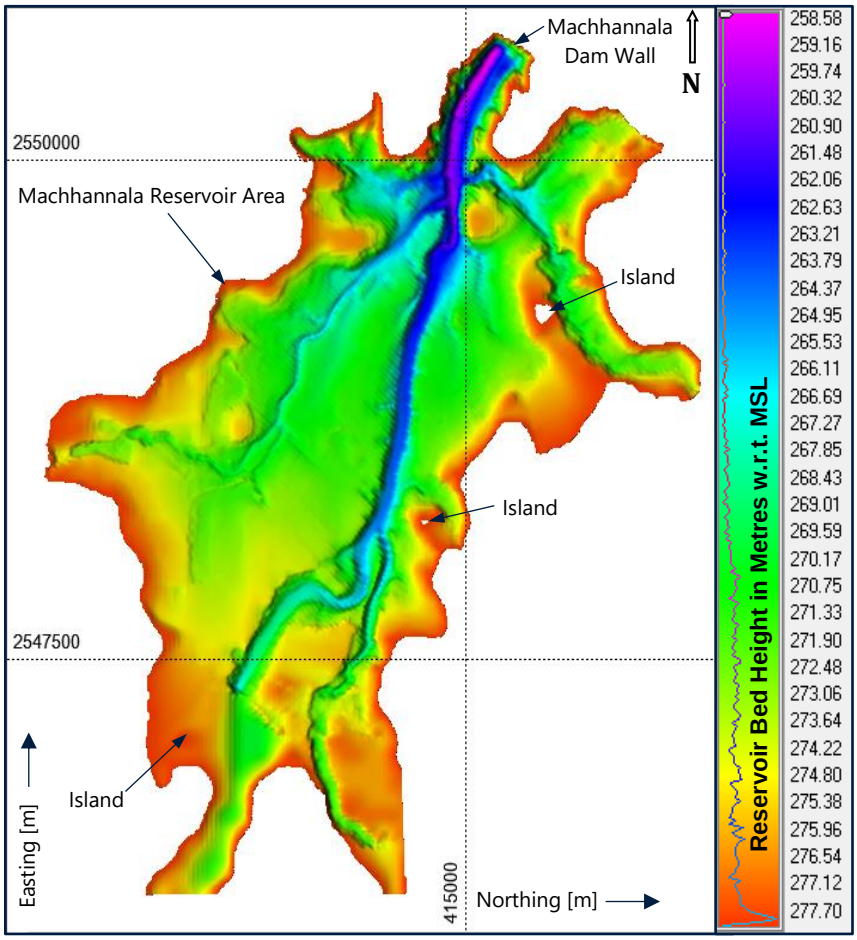

Providing Services for Conducting Bathymetric Survey of Reservoirs of Central Gujarat Under National Hydrology Project

Survey Results of Machhannala Reservoir Location | Central Gujarat

JHYD20-174630-Volume 4-Machhannala Reservoir/R2 [02] | 24 September 2021

Final Report

Narmada Water Resources, Water Supply and Kalpsar Department / Government of Gujarat

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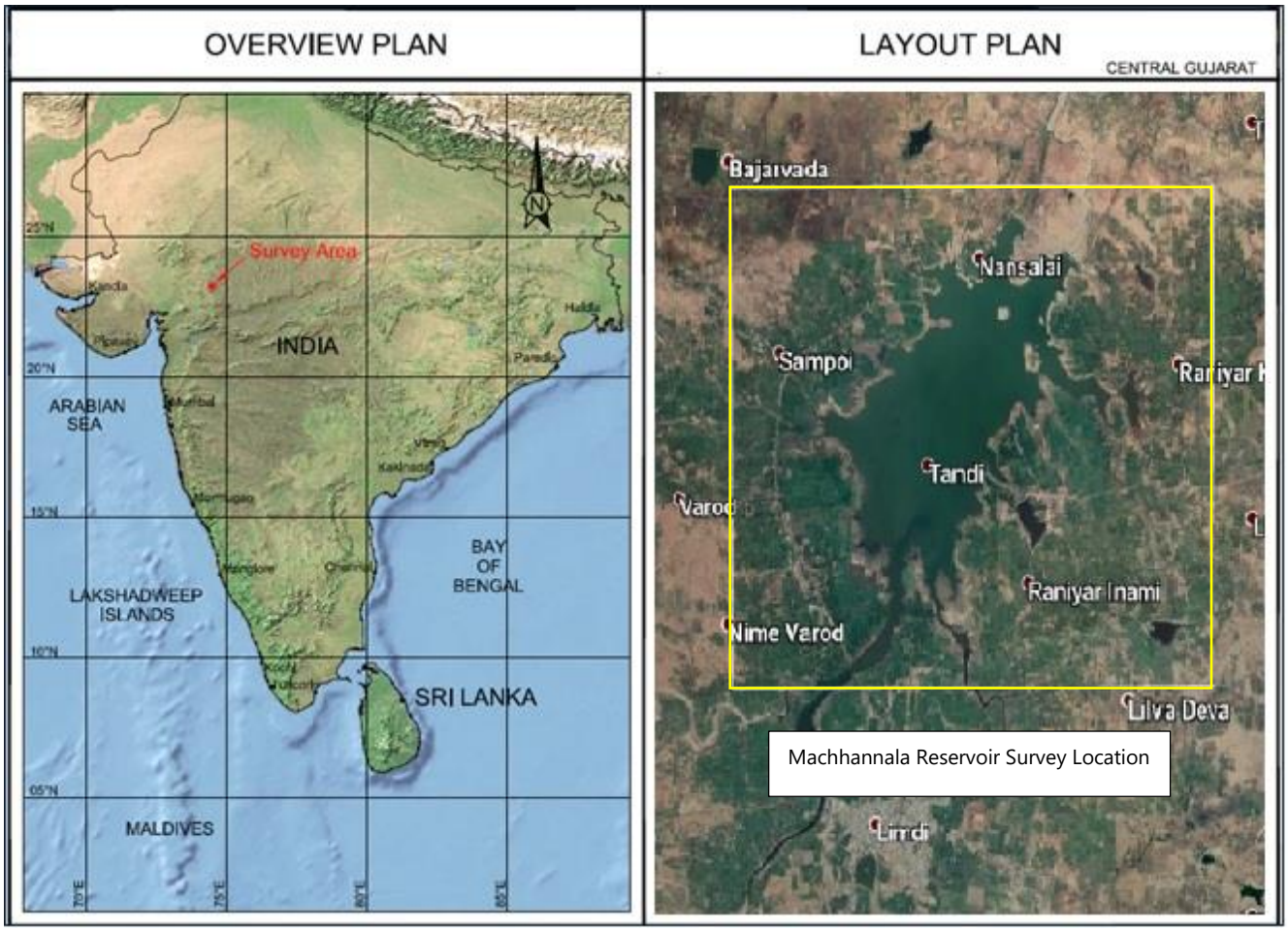
Rev	Date	Status	Prepared By	Checked By	Approved By
[02]	24 September 2021	Final Report	Alok A /Sukla C.	G.N. Hariharan	Rahul Patkar

LOCATION MAP



EXECUTIVE SUMMARY

Survey Overview– Machhannala Reservoir Location	
Preamble:	The Gujarat State Government is implementing World Bank assisted national hydrology project. This project aims to improve the planning, development, and management of water resources, as well as flood forecasting and reservoir operations in real-time. Various activities, including Sediment survey, Water Quality monitoring have been planned under this project. Water Resources department have evolved a comprehensive plan for periodic assessment of reservoir storage capacity and sedimentation of eleven (11) reservoirs. In this regard, **Narmada Water Resources, Water Supply and Kalpsar Department/ Government of Gujarat** contracted **Fugro Survey (India) Pvt. Ltd. (FSINPVT)** to carry out the Bathymetry and Topography survey. Fugro's scope of work consist of Bathymetry and Topography survey at the eleven (11) reservoirs In order to complete the scope, the survey was carried out in two passes at Machhannala reservoir location; • Pass 1: Bathymetry / Hydrographic Survey. • Pass 2: Topographical Survey
Data Acquisition:	**FSINPVT** mobilised their bathymetry and topographical survey team and equipment along with survey boat 'Polaris' in the months of February -March 2021 and June 2021 respectively, in order to acquire survey data as per mutually agreed scope and relevant survey specifications.
Survey Location	Machhannala Reservoir, Nansalai village, Jhalod Taluka, Dahod District, Gujarat.
Survey Geodesy:	The survey was conducted in WGS 84 datum, Universal Transverse Mercator (UTM) Projection, Zone 43 N, CM 075°E.
Scope Compliance & Meets Client's objectives:	FSINPVT performed this survey methodically as per the scope of work defined in the contract and the results obtained have met the client's objectives in following areas: ▪ To assess the reservoir storage capacity; ▪ To assess the variations in the reservoir capacity; ▪ To estimate and study sedimentation behaviour in horizontal zones and vertical zones, namely dead storage, live storage and flood storage; ▪ To upgrade Elevation–Area-Capacity tables / curves of reservoir at regular intervals; ▪ To create historical database for further water resources usage planning.
Accuracy and Reliability	The accuracy of the data logged was ensured by calibrating each and every sensor deployed in the current survey. Statistical techniques were applied during the execution of the survey to ensure that the results of survey conform to the agreed levels of accuracy and precision.
Tidal Corrections	All raw water depths were reduced to reservoir water levels. The water level heights or reservoir water levels w.r.t. MSL were observed for the entire survey period and the same was used to calculate the reservoir bed heights w.r.t. MSL.

Survey Findings – Machhannala Reservoir Location	
Reservoir Bed Heights	In general, lowest reservoir bed level was found at the upstream face of the dam and it becomes less deeper as we go further upstream from the dam face. Lowest reservoir bed level recorded during bathymetry survey was 258.6 m (415 146 mE, 2 550 256 mN) w.r.t. MSL.
Capacity Survey (2020-2021)	Elevation Area Capacity table and curve of Machhannala reservoir was prepared based on bathymetry and topography survey data acquired at 25 m line spacing and 25 m x 25 m grid interval respectively. The processed xyz data was used to prepare DTM. Capacity and areas at various elevations from lowest bed level (258.6 m) to FRL (277.64 m) was calculated using GIS software.
Revised elevation area capacity details	In comparison with 1982 Original Project data, the present survey results indicate that the gross storage capacity has decreased.
Loss in gross storage capacity	As per 2020-21 survey results, the loss in Gross storage capacity w.r.t. 1982 or volume of sediment deposited in the Machhannala reservoir is 4.80 Mm^3.
Trap efficiency & Sedimentation Index	Trap Efficiency and sedimentation Index calculated for Machhannala reservoir as per methodology give in IS 12182-1987 is 95% and 7.38 x 10^{10} s^2/m respectively
Sedimentation rate	The rate of siltation in Machhannala reservoir is 0.123 Mm^3/year
Average rate of siltation	The observed rate of siltation in the Machhannala reservoir during the 39 year life span (1982 – 2021), works out to 5.03 Ha m/100 sq km/year.
Annual % loss	The annual % loss in gross storage capacity for Machhannala reservoir during the 39 year life span is 0.32% and hence, the reservoir is classified as “Significant category” as per IS 12182 (1987).

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APPENDICES

TABLES

FIGURES

LIST OF ABBREVATIONS

BM	Benchmark
Ch	Channel
CM	Central Meridian
CVT	Calibration, Verification & Test
DF	Dual Frequency
DGNSS	Differential Global Navigation Satellite System
DPR	Daily Progress Report
FBF	Fugro Binary Format
FRL	Full Reservoir Level
FSINPVT	Fugro Survey (India) Private Limited
FSL	Full Supply Level
ft	Feet
GLONASS	Global Navigation Satellite System
GPS	Global Positioning System
Ha	Hectare
HSE	Health, Safety and Environment
km	kilometre
m	metre
M ft^3	Millions cubic feet
M m^3	Millions cubic meter
MDDL	Minimum Draw Down Level
m/s	meter per second
ms	milliseconds
MSL	Mean Sea Level
OEM	Original Equipment Manufacturer
QA/QC	Quality Assurance / Quality Control
QMS	Quality Management System
Rel	Release
Rev	Revision
RL	Reference Level
SBES	Single beam Echosounder
Sr	Senior
SoW	Scope of Work
UTM	Universal Transverse Mercator
WGS	World Geodetic System
w.r.t	With respect to

UNITS

UTM grid coordinates and all linear measurements are reported in metres [m].

Angular values are reported in degrees (°).

Time and dates are reported as “18:00 on 23 September 2021

1. Introduction

1.1 General

Reservoirs originated by the construction of dams, is essential for the sustainable health and welfare of civilizations since it supplies water for human consumption, irrigation and energy production. Furthermore, dam reservoirs are used for recreation, navigation and they provide safety in the downstream valleys against extreme flood events and droughts (Bengtsson et al., 2012). All reservoirs are subjected to sedimentation which, without adequate prevention and mitigation counter-measures, threatens their sustainability.

Reservoir sedimentation is the gradual accumulation of the incoming sediment load from a river. This accumulation is a serious problem in many parts of the world and has severe consequences for water management, flood control, and production of energy. Sedimentation affects the safety of dams and reduces energy production, storage, discharge capacity and flood attenuation capabilities. It increases loads on the dam and gates, damages mechanical equipment and creates a wide range of environmental impacts (Schleiss et al., 2016).

Reservoir sedimentation is a process of erosion, transportation, deposition and compaction of sediments carried into reservoirs formed and contained by dams. In unregulated, mature rivers with stable catchments, sediment processes are relatively balanced. Construction of a dam decreases flow velocities, initiating or accelerating sedimentation.

Most of the world's reservoirs are in the continuous sediment accumulation stage. Many were designed by estimating sedimentation rates in order to provide a pool with sufficient volume to achieve a specified design life. However, this design life is typically far less than what is actually achievable. Therefore, managing reservoirs to achieve a full sediment balance is essential in order to maximize their lives. As every year sediment gets deposited in dead storage and in live storage of the reservoir, it has long and short range impact on the storage capacity of reservoir (Schellenberg et al., 2017). Correct assessment of the reservoir storage capacity is essential for assessing useful life of the reservoir as well as optimum reservoir operation schedule.

The Gujarat State Government is implementing World Bank assisted national hydrology project. This project aims to improve the planning, development, and management of water resources, as well as flood forecasting and reservoir operations in real-time. Various activities, including Sediment survey, Water Quality monitoring have been planned under this project. Water Resources department have evolved a comprehensive plan for periodic assessment of reservoir storage capacity and sedimentation of eleven (11) reservoirs.

In this regard, **Narmada Water Resources, Water Supply and Kalpsar Department/ Government of Gujarat** contracted **Fugro Survey (India) Pvt. Ltd. (FSINPVT)** to carry out the Bathymetry and Topography survey. Fugro's scope of work consist of Bathymetry and Topography survey at the eleven (11) reservoir as specified by Client.

These survey services comprised of the provision of suitable personnel and equipment in order to obtain, interpret and report on the bathymetry and topography within the survey area. In order to complete the scope, the survey was carried out in two passes at Machhannala reservoir;

Pass 1: Bathymetry / Hydrographic Survey;

Pass 2: Topographical Survey.

The bathymetry survey work was performed from the shallow draft boat 'Polaris'.

The survey reports are submitted in separate volumes for each reservoir location. This report covers **Bathymetry / Hydrographic and Topographical survey results for Machhannala Reservoir location.**

1.2 Study Area

The present study area – Machhannala reservoir falls under Machhan river basin (refer Figure 1.1) which is a part of Mahi basin; and is situated in Dahod district which is located in the north-east direction in state of Gujarat. This Machhan river basin consisting Machhan river is flowing through Jhalod taluka. Jhalod taluka is situated on the eastern border of the Gujarat state, 5 km from Kushalgarh Tehsil in Bunswara district of Rajasthan state border near Titodi river. The Jhalod taluka is bounded by Panchmahal district to the west, Limkheda & Dahod block to the south, Jhaua district (Madhya Pradesh) to the east and Banswada district (Rajasthan) to the north.

The catchment area of the Machhan river basin is 431 km^2 up to its meeting place with Anas River which is a major tributary of river Mahi (Shrimali, 2017).

The overall topography of the region is highly undulating and of varying slopes. The Machhan river basin can be topographically divided into parts; viz. hilly area and flat agricultural land area. Western and southern part of basin comprises hilly region, while central part consist of flat agricultural land. The ground in this basin area generally slopes from south-west to north-east (Guruji et al., 2008).

The data on land utilization and irrigation shows that, in Dahod district, cultivation and sowing land covers 3090 Ha, where area sown more than once covers 945 Ha. In the district, forest area covers 884 Ha (Nayak, 2014).

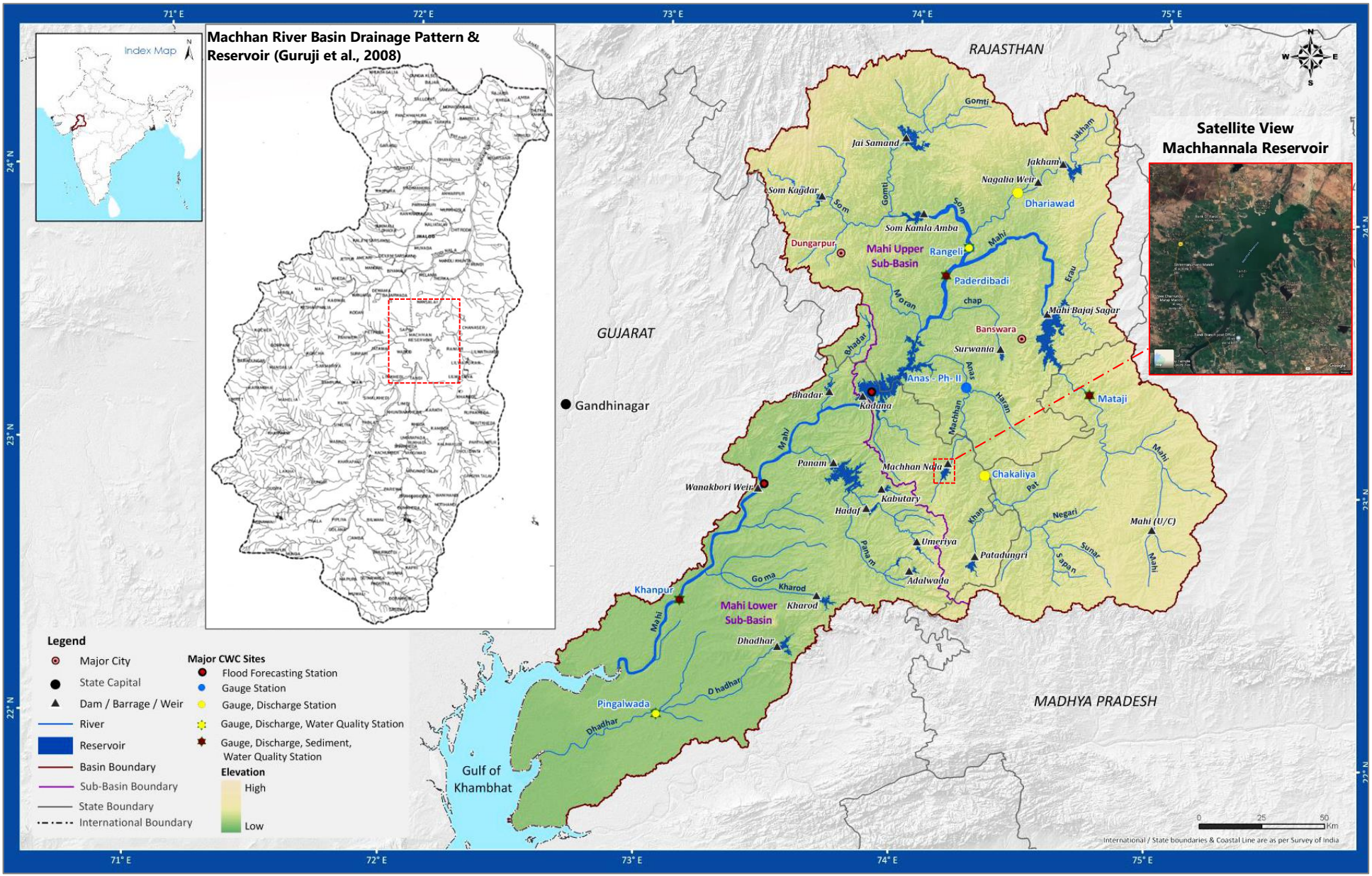

Figure 1.1: Mahi basin showing major tributaries – Drainage and sub- basins (India-WRIS, 2014)

1.3 Geology of Study Area

Basalts occupy the south-west part of the Machhan basin. It is found with irregular boundaries and extending from Patadungri (near Dahod) in the south and upto Jhalod in north. The basalts occur as small flat-topped to conical hills rising above the flatness of Precambrian terrain which is covered with residual black cotton soil. The area is covered by compact metamorphic rock of Proterozoic succession. Quartzite and Phyllite belonging to Lunawada group are encountered in the area. Along Quartzite and Phyllite, the south western boundary is observed by a cover of Deccan trap and infra trappen cretaceous rocks. The Deccan trap found in area is black in colour, weathered on top but becomes very compact at depth. It is formed due to volcanic activity.

Common rock types found in the basin are granites, gneisses, quartzite, schist and associated phyllites, slate etc. (Guruji et al., 2008).

1.4 Soil Types

The soil type of Dahod district is broadly categorized depending on the source rock, i.e., Phyllite, Granite and Basalt. Intense weathering of basalts in this area resulted in formation of black cotton soils which have high fertility value. In this area, sandy loamy soil (from granite) and yellowish light soil (from phyllite) are also found at places of intense weathering (Nayak, 2014).

1.5 Machhannala Reservoir Characteristics

The Machhannala reservoir for Machhannala dam is constructed over the Machhan river in India. It is located near Jhalod town, Dahod District in State of Gujarat. The Dahod district in Gujarat comes under heavy rainfall areas in Gujarat, having sub-tropical climate with moderately low humidity (Nayak, 2014).

The Machhannala dam is earthen (Rolled Filled Zoned) type dam and its reservoir's catchment area is 244.91 km^2. Salient features of the Machhannala reservoir are tabulated below:

Table 1.1: Client Supplied Machhannala Reservoir Salient Features

Characteristics	Feature
Reservoir name	Machhannala Reservoir
Name of Dam	Machhannala Dam
Type	Earthen (Rolled Filled Zoned)
Purpose	Irrigation
River	Machhan
Location	Nansalai village
Latitude	23° 3′ 00″ N
Longitude	74° 10′ 00″ E
Nearest Township	Jhalod
Taluka	Jhalod

Characteristics	Feature
District	Dahod
State	Gujarat
Construction Started	1977
Construction Completed	1988
Year of Impounding	1982
Total Catchment Area	244.91 km^2
Gujarat	244.91 km^2
Other	0
Average Annual Rainfall	869.70 mm
Yield at	
i) 50% reliability	54.65 Mm^3
ii) 60% reliability	50.76 Mm^3
ii) 75% reliability	41.20 Mm^3
Standard Project Flood	159270 cusecs
Maximum Observed Flood	8585.92 cusecs
Reservoir Details	
Full Reservoir Level (F.R.L.)	277.64 m
Dead Storage Level	271.31 m
High Flood Level (H.F.L.)	281.33 m
Lowest flood level (L.W.L.)	271.30 m
Gross Storage (As per Project capacity)	37.91 Mm^3
Dead Storage at R.L. 271.31 m (As per Project capacity)	8.75 Mm^3
Live Storage (As per Project capacity)	29.16 Mm^3
Area at FRL (As per Project capacity)	7.96 km^2
Type of Spillway	Ogee
Length of Spillway	260 m
Spillway Crest Level	277.64 m
Top Level of Dam	283.80 m
Types of Gate	Ungated
Nos. of Gate	-
Maximum Height from Base of Footing	25.44 m
Maximum Length at top	2100 m
Gross Capacity (At FRL and as per Dec 1999 survey)	27.12 Mm^3
Dead Storage	5.92 Mm^3
Live Storage	21.20 Mm^3
Left Bank Main Canal	12300 m
Capacity	2.32 Cum/Sec

Characteristics	Feature
Right Bank Main Canal	14.40 km
Capacity	1.42 Cum/Sec
Gross Command Area (G.C.A.)	3944 Ha. (Left Bank: 2000, Right Bank: 1944)
Culturable Command Area (C.C.A.)	2463 Ha. (Left Bank: 1450, Right Bank: 1013)
Runoff water in catchment	54.65 Mm^3
Base Rock	Quartzite

1.6 Project Objectives

Primarily the main objective of the survey was to:

- Assess the reservoir storage capacity;
- Assess the variations in the reservoir storage capacity;
- Create historical database for further water resources usage planning.
- However, the main objective of the bathymetry survey was to:
- Estimate and study the sedimentation behaviour of reservoirs in different zones including horizontal zones throughout the reservoirs as well as vertical zones namely:
    a) Dead storage
    b) Live storage
    c) Flood storage
- Upgrade Elevation-Area-Capacity tables / curves of reservoirs at regular intervals.

Table 1.2 provides bathymetry and topography survey area details for Machhannala reservoir.

Table 1.2: Machhannala Reservoir details for Bathymetry and Topography Survey

Name of Dam / Reservoir	Actual Area (km^2) surveyed	
	Bathymetry Survey	Topography Survey
Machhannala	2.98	4.07

1.7 Scope of Work

To achieve the above objective, Fugro carried out survey for eleven (11) reservoir areas in two (02) passes. The scope of work undertaken for Machhannala reservoir is as follows:

1.7.1 Pass 1: Bathymetry / Hydrographic Survey

The scope of work for bathymetry survey conforms bathymetry survey for total area of approximately 2.98 km^2.

The following scope of work was undertaken in-order to achieve client objectives:

- Bathymetry / Hydrographic survey work was conducted using echosounder for assessment of reservoir capacity and sedimentation at Machhannala reservoir of Gujarat.

- Survey lines were run at 25 m segment line spacing and along the survey line continuous data of 25 m x 25 m grid point were captured so that each and every point is included. Additional survey lines were executed as and when required.
- DGNSS positioning system, Dual frequency singlebeam echosounder system along with associated Navigational system were deployed on all the survey lines.

1.7.2 Pass 2: Topographical Survey

Topographical survey was carried out using Total station and equivalent levelling instruments. The total area covered in Topographical survey is 4.07 km^2. Following scope of work was undertaken in order to achieve client objectives:

- Topographical survey was conducted to facilitate hydrographic survey so as to fill up the gaps between MWL area and reservoir submergence area till current water level for assessment of reservoir capacity and sedimentation at the reservoir locations.
- Topographical survey was carried out from FSL to present water level of reservoir, with sufficient overlap with hydrographic survey for preparing overall contour map of reservoir.
- The area not covered through hydrographic survey upto maximum water level (MWL), was surveyed by taking levels at 25 m interval along range lines laid at 25 m interval (25 m x 25 m grid).

1.8 Survey Execution

The survey boat 'Polaris' was mobilized at Machhannala reservoir location to carry out the survey. Survey operations were executed as per the mutually agreed survey execution schedule.

1.9 Reference Documents

Table 1.3: Reference Documentation

Sl/No.	Document Name	Document identity
1	FSINPVT Quote / Contract	NOA No. WRIDn/SK/NOA/1588/2020 Dated 09 November 2020
2	FSINPVT Survey Procedure	JHYD20-174630/SP/P0/Rev.0 dated 01 December 2020

1.10 Deliverables

Final report and Charts / Drawings to be delivered as per the contract, as listed in Appendix G to this Report, have been duly submitted. Details of the Charts accompanying this report are also placed at Appendix G.

2. Survey Specifications and Resources

The bathymetry / hydrographic survey and topography survey conformed to the following mutually agreed scope of work and were conducted as per the methodology described in the standard work instruction by FSINPVT.

2.1 Survey Geodesy

The survey was conducted in WGS84 Datum and grid coordinates in terms of Universal Transverse Mercator (UTM) projection (Zone 43 N, CM 075° E) as per client's instruction. The details of the Geodetic parameters are as follows:

Table 2.1: Geodetic Datum, Projection Parameters

Global Positioning System Geodetic Parameters	
Datum:	World Geodetic System 1984
Spheroid:	World Geodetic System 1984
Semi major axis:	a = 6 378 137.000 m
Inverse Flattening:	1/f = 298.257 223 563
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
Scale factor on Central Meridian:	0.9996
Units:	Metre
Notes: • The Client has specified the above Datum and Transformation parameters to be used for this survey. • Fugro's Starfix software suite always uses WGS84 as the primary datum for all geodetic calculations.	

2.2 Horizontal Control

Spatial Dual was used for positioning the survey vessel during this survey. Spatial Dual is a rugged GPS aided inertial navigation system that provides accurate position, velocity, acceleration and orientation under the most demanding conditions. It combines temperature calibrated accelerometers, gyroscopes, magnetometers and a pressure sensor with a dual antenna RTK GNSS receiver. They are coupled in a sophisticated fusion algorithm to deliver accurate and reliable navigation and orientation.

The computer running Starfix NG was used for navigation, data logging and online quality control of the survey data.

2.3 Vertical Control / Water Level Corrections

All vertical levels were reduced to respective water level references. The water level heights or reservoir water levels w.r.t. MSL were observed for the entire survey period and the same was used to calculate the reservoir bed height. Observed reservoir water level heights is tabulated below:

Table 2.2: Observed Reservoir Water Level Heights at Machhannala Reservoir

Date	Observed Reservoir Water Level Heights w.r.t. MSL at Machhannala Reservoir [m]
20-02-2021	274.25
21-02-2021	274.20
22-02-2021	274.17
23-02-2021	274.11
24-02-2021	274.07
25-02-2021	274.03
26-02-2021	274.00
27-02-2021	273.96
28-02-2021	273.93

2.4 Accuracy and Precision of Results

The accuracy of the data logged was ensured by calibrating each and every survey sensor deployed for the current survey, for eliminating systematic errors or bias. Internationally accepted survey work practices were adopted for carrying out such calibrations, sensor alignments and field verifications.

The quality of the data logged was monitored on-line using Fugro's on-line QC tools and ensured it met the agreed accuracy and precision levels. At the data processing, charting and reporting stages, the results of survey were further analysed and checked to ensure that they conformed to the agreed levels of accuracy and precision. The precision (or the repeatability) of the results of survey were controlled by adopting 'Statistical' techniques.

2.5 Survey Personnel Deployed

Following FSINPVT staffs were associated to bathymetry survey for this project.

Table 2.3: List of Survey Personnel – Bathymetry Survey 'Polaris'

Bathymetry Survey Personnel	
Personnel Name	**Function**
Arpit Bose	Party Chief / Surveyor
Mathiyazhagan V.	Engineer
Sunil Singh	Polaris Operator

Following FSINPVT staffs were associated to topography survey for this project.

Table 2.4: List of Survey Personnel – Topography Survey

Topography Survey Personnel	
Personnel Name	Function
Arunabha Chakraborty+ Survey Assistants	Topography Survey Team

Following onshore FSINPVT staffs were associated to this project.

Table 2.5: List of Personnel – Onshore Project Management and Data QC

Onshore Project Management and Data QC	
Rahul Patkar	Service Line Manager
Vikas Walanj/Anantha Krishnan	Project Manager
R.B. Jayaraman	Client Deliverable Manager
Avijit Nag	Survey Manager
G.N. Hariharan	Chief Geophysicist
Avinash Vasudevan	Reporting Manager
Prashant Mishra	Reporting Project Supervisor
K. Srinivas	Data Centre Manager

2.6 Equipment Deployed

Following equipment and systems were deployed for the survey work. The equipment setup and configuration diagram on the survey boat Polaris is placed at Appendix C to this document.

Table 2.6: Survey Equipment / Systems Deployed for Bathymetry Survey in Polaris

Equipment / System	Description / Make / Model/Resolution /Accuracies
Software / Navigation	Starfix.NG PC based data acquisition and survey vessel navigation package.
Positioning	Trimble BX-992 & Spatial Dual Receivers
Heading Sensor	Spatial Dual
Motion Sensor	Spatial Dual
Sound Velocity	Odom DigiBar Pro
Single beam Echosounder	Echotrac E20 Dual Frequency Single Beam Echosounder

Table 2.7: Survey Equipment / Systems Deployed for Topographical Survey

Equipment / System	Description / Make / Model/Resolution /Accuracies
Land Survey	GNSS RTK LYNX H6 System along with accessories and consumables.

2.7 Survey Vessel

Shallow draft boat 'Polaris' was used to carry out the bathymetry / hydrographic survey.

Figure 2.1: Survey boat Polaris

2.8 Survey Database Used

Details of all existing engineering structures within the survey area, as supplied by the Client and interface boundaries drawn between land and water body, shallow patches taken from Google Earth images, were used as a background file in the navigation system during the entire tenure of survey.

- Client supplied FRL/FSL RL height – 277.64 m w.r.t. MSL
- Full Supply Level (FSL) – 277.64 m w.r.t. MSL
- Water line – 274.07 m approximately.

3. Survey Data Acquisition

3.1 Survey planning, Preparation & Transportation to Site

The bathymetry survey equipment and personnel with survey boat 'Polaris' arrived at Machhannala reservoir location on 16 February 2021 and equipment was mobilised on-board the survey boat on 17 February 2021.

After field testing / verification / calibration of all survey equipment bathymetry survey was carried out and completed on 01 March 2021. Refer Appendix A to this document for diary of events.

The topography survey equipment and personnel arrived at Machhannala reservoir location and commenced survey on 21 June 2021. The topography survey was completed on 24 June 2021.

3.2 Equipment Setup Configuration and Calibration

All survey equipment was installed and configured on-board the survey boat as per the 'Equipment Layout Diagram' placed at Appendix C to this document.

The location of the various survey sensors on the survey boat is given in the 'Vessel Offset Diagram' placed at Appendix B to this document.

3.3 Field Calibration and Verifications

All equipment used for the survey work were calibrated and bench tested prior to their mobilisation for this task. In addition, after installation on the survey vessels, extensive calibration, verification and tests were carried out in the field before deploying them for actual data acquisition. Standard survey methods were used for carrying out these calibrations / verifications and data acquisition, as described in the following paragraphs.

Refer to Appendix D of this document for the 'Results of the Calibrations / Verifications of Survey Sensors'.

3.3.1 Heading Sensor Alignment

Vessel heading was obtained onboard 'Polaris' from Spatial Dual. Spatial dual features dual antenna moving baseline RTK. This enables it to provide extremely accurate heading both at rest and at movement. It's a great option for situations where magnetic heading isn't possible due to interference or where extra precision is required. The system was tested at FSINPVT workshop prior to mobilization for the survey. The performance of the system was found to be satisfactory during the period of survey.

3.3.2 Navigation System – DGNSS

The Positioning System on board 'Polaris' was Spatial Dual. Position observations were done at Machhannala reservoir benchmark locations, using Trimble BX-992 and Spatial Dual receiver. Refer Appendix E for Benchmark description and Appendix D for details on position system verification results. The performance of the system was found to be satisfactory. Summary of the results of the position system verification is tabulated below:

Table 3.1: Results of Positioning System Verification

Sensor	Serial No.	Easting (mE)	Northing (mN)	Latitude	Longitude	Ellipsoidal Height (m)
Positioning System Verification Results With BX-992 and Spatial Dual Receiver (Polaris)						
Trimble BX-992	025-00009601	415163.02	2550607.461	23°03'42.682"N	74°10'18.534"E	208.15
Spatial Dual	025-272968	415162.981	2550607.45	23°03'42.682"N	074°10'18.533"E	208.32
Difference		**0.039**	**0.011**	**--**	**--**	**-0.17**

3.3.3 Sound Velocity Measurements

Sound Velocity in the water column was measured in the survey area at regular intervals using sound velocity probe. Sound velocity profiles (cast) thus generated were used during post processing of SBES data.

3.3.4 Heave Compensator

Spatial dual is a high precision source for heave information. The system was tested at FSINPVT workshop prior to mobilization for the survey. The performance of the system was found to be satisfactory during the period of survey.

3.3.5 Single Beam Echosounder

Echotrac E20 dual frequency single beam echosounder was used for measuring water depths within the survey corridor. The echo sounder system was bench tested at FSINPVT workshop prior to mobilization for the survey. The echo sounder transducer was vertically side mounted on the survey boat and its draft below the waterline was measured and recorded. Heave compensator was connected to the echo sounder receiver. The echo sounder system was interfaced with the Starfix NG navigation and survey system for logging the depth vs position data. Sound velocity within water column was measured on a regular basis using sound velocity profiler and average sound velocity was entered in the top side unit of the echo sounder.

Table 3.2: Summary of Single Beam Echosounder Calibration Results by 'Bar Check' Method

Date	SBES Sensor Type	Average (m)	Standard Deviation
Summary of SBES Calibration Results on-board 'Polaris'			
17 February 2021	Echotrac E20 SBES	0.00	0.0038

3.4 Data Acquisition and Online Quality Control

On successful completion of mobilization and Calibration, Verification & Testing of all equipment as per the standard work practices, the survey data acquisition commenced as per the project plan to achieve the objectives of survey.

Navigation System, Heading and Bathymetry

The navigation data and vessel heading from the spatial dual, was logged continuously and monitored using the Starfix NG navigation suite. The survey data was logged in Fugro Binary Format (.FBF).

Event Markings

The on-line computer system was interfaced for closure to the analogue traces on the survey vessel. Event marks corresponding to position fixes were generated automatically from the on-line Navigation Computer interface at regular intervals of 25 m across the ground.

Survey Run-Line Logs

Survey lines were planned as per scope of work and digital pre-plots for the area was prepared prior to commencement of survey. These lines were run on the navigational computer while doing the survey and this enabled the Navigator to guide the boat along the planned survey line all the time. A survey line log was maintained which consists the particulars about the surveyed line, Date, Time, Session Number, Event Number, KP, Sensors Deployed and all the significant events occurred during the survey.

3.4.1 On-line QC of Data Logged

FSINPVT follows standard procedures and has standard formats for documenting the Quality Control of acquired data for each sensor deployed during the survey. Experienced operators were constantly monitoring the real time data quality as the survey progressed. A log of profiles was maintained, and quality of data was noted. Re-shoots of survey lines were carried out as and when required.

All computers connected to the Navigation network were synchronized with the GPS (high precision) 1PPS time signal by means of the Starfix Timing Module, allowing all data to be time stamped.

The quality of data being recorded was constantly monitored in real time and fine-tuned to obtain the best quality. The data / record obtained from each survey sensor such as Navigation, Heading, SBES and Spatial dual were quality checked and an extract of the same were made available for verification and confirmation to proceed further.

3.5 Topography Survey Control of Work

3.5.1 RTK Verification

The RTK system verification was carried out by 'Static Observations' for 30 minutes at Machhannala Dam Benchmark (FSL-TBM) and Temporary Benchmark location (TBM-02).

3.5.2 RTK Position Comparison

The RTK observed position at Machhannala benchmark (FSL-TBM) and Temporary Benchmark location (TBM-02) was compared with Trimble BX-992 Receiver position. Results of the comparison is tabulated below:

Table 3.3: Results of RTK Position Comparison

Sensor	Model No.	Easting (mE)	Northing (mN)
FSL-TBM (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	415163.020	2550607.461
RTK Rover 1	Lynx-H6	415163.042	2550607.455
Difference		-0.022	0.006
FSL-TBM (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	415163.020	2550607.461
RTK Rover 2	Lynx-H6	415163.018	2550607.465
Difference		0.002	-0.004
FSL-TBM (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	415163.020	2550607.461
RTK Rover 3	Lynx-H6	415163.030	2550607.464
Difference		-0.010	-0.003

Refer Appendix D for RTK comparison details.

3.5.3 Topographical Survey Methodology

The area not covered under hydrographic survey i.e., between the existing water level at the time of survey up to Full Supply Level (FSL)- 277.640 m has been carried out by topography survey method.

The topography survey was carried out using GNSS RTK Lynx-H6 system. The RTK system consist of two units i.e., Base receiver and Rover receiver. Corrected GPS signals are transmitted in real time from a base receiver at a known location to one or more rover receivers. Following steps were carried out while commencing and executing the topography survey operations:

- Components of Base and Rover receivers were setup at benchmark locations.
- Tripod was setup at base station i.e., at the temporary benchmark location (TBM-02) established by Fugro by levelling method and thereafter the tripod was levelled and the RTK base station was configured.
- The rover receiver along with RTK pole was installed at FSL-TBM location. Static observation was carried out subsequently as part of verification.
- The Base receiver is installed at TBM-02 and configured the system with known coordinates and elevation (levelling carried out by Fugro). The rover receiver position and elevation are verified by setting up the system at FSL-TBM.
- Thereafter survey commenced by placing the rover receiver at 25 m grid interval and logging the position (easting, northing) and the elevation in relation to the base.
- Whenever the radio RTK coverage between rover receiver and base receiver is reduced, new check points were created and the base receiver was shifted to this newly created check point.
- Above procedure was followed and survey completed from the existing water line till achieving the HFL mark.

Figure 3.1: Machhannala Dam Benchmark (FSL-TBM)

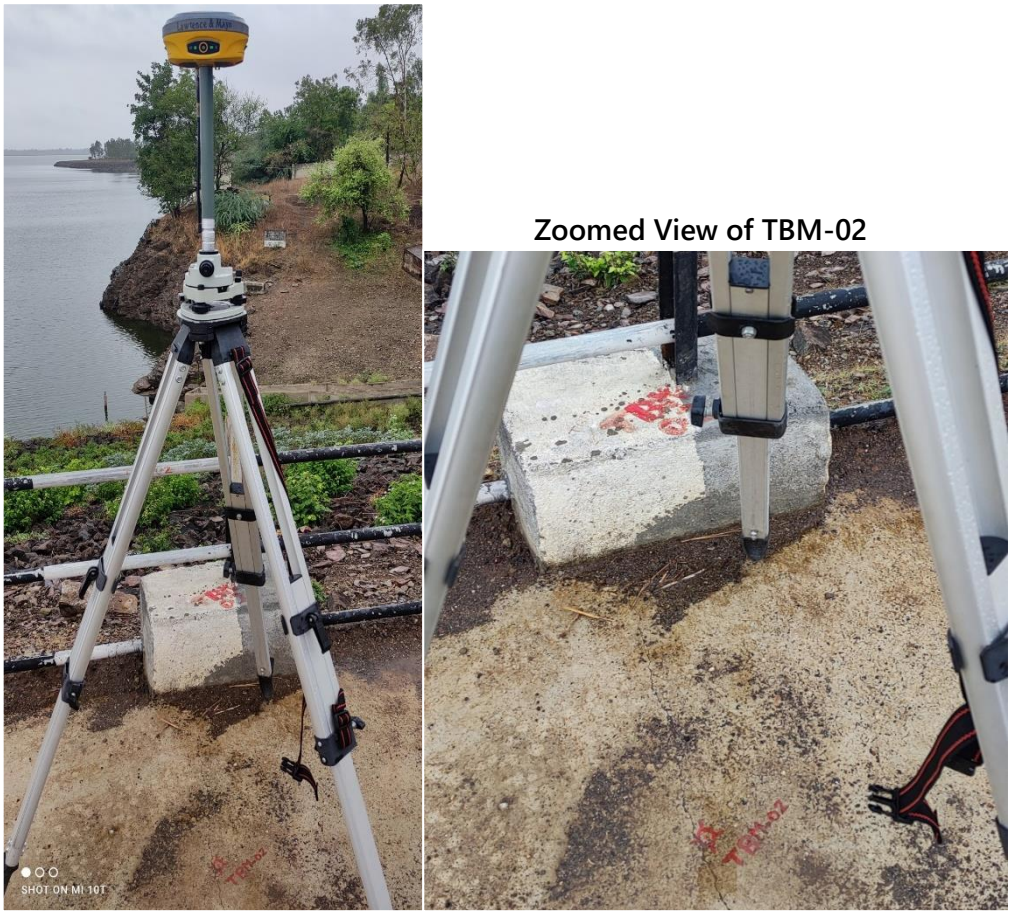

Figure 3.2: Temporary Benchmark (TBM-02)

Figure 3.3: Photograph showing rock exposure and steep relief of ground noticed close to waterline

3.6 Survey Coverage and Scope Completion

FSINPVT carried out the bathymetry and topography survey operation methodically to meet the client's objectives from this survey.

- The survey work was carried out on par with the mutually agreed scope and objectives mentioned in the Section 1.6 of this document.
- Survey scope from existing water level up to the Full Supply Level (FSL)- 277.640 m, was achieved by undertaking topography survey.

All the bathymetric survey lines were run at appropriate spacing i.e., 25 m, so as to obtain data of 25 m x 25 m grid points.

4. Data Processing and Interpretation

4.1 Navigation and Positioning

- The survey data was logged in Fugro Binary format (FBF), and processed using the Starfix.Proc software. Heading, motion and position data were processed and checked to ensure good data quality. The position data for the various survey sensors were processed and plotted to allow commencement of the interpretation of the bathymetry data.
- The measured offsets for all survey sensors were entered into the navigation system and processed using Starfix.Proc to enable track charts to be plotted and 'corrected' navigation files to be integrated with other sensor data at a later stage. These included:
    - GPS position absolute of the primary & secondary positioning systems.
    - Common Reference Point

4.2 Bathymetry Data Processing

- SBES bathymetry data was reduced to MSL, applying observed Reservoir Water Level / Height heights recorded at Dam. (Refer Figure 4.1)
- The data was filtered, cleaned, and combined to create geographically positioned bathymetric data set that has been corrected for MSL and sound speed.
- Starfix.Workbench & Mproc was used to quality check the data.

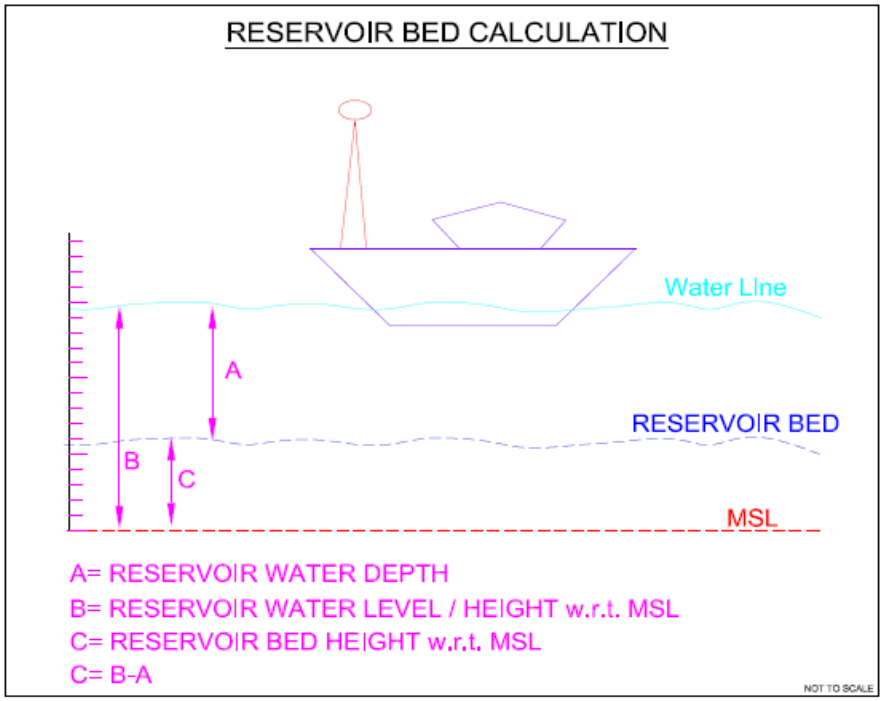

Figure 4.1: Reservoir Bed Height Calculation w.r.t. MSL

4.3 Creating Digital Terrain Model (DTM)

The bathymetric data and topographic data were then combined to create a vector point shapefile in GIS software. The boundary of the reservoir was then digitized around the point shapefile. Two types of boundary were constructed. First boundary is outside the reservoir and second type of boundary consisted of the boundary around islands in the reservoir. This point shapefile was then utilized for creation of DTM. The DTM for the reservoir can be created by use of various algorithms such as Kriging, Radial Basis function, Inverse Distance Weighting (IDW) method and local polynomial function. Among these various methods, IDW can give the best interpolation accuracy for reservoirs (Shiferaw and Abebe, 2020). IDW method is a weighted average interpolation method. For every grid node, the resulting value Z will be calculated using the formula as given in (1).

$$Z = \frac{\sum_{i=1}^{n} \frac{Z_i}{r_i^p}}{\sum_{i=1}^{n} \frac{1}{r_i^p}} \quad (1)$$

Where:

- Z_i is the known value at point i,
- r_i is the distance from grid node to point i,
- p is the weighting power,
- n is the number of points in Search Ellipse.

Therefore, in this study IDW method has been used for the interpolation for the creation of DTM. The DTM thus created was saved in Tiff format. The created DTM was smoothed by use of various filtering operations. Thereafter, the DTM was clipped through extract by mask operations using the mask of boundary shapefiles created before. The final DTM thus obtained after clipping the DTM was then used for further analysis.

Contour maps at 1 m interval was also prepared using the DTM in Starfix.Workbench software.

4.4 Development of Area Capacity Curves

Area Capacity curves are useful tools for operational and planning purposes such as water management and sediment monitoring. By comparing the area capacity curves at different times, the rate of sedimentation in the reservoirs can be determined. These curves show the capacity and surface area of the reservoir at an indicated elevation above the reference elevation level. The elevation area capacity curves are prepared using the DTM for the reservoir site. For, this study the reference elevation level used for the preparation of Area capacity curve is 258.6 m which is the lowest bed level for the reservoir and the maximum level considered is 277.640 m which is Full Supply Level (FSL) of the reservoir. The incremental value for elevation used for developing these curves is kept at 0.1 m. The surface area at the successive intervals was obtained in GIS software by intersecting the DTM with horizontal planes at an interval of 0.1 m starting from the zero-bed elevation till the MWL. The incremental volume (ΔV_i) between two contours was then calculated and integrated from bottom to specified elevation to obtain

the required capacity at specified elevation. The method and formula used for volume calculation is the cone formula given by the equation 2.

$$\Delta V = \frac{h}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right) \quad (2)$$

Where, ΔV is the incremental volume between two successive elevations; h is the incremental height between two successive elevations; A1 and A2 are the areas of two successive elevations.

4.5 Sedimentation in Different Zones of Reservoir

The sediment entering into the reservoir carried by the flowing river from the upstream catchments get deposited in the reservoir with the passage of time and reduces the live as well as dead storage capacity of the reservoir. This causes the bed level near the dam to rise. Live storage is from the level MDDL to FRL. Dead storage is from Bed Level to MDDL. Gross storage is from Bed Level to FRL. The sedimentation in different zones of reservoir is shown in Figure 4.2.

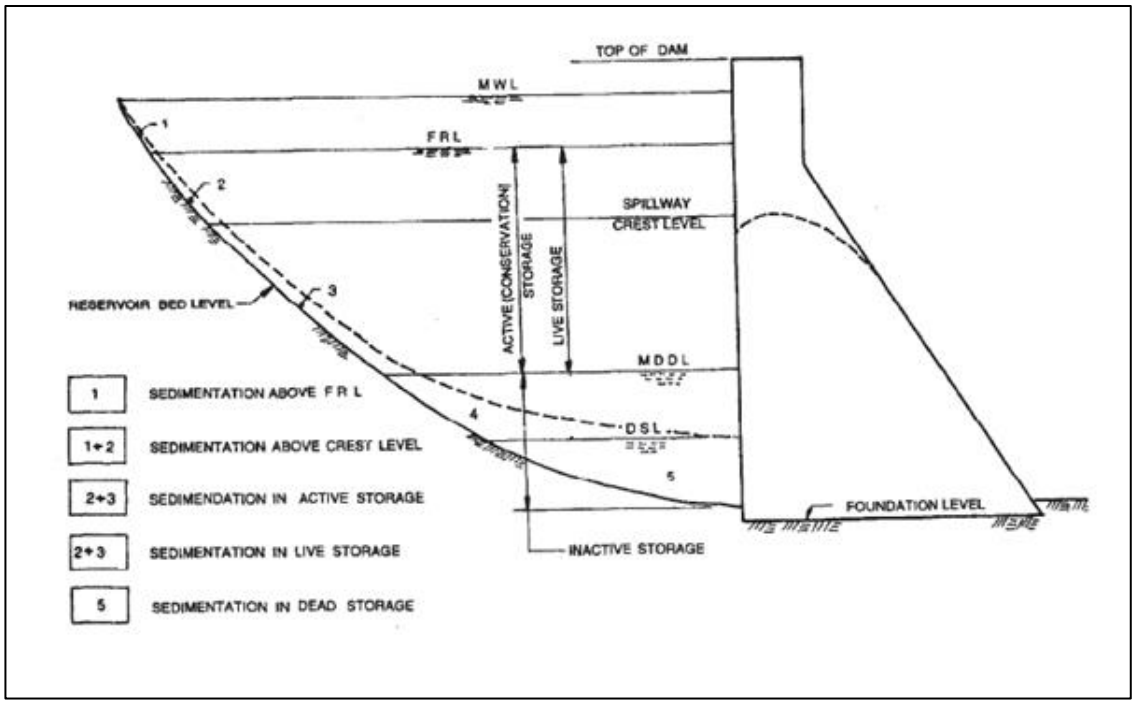

Figure 4.2: Sedimentation in different zones of reservoir (Ref: IS 5477-Part 1,1999)

The trap efficiency and the silt index has been calculated based on the methodology given in IS 12182, 1987. The gross capacity of reservoir as per present survey at FSL is 33.11 Mm^3 and client supplied Mean Annual inflow is 54.65 Mm^3. The values of trap efficiency were calculated using Brune's curve for the capacity inflow ratio for the reservoir. The silt index is calculated as the ratio of period of retention and flow velocity in the reservoir. The details of the calculations of period of retention and flow velocity are given in standard codes such as IS 12182, 1987. The values for Machhannala reservoir are shown in Table 5.4.

At last, sedimentation volumes are compared with sedimentation volumes from previous year surveys (if available) and rate of sedimentation, loss of capacity as well as annual loss percentage is computed and compared with the values of previous years (if available) to arrive at meaningful conclusions. The sedimentation quantities as well as loss of storage capacities, rate of siltation as well as trap efficiency and sedimentation index are shown in Section 5.3.

The Sedimentation rate and Annual % loss is calculated using the equations (3) and (4)

$$\textit{Sedimentation rate (Ha m/ 100 Sq km/year)} = \frac{100 * \text{loss of gross capacity (Ha m)}}{\text{Catchment Area (Sq km)} * \text{Number of years between the surveys}} \quad (3)$$

$$\textit{Annual \% loss} = \frac{\text{Annual Sedimentation rate (M cu m)}}{\text{Original Gross capacity of reservoir (M cu m)}} \; x \; 100 \quad (4)$$

4.6 Charting the Results of Bathymetry and Topography Data

- Chart showing reservoir bed heights are provided for the current survey at 1:6000 scale.
- Chart showing contour map at 1 m interval for Machhannala reservoir is also provided at 1:6000 scale.
- Chart showing reservoir bed relief image prepared from bathymetry and topography survey data is provided at 1:6000 scale.
- L-section of the reservoir and C-section at 100 m interval are provided as soft copy.

The results of the survey were submitted as per the documents in the 'List of Deliverables' placed at Appendix G.

5. Survey Results – Machhannala Reservoir

Survey results are detailed in the following sections. The following text should be read in conjunction with the Charts as listed in Appendix G to this document.

Data acquisition for Machhannala reservoir was carried out up to Full Supply Level (FSL)/Full Reservoir Level (FRL) of 277.64 m.

5.1 Reservoir Bed Heights

The lowest reservoir bed level was found at the upstream face of the dam & it becomes less deeper as we go further upstream from the dam face.

The reservoir topography was uneven with reservoir bed level ranging 258.60 m to 277.64 m w.r.t. MSL.

The reservoir bed tends to get shallower as we go further towards east, west & south away from the reservoir dam wall within the survey area. Reservoir area is spreading towards east, west and south directions. At eastern side two islands are observed, while at southern side, one island is observed within the reservoir area.

Lowest reservoir bed level recorded was 258.6 m (415 146 mE, 2 550 256 mN) w.r.t. MSL, within the survey area.

The following figures show the gridded bathymetry and topography data for the Machhannala reservoir.

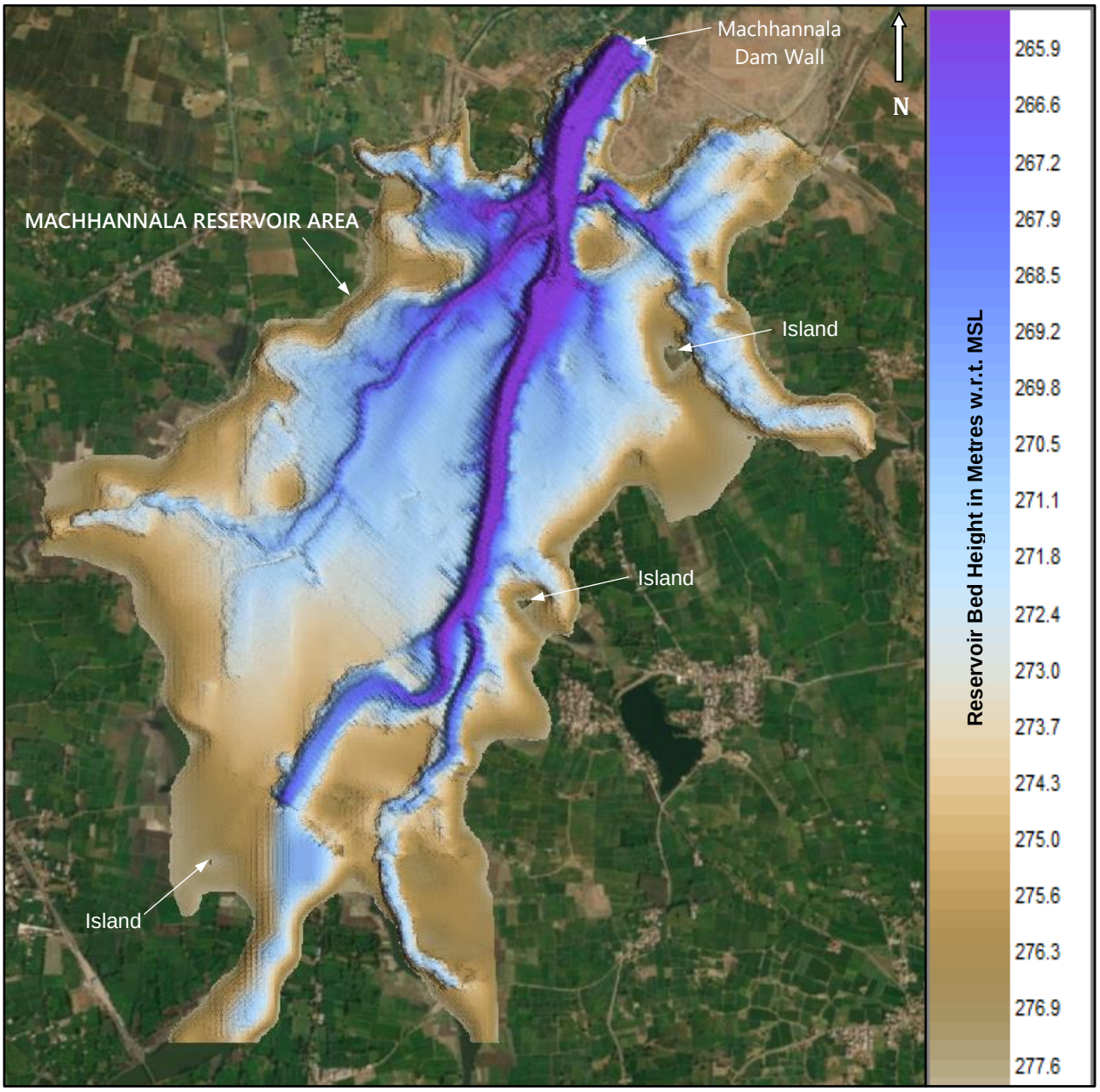

Figure 5.1: Image showing gridded SBES Bathymetry and topography data (superimposed with satellite imagery) of reservoir bed heights in metres from lowest bed level to FRL

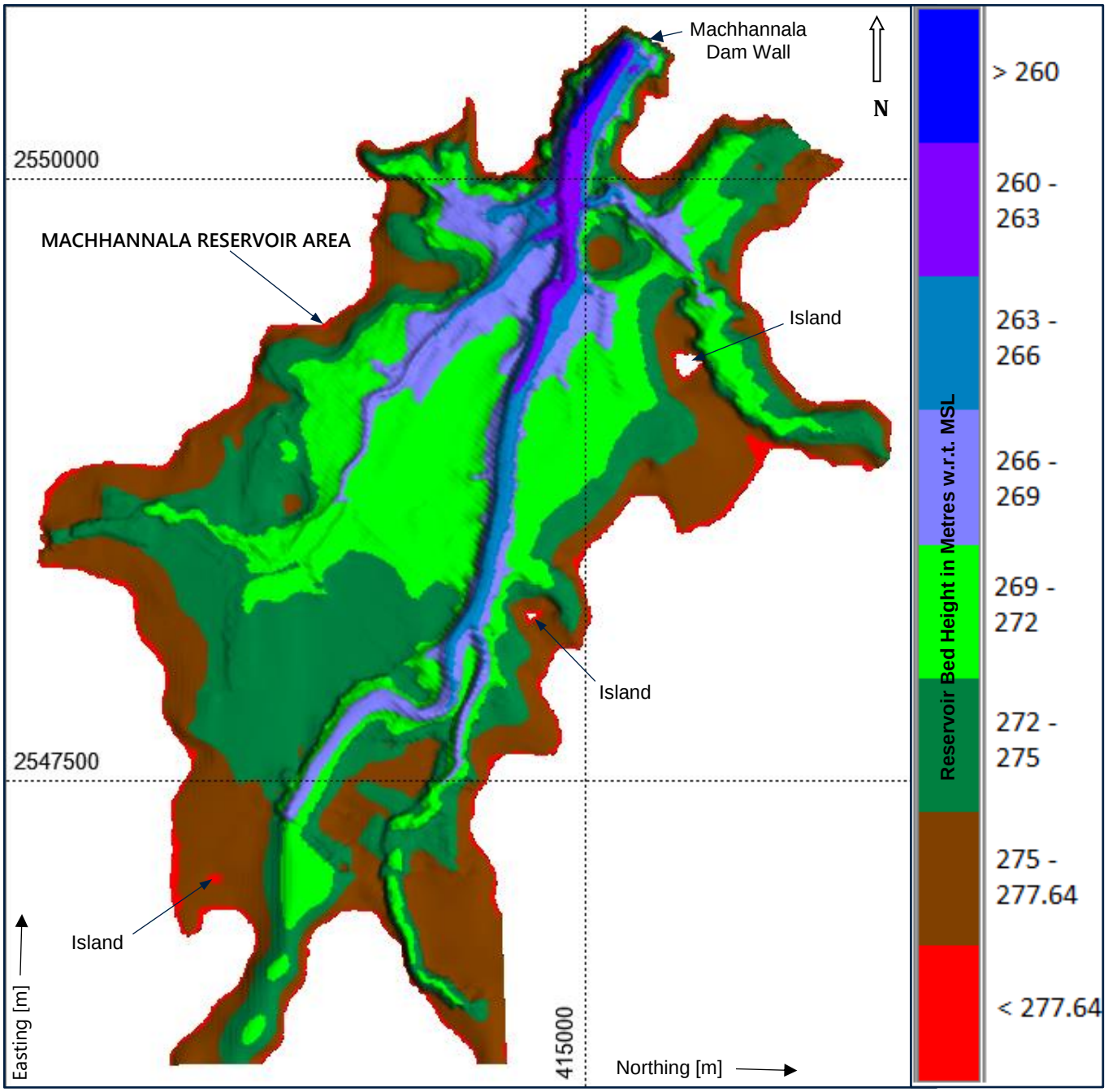

Figure 5.2: Image showing gridded SBES Bathymetry and topography data of reservoir bed heights in metres from lowest bed level to FRL.

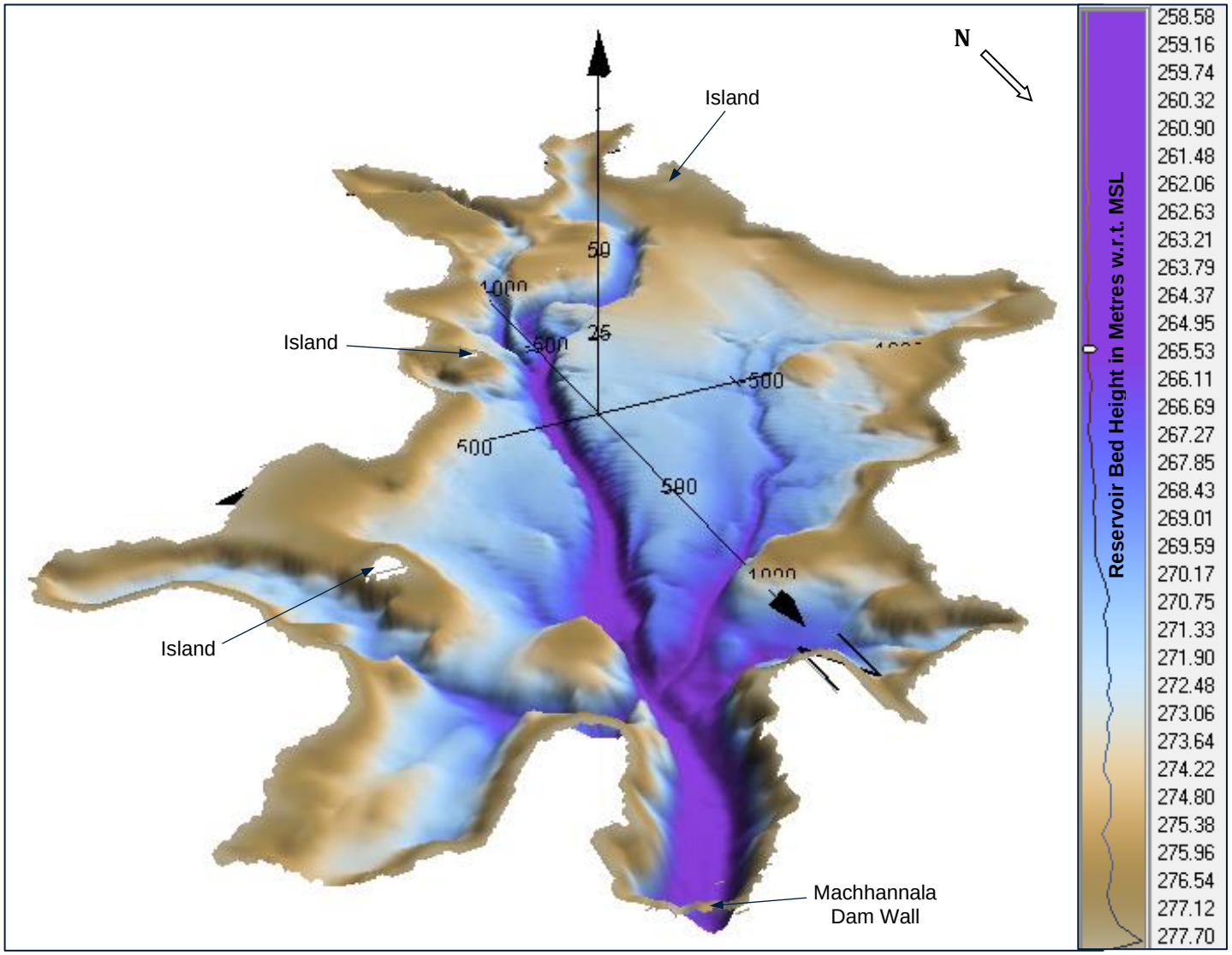

Figure 5.3: 3D view of Machhannala Reservoir

Photograph A: Rocky Island in Northern part of the Machhannala Reservoir (415083 mE, 2549897 mN)

Photograph B: North-western most approachable part of the Machhannala Reservoir (414026 mE, 2550161 mN) with shallow water depth

Photograph C: Southernmost approachable part of the Machhannala Reservoir (413663 mE, 2547271 mN) with partially submerged section of road and shallow water depth.

Photograph D: Western most approachable part of Machhannala Reservoir (412936 mE, 2548668 mN) with shallow water depth.

Figure 5.4: Photographs A, B, C and D showing rock exposures and shallow depths in the northern, north-western, southern and western areas within Machhannala Reservoir respectively

5.2 Elevation Area Capacity Curve (2021)

The area and capacity of the Machhannala reservoir was tabulated against the respective increasing elevation starting from lowest bed elevation (i.e., 258.60 m) up to FRL (277.64 m) at an increment of 0.1 m as shown in Table 5.1. Area capacity curve for Machhannala reservoir is shown in Figure 5.5.

Table 5.1: Revised Elevation Area Capacity table at every 0.1 m interval starting from lowest bed level to FRL for the Survey Year 2021

Elevation Area Capacity Table (2021): Machhannala Dam				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
1	258.60	0.000	0.000	Bed level
2	258.70	0.001	0.000	-
3	258.80	0.002	0.000	-
4	258.90	0.004	0.000	-
5	259.00	0.005	0.001	-
6	259.10	0.006	0.001	-
7	259.20	0.008	0.002	-
8	259.30	0.009	0.003	-
9	259.40	0.010	0.004	-
10	259.50	0.011	0.005	-
11	259.60	0.012	0.006	-
12	259.70	0.013	0.007	-
13	259.80	0.015	0.009	-
14	259.90	0.016	0.010	-
15	260.00	0.017	0.012	-
16	260.10	0.020	0.014	-
17	260.20	0.024	0.016	-
18	260.30	0.028	0.019	-
19	260.40	0.031	0.022	-
20	260.50	0.035	0.025	-
21	260.60	0.038	0.029	-
22	260.70	0.041	0.033	-
23	260.80	0.044	0.037	-
24	260.90	0.047	0.041	-
25	261.00	0.050	0.046	-
26	261.10	0.053	0.051	-
27	261.20	0.056	0.057	-
28	261.30	0.059	0.063	-
29	261.40	0.062	0.069	-
30	261.50	0.064	0.075	-
31	261.60	0.067	0.082	-
32	261.70	0.069	0.088	-
33	261.80	0.072	0.095	-

Elevation Area Capacity Table (2021): Machhannala Dam				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
34	261.90	0.074	0.103	-
35	262.00	0.077	0.110	-
36	262.10	0.079	0.118	-
37	262.20	0.083	0.126	-
38	262.30	0.086	0.135	-
39	262.40	0.091	0.144	-
40	262.50	0.098	0.153	-
41	262.60	0.105	0.163	-
42	262.70	0.113	0.174	-
43	262.80	0.119	0.186	-
44	262.90	0.125	0.198	-
45	263.00	0.132	0.211	-
46	263.10	0.140	0.224	-
47	263.20	0.147	0.239	-
48	263.30	0.155	0.254	-
49	263.40	0.163	0.270	-
50	263.50	0.171	0.286	-
51	263.60	0.178	0.304	-
52	263.70	0.186	0.322	-
53	263.80	0.193	0.341	-
54	263.90	0.200	0.361	-
55	264.00	0.209	0.381	-
56	264.10	0.218	0.402	-
57	264.20	0.224	0.425	-
58	264.30	0.230	0.447	-
59	264.40	0.237	0.471	-
60	264.50	0.245	0.495	-
61	264.60	0.254	0.520	-
62	264.70	0.262	0.545	-
63	264.80	0.270	0.572	-
64	264.90	0.278	0.599	-
65	265.00	0.285	0.628	-
66	265.10	0.293	0.656	-

Elevation Area Capacity Table (2021): Machhannala Dam				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
67	265.20	0.301	0.686	-
68	265.30	0.309	0.717	-
69	265.40	0.317	0.748	-
70	265.50	0.325	0.780	-
71	265.60	0.333	0.813	-
72	265.70	0.342	0.847	-
73	265.80	0.350	0.881	-
74	265.90	0.360	0.917	-
75	266.00	0.369	0.953	-
76	266.10	0.379	0.991	-
77	266.20	0.389	1.029	-
78	266.30	0.398	1.068	-
79	266.40	0.410	1.109	-
80	266.50	0.422	1.150	-
81	266.60	0.435	1.193	-
82	266.70	0.447	1.237	-
83	266.80	0.460	1.283	-
84	266.90	0.475	1.329	-
85	267.00	0.491	1.378	-
86	267.10	0.506	1.427	-
87	267.20	0.522	1.479	-
88	267.30	0.538	1.532	-
89	267.40	0.554	1.586	-
90	267.50	0.570	1.643	-
91	267.60	0.588	1.700	-
92	267.70	0.608	1.760	-
93	267.80	0.629	1.822	-
94	267.90	0.650	1.886	-
95	268.00	0.673	1.952	-
96	268.10	0.696	2.021	-
97	268.20	0.719	2.091	-
98	268.30	0.743	2.164	-
99	268.40	0.767	2.240	-
100	268.50	0.793	2.318	-
101	268.60	0.820	2.399	-
102	268.70	0.846	2.482	-
103	268.80	0.870	2.568	-
104	268.90	0.893	2.656	-
105	269.00	0.917	2.746	-
106	269.10	0.942	2.839	-
107	269.20	0.968	2.935	-

Elevation Area Capacity Table (2021): Machhannala Dam				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
108	269.30	0.995	3.033	-
109	269.40	1.026	3.134	-
110	269.50	1.059	3.238	-
111	269.60	1.092	3.346	-
112	269.70	1.128	3.457	-
113	269.80	1.165	3.571	-
114	269.90	1.204	3.690	-
115	270.00	1.247	3.812	-
116	270.10	1.307	3.940	-
117	270.20	1.362	4.074	-
118	270.30	1.419	4.213	-
119	270.40	1.479	4.357	-
120	270.50	1.546	4.509	-
121	270.60	1.608	4.666	-
122	270.70	1.674	4.830	-
123	270.80	1.746	5.001	-
124	270.90	1.821	5.180	-
125	271.00	1.882	5.365	-
126	271.10	1.944	5.556	-
127	271.20	2.005	5.754	-
128	271.30	2.071	5.957	-
129	271.31	2.090	6.020	MDDL
130	271.40	2.141	6.168	-
131	271.50	2.222	6.386	-
132	271.60	2.304	6.612	-
133	271.70	2.378	6.846	-
134	271.80	2.454	7.088	-
135	271.90	2.526	7.337	-
136	272.00	2.592	7.593	-
137	272.10	2.657	7.856	-
138	272.20	2.723	8.124	-
139	272.30	2.792	8.400	-
140	272.40	2.864	8.683	-
141	272.50	2.939	8.973	-
142	272.60	3.018	9.271	-
143	272.70	3.096	9.577	-
144	272.80	3.172	9.890	-
145	272.90	3.254	10.211	-
146	273.00	3.336	10.541	-
147	273.10	3.411	10.878	-
148	273.20	3.477	11.223	-

Elevation Area Capacity Table (2021): Machhannala Dam				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
149	273.30	3.539	11.573	-
150	273.40	3.590	11.930	-
151	273.50	3.642	12.291	-
152	273.60	3.694	12.658	-
153	273.70	3.751	13.030	-
154	273.80	3.808	13.408	-
155	273.90	3.867	13.792	-
156	274.00	3.931	14.182	-
157	274.10	3.997	14.578	-
158	274.20	4.066	14.982	-
159	274.30	4.130	15.391	-
160	274.40	4.199	15.808	-
161	274.50	4.274	16.231	-
162	274.60	4.345	16.662	-
163	274.70	4.417	17.100	-
164	274.80	4.490	17.546	-
165	274.90	4.562	17.998	-
166	275.00	4.638	18.458	-
167	275.10	4.709	18.926	-
168	275.20	4.779	19.400	-
169	275.30	4.849	19.882	-
170	275.40	4.917	20.370	-
171	275.50	4.983	20.865	-
172	275.60	5.049	21.366	-
173	275.70	5.112	21.874	-
174	275.80	5.175	22.389	-
175	275.90	5.240	22.910	-
176	276.00	5.311	23.437	-
177	276.10	5.407	23.973	-
178	276.20	5.483	24.517	-
179	276.30	5.553	25.069	-
180	276.40	5.622	25.628	-
181	276.50	5.691	26.194	-
182	276.60	5.760	26.766	-
183	276.70	5.828	27.346	-
184	276.80	5.897	27.932	-
185	276.90	5.960	28.525	-
186	277.00	6.024	29.124	-
187	277.10	6.087	29.729	-
188	277.20	6.150	30.341	-
189	277.30	6.215	30.959	-

Elevation Area Capacity Table (2021): Machhannala Dam				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
190	277.40	6.283	31.584	-
191	277.50	6.355	32.216	-
192	277.60	6.429	32.856	-
193	277.64	6.460	33.110	FRL
194	277.70	6.502	33.502	-

5.3 Comparison of Elevation Capacity Details

Comparison of the elevation capacity details for the year 2021 with the capacity for the previous years 1982 and 1999 are shown in Table 5.2. In addition, the comparison plots of capacity curve for the year 2021, 1999, and 1982 are shown in Figure 5.5.

In general, the 2021 survey results indicate that there is loss in gross storage capacity w.r.t. 1982 project capacity. However, w.r.t. 1999 results, the 2021 survey results indicate increase in gross storage capacity between FRL and 271.64 m. Below 217.64 m there is decrease in the gross storage capacity.

Table 5.2: Comparison of Elevation Capacity details of 2021, 1999 and 1982 data

Sr. No	Elevation (wrt MSL) [m]	Original 1982	Survey in year 1999	Survey in year 2021	
		Gross Capacity [Mm^3]	Gross Capacity [Mm^3]	Gross Capacity [Mm^3]	Area [km^2]
1	277.64	37.91	27.12	33.10	6.46
2	276.64	30.38	22.25	26.99	5.79
3	275.64	23.94	17.85	21.56	5.07
4	274.64	19.46	14.01	16.84	4.37
5	273.64	14.99	10.81	12.80	3.72
6	272.64	11.41	8.35	9.42	3.05
7	271.64	9.42	6.45	6.74	2.33
8	270.64	7.44	4.85	4.77	1.63
9	269.64	5.88	3.62	3.40	1.11
10	268.64	5.07	2.69	2.44	0.83
11	267.64	4.27	1.94	1.73	0.60
12	266.64	3.39	1.38	1.21	0.44
13	265.64	2.41	0.99	0.83	0.34
14	264.64	1.42	0.68	0.53	0.26
15	263.64	0.69	0.44	0.31	0.18
16	262.64	0.42	0.26	0.17	0.11
17	261.64	0.23	0.15	0.08	0.07
18	260.64	0.17	0.08	0.03	0.04
19	259.64	0.11	0.033	0.005	0.013
20	258.64	0.05	0.0028	0.0001	0.0003

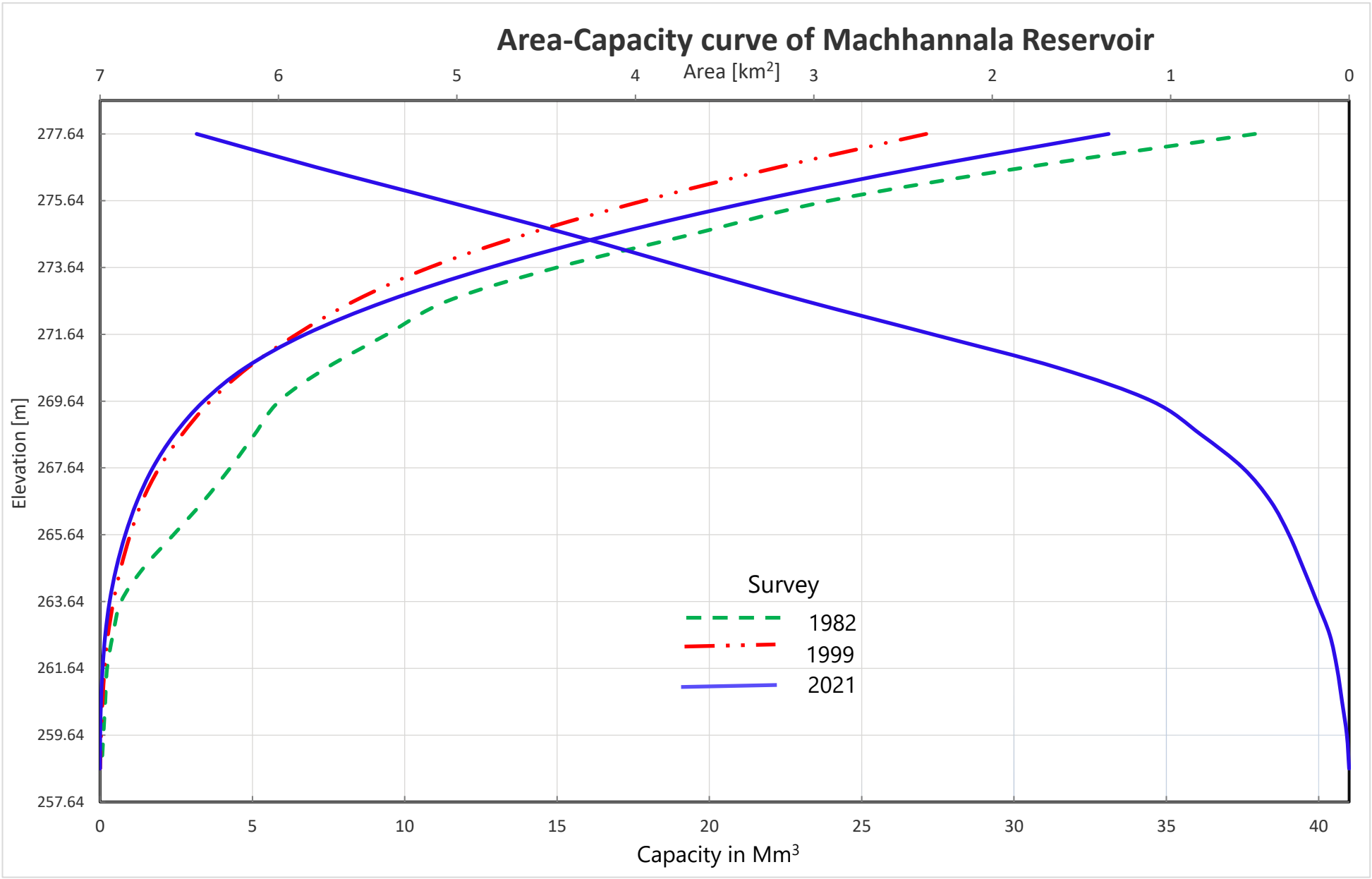

Figure 5.5: Area capacity curve for 2021 survey compared with elevation capacity details of 1982 and 1999 for Machhannala Reservoir

5.4 Sedimentation in Reservoir

The present survey of Machhannala reservoir was carried out between February -March 2021 and June 2021. Previous survey was carried out in the year 1999. The catchment area considered for sedimentation studies is 244.91 km^2. In the present study, the age of the reservoir is considered as 39 years (1982 – 2021). As per 2020-2021 survey, the total area of reservoir at FRL 277.64 m is 6.46 km^2 and the corresponding gross storage capacity is 33.11 Mm^3. Table 5.3 details the gross capacity loss, rate of sedimentation and annual % loss in gross storage capacity w.r.t. original project capacity (1982).

Table 5.3: Sedimentation in Machhannala Reservoir

Year	1982	1999	2021	2021
Storage Capacity in Mm^3				
Dead	8.75	5.92	6.02	6.02
Live	29.16	21.20	27.09	27.09
Gross	37.91	27.12	33.11	33.11
Loss of Storage Capacity in Mm^3		(wrt 1982)	(wrt 1999)	(wrt 1982)
Dead	NA	2.83	-0.10	2.73
Live	NA	7.96	-5.89	2.07
Gross	NA	10.79	-5.99	4.80
Sedimentation Rate in Ham/100 km^2/Year		(wrt 1982)	(wrt 1999)	(wrt 1982)
Dead	NA	6.80	-0.19	2.86
Live	NA	19.12	-10.93	2.17
Gross	3.35	25.92	-11.12	5.03
Annual % loss		(wrt 1982)	(wrt 1999)	(wrt 1982)
Dead		0.439	-0.017	0.18
Live		1.235	-0.987	0.14
Gross		1.674	-1.004	0.32
Class of reservoir as per IS - 12182 (1987)	As per design	Serious	Desiltation	Significant
Volume of sediment (w.r.t. 1982) deposited on bed in 2021= Loss of storage capacity= 4.80 Mm^3				
Note: Sign Convention: -ve sign shows desiltation and +ve sign shows siltation				

Table 5.4 gives the results of the Trap efficiency and Sedimentation Index calculated for Machhannala reservoir as per the methodology given in IS 12182-1987.

Table 5.4: Trap Efficiency and Sedimentation Index for Machhannala Reservoir

Trap Efficiency	Sedimentation Index
95%	7.38 x 10^{10} (sec^2/m)

In Table 5.3, the Project data of 1982 has been compared with 2021 survey results to understand the sedimentation in Machhannala reservoir. It may be observed that there is a reduction in the storage capacity of the reservoir due to siltation.

In comparison with 1999 survey, the present survey results indicate desiltation process in the reservoir. As per 1999 survey results, serious siltation in the reservoir was reported when it was compared with 1982 (original capacity) survey. The reason behind the present survey results showing siltation w.r.t. 1982 Original capacity could be due to change of upstream catchment characteristics. Also, there could be some anthropogenic activities in the catchment area which might result in siltation in the reservoir. The classification of reservoir from "Serious" category reported in the year 1999 to "Significant" category in the year 2021 (w.r.t. 1982 Project data) indicate decrease in annual % loss in gross capacity.

Table 5.5: Sedimentation Volumes from Surveys of Previous Year

Sr. No.	Year of Survey	Source of Data	Period (years)	Reservoir Capacity (Mm^3)			Loss of Gross Capacity (Mm^3)			Observed Rate of Sedimentation Since 1982 survey (Ha m / 100 Sq km/Yr)
				Gross	Live	Dead	Since 1982 survey	% Cumulative	Remark	
1	1982 (Original)	St Govt (HS)	-	37.91	29.16	8.75				
2	1999	St Govt (HS)	17	27.12	21.2	5.92	10.79	28.46	Siltation	25.92
3	2021	Present survey	39	33.11	27.09	6.02	4.80	12.66	Desiltation	5.03

- As per 2021 survey results, the volume of sediment deposited or the loss in gross storage capacity w.r.t. 1982 Project data is 4.80 Mm^3.
- The rate of siltation in Machhannala reservoir is 0.123 Mm^3/year.
- The average rate of siltation in the Machhannala reservoir during the 39 years life span (1982 – 2021), works out to 5.03 Ha m/100 sq km/year.
- The annual % loss in Machhannala reservoir during the 39 years life span is 0.32 % and hence, the reservoir is classified as "Significant" category as per IS 12182 (1987).
- Trap Efficiency and sedimentation Index calculated for Machhannala reservoir as per methodology give in IS 12182-1987 is 95% and 7.38 x 1010 (sec2/m) respectively.

Table 5.6 gives the gross, live and dead storage capacity from bed level to FRL at 0.1 m interval.

Table 5.6: Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Machhannala reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
1	258.60	0.000	--	0.000	**Bed level**
2	258.70	0.000	--	0.000	--
3	258.80	0.000	--	0.000	--
4	258.90	0.000	--	0.000	--
5	259.00	0.001	--	0.001	--
6	259.10	0.001	--	0.001	--
7	259.20	0.002	--	0.002	--
8	259.30	0.003	--	0.003	--
9	259.40	0.004	--	0.004	--
10	259.50	0.005	--	0.005	--
11	259.60	0.006	--	0.006	--
12	259.70	0.007	--	0.007	--
13	259.80	0.009	--	0.009	--
14	259.90	0.010	--	0.010	--
15	260.00	0.012	--	0.012	--
16	260.10	0.014	--	0.014	--
17	260.20	0.016	--	0.016	--
18	260.30	0.019	--	0.019	--
19	260.40	0.022	--	0.022	--
20	260.50	0.025	--	0.025	--
21	260.60	0.029	--	0.029	--
22	260.70	0.033	--	0.033	--
23	260.80	0.037	--	0.037	--
24	260.90	0.041	--	0.041	--
25	261.00	0.046	--	0.046	--
26	261.10	0.051	--	0.051	--
27	261.20	0.057	--	0.057	--
28	261.30	0.063	--	0.063	--
29	261.40	0.069	--	0.069	--
30	261.50	0.075	--	0.075	--
31	261.60	0.082	--	0.082	--
32	261.70	0.088	--	0.088	--
33	261.80	0.095	--	0.095	--
34	261.90	0.103	--	0.103	--
35	262.00	0.110	--	0.110	--
36	262.10	0.118	--	0.118	--
37	262.20	0.126	--	0.126	--
38	262.30	0.135	--	0.135	--
39	262.40	0.144	--	0.144	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Machhannala reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
40	262.50	0.153	--	0.153	--
41	262.60	0.163	--	0.163	--
42	262.70	0.174	--	0.174	--
43	262.80	0.186	--	0.186	--
44	262.90	0.198	--	0.198	--
45	263.00	0.211	--	0.211	--
46	263.10	0.224	--	0.224	--
47	263.20	0.239	--	0.239	--
48	263.30	0.254	--	0.254	--
49	263.40	0.270	--	0.270	--
50	263.50	0.286	--	0.286	--
51	263.60	0.304	--	0.304	--
52	263.70	0.322	--	0.322	--
53	263.80	0.341	--	0.341	--
54	263.90	0.361	--	0.361	--
55	264.00	0.381	--	0.381	--
56	264.10	0.402	--	0.402	--
57	264.20	0.425	--	0.425	--
58	264.30	0.447	--	0.447	--
59	264.40	0.471	--	0.471	--
60	264.50	0.495	--	0.495	--
61	264.60	0.520	--	0.520	--
62	264.70	0.545	--	0.545	--
63	264.80	0.572	--	0.572	--
64	264.90	0.599	--	0.599	--
65	265.00	0.628	--	0.628	--
66	265.10	0.656	--	0.656	--
67	265.20	0.686	--	0.686	--
68	265.30	0.717	--	0.717	--
69	265.40	0.748	--	0.748	--
70	265.50	0.780	--	0.780	--
71	265.60	0.813	--	0.813	--
72	265.70	0.847	--	0.847	--
73	265.80	0.881	--	0.881	--
74	265.90	0.917	--	0.917	--
75	266.00	0.953	--	0.953	--
76	266.10	0.991	--	0.991	--
77	266.20	1.029	--	1.029	--
78	266.30	1.068	--	1.068	--
79	266.40	1.109	--	1.109	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Machhannala reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
80	266.50	1.150	--	1.150	--
81	266.60	1.193	--	1.193	--
82	266.70	1.237	--	1.237	--
83	266.80	1.283	--	1.283	--
84	266.90	1.329	--	1.329	--
85	267.00	1.378	--	1.378	--
86	267.10	1.427	--	1.427	--
87	267.20	1.479	--	1.479	--
88	267.30	1.532	--	1.532	--
89	267.40	1.586	--	1.586	--
90	267.50	1.643	--	1.643	--
91	267.60	1.700	--	1.700	--
92	267.70	1.760	--	1.760	--
93	267.80	1.822	--	1.822	--
94	267.90	1.886	--	1.886	--
95	268.00	1.952	--	1.952	--
96	268.10	2.021	--	2.021	--
97	268.20	2.091	--	2.091	--
98	268.30	2.164	--	2.164	--
99	268.40	2.240	--	2.240	--
100	268.50	2.318	--	2.318	--
101	268.60	2.399	--	2.399	--
102	268.70	2.482	--	2.482	--
103	268.80	2.568	--	2.568	--
104	268.90	2.656	--	2.656	--
105	269.00	2.746	--	2.746	--
106	269.10	2.839	--	2.839	--
107	269.20	2.935	--	2.935	--
108	269.30	3.033	--	3.033	--
109	269.40	3.134	--	3.134	--
110	269.50	3.238	--	3.238	--
111	269.60	3.346	--	3.346	--
112	269.70	3.457	--	3.457	--
113	269.80	3.571	--	3.571	--
114	269.90	3.690	--	3.690	--
115	270.00	3.812	--	3.812	--
116	270.10	3.940	--	3.940	--
117	270.20	4.074	--	4.074	--
118	270.30	4.213	--	4.213	--
119	270.40	4.357	--	4.357	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Machhannala reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
120	270.50	4.509	--	4.509	--
121	270.60	4.666	--	4.666	--
122	270.70	4.830	--	4.830	--
123	270.80	5.001	--	5.001	--
124	270.90	5.180	--	5.180	--
125	271.00	5.365	--	5.365	--
126	271.10	5.556	--	5.556	--
127	271.20	5.754	--	5.754	--
128	271.30	5.957	--	5.957	--
129	271.31	6.020	0.000	6.020	**MDDL**
130	271.40	6.168	0.148	6.020	--
131	271.50	6.386	0.366	6.020	--
132	271.60	6.612	0.592	6.020	--
133	271.70	6.846	0.826	6.020	--
134	271.80	7.088	1.068	6.020	--
135	271.90	7.337	1.317	6.020	--
136	272.00	7.593	1.573	6.020	--
137	272.10	7.856	1.836	6.020	--
138	272.20	8.124	2.104	6.020	--
139	272.30	8.400	2.380	6.020	--
140	272.40	8.683	2.663	6.020	--
141	272.50	8.973	2.953	6.020	--
142	272.60	9.271	3.251	6.020	--
143	272.70	9.577	3.557	6.020	--
144	272.80	9.890	3.870	6.020	--
145	272.90	10.211	4.191	6.020	--
146	273.00	10.541	4.521	6.020	--
147	273.10	10.878	4.858	6.020	--
148	273.20	11.223	5.203	6.020	--
149	273.30	11.573	5.553	6.020	--
150	273.40	11.930	5.910	6.020	--
151	273.50	12.291	6.271	6.020	--
152	273.60	12.658	6.638	6.020	--
153	273.70	13.030	7.010	6.020	--
154	273.80	13.408	7.388	6.020	--
155	273.90	13.792	7.772	6.020	--
156	274.00	14.182	8.162	6.020	--
157	274.10	14.578	8.558	6.020	--
158	274.20	14.982	8.962	6.020	--
159	274.30	15.391	9.371	6.020	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Machhannala reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
160	274.40	15.808	9.788	6.020	--
161	274.50	16.231	10.211	6.020	--
162	274.60	16.662	10.642	6.020	--
163	274.70	17.100	11.080	6.020	--
164	274.80	17.546	11.526	6.020	--
165	274.90	17.998	11.978	6.020	--
166	275.00	18.458	12.438	6.020	--
167	275.10	18.926	12.906	6.020	--
168	275.20	19.400	13.380	6.020	--
169	275.30	19.882	13.862	6.020	--
170	275.40	20.370	14.350	6.020	--
171	275.50	20.865	14.845	6.020	--
172	275.60	21.366	15.346	6.020	--
173	275.70	21.874	15.854	6.020	--
174	275.80	22.389	16.369	6.020	--
175	275.90	22.910	16.890	6.020	--
176	276.00	23.437	17.417	6.020	--
177	276.10	23.973	17.953	6.020	--
178	276.20	24.517	18.497	6.020	--
179	276.30	25.069	19.049	6.020	--
180	276.40	25.628	19.608	6.020	--
181	276.50	26.194	20.174	6.020	--
182	276.60	26.766	20.746	6.020	--
183	276.70	27.346	21.326	6.020	--
184	276.80	27.932	21.912	6.020	--
185	276.90	28.525	22.505	6.020	--
186	277.00	29.124	23.104	6.020	--
187	277.10	29.729	23.709	6.020	--
188	277.20	30.341	24.321	6.020	--
189	277.30	30.959	24.939	6.020	--
190	277.40	31.584	25.564	6.020	--
191	277.50	32.216	26.196	6.020	--
192	277.60	32.856	26.836	6.020	--
193	277.64	33.110	27.090	6.020	**FRL**

6. Conclusions

- The reservoir topography was uneven, with reservoir bed level ranging from 258.60 m to 277.64 m w.r.t. MSL. The lowest reservoir bed level 256.8 m was found near the upstream face of the dam boundary and it becomes shallower as we go further upstream from the dam face. Also, the reservoir bed tends to get shallower as we go further in east, west and south directions away from the dam wall within the survey area.
- Current survey results indicate that the loss of gross storage capacity (w.r.t. 1982 project data) due to siltation in Machhannala reservoir is 4.80 Mm^3. The probable reasons for the decrease of gross storage capacity could be change in hydrodynamics due to change of upstream discharges as sediment carrying capacity of the river and its tributaries. Moreover, the cause of changes could be anthropogenic intervention towards siltation of the reservoir.
- In comparison with 1982 survey results, 2021 results indicate decrease in storage capacity due to siltation. The annual % loss in gross storage capacity is 0.32 % and hence, the reservoir is classified as "Significant" category as per IS 12182 (1987).
- The sedimentation volumes, sedimentation rates, loss of storage capacity, trap efficiency, sedimentation index have been reported in the study. Moreover, the tables for gross, live and dead storage capacity of reservoir at every 0.1 m interval from lowest bed level to FRL have been provided.

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Appendix A

Diary of Events

(01 page)

Diary of Events (Bathymetry and Topography Survey)	
Date	**Events**
Bathymetry Survey	
16 February 2021	Survey personnel with survey boat 'Polaris' reached Machhannala reservoir.
17 February 2021	Polaris deployed on Machhannala reservoir and mobilization completed
18 February 2021	Calibration/verification started.
19 February 2021	Calibration/verification in progress
20 February 2021	Calibration/verification completed, and survey started.
21 - 28 February 2021	Survey continued.
01 March 2021	Survey completed and demobilization started.
02 March 2021	Demobilization completed.
Topography Survey	
21 June 2021	Topography survey team with equipment reached Machhannala Dam. Mobilisation and calibration commenced and completed.
22 June 2021	Topography survey commenced
23 June 2021	Topography survey continued.
24 June 2021	Topography survey completed.

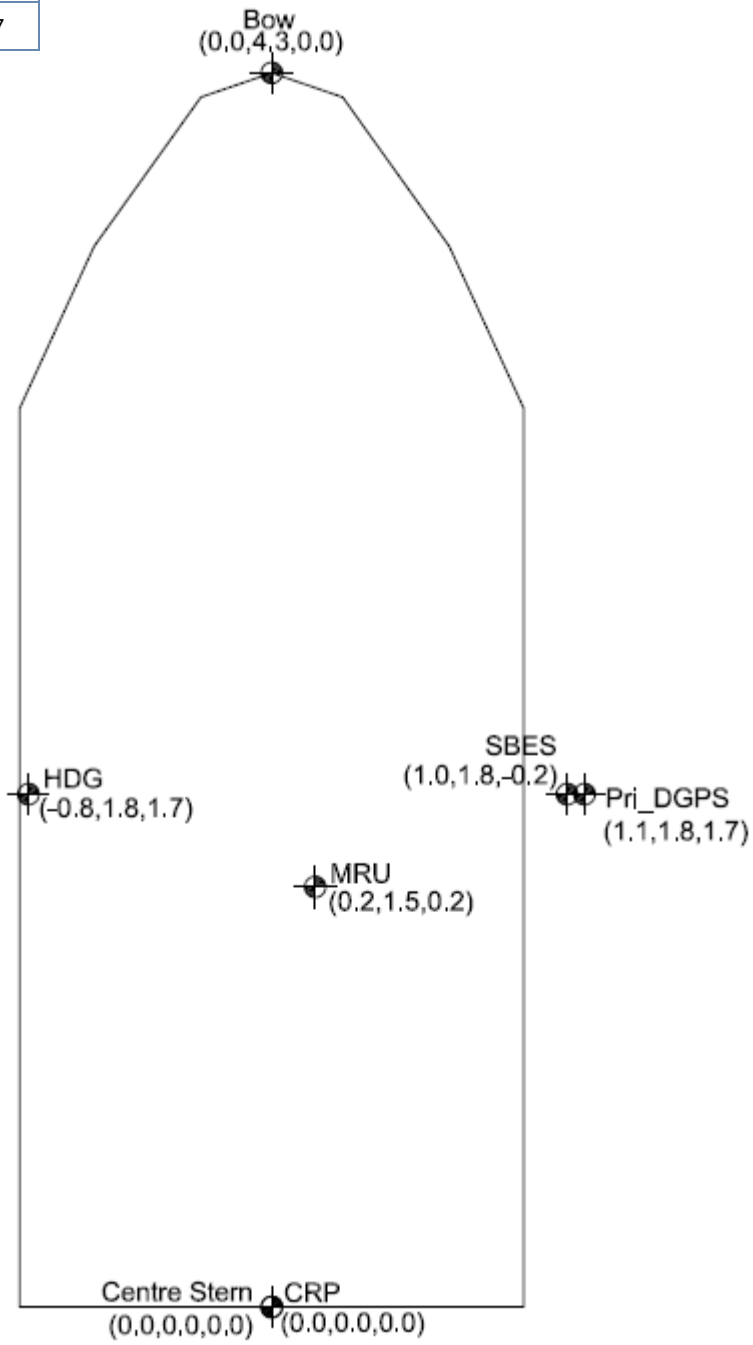
Appendix B

Survey Vessel Sensor Offsets

(01 Page)

Survey Vessel 'Polaris' Sensor Offset Diagram

Sensor Offsets: Polaris			
Starfix.Suite Name	**X [m]**	**Y [m]**	**Z [m]**
CRP	0.00	0.00	0.00
Centre Stern	0.00	0.00	0.00
Bow	0.00	4.26	0.00
Pri_DGPS	1.08	1.82	1.77
HDG	-0.84	1.82	1.77
SBES	1.02	1.77	-0.22
MRU	0.2	1.45	0.17

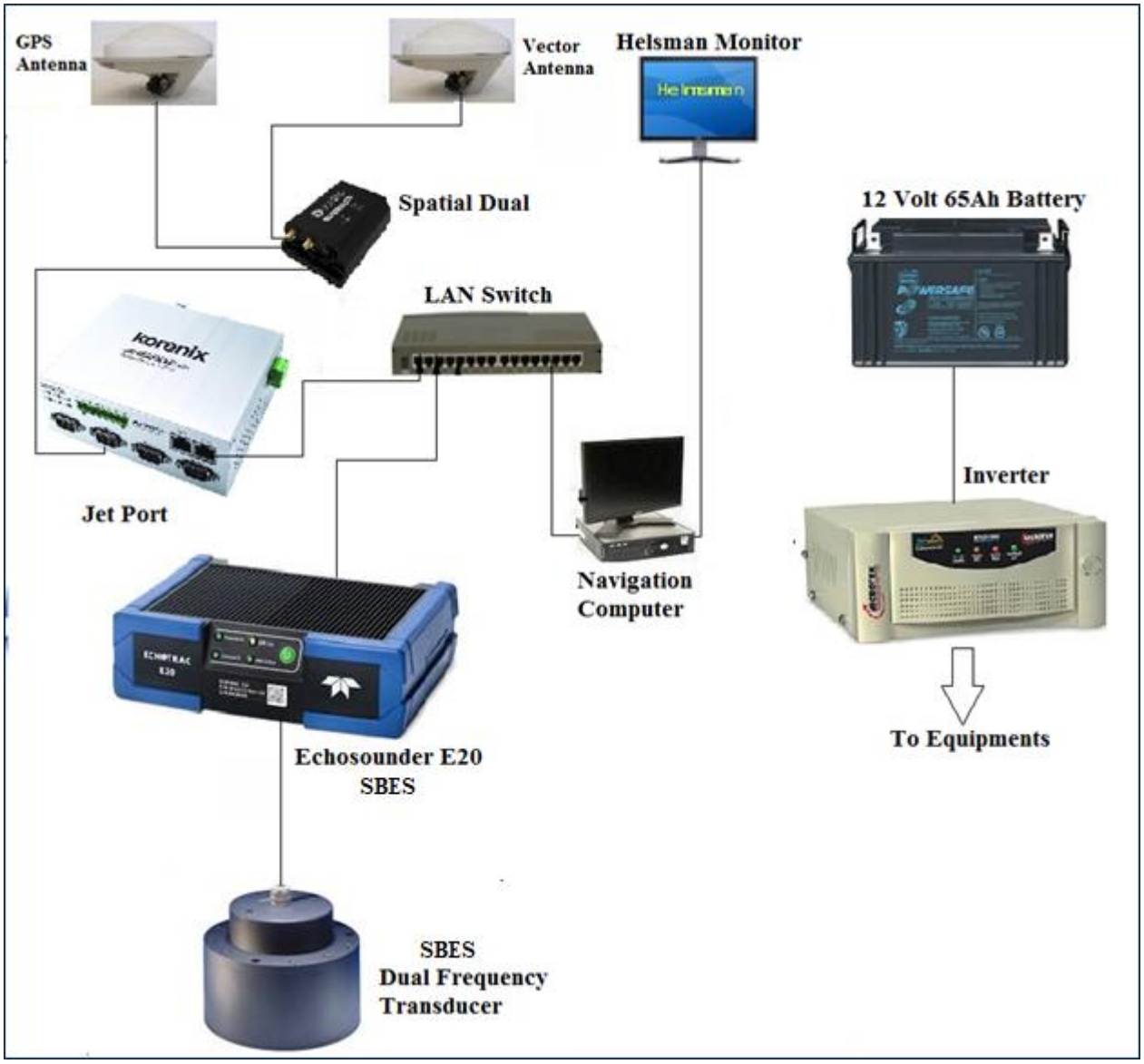


Appendix C

Equipment Layout Diagram

(01 Page)

Equipment Layout Diagram onboard Polaris



Appendix D

Results of Field Calibrations / Verifications

(18 pages)

FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of Machhannala Dam BM (FSL-TBM)

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	Machhannala Dam	**Location:**	Gujarat, West Coast of India
Party Chief :	Arpit Bose	**Job Engineer/Surveyor :**	Mathiazhagan V.
Date of Observation: (Date & Time)	19-02-2021 & 16:16hrs	**End of Observation: (Date & Time)**	19-02-2021 & 16:46hrs

1. Station Name: FSL-TBM.

Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
TRIMBLE BX992 RECEIVER	025-00009601	PRI_DGPS	Mean position report	FBF	NA	0.01

A= FSL-TBM Height from MSL 277.860m

B= Antenna Height from BM 0.720m (Measured by Tape)

Ellipsoidal height of Antenna= 208.870m

Ellipsoidal Height of BM 208.870m-0.72m=208.15m

C is the center point of BM.

Position Of Antenna:-

Latitude: 23°03'42.68277"N, **Longitude:** 74°10'18.53477"E

Easting: 4,15,163.020m E **Northing:** 25,50,607.461m N

Prepared By: Arpit Bose.

BATHYMETRIC SURVEY FOR RESERVOIRS
MEAN POSITION REPORT

Project ID	J-HYD-20-174630_clone		
Location	Central Gujarat		
Client	Narmada Water Resources Govt. of Gujarat	**Vessel**	Tripod
Comment			

Session Name: FSL-TBM-v3 Records Used: 1230 of 1789

Start Time: 19 Feb 2021, 16:16:03+05:30 End Time: 19 Feb 2021, 16:46:03+05:30 Session Length: 00:29:59

Mean Position for Tripod CentreOfGravity		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	23°03’42.68277”N	23°03’42.68277”N
Longitude	74°10’18.53477”E	74°10’18.53477”E
Height	208.870m Ell.	208.870m Ell.
Easting	4,15,163.020m E (SD: ±0.01m)	
Northing	25,50,607.461m N (SD: ±0.01m)	
Height	264.972m Ort. (SD: ±0.05m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	0.00°T 0.00°G	±0.0°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

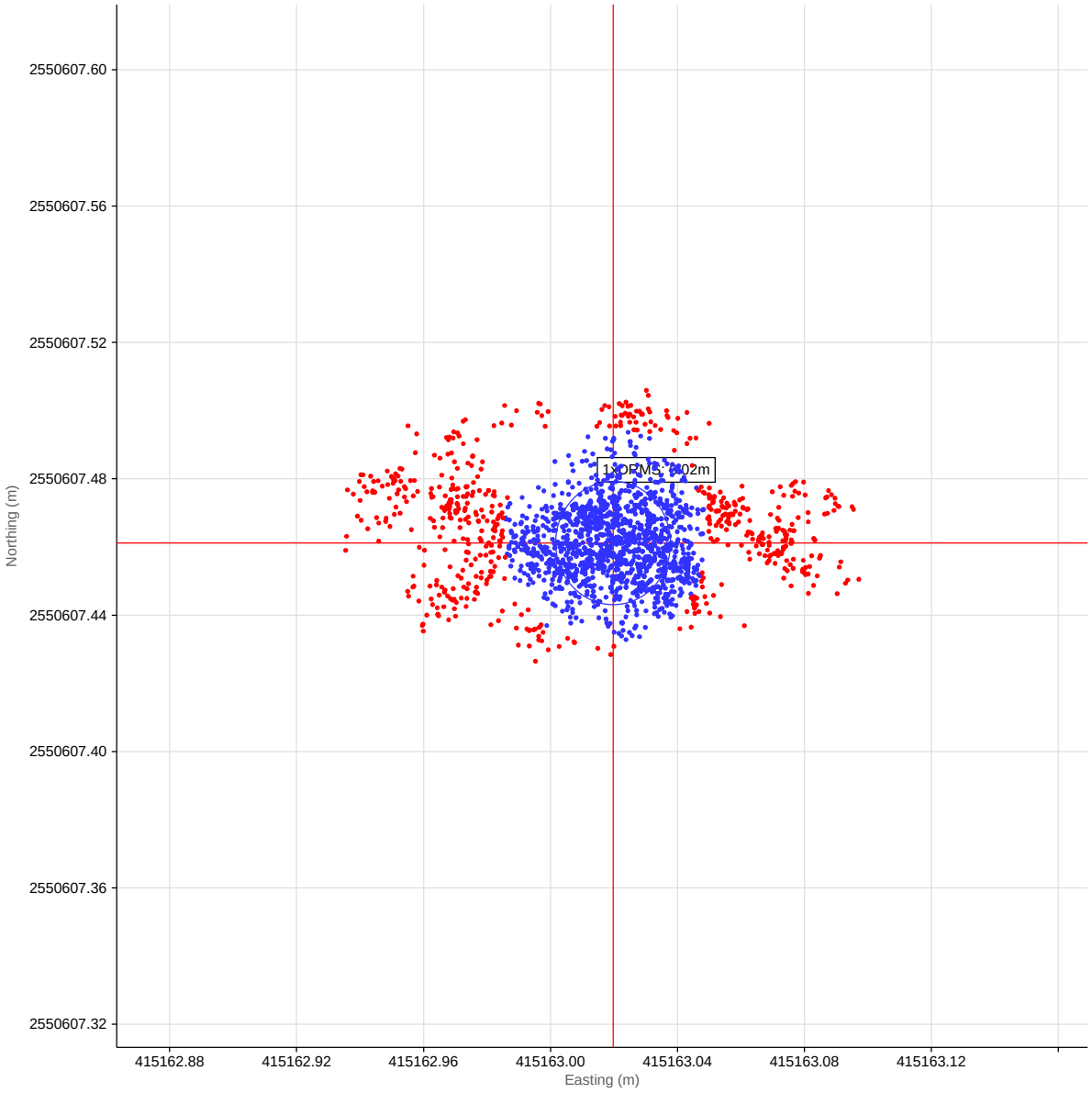
Arpit Bose
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Section Officer
End Client Representative
Narmada Water Resources Govt. of Gujarat

Geodetic Parameters

Name : WGS 84 / UTM zone 43N		
EPSG Code	EPSG::32643	
Local Geodetic Datum Parameters		
Datum	World Geodetic System 1984	EPSG::6326
Ellipsoid	WGS 84	
Semi major axis	a = 63,78,137.000 m	
Inverse flattening	1/f = 298.257223563	
Local Projection Parameters		
Map Projection	Transverse Mercator	
Grid System	UTM zone 43N	EPSG::16043
Latitude Origin	00° 00’ 00.000” N	
Central Meridian	075° 00’ 00.000” E	
Scale Factor on Central Meridian	0.9996	
False Easting	500 000 m	
False Northing	0 m	

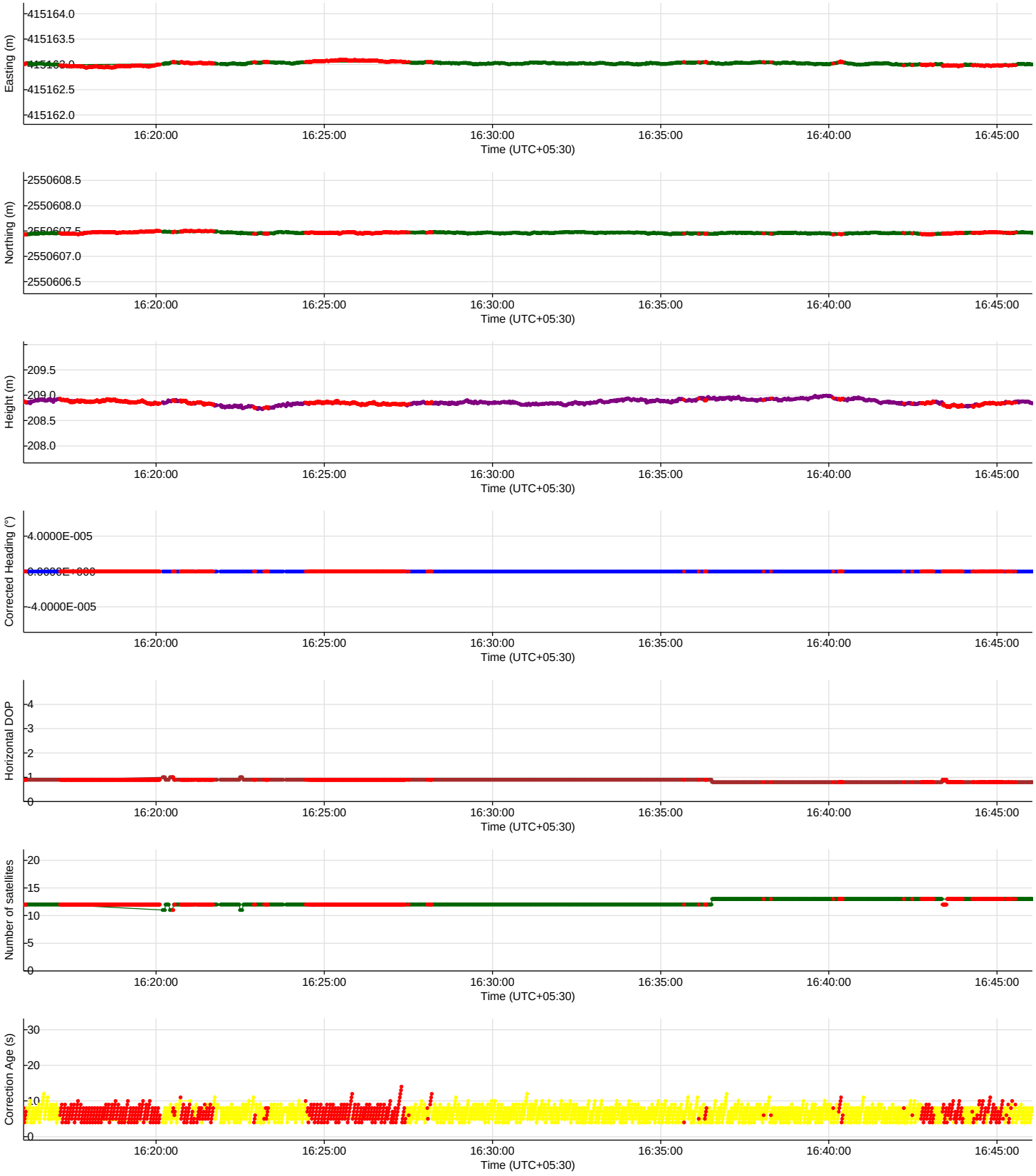
Scatter Plot



Mean Position

	Easting	Northing
Tripod	4,15,163.020m E	25,50,607.461m N

Time Series Plots for Tripod



FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of Machhannala Dam BM (FSL-TBM)

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	Machhannala Dam	**Location:**	Gujarat, West Coast of India
Party Chief :	Arpit Bose	**Job Engineer/Surveyor :**	Mathiazhagan V.
Date of Observation: (Date & Time)	19-02-2021 & 12:27hrs	**End of Observation: (Date & Time)**	19-02-2021 & 12:57hrs

1. Station Name: FSL-TBM.

Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
TRIMBLE BX992 RECEIVER	025-272968	PRI_DGPS	Mean position report	FBF	NA	0.01

A= FSL-TBM Height from MSL 277.860m

B= Antenna Height from BM 0.720m (Measured by Tape)

Ellipsoidal height of Antenna= 209.018m

Ellipsoidal Height of BM 209.018m-0.698m=208.320m

C is the center point of BM.

Position Of Antenna:-

Latitude: 23°03’42.68240”N **Longitude:** 074°10’18.53341”E
A

Easting: 4,15,162.981m E **Northing:** 25,50,607.450m N

Prepared By: Arpit Bose.

DAM SURVEY
MEAN POSITION REPORT

Project ID	Gujarat Dam		
Location	GUJARAT		
Client	Govt. of Gujarat	**Vessel**	Tripod
Comment			

Session Name: Spatial Dual -FSL-v1 Records Used: 1131 of 1799

Start Time: 20 Feb 2021, 12:27:57+05:30 End Time: 20 Feb 2021, 12:57:56+05:30 Session Length: 00:29:59

Mean Position for Tripod CentreOfGravity		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	23°03’42.68240”N	23°03’42.68240”N
Longitude	074°10’18.53341”E	074°10’18.53341”E
Height	209.018m Ell.	209.018m Ell.
Easting	4,15,162.981m E (SD: ±0.01m)	
Northing	25,50,607.450m N (SD: ±0.01m)	
Height	265.119m Ort. (SD: ±0.04m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	0.00°T 0.00°G	±0.0°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

Mean Position to Waypoint	
Waypoint	FSL
Easting	4,15,163.020m E
Northing	25,50,607.461m N
Range	0.04m Geodetic
Bearing TO	74.02°True
Bearing FROM	254.02°True

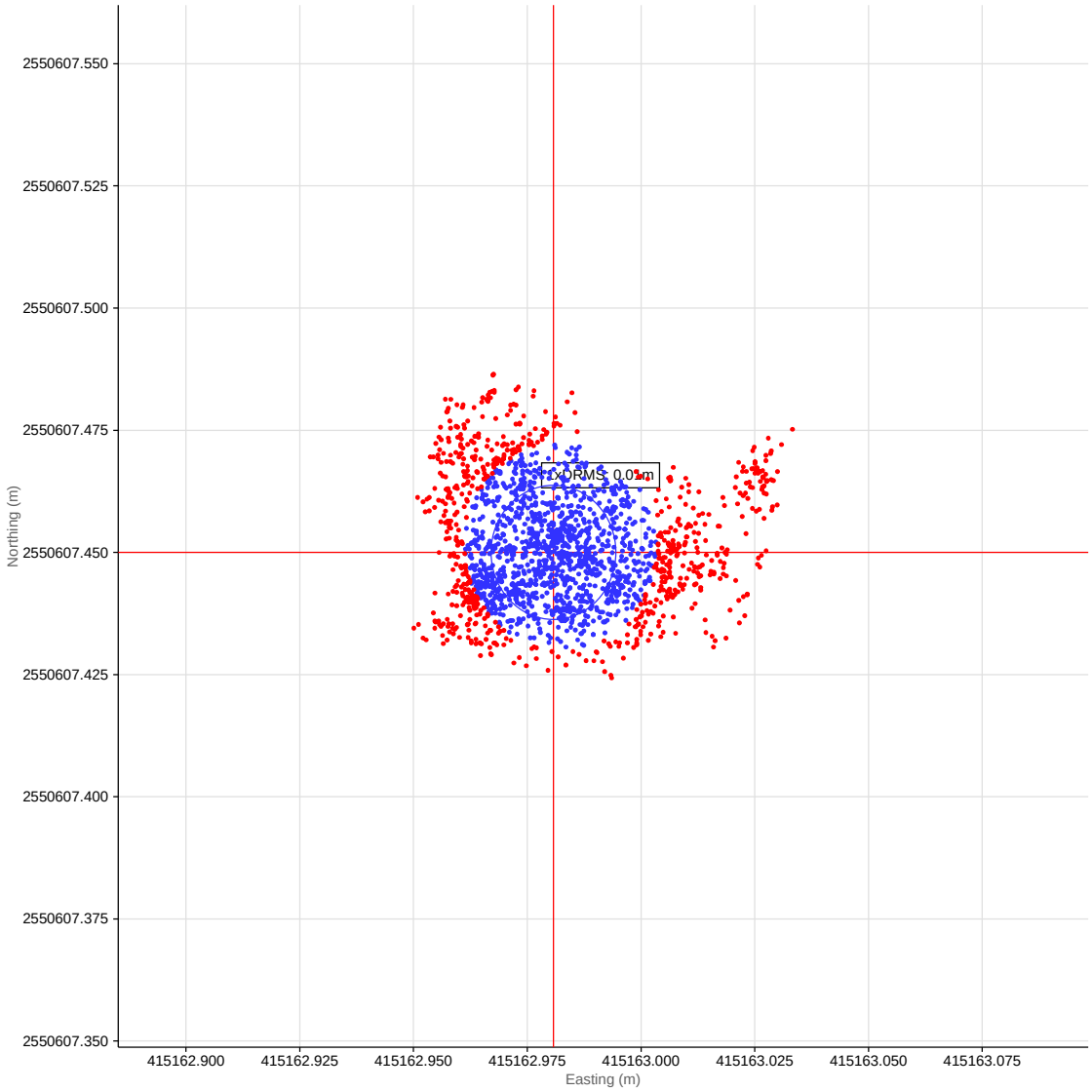
Arpit Bose
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Section Officer
Client Representative
Govt. of Gujarat

Geodetic Parameters

Name : WGS 84 / UTM zone 43N		
EPSG Code	EPSG::32643	
Local Geodetic Datum Parameters		
Datum	World Geodetic System 1984	EPSG::6326
Ellipsoid	WGS 84	
Semi major axis	a = 63,78,137.000 m	
Inverse flattening	1/f = 298.257223563	
Local Projection Parameters		
Map Projection	Transverse Mercator	
Grid System	UTM zone 43N	EPSG::16043
Latitude Origin	00° 00’ 00.000” N	
Central Meridian	075° 00’ 00.000” E	
Scale Factor on Central Meridian	0.9996	
False Easting	500 000 m	
False Northing	0 m	

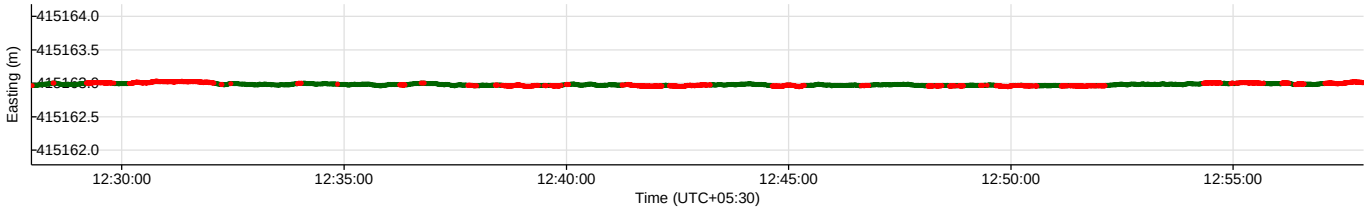
Scatter Plot

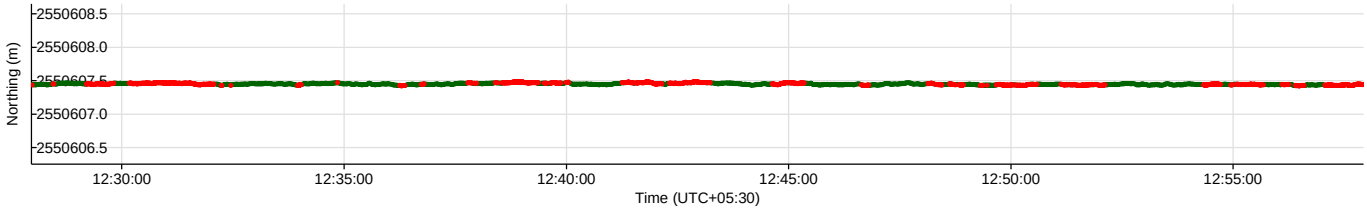


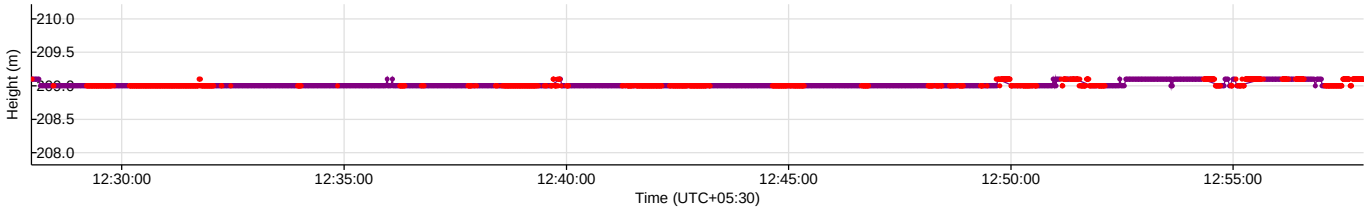
Mean Position

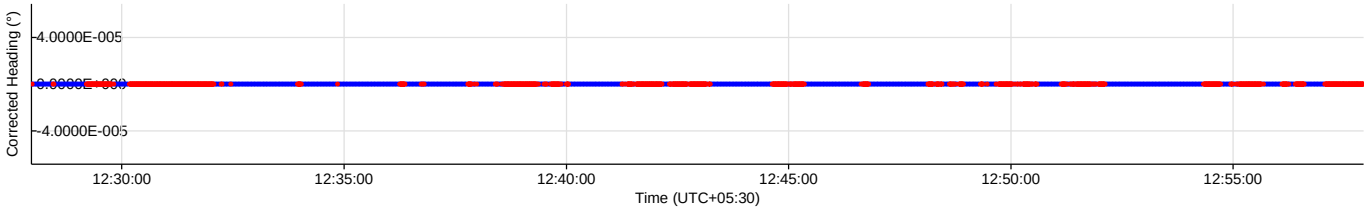
	Easting	Northing
Tripod	4,15,162.981m E	25,50,607.450m N

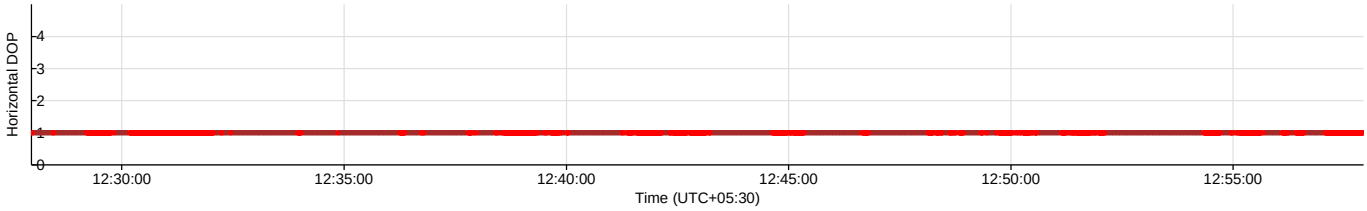
Time Series Plots for Tripod

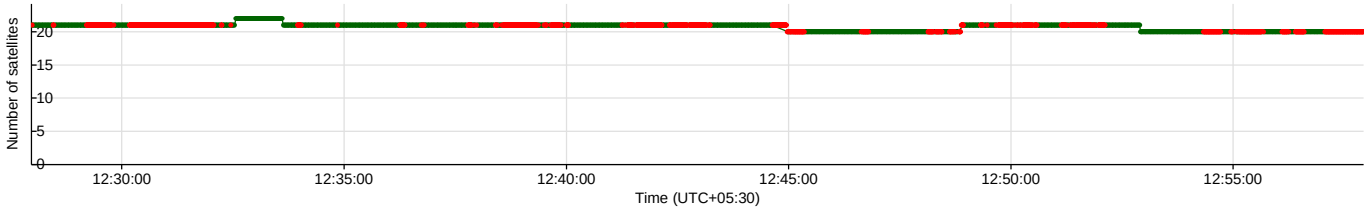


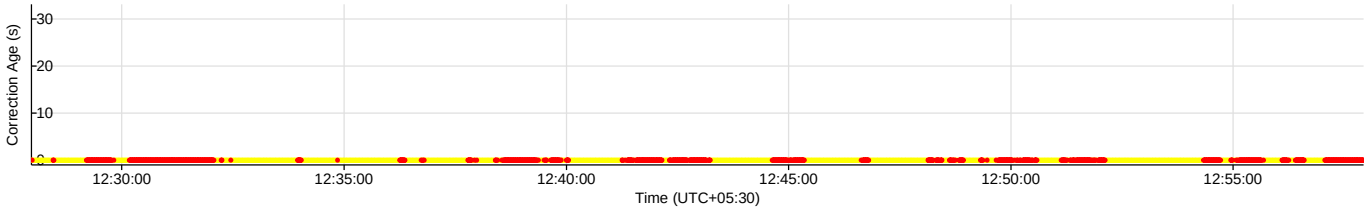












FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of Machhannala Dam Temporary BM (TBM-02)

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	Machhannala Dam	**Location:**	Gujarat, West Coast of India
Party Chief :	Arpit Bose	**Job Engineer/Surveyor :**	Mathiazhagan V.
Date of Observation: (Date & Time)	19-02-2021 & 17:49hrs	**End of Observation: (Date & Time)**	19-02-2021 & 18:19hrs

1. Station Name: TBM-02.

Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
TRIMBLE BX992 RECEIVER	025-00009601	PRI_DGPS	Mean position report	FBF	NA	0.04

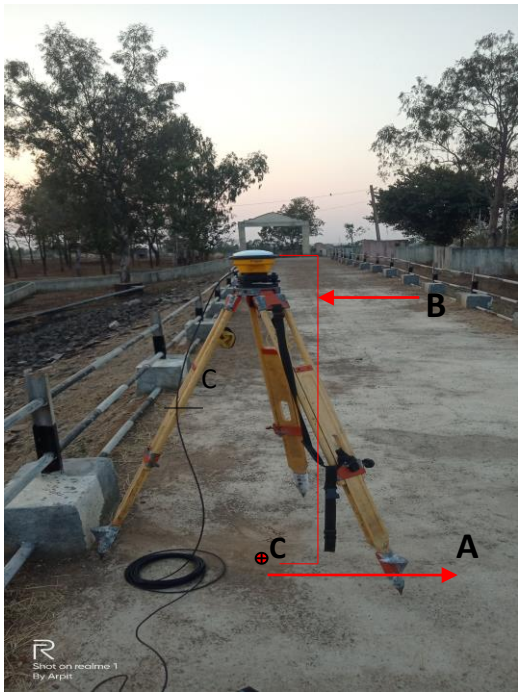
A= TBM-02 Height from MSL 283.986m

B= Antenna Height from BM 1.389m (Measure by Tape)

Ellipsoidal height of Antenna= 215.831m

Ellipsoidal Height of BM 215.831m-1.389m=214.442m

C is the center point of BM.



Position Of Antenna:-

Latitude: 23°03’43.72157”N, **Longitude:** 74°10’19.64787”E

Easting: 4,15,194.875m E**Northing:** 25,50,639.228m N

Prepared By: Arpit Bose.

BATHYMETRIC SURVEY FOR RESERVOIRS
MEAN POSITION REPORT

Project ID	J-HYD-20-174630_clone		
Location	Central Gujarat		
Client	Narmada Water Resources Govt. of Gujarat	**Vessel**	Tripod
Comment			

Session Name: TBM-02-MACHCHANALA DAM-v1 Records Used: 859 of 1799

Start Time: 19 Feb 2021, 17:49:16+05:30 End Time: 19 Feb 2021, 18:19:15+05:30 Session Length: 00:29:59

Mean Position for Tripod CentreOfGravity		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	23°03'43.72157"N	23°03'43.72157"N
Longitude	74°10'19.64787"E	74°10'19.64787"E
Height	215.831m Ell.	215.831m Ell.
Easting	4,15,194.875m E (SD: ±0.04m)	
Northing	25,50,639.228m N (SD: ±0.02m)	
Height	271.932m Ort. (SD: ±0.06m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	0.00°T 0.00°G	±0.0°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

Mean Position to Waypoint	
Waypoint	FSL
Easting	4,15,163.020m E
Northing	25,50,607.461m N
Range	45.00m Geodetic
Bearing TO	224.76°True
Bearing FROM	44.76°True

Arpit Bose
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Section Officer
End Client Representative
Narmada Water Resources Govt. of Gujarat

Geodetic Parameters

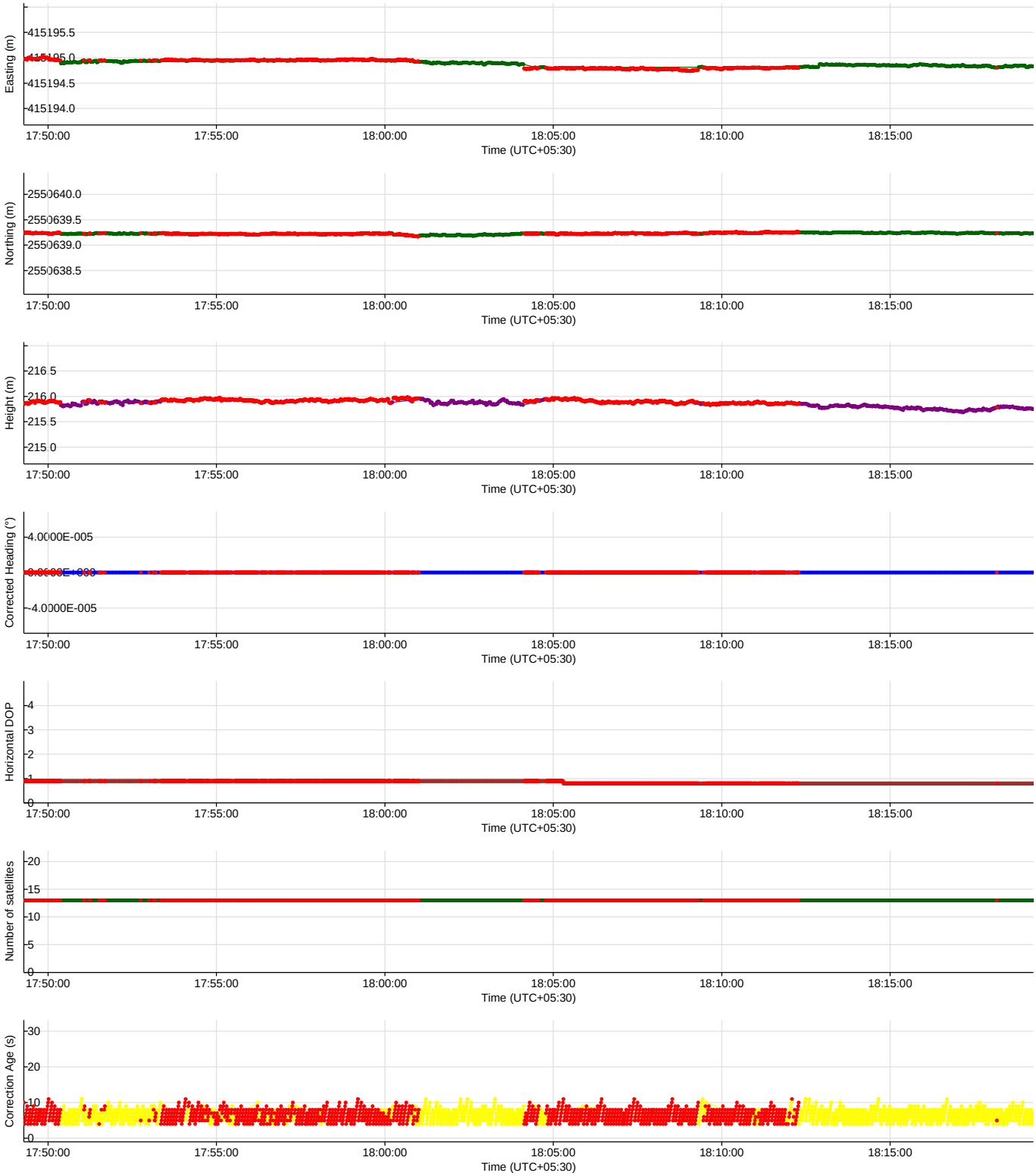
Name : WGS 84 / UTM zone 43N		
EPSG Code	EPSG::32643	
Local Geodetic Datum Parameters		
Datum	World Geodetic System 1984	EPSG::6326
Ellipsoid	WGS 84	
Semi major axis	a = 63,78,137.000 m	
Inverse flattening	1/f = 298.257223563	
Local Projection Parameters		
Map Projection	Transverse Mercator	
Grid System	UTM zone 43N	EPSG::16043
Latitude Origin	00° 00’ 00.000” N	
Central Meridian	075° 00’ 00.000” E	
Scale Factor on Central Meridian	0.9996	
False Easting	500 000 m	
False Northing	0 m	

Scatter Plot

Mean Position

	Easting	Northing
Tripod	4,15,194.875m E	25,50,639.228m N

Time Series Plots for Tripod



Station Name: FSL-TBM Machchanala Dam

Positioning System Verification With BX-992 Reciever and Spatial Dual						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Easting mE**	**Northing mN**	**Latitude**	**Longitude**	**Ellipsoidal height (m)**
TRIMBLE BX992 RECEIVER	025-00009601	415163.020	2550607.461	23°03'42.682"N	74°10'18.534"E	208.15
Spatial Dual	025-272968	415162.981	2550607.45	23°03'42.682"N	074°10'18.533"E	208.32
	Difference	**0.039**	**0.011**	**--**	**--**	**-0.17**

SBES Calibration

SBES Barcheck Correction Table

FUGRO

Project No.	Project Title:	Vessel:	Place:
J-HYD-20-174630	**Bathymetry Survey**	**POLARIS**	**MACHCHANALA DAM**
Date:	Time:	Client:	
17-Feb-21	**17:31**	**GOV. OF GUJRAT**	
Observed By: PRITAM SETH		Echo Sounder Model and SL. No.	Area Depth
Project No. J-HYD-20-174630		**E20 ECHOTRAC**	**10**

Echo Sounder Settings

Draft HI	Draft LO	Sound Velocity	
		Average	Upto Depth
0.3	**0.3**	**1483**	**10**
Barcheck Frequency selected	**Survey Frequency:**	Manufacturer's Accuracy	
High 200 KHz	**33 and 200 KHz**	0.10 % of Depth	0.01 m

Observations while lowering			Observations while hoisting		
Bar Depth (m)	ES Reading (m)	Difference (m)	Bar Depth (m)	ES Reading (m)	Difference (m)
1	1	0	8	8	0
2	2	0	7	7	0
3	3.01	-0.01	6	6	0
4	4	0	5	5	0
5	5	0	4	4	0
6	5.99	0.01	3	3	0
7	7	0	2	2	0
8	8	0	1	1	0

Average	0.00	Average	0.00
Std. Dev	0.0053	Std. Deviation	0.0000
		Cumulative Average	0.00
		Cumulative Std. Deviation	0.0038

Arpit Bose

Partychief
Arpit Bose
FSINPVT

Deputy Executive Engineer

Machhanala Dam,Govt. of Gujrat

Location Name:	Machhannala Dam	Date:	21/06/2021	Instrument Name	LYNX
Work:	RTK Observation by Topography Team			Model no.	H6

Station Name		Observation Duration	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)	Remarks	
Machhannala DAM FSL-TBM	By rover 1	2 sec	415163.042	2550607.455	277.881	XYZ Value generated by RTK of Topography Team, Base Station on Machhannala DAM TBM 2 Fugro Pr	Field Photo\IMG_20210621_104706.jpg
Machhannala DAM FSL-TBM	By rover 2	2 sec	415163.018	2550607.465	277.906	XYZ Value generated by RTK of Topography Team, Base Station on Machhannala DAM TBM 2 Fugro Pr	Field Photo\IMG_20210621_112053.jpg
Machhannala DAM FSL-TBM	By rover 3	2 sec	415163.030	2550607.464	277.911	XYZ Value generated by RTK of Topography Team, Base Station on Machhannala DAM TBM 2 Fugro Pr	Field Photo\IMG_20210621_112138.jpg

		Fugro Provided XYZ Value								Difference With Fugro Provided XYZ Value		
Station Name	Remarks	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)	Station Name	Remarks	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)
MACHHANALA DAM FSL-TBM	Fugro Provided Value	415163.020	2550607.461	277.860	Machhannala DAM FSL-TBM	Check by Rover 1	415163.042	2550607.455	277.881	-0.022	0.006	-0.021
					Machhannala DAM FSL-TBM	Check by Rover 2	415163.018	2550607.465	277.906	0.002	-0.004	-0.046
					Machhannala DAM FSL-TBM	Check by Rover 3	415163.030	2550607.464	277.911	-0.010	-0.003	-0.051

Note: Machhannala DAM FSL(Full Supply Level)-277.640m w.r.t MSL (Client Provided), Machhannala DAM FSL-TBM Transferred from FSL.
Note: Base station was on Machhannala DAM TBM 2 (Fugro provided XYZ value), 3 reading taken for 2 sec each on Machhannala DAM FSL-TBM by 3 rovers on pole mounted.

Prepared by Arunabha Chakraborty

Appendix E

Benchmark Descriptions

(7 pages)

Job No. :	J_HYD_20_174630	Station Name:
Client :	Govt. Of Gujarat	
Location :	Machhannala Dam	FSL
Date:	24-02-2021	

1. Client provided FSL RL Value is 277.640m above MSL

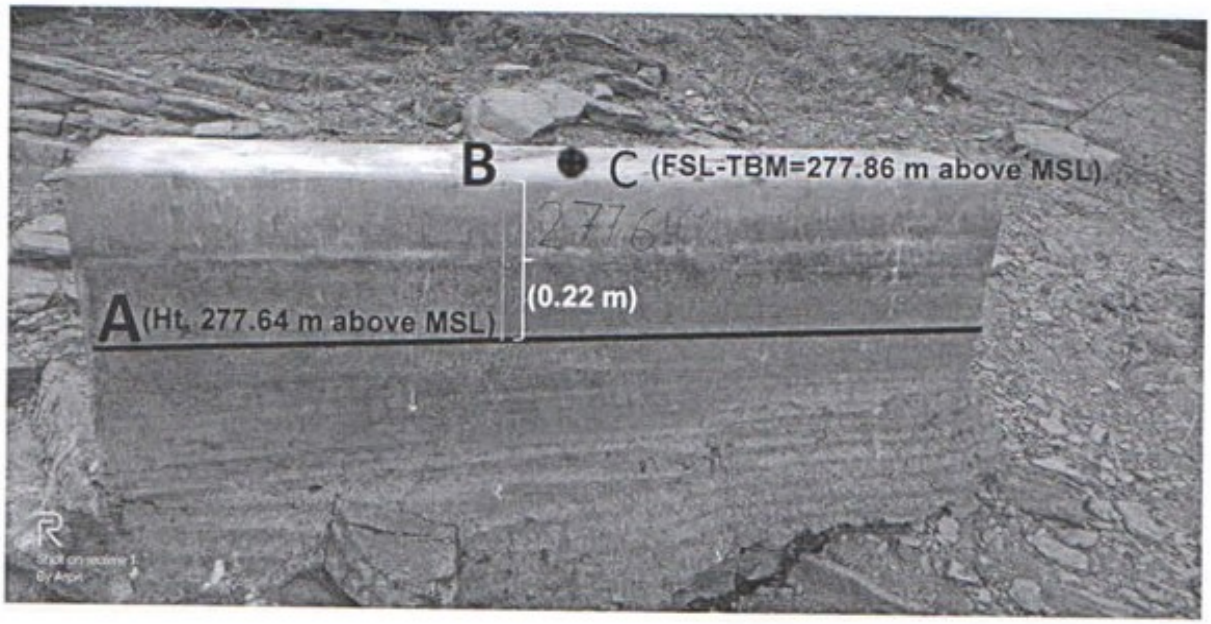
A=FSL RL Value stands on black mark line = 277.640 m above MSL

B=From black mark line to top of pillar is 0.22m (measured by tape).

C=Centre point of the pillar and name would be FSL-TBM.

Fugro will transfer all levels with respect to **FSL-TBM**.

So the value of top of pillar (point "C") is 277.860 m with respect to MSL and is named as FSL-TBM.



Arpit Bose
ARPIT BOSE
FSINPVT

CLIENT REP. H L Patelia DEE
GOVT. OF GUJRAT

FUGRO

Fugro Survey (India) Pvt. Ltd.
D-222/30, TTC Industrial Area,
MIDC, Nerul, Navi Mumbai
Pin - 400 075 (India)

Station / Bench Mark Description

Job No. :	J_HYD_20_174630	Station Name:
Client :	Govt. Of Gujarat	
Location :	Machchanala Dam	FSL-TBM
Observed By:	Arpit Bose,Mathiazhagan	
Date:	24-02-2021	

Brief Description of the Method Adopted

1. Purpose of Establishing the station :- Ref. Station for Bathymetric Survey of Reservoir and Topography survey
2. Equipment Deployed :- Trimble BX992 Receiver
3. Method Used :- 30 minutes Mean Position for Tripod Centre Of Gravity

Final Coordinates in WGS84 Datum/UTM zone-43N

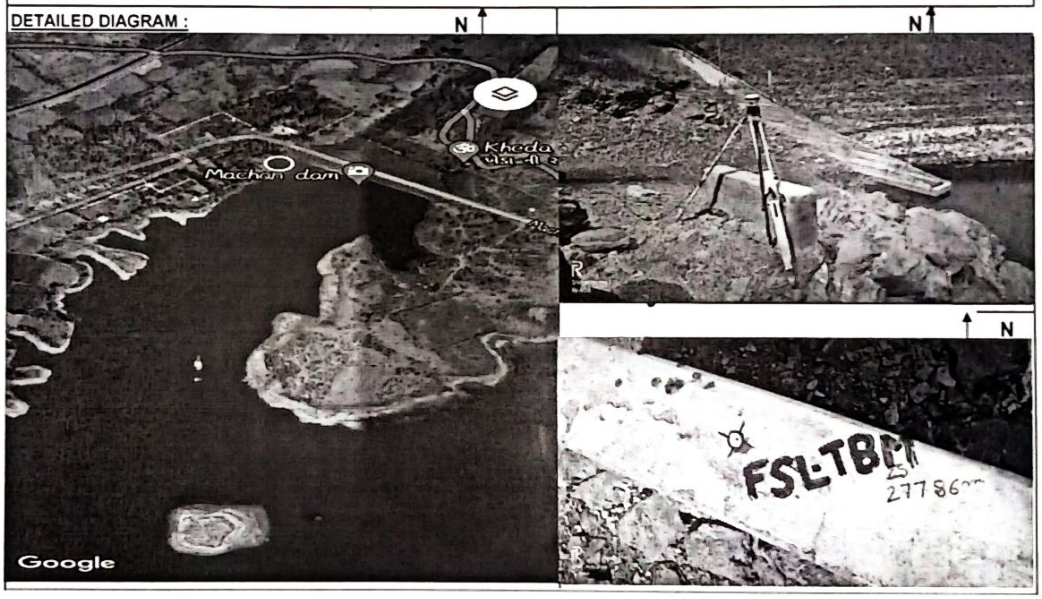
GEOGRAPHICAL COORDINATES:		UTM COORDINATES:		CM: 75° E
LATITUDE:	23°03'42.68277"N	EASTING:	415163.020m E m	σ = +/- 0.01 m
LONGITUDE :	74°10'18.53477"E	NORTHING:	2550607.461m N m	σ = +/- 0.01 m
ELLIPSOIDAL HEIGHT:	208.15m	CONVERGENCE :	-0.50293 Degrees	
HEIGHT ABOVE LAT/CD:	NA	Ht above Local MSL:	277.860m	

LOCATION & ACCESS : It's a Concrete Piller which is situated near water body after entering of main gate there has stair to water body along with water level plates and station is 30m beside of water level plate.

STATION MARKING : It's a Concrete Piller establised by Govt. of Gujarat. And point is marked with red paint.

Expected durability of the Station (Years) : 10years

DETAILED DIAGRAM :



Note:-

Coordinates are measured by DGPS observation.
Client hasn't supplied any BM value.
Client has supplied FSL RL Value.
FSL RL Value stands with respect to MSL.
FSL RL Value is stands 22cm down from top of pillar.
So FSL RL Value is 277.640m therefore FSL-TBM Value is 277.640m+0.22m=277.860m with respect MSL.
Value has checked and verified in front of deputy executive engineer in site.

Arpit Bose
Party chief (FSINPVT)

Deputy Executive Engineer
Machhanala Dam
GOVT. OF GUJRAT

FUGRO

Fugro Survey (India) Pvt. Ltd.
D-222/30, TTC Industrial Area,
MIDC, Nerul, Navi Mumbai
Pin - 400 075 (India)

Station / Bench Mark Description

Job No. :	J_HYD_20_174630
Client :	Govt. Of Gujarat
Location :	Machchanala Dam
Observed By:	Arpit Bose,Mathiazhagan
Date:	24-02-2021

Station Name: **TBM-02**

Brief Description of the Method Adopted

1. Purpose of Establishing the station :- Ref. Station for Bathymetric Survey of Reservoir and Topography survey.
2. Equipment Deployed :- Trimble BX992 Receiver
3. Method Used :- 30 minutes Mean Position for Tripod Centre Of Gravity

Final Coordinates in WGS84 Datum/UTM zone-43N

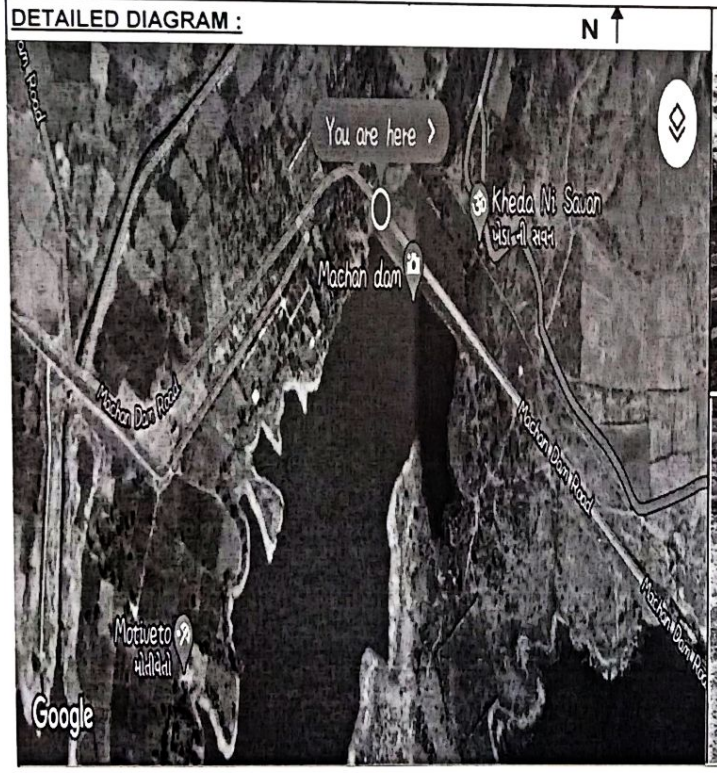
GEOGRAPHICAL COORDINATES:		UTM COORDINATES:		CM: 75° E
LATITUDE:	23°03'43.72157"N	EASTING:	415194.875m E	σ = +/- 0.04 m
LONGITUDE :	74°10'19.64787"E	NORTHING:	2550639.228m N	σ = +/- 0.02 m
ELLIPSOIDAL HEIGHT:	214.442m	CONVERGENCE :	-0.50293 Degrees	
HEIGHT ABOVE LAT/CD:	NA	Ht above Local MSL:	283.986m	

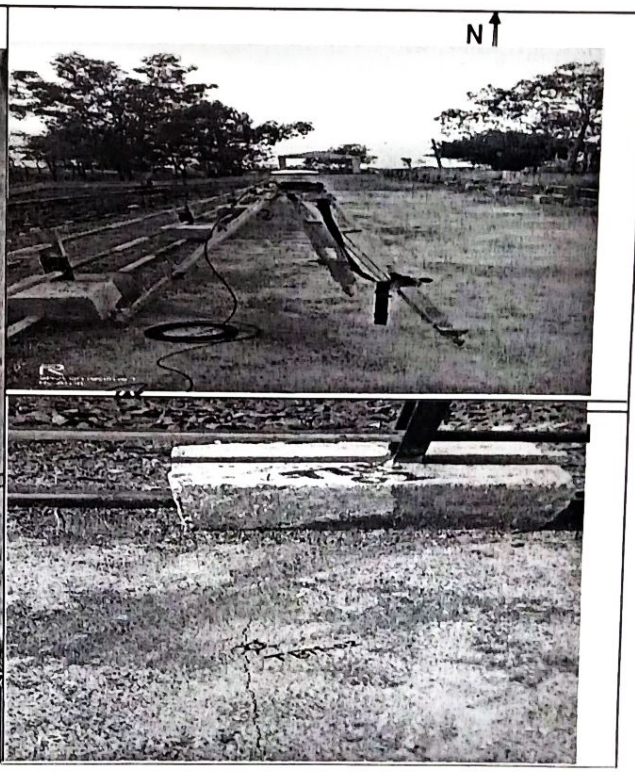
LOCATION & ACCESS : Station has established on machchanala Dam road which is 180m from entering of main gate.

STATION MARKING : Station has marked with red paint.

Expected durability of the Station (Years) : 01 year

DETAILED DIAGRAM :





Note:-

Coordinates are measured by DGPS observation.
RL value of TBM-02 has transferred from FSL-TBM RL value .
FSL-TBM RL value is stands with respect to MSL.

Arpit Bose
Party chief (FSINPVT)

Deputy Executive Engineer
Machhanala Dam(Govt. Of Gujarat)

LEVELLING RECORD FROM FSL TO TBM-02

Job No :	J-HYD-20-174630	Client Name :	GOVT. OF GUJARAT
Levelling Equpt Used:	AUTO LEVEL	Equipment Serial/Asset No:	258398 / 273746
Area/Location Name:	MACHCHANALA DAM	Date of Observation:	19-02-2021
Observer's Name:	Arpit Bose	Staff Holder's Name:	Mathizaghan

LEVELLING FROM FSL TO TBM-02 & REVERSE

FSL-TBM to TBM-02		
LEG NO	BACK SIGHT(m)	FORE SIGHT(m)
1	3.76	1.379
2	3.977	0.232
SUM	7.737	1.611

TBM-02 to FSL-TBM		
LEG NO	BACK SIGHT(m)	FORE SIGHT(m)
1	0.224	3.967
2	1.361	3.744
SUM	1.585	7.711

LEVELLING FROM FSL - TBM-02

A) Height Difference between FSL-TBM to TBM-02 = 7.737m-1.611m= 6.126m

B) Height Difference between TBM-02 to FSL-TBM = 1.585m-7.711m=-6.126m

C)The station FSL-TBM is 277.860m above the MSL

D) The station TBM-02 is 6.126m above the FSL-TBM point. **277.860m+6.126m= 283.986m**

So the Station TBM-02 is 283.986m above the MSL.

NOTE-

1. **Client did not provided any XYZ value of BM.**
2. **Client has provided FSL RL value is 277.640m with respect to MSL.**
3. **Station FSL-TBM is 22cm up from FSL RL Value so level of FSL-TBM is 277.860m above MSL**

Arpit Bose

Party Chief
ARPIT BOSE
FSINPVT

Deputy Executive Engineer
Machhanala Dam
GOVT. OF GUJRAT

RECORD OF LEVELLING

(To be used for levelling from an established BM to the Zero of ATG / Tide Pole)

FUGRO

Job No :	J-HYD-20-174630			Client Name :	Govt. of Gujrat
Levelling Equpt Used:	TOTAL STATION TRIMBLE S3			Equipment Serial/Asset No.	91210063
Area/Location Name:	MACHCHANALA DAM			Date of Observation:	24-02-2021
Tide Guage Installed ?:	Yes, ATG RADAR SENSOR			Observer's Name:	Arpit Bose
ATG Zero setup at (m):	0		TBM Level at ATG Site	Prism Holder's Name:	Mathiazhagan V.

Start Point BM Name/ID:	**FSL-TBM**		
Start Point BM Value (RL) (m):	**277.860**	FROM	**MSL**

End Point Level Name:	**Bottom of ATG RADAR**		
End Point Level Value (m):	**275.739**		

FSL-TBM to ATG		
Station Name	Backsight(TBM-02)	Fore Sight(ATG)
FSL-TBM	283.987	275.739

ATG to FSL-TBM		
Station Name	Backsight(ATG)	Fore Sight(TBM-02)
FSL-TBM	275.739	283.986

Misclosure =	0.000	meters
Adjusted Tide Gauge Height =	**0.000**	meters
Hence, the Zero of Tide Gauge is	**275.739**	**metres Above MSL**

Checked by:Arpit Bose
Surveyor's Name:Arpit Bose
Date:24-02-2021

1.RL Value of station TBM-02 is 283.986m above MSL.

Arpit Bose

Party Chief
ARPIT BOSE
FSINPVT

Deputy Executive Engineer
Machhanala Dam
GOVT. OF GUJRAT

LEVELLING RECORD-Verification of Client provided level of FSL and WLP

Job No :	J-HYD-20-174630	Client Name :	GOVT. OF GUJARAT
Levelling Equpt Used:	TOTAL STATION TRIMBLE S3	Equipment Serial/Asset No:	258398 / 273746
Area/Location Name:	MACHHANALA DAM	Date of Observation:	24-02-2021
Observer's Name:	Arpit Bose	Staff Holder's Name:	Mathizaghan

LEVELLING FROM FSL-TBM TO WLP & REVERSE

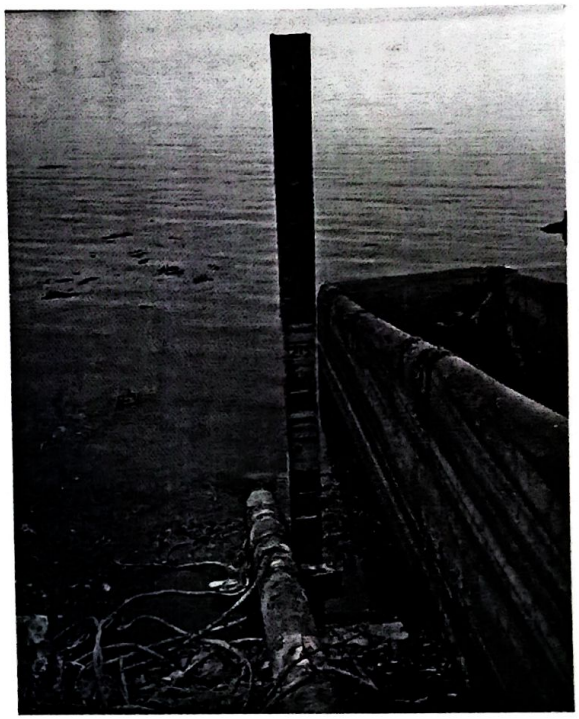
FSL-TBM to WLP		
Station Name	Backsight(TBM-02)	Fore Sight(WLP)
FSL-TBM	283.986	275.001

WLP to FSL-TBM		
Station Name	Backsight(WLP)	Fore Sight(TBM-02)
FSL-TBM	275	283.987

LEVELLING FROM FSL - WLP

FSL-TBM RL Value w.r.t MSL is 277.860m
TBM-02 RL Value w.r.t MSL is 283.986m

So the WLP point is 275m above the MSL.



NOTE-

1. **Levelling is done for verify FSL-TBM RL value with WLP RL Value w.r.t MSL.**
2. **Client did not provided any RL value of BM.**
3. **Client has provided FSL RL value is 277.640m. above MSL.**
4. **Station FSL-TBM is 22cm up from FSL RL Value so level of FSL-TBM is 277.860m above MSL.**
5. **WLP RL value is showing 275m and our levelling value is 275m.**
6. **Everyday fugro will observe water level from this water level plate.**

Arpit Bose

Party Chief
ARPIT BOSE
FSINPVT

Deputy Executive Engineer
Machhanala Dam
GOVT. OF GUJRAT

FUGRO

REPORT ON RADAR ATG SETUP FOR DATA LOGGING

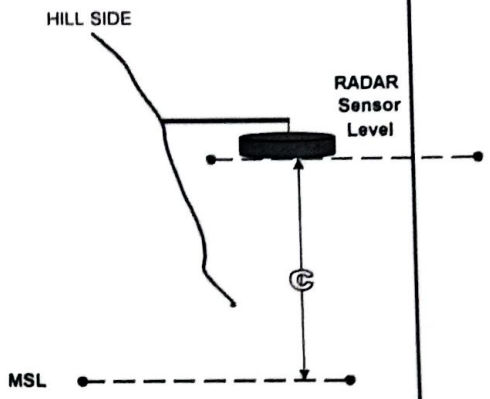
Job No: J-HYD-20-174630	**Job Name:** Singlebeam Bathymetry Survey
Client: Govt. of Gujrat	**Survey Area / Site:** Central Gujrat.

ATG Setup, Recovery and Data Download Information

a) ATG Setup on: 19-Feb-21 At: 1400 hrs By: Mathizhagan V.,Arpit Bose
b) ATG Time set to: UTC Logging interval set to: 10 min
c) Recovered on: - At: -
d) Data Downloaded on: 20-Feb-21 At: 18:00

ATG Set up & BM Details		Remarks
BM Name :	FSL-TBM	
BM Source :	FSL-TBM	
BM to CD (m) :	NA	
MSL to CD (Z_0) (m):	NA	NA
BM to ATG (m) :	0.000	
ATG to MSL (m) :	275.739	
C-O from ATG Calibration (m):	-0.023	from calibration report
RADAR offset value to be entered in the Tide Master deck unit (m):	275.716	

RADAR ATG Setup Diagram



Key to RADAR ATG Setup Diagram	
RADAR ATG sensor set up above BM	
A Ht of BM above CD/LAT (m)	NA
B Ht of ATG Sensor above BM (m)	0.000
C Ht of ATG sensor from MSL (m)	275.739
D Ht of MSL Above CD in metres (Z_0)	NA

Note: Value of **B** should be negetive if RADAR sensor level is below BM

ATG Calibration and Daily Verifications Carriedout at Site

a) **Method of Calibration Adopted**: Measured the actual height of water-level from the Bottom surface of Radar using pre-calibrated tape.

b) **Daily Verifications Carried out**:

Results of ATG Calibration

Date & Time	Measured by (m): Tape (C:)	Measured by (m): ATG (O:)	C-O (m)
20 Feb/17:50	1.520	-1.547	-0.027
20 Feb/18:00	1.527	-1.547	-0.020
20 Feb/18:10	1.530	-1.553	-0.023
		Mean (C-O)	-0.023

Header Information for the ATG Data Logged

Firmware version: 0741705B8
File Creation Date: 19/02/2021 17:41:47
Battery Level: 5.5
TideMaster S/N: 48693
Station ID: 01
Site info: GUJARAT
Calibrated: 17/12/2014
Mode: B3
Pressure units: m
output format: TIDEMASTER
Radar:
Mode: Tide
Firmware: 0745703.c A
Serial Number: 46404
Min limit: 0.11
Max Limit: 50
Datum: 0
Pre amble: 6
Wind speed units: m\sec
Air Pressure units: mBar
Air Temperature units: DegC

Place: Machchanala Dam
Date: 19-Feb-21

Set up by :

Name: Mathiazhagan V.
Engineer

Checked by :

Name: Arpit Bose
Party Chief

Notes:-

1 **ATG Header Info**:- a) Copy and Paste ATG Configuration Header File Information from the Logged file.
b) Select Tide File– Right Click–Open with Text Pad –Copy Header Information -- Paste in Header Information Window

2 **ATG Calibration**:-

Party Chief
ARPIT BOSE
FSINPVT

Deputy Executive Engineer
Machhanala Dam
GOVT. OF GUJRAT

Appendix F

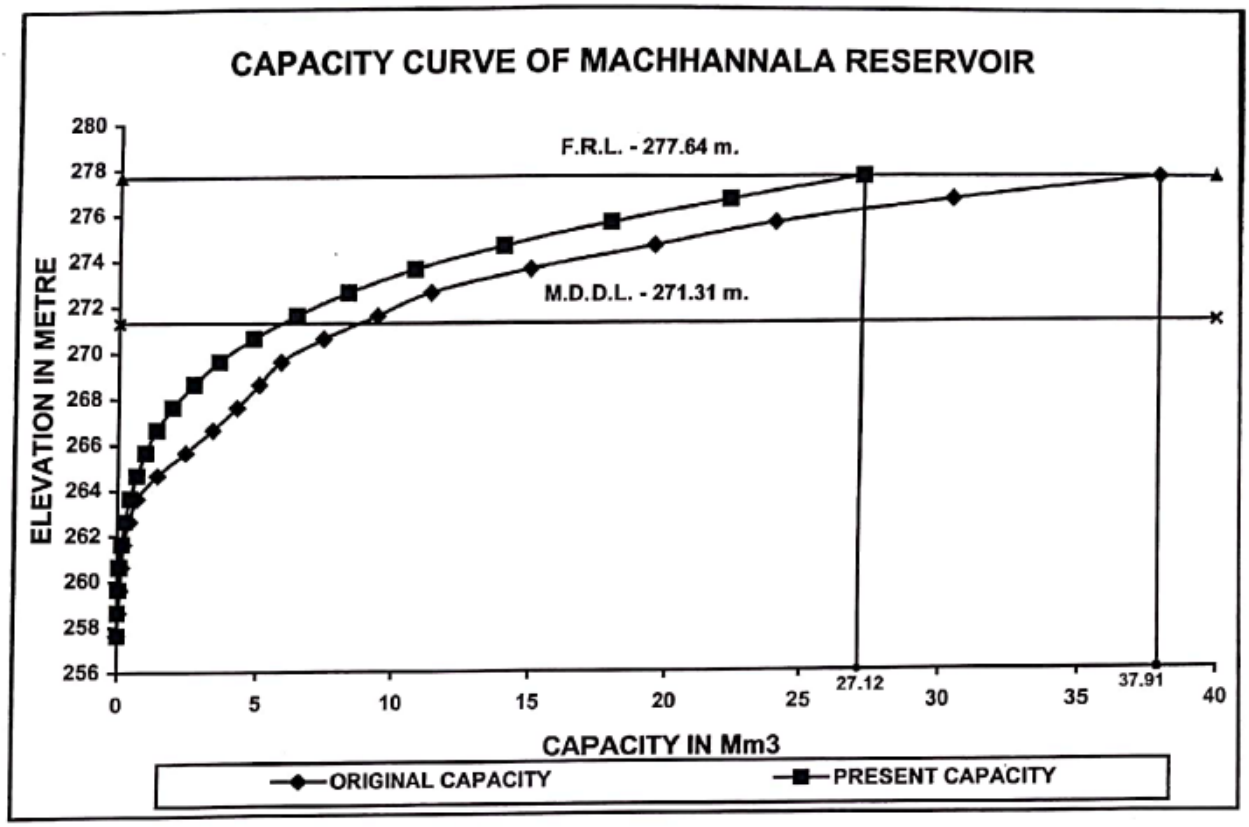
Client Supplied Capacity Curve

(1982 and 1999)

(2 pages)

Strip No.	Strip R. L. in m.	Cumulative Capacity in Mm^3 Original	Present	Remarks
1	277.64 -276.64	37.91	27.12	F.R.L.
2	276.64 -275.64	30.38	22.25	
3	275.64 -274.64	23.94	17.85	
4	274.64 -273.64	19.46	14.01	
5	273.64 -272.64	14.99	10.81	
6	272.64 -271.64	11.41	8.35	
7	271.64 -270.64	9.42	6.45	
8	270.64 -269.64	7.44	4.85	
9	269.64 -268.64	5.88	3.62	
10	268.64 -267.64	5.07	2.69	
11	267.64 -266.64	4.27	1.94	
12	266.64 -265.64	3.39	1.38	
13	265.64 -264.64	2.41	0.99	
14	264.64 -263.64	1.42	0.68	
15	263.64 -262.64	0.69	0.44	
16	262.64 -261.64	0.42	0.26	
17	261.64 -260.64	0.23	0.15	
18	260.64-259.64	0.17	0.08	
19	259.64-258.63	0.11	0.033	
20	258.64-257.76	0.05	0.0028	

Client Supplied Capacity Curve (1982 and 1999)



Appendix G

List of Charts

(1 page)

List of Reports / Documents to be Submitted

Sr. No.	Type of Report / Document	Reporting Schedule	No. of Copies (Hard)	Remarks
1	Survey Procedure (QA Document)	01 December 2020	1	Submitted
2	Mobilisation Report (With Results of Calibration)	26 October 2020	--	Fugro Office copy only
4	Draft Report	30 days from completion of survey	1	Submitted
5	Final Report on Survey	1 week from receipt of client's comments	10	**This Document**

Details of Charts Accompanying this Report

Details of Charts							
Sl. No.	Charts showing Results of Bathymetry and Topography Survey at Machhannala Reservoir	Sheet No.	Encl. No.	Drawing No.: JHYD-20-174630/WRD/GUJARAT/BS/	Rev. No	HS	VS
1	Reservoir Bed and Topographic Heights	01 of 01	01 of 03	B/01/9515	0	1:6000	-
2	Contour Map of Machhannala Reservoir	01 of 01	02 of 03	B/01/9659	0	1:6000	-
3	Shaded Relief Image Prepared from SBES Data	01 of 01	03 of 03	I/01/9660	0	1:6000	-
Details of Other Deliverables							
1	L-section	Soft copy					
2	C-section at every 100 m	Soft copy					