JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF ENERGY
THE REPUBLIC OF KENYA

FEASIBILITY STUDY
ON
MUTONGA/GRAND FALLS HYDROPOWER PROJECT

FINAL REPORT

VOLUME II
SUPPORTING REPORT(1)
(ENGINEERING STUDY)

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

ANNEX A : Topographic Survey

ANNEX B : Hydrological Analysis

ANNEX C : Geological Investigation

ANNEX D : Dam Reservoir Simulation Results

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TOPOGRAPHIC SURVEY

ANNEX-A TOPOGRAPHIC SURVEY

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A1 INTRODUCTION

This report was prepared to describe activities relevant to the topographic survey (hereinafter referred to as the Works), which was carried out by the JICA Study Team for the Feasibility Study (hereinafter referred to as the Study) on the Mutonga/Grand Falls Hydropower Project (hereinafter referred to as the Project). The topographic survey was executed in three stages ; the first stage during the period from February to March 1994, the second stage during the period from July to September 1994, and the third stage during the period from June to August 1995. The Work involved the following activities.

1) Collection of photo mosaic, existing topographic maps and relevant survey data

2) Arrangement for subletting the works to a local survey firm (contractor).

3) Execution of Aerial photography, photo mosaic, photogrammetric mapping, cross selection survey, profile survey and positioning survey for boring points.

4) Supervision of survey works executed by Contractor.

5) Check Survey of subletting works.

The objective of the survey is to prepare aerial photographs, aerial photo mosaic, topographic maps, river cross sections and longitudinal profiles for basic material to be used for environmental assessment and preliminary planning of hydropower development schemes in the Study.

A2 COLLECTION OF EXISTING AERIAL PHOTO MOSAIC, MAPS AND RELEVANT SURVEY DATA

Prior to the commencement of actual topographic survey, existing aerial photo mosaic, maps and survey data were collected from Survey of Kenya (SK) and TARDA. Of the collected information, the following data were utilized as the basic data for topographic survey works:

(1) Existing aerial photo mosaic

Uncontrolled aerial photo mosaic at a scale of 1 to 25,000 prepared by TARDA in 1992, covering the river course between Sailoni and Makere Ya Gwano.

(2) Existing topographic maps

(a) Topographic maps at a scale of 1 to 50,000 with contour intervals of 20 m or 50ft. published by SK since 1962, covering the whole study area, 42 sheets in total.

(b) Topographic maps at a scale of 1 to 250,000 with contour intervals of 200 m or 5000 ft published by SK since 1963 covering the whole study area, 10 sheets in total.

(3) Existing land use maps

(a) Vegetation and present land use map in a scale of 1 to 50,000 prepared by JICA in 1983 and published by SK since 1984, covering whole Tana Delta area, 12 sheets in total.

(b) Land use and vegetation map for EMU - Mere - Oslo project at a scale of 1 to 50,000, prepared by Overseas Development Natural Resource Institute UK in 1979-80, covering left bank of Tana river at Mutonga/ Grand Falls reservoir area, 5 sheets in total.

(4) Survey datum information

(a) Description of Level BM by SK

(b) Trigonometric Index Card by SK

A3 ARRANGEMENT FOR TOPOGRAPHIC SURVEY WORKS

A3.1 Preparation of Technical Specifications

Technical specifications for aerial photography and topographic survey were prepared making reference to " Specifications of Overseas Surveying Works for Development Study" by JICA and " Air Survey Contract and Specification " by SK. Class B of the specifications by JICA was applied to keep the accuracy of the topographic survey works.

A3.2 Topographic Survey Schedule

Topographic survey works were carried out by a local survey firm, PHOTOMAP INTERNATIONAL INC. in accordance with the terms, conditions, requirements of the Contract and Technical Specifications under the supervision of Topographic Survey Expert of the JICA Study Team. The contracted works comprise the following:

(1) Stage 1

Aerial photography for the Mutonga, Low Grand Falls and High Grand Falls reservoir areas with an approximate coverage of 300 km^2 at a scale of 1 to 20,000 and Tana Delta area with an approximate coverage of 1,300 km^2 at a scale of 1:25,000 .

(2) Stage 2

(a) Photogrammetric mapping for the Mutonga, Low Grand Falls and High Grand Falls reservoir areas with a total of 300 km^2 at a scale of 1:5,000 with contour intervals of 2 m.

(b) Production of uncontrolled photo mosaic for the Mutonga, Low Grand Falls and High Grand Falls reservoir areas with an approximate coverage of 300 km^2 at a scale of 1:50,000 and Tana Delta area with an approximate coverage of 2,000 km^2 at a scale of 1:50,000.

(c) Production of river comparison maps along the Tana river between Tana river mouth and Makere Ya Gwano area with an approximate coverage of 2,300 km^2 at a scale of 1:50,000.

(d) Positioning survey of boring points at the Low Grand Falls dam site, comprising 4 points in total.

(3) Stage 3

(a) Aerial photography for the Mutonga and Low Grand Falls dam sites with an approximate coverage of 7.6 km^2 at a scale of 6,000.

(b) Photogrammetric mapping for the Mutonga and Low Grand Falls dam sites with a total of 7.6 km^2 at a scale of 1:1,000 with contour intervals of 1 m.

(c) Positioning survey of boring points at the Mutonga and Low Grand Falls dam sites, comprising 24 points in total.

(d) River cross section survey along the Tana, Mutonga and Kazita rivers comprising 150 sections in total with an approximate length of 44.95 km.

(e) River longitudinal profile survey along the Tana, Mutonga and Kazita rivers comprising 4 sections with an approximate length of 9.3 km.

(f) Positioning survey of boring points at the Mutonga and Grand Falls dam sites, comprising 24 points in total.

All the above topographic survey works were executed under the following three separate contracts. The contractor was selected by a comparison and valuation of quotations or tender proposals.

Contract Works	Contractor	: Date of Contract (Date of Completion)
(stage-1) Aerial photography for Mutonga /Grand Falls reservoir areas and Tana Delta area	PHOTOMAP INTERNATIONAL INC.	: 1st March, 1994 (21st March, 1994)
(Stage-2) Topographic survey work for Mutonga/Grand Falls reservoir areas	PHOTOMAP INTERNATIONAL INC.	: 20th July, 1994 (22nd Sept., 1994)
(Stage-3) Topographic survey work for Mutonga and Low Grand Falls Damsites	PHOTOMAP INTERNATIONAL INC.	: 22nd June, 1995 (31st August, 1995)

Further all the above contracted works were satisfactorily completed by the time specified in the contract agreements. The final products of each topographic survey were submitted to the JICA Study Team by the Contractor as listed in Table A3.1.

All the original negative films produced in the topographic survey are kept by Survey of Kenya in accordance with Regulations of Defense in Kenya.

A4 AERIAL PHOTOGRAPHY OF RESERVOIR AREAS AND TANA DELTA AREA (STAGE 1)

Two different scale of aerial photos were shot and produced, one is at a scale of 1 to 25,000 to be used for environmental assessment of the Tana delta area and the other is at a scale of 1 to 20,000 to be used for 1:5,000 scaled photogrammetric mapping and environmental assessment of the Mutonga/Grand Falls reservoir area. The photo shooting was started from 3rd March and completed on 10th March, 1994. After shooting aerial photos, photographic processing and printing works were carried out for the period from 11th March to 17th March, 1994. The principal data and information of the aerial photography works are as follows:

(1) Equipment used in aerial photography

(a)	Aircraft	: Piper, Navajo, PA31
(b)	Aerial Camera	: Wild, RC-10, No. 1099
(c)	Navigation Aids	: Milligan GPS 4000
(c)	Film and Print Processor	: Zeiss, FE 120's
(d)	Contact Printer	: Milligan Electric Printer
(e)	Print Processor	: Kodakmatic 65A Automatic Processor

(2) Data of aerial photography

		Reservoir Area	Tana Delta Area
(a)	Scale of aerial photography	:Approx.1:20,000	Approx.1:25,000
(b)	Area coverage by photography	:Approx.300 km^2	Approx.1,300 km^2
(c)	Focal length of aerial camera	: F= 151.19 mm	F= 151.19 mm
(d)	Over lapping	:Approx. 60% + 5%	Approx. 60% + 5%
(e)	Side lapping	:Approx. 30% + 5%	Approx. 30% + 5%
(f)	Flight altitude	:Approx. 3,500 m	Approx. 3,750 m
(g)	Flight direction	:West-East	South-North
(h)	Number of flight course	:7 course	14 course
(i)	Aerial film	:Kodak Double X	Kodak Double X
(j)	Duplication Materials	:Kodak RC paper	Kodak RC paper
(k)	Number of print	:170 prints	306 prints

(3) New aerial photo index map

Aerial photo index map for the Tana Delta area and the reservoir area were prepared after completion of the aerial photography as shown in Figures A4.1 and A4.2, respectively.

(4) Annotation of new aerial photos

The following titles and information were noted on the outside of each frame of the negative film at the beginning and end.

(a) F/S Grand Falls (Tana Delta Area) and (Reservoir Area)
(b) Scale of aerial photography
(c) Date of aerial photography
(d) Run number
(e) JICA

All the results of new aerial photography were checked referring to the Technical Specification by the survey expert of JICA Study Team. It was judged that the results were acceptable for preparing the 1:5,000 scaled topographic maps.

A5 TOPOGRAPHIC SURVEY WORK FOR RESERVOIR AREAS (STAGE 2)

A5.1 Scale Photogrammetric Mapping at a Scale of 1:5,000

A5.1.1 Photogrammetric Mapping Area

Photogrammetric mapping area covering. the Mutonga, Low Grand Falls and High Grand Falls reservoir with a total of 300 km^2 is as shown in Figure A4.1.

A5.1.2 Monumentation of Control Points

Before starting traverse and leveling survey, 26 new control points for a traverse network were established in and around the mapping area..

A5.1.3 Control Point Survey

Control point survey was executed to determine the UTM coordinates of 26 new control points and 41 photo control points to be used for the computation of aerial triangulation during the period of 4th August to 20th August, 1994. A traverse network was made basis on SK Secondly traverse points of 123ST5, 136ST14 and 136ST15, and planned to enclose the mapping area. The heights and coordinates of control points and photo control points are listed in Table A5.1 and A5.2, respectively. The survey works carried out are summarised below:

(1) Equipment used in control point survey

(a) Theodolite : Wild T2, No.298781
(b) EDM : AGA 14A Geodimeter, No.14999

(2) Datum coordinates

Kenyan datum coordinates of UTM Projection System, Zone 36 on the Clarke Spheroid of 1880 were applied for computation of the traverse network and photo control points.

(3) Method and accuracy

Traverse routes of the network were formed by a closed loop. Coordinates of the network points were fixed by polar method. Mis-closure of the traverse has been confirmed to be more than 1:15,000 of the total length for each traverse route. The photo control points to be pricked on the aerial photos were measured by double radiation traverse from the network control point. The method and specified accuracy of the traverse observation and measurement are as follows:

Horizontal angle observation

Horizontal angle was observed by 2 rounds of angle measurement on different zero settings. The discrepancy in angle observations between the first setting and the second setting has been stipulated not to exceed 20 seconds of double angle difference and 10 seconds difference of angle.

(2) Vertical angle observation

Vertical angle were observed by a round of angle measurement. The discrepancy between 1 set of measurement did not exceed 15 seconds.

(3) Distance measurement

Distance between control points was measured twice by EDM with an accuracy of more than 10mm + 3ppm/measured distance. The discrepancy between 2 sets of measurement was more than 1:40,000 of the measured distance.

A5.1.4 Photo Pricking

Planimetric features clearly identifiable on the photographs, whose position can be exactly deduced from the network control point, were pricked at the field for photo control. All of these pricked points were enclosed with small red circle on each contact print.

A5.1.5 Leveling

Leveling was executed to obtain the heights of control points and photo control points necessary for the computation of aerial triangulation in the course of the control point survey. Leveling routes were formed by closed loop. The heights and coordinates of control points and photo control are shown in Tables A5.1 and A5.2, respectively. The leveling works carried out are described below:

(1) Datum height

Datum height of Mean Sea Level of Kenya was employed for the leveling.

(2) Equipment used in leveling

Automatic levels, Wild NI 12 and others were used for the leveling.

(3) Accuracy of leveling

Misclosure of leveling was not to exceed + 50 mm$\sqrt{D}$ between bench marks and/or control points (D: a single distance in km between bench marks), as stipulated in the Technical Specifications prepared by the Study Team.

A5.1.6 Field Verification

The field verification was carried out using the 1:20,000 scaled aerial photographs at the time of the control point survey. In compliance with the map symbols, annotation and its application rules, the roads, houses/buildings, rivers, irrigation canals, vegetation covers, specified area, name of school, government offices, bridges, geographical and administrative etc. in the photographs were verified and/or confirmed and necessary annotations on them were drawn on the photographs in the field.

A5.1.7 Aerial Triangulation

Aerial triangulation was done analytically by the block adjustment method by means of independent models. The aerial triangulation was completed on 30th September, 1994.

After preparing contact prints and diapositives of the aerial photographs , locations of pass points and tie points were selected on the contact prints. These points were stereoscopically observed with a pricking device on the diapositive. 3 pass points and 2 tie points were pricked on each diapositive so that at least 6 points were included within a stereo model. The established control points with pre-marks, minor control points and Spot height points were also pricked on the diapositives. All of these pricked points as well as with the fiducial marks on each photograph were stereoscopically observed and measured with an analytical plotter. The X and Y photo coordinates obtained by analytical plotter measurement were processed by a digital data processing system for analytical aerial triangulation.

The total numbers of photo models of aerial triangulation and control points used for the computation of aerial triangulation were as follows:

Photo Model	: 154 models
Horizontal and vertical control point	: 67 points

(1) Equipment and program used in aerial triangulation

(a)	Pricking Device	: Wild, PUG 4
(b)	Analytical Plotter	: Wild, BC 1
(c)	Computer	: VAX 11/750
(d)	Program	: J.K.KENEFICK

(2) Accuracy of aerial triangulation

Residuals of height and coordinates of control points did not exceed values of 1.6 % of the flight height and discrepancies of pass and ties did not exceed values of 0.08 % of flight height for both planimmetry(X and Y) and height (Z). These results were confirmed by the survey expert. Accordingly it was judged that the results of aerial triangulation had enough accuracy for photogrammetric mapping at a scale of 1:5,000.

A5.1.8 Sheet Index, Legend and Marginal Information of Topographic Maps

Map sheet size is about 70 cm x 110 cm with neat lines of 60 cm x 80 cm. Sheet layout, marginal information style, map symbols of legend, annotations and their application rules for the 1:5,000 scaled topographic maps were decided by the JICA Survey Team and instructed to the Contractor.

A5.1.9 Machine Plotting

The machine plotting for 1: 5,000 scaled topographic maps were carried out based on new aerial photos at a scale of 1:20,000, results of control point survey , leveling and aerial triangulation. The plotting work covering the reservoir area of 300 km^2 was completed at the beginning of September, 1994.

The control points and photo control points were plotted and Planimetric details on the ground such as vegetation boundaries, road/footpath, river/stream, house, bridge, fence/hedge, rock, cliff, land slide, other artificial structures and 2 meter contour lines were delineated by analog stereo plotter on 44 original plotting sheets in accordance with the map symbols, annotation and its application rules. The equipment used for plotting were Wild, Aviograph A8 and B8.

A5.1.10 Compilation and Drawing

In compliance to map symbols, annotation and its application rules, the results of field verification such as roads, houses/buildings, rivers, irrigation canals, vegetation covers, specified area, name of school, government offices, bridges, geographical and administrative etc. in the photographs were delineated and compiled on the original plotting sheets. The relations among the contour lines, spot heights, topographic conditions, sheet size, marginal information and other information on the draft drawing sheets were checked by the survey expert for production of final drawing.

Fair drawing was produced on the transparent polyester by a plotter. The drawing was completed on 21st September, 1994.

A5.2 Production of Uncontrolled Photo Mosaic and River Comparison Map

A5.2.1 Photo Mosaicking Areas and River Comparison Map Area

Photo mosaiking areas covering the Mutonga, Low Grand Falls and High Grand Falls reservoir areas, Tana Delta area along the Tana river between Garsen and Makere Ya Gwano areas with an approximate area of 2,300 km^2 and river comparison map area along the Tana river between Tana river mouth and Makere Ya Gwano with an approximate area of 1,800 km^2 as shown in Figures A5.1 to A5.4.

A5.2.2 Preparing of Aerial Photos

Three different scale of aerial photographs were used for photo mosaiking: one is at a scale of 1:20,000 by JICA in March 1994, covering the Mutonga/Grand Falls reservoir area and two is at a scale of 1:25,000 by JICA in March 1994, covering the Tana delta area and other is at a scale of 1:40,000 by TARDA in January 1992, covering along the Tana river between Garsen and Makere Ya Gwano area. Data and information of the photographs by JICA were described in the foregoing Chapter A4. The photographs produced by TARDA were refered in the foregoing A2.1.

A5.2.3 Sheet Index, Legend and Marginal Information of Photo Mosaic and River Comparison Map

Map sheet size, sheet layout and marginal information style for the 1:50,000 scaled photo mosaic sheets and river comparison maps were decided by the JICA Survey Team and instructed to the Contractor. The both sheet layout is shown in Figures A5.1 to A5.4.

A5.2.4 Photo Mosaicking

Photo mosaicking was carried out by visual method using the above photos. The work consisted of reprinting, laying and cutting, trimming and sanding, pasting, photographs and printing. Final 1:50,000 scaled photo mosaics were printed on contact print paper by rectifier using scaled off grid from 1:50,000 scaled topographic maps of SK.

(1) Equipment used in photo mosaicking

(a)	Rectifier	: Zeiss SEG. V
(b)	Film Processor	: Zeiss, FE 120's
(c)	Contact Printer	: Milligan Electric Printer
(d)	Print Processor	: Kodakmatic 65 A Automatic Processor

(2) Materials used in photo mosaic

(a)	Film	: Kodak C film
(b)	Photo print	: Kodak RC paper

A5.2.5 River Comparison Map Drawing

River comparison maps were prepared on the transparent polyester film sheets using by above the 1:50,000 scaled mosaic sheets and 1:50,000 scaled topographic maps from SK .Overlaid Tana river line on the mosaic and maps were delineated and shown on 2 drawing sheets separately. Reduced copy of the river comparison maps are shown in Figure A5.4.

A5.3 Positioning Survey of Boring Points

4 boring points in total were measured for the period from 4th August to 7th August, 1994. Elevation and coordinates of these points were used for the geological investigation.

A6 TOPOGRAPHIC SURVEY WORK FOR DAMSITES (STAGE 3)

A6.1 Aerial Photography

Aerial photos at a scale of 1 to 6,000 were shot for photogrammetric mapping of the Mutonga and Low Grand Falls damsites at a scale of 1:1,000. The photos shooting was started from 23rd June and completed on 25th June, 1995. After shooting aerial photos, photographic processing and printing works were carried out for the period from 26th June to 30th June, 1995.

The aerial photography was carried out by same equipment as described in the foregoing Chapter A4. The principal data and information used for the aerial photography works are as follows:

(1) Data of aerial photography

	Mutonga damsite	Low Grand Falls damsite
(a) Scale of aerial photography	:Approx. 1:6,000	Approx. 1:6,000
(b) Area coverage by photography	:Approx. 1.1 km^2	Approx. 6.5 km^2
(c) Focal length of aerial camera	:F= 151.19 mm	F= 151.19 mm
(d) Over lapping	:Approx. 60% + 5%	Approx. 60% + 5%
(e) Side lapping	:Approx. 30% + 5%	Approx. 30% + 5%
(f) Flight altitude	:Approx. 900 m	Approx. 900 m
(g) Flight direction	:West-East	South-North
(h) Number of flight course	:2 course	3 course
(i) Aerial film	:Kodak Double X	Kodak Double X
(j) Duplication Materials	:Kodak RC paper & diapositive	
(k) Number of print	:9 prints	30 prints

(2) New aerial photo index map

Aerial photo index map for the Mutonga and Low Grand Falls damsites were prepared after completion of the aerial photography as shown in Figures A6.1 and A6.2, respectively.

(3) Annotation of new aerial photos

The following titles and information were noted on the outside of each frame of the negative film at the beginning and end.

(a) F/S Mutonga/Grand Falls
(b) Scale of aerial photography
(c) Date of aerial photography
(d) Run number
(e) JICA

All the results of new aerial photography were checked referring to the technical Specification by the survey expert of the JICA Study Team. It was judged that the results were acceptable for preparing the 1:1,000 scaled topographic maps.

A6.2 Scale Photogrammetric Mapping at a Scale of 1:1,000

A6.2.1 Photogrammetric Mapping Area

Photogrammetric mapping area covering both the Mutonga damsite with a total area of 1.1 km^2 and Low Grand Falls damsites with a total area of 6.5 km^2 is as shown in Figure A6.1 and A6.2.

A6.2.2 Monumentation of Control Points

Before starting traverse and leveling, 21 new control points for a traverse network were established in and around the mapping area..

A6.2.3 Control Point Survey

Control point survey was executed to determine the UTM coordinates of 21 new control points to be used for the computation of aerial triangulation during the period of 14th June to 28th June, 1995. A traverse network was planned to enclose the mapping area.

The same equipment, datum coordinates, method and accuracy as described in the foregoing Subsection A5.13 were applied.

A6.2.4 Photo Pricking

The same manner as explained in the foregoing Subsection A5.1.4 were applied.

A6.2.5 Leveling

The leveling work was carried out in the same datum, equipment, and accuracy as described in the foregoing Subsection A5.1.5. The works were executed in the course of the control point survey.

A6.2.6 Field Verification

The field verification was carried out using the 1:6,000 scaled aerial photographs at the time of the control point survey. The same manner as explained in the foregoing Subsection A5.1.6 were applied.

A6.2.7 Aerial Triangulation

The same method, equipment and accuracy as stated in the foregoing Subsection B5.1.7 were applied for and the total numbers of photo models of aerial triangulation and control points used for the computation of aerial triangulation are shown below:

Mapping area	Photo model	Horizontal control points	Vertical control points
Mutonga Damsite	6	17	18
Low Grand Falls Damsite	24	22	25

A6.2.8 Sheet Index, Legend and Marginal Information of Topographic Maps

Map sheet size, sheet layout, marginal information style, map symbols of legend, annotations and their application rules for the 1:5,000 scaled topographic maps were decided by the JICA Survey Team and instructed to the Contractor.

A6.2.9 Machine Plotting

The machine plotting for 1: 1,000 scale topographic maps were carried out based on new aerial photos at a scale of 1:6,000, results of control point survey , leveling and aerial triangulation. The plotting work covering the both damsites area of 7.6 km^2 was completed in the middle of August, 1995.

The control points and photo control points were plotted and Planimetric details on the ground such as trees, bush, vegetation boundaries, road/footpath, river/stream, house, bridge, fence/hedge, rock, cliff, land slide, other artificial structures and 1 meter contour lines were delineated by analog stereo plotter on original plotting sheets in accordance with the map symbols, annotation and its application rules. The equipment used for plotting were Wild, Aviograph A8 and B8.

A6.2.10 Compilation and Drawing

The compilation was carried out in the same manners as described in the foregoing Subsection A5.1.10.

Fair drawing was produced on the transparent polyester film by a plotter. The drawing was completed on 24th August, 1995.

A6.3 River Cross Section and Profile Survey

6.3.1 Location of Cross Section and Profile Line

The location maps of the river cross section and profile section at the Mutonga dam site, along the Tana river and Mutonga river and at the Low Grand Falls dam site, along the Tana river and Kazita river section were prepared by the JICA Study Team to notify them to the Contractor before starting the river cross section survey. These map were handed over to the Contractor.

A6.3.2 Installation of Bench Marks

Prior to the commencement of the river cross section and profile survey, bench marks (cross section post) of concrete pegs was installed on the Mutonga and Low Grand Falls dam axis line and their dam cross section lines and at the right bank of the cross section lines along the Tana river, Mutonga river and Kazita river. The location of these bench marks was instructed by JICA Study Team to the Contractor at the field.

A6.3.3 River Cross Section and Profile Survey

The river cross section survey was carried out for the period from 25th June and completed 3rd August, 1995. Heights and distances of slope changing points, road, canal etc. along the cross section line were measured by using a level, surveying tape, Theodolite, and EDM. Water level and water depths of the river were measured using a survey rod, and the distances between bench marks or right bank pegs and these measured points were measured simultaneously. The river cross sections at existing stream gauging station on the Tana river, Mutonga river and Kazita river were also measured. Profile sections were prepared using by survey data of the river cross section survey. Total number of both dam axis cross sections and river cross sections was 150 and total number of dam axis and river profile section was 6. Total length of cross section was approximately 44.95 km and total length of profile section was approximately 27 km. Locations of the river cross section and profile survey and their volume of work are listed blow:

(1) Low Grand Falls dam site and its up and dawn stream of the Tana river and Kazita river.

	Dam site	Tana river	Kazita river
(a) Length of profile	:3.6 km	9 km	2 km
(b) Length of cross section	:25 km	11.1 km	1.2 km
(c) Number of cross section	:71 sections	37 sections	4 sections
(d) Number of profile	:1 section	1 section	1 section
(e) Interval	:50 m	250 m	500 m
(f) Cross sectional width	:350 m	300 m	300 m
(g) Plotting scale of cross section	:V = 1/1,000	V = 1/1,000	V= 1/1,000
	H = 1/1,000	H= 1/1,000	H= 1/ 1,000
(h) Plotting scale of profile section	:V = 1/500	V = 1/500	V= 1/500
	H = 1/10,000	H= 1/25,000	H= 1/25,000

(2) Mutonga dam site and its up and dawn stream of the Tana river and Mutonga river.

	Dam site	Tana river	Mutonga river
(a) Length of profile	: 0.8 km	5.5 km	10 km
(b) Length of cross section	:8.8 km	3.3 km	3 km
(c) Number of cross section	:17 sections	11 sections	10 sections
(d) Number of profile	:1 section	1 section	1 section
(e) Interval	:50 m	500 m	1,000 m
(f) Cross sectional width	:350 m	300 m	300 m
(g) Plotting scale of cross section	:V = 1/1,000	V = 1/1,000	V= 1/1,000
	H = 1/1,000	H= 1/1,000	H= 1/ 1,000
(h) Plotting scale of profile section	:V = 1/500	V = 1/500	V= 1/500
	H = 1/10,000	H= 1/25,000	H= 1/25,000

(3) Equipment used in river cross section survey

(a) Level : Zeiss NI 12
(c) Theodolite : Wild, T2 and Topcon, Gts-6
(d) EDM : AGA 14 A

A6.3.4 Sheet Index and Marginal Information of Cross Sections and Profile Sections

Sheet size, sheet layout and marginal information style for the cross section and profile section were specified by the JICA Survey Team and instructed to the Contractor.

A6.3.5 Plotting and Drawing

Cross section and Profile section were prepared firstly by pencil on the millimeter graph paper (original pencil plotting sheet). Fair drawing was then made on the transparent polyester film.

The figure of cross section and profile section and transferred spot height point on the original pencil plotting sheets and marginal information of the fair drawing sheets were checked by the survey expert.

A6.4 Positioning Survey of Boring Points

24 boring points in total were measured on the beginning of August, 1995. Height and coordinates list of these point were submitted to the Study Team.

Table A3.1 (1) List of Final Products

Description	Quantity
1. Aerial Photography for Reservoir Areas and Tana Delta Area (Stage 1)	
(a) Original film negatives(S=1:20,000 and 1:25,000)	One set
(b) Contact prints	One set
(c) Original flight index map	One set
(d) Flight records	One set
(e) Progress report and a copy of camera calibration certificate	One set
2. Topographic Survey Work for Reservoir Areas (Stage 2)	
(1) 1:5,000 scale photogrammetric mapping	
(a) Observation and computation sheets	One set
(b) Survey mark description sheets	One set
(c) Diapositives(s=1:20,000)	One set
(d) Diagram of mapping area	One set
(a) Original 1:5,000 scale topographic maps	One set
(c) Duplicate of topographic maps	One set
(d) Dyeline paper copies of topographic maps	Three sets
(2)Uncontrolled Photo Mosaic and River Comparison Map Production	
(a) 1:50,000 scale photo mosaic sheets	One set
(b) River comparison maps	One set
(c)Diagram of photo mosaic and river comparison maps	One set
(3) Positioning Survey of Boring Points	
(a) Observation and computation sheets	One set

Table A3.1 (2) List of Final Products

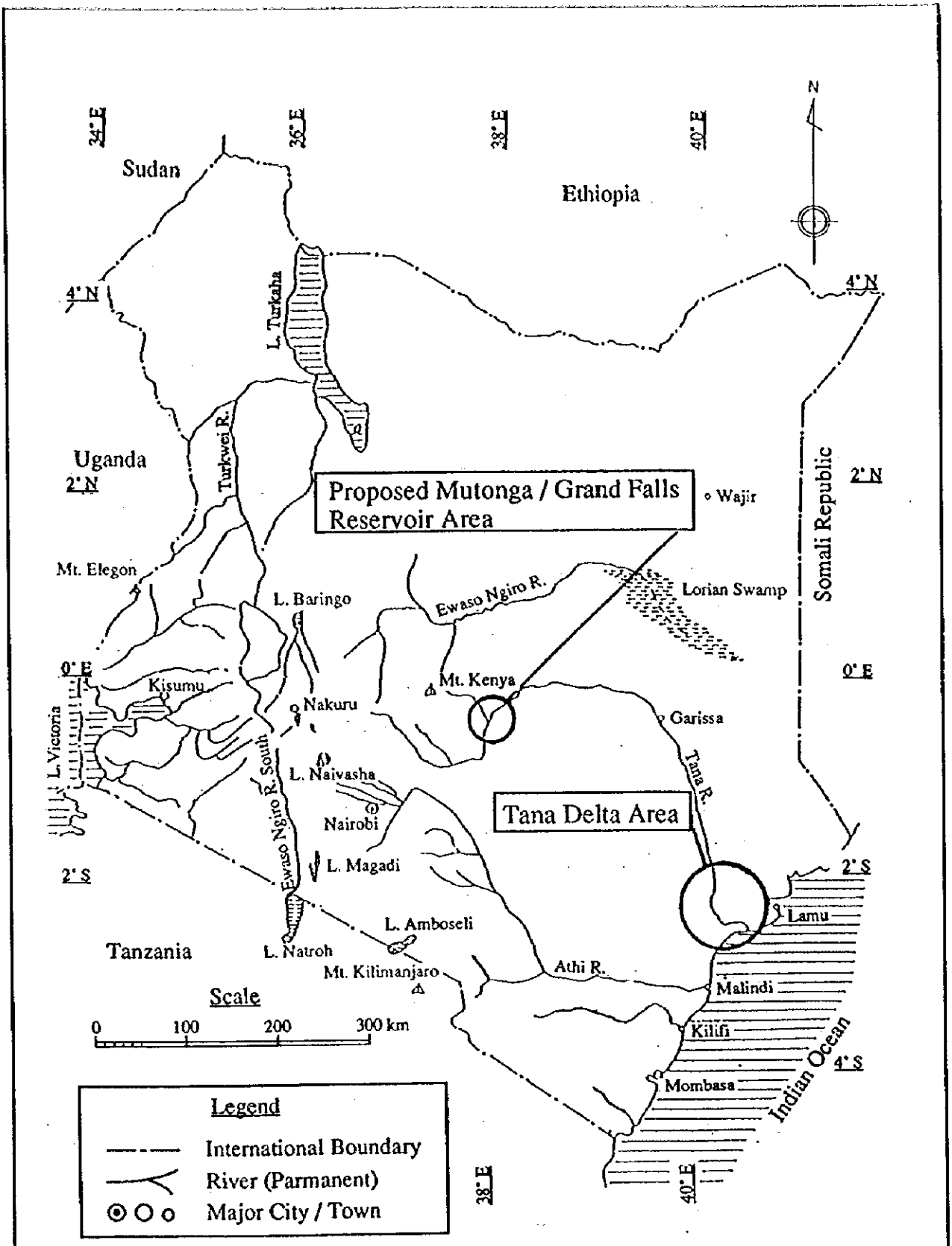
Description	Quantity
3. Topographic Survey Work for Dam Sites (Stage 3)	
(1) Aerial Photography	
(a) Original film negatives(S=1:6,000)	One set
(b) Diapositives	One set
(c) Contact prints	Two sets
(d) Original flight index map	One set
(e) Flight records, progress report and a copy of camera calibration certificate	One set
(2) 1:5,000 scale photogrammetric mapping	
(a) Descriptions and list tables of control points	One set
(c) Diagram of control point survey	One set
(d) Aerial triangulation index map and report	One set
(e) Original manuscriptions	One set
(f) Original 1:1,000 scale topographic maps	One set
(g) Photo paper copies of topographic maps	Three sets
(3)River Cross Section and Profile Survey	
(a) Description and list table of BMs	One set
(c) Diagram of river cross sections and profile sections	One set
(e) Original plotting sheets	One set
(f) Original drawing sheet	One set
(g) Photo paper copies of topographic maps	Two sets
(4) Positioning Survey of Boring Points	
(a) Observation and computation sheets	One set

Table A5.1 List of Coordinates and Height of Permanent Points for Photogrammetric Mapping of Mutonga / Grand Falls Hydropower Project

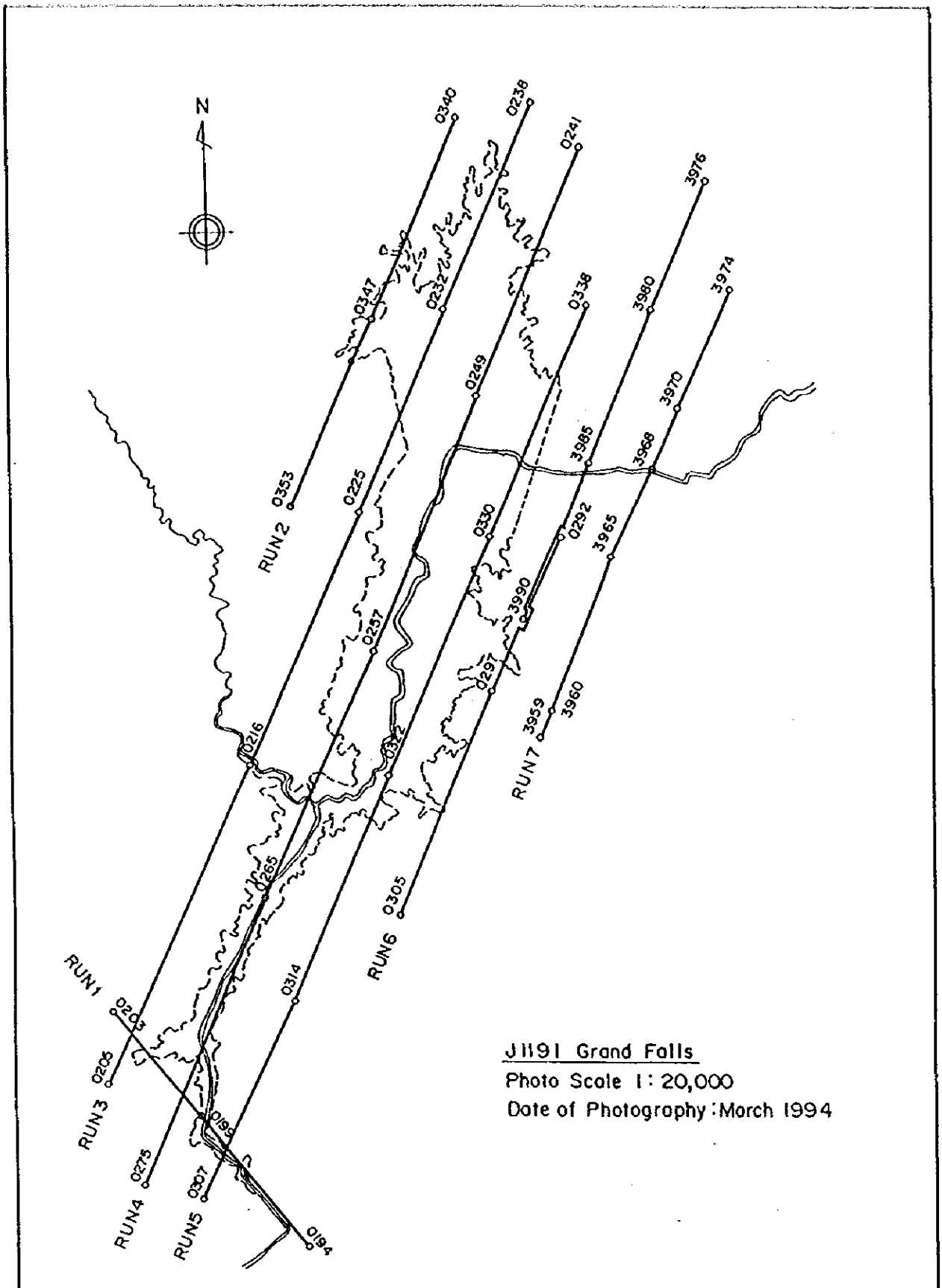
Station	Coordinates (m) UTM 36 N	E	Height	Remarks
I. Existing Points				
123ST5	9,963,438.02	394,123.87	921.70	Trace of centerpipe in pillar foundation
136ST14	9,936,641.88	367,945.25	-	Hole in ground
TR 5	9,938,903.71	379,189.58	853.29	Iron pin in concrete
TR 8	9,951,650.65	378,383.42	666.58	-ditto-
TR10	9,959,365.18	383,261.81	604.62	Chisel cross in rock
TR14	9,976,679.18	395,140.34	737.65	-ditto-
BM 1	9,970,624.32	393,040.84	630.29	Hole in rock
BM 2	9,968,023.92	391,833.38	592.37	-ditto-
II. New Points				
GF 1	9,982,369.32	387,806.80	611.01	Hole in rock
GF 2	9,985,065.07	396,797.81	775.23	-ditto-
GF 3	9,974,802.53	385,069.85	717.90	-ditto-
GF 4	9,972,026.76	393,626.13	971.57	-ditto-
GF 5	9,970,183.96	393,759.60	536.95	-ditto-
GF 6	9,957,980.49	391,122.89	672.70	-ditto-
GF 7	9,950,367.78	384,137.35	788.23	Hole in Boulder
GF 8	9,946,710.53	381,226.46	791.19	-ditto-
123ST5x1	9,963,443.36	394,123.59	922.07	-ditto-
123ST5x2	9,963,387.14	394,093.72	917.34	-ditto-
136ST14x	9,936,682.46	367,953.43	879.60	-ditto-
SAT14-1	9,937,094.04	370,957.76	809.11	-ditto-
TRI8 NEW	9,954,470.14	386,536.38	603.95	Hole in Bedrock
TRI7 NEW	9,957,020.29	379,425.50	812.33	Hole in Boulder
PH 2x	9,984,061.00	393,602.39	652.90	Hole in rock
PH 5x	9,979,730.96	393,912.55	610.89	-ditto-
PH11x	9,957,290.17	377,187.13	659.19	Hole in Boulder
PH12x	9,965,573.85	391,438.74	584.81	Hole in Bedrock
PH14x	9,959,325.37	389,514.36	609.41	-ditto-
PH15x	9,962,114.15	386,335.59	506.05	-ditto-
PH17x	9,955,467.19	376,209.50	656.88	-ditto-
PH19x	9,950,824.70	388,651.72	654.20	Hole in Boulder
PH24x	9,940,044.23	369,963.53	717.25	-ditto-
PH30x	9,975,219.59	398,694.42	570.61	Hole in Bedrock
PH31x	9,973,229.23	401,629.08	522.39	Hole in Boulder
TRI5 NEW	9,974,366.02	397,256.54	622.15	Hole in Bedrock

Table A5.2 List of Coordinates and Height of Photo Control Points for Photogrammetric Mapping of Mutonga / Grand Falls Hydropower Project

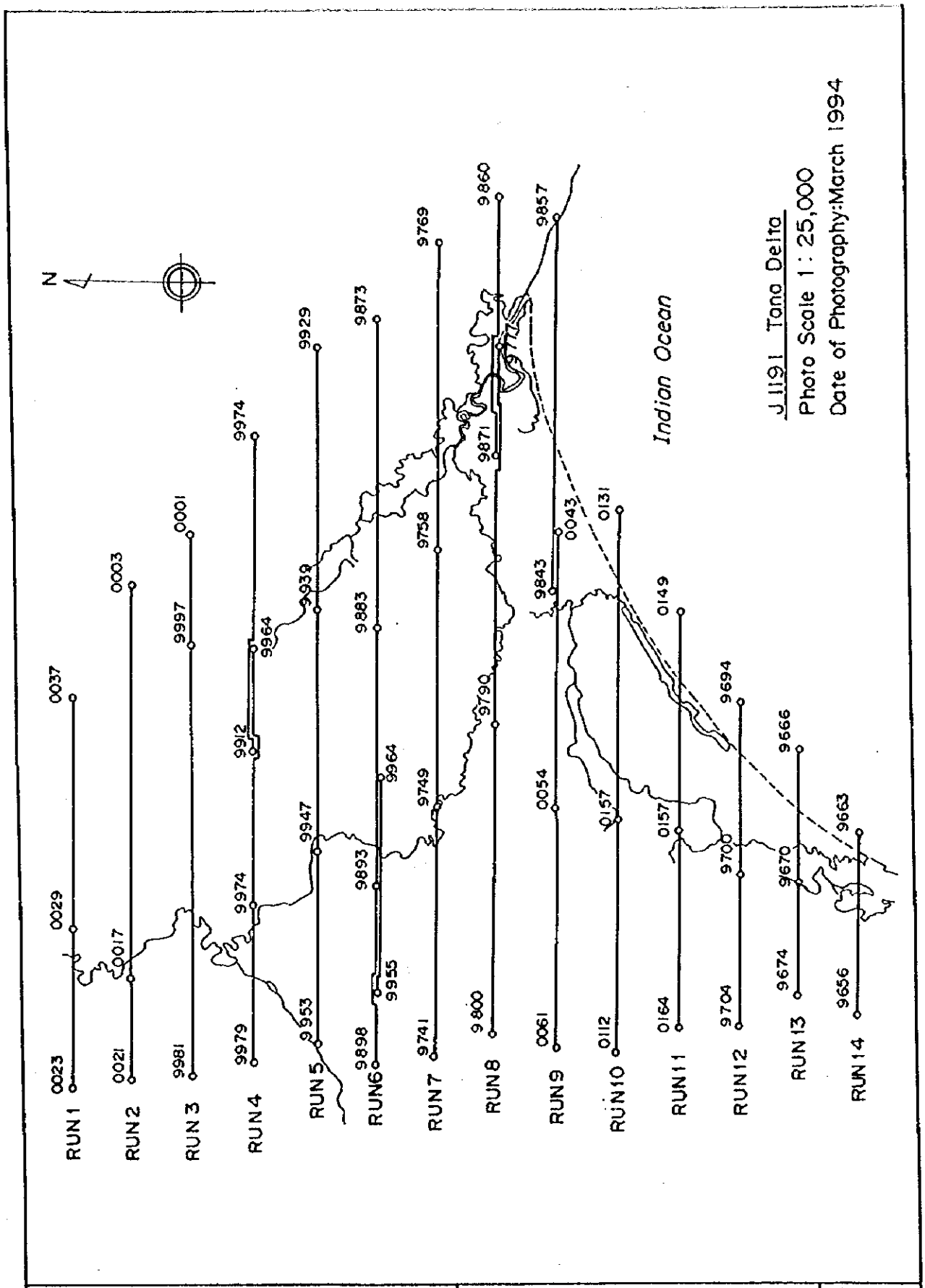
Station	Coordinates (m) UTM 36 N	E	Height	Remarks
PH 1	9,986,674.92	389,519.87	586.65	
PH 1A	9,986,648.71	389,524.65	586.37	
PH 1B	9,986,582.09	389,520.34	585.49	
PH 2	9,984,232.37	392,793.85	602.08	
PH 3	9,980,871.31	387,638.38	591.20	
PH 4	9,980,207.51	383,836.69	606.02	
PH 5	9,979,900.55	393,939.34	587.55	
PH 6	9,976,205.99	396,725.38	567.30	
PH 6A	9,976,306.94	396,645.03	568.30	
PH 7	9,971,466.88	390,779.18	503.59	
PH 8	9,974,718.39	388,750.24	513.34	
PH 8A	9,971,675.18	387,225.39	513.51	
PH 9	9,975,818.28	385,282.50	542.81	
PH10	9,975,196.24	381,999.05	566.42	
PH11	9,957,281.63	377,221.32	654.45	
PH12	9,965,611.67	391,488.85	562.78	
PH13	9,961,107.89	393,382.07	654.99	
PH14	9,959,342.39	389,497.25	607.96	
PH15	9,962,278.66	386,221.71	487.45	
PH16	9,961,362.35	383,593.35	600.04	
PH16A	9,961,376.16	383,602.37	-	
PH16B	9,961,367.06	383,598.66	-	
PH17	9,955,411.48	376,162.77	659.04	
PH18	9,952,580.87	386,354.58	634.37	
PH19	9,950,735.13	388,746.76	718.61	
PH20	9,948,245.44	380,701.32	646.21	
PH21	9,951,542.81	378,190.72	673.69	
PH22	9,942,918.00	371,066.15	724.99	
PH23	9,943,768.86	379,349.20	686.38	
PH24	9,939,965.95	369,864.68	712.64	
PH25	9,937,449.27	372,469.92	715.51	
PH26	9,933,853.93	376,198.01	691.79	
PH26A	9,934,620.38	375,122.19	660.54	
PH27	9,933,281.43	379,973.61	674.05	
PH28	9,965,818.31	395,747.48	564.37	
PH29	9,970,305.14	396,912.55	476.76	
PH30	9,975,240.52	398,693.56	570.53	
PH31	9,973,254.84	401,642.99	520.15	
PH32	9,967,524.36	399,158.76	490.20	
PH33	9,963,550.27	397,323.92	593.17	
PH34	9,970,282.11	393,525.19	500.80	



JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Location Map Tana Delta and Mutonga/Grand Falls Reservoir Area	Fig. No. A1.1



JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Aerial Photo Index Map of Grand Falls Reservoir Area	Fig. No. A4.1



JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Aerial Photo Index of Tana Delta Area	Fig. No. A4.2

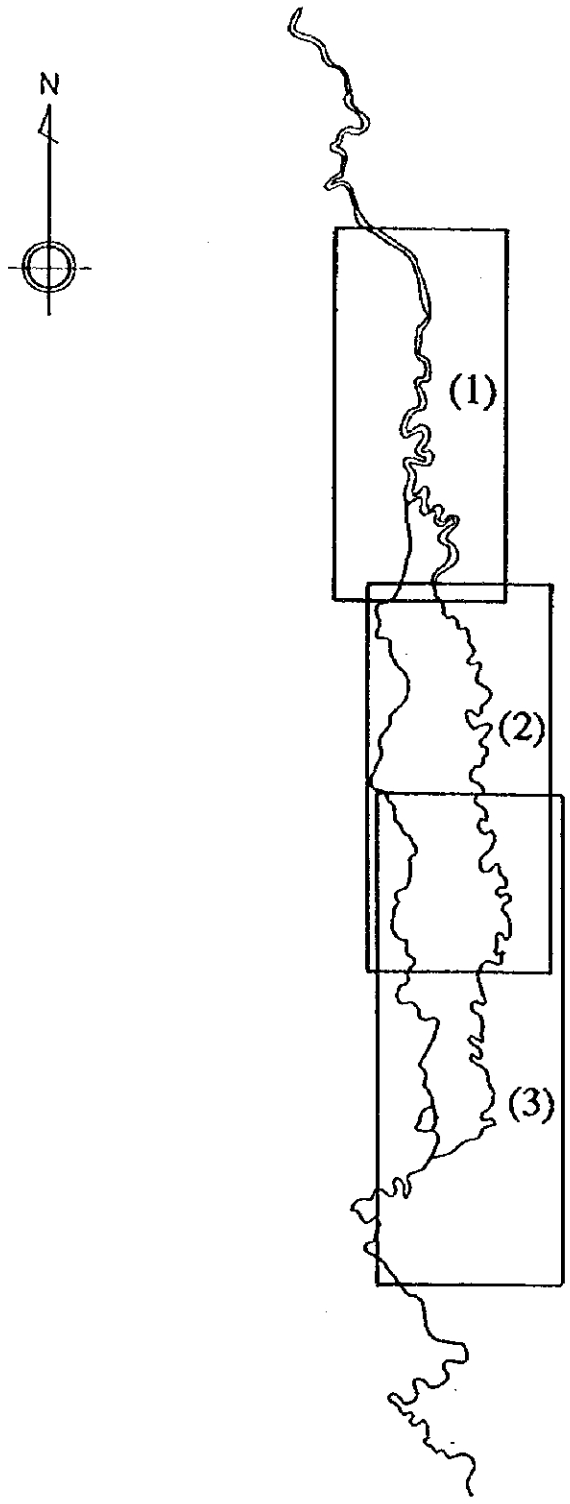
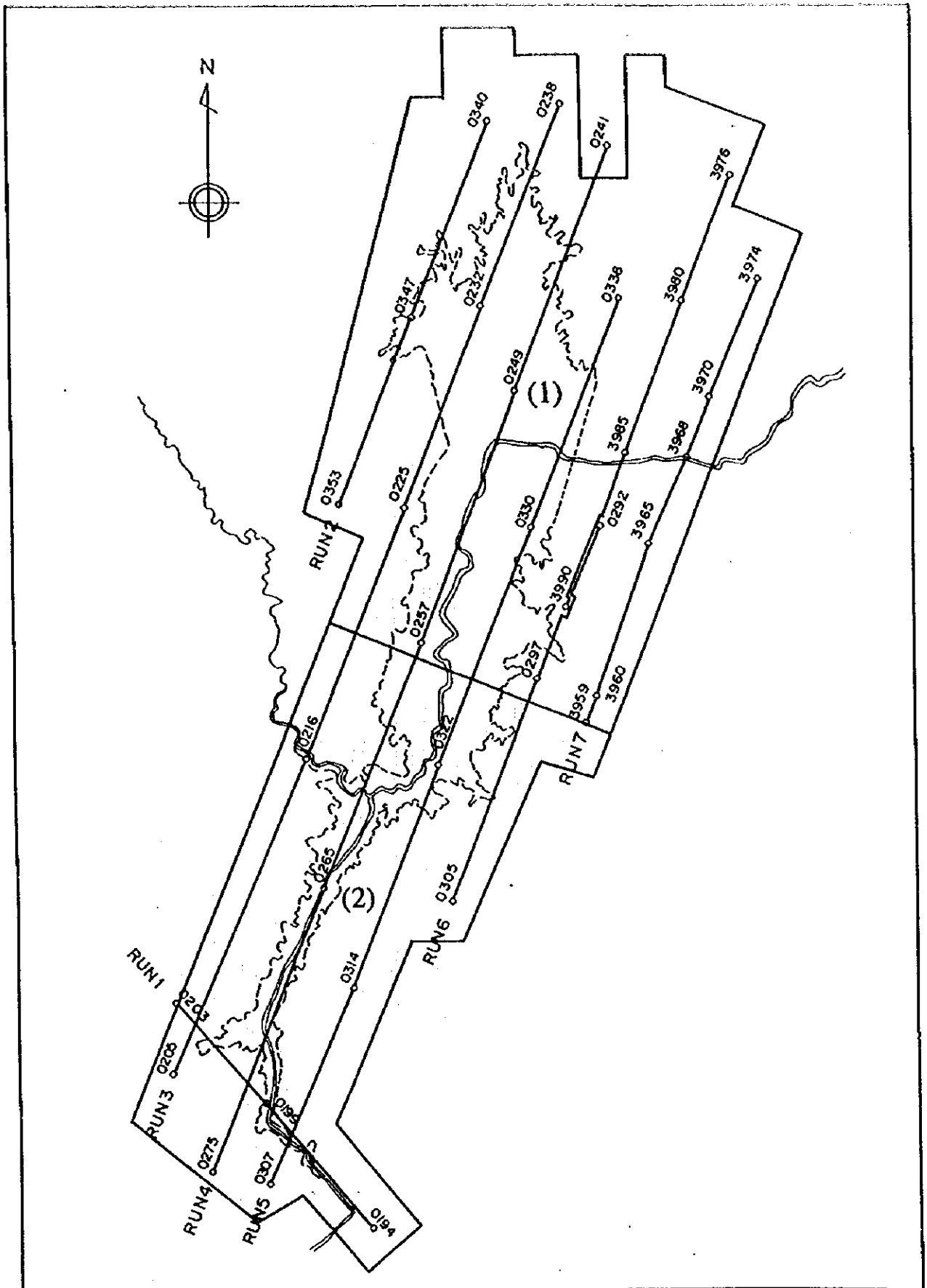
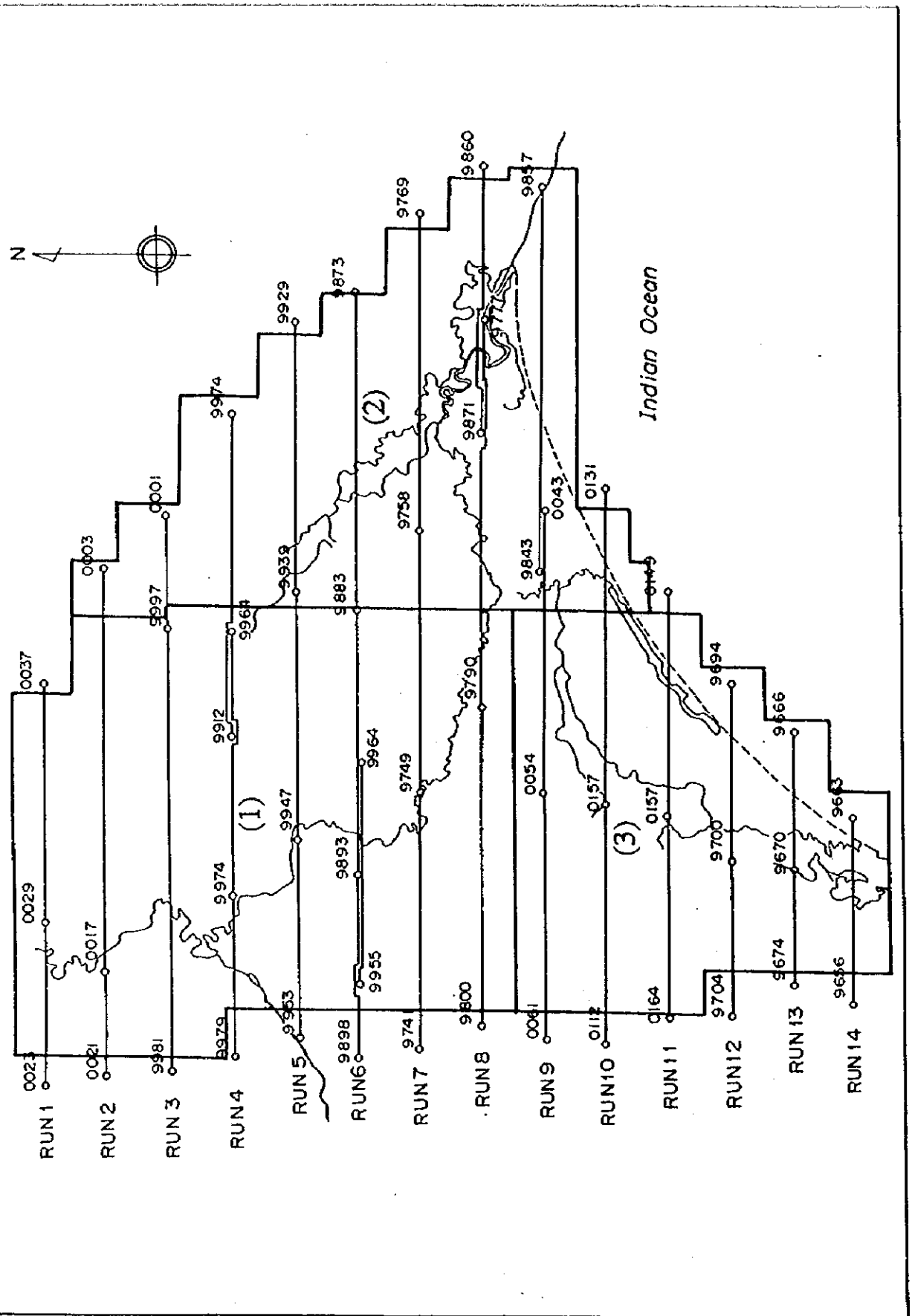


Photo Scole 1 : 50,000

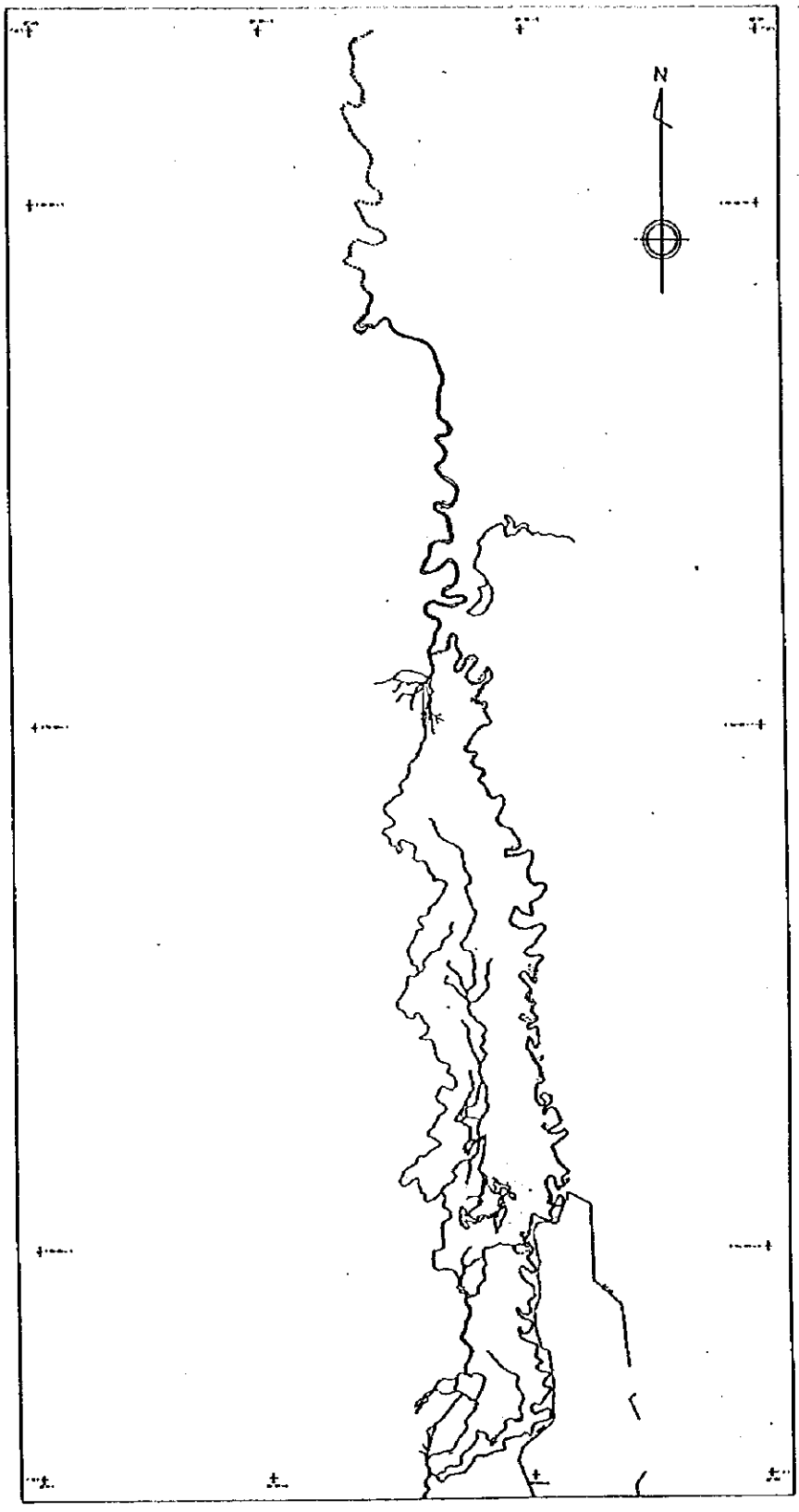
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Diagram of Tana River Photo Mosaic	Fig. No. A5.1



JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Diagram of Grand Falls Photo Mosaic	Fig. No. A5.2



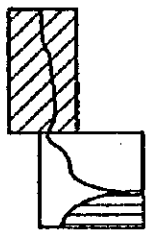
JAPAN INTERNATIONAL COOPERATION AGENCY	Diagram of Tana Delta Photo Mosaic	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		A5.3



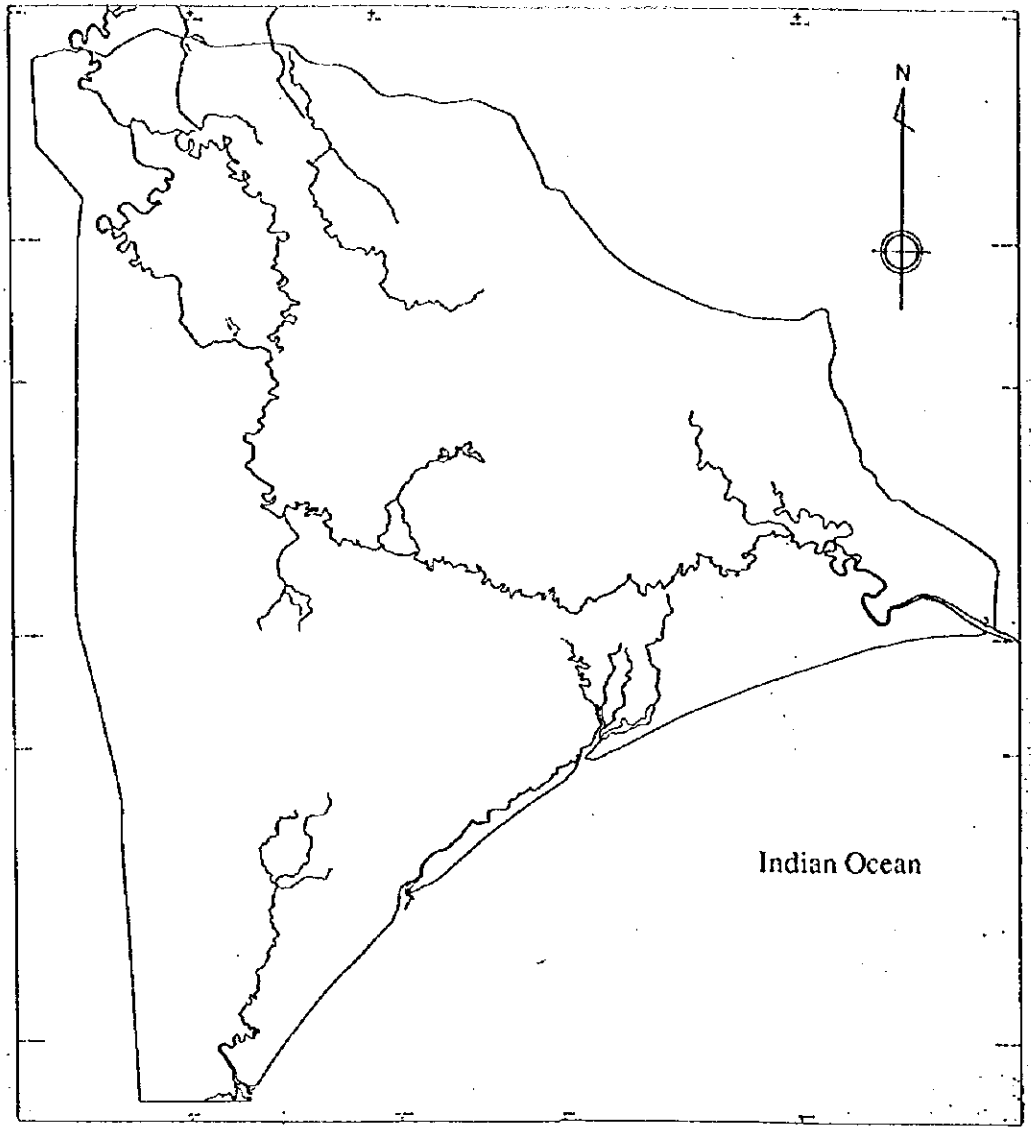
Tana River

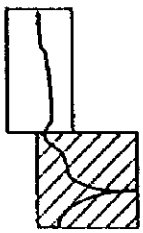
River traced from 1:50,000 scale maps 1980 - 81

Details traced from aerial photography 1992 and 1994



JAPAN INTERNATIONAL COOPERATION AGENCY	River Comparison Maps of Tana Delta	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		A5.4 (1)



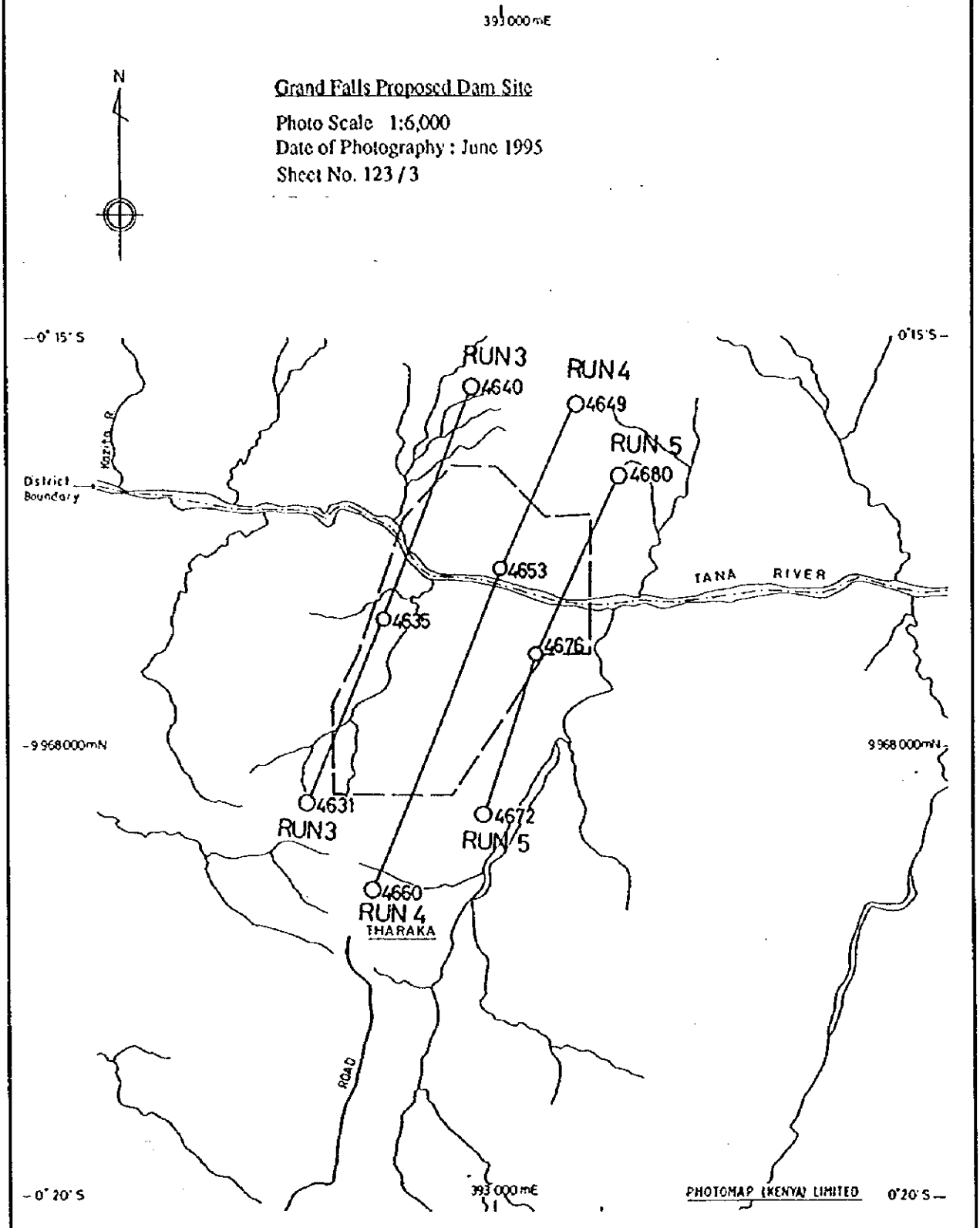


Tana River

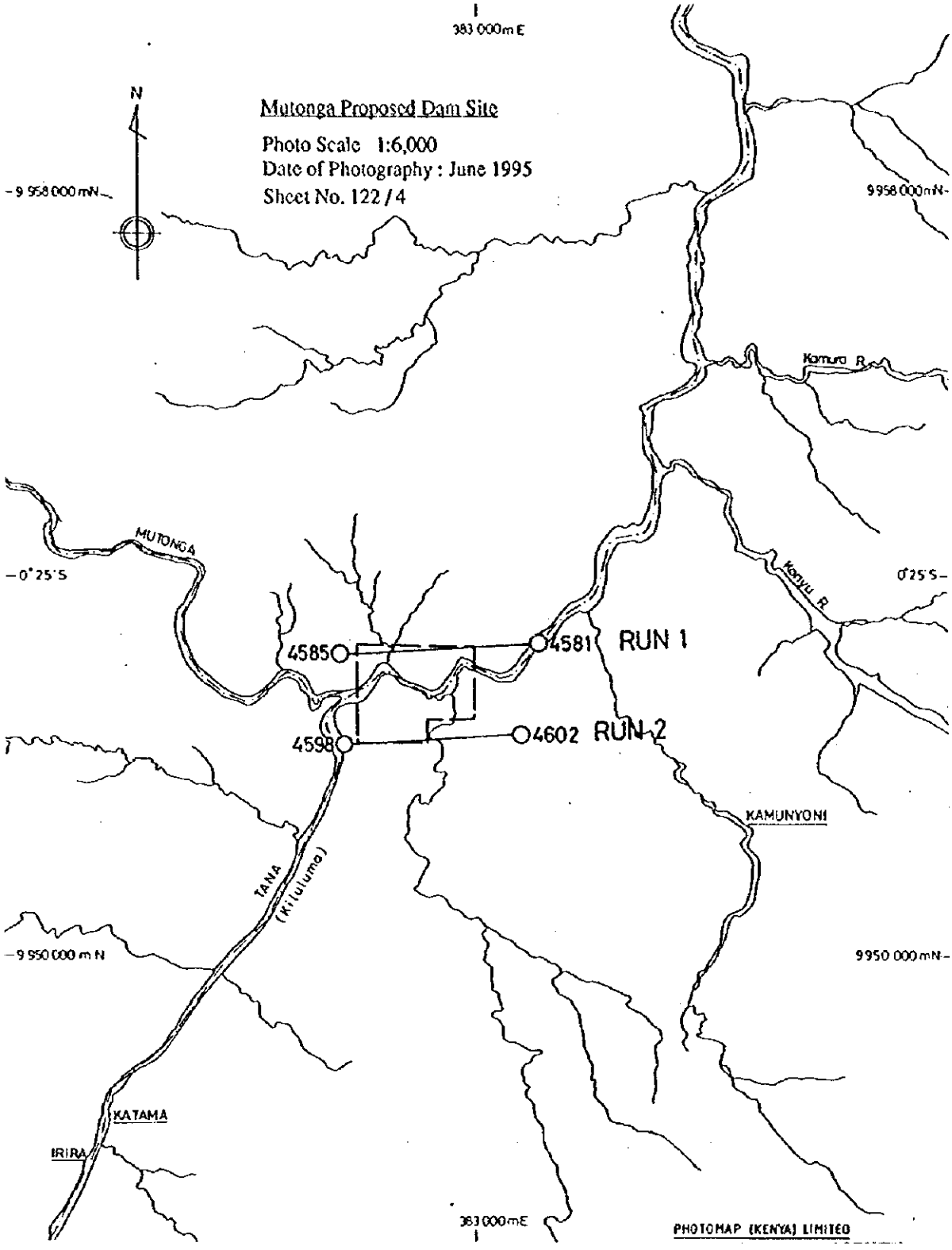
River traced from 1:50,000 scale maps 1980 - 81

Details traced from aerial photography 1992 and 1994

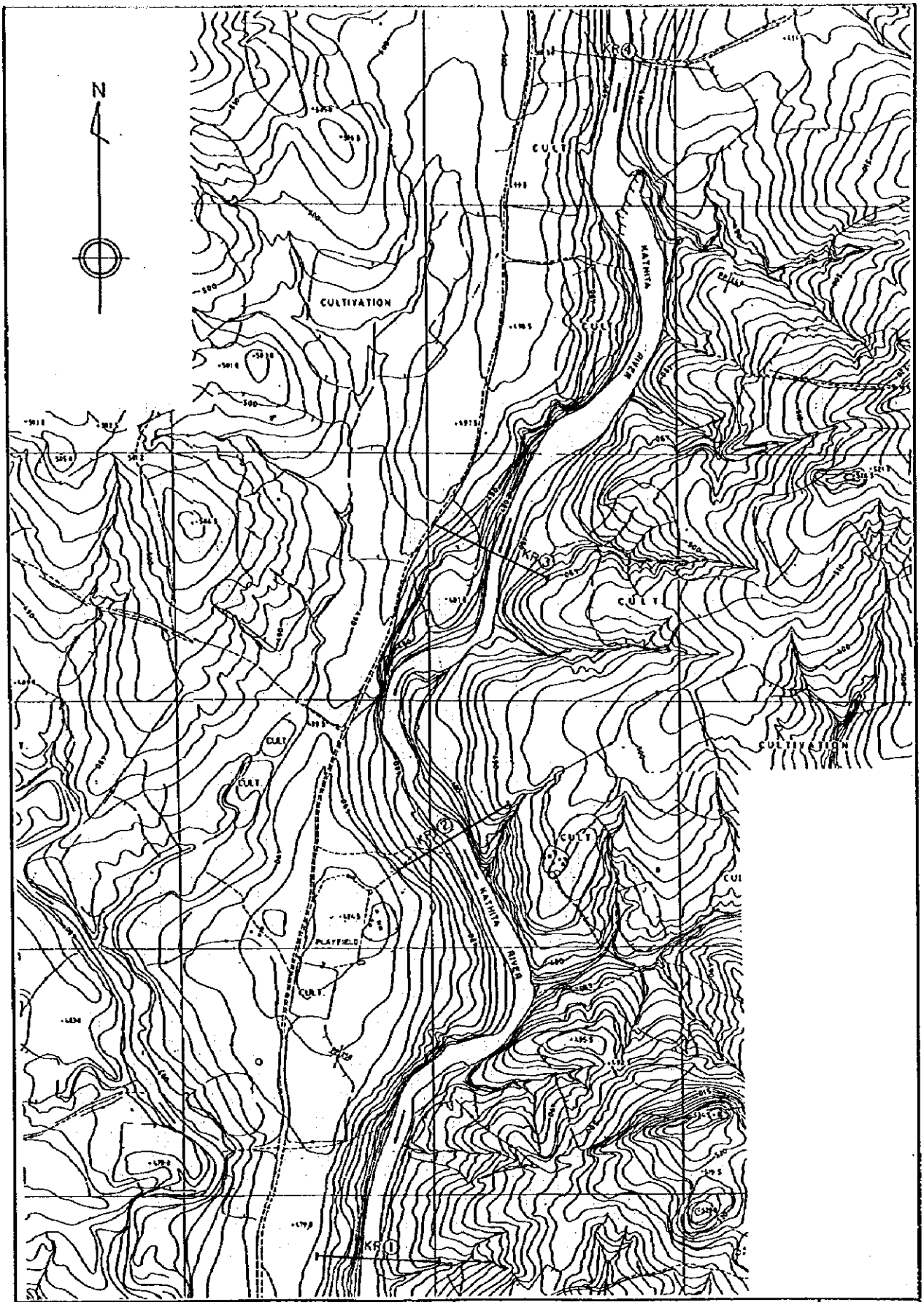
JAPAN INTERNATIONAL COOPERATION AGENCY	River Comparison Maps of Tana Delta	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		A5.4 (2)



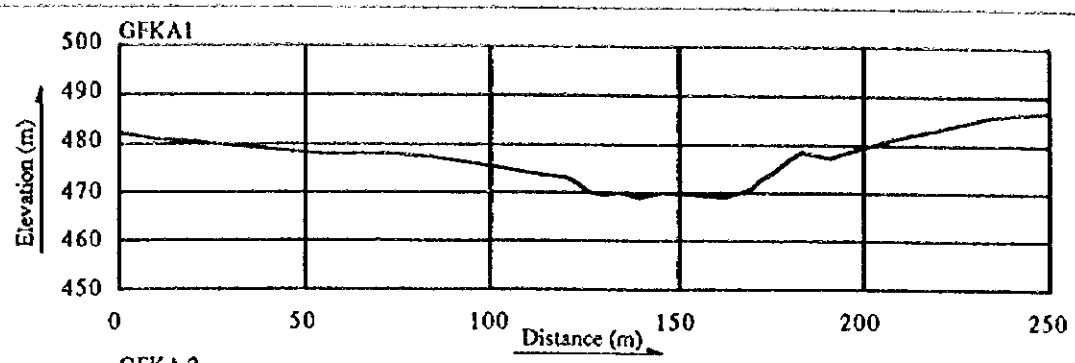
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Aerial Photo Index Map of Grand Falls Dam Site	Fig. No. A6.1

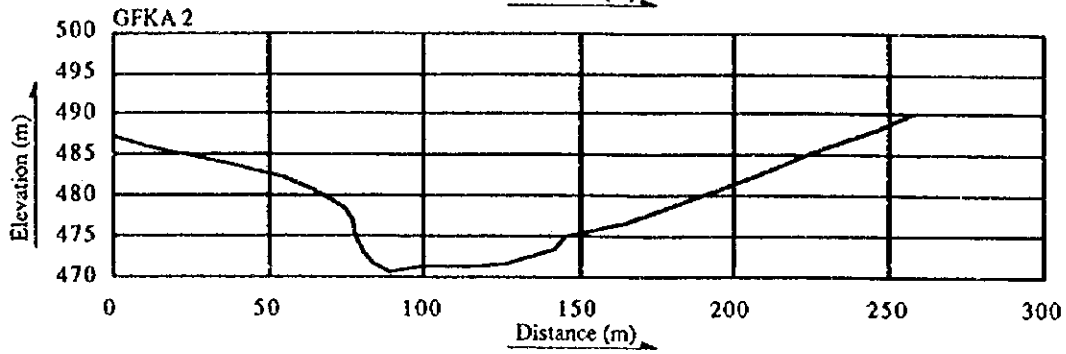


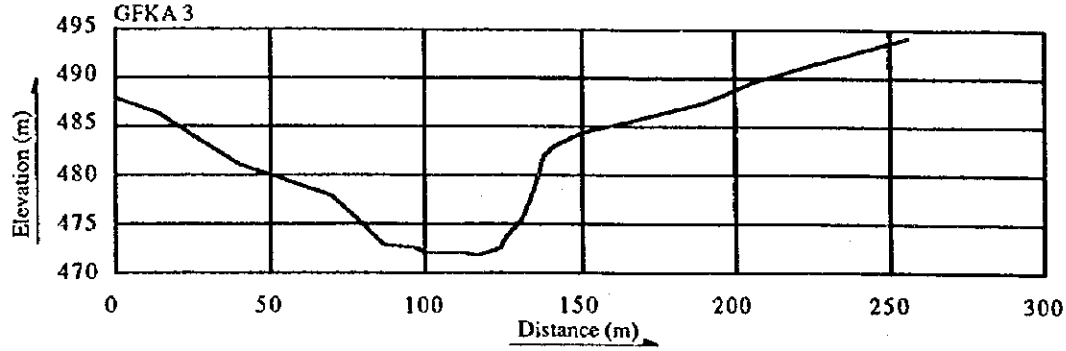
JAPAN INTERNATIONAL COOPERATION AGENCY	Aerial Photo Index Map of Mutonga Dam Site	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		A6.2

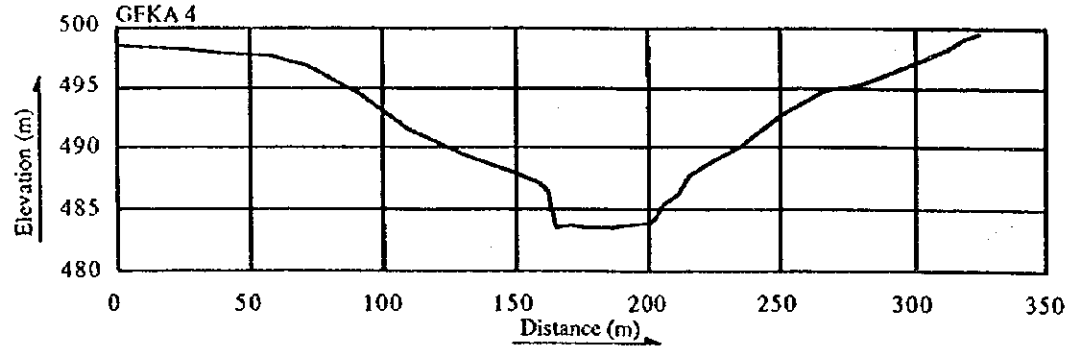


JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Location Map of River Cross Section for Kathta River	Fig. No. A6.3

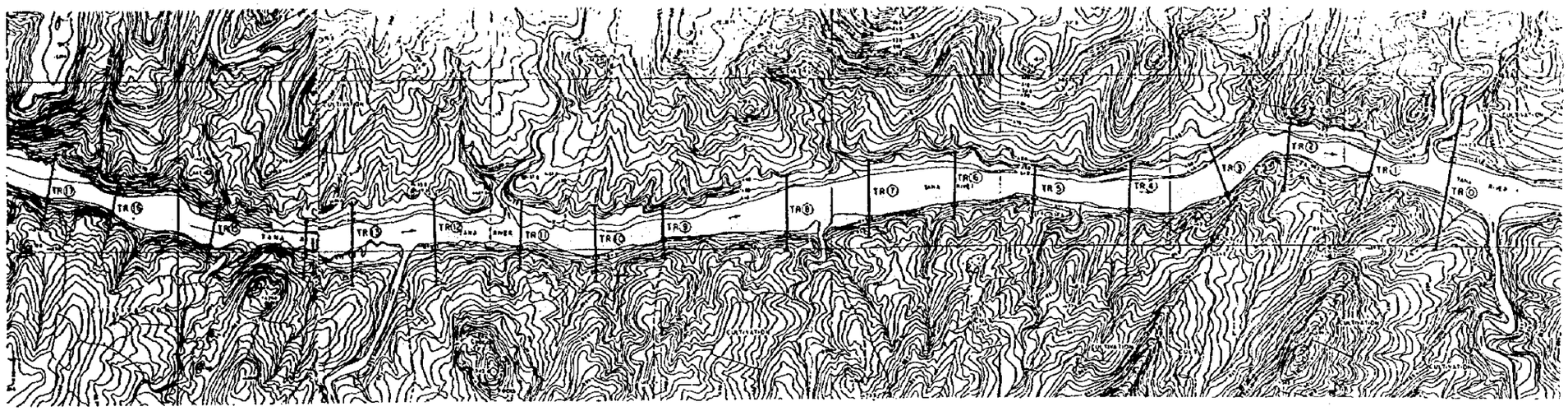




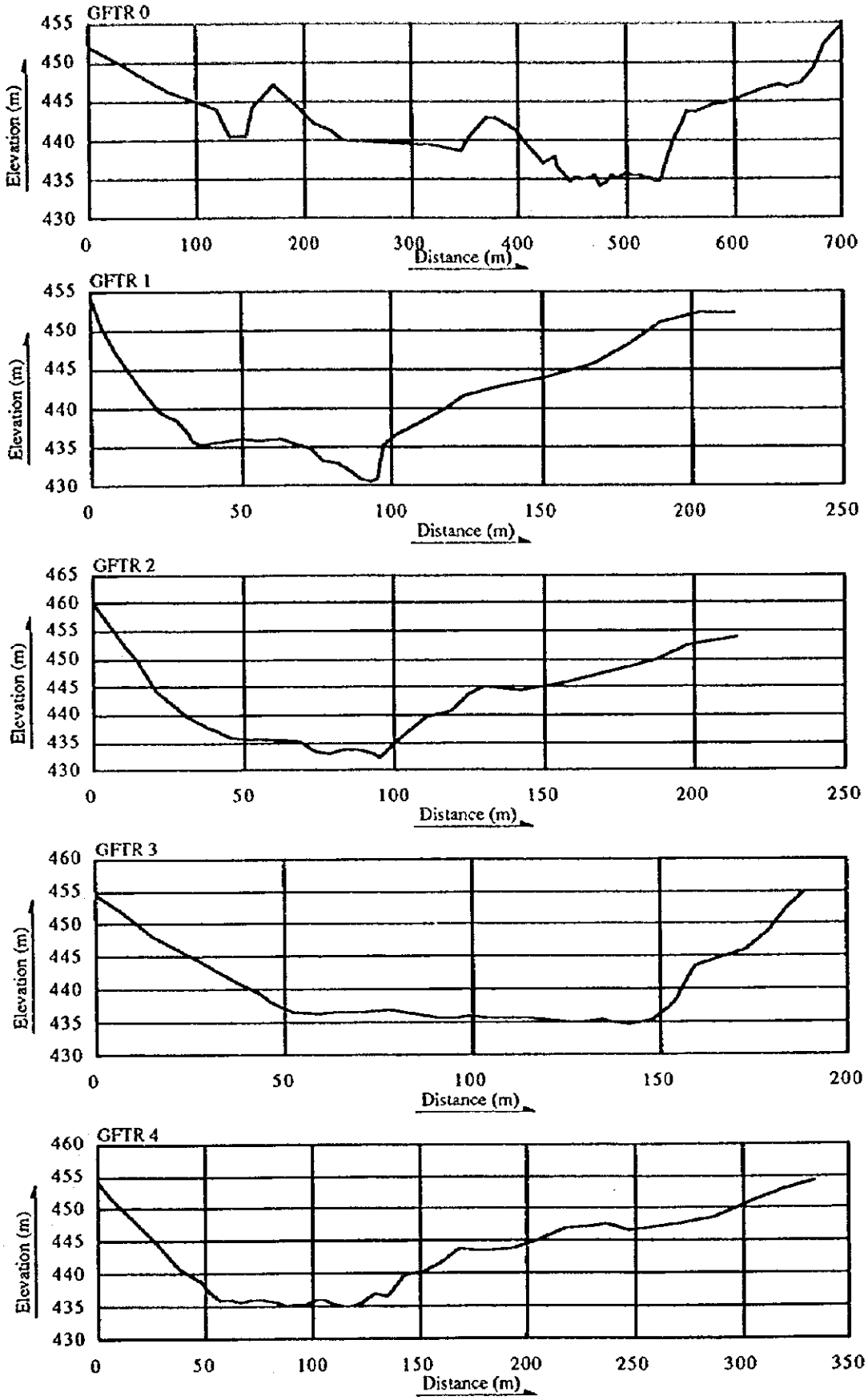




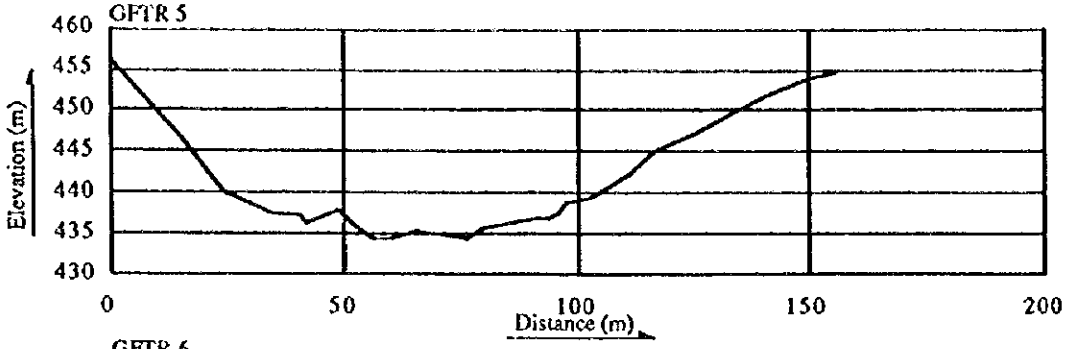
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	River Cross Section for Kathta River	Fig. No. A6.4

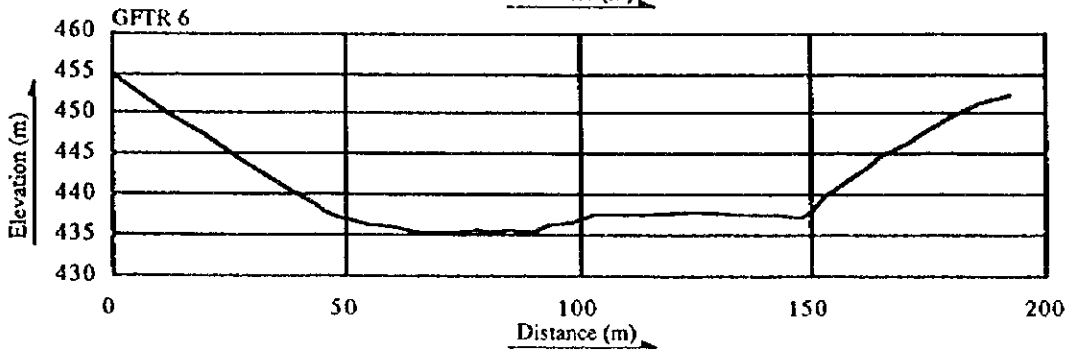


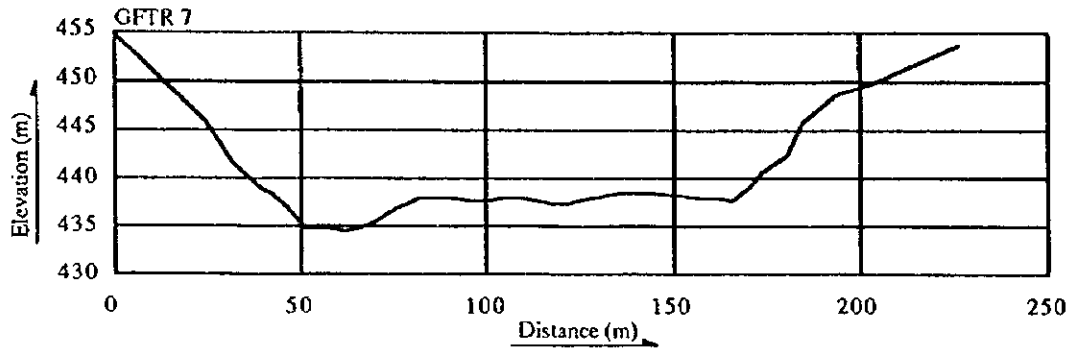
JAPAN INTERNATIONAL COOPERATION AGENCY	Location Map of River Cross Section for Tana River	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		A6.5

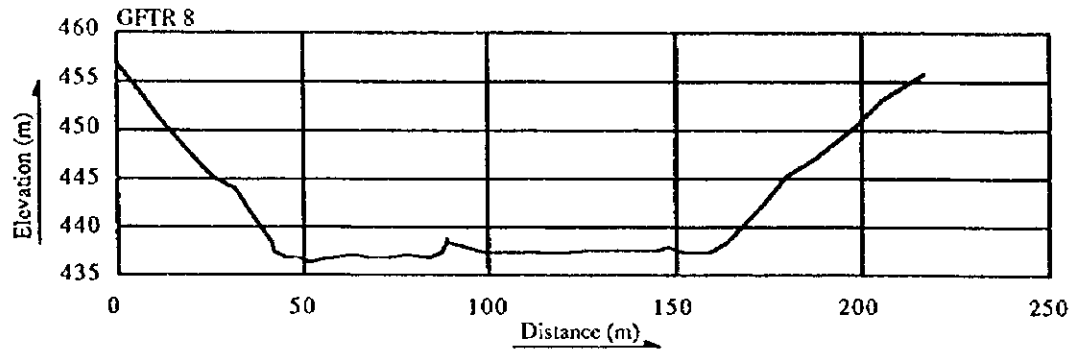


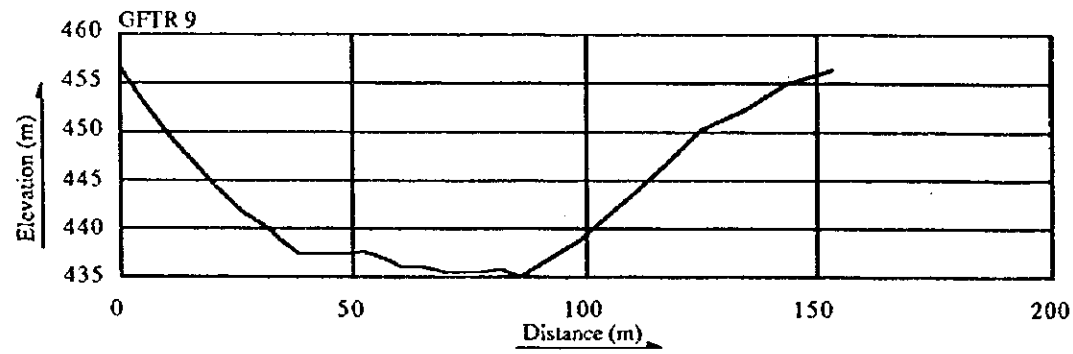
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	River Cross Section for Tana River	Fig. No. A6.6 (1)



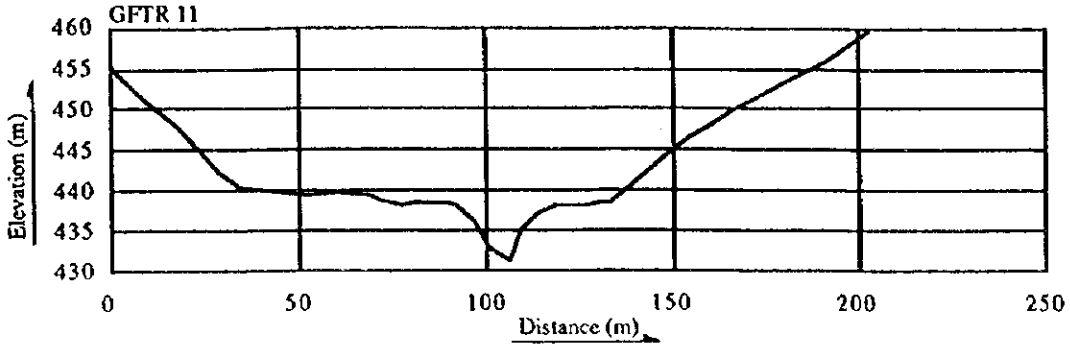


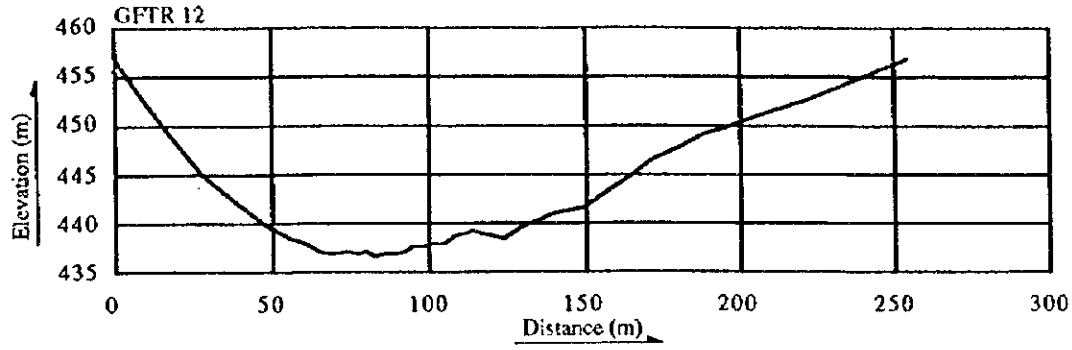


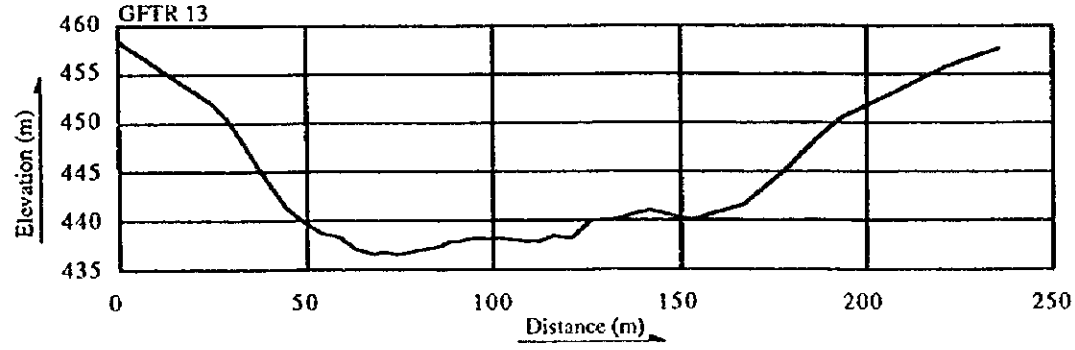


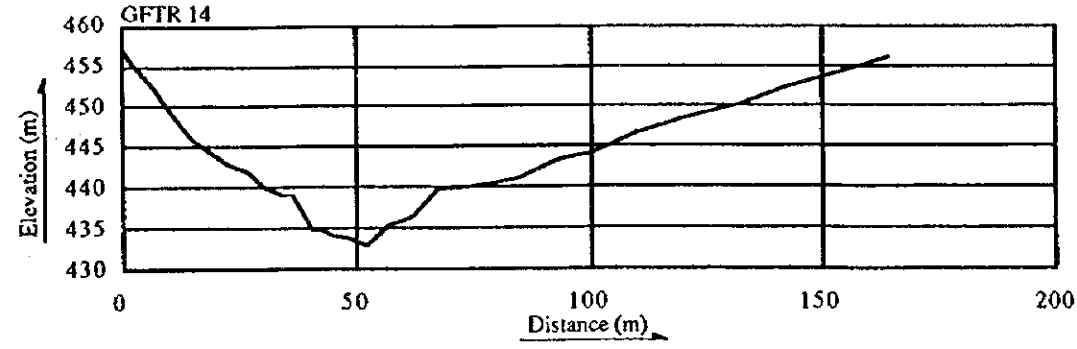


JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	River Cross Section for Tana River	Fig. No. A6.6 (2)

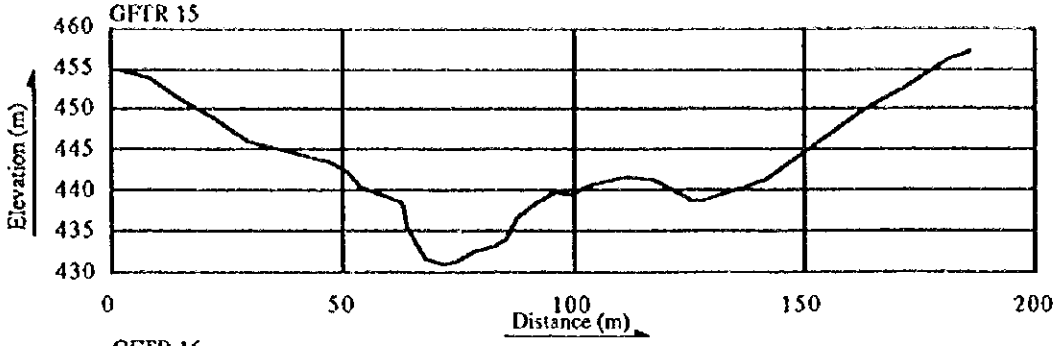


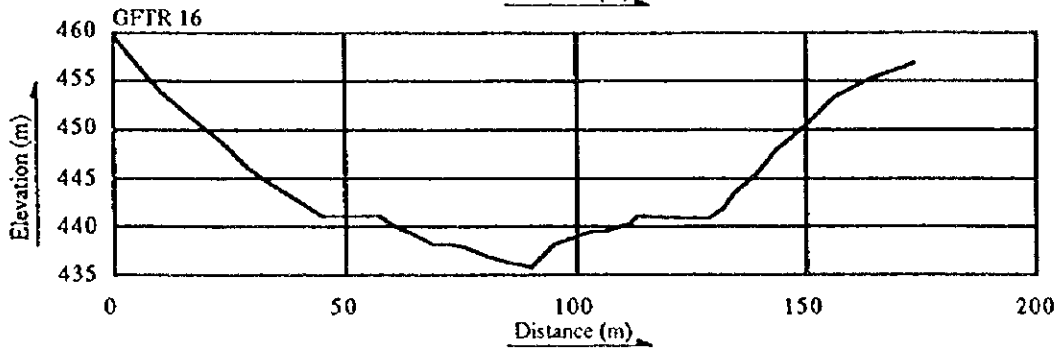


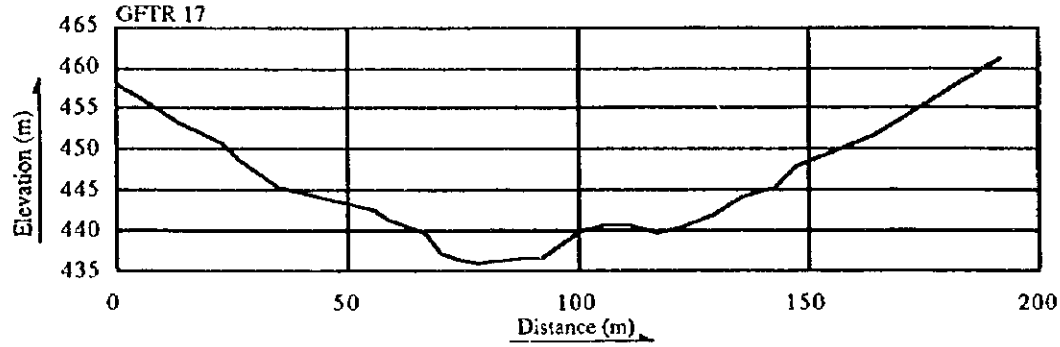


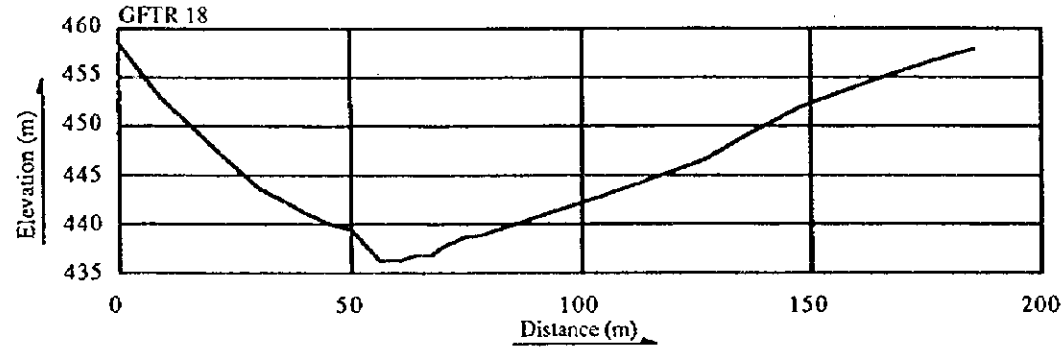


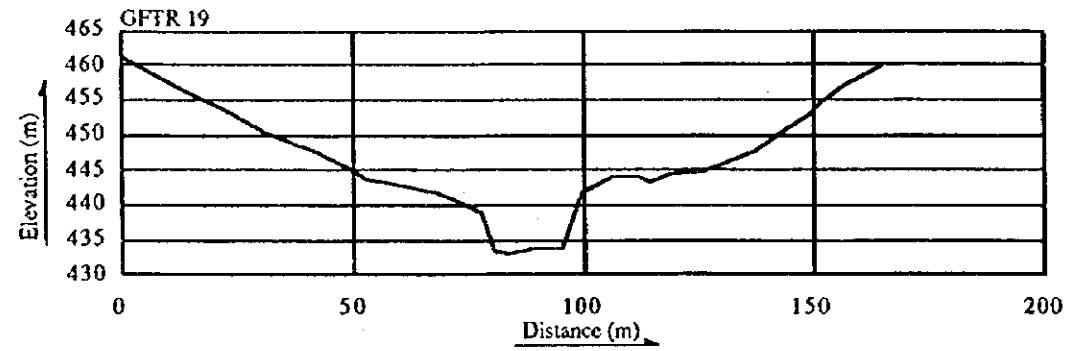
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	River Cross Section for Tana River	Fig. No. A6.6 (3)



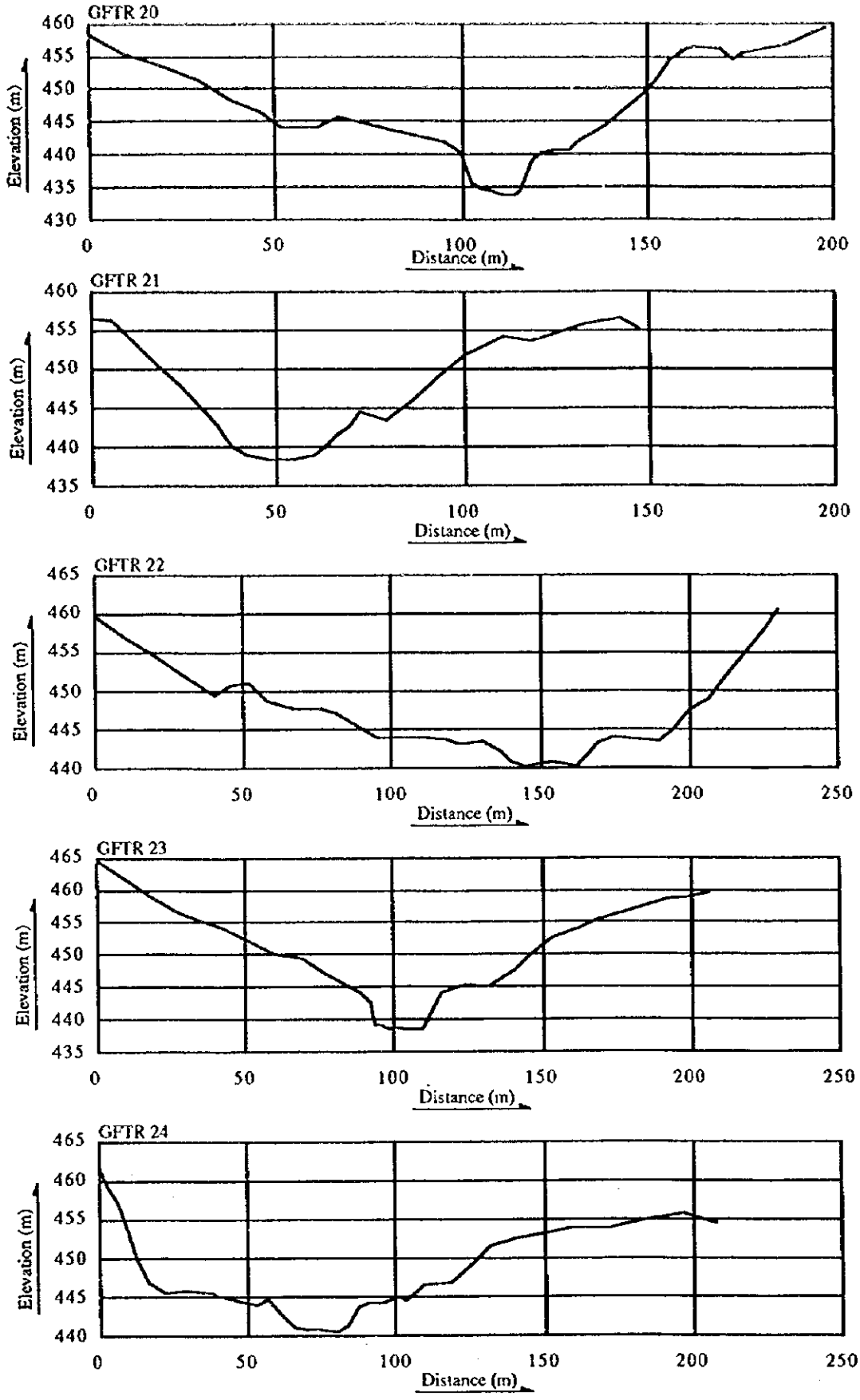




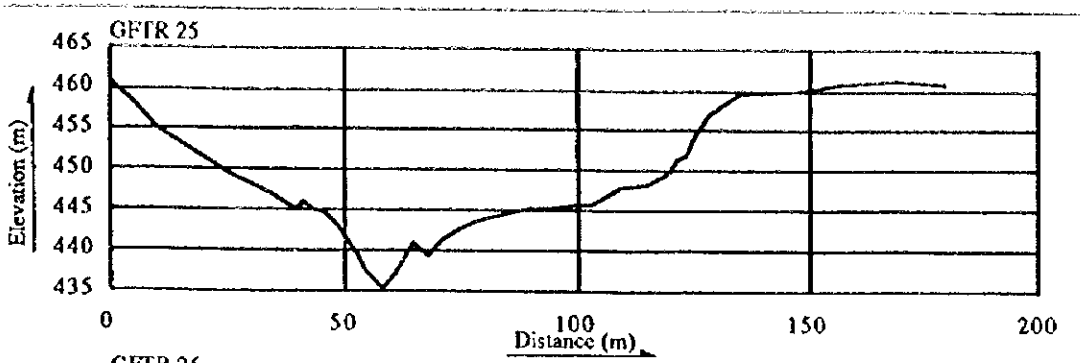


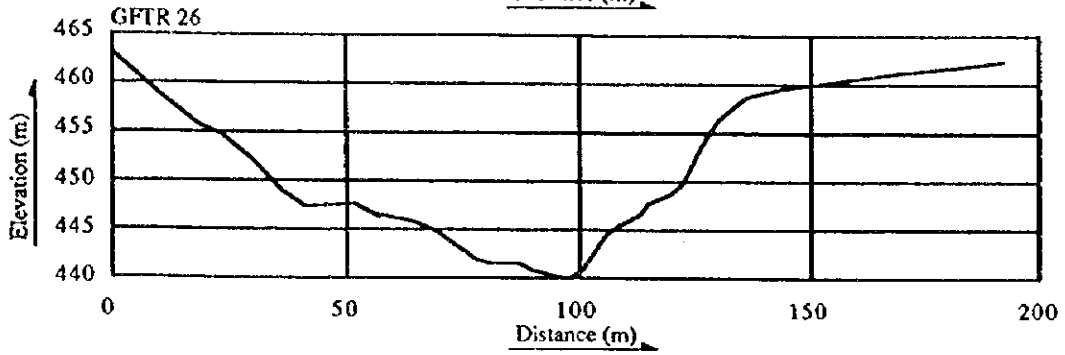


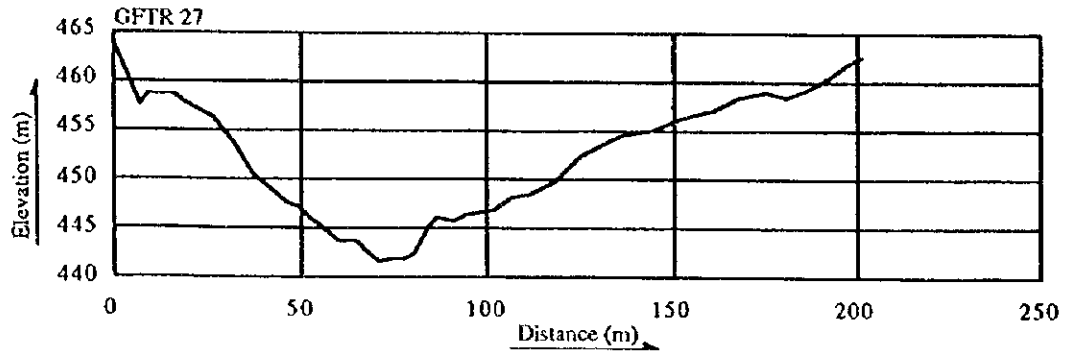
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	River Cross Section for Tana River	Fig. No. A6.6 (4)

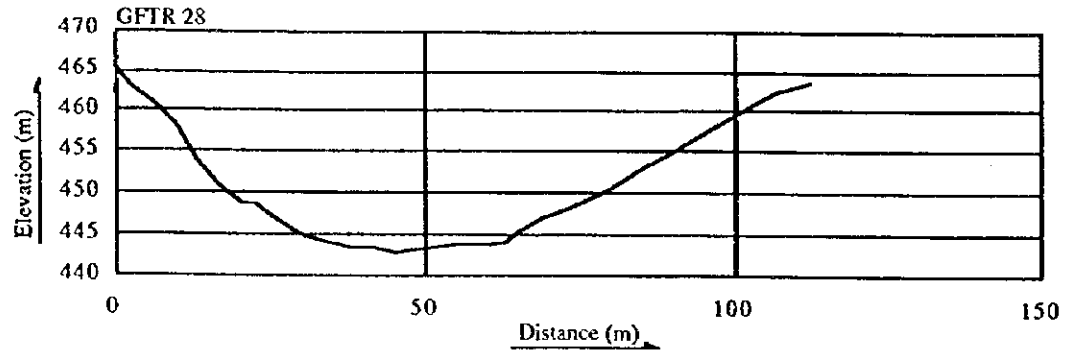


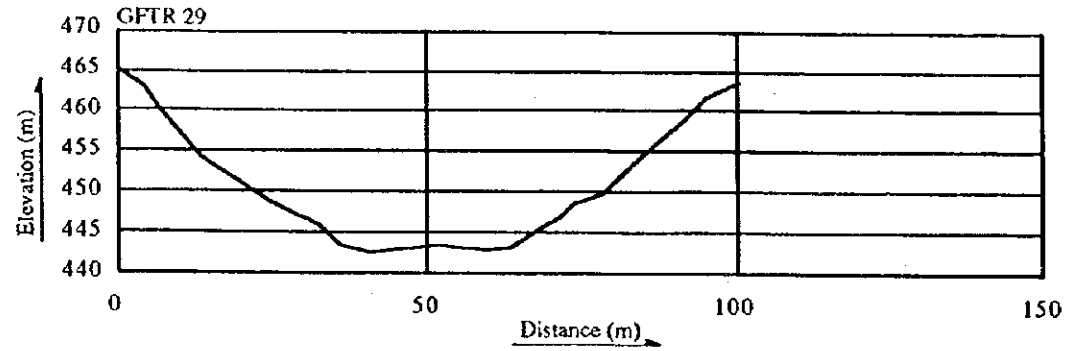
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	River Cross Section for Tana River	Fig. No. A6.6 (5)



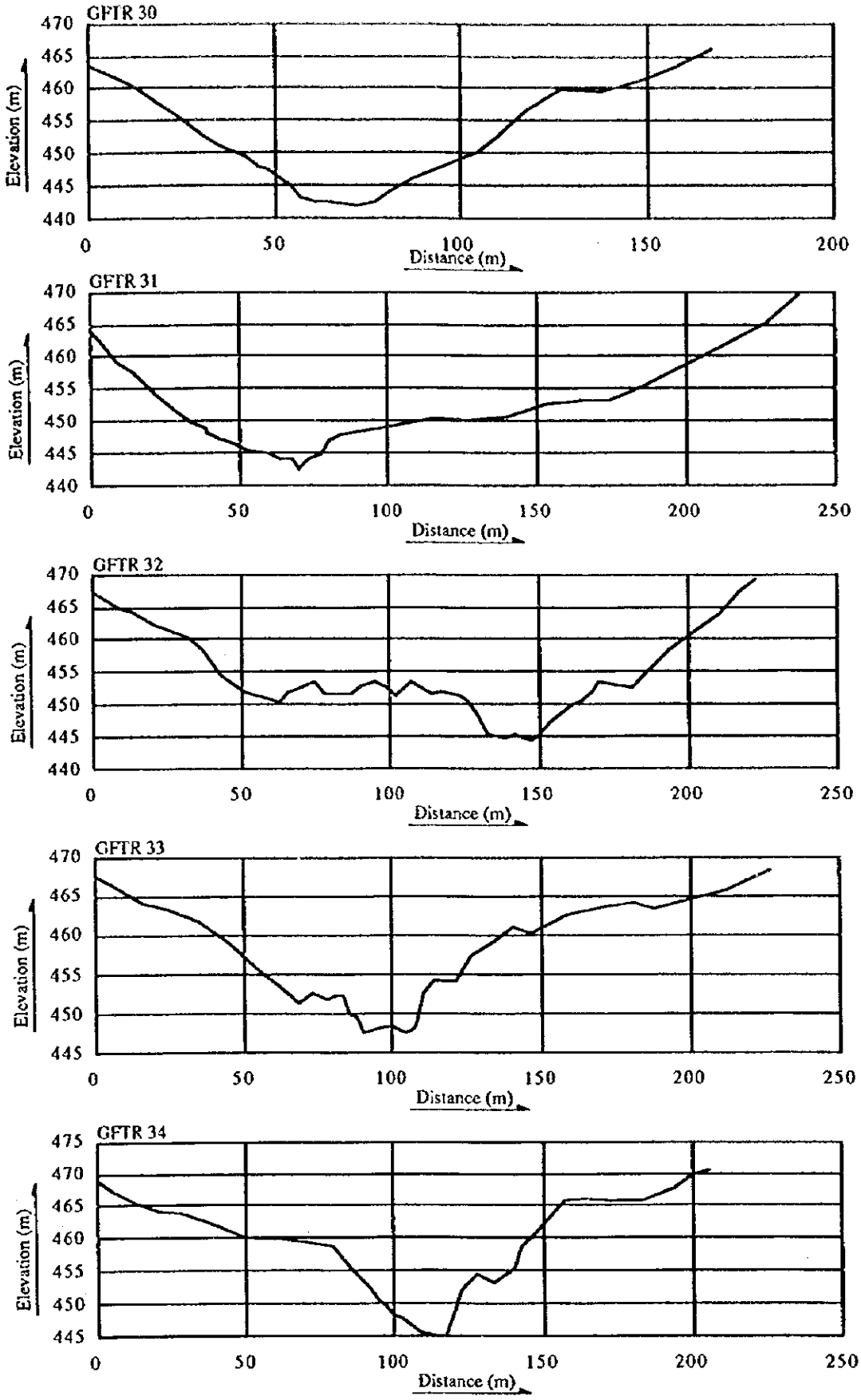








JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	River Cross Section for Tana River	Fig. No. A6.6 (6)



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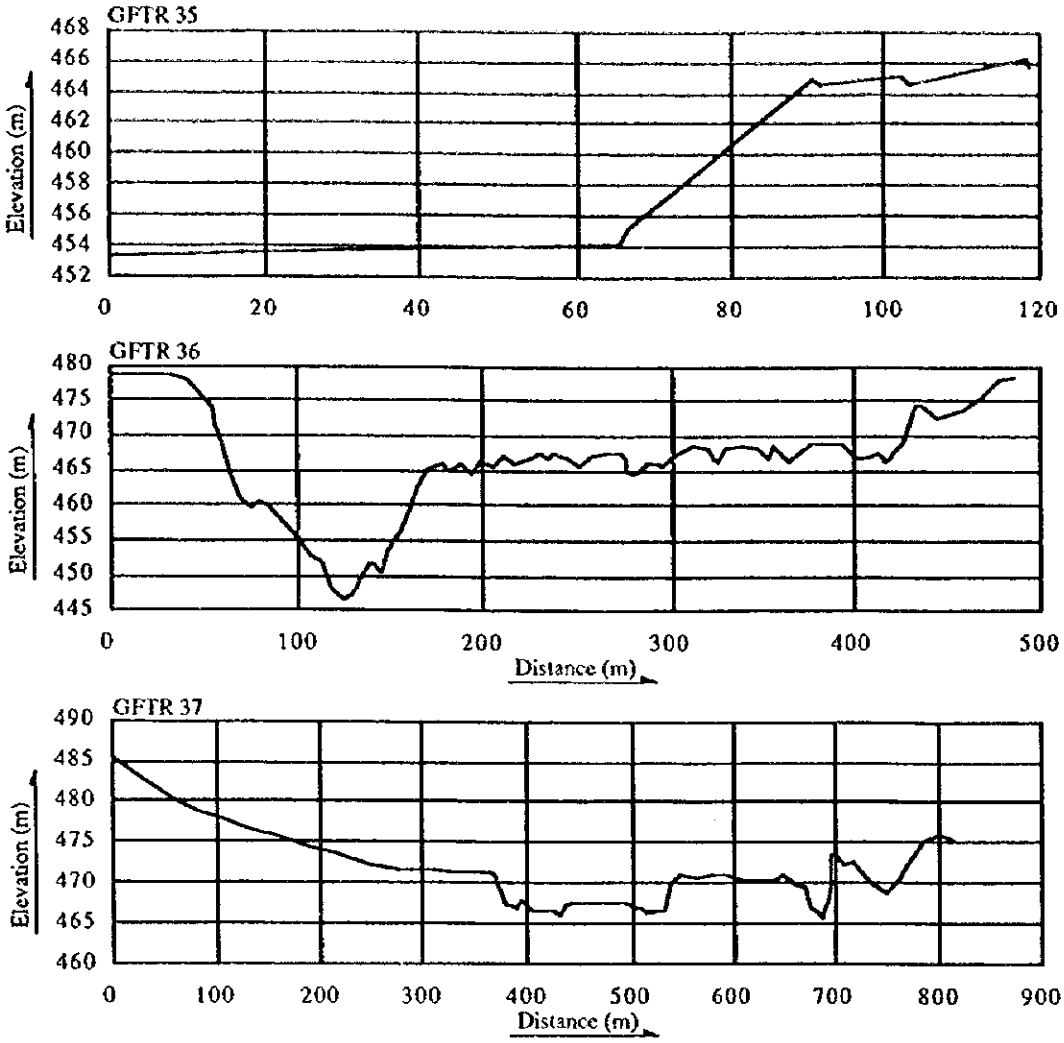

JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	River Cross Section for Tana River	Fig. No. A6.6 (8)

ANNEX - B

HYDROLOGICAL ANALYSIS

ANNEX-B HYDROLOGICAL ANALYSIS

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B1 BACKGROUND

The initial hydrological study for the Mutonga/Grand Falls Hydropower Project was carried out between the middle of February 1994 and the end of March 1995 in the context of a prefeasibility study. The initial hydrological study covered mainly the estimate of long-term streamflow on a monthly basis, flood analysis and estimate of sediment transport at the proposed Grand Falls and Mutonga dam sites at a level of prefeasibility study.

In succession to the initial hydrological study, the additional hydrological investigation was carried out for the period from the early June 1995 to the middle of July 1995 in order to raise up the study level to that of the feasibility study. During the field investigation, an focus was placed on collection of supplemental meteo-hydrological data and information and clarification of the inconsistent data found out in the course of the previous study stages. The field investigation was performed in collaboration with counterpart personnel of TARDA to gather the meteo-hydrological data and information as much as possible from the concerned governmental organizations of Kenya. After then, the consistency of those meteo-hydrological data were carefully checked in the subsequent home office work to finally determine those to be applied to the hydrological analysis at a level of feasibility study.

In the present hydrological analysis, the simulation models were attempted to be applied to the low flow analysis for estimating the long-term naturalized streamflows and probable floods analysis at the planned Grand Falls and Mutonga dam sites. Concerning the low flow, the Tank Model was used to generate the long-term daily discharges from daily rainfalls. While, the Storage Function Model was applied to estimate the probable floods at the planned dam sites for the different return periods. These simulation models have been widely used in the water resources development projects not only in Japan, but also in other countries.

The hydrological analysis carried out in the present study stage comprises the following:

- Low flow analysis for estimating the long-term daily discharges at the proposed Mutonga and Grand Falls dam sites by means of the Tank Model to simulate runoff from rainfall,

- Flood analysis for estimating the probable floods of different return periods at the proposed Mutonga and Grand Falls dam sites by means of the frequency analysis for the annual maximum peak discharges recorded in the upper Tana basin and the Storage Function Model

- Sedimentation study for estimating the long-term sediment transport at the planned dam sites applying the suspended load rating curves, which show a relation between the mean daily discharge and daily suspended load yield

This Appendix-B compiles all the results of the hydrological investigation performed in the present feasibility study for the Mutonga/Grand Falls Hydropower Project.