GEOSERVICES MARITIME PVT. LTD.

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

GMPL REPORT NUMBER: P-SUR-BATHY-004-2020-WRD-KELIYA
SURVEY PERIOD: 16 OCT TO 20 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

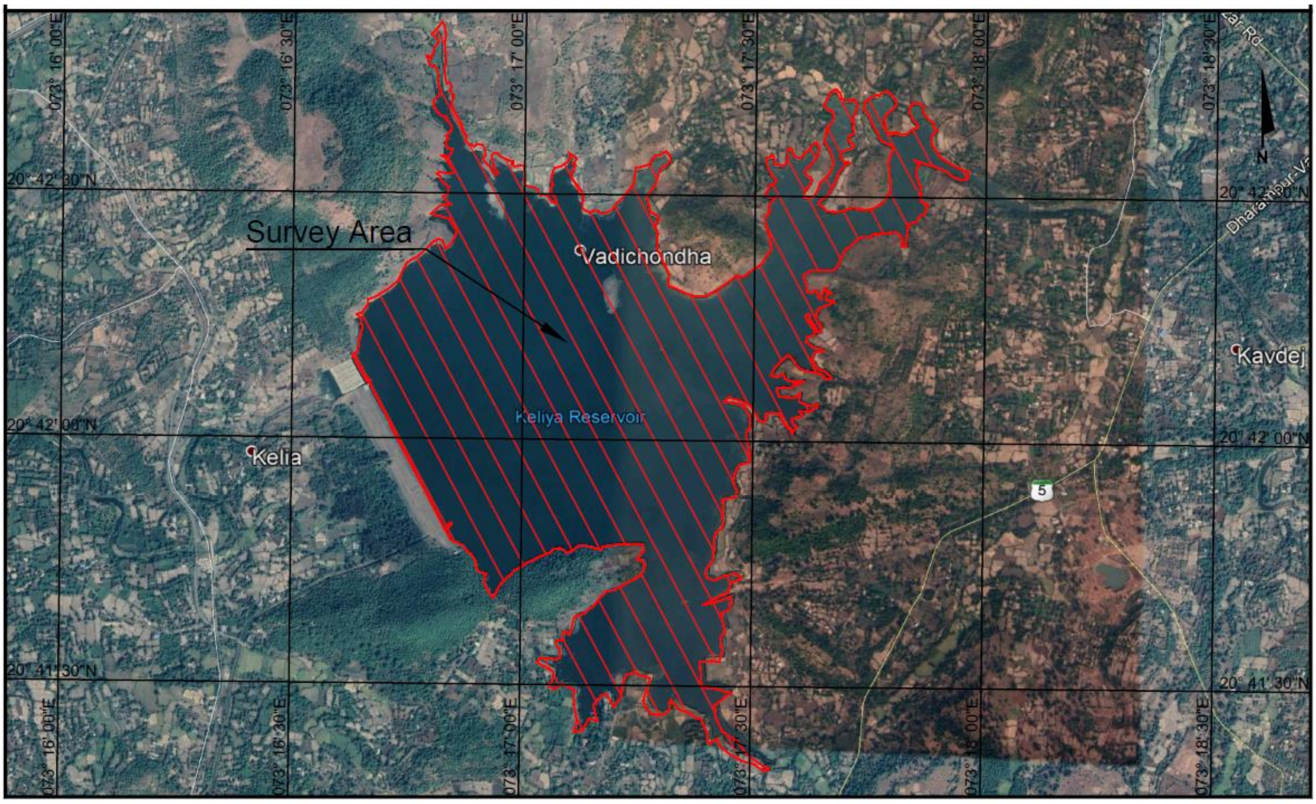


Figure 1.1-1 LOCATION MAP

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

DOCUMENT ARRANGEMENT

REPORT OF SURVEY WITH CHART / DRAWING

CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 Keliya 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 Keliya 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 main objective of the topographic and bathymetric survey of reservoir is as follow:

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 Keliya Reservoir.

The detailed scope of work was:

i) To measure the water depth of the Keliya 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.

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 KELIYA RESERVOIR

Keliya Irrigation Scheme envisage construction of Dam across river Kharera a tributary of river Kaveri near village Keliya of Vansada Taluka of Navasari district in Gujarat. The scheme was impounded in the year 1984, and the project is mainly for irrigation.

The total Catchment Area of Keliya Reservoir is 27.58 Sq. Km. The Full Reservoir Level (FRL) is 112.60m at impounding and 113.40 m after increasing Dam height and Minimum Draw Down Level (MDDL) is 98.10 m. The gross storage capacity at time of impounding was 18.10 M Cu. m and after increasing dam height is 19.98 M Cu. m. The dead storage was 0.738 M Cu. m and live storage was 17.362 M Cu. m at time of impounding and 19.242 M Cu. m after increasing dam height.

I	**LOCATION**		
	State	Gujarat	
	District	Navasari	
	River	Kharera Tributary of River Kaveri	
II	**HYDROLOGY**		
	Catchment Area	27.58 Sq. Km	
	Average Annual weighted Rainfall.	1970 mm	
	Maximum Discharge	1181.00 cumecs	
III	**RESERVOIR**	**At impounding (Year 1984)**	**After increasing Dam Height**
	Full Reservoir level	112.60 m	113.40 m
	Maximum Water level (HFL)	115.12 m	115.79 m
	Minimum Draw Down Level (MDDL)	98.10 m	98.10 m
	Gross Storage Capacity at FRL	18.10 M Cu. m	19.98 M Cu. m
	Dead Storage Capacity at 98.10 m	0.738 M Cu. m	0.738 M Cu. m
	Live Storage Capacity at FRL	17.362 M Cu. m	19.242 M Cu. m
	Submergence (spreaded area) at FRL.	2.188 Sq. Km	2.303 Sq. Km
IV	**DAM**		
	1. Type of Dam	Rolled filled zone type earthen dam.	
	2. Length of Dam	701 m	
	3. Top of Dam	118.60 m	
	4. Max. height from deepest foundation level	26.50 m	
	5. Length of Spillway	113.00 m (At impounding) & 113.40 m (After increasing height)	
	6. Crest level of Spillway	113.40 m	
	7. Gated/un-gated	Un-gated	

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 Keliya Reservoir survey area from 16 Oct to 20 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 Keliya 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 was 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 Keliya reservoir area.

Four (4) hours of DGPS observation was carried out at Bench Mark location, which was on the top of Dam, near spillway. Two (2) Temporary Bench Marks, one (TBM1) at top of Keliya Dam Site office and second one (TBM2) near road in the Vadichondha village were set up.

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

- The Minimum elevation within Keliya reservoir is 95.04 m above MSL.
- The Maximum depth within Keliya reservoir is 18.36 m.
- Area covered by bathymetric survey is 2.2 Sq. Km.
- Area covered by topographic survey is 0.8 Sq. Km.

According to recent survey, total area of reservoir at FRL 112.60 m (at impounding) is 2.17 Sq. Km and at FRL 113.40 m (after increasing dam height) is 2.354 Sq. Km, corresponding storage capacity is 15.664 M Cu. m and 17.465 M Cu. m respectively. Dead storage at 98.10m is 0.108 M Cu. m.

The comparison between 1984 and 2020(36 years) data results in a rate of siltation (silt index) of 24.66 Ham/100 Sq. Km/year. Annual percentage loss of gross storage capacity, live storage capacity and dead storage capacity is 0.37%, 0.29% and 2.37 % respectively for FRL 112.60 m (at impounding). And for FRL 113.40 m (after increasing dam height) rate of siltation (silt index) is 25.33 Ham/100 Sq. Km/year whereas annual percentage loss in gross storage capacity, live storage capacity and dead storage capacity is 0.35%, 0.27% and 2.37 % respectively.

The comparison of 2013 and 2020 data with respect to 1984 impounding data at FRL 113.40 m results in silt index of 47.63 Ham/100 Sq. Km/year and 25.33 Ham/100 Sq. Km/year 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 Keliya 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.

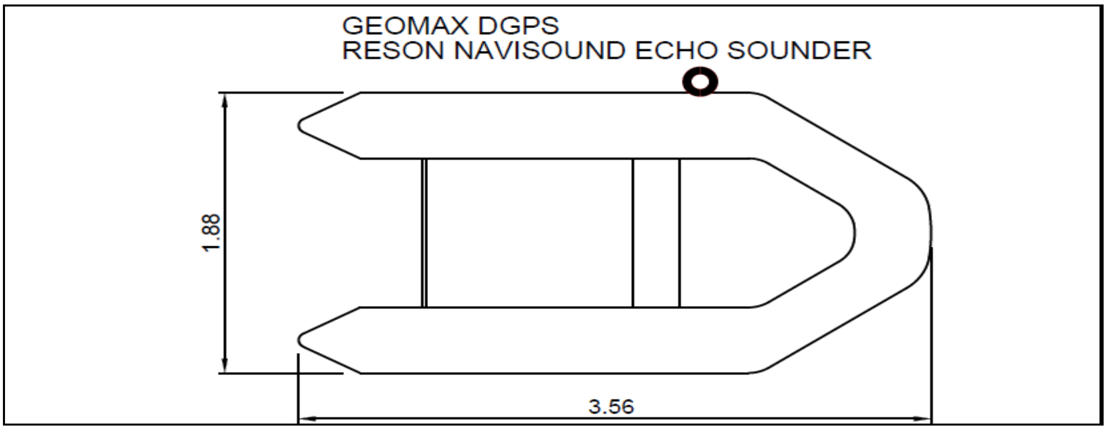


Figure 4.3-1 SURVEY BOAT ' AQUA MARINE' OFFSET DIAGRAM

5 DETAILED METHODOLOGY OF SURVEY

5.1 Mobilisation

The bathymetric survey equipment were mobilised on board "Aqua Marine" on 16 Oct 2020. After successful installation, testing and calibrations of survey equipment, the team proceeded for Data acquisition.

Geomax RTK 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.

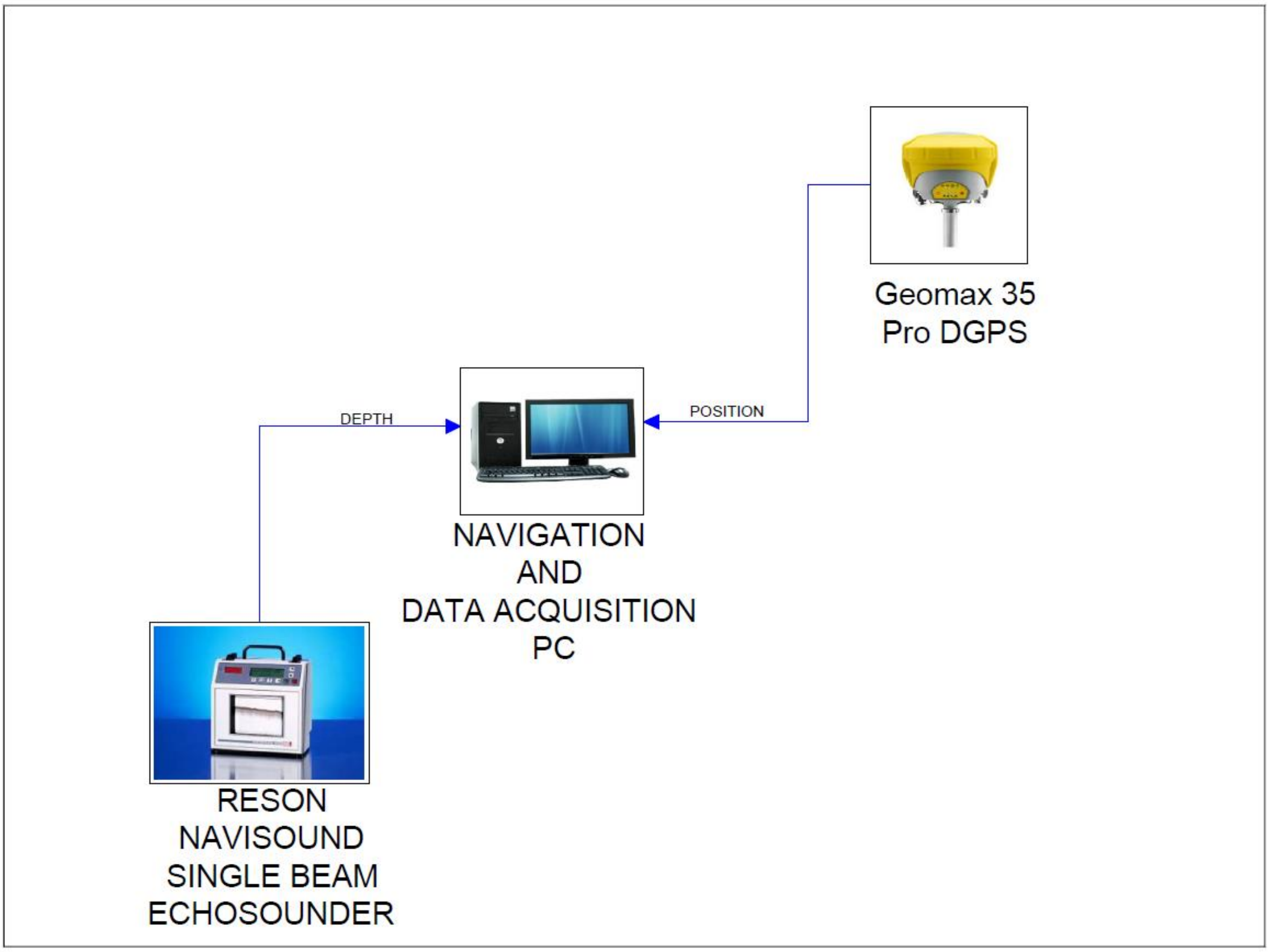


Figure 5.1-1 SBES SURVEY EQUIPMENT CONFIGURATION DIAGRAM ON BOARD

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 BM (118.601 m above MSL), made by GMPL and configured to transmit the correction.
Geomax RTK base was used for DGPS observation on top of dam, near spillway. Four Hrs. of DGPS observation was carried out. Dam authority provided benchmark elevation value of 118.601 m.

BM Observation and T.BM. Information _ Keliya Reservoir South Gujarat					
Location	**Latitude (N)**	**Longitude (E)**	**Easting (m)**	**Northing (m)**	**Elevation (m) W.r.t MSL**
BM_Observation	20°42'06.4189"	73°16'39.2134"	320615.224	2290097.099	118.601
T.B.M.01	20°41'45.9018"	73°16'51.0794"	320951.885	2289462.513	126.294
T.B.M.02	20°41'41.6769"	73°17'28.314"	322027.968	2289321.194	120.426

Table 5.3-1 BENCH MARK DETAILS

Figure 5.3-1 DGPS Observation at Dam top

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. Dam authority provided benchmark elevation value of 118.601 m. RTK DGPS Base station was set up at BM (118.601 m above MSL), 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 NaviSound' 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 altitude sensors.

5.4.4 RTK System

Geomax RTK system consists of one Base and two Rover Module. Base is set up on a known point usually Benchmark whose co-ordinates are known and is configured to transmit correction in real time to the two rovers using radio modem.

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.

Navigation

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

Echo Sounder

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 Keliya Reservoir with due, consent from Client Representative, the survey equipment on board were demobilised on 20 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)
16/10/2020	0700	113.4
16/10/2020	1900	113.4
17/10/2020	0700	113.4
17/10/2020	1900	113.4
18/10/2020	0700	113.4
18/10/2020	1900	113.4
19/10/2020	0700	113.4
9/10/2020	1900	113.4
20/10/2020	0700	113.4
20/10/2020	1900	113.4

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 Keliya 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-KELIYA-BATHY-01	Chart contains bathy , contour and cross section segments	Paper size A0 (1:5000)	PDF & CAD
2	P-SUR-004-KELIYA-OVERVIEW-01	Overview Map of Reservoir	Paper size A3	PDF & CAD
3	Area Capacity Curve Keliya - 2020	Area Capacity curve of Reservoir	Paper size A3	PDF & CAD
4	Keliya Cross Sections	23 Cross Section at 100 m interval	Only soft copy	CAD
5	Keliya L-Section	L-Section of Reservoir	Only soft copy	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 Keliya reservoir.
The values depicted in the charts are the elevation with respect to MSL.

- The Minimum elevation within Keliya reservoir is 95.04 m above MSL and
- The Maximum depth within Keliya reservoir is 18.36 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 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 model (M Cu. m)	Gross Storage Capacity using Prismoidal formula (M Cu. m)	Spread Area Sq. Km	Remarks
95.0	0.000	0.000	0.000	0.000	0.000	
95.1	0.000	0.000	0.000	0.000	0.000	
95.2	0.000	0.000	0.000	0.000	0.000	
95.3	0.000	0.000	0.000	0.000	0.000	
95.4	0.000	0.000	0.000	0.000	0.000	
95.5	0.000	0.000	0.000	0.000	0.001	
95.6	0.000	0.000	0.000	0.000	0.002	
95.7	0.001	0.000	0.001	0.001	0.003	
95.8	0.001	0.000	0.001	0.001	0.004	
95.9	0.001	0.000	0.001	0.001	0.006	
96.0	0.002	0.000	0.002	0.002	0.008	
96.1	0.003	0.000	0.003	0.003	0.010	
96.2	0.004	0.000	0.004	0.004	0.012	
96.3	0.005	0.000	0.005	0.005	0.015	

Level (m)	Dead Storage Capacity (M Cu. m)	Live Storage Capacity (M Cu. m)	Gross Storage Capacity using TIN model (M Cu. m)	Gross Storage Capacity using Prismoidal formula (M Cu. m)	Spread Area Sq. Km	Remarks
96.4	0.007	0.000	0.007	0.007	0.018	
96.5	0.009	0.000	0.009	0.009	0.022	
96.6	0.011	0.000	0.011	0.011	0.025	
96.7	0.014	0.000	0.014	0.014	0.029	
96.8	0.017	0.000	0.017	0.017	0.033	
96.9	0.021	0.000	0.021	0.021	0.037	
97.0	0.025	0.000	0.025	0.025	0.041	
97.1	0.029	0.000	0.029	0.029	0.046	
97.2	0.034	0.000	0.034	0.034	0.053	
97.3	0.040	0.000	0.040	0.040	0.057	
97.4	0.046	0.000	0.046	0.046	0.063	
97.5	0.052	0.000	0.052	0.052	0.069	
97.6	0.059	0.000	0.059	0.059	0.076	
97.7	0.067	0.000	0.067	0.067	0.084	
97.8	0.076	0.000	0.076	0.076	0.093	
97.9	0.086	0.000	0.086	0.086	0.100	
98.0	0.096	0.000	0.096	0.096	0.109	
98.1	**0.108**	**0.000**	**0.108**	**0.108**	**0.119**	**MDDL**
98.2	0.108	0.012	0.120	0.120	0.127	
98.3	0.108	0.025	0.133	0.133	0.136	
98.4	0.108	0.039	0.147	0.147	0.144	
98.5	0.108	0.054	0.162	0.162	0.153	
98.6	0.108	0.070	0.178	0.178	0.163	
98.7	0.108	0.087	0.195	0.195	0.173	
98.8	0.108	0.105	0.213	0.213	0.185	
98.9	0.108	0.124	0.232	0.232	0.195	
99.0	0.108	0.144	0.252	0.252	0.206	
99.1	0.108	0.165	0.273	0.273	0.216	
99.2	0.108	0.187	0.295	0.295	0.226	
99.3	0.108	0.210	0.318	0.318	0.236	
99.4	0.108	0.234	0.342	0.342	0.245	
99.5	0.108	0.259	0.367	0.367	0.254	
99.6	0.108	0.285	0.393	0.393	0.263	
99.7	0.108	0.312	0.420	0.420	0.272	
99.8	0.108	0.339	0.447	0.447	0.282	
99.9	0.108	0.368	0.476	0.476	0.292	
100.0	0.108	0.398	0.506	0.506	0.303	

Level (m)	Dead Storage Capacity (M Cu. m)	Live Storage Capacity (M Cu. m)	Gross Storage Capacity using TIN model (M Cu. m)	Gross Storage Capacity using Prismoidal formula (M Cu. m)	Spread Area Sq. Km	Remarks
100.1	0.108	0.429	0.537	0.537	0.314	
100.2	0.108	0.461	0.569	0.569	0.326	
100.3	0.108	0.494	0.602	0.602	0.338	
100.4	0.108	0.528	0.636	0.636	0.348	
100.5	0.108	0.563	0.671	0.671	0.359	
100.6	0.108	0.600	0.708	0.708	0.37	
100.7	0.108	0.637	0.745	0.745	0.381	
100.8	0.108	0.676	0.784	0.784	0.391	
100.9	0.108	0.716	0.824	0.823	0.401	
101.0	0.108	0.756	0.864	0.864	0.411	
101.1	0.108	0.798	0.906	0.906	0.422	
101.2	0.108	0.841	0.949	0.949	0.434	
101.3	0.108	0.885	0.993	0.992	0.446	
101.4	0.108	0.930	1.038	1.038	0.459	
101.5	0.108	0.976	1.084	1.084	0.471	
101.6	0.108	1.024	1.132	1.132	0.483	
101.7	0.108	1.073	1.181	1.181	0.495	
101.8	0.108	1.123	1.231	1.231	0.507	
101.9	0.108	1.174	1.282	1.282	0.519	
102.0	0.108	1.227	1.335	1.335	0.531	
102.1	0.108	1.281	1.389	1.388	0.543	
102.2	0.108	1.335	1.443	1.443	0.555	
102.3	0.108	1.391	1.499	1.499	0.567	
102.4	0.108	1.449	1.557	1.557	0.58	
102.5	0.108	1.507	1.615	1.615	0.593	
102.6	0.108	1.567	1.675	1.675	0.605	
102.7	0.108	1.629	1.737	1.736	0.619	
102.8	0.108	1.691	1.799	1.799	0.633	
102.9	0.108	1.755	1.863	1.863	0.647	
103.0	0.108	1.821	1.929	1.928	0.66	
103.1	0.108	1.887	1.995	1.995	0.674	
103.2	0.108	1.955	2.063	2.063	0.688	
103.3	0.108	2.025	2.133	2.133	0.702	
103.4	0.108	2.096	2.204	2.204	0.717	
103.5	0.108	2.168	2.276	2.276	0.732	
103.6	0.108	2.242	2.350	2.350	0.747	
103.7	0.108	2.318	2.426	2.426	0.762	

Level (m)	Dead Storage Capacity (M Cu. m)	Live Storage Capacity (M Cu. m)	Gross Storage Capacity using TIN model (M Cu. m)	Gross Storage Capacity using Prismoidal formula (M Cu. m)	Spread Area Sq. Km	Remarks
103.8	0.108	2.395	2.503	2.502	0.777	
103.9	0.108	2.473	2.581	2.581	0.791	
104.0	0.108	2.553	2.661	2.661	0.805	
104.1	0.108	2.634	2.742	2.742	0.82	
104.2	0.108	2.717	2.825	2.825	0.834	
104.3	0.108	2.801	2.909	2.909	0.848	
104.4	0.108	2.886	2.994	2.994	0.862	
104.5	0.108	2.973	3.081	3.081	0.876	
104.6	0.108	3.062	3.170	3.169	0.89	
104.7	0.108	3.151	3.259	3.259	0.905	
104.8	0.108	3.243	3.351	3.351	0.92	
104.9	0.108	3.335	3.443	3.443	0.936	
105.0	0.108	3.430	3.538	3.538	0.953	
105.1	0.108	3.526	3.634	3.634	0.97	
105.2	0.108	3.624	3.732	3.732	0.987	
105.3	0.108	3.723	3.831	3.831	1.004	
105.4	0.108	3.825	3.933	3.933	1.021	
105.5	0.108	3.928	4.036	4.035	1.038	
105.6	0.108	4.032	4.140	4.140	1.055	
105.7	0.108	4.139	4.247	4.246	1.072	
105.8	0.108	4.247	4.355	4.354	1.09	
105.9	0.108	4.356	4.464	4.464	1.109	
106.0	0.108	4.468	4.576	4.576	1.129	
106.1	0.108	4.582	4.690	4.690	1.147	
106.2	0.108	4.698	4.806	4.806	1.166	
106.3	0.108	4.815	4.923	4.923	1.184	
106.4	0.108	4.935	5.043	5.043	1.202	
106.5	0.108	5.056	5.164	5.164	1.221	
106.6	0.108	5.179	5.287	5.287	1.239	
106.7	0.108	5.304	5.412	5.411	1.257	
106.8	0.108	5.430	5.538	5.538	1.275	
106.9	0.108	5.559	5.667	5.666	1.293	
107.0	0.108	5.689	5.797	5.797	1.311	
107.1	0.108	5.821	5.929	5.929	1.329	
107.2	0.108	5.954	6.062	6.062	1.346	
107.3	0.108	6.090	6.198	6.198	1.363	
107.4	0.108	6.227	6.335	6.335	1.380	

Level (m)	Dead Storage Capacity (M Cu. m)	Live Storage Capacity (M Cu. m)	Gross Storage Capacity using TIN model (M Cu. m)	Gross Storage Capacity using Prismoidal formula (M Cu. m)	Spread Area Sq. Km	Remarks
107.5	0.108	6.366	6.474	6.474	1.398	
107.6	0.108	6.507	6.615	6.614	1.415	
107.7	0.108	6.649	6.757	6.757	1.431	
107.8	0.108	6.793	6.901	6.901	1.448	
107.9	0.108	6.938	7.046	7.046	1.464	
108.0	0.108	7.086	7.194	7.194	1.480	
108.1	0.108	7.235	7.343	7.342	1.496	
108.2	0.108	7.385	7.493	7.493	1.512	
108.3	0.108	7.537	7.645	7.645	1.528	
108.4	0.108	7.691	7.799	7.798	1.544	
108.5	0.108	7.846	7.954	7.954	1.561	
108.6	0.108	8.003	8.111	8.111	1.577	
108.7	0.108	8.161	8.269	8.269	1.594	
108.8	0.108	8.321	8.429	8.429	1.610	
108.9	0.108	8.483	8.591	8.591	1.627	
109.0	0.108	8.647	8.755	8.755	1.644	
109.1	0.108	8.812	8.920	8.920	1.660	
109.2	0.108	8.979	9.087	9.087	1.677	
109.3	0.108	9.147	9.255	9.255	1.694	
109.4	0.108	9.318	9.426	9.425	1.710	
109.5	0.108	9.489	9.597	9.597	1.727	
109.6	0.108	9.663	9.771	9.771	1.743	
109.7	0.108	9.838	9.946	9.946	1.760	
109.8	0.108	10.015	10.123	10.123	1.777	
109.9	0.108	10.194	10.302	10.301	1.794	
110.0	0.108	10.374	10.482	10.482	1.811	
110.1	0.108	10.556	10.664	10.664	1.827	
110.2	0.108	10.739	10.847	10.847	1.842	
110.3	0.108	10.924	11.032	11.032	1.858	
110.4	0.108	11.111	11.219	11.219	1.873	
110.5	0.108	11.299	11.407	11.407	1.889	
110.6	0.108	11.488	11.596	11.596	1.903	
110.7	0.108	11.679	11.787	11.787	1.918	
110.8	0.108	11.872	11.980	11.980	1.933	
110.9	0.108	12.066	12.174	12.174	1.946	
111.0	0.108	12.261	12.369	12.369	1.959	
111.1	0.108	12.458	12.566	12.566	1.973	

Level (m)	Dead Storage Capacity (M Cu. m)	Live Storage Capacity (M Cu. m)	Gross Storage Capacity using TIN model (M Cu. m)	Gross Storage Capacity using Prismoidal formula (M Cu. m)	Spread Area Sq. Km	Remarks
111.2	0.108	12.656	12.764	12.764	1.986	
111.3	0.108	12.855	12.963	12.963	1.999	
111.4	0.108	13.056	13.164	13.163	2.011	
111.5	0.108	13.257	13.365	13.365	2.023	
111.6	0.108	13.460	13.568	13.568	2.035	
111.7	0.108	13.664	13.772	13.772	2.047	
111.8	0.108	13.870	13.978	13.977	2.058	
111.9	0.108	14.076	14.184	14.184	2.070	
112.0	0.108	14.284	14.392	14.391	2.082	
112.1	0.108	14.492	14.600	14.600	2.094	
112.2	0.108	14.702	14.810	14.810	2.106	
112.3	0.108	14.913	15.021	15.021	2.118	
112.4	0.108	15.126	15.234	15.234	2.133	
112.5	0.108	15.340	15.448	15.448	2.152	
112.6	**0.108**	**15.556**	**15.664**	**15.664**	**2.17**	**FRL At impounding**
112.7	0.108	15.774	15.882	15.882	2.189	
112.8	0.108	15.994	16.102	16.102	2.206	
112.9	0.108	16.215	16.323	16.323	2.224	
113.0	0.108	16.439	16.547	16.547	2.243	
113.1	0.108	16.664	16.772	16.772	2.268	
113.2	0.108	16.893	17.001	17.000	2.295	
113.3	0.108	17.123	17.231	17.231	2.322	
113.4	**0.108**	**17.357**	**17.465**	**17.465**	**2.354**	**FRL after increasing dam height**
113.5	0.108	17.594	17.702	17.702	2.383	
113.6	0.108	17.833	17.941	17.941	2.405	
113.7	0.108	18.075	18.183	18.183	2.426	
113.8	0.108	18.319	18.427	18.426	2.446	
113.9	0.108	18.564	18.672	18.672	2.466	
114.0	0.108	18.812	18.920	18.920	2.486	
114.1	0.108	19.062	19.170	19.169	2.506	
114.2	0.108	19.313	19.421	19.421	2.527	
114.3	0.108	19.567	19.675	19.675	2.547	
114.4	0.108	19.823	19.931	19.930	2.568	

Level (m)	Dead Storage Capacity (M Cu. m)	Live Storage Capacity (M Cu. m)	Gross Storage Capacity using TIN model (M Cu. m)	Gross Storage Capacity using Prismoidal formula (M Cu. m)	Spread Area Sq. Km	Remarks
114.5	0.108	20.080	20.188	20.188	2.589	
114.6	0.108	20.340	20.448	20.448	2.611	
114.7	0.108	20.603	20.711	20.710	2.633	
114.8	0.108	20.867	20.975	20.975	2.655	
114.9	0.108	21.134	21.242	21.241	2.677	
115.0	0.108	21.402	21.510	21.510	2.700	
115.1	0.108	21.674	21.782	21.782	2.725	
115.2	0.108	21.948	22.056	22.056	2.756	
115.3	0.108	22.225	22.333	22.333	2.788	
115.4	0.108	22.505	22.613	22.613	2.817	
115.5	0.108	22.788	22.896	22.896	2.846	
115.6	0.108	23.074	23.182	23.182	2.873	
115.7	0.108	23.363	23.471	23.471	2.901	
115.79	**0.108**	**23.625**	**23.733**	**23.733**	**2.929**	**HFL**

Table 6.2-1 CAPACITY AND AREA

6.3 Comparative Statement of Keliya Reservoir

RL in m	Original		As per 2013 survey		As per 2020 survey		Remarks
	Gross Capacity in M Cu. m	Area in Sq. Km	Gross Capacity in M Cu. m	Area in Sq. Km	Gross Capacity in M Cu. m	Area in Sq. Km	
94	0.0085	0.002	0	0	0	0	
95	0.085	0.098	0	0	0	0	
96	0.1787	0.176	0	0	0.002	0.008	
97	0.4377	0.256	0	0	0.025	0.041	
98	0.6967	0.337	0	0	0.096	0.109	
98.1	0.7381	0.345	0.056	0.107	0.108	0.119	**MDDL**
99	1.25	0.417	0.222	0.246	0.252	0.206	
100	1.7	0.497	0.513	0.332	0.506	0.303	
101	2.25	0.61	0.875	0.392	0.864	0.411	
102	2.85	0.722	1.305	0.475	1.335	0.531	
103	3.6	0.851	1.844	0.602	1.929	0.66	
104	4.6	0.98	2.493	0.695	2.661	0.805	
105	5.65	1.134	3.26	0.855	3.538	0.953	
106	6.9	1.288	4.191	1.003	4.576	1.129	
107	8.3	1.409	5.285	1.202	5.797	1.311	
108	9.7	1.529	6.591	1.404	7.194	1.48	
109	11.3	1.656	8.073	1.549	8.755	1.644	
110	13	1.784	9.689	1.683	10.482	1.811	
111	14.8	1.943	11.433	1.801	12.369	1.959	
112	16.8	2.102	13.298	1.942	14.392	2.082	
112.6	18.1	2.188	14.494	2.037	15.664	2.17	**FRL (At Impounding)**
113	19.04	2.246	15.319	2.09	16.547	2.243	
113.4	19.98	2.303	16.17	2.186	17.465	2.354	**FRL (After Increasing Height of Dam)**

Table 6.3-1 COMPARATIVE STATEMENT OF KELIYA RESERVOIR

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

RL (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
95	0	0	0	0	0	0	0	0.001	0.001	0.001
96	0.002	0.003	0.004	0.005	0.007	0.009	0.011	0.014	0.017	0.021
97	0.025	0.029	0.034	0.04	0.046	0.052	0.059	0.067	0.076	0.086
98	0.096	**0.108**	0.12	0.133	0.147	0.162	0.178	0.195	0.213	0.232
99	0.252	0.273	0.295	0.318	0.342	0.367	0.393	0.42	0.447	0.476
100	0.506	0.537	0.569	0.602	0.636	0.671	0.708	0.745	0.784	0.824
101	0.864	0.906	0.949	0.993	1.038	1.084	1.132	1.181	1.231	1.282
102	1.335	1.389	1.443	1.499	1.557	1.615	1.675	1.737	1.799	1.863
103	1.929	1.995	2.063	2.133	2.204	2.276	2.35	2.426	2.503	2.581
104	2.661	2.742	2.825	2.909	2.994	3.081	3.17	3.259	3.351	3.443
105	3.538	3.634	3.732	3.831	3.933	4.036	4.14	4.247	4.355	4.464
106	4.576	4.69	4.806	4.923	5.043	5.164	5.287	5.412	5.538	5.667
107	5.797	5.929	6.062	6.198	6.335	6.474	6.615	6.757	6.901	7.046
108	7.194	7.343	7.493	7.645	7.799	7.954	8.111	8.269	8.429	8.591
109	8.755	8.92	9.087	9.255	9.426	9.597	9.771	9.946	10.123	10.302
110	10.482	10.664	10.847	11.032	11.219	11.407	11.596	11.787	11.98	12.174
111	12.369	12.566	12.764	12.963	13.164	13.365	13.568	13.772	13.978	14.184
112	14.392	14.6	14.81	15.021	15.234	15.448	**15.664**	15.882	16.102	16.323
113	16.547	16.772	17.001	17.231	**17.465**	17.702	17.941	18.183	18.427	18.672
114	18.92	19.17	19.421	19.675	19.931	20.188	20.448	20.711	20.975	21.242
115	21.51	21.782	22.056	22.333	22.613	22.896	23.182	23.471		
115.79	**23.733**									

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

Note: Gross storage capacity for FRL112.60 m at impounding is 15.664 M Cu. m and for FRL at 113.40 m after increasing dam height is 17.465 M Cu. m. In addition, dead storage at 98.10 m is 0.108 M Cu. m. Whereas gross storage at HFL 115.79 m is 23.733 M Cu. m.

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

RL (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
98	0.000	0.000	0.012	0.025	0.039	0.054	0.070	0.087	0.105	0.124
99	0.144	0.165	0.187	0.210	0.234	0.259	0.285	0.312	0.339	0.368
100	0.398	0.429	0.461	0.494	0.528	0.563	0.600	0.637	0.676	0.716
101	0.756	0.798	0.841	0.885	0.930	0.976	1.024	1.073	1.123	1.174
102	1.227	1.281	1.335	1.391	1.449	1.507	1.567	1.629	1.691	1.755
103	1.821	1.887	1.955	2.025	2.096	2.168	2.242	2.318	2.395	2.473
104	2.553	2.634	2.717	2.801	2.886	2.973	3.062	3.151	3.243	3.335
105	3.430	3.526	3.624	3.723	3.825	3.928	4.032	4.139	4.247	4.356
106	4.468	4.582	4.698	4.815	4.935	5.056	5.179	5.304	5.430	5.559
107	5.689	5.821	5.954	6.090	6.227	6.366	6.507	6.649	6.793	6.938
108	7.086	7.235	7.385	7.537	7.691	7.846	8.003	8.161	8.321	8.483
109	8.647	8.812	8.979	9.147	9.318	9.489	9.663	9.838	10.015	10.194
110	10.374	10.556	10.739	10.924	11.111	11.299	11.488	11.679	11.872	12.066
111	12.261	12.458	12.656	12.855	13.056	13.257	13.460	13.664	13.870	14.076
112	14.284	14.492	14.702	14.913	15.126	15.340	**15.556**	15.774	15.994	16.215
113	16.439	16.664	16.893	17.123	**17.357**	17.594	17.833	18.075	18.319	18.564
114	18.812	19.062	19.313	19.567	19.823	20.080	20.340	20.603	20.867	21.134
115	21.402	21.674	21.948	22.225	22.505	22.788	23.074	23.363		
115.79	**23.625**									

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

Note: Live storage capacity for FRL112.60 m at impounding is 15.556 M Cu. m and for FRL at 113.40 m after increasing dam height is 17.357 M Cu. m in addition live storage capacity for HFL 115.79 m is 23.625 M Cu. m.

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

RL (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
95	0	0	0	0	0.001	0.001	0.002	0.003	0.004	0.006
96	0.008	0.01	0.012	0.015	0.018	0.022	0.025	0.029	0.033	0.037
97	0.041	0.046	0.053	0.057	0.063	0.069	0.076	0.084	0.093	0.1
98	0.109	0.119	0.127	0.136	0.144	0.153	0.163	0.173	0.185	0.195
99	0.206	0.216	0.226	0.236	0.245	0.254	0.263	0.272	0.282	0.292
100	0.303	0.314	0.326	0.338	0.348	0.359	0.37	0.381	0.391	0.401
101	0.411	0.422	0.434	0.446	0.459	0.471	0.483	0.495	0.507	0.519
102	0.531	0.543	0.555	0.567	0.58	0.593	0.605	0.619	0.633	0.647
103	0.66	0.674	0.688	0.702	0.717	0.732	0.747	0.762	0.777	0.791
104	0.805	0.82	0.834	0.848	0.862	0.876	0.89	0.905	0.92	0.936
105	0.953	0.97	0.987	1.004	1.021	1.038	1.055	1.072	1.09	1.109
106	1.129	1.147	1.166	1.184	1.202	1.221	1.239	1.257	1.275	1.293
107	1.311	1.329	1.346	1.363	1.38	1.398	1.415	1.431	1.448	1.464
108	1.48	1.496	1.512	1.528	1.544	1.561	1.577	1.594	1.61	1.627
109	1.644	1.66	1.677	1.694	1.71	1.727	1.743	1.76	1.777	1.794
110	1.811	1.827	1.842	1.858	1.873	1.889	1.903	1.918	1.933	1.946
111	1.959	1.973	1.986	1.999	2.011	2.023	2.035	2.047	2.058	2.07
112	2.082	2.094	2.106	2.118	2.133	2.152	**2.17**	2.189	2.206	2.224
113	2.243	2.268	2.295	2.322	**2.354**	2.383	2.405	2.426	2.446	2.466
114	2.486	2.506	2.527	2.547	2.568	2.589	2.611	2.633	2.655	2.677
115	2.700	2.725	2.756	2.788	2.817	2.846	2.873	2.901		
115.79	**2.929**									

Table 6.6-1 SPREAD AREA IN Sq. Km YEAR -2020

Note: Area for FRL112.60 m at impounding is 2.17 Sq. Km and for FRL at 113.40 m after increasing dam height is 2.354 Sq. Km., in addition area for HFL 115.79 m is 2.929 Sq. Km.

6.7 Sediment Analysis:

6.7.1 Observed Rate of Sedimentation

The reservoir was impounded during the year 1984. As per report of the year 1984, total area of reservoir at FRL 112.60 m (at impounding) was 2.188 Sq. Km and at FRL 113.40 m (after increasing dam height) was 2.303 Sq. Km, corresponding storage capacity was 18.10 M Cu. m and 19.98 M Cu. m respectively. Dead storage at 98.10m was 0.738 M Cu. m.

G.E.R.I surveyed the reservoir by Remote Sensing Technique in the year 2013. As per survey of the year 2013, total area of reservoir at FRL 112.60 m (at impounding) was 2.037 Sq. Km and at FRL 113.40 m (after increasing dam height) was 2.186 Sq. Km, corresponding storage capacity was 14.494 M Cu. m and 16.17 M Cu. m respectively. Dead storage at 98.10m was 0.056 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 112.60 m (at impounding) is 2.17 Sq. Km and at FRL 113.40 m (after increasing dam height) is 2.354 Sq. Km, corresponding storage capacity is 15.664 and 17.465 M Cu. m respectively. Dead storage at 98.10 m is 0.108 M Cu. m.

Rate of siltation in reservoir up to FRL 112.60 m (at impounding) and FRL 113.40 m (after increasing dam height) during last 36 years (1984-2020) is observed to 0.068 and 0.070 M Cu. m / year respectively.

Original Reservoir data

Year of Impounding	:	1984			
Catchment Area	:	27.58 Sq. Km			
Spread Area at FRL 112.60 m	:	2.188 Sq. Km	Spread area at 113.40 m	:	2.303 Sq. Km
Live storage at FRL112.60 m	:	17.362 M Cu. m	Live storage at 113.40 m	:	19.242 M Cu. m
Dead storage at 98.10m	:	0.738 M Cu. m	Dead storage at 98.10 m	:	0.738 M Cu. m
Gross storage at FRL112.60 m	:	18.10 M Cu. m	Gross storage at 113.40 m	:	19.98 M Cu. m

Rate of Sedimentation (at FRL 112.60 m: at impounding) with respect to impounding year

Sr. No	Year of Survey	Capacity in M Cu. m			Silt Deposited in M Cu. m	Period in years	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	1984	0.738	17.362	18.10	-	-	-	-	-	-	-	-	
2	2013 by Remote Sensing	0.056	14.438	14.494	3.606	29	0.124	0.682 92.41%	2.924 16.84%	3.606 19.92%	44.96	0.69%	**Serious Category**
3	2020 by integrated bathymetric and topographic survey	0.108	15.556	15.664	2.436	36	0.068	0.63 85.36%	1.806 10.4%	2.436 13.46%	24.66	0.37%	**Significant Category**

Table 6.7-1 RATE OF SEDIMENTATION (FRL 112.60m)

Rate of Sedimentation (at FRL 113.40: after increasing dam height) with respect to impounding year													
Sr. No	**Year of Survey**	**Capacity in M Cu. m**			**Silt Deposited in M Cu. m**	**Period in years**	**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	1984	0.738	19.242	19.98	-	-	-	-	-	-	-	-	
2	2013 by Remote Sensing	0.056	16.114	16.17	3.81	29	0.131	0.682 92.41%	3.128 16.26%	3.81 19.07%	47.63	0.66%	**Serious Category**
3	2020 by integrated bathymetric and topographic survey	0.108	17.537	17.465	2.515	36	0.070	0.63 85.36%	1.885 9.80%	2.515 12.59%	25.33	0.35%	**Significant Category**

Table 6.7-2 RATE OF SEDIMENTATION (FRL 113.40m)

<u>According to IS -12182 (1987)</u>

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/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. The annual percentage loss from survey of the year 2013 and 2020 is 0.66% and 0.35% respectively for FRL 113.40 m.
- The decrease in annual percentage loss from 0.66% (2013 survey) to 0.35% (2020 survey) for FRL 1130.40 m is because at initial stage after dam construction sedimentation takes place at higher rate compare to later on.
- The increase in storage capacity (1.295 M Cu. m increased in Gross Storage capacity) in 2020 survey data compared to 2013 survey data is due to difference in method used to acquire survey data of the reservoir during 2013 and 2020.
- Remote Sensing method used in previous survey works on estimations of water spread area. In remote sensing method, the difference between water spread area between year of survey and earlier survey year is a real extent of silting at these levels. This change in water spread area at that water level is used to calculate storage capacity. This is the disadvantage of this method as it can only estimate area. In addition, this method is time consuming, as we will have to wait for water level to change from MDDL (lowest water level reservoir has recorded) to FRL. Also data acquired by this method is less reliable as compared to recent survey method.

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 Keliya Reservoir:

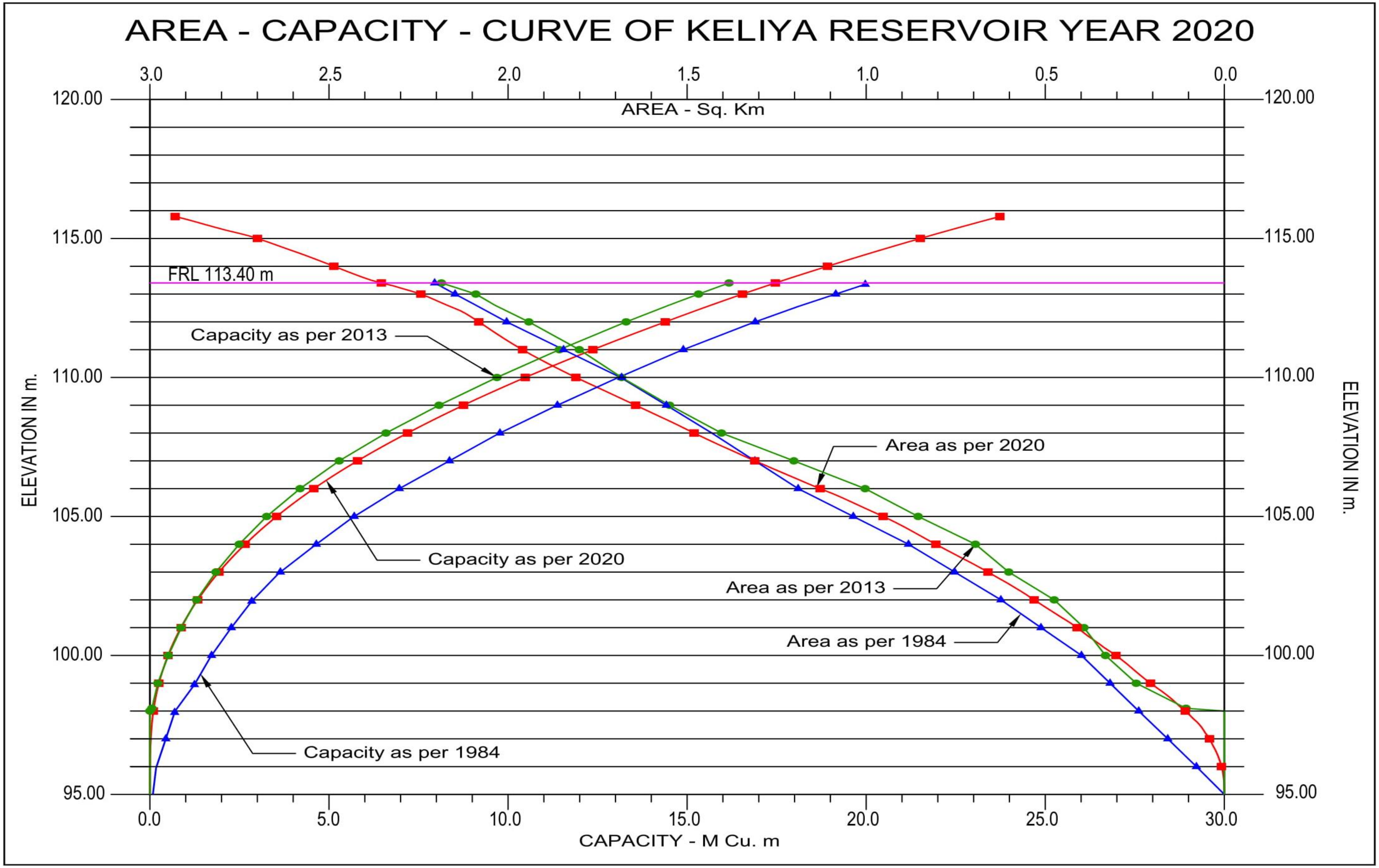


Figure 6.10-1 AREA – CAPACITY - CURVE

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

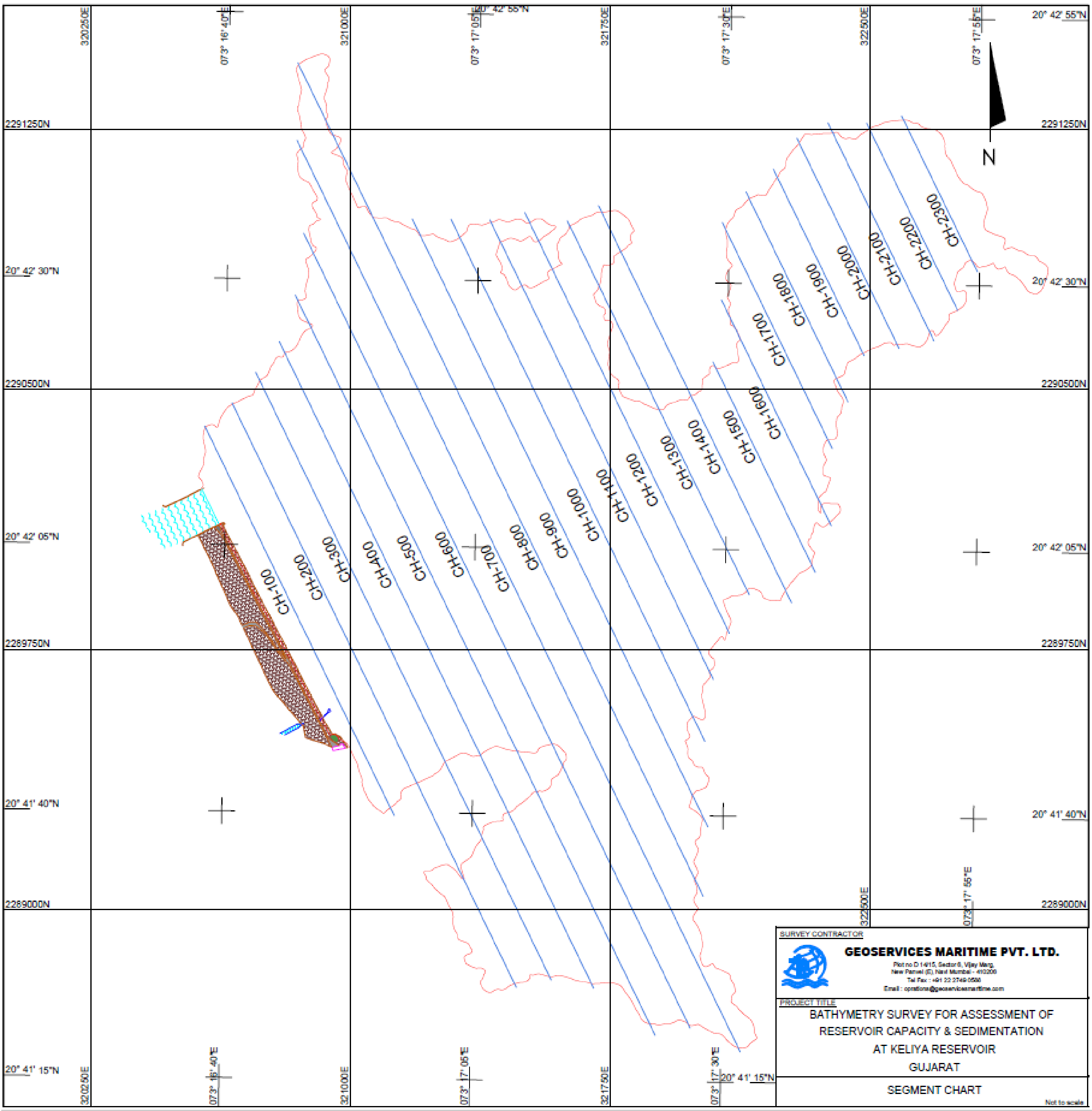


Figure 6.11-1 SEGMENT MAP FOR CROSS SECTION

Cross sections showing bed profile at 100m interval were prepared and are provided as soft copy in CD/Hard Disc. Total 23 cross section profiles were prepared.

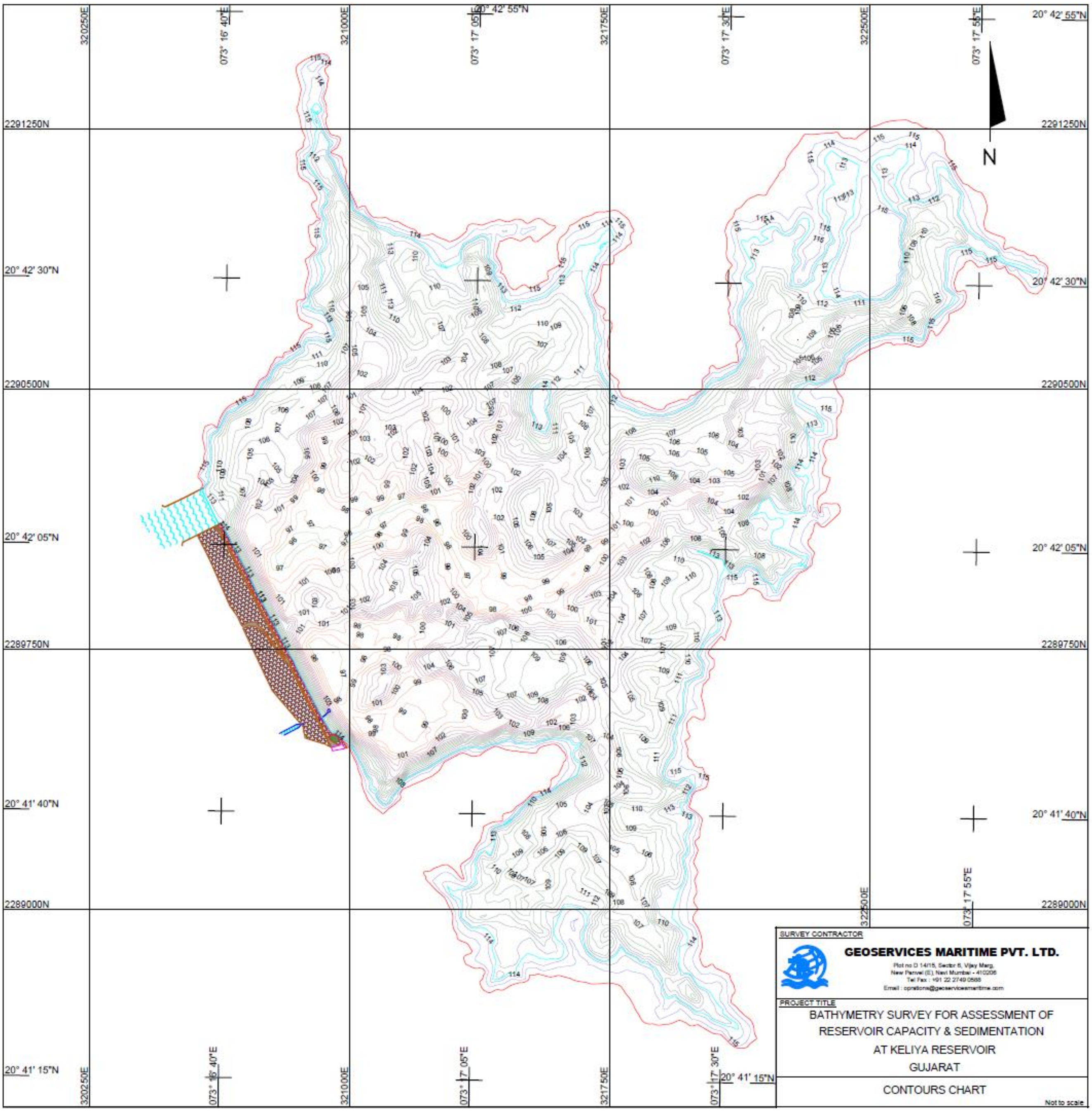


Figure 6.11-2 CONTOUR MAP

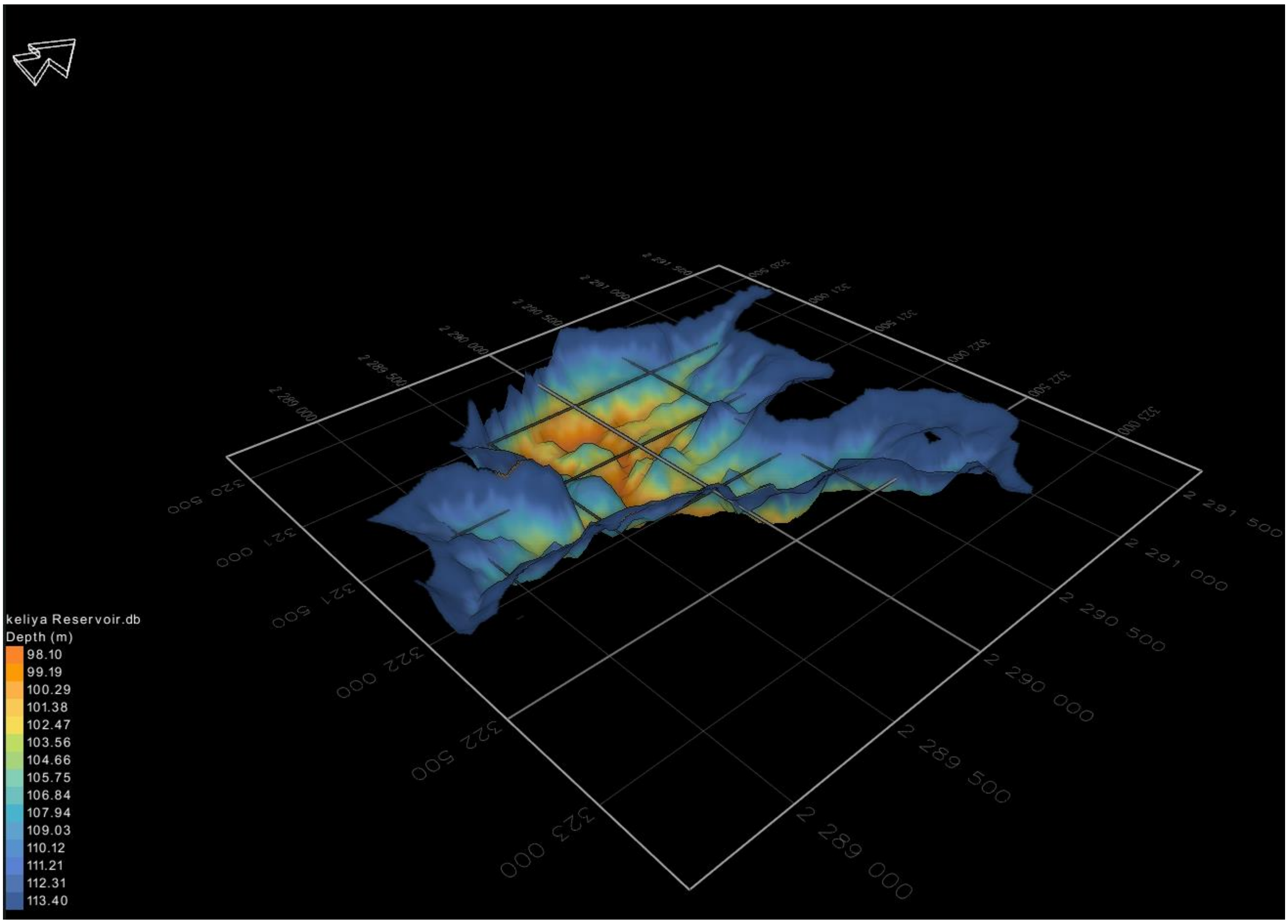


Figure 6.11-3 WIRE FRAME MAP

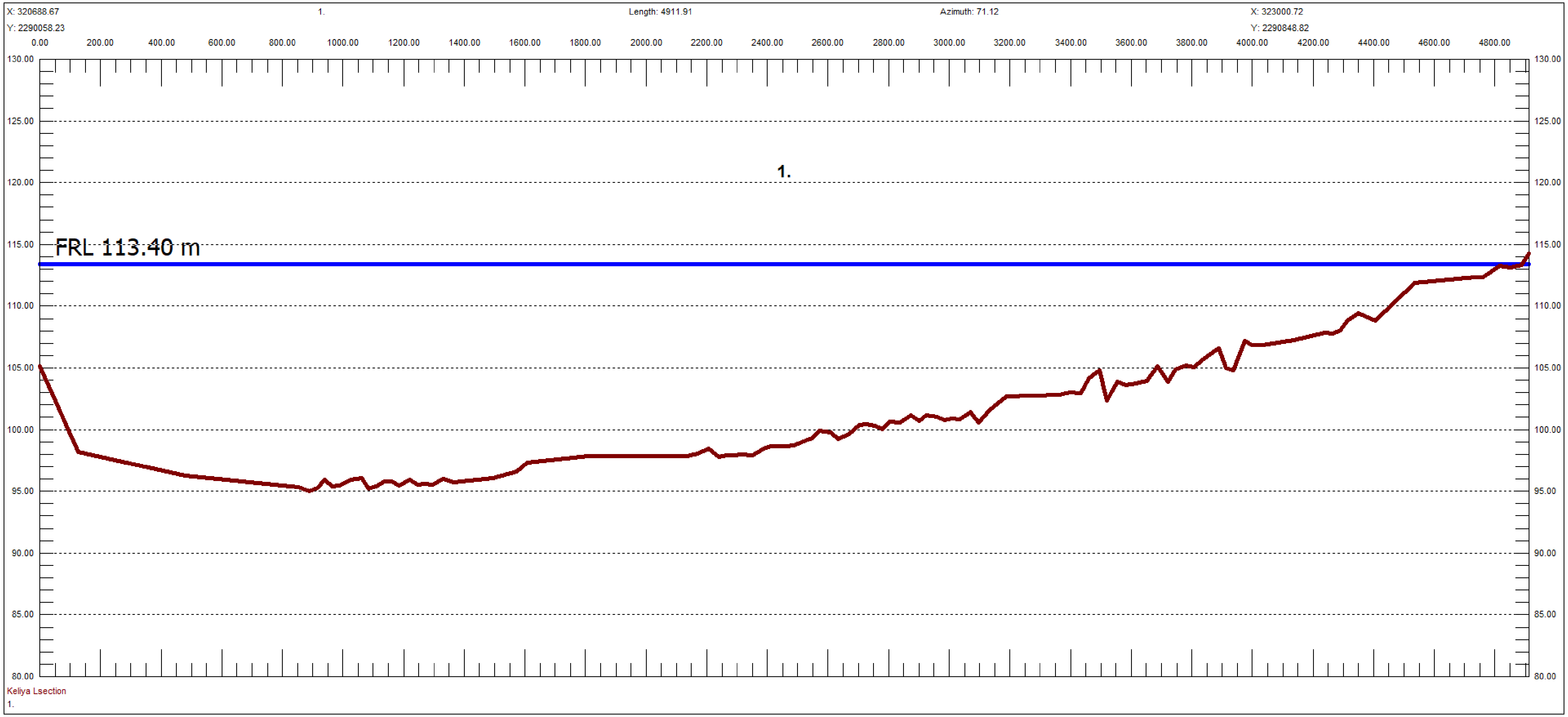


Figure 6.11-4 L Section

7 DGPS OBSERVATION REPORT

CSRS-PPP 2.32.0 (2020-03-31)

1710291m21.20O
17102020

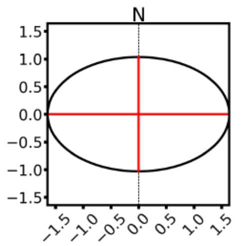
Data Start	**Data End**	**Duration of Observations**
2020-10-17 06:22:00.00	2020-10-17 10:58:30.00	4:36:30
Processing Time		**Product Type**
03:36:33 UTC 2020/10/18		NRCan Ultra-rapid
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static
Elevation Cut-Off	**Rejected Epochs**	**Estimation Steps**
7.5 degrees	0.00 %	30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
GMXZENITH35	L1 = 0.125 m L2 = 0.132 m	H:1.402m / E:0.000m / N:0.000m

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

Estimated Position for 1710291m21.20O

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2020.7)	20° 42' 6.41897"	73° 16' 39.21340"	52.687 m
Sigmas(95%)	0.009 m	0.013 m	0.040 m
A priori*	20° 42' 6.43662"	73° 16' 39.30433"	55.526 m
Estimated – A priori	-0.543 m	-2.631 m	-2.839 m

95% Error Ellipse (cm)
semi-major: 1.6 cm
semi-minor: 1.0 cm
semi-major azimuth: -89° 0' 1.18"



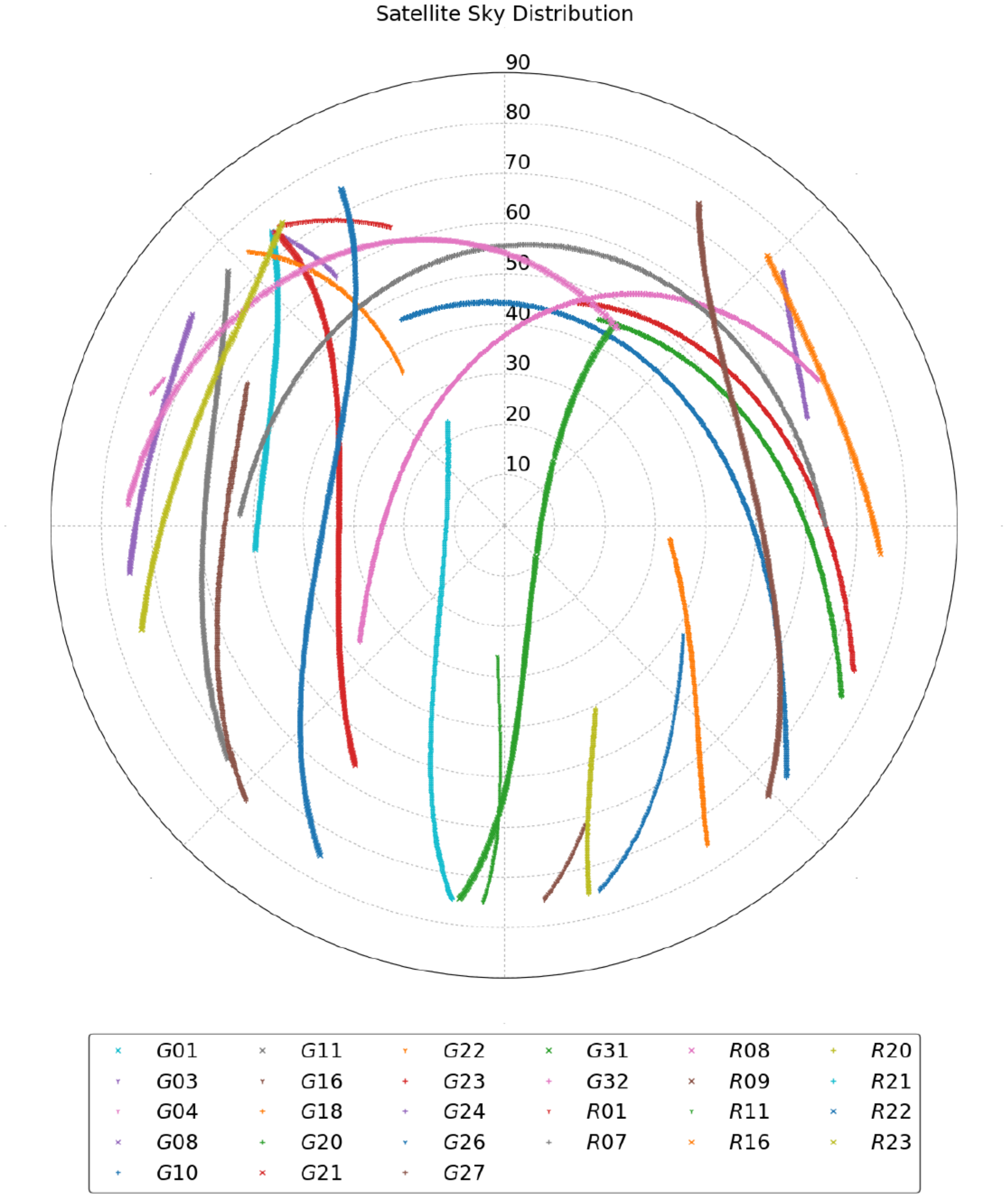
UTM (North)
Zone 43

2290097.099 m (N)
320615.224 m (E)

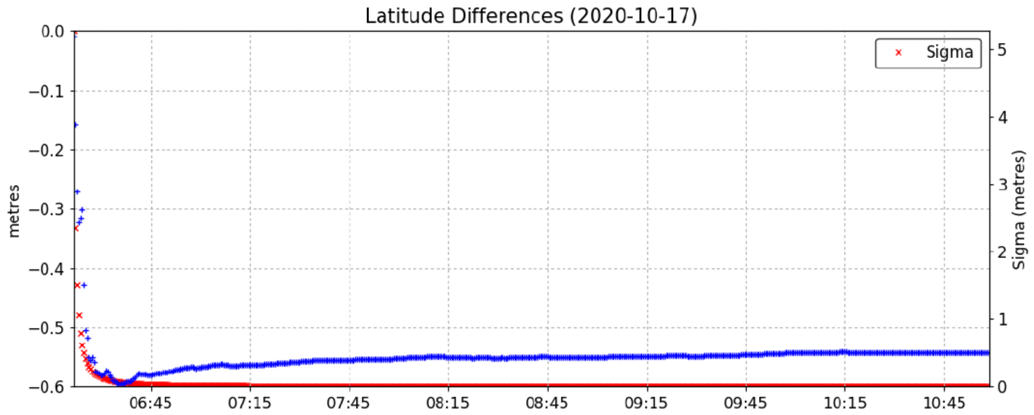
Scale Factors
0.99999769 (point)
0.99998941 (combined)

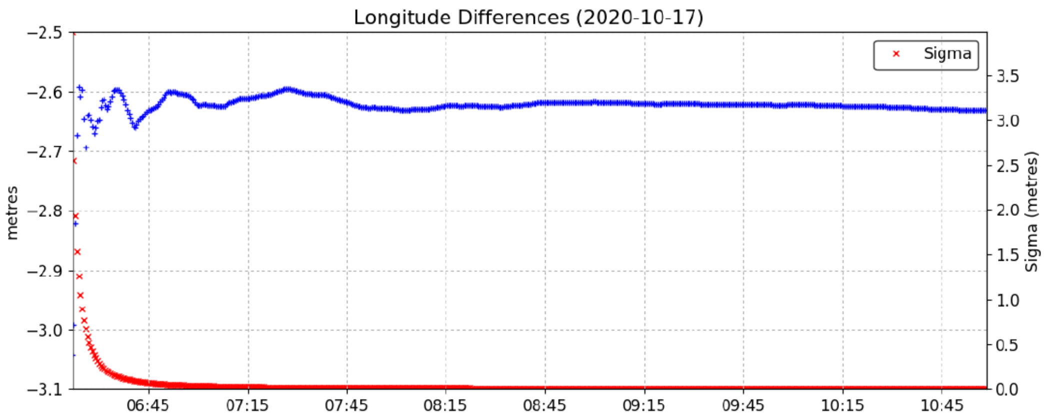
*(Coordinates from RINEX header used as a priori position)

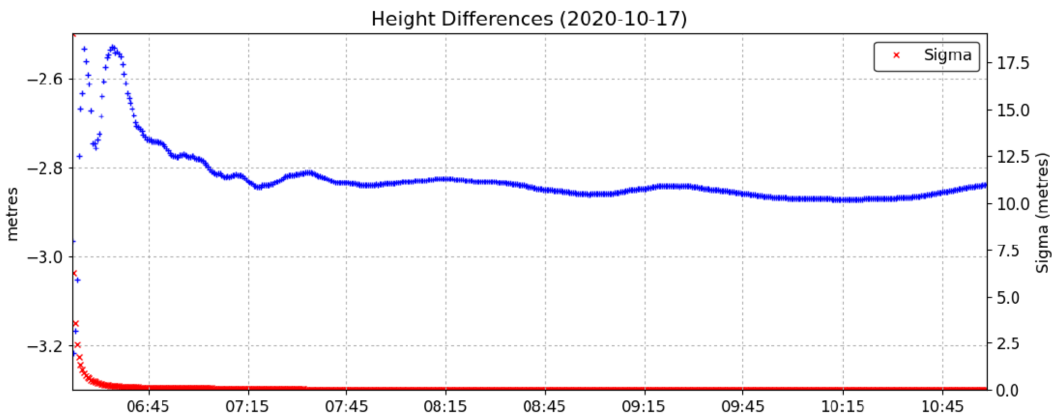
1


Satellite Sky Distribution
90
80
70
60
50
40
30
20
10
G01
G03
G04
G08
G10
G11
G16
G18
G20
G21
G22
G23
G24
G26
G27
G31
G32
R01
R07
R08
R09
R11
R16
R20
R21
R22
R23

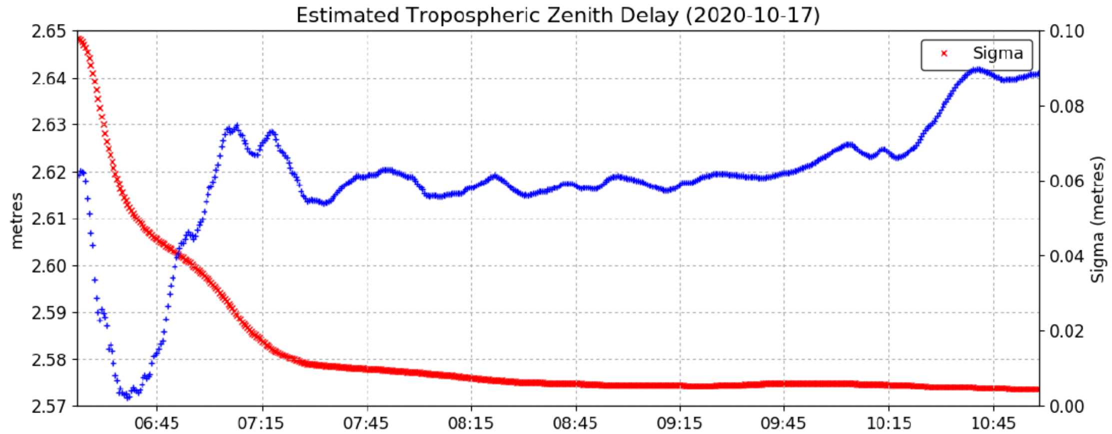
2

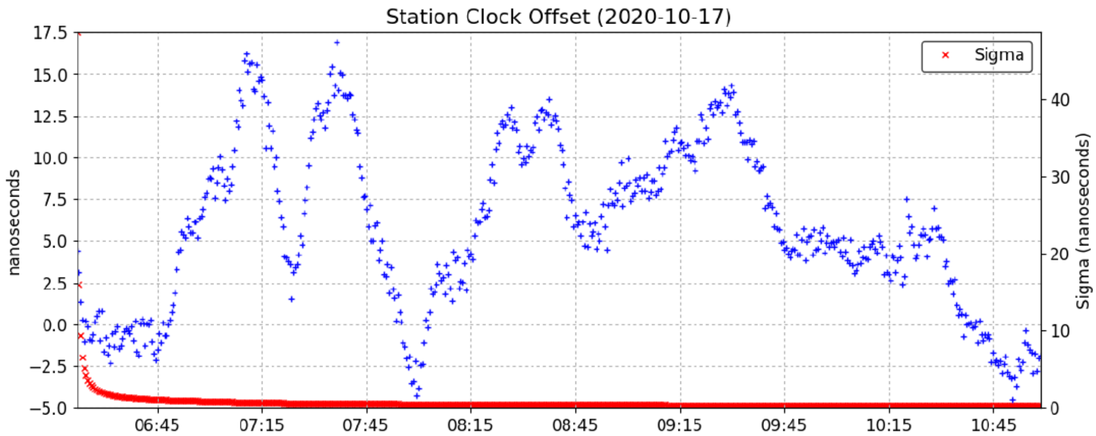

Latitude Differences (2020-10-17)
Sigma
metres
Sigma (metres)
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
5
4
3
2
1
0
06:45
07:15
07:45
08:15
08:45
09:15
09:45
10:15
10:45

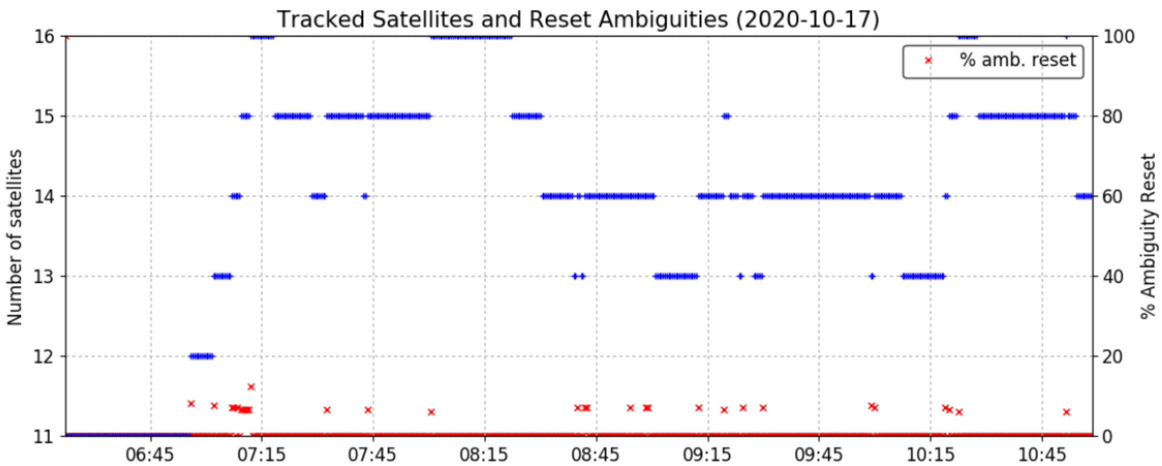

Longitude Differences (2020-10-17)
Sigma
metres
Sigma (metres)
−2.5
−2.6
−2.7
−2.8
−2.9
−3.0
−3.1
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
06:45
07:15
07:45
08:15
08:45
09:15
09:45
10:15
10:45


Height Differences (2020-10-17)
Sigma
metres
Sigma (metres)
−2.6
−2.8
−3.0
−3.2
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
06:45
07:15
07:45
08:15
08:45
09:15
09:45
10:15
10:45

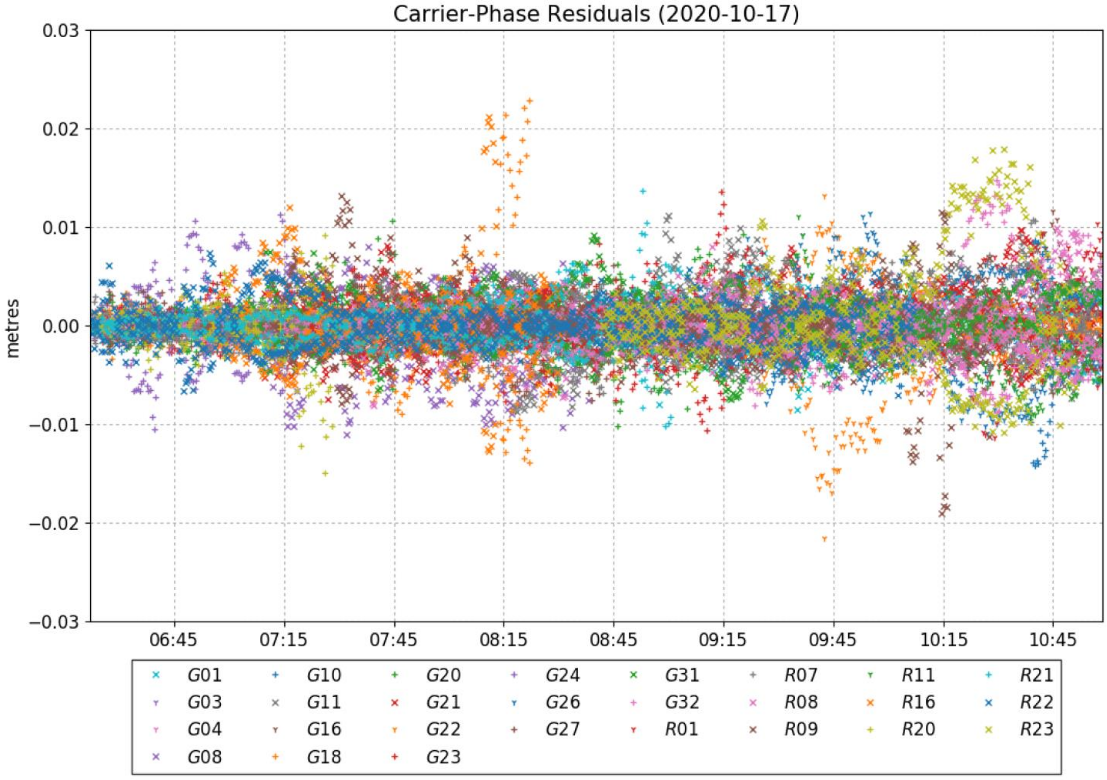
3

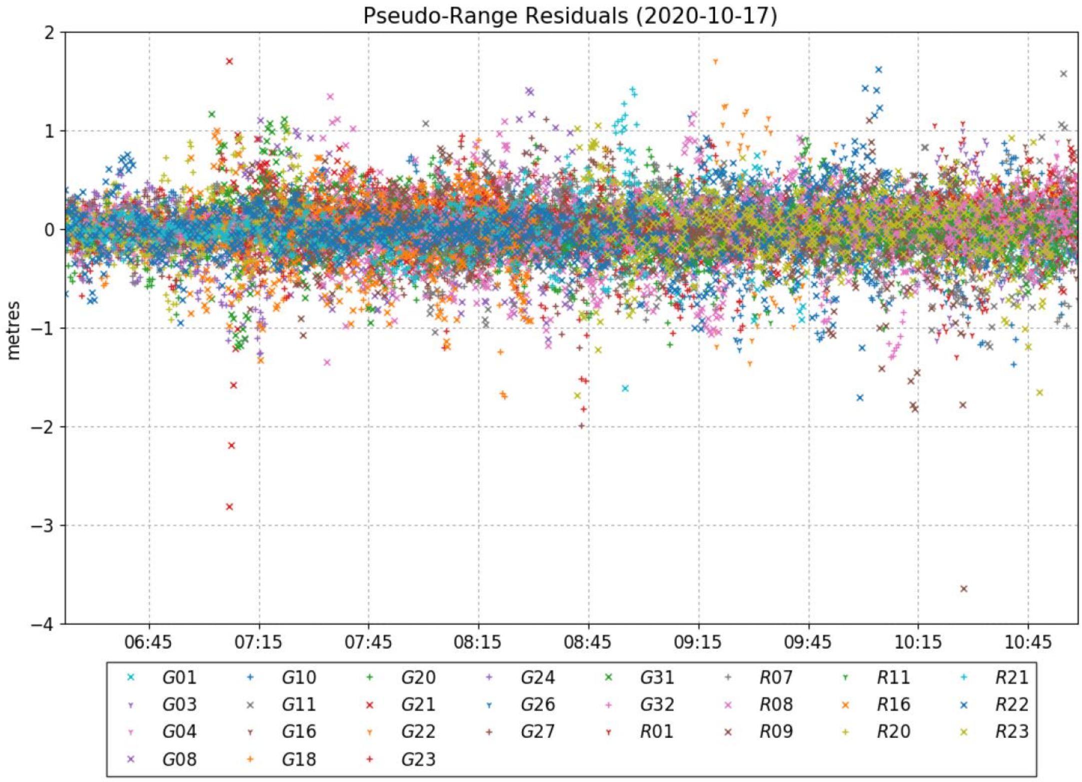

Estimated Tropospheric Zenith Delay (2020-10-17)
Sigma
metres
Sigma (metres)
2.65
2.64
2.63
2.62
2.61
2.60
2.59
2.58
2.57
0.10
0.08
0.06
0.04
0.02
0.00
06:45
07:15
07:45
08:15
08:45
09:15
09:45
10:15
10:45


Station Clock Offset (2020-10-17)
Sigma
nanoseconds
Sigma (nanoseconds)
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−2.5
−5.0
40
30
20
10
0
06:45
07:15
07:45
08:15
08:45
09:15
09:45
10:15
10:45


Tracked Satellites and Reset Ambiguities (2020-10-17)
% amb. reset
Number of satellites
% Ambiguity Reset
16
15
14
13
12
11
100
80
60
40
20
0
06:45
07:15
07:45
08:15
08:45
09:15
09:45
10:15
10:45

4


Carrier-Phase Residuals (2020-10-17)
metres
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
06:45
07:15
07:45
08:15
08:45
09:15
09:45
10:15
10:45
G01 G10 G20 G24 G31 R07 R11 R21
G03 G11 G21 G26 G32 R08 R16 R22
G04 G16 G22 G27 R01 R09 R20 R23
G08 G18 G23


Pseudo-Range Residuals (2020-10-17)
metres
2
1
0
−1
−2
−3
−4
06:45
07:15
07:45
08:15
08:45
09:15
09:45
10:15
10:45
G01 G10 G20 G24 G31 R07 R11 R21
G03 G11 G21 G26 G32 R08 R16 R22
G04 G16 G22 G27 R01 R09 R20 R23
G08 G18 G23

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: **Bathymetric Survey**	Vessel:	Place: **Keliya Dam**
Date: **17-Oct-20**	Time: **1200hrs**	Client:	
Observed By: **Amit Singh**		Echosounder Model and SL. No. **Reason Navisound 215**	Area Depth **12**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity Average	Sound Velocity Upto Depth
0.6				1500	12

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	2.02	-0.02	10	9.98	0.02
4	4.03	-0.03	8	8.02	-0.02
6	6.02	-0.02	6	6.01	-0.01
8	8.01	-0.01	4	4.03	-0.03
10	10.03	-0.03	2	2.01	-0.01
	Average	-0.0220		Average	-0.0100
	Std. Dev	0.0084		Std. Deviation	0.0187
				Cumulative Average	-0.02
				Cumulative Std. Deviation	0.0073

The Echosounder Barcheck Values are Negligible for Application

....

GMPL Party Chief

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title: **Bathymetric Survey**	Vessel:	Place: **Keliya Dam**
Date: **18-Oct-20**	Time: **800hrs**	Client:	
Observed By: **Amit Singh**		Echosounder Model and SL. No. **Reason Navisound 215**	Area Depth **12**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	Upto Depth
0.6				1500	12
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)
1	1.01	-0.01	8	7.98	0.02
2	2.01	-0.01	7	6.99	0.01
3	3.02	-0.02	6	6.01	-0.01
4	4.01	-0.01	5	5.02	-0.02
5	4.99	0.01	4	4.01	-0.01
6	5.99	0.01	3	2.99	0.01
7	7.01	-0.01	2	1.99	0.01
8	7.99	0.01	1	1.01	-0.01
		0			0
	Average	-0.0033		Average	0.0000
	Std. Dev	0.0112		Std. Deviation	0.0132
				Cumulative Average	0.00
				Cumulative Std. Deviation	0.0014

The Echosounder Barcheck Values are Negligible for Application

....

GMPL Party Chief

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title: **Bathymetric Survey**	Vessel:	Place: **Keliya Dam**
Date: **19-Oct-20**	Time: **8:00 Hours**	Client:	
Observed By: **Amit Singh**		Echosounder Model and SL. No. **Reason Navisound 215**	Area Depth **12**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	Upto Depth
0.6				1500	14
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	8	7.98	0.02
4	4.00	0	6	5.98	0.02
6	5.99	0.01	4	3.99	0.01
8	8.01	-0.01	2	1.97	0.03
	Average	-0.0025		Average	0.0200
	Std. Dev	0.0096		Std. Deviation	0.0082
				Cumulative Average	0.01
				Cumulative Std. Deviation	0.0010

The Echosounder Barcheck Values are Negligible for Application

....

GMPL Party Chief

9 PHOTOGRAPHS

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

Configuration of SBES Equipment

DGPS Observation At Dam Top

TBM2 On Road Near Vadichondha

Level Of Water And Stairs

Top Level On Spillway

Forest Area

Head Regulator

END OF REPORT