GEOSERVICES
MARITIME PVT. LTD.

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

GMPL REPORT NUMBER: P-SUR-BATHY-009-2020-21-WRD-WATRAK
SURVEY PERIOD: Bathymetry: 10 FEB TO 28 FEB 2021.
Topography: 24 FEB TO 09 MAR 2021

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

LOCATION MAP

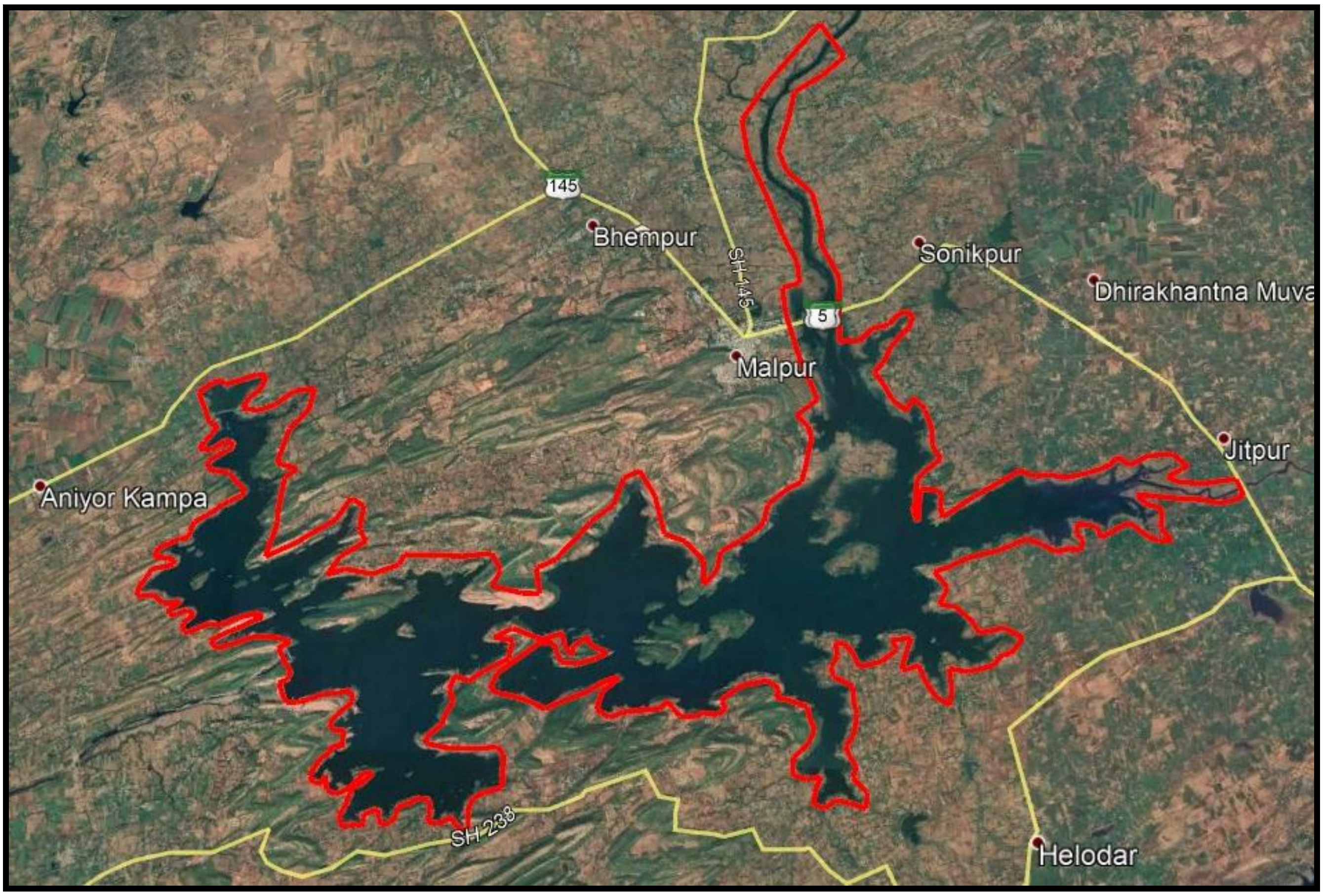

Figure 1.1-1 LOCATION MAP

LOCATION MAP SHOWING SURVEY AREA “WATRAK DAM”, GURAJAT, INDIA

DOCUMENT ARRANGEMENT

REPORT OF SURVEY WITH CHART / DRAWING

CONTENTS

1 INTRODUCTION, OBJECTIVE & SCOPE OF WORK 5
1.1 GENERAL 5
1.1.1 LIST OF ABBREVIATIONS USED 5
1.1.2 Units 6
1.2 OBJECTIVE 6
1.3 SCOPE OF WORK 6
2 SALIENT FEATURES OF WATRAK RESERVOIR 7
3 EXECUTIVE SUMMARY OF RESULTS 8
4 RESOURCES FOR SURVEY WORK 9
4.1 PERSONNEL 9
4.2 DETAILS OF EQUIPMENT USED 9
4.3 SURVEY VESSEL 10
4.3.1 Survey Boat Specifications 10
4.3.2 Survey Boat Offset Diagram 10
5 DETAILED METHODOLOGY OF SURVEY 11
5.1 MOBILISATION 11
5.2 GEODESY 12
5.3 SURVEY WORK AT FIELD 12
5.3.1 Benchmark and Base station setup 12
5.3.2 Topographic and Bathymetric Survey 13
5.4 SURVEY SYSTEMS 14
5.4.1 TRIMBLE DGPS: 14
5.4.2 Single beam Echo sounder 14
5.4.3 HYPACK Software 14
5.4.4 RTK System 15
5.5 DATA ACQUISITION AND QUALITY CONTROL 15
5.5.1 Online Data Quality Control 15
5.5.2 Data Processing 15
5.6 QUALITY ASSURANCE AND HSE PROCEDURES 15
5.7 DEMOBILISATION 16
5.8 SURVEY DATA PROCESSING AND INTERPRETATION METHODS 16
5.8.1 General 16
5.8.2 Navigation and Positioning 16
5.8.3 Bathymetry Data Processing and Analysis 16
5.8.4 Topographic Data Processing and Analysis 17
5.8.5 Preparation of Drawings 17
6 DETAILED TOPOGRAPHIC AND BATHYMETRIC SURVEY RESULTS 19

6.1 GENERAL 19
6.2 CAPACITY AND AREA CALCULATION: 19
6.3 COMPARATIVE STATEMENT OF WATRAK DAM 29
6.4 GROSS STORAGE CAPACITY IN M CU. M OF THE RESERVOIR - YEAR 2021: 30
6.5 LIVE STORAGE CAPACITY IN M CU. M OF THE RESERVOIR - YEAR 2021: 32
6.6 SPREAD AREA IN SQ.KM OF THE RESERVOIR - YEAR 2020: 33
6.7 SEDIMENT ANALYSIS: 35
6.7.1 Observed Rate of Sedimentation 35
6.8 CONCLUSION 37
6.9 METHODS FOR CONTROLLING THE SEDIMENTATION 37
6.9.1 Design of Reservoirs 37
6.9.2 Control of Sediment Inflow 38
6.9.3 Control of Sediment Deposition 39
6.9.4 Removal of Sediment Deposit 41
6.10 AREA – CAPACITY – CURVE OF WATRAK DAM: 43
6.11 SEGMENT, CONTOUR, WIRE FRAME MAP AND L-SECTION: 44

7 DGPS OBSERVATION REPORT 48

8 SINGLE BEAM ECHOSOUNDER BAR CHECK RESULTS 55

9 PHOTOGRAPHS 71

TABLES

TABLE 2-1 SALIENT FEATURES OF RESERVOIR 7
TABLE 4.1-1 LIST OF PERSONNEL 9
TABLE 4.2-1 LIST OF EQUIPMENT USED FOR SURVEY 9
TABLE 3.3-1 SURVEY BOAT SPECIFICATIONS - 'AQUA MARINE' 10
TABLE 5.2-1 GEODETIC PARAMETERS 12
TABLE 5.3-1 BENCH MARK DETAILS 13
TABLE 5.8-1 WATER LEVELS 17
TABLE 5.8-2 LIST OF CHARTS 18
TABLE 5.3-1 CAPACITY AND AREA 28
TABLE 5.5-1 COMPARATIVE STATEMENT OF WATRAK DAM 29
TABLE 6.4-1 GROSS STORAGE CAPACITY IN M CU. M YEAR -2021 31
TABLE 6.4-1 LIVE STORAGE CAPACITY IN M CU. M YEAR -2021 32
TABLE 5.7-1 SPREAD AREA IN SQ. KM YEAR -2021 34
TABLE 5.4-1 RATE OF SEDIMENTATION 36

FIGURES

FIGURE 1.1-1 LOCATION MAP 2
FIGURE 3.3-1 SURVEY BOAT ' AQUA MARINE' OFFSET DIAGRAM 10
FIGURE 5.1-1 SBES SURVEY EQUIPMENT CONFIGURATION DIAGRAM ON BOARD 11
FIGURE 5.3-1 OBS VAT 13
FIGURE 6.10-1 AREA – CAPACITY - CURVE 43
FIGURE 6.11-1 SEGMENT MAP FOR CROSS SECTION 44
FIGURE 6.11-2 CONTOUR MAP 45
FIGURE 6.11-3 WIRE FRAME MAP 46
FIGURE 6.11-4 L-SECTION 47

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 Watrak 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 Watrak 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 Watrak Dam.

The detailed scope of work was:

i) To measure the water depth of the Watrak 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 WATRAK RESERVOIR

WATRAK RESERVOIR PROJECT		
I	**LOCATION**	
	Coordinates	Latitude 23°19'14"N Longitude 73°24'24"E
	River	Watrak
	Village	Pahadia
	Taluka	Malpur
	District	Sabarkantha
	State	Gujarat
	Nearest Railway Station	Modasa Railway Station
	Purpose	Irrigation
II	**HYDROLOGY**	
	Catchment Area	1114 Sq. Km
	Mean Annual Rainfall	827 mm
III	**DAM**	
	Dam Type	Composite
	Length of the top of the dam	313 m
IV	**RESERVOIR**	
	MDDL	126.39 m
	FRL	136.25 m
	HFL/MWL	140.49 m
	Gross Storage Capacity at F.R.L.	176.20 M Cu. m
	Dead Storage Capacity	23.41 M Cu. m
	Live Storage Capacity	152.79 M Cu. m
	Area at FRL	44.75 Sq. km
V	**SPILLWAY**	
	Type	Ogee
	Length of Spillway	89 m
	Maximum Discharge	5669 m^3/s
	Type, Nos. and Size of Gates	Radial, 6, (12.5 m x 8.23 m)
VII	**CANAL**	
	Length of canal	26.91 km
	Capacity	[10.19 (Left), 2.20 (Right)] m3/s
	Gross command area	25,914 ha
	Culturable command area	22,977 ha

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 Watrak 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.

Trimble DGPS system, Sonarmite Echo sounder (215 kHz) were utilised to acquire the bathymetric data within the Watrak Dam 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 / 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 Watrak Dam area.

Four (4) hours of DGPS observation was carried out at OBS VAT, which was on the top of Dam, near spill way. Nine (9) Temporary Bench Marks were established to cover whole area.

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

- The Minimum elevation within Watrak Dam is 111.72 m above MSL and
- The Maximum depth within Watrak Dam is 21.4 m.
- Area covered by bathymetric survey is 17.58 Sq. Km
- Area covered by topographic survey is 42.707 Sq. Km

According to recent survey, total area of reservoir at FRL 136.25 m is 31.563 Sq. Km, corresponding storage capacity is 168.493 M Cu. m, and Dead storage at 126.39 m is 21.931 M Cu. m.

The comparison between 1984 and 2021(37 years) data results in a rate of siltation (silt index) of 1.87 Ham/100 Sq. Km/year. Annual percentage loss of gross storage capacity, live storage capacity and dead storage capacity is 0.12%, 0.11% and 0.17 % respectively for FRL 136.25 m.

The comparison of 1999 and 2021 data with respect to 1984 impounding data at FRL 136.25 m results in silt index of 10.77 Ham/100 Sq. Km/year and 1.87 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
Samraj Dwivedi	Survey Engineer
Ashish Patil	Survey Engineer
Abhijith Cherapi	Surveyor
Jomon	Surveyor
Abhijith K	Land Surveyor
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 Watrak Dam. 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 351 DGPS
Single Beam Echo Sounder	Sonarmite 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 '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.

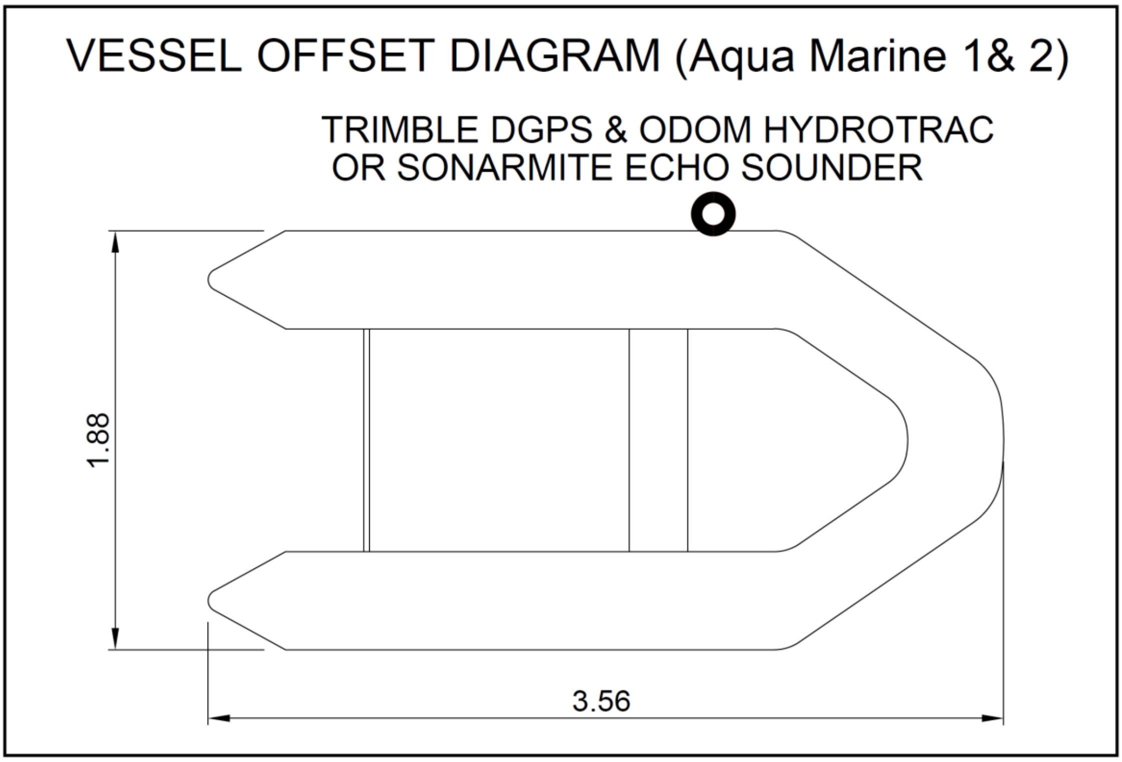

Figure 4.3-1 SURVEY BOAT ' AQUA MARINE' OFFSET DIAGRAM

5 DETAILED METHODOLOGY OF SURVEY

5.1 Mobilisation

The bathymetric survey equipment were mobilised on board “Aqua Marine” on 10 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.

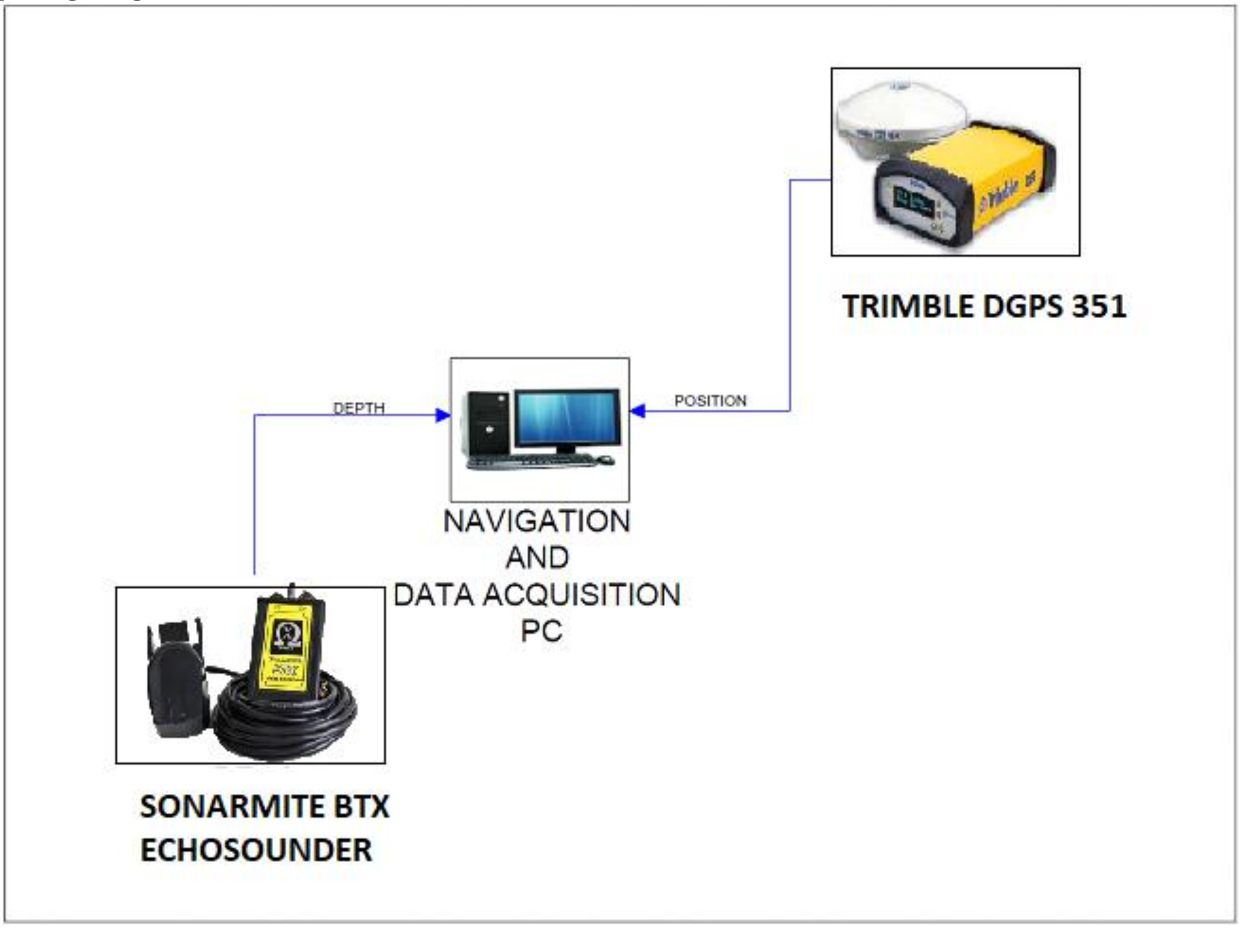

Figure 5.1-1 SBES SURVEY EQUIPMENT CONFIGURATION DIAGRAM ON BOARD

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 Hours at Dam top near spill way. Nine Temporary Bench Marks were established.
The details of Bench Marks are presented in the table below:

BM Observation and T.BM. Information _ Watrak Dam South Gujarat					
Location	**Latitude (N)**	**Longitude (E)**	**Easting (m)**	**Northing (m)**	**Elevation (m) W.r.t MSL**
OBS VAT	23°19'5.348"	073°24'21.953"	337025.308	2579637.320	145.000
T.B.M.01	23°21'4.893"	073°23'53.125"	336247.108	2583323.502	154.148
T.B.M.02	23°17'43.658"	073°25'26.845"	338841.378	2577104.409	149.738
T.B.M.03	23°18'14.736"	073°26'43.645"	341033.684	2578036.759	158.932
T.B.M.04	23°21'54.244"	073°28'15.239"	343707.251	2584760.857	153.285
T.B.M.05	23°21'57.174"	073°28'37.548"	344341.713	2584844.285	142.395

T.B.M.06	23 21'5.170"	073°28'23.109"	343914.794	2583249.026	142.313
T.B.M.07	23 23'40.639"	073°27'24.475"	342300.706	2588048.793	146.976
T.B.M.08	23 20'38.902"	073°32'8.789"	350315.807	2582374.740	143.939
T.B.M.T	23 20'38.955"	073°32'8.757"	350314.933	2582376.369	144.767

Table 5.3-1 BENCH MARK DETAILS

Figure 5.3-1 OBS VAT

5.3.2 Topographic and Bathymetric Survey

For topographic survey, Pentax RTK base was used for DGPS observation on top of dam. Four Hrs. of DGPS observation was carried out. Dam authority provided benchmark elevation value of 145 m. RTK DGPS Base station was set up at OBS VAT made by GMPL and configured to transmit the correction. Two rovers receiving RTK corrections from the base took spot level from water level to HFL.

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

5.4 Survey Systems

5.4.1 TRIMBLE DGPS:

TRIMBLE 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 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 Echosounder' 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 the OBS VAT 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 145 m 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 Watrak Dam with due, consent from Client Representative, the survey equipment on board were demobilised on 28 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)
10/02/2021	0700	133.39
	1900	133.39
11/02/2021	0700	133.36
	1900	133.36
12/02/2021	0700	133.33
	1900	133.33
13/02/2021	0700	133.30
	1900	133.30
14/02/2021	0700	133.25
	1900	133.25
16/02/2021	0700	133.18
	1900	133.18

Date	Time	Water Level (meters)
18/02/2021	0700	133.20
	1900	133.20
19/02/2021	0700	133.08
	1900	133.08
20/02/2021	0700	133.05
	1900	133.05
21/02/2021	0700	133.05
	1900	133.05
22/02/2021	0700	133.04
	1900	133.04
23/02/2021	0700	133.00
	1900	133.00
24/02/2021	0700	132.99
	1900	132.99
25/02/2021	0700	132.96
	1900	132.96
26/02/2021	0700	132.93
	1900	132.93
27/02/2021	0700	132.90
	1900	132.90

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 Watrak 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-Watrak-Bathy-01	Bathymetry chart part 01	1:5000	PDF & CAD
2	P-SUR-009-Watrak-Bathy-02	Bathymetry chart part 02	1:5000	PDF & CAD
3	P-SUR-009-Watrak-Bathy-03	Bathymetry chart part 03	1:5000	PDF & CAD
4	P-SUR-009-Watrak-Bathy-04	Bathymetry chart part 04	1:5000	PDF & CAD
5	P-SUR-009-Watrak-Bathy-05	Bathymetry chart part 05	1:5000	PDF & CAD
6	P-SUR-009-Watrak-Bathy-06	Bathymetry chart part 06	1:5000	PDF & CAD
7	P-SUR-009-Watrak-Bathy-07	Bathymetry chart part 07	1:5000	PDF & CAD

8	P-SUR-009-Watrak-Bathy-08	Bathymetry chart part 08	1:5000	PDF & CAD
9	P-SUR-009-Watrak-Bathy-09	Bathymetry chart part 09	1:5000	PDF & CAD
10	P-SUR-009-Watrak-Bathy-10	Bathymetry chart part 10	1:5000	PDF & CAD
11	P-SUR-009-Watrak-Contour-01	Contour chart	1:21000	PDF & CAD
12	P-SUR-009-Watrak-Overview-01	Overview Map of Reservoir	Paper size A3	PDF & CAD
13	Area Capacity Curve Watrak - 2021	Area Capacity curve of Reservoir	Paper size A3	PDF & CAD
14	Watrak Cross Sections	162 Cross Section at 100 m interval	Only soft copy	CAD
15	Watrak L-Section	L-Section of Reservoir	Paper size A3	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 Watrak Dam.
The values depicted in the charts are the depths with respect to MSL.

- The Minimum elevation within Watrak Dam is 111.72 m above MSL and
- The Maximum depth within Watrak Dam is 21.4 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
111.70	0.000	0.000	0.000	0.000	0.000	
111.80	0.000	0.000	0.000	0.000	0.000	
111.90	0.000	0.000	0.000	0.000	0.000	
112.00	0.000	0.000	0.000	0.000	0.000	
112.10	0.000	0.000	0.000	0.000	0.000	
112.20	0.000	0.000	0.000	0.000	0.000	
112.30	0.000	0.000	0.000	0.000	0.000	
112.40	0.000	0.000	0.000	0.000	0.000	
112.50	0.000	0.000	0.000	0.000	0.000	
112.60	0.000	0.000	0.000	0.000	0.001	
112.70	0.000	0.000	0.000	0.000	0.001	
112.80	0.000	0.000	0.000	0.000	0.001	
112.90	0.000	0.000	0.000	0.000	0.001	
113.00	0.000	0.000	0.000	0.000	0.001	
113.10	0.001	0.000	0.001	0.001	0.002	

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
113.20	0.001	0.000	0.001	0.001	0.002	
113.30	0.001	0.000	0.001	0.001	0.003	
113.40	0.001	0.000	0.001	0.001	0.005	
113.50	0.002	0.000	0.002	0.002	0.008	
113.60	0.003	0.000	0.003	0.003	0.012	
113.70	0.004	0.000	0.004	0.004	0.016	
113.80	0.006	0.000	0.006	0.006	0.020	
113.90	0.009	0.000	0.009	0.009	0.025	
114.00	0.011	0.000	0.011	0.011	0.031	
114.10	0.015	0.000	0.015	0.015	0.036	
114.20	0.019	0.000	0.019	0.019	0.043	
114.30	0.023	0.000	0.023	0.023	0.050	
114.40	0.029	0.000	0.029	0.029	0.058	
114.50	0.035	0.000	0.035	0.035	0.067	
114.60	0.042	0.000	0.042	0.042	0.075	
114.70	0.050	0.000	0.050	0.050	0.084	
114.80	0.059	0.000	0.059	0.059	0.093	
114.90	0.069	0.000	0.069	0.069	0.103	
115.00	0.080	0.000	0.080	0.080	0.114	
115.10	0.091	0.000	0.091	0.091	0.126	
115.20	0.105	0.000	0.105	0.105	0.138	
115.30	0.119	0.000	0.119	0.119	0.151	
115.40	0.135	0.000	0.135	0.135	0.166	
115.50	0.152	0.000	0.152	0.152	0.183	
115.60	0.172	0.000	0.172	0.172	0.200	
115.70	0.192	0.000	0.192	0.192	0.217	
115.80	0.215	0.000	0.215	0.215	0.234	
115.90	0.239	0.000	0.239	0.239	0.252	
116.00	0.265	0.000	0.265	0.265	0.271	
116.10	0.294	0.000	0.294	0.294	0.291	
116.20	0.324	0.000	0.324	0.324	0.311	
116.30	0.356	0.000	0.356	0.356	0.332	
116.40	0.390	0.000	0.390	0.390	0.353	
116.50	0.426	0.000	0.426	0.426	0.375	

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
116.60	0.465	0.000	0.465	0.465	0.395	
116.70	0.506	0.000	0.506	0.506	0.417	
116.80	0.548	0.000	0.548	0.548	0.440	
116.90	0.594	0.000	0.594	0.594	0.464	
117.00	0.641	0.000	0.641	0.641	0.487	
117.10	0.691	0.000	0.691	0.691	0.512	
117.20	0.744	0.000	0.744	0.744	0.537	
117.30	0.799	0.000	0.799	0.799	0.563	
117.40	0.856	0.000	0.856	0.856	0.588	
117.50	0.916	0.000	0.916	0.916	0.613	
117.60	0.979	0.000	0.979	0.979	0.639	
117.70	1.044	0.000	1.044	1.044	0.665	
117.80	1.112	0.000	1.112	1.112	0.687	
117.90	1.181	0.000	1.181	1.181	0.710	
118.00	1.254	0.000	1.254	1.254	0.734	
118.10	1.328	0.000	1.328	1.328	0.756	
118.20	1.405	0.000	1.405	1.405	0.778	
118.30	1.484	0.000	1.484	1.484	0.801	
118.40	1.565	0.000	1.565	1.565	0.824	
118.50	1.649	0.000	1.649	1.649	0.848	
118.60	1.735	0.000	1.735	1.735	0.872	
118.70	1.823	0.000	1.823	1.823	0.896	
118.80	1.914	0.000	1.914	1.914	0.921	
118.90	2.007	0.000	2.007	2.007	0.947	
119.00	2.103	0.000	2.103	2.103	0.974	
119.10	2.202	0.000	2.202	2.202	1.001	
119.20	2.304	0.000	2.304	2.303	1.031	
119.30	2.408	0.000	2.408	2.408	1.062	
119.40	2.516	0.000	2.516	2.516	1.095	
119.50	2.627	0.000	2.627	2.627	1.128	
119.60	2.741	0.000	2.741	2.741	1.161	
119.70	2.859	0.000	2.859	2.859	1.196	
119.80	2.981	0.000	2.981	2.981	1.233	
119.90	3.106	0.000	3.106	3.106	1.270	

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
120.00	3.235	0.000	3.235	3.235	1.309	
120.10	3.368	0.000	3.368	3.368	1.351	
120.20	3.505	0.000	3.505	3.505	1.391	
120.30	3.646	0.000	3.646	3.646	1.432	
120.40	3.791	0.000	3.791	3.791	1.472	
120.50	3.940	0.000	3.940	3.940	1.513	
120.60	4.094	0.000	4.094	4.094	1.557	
120.70	4.252	0.000	4.252	4.252	1.603	
120.80	4.415	0.000	4.415	4.415	1.650	
120.90	4.582	0.000	4.582	4.582	1.696	
121.00	4.754	0.000	4.754	4.754	1.740	
121.10	4.930	0.000	4.930	4.930	1.785	
121.20	5.111	0.000	5.111	5.111	1.830	
121.30	5.296	0.000	5.296	5.296	1.874	
121.40	5.486	0.000	5.486	5.485	1.918	
121.50	5.679	0.000	5.679	5.679	1.962	
121.60	5.878	0.000	5.878	5.878	2.007	
121.70	6.081	0.000	6.081	6.081	2.052	
121.80	6.288	0.000	6.288	6.288	2.098	
121.90	6.501	0.000	6.501	6.501	2.146	
122.00	6.718	0.000	6.718	6.718	2.194	
122.10	6.940	0.000	6.940	6.940	2.244	
122.20	7.167	0.000	7.167	7.166	2.294	
122.30	7.398	0.000	7.398	7.398	2.340	
122.40	7.634	0.000	7.634	7.634	2.383	
122.50	7.875	0.000	7.875	7.875	2.426	
122.60	8.120	0.000	8.120	8.120	2.470	
122.70	8.369	0.000	8.369	8.369	2.515	
122.80	8.623	0.000	8.623	8.623	2.561	
122.90	8.881	0.000	8.881	8.881	2.608	
123.00	9.144	0.000	9.144	9.144	2.656	
123.10	9.412	0.000	9.412	9.412	2.705	
123.20	9.685	0.000	9.685	9.685	2.757	
123.30	9.964	0.000	9.964	9.964	2.811	

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
123.40	10.248	0.000	10.248	10.248	2.868	
123.50	10.537	0.000	10.537	10.537	2.926	
123.60	10.833	0.000	10.833	10.833	2.986	
123.70	11.135	0.000	11.135	11.135	3.048	
123.80	11.443	0.000	11.443	11.443	3.114	
123.90	11.757	0.000	11.757	11.757	3.178	
124.00	12.078	0.000	12.078	12.078	3.241	
124.10	12.406	0.000	12.406	12.406	3.306	
124.20	12.740	0.000	12.740	12.740	3.374	
124.30	13.080	0.000	13.080	13.080	3.443	
124.40	13.428	0.000	13.428	13.428	3.512	
124.50	13.783	0.000	13.783	13.783	3.582	
124.60	14.145	0.000	14.145	14.145	3.654	
124.70	14.514	0.000	14.514	14.514	3.725	
124.80	14.890	0.000	14.890	14.890	3.797	
124.90	15.273	0.000	15.273	15.273	3.868	
125.00	15.663	0.000	15.663	15.663	3.941	
125.10	16.061	0.000	16.061	16.061	4.016	
125.20	16.467	0.000	16.467	16.466	4.090	
125.30	16.879	0.000	16.879	16.879	4.165	
125.40	17.300	0.000	17.300	17.300	4.243	
125.50	17.728	0.000	17.728	17.728	4.323	
125.60	18.164	0.000	18.164	18.164	4.408	
125.70	18.610	0.000	18.610	18.610	4.494	
125.80	19.063	0.000	19.063	19.063	4.582	
125.90	19.526	0.000	19.526	19.526	4.672	
126.00	19.998	0.000	19.998	19.998	4.764	
126.10	20.479	0.000	20.479	20.479	4.860	
126.20	20.970	0.000	20.970	20.970	4.961	
126.30	21.471	0.000	21.471	21.471	5.062	
126.39	**21.931**	**0.000**	**21.931**	**21.931**	**5.154**	**MDDL**
126.40	21.931	0.051	21.982	21.982	5.164	
126.50	21.931	0.573	22.504	22.504	5.267	
126.60	21.931	1.105	23.036	23.036	5.374	

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
126.70	21.931	1.648	23.579	23.579	5.488	
126.80	21.931	2.203	24.134	24.134	5.605	
126.90	21.931	2.769	24.700	24.700	5.723	
127.00	21.931	3.347	25.278	25.278	5.842	
127.10	21.931	3.938	25.869	25.869	5.968	
127.20	21.931	4.541	26.472	26.472	6.104	
127.30	21.931	5.158	27.089	27.089	6.233	
127.40	21.931	5.788	27.719	27.719	6.363	
127.50	21.931	6.431	28.362	28.362	6.498	
127.60	21.931	7.087	29.018	29.019	6.636	
127.70	21.931	7.758	29.689	29.690	6.781	
127.80	21.931	8.443	30.374	30.375	6.924	
127.90	21.931	9.143	31.074	31.074	7.067	
128.00	21.931	9.857	31.788	31.788	7.210	
128.10	21.931	10.585	32.516	32.517	7.360	
128.20	21.931	11.329	33.260	33.261	7.516	
128.30	21.931	12.089	34.020	34.020	7.674	
128.40	21.931	12.864	34.795	34.796	7.836	
128.50	21.931	13.656	35.587	35.587	8.001	
128.60	21.931	14.464	36.395	36.396	8.172	
128.70	21.931	15.290	37.221	37.222	8.349	
128.80	21.931	16.134	38.065	38.066	8.532	
128.90	21.931	16.997	38.928	38.929	8.723	
129.00	21.931	17.879	39.810	39.810	8.912	
129.10	21.931	18.780	40.711	40.711	9.103	
129.20	21.931	19.700	41.631	41.631	9.298	
129.30	21.931	20.639	42.570	42.571	9.496	
129.40	21.931	21.599	43.530	43.530	9.687	
129.50	21.931	22.577	44.508	44.509	9.883	
129.60	21.931	23.575	45.506	45.507	10.075	
129.70	21.931	24.592	46.523	46.523	10.263	
129.80	21.931	25.628	47.559	47.559	10.451	
129.90	21.931	26.682	48.613	48.614	10.642	
130.00	21.931	27.756	49.687	49.688	10.835	

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
130.10	21.931	28.849	50.780	50.781	11.026	
130.20	21.931	29.961	51.892	51.893	11.223	
130.30	21.931	31.093	53.024	53.025	11.413	
130.40	21.931	32.244	54.175	54.175	11.597	
130.50	21.931	33.413	55.344	55.344	11.776	
130.60	21.931	34.599	56.530	56.531	11.959	
130.70	21.931	35.804	57.735	57.736	12.146	
130.80	21.931	37.029	58.960	58.960	12.335	
130.90	21.931	38.272	60.203	60.203	12.524	
131.00	21.931	39.533	61.464	61.465	12.707	
131.10	21.931	40.813	62.744	62.744	12.892	
131.20	21.931	42.112	64.043	64.043	13.081	
131.30	21.931	43.429	65.360	65.361	13.274	
131.40	21.931	44.767	66.698	66.699	13.484	
131.50	21.931	46.126	68.057	68.057	13.683	
131.60	21.931	47.503	69.434	69.435	13.873	
131.70	21.931	48.900	70.831	70.832	14.062	
131.80	21.931	50.316	72.247	72.247	14.247	
131.90	21.931	51.750	73.681	73.681	14.435	
132.00	21.931	53.203	75.134	75.134	14.630	
132.10	21.931	54.679	76.610	76.610	14.886	
132.20	21.931	56.179	78.110	78.110	15.110	
132.30	21.931	57.701	79.632	79.632	15.333	
132.40	21.931	59.245	81.176	81.176	15.557	
132.50	21.931	60.813	82.744	82.744	15.789	
132.60	21.931	62.404	84.335	84.335	16.032	
132.70	21.931	64.020	85.951	85.951	16.298	
132.80	21.931	65.668	87.599	87.600	16.678	
132.90	21.931	67.351	89.282	89.283	16.990	
133.00	21.931	69.065	90.996	90.997	17.285	
133.10	21.931	70.808	92.739	92.740	17.580	
133.20	21.931	72.581	94.512	94.513	17.879	
133.30	21.931	74.385	96.316	96.317	18.190	
133.40	21.931	76.220	98.151	98.152	18.518	

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
133.50	21.931	78.091	100.022	100.027	18.979	
133.60	21.931	80.010	101.941	101.945	19.380	
133.70	21.931	81.966	103.897	103.901	19.749	
133.80	21.931	83.959	105.890	105.894	20.112	
133.90	21.931	85.989	107.920	107.923	20.474	
134.00	21.931	88.054	109.985	109.989	20.840	
134.10	21.931	90.157	112.088	112.092	21.218	
134.20	21.931	92.299	114.230	114.235	21.653	
134.30	21.931	94.498	116.429	116.431	22.211	
134.40	21.931	96.740	118.671	118.673	22.627	
134.50	21.931	99.023	120.954	120.956	23.032	
134.60	21.931	101.347	123.278	123.280	23.433	
134.70	21.931	103.710	125.641	125.643	23.836	
134.80	21.931	106.114	128.045	128.047	24.254	
134.90	21.931	108.562	130.493	130.495	24.706	
135.00	21.931	111.067	132.998	132.998	25.345	
135.10	21.931	113.625	135.556	135.556	25.812	
135.20	21.931	116.229	138.160	138.160	26.269	
135.30	21.931	118.879	140.810	140.809	26.720	
135.40	21.931	121.573	143.504	143.504	27.176	
135.50	21.931	124.314	146.245	146.245	27.645	
135.60	21.931	127.103	149.034	149.034	28.147	
135.70	21.931	129.951	151.882	151.883	28.819	
135.80	21.931	132.860	154.791	154.790	29.338	
135.90	21.931	135.819	157.750	157.749	29.837	
136.00	21.931	138.827	160.758	160.757	30.327	
136.10	21.931	141.884	163.815	163.814	30.816	
136.20	21.931	144.990	166.921	166.921	31.313	
136.25	**21.931**	**146.562**	**168.493**	**168.493**	**31.563**	**FRL**
136.30	21.931	148.147	170.078	170.077	31.816	
136.40	21.931	151.358	173.289	173.292	32.490	
136.50	21.931	154.636	176.567	176.570	33.066	
136.60	21.931	157.970	179.901	179.904	33.602	
136.70	21.931	161.356	183.287	183.290	34.128	

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
136.80	21.931	164.795	186.726	186.729	34.651	
136.90	21.931	168.287	190.218	190.221	35.180	
137.00	21.931	171.831	193.762	193.766	35.721	
137.10	21.931	175.433	197.364	197.368	36.327	
137.20	21.931	179.111	201.042	201.039	37.090	
137.30	21.931	182.849	204.780	204.776	37.663	
137.40	21.931	186.643	208.574	208.571	38.220	
137.50	21.931	190.493	212.424	212.420	38.777	
137.60	21.931	194.399	216.330	216.326	39.343	
137.70	21.931	198.362	220.293	220.290	39.929	
137.80	21.931	202.386	224.317	224.315	40.563	
137.90	21.931	206.491	228.422	228.414	41.433	
138.00	21.931	210.667	232.598	232.590	42.085	
138.10	21.931	214.907	236.838	236.830	42.713	
138.20	21.931	219.210	241.141	241.133	43.341	
138.30	21.931	223.576	245.507	245.498	43.977	
138.40	21.931	228.006	249.937	249.929	44.633	
138.50	21.931	232.503	254.434	254.427	45.327	
138.60	21.931	237.084	259.015	259.007	46.286	
138.70	21.931	241.749	263.680	263.672	47.012	
138.80	21.931	246.485	268.416	268.408	47.705	
138.90	21.931	251.290	273.221	273.213	48.389	
139.00	21.931	256.163	278.094	278.085	49.068	
139.10	21.931	261.104	283.035	283.027	49.759	
139.20	21.931	266.116	288.047	288.039	50.490	
139.30	21.931	271.212	293.143	293.134	51.552	
139.40	21.931	276.407	298.338	298.329	52.326	
139.50	21.931	281.675	303.606	303.597	53.037	
139.60	21.931	287.013	308.944	308.934	53.719	
139.70	21.931	292.418	314.349	314.339	54.379	
139.80	21.931	297.889	319.820	319.810	55.030	
139.90	21.931	303.424	325.355	325.345	55.680	
140.00	21.931	309.025	330.956	330.946	56.334	
140.10	21.931	314.692	336.623	336.613	57.012	

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
140.20	21.931	320.429	342.360	342.351	57.757	
140.30	21.931	326.246	348.177	348.169	58.595	
140.40	21.931	332.150	354.081	354.072	59.484	
140.49	**21.931**	**337.540**	**359.471**	**359.462**	**60.287**	**HFL**

Table 6.2-1 Capacity and Area

6.3 Comparative Statement of Watrak Dam

Elevation (m)	As per 1999 Survey		AS per 2021 survey		Remarks
	Area (Sq. Km)	Gross Storage capacity (M Cu. M)	Area (Sq. Km)	Gross Storage capacity (M Cu. M)	
126.39	**4.440**	**23.413**	**5.154**	**21.931**	**MDDL**
127.00	5.140	26.333	5.842	25.278	
128.00	6.480	32.133	7.210	31.788	
129.00	8.060	39.383	8.912	39.810	
130.00	9.885	48.353	10.835	49.687	
131.00	11.946	59.263	12.707	61.464	
132.00	14.262	72.373	14.630	75.134	
133.00	16.817	87.913	17.285	90.996	
134.00	19.638	106.133	20.840	109.985	
135.00	22.688	127.283	25.345	132.998	
136.00	25.976	151.593	30.327	160.758	
136.25	**26.836**	**158.203**	**31.563**	**168.493**	**FRL**

Table 6.3-1 COMPARATIVE STATEMENT OF WATRAK DAM

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

RL (m)	0	0.1	0.2	0.25	0.3	0.39	0.4	0.49	0.5	0.6	0.7	0.8	0.9
111											0.000	0.000	0.000
112	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.004	0.006	0.009
114	0.011	0.015	0.019	0.021	0.023	0.028	0.029	0.034	0.035	0.042	0.050	0.059	0.069
115	0.080	0.091	0.105	0.112	0.119	0.133	0.135	0.151	0.152	0.172	0.192	0.215	0.239
116	0.265	0.294	0.324	0.339	0.356	0.387	0.390	0.423	0.426	0.465	0.506	0.548	0.594
117	0.641	0.691	0.744	0.771	0.799	0.850	0.856	0.910	0.916	0.979	1.044	1.112	1.181
118	1.254	1.328	1.405	1.444	1.484	1.557	1.565	1.640	1.649	1.735	1.823	1.914	2.007
119	2.103	2.202	2.304	2.355	2.408	2.505	2.516	2.616	2.627	2.741	2.859	2.981	3.106
120	3.235	3.368	3.505	3.575	3.646	3.777	3.791	3.925	3.940	4.094	4.252	4.415	4.582
121	4.754	4.930	5.111	5.203	5.296	5.466	5.486	5.660	5.679	5.878	6.081	6.288	6.501
122	6.718	6.940	7.167	7.282	7.398	7.611	7.634	7.851	7.875	8.120	8.369	8.623	8.881
123	9.144	9.412	9.685	9.824	9.964	10.219	10.248	10.508	10.537	10.833	11.135	11.443	11.757
124	12.078	12.406	12.740	12.909	13.080	13.393	13.428	13.747	13.783	14.145	14.514	14.890	15.273
125	15.663	16.061	16.467	16.672	16.879	17.257	17.300	17.685	17.728	18.164	18.610	19.063	19.526
126	19.998	20.479	20.970	21.219	21.471	**21.931**	21.982	22.451	22.504	23.036	23.579	24.134	24.700
127	25.278	25.869	26.472	26.779	27.089	27.655	27.719	28.297	28.362	29.018	29.689	30.374	31.074
128	31.788	32.516	33.260	33.638	34.020	34.717	34.795	35.507	35.587	36.395	37.221	38.065	38.928
129	39.810	40.711	41.631	42.098	42.570	43.433	43.530	44.409	44.508	45.506	46.523	47.559	48.613
130	49.687	50.780	51.892	52.456	53.024	54.059	54.175	55.226	55.344	56.530	57.735	58.960	60.203
131	61.464	62.744	64.043	64.699	65.360	66.564	66.698	67.920	68.057	69.434	70.831	72.247	73.681
132	75.134	76.610	78.110	78.868	79.632	81.021	81.176	82.586	82.744	84.335	85.951	87.599	89.282

RL (m)	0	0.1	0.2	0.25	0.3	0.39	0.4	0.49	0.5	0.6	0.7	0.8	0.9
133	90.996	92.739	94.512	95.410	96.316	97.966	98.151	99.833	100.022	101.941	103.897	105.890	107.920
134	109.985	112.088	114.230	115.324	116.429	118.445	118.671	120.724	120.954	123.278	125.641	128.045	130.493
135	132.998	135.556	138.160	139.479	140.810	143.233	143.504	145.969	146.245	149.034	151.882	154.791	157.750
136	160.758	163.815	166.921	**168.493**	170.078	172.964	173.289	176.237	176.567	179.901	183.287	186.726	190.218
137	193.762	197.364	201.042	202.904	204.780	208.192	208.574	212.036	212.424	216.330	220.293	224.317	228.422
138	232.598	236.838	241.141	243.316	245.507	249.491	249.937	253.982	254.434	259.015	263.680	268.416	273.221
139	278.094	283.035	288.047	290.581	293.143	297.815	298.338	303.076	303.606	308.944	314.349	319.820	325.355
140	330.956	336.623	342.360	345.258	348.177	353.487	354.081	**359.471**					

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

Note: Gross storage capacity for FRL at 136.25 m is 168.493 M Cu. m, dead storage at 126.39 00 m is 21.931 M Cu. m and HFL at 140.49 m is 359.471 M Cu. m.

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

RL (m)	0	0.1	0.2	0.25	0.3	0.39	0.4	0.49	0.5	0.6	0.7	0.8	0.9
126	0.000	0.000	0.000	0.000	0.000	0.000	0.051	0.520	0.573	1.105	1.648	2.203	2.769
127	3.347	3.938	4.541	4.848	5.158	5.724	5.788	6.366	6.431	7.087	7.758	8.443	9.143
128	9.857	10.585	11.329	11.707	12.089	12.786	12.864	13.576	13.656	14.464	15.290	16.134	16.997
129	17.879	18.780	19.700	20.167	20.639	21.502	21.599	22.478	22.577	23.575	24.592	25.628	26.682
130	27.756	28.849	29.961	30.525	31.093	32.128	32.244	33.295	33.413	34.599	35.804	37.029	38.272
131	39.533	40.813	42.112	42.768	43.429	44.633	44.767	45.989	46.126	47.503	48.900	50.316	51.750
132	53.203	54.679	56.179	56.937	57.701	59.090	59.245	60.655	60.813	62.404	64.020	65.668	67.351
133	69.065	70.808	72.581	73.479	74.385	76.035	76.220	77.902	78.091	80.010	81.966	83.959	85.989
134	88.054	90.157	92.299	93.393	94.498	96.514	96.740	98.793	99.023	101.347	103.710	106.114	108.562
135	111.067	113.625	116.229	117.548	118.879	121.302	121.573	124.038	124.314	127.103	129.951	132.860	135.819
136	138.827	141.884	144.990	**146.562**	148.147	151.033	151.358	154.306	154.636	157.970	161.356	164.795	168.287
137	171.831	175.433	179.111	180.973	182.849	186.261	186.643	190.105	190.493	194.399	198.362	202.386	206.491
138	210.667	214.907	219.210	221.385	223.576	227.560	228.006	232.051	232.503	237.084	241.749	246.485	251.290
139	256.163	261.104	266.116	268.650	271.212	275.884	276.407	281.145	281.675	287.013	292.418	297.889	303.424
140	309.025	314.692	320.429	323.327	326.246	331.556	332.150	**337.540**					

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

Note: Live storage capacity for FRL at 136.25 m is 146.562 M Cu. m and HFL at 140.49 m is 337.540 M Cu. m.

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

RL (m)	0	0.1	0.2	0.25	0.3	0.39	0.4	0.49	0.5	0.6	0.7	0.8	0.9
111											0.000	0.000	0.000
112	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
113	0.001	0.002	0.002	0.003	0.003	0.005	0.005	0.007	0.008	0.012	0.016	0.020	0.025
114	0.031	0.036	0.043	0.046	0.050	0.057	0.058	0.066	0.067	0.075	0.084	0.093	0.103
115	0.114	0.126	0.138	0.145	0.151	0.165	0.166	0.181	0.183	0.200	0.217	0.234	0.252
116	0.271	0.291	0.311	0.321	0.332	0.351	0.353	0.373	0.375	0.395	0.417	0.440	0.464
117	0.487	0.512	0.537	0.550	0.563	0.586	0.588	0.611	0.613	0.639	0.665	0.687	0.710
118	0.734	0.756	0.778	0.790	0.801	0.822	0.824	0.845	0.848	0.872	0.896	0.921	0.947
119	0.974	1.001	1.031	1.046	1.062	1.091	1.095	1.124	1.128	1.161	1.196	1.233	1.270
120	1.309	1.351	1.391	1.412	1.432	1.468	1.472	1.509	1.513	1.557	1.603	1.650	1.696
121	1.740	1.785	1.830	1.852	1.874	1.913	1.918	1.957	1.962	2.007	2.052	2.098	2.146
122	2.194	2.244	2.294	2.318	2.340	2.379	2.383	2.421	2.426	2.470	2.515	2.561	2.608
123	2.656	2.705	2.757	2.784	2.811	2.862	2.868	2.920	2.926	2.986	3.048	3.114	3.178
124	3.241	3.306	3.374	3.409	3.443	3.505	3.512	3.575	3.582	3.654	3.725	3.797	3.868
125	3.941	4.016	4.090	4.128	4.165	4.235	4.243	4.315	4.323	4.408	4.494	4.582	4.672
126	4.764	4.86	4.961	5.011	5.062	5.154	5.164	5.257	5.267	5.374	5.488	5.605	5.723
127	5.842	5.968	6.104	6.169	6.233	6.350	6.363	6.484	6.498	6.636	6.781	6.924	7.067
128	7.210	7.360	7.516	7.595	7.674	7.82	7.836	7.984	8.001	8.172	8.349	8.532	8.723
129	8.912	9.103	9.298	9.399	9.496	9.668	9.687	9.863	9.883	10.075	10.263	10.451	10.642
130	10.835	11.026	11.223	11.32	11.413	11.579	11.597	11.758	11.776	11.959	12.146	12.335	12.524

RL (m)	0	0.1	0.2	0.25	0.3	0.39	0.4	0.49	0.5	0.6	0.7	0.8	0.9
131	12.707	12.892	13.081	13.176	13.274	13.463	13.484	13.664	13.683	13.873	14.062	14.247	14.435
132	14.630	14.886	15.110	15.221	15.333	15.534	15.557	15.765	15.789	16.032	16.298	16.678	16.990
133	17.285	17.580	17.879	18.033	18.190	18.484	18.518	18.933	18.979	19.380	19.749	20.112	20.474
134	20.840	21.218	21.653	21.991	22.211	22.587	22.627	22.992	23.032	23.433	23.836	24.254	24.706
135	25.345	25.812	26.269	26.494	26.720	27.129	27.176	27.597	27.645	28.147	28.819	29.338	29.837
136	30.327	30.816	31.313	**31.563**	31.816	32.423	32.490	33.011	33.066	33.602	34.128	34.651	35.180
137	35.721	36.327	37.090	37.380	37.663	38.165	38.220	38.721	38.777	39.343	39.929	40.563	41.433
138	42.085	42.713	43.341	43.657	43.977	44.566	44.633	45.255	45.327	46.286	47.012	47.705	48.389
139	49.068	49.759	50.490	50.888	51.552	52.252	52.326	52.967	53.037	53.719	54.379	55.030	55.680
140	56.334	57.012	57.757	58.166	58.595	59.394	59.484	**60.287**					

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

Note: Spread Area for FRL at 136.25 m is 31.563 Sq. Km and HFL at 140.49 m is 60.287 Sq. 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 136.25 m was 43.85 Sq. Km, corresponding storage capacity was 176.202 M Cu. m and Dead storage at 126.39 was 23.413 M Cu. m.

The reservoir was surveyed by Remote Sensing Technique in the year 1999. As per survey of the year 1999, total area of reservoir at FRL 136.25 m was 26.836 Sq. Km, corresponding storage capacity was 158.203 M Cu. m and Dead storage at 126.39 was 23.413 M Cu. m.

The reservoir was surveyed by Remote Sensing Technique in the year 2019. As per survey of the year 2019, total area of reservoir at FRL 136.25 m was 26.30 Sq. Km, corresponding live storage capacity was 123.15 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 136.25 m is 31.563 Sq. Km, corresponding storage capacity is 168.493 M Cu. m and Dead storage at 126.39 m is 21.931 M Cu. m.

The rate of siltation in the reservoir (up to FRL 136.25 m) during the last 37 years (1984-2021), was found to be 0.208 M Cu. m / year.

Original Reservoir data:

Year of Impounding : 1984
Catchment Area : 1114 Sq. Km
Surface area at 136.25 m : 43.85 Sq. Km
Live storage at 136.25 m : 152.789 M Cu. m
Dead storage at 126.39 m : 23.413 M Cu. m
Gross storage at 136.25 m : 176.202 M Cu. m

Rate of Sedimentation (at FRL 136.25) 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	23.413	152.789	176.202	-	-	-	-	-	-	-	-	
2	1999 (Remote Sensing Technique)	23.413	134.79	158.203	15	17.999	1.200	0 0.00%	17.999 11.78%	17.999 10.21%	10.77	0.68%	**Serious Category**
3	2021 (Hydrographic survey)	21.931	146.562	168.493	37	7.709	0.208	1.482 6.33%	6.227 4.08%	7.709 4.38%	1.87	0.12%	**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 1999 and 2021 is 0.68% and 0.12% respectively for FRL 136.25 m.
- The increase in storage capacity (10.29 M Cu. m increased in gross storage capacity) in 2021 survey data compared to 1999 survey data is due to difference in method used to acquire survey data of the reservoir during 1999 and 2021.
- 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.
- 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 Watrak Dam:

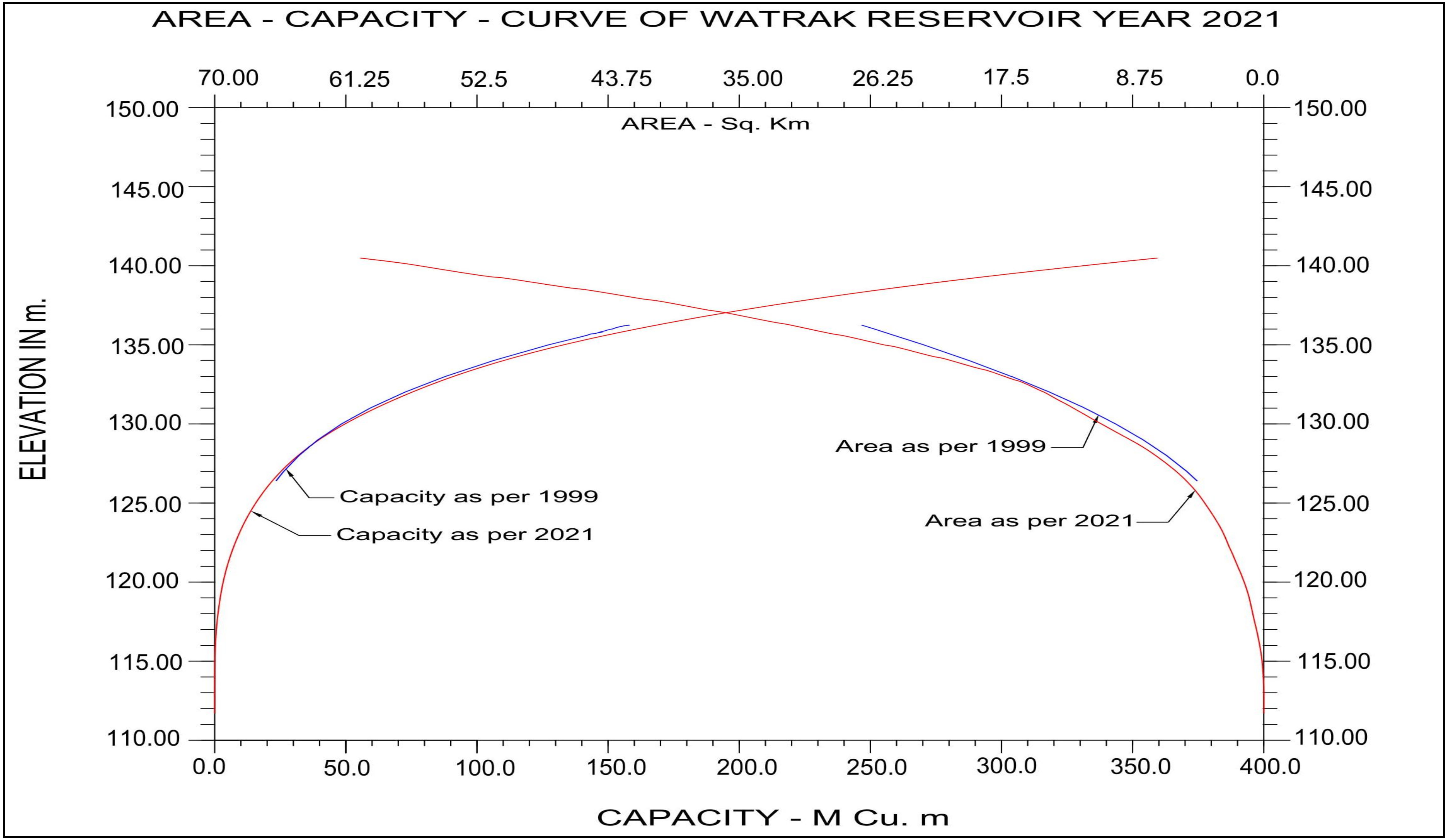

Figure 6.10-1 AREA – CAPACITY - CURVE

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

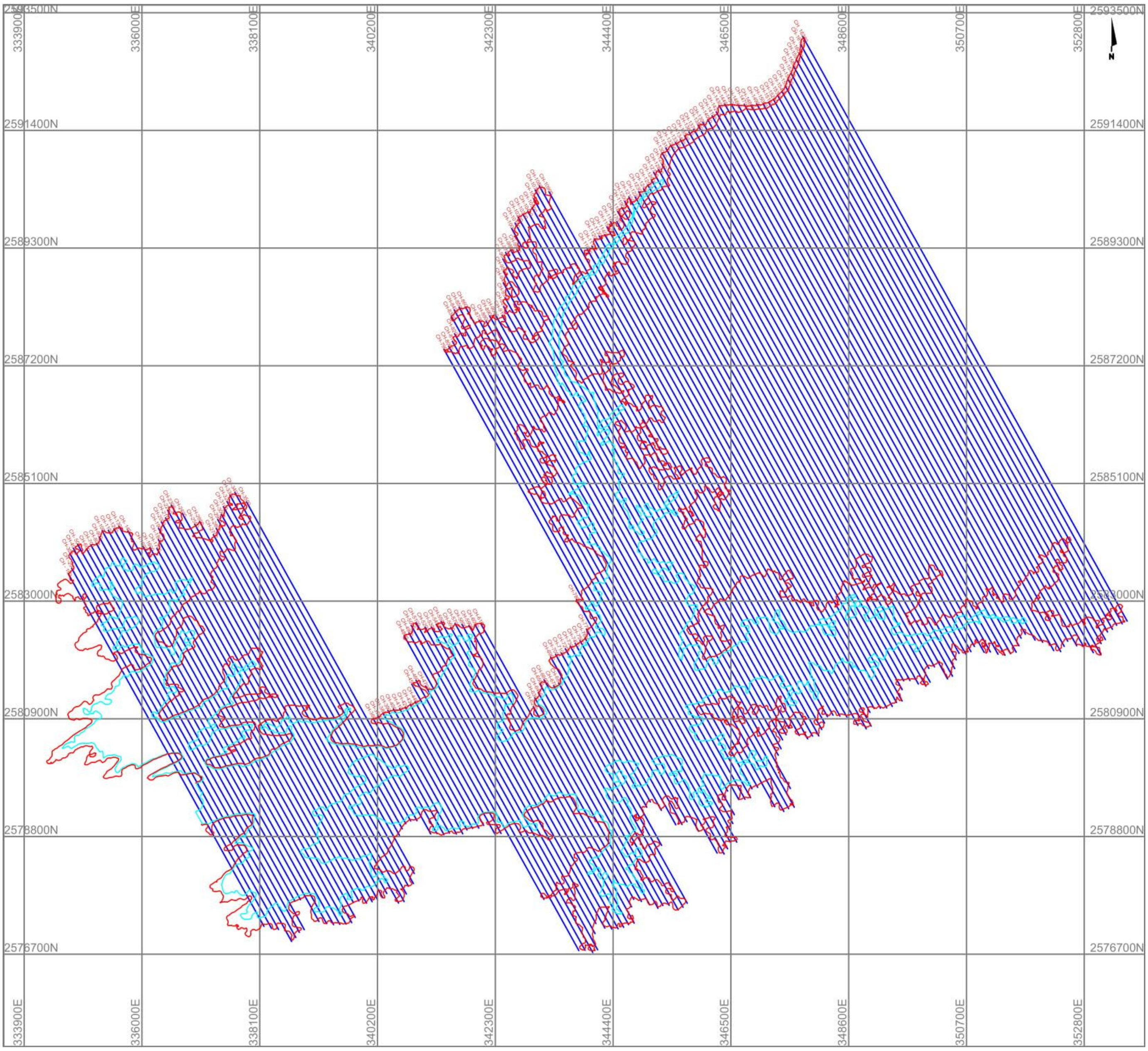

Figure 6.11-1 SEGMENT MAP FOR CROSS SECTION

Cross sections showing bed profile at 100m interval were prepared and are provided as soft copy in CD/Hard Disc. Total 162 cross section profiles were prepared.

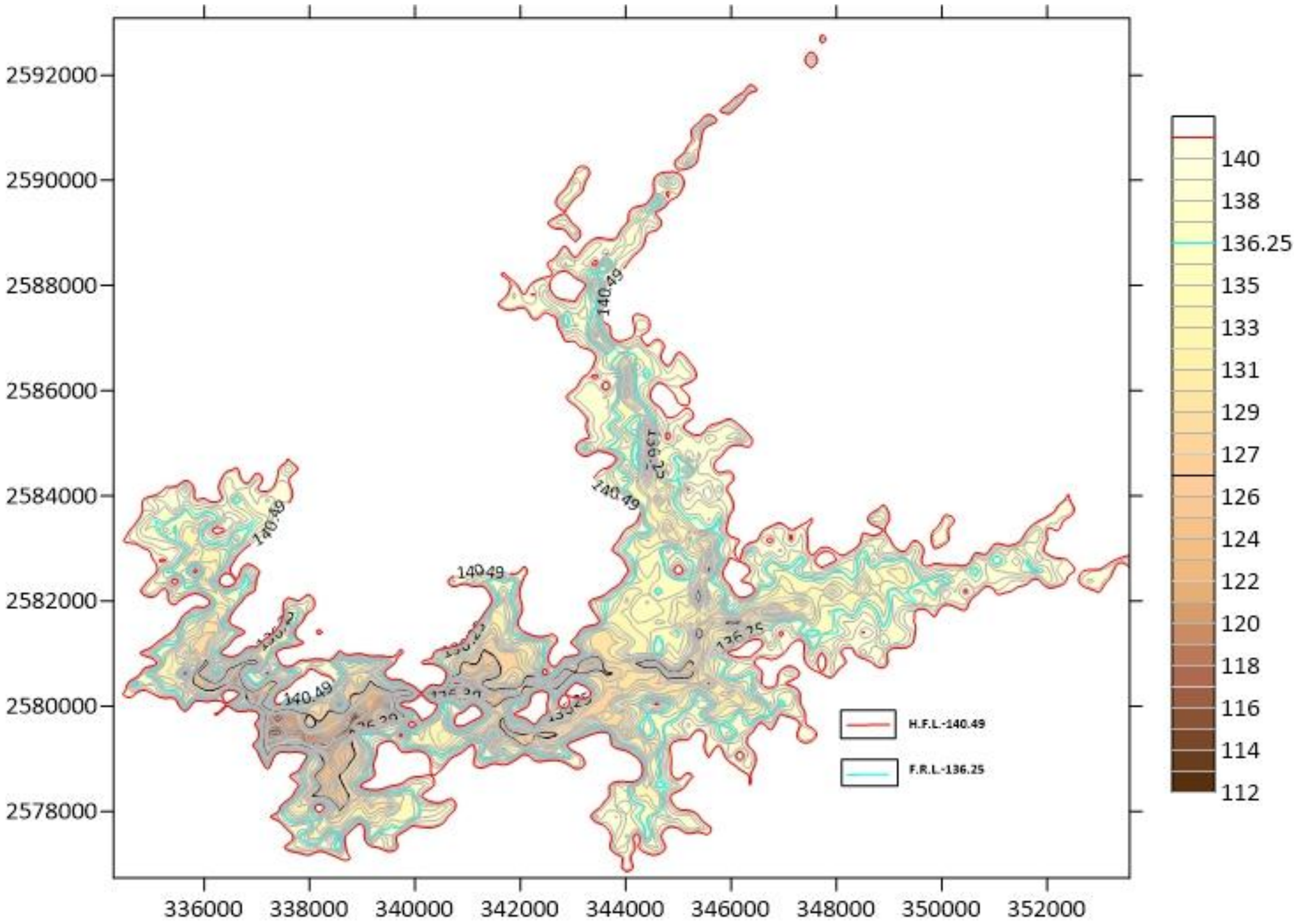

Figure 6.11-2 CONTOUR MAP

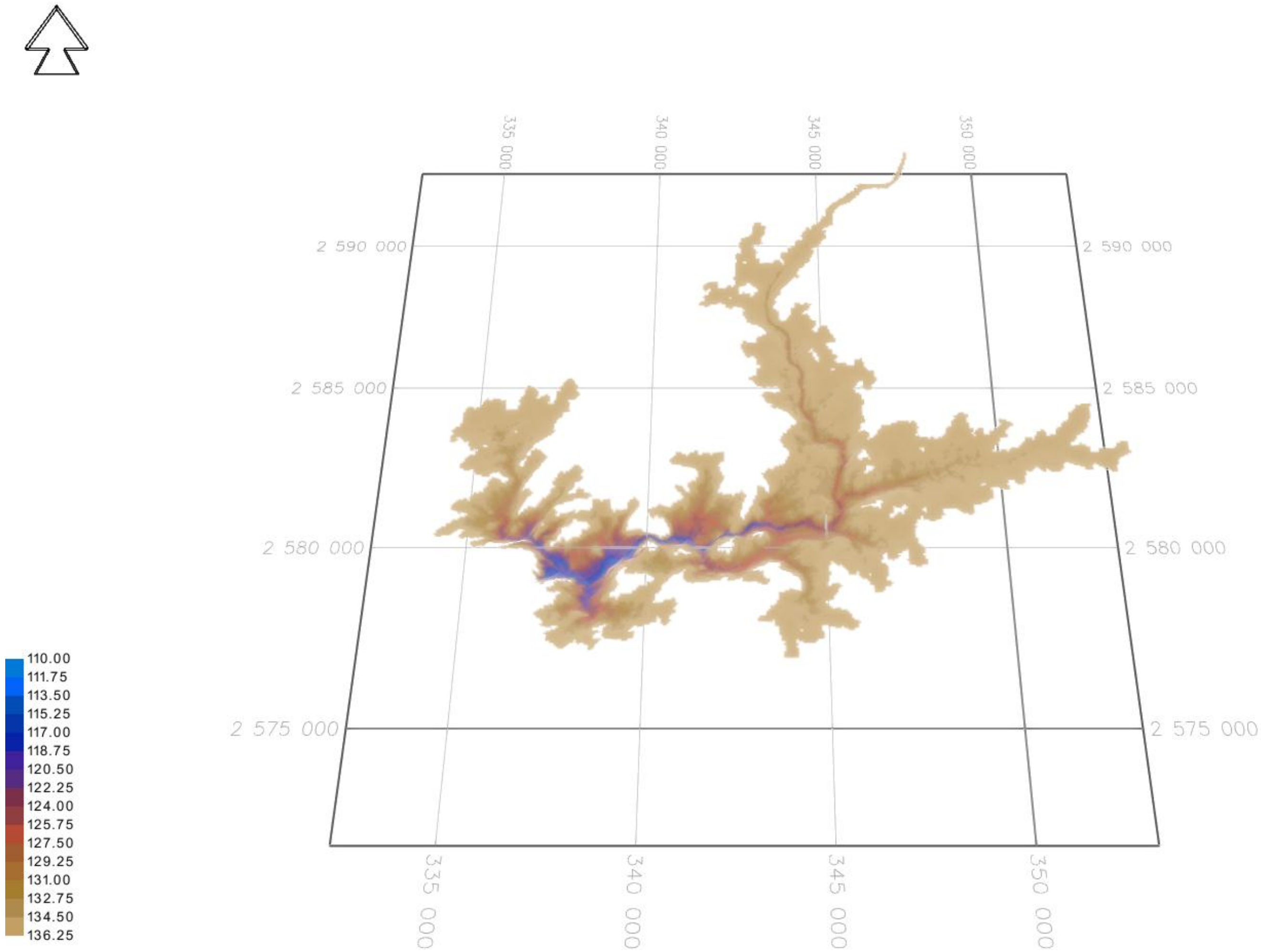

Figure 6.11-3 WIRE FRAME MAP

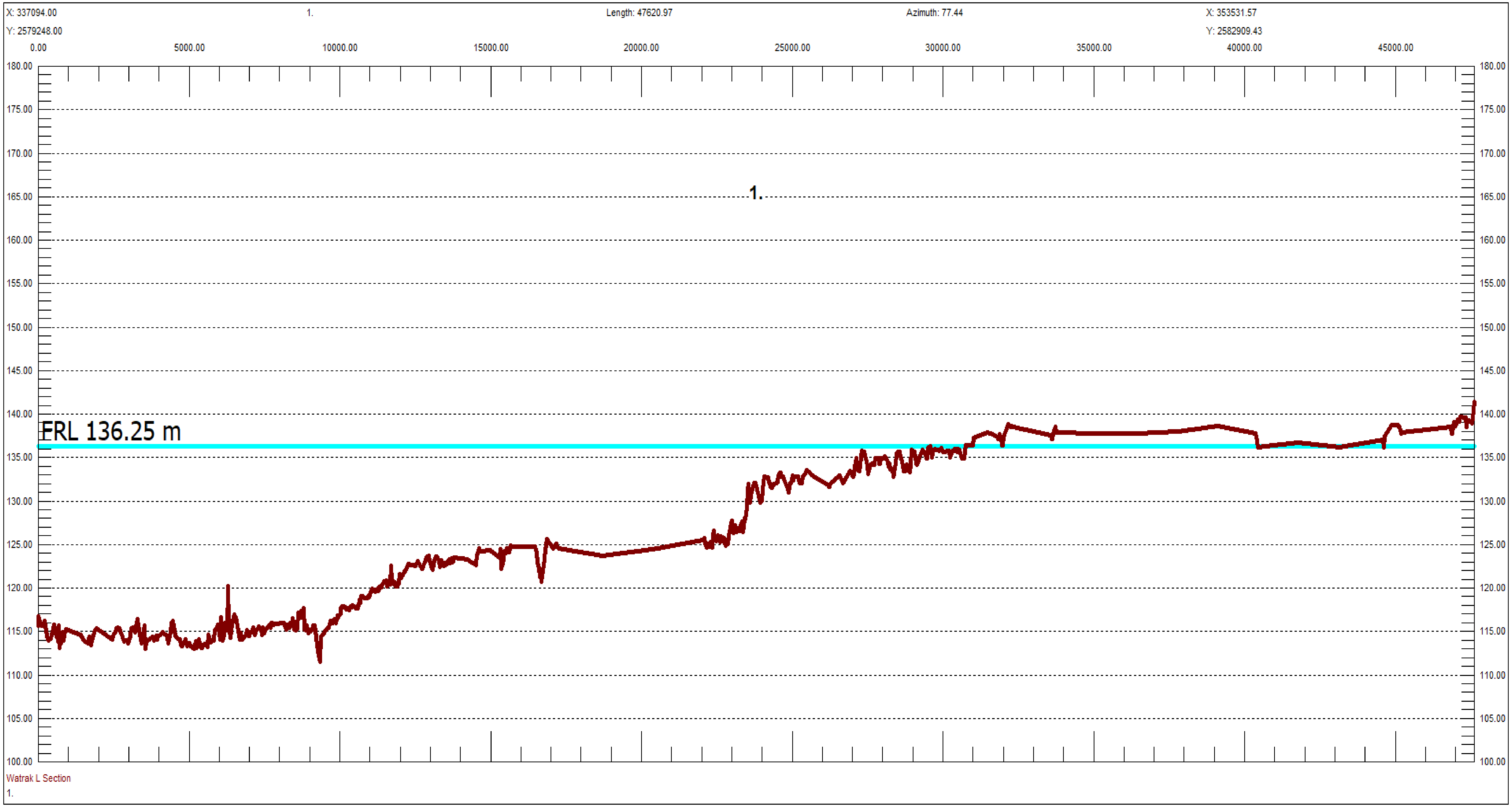

Figure 6.11-4 L-Section

7 DGPS OBSERVATION REPORT

AUSPOS GPS Processing Report

February 25, 2021

This document is a report of the GPS data processing undertaken by the AUSPOS Online GPS Processing Service (version: AUSPOS 2.4) . The AUSPOS Online GPS Processing Service uses International GNSS Service (IGS) products (final, rapid, ultra-rapid depending on availability) to compute precise coordinates in International Terrestrial Reference Frame (ITRF) anywhere on Earth and Geocentric Datum of Australia (GDA) within Australia. The Service is designed to process only dual frequency GPS phase data.

An overview of the GPS processing strategy is included in this report.

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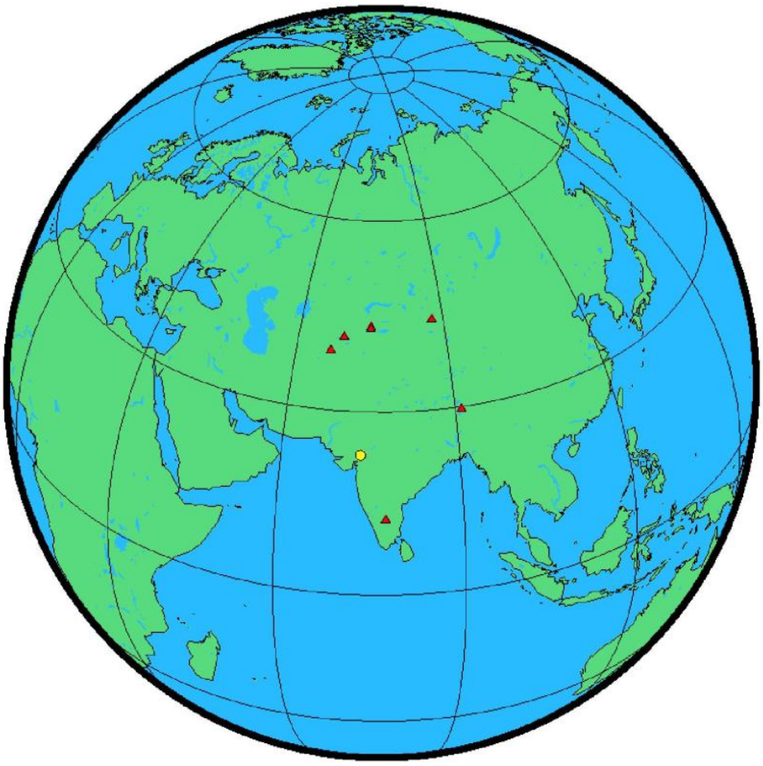
Australian Government
Geoscience Australia

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
_VAT	_VAT_24022021_134827.210	TIAPENG6 NONE	1.752	2021/02/24 05:49:00	2021/02/24 09:12:00

2 Processing Summary



Date	User Stations	Reference Stations	Orbit Type
2021/02/24 05:49:00	_VAT	CHUM IISC KIT3 LHAZ POL2 TASH URUM	IGS ultra rapid

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 @
_VAT	1673631.463	5616268.392	2509149.654	24/02/2021
CHUM	1228950.353	4508080.000	4327868.531	24/02/2021
IISC	1337935.753	6070317.124	1427877.337	24/02/2021
KIT3	1944944.697	4556652.354	4004326.061	24/02/2021
LHAZ	-106942.192	5549269.756	3139215.231	24/02/2021
POL2	1239970.925	4530790.160	4302578.872	24/02/2021
TASH	1695944.773	4487138.667	4190140.754	24/02/2021
URUM	193030.136	4606851.286	4393311.536	24/02/2021

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)
_VAT	23 19 05.34849	73 24 21.95347	89.638	145.400
CHUM	42 59 54.60548	74 45 03.97444	716.329	759.319
IISC	13 01 16.21570	77 34 13.37609	843.689	929.610
KIT3	39 08 05.16369	66 53 07.62186	622.476	659.573
LHAZ	29 39 26.40334	91 06 14.51943	3624.614	3659.305
POL2	42 40 47.17462	74 41 39.37368	1714.205	1754.271
TASH	41 19 40.97918	69 17 44.05697	439.695	483.265
URUM	43 48 28.61998	87 36 02.41981	858.871	922.250

3.3 UTM Grid, GRS80 Ellipsoid, ITRF2014

Station	East (m)	North (m)	Zone	Ellipsoidal Height (m)	Derived Above Geoid Height(m)
_VAT	337025.308	2579637.320	43	89.638	145.400
CHUM	479712.401	4760678.444	43	716.329	759.319
IISC	778796.705	1440886.657	43	843.689	929.610
KIT3	317236.778	4333861.161	42	622.476	659.573
LHAZ	316496.212	3282318.869	46	3624.614	3659.305
POL2	474951.461	4725300.182	43	1714.205	1754.271
TASH	524734.362	4575216.870	42	439.695	483.265
URUM	548313.465	4850717.945	45	858.871	922.250

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

Station	Longitude(East) (m)	Latitude(North) (m)	Ellipsoidal Height(Up) (m)
_VAT	0.014	0.013	0.052
CHUM	0.007	0.006	0.013
IISC	0.011	0.008	0.016
KIT3	0.008	0.006	0.015
LHAZ	0.011	0.008	0.016
POL2	0.007	0.006	0.013
TASH	0.007	0.006	0.013
URUM	0.012	0.010	0.031

4 Ambiguity Resolution - Per Baseline

Baseline	Ambiguities Resolved	Baseline Length (km)
KIT3 - TASH	80.0 %	318.371
CHUM - POL2	75.0 %	35.732
LHAZ - _VAT	70.6 %	1889.951
_VAT - TASH	83.3 %	2025.133
POL2 - URUM	76.9 %	1053.614
CHUM - TASH	63.1 %	487.331
IISC - _VAT	73.4 %	1219.837
AVERAGE	73.7%	1004.281

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.

Australian Government
Geoscience Australia

5 Computation Standards

5.1 Computation System

Software	Bernese GNSS Software Version 5.2.
GNSS system(s)	GPS only.

5.2 Data Preprocessing and Measurement Modelling

Data preprocessing	Phase preprocessing is undertaken in a baseline by baseline mode using triple-differences. In most cases, cycle slips are fixed by the simultaneous analysis of different linear combinations of L1 and L2. If a cycle slip cannot be fixed reliably, bad data points are removed or new ambiguities are set up A data screening step on the basis of weighted postfit residuals is also performed, and outliers are removed.
Basic observable	Carrier phase with an elevation angle cutoff of 7° and a sampling rate of 3 minutes. However, data cleaning is performed a sampling rate of 30 seconds. Elevation dependent weighting is applied according to $1/\sin(e)^2$ where e is the satellite elevation.
Modelled observable	Double differences of the ionosphere-free linear combination.
Ground antenna phase centre calibrations	IGS14 absolute phase-centre variation model is applied.
Tropospheric Model	A priori model is the GMF mapped with the DRY-GMF.
Tropospheric Estimation	Zenith delay corrections are estimated relying on the WET-GMF mapping function in intervals of 2 hour. N-S and E-W horizontal delay parameters are solved for every 24 hours.
Tropospheric Mapping Function	GMF
Ionosphere	First-order effect eliminated by forming the ionosphere-free linear combination of L1 and L2. Second and third effect applied.
Tidal displacements	Solid earth tidal displacements are derived from the complete model from the IERS Conventions 2010, but ocean tide loading is not applied.
Atmospheric loading	Applied
Satellite centre of mass correction	IGS14 phase-centre variation model applied
Satellite phase centre calibration	IGS14 phase-centre variation model applied
Satellite trajectories	Best available IGS products.
Earth Orientation	Best available IGS products.

5.3 Estimation Process

Adjustment	Weighted least-squares algorithm.
Station coordinates	Coordinate constraints are applied at the Reference sites with standard deviation of 1mm and 2mm for horizontal and vertical components respectively.
Troposphere	Zenith delay parameters and pairs of horizontal delay gradient parameters are estimated for each station in intervals of 2 hours and 24 hours.
Ionospheric correction	An ionospheric map derived from the contributing reference stations is used to aid ambiguity resolution.
Ambiguity	Ambiguities are resolved in a baseline-by-baseline mode using the Code-Based strategy for 180-6000km baselines, the Phase-Based L5/L3 strategy for 18-200km baselines, the Quasi-Ionosphere-Free (QIF) strategy for 18-2000km baselines and the Direct L1/L2 strategy for 0-20km baselines.

5.4 Reference Frame and Coordinate Uncertainty

Terrestrial reference frame	IGS14 station coordinates and velocities mapped to the mean epoch of observation.
Australian datums	GDA2020 and GDA94.
Derived AHD	For stations within Australia, AUSGeoid2020 (V20180201) is used to compute AHD. AUSGeoid2020 is the Australia-wide gravimetric quasigeoid model that has been a posteriori fitted to the AHD. For reference, derived AHD is always determined from the GDA2020 coordinates. In the GDA94 section of the report, AHD values are assumed to be identical to those derived from GDA2020.
Above-geoid heights	Earth Gravitational Model EGM2008 released by the National Geospatial-Intelligence Agency (NGA) EGM Development Team is used to compute above-geoid heights. This gravitational model is complete to spherical harmonic degree and order 2159, and contains additional coefficients extending to degree 2190 and order 2159.
Coordinate uncertainty	Coordinate uncertainty is expressed in terms of the 95% confidence level for GDA94, GDA2020 and ITRF2014. Uncertainties are scaled using an empirically derived model which is a function of data span, quality and geographical location.

8 SINGLE BEAM ECHOSOUNDER BAR CHECK RESULTS

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title:	BOAT:	Place:
	Bathymetric Survey	**AQUA MARINA**	**VATRAK DAM**
Date:			
10-Feb-21	**9:00**		
Observed By:		Echosounder Model	Area Depth
JOMON MJ		**SONARMITE**	**11.2**

Draft		Sound Velocity	
		Average	**Upto Depth**
0.40		**1510**	**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)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02	10	10.01	-0.01
4	4.01	-0.01	9	9	0
5	5	0	8	8.03	-0.03
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5	0
9	9.03	-0.03	4	4.02	-0.02
10	10.02	-0.02	3	2.99	0.01
	Average	-0.0112		Average	-0.0112
	Std. Dev	0.0155		Std. Deviation	0.0136
				Cumulative Average	-0.01
				Cumulative Std. Deviation	0.0014

The Echosounder Barcheck Values arε 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**	BOAT: **AQUA MARINA**	Place: **VATRAK DAM**
Date: **11-Feb-21**	**9:30**		
Observed By: **JOMON MJ**		Echosounder Model **SONARMITE**	Area Depth **11.2**

Draft	Sound Velocity Average	Sound Velocity Upto Depth
0.40	**1510**	**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)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02			
4	4.01	-0.01	9	9	0
5	5	0	8	8.03	-0.03
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5	0
9	9.03	-0.03	4	4.02	-0.02
			3	2.99	0.01
	Average	-0.0100		Average	-0.0114
	Std. Dev	0.0163		Std. Deviation	0.0146
				Cumulative Average	-0.01
				Cumulative Std. Deviation	0.0012

The Echosounder Barcheck Values ar(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	BOAT: AQUA MARINA	Place: VATRAK DAM
Date: 12-Feb-21	9:30		
Observed By: JOMON MJ		Echosounder Model SONARMITE	Area Depth 10

Draft		Sound Velocity	
		Average	Upto Depth
0.40		1510	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)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02			
4	4.01	-0.01			
5	5	0	8	8.03	-0.03
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5	0
			4	4.02	-0.02
			3	2.99	0.01
	Average	-0.0067		Average	-0.0133
	Std. Dev	0.0151		Std. Deviation	0.0151
				Cumulative Average	-0.01
				Cumulative Std. Deviation	0.0000

The Echosounder Barcheck Values ar(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**	BOAT: **AQUA MARINA**	Place: **VATRAK DAM**
Date: **13-Feb-21**	**9:30**		
Observed By: **JOMON MJ**		Echosounder Model **SONARMITE**	Area Depth **10**

Draft		Sound Velocity	
		Average	**Upto Depth**
0.40		**1510**	**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)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02			
4	4.01	-0.01			
5	5.01	-0.01	8	8.01	-0.01
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5.01	-0.01
			4	4.02	-0.02
			3	2.99	0.01
	Average	-0.0083		Average	-0.0117
	Std. Dev	0.0147		Std. Deviation	0.0117
				Cumulative Average	-0.01
				Cumulative Std. Deviation	0.0021

The Echosounder Barcheck Values ar‹ 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:	BOAT:	Place:
	Bathymetric Survey	AQUA MARINA	VATRAK DAM
Date: 14-Feb-21	10:00		
Observed By: JOMON MJ		Echosounder Model: SONARMITE	Area Depth: 10

Draft	Sound Velocity Average	Sound Velocity Upto Depth
0.40	1510	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)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02			
4	4.01	-0.01			
5	5.02	-0.02	8	8.01	-0.01
6	6.02	-0.02	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5.01	-0.01
			4	4.02	-0.02
			3	2.99	0.01
	Average	-0.0117		Average	-0.0117
	Std. Dev	0.0160		Std. Deviation	0.0117
				Cumulative Average	-0.01
				Cumulative Std. Deviation	0.0031

The Echosounder Barcheck Values ar‹ 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:	BOAT:	Place:
	Bathymetric Survey	**AQUA MARINA**	**VATRAK DAM**
Date:			
16-Feb-21	**9:00**		
Observed By:		Echosounder Model	Area Depth
JOMON MJ		**SONARMITE**	**13**

Draft		**Sound Velocity**	
		Average	**Upto Depth**
0.40		**1510**	**15**
Barcheck Frequency selected	**Survey Frequency:**	Manufacturer's Accuracy	
210	**210**	0.20 % of Depth	0.03 m

Observations while lowering			**Observations while hoisting**		
Bar Depth (m)	ES Reading (m)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02	10	10.01	-0.01
4	4.01	-0.01	9	9	0
5	5	0	8	8.03	-0.03
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5	0
9	9.03	-0.03	4	4.02	-0.02
10	10.02	-0.02	3	2.99	0.01
	Average	-0.0112		Average	-0.0112
	Std. Dev	0.0155		Std. Deviation	0.0136
			Cumulative Average		-0.01
			Cumulative Std. Deviation		0.0014

The Echosounder Barcheck Values ar‹ 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:	BOAT:	Place:
	Bathymetric Survey	**AQUA MARINA**	**VATRAK DAM**
Date:			
18-Feb-21	**0:00**		
Observed By:		Echosounder Model	Area Depth
JOMON MJ		**SONARMITE**	**10**

Draft		Sound Velocity	
		Average	**Upto Depth**
0.40		**1510**	**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)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02			
4	4.01	-0.01			
5	5.02	-0.02	8	8.03	-0.03
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5.01	-0.01
			4	4.02	-0.02
			3	2.99	0.01
	Average	-0.0100		Average	-0.0150
	Std. Dev	0.0155		Std. Deviation	0.0138
				Cumulative Average	-0.01
				Cumulative Std. Deviation	0.0012

The Echosounder Barcheck Values ar‹ 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:	BOAT:	Place:
	Bathymetric Survey	**AQUA MARINA**	**VATRAK DAM**
Date:			
19-Feb-21	**10:30:00**		
Observed By:		Echosounder Model	Area Depth
JOMON MJ		**SONARMITE**	**10**

Draft		Sound Velocity	
		Average	**Upto Depth**
0.40		**1510**	**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)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02			
4	4.01	-0.01			
5	5.02	-0.02	8	8.03	-0.03
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5.01	-0.01
			4	4.02	-0.02
			3	2.99	0.01
	Average	-0.0100		Average	-0.0150
	Std. Dev	0.0155		Std. Deviation	0.0138
				Cumulative Average	-0.01
				Cumulative Std. Deviation	0.0012

The Echosounder Barcheck Values arϵ 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:	BOAT:	Place:
	Bathymetric Survey	**AQUA MARINA**	**VATRAK DAM**
Date: **20-Feb-21**	**9:00**		
Observed By: **JOMON MJ**		Echosounder Model **SONARMITE**	Area Depth **10**

Draft		Sound Velocity	
		Average	Upto Depth
0.40		**1510**	**15**
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)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02			
4	4.01	-0.01			
5	5	0	8	8.03	-0.03
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5	0
			4	4.02	-0.02
			3	2.99	0.01
	Average	-0.0067		Average	-0.0133
	Std. Dev	0.0151		Std. Deviation	0.0151
				Cumulative Average	-0.01
				Cumulative Std. Deviation	0.0000

The Echosounder Barcheck Values ar‹ 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**	BOAT: **AQUA MARINA**	Place: **VATRAK DAM**
Date: **21-Feb-21**	**9:00**		
Observed By: **JOMON MJ**		Echosounder Model **SONARMITE**	Area Depth **10**

Draft		Sound Velocity Average	Sound Velocity Upto Depth
0.40		**1510**	**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)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02			
4	4.01	-0.01	9	9	0
5	4.99	0.01	8	8.03	-0.03
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5.01	-0.01
9	9.03	-0.03	4	4.02	-0.02
			3	2.99	0.01
	Average	-0.0086		Average	-0.0129
	Std. Dev	0.0177		Std. Deviation	0.0138
				Cumulative Average	-0.01
				Cumulative Std. Deviation	0.0028

The Echosounder Barcheck Values ar(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**	BOAT: **AQUA MARINA**	Place: **VATRAK DAM**
Date: **22-Feb-21**	**10:00**		
Observed By: **JOMON MJ**		Echosounder Model **SONARMITE**	Area Depth **10**

Draft		**Sound Velocity**	
		Average	**Upto Depth**
0.40		**1510**	**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)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02			
4	4.01	-0.01			
5	5.02	-0.02	8	8.01	-0.01
6	6.02	-0.02	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5.01	-0.01
			4	4.02	-0.02
			3	2.99	0.01
	Average	-0.0117		Average	-0.0117
	Std. Dev	0.0160		Std. Deviation	0.0117
			Cumulative Average		-0.01
			Cumulative Std. Deviation		0.0031

The Echosounder Barcheck Values ar 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	BOAT: AQUA MARINA	Place: VATRAK DAM
Date: 23-Feb-21	9:30	Client: GOVT OF GUJARAT WATER RESOURCES INVESTIGATION DIV	
Observed By: JOMON MJ		Echosounder Model SONARMITE	Area Depth 10

Draft	Sound Velocity	
	Average	Upto Depth
0.40	1510	10
	Manufacturer's Accuracy	
	0.20 % of Depth	0.02 m

Observations while lowering			Observations while hoisting		
Bar Depth (m)	ES Reading (m)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02			
4	4.01	-0.01			
5	5.01	-0.01	8	8.01	-0.01
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5.01	-0.01
			4	4.02	-0.02
			3	2.99	0.01
	Average	-0.0083		Average	-0.0117
	Std. Dev	0.0147		Std. Deviation	0.0117
			Cumulative Average		-0.01
			Cumulative Std. Deviation		0.0021

The Echosounder Barcheck Values ar Negligible for Application

GMPL Party Chief

Client's Representative

Page 1

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title:	BOAT:	Place:
	Bathymetric Survey	**AQUA MARINA**	**VATRAK DAM**
Date:			
24-Feb-21	**9:30**		
Observed By:		Echosounder Model	Area Depth
JOMON MJ		**SONARMITE**	**12**

Draft		**Sound Velocity**	
		Average	**Upto Depth**
0.40		**1510**	**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)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02			
4	4.01	-0.01	9	9.01	-0.01
5	5.01	-0.01	8	8.03	-0.03
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5.01	-0.01
9	9.03	-0.03	4	4.02	-0.02
			3	2.99	0.01
	Average	-0.0114		Average	-0.0143
	Std. Dev	0.0157		Std. Deviation	0.0127
				Cumulative Average	-0.01
				Cumulative Std. Deviation	0.0021

The Echosounder Barcheck Values ar‹ 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:	BOAT:	Place:
	Bathymetric Survey	**AQUA MARINA**	**VATRAK DAM**
Date:			
25-Feb-21	**9:30**		
Observed By:		Echosounder Model	Area Depth
JOMON MJ		**SONARMITE**	**11.2**

Draft		**Sound Velocity**	
		Average	**Upto Depth**
0.40		**1510**	**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)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02			
4	4.01	-0.01	9	9	0
5	5	0	8	8.03	-0.03
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5	0
9	9.03	-0.03	4	4.02	-0.02
			3	2.99	0.01
	Average	-0.0100		Average	-0.0114
	Std. Dev	0.0163		Std. Deviation	0.0146
			Cumulative Average		-0.01
			Cumulative Std. Deviation		0.0012

The Echosounder Barcheck Values arɛ 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:	BOAT:	Place:
	Bathymetric Survey	**AQUA MARINA**	**VATRAK DAM**
Date: **26-Feb-21**	**9:00**		
Observed By: **JOMON MJ**		Echosounder Model **SONARMITE**	Area Depth **13**

Draft		Sound Velocity	
		Average	**Upto Depth**
0.40		**1510**	**15**
Barcheck Frequency selected	**Survey Frequency:**	Manufacturer's Accuracy	
210	**210**	0.20 % of Depth	0.03 m

Observations while lowering			Observations while hoisting		
Bar Depth (m)	ES Reading (m)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02	10	10.01	-0.01
4	4.01	-0.01	9	9	0
5	5	0	8	8.03	-0.03
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5	0
9	9.03	-0.03	4	4.02	-0.02
10	10.02	-0.02	3	2.99	0.01
	Average	-0.0112		Average	-0.0112
	Std. Dev	0.0155		Std. Deviation	0.0136
				Cumulative Average	-0.01
				Cumulative Std. Deviation	0.0014

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**	BOAT: **AQUA MARINA**	Place: **VATRAK DAM**
Date: **27-Feb-21**	**15:30**		
Observed By: **JOMON MJ**		Echosounder Model **SONARMITE**	Area Depth **11.2**

Draft			Sound Velocity	
			Average	**Upto Depth**
0.40			**1510**	**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)	ifference (m	Bar Depth (m)	ES Reading (m)	Difference (m)
3	2.98	0.02	10	10.01	-0.01
4	4.01	-0.01	9	9	0
5	5	0	8	8.03	-0.03
6	6.01	-0.01	7	7.02	-0.02
7	7.02	-0.02	6	6.02	-0.02
8	8.02	-0.02	5	5	0
9	9.03	-0.03	4	4.02	-0.02
10	10.02	-0.02	3	2.99	0.01
	Average	-0.0112		Average	-0.0112
	Std. Dev	0.0155		Std. Deviation	0.0136
				Cumulative Average	-0.01
				Cumulative Std. Deviation	0.0014

The Echosounder Barcheck Values ar‹ Negligible for Application

GMPL Party Chief

Approved By: Survey Manager

9 PHOTOGRAPHS

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

DGPS Observation At Dam

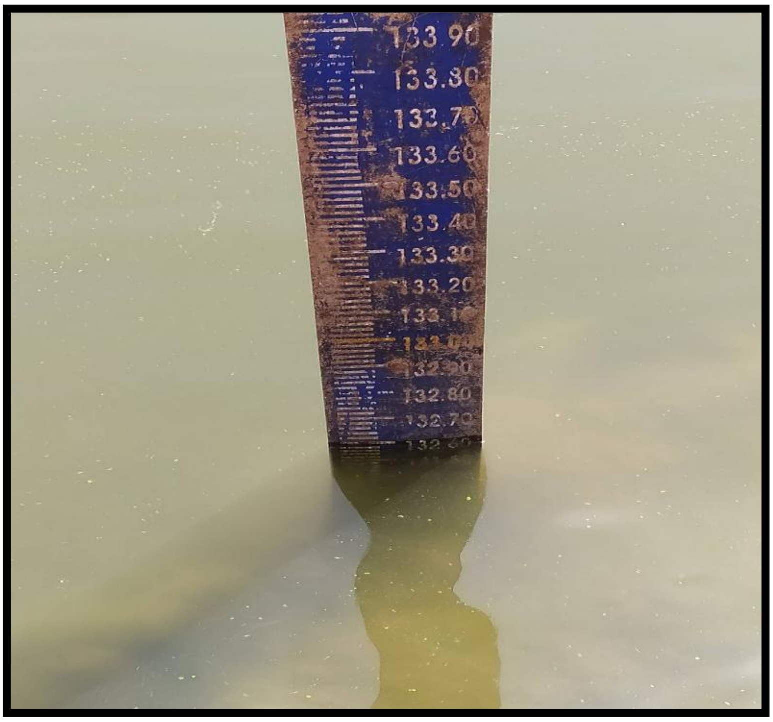
Dam View

TBM 1 Spillway

Topographic survey

TBM 4 (near Shri Raksheshwar Mahadev Temple, Malpur)

OLD BM TBM



Water Level Guage

Old BM

HFL on Check Dam

END OF REPORT