brushless excitor
- Rated output	2 x 70,000 kW	2 x 30,000 kW
(8) Transmission line		
- Voltage	220 kV double-circuit, 45 km	220 kV double-circuit, 4 km
- Conductor size	Canary (ACSR 460 mm^2)	Canary (ACSR 460 mm^2)
4. Construction Period		
- Detailed design and tender	3 years	1 year (Parallel with constrcution of Low Gamd Falls)
- Main construction works	5 years	4.5 years (half year overlapped with Low Grand Falls)
- Total construction period	12 years	
5. Construction Cost (US$ million as of June 1997)		
- Total construction cost without price escalation	381.6	184.3
- Low Grand Falls and Mutonga	565.9	
- Total construction cost with price escalation	444.5	234.9
- Low Grand Falls and Mutonga	679.4	

ABBREVIATIONS

(1) Domestic organization

GOK	:	Government of Kenya
MOE	:	Ministry of Energy
TARDA	:	Tana and Athi Rivers Development Authority
KPC	:	Kenya Power Co., Ltd.
KPLC		Kenya Power & Lighting Co., Ltd.
MOWD	:	Ministry of Water Development
MOALD	:	Ministry of Agriculture and Livestock Development
NWCPC	:	National Water Conservation & Pipeline Corporation
TRDC	:	Tana River Development Co., Ltd.
WWF	:	World Wide Fund for Nature
KWS	:	Kenya Wildlife Service
NIB	:	National Irrigation Board

(2) Foreign organization

GOJ	:	Government of Japan
JICA	:	Japan International Cooperation Agency
WB	:	World Bank
UNDP	:	United Nation Development Program
IUCN	:	International Environmental Organizations

(3) Measurement

Length

mm	=	millimeter
cm	=	centimeter
m	=	meter
km	=	kilometer

Electrical Measures

V	=	Volt
kW	=	kilowatt
MW	=	Megawatt
kWh	=	kilowatt hour
MWh	=	Megawatt hour
GWh	=	Gigawatt hour

Area

km^2	=	square kilometer

Money

KShs.	=	Kenya Shilling
K.£	=	Kenya Pound
US$	=	US dollar
US ¢	=	US cent
¥	=	Japanese Yen

Volume

MCM	=	million cubic meter
m^3	=	cubic meter

Weight

kg	=	kilogram
ton	=	metric ton

Time

sec, s	=	second
min	=	minute
hr	=	hour
yr	=	year

Other Measures

%	=	per cent
°	=	degree
'	=	minute
"	=	second
m^3/s	=	cubic meter per second
ppm	=	parts per million
℃	=	degree centigrade
BOD	=	biochemical oxygen demand
COD	=	chemical oxygen demand
DO	=	dissolved oxygen
pH	=	exponent of hydrogen ion concentration
TDS	=	total dissolved solids
SS	=	suspended solids

(4) Economy and finance

EIRR	:	Economic Internal Rate of Return
FIRR	:	Financial Internal Rate of Return
FC	:	Foreign Currency
LC	:	Local Currency
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
GRDP	:	Gross Regional Domestic Product
OMR	:	Operation, Maintenance and Replacement
LS	:	Lump Sum

(5) Elevation

EL.	:	Elevation above mean sea level
FWL	:	Flood water level
HWL	:	High water level
LWL	:	Low water level

(6) Exchange rates (as of June 1997)

US$ 1.00 = KShs. 54 = J. Yen 120

K.£ = KShs. 20

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EXECUTIVE SUMMARY

The Project

1. The Tana river annually drains a water quantity of 3,740 million m^3, which is equivalent to about 19.1 % of the total perennial river flow in Kenya. The basin is supplying an estimated amount of 175 million m^3 for municipal water supply in the upstream districts and at 2,300 million m^3 for irrigation, which are 29 % and 19 % of the total demands in Kenya, respectively.

Hydropower development of the Tana river began in 1968 with the completion of the Kindaruma dam with an installed capacity of 44 MW. Thereafter, four dams with power plants have been built at Kamburu (94.2 MW in 1975), Gitaru (145 MW in 1978), Masinga (40 MW in 1981) and Kiambere Gorge (144 MW in 1988). In addition, relatively small hydropower stations such as Wanjii (7.4 MW) and Tana (14.4 MW) have been in operation in the upstream tributaries of the Tana river. The total installed capacity of power plants on the Tana river was 489 MW corresponding to 61 % of the total installed capacity in the interconnected system in Kenya in 1997. The minimum annual energy output was estimated at 2,800 GWh compared to the annual total supply of 3,100 GWh in 1997. Figure S.1 shows the hydropower development cascade on the Tana river.

2. A project has been envisaged with an aim of developing the hydropower potential downstream of the Kiambere George on the Tana river. The Project was studied in three previous studies: 1) Feasibility Study for Kiambere Development in 1980, 2) National Power Development Plan in 1987 and 1992 (UNDP/World Bank), and 3) National Water Master Plan in 1992 (JICA).

Object of the Study

3. The Government of Kenya envisaged to develop the Mutonga/Grand Falls Hydropower Project in line with its energy and water supply development policy, i.e. exploration of indigenous energy resources and achievement of self-sufficiency in staple foods, and requested the Government of Japan to provide technical cooperation to carry out a feasibility study in the Project.

4. In response to the request of the Government of Kenya, the Government of Japan dispatched in August 1993 a mission consisting of officials of Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of technical cooperation programs of the Japanese Government, to Kenya for discussing the scope of works of the Study with its counterpart agency, the Tana and Athi Rivers Development Authority (TARDA).

The scope of works envisaged four alternative development plans as listed below, which would contribute to hydroelectric power generation as well as to water supplies for agricultural and municipal uses:

- Mutonga dam only
- Low Grand Falls dam only
- Low Grand Falls dam + Mutonga dam
- High Grand Falls dam only

The Study was divided into three stages as follows:

Stage 1	:	Initial Environmental Impact Study
Stage 2	:	Definite Plan/Pre-feasibility Study
Stage 3	:	Feasibility Study

The objective of the Study was to formulate an optimal plan for the Mutonga/Grand Falls Hydropower Project and to assess its technical and economic feasibility. Another implicit objective of the Study was an environmental assessment covering a wide range of environmental aspects on not only the impact of dam construction on the reservoir area, but also the impact on the downstream river corridor.

Work Progress

5. Figure S.2 shows the overall flow of the Study. The Stage 1 study was commenced in February 1994 with the arrival of a JICA Study Team in Kenya for the initial environmental assessment, and completed with the compilation of the Report on Initial Environmental Assessment in August 1994. The Workshop No.1 on the report was held at Embu (September 13 to 16, 1994) and a number of issues were identified for further study.

6. The Stage 2 study started in September 1994 immediately after the completion of the Stage 1 study, with the objective to select a definitive plan for the Project among the alternatives. Progress Report (1) recommended the Low Grand Falls + Mutonga schemes as the optimum development scheme from technical, economical and environmental viewpoints. The study results were reported and discussed among the attendants at Workshop No. 2 held in Nairobi, from 20 to 22 March 1995.

7. The Stage 3 study was commenced in April 1995 after the Workshop No.2, and was divided into two parts: Part 1 consisting of topographic mapping, geological investigation and transmission line system survey which were used for feasibility design and study on optimization of plant scale, and Part 2 consisting, preliminary design, construction cost estimate and plan, and project evaluation. In Part-1, field investigations were carried out from June to September 1995. Hydrological analysis was reviewed at the feasibility study level. All the study results were presented in the Interim Report and Progress Report (2)

submitted in November 1995 and March 1996 respectively, and discussed and accepted by the Steering Committee at the meeting held from June 13 to 17, 1997.

Part 2 of Stage 3 was commenced in July 1997. The Draft Final Report presenting all the results obtained in this study was submitted in October 1997 by dealing with all the results achieved in this study. Workshop No. 3 was held in Nairobi, from 26 to 29 January 1998 with a total of 188 participants officially invited from concemed organizations and public attendants. The results of the Stage 3 study presented in the Final Draft Report were explained by the JICA Study Team, and discussed among the attendants. The Steering Committee met on January 20 and 21, 1998 and February 2 and 3, 1998 to the study results of Part 2, Stage 3 presented in the Draft Final Report discuss with the JICA Study Team. The Minutes of Meeting was signed between the Steering Committee and the JICA Study Team on February 4, 1998.

Site Conditions

(1) Location and Topography

8. The Tana river, the largest river in Kenya, originates from Mount Kenya and Nyandarua Ranges. Its catchment area covers some 100,000 km^2 and stretches over about 1,000 km between the Kenya Highlands with the peak of Mt. Ol-dolinyo at EL. 3,999 m and the Indian Ocean.

The proposed Mutonga and Grand Falls Hydropower dams (the Project) are located 25 and 50km downstream of the existing Kiambere power station and about 150 km northeast of Nairobi at the shortest aerial distance. The Mutonga dam site is located immediately downstream of the confluence of the Tana river and the Mutonga river, one of main tributaries of the Tana river. The Grand Falls dam site is located about 4 km downstream of the Grand Falls rapids. The location of the Project is shown in Figure S.3.

The Tana river reaches the Koreh rapids after flowing down about 100 km from the Grand Falls. The river bed elevations are about 450 m at the Grand Falls dam site and about 200 m at the Koreh rapids, creating a water head of about 250 m between the two locations. Thereafter the river runs through a vast alluvial flood plain and finally reaches the Indian Ocean after flowing down about 700 km. The main river channel which has a width of about 100 m only meanders through a flood plain with a width of 3 to 4 km.

(2) Meteorology and Hydrology

9. The temperature in the Tana river basin varies from below the freezing point on snow-capped Mt. Kenya as its lowest, to over 40°C in the delta in the northeastern part of Kenya as its highest. The monthly temperature at Marimanti, the nearest meteorological station around the Project area ranges from 32°C at the maximum and 20°C at the minimum. The day time temperature varies from 24°C to 31°C.

10. The annual rainfall in the Tana basin varies from more than 2,000 mm in the mountainous areas located around Mount Kenya to less than 300 mm in the low-lying areas near Garissa in the lower reaches of the Tana mainstream. The aerial distribution of annual rainfall in the project catchment area was clarified based on long-term mean rainfalls recorded at some 160 rainfall stations in and around the project area. The isohyetal map of the project catchment area is illustrated in Figure S.4, showing that the high annual rainfall of more than 2,000 mm takes place in the northern and western parts of the project catchment area. It decreases as the altitude goes down toward the Tana mainstream, coming to less than 800 mm in the right bank area downstream of the existing Masinga dam. The annual mean rainfall in the basin is 1,250 mm.

11. The project catchment area has 17,234 km^2 at the Grand Falls dam site. The naturalized long-term daily runoff at the planned Mutonga and Grand Falls dams was estimated by the Tank Model, taking into account the availability of meteo-hydrological data. The mean discharges at the planned Mutonga and Grand Falls dam sites for a period of 34 years from 1957 to 1990 were estimated to be 157 and 173 m^3/sec. The comparison of flow duration curves at SGS 4F13 (Grand Falls dam site) is shown in Figure S.5.

12. The flood hydrographs at the proposed Mutonga and Low Grand Falls dam sites were presented by the Storage Function Model. The peak flood discharges of the proposed Mutonga and Low Grand Falls dams were at 4,000 m^3/sec and 4,500 m^3/sec for floods with a 200-year return period, and at 10,900 m^3/sec and 12,800 m^3/sec for the floods with a 10,000-year return period without the upstream reservoirs. The estimated flood hydrographs at the Mutonga and Grand Falls dam sites are shown in Figure S.6.

13. The mean annual sediment yield was estimated by simulating the daily runoff from 1957 to 1990 to the developed runoff-sediment yield curve, resulting in 2.62 million m^3 /year or 0.152 mm/km^2/year at the Grand Falls dam site in terms of the denudation rate.

(3) Geology

14. The reservoir areas and dam site of the Mutonga/Grand Falls Project are located in the middle reaches of the Tana River. The geology in the area is mainly composed of high-graded, metamorphosed gneisses of Kenya Basement System of Archaean age. No significant faults are found in the reservoir and damsite area. Figure S.7 shows the geological setting of the project area.

15. When gneisses are in moderately to slightly weathered or fresh condition (CM-CH-B), they are medium hard to hard rock and have sufficient strength as the foundation rock for both the Mutonga and Grand Falls dams. Rather deep foundation excavation, more than 10 meters in some places, will be required for the foundation of both dams because of deep weathering of the rocks. Even though the permeability of gneisses is generally low, foundation treatment (curtain grouting and consolidation or blanket grouting) is still required for the foundation of both dams in order to improve locations with high leakage potential. Figure S.8 and S.9 show the geological profiles of the Mutonga and Low Grand Falls dam sites.

16. The result of seismic analysis shows that: (a) the design seismic coefficient of 0.10g for the Mutonga/ Grand Falls project is reasonable, and (b) the risk of a reservoir-induced earthquake can be covered by the design with the above seismic coefficient.

Environmental Assessment

17. The environmental assessment study was carried out in the feasibility study of the Project to assess the environmental issues which would eventually be raised by the implementation of the Project consisting of: 1) resettlement, 2) reservoir environment, 3) downstream population and environment, 4) flood and sediment release, 5) downstream river morphology and 6) power transmission line. As a result, the environmental assessment study recommended a resettlement within a Special Management Zone (SMZ) by establishing a resettlement organization and taking mitigation measures against the deterioration of the environmental condition in the downstream reaches of the Tana river (refer to the Executive Summary for Environmental Assessment) as follows:

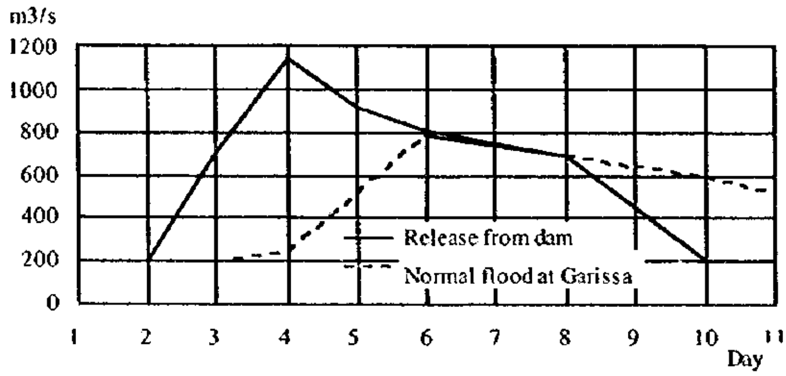
- Resettlement

  The reservoir areas and 100 m wide buffer zones where people would be excluded were set as an intensive management zone. Surrounding the reservoirs and the 100 m buffer zone, a more or less 3 km wide Special Management Zone (SMZ) where the majority of the required resettlement to be managed was proposed (refer to Figure S.10). Some 1,017 households with 6,125 people within the reservoir areas of the Low Grand Falls and Mutonga dams and the buffer zones were assumed to be resettled in SMZ by 2005. The total resettlement area was estimated at 10,600 ha, and the total compensation cost required for relocation of resettled households and people was estimated at KShs. 332 million.

It is recommended that an outline plan and program for resettlement and proper management be prepared by establishing an organization committee.

- Downstream environmental condition

The construction of the dams without any countermeasures for the maintenance of the normal floods (twice-yearly) would hasten the deterioration of the downstream environment. The environmental condition in the area downstream of the existing five dams has been deteriorated to some extent due to the decrease of normal floods (twice-yearly). It is therefore recommended to release artificial floods with a peak discharge of 1,100 m^3/sec and a volume of 490 million m^3 twice-yearly from the Low Grand Falls dam in order to at maintain the normal flood with a peak flow of 785 m^3/sec and a volume of 390 million m^3 at Garissa, as shown below:



The artificial flood would inundate the flood plain both upstream and downstream of Garissa for a period sufficient to maintain the environment and the level of economic activity. In addition, the artificial flood could mitigate the deterioration of the downstream environmental condition.

Accordingly, the Project implemented with the artificial flood release will bring about significant economic benefits from its positive effect on the downstream environmental systems in addition to the benefits of power generation and other water uses.

Power Survey

18. Kenya is divided into six regions in terms of power supply: 1) Nairobi region, 2) Coast region, 3) Central Rift Valley region, 4) Western region, 5) Mt. Kenya region, and 6) North Rift Valley region. Energy sales in the whole KPLC's network were 3,269 GWh in 1995/96, of which the sales in the Nairobi region shared 1,785 GWh, followed by the Coast region with 719 GWh, that is 75% of KPLC's sold energy.

The total installed capacity of the generating facilities in the interconnected power system was 777.6 MW as of 1996/97. In addition, there are isolated power plants with a total installed capacity of about 9 MW and energy imported from Uganda.

By type, hydropower plants shared 77% of installed capacity, 80% of effective capacity, and 81% of annual energy production in 1996/97. The installed capacity, effective capacity and average annual energy production in the country in 1996/97 by type of power plant are summarized below:

Sources	Installed Capacity (MW)	Effective Capacity (MW)	Annual Production (GWh)
Hydro	601.3	571.1	3,353.6
Conventional Thermal	119.0	86.0	373.7
Geothermal	45.0	45.0	392.8
Diesel (Interconnected)	12.3	12.0	9.6
Diesel (Isolated)	9.0	-	22.0
Imports from Uganda (agreed max. power)	30.0	0.0	143.8
Wind	0.6	0.4	0.5
Total	817.2	714.5	4,296.0

19. Power demand and energy demand were forecast for three scenarios: high, reference and low as shown in Figure S.11. The forecast for the reference growth scenario showed that the requirement of the nation's energy and peak power demand will increase continuously at an annual growth rate of 6.0% and 6.2% respectively over the period of 1995/96 to 2019/20.

20. To meet the construction schedule of the Project, the planned transmission line for the Project will be constructed in two phases. A double-circuit line from Low Grand Falls power plant to the existing Kiambere power plant will be constructed first during the construction stage of the Low Grand Falls power plant. Then a double-circuit section branched from this line to the new Mutonga power plant will be constructed during the Mutonga project construction. The planned route of the 220 kV transmission line is shown in Figure S.13.

The generated power at the Low Grand Falls power station, in its commissioning year 2008, will be mainly transmitted to Nairobi through the existing 220 kV double-circuit transmission line from the Kiambere to Dandora substations via the Kamburu power station and also through the committed 220 kV single-circuit line from the Kiambere to Embakasi substations (see Figure S.12).

An additional single-circuit 220 kV line between the Kiambere and Embakasi substations will be required to meet the increase of power to be transmitted to Nairobi in the commissioning year of the Mutonga power plant in 2012.

Plan Formulation

21. The Project intends to develop the hydropower potential of the Tana river, and irrigation and municipal water supply in the areas downstream of the river. Economic indices of the alternative power development schemes in consideration of the power development indicate that the Low Grand Falls + Mutonga scheme (implementation of the Low Grand Falls scheme followed by the Mutonga scheme) is the optimum development scheme as summarized below:

Items	Alternatives			
	Mutonga	Low GF	Low GF + Mutonga	High GF
Economic Cost (10^6 US$)	187.7	362.5	550.2	673.4
Installed Capacity (MW)	60	140	200	200
Firm Output (MW)	58	134	192	197
Annual Average Energy (GWh/yr)	337	715	1,052	1,108
Net Benefit (10^6 US$)	20.2	54.0	67.7	-99.7
Internal Rate of Return: IRR (%)	13.4	13.8	13.8	10.1
Unit Generation Cost (US¢/kWh)	8.1	7.9	7.9	11.0

Further, a reversed sequence of implementation (Mutonga + Low GF) shows lower economic indices: net benefit of US$ 48.8 million and IRR of 13.4 %, when compared to those of the Low GF + Mutonga scheme. A plan of raising the Low GF dam height also shows low indices: net benefit of US$ 36.6 million and IRR of 13.2 %.

22. The Project will also generate an effect on the irrigation water supply and municipal water supply to the downstream areas. The increased irrigable area, which will be produced through improvement of the river flow by the dams constitutes the irrigation benefit of the Project. Taking into account the releasing patterns for the downstream irrigation area and the water abstraction in the upstream basin in 2020, the river flow at the Grand Falls dam site was simulated in the case of "with/without project" and "irrigation purpose" for the Low GF and the High GF schemes. The result shows that the irrigation area would be increased by 19,000 ha under the Low GF scheme and 41,000 ha under the High GF scheme. In addition, the firm power output and annual average energy were calculated at 48 MW and 912 GWh respectively for the Low GF + Mutonga scheme, and 32 MW and 968 GWh respectively for the High GF scheme.

The results of economic comparison indicate that the Low GF and Mutonga scheme was more economical than the High GF scheme since the net benefit of US $ 4.5 million and IRR of 12.1 % of the Low GF + Mutonga scheme are higher than those of the High GF (net benefit of US $ -88.7 million and IRR of 10.6 %).

Further, the additional effect of municipal water supply derived from the dams was examined for both schemes. The unit cost of 1.35 US¢/m^3 estimated for the Low GF + Mutonga scheme is lower than 3.04 US¢/m^3 for the High GF scheme.

23. The environmental assessment study recommended the release of normal floods (twice-yearly) and sediment through the dams to maintain the existing conditions of the environment and river morphology. When artificial floods are twice-yearly released to the downstream river reaches, the power and energy outputs will be decreased due to the decrease of water from the water for power generation. The result of reservoir simulation for both the Low GF + Mutonga scheme and the High GF scheme reveals that the firm output and average energy would be 136 MW and 871 GWh respectively for the Low GF + Mutonga scheme, and 178MW and 962GWh respectively for the High GF scheme. On the basis of these values, the economic comparison of both schemes was carried out as summarized below:

Items	Unit	Low GF + Mutonga	High Grand Falls
Firm Power	MW	136.4	178.4
Annual Energy	GWh/yr	870.9	962.3
Annual Power Benefit	x 10^6 $	78.0	89.5
Present Worth of Cost	x 10^6 $	387.9	514.1
Present Worth of Benefit	x 10^6 $	352.2	376.7
Benefit/Cost		0.91	0.73
Benefit - Cost	x 10^6 $	-35.7	-137.4
Internal Rate of Return: IRR	%	11.0	9.4

Though negative net benefits would be induced by the artificial flood release in the case of both the Low GF + Mutonga and High GF schemes when calculated with a discount rate of 12%, the economic comparison revealed that the Low GF + Mutonga scheme was more economical than the High GF scheme since IRR of 11.0 % of the Low GF + Mutonga scheme was higher than that of 9.4 % of the High GF scheme.

24. Through the optimization and comparison study to determine the dam operation level and plant scale of the Project, the following basic dimensions were arrived at:

	Low Grand Falls Scheme	Mutonga Scheme
- Full Supply Level (FSL)	EL. 512.0 m	EL. 550.0 m
- Minimum Operation Level (MOL)	EL. 491.4 m	EL. 538.5 m
- Effective Storage Capacity (million m^3)	955	85
- Installed Capacity	140 MW (70 MW x 2 units)	60 MW (30 MW x 2 units)
- Firm Output	134 MW	58 MW
- Annual Average Energy	715 GWh/year	337 GWh/year
- Maximum Plant Discharge	227.6 m^3/sec	175.0 m^3/sec

Preliminary Design

25. The preliminary design of the Low Grand Falls scheme and the Mutonga scheme (refer to General Layout of the Project in Figure S.13) was carried out on a feasibility study level, and the main features obtained are summarized as follows:

	Structures	Low Grand Falls (Refer to Figures S.14 to 16)	Mutonga (Refer to Figures S.17 to 19)
(1)	River diversion	Two 10.5 m dia. tunnels	One 11.0 m dia. tunnel
(2)	Main dam	90 m high combined type with concrete and rockfill dam	60 m high concrete dam type
(3)	Spillway	Gated type, 105 m wide with a roller bucket	Gated type, 79 m wide with a stilling basin
(4)	Artificial flood and sediment release facilities	Two lanes of 5.0 m wide and 5.0 m high steel conduits with high pressure roller gates with stoplog gates	Two lanes of 5.0 m wide and 5.0 m high steel conduits with high pressure roller gate with stoplog gates and radial gates
(5)	Waterway	5.4 m dia. and 90 m long penstock	4.7 m dia. and 60 m long penstock
(6)	Powerhouse	Open-air type (32 m wide, 60 m long, and 50 m high)	Open-air type (30 m wide, 49 m long, and 44 m high)
(7)	Generating equipment		
	- Max. plant discharge	227.6 m³/sec	175.0 m³/sec
	- Rated head	69 m	39 m
	- Turbine	Francis type	Francis type
	- Generator	3-phase synchronous alternator of vertical shaft type with brushless excitor	3-phase synchronous alternator of vertical shaft type with brushless excitor
	- Number of units	Two	Two
	- Rated output	2 x 70,000 kW	2 x 30,000 kW
(8)	Transmission line	220 kV double-circuit, 45 km Canary,(ACSR 460 mm²)	220 kV double-circuit, 4 km Canary (ACSR 460 mm²)

26. It is noted that artificial flood and sediment release facilities will be provided in the concrete dam section. The facilities will be able to release artificial flood from the dam by evacuating a reservoir water volume of water 490 million m^3 between EL. 504.0 m and the minimum operation level at EL.491.4 m (MOL). They can release sediments which include sand and suspended loads associated with phosphate and organic matters. The artificial flood release operation will be carried out twice-yearly at the beginning of the rainy seasons (April and November), to effectively release clay particles flushed into the reservoir at the beginning of the rainy season. Figure S.16 and S.19 show the release facilities of the Low Grand Falls and Mutonga dams.

Construction Plan and Cost Estimate

27. The construction works of the Low Grand Falls and Mutonga hydropower schemes will be divided into four packages for each scheme, and will be executed by contractors selected by international competitive tenders for the respective package:

(1) Main civil works including preparatory works
(2) Metal works
(3) Generating equipment
(4) Transmission line

28. Immediately after this feasibility study and financial arrangement for 6 months from January 1998 to June 1998, an additional environmental assessment study is required to be executed for two years from July 1998 to June 2000. Based on the results of the additional environmental assessment, the detailed design and preparation of tender documents will be executed for 18 months from October 2000 to March 2002 after financial arrangement for the detailed design and selection of the consultant for the design work is completed, which will take 9 months from January 2000 to September 2000. The tendering procedure for the civil construction works of the Low Grand Falls scheme will be carried out for 12 months from July 2002 to June 2003 after selection of the consultant for construction supervision. The construction works of the Low Grand Falls scheme are scheduled to commence in July 2003 after contract awards, and the commissioning of the power plant is expected to be in July 2008. The Mutonga scheme construction will start in January 2008 and be completed in June 2012. The total period of construction is 9 years (108 months) for both schemes (refer to Figure S.20).

29. The construction cost of the Low Grand Falls without and with price escalation is estimated at KShs. 20,609 million (US$ 382 million) and KShs. 24,002 million (US$ 444 million) respectively as shown below:

Items	Foreign Currency (1,000US$)	Local Currency (1,000KShs.)	Total Equivalent (1,000KShs.)
Direct cost	228,738	4,248,173	16,600,050
Land acquisition	0	407,220	407,220
Administration expenses	0	83,000	83,000
Engineering services	29,624	282,300	1,881,996
Physical contingency	21,709	463,959	1,636,234
Total without price escalation	280,071	5,484,652	20,608,500 (US$ 381.6 mill.)
Price escalation	62,849	0	3,393,832
Total with price escalation	342,920	5,484,652	24,002,332 (US$ 444.5 mill.)

30. The construction cost of the Mutonga scheme without and with price escalation is estimated at KShs. 9,953 million (US$ 184 million) and KShs. 12,684 million (US$ 235 million) respectively as shown below:

Items	Foreign Currency (1,000US$)	Local Currency (1,000KShs.)	Total Equivalent (1, 000KShs.)
Direct cost	119,374	1,970,450	8,416,672
Land acquisition	0	89,402	89,402
Administration expenses	0	42,083	42,083
Engineering services	10,312	98,264	655,112
Physical contingency	10,178	199,836	749,437
Total without price escalation	139,864	2,400,035	9,952,706 (US$ 184.3 mill.)
Price escalation	50,576	0	2,731,080
Total with price escalation	190,440	2,400,035	12,683,786 (US$ 234.9 mill.)

31. The construction cost of the whole Project including the Low Grand Falls scheme and Mutonga scheme without and with price escalation is estimated at Kshs. 30,561 million (US$ 566 million) and KShs. 36,686 million (US$ 679 million) respectively.

The annual disbursement of the construction cost in the foreign and local currency potions is estimated on the basis of the construction schedule, as summarized below:

Year	Foreign Currency (1,000 US$.)	Local Currency (1,000 KShs.)	Total Equivalent (1,000 KShs.)
2000	2,642	23,760	166,443
2001	8,261	183,266	629,333
2002	3,154	247,731	418,042
2003	45,851	1,012,065	3,488,004
2004	44,581	476,518	2,883,887
2005	54,125	1,010,731	3,933,488
2006	83,911	1,388,796	5,919,993
2007	88,772	1,125,163	5,918,843
2008	59,867	705,609	3,938,443
2009	22,004	312,082	1,500,276
2010	48,197	731,024	3,333,683
2011	61,481	574,563	3,894,546
2012	10,514	93,383	661,143
Total	533,360	7,884,691	36,686,122 (US$ 679.4 million)

Project Evaluation

(1) Economic Evaluation

32. Economic viability of the Project consisting of the Low Grand Falls scheme and the Mutonga scheme was assessed based on the preliminary design and the estimated construction cost. This evaluation result indicates a high viability of the serial development of two hydropower schemes by a net benefit of US$ 56.87 million at a discount rate of 12 % and an economic internal rate of return (EIRR) of 14.98%, which is higher than the opportunity cost in Kenya (12%).

33. A study of the installation timing of the Low Grand Falls and Mutonga hydropower plants was carried out, taking into other promising candidate thermal power plants consideration, and changing the fuel price and installation sequence. The study revealed that the Low Grand Falls and Mutonga schemes added a capacity of 140 MW to the national power grid in 2008 and 60 MW in 2012. The plant installation timing proposed in this study is shown in Figure S.21.

(2) Financial Evaluation

34. Financial viability of the Project was evaluated in terms of financial internal rate of return (FIRR) by applying the project cost including price escalation, average electricity tariff of KShs.10.42/kWh (US$ 0.193/kWh) in 2008 which is projected by assuming an annual increase rate of 5 % from the average tariff of KShs.6.72/kWh in 1999, and energy output of the Low Grand Falls and the Mutonga schemes. The evaluation result demonstrates that the Project is viable with FIRR of 15.10%.

35. Table S.1 summarizes the result of examination of loan repayability based on the foreign loan condition as follows:

- Amount of loan : 85% of total cost
- Interest rate : 2.3%
- Repayment period : 30 years
- Grace period : 10 years

As shown in Table S.1, the Project will start producing a surplus from Year 9, when the revenue from the Low Grand Falls scheme is expected for the first time. From that year, the revenue would counterbalance the cumulative deficit, and a surplus would appear in Year 10.

(3) Artificial Flood Release

36. The environmental assessment recommended a twice-yearly release of a normal flood with a peak discharge of 1,100 m^3/sec and a total volume of 490 million m^3 from the Low Grand Falls dam to maintain the existing environmental conditions in the lower reach of the river. This will lead to a decrease in the firm power and energy. The result of the reservoir simulation shows that the firm power and annual average energy were 77.3 MW and 533.4 GWh/year in the case of single operation of the Low Grand Falls, and 136.4 MW and 870.9 GWh/year in the case of combined operation of the Low Grand Falls and Mutonga.

EIRR and net benefit are calculated at 11.2 % and US$ -15.3 million respectively in the case the artificial flood release is included in the Project. However, it could be said that the Project is economically viable for the following reasons:

- The downstream environment and production systems have already been affected by the existing five dams and deteriorated due to the decrease of biannual normal floods. .The construction of additional dams without flood release will hasten this destruction. However, an additional dam with flood release measure would be able to the reverse negative situation and improve the downstream environment.

  Though the value of artificial flood release is not quantified because of its intangible nature, it could contribute to an increase of the benefit. Therefore, the planned artificial flood release of the Project should have a positive aspect in this context.

The volume of artificial flood release was estimated at 490 million m^3, which occupies about 51 % of the effective storage volume of 955 million m^3 of the Low Grand Falls reservoir. Assuming that the above percentage of the construction cost of the dams including cofferdams and diversion tunnels is allocated to the environmental component, the cost born by the power generation will be decreased, resulting in EIRR at 14.4 % and a net benefit of US$ 37.5 million.

- The 490 million m^3 is the maximum volume of artificial flood release with the adoption of "Predefined Fixed Flood Release" of the Main Report. By adopting the "Variable Supplementary Flood Release" method which takes into consideration the contribution of additional flows from the downstream catchment area, the volume of artificial flood release will be decreased by about 12% as an initial estimate, which will increase the EIRR to 12.5%. It is clear that if the entire upstream system of 7 reservoirs is managed according to upstream rainfall events to maximise the use of seasonal flows, the potential to increase power output from the whole system would also be increased.

Additional Environmental Assessment

37. The environmental assessment study recommended to carry out an additional assessment of the environments in the lower reaches of the Tana river without delay, taking into consideration the present adverse effects of the existing dams on the downstream environment and possible further increase of the impacts eventually caused by the implementation of the Project.

The additional environmental assessment study will aim at the implementation of long-term and overall environmental management plan in the Tana river flood plain and delta, which is assumed to be realized through the following procedures:

(1) Implementation of an environmental assessment study
(2) Development of a management plan based on the assessment
(3) Implementation of the monitoring management plan

The object of the study covers step (1) which is to conduct an environmental assessment on the Tana river flood plain and delta, paying due attention to the linkage among the resources, human activities and river flow regime. The study will include:

1) Review and compilation of data and information
2) Survey and investigation of physical conditions
3) Identification of values, functions and sensitivities of ecosystem
4) Identification of uses and dependencies on natural resources
5) Investigation of impacts on socio-economic activities
6) Identification of development opportunity and constraints
7) Identification of management issues

8) Development of management policy
9) Training and technology transfer

The study area will cover: 1) The river reaches downstream of the Grand Falls dam, the Tana river flood plain downstream of Garissa, and the Tana delta which will include all permanent and seasonal wetlands and coastal resources, including marine resources off-shore of the delta to a depth of 15 meters as well as "hinterland" resources seasonally dependent on the Tana river, and 2) the Tana river reaches upstream of Garissa in relation to flow regime including sediment.

The study period is assumed to be 24.0 months in total from the time of commencement, in which two wet seasons in the early study period will be allocated for the measurement of runoff and sediment because the flow regime in this nature will have key role on the environment in the flood plain. The time schedule of the respective study items is assumed to be as shown in Figure S.22.

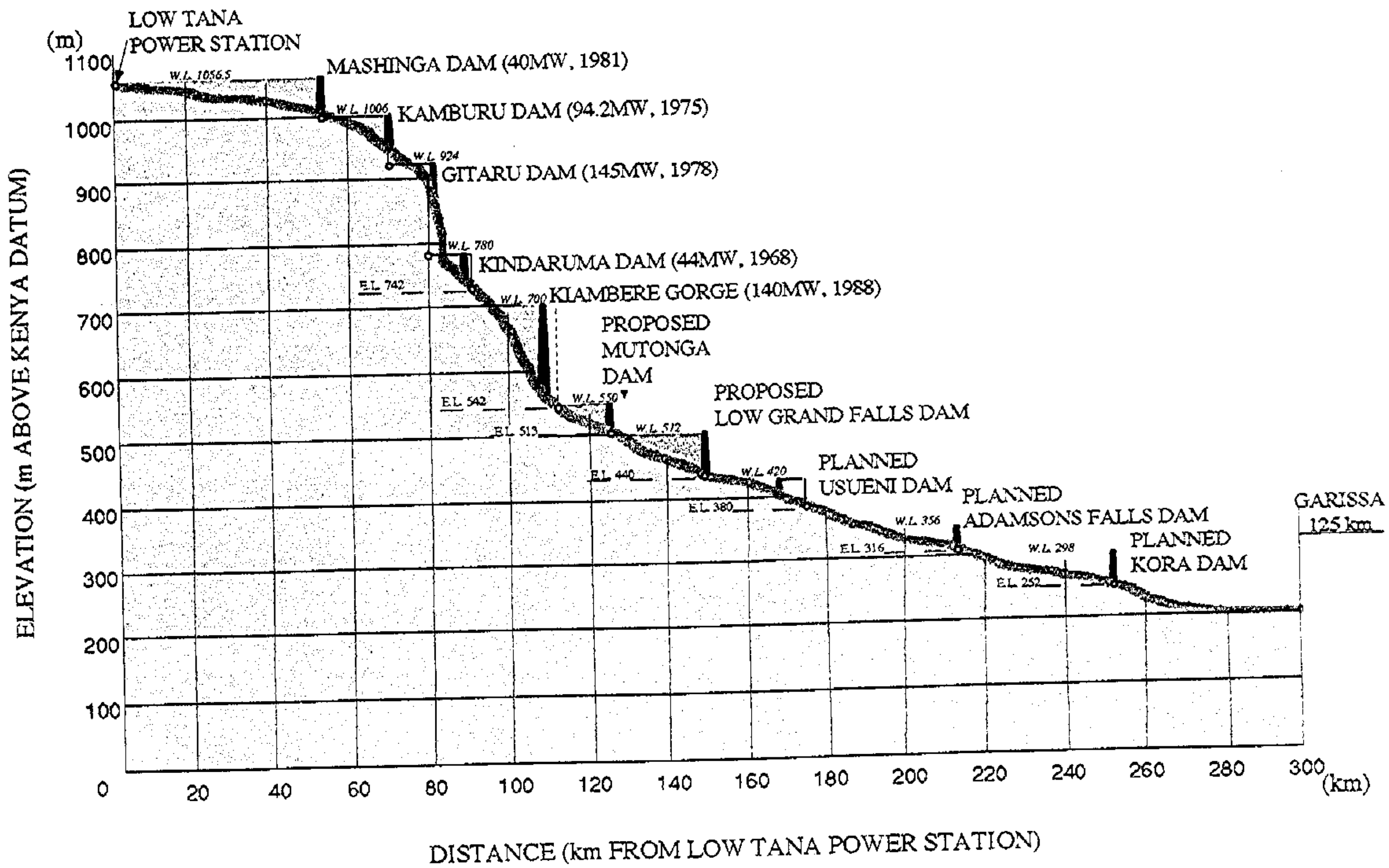
Tables

Table S.1 Loan Repayability

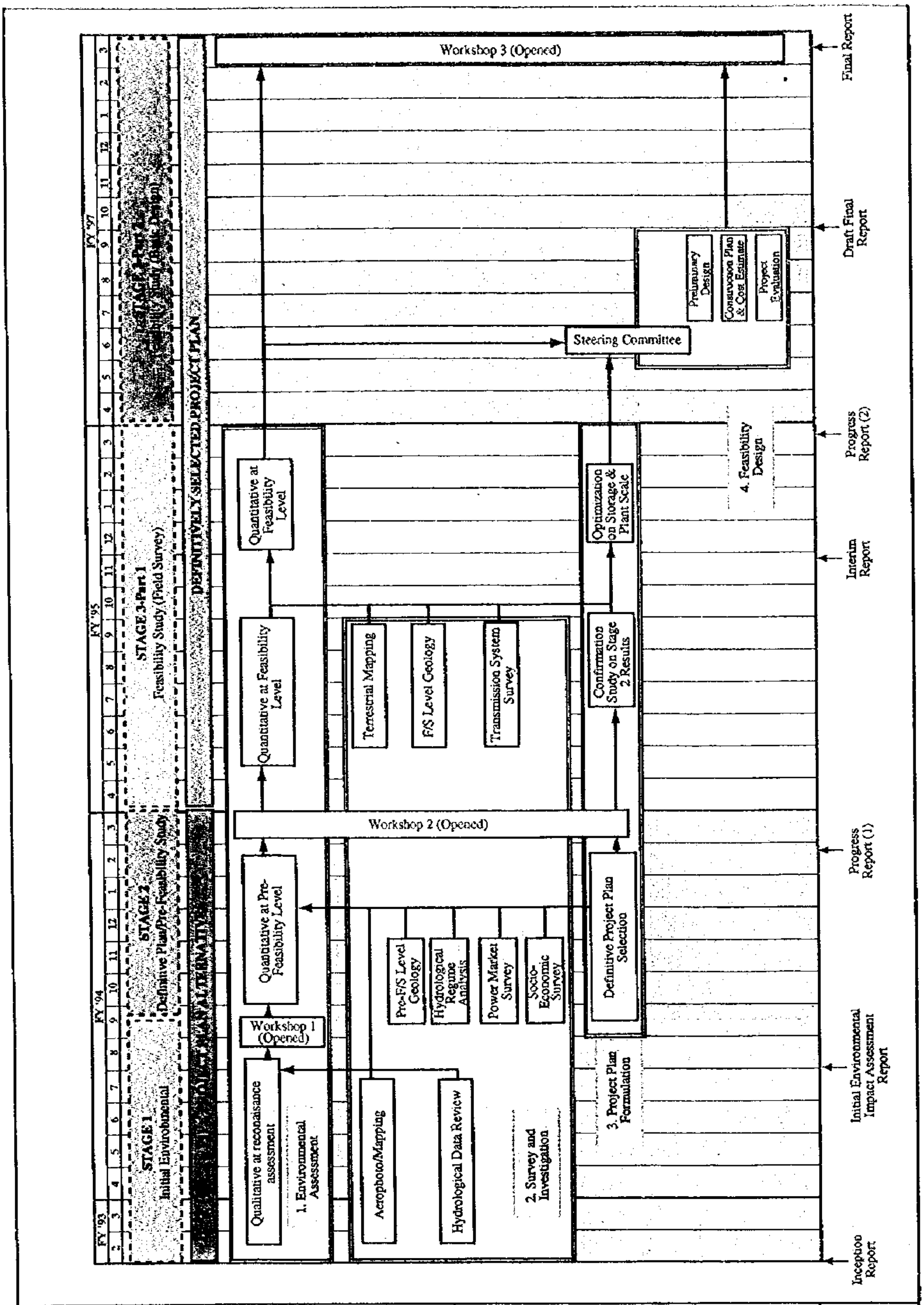
Interest rate of Loan: 2.30%
Capital recovery factor: 0.06294
(US$1,000)

Year in order	Year	Initial Investment Cost (LGF)	Initial Investment Cost (MTG)	Loan Disbursement (LGF)	Loan Disbursement (MTG)	Expenditure (Incl. Loan Disbursement): Repayment: Low Grand Falls: Interest	Low Grand Falls: Principal	Low Grand Falls: Total	Mutonga: Interest	Mutonga: Principal	Mutonga: Total	Grand total	Amount to be expended by the Government: Low Grand Falls Scheme	Mutonga Scheme	O/M cost (LGF)	O/M cost (MTG)	Subtrans. and Distri. Cost	Total out flow	Accumulated total outflow	Revenue: Annual revenue	Revenue: Accumulated total revenue	Cashb alance	Accumulated cash balance
1	2000	3,082		2,620	0	0	0	0				0	462	0	0	0		462	462	0	0	-462	-462
2	2001	11,654		9,906	0	0	0	0				0	1,748	0	0	0		1,748	2,210	0	0	-1,748	-2,210
3	2002	7,742		6,581	0	0	0	0				0	1,161	0	0	0		1,161	3,372	0	0	-1,161	-3,372
4	2003	64,593		54,904	0	0	0	0				0	9,689	0	0	0		9,689	13,061	0	0	-9,689	-13,061
5	2004	53,405		45,394	0	0	0	0				0	8,011	0	0	0		8,011	21,071	0	0	-8,011	-21,071
6	2005	72,842		61,916	0	0	0	0				0	10,926	0	0	0		10,926	31,998	0	0	-10,926	-31,998
7	2006	108,552	1078	92,269	916	0	0	0				0	16,283	162	0	0		16,445	48,442	0	0	-16,445	-48,442
8	2007	108,509	1,099	92,233	934	0	0	0				0	16,276	165	0	0		16,441	64,883	0	0	-16,441	-64,883
9	2008	14,108	58,826	11,992	50,002	0	0	0				0	2,116	8,824	1,018	0	9,009	20,967	85,851	57,947	57,947	36,980	-27,904
10	2009		27,783	0	23,616	0	0	0				0	0	4,167	2,035	0	18,018	24,220	110,071	115,894	173,841	91,674	63,770
11	2010		61,735	0	52,475	10,754	15,090	25,845				25,845		9,260	2,035	0	18,018	55,158	165,229	115,894	289,735	60,736	124,506
12	2011		72,121	0	61,303	10,407	15,438	25,845				25,845		10,818	2,035	0	18,018	56,716	221,945	115,894	405,629	59,178	183,684
13	2012		12,243	0	10,407	10,052	15,793	25,845				25,845		1,836	2,035	538	22,264	52,518	274,464	143,206	548,835	90,688	274,371
14	2013					9,689	16,156	25,845				25,845		0	2,035	1,075	26,510	55,465	329,929	170,518	719,353	115,053	389,424
15	2014					9,317	16,527	25,845				25,845			2,035	1,075	26,510	55,465	385,394	170,518	889,871	115,053	504,477
16	2015					8,937	16,908	25,845				25,845			2,035	1,075	26,510	55,465	440,859	170,518	1,060,389	115,053	619,530
17	2016					8,548	17,296	25,845	6,107	7,974	14,081	39,926			2,035	1,075	26,510	69,546	510,406	170,518	1,230,907	100,972	720,501
18	2017					8,151	17,694	25,845	5,923	8,158	14,081	39,926			2,035	1,075	26,510	69,546	579,952	170,518	1,401,425	100,972	821,473
19	2018					7,744	18,101	25,845	5,736	8,345	14,081	39,926			2,035	1,075	26,510	69,546	649,498	170,518	1,571,943	100,972	922,445
20	2019					7,327	18,518	25,845	5,544	8,537	14,081	39,926			2,035	1,075	26,510	69,546	719,044	170,518	1,742,461	100,972	1,023,417
21	2020					6,901	18,943	25,845	5,347	8,734	14,081	39,926			2,035	1,075	26,510	69,546	788,590	170,518	1,912,979	100,972	1,124,389
22	2021					6,466	19,379	25,845	5,146	8,935	14,081	39,926			2,035	1,075	26,510	69,546	858,137	170,518	2,083,497	100,972	1,225,360
23	2022					6,020	19,825	25,845	4,941	9,140	14,081	39,926			2,035	1,075	26,510	69,546	927,683	170,518	2,254,015	100,972	1,326,332
24	2023					5,564	20,281	25,845	4,731	9,350	14,081	39,926			2,035	1,075	26,510	69,546	997,229	170,518	2,424,533	100,972	1,427,304
25	2024					5,098	20,747	25,845	4,516	9,565	14,081	39,926			2,035	1,075	26,510	69,546	1,066,775	170,518	2,595,051	100,972	1,528,276
26	2025					4,620	21,224	25,845	4,296	9,785	14,081	39,926			2,035	1,075	26,510	69,546	1,136,322	170,518	2,765,569	100,972	1,629,247
27	2026					4,132	21,713	25,845	4,071	10,010	14,081	39,926			2,035	1,075	26,510	69,546	1,205,868	170,518	2,936,087	100,972	1,730,219
28	2027					3,633	22,212	25,845	3,840	10,241	14,081	39,926			2,035	1,075	26,510	69,546	1,275,414	170,518	3,106,605	100,972	1,831,191
29	2028					3,122	22,723	25,845	3,605	10,476	14,081	39,926			2,035	1,075	26,510	69,546	1,344,960	170,518	3,277,123	100,972	1,932,163
30	2029					2,599	23,246	25,845	3,364	10,717	14,081	39,926			2,035	1,075	26,510	69,546	1,414,507	170,518	3,447,641	100,972	2,033,134
31	2030								3,117	10,964	14,081	14,081			2,035	1,075	26,510	43,701	1,458,208	170,518	3,618,159	126,817	2,159,951
32	2031								2,865	11,216	14,081	14,081			2,035	1,075	26,510	43,701	1,501,909	170,518	3,788,677	126,817	2,286,768
33	2032								2,607	11,474	14,081	14,081			2,035	1,075	26,510	43,701	1,545,611	170,518	3,959,195	126,817	2,413,584
34	2033								2,343	11,738	14,081	14,081			2,035	1,075	26,510	43,701	1,589,312	170,518	4,129,713	126,817	2,540,401
35	2034								2,073	12,008	14,081	14,081			2,035	1,075	26,510	43,701	1,633,014	170,518	4,300,231	126,817	2,667,217
36	2035								1,797	12,284	14,081	14,081			2,035	1,075	26,510	43,701	1,676,715	170,518	4,470,749	126,817	2,794,034
37	2036														2,035	1,075	26,510	29,620	1,706,335	170,518	4,641,267	140,898	2,934,932
38	2037														2,035	1,075	26,510	29,620	1,735,956	170,518	4,811,785	140,898	3,075,829
39	2038														49,707	1,075	26,510	77,292	1,813,248	170,518	4,982,303	93,226	3,169,055
40	2039														2,035	1,075	26,510	29,620	1,842,869	170,518	5,152,821	140,898	3,309,952
	Total	444,487	234,885	377,814	199,652	139,083	377,814	516,897	81,968	199,652	281,620	798,517	66,673	35,233	111,775	29,563	801,108	1,842,869		5,152,821		3,309,952	

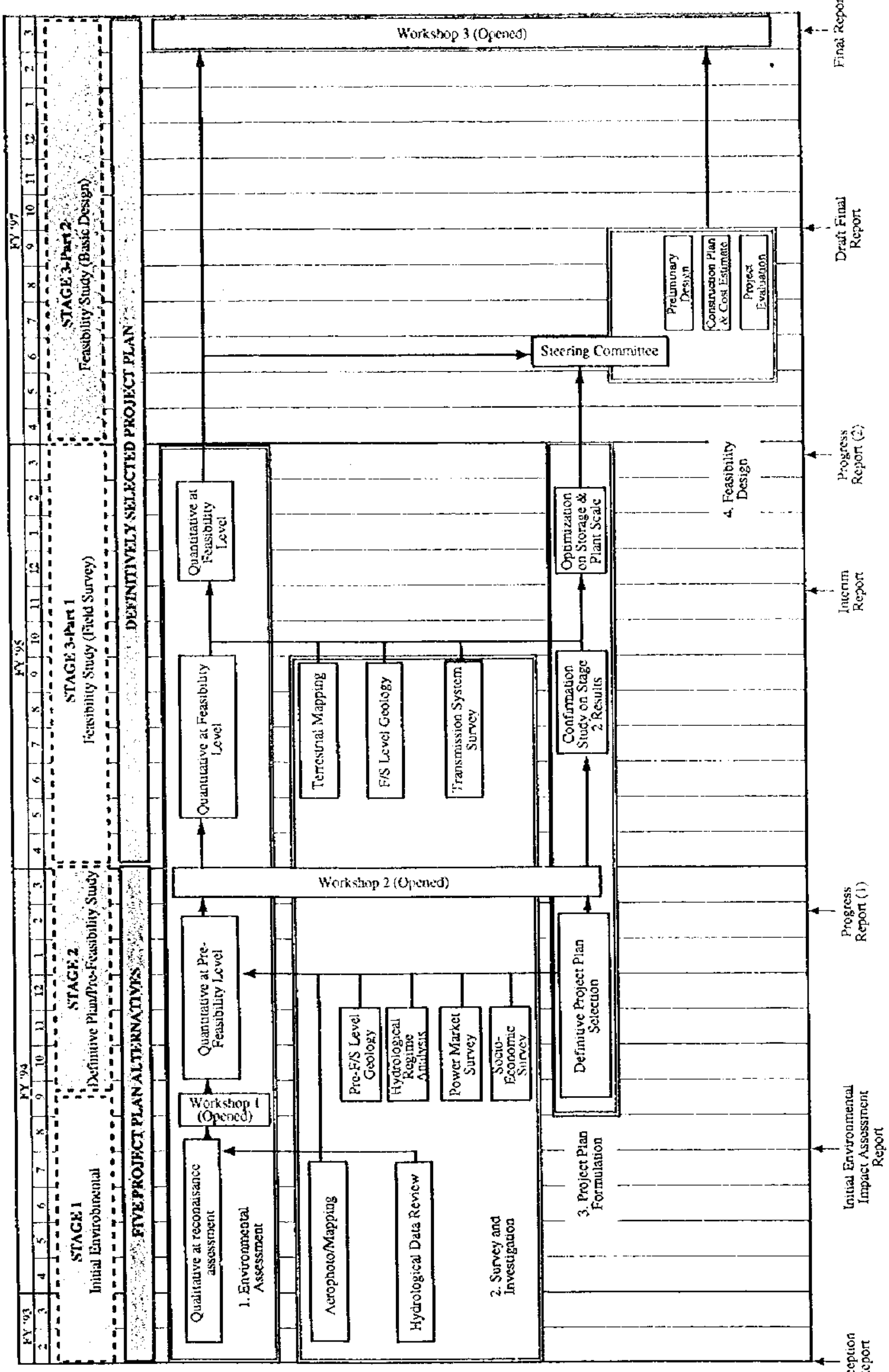
Figures



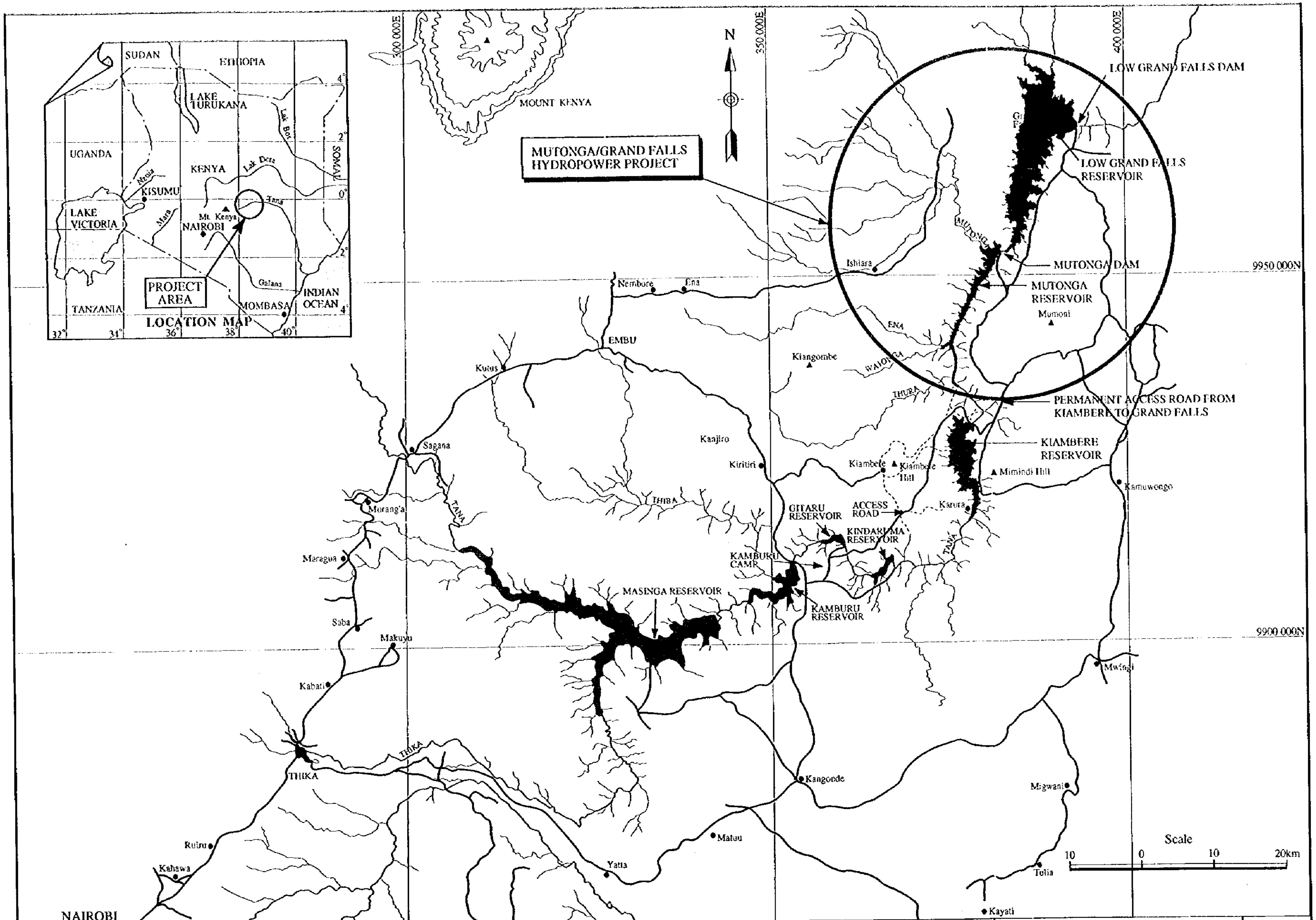
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Tana River Cascade Hydropower	Fig. No. S.1



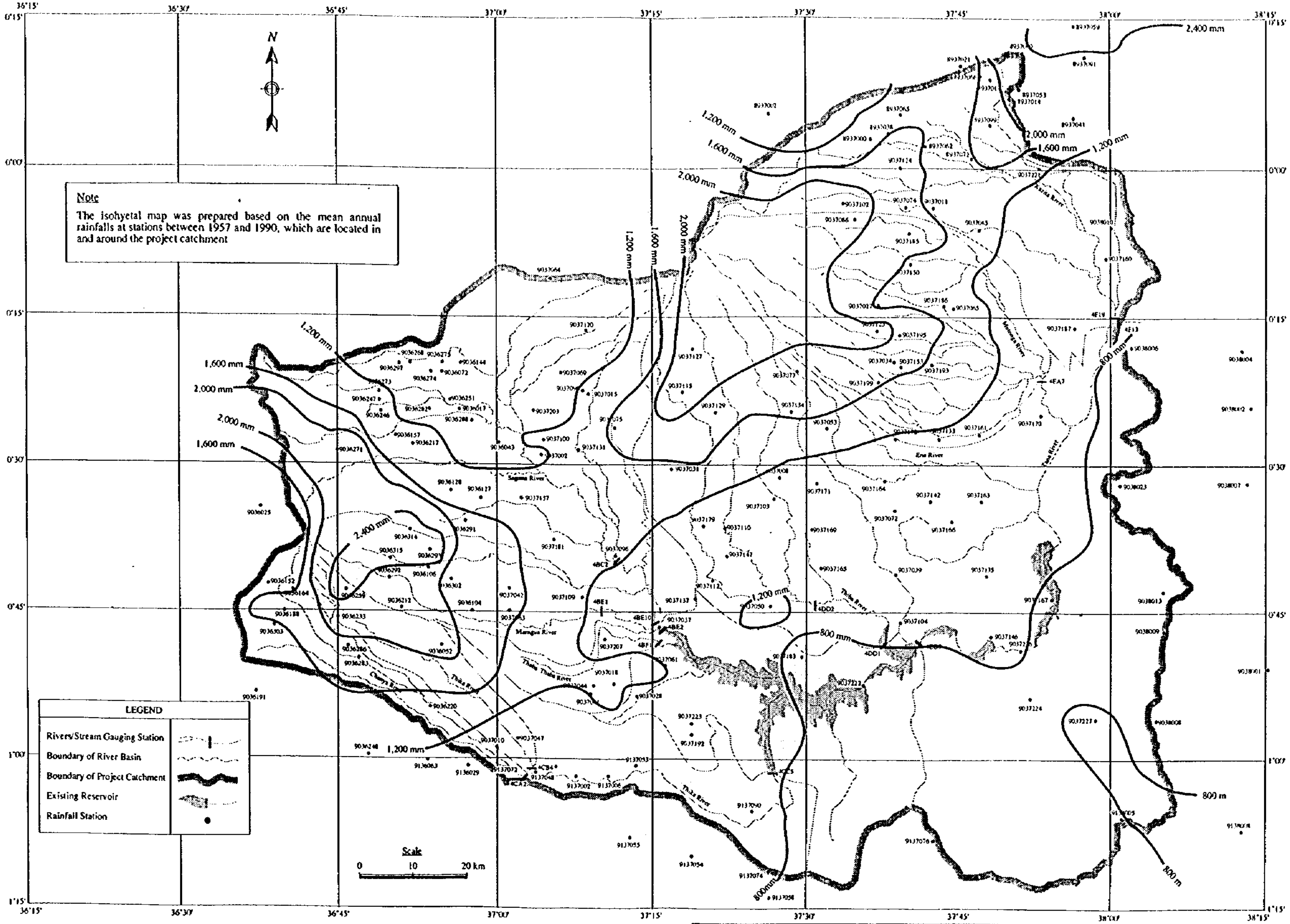
JAPAN INTERNATIONAL COOPERATION AGENCY	Overall Flow of Study	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		S.2



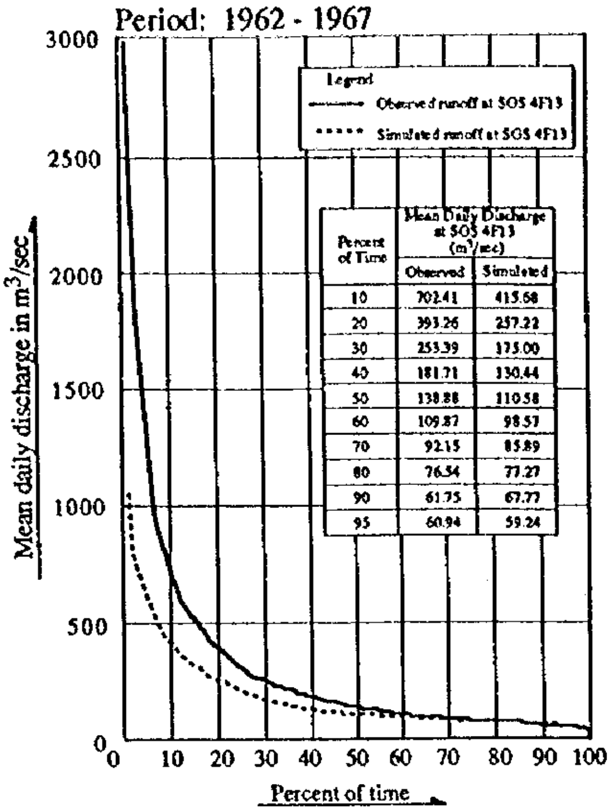
JAPAN INTERNATIONAL COOPERATION AGENCY	Overall Flow of Study	Fig. No.
REPUBLIC OF KENYA		S.2
MUTONGA/GRAND FALLS HYDROPOWER PROJECT		



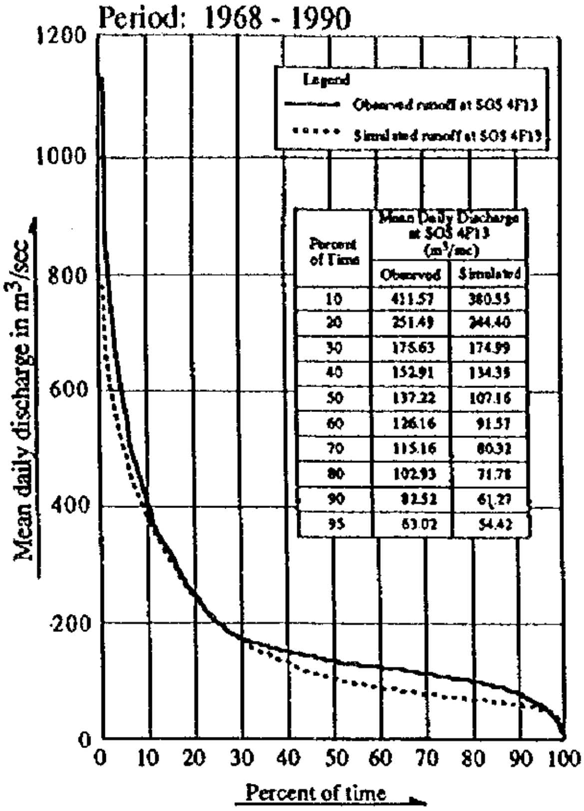
JAPAN INTERNATIONAL COOPERATION AGENCY	Vicinity Map	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		S.3



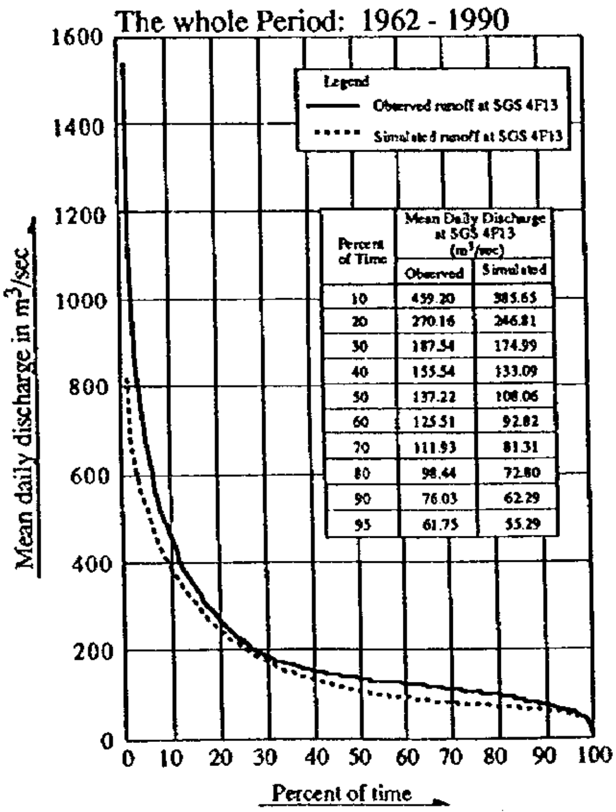
JAPAN INTERNATIONAL COOPERATION AGENCY	Isohyetal Map for Project Catchment	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		S.4



Percent of Time	Mean Daily Discharge at SGS 4F13 (m^3/sec)	
	Observed	Simulated
10	702.41	415.68
20	393.26	257.22
30	253.39	175.00
40	181.71	130.44
50	138.88	110.58
60	109.87	98.57
70	92.15	85.89
80	76.54	77.27
90	61.75	67.77
95	60.94	59.24



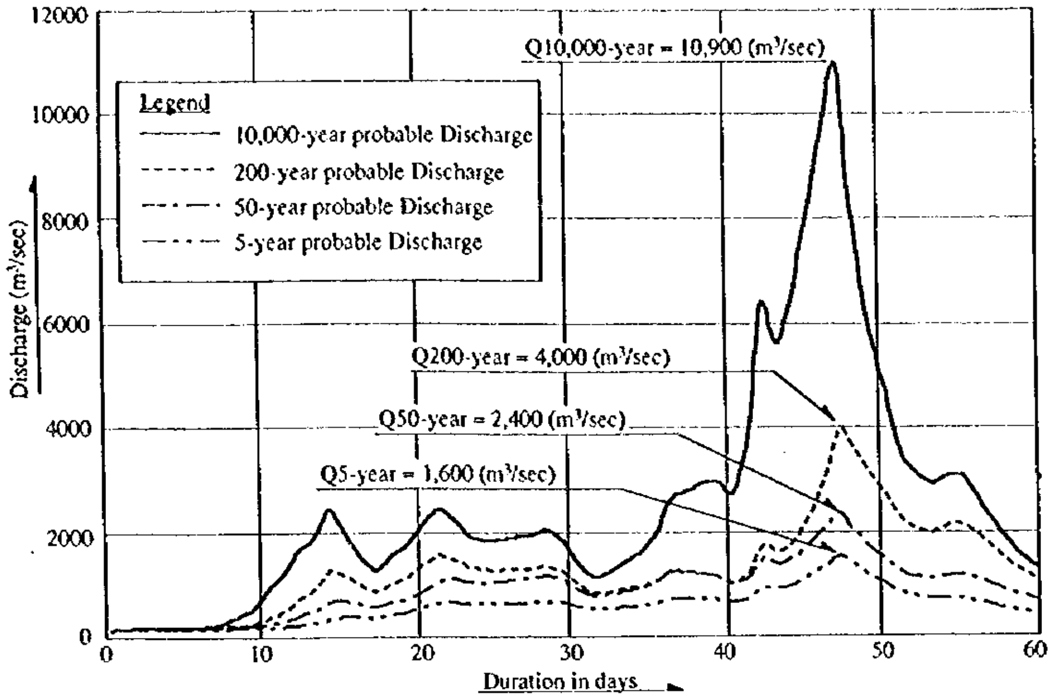
Percent of Time	Mean Daily Discharge at SGS 4F13 (m^3/sec)	
	Observed	Simulated
10	411.57	380.55
20	251.49	244.40
30	175.63	174.99
40	152.91	134.35
50	137.22	107.16
60	126.16	91.57
70	115.16	80.32
80	102.93	71.78
90	82.52	61.27
95	63.02	54.42



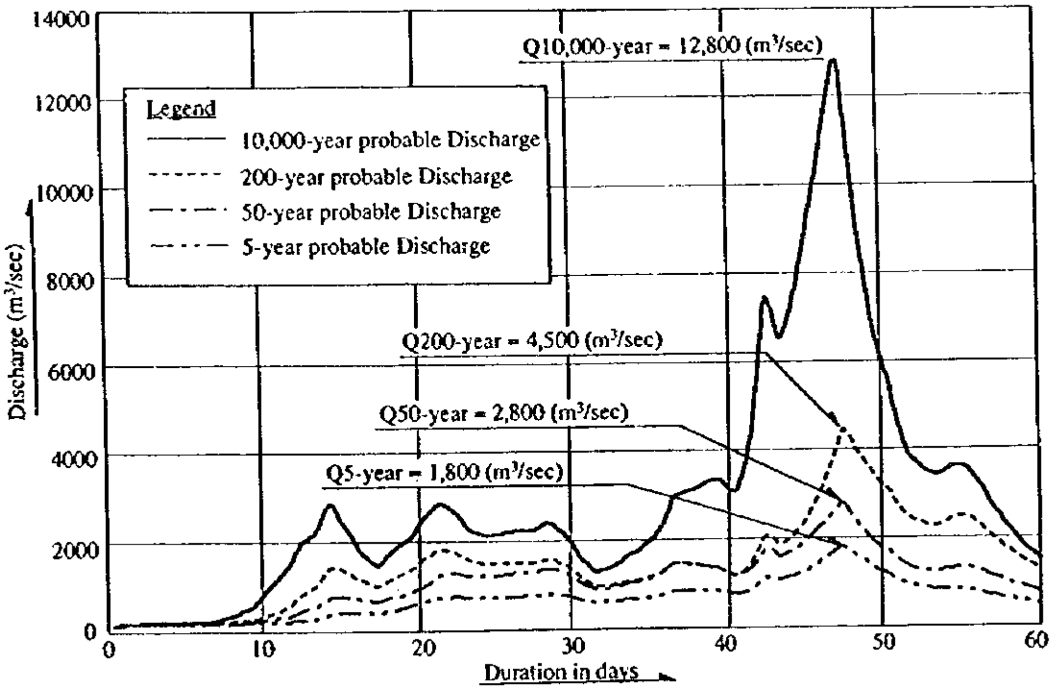
Percent of Time	Mean Daily Discharge at SGS 4F13 (m^3/sec)	
	Observed	Simulated
10	459.20	385.65
20	270.16	246.81
30	187.54	174.99
40	155.54	133.09
50	137.22	108.06
60	125.51	92.82
70	111.93	81.31
80	98.44	72.80
90	76.03	62.29
95	61.75	55.29

Note
The "Simulated" and "Simulated runoff" are the mean daily discharges derived by summing up those in the upstream 14 subbasins, which were estimated by means of the Tank Model Method.

JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Comparison of Flow Duration Curves at SGS 4F13, Worked out Based on Mean Daily Discharges Observed and Estimated by Summing up those in Upstream 14 Subbasins	Fig. No. S.5

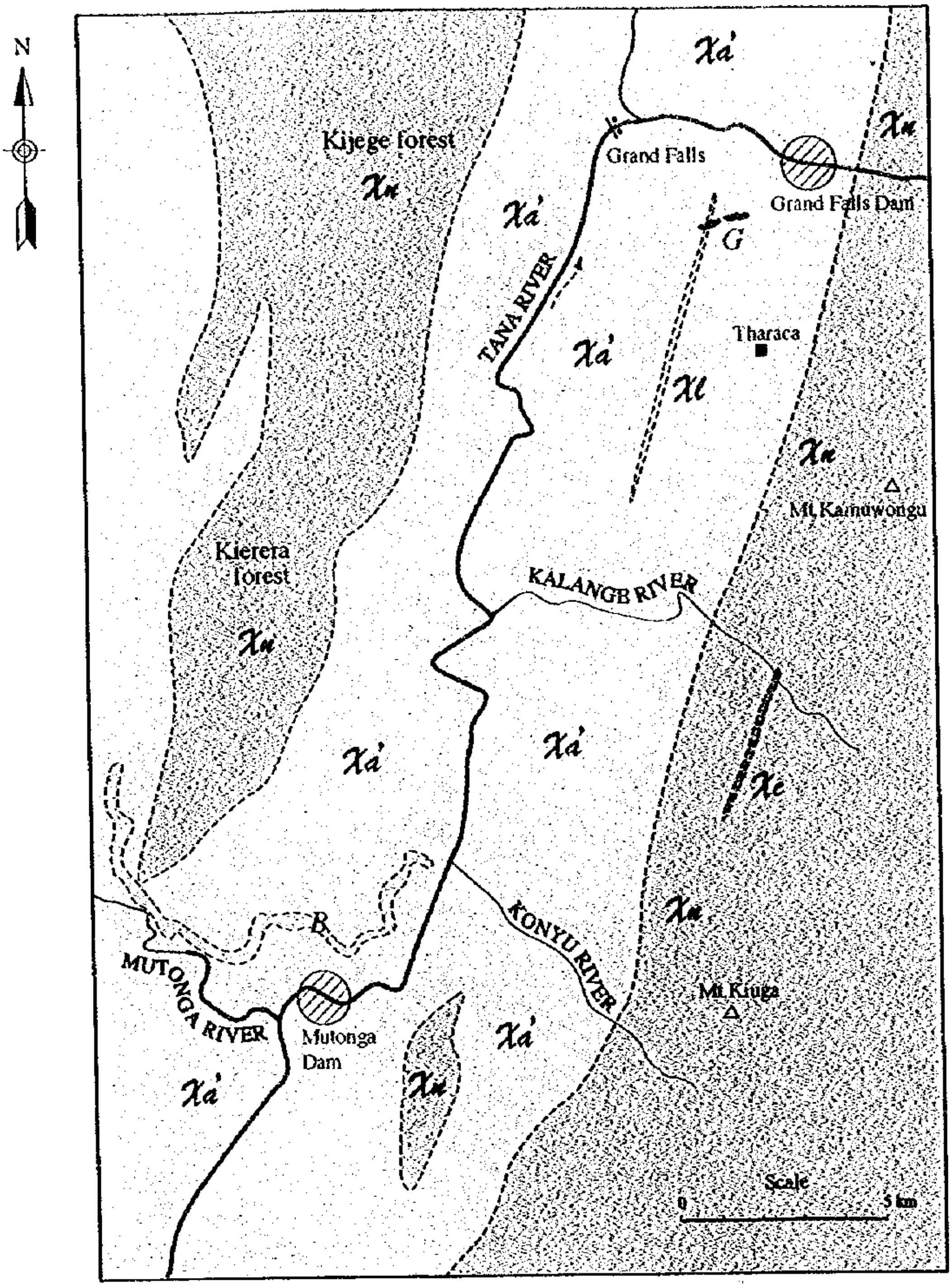


Hydrographs of Probable Floods at Mutonga Dam Site



Hydrographs of Probable Floods at Grand Falls Site

JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Estimated Flood Hydrographs at Mutonga and Grand Falls Dam Site (without Upstream Reservoirs Condition)	Fig. No. S.6



From * Geology of the North Kitui Area. Geological Survey of Kenya. Report No.33, 1/125,000.

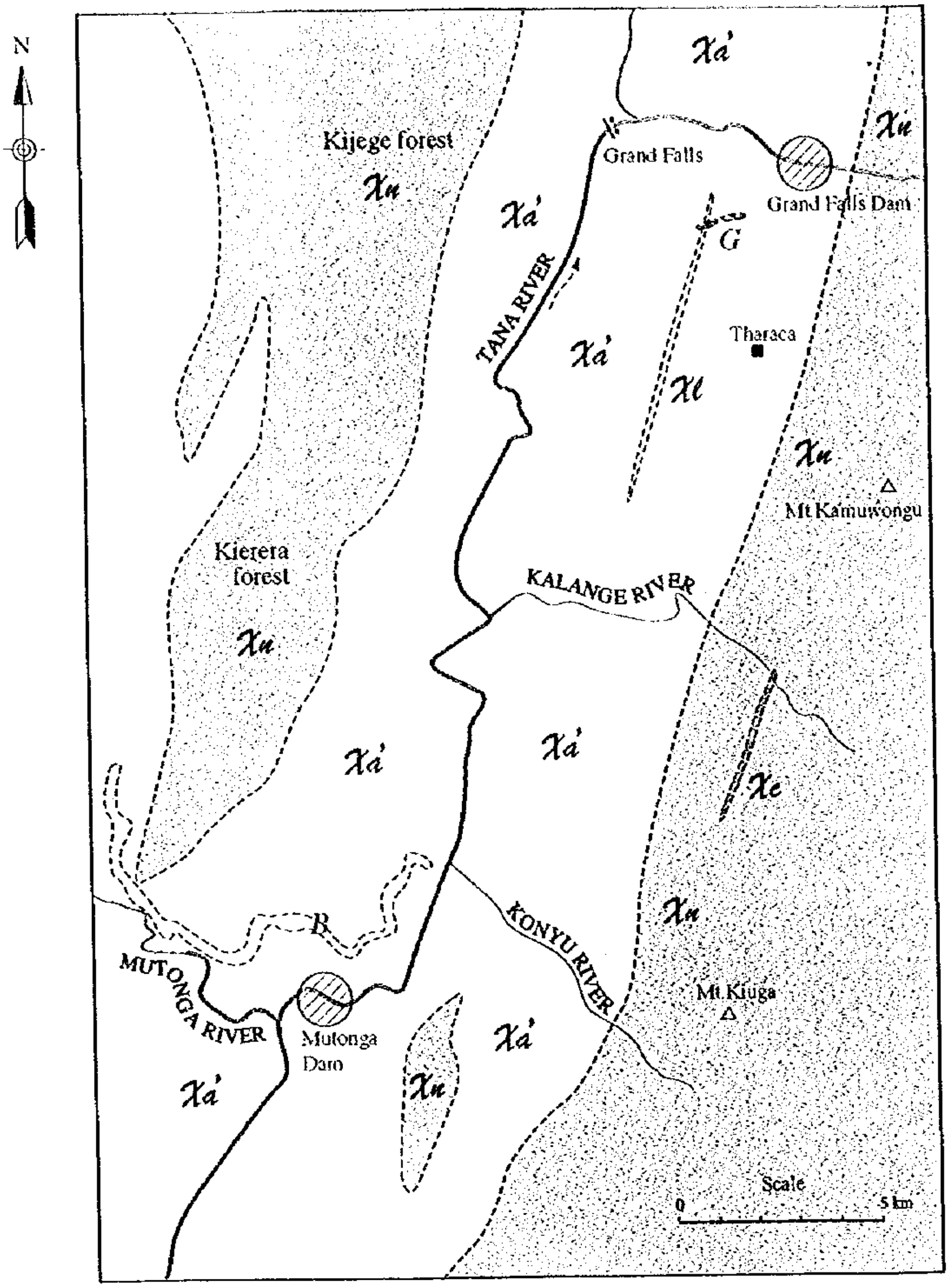
* A Geological Reconnaissance of the country between Embu and Meru. Geological Survey of Kenya Report No.17, 1/125,000.

LEGEND

- B : Basalt (Pleistocene?)
- ■ : Granite (Archaean?)
- Xn : Granitic gneiss
- Xa' : Semi-pelitic gneiss
- Xl : Crystaline limestone
- ▦ : Calc-silicate gneiss
- - - : Geological boundary

(Granitic gneiss, Semi-pelitic gneiss, Crystaline limestone, Calc-silicate gneiss: Kenya Basement System (Archaean))

JAPAN INTERNATIONAL COOPERATION AGENCY	Geology of the Reservoir Area	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		S.7



From * Geology of the North Kitui Area. Geological Survey of Kenya. Report No.33, 1/125,000.
* A Geological Reconnaissance of the country between Embu and Meru. Geological Survey of Kenya Report No.17, 1/125,000.

LEGEND

- B : Basalt (Pleistocene?)
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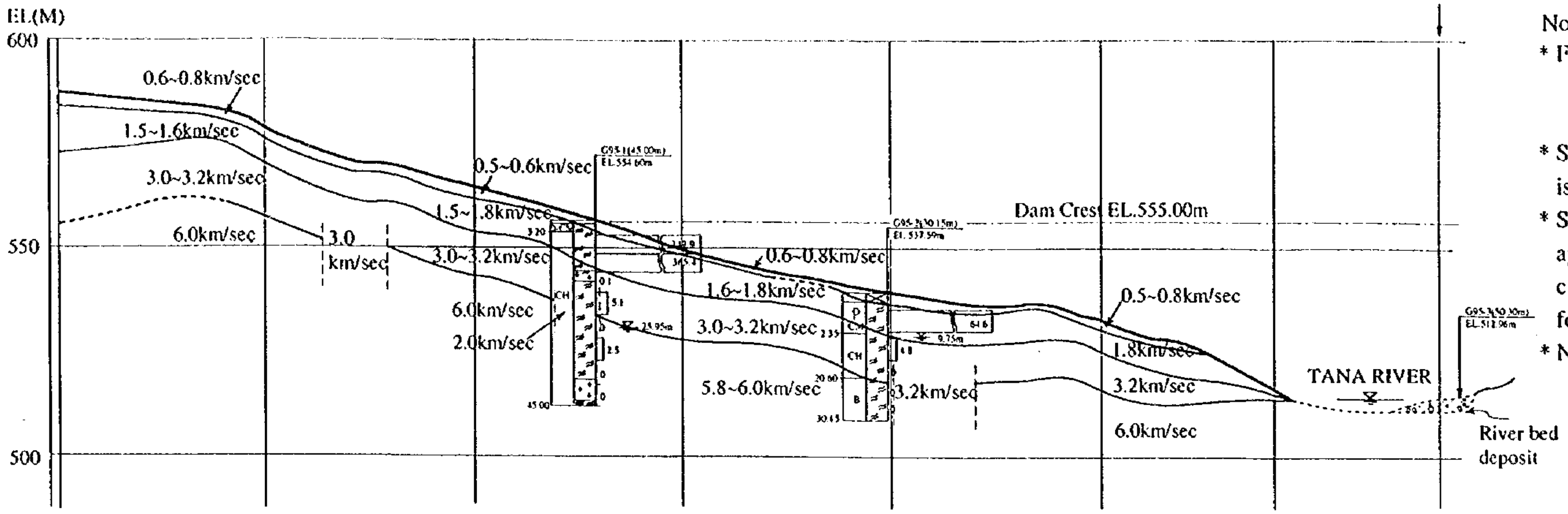
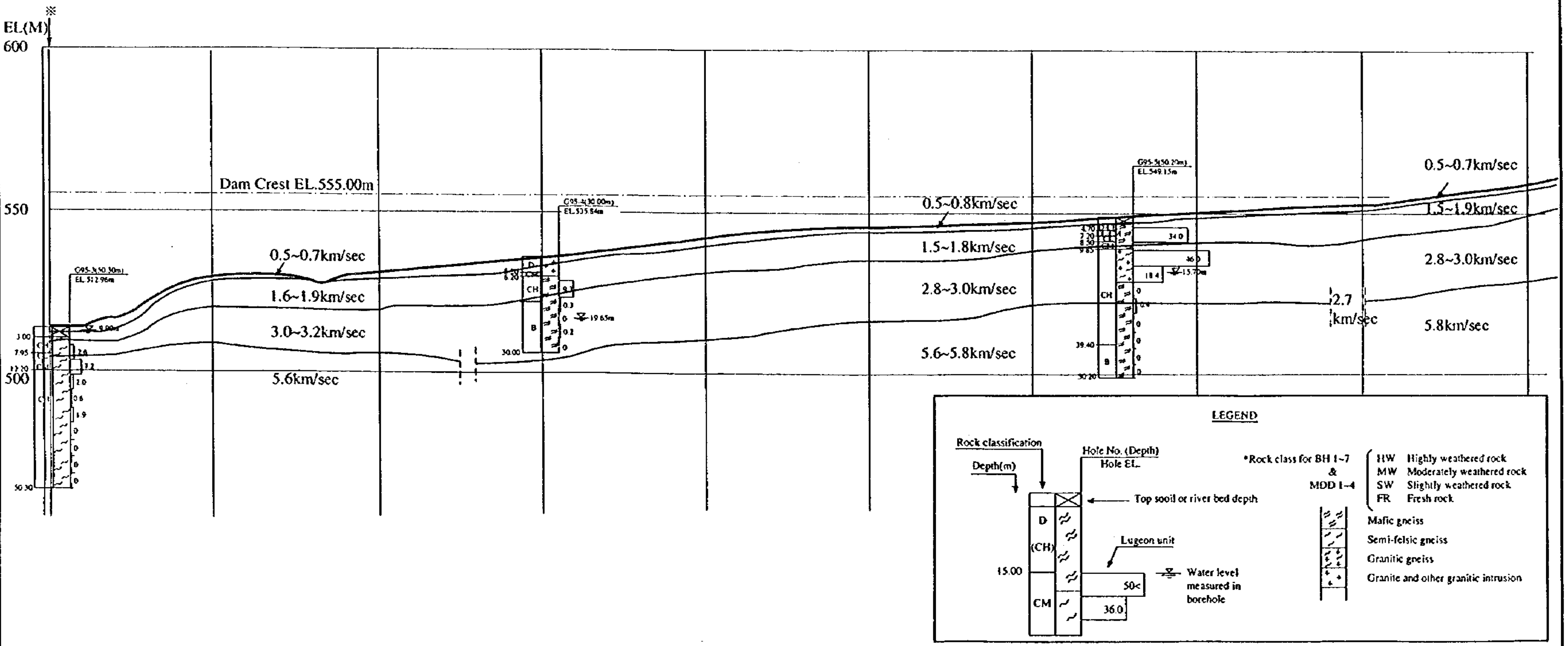
- Xn : Granitic gneiss
- Xa' : Semi-pelitic gneiss
- Xl : Crystaline limestone
- Xe : Calc-silicate gneiss
- Geological boundary

(Xn, Xa', Xl, Xe: Kenya Basement System (Archaean))

JAPAN INTERNATIONAL COOPERATION AGENCY	Geology of the Reservoir Area	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		S.7

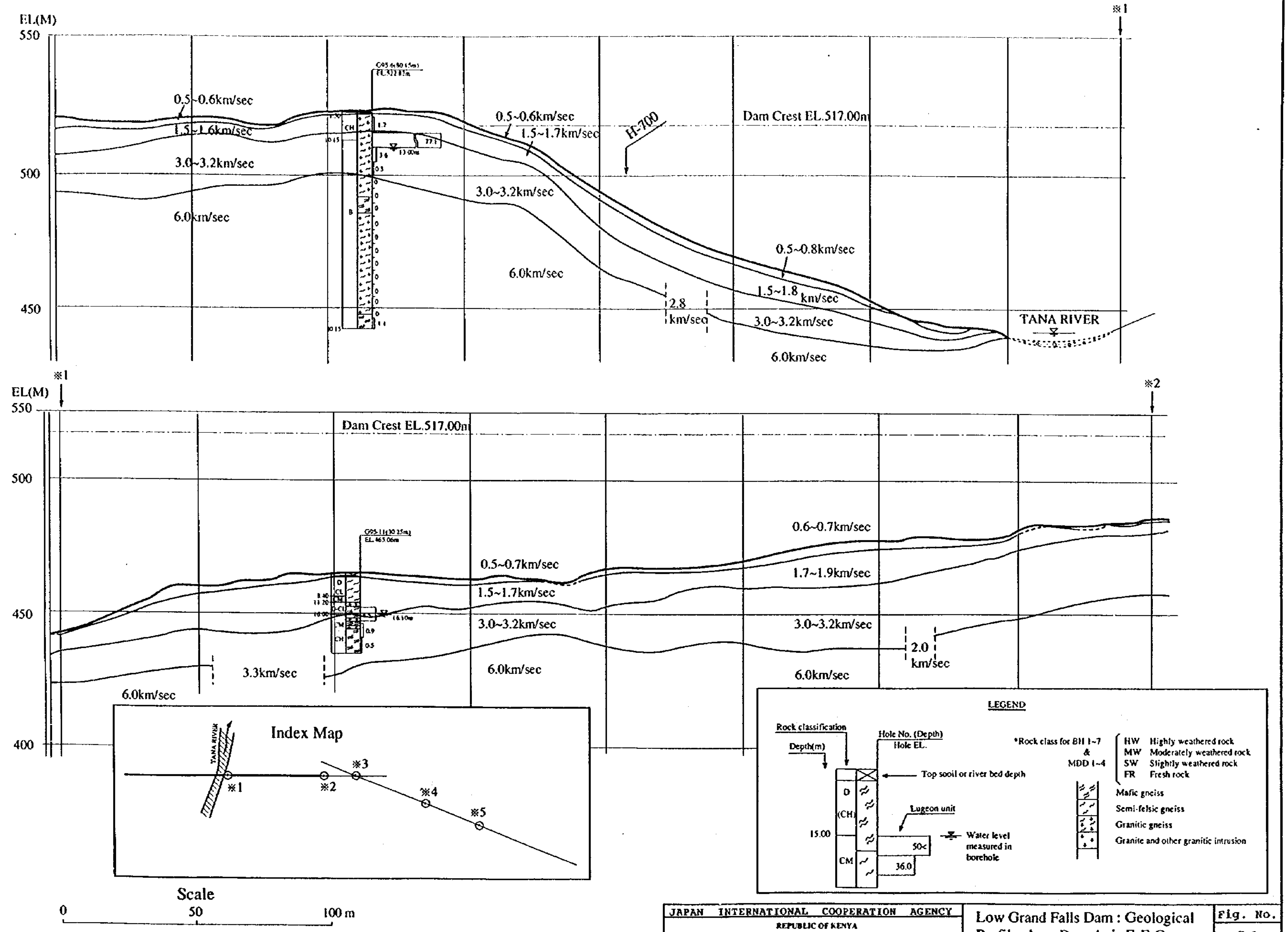
Notes
* Foundation rocks : Gneisses of Kenya Basement System and some granitic intrusions.
* Seismic velocity zone of 0.5~0.8km/sec is overburden (residual soil).
* Seismic velocity zones more than 2.8km/sec approximately correspond to CM-CH-B class rocks which will be appropriate for the foundation of concrete gravity dam.
* No noticeable faults are seen in the profile.





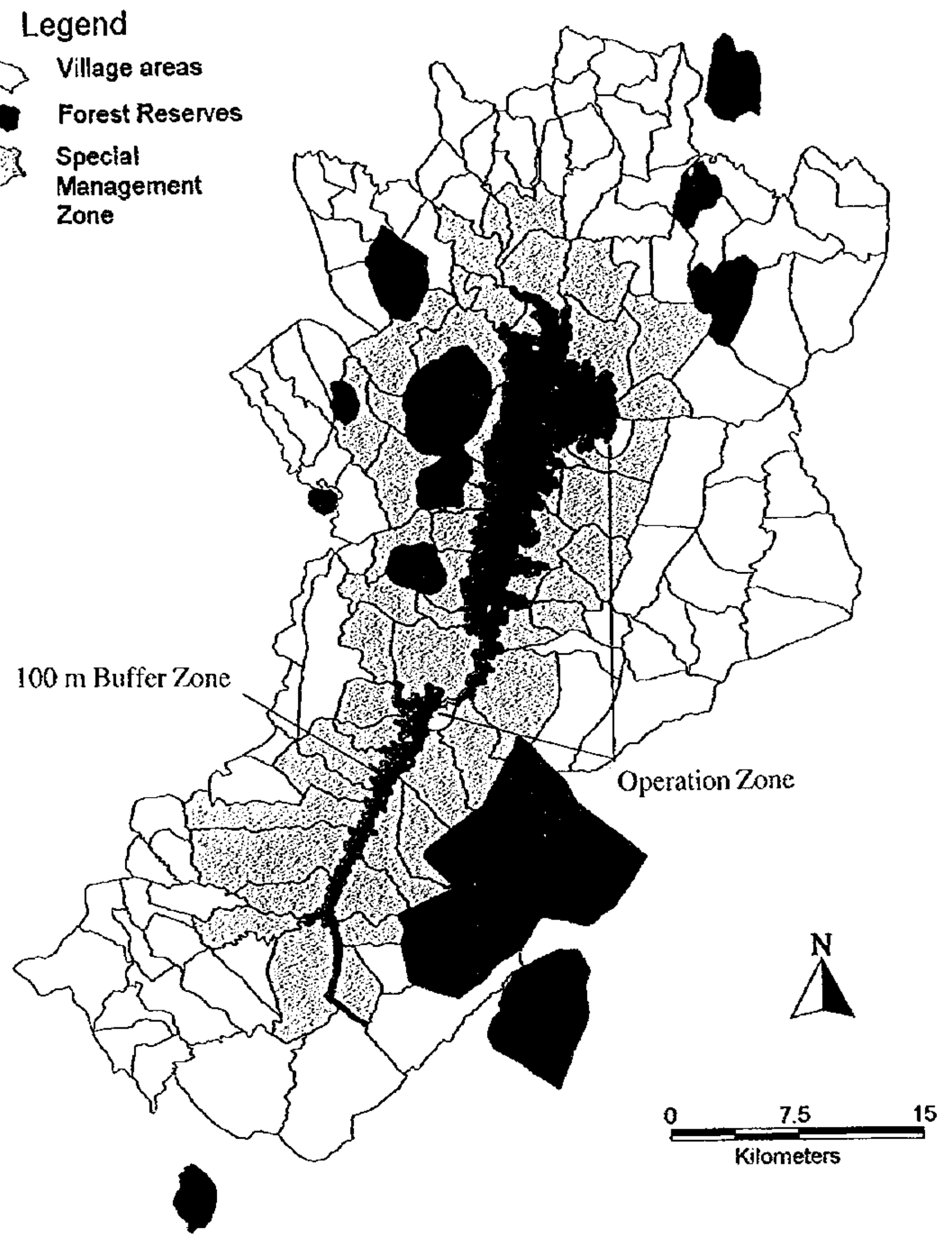
Scale
0 50 100 m

JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	MUTONGA DAM : Geological Profile along Dam Axis	Fig. No. S.8

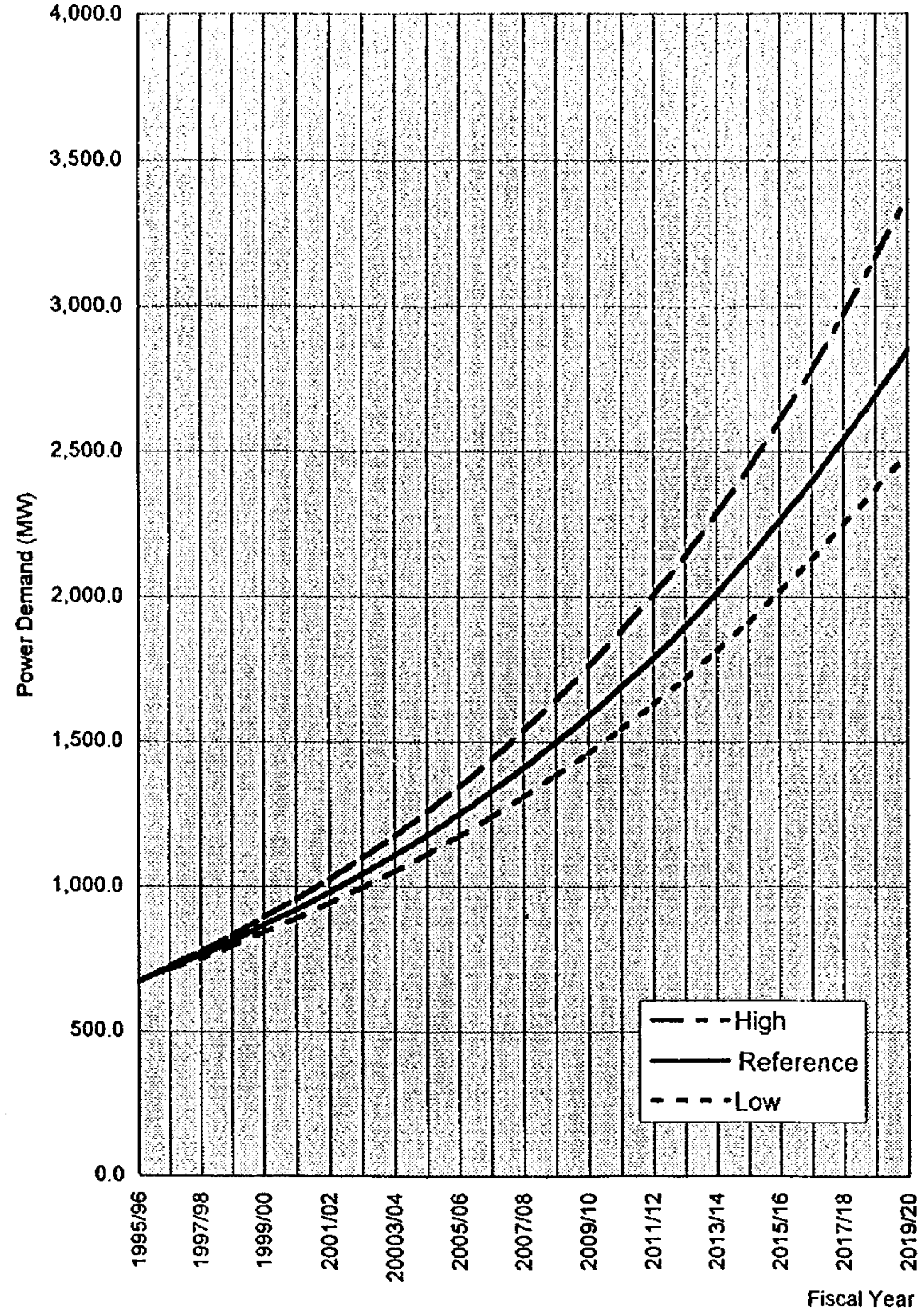


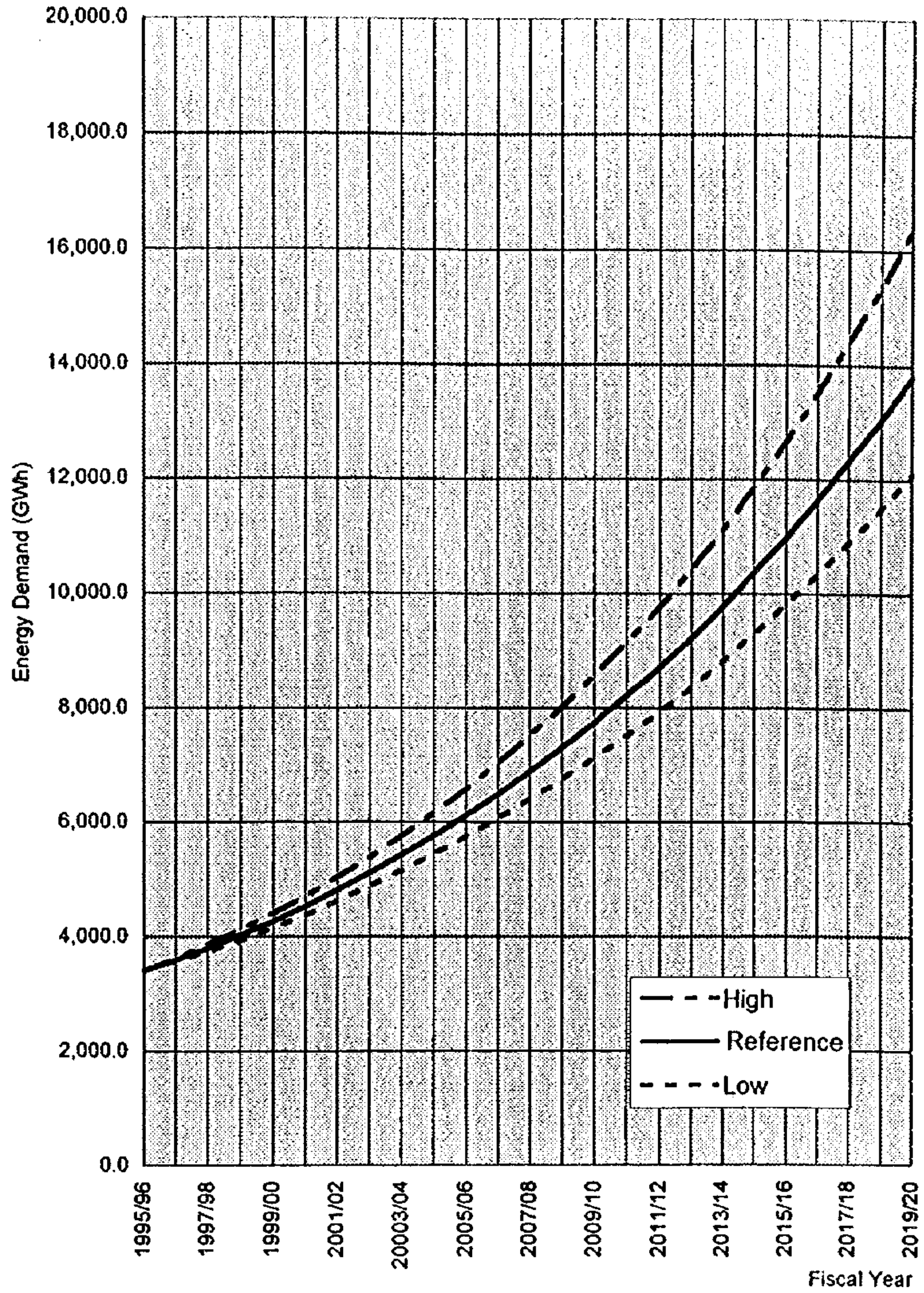
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Low Grand Falls Dam : Geological Profile along Dam Axis E-F-G	Fig. No. S.9

The map indicates village areas, proposed reservoirs, 100 metre buffer and operations zones, forest reserves and the proposed SMZ.

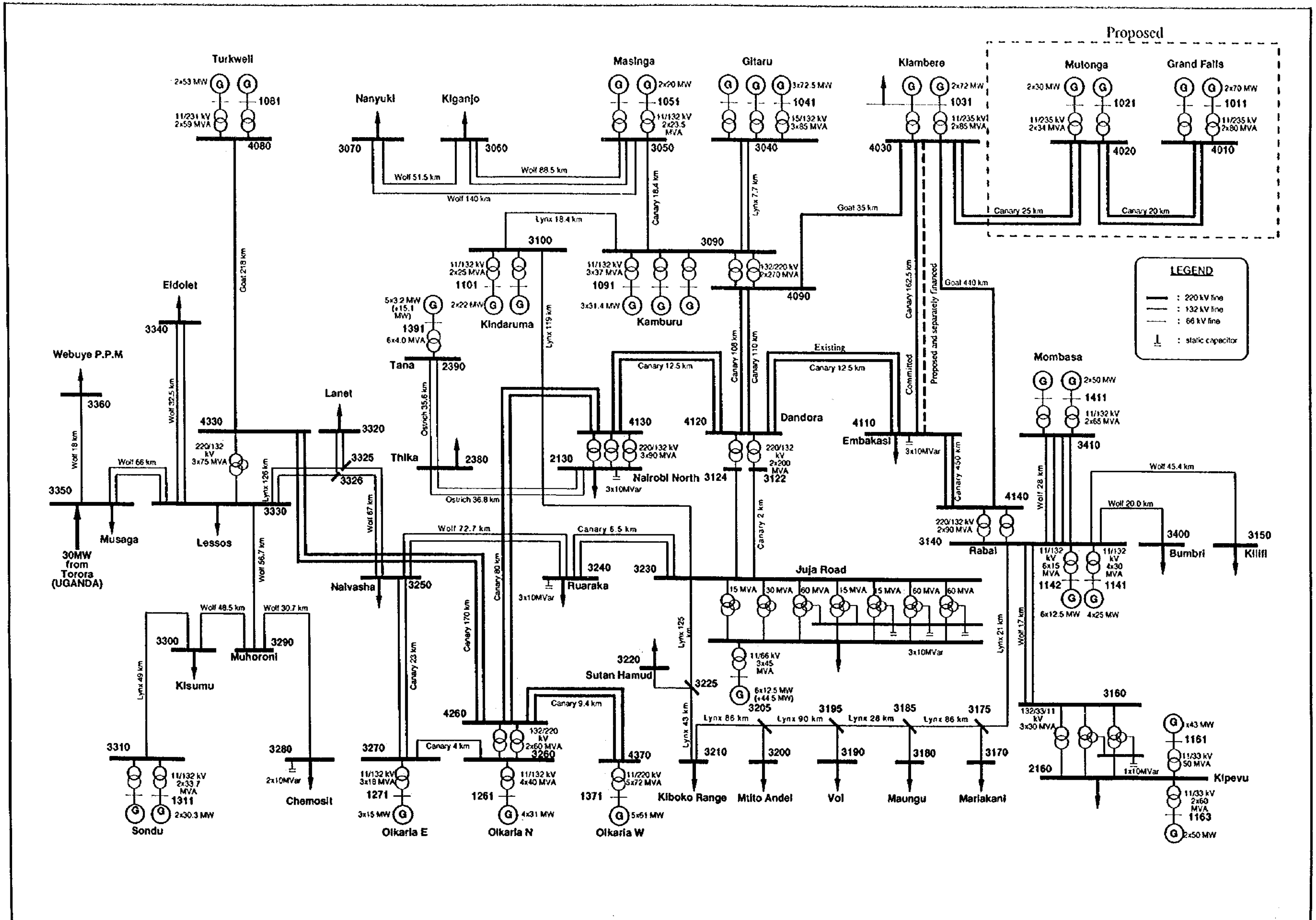


JAPAN INTERNATIONAL COOPERATION AGENCY	Proposed Special Management Zone for Low Grand Falls and Mutonga Reservoirs	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		S.10

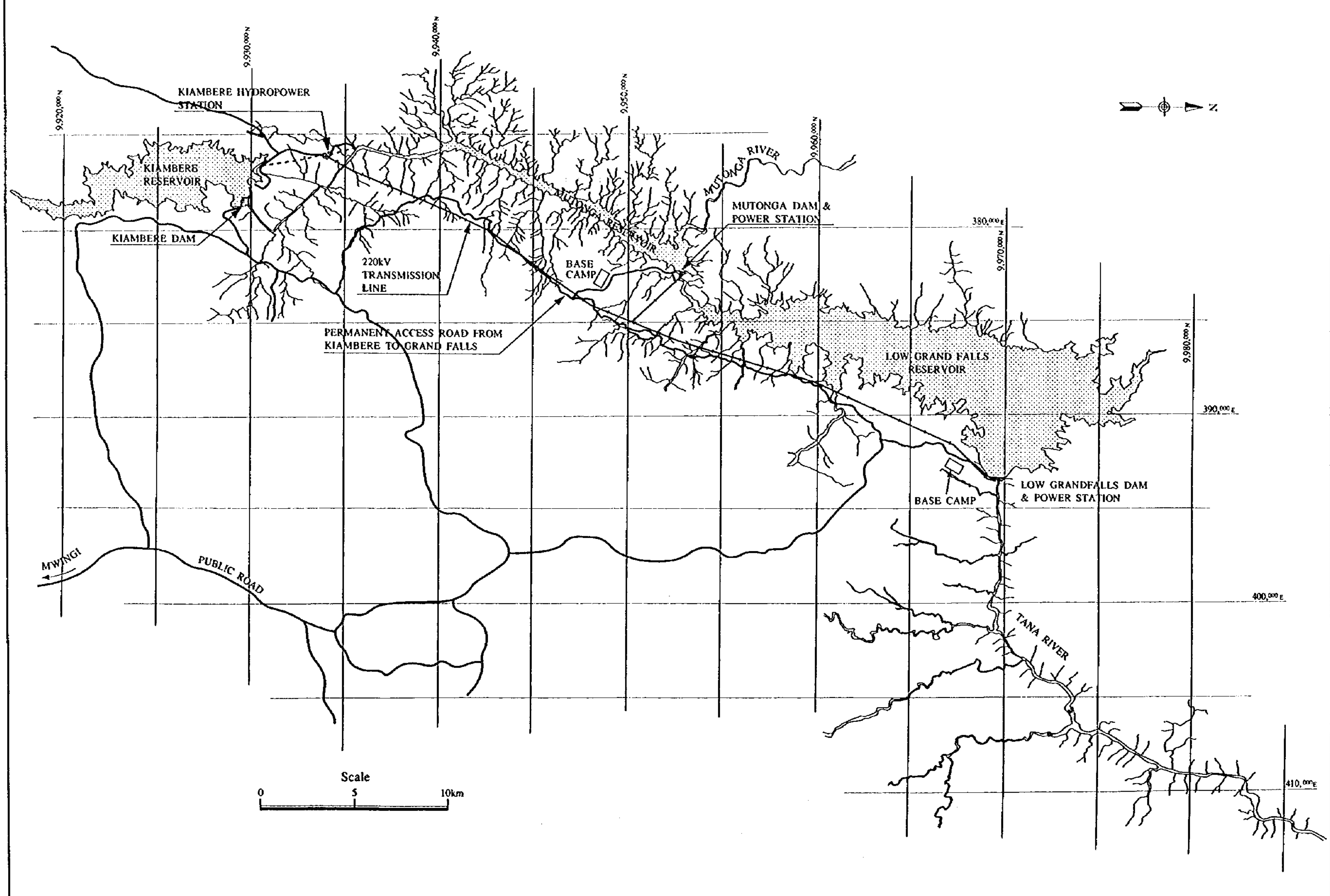




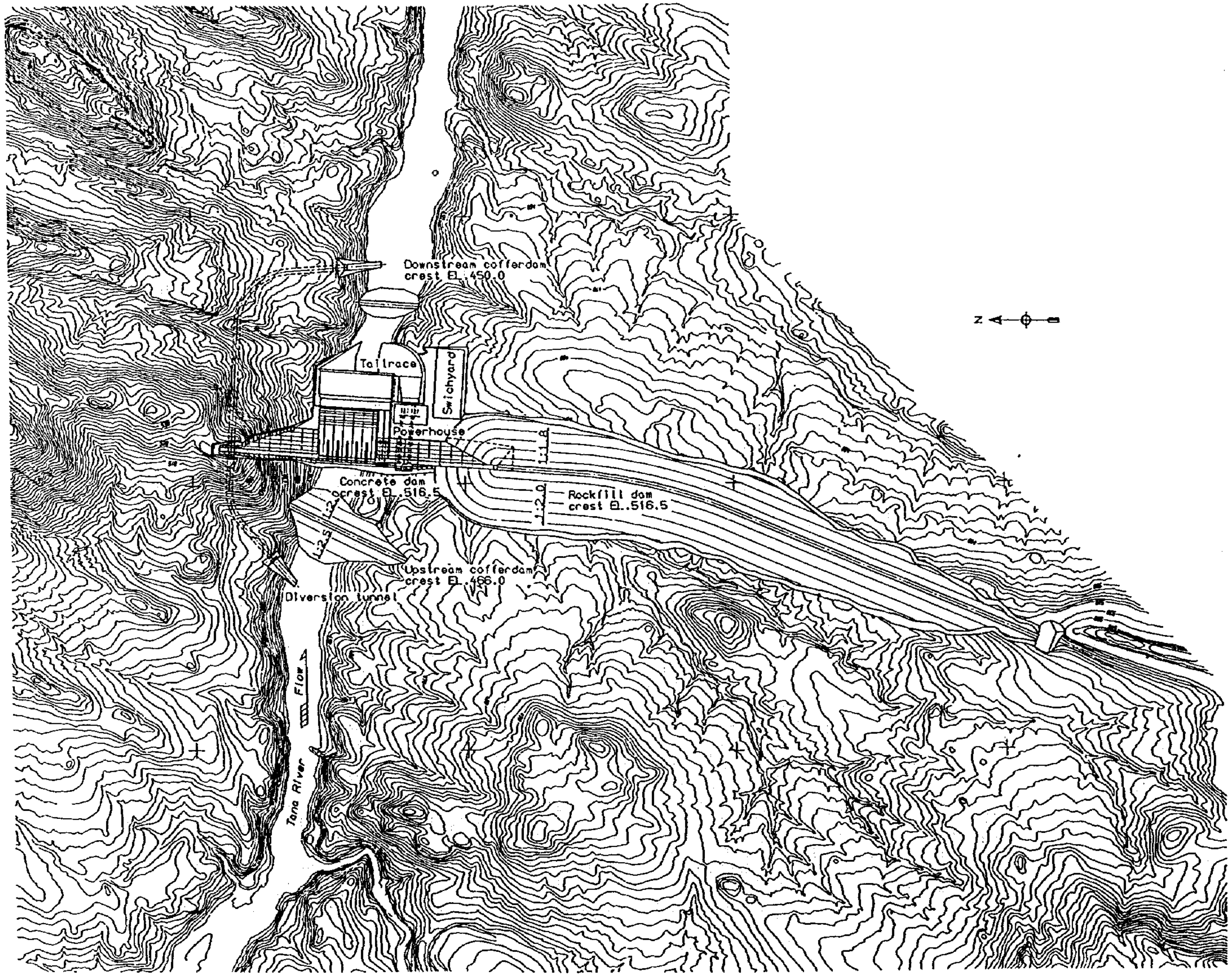
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Power and Energy Demand Forecast	Fig. No. S.11



JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Power System Diagram in 2012	Fig. No. S.12

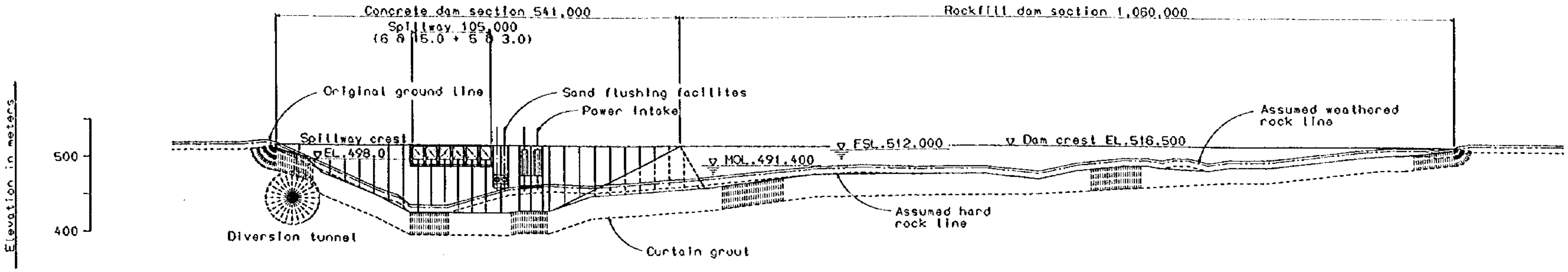


JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	General Layout of Project	Fig. No. S.13

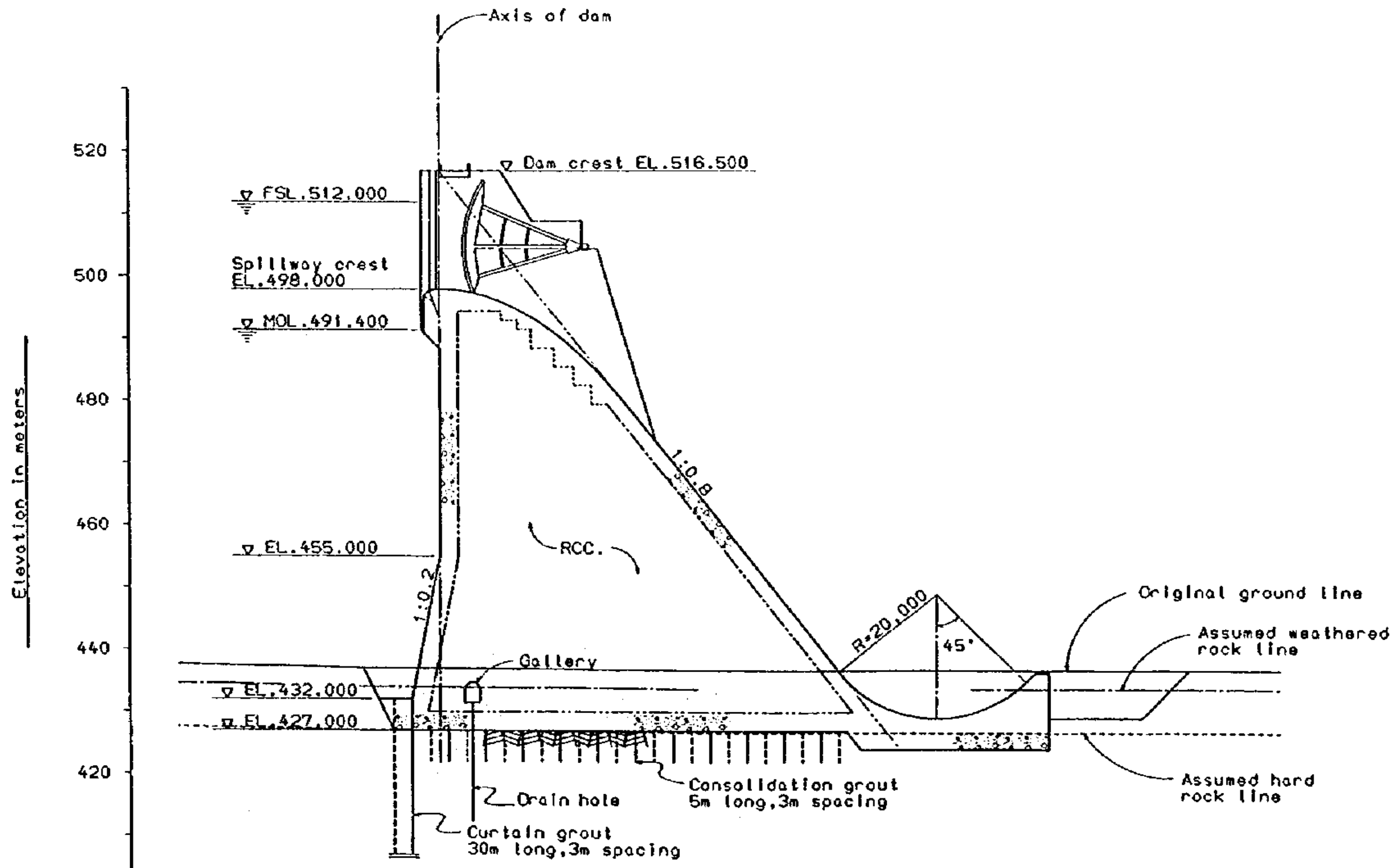


SCALE A 0 400 m

JAPAN INTERNATIONAL COOPERTION AGENCY	LOW GRAND FALLS DAM	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	GENERAL PLAN	S.14



UPSTREAM ELEVATION SCALE A

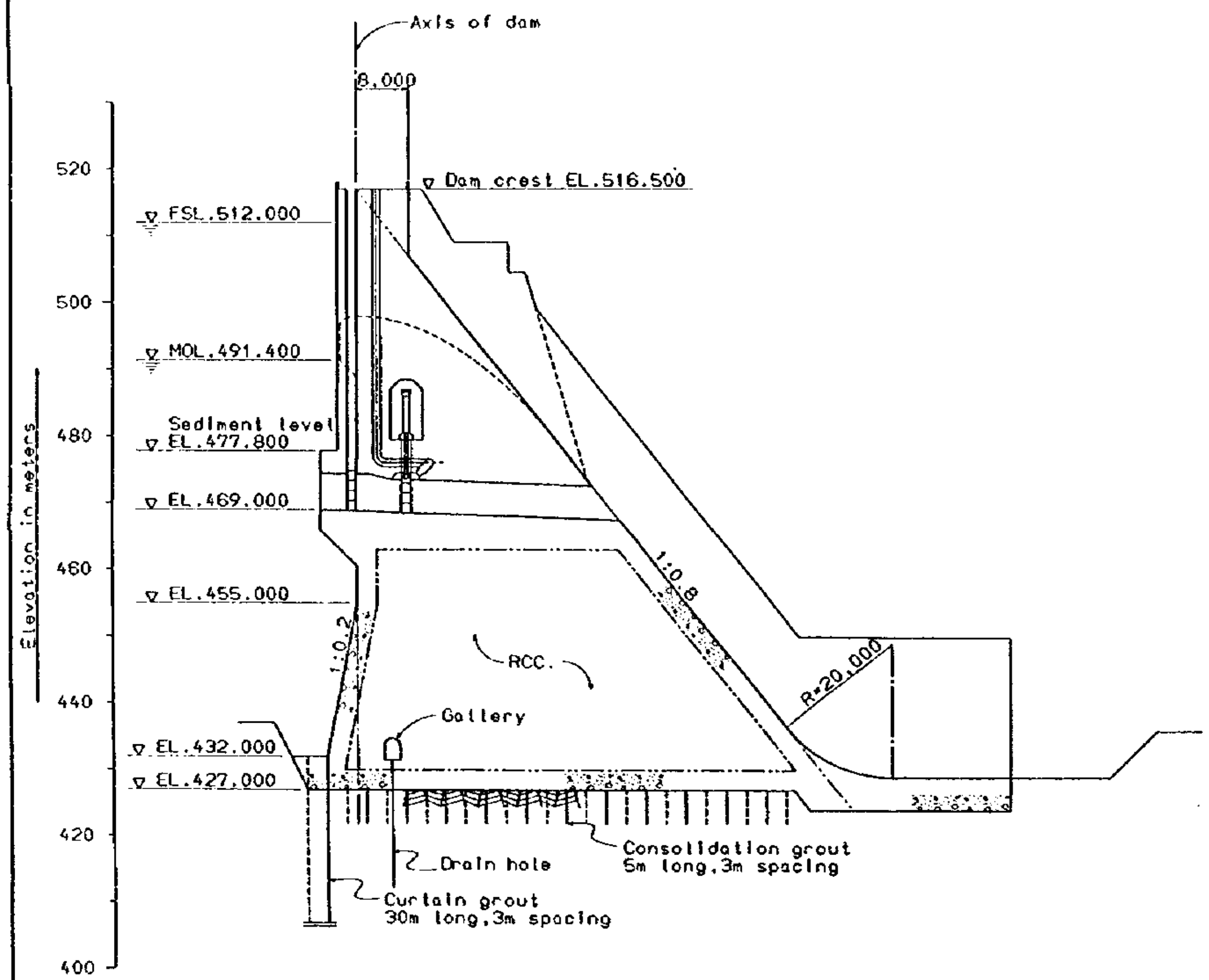


OVER FLOW SECTION SCALE B

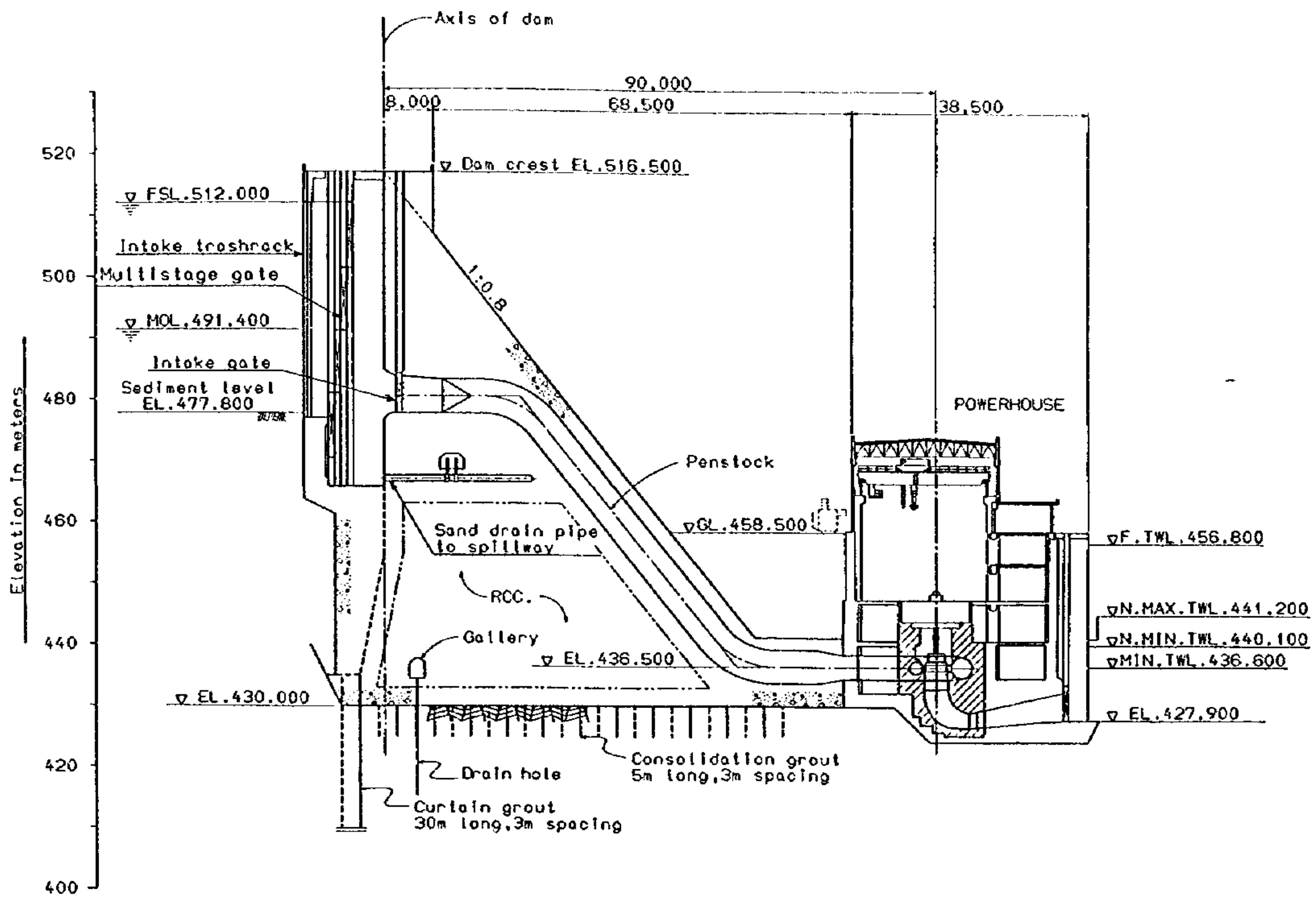
SCALE A 0 — 300m

SCALE B 0 — 50m

JAPAN INTERNATIONAL COOPERTION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	LOW GRAND FALLS ELEVATION AND TYPICAL SECTION	Fig. No. S.15



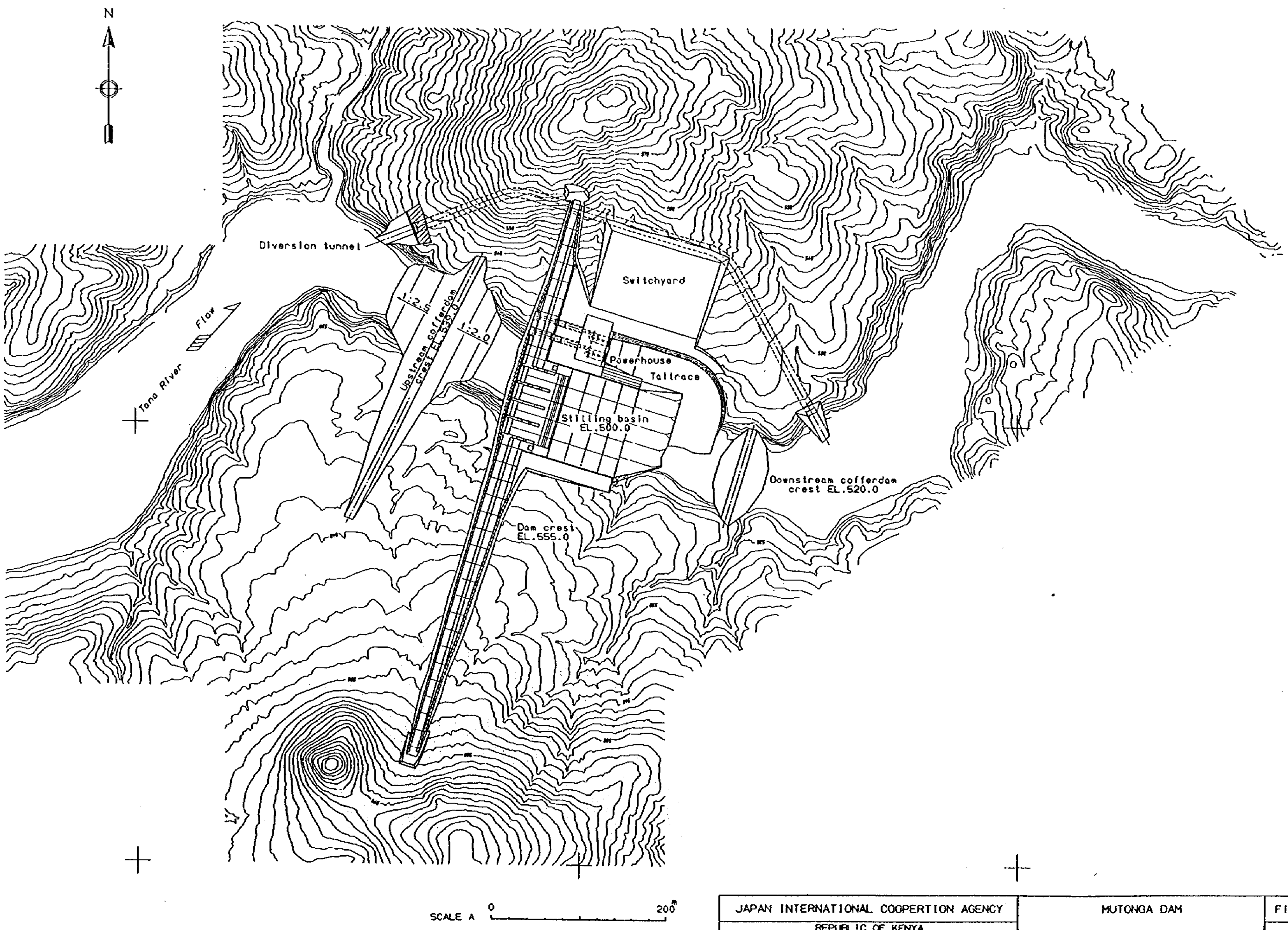
ARTIFICIAL FLOOD AND SEDIMENT RELEASE FACILITY



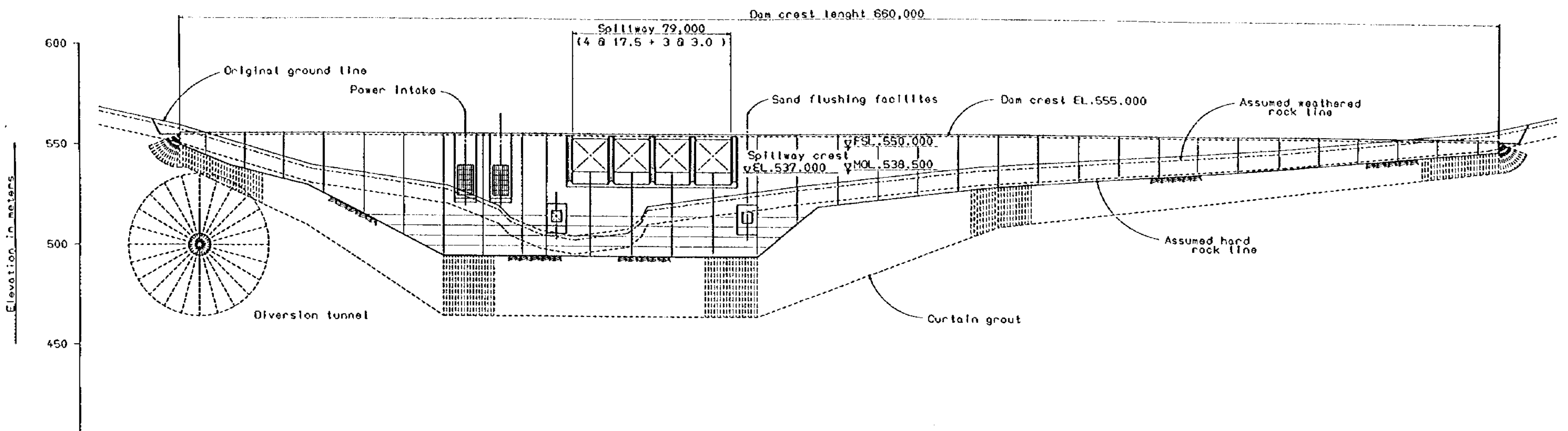
POWER STATION

SCALE A 0 50m

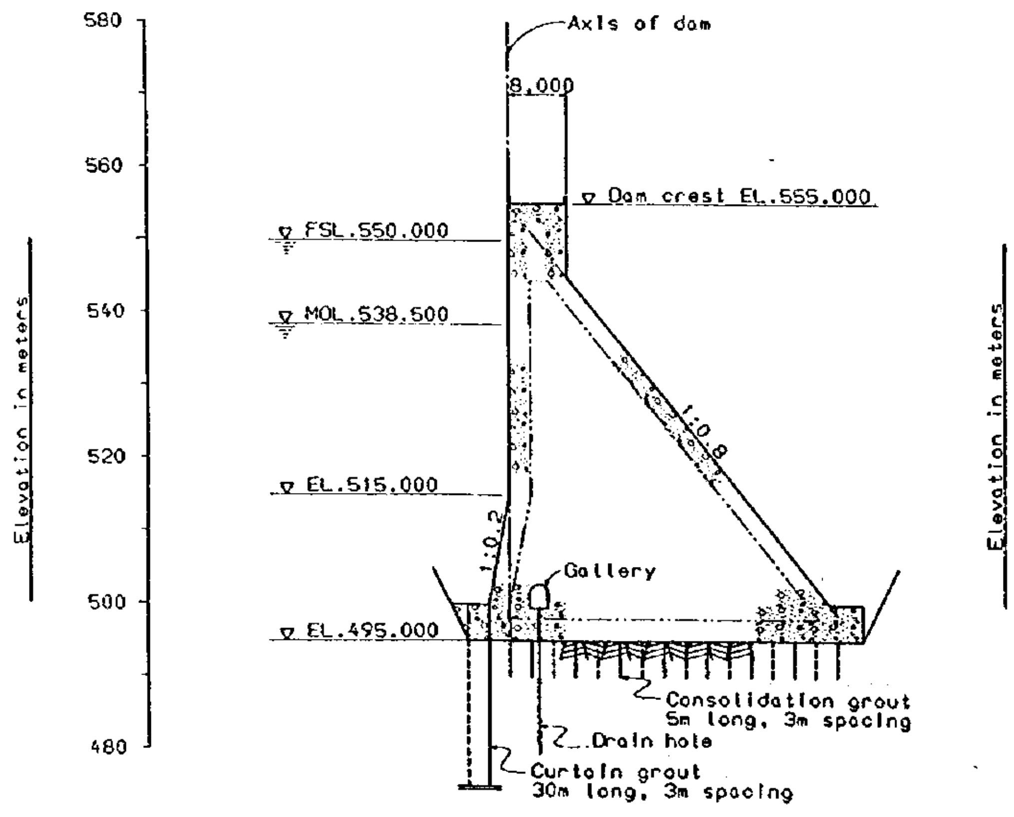
JAPAN INTERNATIONAL COOPERTION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	LOW GRAND FALLS ARTIFICIAL FLOOD AND SEDIMENT RELEASE FACILITY AND POWER STATION	Fig. No. S.16



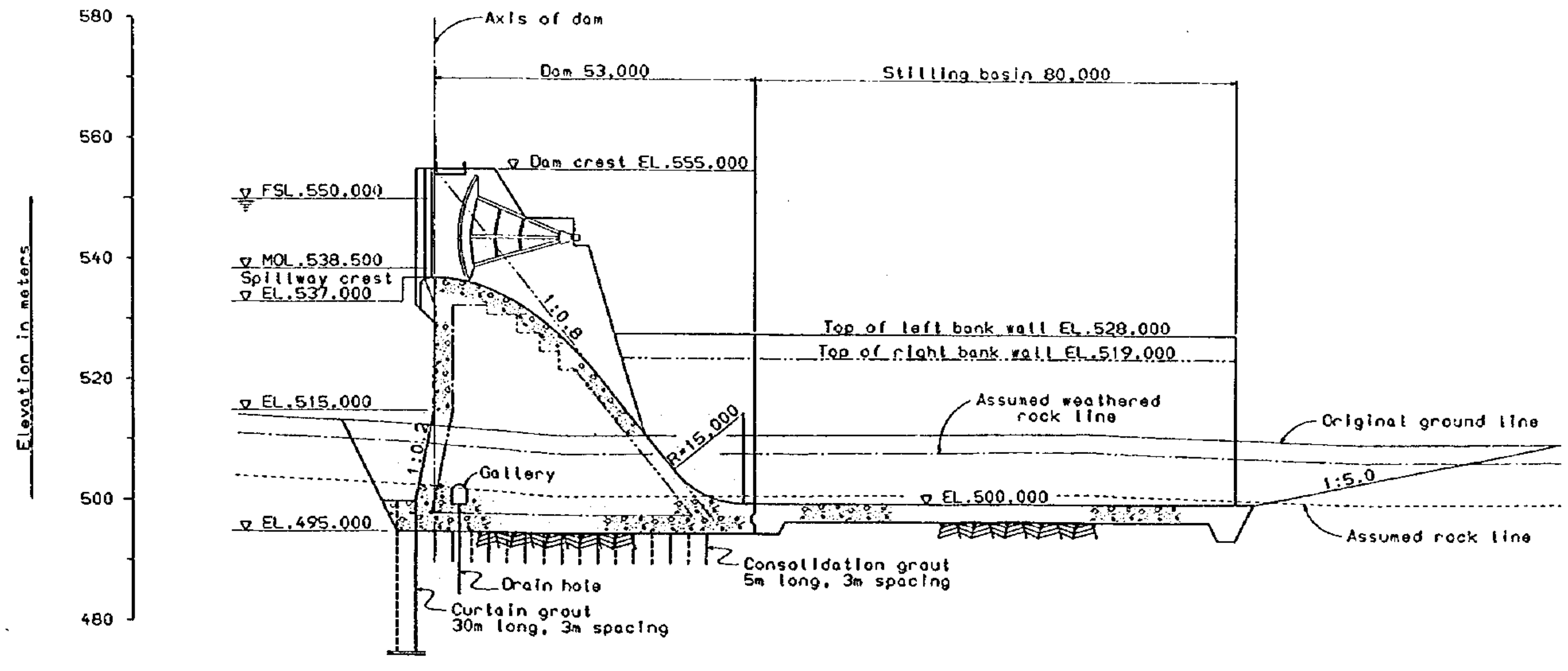
JAPAN INTERNATIONAL COOPERTION AGENCY	MUTONGA DAM	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	GENERAL PLAN	S.17



UPSTREAM ELEVATION SCALE A



NON-OVER FLOW SECTION SCALE B

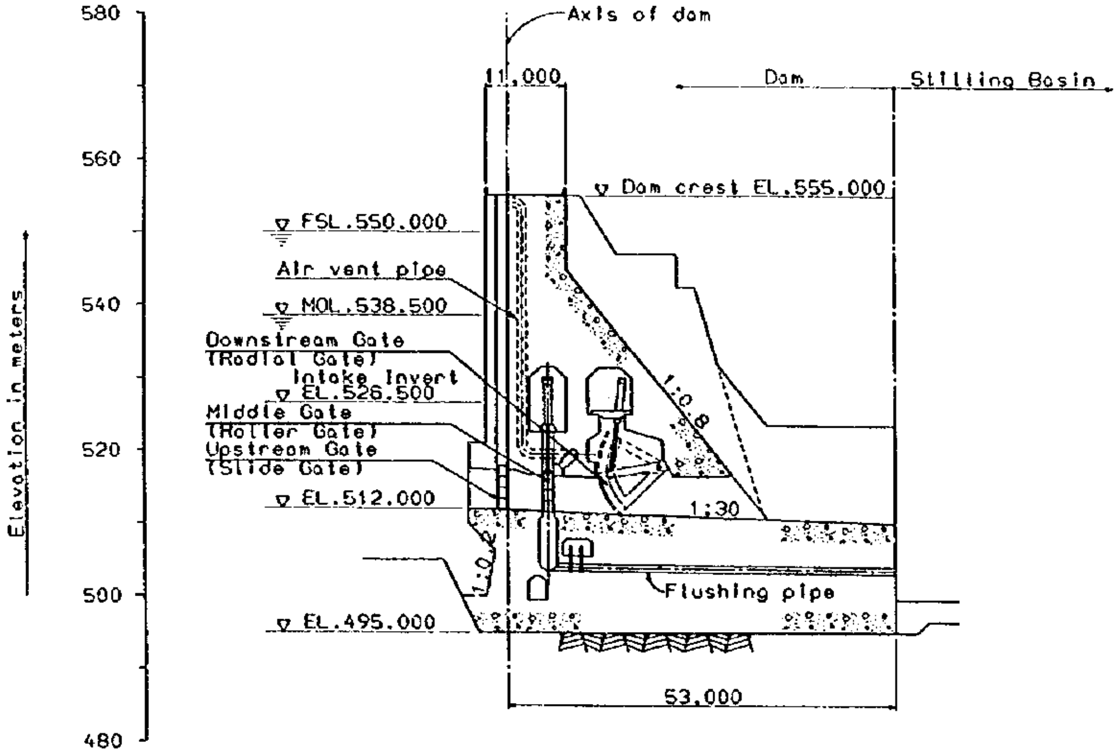


OVER FLOW SECTION SCALE B

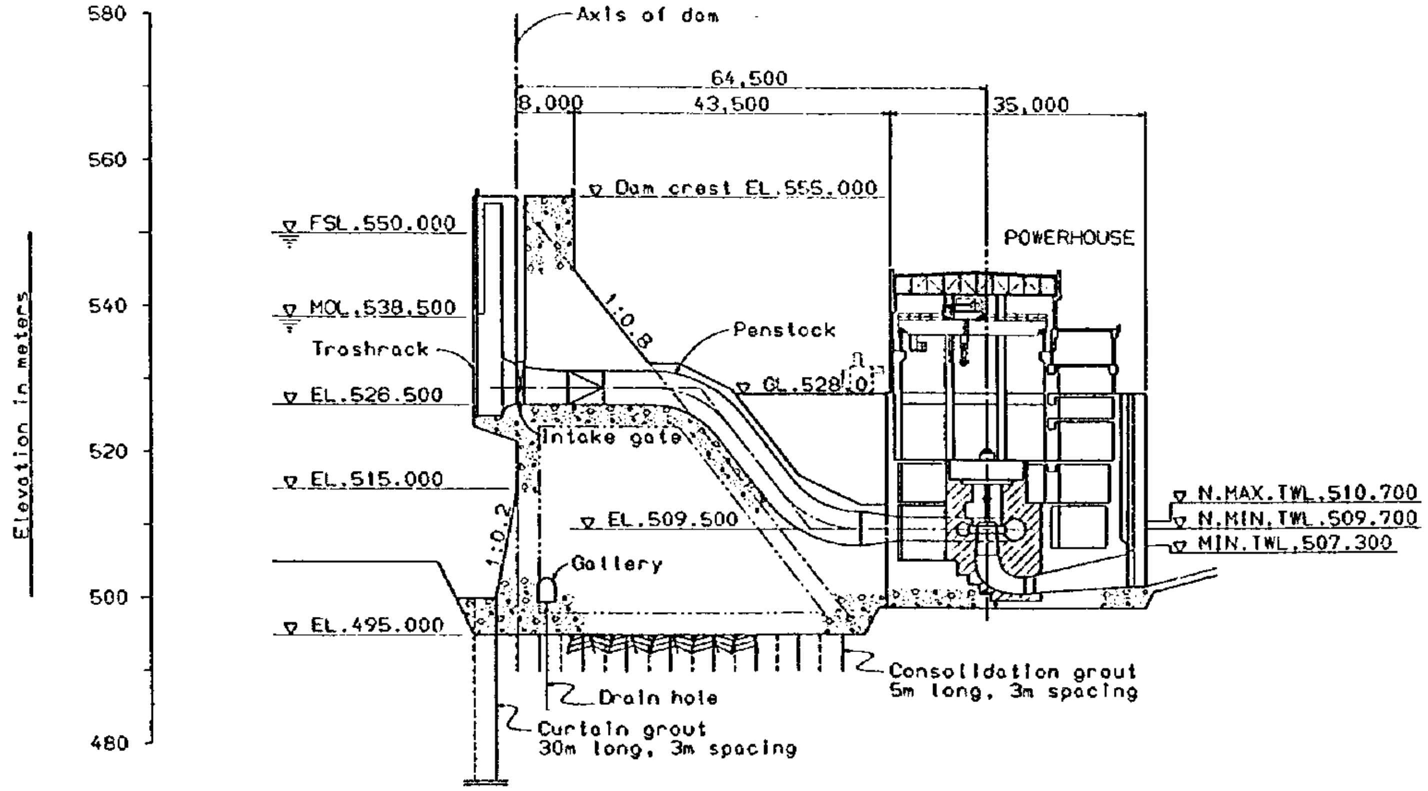
SCALE A 0 ——— 100 m

SCALE B 0 ——— 50 m

JAPAN INTERNATIONAL COOPERTION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	MUTONGA DAM ELEVATION AND TYPICAL SECTIONS	Fig. No. S.18



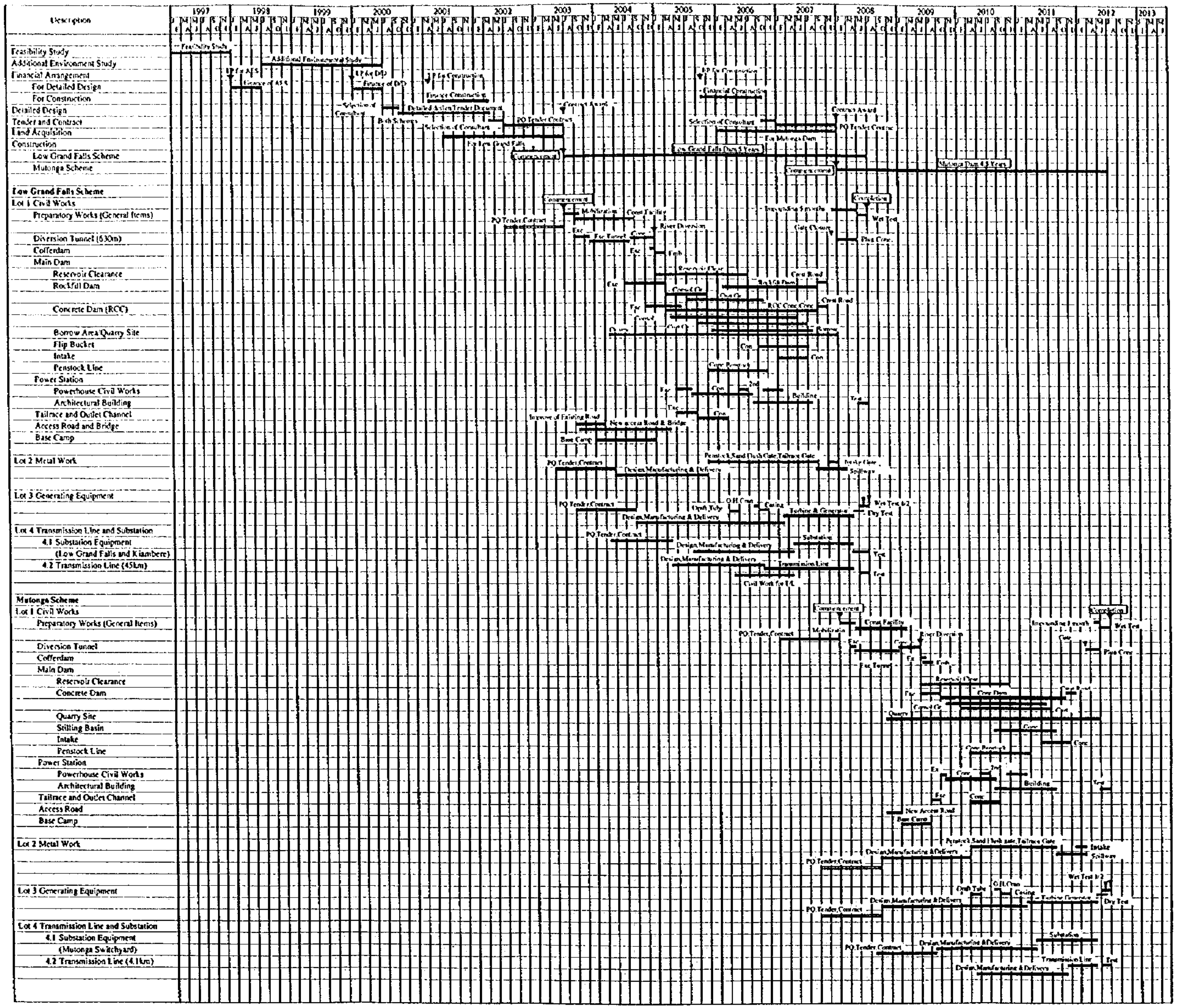
ARTIFICIAL FLOOD AND SEDIMENT RELEASE FACILITY



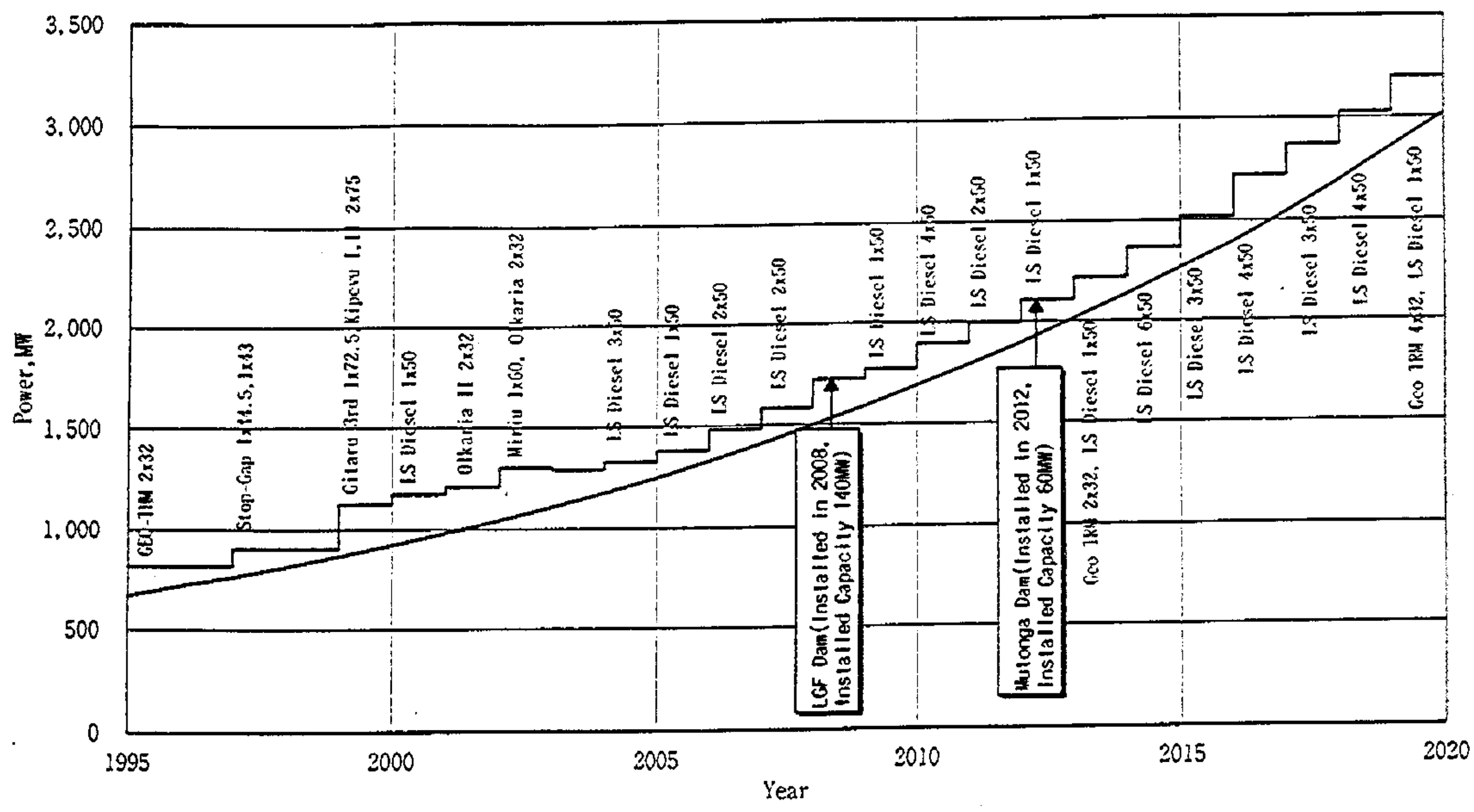
POWER STATION

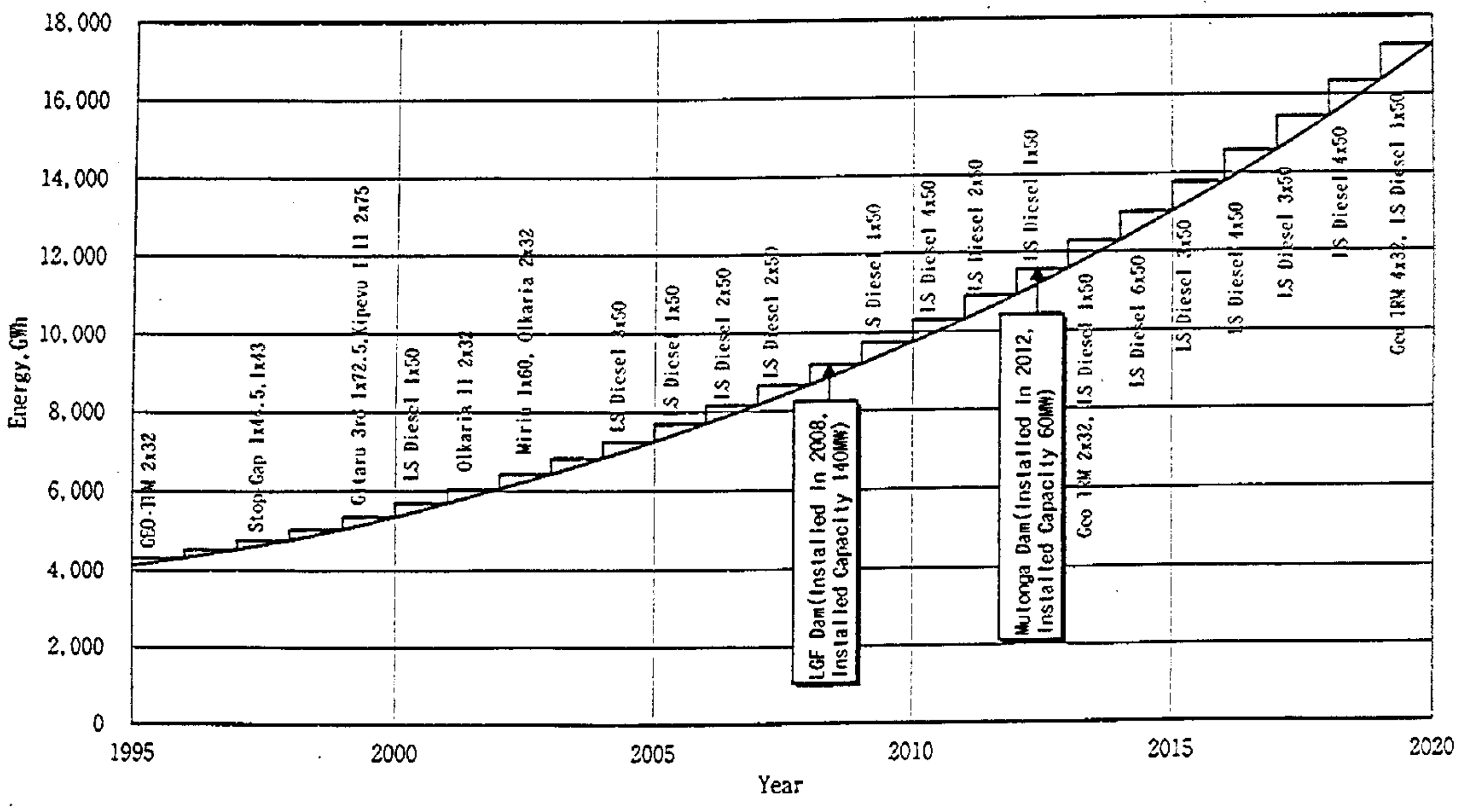
SCALE A 0 50m

JAPAN INTERNATIONAL COOPERTION AGENCY	MUTONGA DAM	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	ARTIFICIAL FLOOD AND SEDIMENT RELEASE FACILITY AND POWER STATION	S.19

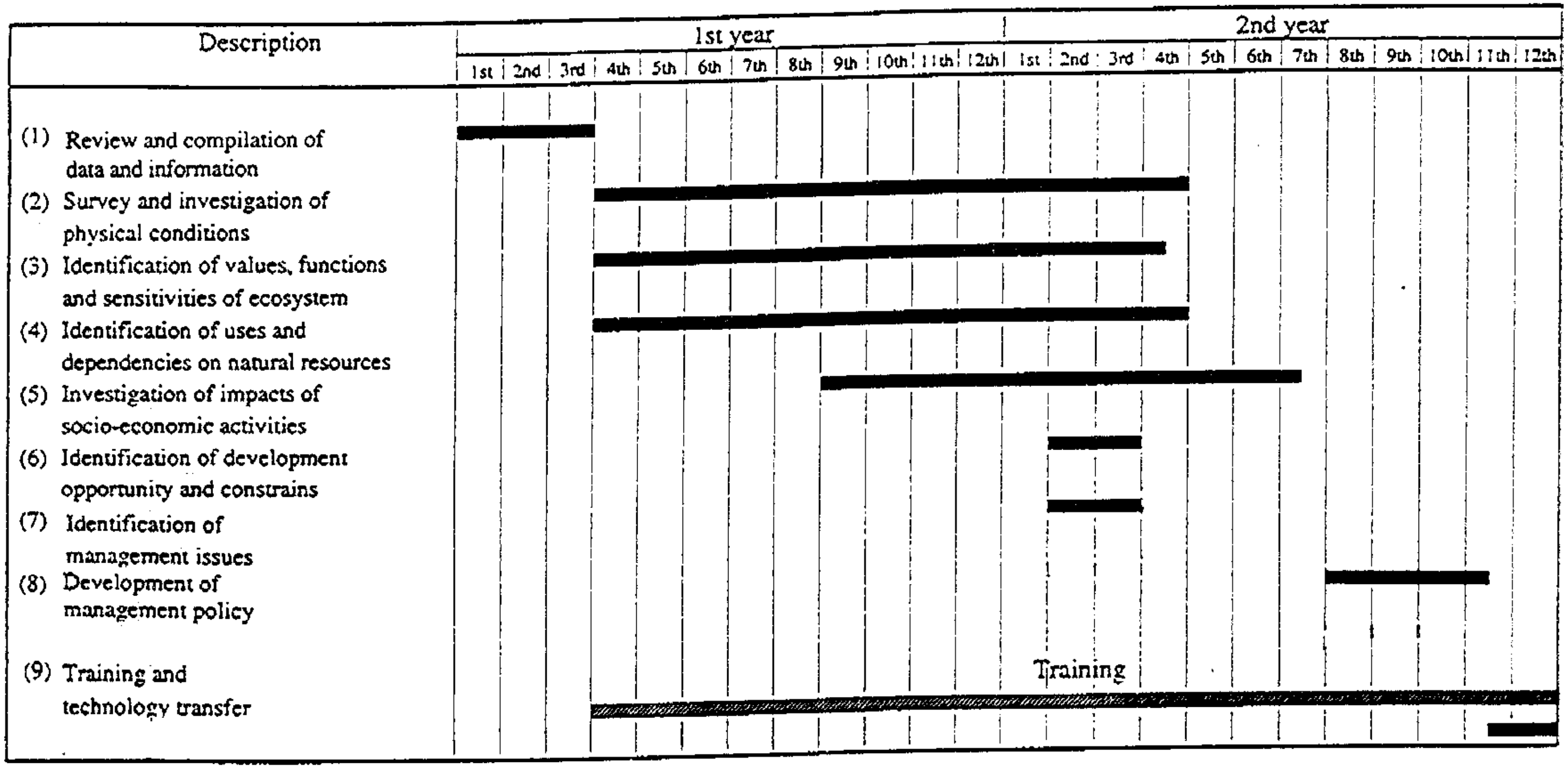


JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Construction Schedule	Fig. No. S.20





JAPAN INTERNATIONAL COOPERATION AGENCY	Power and Energy Balance	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		S.21



JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Schedule of Additional Environmental Assessment Study	Fig. No. S.22

JICA