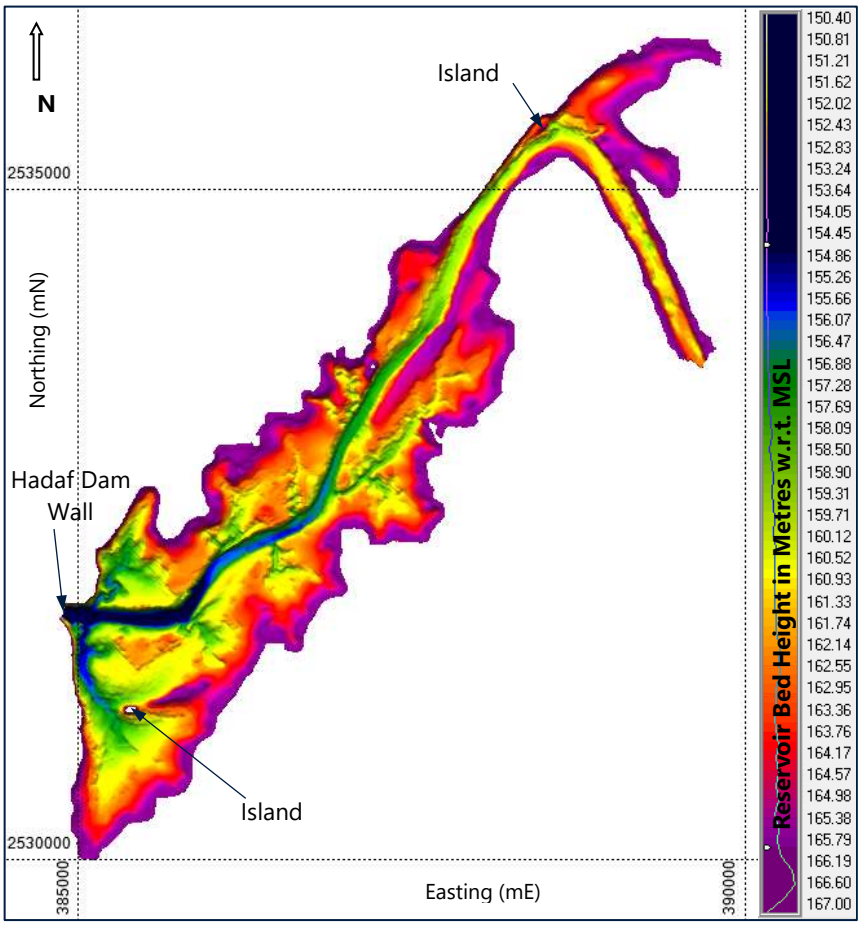

Providing Services for Conducting Bathymetric Survey of Reservoirs of Central Gujarat Under National Hydrology Project

Survey Results of Hadaf Reservoir Location | Central Gujarat

JHYD20-174630-Volume 9-Hadaf Reservoir/R1 [01] | 11 November 2021

Final Report

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

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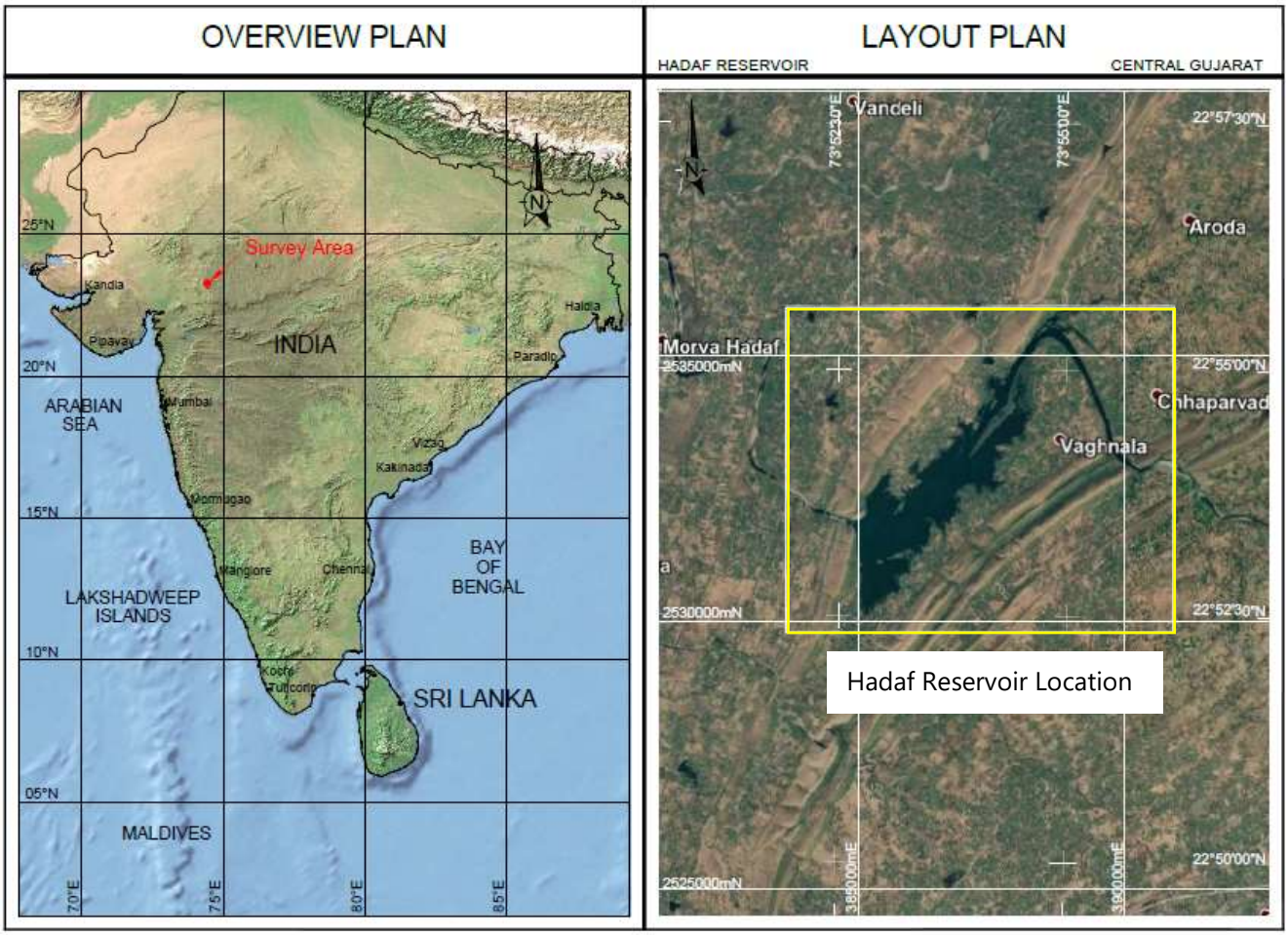
LOCATION MAP



EXECUTIVE SUMMARY

Survey Overview– Hadaf 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 Hadaf 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 – April 2021 and June 2021 respectively, in order to acquire survey data as per mutually agreed scope and relevant survey specifications.
Survey Location	Hadaf Reservoir, Mataria (Vejma) village, Morva (Hadaf) Taluka, Panchmahal 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 – Hadaf 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 150.40 m (384896 mE, 2531841 mN) w.r.t. MSL.
Area Capacity Survey (2021)	Elevation Area Capacity table and curve of Hadaf 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 (150.40 m) to FRL (166.20 m) was calculated using GIS software.
Elevation area capacity details	In comparison with 1986 survey data, the present survey results indicate that the gross storage capacity has decreased.
Loss in gross storage capacity	As per 2021 survey results, the loss in Gross storage capacity w.r.t. 1986 or volume of sediment deposited in the Hadaf reservoir is 4.828 Mm^3.
Trap efficiency & Sedimentation Index	Trap Efficiency and sedimentation Index calculated for Hadaf reservoir as per methodology give in IS 12182-1987 is 92% and 8.201 x 10^9 sec^2/m respectively
Sedimentation rate	The rate of siltation in Hadaf reservoir is 0.138 Mm^3/year
Average rate of siltation	The observed rate of siltation in the Hadaf reservoir during the 35 year life span (1986 – 2021), works out to 2.718 Ha m/100 sq km/year.
Annual % loss	The annual % loss in gross storage capacity for Hadaf reservoir during the 35 year life span is 0.428 % 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 10 August 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 Hadaf reservoir;

Pass 1: Bathymetry / Hydrographic Survey;

Pass 2: Topographical Survey.

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

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

1.2 Study Area

Hadaf reservoir is located in Panchmahal district. Panch-mahal refers to the five sub-divisions i.e., Godhra, Dahod, Halol, Kalol, and Jhalod

The district, with a total area of 5210 km^2, currently comprises 11 talukas viz. Godhra, Halol, Kalol, Lunawada, Santrampur, Kadana, Jambughoda, Shahera, Morva-Hadaf, Khanpur, Ghoghamba. It is bordered on the north by the Sabarkantha district and Rajasthan state, on the south by the Dahod and Vadodara districts, on the west by the Kheda district, and on the east by the Madhya Pradesh state.

The Hadaf reservoir was built between 1978 and 1986 and is mainly used for irrigation. Hadaf reservoir, which is located in Morva-Hadaf taluka, falls within the Mahi basin. The basin drainage and boundary of the sub-basin are shown in Figure 1.1. The basin has a maximum width of about 250 km. The upper Mahi sub-basin (65.11 % of the total basin area) consists of 41 watersheds and the lower Mahi sub-basin (34.89 % of the total basin area) consists of 22 watersheds. The river supply to the Hadaf reservoir is from the perennial Hadaf river which is a left bank tributary of the Mahi River.

The river Hadaf originates in the Limkheda taluka village of Kantu. It flows through the Limkheda taluka villages of Kaliyavad, Dolaria, Madav, Mahunala, Budhpur, Umaria, Patwan, Vislanga, Khankhria, Kundha, Bandipur, Piplia, and Torni. The river also flows through the Godhra taluka villages of Mataria, Vejama, Balukhedi, Ganesh Muvadi, Bamana, and Mekhar. After a course of about 73 kms, the river meets the Panam River at Boriavi village of Shehera taluka of this district.

The Morva-Hadaf taluka falls under central Gujarat sub-climatic zone having extreme semi arid climatic condition, heterogeneous landscape and partially hilly topography.

According to data on land use and irrigation, forest land covers 3,438.1 Ha in Morva-Hadaf taluka, while non-agricultural land covers 1,346.3 Ha. 1,471.2 Ha is uncultivated land, 1,048.7 Ha is permanent pastures and other grazing lands, and 1,285 Ha is fallow land. The net area sown

is 20,566 Ha, with total irrigated land area in this taluka being 7,802.1 Ha (Directorate of Census Operations Gujarat, 2011)

1.3 Geology of Study Area

Geologically, Panchmahal district is the manifestation of diverse geological extension from Lower Proterozoic to Holocene with different rock types such as granitic to basalt and limestone to alluvium. The oldest formation in the area is Aravallis Supergroup. Godhra granite and gneisses were intruded into older Aravalli. They are overlain at places by Lower cretaceous fluvial and marine sequences. Lower Cretaceous rocks are overlain by Deccan basalts, an extrusive rock formation and occur as sporadic exposure in the form of cappings over older rocks. The youngest formation found in the district is the alluvium, occur as pediments, sand dunes, valley fills and flood plain as isolated patches. The bed rock type in the reservoir area is quartzite.

1.4 Soil Types

The soil of the 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 of light brown to brownish black colour are produced. These medium soils are more than a meter depth. The black cotton soils produced by intense weathering of basalts are however deep, heavy and become sticky when saturated. They have high fertility value (Nayak, 2014).

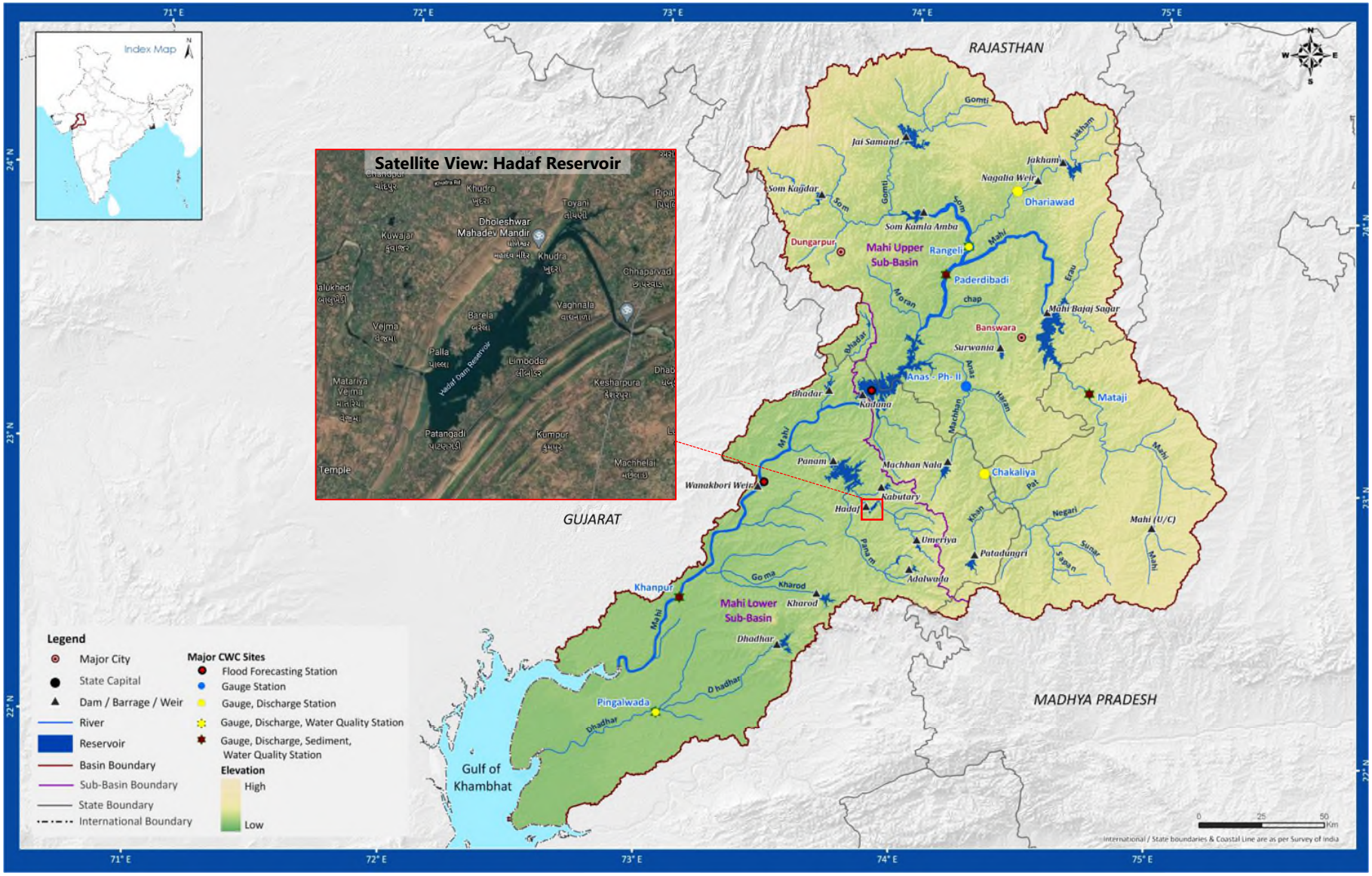

Figure 1.1: Mahi basin showing major tributaries – Drainage and sub-basin (Courtesy: India-WRIS, 2014)

1.5 Hadaf Reservoir Characteristics

The Hadaf dam is a masonry type of dam constructed over the Hadaf river with catchment area of 507.64 km^2. Salient features of the Hadaf reservoir are tabulated below:

Table 1.1: Client Supplied Hadaf Reservoir Salient Features

Characteristics	Feature
Reservoir name	Hadaf Reservoir
Name of Dam	Hadaf Dam
Type	Masonry
Purpose	Irrigation
River	Hadaf
Location	Mataria (Vejma) village
Latitude	22° 52′ N
Longitude	74° 03′ E
Nearest Township	Godhra
Taluka	Morva (Hadaf)
District	Panchmahals
State	Gujarat
Total Catchment Area	507.64 km^2
Gujarat	507.64 km^2
Other	0
Rainfall	
Maximum	2295 mm
Minimum	300 mm
Average	842 mm
Yield	
Maximum	107.65 Mm^3
Minimum	182.79 Mm^3
Average	48.75 Mm^3
Flood	
Maximum observed flood	4672 cumecs.
Maximum probable flood (M.P.F.)	6852 cumecs.
Standard probable flood (S.P.F.)	5592 cumecs.
Reservoir Levels	
Riverbed level	146.00 m
Sill R.L. of B.P.O.	No.
Sill R. L. of Canal H.R.	161.50 m
Crest level of spillway	155.53 m
F.R.L.	166.20 m

Characteristics	Feature
H.F.L.	168.32 m
Top of Dam	171.63 m
Reservoir Capacity Data	
Gross capacity at F.R.L.	22.08 Mm^3
Dead storage	4.82 Mm^3
Live storage	17.26 Mm^3
Details of Dam	
River gorge portion	
a) Earthen dam	No.
b) Spillway & Masonry Dam	
1) Spillway	89.60 m
2) Non overflow	30.00 m
Saddle portion in Dykes, if any	No.
Total length of dam	119.60 m
Maximum height from the deepest foundation to the top of roadway	
a) Masonry dam (Non overflow)	29.50 m
b) Overflow	13.40 m
c) Earthen dam in gorge portion	No.
Width of roadway	
a) Masonry dam	6.00 m
b) Earthen dam	No
Bedrock	Quartzite
Type of Spillway	Ogee gated spillway
Length of Spillway	89.60 m
Maximum head over crest at F.R.L.	10.67 m
Shape of crest	Ogee shape
Nos. & size of Radial gates	5 nos. 14.95 x 10.67 m
Piers	4 nos.
D/S Protective work	Roller bucket
Canal	
Length of canal	22.30 km.
Capacity	3.40 cumecs.
Section in initial reach	1.40 x 1.20 + 0.60 m
Left Bank	1.40x1.20+0.60 mt.
Right Bank	1.20x1.00 + 0.60 mt.
Lined system	Lined upto 8 hectare block
Gradient	1 : 4000

Characteristics	Feature
Sequence of works	
Year in which canal work was taken up	1981
Year in which water impounded	1986
Year in which Water first time supplied for Irrigation	1986
Year of completion of Head works	1986
Year of completion of main canal & branches	1992
Year of completion of distribution system	1994

1.6 Project Objectives

Primarily the main objective of the survey was to:

- Assess the reservoir storage capacity;
- Assess the variations in the reservoir storage capacity;
- Create historical database for further water resources usage planning.

However, the main objective of the bathymetry survey was to:

- Estimate and study the sedimentation behaviour of reservoirs in different zones including horizontal zones throughout the reservoirs as well as vertical zones namely:
    a) Dead storage
    b) Live storage
    c) Flood storage
- Upgrade Elevation-Area-Capacity tables / curves of reservoirs at regular intervals.

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

Table 1.2: Hadaf Reservoir details for Bathymetry and Topography Survey

Name of Dam / Reservoir	Actual Area (km^2) surveyed	
	Bathymetry Survey	Topography Survey
Hadaf	3.01	4.16

1.7 Scope of Work

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

1.7.1 Pass 1: Bathymetry / Hydrographic Survey

The scope of work conforms bathymetry survey for total area of approximately 3.01 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 Hadaf reservoir of Gujarat.

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

1.7.2 Pass 2: Topographical Survey

Topographical survey was carried out using Total station and equivalent levelling instruments. The total area covered in topographical survey is 4.16km^2. Following scope of work was undertaken in order to achieve client objectives:

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

1.8 Survey Execution

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

1.9 Reference Documents

Table 1.3: Reference Documentation

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

1.10 Deliverables

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

2. Survey Specifications and Resources

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

2.1 Survey Geodesy

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

Table 2.1: Geodetic Datum, Projection Parameters

Global Positioning System Geodetic Parameters	
Datum:	World Geodetic System 1984
Spheroid:	World Geodetic System 1984
Semi major axis:	a = 6 378 137.000 m
Inverse Flattening:	1/f = 298.257 223 563
Map Projection:	Universal Transverse Mercator
Grid System:	UTM Zone 43 N;
Central Meridian:	075° 00′ 00″ East
Latitude of Origin:	0° 00′ 00″ North
False Easting:	500 000 m
False Northing:	0 m
Scale factor on Central Meridian:	0.9996
Units:	Metre
Notes: • The Client has specified the above Datum and Transformation parameters to be used for this survey. • Fugro's Starfix software suite always uses WGS84 as the primary datum for all geodetic calculations.	

2.2 Horizontal Control

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

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

2.3 Vertical Control / Water Level Corrections

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

Table 2.2: Observed Reservoir Water Level Heights at Hadaf Reservoir

Date	Observed Reservoir Water Level Heights w.r.t. MSL at Hadaf Reservoir [m]
28-03-2021	164.50
30-03-2021	164.44
31-03-2021	164.44
01-04-2021	164.44
02-04-2021	164.43
03-04-2021	164.43
04-04-2021	164.43
05-04-2021	164.43
06-04-2021	164.42
07-04-2021	164.42
08-04-2021	164.40
09-04-2021	164.38
10-04-2021	164.38
11-04-2021	164.37
12-04-2021	164.37
13-04-2021	164.33
14-04-2021	164.32
15-04-2021	164.31

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
Ganesh Sonawale	Engineer
Vishal Kumar	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 CV 100 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 – 166.20 m w.r.t. MSL
- Full Resevoir Level (FRL) – 166.20 m w.r.t. MSL
- Water line – 164.40 m approximately.

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 Hadaf reservoir location on 25 March 2021 and equipment was mobilised on-board the survey boat between 25 - 28 March 2021.

After field testing / verification / calibration of all survey equipment bathymetry survey was carried out and completed on 15 April 2021. Refer Appendix A to this document for diary of events.

The topography survey equipment and personnel arrived at Hadaf reservoir location and commenced survey on 16 June 2021. The topography survey was completed on 20 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 Hadaf 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	384885.185	2531813.438	22°53'25.040"N	073°52'39.653"E	114.444
Spatial Dual	025-00006405	384885.383	2531813.425	22°53'25.039"N	073°52'39.660"E	114.597
Difference		-0.198	0.013	--	--	-0.153

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 CV 100 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	Cumulative Average [m]	Cumulative Standard Deviation
Summary of SBES Calibration Results on-board 'Fugro Zodiac'			
28 March 2021	Echotrac CV 100 SBES	0.00	0.000

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 Hadaf Dam Temporary Benchmark 1 (Hadaf Dam TBM 1) and Temporary Benchmark 2 (Hadaf Dam TBM 2).

3.5.2 RTK Position Comparison

The RTK observed position at Hadaf Dam Temporary Benchmark 1 (Hadaf Dam TBM 1) 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)
Hadaf Dam TBM 1 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	384885.185	2531813.438
RTK Rover 1	Lynx-H6	384885.204	2531813.463
Difference		-0.025	-0.006
Hadaf Dam TBM 1 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	384885.185	2531813.438
RTK Rover 2	Lynx-H6	384885.200	2531813.477
Difference		-0.039	-0.018

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 Reservoir Level (FRL)- 166.20 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 (Hadaf Dam TBM 2) 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 Hadaf Dam TBM 1 location. Static observation was carried out subsequently as part of verification.
- The Base receiver is installed at Hadaf Dam TBM 2 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 Hadaf Dam TBM 1.
- 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: Hadaf Dam Temporary Benchmark (Hadaf Dam TBM 1)

Figure 3.2: Temporary Benchmark (Hadaf Dam TBM 2)

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

3.6 Survey Coverage and Scope Completion

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

- The survey work was carried out on par with the mutually agreed scope and objectives mentioned in the Section 1.6 of this document.
- Survey scope from existing water level up to the Full Reservoir Level (FRL)- 166.20 m, was achieved by undertaking topography survey.

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

4. Data Processing and Interpretation

4.1 Navigation and Positioning

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

4.2 Bathymetry Data Processing

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

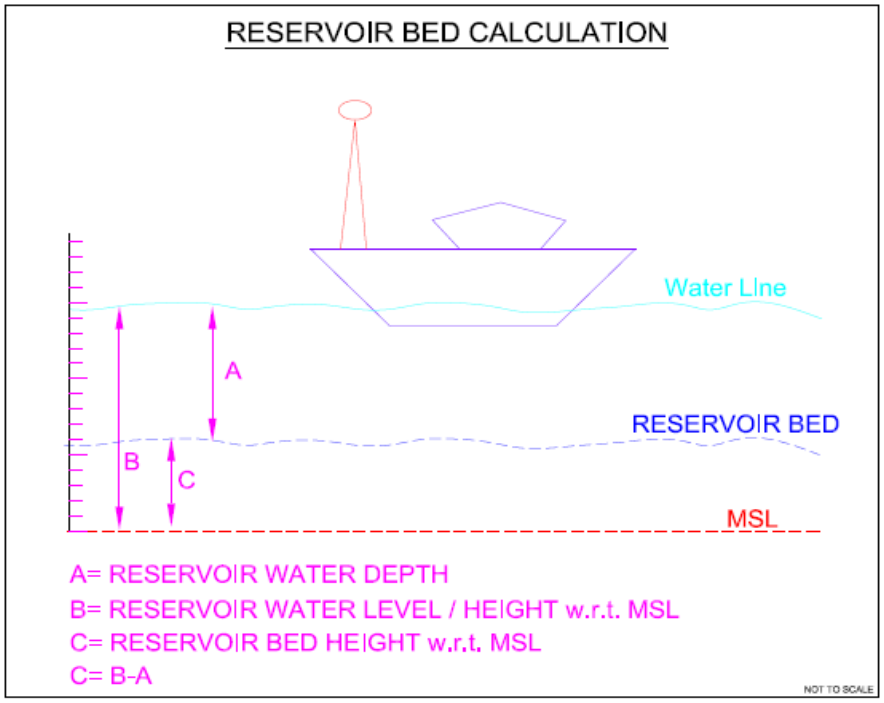

Figure 4.1: Reservoir Bed Height Calculation w.r.t. MSL

4.3 Creating Digital Terrain Model (DTM)

The bathymetric data and topographic data were then combined to create a vector point shapefile in GIS software. The boundary of the reservoir was then digitized around the point shapefile. Two types of 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 150.40 m which is the lowest bed level for the reservoir and the maximum level considered is 166.20 m which is Full Reservoir Level (FRL of the reservoir. The incremental value for elevation used for developing these curves is kept at 0.1 m. The surface area at the successive intervals was obtained in GIS software by intersecting the DTM with horizontal planes at an interval of 0.1 m starting from the zero-bed elevation till the MWL. The incremental volume (ΔV_i) between two contours was then calculated and integrated from bottom to specified

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

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

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

4.5 Sedimentation in Different Zones of Reservoir

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

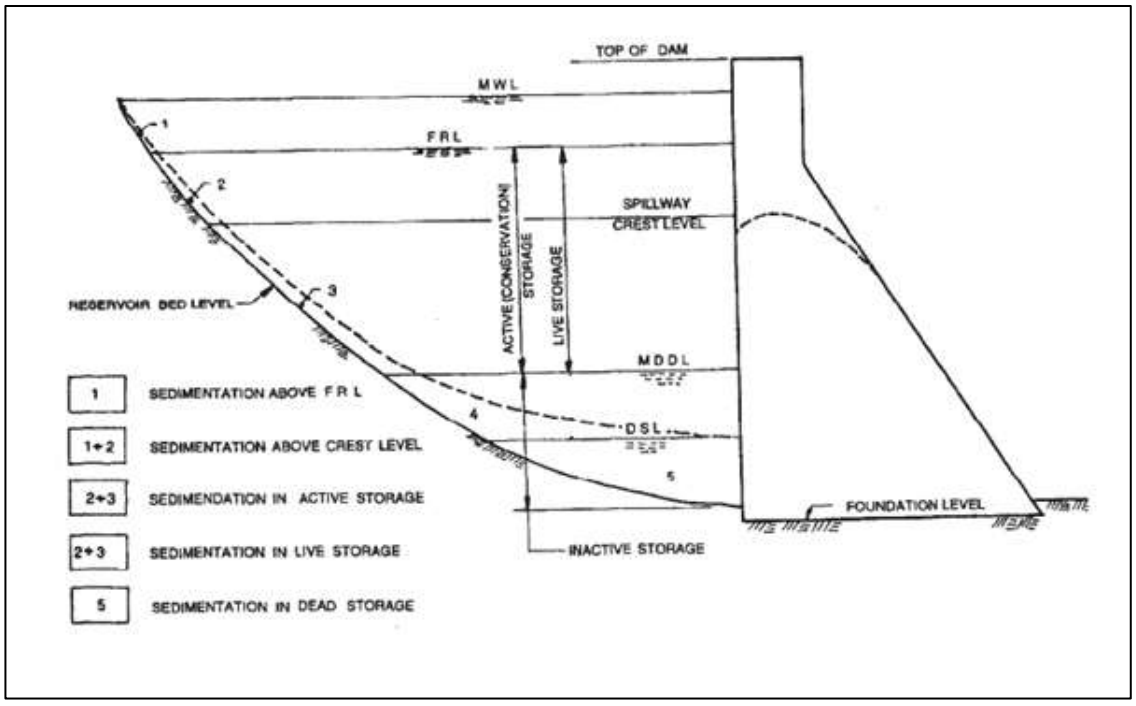

Figure 4.2: Sedimentation in different zones of reservoir (Ref: IS 5477-Part 1,1999)

The trap efficiency and the silt index has been calculated based on the methodology given in IS 12182, 1987. The gross capacity of reservoir as per present survey at FRL is 27.432 Mm^3 and client supplied Mean Annual inflow is 107.65 Mm^3. The values of trap efficiency were calculated using Brune's curve for the capacity inflow ratio for the reservoir. The silt index is calculated as the ratio of period of retention and flow velocity in the reservoir. The details of the calculations of period of retention and flow velocity are given in standard codes such as IS 12182, 1987. The values for Hadaf reservoir are shown in Table 5.4.

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

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

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

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

4.6 Charting the Results of Bathymetry and Topography Data

- Chart showing reservoir bed heights are provided for the current survey at 1:8000 scale.
- Chart showing contour map at 1 m interval for Hadaf reservoir is also provided at 1:8000 scale.
- Chart showing reservoir bed relief image prepared from bathymetry and topography survey data is provided at 1:8000 scale.
- L-section of the reservoir and C-section at 100 m interval are provided as soft copy.

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

5. Survey Results – Hadaf 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 Hadaf reservoir was carried out up to Full Reservoir Level (FRL) of 116.20 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 from 150.40 m to 166.20 m w.r.t. MSL.

The reservoir topography was uneven, height ranging from 150.40 m to 166.20 m w.r.t. MSL.

The reservoir bed tends to get shallower as we go further towards east, north & south directions away from the reservoir dam wall. Reservoir area is spreading towards south-east and north-west direction. Total two islands are observed, one near the dam wall at the southern side of the reservoir and other at north-eastern bend of outlet.

Lowest reservoir bed level recorded was 150.40 m (384896 mE, 2531841 mN) w.r.t. MSL, within the survey area.

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

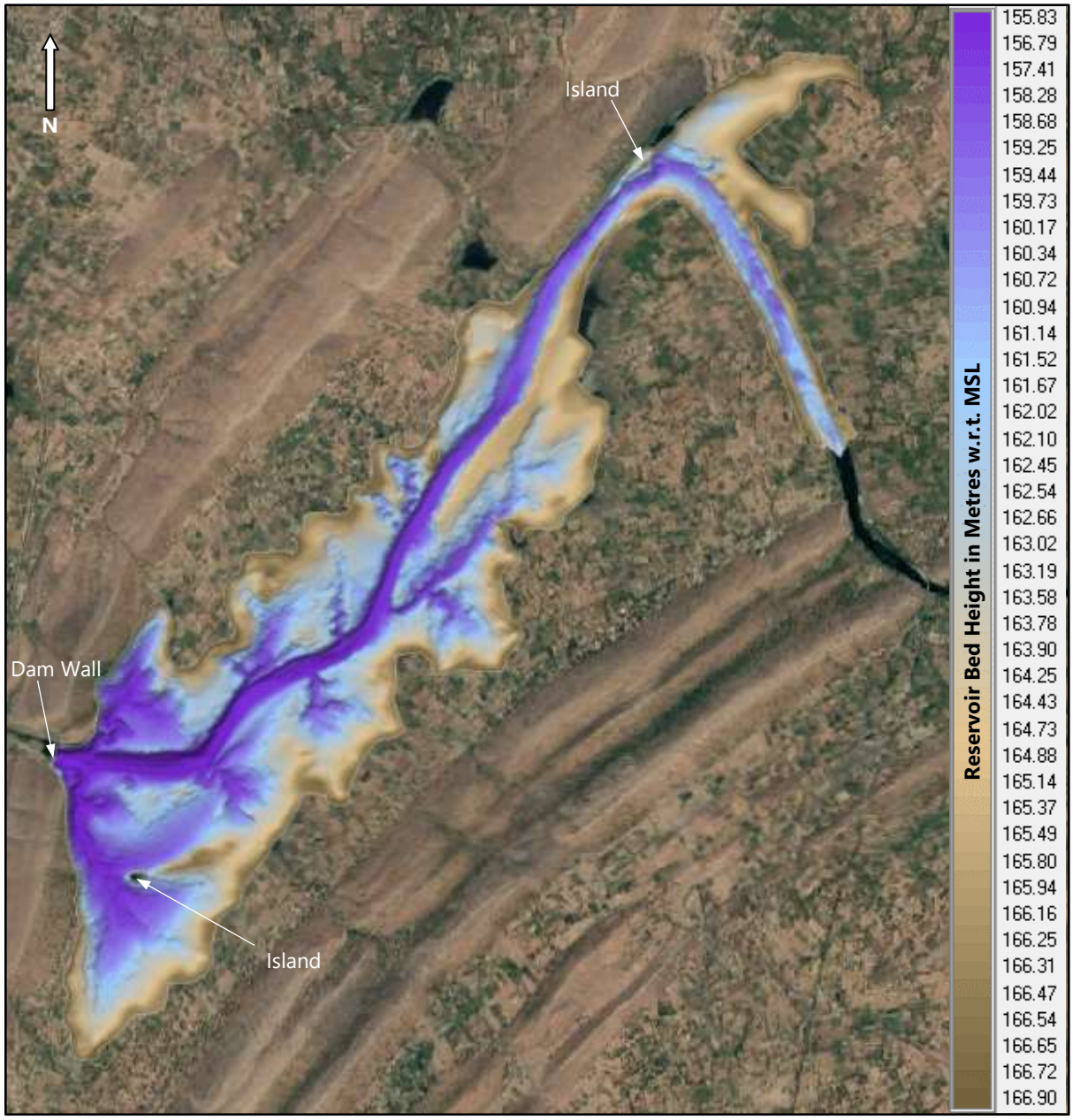

Figure 5.1: Image showing gridded SBES Bathymetry and topography data (superimposed with satellite imagery) of reservoir bed heights in metres from lowest bed level to FRL

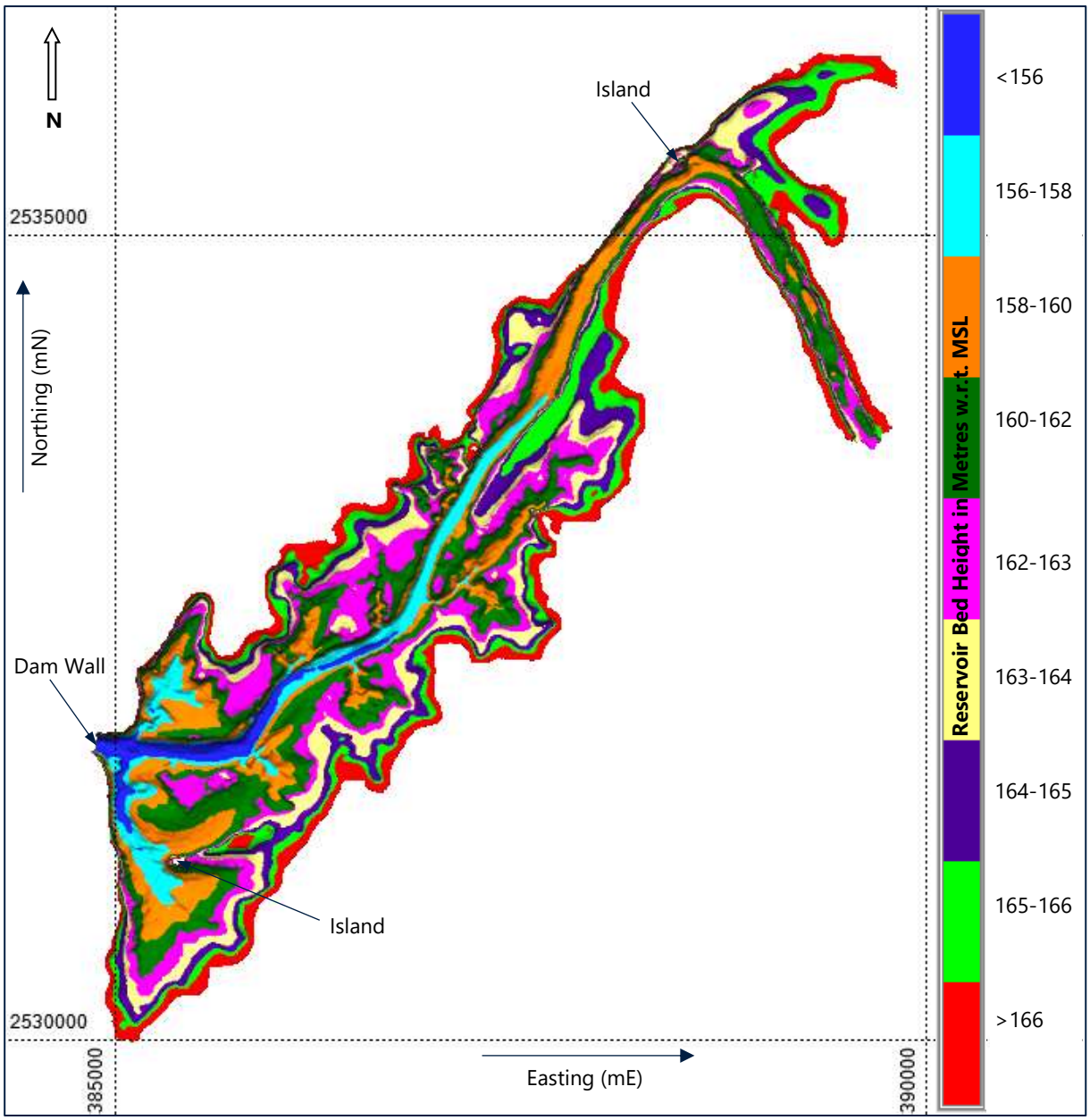

Figure 5.2: Shaded relief image showing gridded SBES Bathymetry and topography data of reservoir bed heights in metres from lowest bed level to FRL.

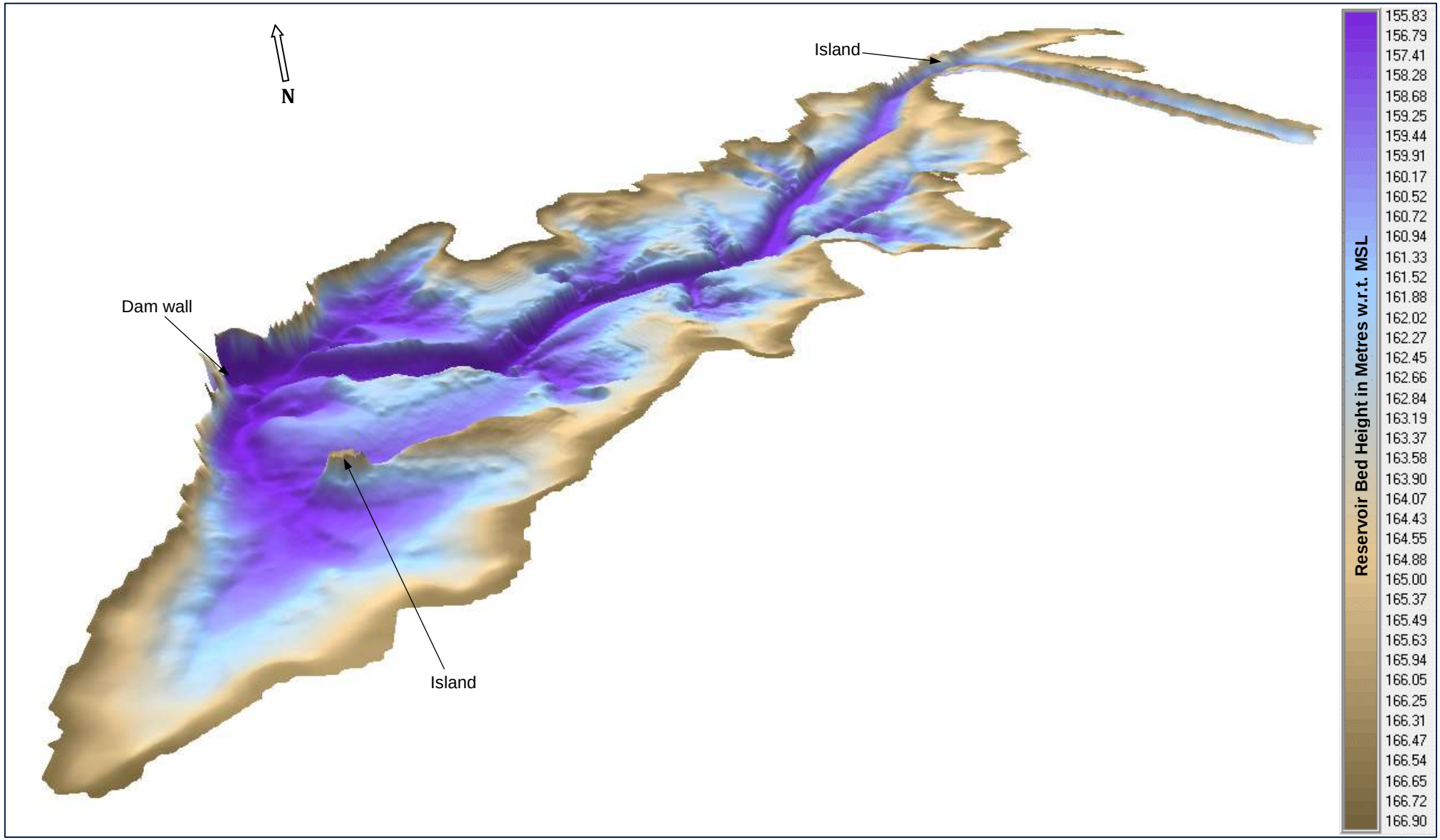

Figure 5.3: 3D view of Hadaf Reservoir

Photograph A: South-west part of Hadaf Reservoir (385014 mE, 2531394 mN) with shallow water depth and dense aquatic vegetation.

Photograph B: North-eastern part of Hadaf Reservoir (389448 mE, 2534187 mN) having rock outcrop and shallow water depth.

Photograph C: Northern part of Hadaf Reservoir (387580 mE, 2533746 mN) with shallow water depth and dense aquatic vegetation.

Photograph D: Eastern part of Hadaf Reservoir (386711 mE, 2531940 mN) showing shallow water depth and fishing activities.

Figure 5.4: Photographs A, B, C and D showing the south-western, north-eastern, northern and eastern areas within Hadaf Reservoir respectively

5.2 Elevation Area Capacity Curve (2021)

The area and capacity of the Hadaf reservoir was tabulated against the respective increasing elevation starting from zero bed elevation (i.e., 150.40 m) up to 167.00 m (FRL :166.20 m) at an increment of 0.1 m as shown in Table 5.1. Area capacity curve for Hadaf reservoir is shown in figure 5.5.

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

Elevation Area Capacity Table (2021): Hadaf Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
1	150.40	0.0001	0.0000	Bed level
2	150.50	0.0002	0.0000	-
3	150.60	0.0003	0.0000	-
4	150.70	0.0006	0.0001	-
5	150.80	0.0013	0.0002	-
6	150.90	0.0024	0.0004	-
7	151.00	0.003	0.001	-
8	151.10	0.004	0.001	-
9	151.20	0.005	0.002	-
10	151.30	0.006	0.002	-
11	151.40	0.007	0.003	-
12	151.50	0.007	0.003	-
13	151.60	0.008	0.004	-
14	151.70	0.008	0.005	-
15	151.80	0.009	0.006	-
16	151.90	0.010	0.007	-
17	152.00	0.010	0.008	-
18	152.10	0.011	0.009	-
19	152.20	0.012	0.010	-
20	152.30	0.015	0.011	-
21	152.40	0.017	0.013	-
22	152.50	0.020	0.015	-
23	152.60	0.023	0.017	-
24	152.70	0.026	0.019	-
25	152.80	0.028	0.022	-
26	152.90	0.030	0.025	-
27	153.00	0.033	0.028	-
28	153.10	0.035	0.031	-
29	153.20	0.037	0.035	-
30	153.30	0.040	0.039	-
31	153.40	0.043	0.043	-
32	153.50	0.046	0.047	-
33	153.60	0.051	0.052	-

Elevation Area Capacity Table (2021): Hadaf Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
34	153.70	0.056	0.058	-
35	153.80	0.060	0.063	-
36	153.90	0.064	0.070	-
37	154.00	0.068	0.076	-
38	154.10	0.072	0.083	-
39	154.20	0.077	0.091	-
40	154.30	0.081	0.099	-
41	154.40	0.085	0.107	-
42	154.50	0.089	0.116	-
43	154.60	0.094	0.125	-
44	154.70	0.098	0.134	-
45	154.80	0.102	0.144	-
46	154.90	0.106	0.155	-
47	155.00	0.111	0.165	-
48	155.10	0.115	0.177	-
49	155.20	0.120	0.189	-
50	155.30	0.125	0.201	-
51	155.40	0.130	0.214	-
52	155.50	0.138	0.227	-
53	155.60	0.145	0.241	-
54	155.70	0.153	0.256	-
55	155.80	0.164	0.272	-
56	155.90	0.177	0.289	-
57	156.00	0.190	0.307	-
58	156.10	0.203	0.327	-
59	156.20	0.216	0.348	-
60	156.30	0.232	0.370	-
61	156.40	0.249	0.394	-
62	156.50	0.267	0.420	-
63	156.60	0.284	0.447	-
64	156.70	0.303	0.477	-
65	156.80	0.323	0.508	-

Elevation Area Capacity Table (2021): Hadaf Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
66	156.90	0.346	0.541	-
67	157.00	0.370	0.577	-
68	157.10	0.395	0.616	-
69	157.20	0.417	0.656	-
70	157.30	0.439	0.699	-
71	157.40	0.460	0.744	-
72	157.50	0.485	0.791	-
73	157.60	0.511	0.841	-
74	157.70	0.537	0.893	-
75	157.80	0.562	0.948	-
76	157.90	0.589	1.006	-
77	158.00	0.618	1.066	-
78	158.10	0.649	1.129	-
79	158.20	0.683	1.196	-
80	158.30	0.716	1.266	-
81	158.40	0.751	1.339	-
82	158.50	0.785	1.416	-
83	158.60	0.823	1.496	-
84	158.70	0.869	1.581	-
85	158.80	0.915	1.670	-
86	158.90	0.965	1.764	-
87	159.00	1.015	1.863	-
88	159.10	1.066	1.967	-
89	159.20	1.117	2.076	-
90	159.30	1.170	2.191	-
91	159.40	1.222	2.310	-
92	159.50	1.276	2.435	-
93	159.60	1.333	2.566	-
94	159.70	1.388	2.702	-
95	159.80	1.442	2.843	-
96	159.90	1.498	2.990	-
97	160.00	1.558	3.143	-
98	160.10	1.625	3.302	-
99	160.20	1.692	3.468	-
100	160.30	1.757	3.640	-
101	160.40	1.824	3.819	-
102	160.50	1.895	4.005	-
103	160.60	1.964	4.198	-
104	160.70	2.033	4.398	-
105	160.80	2.097	4.605	-
106	160.90	2.167	4.818	-

Elevation Area Capacity Table (2021): Hadaf Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
107	161.00	2.238	5.038	-
108	161.10	2.304	5.265	-
109	161.20	2.369	5.499	-
110	161.30	2.433	5.739	-
111	161.40	2.498	5.985	-
112	161.50	2.562	6.238	MDDL
113	161.60	2.627	6.498	
114	161.70	2.696	6.764	-
115	161.80	2.769	7.037	-
116	161.90	2.850	7.318	-
117	162.00	2.941	7.608	-
118	162.10	3.041	7.907	-
119	162.20	3.137	8.216	-
120	162.30	3.231	8.534	-
121	162.40	3.326	8.862	-
122	162.50	3.431	9.200	-
123	162.60	3.541	9.548	-
124	162.70	3.649	9.908	-
125	162.80	3.756	10.278	-
126	162.90	3.852	10.658	-
127	163.00	3.943	11.048	-
128	163.10	4.022	11.446	-
129	163.20	4.095	11.852	-
130	163.30	4.164	12.265	-
131	163.40	4.232	12.685	-
132	163.50	4.296	13.111	-
133	163.60	4.357	13.544	-
134	163.70	4.421	13.983	-
135	163.80	4.491	14.428	-
136	163.90	4.579	14.882	-
137	164.00	4.657	15.344	-
138	164.10	4.729	15.813	-
139	164.20	4.800	16.289	-
140	164.30	4.871	16.773	-
141	164.40	4.941	17.264	-
142	164.50	5.010	17.761	-
143	164.60	5.087	18.266	-
144	164.70	5.171	18.779	-
145	164.80	5.252	19.300	-
146	164.90	5.336	19.829	-
147	165.00	5.415	20.367	-

Elevation Area Capacity Table (2021): Hadaf Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
148	165.10	5.493	20.912	-
149	165.20	5.574	21.466	-
150	165.30	5.654	22.027	-
151	165.40	5.735	22.597	-
152	165.50	5.814	23.174	-
153	165.60	5.891	23.759	-
154	165.70	5.971	24.353	-
155	165.80	6.051	24.954	-
156	165.90	6.123	25.562	-
157	166.00	6.192	26.178	-

Elevation Area Capacity Table (2021): Hadaf Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
158	166.10	6.266	26.801	-
159	166.20	6.347	27.432	FRL
160	166.30	6.470	28.072	-
161	166.40	6.579	28.725	-
162	166.50	6.695	29.389	-
163	166.60	6.835	30.065	-
164	166.70	6.952	30.754	-
165	166.80	7.023	31.453	-
166	166.90	7.061	32.157	-
167	167.00	7.099	32.865	-

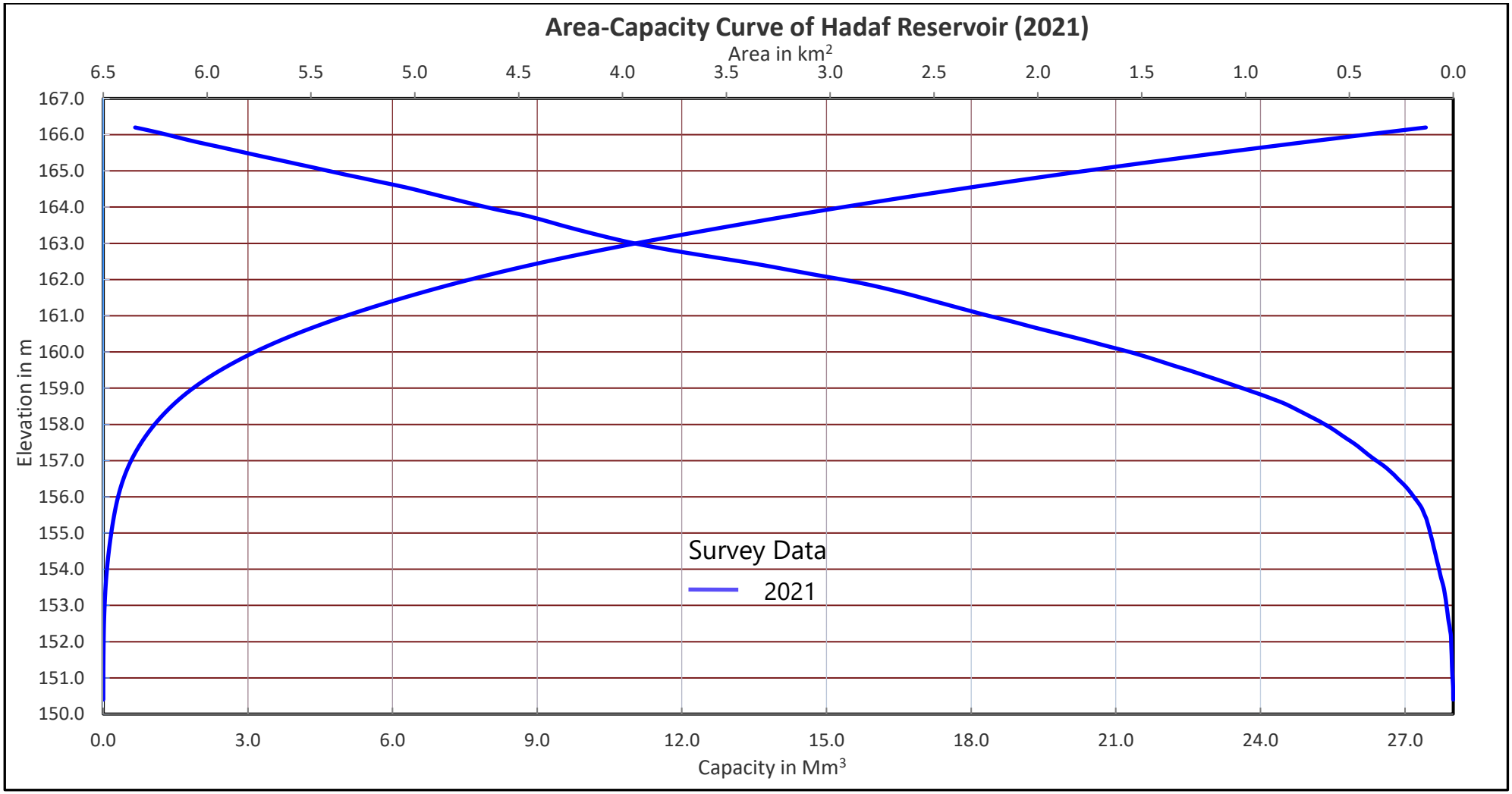

Figure 5.5: Area Capacity Curve (2021) for Hadaf Reservoir

5.3 Comparison of Elevation Area Capacity Details

Comparison of the elevation area capacity details for the year 2021 with the elevation area capacity for the previous years 1986 and 2009 are shown in Table 5.2. In addition, the comparison plots of capacity curve for the year 1986, 2009 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. 1986 survey. However, while comparing the 2021 survey results w.r.t 2009 survey results an increase in the gross storage capacity is observed.

Table 5.2: Comparison of Elevation Capacity details of 2021, 2009 and 1986 data for Hadaf Reservoir

Sr. No	Elevation (w.r.t. MSL) [m]	1986 Survey		2009 Survey		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
1	150.2	0.000	0.000	0.000	0.000	--	--
2	150.3	--	--	0.001	0.000	--	--
3	150.4	--	--	0.001	0.001	0.000	0.000
4	150.5	--	--	0.002	0.001	0.000	0.000
5	150.6	--	--	0.002	0.002	0.000	0.000
6	150.7	--	--	0.003	0.002	0.001	0.000
7	150.8	--	--	0.003	0.002	0.001	0.000
8	150.9	--	--	0.004	0.003	0.002	0.000
9	151.0	--	--	0.004	0.003	0.003	0.001
10	151.1	--	--	0.005	0.004	0.004	0.001
11	151.2	0.000	0.000	0.005	0.004	0.005	0.002
12	151.3	--	--	0.005	0.005	0.006	0.002
13	151.4	--	--	0.006	0.005	0.007	0.003
14	151.5	--	--	0.006	0.006	0.007	0.003
15	151.6	--	--	0.007	0.006	0.008	0.004
16	151.7	--	--	0.007	0.006	0.008	0.005
17	151.8	--	--	0.008	0.007	0.009	0.006
18	151.9	--	--	0.008	0.007	0.010	0.007
19	152.0	--	--	0.009	0.008	0.010	0.008
20	152.1	--	--	0.009	0.008	0.011	0.009
21	152.2	--	--	0.010	0.009	0.012	0.010
22	152.3	--	--	0.011	0.009	0.015	0.011
23	152.4	--	--	0.011	0.010	0.017	0.013
24	152.5	--	--	0.012	0.011	0.020	0.015

Sr. No	Elevation (w.r.t. MSL) [m]	1986 Survey		2009 Survey		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
25	152.6	--	--	0.012	0.011	0.023	0.017
26	152.7	--	--	0.013	0.012	0.026	0.019
27	152.8	--	--	0.013	0.012	0.028	0.022
28	152.9	--	--	0.013	0.013	0.030	0.025
29	153.0	--	--	0.014	0.013	0.033	0.028
30	153.1	--	--	0.014	0.014	0.035	0.031
31	153.2	0.000	0.000	0.015	0.014	0.037	0.035
32	153.3	--	--	0.017	0.017	0.040	0.039
33	153.4	--	--	0.020	0.019	0.043	0.043
34	153.5	--	--	0.022	0.022	0.046	0.047
35	153.6	--	--	0.025	0.024	0.051	0.052
36	153.7	--	--	0.027	0.027	0.056	0.058
37	153.8	--	--	0.029	0.030	0.060	0.063
38	153.9	--	--	0.032	0.032	0.064	0.070
39	154.0	--	--	0.034	0.035	0.068	0.076
40	154.1	--	--	0.037	0.037	0.072	0.083
41	154.2	0.080	0.200	0.039	0.040	0.077	0.091
42	154.3	--	--	0.042	0.046	0.081	0.099
43	154.4	--	--	0.046	0.051	0.085	0.107
44	154.5	--	--	0.049	0.057	0.089	0.116
45	154.6	--	--	0.053	0.062	0.094	0.125
46	154.7	--	--	0.056	0.068	0.098	0.134
47	154.8	--	--	0.059	0.073	0.102	0.144
48	154.9	--	--	0.063	0.079	0.106	0.155
49	155.0	--	--	0.066	0.084	0.111	0.165
50	155.1	--	--	0.070	0.089	0.115	0.177
51	155.2	0.090	0.300	0.073	0.095	0.120	0.189
52	155.3	--	--	0.080	0.106	0.125	0.201
53	155.4	--	--	0.088	0.116	0.130	0.214
54	155.5	--	--	0.095	0.127	0.138	0.227
55	155.6	--	--	0.103	0.137	0.145	0.241
56	155.7	--	--	0.110	0.148	0.153	0.256

Sr. No	Elevation (w.r.t. MSL) [m]	1986 Survey		2009 Survey		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
57	155.8	--	--	0.117	0.158	0.164	0.272
58	155.9	--	--	0.125	0.169	0.177	0.289
59	156.0	--	--	0.132	0.179	0.190	0.307
60	156.1	--	--	0.140	0.189	0.203	0.327
61	156.2	0.160	0.551	0.147	0.200	0.216	0.348
62	156.3	--	--	0.159	0.220	0.232	0.370
63	156.4	--	--	0.171	0.241	0.249	0.394
64	156.5	--	--	0.184	0.261	0.267	0.420
65	156.6	--	--	0.196	0.281	0.284	0.447
66	156.7	--	--	0.208	0.301	0.303	0.477
67	156.8	--	--	0.220	0.322	0.323	0.508
68	156.9	--	--	0.232	0.342	0.346	0.541
69	157.0	--	--	0.245	0.362	0.370	0.577
70	157.1	--	--	0.257	0.383	0.395	0.616
71	157.2	0.450	0.807	0.269	0.403	0.417	0.656
72	157.3	--	--	0.288	0.438	0.439	0.699
73	157.4	--	--	0.308	0.474	0.460	0.744
74	157.5	--	--	0.327	0.509	0.485	0.791
75	157.6	--	--	0.346	0.545	0.511	0.841
76	157.7	--	--	0.365	0.580	0.537	0.893
77	157.8	--	--	0.385	0.616	0.562	0.948
78	157.9	--	--	0.404	0.652	0.589	1.006
79	158.0	--	--	0.423	0.687	0.618	1.066
80	158.1	--	--	0.443	0.723	0.649	1.129
81	158.2	0.820	1.444	0.462	0.758	0.683	1.196
82	158.3	--	--	0.501	0.822	0.716	1.266
83	158.4	--	--	0.540	0.887	0.751	1.339
84	158.5	--	--	0.579	0.951	0.785	1.416
85	158.6	--	--	0.618	1.015	0.823	1.496
86	158.7	--	--	0.657	1.080	0.869	1.581
87	158.8	--	--	0.696	1.144	0.915	1.670
88	158.9	--	--	0.735	1.208	0.965	1.764

Sr. No	Elevation (w.r.t. MSL) [m]	1986 Survey		2009 Survey		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
89	159.0	--	--	0.774	1.272	1.015	1.863
90	159.1	--	--	0.813	1.337	1.066	1.967
91	159.2	1.500	3.200	0.852	1.401	1.117	2.076
92	159.3	--	--	0.908	1.513	1.170	2.191
93	159.4	--	--	0.965	1.625	1.222	2.310
94	159.5	--	--	1.021	1.736	1.276	2.435
95	159.6	--	--	1.077	1.848	1.333	2.566
96	159.7	--	--	1.134	1.960	1.388	2.702
97	159.8	--	--	1.190	2.072	1.442	2.843
98	159.9	--	--	1.246	2.184	1.498	2.990
99	160.0	--	--	1.302	2.295	1.558	3.143
100	160.1	--	--	1.359	2.407	1.625	3.302
101	160.2	2.180	4.957	1.415	2.519	1.692	3.468
102	160.3	--	--	1.469	2.688	1.757	3.640
103	160.4	--	--	1.523	2.856	1.824	3.819
104	160.5	--	--	1.577	3.025	1.895	4.005
105	160.6	--	--	1.631	3.194	1.964	4.198
106	160.7	--	--	1.685	3.362	2.033	4.398
107	160.8	--	--	1.738	3.531	2.097	4.605
108	160.9	--	--	1.792	3.700	2.167	4.818
109	161.0	--	--	1.846	3.869	2.238	5.038
110	161.1	--	--	1.900	4.037	2.304	5.265
111	161.2	2.840	6.713	1.954	4.206	2.369	5.499
112	161.3	--	--	2.006	4.409	2.433	5.739
113	161.4	--	--	2.059	4.613	2.498	5.985
114	161.5	3.060	7.240	2.111	4.816	2.562	6.238
115	161.6	--	--	2.164	5.045	2.627	6.498
116	161.7	--	--	2.217	5.275	2.696	6.764
117	161.8	--	--	2.270	5.504	2.769	7.037
118	161.9	--	--	2.324	5.734	2.850	7.318
119	162.0	--	--	2.377	5.963	2.941	7.608
120	162.1	--	--	2.430	6.193	3.041	7.907

Sr. No	Elevation (w.r.t. MSL) [m]	1986 Survey		2009 Survey		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
121	162.2	3.630	9.988	2.483	6.422	3.137	8.216
122	162.3	--	--	2.559	6.708	3.231	8.534
123	162.4	--	--	2.635	6.994	3.326	8.862
124	162.5	--	--	2.710	7.280	3.431	9.200
125	162.6	--	--	2.786	7.566	3.541	9.548
126	162.7	--	--	2.862	7.852	3.649	9.908
127	162.8	--	--	2.938	8.138	3.756	10.278
128	162.9	--	--	3.014	8.424	3.852	10.658
129	163.0	--	--	3.089	8.710	3.943	11.048
130	163.1	--	--	3.165	8.996	4.022	11.446
131	163.2	4.790	14.503	3.241	9.282	4.095	11.852
132	163.3	--	--	3.305	9.638	4.164	12.265
133	163.4	--	--	3.368	9.994	4.232	12.685
134	163.5	--	--	3.432	10.350	4.296	13.111
135	163.6	--	--	3.495	10.706	4.357	13.544
136	163.7	--	--	3.559	11.062	4.421	13.983
137	163.8	--	--	3.623	11.418	4.491	14.428
138	163.9	--	--	3.686	11.774	4.579	14.882
139	164.0	--	--	3.750	12.130	4.657	15.344
140	164.1	--	--	3.813	12.486	4.729	15.813
141	164.2	5.870	19.413	3.877	12.842	4.800	16.289
142	164.3	--	--	3.946	13.265	4.871	16.773
143	164.4	--	--	4.014	13.687	4.941	17.264
144	164.5	--	--	4.083	14.110	5.010	17.761
145	164.6	--	--	4.151	14.532	5.087	18.266
146	164.7	--	--	4.220	14.955	5.171	18.779
147	164.8	--	--	4.288	15.378	5.252	19.300
148	164.9	--	--	4.357	15.800	5.336	19.829
149	165.0	--	--	4.425	16.223	5.415	20.367
150	165.1	--	--	4.494	16.645	5.493	20.912
151	165.2	6.650	25.898	4.562	17.068	5.574	21.466
152	165.3	--	--	4.637	17.538	5.654	22.027

Sr. No	Elevation (w.r.t. MSL) [m]	1986 Survey		2009 Survey		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
153	165.4	--	--	4.713	18.009	5.735	22.597
156	165.7	--	--	4.967	19.510	5.971	24.353
157	165.8	--	--	5.057	20.025	6.051	24.954
158	165.9	--	--	5.146	20.540	6.123	25.562
159	166.0	--	--	5.236	21.055	6.192	26.178
160	166.1	--	--	5.325	21.571	6.266	26.801
161	166.2	7.480	32.260	5.415	22.086	6.347	27.432

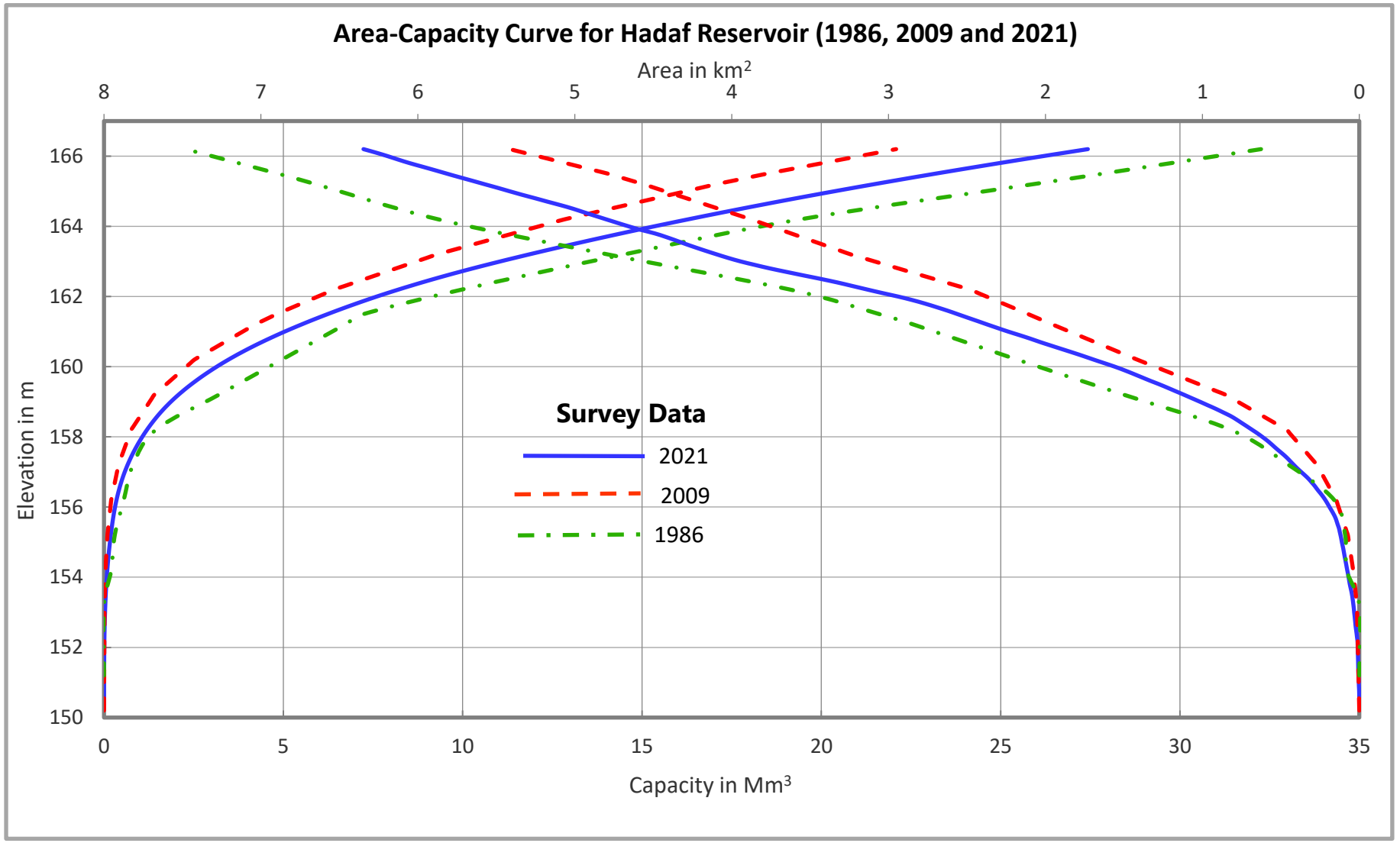

Figure 5.6: Comparison of Elevation Area capacity curves for 1986, 2009 and 2021 surveys of Hadaf Reservoir

5.4 Sedimentation in Reservoir

The present survey of Hadaf reservoir was carried out between March-April 2021 and June 2021. Previous survey was carried out in the year 2009. The catchment area considered for sedimentation studies is 507.64 km^2. In the present study, the age of the reservoir is considered as 35 years (1986 – 2021). As per 2021 survey, the total area of reservoir at FRL of 166.20 m is 6.347 km^2 and the corresponding gross storage capacity is 27.432 Mm^3. Table 5.3 details the gross capacity loss, rate of sedimentation and annual % loss in gross storage capacity w.r.t. 1986 survey results.

Table 5.3: Sedimentation in Hadaf Reservoir

	1986	2009	2021	2021
Storage Capacity in Mm^3				
Dead	7.240	4.816	6.238	6.238
Live	25.020	17.270	21.193	21.193
Gross	32.260	22.086	27.432	27.432
Loss of Storage Capacity in Mm^3		(w.r.t. 1986)	(w.r.t. 2009)	(w.r.t. 1986)
Dead	NA	2.424	-1.422	1.002
Live	NA	7.750	-3.923	3.827
Gross	NA	10.174	-5.346	4.828
Sedimentation Rate in Ha m /100 km^2/Year		(w.r.t. 1986)	(w.r.t. 2009)	(w.r.t. 1986)
Dead	NA	2.076	-2.335	0.564
Live	NA	6.638	-6.440	2.154
Gross	NA	8.714	-8.775	2.718
Annual % loss		(w.r.t. 1986)	(w.r.t. 2009)	(w.r.t. 1986)
Dead	NA	0.327	-0.537	0.089
Live	NA	1.045	-1.480	0.339
Gross	NA	1.371	-2.017	0.428
Remarks	As per design	Serious	Desiltation	Significant
Volume of sediment (w.r.t. 1986) deposited on bed in 2021= Loss of storage capacity= 4.828 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 Hadaf reservoir as per the methodology given in IS 12182-1987.

Table 5.4: Trap Efficiency and Sedimentation Index for Hadaf Reservoir

Trap Efficiency	Sedimentation Index
92%	8.201 x 10^9 sec^2/m

In Table 5.3 and Table 5.5 the survey data of 1986 was compared with 2021 survey results to understand the sedimentation in Hadaf reservoir. It may be observed that there is a reduction in the storage capacity of the reservoir due to siltation process happening over the lifespan of the reservoir. The reason behind siltation could be change of upstream catchment characteristics. Also, there could be some anthropogenic activities, which might be the cause for siltation.

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 (Since 1986 survey)			Observed Rate of Sedimentation Since 1986 survey (Ha m / 100 Sq km/Yr)
				Gross	Mm^3	% Cumulative	Remark	
1	1986	Govt.	-	32.260	-			
2	2009	Govt.	23	22.086	10.174	31.538	Siltation	8.714
3	2021	Present Survey	35	27.432	4.828	14.967	Desiltation	2.718

- As per 2021 survey results, the volume of sediment deposited or the loss in gross storage capacity w.r.t. 1986 survey data is 4.828 Mm^3.
- The rate of siltation in Hadaf reservoir is 0.138 Mm^3/year.
- The average rate of siltation in the Hadaf reservoir during the 35 years life span (1986 – 2021), works out to 2.718 Ha m/100 sq km/year.
- The annual % loss in Hadaf reservoir during the 35 years life span is 0.428 % and hence, the reservoir is classified as "Significant" category as per IS 12182 (1987).
- Trap Efficiency and sedimentation Index calculated for Hadaf reservoir as per methodology give in IS 12182-1987 is 92% and 8.201 x 10^9 sec^2/m respectively.

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

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

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Hadaf reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
1	150.40	0.0000	--	0.0000	Bed level
2	150.50	0.0000	--	0.0000	--
3	150.60	0.0000	--	0.0000	--
4	150.70	0.0001	--	0.0001	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Hadaf reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
5	150.80	0.0002	--	0.0002	--
6	150.90	0.0004	--	0.0004	--
7	151.00	0.001	--	0.001	--
8	151.10	0.001	--	0.001	--
9	151.20	0.002	--	0.002	--
10	151.30	0.002	--	0.002	--
11	151.40	0.003	--	0.003	--
12	151.50	0.003	--	0.003	--
13	151.60	0.004	--	0.004	--
14	151.70	0.005	--	0.005	--
15	151.80	0.006	--	0.006	--
16	151.90	0.007	--	0.007	--
17	152.00	0.008	--	0.008	--
18	152.10	0.009	--	0.009	--
19	152.20	0.010	--	0.010	--
20	152.30	0.011	--	0.011	--
21	152.40	0.013	--	0.013	--
22	152.50	0.015	--	0.015	--
23	152.60	0.017	--	0.017	--
24	152.70	0.019	--	0.019	--
25	152.80	0.022	--	0.022	--
26	152.90	0.025	--	0.025	--
27	153.00	0.028	--	0.028	--
28	153.10	0.031	--	0.031	--
29	153.20	0.035	--	0.035	--
30	153.30	0.039	--	0.039	--
31	153.40	0.043	--	0.043	--
32	153.50	0.047	--	0.047	--
33	153.60	0.052	--	0.052	--
34	153.70	0.058	--	0.058	--
35	153.80	0.063	--	0.063	--
36	153.90	0.070	--	0.070	--
37	154.00	0.076	--	0.076	--
38	154.10	0.083	--	0.083	--
39	154.20	0.091	--	0.091	--
40	154.30	0.099	--	0.099	--
41	154.40	0.107	--	0.107	--
42	154.50	0.116	--	0.116	--
43	154.60	0.125	--	0.125	--
44	154.70	0.134	--	0.134	--
45	154.80	0.144	--	0.144	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Hadaf reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
46	154.90	0.155	--	0.155	--
47	155.00	0.165	--	0.165	--
48	155.10	0.177	--	0.177	--
49	155.20	0.189	--	0.189	--
50	155.30	0.201	--	0.201	--
51	155.40	0.214	--	0.214	--
52	155.50	0.227	--	0.227	--
53	155.60	0.241	--	0.241	--
54	155.70	0.256	--	0.256	--
55	155.80	0.272	--	0.272	--
56	155.90	0.289	--	0.289	--
57	156.00	0.307	--	0.307	--
58	156.10	0.327	--	0.327	--
59	156.20	0.348	--	0.348	--
60	156.30	0.370	--	0.370	--
61	156.40	0.394	--	0.394	--
62	156.50	0.420	--	0.420	--
63	156.60	0.447	--	0.447	--
64	156.70	0.477	--	0.477	--
65	156.80	0.508	--	0.508	--
66	156.90	0.541	--	0.541	--
67	157.00	0.577	--	0.577	--
68	157.10	0.616	--	0.616	--
69	157.20	0.656	--	0.656	--
70	157.30	0.699	--	0.699	--
71	157.40	0.744	--	0.744	--
72	157.50	0.791	--	0.791	--
73	157.60	0.841	--	0.841	--
74	157.70	0.893	--	0.893	--
75	157.80	0.948	--	0.948	--
76	157.90	1.006	--	1.006	--
77	158.00	1.066	--	1.066	--
78	158.10	1.129	--	1.129	--
79	158.20	1.196	--	1.196	--
80	158.30	1.266	--	1.266	--
81	158.40	1.339	--	1.339	--
82	158.50	1.416	--	1.416	--
83	158.60	1.496	--	1.496	--
84	158.70	1.581	--	1.581	--
85	158.80	1.670	--	1.670	--
86	158.90	1.764	--	1.764	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Hadaf reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
87	159.00	1.863	--	1.863	--
88	159.10	1.967	--	1.967	--
89	159.20	2.076	--	2.076	--
90	159.30	2.191	--	2.191	--
91	159.40	2.310	--	2.310	--
92	159.50	2.435	--	2.435	--
93	159.60	2.566	--	2.566	--
94	159.70	2.702	--	2.702	--
95	159.80	2.843	--	2.843	--
96	159.90	2.990	--	2.990	--
97	160.00	3.143	--	3.143	--
98	160.10	3.302	--	3.302	--
99	160.20	3.468	--	3.468	--
100	160.30	3.640	--	3.640	--
101	160.40	3.819	--	3.819	--
102	160.50	4.005	--	4.005	--
103	160.60	4.198	--	4.198	--
104	160.70	4.398	--	4.398	--
105	160.80	4.605	--	4.605	--
106	160.90	4.818	--	4.818	--
107	161.00	5.038	--	5.038	--
108	161.10	5.265	--	5.265	--
109	161.20	5.499	--	5.499	--
110	161.30	5.739	--	5.739	--
111	161.40	5.985	--	5.985	--
112	161.50	6.238	--	6.238	MDDL
113	161.60	6.498	0.259	6.238	--
114	161.70	6.764	0.526	6.238	--
115	161.80	7.037	0.799	6.238	--
116	161.90	7.318	1.080	6.238	--
117	162.00	7.608	1.369	6.238	--
118	162.10	7.907	1.668	6.238	--
119	162.20	8.216	1.977	6.238	--
120	162.30	8.534	2.296	6.238	--
121	162.40	8.862	2.623	6.238	--
122	162.50	9.200	2.961	6.238	--
123	162.60	9.548	3.310	6.238	--
124	162.70	9.908	3.669	6.238	--
125	162.80	10.278	4.040	6.238	--
126	162.90	10.658	4.420	6.238	--
127	163.00	11.048	4.810	6.238	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Hadaf reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
128	163.10	11.446	5.208	6.238	--
129	163.20	11.852	5.614	6.238	--
130	163.30	12.265	6.027	6.238	--
131	163.40	12.685	6.447	6.238	--
132	163.50	13.111	6.873	6.238	--
133	163.60	13.544	7.306	6.238	--
134	163.70	13.983	7.744	6.238	--
135	163.80	14.428	8.190	6.238	--
136	163.90	14.882	8.644	6.238	--
137	164.00	15.344	9.105	6.238	--
138	164.10	15.813	9.575	6.238	--
139	164.20	16.289	10.051	6.238	--
140	164.30	16.773	10.535	6.238	--
141	164.40	17.264	11.025	6.238	--
142	164.50	17.761	11.523	6.238	--
143	164.60	18.266	12.028	6.238	--
144	164.70	18.779	12.541	6.238	--
145	164.80	19.300	13.062	6.238	--
146	164.90	19.829	13.591	6.238	--
147	165.00	20.367	14.129	6.238	--
148	165.10	20.912	14.674	6.238	--
149	165.20	21.466	15.228	6.238	--
150	165.30	22.027	15.789	6.238	--
151	165.40	22.597	16.358	6.238	--
152	165.50	23.174	16.936	6.238	--
153	165.60	23.759	17.521	6.238	--
154	165.70	24.353	18.114	6.238	--
155	165.80	24.954	18.715	6.238	--
156	165.90	25.562	19.324	6.238	--
157	166.00	26.178	19.940	6.238	--
158	166.10	26.801	20.563	6.238	--
159	166.20	27.432	21.193	6.238	FRL

6. Conclusions

- The reservoir topography was uneven, with reservoir bed level ranging from 150.40 m to 166.20 m w.r.t. MSL. The lowest reservoir bed level 150.40 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 east, north & south directions away from the dam wall within the survey area.
- Current survey results indicate that the loss of gross storage capacity (w.r.t. 1986 survey data) due to siltation in Hadaf reservoir is 4.828 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 1986 survey data, 2021 results indicate decrease in storage capacity due to siltation. The annual % loss in gross storage capacity is 0.428 % 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. Reference

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Appendix A

Diary of Events

(01 page)

Diary of Events (Bathymetry and Topography Survey)	
Date	**Events**
Bathymetry Survey	
25 March 2021	Survey personnel with survey boat 'Fugro Zodiac' reached Hadaf reservoir. Mobilization commenced
26-27 March 2021	Mobilization and Calibration/verification continued
28 March 2021	Mobilization and Calibration/verification completed
29 March 2021	Survey team standby due to unavailability of local boat personnel
30 March 2021	Bathymetry survey commenced.
31 March 2021 – 14 April 2021	Bathymetry survey continued.
15 April 2021	Bathymetry survey completed
16 April 2021	Demobilization started but suspended to rains in the afternoon.
17 April 2021	Survey team went for Dosvada Dam site visit.
18 April 2021	Survey team came back to Hadaf dam and completed demobilization.
Topography Survey	
16 June 2021	Topography survey team with equipment reached Hadaf Dam. Mobilisation and calibration commenced and completed. Topography survey commenced
17 - 19 June 2021	Topography survey continued.
20 June 2021	Topography survey completed.

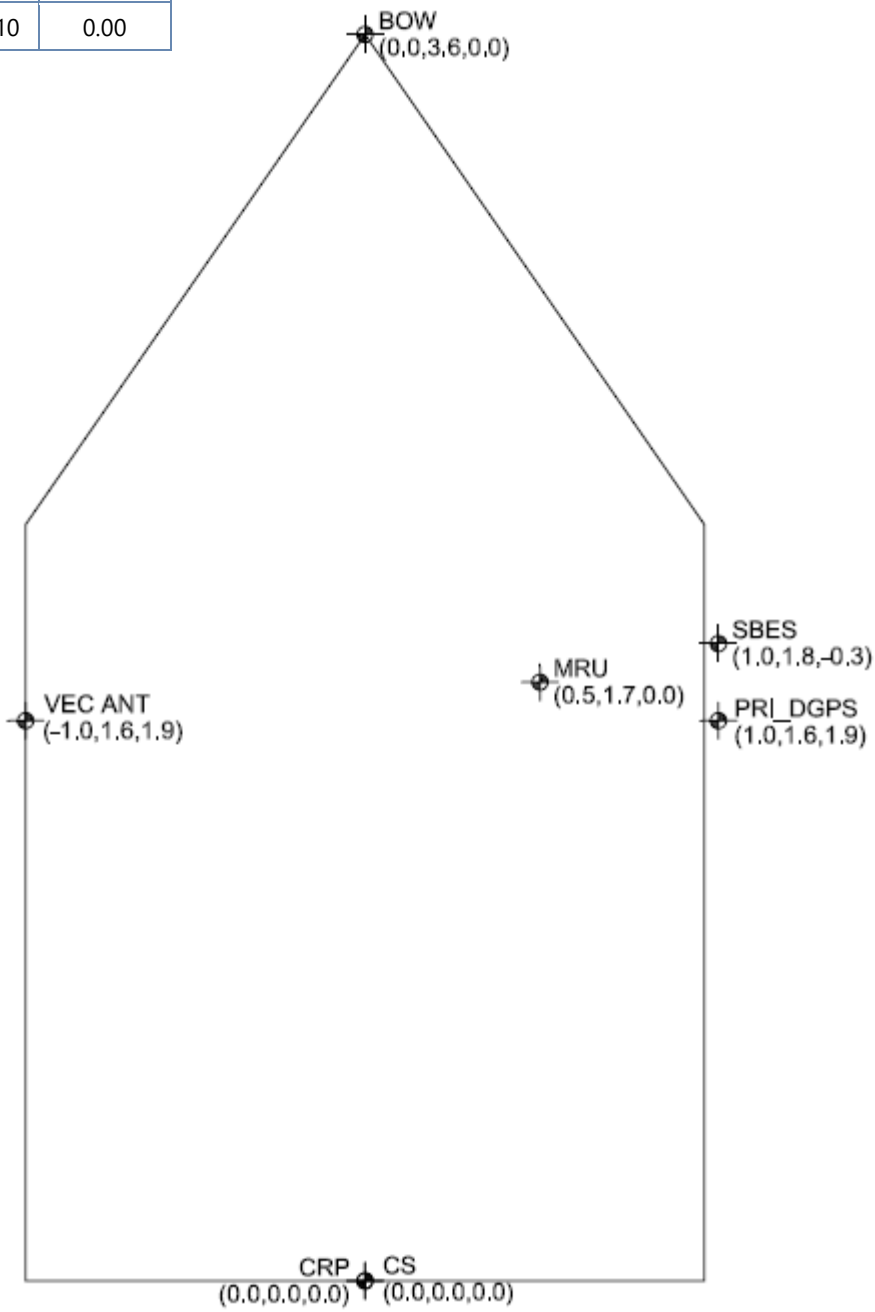
Appendix B

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

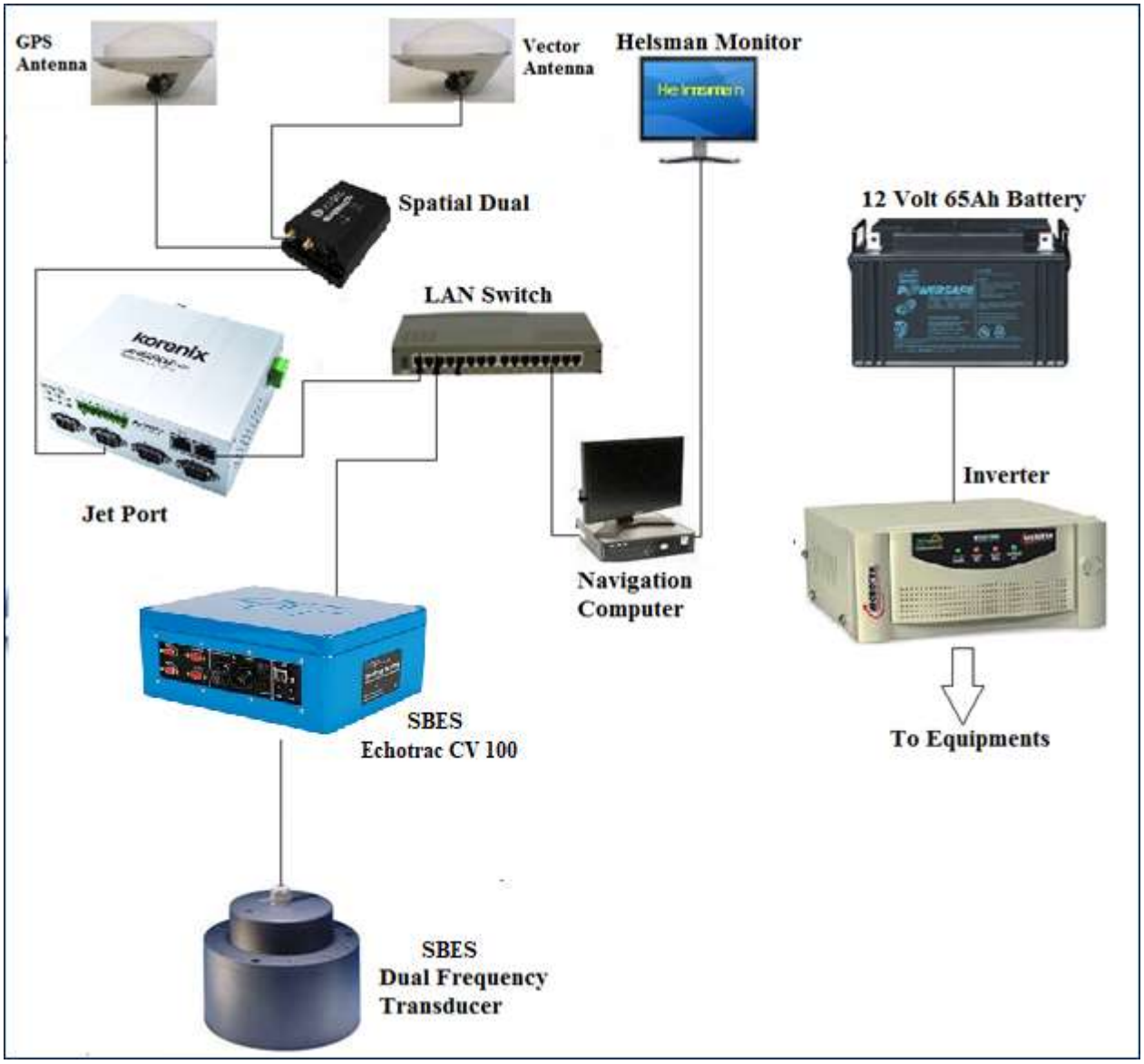


Appendix C

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 HADAF DAM TBM1

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	HADAF DAM TBM1	**Location:**	HADAF DAM, Gujarat
Party Chief :	Pritam Seth	**Job Engineer/Surveyor :**	Ganesh Sonawale.
Date of Observation: (Date & Time)	13-03-2021 & 13:18hrs	**End of Observation: (Date & Time)**	27-03-2021 & 13:48hrs

1. Station Name: HADAF DAM TBM1**.**

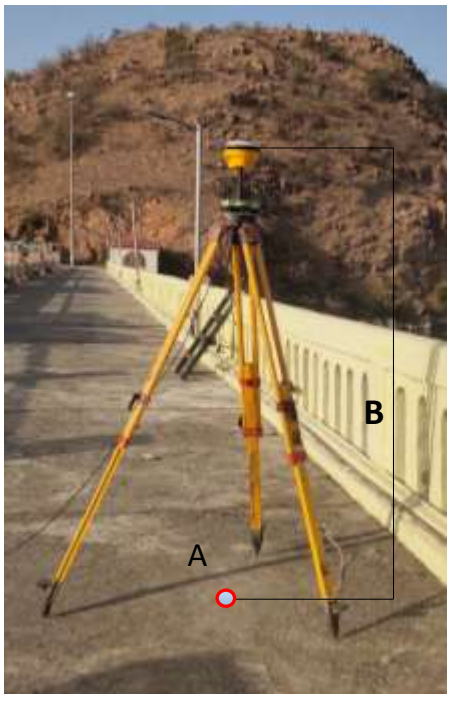
Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
TRIMBLE BX992 RECEIVER	025-00009601	PRI_DGPS	Mean position report	FBF	NA	0.02

A=Center Point of HADAF DAM TBM1 Height from MSL 171.709m

B= Antenna Height from BM 1.710m (Measure by Tape)

Ellipsoidal height of Antenna= 116.154m

Ellipsoidal Height of BM 116.154m - 1.710m=114.444m



Position Of Antenna:-

Latitude: 22°53'25.040"N, Longitude: 073°52'39.653"E

Easting: 3,84,885.185mE, Northing: 25,31,813.438mN

Prepared By: Pritam Seth.

BATHYMETRY
MEAN POSITION REPORT

Project ID	J-HYD-20-174630-BM		
Location	GUJARAT		
Client	Govt. of Gujarat	**Vessel**	Prism
Comment	BX 992 HADAF DAM TBM1-STN HT 1.710m		

Session Name: MPR-20210327073616-v1 Records Used: 1370 of 1799

Start Time: 27 Mar 2021, 13:18:56+05:30 End Time: 27 Mar 2021, 13:48:55+05:30 Session Length: 00:29:59

Mean Position for Prism CommonReferencePoint		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	22°53’25.04004”N	22°53’25.04004”N
Longitude	073°52’39.65381”E	073°52’39.65381”E
Height	116.154m Ell.	116.154m Ell.
Easting	3,84,885.185m E (SD: ±0.02m)	
Northing	25,31,813.438m N (SD: ±0.02m)	
Height	173.097m Ort. (SD: ±0.05m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	7.42°T 7.85°G	±70.7°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

BX 992 HADAF DAM TBM1

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

Deputy Executive Engineer
HADAF DAM
Govt. of Gujarat

Geodetic Parameters

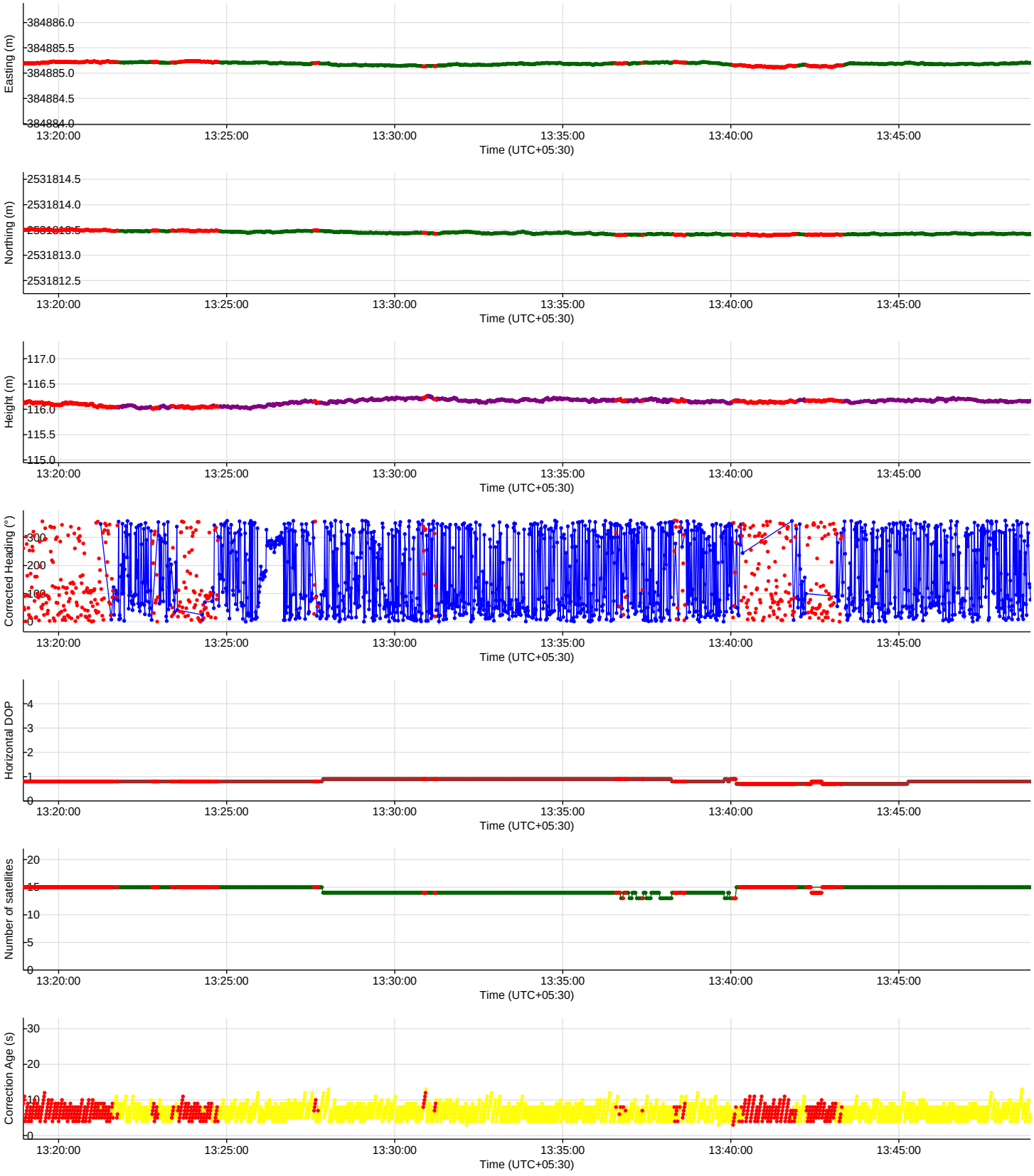
Name : WGS 84 / UTM zone 43N		
EPSG Code	EPSG::32643	
Local Geodetic Datum Parameters		
Datum	World Geodetic System 1984	EPSG::6326
Ellipsoid	WGS 84	
Semi major axis	a = 63,78,137.000 m	
Inverse flattening	1/f = 298.257223563	
Local Projection Parameters		
Map Projection	Transverse Mercator	
Grid System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

Scatter Plot

Mean Position

	Easting	Northing
Prism	3,84,885.185m E	25,31,813.438m N

Time Series Plots for Prism



FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of HADAF DAM TBM1

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	**HADAF DAM TBM1**	**Location:**	HADAF DAM, Gujarat
Party Chief :	Pritam Seth	**Job Engineer/Surveyor :**	Ganesh Sonawale.
Date of Observation: (Date & Time)	27-03-2021 & 14:31hrs	**End of Observation: (Date & Time)**	27-03-2021 & 15:01hrs

1. Station Name: HADAF DAM TBM1.

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 **HADAF DAM TBM1** Height from MSL 171.709m

B= Antenna Height from BM 1.663m (Measure by Tape)

Ellipsoidal height of Antenna= 116.260m

Ellipsoidal Height of BM 116.260 - 1.663m=114.597m

Position Of Antenna:-

Latitude: 22°53’25.039”N, **Longitude:** 073°52’39.660”E

Easting: 3, 84,885.383mE**, Northing:** 25, 31,813.425mN

Prepared By: Pritam Seth.

BATHYMETRY
MEAN POSITION REPORT

Project ID	J-HYD-20-174630-BM		
Location	GUJARAT		
Client	Govt. of Gujarat	**Vessel**	Prism
Comment	HADAF DAM TBM1-STN HT 1.663m		

Session Name: MPR-20210327084900-v1 Records Used: 1573 of 1800

Start Time: 27 Mar 2021, 14:31:11+05:30 End Time: 27 Mar 2021, 15:01:10+05:30 Session Length: 00:29:59

Mean Position for Prism CommonReferencePoint		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	22°53’25.03967”N	22°53’25.03967”N
Longitude	073°52’39.66075”E	073°52’39.66075”E
Height	116.260m Ell.	116.260m Ell.
Easting	3,84,885.383m E (SD: ±0.01m)	
Northing	25,31,813.425m N (SD: ±0.01m)	
Height	173.203m Ort. (SD: ±0.06m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	15.51°T 15.94°G	±76.3°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

HADAF DAM TBM1-STN HT 1.663m

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

Deputy Executive Engineer
HADAF DAM
Govt. of Gujarat

Geodetic Parameters

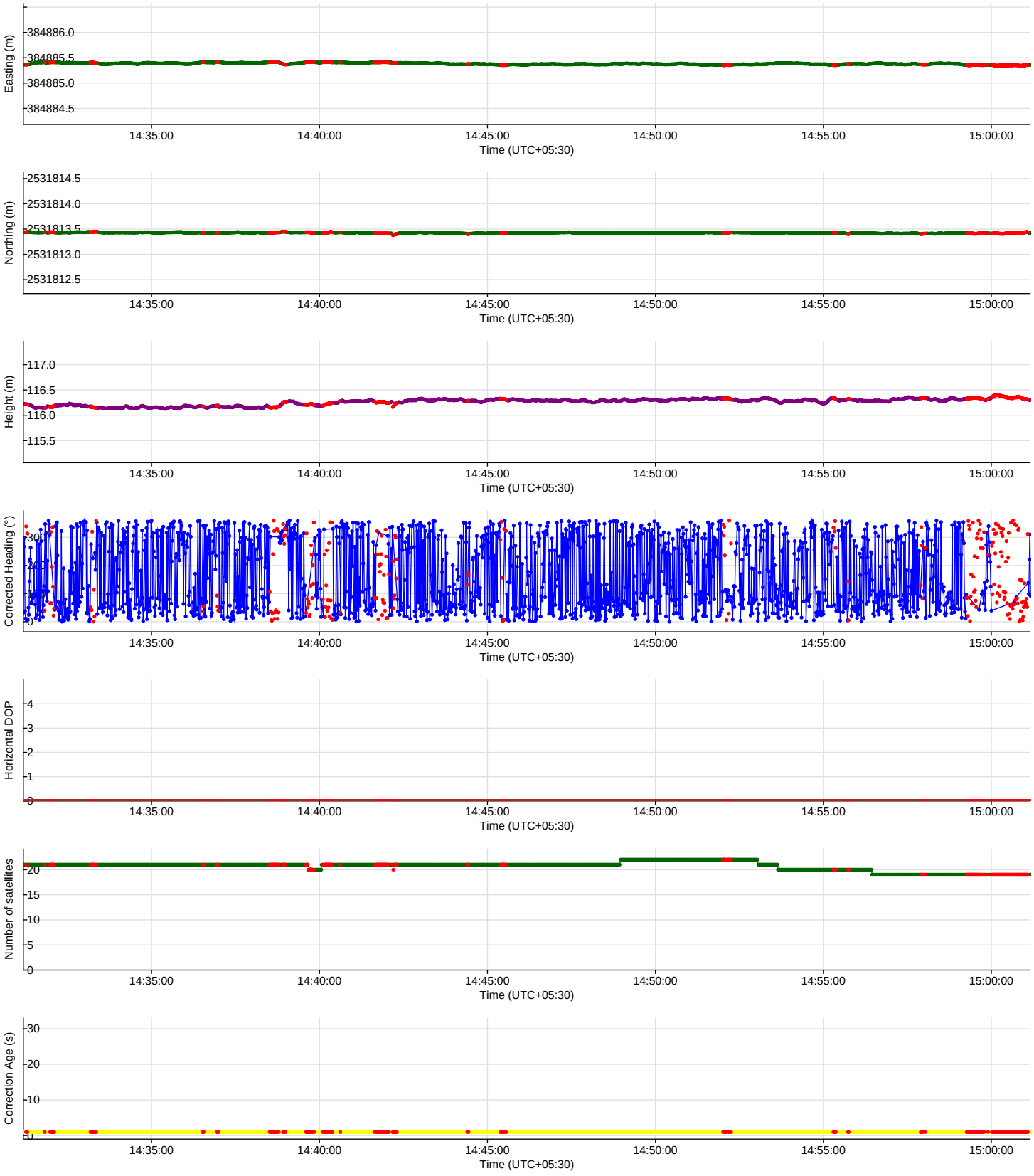
Name : WGS 84 / UTM zone 43N		
EPSG Code	EPSG::32643	
Local Geodetic Datum Parameters		
Datum	World Geodetic System 1984	EPSG::6326
Ellipsoid	WGS 84	
Semi major axis	a = 63,78,137.000 m	
Inverse flattening	1/f = 298.257223563	
Local Projection Parameters		
Map Projection	Transverse Mercator	
Grid System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

Scatter Plot

Mean Position

	Easting	Northing
Prism	3,84,885.383m E	25,31,813.425m N

Time Series Plots for Prism



FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of HADAF DAM TBM2

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	**HADAF DAM TBM2**	**Location:**	HADAF DAM, Gujarat
Party Chief :	Pritam Seth	**Job Engineer/Surveyor :**	Ganesh Sonawale.
Date of Observation: (Date & Time)	27-03-2021 & 16:46hrs	**End of Observation: (Date & Time)**	27-03-2021 & 17:16hrs

1. Station Name: HADAF DAM TBM2.

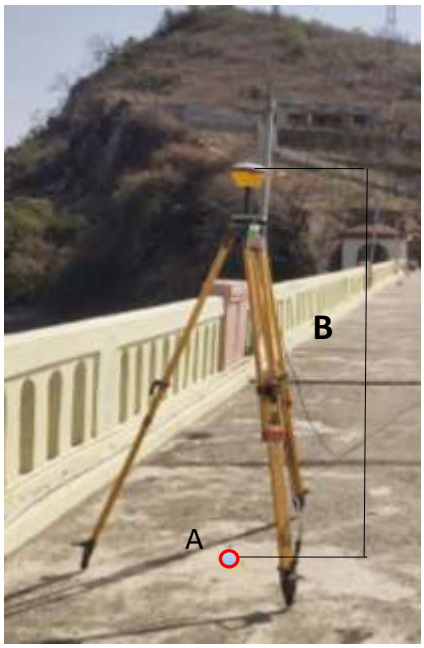
Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
Trimble BX 992 RECEIVER	025-00009601	PRI_DGPS	Mean position report	FBF	NA	0.02

A=Center Point of HADAF DAM TBM2 Height from MSL 171.702m

B= Antenna Height from BM 1.768m (Measure by Tape)

Ellipsoidal height of Antenna= 116.297m

Ellipsoidal Height of BM 116.297m - 1.768m=114.529m



Position Of Antenna:-

Latitude: 22°53’26.652”N, **Longitude:** 073°52’40.299”E

Easting: 3, 84,903.952mE, **Northing:** 25, 31,862.880mN

Prepared By: Pritam Seth.

BATHYMETRY
MEAN POSITION REPORT

Project ID	J-HYD-20-174630-BM		
Location	GUJARAT		
Client	Govt. of Gujarat	**Vessel**	Prism
Comment	HADAF DAM TBM2-STN HT- 1.768		

Session Name: MPR-20210327094830-v3 Records Used: 1498 of 1799

Start Time: 27 Mar 2021, 16:46:31+05:30 End Time: 27 Mar 2021, 17:16:30+05:30 Session Length: 00:29:59

Mean Position for Prism CommonReferencePoint		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	22°53'26.65229"N	22°53'26.65229"N
Longitude	073°52'40.29921"E	073°52'40.29921"E
Height	116.297m Ell.	116.297m Ell.
Easting	3,84,903.952m E (SD: ±0.02m)	
Northing	25,31,862.880m N (SD: ±0.02m)	
Height	173.238m Ort. (SD: ±0.04m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	335.17°T 335.61°G	±44.4°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

HADAF DAM TBM2-STN HT- 1.768

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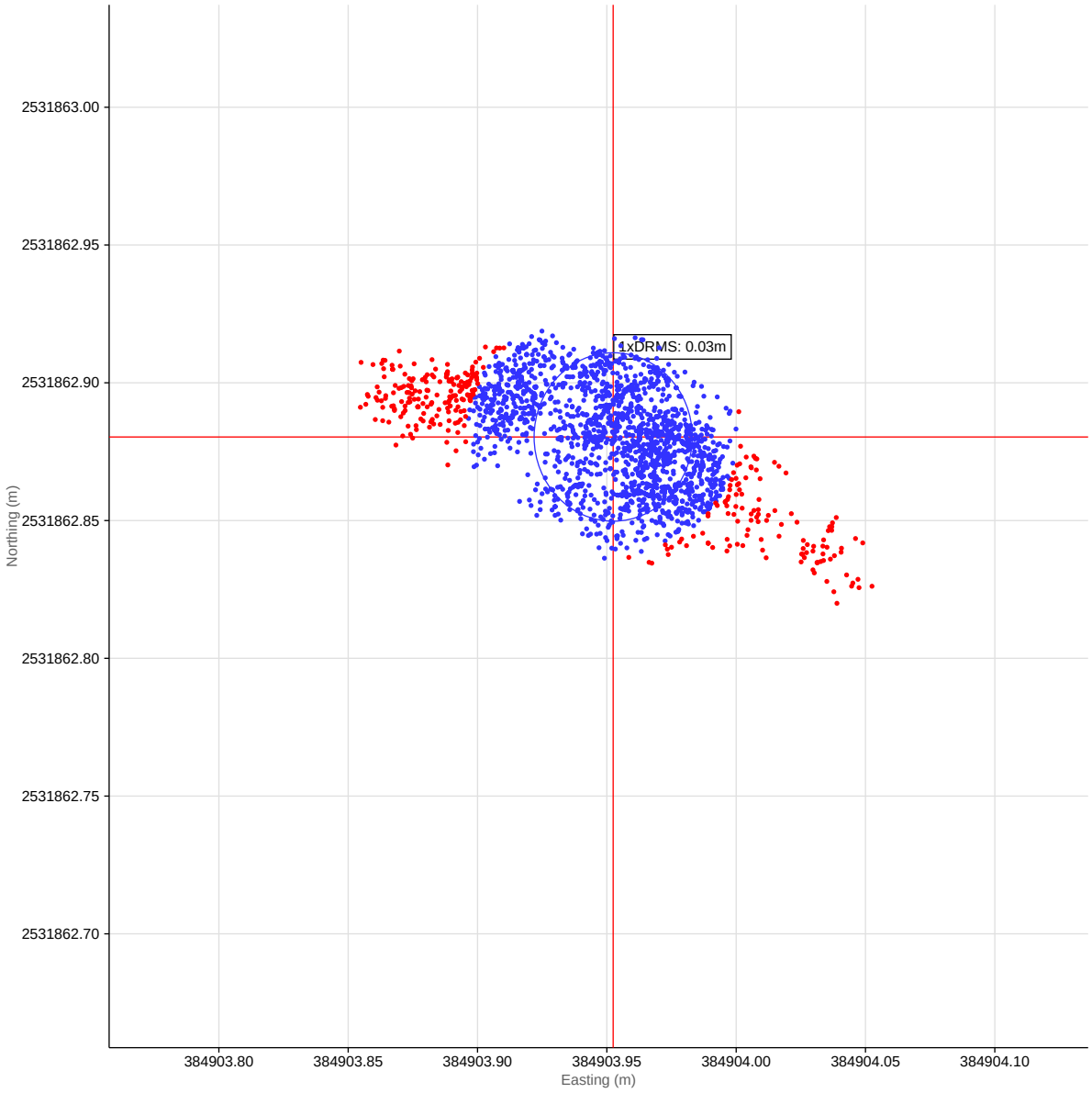
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Deputy Executive Engineer
HADAF DAM
Govt. of Gujarat

Geodetic Parameters

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

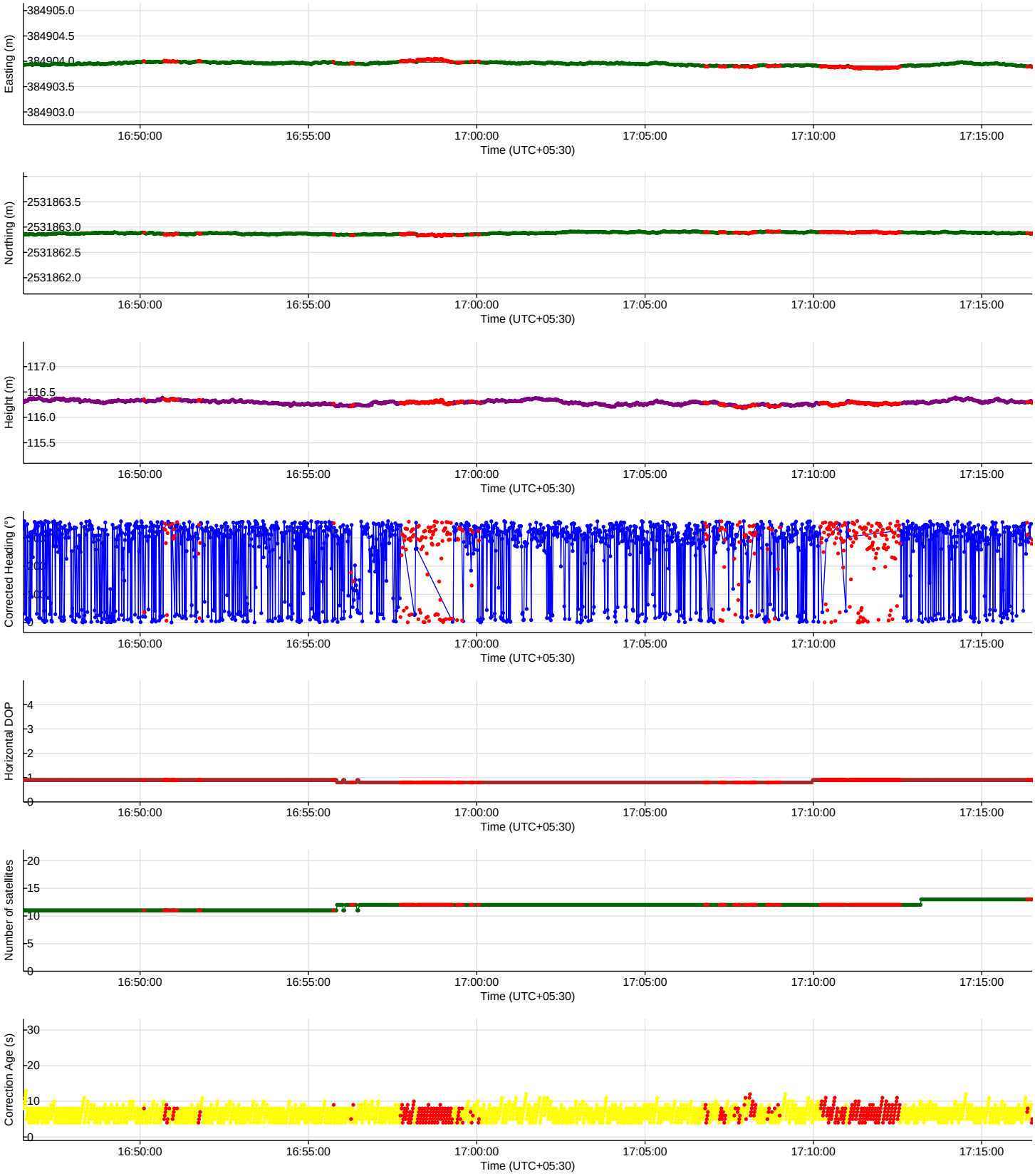
Scatter Plot



Mean Position

	Easting	Northing
Prism	3,84,903.952m E	25,31,862.880m N

Time Series Plots for Prism



SBES Calibration

SBES Barcheck Correction Table

Project No.	Project Title:	Vessel:	Place:
J-HYD-20-174630	**Bathymetry Survey**	**FUGRO ZODIAC**	**HADAF DAM**
Date:	Time:	Client:	
28-Mar-21	**14:50**	**GOV. OF GUJARAT**	
Observed By: PRITAM SETH		Echo Sounder Model and SL. No.	Area Depth
Project No. J-HYD-20-174630		**ODOM ECHOTRAC CV 100/ 007169**	**7**

Echo Sounder Settings

Draft HI	**Draft LO**	**Sound Velocity**	
0.32	**0.32**	**Average**	**Upto Depth**
		1470	**9**
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	1.03	-0.03	5	4.97	0.03
2	2.02	-0.02	4	3.98	0.02
3	3.01	-0.01	3	2.99	0.01
4	3.99	0.01	2	2.03	-0.03
5	4.97	0.03	1	1.01	-0.01

Average	0.00	Average	0.00
Std. Dev	0.0241	Std. Deviation	0.0241
		Cumulative Average	0.00
		Cumulative Std. Deviation	0.0000

Partychief
Pritam Seth
FSINPVT

Deputy Executive Engineer
HADAF DAM
Govt. of Gujarat

Station Name: HADAF DAM

Positioning System Verification With BX-992 Reciever and Spatial Dual						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Easting mE**	**Northing mN**	**Latitude**	**Longitude**	**Ellipsoidal height (m)**
TRIMBLE BX992 RECEIVER	025-00009601	384,885.185	2,531,813.438	22°53’25.040”N	073°52’39.653”E	114.444
Spatial Dual	025-00006405	384,885.383	2,531,813.425	22°53’25.039”N	073°52’39.660”E	114.597
	Difference	**-0.198**	**0.013**	**--**	**--**	**-0.153**

Location Name:	Hadaf Dam	Date:	16/06/2021	Instrument Name	LYNX
Work:	RTK Observation by Topography Team			Model no.	H6

Station Name		Observation Duration	Easting (mE)	Northing (mN)	MSL Height (m)	Remarks		
Hadaf Dam TBM 1	By rover 1	2 sec	384885.204	2531813.463	171.715	XYZ Value generated by RTK of Topography Team, Base Station on Hadaf Dam TBM 2 Fugro P	Field Photo\IMG_20210616_120049.jpg	
Hadaf Dam TBM 1	By rover 2	2 sec	384885.200	2531813.477	171.727	XYZ Value generated by RTK of Topography Team, Base Station on Hadaf Dam TBM 2 Fugro P	Field Photo\IMG_20210616_120235.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)
Hadaf Dam TBM 1	Fugro Provided Value	384885.185	2531813.438	171.709	Hadaf Dam TBM 1	Check by Rover 1	384885.204	2531813.463	171.715	-0.019	-0.025	-0.006
					Hadaf Dam TBM 1	Check by Rover 2	384885.200	2531813.477	171.727	-0.015	-0.039	-0.018

Note: HADAF DAM FRL-166.20m w.r.t MSL (Client Provided) transfered from FRL .

Note: Base station was on Hadaf Dam TBM 2 (Fugro provided base value), 2 reading taken for 2 sec each on Hadaf Dam TBM 1 by 2 rovers on pole mounted.

Prepared by Arunabha Chakraborty

Appendix E

Benchmark Descriptions

(3 pages)

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 :	HADAF DAM	**HADAF DAM TBM1**
	Observed By:	Pritam Seth,Ganesh Sonawale	
	Date:	27/03/2021	

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

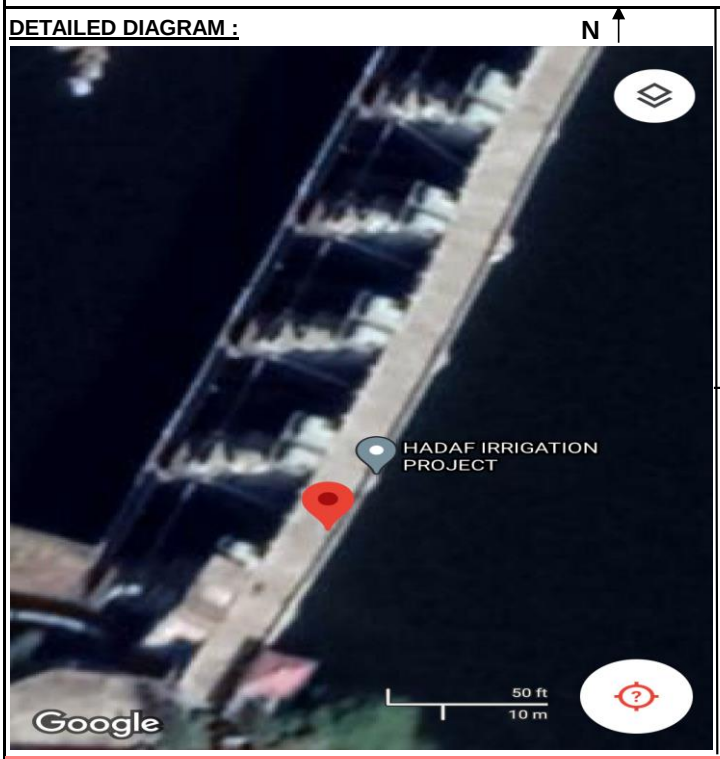
GEOGRAPHICAL COORDINATES:		**UTM COORDINATES:**		CM: 75° E
LATITUDE:	22°53'25.04"N	EASTING:	3,84,885.185m E	σ = +/- 0.02 m
LONGITUDE :	073°52'39.65"E	NORTHING:	25,31,813.438m N	σ = +/- 0.02 m
ELLIPSOIDAL HEIGHT:	114.444m	CONVERGENCE :	-0.43659 Degrees	
HEIGHT ABOVE LAT/CD:	NA	TBM VALUE:	171.709m w.r.t MSL	

LOCATION & ACCESS : Its established in Top of Dam. Near lockgate no. 1

STATION MARKING : HADAF DAM TBM1 estabilised 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)

Deputy Executive Engineer
HADAF DAM
GOVT. OF GUJRAT

Station / Bench Mark Description

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

Job No. :	**J_HYD_20_174630**
Client :	**Govt. Of Gujarat**
Location :	HADAF DAM
Observed By:	Pritam Seth,Ganesh Sonawale
Date:	27/03/2021

Station Name:

HADAF DAM TBM2

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

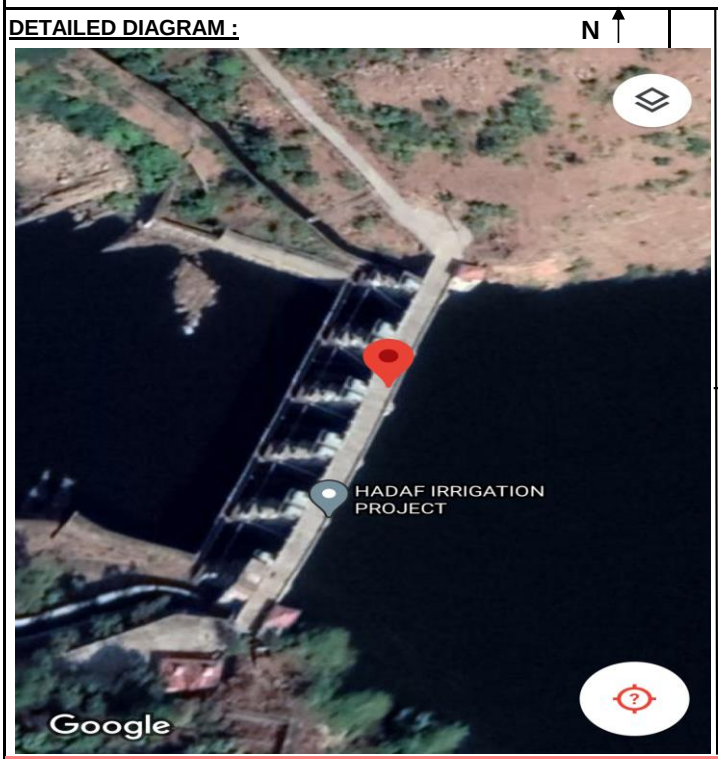
GEOGRAPHICAL COORDINATES:		**UTM COORDINATES:**		CM: 75° E
LATITUDE:	22°53'26.65"N	EASTING:	3,84,903.952m E	σ = +/- 0.02 m
LONGITUDE :	073°52'40.299"E	NORTHING:	25,31,862.880m N	σ = +/- 0.02 m
ELLIPSOIDAL HEIGHT:	114.529m	CONVERGENCE :	-0.43653 Degrees	
HEIGHT ABOVE LAT/CD:	NA	TBM VALUE:	171.702m w.r.t MSL	

LOCATION & ACCESS : Its established in Top of Dam. Near lockgate no. 4

STATION MARKING : HADAF DAM TBM2 estabilised 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)

Deputy Executive Engineer
HADAF DAM
GOVT. OF GUJRAT

LEVELLING RECORD FROM FRL HADAF DAM TO ALL TBM POINTS

Job No :	J-HYD-20-174630	Client Name :	GOVT. OF GUJARAT
Levelling Equpt Used:	AUTO LEVEL	Equipment Serial/Asset No:	256726
Area/Location Name:	HADAF DAM	Date of Observation:	26/03/2021
Observer's Name:	Pritam Seth	Staff Holder's Name:	Ganesh Sonawale

TOP OF DAM TO HADAF DAM TBM1

BACK SIGHT	FORE SIGHT	RL Value	Point Name
		171.5	TOP OF DAM
1.532	1.323	171.709	HADAF DAM TBM1
1.324	1.533	171.5	TOP OF DAM
Miscloser value	0		

HADAF DAM TBM1 TO HADAF DAM TBM2

BACK SIGHT	FORE SIGHT	RL Value	Point Name
		171.709	HADAF DAM TBM1
1.325	1.332	171.702	HADAF DAM TBM2
1.32	1.313	171.709	HADAF DAM TBM1
Miscloser value	0		

HADAF DAM TBM1 TO TBM ATG POINT

BACK SIG	FORE SIG	RL Value	Point Name
		171.709	HADAF DAM TBM1
0.646	3.829	168.526	TBM OF ATG POINT
3.841	0.658	171.709	HADAF DAM TBM1
Miscloser v	0		

NOTE-	
	FRL Value 166.20m w.r.t MSL Provided by Client
	FRL level to TOP OF DAM mesurement by mesuring tape 5.30m
	FRL Of HADAF DAM 166.20m + 5.30m = 171.500m

Photograph showing the Water Level Measurement Pillar at Hadaf Dam

PRITAM SETH
PARTY CHIEF
FSINPVT

Deputy Executive Engineer
HADAF DAM
GOVT. OF GUJRAT

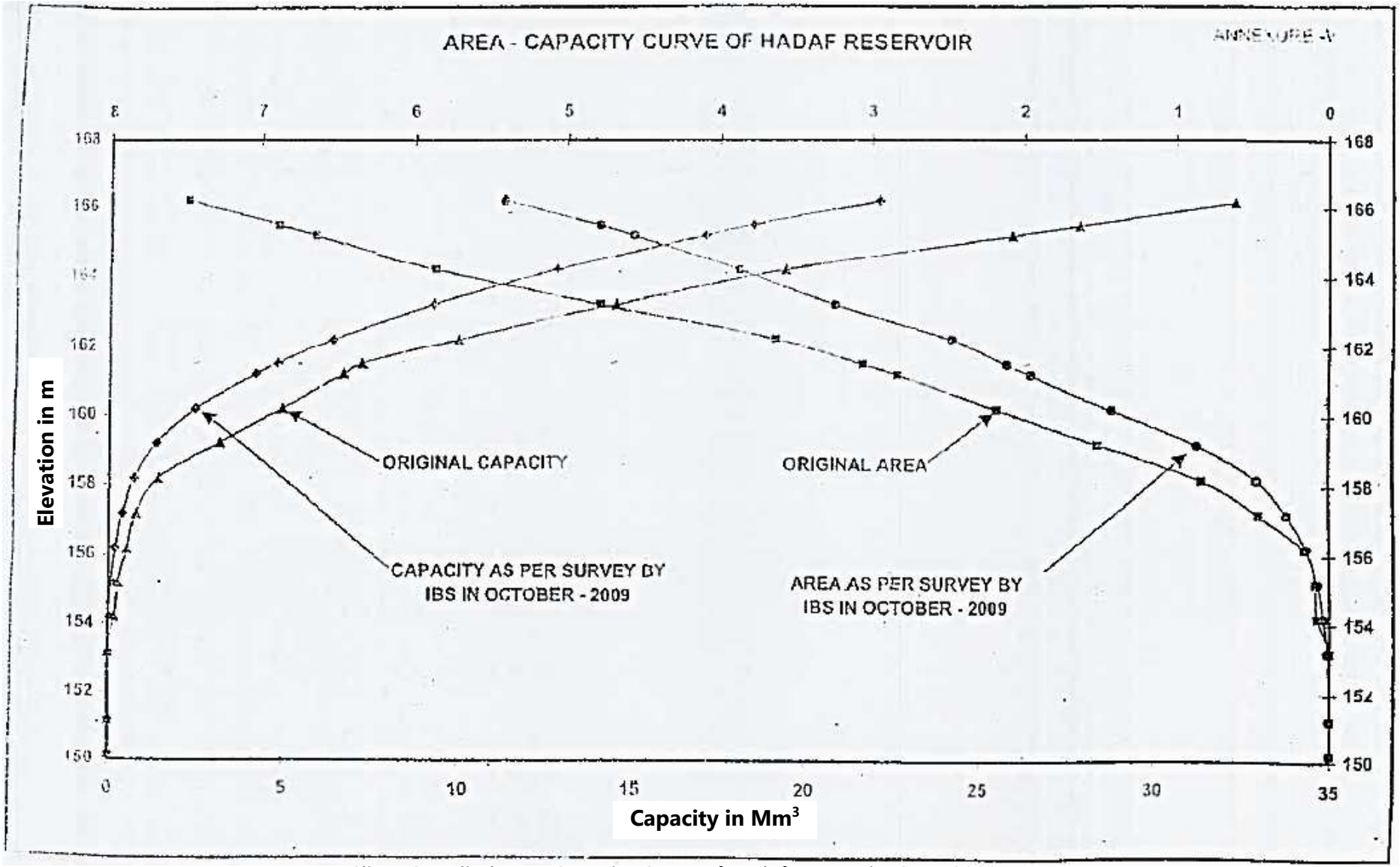
Appendix F

Client Supplied Area Capacity Curve

(2 pages)

The original and revised Area Capacity Details of Hadaf Reservoir (GERI, 2009)

Sr. No.	R.L m.	ORIGINAL		AS PER SURVEYBY IBS IN October- 2009		REMARKS
		Capacity Mcum	AREA Sq.km.	Capacity Mcum	AREA Sq.km.	
1	166.20	32.260	7.48	22.086	5.415	Satellite Image at FRL
2	165.50	27.843	6.69	18.479	4.788	W.L.during survey
3	165.20	25.898	6.65	17.058	4.562	
4	164.20	19.413	5.87	12.842	3.877	
5	163.20	14.503	4.79	9.282	3.241	
6	162.20	9.988	3.63	6.422	2.483	
7	161.50	7.240	3.06	4.816	2.111	MDDL
8	161.20	6.713	2.84	4.206	1.954	
9	160.20	4.957	2.18	2.519	1.415	
10	159.20	3.200	1.50	1.401	0.652	
11	158.20	1.444	0.82	0.758	0.462	
12	157.20	0.607	0.45	0.403	0.269	
13	156.20	0.551	0.16	0.200	0.147	
14	155.20	0.300	0.09	0.095	0.073	
15	154.20	0.200	0.08	0.040	0.039	
16	153.20	0.000	0.00	0.014	0.015	
17	151.20	0.000	0.00	0.004	0.005	
18	150.20	0.000	0.00	0.000	0.000	



Client Supplied Area Capacity Curve of Hadaf Reservoir (GERI, 2009)

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 Hadaf Reservoir	Sheet No.	Encl. No.	Drawing No.: JHYD-20-174630/ WRD/GUJARAT/BS/	Rev. No	HS	VS
1	Reservoir Bed and Topography Heights	01 of 01	01 of 03	B/01/9710	R0/Rev. 0	1:8000	-
2	Contour Map of Hadaf Reservoir	01 of 01	02 of 03	B/01/9711	R0/Rev. 0	1:8000	-
3	Shaded Relief Image Prepared from SBES Data	01 of 01	03 of 03	I/01/9712	R0/Rev. 0	1:8000	-
Details of Other Deliverables							
1	L-section	Soft copy					
2	C-section at every 100 m	Soft copy					