GEOSERVICES
MARITIME PVT. LTD.

REPORT ON TOPOGRAPHIC & BATHYMETRIC SURVEY FOR ASSESSMENT OF RESERVOIR CAPACITY & SEDIMENTATION IN VER_2-AMLI RESERVOIR, GUJARAT, INDIA UNDER NATIONAL HYDROLOGY PROJECT

GMPL REPORT NUMBER: P-SUR-BATHY-004-2020-WRD-VER_2-AMLI
SURVEY PERIOD: 30 OCT TO 03 NOV 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

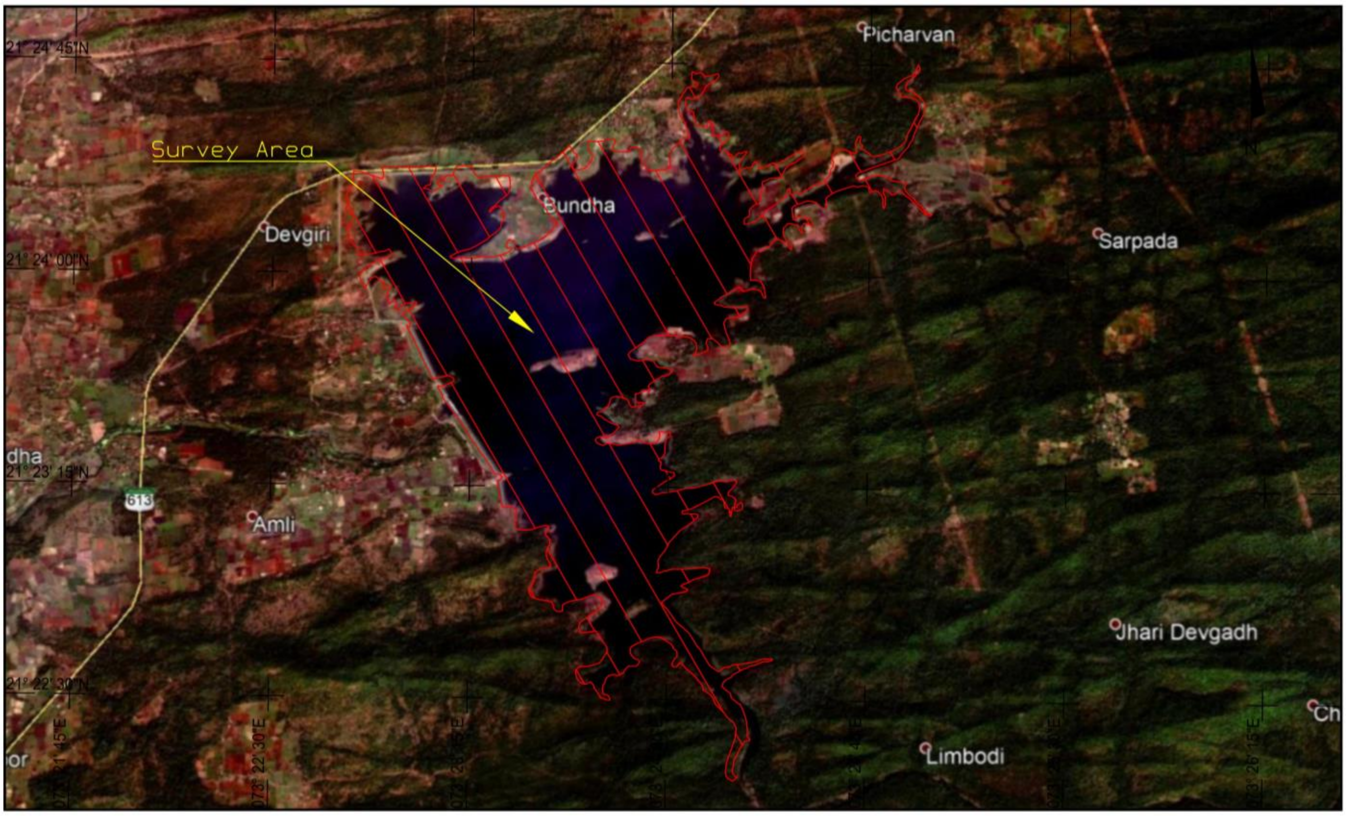

Figure 1.1-1 LOCATION MAP

LOCATION MAP SHOWING SURVEY AREA "VER_2-AMLI 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 Ver_2-Amli 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 Ver_2-Amli 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 VER_2-AMLI RESERVOIR

Ver_2-Amli reservoir project envisage construction of Dam across river Ver near village Amli of Mandvi Taluka of Surat district in Gujarat. The scheme was impounded in the year 1984, and the project is mainly for irrigation.

The total Catchment Area of Ver_2-Amli Reservoir is 90 Sq. Km. The Full Reservoir Level (FRL) is 115.80 m and Minimum Draw Down Level (MDDL) is 101 m. The gross storage capacity at time of impounding was 38.30 M Cu. m. and dead storage was 1.25 M Cu. m. whereas live storage was 37.05 M Cu. m. at time of impounding.

VER_2-AMLI RESERVOIR PROJECT			
I	**Location**		
	Coordinates	Latitude 21°24' N Longitude 73°23' E	
	River	Ver	
	Village	Amli	
	Taluka	Mandvi	
	District	Surat	
	State	Gujarat	
	Nearest Railway Station	Umarpada, on Kosamba to Zankhvav Narrow gauage section of Western Railway 12 Km from Project Site	
	Road Communication	The Dam is easily accessible from Mandvi city by an asphalt paved road, its 22 Km from village Amli being state highway No 00 (Mandiv – Umarpada) on right side of dam.	
II	**HYDROLOGY**		
	1. Catchment Area	**Sq. Km**	**Sq. Miles**
	Total Catchment Area at dam site	90.00	34.75
	Catchment area considered for availability of water at Ver_2-Amli	6.27	2.421
	Net free catchment area available at Ver_2-Amli for water planning	5.81	2.243
	2. Rainfall	**Millimeter**	**Inches**
	Average rainfall in entire catchment area	1510	59.45
	Maximum rainfall in year 1964	2760	108.66
	Minimum rainfall in year 1974	760	29.92
	3. Floods	**Cumecs**	**Cusecs**
	Maximum flood released from dam (23-08-1997)	766.5	27065
	Maximum Probable Flood (M.P.F)	2152	79690
	Standard Probable Flood (S.P.F)	2152	76000
	Moderated out flow corresponding of M.P.F	2039	72018
	Design flood with full opening of 8 gates	2512	76000
III	**RESERVOIR**	**Meter**	**Feet**

	Riverbed Level	98.80	324.15
	Sill R.L of by-pass outlet	101.00	331.36
	Crest level of spillway	109.73	360.01
	MDDL	101	331.36
	FRL	115.80	379.92
	HFL/MWL	116.00	380.58
	Top of Dam	119.50	392.06
	Reservoir Capacity	**M Cu. M**	**M Cu. Ft**
	Gross Storage	38.30	1348.16
	Dead Storage	1.25	44.15
	Live Storage	37.05	1308.61
IV	**DAM**	**Meter**	**Feet**
	Length of Earthen Dam	3576.00	11732.28
	Length of Spillway (8 Gates of 30' x 20')	90.22	296.00
	Length of non-overflow portion	81.22	266.47
	Total Length of Dam	3747.44	12295.00
	Maximum height from deepest foundation to the top of roadway for Masonry Dam (Non over flow)	28.50	93.50
	Length of Roadway for Masonry Dam	6.00	19.69
	Length of Roadway for Earthen Dam	6.00	19.69

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 Ver_2-Amli Reservoir survey area from 30 Oct to 03 Nov 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 Ver_2-Amli 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 Ver_2-Amli reservoir area.

Four (4) hours of DGPS observation was carried out on OBS-Amli (Levelling was carried out from BC Line to above mention observation point and level of BC Line was provided by Dam Authority). Two (2) Temporary Bench Marks, TBM 1(on Top of site office terrace marked by yellow paint) and TBM 2 (on bottom of electric pole concrete structure marked by yellow paint).

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

- The Minimum elevation within Ver_2-Amli reservoir is 98.83 m above MSL and
- The Maximum depth within Ver_2-Amli reservoir is 17.03 m.
- Area covered by bathymetric survey is 5.27 Sq. Km.
- Area covered by topographic survey is 0.68 Sq. Km.

According to recent survey, total area of reservoir at FRL 115.80 m is 5.271 Sq. Km, corresponding storage capacity is 31.876 M Cu. m, and Dead storage at 101 m is 0.157 M Cu. m.

The comparison between 1984 and 2020(36 years) data results in a rate of siltation (silt index) of 19.827 Ham/100 Sq. Km/year. Annual percentage loss of gross storage capacity, live storage capacity and dead storage capacity is 0.47%, 0.39% and 2.43 % respectively for FRL 115.80 m.

The comparison of 1998, 2015 and 2020 data with respect to 1984 impounding data at FRL 115.80 m results in silt index of 45 Ham/100 Sq. Km/year, 26.376 Ham/100 Sq. Km/year and 19.827 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 Ver_2-Amli reservoir. The equipment setup and configuration diagram has been presented in Figure 4.1.

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.

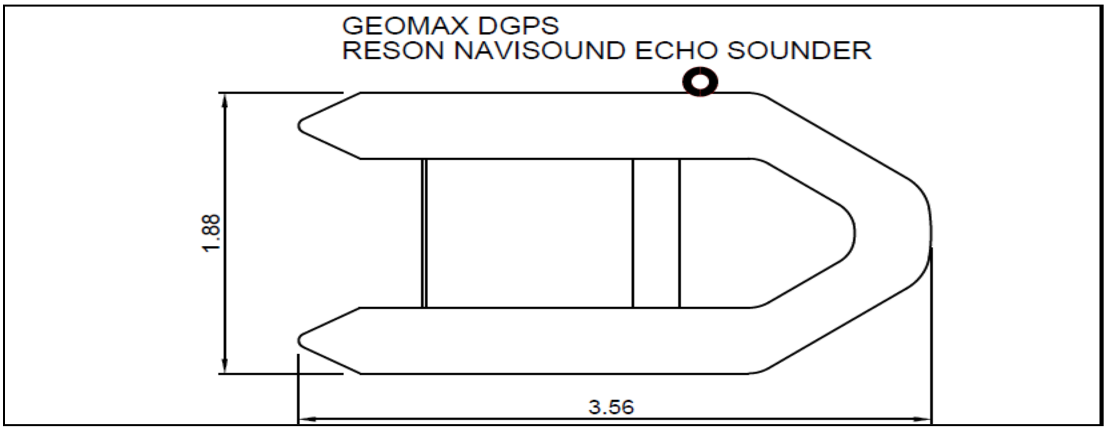

Figure 4.3-1 SURVEY BOAT ‘ AQUA MARINE’ OFFSET DIAGRAM

5 DETAILED METHODOLOGY OF SURVEY

5.1 Mobilisation

The bathymetric survey equipment were mobilised on board “Aqua Marine” on 30 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.

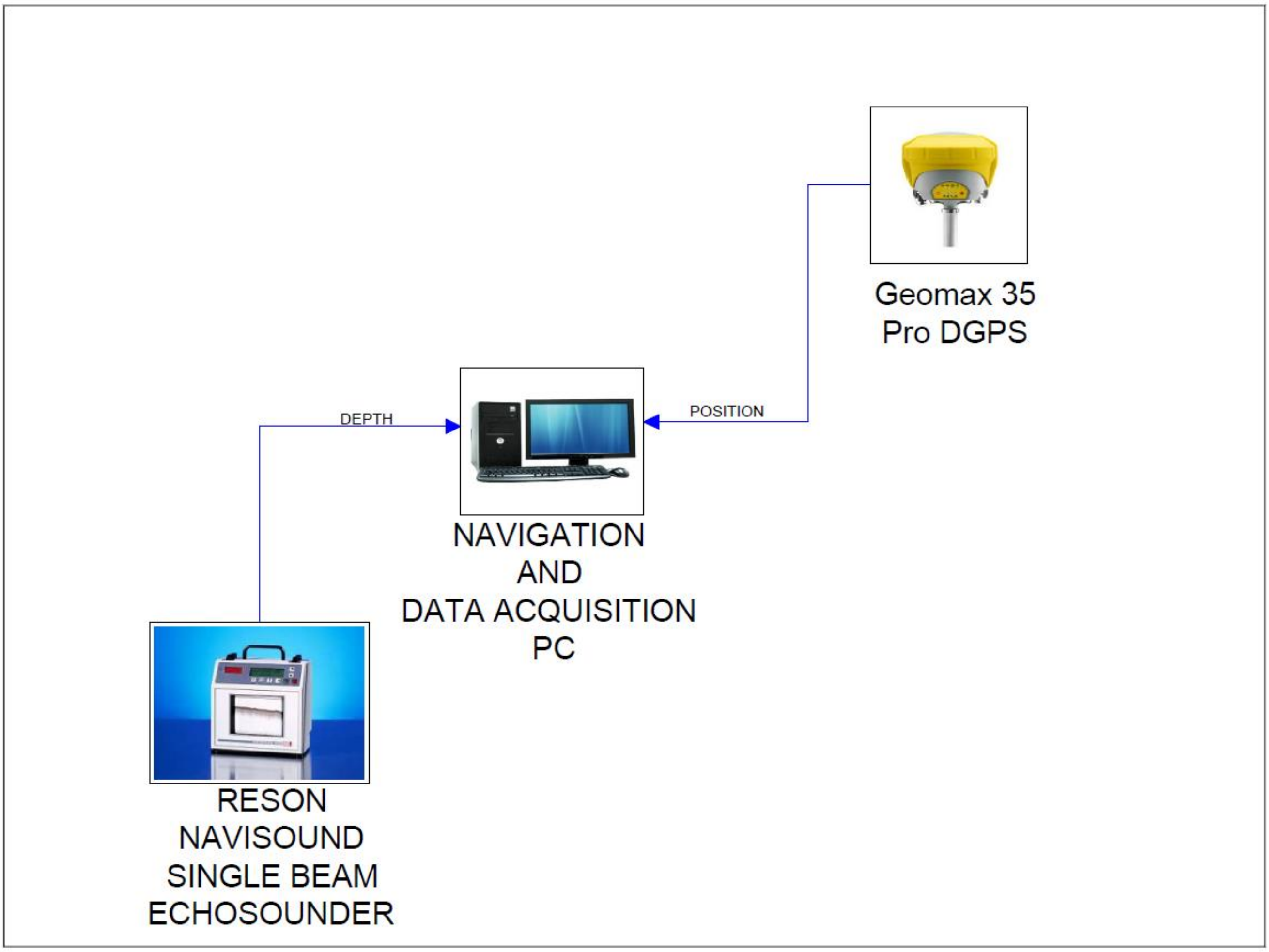

Figure 5.1-1 SBES SURVEY EQUIPMENT CONFIGURATION DIAGRAM ON BOARD

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 AMLI, made by GMPL and configured to transmit the correction.

Four (4) hours of DGPS observation was carried out on OBS-Amli (Levelling was carried out from BC Line to above mention observation point and level of BC Line was provided by Dam Authority).

Levelling From BC Line To OBS-AMLI				
BS	**FS**	**HI**	**RL**	**Remark**
1.419		120.919	119.5	BC Line (Provided by Dam Authority)
	1.494		119.425	OBS-Amli
Levelling From OBS-AMLI To BC Line (Closing Loop)				
1.443		120.868	119.425	OBS-Amli
	1.368		119.5	BC Line

Table 5.3-1 LEVELLING FROM BC LINE TO OBS-AMLI

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

T.BM. Information - Ver_2-Amli Reservoir, South Gujarat					
Location	**Latitude (N)**	**Longitude (E)**	**Easting (m)**	**Northing (m)**	**Elevation (m) W.r.t MSL**
OBS-AMLI	21°23'32.9359"	73°23'9.1049"	332670.704	2366445.609	119.425
T.B.M. 1	21°23'33.2966"	73°23'8.5586"	332655.083	2366456.862	122.816
T.B.M. 2	21°23'29.2033"	73°23'11.8184"	332747.679	2366330.016	119.786

Table 5.3-2 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 OBS-Amli. Four (4) hours of DGPS observation was carried out on OBS-Amli (Levelling was carried out from BC Line to above mention observation point and level of BC Line was provided by Dam Authority). 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)
31/10/2020	0700	115.8
31/10/2020	1900	115.8

Date	Time	Water Level (meters)
01/11/2020	0700	115.8
01/11/2020	1900	115.8
02/11/2020	0700	115.8
02/11/2020	1900	115.8
03/11/2020	0700	115.8
03/11/2020	1900	115.8

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 Ver_2-Amli 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-VER_2-AMLI-BATHY-01	Chart contains bathy , contour and cross section segments	Paper size A0 (1:5000)	PDF & CAD
2	P-SUR-004-VER_2-AMLI-OVERVIEW-01	Overview Map of Reservoir	Paper size A3	PDF & CAD
3	Area Capacity Curve Ver_2-Amli -2020	Area Capacity curve of Reservoir	Paper size A3	PDF & CAD
4	Ver_2-Amli Cross Sections	37 Cross Section at 100 m interval	Only soft copy	CAD
5	Ver_2-Amli 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 Ver_2-Amli reservoir.

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

- The Minimum elevation within Ver_2-Amli reservoir is 98.83 m above MSL and
- The Maximum depth within Ver_2-Amli reservoir is 17.03 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 Model (M Cu. m)	Gross Storage Capacity using Prismoidal formula (M Cu. m)	Spread Area (Sq. Km)	Remarks
98.80	0.000	0.000	0.000	0.000	0.000	
98.90	0.000	0.000	0.000	0.000	0.001	
99.00	0.000	0.000	0.000	0.001	0.009	
99.10	0.002	0.000	0.002	0.002	0.018	
99.20	0.004	0.000	0.004	0.004	0.026	
99.30	0.007	0.000	0.007	0.007	0.032	
99.40	0.011	0.000	0.011	0.011	0.039	
99.50	0.015	0.000	0.015	0.015	0.044	
99.60	0.019	0.000	0.019	0.019	0.049	
99.70	0.025	0.000	0.025	0.025	0.055	

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
99.80	0.030	0.000	0.030	0.030	0.060	
99.90	0.037	0.000	0.037	0.037	0.066	
100.00	0.044	0.000	0.044	0.044	0.073	
100.10	0.051	0.000	0.051	0.051	0.079	
100.20	0.060	0.000	0.060	0.059	0.086	
100.30	0.069	0.000	0.069	0.068	0.093	
100.40	0.078	0.000	0.078	0.078	0.101	
100.50	0.089	0.000	0.089	0.089	0.109	
100.60	0.100	0.000	0.100	0.100	0.118	
100.70	0.112	0.000	0.112	0.112	0.126	
100.80	0.125	0.000	0.125	0.125	0.138	
100.90	0.140	0.000	0.140	0.140	0.155	
101.00	**0.157**	**0.000**	**0.157**	**0.157**	**0.177**	**MDDL**
101.10	0.157	0.018	0.175	0.175	0.192	
101.20	0.157	0.038	0.195	0.195	0.209	
101.30	0.157	0.060	0.217	0.217	0.227	
101.40	0.157	0.084	0.241	0.241	0.243	
101.50	0.157	0.109	0.266	0.266	0.263	
101.60	0.157	0.136	0.293	0.293	0.281	
101.70	0.157	0.165	0.322	0.322	0.295	
101.80	0.157	0.195	0.352	0.352	0.308	
101.90	0.157	0.226	0.383	0.383	0.320	
102.00	0.157	0.259	0.416	0.416	0.332	
102.10	0.157	0.293	0.450	0.450	0.344	
102.20	0.157	0.328	0.485	0.485	0.357	
102.30	0.157	0.364	0.521	0.521	0.369	
102.40	0.157	0.402	0.559	0.558	0.381	
102.50	0.157	0.440	0.597	0.597	0.393	
102.60	0.157	0.480	0.637	0.637	0.407	
102.70	0.157	0.522	0.679	0.678	0.420	
102.80	0.157	0.564	0.721	0.721	0.432	
102.90	0.157	0.608	0.765	0.765	0.444	
103.00	0.157	0.653	0.810	0.810	0.457	
103.10	0.157	0.699	0.856	0.856	0.470	
103.20	0.157	0.747	0.904	0.904	0.489	

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
103.30	0.157	0.797	0.954	0.954	0.508	
103.40	0.157	0.849	1.006	1.006	0.528	
103.50	0.157	0.903	1.060	1.060	0.547	
103.60	0.157	0.958	1.115	1.115	0.569	
103.70	0.157	1.017	1.174	1.174	0.595	
103.80	0.157	1.077	1.234	1.234	0.620	
103.90	0.157	1.141	1.298	1.298	0.644	
104.00	0.157	1.206	1.363	1.363	0.667	
104.10	0.157	1.274	1.431	1.431	0.690	
104.20	0.157	1.344	1.501	1.501	0.712	
104.30	0.157	1.416	1.573	1.573	0.735	
104.40	0.157	1.491	1.648	1.648	0.759	
104.50	0.157	1.568	1.725	1.725	0.782	
104.60	0.157	1.648	1.805	1.805	0.806	
104.70	0.157	1.729	1.886	1.886	0.830	
104.80	0.157	1.814	1.971	1.970	0.853	
104.90	0.157	1.900	2.057	2.057	0.876	
105.00	0.157	1.989	2.146	2.146	0.900	
105.10	0.157	2.080	2.237	2.237	0.925	
105.20	0.157	2.174	2.331	2.331	0.950	
105.30	0.157	2.270	2.427	2.427	0.974	
105.40	0.157	2.369	2.526	2.525	0.997	
105.50	0.157	2.469	2.626	2.626	1.020	
105.60	0.157	2.573	2.730	2.729	1.044	
105.70	0.157	2.678	2.835	2.835	1.070	
105.80	0.157	2.787	2.944	2.944	1.098	
105.90	0.157	2.898	3.055	3.055	1.128	
106.00	0.157	3.012	3.169	3.169	1.157	
106.10	0.157	3.129	3.286	3.286	1.185	
106.20	0.157	3.249	3.406	3.406	1.212	
106.30	0.157	3.372	3.529	3.529	1.238	
106.40	0.157	3.497	3.654	3.654	1.266	
106.50	0.157	3.625	3.782	3.782	1.294	
106.60	0.157	3.756	3.913	3.913	1.322	
106.70	0.157	3.889	4.046	4.046	1.351	

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
106.80	0.157	4.026	4.183	4.183	1.381	
106.90	0.157	4.166	4.323	4.323	1.412	
107.00	0.157	4.309	4.466	4.465	1.445	
107.10	0.157	4.455	4.612	4.611	1.477	
107.20	0.157	4.604	4.761	4.761	1.508	
107.30	0.157	4.756	4.913	4.913	1.539	
107.40	0.157	4.912	5.069	5.068	1.569	
107.50	0.157	5.070	5.227	5.227	1.595	
107.60	0.157	5.231	5.388	5.387	1.621	
107.70	0.157	5.394	5.551	5.551	1.646	
107.80	0.157	5.560	5.717	5.717	1.673	
107.90	0.157	5.729	5.886	5.885	1.700	
108.00	0.157	5.900	6.057	6.057	1.730	
108.10	0.157	6.075	6.232	6.231	1.759	
108.20	0.157	6.252	6.409	6.409	1.788	
108.30	0.157	6.432	6.589	6.589	1.819	
108.40	0.157	6.616	6.773	6.772	1.848	
108.50	0.157	6.802	6.959	6.959	1.878	
108.60	0.157	6.991	7.148	7.148	1.908	
108.70	0.157	7.184	7.341	7.340	1.939	
108.80	0.157	7.379	7.536	7.536	1.971	
108.90	0.157	7.578	7.735	7.734	2.003	
109.00	0.157	7.780	7.937	7.936	2.036	
109.10	0.157	7.985	8.142	8.142	2.071	
109.20	0.157	8.194	8.351	8.351	2.106	
109.30	0.157	8.406	8.563	8.563	2.145	
109.40	0.157	8.623	8.780	8.780	2.184	
109.50	0.157	8.843	9.000	9.000	2.222	
109.60	0.157	9.067	9.224	9.224	2.260	
109.70	0.157	9.295	9.452	9.452	2.301	
109.80	0.157	9.527	9.684	9.684	2.340	
109.90	0.157	9.763	9.920	9.920	2.380	
110.00	0.157	10.003	10.160	10.160	2.421	
110.10	0.157	10.248	10.405	10.404	2.462	
110.20	0.157	10.496	10.653	10.653	2.503	

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
110.30	0.157	10.748	10.905	10.905	2.545	
110.40	0.157	11.005	11.162	11.162	2.587	
110.50	0.157	11.266	11.423	11.423	2.631	
110.60	0.157	11.531	11.688	11.688	2.672	
110.70	0.157	11.800	11.957	11.957	2.714	
110.80	0.157	12.074	12.231	12.231	2.756	
110.90	0.157	12.352	12.509	12.508	2.802	
111.00	0.157	12.634	12.791	12.791	2.846	
111.10	0.157	12.921	13.078	13.078	2.892	
111.20	0.157	13.212	13.369	13.369	2.936	
111.30	0.157	13.508	13.665	13.665	2.978	
111.40	0.157	13.808	13.965	13.965	3.020	
111.50	0.157	14.112	14.269	14.269	3.061	
111.60	0.157	14.420	14.577	14.577	3.103	
111.70	0.157	14.733	14.890	14.889	3.145	
111.80	0.157	15.049	15.206	15.206	3.187	
111.90	0.157	15.370	15.527	15.527	3.230	
112.00	0.157	15.695	15.852	15.852	3.275	
112.10	0.157	16.025	16.182	16.182	3.320	
112.20	0.157	16.359	16.516	16.516	3.365	
112.30	0.157	16.698	16.855	16.855	3.411	
112.40	0.157	17.041	17.198	17.198	3.458	
112.50	0.157	17.390	17.547	17.547	3.508	
112.60	0.157	17.743	17.900	17.900	3.559	
112.70	0.157	18.102	18.259	18.258	3.611	
112.80	0.157	18.465	18.622	18.622	3.664	
112.90	0.157	18.834	18.991	18.991	3.718	
113.00	0.157	19.209	19.366	19.366	3.769	
113.10	0.157	19.588	19.745	19.745	3.821	
113.20	0.157	19.973	20.130	20.130	3.873	
113.30	0.157	20.363	20.520	20.520	3.926	
113.40	0.157	20.758	20.915	20.915	3.978	
113.50	0.157	21.159	21.316	21.316	4.030	
113.60	0.157	21.564	21.721	21.721	4.083	
113.70	0.157	21.975	22.132	22.132	4.137	

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
113.80	0.157	22.392	22.549	22.548	4.189	
113.90	0.157	22.813	22.970	22.970	4.241	
114.00	0.157	23.240	23.397	23.397	4.290	
114.10	0.157	23.671	23.828	23.828	4.335	
114.20	0.157	24.107	24.264	24.263	4.379	
114.30	0.157	24.547	24.704	24.703	4.421	
114.40	0.157	24.991	25.148	25.148	4.462	
114.50	0.157	25.439	25.596	25.596	4.503	
114.60	0.157	25.892	26.049	26.048	4.545	
114.70	0.157	26.348	26.505	26.505	4.586	
114.80	0.157	26.809	26.966	26.965	4.627	
114.90	0.157	27.273	27.430	27.430	4.670	
115.00	0.157	27.743	27.900	27.899	4.716	
115.10	0.157	28.217	28.374	28.373	4.765	
115.20	0.157	28.696	28.853	28.853	4.820	
115.30	0.157	29.181	29.338	29.338	4.885	
115.40	0.157	29.673	29.830	29.830	4.961	
115.50	0.157	30.173	30.330	30.330	5.039	
115.60	0.157	30.681	30.838	30.838	5.115	
115.70	0.157	31.196	31.353	31.353	5.192	
115.80	**0.157**	**31.719**	**31.876**	**31.876**	**5.271**	**FRL**
115.90	0.157	32.250	32.407	32.408	5.353	
116.00	**0.157**	**32.790**	**32.947**	**32.947**	**5.442**	**HFL**

Table 6.2-1 CAPACITY AND AREA

6.3 Comparative Statement of Ver_2-Amli Reservoir

RL in m	Original		As per 2015 survey		As per 2020 survey		Remarks
	Gross storage in M Cu. m	Spread Area in Sq. Km	Gross storage in M Cu. m	Spread Area in Sq. Km	Gross storage in M Cu. m	Spread Area in Sq. Km	
100.58	1.100	0.390		0.314	0.098	0.116	
101.00	**1.250**	**0.434**	**0.138**	**0.345**	**0.157**	**0.177**	**MDDL**
102.10	1.690	0.550	0.579	0.453	0.450	0.344	
103.63	2.340	0.740	1.429	0.664	1.132	0.577	
105.15	3.960	1.020	2.646	0.947	2.283	0.937	
106.68	6.220	0.158	4.360	1.303	4.018	1.345	
108.20	9.060	2.130	6.657	1.729	6.409	1.788	
109.73	12.030	2.780	9.677	2.230	9.519	2.312	
111.25	16.980	3.460	13.492	2.800	13.514	2.957	
112.77	22.650	4.360	18.226	3.441	18.509	3.648	
114.30	29.440	5.570	24.031	4.159	24.704	4.421	
115.80	**38.300**	**6.270**	**30.941**	**4.944**	**31.876**	**5.271**	**FRL**

Table 6.3-1 COMPARATIVE STATEMENT OF VER_2-AMLI 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
98	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99	0.000	0.002	0.004	0.007	0.011	0.015	0.019	0.025	0.030	0.037
100	0.044	0.051	0.060	0.069	0.078	0.089	0.100	0.112	0.125	0.140
101	**0.157**	0.175	0.195	0.217	0.241	0.266	0.293	0.322	0.352	0.383
102	0.416	0.450	0.485	0.521	0.559	0.597	0.637	0.679	0.721	0.765
103	0.810	0.856	0.904	0.954	1.006	1.060	1.115	1.174	1.234	1.298
104	1.363	1.431	1.501	1.573	1.648	1.725	1.805	1.886	1.971	2.057
105	2.146	2.237	2.331	2.427	2.526	2.626	2.730	2.835	2.944	3.055
106	3.169	3.286	3.406	3.529	3.654	3.782	3.913	4.046	4.183	4.323
107	4.466	4.612	4.761	4.913	5.069	5.227	5.388	5.551	5.717	5.886
108	6.057	6.232	6.409	6.589	6.773	6.959	7.148	7.341	7.536	7.735
109	7.937	8.142	8.351	8.563	8.780	9.000	9.224	9.452	9.684	9.920
110	10.160	10.405	10.653	10.905	11.162	11.423	11.688	11.957	12.231	12.509
111	12.791	13.078	13.369	13.665	13.965	14.269	14.577	14.890	15.206	15.527
112	15.852	16.182	16.516	16.855	17.198	17.547	17.900	18.259	18.622	18.991
113	19.366	19.745	20.130	20.520	20.915	21.316	21.721	22.132	22.549	22.970
114	23.397	23.828	24.264	24.704	25.148	25.596	26.049	26.505	26.966	27.430
115	27.900	28.374	28.853	29.338	29.830	30.330	30.838	31.353	**31.876**	32.407
116	**32.947**									

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

Note: Gross storage capacity for FRL at 115.80 m is 31.876 M Cu. m, dead storage at 101.00 m is 0.157 M Cu. m and HFL at 116.00 m is 32.947 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
101	0.000	0.018	0.038	0.060	0.084	0.109	0.136	0.165	0.195	0.226
102	0.259	0.293	0.328	0.364	0.402	0.440	0.480	0.522	0.564	0.608
103	0.653	0.699	0.747	0.797	0.849	0.903	0.958	1.017	1.077	1.141
104	1.206	1.274	1.344	1.416	1.491	1.568	1.648	1.729	1.814	1.900
105	1.989	2.080	2.174	2.270	2.369	2.469	2.573	2.678	2.787	2.898
106	3.012	3.129	3.249	3.372	3.497	3.625	3.756	3.889	4.026	4.166
107	4.309	4.455	4.604	4.756	4.912	5.070	5.231	5.394	5.560	5.729
108	5.900	6.075	6.252	6.432	6.616	6.802	6.991	7.184	7.379	7.578
109	7.780	7.985	8.194	8.406	8.623	8.843	9.067	9.295	9.527	9.763
110	10.003	10.248	10.496	10.748	11.005	11.266	11.531	11.800	12.074	12.352
111	12.634	12.921	13.212	13.508	13.808	14.112	14.420	14.733	15.049	15.370
112	15.695	16.025	16.359	16.698	17.041	17.390	17.743	18.102	18.465	18.834
113	19.209	19.588	19.973	20.363	20.758	21.159	21.564	21.975	22.392	22.813
114	23.240	23.671	24.107	24.547	24.991	25.439	25.892	26.348	26.809	27.273
115	27.743	28.217	28.696	29.181	29.673	30.173	30.681	31.196	**31.719**	32.250
116	**32.790**									

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

Note: Live storage capacity for FRL at 115.80 m is 31.719 M Cu. m and HFL at 116.00 m is 32.790 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
98	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
99	0.009	0.018	0.026	0.032	0.039	0.044	0.049	0.055	0.060	0.066
100	0.073	0.079	0.086	0.093	0.101	0.109	0.118	0.126	0.138	0.155
101	0.177	0.192	0.209	0.227	0.243	0.263	0.281	0.295	0.308	0.320
102	0.332	0.344	0.357	0.369	0.381	0.393	0.407	0.420	0.432	0.444
103	0.457	0.470	0.489	0.508	0.528	0.547	0.569	0.595	0.620	0.644
104	0.667	0.690	0.712	0.735	0.759	0.782	0.806	0.830	0.853	0.876
105	0.900	0.925	0.950	0.974	0.997	1.020	1.044	1.070	1.098	1.128
106	1.157	1.185	1.212	1.238	1.266	1.294	1.322	1.351	1.381	1.412
107	1.445	1.477	1.508	1.539	1.569	1.595	1.621	1.646	1.673	1.700
108	1.730	1.759	1.788	1.819	1.848	1.878	1.908	1.939	1.971	2.003
109	2.036	2.071	2.106	2.145	2.184	2.222	2.260	2.301	2.340	2.380
110	2.421	2.462	2.503	2.545	2.587	2.631	2.672	2.714	2.756	2.802
111	2.846	2.892	2.936	2.978	3.020	3.061	3.103	3.145	3.187	3.230
112	3.275	3.320	3.365	3.411	3.458	3.508	3.559	3.611	3.664	3.718
113	3.769	3.821	3.873	3.926	3.978	4.030	4.083	4.137	4.189	4.241
114	4.290	4.335	4.379	4.421	4.462	4.503	4.545	4.586	4.627	4.670
115	4.716	4.765	4.820	4.885	4.961	5.039	5.115	5.192	**5.271**	5.353
116	**5.442**									

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

Note: Spread year for FRL at 115.80 m is 5.271 Sq. Km and HFL at 116.00 m is 5.442 Sq. Km.

6.7 Sediment Analysis:

6.7.1 Observed Rate of Sedimentation

The reservoir was impounded during the year 1984. As per the original report, total area of reservoir at FRL 115.80 m was 6.27 Sq. Km, corresponding storage capacity was 38.30 M Cu. m, and Dead storage at 101.00 m was 1.25 M Cu. m.

The silt survey was carried out in the year 1998. According to report of 1998, gross storage capacity was 32.63 M Cu. m, and Dead storage at 101.00 m was 0.270 M Cu. m.

G.E.R.I surveyed the reservoir by Remote Sensing Technique in the year 2015. As per survey of the year 2015, total area of reservoir at FRL 115.80 m was 4.944 Sq. Km and corresponding storage capacity was 30.941 M Cu. m, and Dead storage at 101.00 m was 0.138 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 115.80 m is 5.721 Sq. Km, corresponding storage capacity is 31.876 M Cu. m, and Dead storage at 101.00 m is 0.157 M Cu. m.

Rate of siltation in reservoir (up to FRL 115.80 m) during last 36 years (1984-2020) is 0.178 M Cu. m / year.

Original Reservoir data:

Year of Impounding	: 1984
Catchment Area	: 90.00 Sq. Km
Surface area at 115.80m	: 6.27 Sq. Km
Live storage at 115.80m	: 37.05 M Cu. m
Dead storage at 101.00m	: 1.25 M Cu. m
Gross storage at 115.80m	: 38.30 M Cu. m

Rate of Sedimentation (at FRL 115.80 m) with respect to impounding year 1990

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 in M Cu. m and percentage**			**Silt Index ham/100 Sq. Km/Yr.**	**Annual % loss**	**Remarks**
		Dead	**Live**	**Gross**				**Dead**	**Live**	**Gross**			
1	1984	1.25	37.05	38.3	-	-	-	-	-	-	-	-	
2	1998	0.27	32.36	32.63	14	5.67	0.405	0.98 78.40%	4.69 12.66%	5.67 14.80%	45	1.06%	**Serious Category**
3	2015 By Remote Sensing	0.138	30.803	30.941	31	7.359	0.237	1.112 88.96%	6.247 16.86%	7.359 19.21%	26.376	0.62%	**Serious Category**
4	2020 by integrated Bathymetric and Topographic survey	0.157	31.719	31.876	36	6.424	0.178	1.093 87.44%	5.331 14.39%	6.424 16.77%	19.827	0.47%	**Significant Category**

Table 6.7-1 RATE OF SEDIMENTATION

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

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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 1998, 2015 and 2020 is observed to be 1.06%, 0.62% and 0.47% respectively.
- The decrease in annual percentage loss from 1.06% (1998 survey) to 0.62% (2015 survey) and 0.62% (2015 survey) to 0.47% (2020 survey) is because at initial stage after dam construction sedimentation takes place at higher rate compare to later on.
- The increase in gross storage capacity in 2020 survey data compared to 2015 survey data is due to difference in method used to acquire survey data of the reservoir during 2015 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 Ver_2-Amli Reservoir

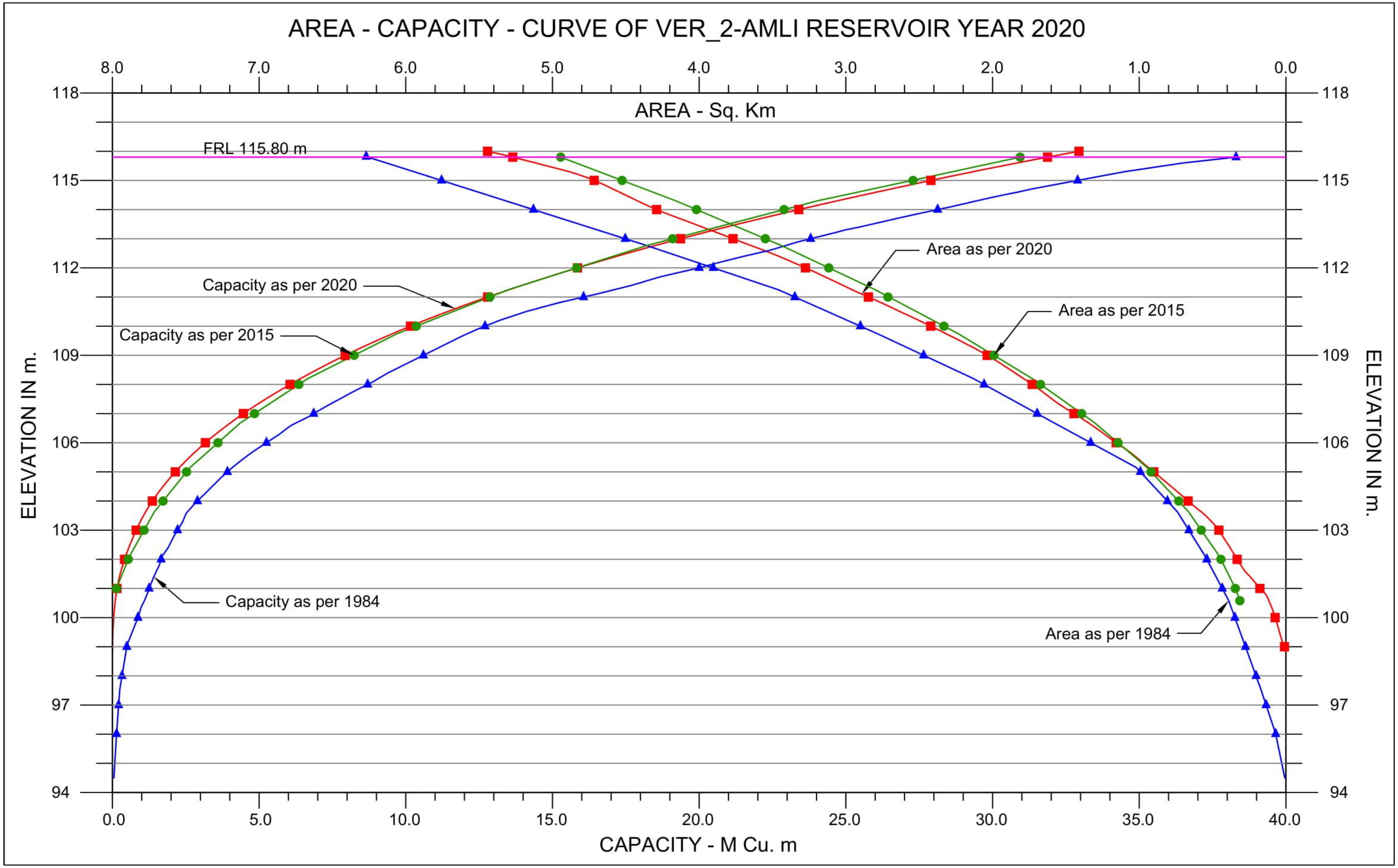


Figure 6.10-1 AREA – CAPACITY - CURVE

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

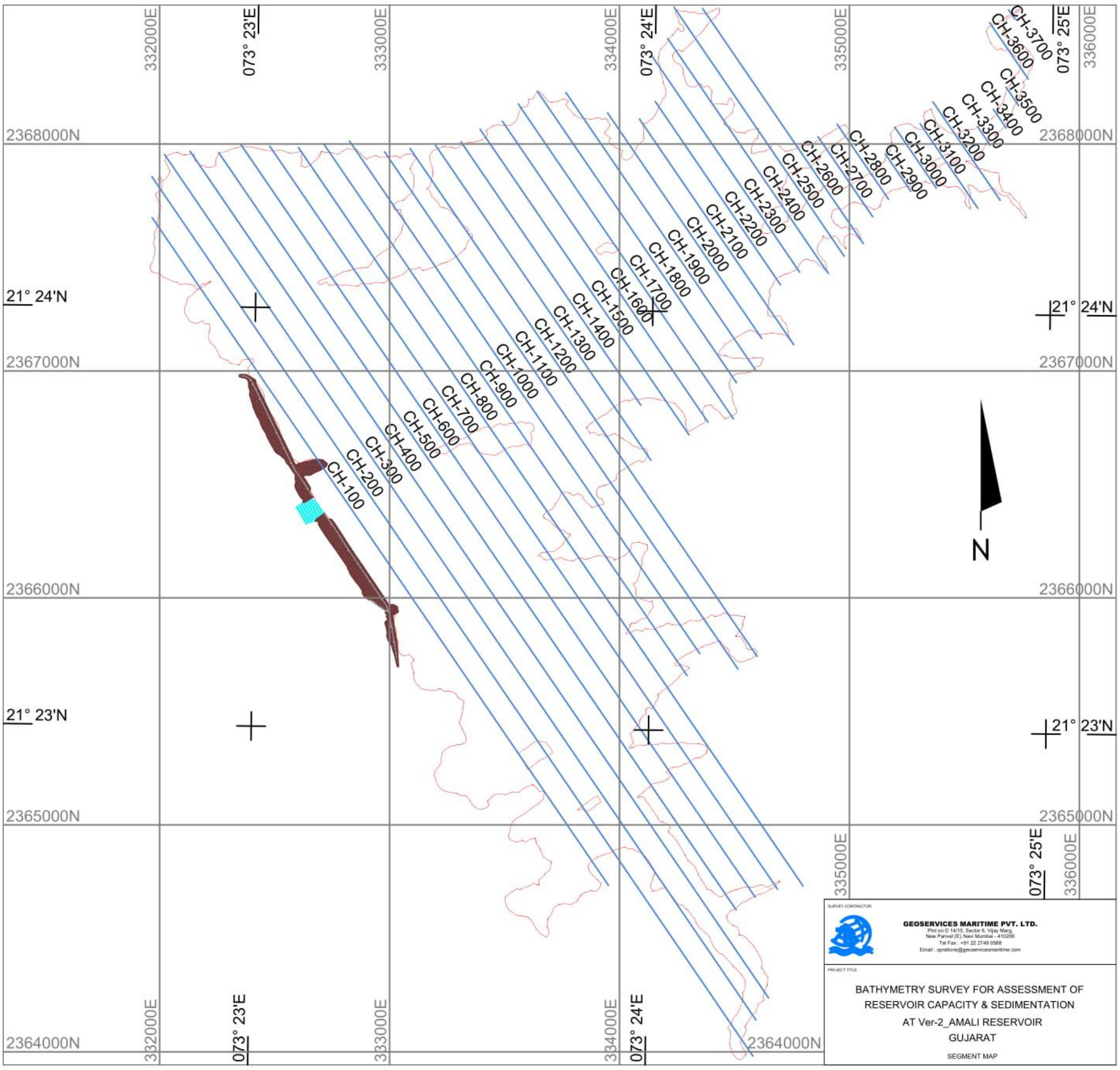


Figure 6.11-1 SEGMENT MAP FOR CROSS SECTION

Cross sections showing bed profile at 100m interval were prepared and are provided as soft copy in CD/Hard Disc. Total 37 cross section profiles were prepared.

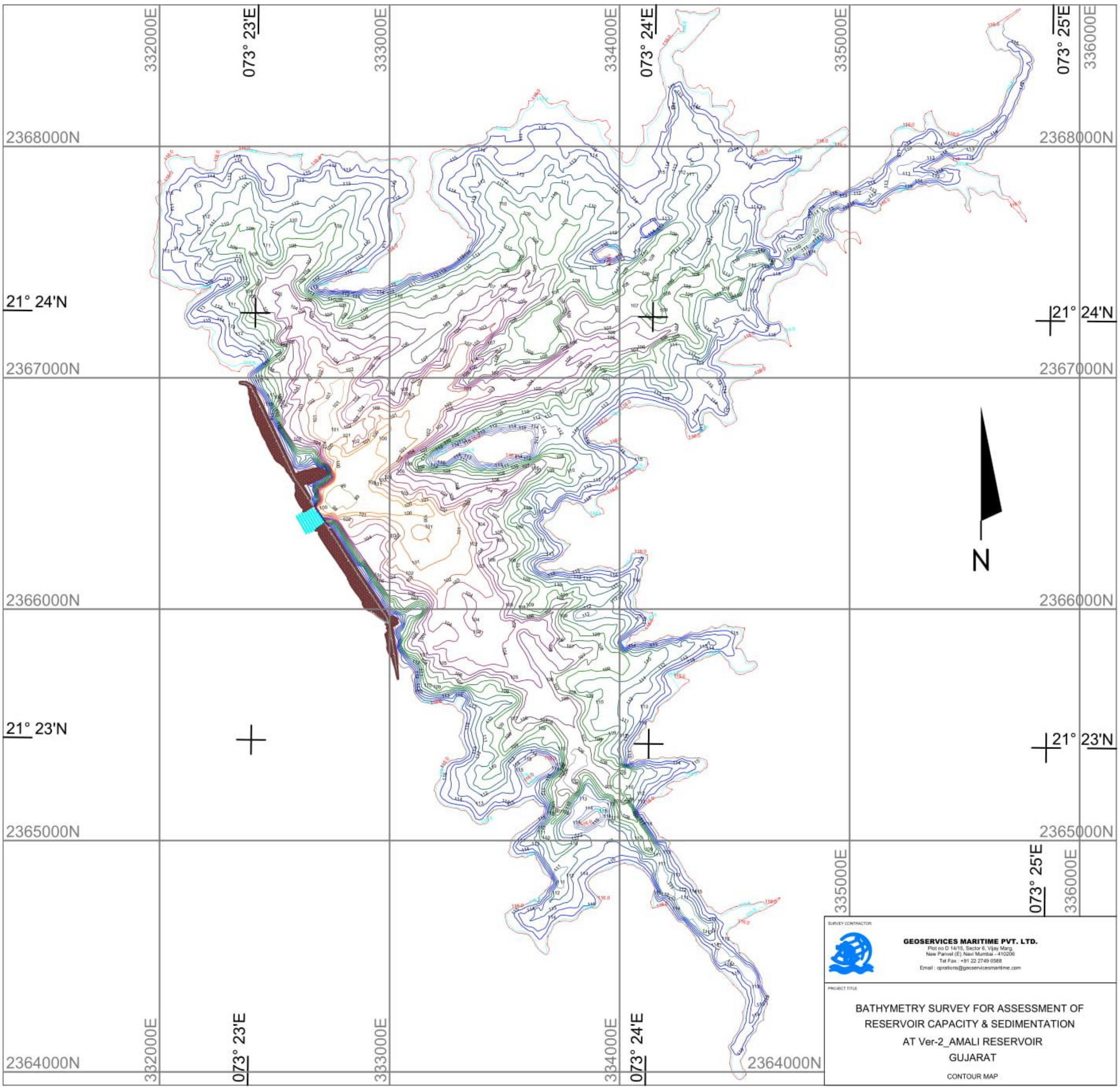


Figure 6.11-2 CONTOUR MAP

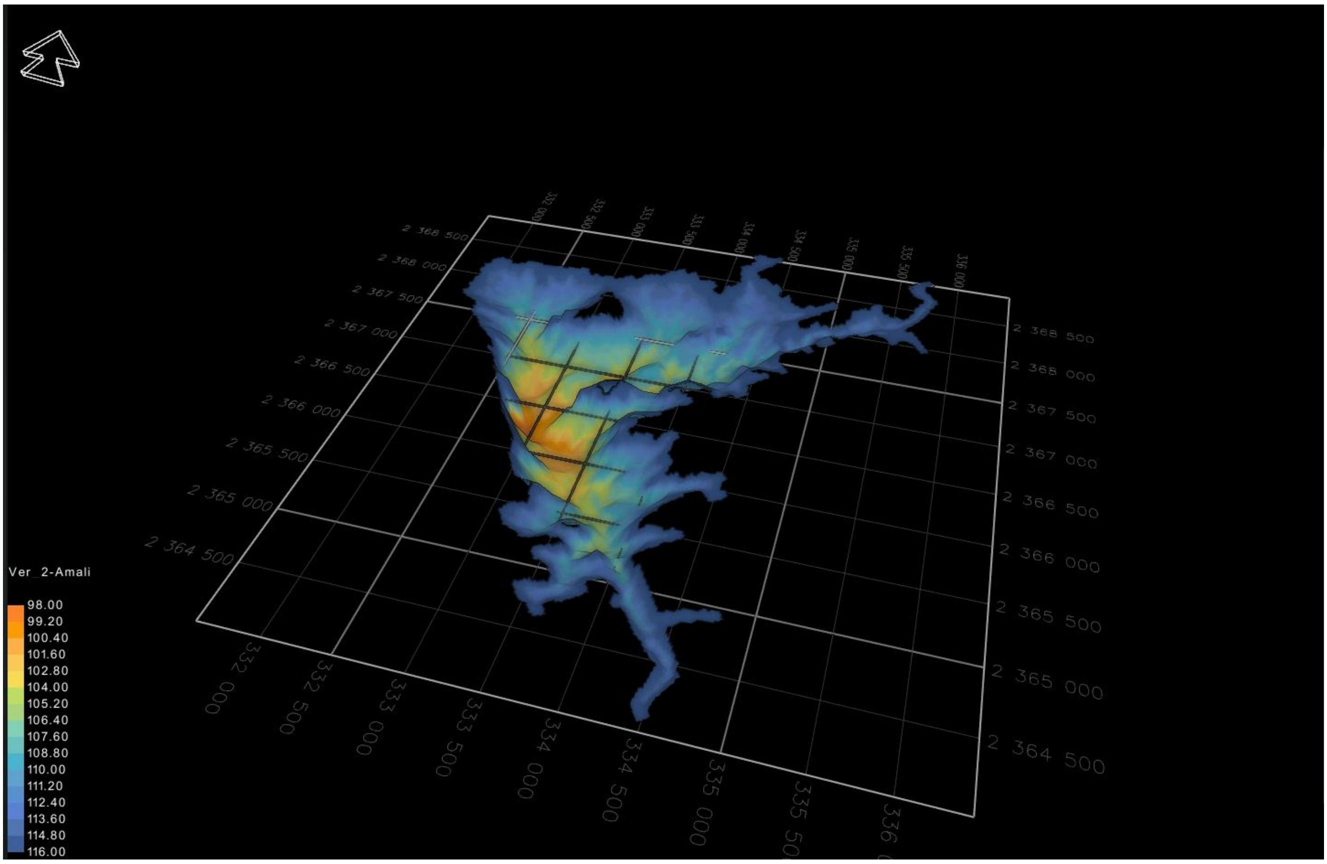


Figure 6.11-3 WIRE FRAME MAP

Figure 6.11-4 L Section

7 DGPS OBSERVATION REPORT

CSRS-PPP 3.45.0 (2020-07-08)

AMLI303q32.20O
AMLI OBS

Data Start	**Data End**	**Duration of Observations**
2020-10-29 10:34:00.00	2020-10-29 14:45:00.00	4:11:00
Processing Time		**Product Type**
16:20:41 UTC 2020/10/29		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 %	98.15 %	60.00 sec

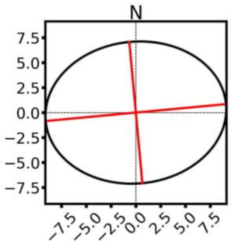
Antenna Model	**APC to ARP**	**ARP to Marker**
GMXZENITH35	L1 = 0.125 m L2 = 0.132 m	H:1.630m / E:0.000m / N:0.000m

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

Estimated Position for AMLI303q32.20O

	Latitude (+n)	**Longitude (+e)**	**Ell. Height**
NAD83(CSRS) (2020.8)	21° 23' 32.93590"	73° 23' 9.10488"	58.710 m
Sigmas(95%)	0.006 m	0.007 m	0.030 m
A priori*	21° 23' 32.97842"	73° 23' 9.15097"	60.825 m
Estimated – A priori	-1.308 m	-1.328 m	-2.115 m

95% Error Ellipse (mm)
semi-major: 9 mm
semi-minor: 7 mm
semi-major azimuth: 84° 41' 10.16"



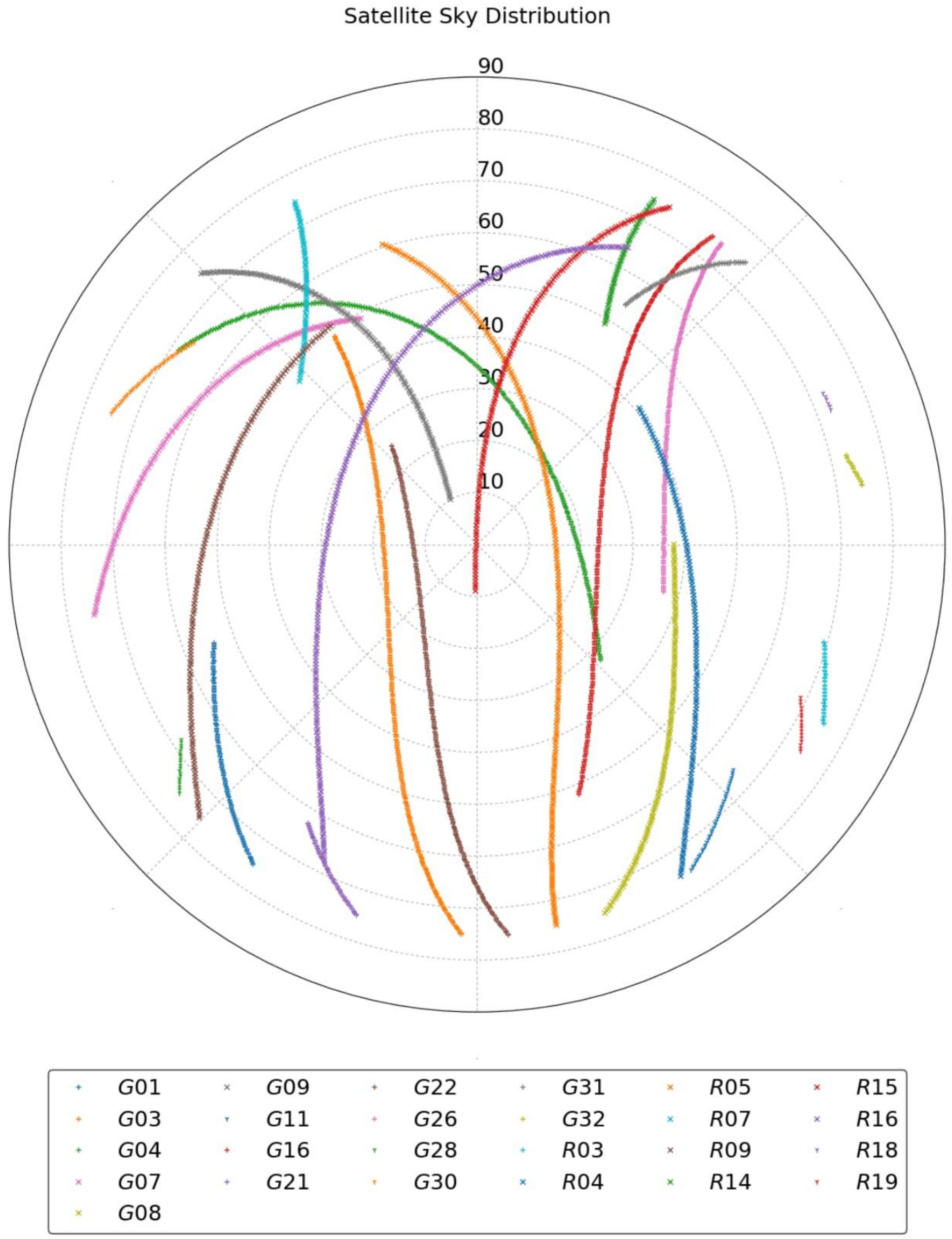
UTM (North)
Zone 43

2366445.609 m (N)
332670.704 m (E)

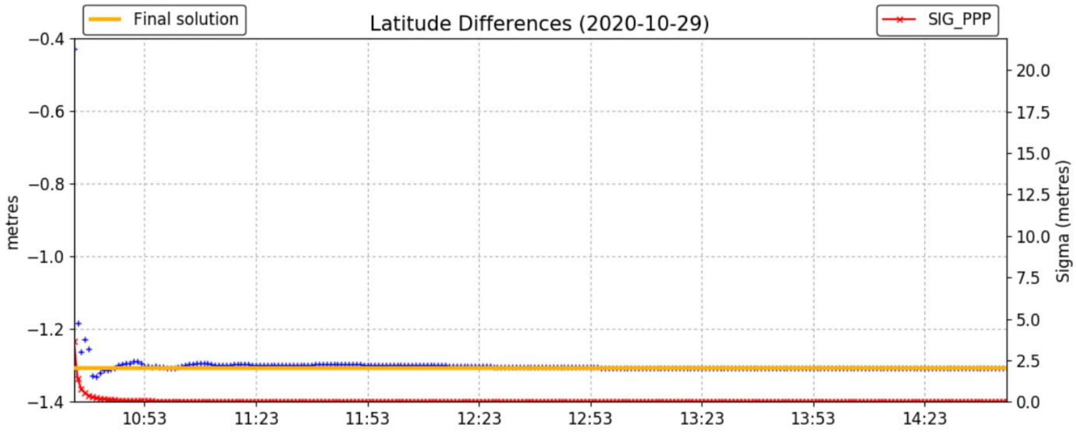
Scale Factors
0.99994599 (point)
0.99993677 (combined)

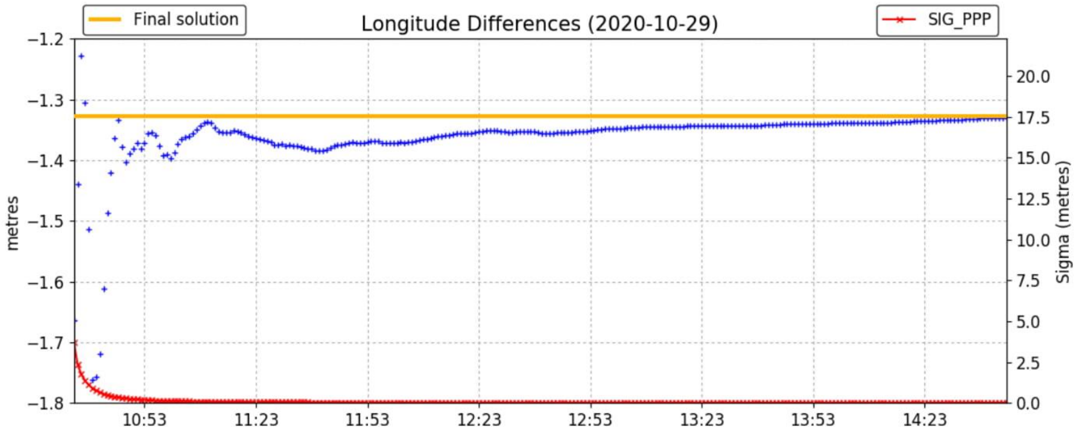
*(Coordinates from RINEX header used as a priori position)

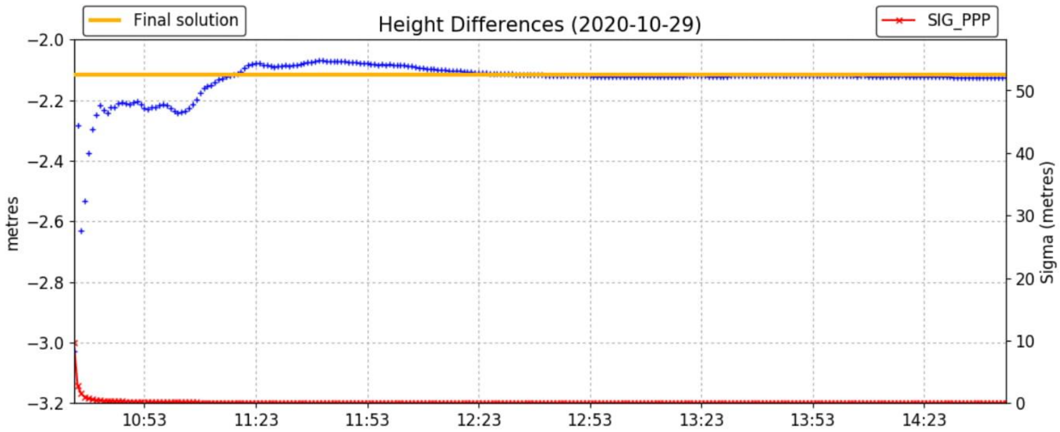
1


Satellite Sky Distribution
90
80
70
60
50
40
30
20
10
G01
G03
G04
G07
G08
G09
G11
G16
G21
G22
G26
G28
G30
G31
G32
R03
R04
R05
R07
R09
R14
R15
R16
R18
R19

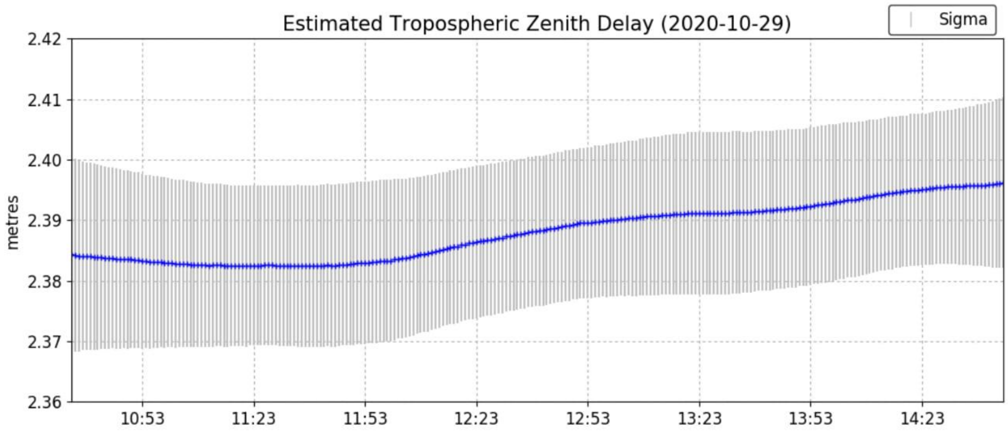
2

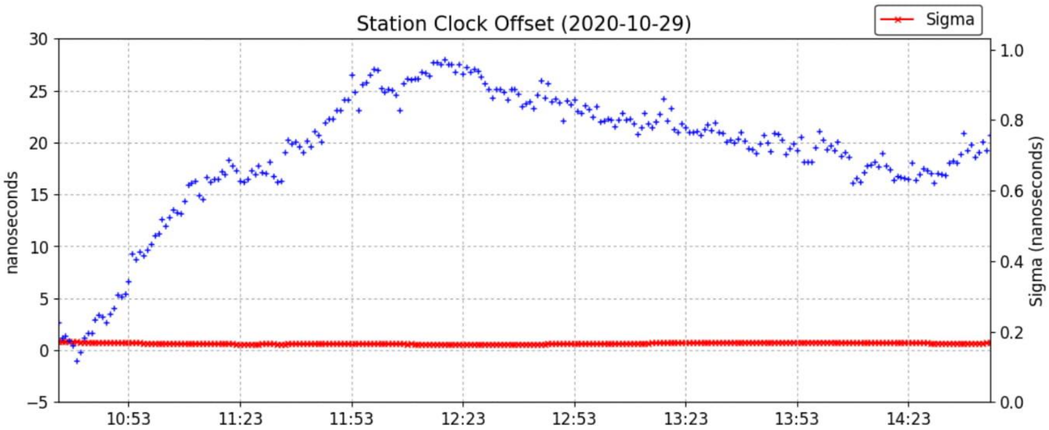

Final solution
Latitude Differences (2020-10-29)
SIG_PPP
metres
Sigma (metres)
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
10:53
11:23
11:53
12:23
12:53
13:23
13:53
14:23

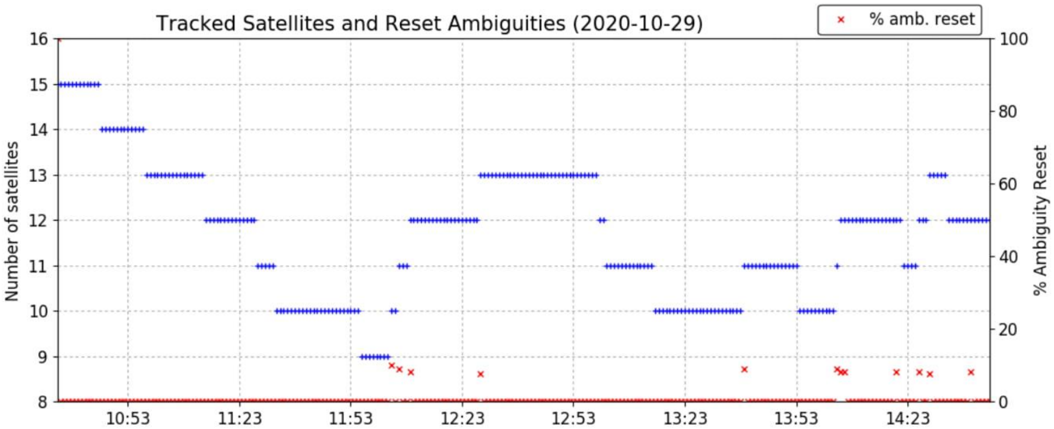

Final solution
Longitude Differences (2020-10-29)
SIG_PPP
metres
Sigma (metres)
−1.2
−1.3
−1.4
−1.5
−1.6
−1.7
−1.8
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
10:53
11:23
11:53
12:23
12:53
13:23
13:53
14:23


Final solution
Height Differences (2020-10-29)
SIG_PPP
metres
Sigma (metres)
−2.0
−2.2
−2.4
−2.6
−2.8
−3.0
−3.2
50
40
30
20
10
0
10:53
11:23
11:53
12:23
12:53
13:23
13:53
14:23

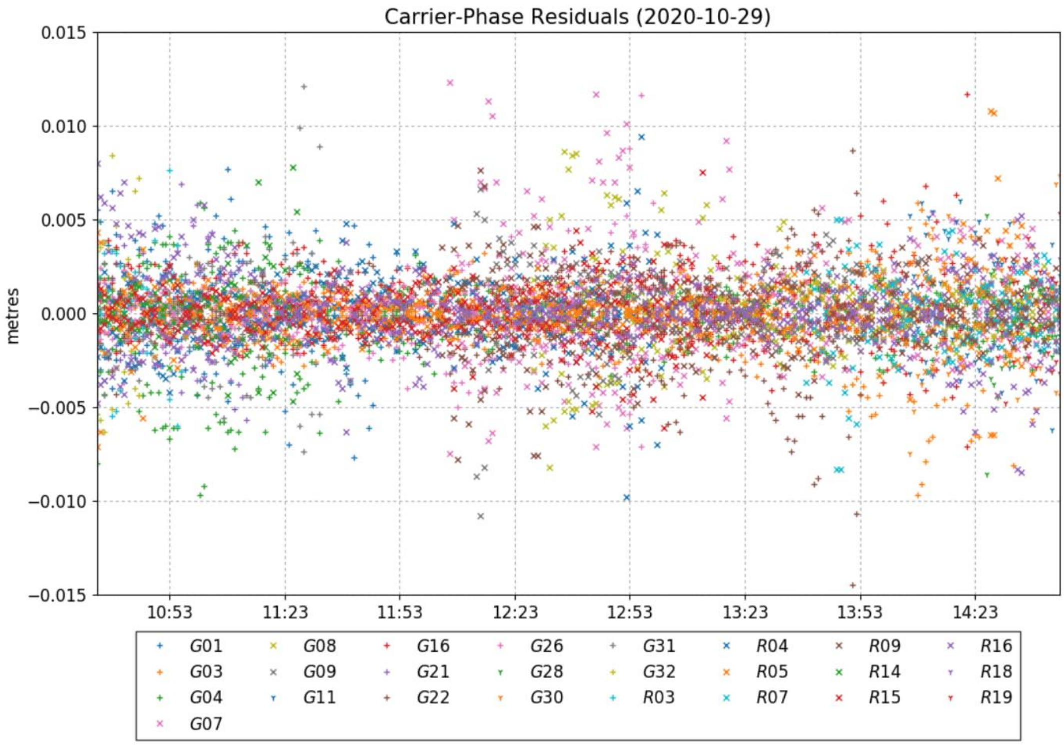
3

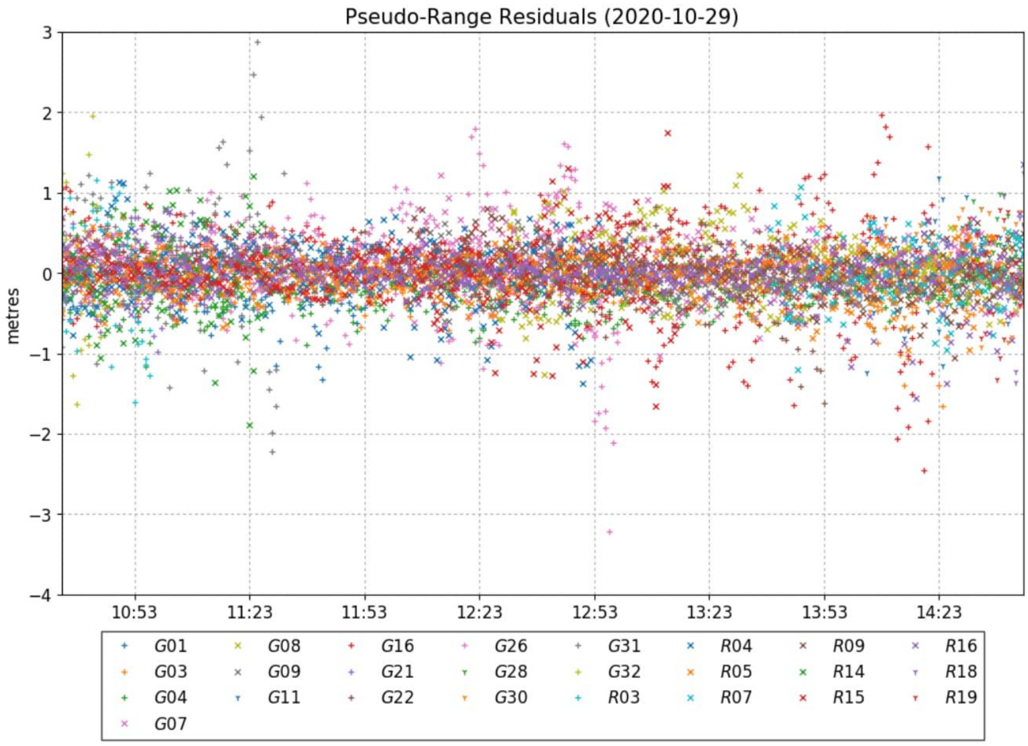

Estimated Tropospheric Zenith Delay (2020-10-29)
Sigma
metres
2.42
2.41
2.40
2.39
2.38
2.37
2.36
10:53
11:23
11:53
12:23
12:53
13:23
13:53
14:23


Station Clock Offset (2020-10-29)
Sigma
nanoseconds
Sigma (nanoseconds)
30
25
20
15
10
5
0
−5
1.0
0.8
0.6
0.4
0.2
0.0
10:53
11:23
11:53
12:23
12:53
13:23
13:53
14:23


Tracked Satellites and Reset Ambiguities (2020-10-29)
% amb. reset
Number of satellites
% Ambiguity Reset
16
15
14
13
12
11
10
9
8
100
80
60
40
20
0
10:53
11:23
11:53
12:23
12:53
13:23
13:53
14:23

4


Carrier-Phase Residuals (2020-10-29)
metres
0.015
0.010
0.005
0.000
−0.005
−0.010
−0.015
10:53
11:23
11:53
12:23
12:53
13:23
13:53
14:23
G01 G08 G16 G26 G31 R04 R09 R16
G03 G09 G21 G28 G32 R05 R14 R18
G04 G11 G22 G30 R03 R07 R15 R19
G07


Pseudo-Range Residuals (2020-10-29)
metres
3
2
1
0
−1
−2
−3
−4
10:53
11:23
11:53
12:23
12:53
13:23
13:53
14:23
G01 G08 G16 G26 G31 R04 R09 R16
G03 G09 G21 G28 G32 R05 R14 R18
G04 G11 G22 G30 R03 R07 R15 R19
G07

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**	**Amli Dam**
Date:	Time:	Client:	
31-Oct-20	**8.50hrs**	**Water Resources Investigation division**	
Observed By:		Echosounder Model and SL. No.	Area Depth
Amit Singh		**Reason Navisound 215**	**11**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	**Upto Depth**
0.4				**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

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title: **Bathymetric Survey**	Vessel: **Aqua Marina**	Place: **Amli Dam**
Date: **01-Nov-20**	Time: **8.10hrs**	Client: **Water Resources Investigation division**	
Observed By: **Amit Singh**		Echosounder Model and SL. No. **Reason Navisound 215**	Area Depth **10**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	Upto Depth
0.4				1500	10
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	3.99	0.01	6	6.02	-0.02
6	6.01	-0.01	4	4.02	-0.02
8	7.98	0.02	2	1.99	0.01

Average	0.0025	Average	-0.0025
Std. Dev	0.0150	Std. Deviation	0.0206
		Cumulative Average	0.00
		Cumulative Std. Deviation	0.0040

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:	Vessel:	Place:
	Bathymetric Survey	**Aqua Marina**	**Amli Dam**
Date: **02-Nov-20**	Time: **8.40hrs**	Client: **Water Resources Investigation division**	
Observed By: **Amit Singh**		Echosounder Model and SL. No. **Reason Navisound 215**	Area Depth **11**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	Upto Depth
0.4				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	6.98	0.02
3	2.99	0.01	6	6.01	-0.01
4	4.02	-0.02	5	4.99	0.01
5	4.99	0.01	4	4.01	-0.01
6	6	0	3	3.02	-0.02
7	6.98	0.02	2	1.99	0.01

	Average	0.0017	Average	0.0000
	Std. Dev	0.0147	Std. Deviation	0.0155
			Cumulative Average	0.00
			Cumulative Std. Deviation	0.0005

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: **Aqua Marina**	Place: **Amli Dam**
Date: **03-Nov-20**	Time: **8.00hrs**	Client: **Water Resources Investigation division**	
Observed By: **Amit Singh**		Echosounder Model and SL. No. **Reason Navisound 215**	Area Depth **11**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	Upto Depth
0.4				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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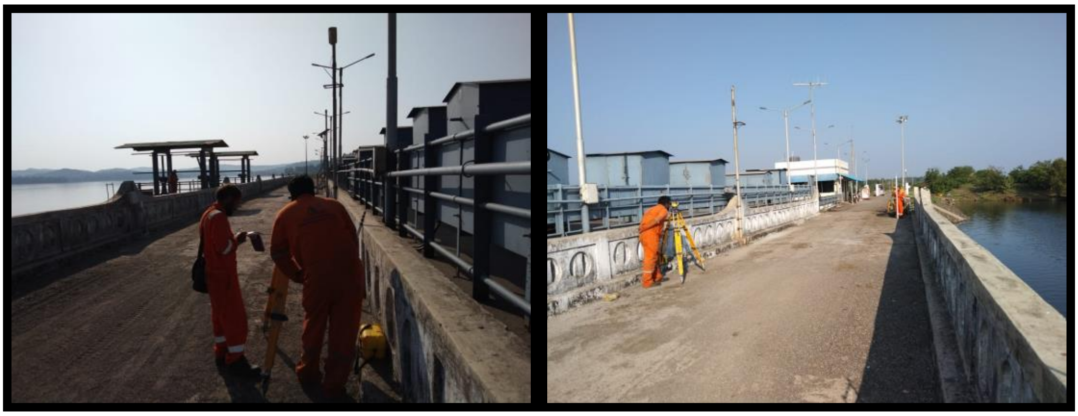
GMPL Party Chief

9 PHOTOGRAPHS

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



Levelling on Dam top

RTK Base Set up At Dam

TBM 2 near Light pole

Bathy survey near Spillway

Spot fixing with RTK Rover

Bathy Survey

END OF REPORT