GEOSERVICES MARITIME PVT. LTD.

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

GMPL REPORT NUMBER: P-SUR-BATHY-009-2020-21-WRD-MAZAM
SURVEY PERIOD: Bathymetry: 21 FEB TO 25 FEB 2021
Topography: 13 MAR TO 16 MAR 2021

Prepared for:	**Water Resources Investigation Division, Ahmedabad** **(Govt. Of Gujarat)**	
Client Reference:	**Executive Engineer** **Water resources investigation Division Ahmedabad.**	

LOCATION MAP

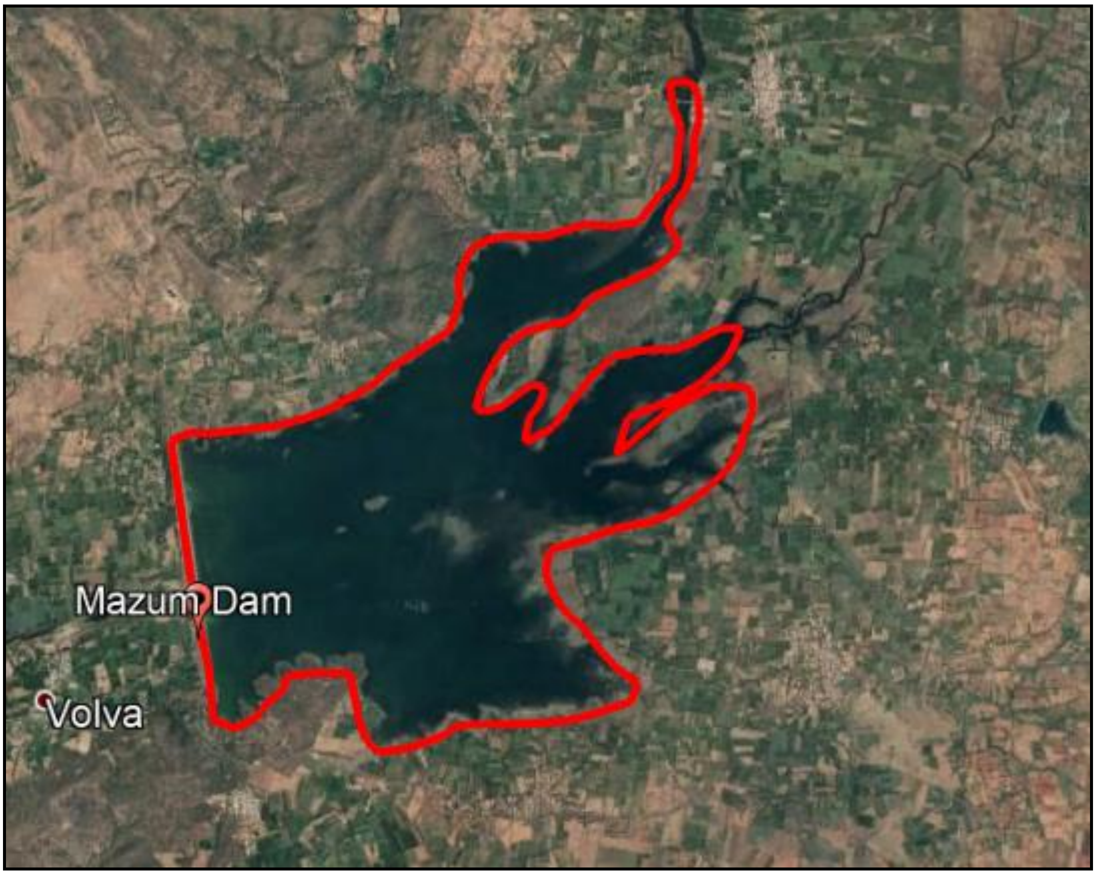

Figure 1.1-1 LOCATION MAP

LOCATION MAP SHOWING SURVEY AREA "MAZAM 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 Mazum Dam, 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 Mazum Dam.

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 Mazam Reservoir.

The detailed scope of work was:

i) To measure the water depth of the Mazam Dam 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 shall be used.

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 and drawings.

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 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 MAZAM RESERVOIR

MAZAM RESERVOIR PROJECT		
I	**LOCATION**	
	Coordinates	Latitude 23°29' 21" N Longitude 73°23' 45"E
	River	Mazam
	Village	Volva
	Taluka	Modasa
	District	Sabarkantha
	State	Gujarat
	Nearest Railway Station	Modasa Railway Station
	Purpose	Flood Control, Irrigation
II	**HYDROLOGY**	
	Catchment Area	407.8 Sq. Km
	Mean Annual Rainfall	736 mm
III	**DAM**	
	Dam Type	Earthen and Masonry with Saddles
	Length of the top of the dam	2400.24 m
	Top of Dam	163.15 m
IV	**RESERVOIR**	
	MDDL	150.77 m
	FRL	157.1 m
	HFL/MWL	158.78m
	Gross Storage Capacity at FRL	43.86 M Cu. m
	Dead Storage Capacity	7.28 M Cu. m
	Live Storage Capacity	36.58 M Cu. m
	Area at FRL	11.685 Sq. Km
V	**SPILLWAY**	
	Type	Ogee
	Length of Spillway	101.84 m
	Maximum Discharge	3313.5 m^3/s
	Type, Nos. and Size of Gates	Radial, 9, (9.15 m x 6.1 m)
VII	**HEAD REGULATOR**	
	Location	Ch 50 m
	Design Discharge	5.66 cumecs
	Still R.L.	150.77 m
	No. and Size	Single, 1.50 m x 1.80 m

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 Mazam Dam survey area from 10 Feb to 28 Feb 2021 to acquire bathymetric survey data and Topographic data as per mutually agreed scope and relevant survey specifications.

Pentax DGPS system, Sonarmite BTX Echo sounder (215 kHz) were utilised to acquire the bathymetric data within the Mazam 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. Pentax RTK / Geomax 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 Mazam Dam area.

The DGPS observation were made for about 4.5 Hours at Dam top near spill way. Two Temporary Bench Marks were established.

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

- The Minimum elevation within Mazam Dam is 143.40 m above MSL and
- The Maximum depth within Mazam Dam is 12.10 m
- Area covered by bathymetric survey is 7.112 Sq. Km
- Area covered by topographic survey is 9.474 Sq. Km

The reservoir was recently surveyed by means of integrated bathymetric and topographic survey in year 2021. As per survey recent survey, total area of reservoir at FRL 157.1 m is 11.685 Sq. Km, corresponding storage capacity is 168.493 M Cu. m and Dead storage at 150.77 m is 5.044 M Cu. m.

The comparison between 1984 and 2021(37 years) data results in a rate of siltation (silt index) of 2.73 Ham/100 Sq. Km/year. Annual percentage loss of gross storage capacity, live storage capacity and dead storage capacity is 0.25%, 0.14% and 0.83 % respectively for FRL 157.1 m.

The comparison of 2021 data with respect to 1984 impounding data at FRL 157.1 m results in silt index of 2.73 Ham/100 Sq. Km/year

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
Pruthviraaj Mohile	Surveyor
Rohit Singh	Land Surveyor
Samraj Dwivedi	Survey Engineer
Ashish Patil	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 Mazam Dam 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	Trimble DSM 232 DGPS
Single Beam Echo Sounder	Sonarmite BTX Echo sounder with Accessories
RTK	Pentax 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 'Acqua 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.

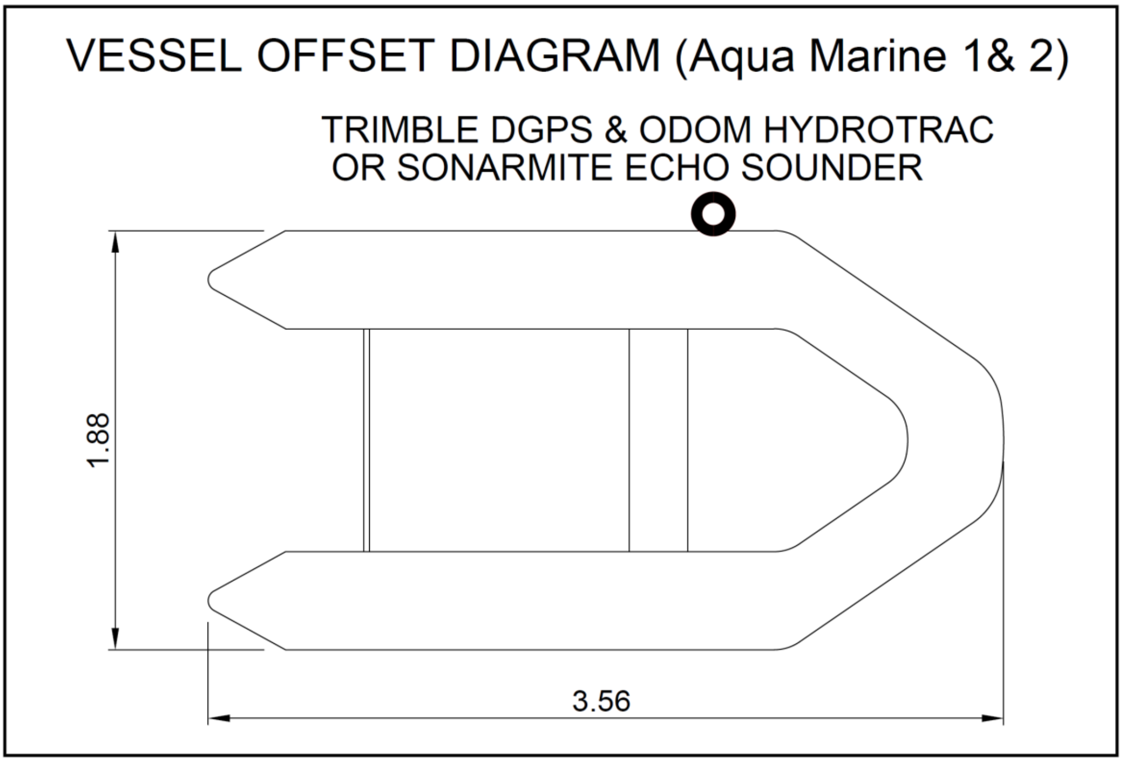


Figure 4.3-1 SURVEY BOAT ' AQUA MARINE' OFFSET DIAGRAM

5 DETAILED METHODOLOGY OF SURVEY

5.1 Mobilisation

The bathymetric survey equipment were mobilised on board “Aqua Marine” on 21 Feb 2021. After successful installation, testing and calibrations of survey equipment, the team proceeded for Data acquisition.

Pentax 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.

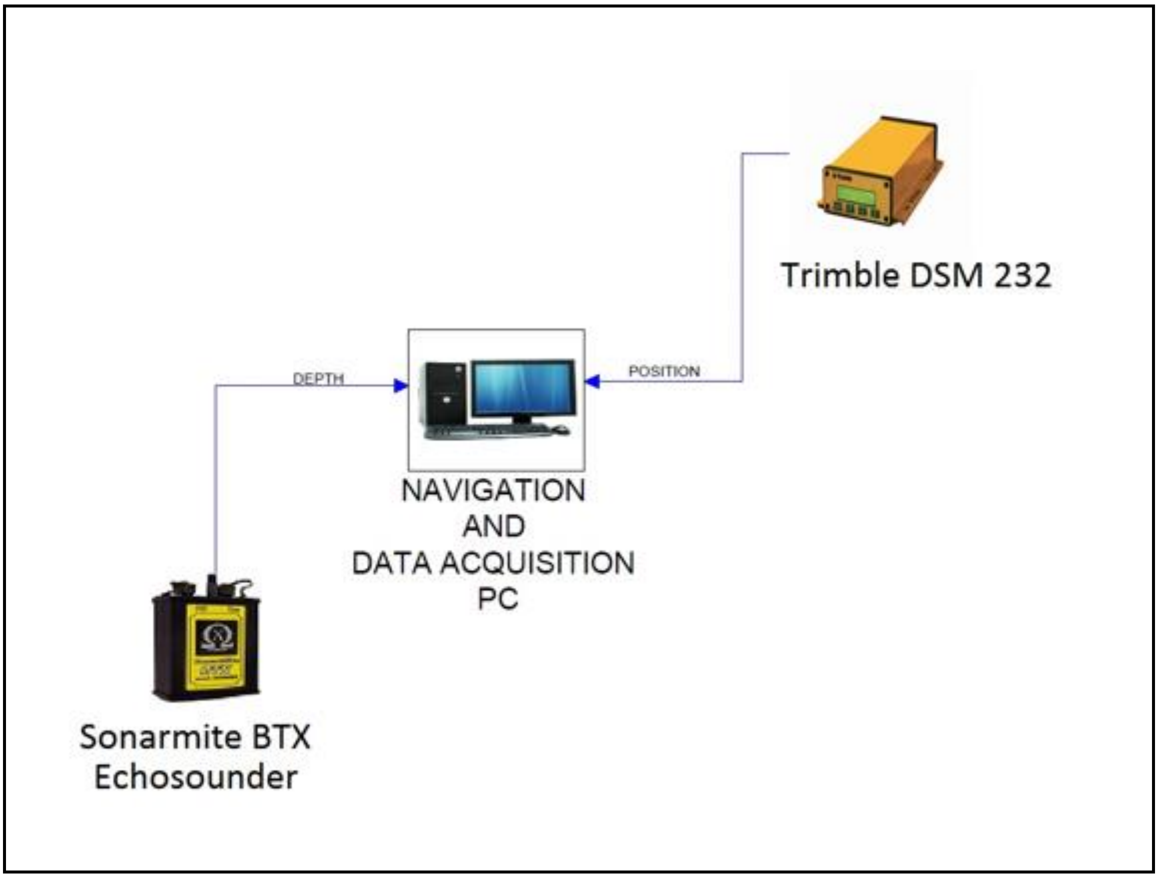


Figure 5.1-1 SBES SURVEY EQUIPMENT CONFIGURATION DIAGRAM ON BOARD

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

The DGPS observation were made for about 4.5 Hours at Dam top near spill way. Two Temporary Bench Marks were established.
The details of Bench Marks are presented in the table below:

BM Observation and T.B.M. Information _ Mazam Dam South Gujarat					
Location	**Latitude (N)**	**Longitude (E)**	**Easting (m)**	**Northing (m)**	**Elevation (m) W.r.t MSL**
OBS MAZ	23°28'59.988"	73°21' 16.328"	331960.797	2597987.595	163.150
T.B.M.01	23°29'2.599"	73°21'16.000"	331952.266	2598068.033	163.167
T.B.M.02	23°28'43.87"	73°21'20.037	332060.374	2597490.618	163.160

Table 5.3-1 BENCH MARK DETAILS

5.4 Survey Systems

5.4.1 Trimble DSM 232 DGPS:

Trimble DSM 232 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.

Trimble DSM 232 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 'Sonarmite BTX' with an accuracy of 0.01m was deployed and in principle, higher frequency of 215 kHz was operated. Echo Sounder equipment was calibrated daily before and after use, by means of a bar-check in the survey area. The calibration results were found satisfactory.

5.4.3 HYPACK Software

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

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

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

5.4.4 RTK System

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

- RTK DGPS Base station was set up at OBS-MAZ Made by GMPL and configured to transmit the corrections.
- Pentax RTK Rover was used for DGPS Observation on the top of Dam, near spill way. 4Hrs of DGPS observation was carried out. Bench Mark elevation value of 163.150m was provided by the Dam authority.

5.5 Data Acquisition and Quality Control

5.5.1 Online Data Quality Control

The online navigation computer was interfaced to Sonarmite 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 Sonarmite 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 Mazam Reservoir with due, consent from Client Representative, the survey equipment on board were demobilised on 25 February 2021.

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)
21/01/2021	0700	155.49
	1900	155.49
22/01/2021	0700	155.47
	19:00	155.47
23/01/2021	0700	155.46
	1900	155.44
24/01/2021	0700	155.44
	1900	155.41
25/02/2021	0700	155.41
	1900	155.38

Table 5.8-1 WATER LEVELS

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

Fifteen drawing has been prepared for Mazam Dam, the details of which are presented in the table below:

Sr. No	Drawing Name	Description	Hard Copy format	Soft Copy format
1	P-SUR-009-Mazam-Bathy-01	Bathymetry chart part 01	1:5000	PDF & CAD
2	P-SUR-009-Mazam-Bathy-01	Bathymetry chart part 02	1:5000	PDF & CAD
3	P-SUR-009-Mazam-Bathy-01	Bathymetry chart part 03	1:5000	PDF & CAD
4	P-SUR-009-Mazam-Contour-01	Contour chart	1:21000	PDF & CAD
5	P-SUR-009-Mazam-Overview-01	Overview Map of Reservoir	Paper size A3	PDF & CAD
6	Area Capacity Curve Mazam - 2021	Area Capacity curve of Reservoir	Paper size A3	PDF & CAD
7	Mazam Cross Sections	71 Cross Section at 100 m interval	Only soft copy	CAD
8	Mazam L-Section	L-Section of Reservoir	Only soft copy	CAD

Table 5.8-2 LIST OF CHARTS

PDF formatted chart has been attached along the report. Native CAD formatted drawing has been provided as softcopy in CD / Hard Disc.

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 Mazam reservoir.

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

- The Minimum elevation within Mazam Dam is 143.40 m above MSL and
- The Maximum depth within Mazam Dam is 12.10 m

6.2 Capacity and Area Calculation:

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

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

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

h is difference between two level and

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

Level (m)	Dead Storage Capacity (M Cu. M)	Live Storage Capacity (M Cu. M)	Gross Storage Capacity using TIN (M Cu. M)	Gross Storage Capacity using Prismoidal formula (M Cu. M)	Spread Area (Sq. Km)	Remarks
143.40	0.000	0.000	0.000	0.000	0.000	
143.50	0.000	0.000	0.000	0.000	0.001	
143.60	0.000	0.000	0.000	0.000	0.003	
143.70	0.001	0.000	0.001	0.001	0.006	
143.80	0.002	0.000	0.002	0.002	0.014	
143.90	0.003	0.000	0.003	0.003	0.019	
144.00	0.006	0.000	0.006	0.006	0.025	
144.10	0.009	0.000	0.009	0.009	0.035	
144.20	0.013	0.000	0.013	0.013	0.046	
144.30	0.018	0.000	0.018	0.018	0.058	
144.40	0.024	0.000	0.024	0.024	0.068	
144.50	0.032	0.000	0.032	0.031	0.077	

Level (m)	Dead Storage Capacity (M Cu. M)	Live Storage Capacity (M Cu. M)	Gross Storage Capacity using TIN (M Cu. M)	Gross Storage Capacity using Prismoidal formula (M Cu. M)	Spread Area (Sq. Km)	Remarks
144.60	0.040	0.000	0.040	0.040	0.084	
144.70	0.048	0.000	0.048	0.048	0.091	
144.80	0.058	0.000	0.058	0.058	0.099	
144.90	0.068	0.000	0.068	0.068	0.107	
145.00	0.079	0.000	0.079	0.079	0.115	
145.10	0.091	0.000	0.091	0.091	0.122	
145.20	0.104	0.000	0.104	0.104	0.130	
145.30	0.117	0.000	0.117	0.117	0.138	
145.40	0.131	0.000	0.131	0.131	0.147	
145.50	0.147	0.000	0.147	0.147	0.157	
145.60	0.163	0.000	0.163	0.163	0.167	
145.70	0.180	0.000	0.180	0.180	0.177	
145.80	0.198	0.000	0.198	0.198	0.188	
145.90	0.217	0.000	0.217	0.217	0.199	
146.00	0.238	0.000	0.238	0.238	0.214	
146.10	0.260	0.000	0.260	0.260	0.230	
146.20	0.284	0.000	0.284	0.284	0.250	
146.30	0.310	0.000	0.310	0.310	0.271	
146.40	0.339	0.000	0.339	0.339	0.295	
146.50	0.369	0.000	0.369	0.369	0.322	
146.60	0.403	0.000	0.403	0.403	0.351	
146.70	0.440	0.000	0.440	0.440	0.380	
146.80	0.479	0.000	0.479	0.479	0.409	
146.90	0.521	0.000	0.521	0.521	0.437	
147.00	0.566	0.000	0.566	0.566	0.464	
147.10	0.614	0.000	0.614	0.614	0.491	
147.20	0.665	0.000	0.665	0.665	0.520	
147.30	0.718	0.000	0.718	0.718	0.551	
147.40	0.775	0.000	0.775	0.775	0.581	
147.50	0.834	0.000	0.834	0.834	0.611	
147.60	0.897	0.000	0.897	0.897	0.642	
147.70	0.963	0.000	0.963	0.963	0.677	
147.80	1.032	0.000	1.032	1.032	0.712	

Level (m)	Dead Storage Capacity (M Cu. M)	Live Storage Capacity (M Cu. M)	Gross Storage Capacity using TIN (M Cu. M)	Gross Storage Capacity using Prismoidal formula (M Cu. M)	Spread Area (Sq. Km)	Remarks
147.90	1.105	0.000	1.105	1.105	0.746	
148.00	1.182	0.000	1.182	1.182	0.783	
148.10	1.262	0.000	1.262	1.262	0.819	
148.20	1.346	0.000	1.346	1.346	0.855	
148.30	1.433	0.000	1.433	1.433	0.895	
148.40	1.525	0.000	1.525	1.525	0.935	
148.50	1.620	0.000	1.620	1.620	0.973	
148.60	1.719	0.000	1.719	1.719	1.012	
148.70	1.823	0.000	1.823	1.823	1.054	
148.80	1.930	0.000	1.930	1.930	1.099	
148.90	2.042	0.000	2.042	2.042	1.139	
149.00	2.158	0.000	2.158	2.158	1.176	
149.10	2.277	0.000	2.277	2.277	1.216	
149.20	2.401	0.000	2.401	2.401	1.258	
149.30	2.529	0.000	2.529	2.529	1.302	
149.40	2.662	0.000	2.662	2.662	1.348	
149.50	2.799	0.000	2.799	2.799	1.395	
149.60	2.941	0.000	2.941	2.941	1.445	
149.70	3.088	0.000	3.088	3.088	1.498	
149.80	3.241	0.000	3.241	3.241	1.561	
149.90	3.400	0.000	3.400	3.400	1.618	
150.00	3.565	0.000	3.565	3.565	1.681	
150.10	3.736	0.000	3.736	3.736	1.746	
150.20	3.914	0.000	3.914	3.914	1.809	
150.30	4.098	0.000	4.098	4.098	1.871	
150.40	4.288	0.000	4.288	4.288	1.931	
150.50	4.484	0.000	4.484	4.484	1.990	
150.60	4.686	0.000	4.686	4.686	2.053	
150.70	4.894	0.000	4.894	4.894	2.115	
150.77	**5.044**	**0.000**	**5.044**	**5.044**	**2.163**	**MDDL**
150.80	5.044	0.065	5.109	5.109	2.184	
150.90	5.044	0.287	5.331	5.331	2.255	
151.00	5.044	0.516	5.560	5.560	2.328	

Level (m)	Dead Storage Capacity (M Cu. M)	Live Storage Capacity (M Cu. M)	Gross Storage Capacity using TIN (M Cu. M)	Gross Storage Capacity using Prismoidal formula (M Cu. M)	Spread Area (Sq. Km)	Remarks
151.10	5.044	0.753	5.797	5.797	2.403	
151.20	5.044	0.997	6.041	6.041	2.479	
151.30	5.044	1.248	6.292	6.292	2.553	
151.40	5.044	1.508	6.552	6.552	2.633	
151.50	5.044	1.775	6.819	6.819	2.719	
151.60	5.044	2.051	7.095	7.095	2.803	
151.70	5.044	2.336	7.380	7.380	2.889	
151.80	5.044	2.629	7.673	7.673	2.973	
151.90	5.044	2.930	7.974	7.975	3.058	
152.00	5.044	3.241	8.285	8.285	3.146	
152.10	5.044	3.560	8.604	8.604	3.231	
152.20	5.044	3.887	8.931	8.931	3.310	
152.30	5.044	4.221	9.265	9.266	3.387	
152.40	5.044	4.564	9.608	9.608	3.468	
152.50	5.044	4.915	9.959	9.959	3.547	
152.60	5.044	5.274	10.317	10.318	3.622	
152.70	5.044	5.639	10.683	10.683	3.694	
152.80	5.044	6.012	11.056	11.056	3.762	
152.90	5.044	6.392	11.436	11.436	3.829	
153.00	5.044	6.778	11.822	11.822	3.894	
153.10	5.044	7.171	12.215	12.215	3.960	
153.20	5.044	7.570	12.614	12.614	4.031	
153.30	5.044	7.977	13.021	13.021	4.107	
153.40	5.044	8.392	13.436	13.436	4.189	
153.50	5.044	8.815	13.859	13.859	4.277	
153.60	5.044	9.247	14.291	14.292	4.372	
153.70	5.044	9.690	14.734	14.734	4.486	
153.80	5.044	10.145	15.189	15.189	4.613	
153.90	5.044	10.612	15.656	15.656	4.719	
154.00	5.044	11.088	16.132	16.132	4.808	
154.10	5.044	11.573	16.617	16.618	4.903	
154.20	5.044	12.069	17.113	17.113	5.005	
154.30	5.044	12.575	17.619	17.619	5.111	

Level (m)	Dead Storage Capacity (M Cu. M)	Live Storage Capacity (M Cu. M)	Gross Storage Capacity using TIN (M Cu. M)	Gross Storage Capacity using Prismoidal formula (M Cu. M)	Spread Area (Sq. Km)	Remarks
154.40	5.044	13.091	18.135	18.135	5.215	
154.50	5.044	13.618	18.662	18.662	5.321	
154.60	5.044	14.155	19.199	19.200	5.433	
154.70	5.044	14.708	19.752	19.752	5.615	
154.80	5.044	15.277	20.321	20.321	5.765	
154.90	5.044	15.861	20.905	20.905	5.918	
155.00	5.044	16.461	21.505	21.505	6.078	
155.10	5.044	17.077	22.121	22.121	6.247	
155.20	5.044	17.711	22.755	22.756	6.456	
155.30	5.044	18.368	23.412	23.413	6.682	
155.40	5.044	19.047	24.091	24.092	6.897	
155.50	5.044	19.748	24.792	24.793	7.112	
155.60	5.044	20.470	25.514	25.515	7.336	
155.70	5.044	21.215	26.259	26.261	7.584	
155.80	5.044	21.991	27.034	27.037	7.914	
155.90	5.044	22.795	27.839	27.841	8.170	
156.00	5.044	23.624	28.668	28.670	8.417	
156.10	5.044	24.478	29.522	29.524	8.669	
156.20	5.044	25.358	30.402	30.405	8.935	
156.30	5.044	26.267	31.311	31.314	9.249	
156.40	5.044	27.210	32.254	32.256	9.598	
156.50	5.044	28.186	33.230	33.232	9.915	
156.60	5.044	29.194	34.238	34.239	10.245	
156.70	5.044	30.235	35.279	35.280	10.569	
156.80	5.044	31.307	36.351	36.353	10.879	
156.90	5.044	32.410	37.454	37.455	11.171	
157.00	5.044	33.541	38.584	38.585	11.435	
157.10	**5.044**	**34.697**	**39.741**	**39.741**	**11.685**	**FRL**
157.20	5.044	35.878	40.922	40.923	11.943	
157.30	5.044	37.087	42.131	42.132	12.246	
157.40	5.044	38.328	43.372	43.373	12.579	
157.50	5.044	39.603	44.647	44.649	12.932	
157.60	5.044	40.914	45.958	45.960	13.285	

Level (m)	Dead Storage Capacity (M Cu. M)	Live Storage Capacity (M Cu. M)	Gross Storage Capacity using TIN (M Cu. M)	Gross Storage Capacity using Prismoidal formula (M Cu. M)	Spread Area (Sq. Km)	Remarks
157.70	5.044	42.260	47.304	47.306	13.644	
157.80	5.044	43.642	48.686	48.688	13.989	
157.90	5.044	45.058	50.102	50.103	14.322	
158.00	5.044	46.506	51.550	51.551	14.632	
158.10	5.044	47.983	53.027	53.028	14.917	
158.20	5.044	49.489	54.533	54.534	15.188	
158.30	5.044	51.021	56.065	56.065	15.450	
158.40	5.044	52.579	57.623	57.624	15.717	
158.50	5.044	54.164	59.208	59.208	15.974	
158.60	5.044	55.773	60.817	60.817	16.211	
158.70	5.044	57.405	62.449	62.449	16.422	
158.78	**5.044**	**58.725**	**63.769**	**63.769**	**16.586**	**HFL**

Table 6.2-1 Capacity and Area

6.3 Comparative Statement of Mazam Dam

Elevation (m)	Original		As per 2021		Remarks
	Area (Sq. Km)	Gross storage Capacity (M Cu. m)	Area (Sq. Km)	Gross storage Capacity (M Cu. m)	
150.77	**2.440**	**7.280**	**2.163**	**5.044**	**MDDL**
151.00	2.628	7.870	2.328	5.560	
152.00	3.628	10.454	3.146	8.285	
153.00	4.566	14.974	3.894	11.822	
154.00	5.690	19.494	4.808	16.132	
155.00	7.045	24.494	6.078	21.505	
156.00	8.394	33.495	8.417	28.670	
157.00	10.195	42.919	11.435	38.585	
157.10	**10.374**	**43.860**	**11.685**	**39.741**	**FRL**

Table 6.3-1 COMPARATIVE STATEMENT OF MAZAM DAM

6.4 Gross Storage Capacity in M Cu. m of the Reservoir - Year 2021:

RL (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.77	0.78	0.8	0.9
143					0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.003
144	0.006	0.009	0.013	0.018	0.024	0.032	0.040	0.048	0.055	0.056	0.058	0.068
145	0.079	0.091	0.104	0.117	0.131	0.147	0.163	0.180	0.193	0.194	0.198	0.217
146	0.238	0.260	0.284	0.310	0.339	0.369	0.403	0.440	0.467	0.471	0.479	0.521
147	0.566	0.614	0.665	0.718	0.775	0.834	0.897	0.963	1.011	1.018	1.032	1.105
148	1.182	1.262	1.346	1.433	1.525	1.620	1.719	1.823	1.897	1.908	1.930	2.042
149	2.158	2.277	2.401	2.529	2.662	2.799	2.941	3.088	3.194	3.210	3.241	3.400
150	3.565	3.736	3.914	4.098	4.288	4.484	4.686	4.894	**5.044**	5.066	5.109	5.331
151	5.560	5.797	6.041	6.292	6.552	6.819	7.095	7.380	7.584	7.614	7.673	7.974
152	8.285	8.604	8.931	9.265	9.608	9.959	10.317	10.683	10.944	10.981	11.056	11.436
153	11.822	12.215	12.614	13.021	13.436	13.859	14.291	14.734	15.051	15.097	15.189	15.656
154	16.132	16.617	17.113	17.619	18.135	18.662	19.199	19.752	20.148	20.206	20.321	20.905
155	21.505	22.121	22.755	23.412	24.091	24.792	25.514	26.259	26.798	26.877	27.034	27.839
156	28.668	29.522	30.402	31.311	32.254	33.230	34.238	35.279	36.026	36.134	36.351	37.454
157	38.584	**39.741**	40.922	42.131	43.372	44.647	45.958	47.304	48.268	48.407	48.686	50.102
158	51.550	53.027	54.533	56.065	57.623	59.208	60.817	62.449	63.604	**63.769**		

Table 6.4-1 GROSS STORAGE CAPACITY IN M cu. m YEAR -2021

Note: Gross storage capacity for FRL at 157.1 m is 39.741M Cu. m, dead storage at 150.77 m is 5.044 M Cu. m and HFL at 158.78 m is 63.769 M Cu. m.

6.5 Live Storage Capacity in M Cu. m of the Reservoir - Year 2021:

RL (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.77	0.78	0.8	0.9
150									0.000	0.022	0.065	0.287
151	0.516	0.753	0.997	1.248	1.508	1.775	2.051	2.336	2.540	2.570	2.629	2.930
152	3.241	3.560	3.887	4.221	4.564	4.915	5.274	5.639	5.900	5.937	6.012	6.392
153	6.778	7.171	7.570	7.977	8.392	8.815	9.247	9.690	10.007	10.053	10.145	10.612
154	11.088	11.573	12.069	12.575	13.091	13.618	14.155	14.708	15.104	15.162	15.277	15.861
155	16.461	17.077	17.711	18.368	19.047	19.748	20.470	21.215	21.754	21.833	21.991	22.795
156	23.624	24.478	25.358	26.267	27.210	28.186	29.194	30.235	30.982	31.090	31.307	32.410
157	33.541	**34.697**	35.878	37.087	38.328	39.603	40.914	42.260	43.224	43.363	43.642	45.058
158	46.506	47.983	49.489	51.021	52.579	54.164	55.773	57.405	58.560	**58.725**		

Table 6.5-1 LIVE STORAGE CAPACITY IN M cu. m YEAR -2021

Note: Live storage capacity for FRL at 157.1 m is 34.697M Cu. m and HFL at 158.78m is 58.725 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	0.77	0.78	0.8	0.9
143					0.000	0.001	0.003	0.006	0.013	0.013	0.014	0.019
144	0.025	0.035	0.046	0.058	0.068	0.077	0.084	0.091	0.097	0.098	0.099	0.107
145	0.115	0.122	0.130	0.138	0.147	0.157	0.167	0.177	0.185	0.186	0.188	0.199
146	0.214	0.230	0.250	0.271	0.295	0.322	0.351	0.380	0.401	0.403	0.409	0.437
147	0.464	0.491	0.520	0.551	0.581	0.611	0.642	0.677	0.701	0.705	0.712	0.746
148	0.783	0.819	0.855	0.895	0.935	0.973	1.012	1.054	1.086	1.090	1.099	1.139
149	1.176	1.216	1.258	1.302	1.348	1.395	1.445	1.498	1.541	1.548	1.561	1.618
150	1.681	1.746	1.809	1.871	1.931	1.990	2.053	2.115	2.163	2.170	2.184	2.255
151	2.328	2.403	2.479	2.553	2.633	2.719	2.803	2.889	2.948	2.957	2.973	3.058
152	3.146	3.231	3.310	3.387	3.468	3.547	3.622	3.694	3.742	3.749	3.762	3.829
153	3.894	3.960	4.031	4.107	4.189	4.277	4.372	4.486	4.578	4.590	4.613	4.719
154	4.808	4.903	5.005	5.111	5.215	5.321	5.433	5.615	5.721	5.736	5.765	5.918
155	6.078	6.247	6.456	6.682	6.897	7.112	7.336	7.584	7.829	7.858	7.914	8.170
156	8.417	8.669	8.935	9.249	9.598	9.915	10.245	10.569	10.786	10.817	10.879	11.171
157	11.435	**11.685**	11.943	12.246	12.579	12.932	13.285	13.644	13.887	13.921	13.989	14.322
158	14.632	14.917	15.188	15.450	15.717	15.974	16.211	16.422	16.565	**16.586**		

Table 6.6-1 SPREAD AREA IN SQ. KM YEAR -2021

Note: Spread Area for FRL at 157.1 m is 11.685Sq. Km and HFL at 158.78m m is 16.586Sq. Km.

6.7 Sediment Analysis:

6.7.1 Observed Rate of Sedimentation

The reservoir was impounded during the year 1984. As per survey of the year 1984, total area of reservoir at FRL 157.1 m was 13.10 Sq. Km, corresponding storage capacity was 43.86 M Cu. m, and Dead storage at 150.77 was 7.28 M Cu. m.

The reservoir was recently surveyed by means of integrated bathymetric and topographic survey in year 2021. As per survey recent survey, total area of reservoir at FRL 157.1 m m is 11.685 Sq. Km, corresponding storage capacity is 168.493 M Cu. m and Dead storage at 150.77 m is 5.044 M Cu. m.

The rate of siltation in the reservoir (up to FRL 157.1 m) during the last 37 years (1984-2021), was found to be 0.111 M Cu. m / year.

Original Reservoir data:

Year of Impounding	: 1984
Catchment Area	: 407.8 Sq. Km
Surface area at 157.10 m	: 13.10 Sq. Km
Live storage at 157.10 m	: 36.58 M Cu. m
Dead storage at 150.77 m	: 7.28 M Cu. m
Gross storage at 157.10 m	: 43.86 M Cu. m

Rate of Sedimentation (at FRL 157.10) with respect to impounding year 1984

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	7.28	36.58	43.86	-	-	-	-	-	-	-	-	
2	2021 (Hydrographic survey)	5.044	34.697	39.741	37	4.119	0.111	2.236 30.71%	1.883 5.15%	4.119 9.39%	2.73	0.25%	**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 years

6.8 Conclusion

- By above table we can conclude that the capacity of reservoir is decreased due to deposition of sediments in the reservoir.
- The annual percentage loss from survey of the year 2021 is 0.25% for FRL 157.10 m.
- Reservoir is classified as "**Significant category**" as per IS 12182-1987 and requires actions to control deposition of sediments in the reservoir.

6.9 Methods for controlling the sedimentation

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

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

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

6.9.1 Design of Reservoirs

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

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

- The rate of sediment delivery increases with the quantum of discharge.
- The percentage of sediment trapped by a reservoir with a given drainage area increases with the increased capacity. In some cases an increased capacity will however, result in greater loss of water due to evaporation. However, with the progress of sedimentation, there is decrease of storage capacity which in turn lowers the trap efficiency of the reservoir.
- The capacity of the reservoir and the size and characteristics of the reservoir and its drainage area are the most important factors governing the annual rate of accumulation of sediment. Periodical reservoir sedimentation surveys provide guidance on the rate of sedimentation. In the absence of observed data for the reservoir concerned, data from other reservoirs of similar capacity and catchment characteristics may be adopted.
- Sedimentation takes place not only in the dead storage but also in the live storage space in the reservoir. The practice for design of reservoir is to use the observed suspended sediment data

available from key hydrologica1 networks and also the data available from hydrographic surveys of other reservoirs in the same region.

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

- Raising the Dam at Periodic Intervals:

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

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

6.9.2 Control of Sediment Inflow

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

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

1.1. The engineering methods

1.1.1. Check Dams

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

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

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

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

1.1.2. Contour Bunding and Trenching

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

1.1.3. Gully Plugging

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

1.1.4. Bank Protection

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

1.2. Agronomy

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

1.3. Forestry

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

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

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

2.2. Construction of by-pass channels or conduits.

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

6.9.3 Control of Sediment Deposition

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

- **Density current**

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

- **Waste-water release**

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

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

- **Scouring Sluicing**

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

The distinctions amongst them are the following:

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

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

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

Scouring sluicing method can be used in the following:

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

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

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

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

6.9.4 Removal of Sediment Deposit

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

1. Excavation

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

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

2. Dredging

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

Dredging practices are grouped as:

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

NOTES

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

3. Draining and Flushing

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

4. Sluicing with Controlled Water

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

5. Sluicing with Hydraulic and Mechanical Agitation

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

6.10 Area – Capacity – Curve of Mazam Reservoir:

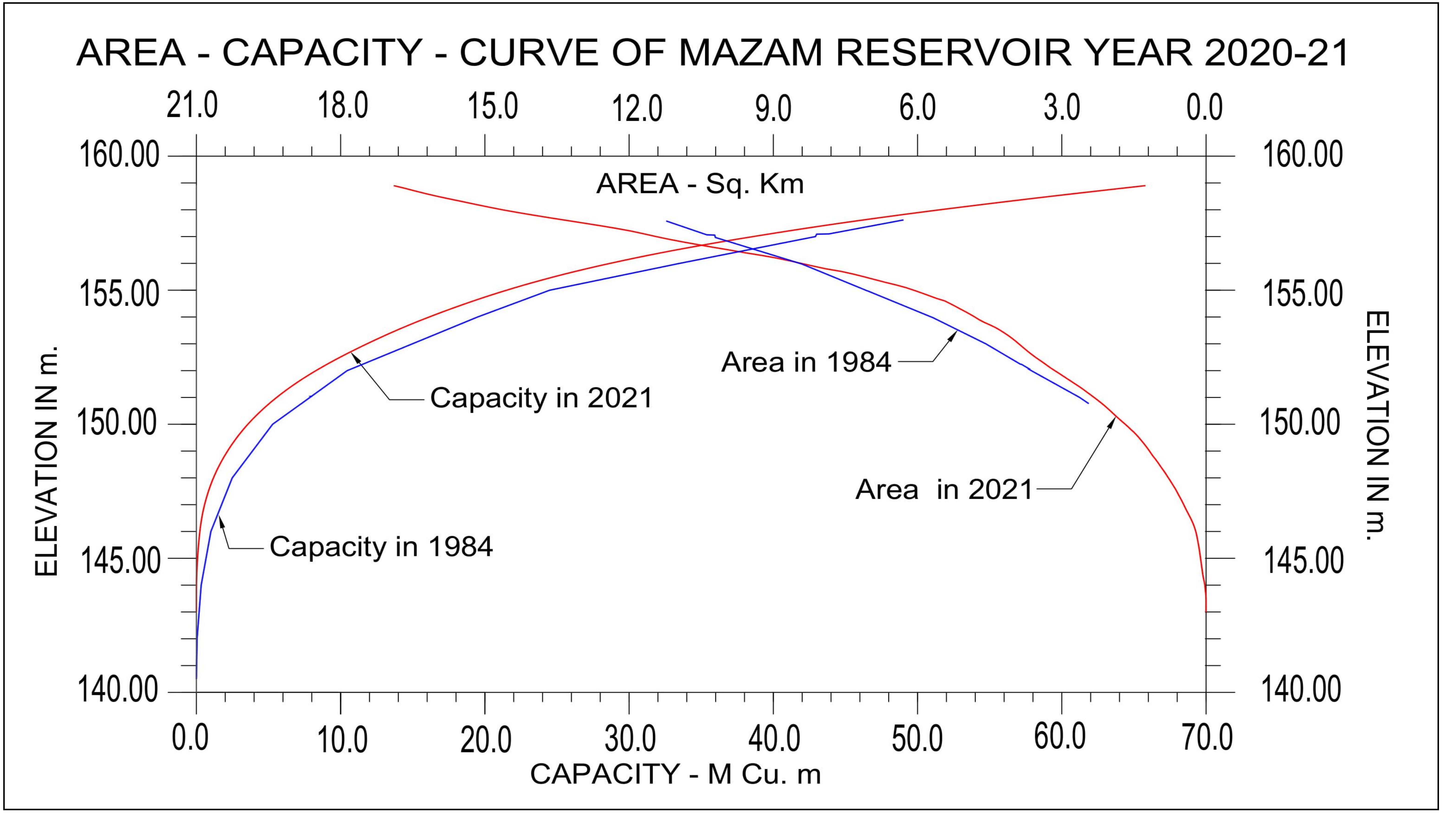


Figure 6.10-1 AREA – CAPACITY - CURVE

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

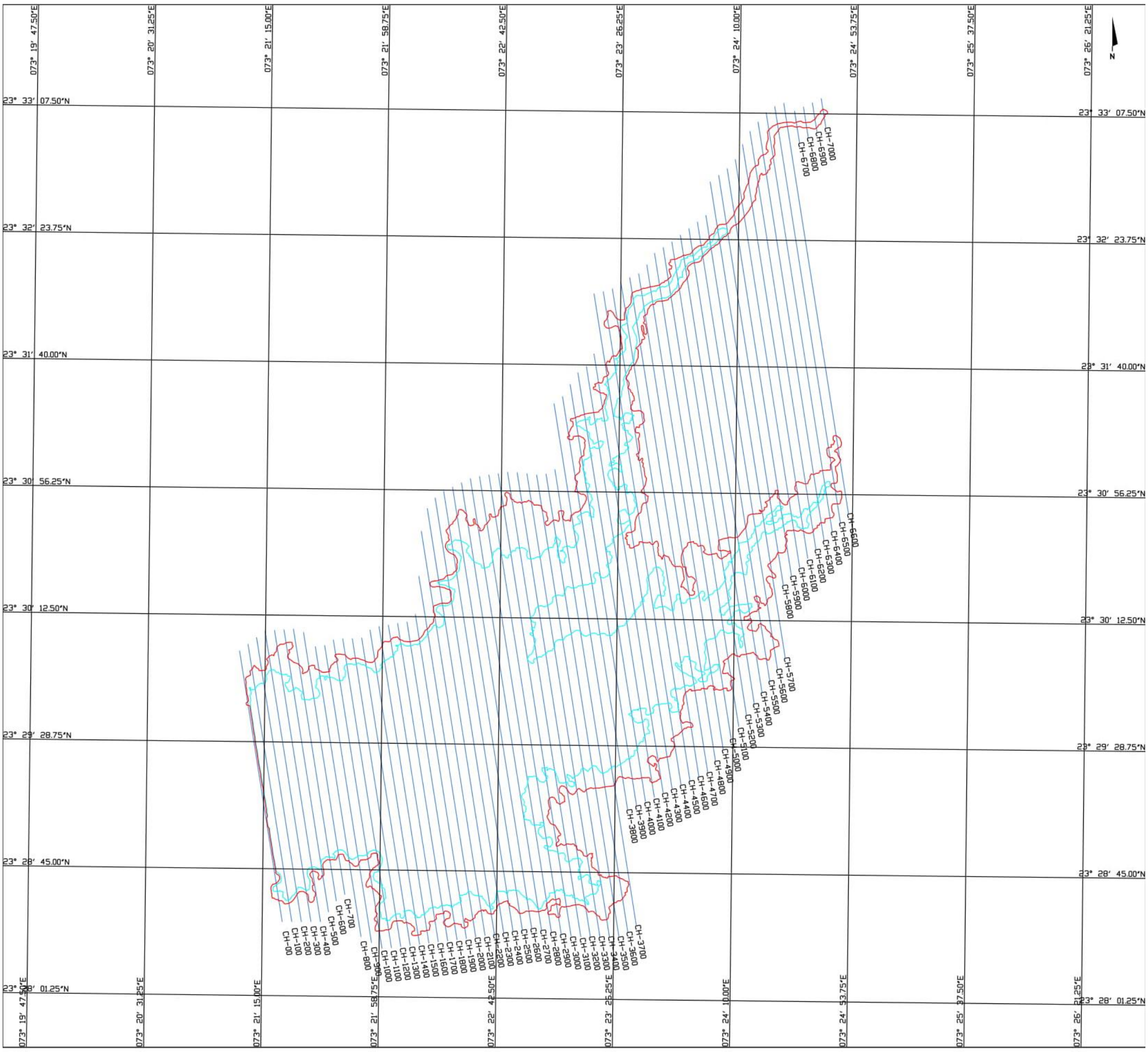


Figure 6.11-1 SEGMENT MAP FOR CROSS SECTION

Cross sections showing bed profile at 100m interval were prepared and are provided as soft copy in CD/Hard Disc. Total 71 cross section profiles were prepared.

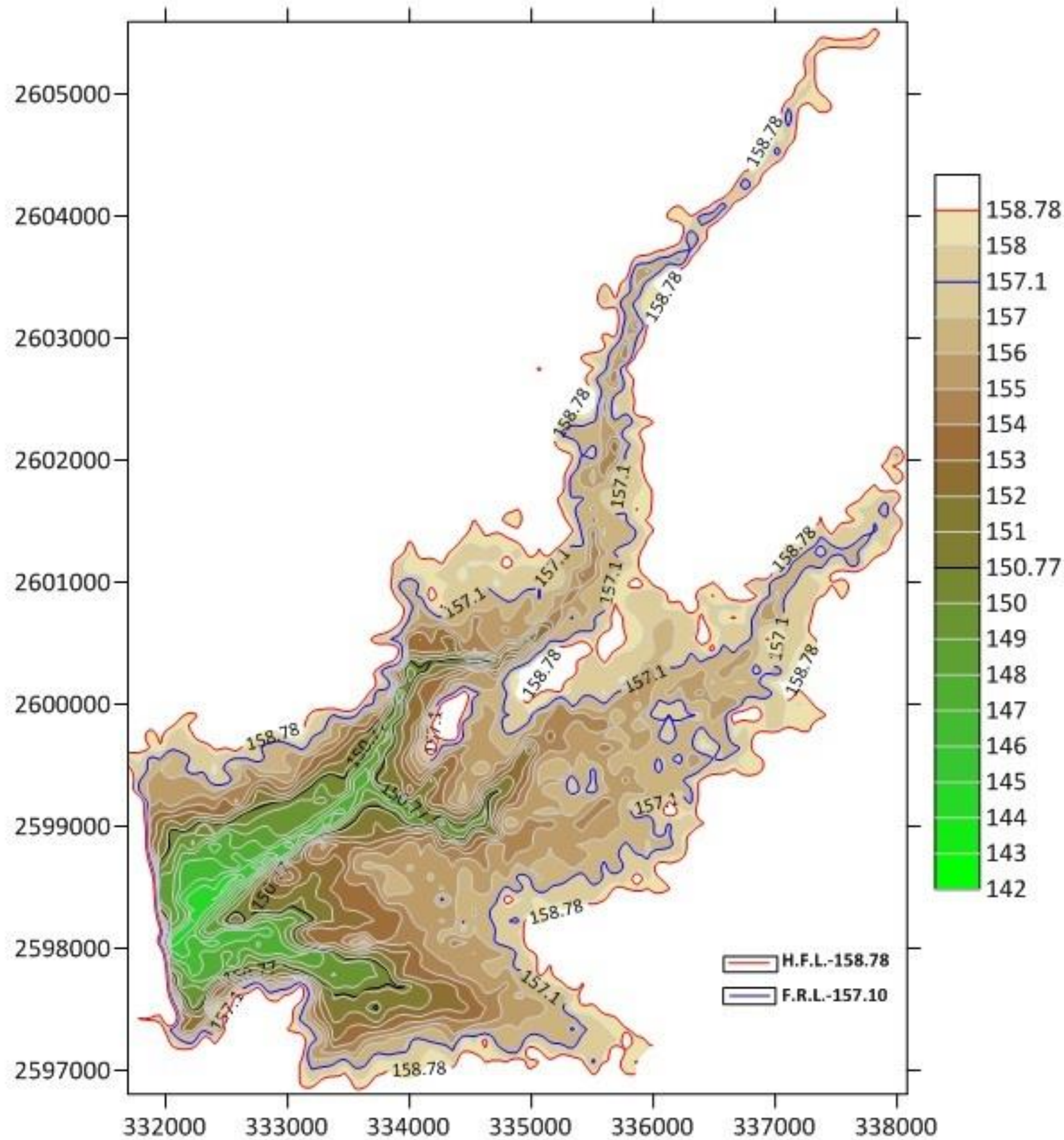


Figure 6.11-2 CONTOUR MAP

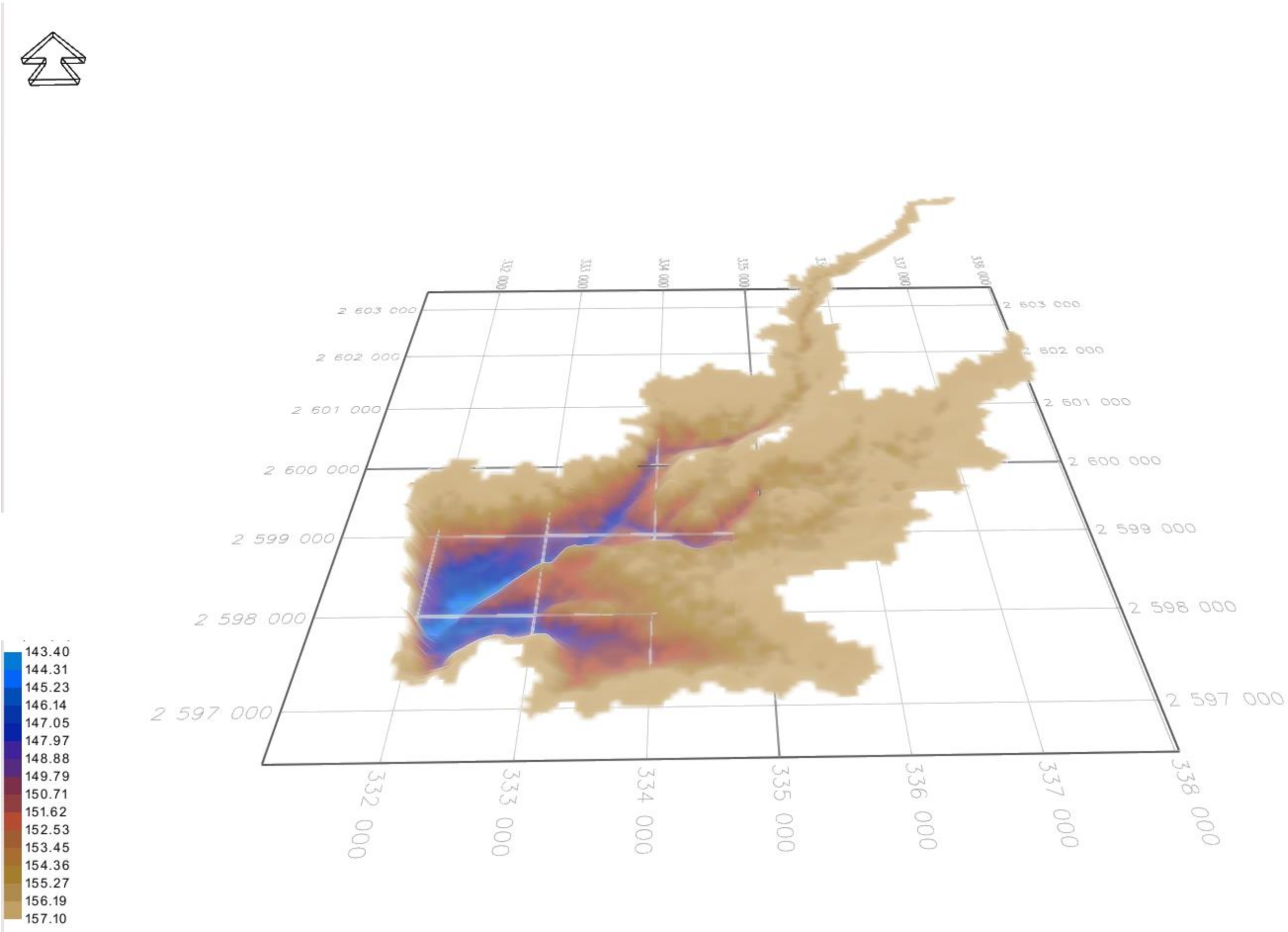


Figure 6.11-3 WIRE FRAME MAP

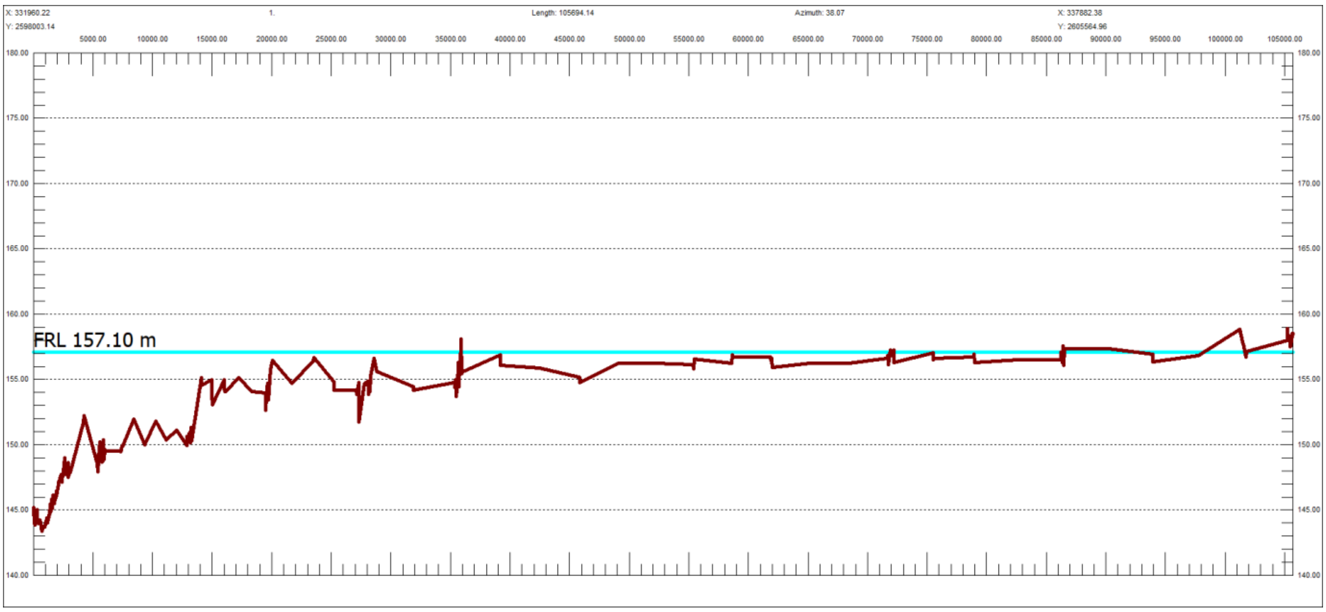
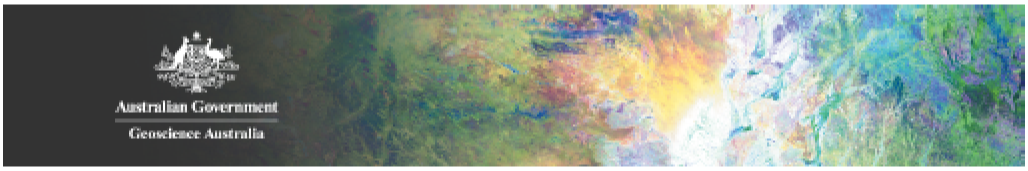


Figure 6.11-4 L SECTION

7 DGPS OBSERVATION REPORT

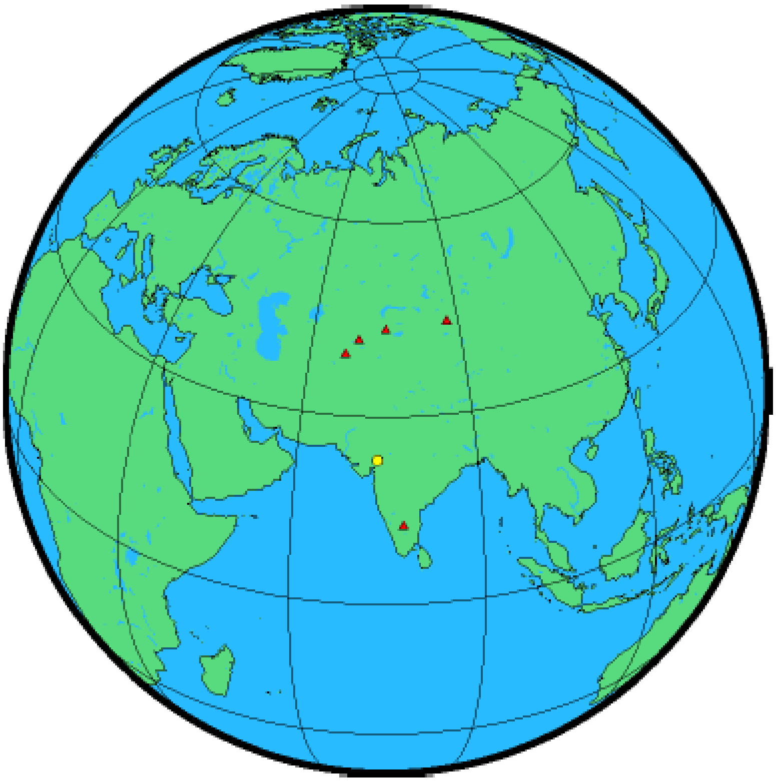


1 User Data

All antenna heights refer to the vertical distance from the Ground Mark to the Antenna Reference Point (ARP).

Station (s)	Submitted File	Antenna Type	Antenna Height (m)	Start Time	End Time
_MAZ	_MAZ_12032021_184608.21O	TIAPENG6 NONE	1.894	2021/03/12 10:46:30	2021/03/12 15:00:00

2 Processing Summary



Date	User Stations	Reference Stations	Orbit Type
2021/03/12 10:46:30	_MAZ	CHUM IISC KIT3 TASH URUM	IGS ultra rapid

Australian Government
Geoscience Australia

3 Computed Coordinates, ITRF2014

All coordinates are based on the IGS realisation of the ITRF2014 reference frame. All the given ITRF2014 coordinates refer to a mean epoch of the site observation data. All coordinates refer to the Ground Mark.

3.1 Cartesian, ITRF2014

Station	X (m)	Y (m)	Z (m)	ITRF2014 @
_MAZ	1676608.856	5607815.578	2525946.171	12/03/2021
CHUM	1228950.354	4508080.003	4327868.545	12/03/2021
IISC	1337935.753	6070317.125	1427877.333	12/03/2021
KIT3	1944944.699	4556652.354	4004326.059	12/03/2021
TASH	1695944.772	4487138.673	4190140.755	12/03/2021
URUM	193030.117	4606851.303	4393311.547	12/03/2021

3.2 Geodetic, GRS80 Ellipsoid, ITRF2014

Geoid-ellipsoidal separations, in this section, are computed using a spherical harmonic synthesis of the global EGM2008 geoid. More information on the EGM2008 geoid can be found at http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/.

Station	Latitude (DMS)	Longitude (DMS)	Ellipsoidal Height(m)	Derived Above Geoid Height(m)
_MAZ	23 28 59.98820	73 21 16.32837	108.593	163.467
CHUM	42 59 54.60575	74 45 03.97448	716.341	759.331
IISC	13 01 16.21555	77 34 13.37612	843.690	929.611
KIT3	39 08 05.16362	66 53 07.62180	622.476	659.573
TASH	41 19 40.97912	69 17 44.05708	439.699	483.269
URUM	43 48 28.61984	87 36 02.42071	858.890	922.269

3.3 UTM Grid, GRS80 Ellipsoid, ITRF2014

Station	East (m)	North (m)	Zone	Ellipsoidal Height (m)	Derived Above Geoid Height(m)
_MAZ	331960.797	2597987.595	43	108.593	163.467
CHUM	479712.402	4760678.453	43	716.341	759.331
IISC	778796.705	1440886.653	43	843.690	929.611
KIT3	317236.776	4333861.159	42	622.476	659.573
TASH	524734.365	4575216.868	42	439.699	483.269
URUM	548313.485	4850717.941	45	858.890	922.269

Australian Government
Geoscience Australia

3.4 Positional Uncertainty (95% C.L.) - Geodetic, ITRF2014

Station	Longitude(East) (m)	Latitude(North) (m)	Ellipsoidal Height(Up) (m)
_MAZ	0.014	0.010	0.029
CHUM	0.009	0.007	0.015
IISC	0.011	0.009	0.018
KIT3	0.010	0.007	0.016
TASH	0.009	0.007	0.015
URUM	0.018	0.010	0.031

4 Ambiguity Resolution - Per Baseline

Baseline	Ambiguities Resolved	Baseline Length (km)
KIT3 - TASH	90.9 %	318.371
_MAZ - TASH	66.7 %	2006.448
CHUM - URUM	47.1 %	1042.674
CHUM - TASH	80.0 %	487.331
IISC - _MAZ	78.6 %	1238.694
AVERAGE	72.7%	1018.704

Please note for a regional solution, such as used by AUSPOS, ambiguity resolution success rate of 50% or better for a baseline formed by a user site indicates a reliable solution.

7 SINGLE BEAM ECHOSOUNDER BARCHECK RESULTS

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title: **Bathymetric Survey**	Vessel: **Inflatable Boat**	Place: **MAZAM**
Date: **21-Feb-21**	Time: **13:50:00**		
Observed By: **PRUTHVIRAAJ MOHILE**		Echosounder Model and SL. No. **Sonarmite**	Area Depth **10**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity Average	Sound Velocity Upto Depth
0.4 m				1500	8

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	0	8	7.99	0.01
4	4	0	6	6	0
6	6	0	4	3.99	0.01
8	8.01	-0.01	2	2	0
	Average	-0.0025		Average	0.0050
	Std. Dev	0.0050		Std. Deviation	0.0058
				Cumulative Average	0.00
				Cumulative Std. Deviation	0.0005

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Approved By: Survey Manager

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title: **Bathymetric Survey**	Vessel: **Inflatable Boat**	Place: **MAZAM DAM**
Date: **22-Feb-21**	Time: **08:50:00**		
Observed By: **PRUTHVIRAAJ MOHILE**		Echosounder Model and SL. No. **Sonarmite**	Area Depth **10**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity Average	Sound Velocity Upto Depth
0.4 m				1500	8

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	8	0
4	4	0	6	6	0
6	5.99	0.01	4	4	0
8	8	0	2	2.02	-0.02
	Average	0.0000		Average	-0.0050
	Std. Dev	0.0082		Std. Deviation	0.0100
				Cumulative Average	0.00
				Cumulative Std. Deviation	0.0013

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Approved By: Survey Manager

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title: **Bathymetric Survey**	Vessel: **Inflatable Boat**	Place: **MAZAM DAM**
Date: **23-Feb-21**	Time: **9:00:00**		
Observed By: **PRUTHVIRAAJ MOHILE**		Echosounder Model and SL. No. **Sonarmite**	Area Depth **8**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	Upto Depth
0				1500	6
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	0	8	8	0
4	4	0	6	5.99	0.01
6	5.99	0.01	4	4	0
	Average	0.0033		Average	0.0033
	Std. Dev	0.0058		Std. Deviation	0.0058
				Cumulative Average	0.00
				Cumulative Std. Deviation	0.0000

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Approved By: Survey Manager

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title:	Vessel:	Place:
	Bathymetric Survey	**Inflatable Boat**	**MAZAM DAM**
Date:	Time:		
24-Feb-21	**8:50:00**		
Observed By:		Echosounder Model and SL. No.	Area Depth
PRUTHVIRAAJ MOHILE		**Sonarmite**	**8**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	**Upto Depth**
0				**1500**	**6**
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	0	8	7.99	0.01
4	4	0	6	6	0
6	5.99	0.01	4	3.99	0.01
	Average	0.0033		Average	0.0067
	Std. Dev	0.0058		Std. Deviation	0.0058
				Cumulative Average	0.00
				Cumulative Std. Deviation	0.0000

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Approved By: Survey Manager

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title: **Bathymetric Survey**		Vessel: **Inflatable Boat**		Place: **MAZAM DAM**
Date: **25-Feb-21**	Time: **9:00:00**				
Observed By: **PRUTHVIRAAJ MOHILE**			Echosounder Model and SL. No. **Sonarmite**		Area Depth **8**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	Upto Depth
0.4 m				1500	6
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	0	8	7.98	0.02
4	4	0	6	6	0
6	5.99	0.01	4	4	0

Average	0.0033	Average	0.0067
Std. Dev	0.0058	Std. Deviation	0.0115
		Cumulative Average	0.00
		Cumulative Std. Deviation	0.0041

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Approved By: Survey Manager

8 PHOTOGRAPHS

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

CONFIGURATION OF SBES EQUIPMENTS

BATHYMETRIC SURVEY PROGRESSING

ISLAND ON MAZAM DAM

SHALLOW DEPTH AREA

BRIDGE MAZAM DAM

INFORMATIONS OF MAZAM DAM

WATER LEVEL GAUGE

HFL Check-Dam of Canal

END OF REPORT