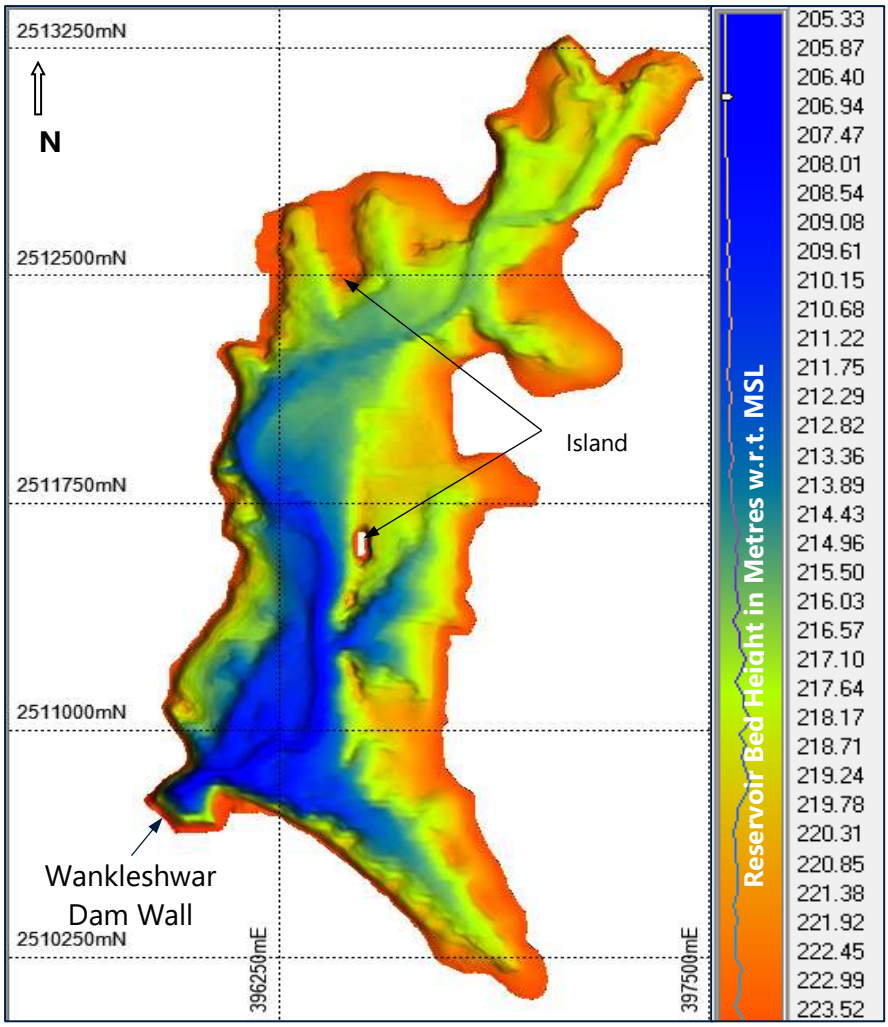

Providing Services for Conducting Bathymetric Survey of Reservoirs of Central Gujarat Under National Hydrology Project

Survey Results of Wankleshwar Bhey Reservoir Location | Central Gujarat

JHYD20-174630-Volume 11- Wankleshwar Bhey Reservoir/R1 [01] | 18 November 2021

Final Report

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

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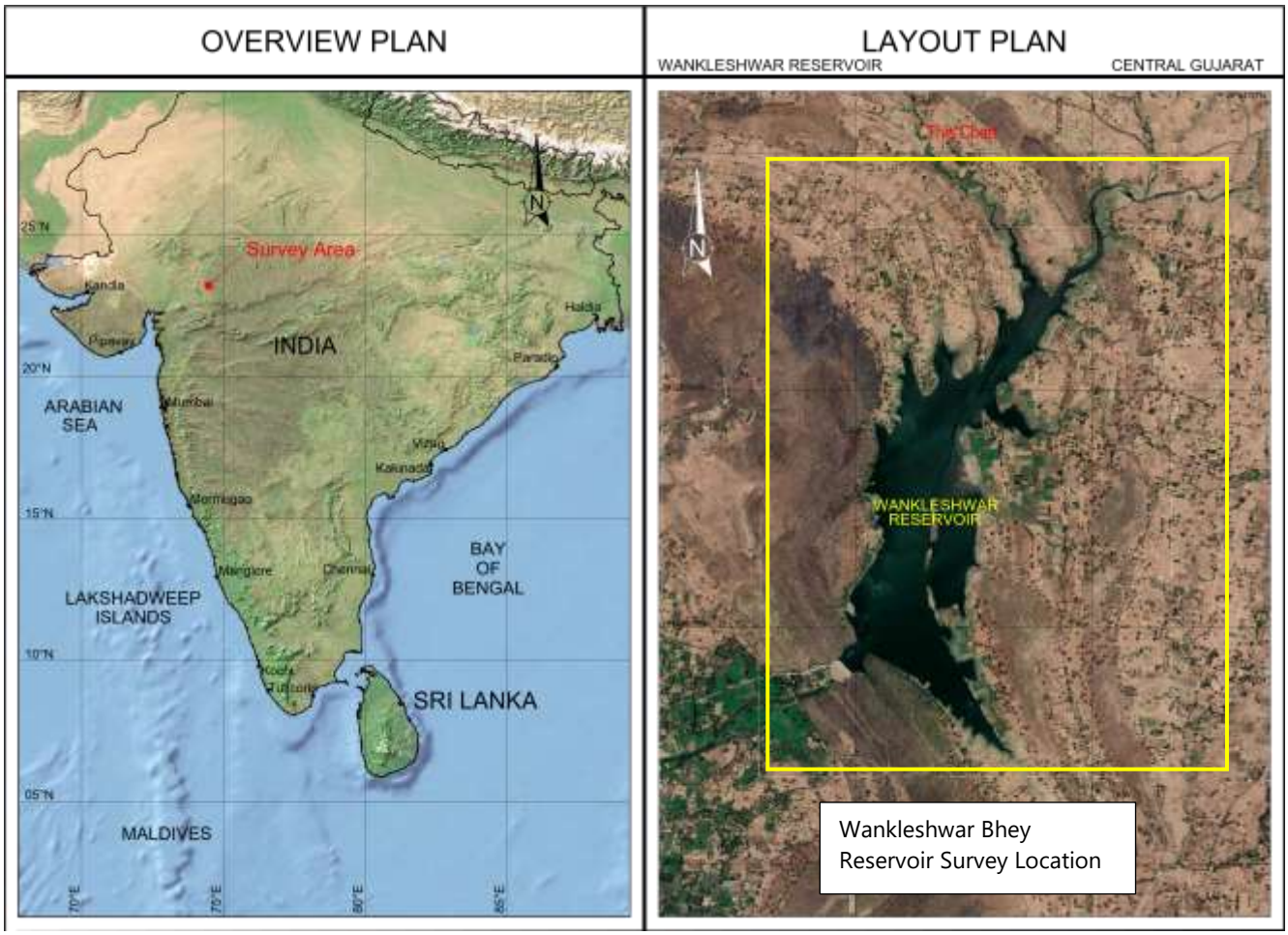
[01]	18 November 2021	Final Report	Paul. B /Sukla C.	G.N. Hariharan	Rahul Patkar
[00]	26 October 2021	Final Report	Paul. B /Sukla C.	G.N. Hariharan	Rahul Patkar

LOCATION MAP



EXECUTIVE SUMMARY

Survey Overview– Wankleshwar Bhey 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 Wankleshwar Bhey 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 'Fugro Zodiac' in the months of March 2021 and June 2021 respectively, in order to acquire survey data as per mutually agreed scope and relevant survey specifications.
Survey Location	Wankleshwar Bhey Reservoir, Moti Khajuri village, Devgadh Baria 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 – Wankleshwar Bhey 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 205.40 (395 887 mE, 2 510 121 mN) w.r.t. MSL.
Capacity Survey (2021)	Elevation Area Capacity table and curve of Wankleshwar Bhey 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 (205.40 m) to FRL (223.57 m) was calculated using GIS software.
Revised elevation area capacity details	In comparison with 1978 data, the present survey results indicate that the gross storage capacity in the reservoir has decreased.
Loss in gross storage capacity	As per 2021 survey results, the loss in Gross storage capacity w.r.t. 1978 or volume of sediment deposited in the Wankleshwar Bhey reservoir is 0.680 Mm^3.
Trap efficiency & Sedimentation Index	Trap Efficiency and sedimentation Index calculated for Wankleshwar Bhey reservoir as per methodology give in IS 12182-1987 is 96% and 1.328 x 10^{11} s^2/m respectively.
Sedimentation rate	The rate of siltation in Wankleshwar Bhey reservoir is 0.016 Mm^3/year.
Average rate of siltation	The observed rate of siltation in the Wankleshwar Bhey reservoir during the 43 year life span (1978 – 2021), works out to 3.554 Ha m/100 km^2/year.
Annual % loss	The annual % loss in gross storage capacity for Wankleshwar Bhey reservoir during the 43 years life span is 0.119 % 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 16 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 Wankleshwar Bhey reservoir.

Pass 1: Bathymetry / Hydrographic Survey;

Pass 2: Topographical Survey.

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

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

1.2 Study Area

Wankleshwar Bhey reservoir falls within Mahi river basin. Basin drainage and sub-basin boundary is given in Figure 1.1. Mahi upper sub basin (65.11% of total basin area) consists of 41 watersheds and Mahi lower sub basin (34.89% of total basin area) consists of 22 watersheds. The basin has maximum length and width of about 330 km and 250 km, respectively. The Mahi basin covers an area of 15,474 km^2 (40.36%) in Gujarat accounting to 41.73% of the total basin area. The Mahi River and its tributaries constitute an inter-state river system flowing through the states of Madhya Pradesh, Rajasthan and Gujarat. Mahi river is comprised of several tributaries on both the banks, viz. Som, Anas, Panam and others.

The Wankleshwar Bhey is an earthen dam built between 1976 and 1978 and the water in the dam is used for irrigation purpose. The Wankleshwar Bhey reservoir is on Bed river, that joins the Panam tributary near Kelia village, in Devgad Baria taluka, Dahod district. The reservoir is situated in Dahod district, near Devgad Baria. Devgad Baria is one of the seven talukas of Dahod district, viz. Devgad Baria, Dhanpur, Dohad, Fatehpura, Garbada, Jhalod & Limkheda.

Wankleshwar Bhey is a canal that is connected to Wankleshwar Bhey reservoir. Total length of this canal is 12.33 km (left bank canal length 4.5 km & right bank canal length 7.83 km) command area of 2958.28 Ha.

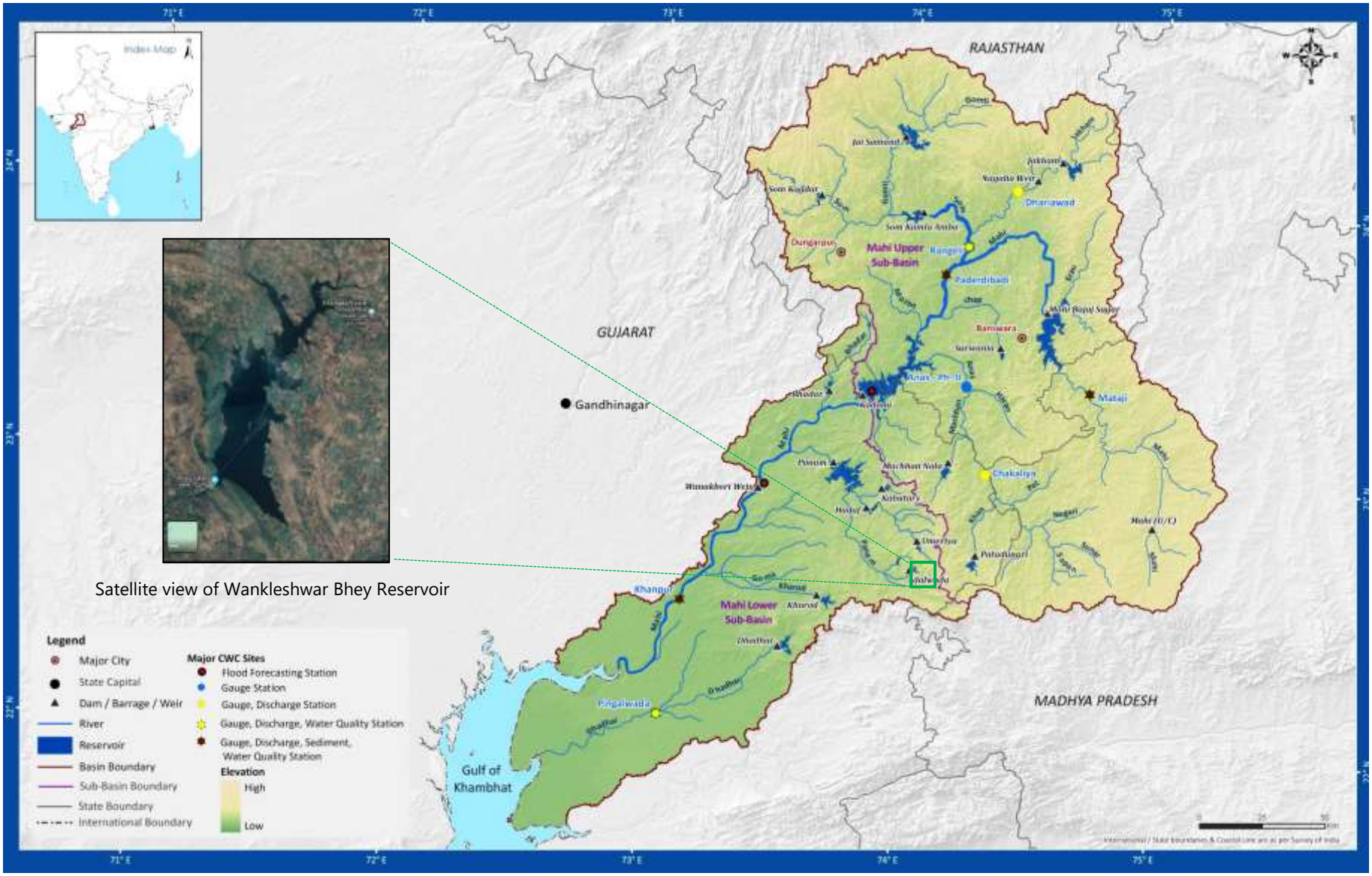

Figure 1.1: Mahi basin showing major tributaries – Drainage and sub-basin (India-WRIS) and Satellite view of Wankleshwar Bhey Reservoir (Google Earth)

1.3 Geology of Study Area

Biotite-schists and gneisses, arkoses, calc-silicate rocks, brucite and forsterite-marbles, graphite-schists and gneisses, and amphibolites comprise the oldest rock types exposed south of the Devgadh Baria. These rock formations are unconformably overlain by Aravalli meta-sedimentaries in the south and northeast, forming quartzites and phyllites. The intrusive granitic rocks can be found along the southern, on the west and north-west sides and they indicate a continuation towards the Godhra in the NW direction (Narayana, 1974).

1.4 Soil Types

The soil of the Dahod district can be divided broadly into three categories depending upon the source rock, namely the phyllite, granites and basalts. The granite normally gives rise to sandy soil but where weathering is intense, sandy loam is produced. The phyllite produced yellowish brown light soils but where weathering is deep, black soil produced. The basaltic rock gives rise to variegated soil depending upon the degree of weathering. The first stage of weathering produces light soil with splinters of *morum* whereas in the second stage medium soil od light brown to brownish black colour are produced (Nayak, 2014).

1.5 Land use patten

The data on land utilisation and irrigated are shows that, the land brought under cultivation and sowing in the Dahod district covers 3090 Ha, where area sown more than once covers 945 Ha. Forest area covers in the district about 884 Ha. The details Geographical area covers 3655 sq km where forest area cover 884 Ha. The Fallow land covers 72 Ha (Nayak, 2014).

1.6 Wankleshwar Bhey Reservoir Characteristics

The Wankleshwar Bhey dam is an earthen (rolled filled long type) dam constructed over the Bed river, which joins Panam tributary. Salient features of the Wankleshwar Bhey reservoir are tabulated below:

Table 1.1: Client Supplied Salient Features for Wankleshwar Bhey Reservoir

Reservoir name	Feature
Reservoir name	Wankleshwar Bhey Reservoir
Name of Dam	Wankleshwar Bhey Dam
Location	
Latitude	22° 40′ N to 22° 45′ N
Longitude	73° 55′ E to 74° 00′ E
Purpose	Irrigation
Name of River	Bed River (River that joins Panam tributary)
River Basin	Mahi Lower Sub-basin
Village	Moti Khajuri

Reservoir name	Feature	
Taluka	Devgadh Baria	
District	Dahod	
State	Gujarat	
Year of commencement of construction work	1976	
Year of completion	1978	
Hydrology		
Area of catchment	44.50 km^2 (17.5 sq. miles)	
Mean annual rainfall	35.6 inches	
Designed Flood Discharge	Maximum 33840 cusecs	
Reservoir Details		
Lowest level of river bed at dam site	R.L. 653.00 ft (199.03 m)	
Sill level of H.R.	R.L. 705.00 ft (214.88 m)	
F.S.L.	R.L. 733.50 ft (223.57 m)	
H.F.L.	R.L. 739.00 ft (225.25 m)	
Top of Dam level	R.L. 747.00 ft (227.69 m)	
Gross storage capacity	R.L. 470.00 Mft^3 (13.30 Mm^3)	
Dead storage capacity	57.00 Mft^3 (1.61 Mm^3)	
Live storage capacity	413.00 Mft^3 (11.69 Mm^3)	
Dam Details		
Type	Earthen (rolled filled long type) dam	
Length	494 ft. (150.57 m)	
Maximum Height from lowest level	84 ft. (25.80 m)	
Top Width	20 ft. (6.10 m)	
Bed Rock	Phyllite & Schist	
Head Regulator Details		
No. of H.R. Gate	1	
Type of H.R. Gate	RCC conduct	
Size of Gates	4' x 41'	
Discharge capacity	80 cusecs	
Canal		
Main Canal	Left Bank	Right Bank
Discharge	30 cusecs	80 cusecs
Length	4.5 km	7.83 km
Command Area	840 Ha.	1675 Ha.
Command Area		
G. C. A.	2960.00 Ha.	
C. C. A.	2514.00 Ha.	

Reservoir name	Feature
I. C. A.	2064.00 Ha.

1.7 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 Wankleshwar Bhey reservoir.

Table 1.2: Wankleshwar Bhey Reservoir details for Bathymetry and Topography Survey

Name of Dam / Reservoir	Actual Area (km^2) surveyed	
	Bathymetry Survey	Topography Survey
Wankleshwar Bhey	1.33	0.79

1.8 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 Wankleshwar Bhey reservoir is as follows:

1.8.1 Pass 1: Bathymetry / Hydrographic Survey

The scope of work conforms bathymetry survey for total area of 1.33 km^2 was completed.

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 Wankleshwar Bhey 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 single beam echosounder system along with associated Navigational system were deployed on all the survey lines.

1.8.2 Pass 2: Topographical Survey

Topographical survey was carried out using Total station and equivalent levelling instruments. The total area covered in Topographical survey is 0.79 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).

1.9 Survey Execution

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

1.10 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

1.11 Deliverables

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

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 Wankleshwar Bhey Reservoir

Date	Observed Reservoir Water Level Heights w.r.t. MSL at Wankleshwar Bhey Reservoir [m]
14-03-2021	220.88
15-03-2021	220.79
16-03-2021	220.76
17-03-2021	220.73
18-03-2021	220.69
19-03-2021	220.65
20-03-2021	220.62
21-03-2021	220.58
22-03-2021	220.56
23-03-2021	220.50

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 'Fugro Zodiac'

Bathymetry Survey Personnel	
Personnel Name	**Function**
Pritam Seth	Party Chief / Surveyor
Atul Bhoyte	Engineer
MD Salman Khan	Fugro Zodiac 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 Fugro Zodiac is placed at Appendix C to this document.

Table 2.6: Survey Equipment / Systems Deployed for Bathymetry Survey in Fugro Zodiac

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 CV100 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 'Fugro Zodiac' was used to carry out the bathymetry / hydrographic survey.

Figure 2.1: Survey boat Fugro Zodiac

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 – 223.57 m w.r.t. MSL
- Full Supply Level (FSL) – 223.57 m w.r.t. MSL
- Approximate Water line during survey 220 m

3. Survey Data Acquisition

3.1 Survey planning, Preparation & Transportation to Site

The bathymetry survey equipment and personnel with survey boat 'Fugro Zodiac' arrived at Wankleshwar Bhey reservoir location on 11th March 2021 and equipment was mobilised on-board the survey boat on 11th– 13th March 2021.

After field testing / verification / calibration of all survey equipment bathymetry survey was carried out and completed on 23rd March 2021. Refer Appendix A to this document for diary of events.

The topography survey equipment and personnel arrived at Wankleshwar Bhey reservoir location and commenced survey on 14th June 2021. The topography survey was completed on 15th 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 'Fugro Zodiac' 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 'Fugro Zodiac' was Spatial Dual. Position observations were done at Wankleshwar Bhey 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

Positioning System Verification Results With BX-992 and Spatial Dual Receiver (Fugro Zodiac)						
WGS 84, UTM Projection, CM 075°E, Zone 43N						
Sensor	Serial No.	Easting (mE)	Northing (mN)	Latitude	Longitude	Ellipsoidal Height (m)
Trimble BX-992	025-00009601	395 873.12	2 510 757.61	22° 42′ 02.978″N	073° 59′ 10.330″E	169.813
Spatial Dual	025-00006405	395 873.05	2 510 757.64	22° 42′ 02.979″N	073° 59′ 10.327″E	169.832
Difference		**0.073**	**-0.035**	--	--	**-0.019**

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 CV100 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 'Fugro Zodiac'			
12th March 2021	Echotrac CV100 SBES	-0.05	0.0061

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 Wankleshwar Bhey Dam Temporary Benchmark (Wankleshwar Bhey TBM) and Temporary Benchmark 4 (TBM 4).

3.5.2 RTK Position Comparison

The RTK observed position at Temporary Benchmark 4 (TBM 4) 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)
TBM 4 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	395893.557	2510734.738
RTK Rover 1	Lynx H6	395893.590	2510734.767
Difference		-0.033	-0.029
TBM 4 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	395893.557	2510734.738
RTK Rover 2	Lynx H6	395893.579	2510734.762
Difference		-0.022	-0.024
TBM 4 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	395893.557	2510734.738
RTK Rover 3	Lynx H6	395893.567	2510734.760
Difference		-0.010	-0.022

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)- 223.57 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 (Wankleshwar Bhey TBM) 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 TBM 4 location. Static observation was carried out subsequently as part of verification.
- The Base receiver is installed at Wankleshwar Bhey TBM 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 TBM 4.
- The level or height transfer for temporary Benchmark established by Fugro were carried out w.r.t. client supplied reference level. The levelling report is placed in Appendix E.
- 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.

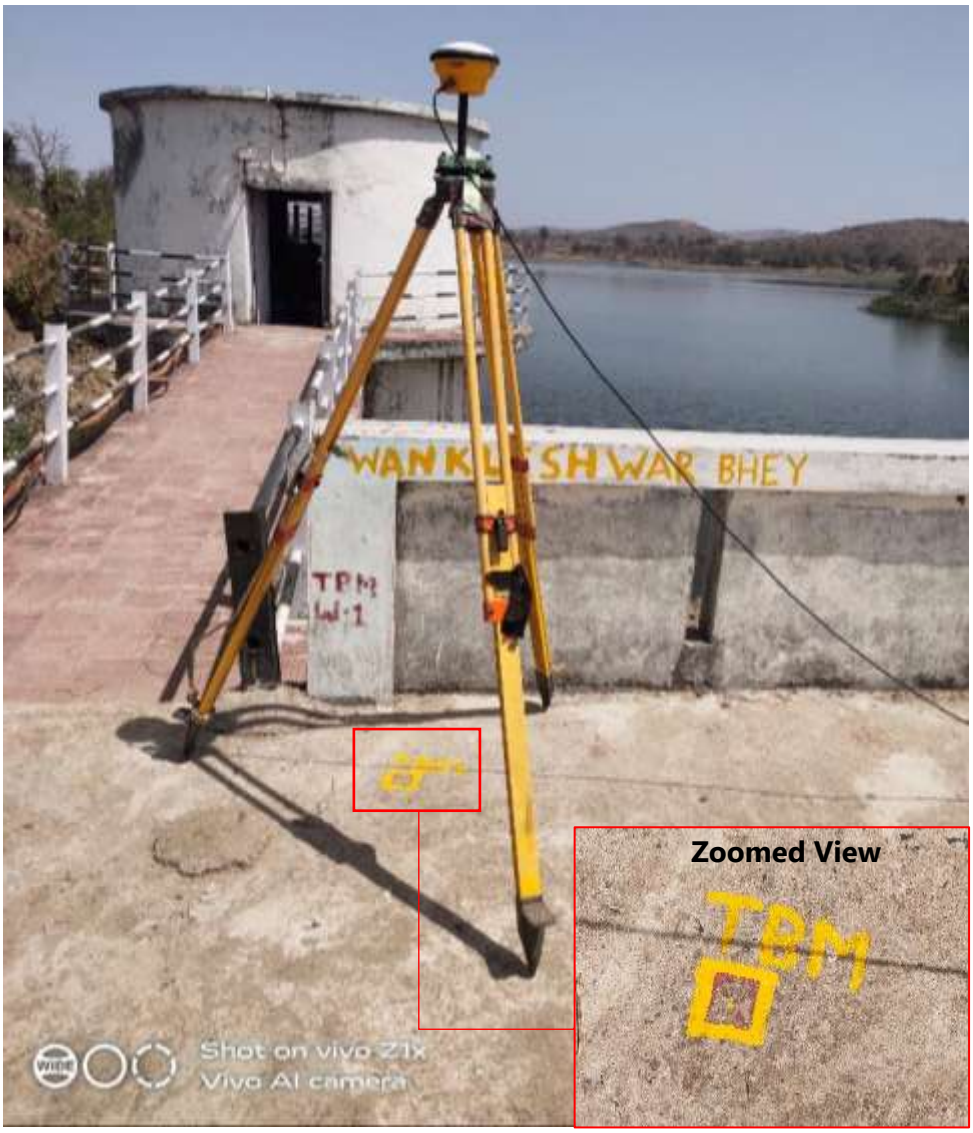

Figure 3.1: Wankleshwar Bhey Temporary Benchmark 1 (Wankleshwar Bhey TBM)

Figure 3.2: Temporary Benchmark 4 (TBM 4)

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)- 223.57 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. At few locations within the reservoir, areas of shallow water depth and fishing nets were observed. Photographs of the same are given below.

Figure 3.3: Area of shallow water depth within the reservoir.

Figure 3.4: Fishing nets within the reservoir.

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.

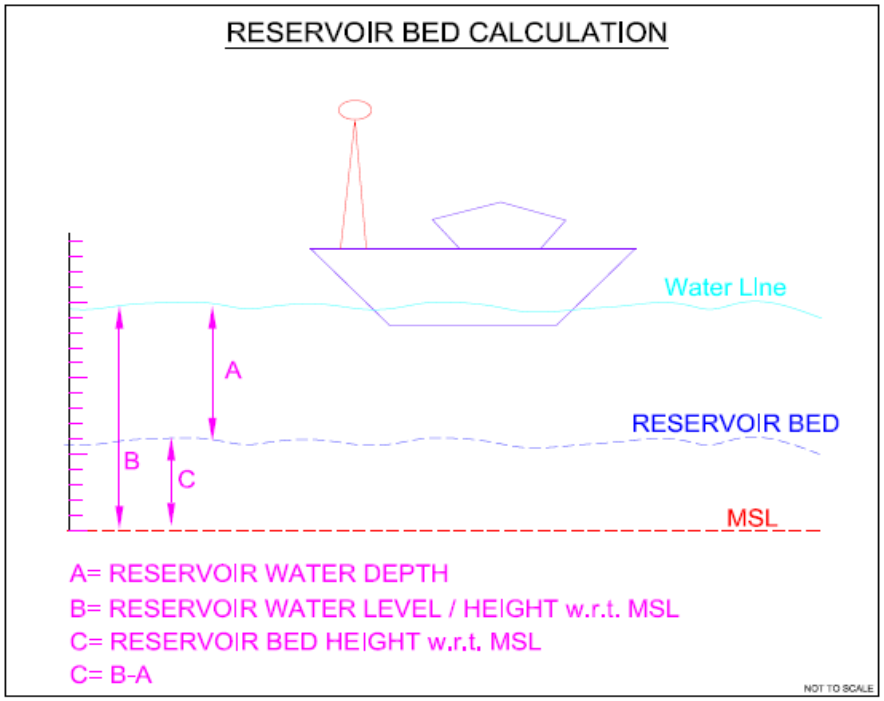

Figure 4.1: Reservoir Bed Height Calculation w.r.t. MSL

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 boundaries 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 205.40 m which is the lowest bed level for the reservoir and the maximum level considered is 223.57 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 / FSL. Dead storage is from Bed Level to MDDL. Gross storage is from Bed Level to FRL / FSL. The sedimentation in different zones of reservoir is shown in Figure 4.2.

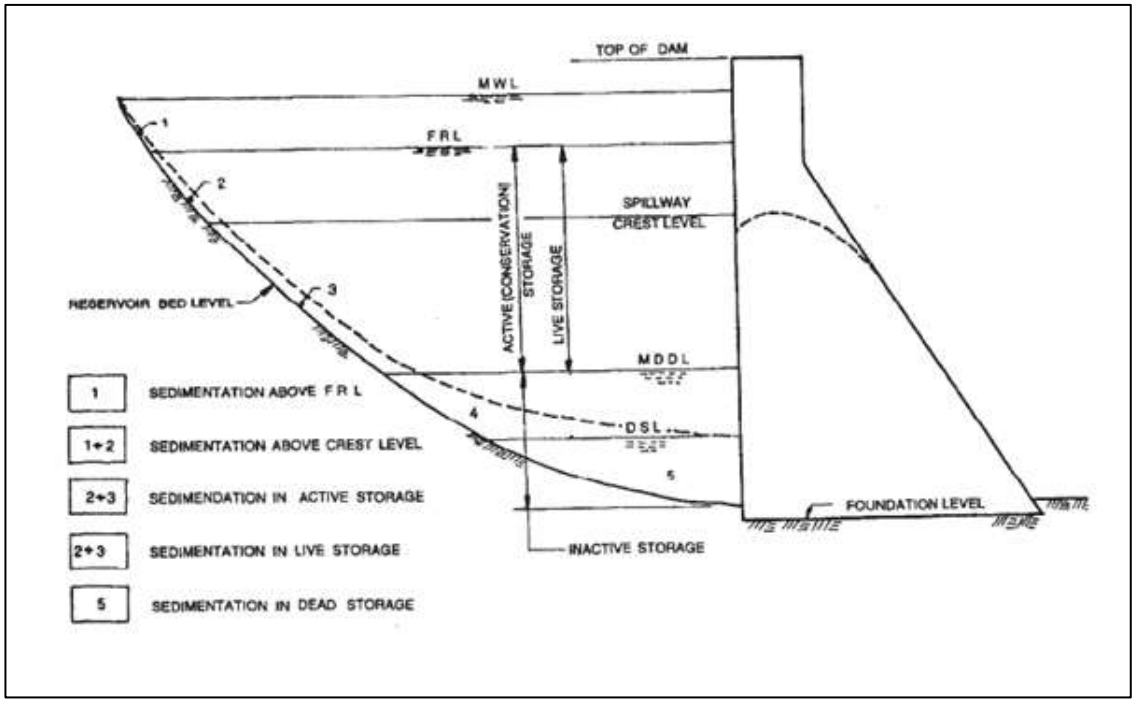

Figure 4.2: Sedimentation in different zones of reservoir (Ref: IS 5477-Part 1,1999)

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 12.620 Mm^3 and client supplied Mean Annual inflow is 18.42 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 Wankleshwar Bhey 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)

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

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

4.6 Charting the Results of Bathymetry and Topography Data

- Chart showing reservoir bed heights are provided for the current survey at 1:3000 scale.
- Chart showing contour map at 1 m interval for Wankleshwar Bhey reservoir is also provided at 1:3000 scale.
- Chart showing reservoir bed relief image prepared from bathymetry and topography survey data is provided at 1:3000 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 F.

5. Survey Results – Wankleshwar Bhey 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 Wankleshwar Bhey reservoir was carried out up to Full Supply Level (FSL) of 223.57 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 205.40 m to 223.57 m w.r.t. MSL.

The reservoir bed tends to get shallower as we go further towards north east, south west & south west away from the reservoir dam wall within the survey area. Reservoir area is spreading towards northeast, southeast, southwest and west directions. At western side, four islands are observed in the reservoir.

Lowest reservoir bed level recorded was 205.40 m (395 887 mE, 2 510 121 mN) w.r.t. MSL, within the survey area.

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

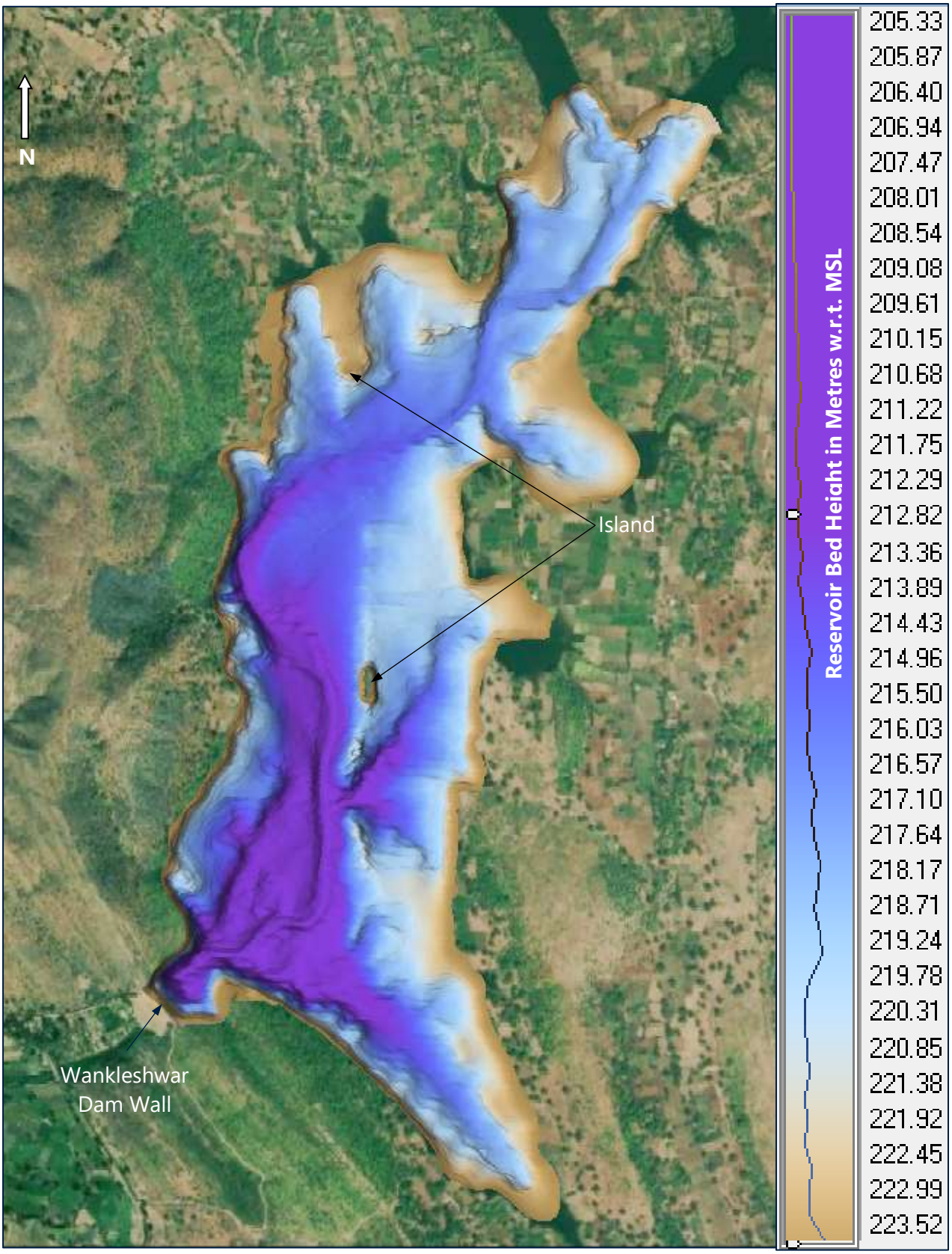

Figure 5.1: Image showing gridded SBES Bathymetry and topography data (superimposed with satellite imagery) of reservoir bed heights in metres from lowest bed level to FRL / FSL

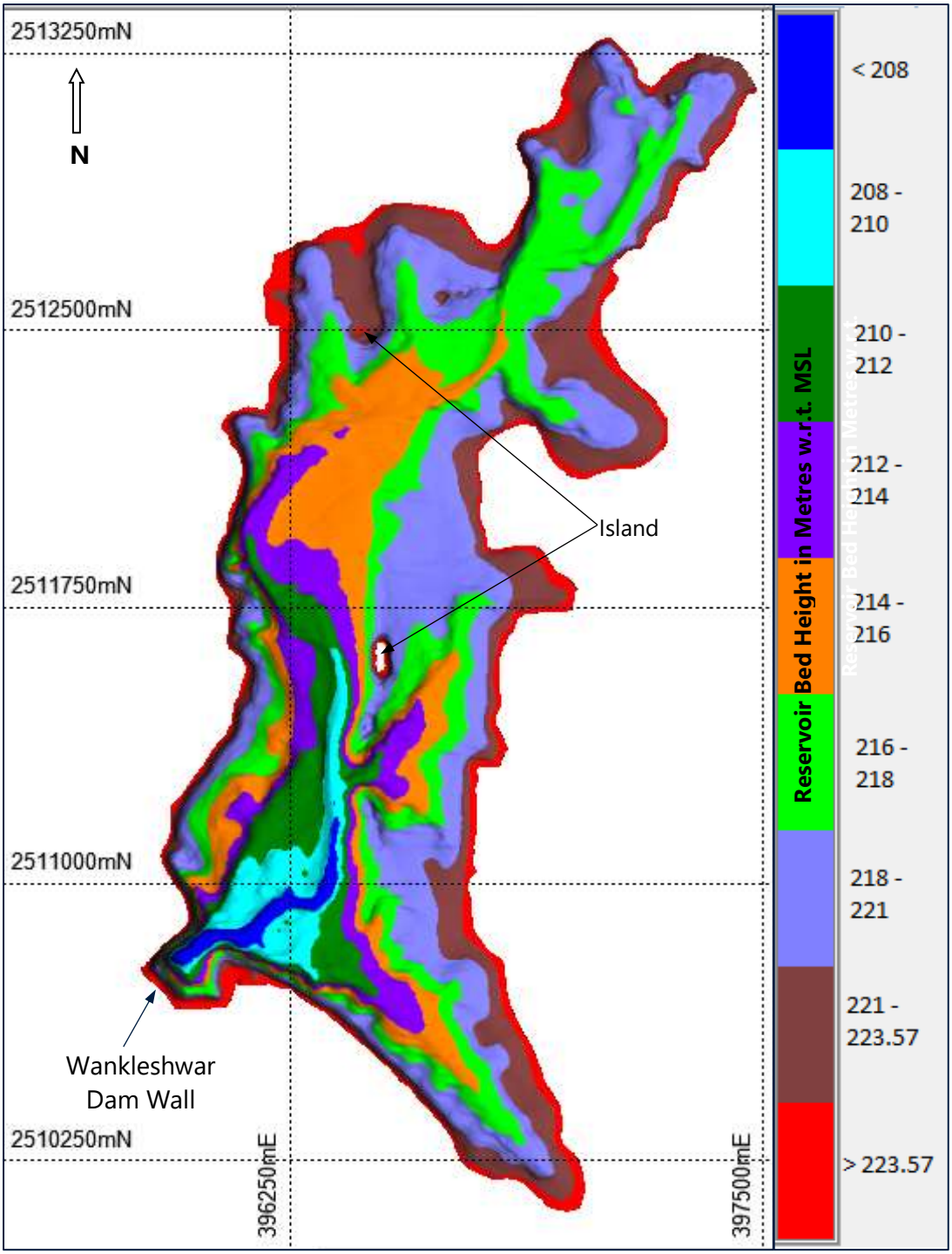

Figure 5.2: Shaded Relief image showing gridded SBES Bathymetry and topography data of reservoir bed heights in metres from lowest bed level to FRL / FSL.

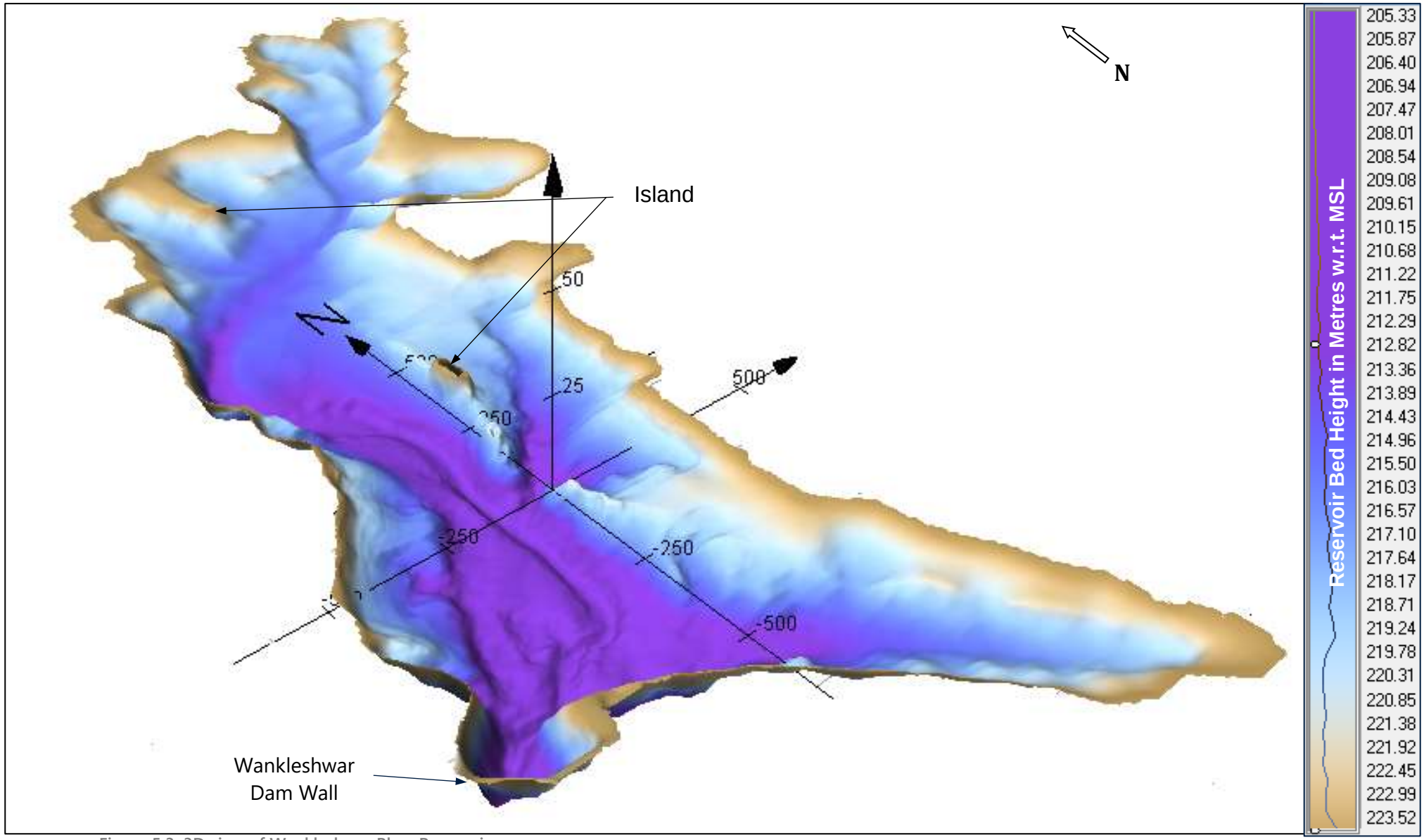

Figure 5.3: 3D view of Wankleshwar Bhey Reservoir

Photograph A: Central part of Wankleshwar Bhey Reservoir (396 495 mE, 2 511 757 mN) with rocky island.

Photograph B: Northern most approachable part of Wankleshwar Bhey Reservoir (397 434 mE, 2 513 146 mN) with shallow water depth and vegetation.

Photograph C: Eastern most part of Wankleshwar Bhey Reservoir (397 185 mE, 2 512 159 mN) with shallow water depth.

Photograph D: Southern most approachable part of the Wankleshwar Bhey reservoir (396 879 mE, 2 510 228 mN) with shallow water depth.

Figure 5.4: Photographs A, B, C and D showing the central, northern, eastern and south-eastern areas within Wankleshwar Bhey Reservoir respectively

5.2 Elevation Area Capacity Curve (2021)

The area and capacity of the Wankleshwar Bhey reservoir was tabulated against the respective increasing elevation starting from lowest bed elevation (i.e. ,205.40 m) up to FRL 223.57 m at an increment of 0.1 m as shown in Table 5.1. Area capacity curve for Wankleshwar Bhey 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 / FSL for the Survey Year 2021

Elevation Area Capacity Table (2021): Wankleshwar Bhey Dam				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
1	205.40	0.0001	0.00000	Bed level
2	205.50	0.0005	0.00003	-
3	205.60	0.0010	0.00010	-
4	205.70	0.0015	0.0002	-
5	205.80	0.0022	0.0004	-
6	205.90	0.0027	0.0007	-
7	206.00	0.0034	0.0010	-
8	206.10	0.0040	0.0013	-
9	206.20	0.004	0.002	-
10	206.30	0.005	0.002	-
11	206.40	0.005	0.003	-
12	206.50	0.006	0.003	-
13	206.60	0.008	0.004	-
14	206.70	0.009	0.005	-
15	206.80	0.010	0.006	-
16	206.90	0.011	0.007	-
17	207.00	0.012	0.008	-
18	207.10	0.013	0.009	-
19	207.20	0.014	0.011	-
20	207.30	0.015	0.012	-
21	207.40	0.017	0.014	-
22	207.50	0.018	0.015	-
23	207.60	0.019	0.017	-
24	207.70	0.020	0.019	-
25	207.80	0.021	0.021	-
26	207.90	0.024	0.023	-
27	208.00	0.026	0.026	-
28	208.10	0.028	0.029	-
29	208.20	0.030	0.032	-
30	208.30	0.033	0.035	-
31	208.40	0.036	0.038	-
32	208.50	0.039	0.042	-
33	208.60	0.042	0.046	-

Elevation Area Capacity Table (2021): Wankleshwar Bhey Dam				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
34	208.70	0.046	0.050	-
35	208.80	0.050	0.055	-
36	208.90	0.053	0.060	-
37	209.00	0.057	0.066	-
38	209.10	0.062	0.072	-
39	209.20	0.067	0.078	-
40	209.30	0.072	0.085	-
41	209.40	0.078	0.093	-
42	209.50	0.083	0.101	-
43	209.60	0.088	0.109	-
44	209.70	0.093	0.118	-
45	209.80	0.097	0.128	-
46	209.90	0.103	0.138	-
47	210.00	0.109	0.148	-
48	210.10	0.114	0.159	-
49	210.20	0.121	0.171	-
50	210.30	0.127	0.184	-
51	210.40	0.132	0.197	-
52	210.50	0.137	0.210	-
53	210.60	0.144	0.224	-
54	210.70	0.151	0.239	-
55	210.80	0.160	0.254	-
56	210.90	0.169	0.271	-
57	211.00	0.178	0.288	-
58	211.10	0.184	0.306	-
59	211.20	0.190	0.325	-
60	211.30	0.196	0.344	-
61	211.40	0.201	0.364	-
62	211.50	0.205	0.384	-
63	211.60	0.211	0.405	-
64	211.70	0.216	0.427	-
65	211.80	0.221	0.448	-
66	211.90	0.226	0.471	-

Elevation Area Capacity Table (2021): Wankleshwar Bhey Dam				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
67	212.00	0.232	0.494	-
68	212.10	0.237	0.517	-
69	212.20	0.243	0.541	-
70	212.30	0.249	0.566	-
71	212.40	0.256	0.591	-
72	212.50	0.263	0.617	-
73	212.60	0.270	0.644	-
74	212.70	0.277	0.671	-
75	212.80	0.284	0.699	-
76	212.90	0.291	0.728	-
77	213.00	0.298	0.757	-
78	213.10	0.307	0.788	-
79	213.20	0.315	0.819	-
80	213.30	0.323	0.850	-
81	213.40	0.331	0.883	-
82	213.50	0.338	0.917	-
83	213.60	0.346	0.951	-
84	213.70	0.355	0.986	-
85	213.80	0.364	1.022	-
86	213.90	0.374	1.059	-
87	214.00	0.384	1.097	-
88	214.10	0.394	1.136	-
89	214.20	0.406	1.176	-
90	214.30	0.417	1.217	-
91	214.40	0.429	1.259	-
92	214.50	0.442	1.303	-
93	214.60	0.456	1.347	-
94	214.70	0.471	1.394	-
95	214.80	0.485	1.442	-
96	214.88	0.495	1.482	MDDL
97	214.90	0.500	1.491	-
98	215.00	0.515	1.542	-
99	215.10	0.529	1.594	-
100	215.20	0.545	1.647	-
101	215.30	0.561	1.703	-
102	215.40	0.579	1.760	-
103	215.50	0.593	1.818	-
104	215.60	0.607	1.878	-
105	215.70	0.621	1.940	-
106	215.80	0.637	2.003	-
107	215.90	0.650	2.067	-

Elevation Area Capacity Table (2021): Wankleshwar Bhey Dam				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
108	216.00	0.664	2.133	-
109	216.10	0.679	2.200	-
110	216.20	0.693	2.268	-
111	216.30	0.708	2.338	-
112	216.40	0.725	2.410	-
113	216.50	0.741	2.483	-
114	216.60	0.759	2.558	-
115	216.70	0.776	2.635	-
116	216.80	0.795	2.714	-
117	216.90	0.813	2.794	-
118	217.00	0.832	2.876	-
119	217.10	0.853	2.961	-
120	217.20	0.874	3.047	-
121	217.30	0.896	3.135	-
122	217.40	0.918	3.226	-
123	217.50	0.940	3.319	-
124	217.60	0.962	3.414	-
125	217.70	0.985	3.511	-
126	217.80	1.009	3.611	-
127	217.90	1.032	3.713	-
128	218.00	1.055	3.817	-
129	218.10	1.078	3.924	-
130	218.20	1.102	4.033	-
131	218.30	1.126	4.144	-
132	218.40	1.150	4.258	-
133	218.50	1.174	4.374	-
134	218.60	1.197	4.493	-
135	218.70	1.219	4.614	-
136	218.80	1.242	4.737	-
137	218.90	1.266	4.862	-
138	219.00	1.289	4.990	-
139	219.10	1.312	5.120	-
140	219.20	1.338	5.253	-
141	219.30	1.364	5.388	-
142	219.40	1.389	5.525	-
143	219.50	1.414	5.665	-
144	219.60	1.434	5.808	-
145	219.70	1.454	5.952	-
146	219.80	1.472	6.098	-
147	219.90	1.488	6.247	-
148	220.00	1.506	6.396	-

Elevation Area Capacity Table (2021): Wankleshwar Bhey Dam				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
149	220.10	1.522	6.548	-
150	220.20	1.538	6.701	-
151	220.30	1.552	6.855	-
152	220.40	1.564	7.011	-
153	220.50	1.577	7.168	-
154	220.60	1.590	7.326	-
155	220.70	1.602	7.486	-
156	220.80	1.613	7.647	-
157	220.90	1.625	7.809	-
158	221.00	1.636	7.972	-
159	221.10	1.648	8.136	-
160	221.20	1.661	8.301	-
161	221.30	1.672	8.468	-
162	221.40	1.686	8.636	-
163	221.50	1.699	8.805	-
164	221.60	1.712	8.976	-
165	221.70	1.724	9.147	-
166	221.80	1.737	9.321	-
167	221.90	1.750	9.495	-
168	222.00	1.763	9.670	-
169	222.10	1.776	9.847	-
170	222.20	1.788	10.026	-
171	222.30	1.801	10.205	-
172	222.40	1.813	10.386	-
173	222.50	1.827	10.568	-
174	222.60	1.840	10.751	-
175	222.70	1.854	10.936	-
176	222.80	1.868	11.122	-
177	222.90	1.885	11.310	-
178	223.00	1.902	11.499	-
179	223.10	1.918	11.690	-
180	223.20	1.935	11.883	-
181	223.30	1.950	12.077	-
182	223.40	1.967	12.273	-
183	223.50	1.983	12.470	-
184	223.57	1.998	12.620	FRL
185	223.60	2.000	12.669	-
186	223.70	2.018	12.870	-
187	223.80	2.038	13.073	-
188	223.90	2.058	13.278	-
189	224.00	2.083	13.485	-

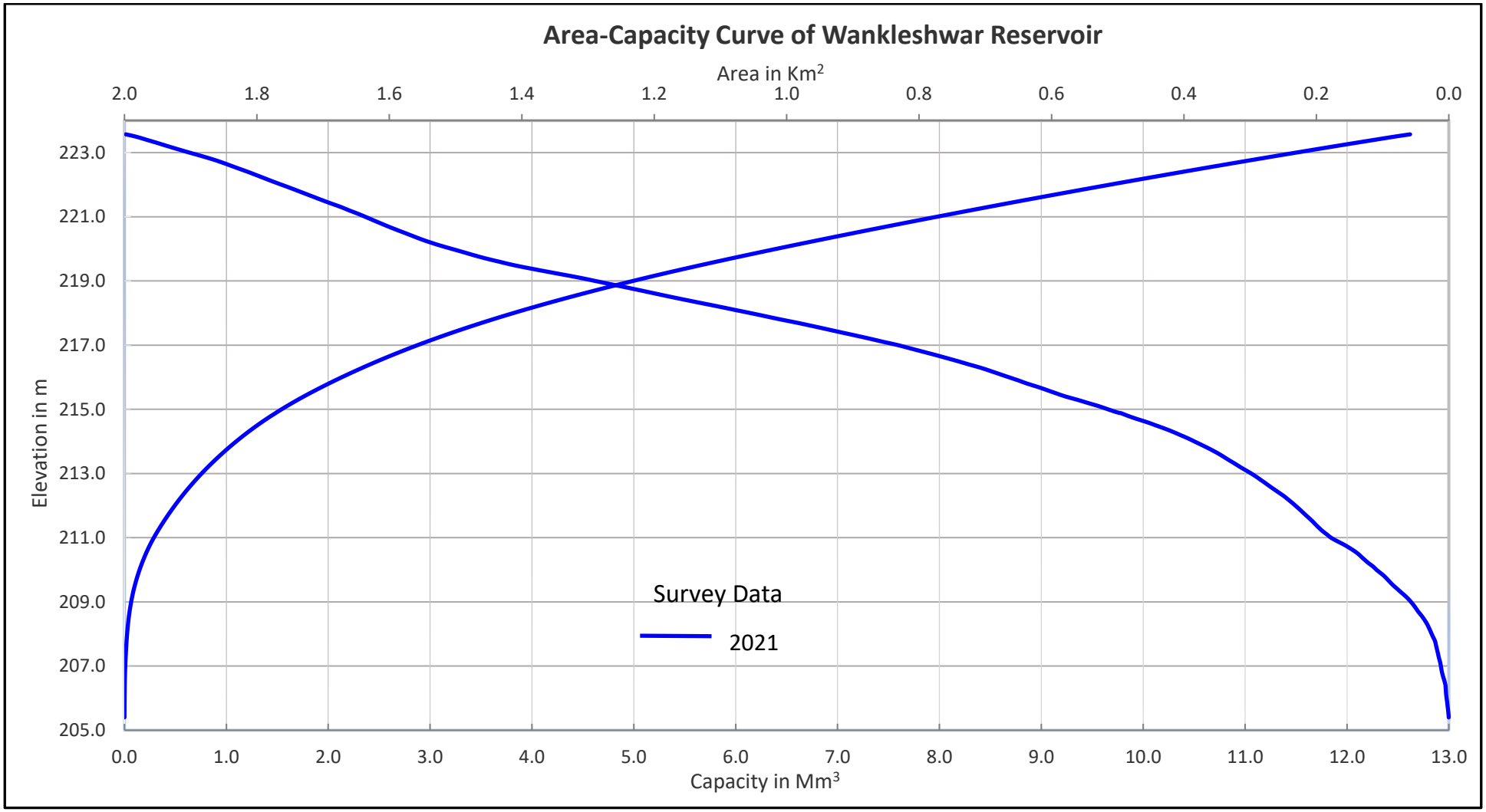

Figure 5.5: Area capacity curve for 2021 survey for Wankleshwar Bhey Reservoir

5.3 Comparison of Elevation Area Capacity Curve

Elevation area capacity details for the project year 1978 is shown in Table 5.2. In addition, the comparison plots of capacity curve for the year 1978 and 2021 are shown in Figure 5.6

In general, the 2021 survey results indicate that there is a reduction in gross storage capacity and area w.r.t. 1978 survey. The capacity curve of 2021 is found close to that of year 1978.

Table 5.2: Project Elevation Capacity details of 1978 for Wankleshwar Bhey Reservoir

Sr. No	Elevation (w.r.t. MSL) [m]	1978 Survey	
		Area [km^2]	Gross Capacity [Mm^3]
1	207.264	0.025	0.048
2	210.312	0.113	0.185
3	211.836	0.219	0.491
4	213.360	0.382	0.942
5	214.884	0.545	1.645
6	216.408	0.752	2.630
7	217.932	1.004	3.965
8	219.456	1.493	5.853
9	220.980	1.776	8.341
10	222.504	2.349	11.502
11	224.028	2.883	15.437
12	225.857	3.404	20.130

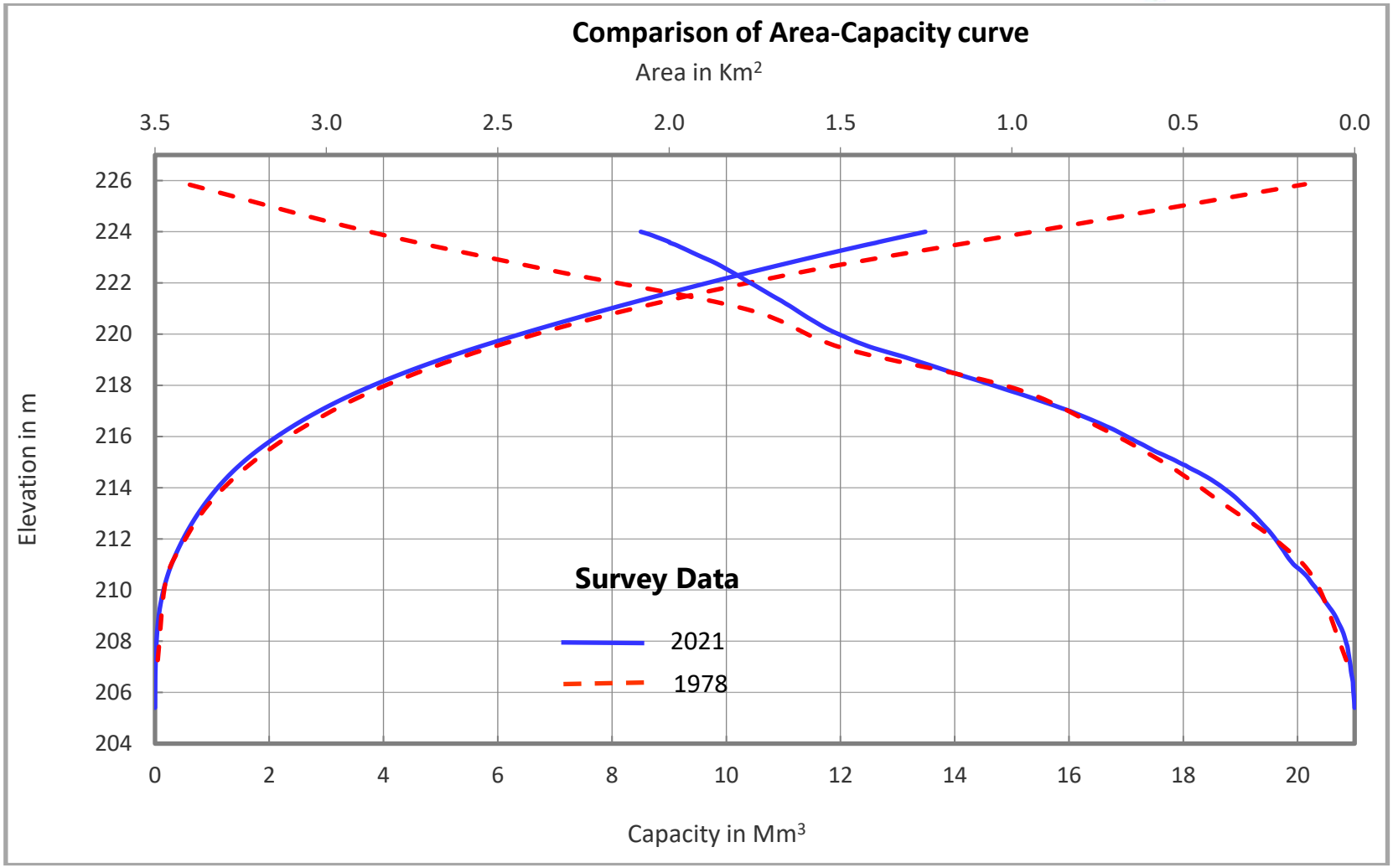

Figure 5.6: Area capacity curve for 2021 survey compared with elevation capacity details of 1978 for Wankleshwar Bhey Reservoir

5.4 Sedimentation in Reservoir

The present survey of Wankleshwar Bhey reservoir was carried out between May - August 2021. Project data is for the year 1978. The catchment area considered for sedimentation studies is 44.5 km^2. In the present study, the age of the reservoir is considered as 43 years (1978 – 2021). As per 2021 survey, the total area of reservoir at FRL 223.57 m is 1.998 km^2 and the corresponding gross storage capacity is 12.620 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 (1978).

Table 5.3: Sedimentation in Wankleshwar Bhey Reservoir

Year	1978	2021
Storage Capacity in Mm^3		
Dead	1.61	1.482
Live	11.69	11.138
Gross	13.3	12.620
Loss of Storage Capacity in Mm^3		(wrt 1978)
Dead	NA	0.128
Live	NA	0.552
Gross	NA	0.680
Sedimentation Rate in Ham/100 km^2/Year		(wrt 1978)
Dead	NA	0.669
Live	NA	2.885
Gross	NA	3.554
Annual % loss		(wrt 1978)
Dead	NA	0.022
Live	NA	0.097
Gross	NA	0.119
Class of reservoir as per IS -12182 (1987)	As per design	Significant
Volume of sediment (wrt 1978) deposited on bed in 2020-21= Loss of storage capacity= 0.680 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 Wankleshwar Bhey reservoir as per the methodology given in IS 12182-1987.

Table 5.4: Trap Efficiency and Sedimentation Index for Wankleshwar Bhey Reservoir

Trap Efficiency	Sedimentation Index
96%	1.328×10^{11} sec^2/m

In Table 5.3, the Project data of 1978 has been compared with 2021 survey results to understand the sedimentation in Wankleshwar Bhey reservoir. It may be observed that there is a reduction in the storage capacity of the reservoir due to siltation.

In comparison with the project data, 1978, the present survey results indicate continuous siltation process in the reservoir. The reason behind the present survey results showing siltation w.r.t. 1978 could be due to change in upstream catchment characteristics. Also, there could be some anthropogenic activities in the catchment area which might result in siltation in the reservoir.

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 1986 survey (Ha m / 100 Sq km/Yr)
				Gross	(Mm^3)	% Cumulative	Remark	
1	1978	Govt.	-	13.300				
2	2021	Present survey	43	12.620	0.680	5.113	Siltation	3.554

- As per 2021 survey results, the volume of sediment deposited or the loss in gross storage capacity w.r.t. project data of 1978 is 0.680 Mm^3.
- The rate of siltation in Wankleshwar Bhey reservoir is 0.016 Mm^3/year.
- The average rate of siltation in the Wankleshwar Bhey reservoir during the 43 years life span (1978 – 2021), works out to 3.554 Ha m/100 sq km/year.
- The annual % loss in Wankleshwar Bhey reservoir during the 43 years life span is 0.119 % and hence, the reservoir is classified as "Serious" category as per IS 12182 (1987).
- Trap Efficiency and sedimentation Index calculated for Wankleshwar Bhey reservoir as per methodology give in IS 12182-1987 is 96 % and 1.328 x 10^{10} sec^2/m respectively.

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 - Wankleshwar Bhey reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
1	205.40	0.00000	--	0.00000	Bed level
2	205.50	0.00003	--	0.00003	--
3	205.60	0.00010	--	0.00010	--
4	205.70	0.0002	--	0.0002	--
5	205.80	0.0004	--	0.0004	--
6	205.90	0.0007	--	0.0007	--
7	206.00	0.0010	--	0.0010	--
8	206.10	0.0013	--	0.0013	--
9	206.20	0.002	--	0.002	--
10	206.30	0.002	--	0.002	--
11	206.40	0.003	--	0.003	--
12	206.50	0.003	--	0.003	--
13	206.60	0.004	--	0.004	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Wankleshwar Bhey reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
14	206.70	0.005	--	0.005	--
15	206.80	0.006	--	0.006	--
16	206.90	0.007	--	0.007	--
17	207.00	0.008	--	0.008	--
18	207.10	0.009	--	0.009	--
19	207.20	0.011	--	0.011	--
20	207.30	0.012	--	0.012	--
21	207.40	0.014	--	0.014	--
22	207.50	0.015	--	0.015	--
23	207.60	0.017	--	0.017	--
24	207.70	0.019	--	0.019	--
25	207.80	0.021	--	0.021	--
26	207.90	0.023	--	0.023	--
27	208.00	0.026	--	0.026	--
28	208.10	0.029	--	0.029	--
29	208.20	0.032	--	0.032	--
30	208.30	0.035	--	0.035	--
31	208.40	0.038	--	0.038	--
32	208.50	0.042	--	0.042	--
33	208.60	0.046	--	0.046	--
34	208.70	0.050	--	0.050	--
35	208.80	0.055	--	0.055	--
36	208.90	0.060	--	0.060	--
37	209.00	0.066	--	0.066	--
38	209.10	0.072	--	0.072	--
39	209.20	0.078	--	0.078	--
40	209.30	0.085	--	0.085	--
41	209.40	0.093	--	0.093	--
42	209.50	0.101	--	0.101	--
43	209.60	0.109	--	0.109	--
44	209.70	0.118	--	0.118	--
45	209.80	0.128	--	0.128	--
46	209.90	0.138	--	0.138	--
47	210.00	0.148	--	0.148	--
48	210.10	0.159	--	0.159	--
49	210.20	0.171	--	0.171	--
50	210.30	0.184	--	0.184	--
51	210.40	0.197	--	0.197	--
52	210.50	0.210	--	0.210	--
53	210.60	0.224	--	0.224	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Wankleshwar Bhey reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
54	210.70	0.239	--	0.239	--
55	210.80	0.254	--	0.254	--
56	210.90	0.271	--	0.271	--
57	211.00	0.288	--	0.288	--
58	211.10	0.306	--	0.306	--
59	211.20	0.325	--	0.325	--
60	211.30	0.344	--	0.344	--
61	211.40	0.364	--	0.364	--
62	211.50	0.384	--	0.384	--
63	211.60	0.405	--	0.405	--
64	211.70	0.427	--	0.427	--
65	211.80	0.448	--	0.448	--
66	211.90	0.471	--	0.471	--
67	212.00	0.494	--	0.494	--
68	212.10	0.517	--	0.517	--
69	212.20	0.541	--	0.541	--
70	212.30	0.566	--	0.566	--
71	212.40	0.591	--	0.591	--
72	212.50	0.617	--	0.617	--
73	212.60	0.644	--	0.644	--
74	212.70	0.671	--	0.671	--
75	212.80	0.699	--	0.699	--
76	212.90	0.728	--	0.728	--
77	213.00	0.757	--	0.757	--
78	213.10	0.788	--	0.788	--
79	213.20	0.819	--	0.819	--
80	213.30	0.850	--	0.850	--
81	213.40	0.883	--	0.883	--
82	213.50	0.917	--	0.917	--
83	213.60	0.951	--	0.951	--
84	213.70	0.986	--	0.986	--
85	213.80	1.022	--	1.022	--
86	213.90	1.059	--	1.059	--
87	214.00	1.097	--	1.097	--
88	214.10	1.136	--	1.136	--
89	214.20	1.176	--	1.176	--
90	214.30	1.217	--	1.217	--
91	214.40	1.259	--	1.259	--
92	214.50	1.303	--	1.303	--
93	214.60	1.347	--	1.347	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Wankleshwar Bhey reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
94	214.70	1.394	--	1.394	--
95	214.80	1.442	--	1.442	--
96	214.88	1.482	--	1.482	MDDL
97	214.90	1.491	0.009	1.482	--
98	215.00	1.542	0.060	1.482	--
99	215.10	1.594	0.112	1.482	--
100	215.20	1.647	0.165	1.482	--
101	215.30	1.703	0.221	1.482	--
102	215.40	1.760	0.278	1.482	--
103	215.50	1.818	0.336	1.482	--
104	215.60	1.878	0.396	1.482	--
105	215.70	1.940	0.458	1.482	--
106	215.80	2.003	0.521	1.482	--
107	215.90	2.067	0.585	1.482	--
108	216.00	2.133	0.651	1.482	--
109	216.10	2.200	0.718	1.482	--
110	216.20	2.268	0.786	1.482	--
111	216.30	2.338	0.856	1.482	--
112	216.40	2.410	0.928	1.482	--
113	216.50	2.483	1.001	1.482	--
114	216.60	2.558	1.076	1.482	--
115	216.70	2.635	1.153	1.482	--
116	216.80	2.714	1.232	1.482	--
117	216.90	2.794	1.312	1.482	--
118	217.00	2.876	1.394	1.482	--
119	217.10	2.961	1.479	1.482	--
120	217.20	3.047	1.565	1.482	--
121	217.30	3.135	1.653	1.482	--
122	217.40	3.226	1.744	1.482	--
123	217.50	3.319	1.837	1.482	--
124	217.60	3.414	1.932	1.482	--
125	217.70	3.511	2.029	1.482	--
126	217.80	3.611	2.129	1.482	--
127	217.90	3.713	2.231	1.482	--
128	218.00	3.817	2.335	1.482	--
129	218.10	3.924	2.442	1.482	--
130	218.20	4.033	2.551	1.482	--
131	218.30	4.144	2.662	1.482	--
132	218.40	4.258	2.776	1.482	--
133	218.50	4.374	2.892	1.482	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Wankleshwar Bhey reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
134	218.60	4.493	3.011	1.482	--
135	218.70	4.614	3.132	1.482	--
136	218.80	4.737	3.255	1.482	--
137	218.90	4.862	3.380	1.482	--
138	219.00	4.990	3.508	1.482	--
139	219.10	5.120	3.638	1.482	--
140	219.20	5.253	3.771	1.482	--
141	219.30	5.388	3.906	1.482	--
142	219.40	5.525	4.043	1.482	--
143	219.50	5.665	4.183	1.482	--
144	219.60	5.808	4.326	1.482	--
145	219.70	5.952	4.470	1.482	--
146	219.80	6.098	4.616	1.482	--
147	219.90	6.247	4.765	1.482	--
148	220.00	6.396	4.914	1.482	--
149	220.10	6.548	5.066	1.482	--
150	220.20	6.701	5.219	1.482	--
151	220.30	6.855	5.373	1.482	--
152	220.40	7.011	5.529	1.482	--
153	220.50	7.168	5.686	1.482	--
154	220.60	7.326	5.844	1.482	--
155	220.70	7.486	6.004	1.482	--
156	220.80	7.647	6.165	1.482	--
157	220.90	7.809	6.327	1.482	--
158	221.00	7.972	6.490	1.482	--
159	221.10	8.136	6.654	1.482	--
160	221.20	8.301	6.819	1.482	--
161	221.30	8.468	6.986	1.482	--
162	221.40	8.636	7.154	1.482	--
163	221.50	8.805	7.323	1.482	--
164	221.60	8.976	7.494	1.482	--
165	221.70	9.147	7.665	1.482	--
166	221.80	9.321	7.839	1.482	--
167	221.90	9.495	8.013	1.482	--
168	222.00	9.670	8.188	1.482	--
169	222.10	9.847	8.365	1.482	--
170	222.20	10.026	8.544	1.482	--
171	222.30	10.205	8.723	1.482	--
172	222.40	10.386	8.904	1.482	--
173	222.50	10.568	9.086	1.482	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Wankleshwar Bhey reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
174	222.60	10.751	9.269	1.482	--
175	222.70	10.936	9.454	1.482	--
176	222.80	11.122	9.640	1.482	--
177	222.90	11.310	9.828	1.482	--
178	223.00	11.499	10.017	1.482	--
179	223.10	11.690	10.208	1.482	--
180	223.20	11.883	10.401	1.482	--
181	223.30	12.077	10.595	1.482	--
182	223.40	12.273	10.791	1.482	--
183	223.50	12.470	10.988	1.482	--
184	223.57	12.620	11.138	1.482	FRL

6. Conclusions

- The reservoir topography was uneven, with reservoir bed level ranging from 205.40 m to FRL 223.57 m w.r.t. MSL. The lowest reservoir bed level 205.40 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 northeast, east and southeast directions away from the dam wall within the survey area.
- Current survey results indicate that the loss of gross storage capacity (w.r.t. 1978 project data) due to siltation in Wankleshwar Bhey reservoir is 0.680 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 1978 survey results, 2021 results indicate decrease in storage capacity due to siltation. The annual % loss in gross storage capacity is 0.119 % 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.

7. References

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Appendix A

Diary of Events

(01 page)

Diary of Events (Bathymetry and Topography Survey)	
Date	**Events**
Bathymetry Survey	
11 March 2021	Survey personnel and equipment with survey boat 'Fugro Zodiac' reached Wankleshwar Bhey reservoir. Fugro Zodiac deployed on Wankleshwar Bhey reservoir
12 March 2021	Mobilization commenced and completed. Calibration/verification commenced.
13 March 2021	Calibration/verification completed.
14 March 2021	Bathymetry survey commenced.
14 - 22 March 2021	Bathymetry Survey continued.
23 March 2021	Bathymetry Survey completed
24 March 2021	Demobilization commenced and Site visit of Hadaf Dam.
25 March 2021	Demobilization completed.
Topography Survey	
14 June 2021	Topography survey team with equipment reached Wankleshwar Bhey Dam. Mobilisation and calibration commenced and completed. Topography survey commenced
15 June 2021	Topography survey completed. Demobilization commenced and completed.

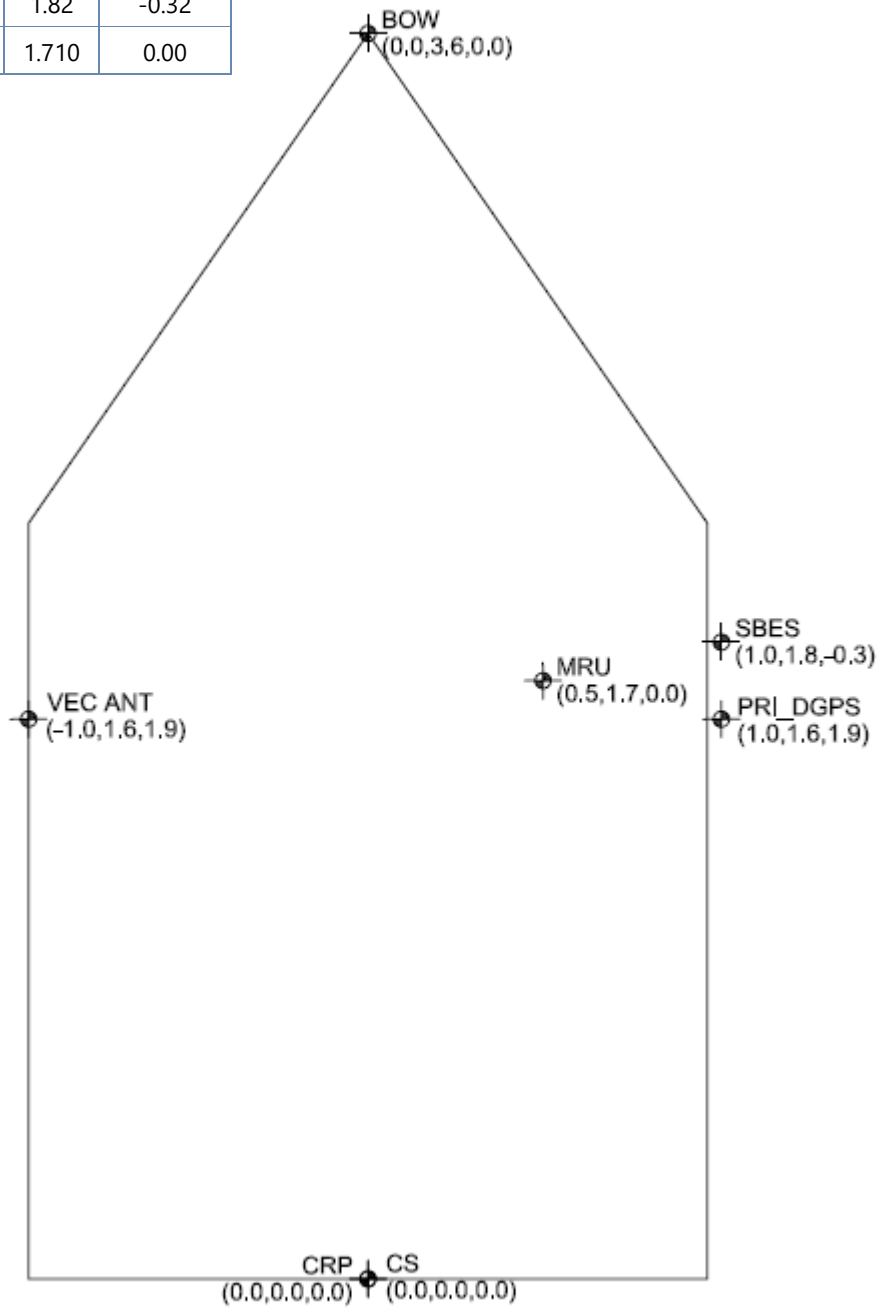
Appendix B

Survey Vessel Sensor Offsets

(01 Page)

Survey Vessel 'Fugro Zodiac' Sensor Offset Diagram

Sensor Offsets: Fugro Zodiac			
Starfix.Suite Name	**X [m]**	**Y [m]**	**Z [m]**
Centre Stern (CS)	0.00	0.00	0.00
Bow	0.00	3.56	0.00
PRI_GPS	1.01	1.60	1.90
VEC_ANT	-0.97	1.60	1.90
SBES	1.01	1.82	-0.32
MRU	0.50	1.710	0.00

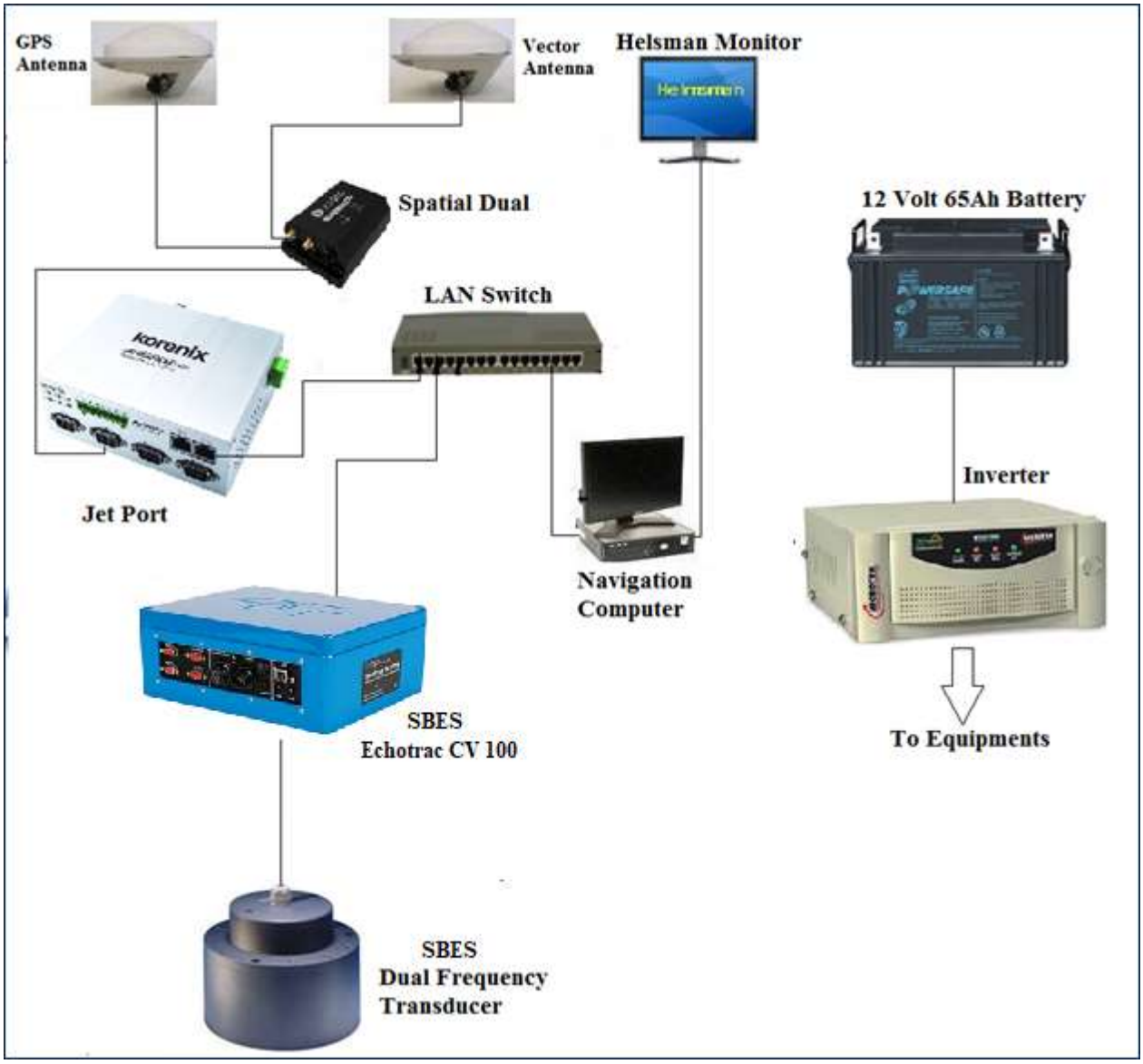


Appendix C

Equipment Layout Diagram

(01 Page)

Equipment Layout Diagram onboard Fugro Zodiac



Appendix D

Results of Field Calibrations / Verifications

(18 pages)

FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of Wankleshwar Bhey TBM

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	**Wankleshwar Bhey TBM**	**Location:**	Wankleswar Bhey, Gujarat
Party Chief :	Pritam Seth	**Job Engineer/Surveyor :**	Ganesh Sonawale.
Date of Observation: (Date & Time)	13-03-2021 & 09:28hrs	**End of Observation: (Date & Time)**	13-03-2021 & 09:58hrs

1. Station Name: Wankleshwar Bhey TBM.

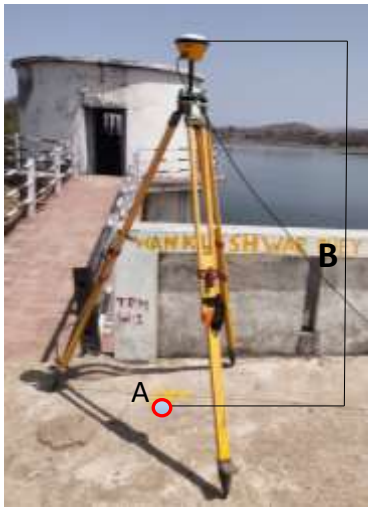
Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
Trimble BX 992 RECEIVER	025-00009601	PRI_DGPS	Mean position report	FBF	NA	0.01

A=Center Point of **Wankleshwar Bhey TBM** Height from MSL 227.675m

B= Antenna Height from BM 1.787m (Measure by Tape)

Ellipsoidal height of Antenna= 171.600m

Ellipsoidal Height of BM 171.600m - 1.787m=169.813m



Position Of Antenna:-

Latitude: 22°42'02.97873"N, **Longitude:** 073°59'10.33008"E

Easting: 3,95,873.119m E**, Northing:** 25,10,757.609m N

Prepared By: Pritam Seth.

JHGH

MEAN POSITION REPORT

Project ID	TEST		
Location	Central Gujarat		
Client	Narmada Water Resources Govt. of Gujarat	**Vessel**	Prism
Comment	BX 992-TBM-ANT HT 1.787m		

Session Name: MPR-20210313034548-v2 Records Used: 1600 of 1800

Start Time: 13 Mar 2021, 09:28:09+05:30 End Time: 13 Mar 2021, 09:58:08+05:30 Session Length: 00:29:59

Mean Position for Prism CommonReferencePoint		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	22°42'02.97873"N	22°42'02.97873"N
Longitude	073°59'10.33008"E	073°59'10.33008"E
Height	171.600m Ell.	171.600m Ell.
Easting	3,95,873.119m E (SD: ±0.02m)	
Northing	25,10,757.609m N (SD: ±0.01m)	
Height	229.025m Ort. (SD: ±0.04m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	355.80°T 356.20°G	±66.7°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

BX 992-TBM-ANT HT 1.787m

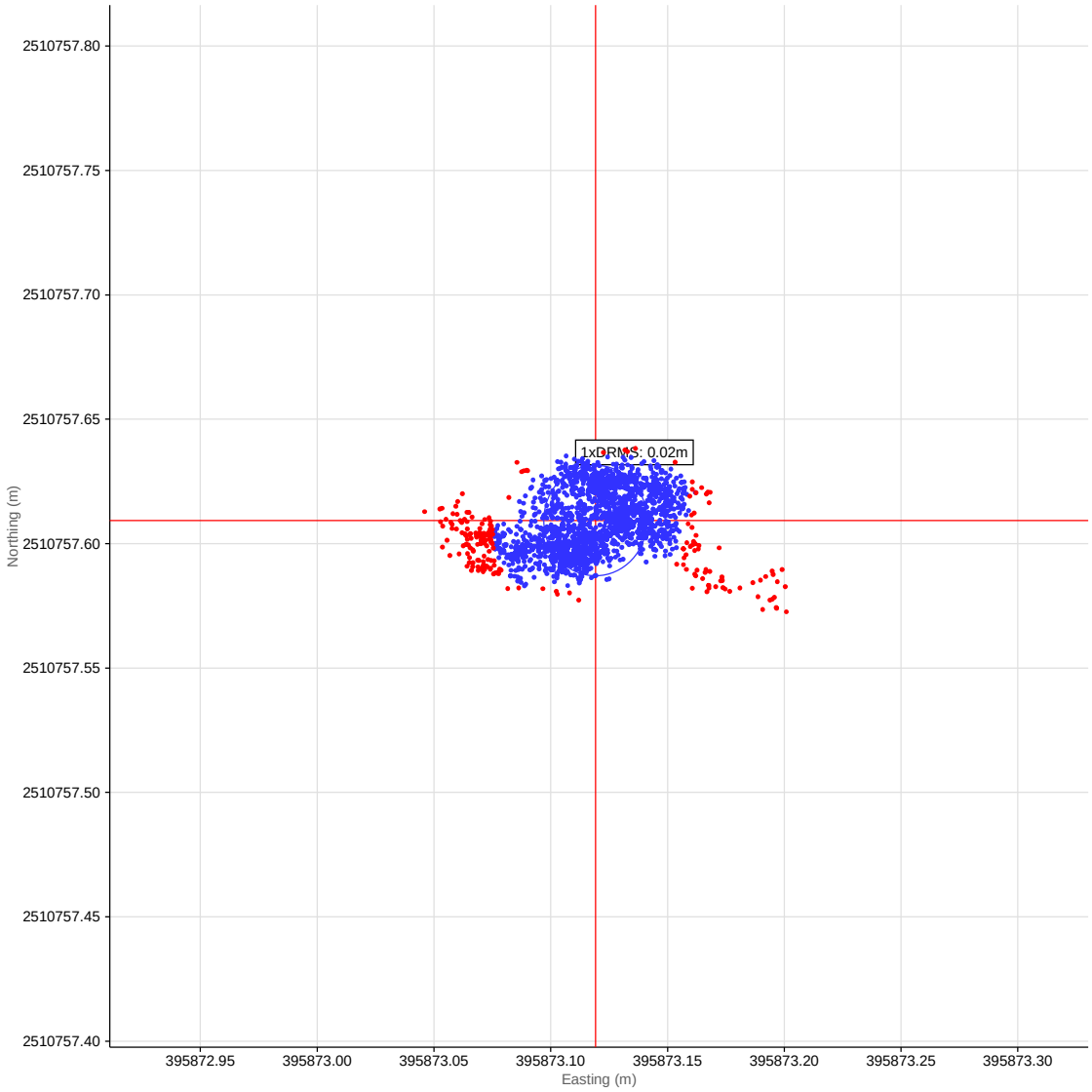
PRITAM SETH
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Client Representative
Narmada Water Resources
Water Supply and Kalpsar Department/ Government 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	

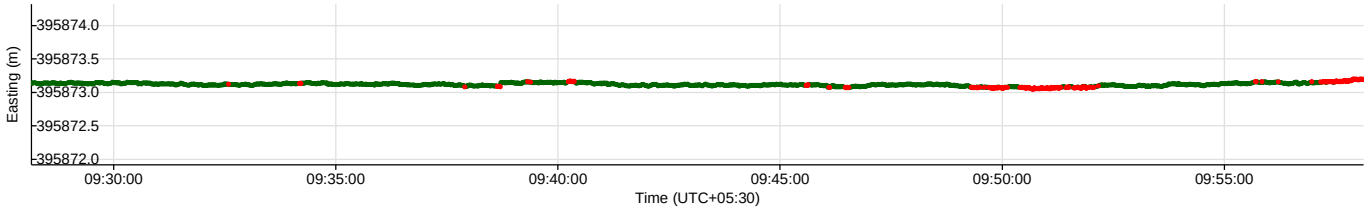
Scatter Plot

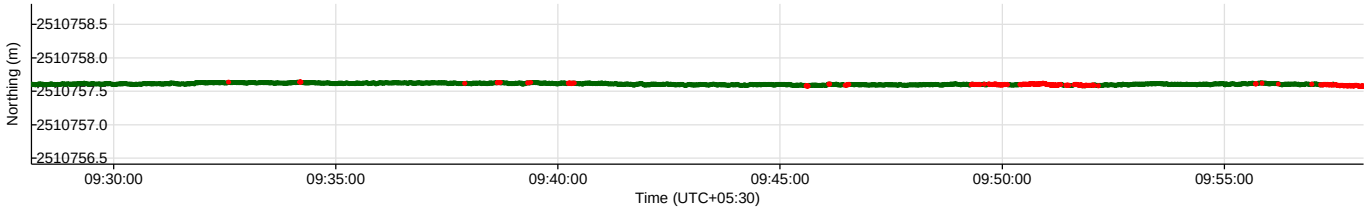


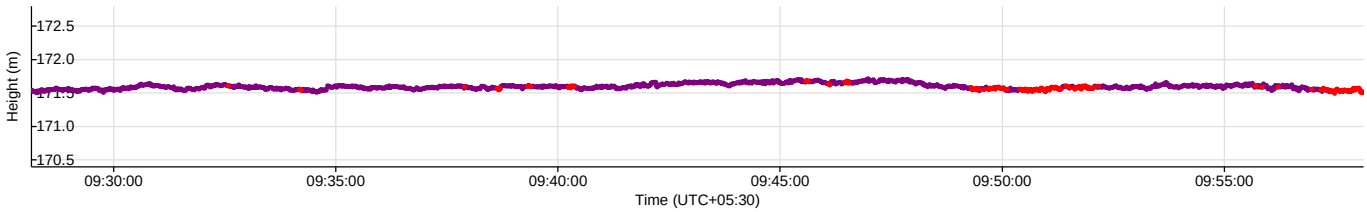
Mean Position

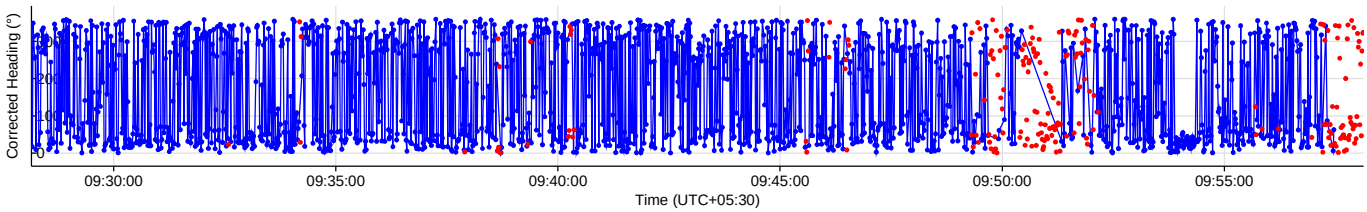
	Easting	Northing
Prism	3,95,873.119m E	25,10,757.609m N

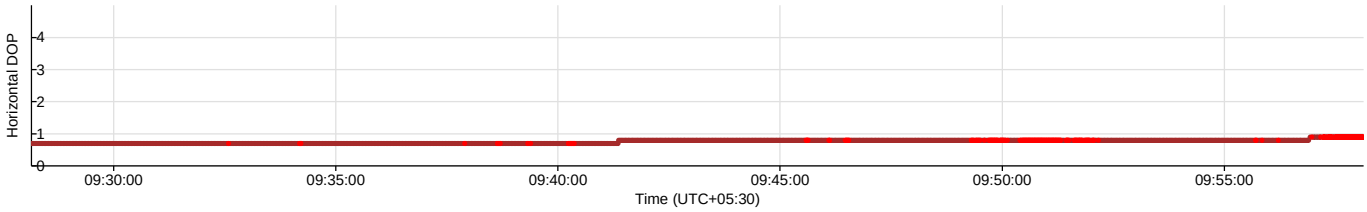
Time Series Plots for Prism

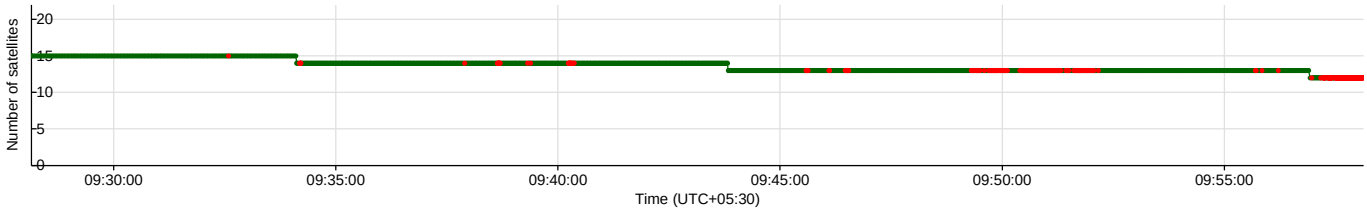


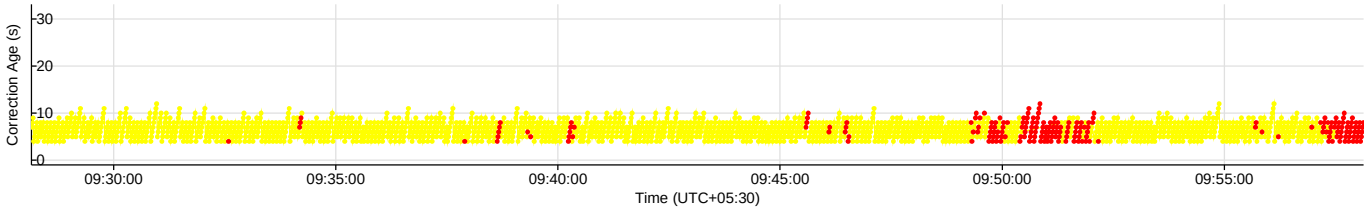












FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of Wankleshwar Bhey TBM

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	**Wankleshwar Bhey TBM**	**Location:**	Wankleswar Bhey, Gujarat
Party Chief :	Pritam Seth	**Job Engineer/Surveyor :**	Ganesh Sonawale.
Date of Observation: (Date & Time)	13-03-2021 & 10:30hrs	**End of Observation: (Date & Time)**	13-03-2021 & 11:00hrs

1. Station Name: Wankleshwar Bhey 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**
SATIAL DUAL RECEIVER	025-00006405	PRI_DGPS	Mean position report	FBF	NA	0.01

A=Center Point of **Wankleshwar Bhey TBM** Height from MSL 227.675m

B= Antenna Height from BM 1.742m (Measure by Tape)

Ellipsoidal height of Antenna= 171.574m

Ellipsoidal Height of BM 171.574m - 1.742m=169.832m

Position Of Antenna:-

Latitude: 22°42'02.97985"N, **Longitude:** 073°59'10.32750"E

Easting: 3,95,873.046m E**, Northing:** 25,10,757.644m N

Prepared By: Pritam Seth.

Project ID	TEST		
Location	Central Gujarat		
Client	Narmada Water Resources Govt. of Gujarat	**Vessel**	Prism
Comment	Spatial Dual-TBM-ANT HT 1.742m		

Session Name: MPR-20210313044517-v2 Records Used: 1576 of 1799

Start Time: 13 Mar 2021, 10:30:02+05:30 End Time: 13 Mar 2021, 11:00:01+05:30 Session Length: 00:29:59

Mean Position for Prism CommonReferencePoint		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	22°42’02.97985”N	22°42’02.97985”N
Longitude	073°59’10.32750”E	073°59’10.32750”E
Height	171.574m Ell.	171.574m Ell.
Easting	3,95,873.046m E (SD: ±0.02m)	
Northing	25,10,757.644m N (SD: ±0.01m)	
Height	228.999m Ort. (SD: ±0.03m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	254.96°T 255.35°G	±85.2°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

Spatial Dual-TBM-ANT HT 1.742m

PRITAM SETH
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Client Representative
Narmada Water Resources
Water Supply and Kalpsar Department/ Government of Gujarat

Geodetic Parameters

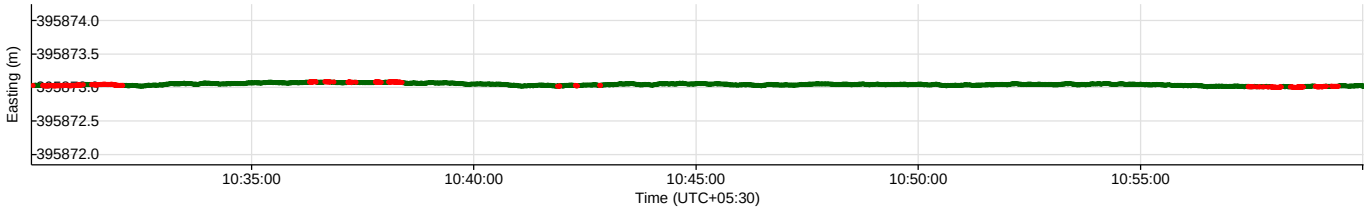
Name : WGS 84 / UTM zone 43N		
EPSG Code	EPSG::32643	
Local Geodetic Datum Parameters		
Datum	World Geodetic System 1984	EPSG::6326
Ellipsoid	WGS 84	
Semi major axis	a = 63,78,137.000 m	
Inverse flattening	1/f = 298.257223563	
Local Projection Parameters		
Map Projection	Transverse Mercator	
Grid System	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	

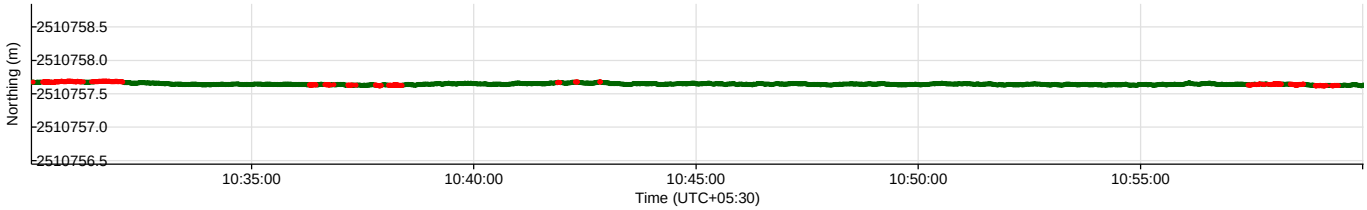
Scatter Plot

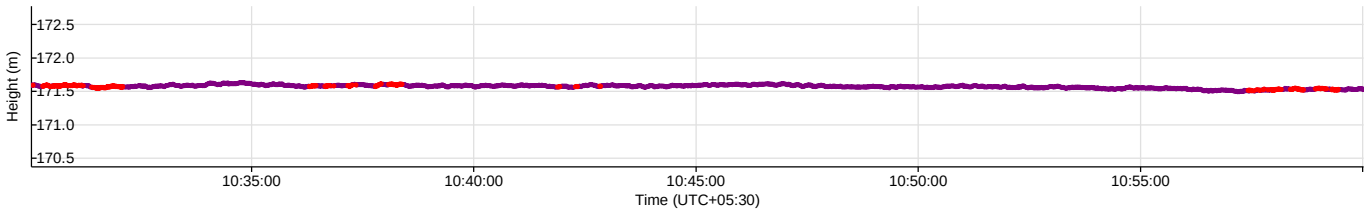
Mean Position

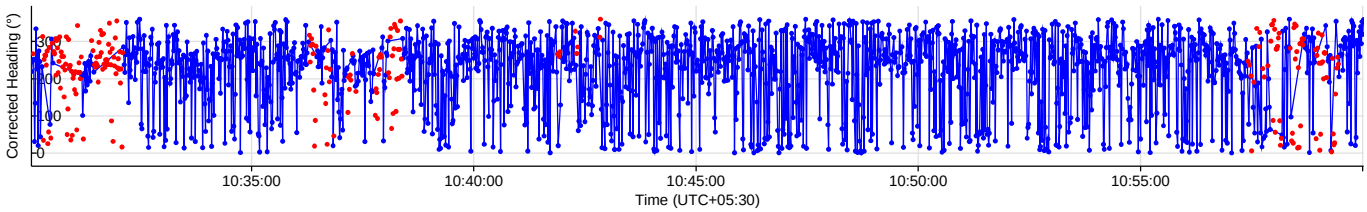
	Easting	Northing
Prism	3,95,873.046m E	25,10,757.644m N

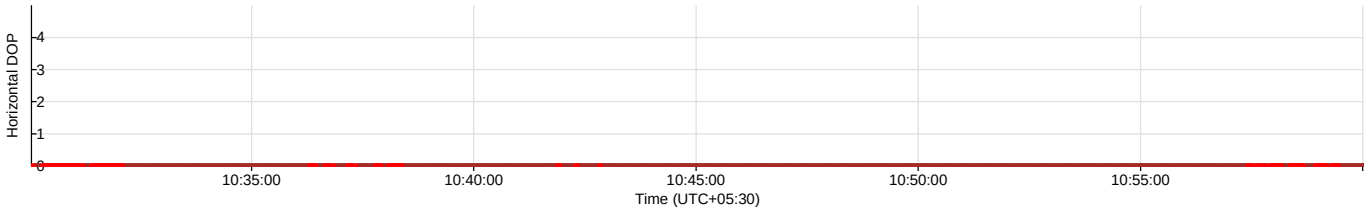
Time Series Plots for Prism

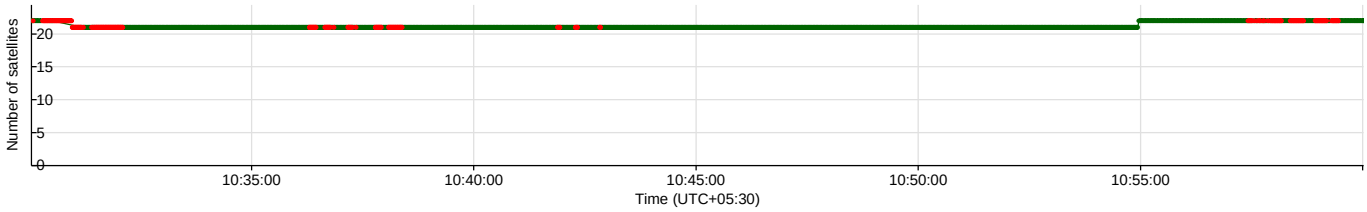


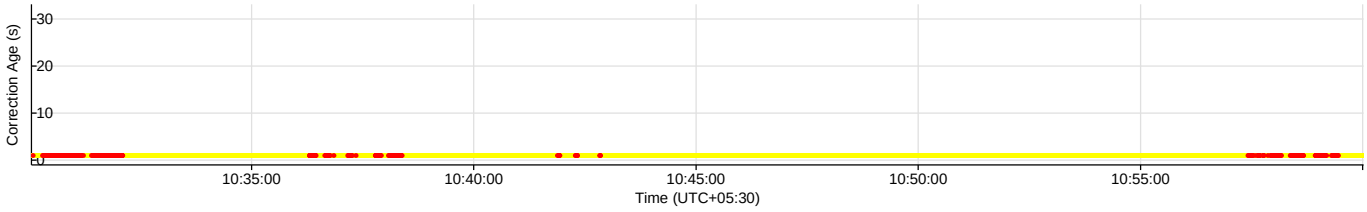












FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of TBM 4

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	TBM 4	**Location:**	Wankleswar Bhey, Gujarat
Party Chief :	Pritam Seth	**Job Engineer/Surveyor :**	Ganesh Sonawale.
Date of Observation: (Date & Time)	13-03-2021 & 11:40hrs	**End of Observation: (Date & Time)**	13-03-2021 & 12:10hrs

1. Station Name: TBM 4.

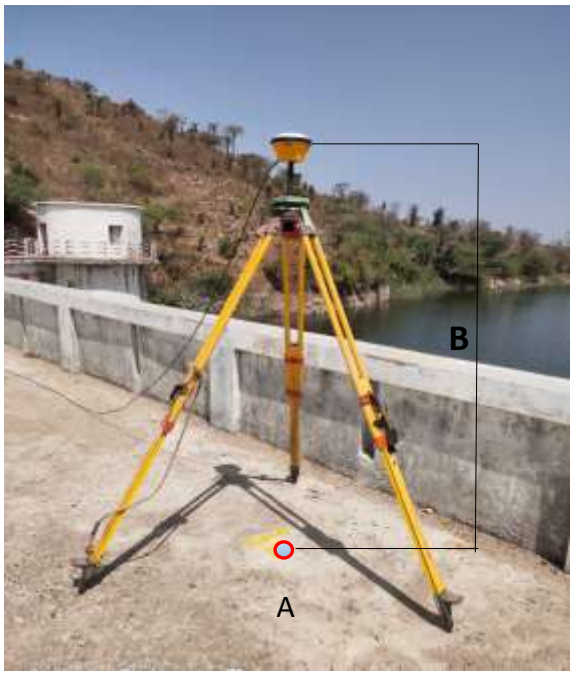
Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
TRIMBLE BX992 RECEIVER	025-00009601	PRI_DGPS	Mean position report	FBF	NA	0.02

A=Center Point of TBM 4 Height from MSL 227.691m

B= Antenna Height from BM 1.720m (Measure by Tape)

Ellipsoidal height of Antenna= 171.533m

Ellipsoidal Height of BM 171.533m - 1.720m=169.813m



Position Of Antenna:-

Latitude: 22°42'02.239"N, Longitude: 073°59'11.051"E

Easting: 395893.557m E, Northing: 2510734.738m N

Prepared By: Pritam Seth.

Project ID	TEST		
Location	Central Gujarat		
Client	Narmada Water Resources Govt. of Gujarat	**Vessel**	Prism
Comment	TBM 4- ANT HT 1.72m		

Session Name: MPR-20210313055131-v2 Records Used: 1282 of 1796

Start Time: 13 Mar 2021, 11:39:54+05:30 End Time: 13 Mar 2021, 12:09:53+05:30 Session Length: 00:29:59

Mean Position for Prism CommonReferencePoint		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	22°42'02.23957"N	22°42'02.23957"N
Longitude	073°59'11.05183"E	073°59'11.05183"E
Height	171.533m Ell.	171.533m Ell.
Easting	3,95,893.557m E (SD: ±0.03m)	
Northing	25,10,734.738m N (SD: ±0.02m)	
Height	228.958m Ort. (SD: ±0.04m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	27.76°T 28.15°G	±85.3°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

TBM 4- ANT HT 1.72m

Mean Position to Waypoint	
Waypoint	BX
Easting	3,95,873.119m E
Northing	25,10,757.609m N
Range	30.68m Geodetic
Bearing TO	317.82°True
Bearing FROM	137.82°True

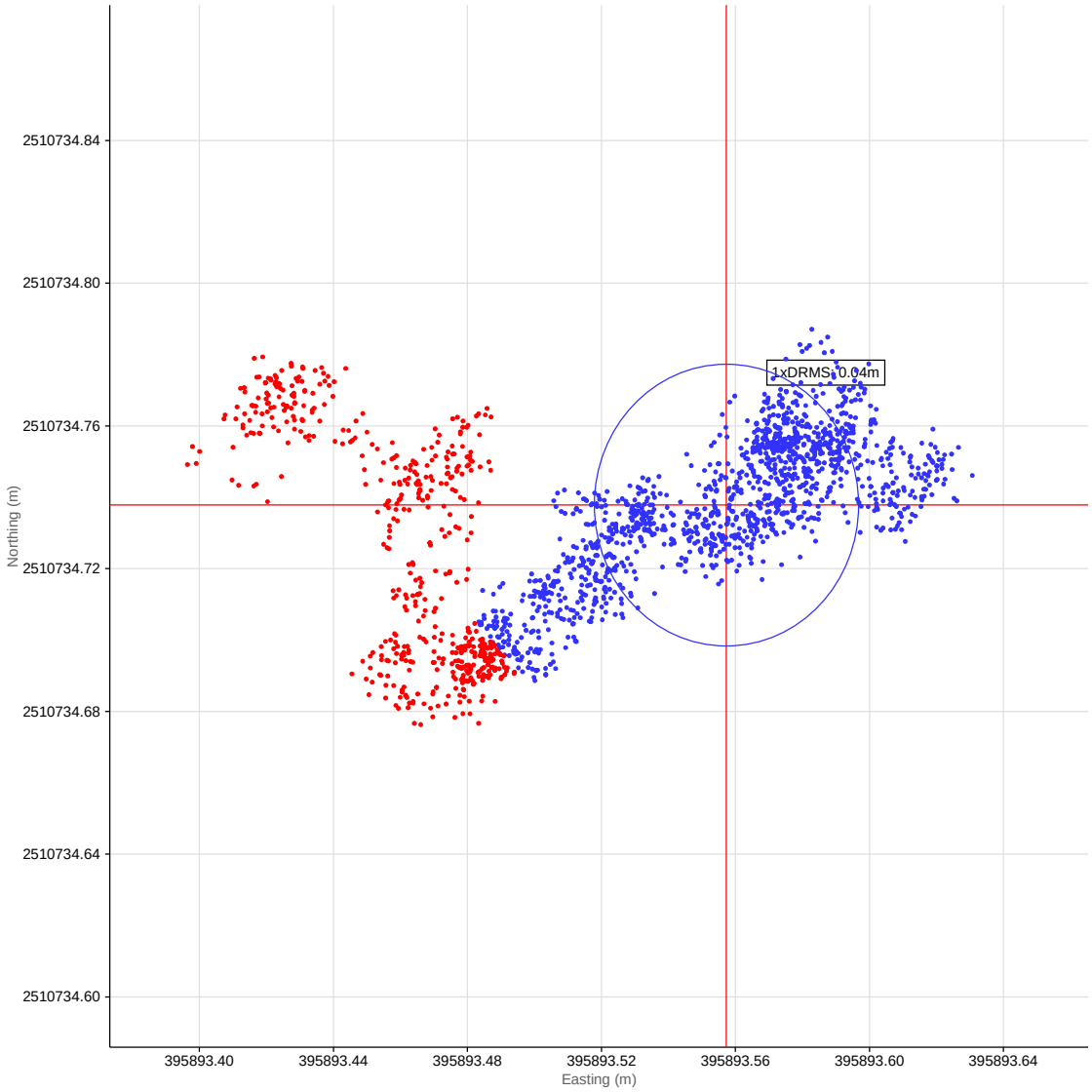
PRITAM SETH
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Client Representative
Narmada Water Resources
Water Supply and Kalpsar Department/ Government 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	

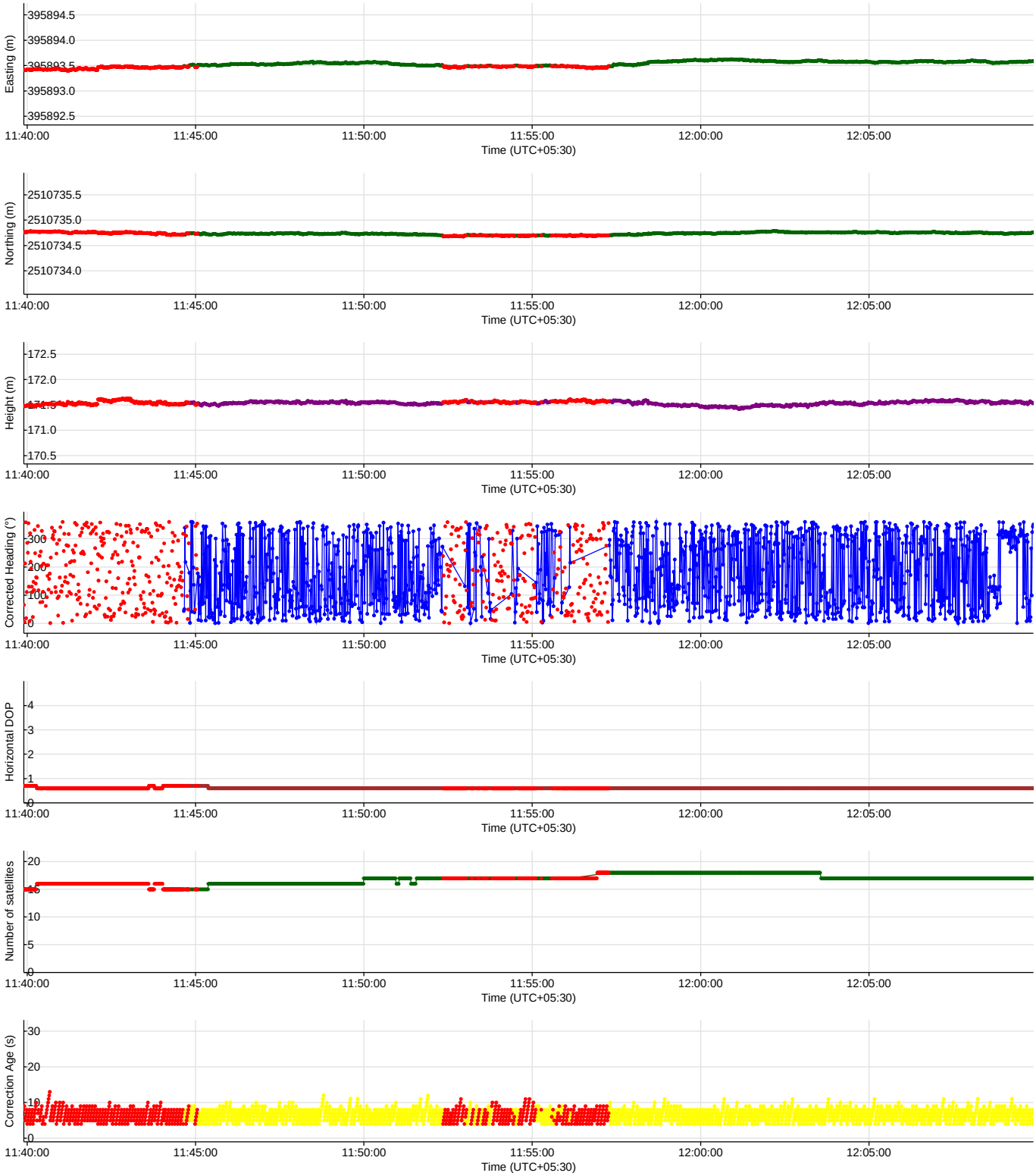
Scatter Plot



Mean Position

	Easting	Northing
Prism	3,95,893.557m E	25,10,734.738m N

Time Series Plots for Prism



Station Name: Wankleshwar Bhey TBM

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	395,873.12	2,510,757.61	22°42'02.978"N	073°59'10.330"E	169.813
Spatial Dual	025-00006405	395,873.05	2,510,757.64	22°42'02.979"N	073°59'10.327"E	169.832
	Difference	**0.073**	**-0.035**	**--**	**--**	**-0.019**

SBES Calibration

SBES Barcheck Correction Table

Project No.	Project Title:	Vessel:	Place:
J-HYD-20-174630	**Bathymetry Survey**	**FUGRO ZODIAC**	**Wankleshwar Bhey**
Date:	Time:	Client:	
12-Mar-21	**17:20**	**GOV. OF GUJRAT**	
Observed By: PRITAM SETH		Echo Sounder Model and SL. No.	Area Depth
Project No. J-HYD-20-174630		**ODOM ECHOTRAC CV 100/ 007169**	**6**

Echo Sounder Settings

Draft HI	Draft LO	Sound Velocity	
		Average	**Upto Depth**
0.32	**0.32**	**1448.8**	**16**
Barcheck Frequency selected	**Survey Frequency:**	Manufacturer's Accuracy	
High 210 KHz	**33 and 210 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	1.08	-0.08	5	5.04	-0.04
2	2.05	-0.05	4	4.05	-0.05
3	3.02	-0.02	3	3.06	-0.06
4	4.05	-0.05	2	2.07	-0.07
5	5.04	-0.04	1	1.07	-0.07

	Average	-0.05	Average	-0.06
	Std. Dev	0.0217	Std. Deviation	0.0130
			Cumulative Average	-0.05
			Cumulative Std. Deviation	0.0061

Partychief
Pritam Seth
FSINPVT

Deputy Executive Engineer

Wankleshwar Bhey Dam,Govt. of Gujrat

Narmada, Water Resources, Water Supply and Kalpsar Department
WRD (Water Resources)

Location Name:	Wankleshwar Bhey DAM	Date:	14/06/2021	Instrument Name	LYNX
Work:	RTK Observation by Topography Team			Model no.	H6

Station Name		Observation Duration	Easting (mE)	Northing (mN)	MSL Height (m)	Remarks	
Wankleshwar Bhey TBM 04	By rover 1	2 sec	395893.590	2510734.767	227.717	XYZ Value generated by RTK of Topography Team, Base Station on Wankleshwar Bhey TBM Fugro Provided	Field Photo\IMG_20210614_095401.jpg
Wankleshwar Bhey TBM 04	By rover 2	2 sec	395893.579	2510734.762	227.708	XYZ Value generated by RTK of Topography Team, Base Station on Wankleshwar Bhey TBM Fugro Provided	Field Photo\IMG_20210614_095423.jpg
Wankleshwar Bhey TBM 04	By rover 3	2 sec	395893.567	2510734.760	227.708	XYZ Value generated by RTK of Topography Team, Base Station on Wankleshwar Bhey TBM Fugro Provided	Field Photo\IMG_20210614_095816.jpg

		Fugro Provided XYZ Value								Difference With Fugro Provided XYZ Value		
Station Name	Remarks	Easting (mE)	Northing (mN)	MSL Height (m)	Station Name	Remarks	Easting (mE)	Northing (mN)	MSL Height (m)	Easting (mE)	Northing (mN)	MSL Height (m)
Wankleshwar Bhey TBM 04	Fugro Provided Value	395893.557	2510734.738	227.691	Wankleshwar Bhey TBM 04	Check by Rover 1	395893.590	2510734.767	227.717	-0.033	-0.029	-0.026
					Wankleshwar Bhey TBM 04	Check by Rover 2	395893.579	2510734.762	227.708	-0.022	-0.024	-0.017
					Wankleshwar Bhey TBM 04	Check by Rover 3	395893.567	2510734.760	227.708	-0.010	-0.022	-0.017

Note: Wankleshwar Bhey FSL-223.570m w.r.t MSL (Client Provided) transferred from FSL.
Note: Base station was on Wankleshwar Bhey TBM (Fugro provided base value), 3 reading taken for 2 sec each on Wankleshwar Bhey TBM 04 by 3 rovers on pole mounted.

Prepared by Arunabha Chakraborty

FUGRO

Appendix E

Benchmark Descriptions

(3 pages)

LEVELLING RECORD FROM FSL-Wankleshwar Bhey to Wankleshwar-TBM to TBM-03

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:	Wankleshwar Bhey	Date of Observation:	13/03/2021
Observer's Name:	Pritam Seth	Staff Holder's Name:	Ganesh Sonawale

LEVELLING FROM FSL-Wankleshwar Bhey to all TBM point.

FSL Wankleshwar Bhey to TBM 4		
Station Name	BACK SIGHT(FSL- Wankleshwar Bhey)	FORE SIGHT (TBM 4)
Wankleshwar Bhey TBM	223.570m	227.691
FSL Wankleshwar Bhey To TBM 1		
Station Name	BACK SIGHT(FSL- Wankleshwar Bhey)	FORE SIGHT (TBM 1)
TBM 4	223.570m	227.715
FSL Wankleshwar Bhey TO Wankleshwar Bhey TBM		
Station Name	BACK SIGHT(FSL- Wankleshwar Bhey)	FORE SIGHT (Wankleshwar Bhey TBM)
TBM 4	223.570m	227.675
FSL Wankleshwar Bhey TO TBM 2		
Station Name	BACK SIGHT(FSL- Wankleshwar Bhey)	FORE SIGHT (TBM 2)
TBM 4	223.570m	221.48
TBM 4 To FSL Wankleshwar Bhey		
Station Name	BACK SIGHT(TBM 4)	FORE SIGHT(FSL- Wankleshwar Bhey)
Wankleshwar Bhey TBM	227.691	223.570m

TBM POINT NAME	VALUES	PURPOSE
FSL Of Wankleshawar Bhey	223.57	
Wankleshwar Bhey TBM	227.675	Survey for Hydrography and Topography
TBM 1	227.715	Setup ATG
TBM 2	221.48	Water Level Mesurement
TBM 4	227.691	Survey for Hydrography and Topography

NOTE-

1.Client did not provided any XY value of BM.
2.Client has provided FSL-Wankleshwar Bhey RL value is 223.570m w.r.t MSL From old refernece.
3.Fugro has cross checked the value between FSL RL value with Wankleswar Bhey TBM value.

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Party Chief
Pritam Seth
FSINPVT

Client Representative
Narmada Water Resources
Water Supply and Kalpsar Department/ Government of Gujarat

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 :	Wankleshwar Bhey	**TBM 4**
	Observed By:	Pritam Seth,Ganesh Sonawale	
	Date:	13/03/2021	

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

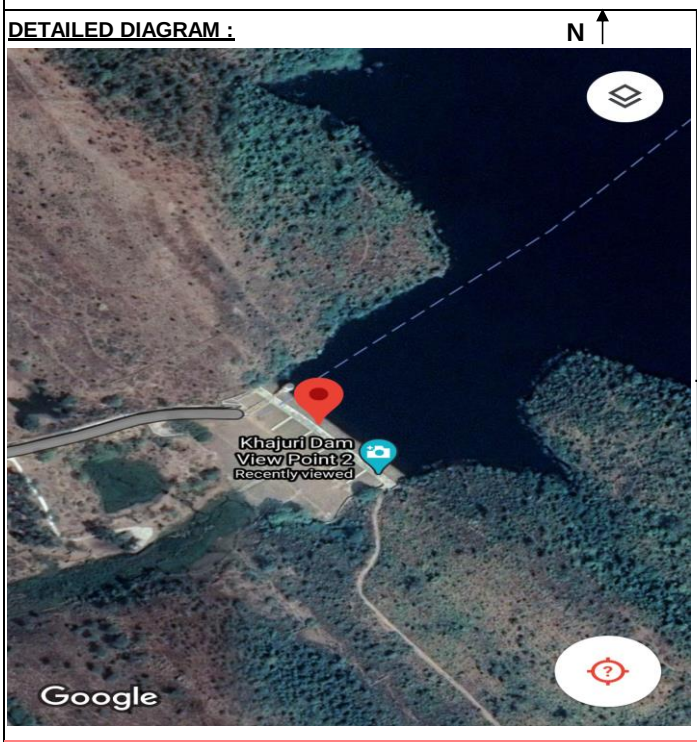
GEOGRAPHICAL COORDINATES:		**UTM COORDINATES:**		CM: 75° E
LATITUDE:	22°42'02.239"N	EASTING:	395,893.56 m	σ = +/- 0.03 m
LONGITUDE :	073°59'11.051"E	NORTHING:	2,510,734.74 m	σ = +/- 0.02 m
ELLIPSOIDAL HEIGHT:	169.813m	CONVERGENCE :	-0.3912 Degrees	
HEIGHT ABOVE LAT/CD:	NA	TBM VALUE:	227.691m	

LOCATION & ACCESS : Its established in Top of Dam. 50m Right side of Steps.

STATION MARKING : TBM establised by Fugro. And point is marked with Yellow paint.

Expected durability of the Station (Years) : 05 years

DETAILED DIAGRAM :



Note:- Coordinates are measured by DGPS observation.
Client hasn't supplied any X,Y Value

Pritam Seth
Party chief (FSINPVT)

Client Representative
Narmada Water Resources
Water Supply and Kalpsar Department/ Government of Gujarat

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 :	Wankleshwar Bhey	**Wankleshwar Bhey TBM**
	Observed By:	Pritam Seth,Ganesh Sonawale	
	Date:	13/03/2021	

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

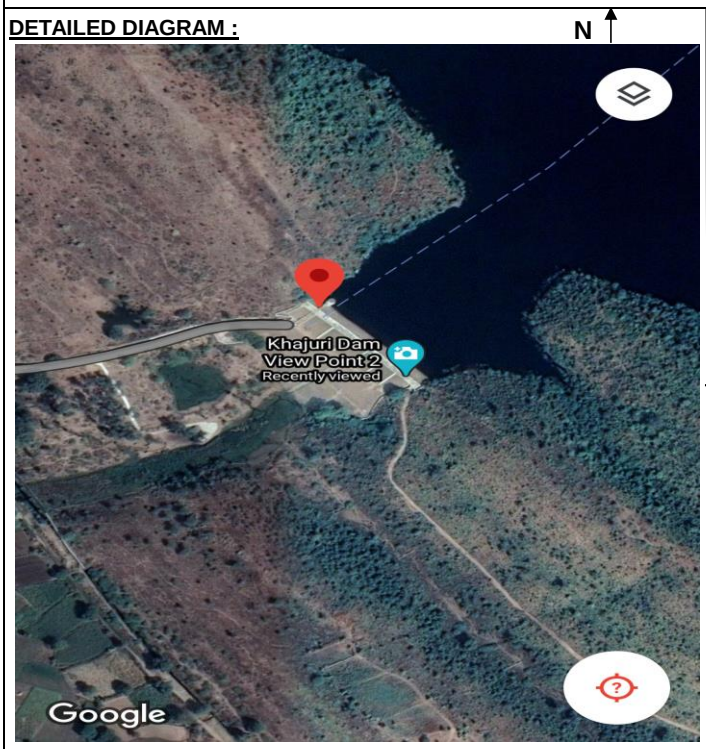
GEOGRAPHICAL COORDINATES:		**UTM COORDINATES:**		CM: 75° E
LATITUDE:	22°42'02.978"N	EASTING:	395,873.12 m	σ = +/- 0.02 m
LONGITUDE :	073°59'10.330"E	NORTHING:	2,510,757.61 m	σ = +/- 0.01 m
ELLIPSOIDAL HEIGHT:	169.813m	CONVERGENCE :	-0.39128 Degrees	
HEIGHT ABOVE LAT/CD:	NA	TBM VALUE:	227.675m	

LOCATION & ACCESS : Its established in Top of Dam. Infront of Steps near Cannel lockgate.

STATION MARKING : TBM establised by Fugro. And point is marked with Yellow paint.

Expected durability of the Station (Years) : 05 years

DETAILED DIAGRAM :



Note:-

Coordinates are measured by DGPS observation.
Client hasn't supplied any X,Y Value

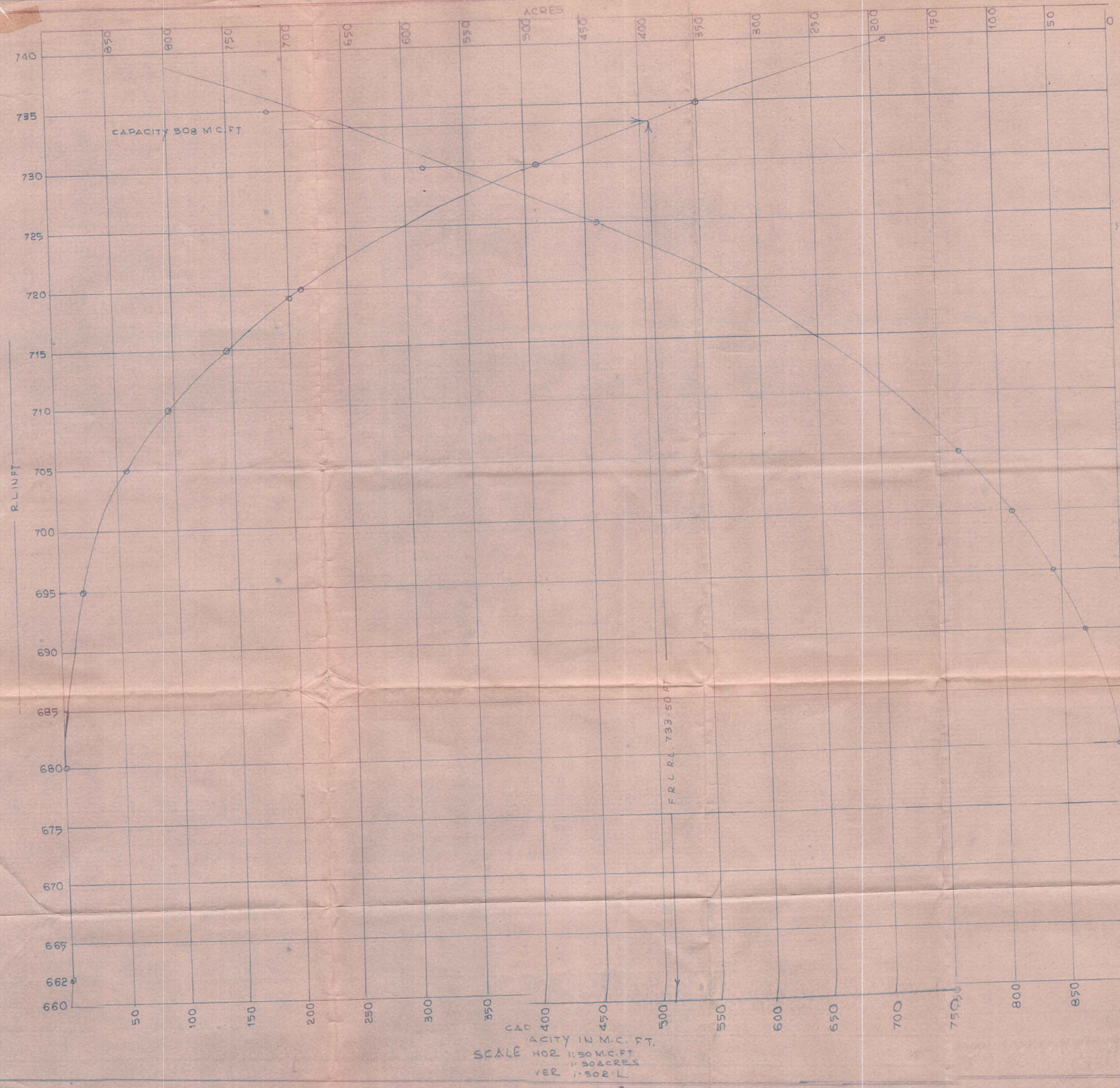
Pritam Seth
Party chief (FSINPVT)

Client Representative
Narmada Water Resources
Water Supply and Kalpsar Department/ Government of Gujarat

Appendix F

Client Supplied Area Capacity Curve

(1 page)



STATEMENT SHOWING THE CAPACITY BETWEEN CONSECUTIVE COUNTOURS & COMULETVE CAPACITY FOR THE RESERVOIR

SR NO	RL OF LOWER CONTOUR	RL OF UPPER CONTOUR	AREA IN SQ.INCH LOWER	AREA IN SQ.INCH UPPER	AREA IN SQ.FT LOWER	AREA IN SQ.FT UPPER	CAPACITY IN M.C.FT BETWEEN CONTOUR	COMULATIVE CAPACITY	AREA UNDER SUBMERGENCE IN ACRES	REMARKS
1	2	3	4	5	6	7	8	9	10	11
1	662	670	0	0.25	0	0.0625	0.17	0.17	1.499	
2	670	680	0.26	1.06	0.0625	0.2650	1.53	1.70	6.082	
3	680	690	1.06	4.81	0.2650	1.2175	6.83	6.55	27.55	
4	690	695	4.87	9.44	1.2175	2.36	3.18	17.33	54.18	
5	695	700	3.44	16.49	2.36	4.1150	15.95	33.28	54.45	
6	700	705	16.46	23.46	4.1150	5.8650	24.88	58.10	134.60	
7	705	710	23.46	32.56	5.865	8.09	34.77	92.87	185.70	
8	710	715	32.36	43.24	8.09	10.81	47.17	140.04	248.10	
9	715	720	43.24	64.29	10.81	16.0725	66.65	206.69	368.10	
10	720	725	64.29	76.48	16.0725	19.12	67.82	274.57	458.90	
11	725	730	76.48	101.15	19.12	25.2875	110.68	406.15	580.60	
12	730	735	101.15	124.12	25.28	31.03	140.53	545.17	712.00	
13	735	741	124.12	140.76	31.03	36.64	165.15	710.87	820.0	

GOVT OF GUJARAT (

DAHOD IRRIGATON DIVISION DAHOD

PLAN NO	AREA CAPACITY CURVE WANKLESHWAR BHEY PROJ D'. BARIA
DATE	
DRAWN BY	
CHECKED BY	
RE TRACED BY	
COMP'D BY	

CHIEF ENGINEER IRRI. GANDHINAGAR

SUPTD'G ENGINEER KADANA PROT CIRCLE DIVADA COLONY

EX. ENGINEER DAHOD IRRI. DIVISION DAHOD

DY. EX. ENGINEER KOLIARI SUB DN NO 1 DEVGADHBARIA.

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	Will be submitted after receiving client's comment
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 Wankleshwar Bhey 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/01/9727	R0/Rev.0	1:3000	-
2	Contour Map of Wankleshwar Bhey Reservoir	01 of 01	02 of 03	B/01/96	R0/Rev.0	1:3000	-
3	Shaded Relief Image Prepared from SBES Data	01 of 01	03 of 03	I/01/9672	R0/Rev.0	1:3000	-
Details of Other Deliverables							
1	L-section	Soft copy					
2	C-section at every 100 m	Soft copy					