GEOSERVICES
MARITIME PVT. LTD.

REPORT ON TOPOGRAPHIC & BATHYMETRIC SURVEY FOR ASSESSMENT OF RESERVOIR CAPACITY & SEDIMENTATION IN KAKDIAMBA RESERVOIR, GUJARAT, INDIA UNDER NATIONAL HYDROLOGY PROJECT

GMPL REPORT NUMBER: P-SUR-BATHY-004-2020-WRD-KAKDIAMBA
SURVEY PERIOD: 27 OCT TO 29 OCT 2020

Prepared for:	**Water Resources Investigation Division, Ahmedabad** **(Govt. of Gujarat)** **Narmada Water Resources, Water Supply and Kalpsar Department**	Equity Efficiency Sustainability WRD
Client Reference:	**Executive Engineer** **Water resources investigation Division Ahmedabad.** **Deputy Executive Engineer** **River Gauging Sub Division Navsari.**	

LOCATION MAP

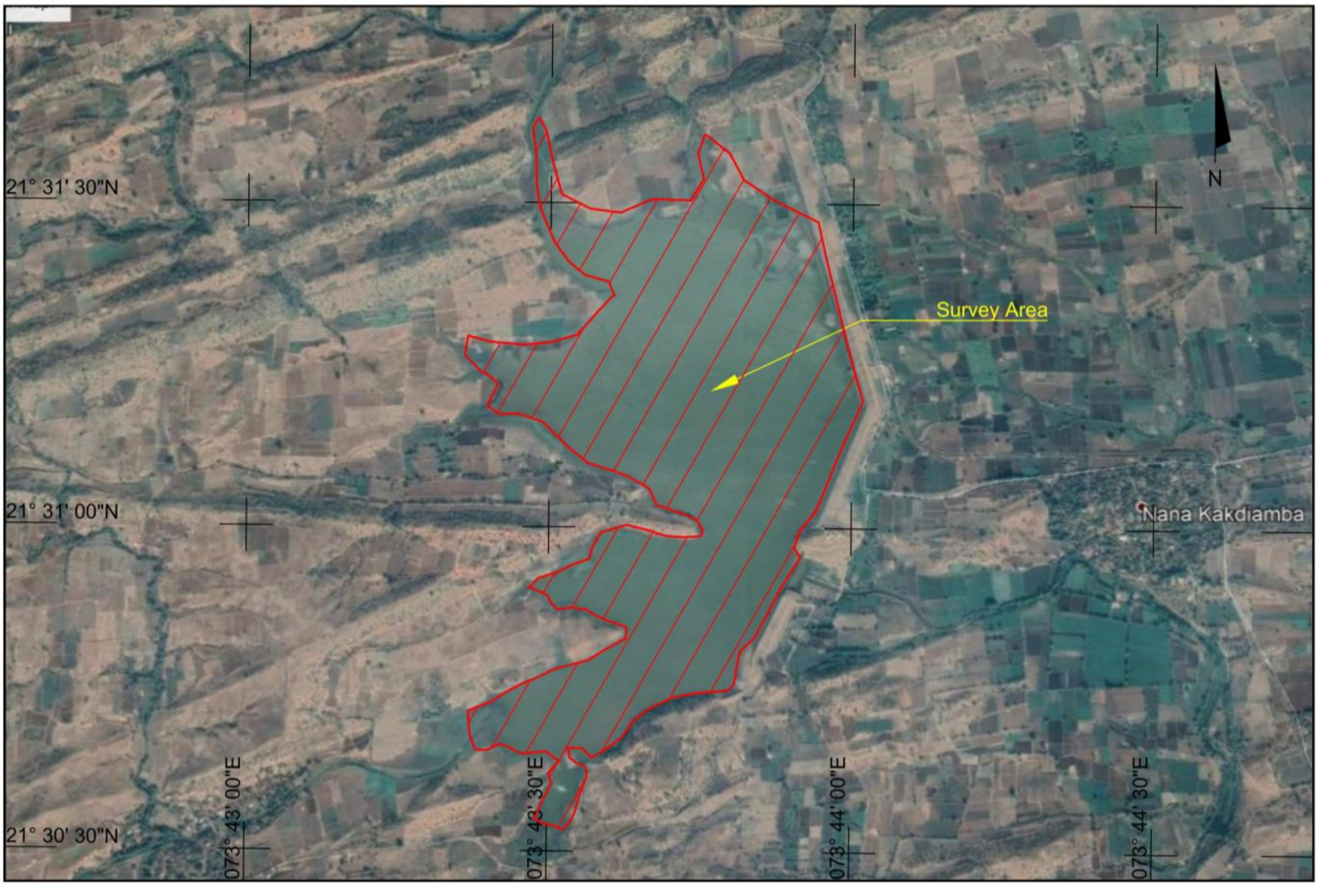

Figure 1.1-1 LOCATION MAP

LOCATION MAP SHOWING SURVEY AREA "KAKDIAMBA RESERVOIR", GURAJAT, INDIA

DOCUMENT ARRANGEMENT

REPORT OF SURVEY WITH CHART / DRAWING

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1 INTRODUCTION, OBJECTIVE & SCOPE OF WORK

1.1 General

Water Resources Investigation Division (WRD) has awarded the contract to Geoservices Maritime Pvt Ltd (GMPL), Navi Mumbai for carrying out Topographic and Bathymetric Survey at Kakdiamba Reservoir, Gujarat. The survey services provided by GMPL comprise of the provision of well-qualified survey personnel and equipment in order to obtain, interpret and report on acquired topographic & bathymetric survey data at the client specified locations.

This report contains the results of survey as against the scope of work and the methodology adopted to achieve the specifications and schedule of the survey work undertaken at Kakdiamba Reservoir.

1.1.1 LIST OF ABBREVIATIONS USED

CM	Central Meridian
DGPS	Differential Global Positioning System
CSRS	Canadian Spatial Reference System
FRL	Full Reservoir Level
GMPL	Geoservices Maritime Private Limited
GPS	Global Positioning System
HDOP	Horizontal Dilution of Precision
KHz	Kilohertz
HSE	Health Safety Environment
MSL	Mean Sea Level
m	metre
M Cu. m	Million Cubic metre
Sq. Km	Square Kilometre
MDDL	Minimum Draw Down Level
m/s	meter per second
ms	milliseconds
MWL	Maximum Water Level
QA/QC	Quality Assurance / Quality Control
Rev	Revision
RTK	Real Time Kinematic
SBES	Single Beam Echo Sounder
TBM	Temporary Bench Mark
UTM	Universal Transverse Mercator
WGS 84	World Geodetic System 1984
WRD	Water Resources Investigation Division

1.1.2 Units

- UTM grid coordinates and all linear measurements expressed in metres (m).
- Angular values expressed in degrees (°).
- Time and dates expressed as "09:00 on 24 Jan 2021".

1.2 Objective

The client's objectives were:

i) To estimate and study the sedimentation behaviour of reservoir in different zones including horizontal zones throughout the reservoir as well as vertical zones namely dead storage, live storage and flood storage if any.

ii) To upgrade Elevation-Area-Capacity table and curves of the reservoir at regular intervals.

iii) To emphasize on the importance of conducting hydrographic surveys at regular intervals for better operation and water management of the reservoir.

1.3 Scope of Work

The Scope of work for Geoservices Maritime Pvt Ltd was to mobilise, install, interface, operate all survey systems and provide all required survey personnel to undertake Topographic and Bathymetric survey services at Jhuj Reservoir.

The detailed scope of work was:

i) To measure the water depth of the Jhuj Reservoir at with respect to MSL.

ii) Line spacing shall be 25 m with continues echo sounding.

iii) Reservoir for water level changes during survey shall be tabulated.

iv) Data processing using HYPACK software.

v) Topographic survey shall be conducted from FRL water level with reasonable overlap with hydrographic survey.

vi) The area not covered under Hydrographic survey up to Maximum Water Level (MWL) shall be surveyed by taking levels at 25 m interval (25 m x 25 m grid).

vii) To carry out the data processing and interpretation of data and preparing of results, charts, drawings and report.

viii) Estimation of Sedimentation in the Reservoir shall be calculated if previous data is available.

ix) Gross and Live storage capacity of the Reservoir at every 0.10 m interval shall be provided.

x) Cross Sections showing the bed profile at 100 m interval shall be prepared.

xi) L-Section of the Reservoir may be prepared with lowest bed level at every survey line.

2 SALIENT FEATURES OF KAKDIAMBA RESERVOIR

Kakdiamba Irrigation Scheme envisage construction of Dam across river Wagti a tributary of river Kaveri near village Nana Kakdiamba of Sagbara Taluka of Narmada district in Gujarat. The scheme was impounded in the year 1984, and the project is mainly for irrigation.

The total Catchment Area of Kakdiamba Reservoir is 24.22 Sq. Km. The Full Reservoir Level (FRL) is 186.71 m at impounding and 186.71 m after installation of fuse gates and Minimum Draw Down Level (MDDL) is 177.21 m. The gross storage capacity at time of impounding was 7.87 M Cu. m. and after installation of fuse gates was 9.37 M Cu. m. The dead storage was 0.65 M Cu. m. and live storage was 7.22 M Cu. m. m at time of impounding and 8.72 M Cu. m. m after installation of fuse gates.

KAKDIAMBA IRRIGATION SCHEME			
I	**Location**		
	Coordinates	Latitude 21°24' N Longitude 73°44' E	
	River	Wagti	
	Village	Nana Kakdiamba	
	Taluka	Sagbara	
	District	Narmada	
II	**Reservoir Details**	**As per original project**	**After installation of fuse gates**
	Catchment Area	24.22 Sq. Km	24.22 Sq. Km
	Top of Dam	192.21 m	192.21 m
	HFL/MWL	188.71 m	188.71 m
	FRL	186.71 m	187.71 m
	MDDL	177.21 m	177.21 m
	River Bed Level	167.80 m	167.80 m
	Sill Level of Canal H.R	177.21 m	177.21 m
	Dead Storage Capacity	0.65 M Cu. m	0.65 M Cu. m
	Live Storage Capacity	7.22 M Cu. m	8.72 M Cu. m
	Gross Storage Capacity	7.87 M Cu. m	9.37 M Cu. m
	Area under submergence at FRL	136.00 Ha	145.00 Ha
III	**Spillway Details**	**As per original project**	**After installation of fuse gates**
	Length	100 m	100 m
	Crest level of Spillway	186.71 m	186.71 m
	Type of Spillway	Ogee	Broad Crest
	Maximum Discharge Capacity	800 Cumecs	674 Cumecs
	No. of Hydroplus fuse Gates	-	55
	Size of Hydroplus fuse Gates	-	1.80 m X 1.00 m
IV	**H.R. Outlet Details**		
	No. of H.R. Gates	2 (Service Gate & Emergency Gate)	
	Size of Gates	1.419 m X 1.419 m	
V	**Dam Details**		
	Type of Dam	Composite (Earthen & Masonary Dam)	
	Length of Earthen Dam	1843.00 m (L.H.S 1302 m & R.H.S 293.00 m)	
VI	**Canal Details**		
	Name of Main Canal	Rachhwada Distributary	

	Length of Main Canal	10.32 Km
	Designed Discharge	43.33 Cusec
	Number of Minor Canal	5
	Length of Distribution System	13.00 Km
	C.C.A of Project	799 Ha
	Number of Beneficiary Villages for Irrigation	15
	Name of Beneficiary Villages for Irrigation	1) Nana Doramba 2) Kuvadawadi 3) Simamli 4) Rozdev 5) Bhavrisvar 6) Dattwada 7) Kel 8) Pati 9) Pat 10) Tavel 11) Panchpipri 12) Ghodmung 13) Rachhwada 14) Nana Kakdiamba 15) Ranbuda
	Number of Piyat Sahkari Mandli	The Navjagruti Piyat Sahkari Mandli Ltd. Pankhala Tal. Sagbara
	Number of registered members in the Mandli	325
VII	**Details of affected villages during a flood**	
	Number of villages	10
	Name of villages	1) Nana Doramba 2) Kuvadawadi 3) Makran 4) Rozdev 5) Dattwada 6) Pati 7) Tavel 8) Ghodmung 9) Nani Devrupan 10) Nana Kakdiamba

Table 2-1 SALIENT FEATURES OF RESERVOIR

3 EXECUTIVE SUMMARY OF RESULTS

GMPL had mobilised their survey team, equipment and Survey Boat "Aqua Marina" which was deployed in the Kakdiamba Reservoir survey area from 27 Oct to 29 Oct 2020 to acquire bathymetric survey data and Topographic data as per mutually agreed scope and relevant survey specifications.

Geomax DGPS system, Reson Navisound Echo sounder (215 kHz) were utilised to acquire the bathymetric data within the Kakdiamba Reservoir area. A value of 1500 m/s was used as the average velocity of sound in water, which was applied in the setup during acquisition. The data so obtained was then processed and contouring was done using Hypack software. Geomax RTK / Auto level and Tripod were used for topographic survey in the area.

Topographic and bathymetric data was reduced to Mean Sea Level (MSL). All the data is plotted on scale of 1:5000 for Kakdiamba reservoir area.

Four (4) hours of DGPS observation was carried out on OBS Kakdiamba (Levelling was carried out from fuse gate to above mention observation point and level of fuse gate was provided by Dam Authority). Two (2) Temporary Bench Marks, TBM 1(near Guesthouse-below the bottom off EWNS direction structure) and TBM 2 (near Head Regulator Control cabin) were set up.

The values depicted in the charts are the elevation with respect to MSL.

- The Minimum elevation within Kakdiamba reservoir is 176.73 m above MSL and
- The Maximum depth within Kakdiamba reservoir is 10.98 m.
- Area covered by bathymetric survey is 1.44 Sq. Km.
- Area covered by topographic survey is 0.21 Sq. Km.

According to recent survey, total area of reservoir at FRL 186.71 m (at impounding) and FRL 187.71m (after installation of fuse gates) is 1.287 Sq. Km and 1.441 Sq. Km respectively, corresponding storage capacity is 5.948 M Cu. m and 7.311 M Cu. m respectively. In addition, Dead storage at 177.21m is 0.019 M Cu. m.

The comparison between 1985 and 2020 (35 years) data results in a rate of siltation (silt index) of 22.673 Ham/100 Sq. Km/year. Annual percentage loss of gross storage capacity, live storage capacity and dead storage capacity is 0.70%, 0.51% and 2.77% respectively for FRL 186.71 m (at impounding). And for FRL 187.71 m (after installation of fuse gates) rate of siltation (silt index) is 24.29 Ham/100 Sq. Km/year whereas annual percentage loss in gross storage capacity, live storage capacity and dead storage capacity is 0.63%, 0.47% and 2.77% respectively.

4 RESOURCES FOR SURVEY WORK

4.1 Personnel

Following staff were involved during the survey work.

Offshore Survey Personnel	
Name	**Function**
Amit Singh	Party Chief
Kalicharan Prusty	Surveyor
Vishnu S	Land Surveyor
Rohit Patwal	Survey Engineer
Onshore Project Management and Data QC	
Sudhir Walia	Project Manager
KSN Murthy	Survey Manager
Dhaval Patel	Data Processor

Table 4.1-1 LIST OF PERSONNEL

4.2 Details of Equipment used

Following equipment and survey sensors were mobilised for the Topographic and Bathymetric survey data acquisition carried out at Kakdiamba reservoir. The equipment setup and configuration diagram has been presented in Figure 5.1-1.

Survey Equipment/Systems Used for the Data Acquisition	
Equipment/System	**Description/Make/Model**
Software / Navigation	HYPACK Navigation and Data Acquisition Software
Positioning	Geomax DGPS
Single Beam Echo Sounder	Reson Navisound Echo sounder with Accessories
RTK	Geomax RTK system
Auto Level	Geomax Auto Level & Tripod
Survey Boat	“Aqua Marine” with OBM
Laptop	Dell Laptops
Power Supply	12v Battery & Inverter

Table 4.2-1 LIST OF EQUIPMENT USED FOR SURVEY

4.3 Survey Vessel

Survey Boat 'Aqua Marine' was utilised for carrying out the bathymetric survey.

4.3.1 Survey Boat Specifications

Survey Boat 'Aqua Marine' Specifications	
Length overall	3.56m
Breadth moulded	1.88m
Draft	0.50m

Table 4.3-1 SURVEY BOAT SPECIFICATIONS - 'AQUA MARINE'

4.3.2 Survey Boat Offset Diagram

The location of the various survey sensors on the survey boat 'Aqua Marine' is given in the vessel-offset diagram on the chart accompanying this report.

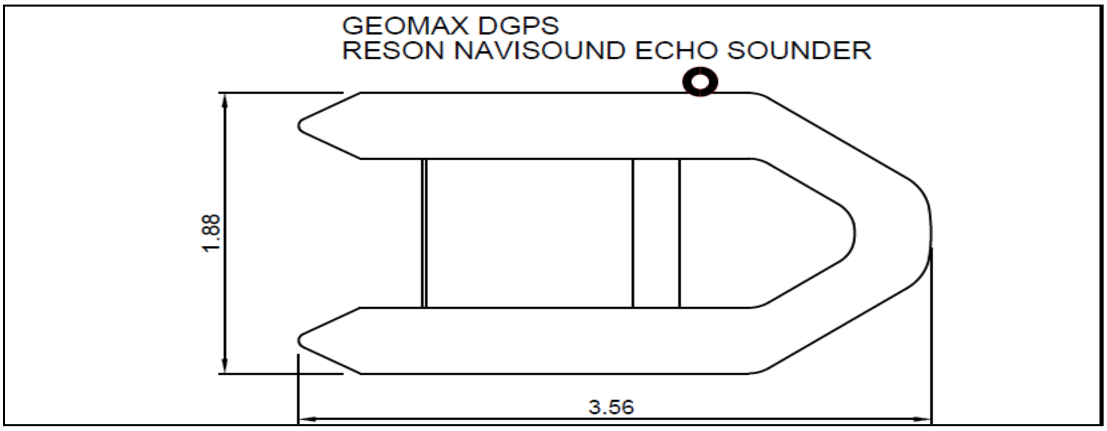


Figure 4.3-1 SURVEY BOAT ' AQUA MARINE' OFFSET DIAGRAM

5 DETAILED METHODOLOGY OF SURVEY

5.1 Mobilisation

The bathymetric survey equipment were mobilised on board “Aqua Marine” on 27 Oct 2020. After successful installation, testing and calibrations of survey equipment, the team proceeded for Data acquisition.

Geomax RTK, auto level, Tripod and necessary supporting equipment/tools were mobilised for Topographic survey.

All survey equipment was installed and configured for bathymetric Survey on board “Aqua Marine” as per figure given below.

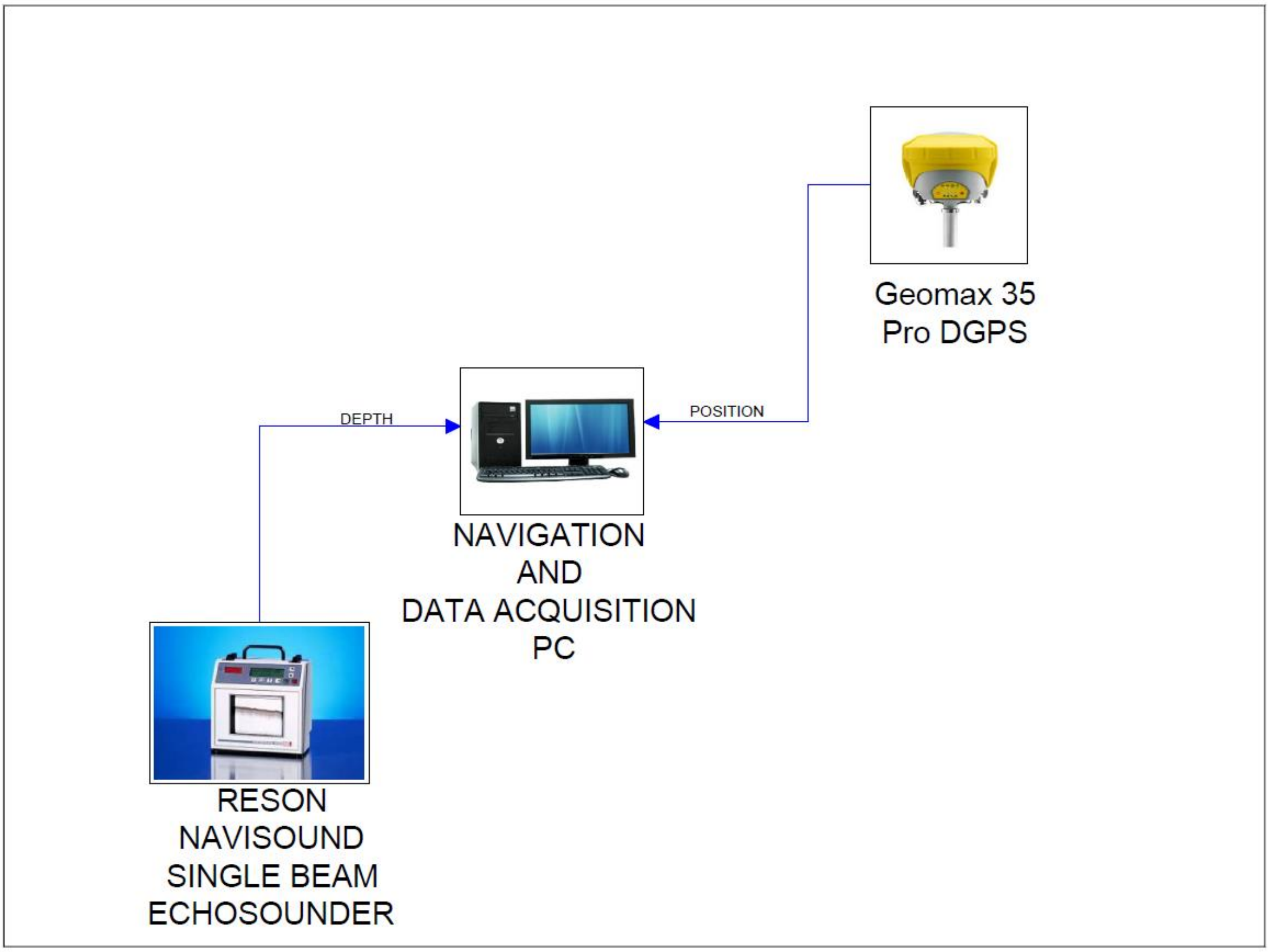


Figure 5.1-1 SBES SURVEY EQUIPMENT CONFIGURATION DIAGRAM ON BOARD

5.2 Geodesy

The survey operations were conducted in WGS 84 spheroid, Universal Transverse Mercator projection system based on following Geodetic parameters:-

Global Positioning System Geodetic Parameters	
Datum:	World Geodetic System 1984 (WGS84)
Spheroid:	World Geodetic System 1984
Semi major axis:	a = 6 378 137.000 m
Semi minor axis:	b = 6 356 752.314 245 m
Inverse Flattening:	$^{1}/_{f}$ = 298.257 223 563
Local Datum Geodetic Parameters	
Datum:	World Geodetic System 1984 (WGS84)
Spheroid:	World Geodetic System 1984
Semi major axis:	a = 6 378 137.000 m
Inverse Flattening:	$^{1}/_{f}$ = 298.257 223 563
Local Projection and Grid Parameters	
Map Projection:	Universal Transverse Mercator
Grid System:	UTM Zone 43 N
Central Meridian:	075° 00’ 00” East
Latitude of Origin:	0° 00’ 00” North
False Easting:	500 000 m
False Northing:	0 m

Table 5.2-1 GEODETIC PARAMETERS

5.3 Survey work at Field

5.3.1 Benchmark and Base station setup

RTK DGPS Base station was set up at OBS Kakdiamba , made by GMPL and configured to transmit the correction.

Four (4) hours of DGPS observation was carried out on OBS Kakdiamba (Levelling was carried out from fuse gate to above mention observation point and level of fuse gate was provided by Dam Authority).

Levelling From Fuse Gate Top To OBS Kakdiamba				
BS	**FS**	**HI**	**RL**	**Remark**
5.272		192.982	187.71	Top of Fuse Gate (Provided by Dam Authority)
	0.859		192.123	OBS Kakdiamba on Dam top
Levelling From OBS Kakdiamba To Fuse Gate Top (Closing Loop)				
0.868		192.991	192.123	OBS Kakdiamba on Dam top
	5.281		187.71	Top of Fuse Gate

Table 5.3-1 LEVELLING FROM FUSE GATE TO OBS KAKDIAMBA

The details of Bench Marks are presented in the table below:

T.BM. Information - Kakdiamba Reservoir, South Gujarat					
Location	**Latitude (N)**	**Longitude (E)**	**Easting (m)**	**Northing (m)**	**Elevation (m) W.r.t MSL**
OBS Kakdaimba	21°30'54.511"	73°43'53.4435"	368617.296	2379694.986	192.123
T.B.M. 1	21°30'59.6064"	73°43'58.767"	368771.747	2379850.426	192.154
T.B.M. 2	21°31'15.2197"	73°44'0.375"	368821.908	2380330.158	192.140

Table 5.3-2 BENCH MARK DETAILS

Figure 5.3-1 RTK Base Set up At Dam

5.3.2 Topographic and Bathymetric Survey

For topographic survey, Geomax RTK base was used for DGPS observation on top of dam, near spillway. Four Hrs. of DGPS observation was carried out on OBS KAKDIAMBA (Levelling was carried out from fuse gate to above mention observation point and level of fuse gate was provided by Dam Authority). RTK DGPS Base station was set up at OBS KAKDIAMBA, made by GMPL and configured to transmit the correction. Two rovers receiving RTK corrections from the base took spot level from water level to HFL.

For bathymetric survey, Aqua Marine boat was mobilised as shown in Figure 5.1-1. Plan line for survey was prepared parallel to dam axis and at 25 m intervals. Survey boat was run on afore mentioned plan line to acquire position as well as depth.

5.4 Survey Systems

5.4.1 GEOMAX DGPS:

GEOMAX DGPS system was used during survey.

• Differential correction signals received on board during survey operations continuously from the Satellite based augmentation system.

• The positioning data as well as heading data received with high reliability and integrity.

GEOMAX DGPS was the primary positioning system currently used for all the surveys. GMPL has provided, install, operate and maintain a Differential Global Positioning System (DGPS) acceptable to the EIC, which fully covered the site of the works and was constantly in operation during the all the surveys. The age of pseudo- range correctors used in position computation was not exceeded 20 seconds; however, any horizontal positioning interpolation was never exceeded the accuracy. Horizontal Dilution of Precision (HDOP) was monitored, and was never exceeded 2 nominally. Satellite geometry alone is not a sufficient statistic for determining horizontal positioning accuracy. Other variables, including satellite pseudo range residual, were used in conjunction with HDOP to estimate horizontal accuracy. A minimum of four satellites were used to compute all positions, Horizontal and Vertical offsets between the GPS antenna and transducer(s) were observed and applied with a precision better than 0.01m. The system was consisting of master receiving reference station (Base) and DGPS Navigator unit (Rover). The navigator's units (Rover) were installed on Survey launch. The composition was consisting navigational software, track plotters, data storage facilities, echo sounders, sufficient spares to enable uninterrupted operation of the system to the accuracy specified and on-board computers.

5.4.2 Single beam Echo sounder

The single beam echo sounder 'Reson Navi Sound' with an accuracy of 0.01m was deployed and in principle, higher frequency of 215 kHz was operated. Echo Sounder equipment was calibrated daily before and after use, by means of a bar-check in the survey area. The calibration results were found satisfactory.

5.4.3 HYPACK Software

HYPACK is a Windows™-based software package used primarily for hydrographic surveying and data processing.

HYPACK performs all of the tasks necessary to complete Single Beam Echo sounder data acquisition /processing from beginning to end. This all-in- one module provides the surveyor with all of the tools needed to design their survey, collect data, process it, reduce it to w.r.t MSL, and generate final products. Whether collecting hydrographic survey data or environmental data, or positioning a vessel in an engineering project, HYPACK provides the tools needed to complete the job.

This software can be interfaced simultaneously to Echo sounders and attitude sensors.

5.4.4 RTK System

Geomax RTK system consists of one Base and Rover Module was used for Topographic Survey.

- Geomax RTK Base station was set up at the OBS Kakdiamba and configured to transmit the corrections.
- Geomax RTK Rover was used for Topographic survey and two TBM were established to cover whole area.

5.5 Data Acquisition and Quality Control

5.5.1 Online Data Quality Control

The online navigation computer was interfaced to Reson Navisound Echo Sounder system. Laptop connected to the Navigation network were time synchronized with the GPS (high precision) time signal allowing all data to be precisely time stamped.

<u>Navigation</u>

The DGPS system performed well at all times and the performance of the system was continuously monitored.

<u>Echo Sounder</u>

The digital output from the Reson Navisound Echo Sounder was satisfactory throughout the duration of the survey. The quality of obtained soundings were verified by running suitable cross lines and depths were found to be matching.

5.5.2 Data Processing

The bathymetric survey data was logged using Hypack on Navigation System. The quality of the bathymetric data acquired in the field was monitored continuously onboard the survey boat. Survey data was processed in office and handed over to the client.

5.6 Quality Assurance and HSE Procedures

GMPL has fully documented and self-audited Quality Assurance and Health, Safety and Environmental System procedures in place. The same were followed during all surveying tasks, which was undertaken by the company and its personnel.

Competent field survey staffs were deployed by GMPL to constantly monitor acquired data quality whilst the survey progressing, and was duly documented.

5.7 Demobilisation

Upon successful completion of topographic and bathymetric survey at Kakdiamba Reservoir with due, consent from Client Representative, the survey equipment on board were demobilised on 29 October 2020.

5.8 SURVEY DATA PROCESSING AND INTERPRETATION METHODS

5.8.1 General

The survey data was logged and was processed using the HYPACK Software. Position and depth data were processed and checked to ensure good data quality. The same was used for the automated and manual processing of logged data sets.

5.8.2 Navigation and Positioning

The measured offsets for various survey sensors used during the survey were entered into the navigation system and post processed using Hypack processing to enable track charts to be plotted and the ‘corrected’ navigation files to be integrated with other sensor data at a later stage.

5.8.3 Bathymetry Data Processing and Analysis

- The SBES bathymetry survey data was logged using HYPACK and further processed.
- Corrected SBES offset position (computed from vessel antenna) was merged into single beam data for true horizontal positioning.
- Velocity value 1500 m/s was used in the survey area.
- SBES data was further corrected for the transducer draft from water level.
- The depth sounding obtained from SBES were reduced to MSL with the help of observed water level in the reservoir.
- The data was filtered, cleaned, and combined to create geographically positioned bathymetric data set that has been corrected for tides and sound speed.
- The water level were observed during the entire period of survey. The details are as follows:-

Date	Time	Water Level (meters)
27/10/2020	0700	187.71
27/10/2020	1900	187.71
28/10/2020	0700	187.71
28/10/2020	1900	187.71
29/10/2020	0700	187.7
29/10/2020	1300	187.7

Table 5.8-1 WATER LEVEL

5.8.4 Topographic Data Processing and Analysis

The topographic survey data was cleaned and converted into xyz format. The converted data was merged with the bathymetric data using TIN module of Hypack software and Gridded data (25 x 25 m) was created. This data was used for volume calculations.

5.8.5 Preparation of Drawings

After the data processing phase, five drawings has been prepared for Kakadiamba Reservoir, the details of which are presented in the table below:

Sr. No	Drawing Name	Description	Hard Copy format	Soft Copy format
1	P-SUR-004-KAKDIAMBA-BATHY-01	Chart contains bathy , contour and cross section segments	Paper size A0 (1:5000)	PDF & CAD
2	P-SUR-004-KAKDIAMBA-OVERVIEW-01	Overview Map of Reservoir	Paper size A3	PDF & CAD
3	Area Capacity Curve Kakdiamba - 2020	Area Capacity curve of Reservoir	Paper size A3	PDF & CAD
4	Kakdiamba Cross Sections	13 Cross Section at 100 m interval	Only soft copy	CAD
5	Kakdiamba L- Section	L-Section of Reservoir	Paper size A3	CAD

Table 5.8-2 LIST OF CHARTS

6 DETAILED TOPOGRAPHIC AND BATHYMETRIC SURVEY RESULTS

6.1 General

Kindly refer to drawings in conjunction with the following:

Topographic and bathymetric data was reduced to the water level w.r.t MSL. All the data is plotted on scale of 1:5000 for Kakdiamba reservoir.

The values depicted in the charts are the elevation with respect to MSL.

- The Minimum elevation within Kakdiamba reservoir is 176.73 m above MSL and
- The Maximum depth within Kakdiamba reservoir is 10.98 m.

6.2 Capacity and Area Calculation:

Hypack software's TIN (Triangulated Irregular Network) MODEL was used to calculate capacity and area of the reservoir at intervals of 10 cm. In addition, volume was also calculated using prismoidal formula as given below:

V=h/3{A1+A2+ Square Root (A1 * A2)}

where V is volume in M Cu. m between two levels,

h is difference between two level and

A1 & A2 is area in Sq. Km of successive levels

Level (m)	Dead Storage Capacity (M Cu. m)	Live Storage Capacity (M Cu. m)	Gross Storage Capacity using TIN (M Cu. m)	Gross Storage Capacity using Prismoidal formula (M Cu. m)	Spread Area (Sq. Km)	Remarks
176.70	0.000	0.000	0.000	0.000	0.000	
176.80	0.000	0.000	0.000	0.000	0.013	
176.90	0.003	0.000	0.003	0.003	0.031	
177.00	0.006	0.000	0.006	0.006	0.043	
177.10	0.011	0.000	0.011	0.011	0.061	
177.20	0.018	0.000	0.018	0.018	0.079	
177.21	**0.019**	**0.000**	**0.019**	**0.019**	**0.080**	**MDDL**
177.30	0.019	0.008	0.027	0.027	0.090	
177.40	0.019	0.017	0.036	0.036	0.099	
177.50	0.019	0.028	0.047	0.046	0.107	
177.60	0.019	0.039	0.058	0.058	0.115	

Level (m)	Dead Storage Capacity (M Cu. m)	Live Storage Capacity (M Cu. m)	Gross Storage Capacity using TIN (M Cu. m)	Gross Storage Capacity using Prismoidal formula (M Cu. m)	Spread Area (Sq. Km)	Remarks
177.70	0.019	0.051	0.070	0.070	0.123	
177.71	0.019	0.052	0.071	0.071	0.124	
177.80	0.019	0.063	0.082	0.082	0.131	
177.90	0.019	0.077	0.096	0.096	0.138	
178.00	0.019	0.091	0.110	0.110	0.146	
178.10	0.019	0.106	0.125	0.125	0.153	
178.20	0.019	0.122	0.141	0.141	0.161	
178.21	0.019	0.123	0.142	0.142	0.162	
178.30	0.019	0.138	0.157	0.157	0.169	
178.40	0.019	0.156	0.175	0.174	0.178	
178.50	0.019	0.174	0.193	0.193	0.189	
178.60	0.019	0.193	0.212	0.212	0.201	
178.70	0.019	0.214	0.233	0.233	0.211	
178.71	0.019	0.216	0.235	0.235	0.212	
178.80	0.019	0.236	0.255	0.254	0.220	
178.90	0.019	0.258	0.277	0.277	0.229	
179.00	0.019	0.281	0.300	0.300	0.238	
179.10	0.019	0.306	0.325	0.324	0.247	
179.20	0.019	0.331	0.350	0.350	0.257	
179.21	0.019	0.333	0.352	0.352	0.257	
179.30	0.019	0.357	0.376	0.376	0.267	
179.40	0.019	0.384	0.403	0.403	0.278	
179.50	0.019	0.412	0.431	0.431	0.289	
179.60	0.019	0.442	0.461	0.461	0.300	
179.70	0.019	0.472	0.491	0.491	0.311	
179.71	0.019	0.476	0.495	0.494	0.312	
179.80	0.019	0.504	0.523	0.523	0.322	
179.90	0.019	0.537	0.556	0.556	0.334	
180.00	0.019	0.571	0.590	0.590	0.346	
180.10	0.019	0.606	0.625	0.625	0.357	
180.20	0.019	0.642	0.661	0.661	0.367	
180.21	0.019	0.646	0.665	0.665	0.368	
180.30	0.019	0.680	0.699	0.698	0.378	
180.40	0.019	0.718	0.737	0.737	0.390	
180.50	0.019	0.758	0.777	0.776	0.402	
180.60	0.019	0.798	0.817	0.817	0.416	
180.70	0.019	0.841	0.860	0.860	0.429	

Level (m)	Dead Storage Capacity (M Cu. m)	Live Storage Capacity (M Cu. m)	Gross Storage Capacity using TIN (M Cu. m)	Gross Storage Capacity using Prismoidal formula (M Cu. m)	Spread Area (Sq. Km)	Remarks
180.71	0.019	0.845	0.864	0.864	0.430	
180.80	0.019	0.884	0.903	0.903	0.440	
180.90	0.019	0.929	0.948	0.948	0.452	
181.00	0.019	0.975	0.994	0.994	0.465	
181.10	0.019	1.022	1.041	1.041	0.477	
181.20	0.019	1.070	1.089	1.089	0.489	
181.21	0.019	1.075	1.094	1.094	0.490	
181.30	0.019	1.119	1.138	1.138	0.500	
181.40	0.019	1.170	1.189	1.189	0.511	
181.50	0.019	1.222	1.241	1.240	0.522	
181.60	0.019	1.274	1.293	1.293	0.533	
181.70	0.019	1.328	1.347	1.347	0.544	
181.71	0.019	1.334	1.353	1.353	0.545	
181.80	0.019	1.383	1.402	1.402	0.556	
181.90	0.019	1.439	1.458	1.458	0.569	
182.00	0.019	1.497	1.516	1.516	0.583	
182.10	0.019	1.556	1.575	1.575	0.597	
182.20	0.019	1.616	1.635	1.635	0.611	
182.21	0.019	1.623	1.642	1.641	0.612	
182.30	0.019	1.678	1.697	1.697	0.626	
182.40	0.019	1.741	1.760	1.760	0.639	
182.50	0.019	1.806	1.825	1.825	0.652	
182.60	0.019	1.872	1.891	1.891	0.665	
182.70	0.019	1.939	1.958	1.958	0.678	
182.71	0.019	1.946	1.965	1.965	0.680	
182.80	0.019	2.008	2.027	2.026	0.693	
182.90	0.019	2.078	2.097	2.097	0.709	
183.00	0.019	2.149	2.168	2.168	0.725	
183.10	0.019	2.223	2.242	2.242	0.742	
183.20	0.019	2.298	2.317	2.317	0.758	
183.21	0.019	2.305	2.324	2.324	0.760	
183.30	0.019	2.374	2.393	2.393	0.776	
183.40	0.019	2.453	2.472	2.472	0.794	
183.50	0.019	2.533	2.552	2.552	0.811	
183.60	0.019	2.615	2.634	2.634	0.827	
183.70	0.019	2.699	2.718	2.718	0.843	
183.71	0.019	2.707	2.726	2.726	0.845	

Level (m)	Dead Storage Capacity (M Cu. m)	Live Storage Capacity (M Cu. m)	Gross Storage Capacity using TIN (M Cu. m)	Gross Storage Capacity using Prismoidal formula (M Cu. m)	Spread Area (Sq. Km)	Remarks
183.80	0.019	2.784	2.803	2.803	0.858	
183.90	0.019	2.870	2.889	2.889	0.873	
184.00	0.019	2.958	2.977	2.977	0.889	
184.10	0.019	3.048	3.067	3.067	0.906	
184.20	0.019	3.140	3.159	3.158	0.924	
184.21	0.019	3.149	3.168	3.168	0.926	
184.30	0.019	3.233	3.252	3.252	0.942	
184.40	0.019	3.328	3.347	3.347	0.957	
184.50	0.019	3.424	3.443	3.443	0.972	
184.60	0.019	3.522	3.541	3.541	0.986	
184.70	0.019	3.622	3.641	3.640	1.001	
184.71	0.019	3.632	3.651	3.651	1.003	
184.80	0.019	3.723	3.742	3.741	1.017	
184.90	0.019	3.825	3.844	3.844	1.033	
185.00	0.019	3.929	3.948	3.948	1.048	
185.10	0.019	4.035	4.054	4.053	1.064	
185.20	0.019	4.142	4.161	4.161	1.079	
185.21	0.019	4.152	4.171	4.171	1.080	
185.30	0.019	4.250	4.269	4.269	1.093	
185.40	0.019	4.360	4.379	4.379	1.108	
185.50	0.019	4.472	4.491	4.491	1.122	
185.60	0.019	4.585	4.604	4.604	1.137	
185.70	0.019	4.699	4.718	4.718	1.151	
185.71	0.019	4.711	4.730	4.729	1.152	
185.80	0.019	4.815	4.834	4.834	1.164	
185.90	0.019	4.932	4.951	4.951	1.177	
186.00	0.019	5.050	5.069	5.069	1.191	
186.10	0.019	5.170	5.189	5.189	1.204	
186.20	0.019	5.291	5.310	5.310	1.217	
186.21	0.019	5.303	5.322	5.322	1.218	
186.30	0.019	5.413	5.432	5.432	1.230	
186.40	0.019	5.537	5.556	5.556	1.244	
186.50	0.019	5.662	5.681	5.681	1.258	
186.60	0.019	5.789	5.808	5.808	1.272	
186.70	0.019	5.917	5.936	5.935	1.285	
186.71	**0.019**	**5.929**	**5.948**	**5.948**	**1.287**	**FRL at impounding**

Level (m)	Dead Storage Capacity (M Cu. m)	Live Storage Capacity (M Cu. m)	Gross Storage Capacity using TIN (M Cu. m)	Gross Storage Capacity using Prismoidal formula (M Cu. m)	Spread Area (Sq. Km)	Remarks
186.80	0.019	6.046	6.065	6.065	1.299	
186.90	0.019	6.176	6.195	6.195	1.314	
187.00	0.019	6.309	6.328	6.327	1.329	
187.10	0.019	6.442	6.461	6.461	1.344	
187.20	0.019	6.578	6.597	6.596	1.359	
187.21	0.019	6.591	6.610	6.610	1.361	
187.30	0.019	6.714	6.733	6.733	1.375	
187.40	0.019	6.853	6.872	6.871	1.391	
187.50	0.019	6.992	7.011	7.011	1.407	
187.60	0.019	7.134	7.153	7.153	1.423	
187.70	0.019	7.277	7.296	7.296	1.439	
187.71	**0.019**	**7.292**	**7.311**	**7.310**	**1.441**	**FRL after installation of fuse gates**
187.80	0.019	7.422	7.441	7.441	1.454	
187.90	0.019	7.568	7.587	7.587	1.470	
188.00	0.019	7.716	7.735	7.735	1.485	
188.10	0.019	7.865	7.884	7.884	1.501	
188.20	0.019	8.016	8.035	8.035	1.518	
188.21	0.019	8.031	8.050	8.050	1.520	
188.30	0.019	8.169	8.188	8.188	1.535	
188.40	0.019	8.323	8.342	8.342	1.551	
188.50	0.019	8.479	8.498	8.498	1.568	
188.60	0.019	8.637	8.656	8.655	1.585	
188.70	0.019	8.796	8.815	8.815	1.603	
188.71	**0.019**	**8.812**	**8.831**	**8.831**	**1.605**	**HFL**

Table 6.2-1 CAPACITY AND AREA

6.3 Comparative Statement of Kakdiamba Reservoir

Levels (m)	Original		As per 2020 survey		Remarks
	Gross storage (M Cu. m)	Area (Sq. K m)	Gross storage (M Cu. m)	Area (Sq. K m)	
177.21	**0.650**	**0.250**	**0.019**	**0.080**	**MDDL**
178.00	0.837	0.300	0.110	0.146	
179.00	1.204	0.375	0.300	0.238	
180.00	1.600	0.475	0.590	0.346	
181.00	2.163	0.600	0.994	0.465	
182.00	2.763	0.735	1.516	0.583	
183.00	3.636	0.870	2.168	0.725	
184.00	4.679	1.020	2.977	0.889	
185.00	5.715	1.170	3.948	1.048	
186.00	6.987	1.285	5.069	1.191	
186.71	**7.870**	**1.360**	**5.948**	**1.287**	**FRL at impounding**
187.00	8.302	1.400	6.328	1.329	
187.71	**9.370**	**1.450**	**7.311**	**1.441**	**FRL after installation of fuse gates**

Table 6.3-1 COMPARATIVE STATEMENT OF KAKDIAMBA RESERVOIR

6.4 Gross Storage Capacity in M Cu. m of the Reservoir - Year 2020:

RL (m)	0	0.1	0.2	0.21	0.3	0.4	0.5	0.6	0.7	0.71	0.8	0.9
176											0.000	0.003
177	0.006	0.011	0.018	**0.019**	0.027	0.036	0.047	0.058	0.070	0.071	0.082	0.096
178	0.110	0.125	0.141	0.142	0.157	0.175	0.193	0.212	0.233	0.235	0.255	0.277
179	0.300	0.325	0.350	0.352	0.376	0.403	0.431	0.461	0.491	0.495	0.523	0.556
180	0.590	0.625	0.661	0.665	0.699	0.737	0.777	0.817	0.860	0.864	0.903	0.948
181	0.994	1.041	1.089	1.094	1.138	1.189	1.241	1.293	1.347	1.353	1.402	1.458
182	1.516	1.575	1.635	1.642	1.697	1.760	1.825	1.891	1.958	1.965	2.027	2.097
183	2.168	2.242	2.317	2.324	2.393	2.472	2.552	2.634	2.718	2.726	2.803	2.889
184	2.977	3.067	3.159	3.168	3.252	3.347	3.443	3.541	3.641	3.651	3.742	3.844
185	3.948	4.054	4.161	4.171	4.269	4.379	4.491	4.604	4.718	4.730	4.834	4.951
186	5.069	5.189	5.310	5.322	5.432	5.556	5.681	5.808	5.936	**5.948**	6.065	6.195
187	6.328	6.461	6.597	6.610	6.733	6.872	7.011	7.153	7.296	**7.311**	7.441	7.587
188	7.735	7.884	8.035	8.050	8.188	8.342	8.498	8.656	8.815	**8.831**		

Table 6.4-1 GROSS STORAGE CAPACITY IN M cu. m YEAR -2020

Note: Gross storage capacity for FRL at 186.71 m (at impounding) is 5.948 M Cu. m
Gross storage capacity for FRL at 187.71 m (after installation of fuse gates) is 7.311 M Cu. m
Gross storage capacity for HFL at 188.71 m is 8.831 M Cu. m
Dead storage capacity at 176.71 m is 0.019 M Cu. m

6.5 Live Storage Capacity in M Cu. m of the Reservoir - Year 2020:

RL (m)	0	0.1	0.2	0.21	0.3	0.4	0.5	0.6	0.7	0.71	0.8	0.9
177				0.000	0.008	0.017	0.028	0.039	0.051	0.052	0.063	0.077
178	0.091	0.106	0.122	0.123	0.138	0.156	0.174	0.193	0.214	0.216	0.236	0.258
179	0.281	0.306	0.331	0.333	0.357	0.384	0.412	0.442	0.472	0.476	0.504	0.537
180	0.571	0.606	0.642	0.646	0.680	0.718	0.758	0.798	0.841	0.845	0.884	0.929
181	0.975	1.022	1.070	1.075	1.119	1.170	1.222	1.274	1.328	1.334	1.383	1.439
182	1.497	1.556	1.616	1.623	1.678	1.741	1.806	1.872	1.939	1.946	2.008	2.078
183	2.149	2.223	2.298	2.305	2.374	2.453	2.533	2.615	2.699	2.707	2.784	2.870
184	2.958	3.048	3.140	3.149	3.233	3.328	3.424	3.522	3.622	3.632	3.723	3.825
185	3.929	4.035	4.142	4.152	4.250	4.360	4.472	4.585	4.699	4.711	4.815	4.932
186	5.050	5.170	5.291	5.303	5.413	5.537	5.662	5.789	5.917	**5.929**	6.046	6.176
187	6.309	6.442	6.578	6.591	6.714	6.853	6.992	7.134	7.277	**7.292**	7.422	7.568
188	7.716	7.865	8.016	8.031	8.169	8.323	8.479	8.637	8.796	**8.812**		

Table 6.5-1 LIVE STORAGE CAPACITY IN M cu. m YEAR -2020

Note: Live storage capacity for FRL at 186.71 m (at impounding) is 5.929 M Cu. m
Live storage capacity for FRL at 187.71 m (after installation of fuse gates) is 7.292 M Cu. m
Live storage capacity for HFL at 188.71 m is 8.812 M Cu. m

6.6 Spread Area in Sq.Km of the Reservoir - Year 2020:

RL (m)	0	0.1	0.2	0.21	0.3	0.4	0.5	0.6	0.7	0.71	0.8	0.9
176	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.031
177	0.043	0.061	0.079	0.080	0.090	0.099	0.107	0.115	0.123	0.124	0.131	0.138
178	0.146	0.153	0.161	0.162	0.169	0.178	0.189	0.201	0.211	0.212	0.220	0.229
179	0.238	0.247	0.257	0.257	0.267	0.278	0.289	0.300	0.311	0.312	0.322	0.334
180	0.346	0.357	0.367	0.368	0.378	0.390	0.402	0.416	0.429	0.430	0.440	0.452
181	0.465	0.477	0.489	0.490	0.500	0.511	0.522	0.533	0.544	0.545	0.556	0.569
182	0.583	0.597	0.611	0.612	0.626	0.639	0.652	0.665	0.678	0.680	0.693	0.709
183	0.725	0.742	0.758	0.760	0.776	0.794	0.811	0.827	0.843	0.845	0.858	0.873
184	0.889	0.906	0.924	0.926	0.942	0.957	0.972	0.986	1.001	1.003	1.017	1.033
185	1.048	1.064	1.079	1.080	1.093	1.108	1.122	1.137	1.151	1.152	1.164	1.177
186	1.191	1.204	1.217	1.218	1.230	1.244	1.258	1.272	1.285	**1.287**	1.299	1.314
187	1.329	1.344	1.359	1.361	1.375	1.391	1.407	1.423	1.439	**1.441**	1.454	1.470
188	1.485	1.501	1.518	1.520	1.535	1.551	1.568	1.585	1.603	**1.605**		

Table 6.6-1 SPREAD AREA IN SQ. KM YEAR -2020

Note: Spread area at FRL at 186.30 m (at impounding) is 1.287 Sq. Km
Spread area at FRL at 187.40 m (after installation of fuse gates) is 1.441 Sq. Km
Spread area at HFL at 188.80 m is 1.605 Sq. Km

6.7 Sediment Analysis:

6.7.1 Observed Rate of Sedimentation

The reservoir was impounded during the year 1985. As per original project report, FRL was 186.71m. After installation of fuse gate FRL was increased to 187.71m. As per original project report and after installing fuse gate, total area of reservoir at FRL 187.71m is 1.441 Sq. Km, corresponding storage capacity is 9.37 M Cu. m, and Dead storage at 177.21m is 0.65 M Cu. m.

The reservoir was recently surveyed by means of integrated bathymetric and topographic survey in year 2020. As per recent survey, , total area of reservoir at FRL 186.71 m (at impounding) and FRL 187.71 m (after installation of fuse gates) is 1.287 Sq. Km and 1.441 Sq. Km respectively, corresponding storage capacity is 5.948 M Cu. m and 7.31 M Cu. m respectively. In addition, Dead storage at 177.21m is 0.019 M Cu. m.

The rate of siltation in the reservoir up to FRL 186.71 m (at impounding) and FRL 187.71 m (after installation of fuse gates) during the last 35 years (1985-2020) according to survey of the year 2020 is 0.055 M Cu. m / year and 0.059 M Cu. m / year repectively.

Original Reservoir data

Year of Impounding	:	1985			
Catchment Area	:	24.22 Sq. Km			
Spread Area at FRL 186.71 m	:	1.36 Sq. Km	Spread area at 187.71 m	:	1.485 Sq. Km
Live storage at FRL 186.71 m	:	7.22M Cu. m	Live storage at 187.71 m	:	8.72 M Cu. m
Dead storage at 177.21 m	:	0.65 M Cu. m	Dead storage at 177.21 m	:	0.65 M Cu. m
Gross storage at FRL 186.71 m	:	7.87 M Cu. m	Gross storage at 187.71 m	:	9.37 M Cu. m

Rate of Sedimentation (at FRL 186.71 m: at impounding) with respect to impounding year 1985													
Sr. No	**Year of Survey**	**Capacity in M Cu. m**			**Period in years**	**Silt Deposited in M Cu. m**	**Silt Rate In M Cu. m /years**	**Loss in Capacity in M Cu. m and percentage**			**Silt Index ham/100 Sq. Km/Yr.**	**Annual % loss**	**Remarks**
		Dead	**Live**	**Gross**				**Dead**	**Live**	**Gross**			
1	1985	0.65	7.22	7.87	-	-	-	-	-	-	-	-	
2	2020 by integrated bathymetry and topographic survey	0.019	5.929	5.948	35	1.922	0.055	0.631 97.08%	1.291 17.88%	1.922 24.42%	22.673	0.698	**Serious Category**

Table 6.7-1 RATE OF SEDIMENTATION (FRL 186.71 m)

Rate of Sedimentation (at FRL 187.71: after installation of fuse gates) with respect to impounding year 1985													
Sr. No	**Year of Survey**	**Capacity in M Cu. m**			**Period in years**	**Silt Deposited in M Cu. m**	**Silt rate in M. Cu. M/year**	**Loss in Capacity M Cu. m**			**Silt Index ham/100 Sq. Km/Yr.**	**Annual % loss**	**Remarks**
		Dead	**Live**	**Gross**				**Dead**	**Live**	**Gross**			
1	1985	0.65	8.72	9.37	-	-	-	-	-	-	-	-	
2	2020 by integrated Bathymetric and Topographic survey	0.019	7.292	7.311	35	2.059	0.059	0.631 97.08%	1.428 16.38%	2.059 21.98%	24.29	0.628	**Serious Category**

Table 6.7-2 RATE OF SEDIMENTATION (FRL 187.71 m)

According to IS -12182 (1987)

Annual % loss	**-**	**Class of Reservoir**
Up to 0.1	-	Insignificant
0.1 to 0.5	-	Significant
Above 0.5	-	Serious

Rate of Silt = Loss in Gross Capacity in M Cu. m/No of Years
Silt Index = (Silt Rate/Catchment area) x 10000
Annual % Loss= Loss in % of Gross Capacity/No of years

6.8 Conclusion

- By above table we can conclude that the capacity of reservoir is decreased significantly due to deposition of sediments in the reservoir especially at Dead Storage level (it is almost full).
- The annual percentage loss from recent survey is 0.628% for FRL 187.71 m.
- Reservoir is classified as "**Serious category**" as per IS 12182-1987 and requires immediate actions to control deposition of sediments in the reservoir.

6.9 Methods for controlling the sedimentation

According to IS-6518:2017 there are several factors involved in controlling sedimentation in reservoirs and they relate to aspects on,

a) Design of reservoir.
b) Control of sediment inflow.
c) Control of sediment deposition.
d) Removal of sediments.

All these aspects are to be simultaneously taken note of and appropriate measures be adopted.

6.9.1 Design of Reservoirs

The capacity of reservoirs is governed by a number of factors which are covered in IS 5477 (Parts 1 to 4). From the point of view of sediment deposition, the following points may be given due consideration:

a) The sediment yield which depends on the topographical, geological and geomorphological set up, meteorological factors, land use/land cover, intercepting tanks, etc.;
b) Sediment delivery characteristics of the channel system;
c) The efficiency of the reservoir as sediment trap;
d) The ratio of capacity of reservoir to the inflow;
e) Configuration of reservoir;
f) Method of operation of reservoir; and
g) Provisions for silt exclusion.

- The rate of sediment delivery increases with the quantum of discharge.
- The percentage of sediment trapped by a reservoir with a given drainage area increases with the increased capacity. In some cases an increased capacity will however, result in greater loss of water due to evaporation. However, with the progress of sedimentation, there is decrease of storage capacity which in turn lowers the trap efficiency of the reservoir.
- The capacity of the reservoir and the size and characteristics of the reservoir and its drainage area are the most important factors governing the annual rate of accumulation of sediment. Periodical reservoir sedimentation surveys provide guidance on the rate of sedimentation. In the absence of

observed data for the reservoir concerned, data from other reservoirs of similar capacity and catchment characteristics may be adopted.

- Sedimentation takes place not only in the dead storage but also in the live storage space in the reservoir. The practice for design of reservoir is to use the observed suspended sediment data available from key hydrologica1 networks and also the data available from hydrographic surveys of other reservoirs in the same region.

This data may be used to simulate sedimentation status over a period of reservoir life as mentioned in IS 12182.

- Raising the Dam at Periodic Intervals:

Engineering economic analysis of some reservoir projects probably would show that it is cheaper to build a substantially lower dam initially, and to raise it at intervals unti1 its ultimate height for the given original capacity so that long useful life may result. Stage-wise construction also provides lower trapping efficiency and less evaporation in the initial stages.

However, this method may not be feasible in all the existing dams. Wherever this method is contemplated, proper consideration should be given on the strength.

6.9.2 Control of Sediment Inflow

There are many methods for controlling sediment inflows and they can be divided as follows:

1. Watershed management/soil conservation measures to check production and transport of sediment in the catchment area

1.1. The engineering methods

1.1.1. Check Dams

a) They help to arrest degradation of stream bed thereby arresting the slope failure; and

b) They reduce the velocity of stream flow, thereby causing the deposition of the sediment load.

Check dams become necessary, where the channel gradients are steep and there is a heavy inflow of sediment from the watershed. They are constructed of local material like earth, rock, timber, etc. These are suitable for small catchment varying in size from 40 to 400 hectares. It is necessary to provide small check dams on the subsidiary streams flowing into the main streams besides the check dams in the main stream. Proper consideration should be given to the number and location of check dams required. It is preferable to minimize the height of the check dams. If the stream has, a very-steep slope, it is desirable to start with a smaller height for the check dams than may ultimately be necessary.

Check dams may generally cost more per unit of storage than the reservoirs they protect. Therefore, it may not always be possible to adopt them as a primary method of sediment control in new reservoirs. However, feasibility of providing check dams at later date should not be overlooked while planning the construction of a new reservoir.

1.1.2. Contour Bunding and Trenching

These are important methods of controlling soil erosion on the hills and sloping lands, where gradients of cultivated fields or terraces are flatter, say up to 10 percent. By these methods the hill side is split up into small compartments on which the rain is retained and surface run-off is modified with prevention of soil erosion. In addition to contour bunding, side trenching is also provided as per requirement.

1.1.3. Gully Plugging

This is done by small rock fill dams. These dams will be effective in filling up the gullies with sediment coming from the upstream of the catchment and also prevent further widening of the gully.

1.1.4. Bank Protection

This is achieved by terracing, revetment, retaining walls, gabions and spurs.

1.2. Agronomy

The agronomic measures include establishment of vegetative screen, contour farming, strip cropping and crop rotation.

1.3. Forestry

Forestry measures include forest conservancy, control on grazing, lumbering, operations and forest fires along with management and protection of forest plantations.

2. Preventive measures to check inflow of sediment into the reservoir

2.1. Restricting the waste/sediment entering into the reservoirs due to agricultural and infrastructural activities surrounding the submergence.

2.2. Construction of by-pass channels or conduits.

The various methods in this category require the construction of some type of diversion dam or weir at the head of the reservoir basin, and a canal, tunnel or conduit leading around the reservoir to a point below the dam where the flow may re-enter the main channels. In such cases the flood flows of sediment laden water are by-passed to the downstream of the dam. In some cases where topography permits construction of new off channel reservoirs can be considered. These reservoirs will invariably have a forebay and check dam on the upstream for trapping the sediment. The stored water in the fore bay is led to the reservoir and the sediment trapped is flushed through by by-pass channel/ conduit/tunnel to the main channel downstream of the dam.

6.9.3 Control of Sediment Deposition

The deposition of sediment in a reservoir may be controlled to a certain extent by designing and operating gates or other outlets in the dam in such a manner as to permit selective withdrawals of water having a higher than average sediment content. The suspended sediment content of the water in reservoirs is higher during and just after flood flow. Thus, more the water wasted at such times, the smaller will be the percentage of the total sediment load to settle into permanent deposits. There are generally three methods:

- **Density current**

Water at various levels of a reservoir often contains radically different concentrations of suspended sediment particularly during and after flood flows. If all wastewater could be withdrawn at those levels where the concentration is highest, a significant amount of sediment might be removed from the reservoir. Because a submerged outlet draws water towards it from all directions, the vertical dimension of the opening should be small with respect to the thickness of the layer and the rate of withdrawal also should be low.

- **Waste-water release**

Controlling the sedimentation by controlling waste- water release is obviously possible only when water can be or should be wasted. This method is applicable only when a reservoir is of such size that a small part of large flood flows will fill it.

In the design of the dam, sediment may be passed through or over it as an effective method of silt control by placing a series of outlets at various elevations. The percentage of total sediment load that might be ejected from the reservoir through proper gate control will differ greatly with different locations. It is probable that as much as 20 percent of the sediment inflow could be passed through many reservoirs by venting through outlets designed and controlled.

- **Scouring Sluicing**

This method is somewhat similar to both the control of waste-water release and the draining and flushing methods

The distinctions amongst them are the following:

a) The waste-water release method ejects sediment laden flood flows through deep spillway gates or large under-sluices at the rate of discharge that prevents sedimentation.

b) Drainage and flushing method involves the slow release of stored water from the reservoir through small gates or valves making use of normal or low flow to entrain and carry the sediment, and

c) Scouring sluicing depends for its efficiency on either the scouring action exerted by the sudden rush of impounded water under a high head through under-sluices or on the scouring action of high flood discharge coming into the reservoir

Scouring sluicing method can be used in the following:

i. Small power dams that depend to a great extent on pondage but not on storage;

ii. Small irrigation reservoirs, where only a small fraction of the total annual flow can be stored;

iii. Any reservoir in narrow channels, gorges, etc, where water wastage can be afforded; and

iv. When the particular reservoir under treatment is a unit in an interconnected system so that the other reservoirs can supply the water needed.

6.9.4 Removal of Sediment Deposit

The most practical means of maintaining the storage capacity are those designed to prevent accumulation of permanent deposits as the removal operations are extremely expensive, unless the material removed is usable. Therefore, the redemption of lost storage by removal should be adopted as a last resort. The removal of sediment deposit implies in general, that the deposits are sufficiently compacted or consolidated to act as a solid and, therefore, are unable to flow along with the water. The removal of sediment deposits may be accomplished by a variety of mechanical and hydraulic or methods, such as excavation, dredging, siphoning, draining, flushing, flood sluicing, and sluicing aided by such measures as hydraulic or mechanical agitation or blasting of the sediment. The excavated sediments may be suitably disposed off so that, these do not find the way again in the reservoir.

1. Excavation

The method involves draining most of or all the water in the basin and removing the sediment by hand or power operated shovel, dragline scraper or other mechanical means.

The excavation of silt and clay, which constitute most of the material in larger reservoirs, is more difficult than the excavation of sand and gravel. Fine-textured sediment cannot be excavated easily from larger reservoirs unless it is relatively fluid or relatively compact.

2. Dredging

This involves the removal of deposits from the bottom of a reservoir and their conveyance to some other point by mechanical or hydraulic means, while water storage is being maintained.

Dredging practices are grouped as:

a) Mechanical dredging by bucket, ladder, etc;
b) Suction dredging with floating pipeline and a pump usually mounted on a barge; and
c) Siphon dredging with a floating pipe extending over the dam or connected to an opening in the dam and usually with a pump on a barge.

NOTES

1) Practicality of the two methods, namely, excavation and dredging, requires to be carefully considered in any particular case.
2) Suitable measures to prevent deposition of the dredged silt in the natural channel where it is discharged need to be adopted.

3. Draining and Flushing

The method involves relatively slow release of all stored water in a reservoir through gates or valves located near bottom of the dam and the maintenance thereafter of open outlets for a shorter or longer period during which normal stream flow cuts into or directed against the sediment deposits. Therefore, this method may be adopted in flood control reservoirs.

4. Sluicing with Controlled Water

This method differs from the flood sluicing in that the controlled water supply permits choosing the time of sluicing more advantageously and that the water may be directed more effectively against the sediment deposits. While the flood sluicing depends either on the occurrence of flood or on being able to release rapidly all of a full or nearly full supply of water in the main reservoir is empty. The advantage of this method is that generally more sediment can be removed per unit of water used than in flood scouring or draining and flushing.

5. Sluicing with Hydraulic and Mechanical Agitation

Methods that stir up break up or move deposits of sediment into a stream current flowing through a drained reservoir basin or into a lake current moving through and out of a full reservoir will tend to make the removal of sediment from the reservoir more complete. Wherever draining, flushing or sluicing appear to be warranted, the additional use of hydraulic means for stirring up the sediment deposits, or sloughing them off, into a stream flowing through the reservoir basin should be considered. It has, however, limited application.

6.10 Area – Capacity – Curve of Kakdiamba Reservoir

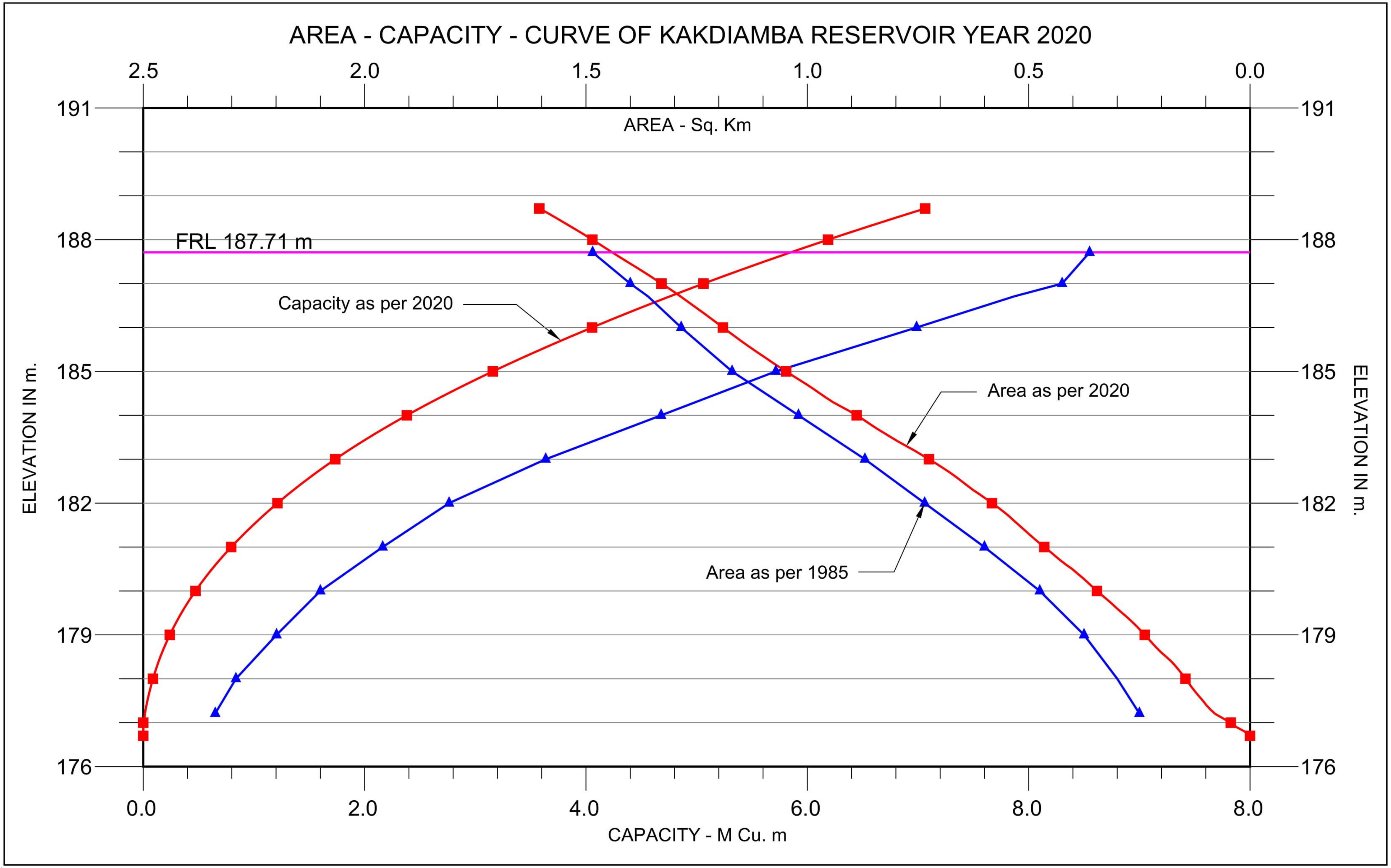


Figure 6.10-1 AREA – CAPACITY - CURVE

6.11 Segment, Contour, Wire Frame Map and L section:

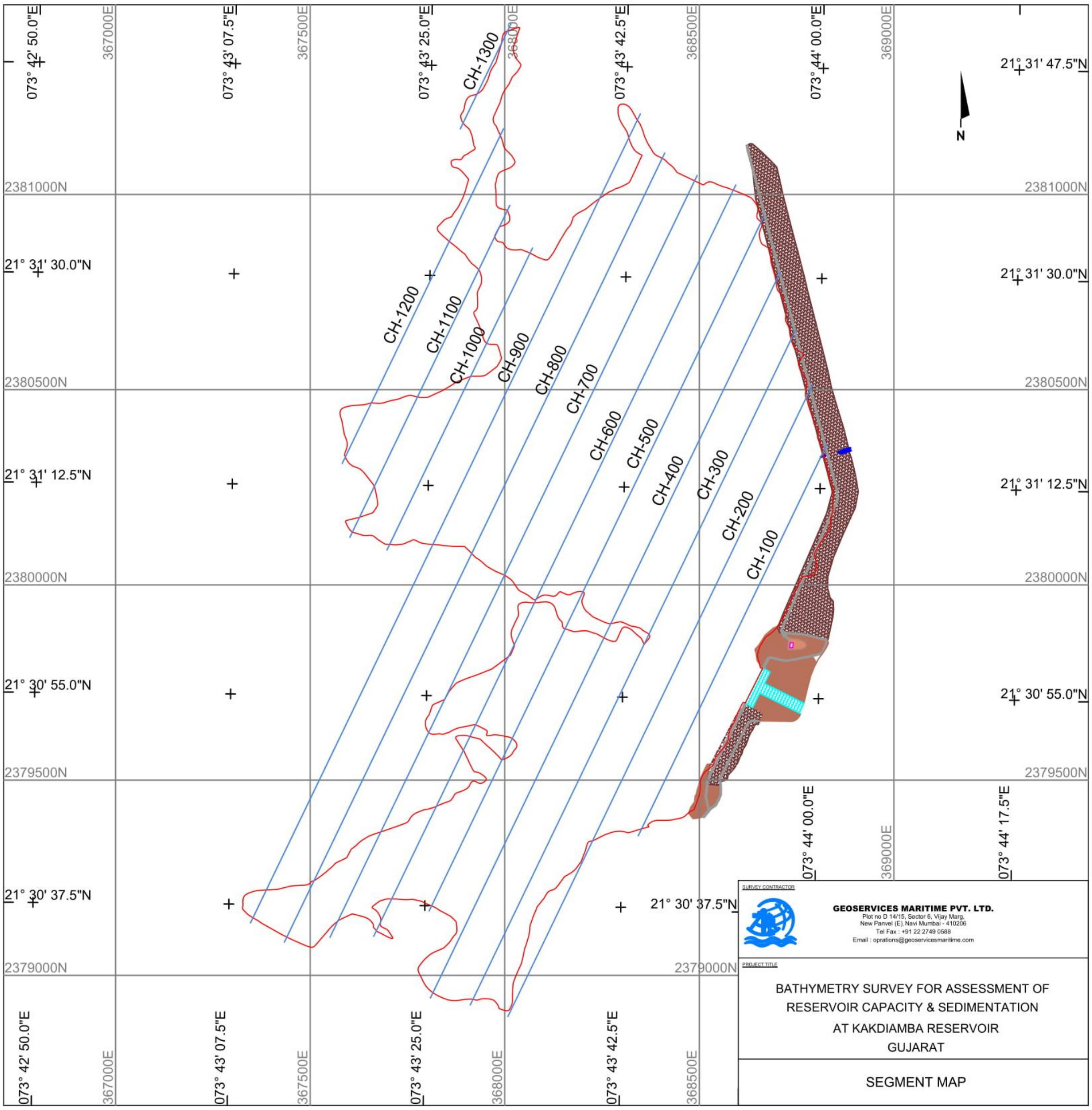


Figure 6.11-1 SEGMENT MAP FOR CROSS SECTION

Cross sections showing bed profile at 100m interval were prepared and are provided as soft copy in CD/Hard Disc. Total 13 cross section profiles were prepared.

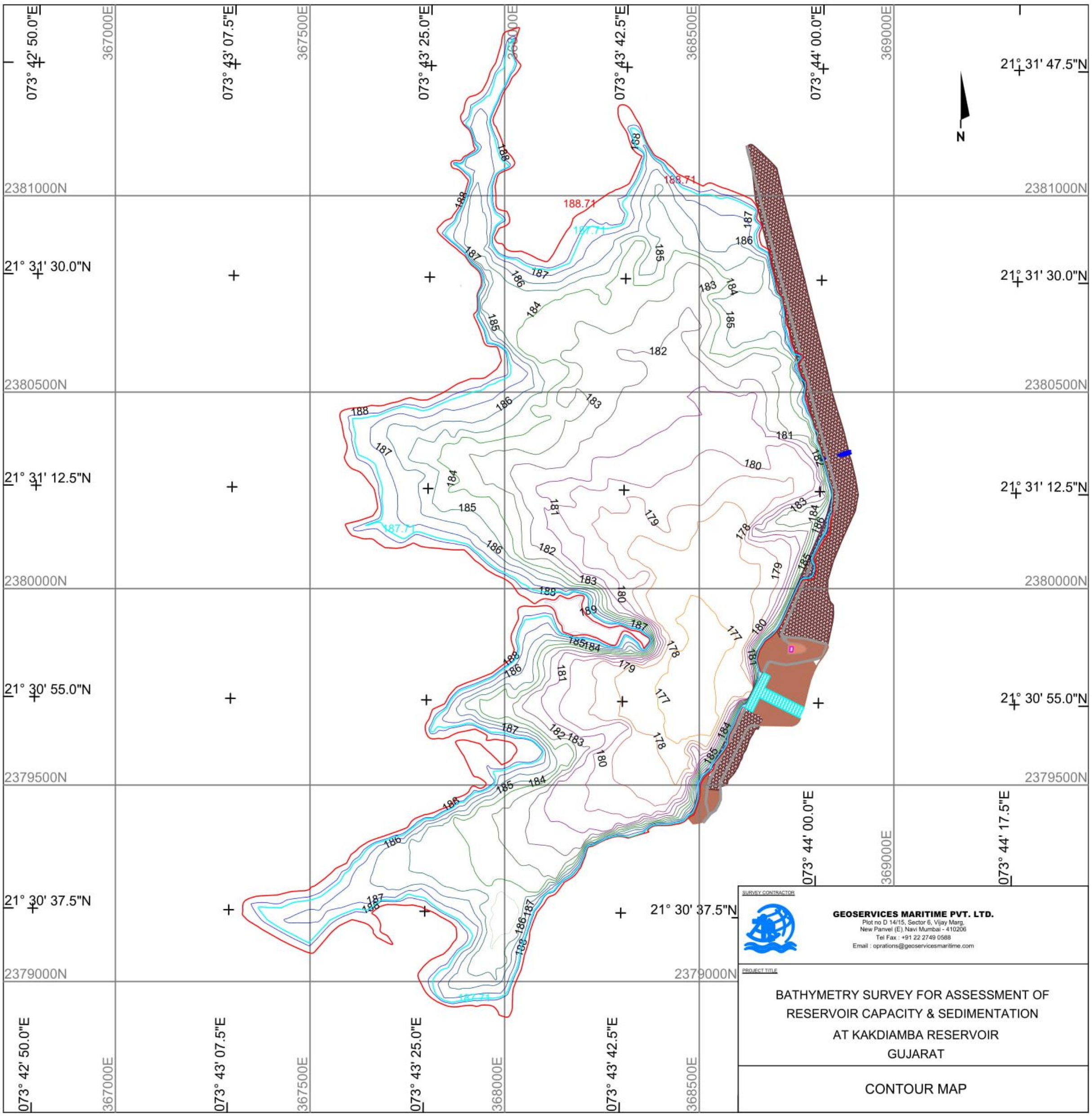


Figure 6.11-2 CONTOUR MAP

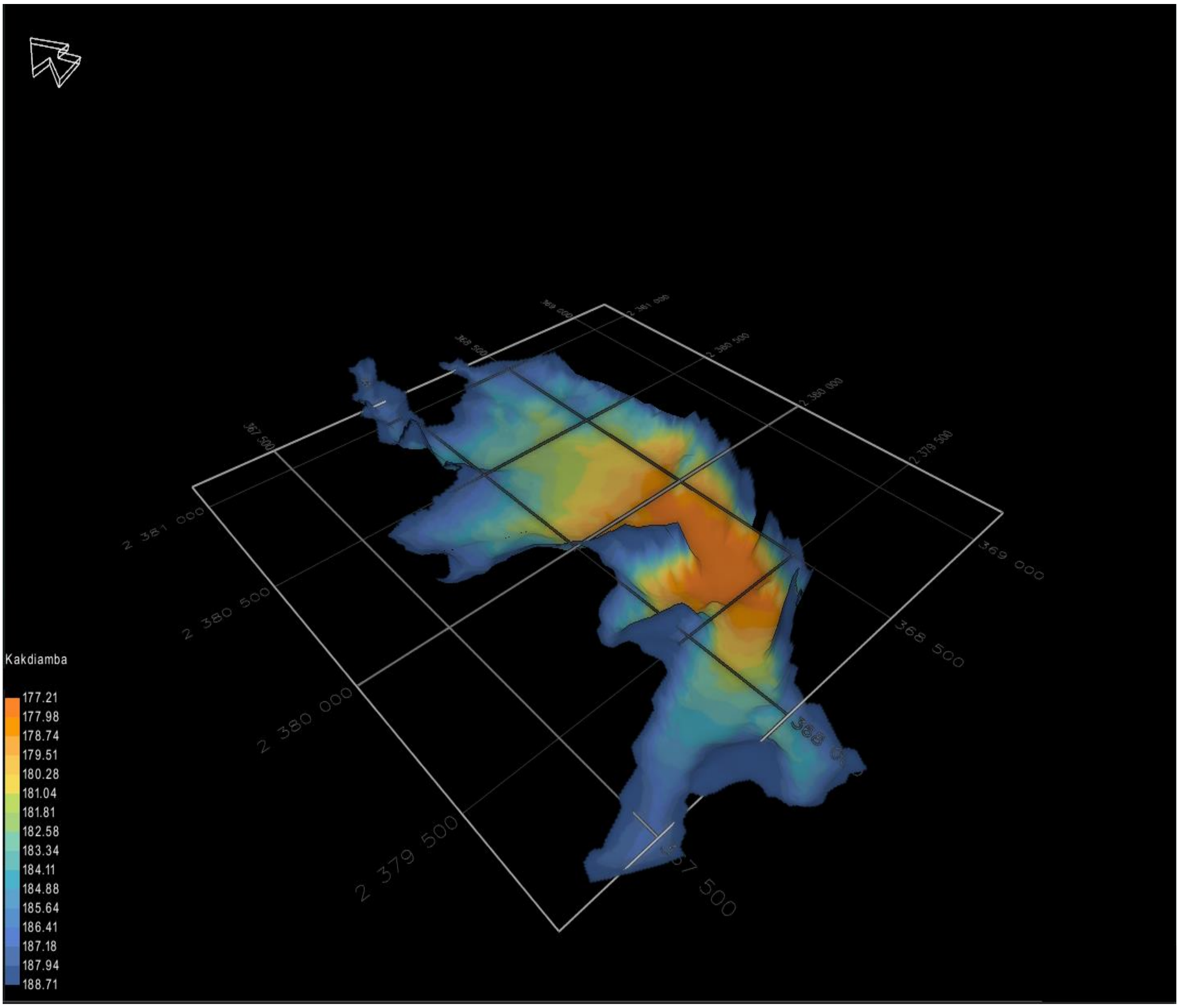


Figure 6.11-3 WIRE FRAME MAP

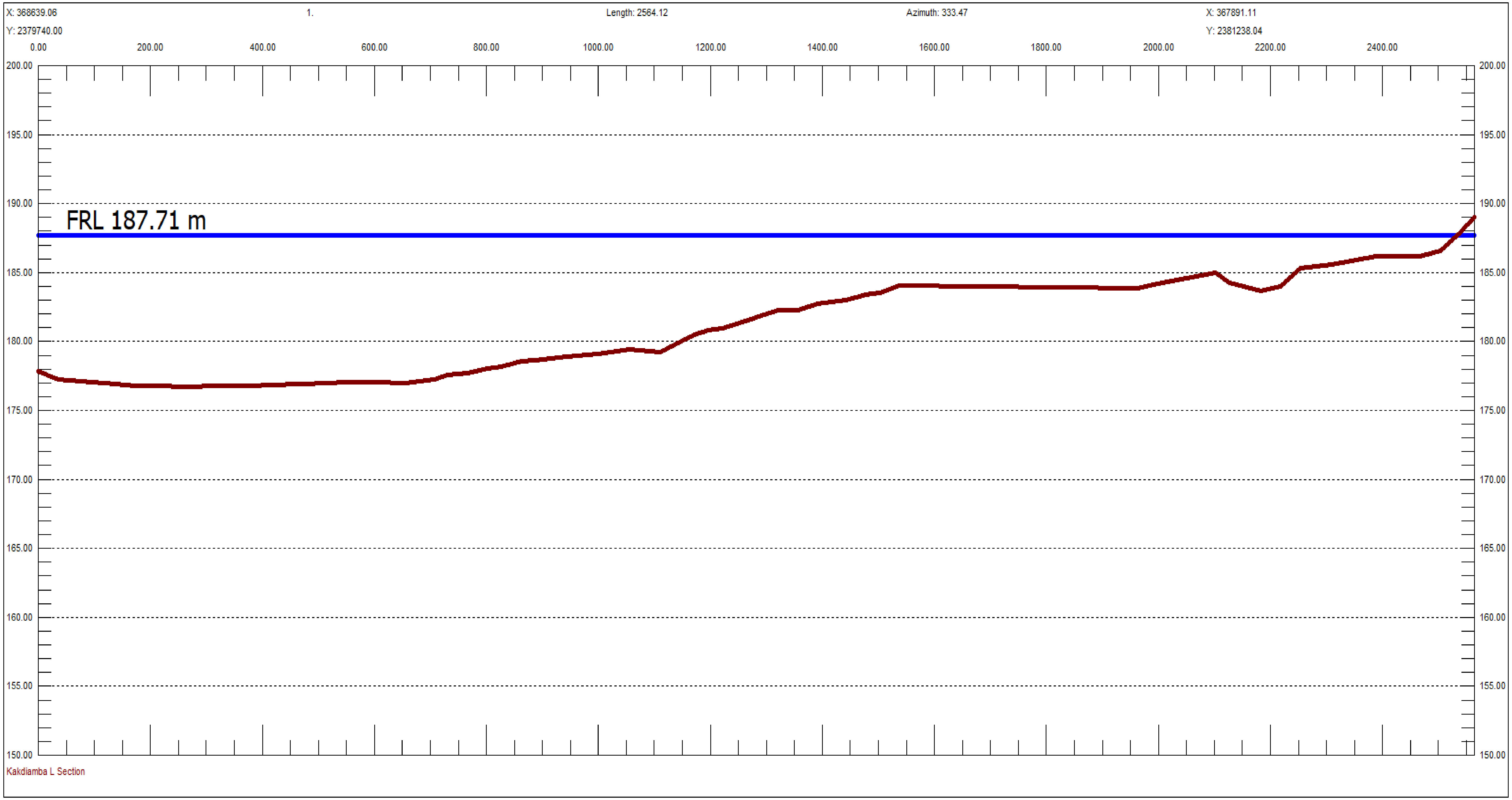


Figure 6.11-4 L Section

7 DGPS OBSERVATION REPORT

CSRS-PPP 3.45.0 (2020-07-08)

OBS_Kakdiamba.20o
2510

Data Start	**Data End**	**Duration of Observations**
2020-10-25 07:44:00.00	2020-10-25 11:54:00.00	4:10:00
Processing Time		**Product Type**
17:18:12 UTC 2020/10/25		NRCan Ultra-rapid
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static

Elevation Cut-Off	**Rejected Epochs**	**Fixed Ambiguities**	**Estimation Steps**
7.5 degrees	0.00 %	96.97 %	60.00 sec

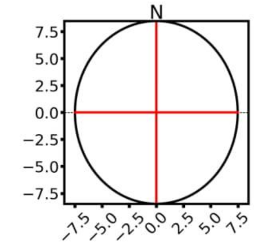
Antenna Model	**APC to ARP**	**ARP to Marker**
GMXZENITH35	L1 = 0.125 m L2 = 0.132 m	H:1.552m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for OBS_Kakdiamba.20o

	Latitude (+n)	**Longitude (+e)**	**Ell. Height**
NAD83(CSRS) (2020.8)	21° 30' 54.51098"	73° 43' 53.44345"	130.168 m
Sigmas(95%)	0.006 m	0.006 m	0.030 m
A priori*	21° 30' 54.52773"	73° 43' 53.52584"	134.529 m
Estimated – A priori	-0.515 m	-2.371 m	-4.361 m

95% Error Ellipse (mm)
semi-major: 8 mm
semi-minor: 7 mm
semi-major azimuth: 0° 0' 4.19"



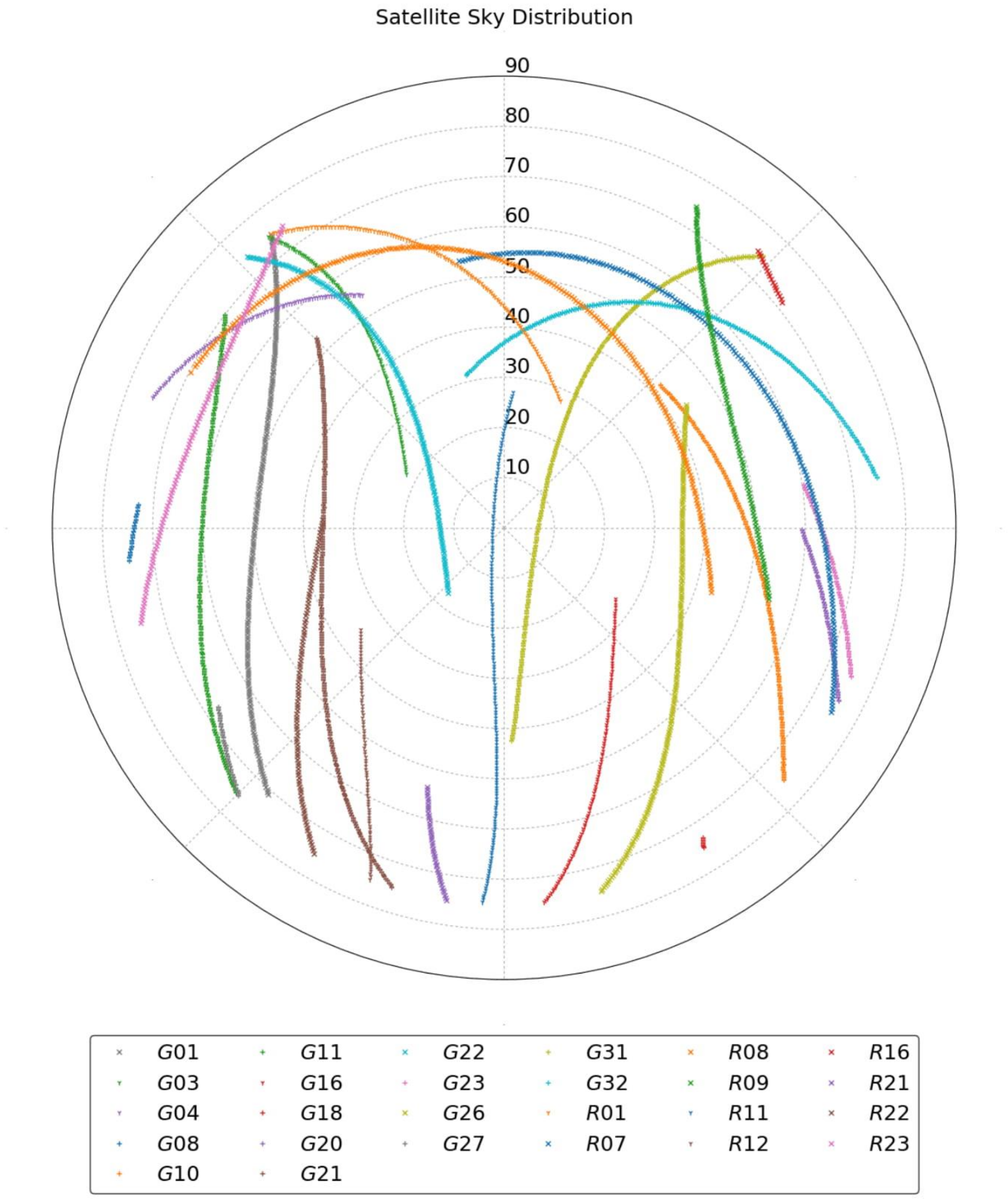
UTM (North)
Zone 43

2379694.986 m (N)
368617.296 m (E)

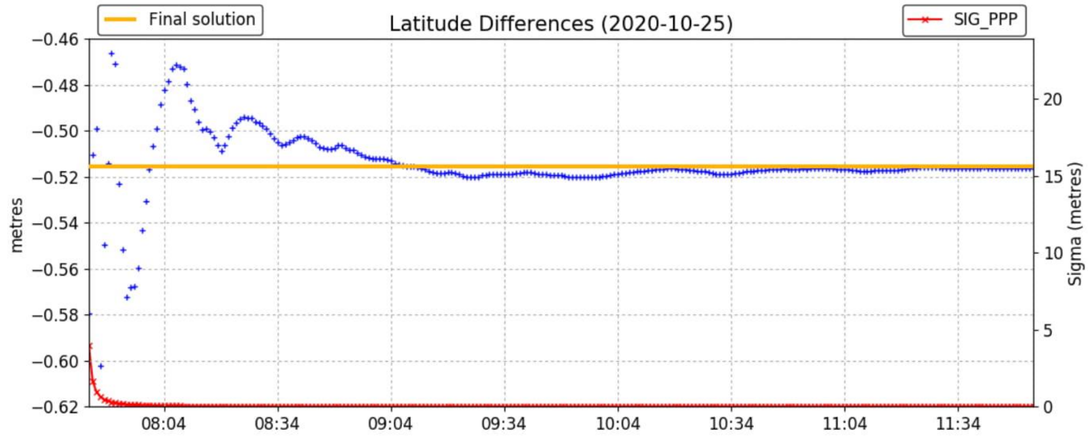
Scale Factors
0.99981330 (point)
0.99979284 (combined)

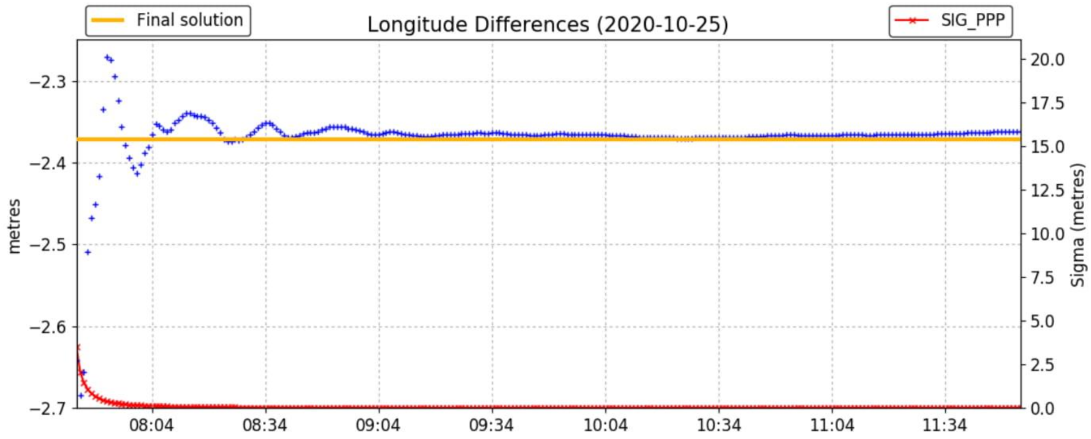
*(Coordinates from RINEX header used as a priori position)

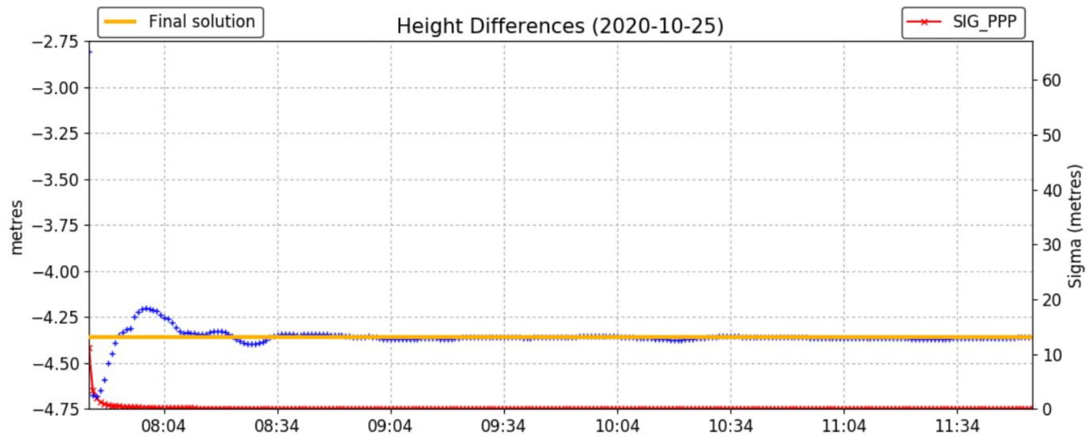
1


Satellite Sky Distribution
90
80
70
60
50
40
30
20
10
G01
G03
G04
G08
G10
G11
G16
G18
G20
G21
G22
G23
G26
G27
G31
G32
R01
R07
R08
R09
R11
R12
R16
R21
R22
R23

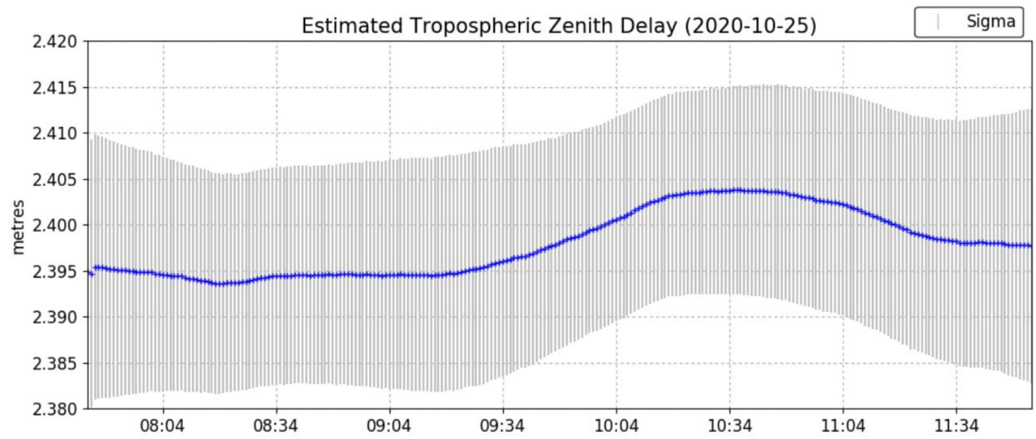
2

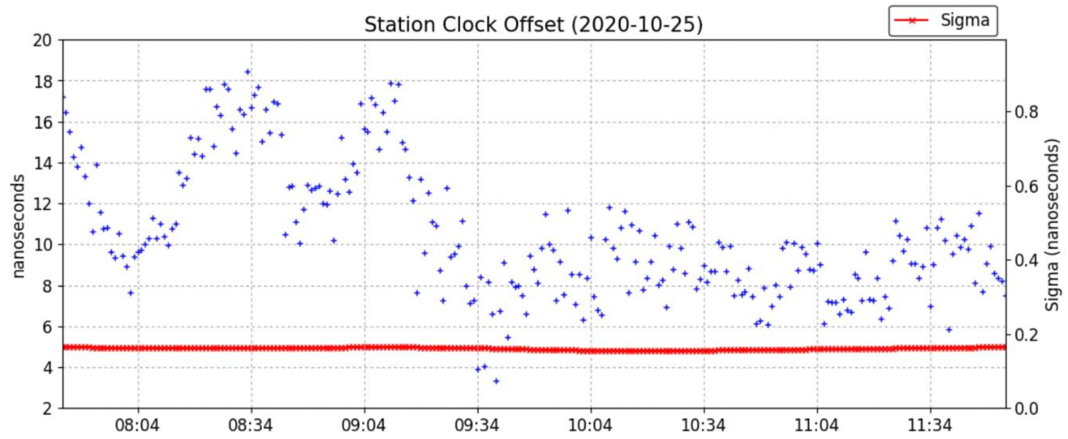

Final solution
Latitude Differences (2020-10-25)
SIG_PPP
metres
Sigma (metres)
−0.46
−0.48
−0.50
−0.52
−0.54
−0.56
−0.58
−0.60
−0.62
20
15
10
5
0
08:04
08:34
09:04
09:34
10:04
10:34
11:04
11:34

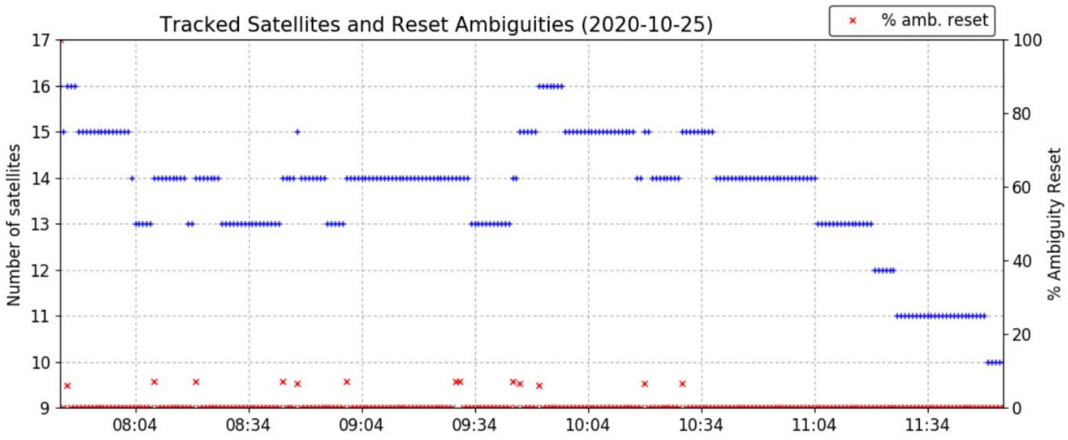

Final solution
Longitude Differences (2020-10-25)
SIG_PPP
metres
Sigma (metres)
−2.3
−2.4
−2.5
−2.6
−2.7
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
08:04
08:34
09:04
09:34
10:04
10:34
11:04
11:34


Final solution
Height Differences (2020-10-25)
SIG_PPP
metres
Sigma (metres)
−2.75
−3.00
−3.25
−3.50
−3.75
−4.00
−4.25
−4.50
−4.75
60
50
40
30
20
10
0
08:04
08:34
09:04
09:34
10:04
10:34
11:04
11:34

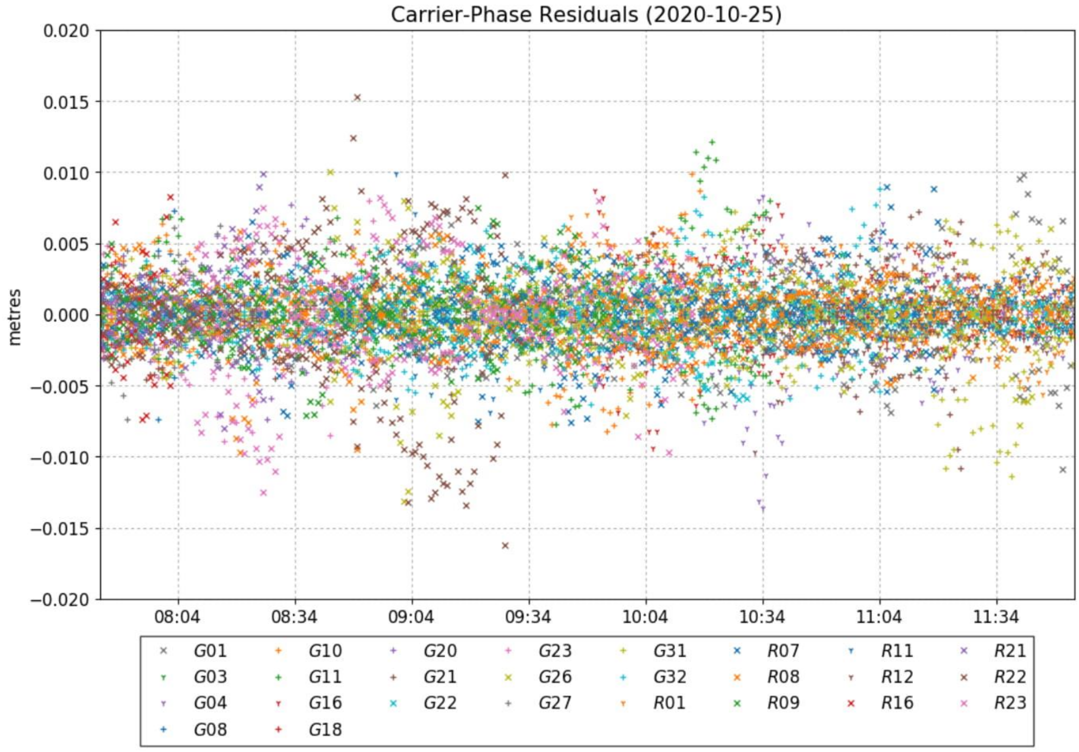
3

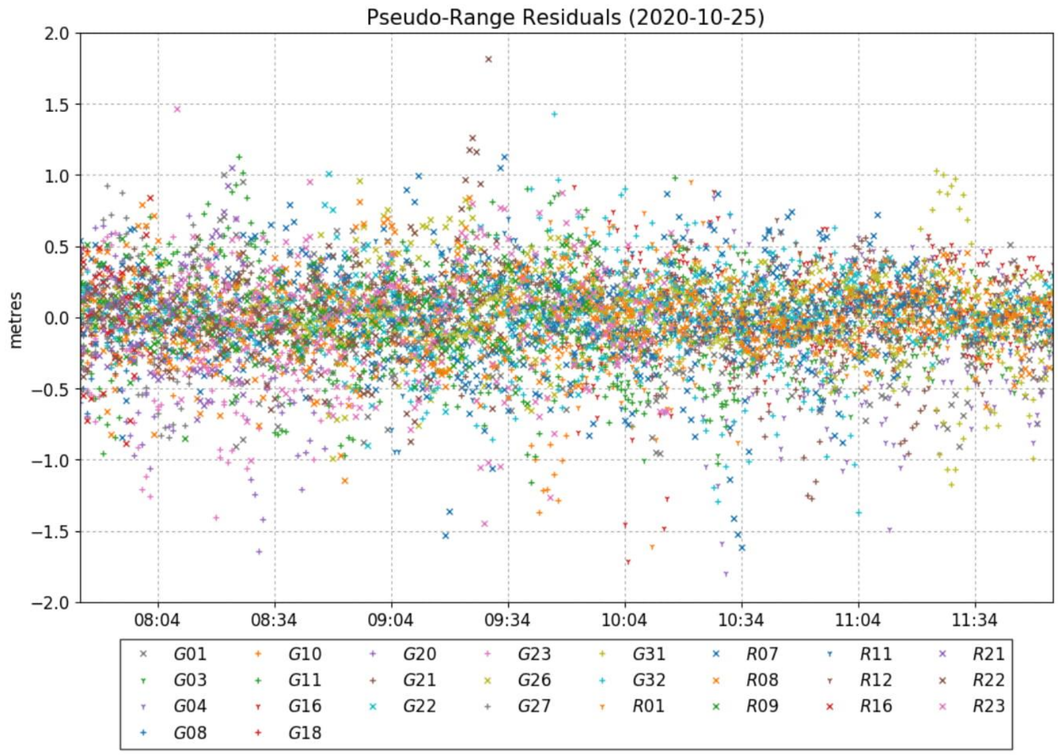

Estimated Tropospheric Zenith Delay (2020-10-25)
Sigma
metres
2.420
2.415
2.410
2.405
2.400
2.395
2.390
2.385
2.380
08:04
08:34
09:04
09:34
10:04
10:34
11:04
11:34


Station Clock Offset (2020-10-25)
Sigma
nanoseconds
Sigma (nanoseconds)
20
18
16
14
12
10
8
6
4
2
0.8
0.6
0.4
0.2
0.0
08:04
08:34
09:04
09:34
10:04
10:34
11:04
11:34


Tracked Satellites and Reset Ambiguities (2020-10-25)
% amb. reset
Number of satellites
% Ambiguity Reset
17
16
15
14
13
12
11
10
9
100
80
60
40
20
0
08:04
08:34
09:04
09:34
10:04
10:34
11:04
11:34

4


Carrier-Phase Residuals (2020-10-25)
metres
0.020
0.015
0.010
0.005
0.000
−0.005
−0.010
−0.015
−0.020
08:04
08:34
09:04
09:34
10:04
10:34
11:04
11:34
G01 G10 G20 G23 G31 R07 R11 R21
G03 G11 G21 G26 G32 R08 R12 R22
G04 G16 G22 G27 R01 R09 R16 R23
G08 G18


Pseudo-Range Residuals (2020-10-25)
metres
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
08:04
08:34
09:04
09:34
10:04
10:34
11:04
11:34
G01 G10 G20 G23 G31 R07 R11 R21
G03 G11 G21 G26 G32 R08 R12 R22
G04 G16 G22 G27 R01 R09 R16 R23
G08 G18

5

8 SINGLE BEAM ECHOSOUNDER BAR CHECK RESULTS

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title:	Vessel:	Place:
	Bathymetric Survey	**Aqua Marina**	**Kakdiamba**
Date: **28-Oct-20**	Time: **08.05hrs**	Client: **Water Resources Investigation division**	
Observed By: **Amit Singh**		Echosounder Model and SL. No. **Reson Navisound 215**	Area Depth **11**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity Average	Sound Velocity Upto Depth
0.5				1500	11

Barcheck Frequency selected	Survey Frequency:	Manufacturer's Accuracy	
210	210	0.20 % of Depth	0.02 m

Observations while lowering			Observations while hoisting		
Bar Depth (m)	ES Reading (m)	Difference (m)	Bar Depth (m)	ES Reading (m)	Difference (m)
2	2.01	-0.01	7	6.99	0.01
3	2.99	0.01	6	6.02	-0.02
4	3.99	0.01	5	4.99	0.01
5	5.01	-0.01	4	4.02	-0.02
6	6.02	-0.02	3	3.01	-0.01
7	6.99	0.01	2	1.99	0.01
	Average	-0.0017		Average	-0.0033
	Std. Dev	0.0133		Std. Deviation	0.0151
				Cumulative Average	0.00
				Cumulative Std. Deviation	0.0012

The Echosounder Barcheck Values are Negligible for Application

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GMPL Party Chief

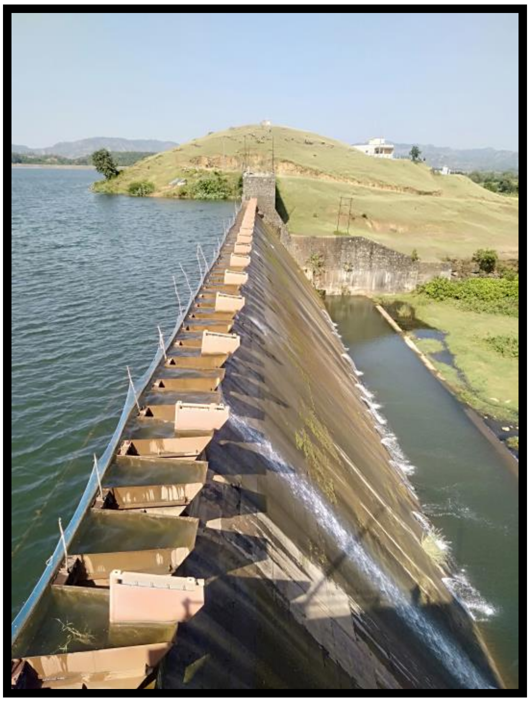
9 PHOTOGRAPHS

The following Photographs showing the Survey activities and features available at site

Level transfer from Fuse Gate to OBS KAKDIAMBA

Control Cabin and TBM 2

Spot fixing with RTK Rover



Spillway

Bathy Survey

TBM 1 near Guesthouse

TBM 2 on near Control cabin

END OF REPORT