

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

Survey Results of Deo (Dev) Reservoir Location | Central Gujarat

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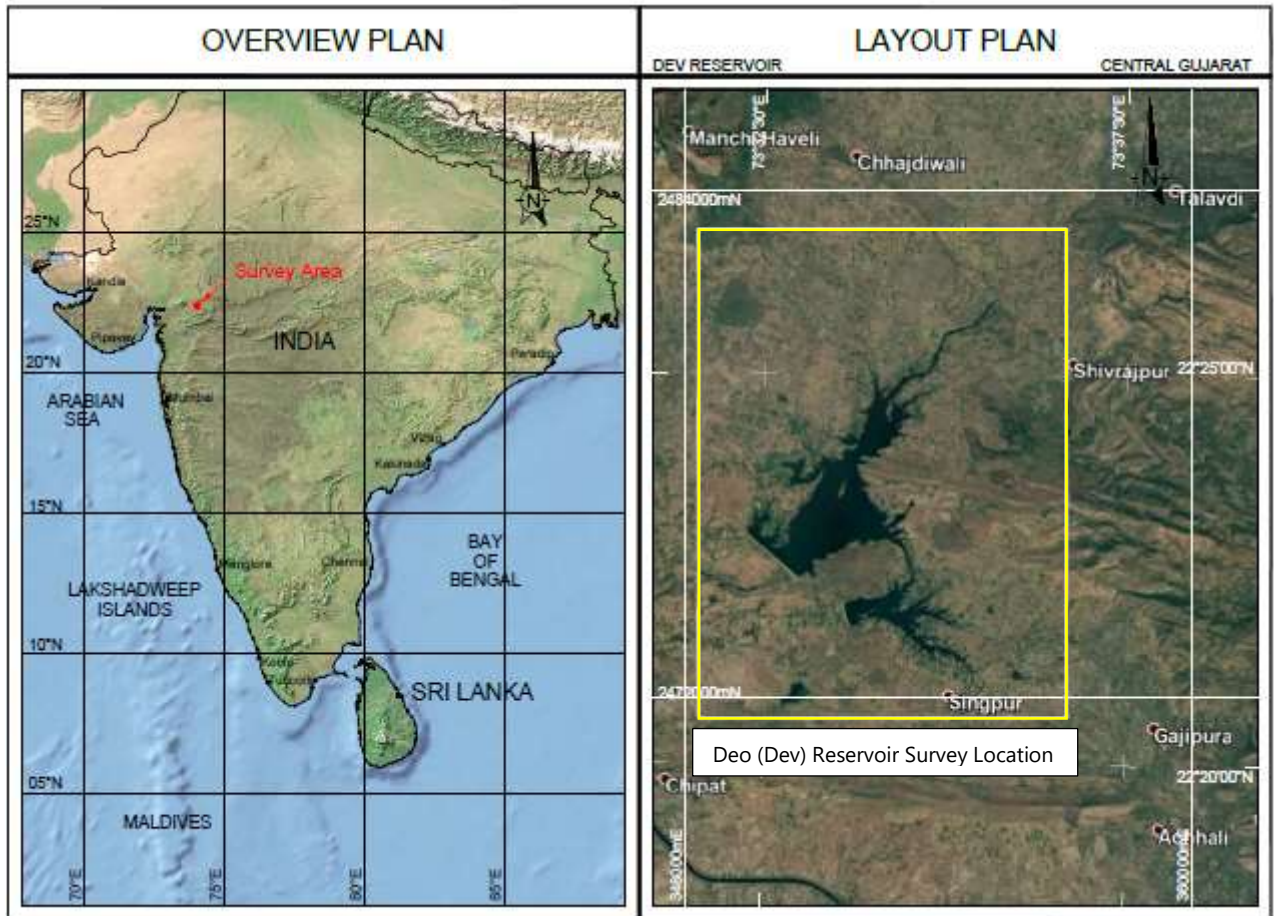
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LOCATION MAP



EXECUTIVE SUMMARY

Survey Overview– Deo (Dev) Reservoir Location

Preamble:	<p>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.</p> <p>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</p> <p>In order to complete the scope, the survey was carried out in two passes at Deo (Dev) reservoir location;</p> <ul style="list-style-type: none"> • <u>Pass 1</u>: Bathymetry / Hydrographic Survey. • <u>Pass 2</u>: Topographical Survey
Data Acquisition:	<p>FSINPVT mobilised their bathymetry and topographical survey team and equipment along with survey boat 'Fugro Zodiac' in the months of May -June 2021 and July-August 2021 respectively, in order to acquire survey data as per mutually agreed scope and relevant survey specifications.</p>
Survey Location	Deo (Dev) Reservoir, Kuberpura, Tariamba village, Halol 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:	<p>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:</p> <ul style="list-style-type: none"> ■ 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 – Deo (Dev) 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 70.3 m (350 720.mE, 2 475 064 mN) w.r.t. MSL.
Capacity Survey (2021)	Elevation Area Capacity table and curve of Deo (Dev) 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 (70.3 m) to FRL (89.65 m) was calculated using GIS software.
Revised elevation area capacity details	In comparison with 1986 data, the present survey results indicate that the gross storage capacity in the reservoir has decreased.
Loss in gross storage capacity	As per 2021 survey results, the loss in Gross storage capacity w.r.t. 1986 or volume of sediment deposited in the Deo (Dev) reservoir is 22.650 Mm ³ .
Trap efficiency & Sedimentation Index	Trap Efficiency and sedimentation Index calculated for Deo (Dev) reservoir as per methodology give in IS 12182-1987 is 96% and $6.218 \times 10^{10} \text{ s}^2/\text{m}$ respectively.
Sedimentation rate	The rate of siltation in Deo (Dev) reservoir is 0.647 Mm ³ /year.
Average rate of siltation	The observed rate of siltation in the Deo (Dev) reservoir during the 35 year life span (1986 – 2021), works out to 24.986 Ha m/100 km ² /year.
Annual % loss	The annual % loss in gross storage capacity for Deo (Dev) reservoir during the 35 year life span is 0.770% and hence, the reservoir is classified as “Serious” category as per IS 12182 (1987).



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LIST OF ABBREVIATIONS

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 ft³	Millions cubic feet
M m³	Millions cubic meter
MDDL	Minimum Draw Down Level
m/s	meter per second
ms	milliseconds
MSL	Mean Sea Level
OEM	Original Equipment Manufacturer
QA/QC	Quality Assurance / Quality Control
QMS	Quality Management System
Rel	Release
Rev	Revision
RL	Reference Level
SBES	Single beam Echosounder
Sr	Senior
SoW	Scope of Work
UTM	Universal Transverse Mercator
WGS	World Geodetic System
w.r.t	With respect to

UNITS

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

Angular values are reported in degrees (°).

Time and dates are reported as "18:00 on 16 September 2021"

1. Introduction

1.1 General

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

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

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

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

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

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

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

Pass 1: Bathymetry / Hydrographic Survey;

Pass 2: Topographical Survey.

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

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

1.2 Study Area

The present study area – Deo (Dev) reservoir falls within Mahi basin. Mahi basin is sub-divided into two sub-basins namely Mahi upper sub basin and Mahi lower sub basin. Basin drainage and sub-basin boundary is given in Figure 1.1. Mahi upper sub basin (65.11% of total basin area) consists of 41 watersheds and Mahi lower sub basin (34.89% of total basin area) consists of 22 watersheds. The basin has maximum length and width of about 330 km and 250 km, respectively. The Mahi basin covers an area of 15,474 km² (40.36%) in Gujarat accounting to 41.73% of the total basin area (India-WRIS, 2014).

A total of 17 major rivers flow through the Mahi basin of which Dhadhar River is one of the major west flowing rivers (India-WRIS, 2014). The Dhadhar River originates from the Pavagadh Hills of Gujarat state and flows through Vadodara and Bharuch districts. The river Dhadhar after flowing 87 km. receives Vishwamitri tributary from right bank at Pingalwada village 500 m. up stream of Gauge and Discharge site. After flowing another 55 km. it falls in to the Gulf of Khambhat. The total length of the river from its source to outfall in the Gulf of Khambhat is about 142 km. The important tributaries of the Dhadhar River are Vishwamitri, Jambua river, Deo and Surya River (Directorate of Census Operations, 2011b).

The Deo (Dev) River, a tributary of the river Dhadhar, originates near the village Jhinhari of Devgadhi Baria taluka of Dahod district. It enters this district near Goraj village of Vaghodia taluka. It passes near Vaswel, Tavra, Vyara and Antoli villages of Vaghodia taluka. Thereafter it enters the Dabhoi taluka and traverses near Vanadra, Karalipura, Dholar and Pragpura. Out of its total length of 38 km; it flows only for 14 km in the Vadodara district. The Deo (Dev) River meets the river Dhadhar near village Abdalpura of Dabhoi taluka of the district (Directorate of Census Operations, 2011b).

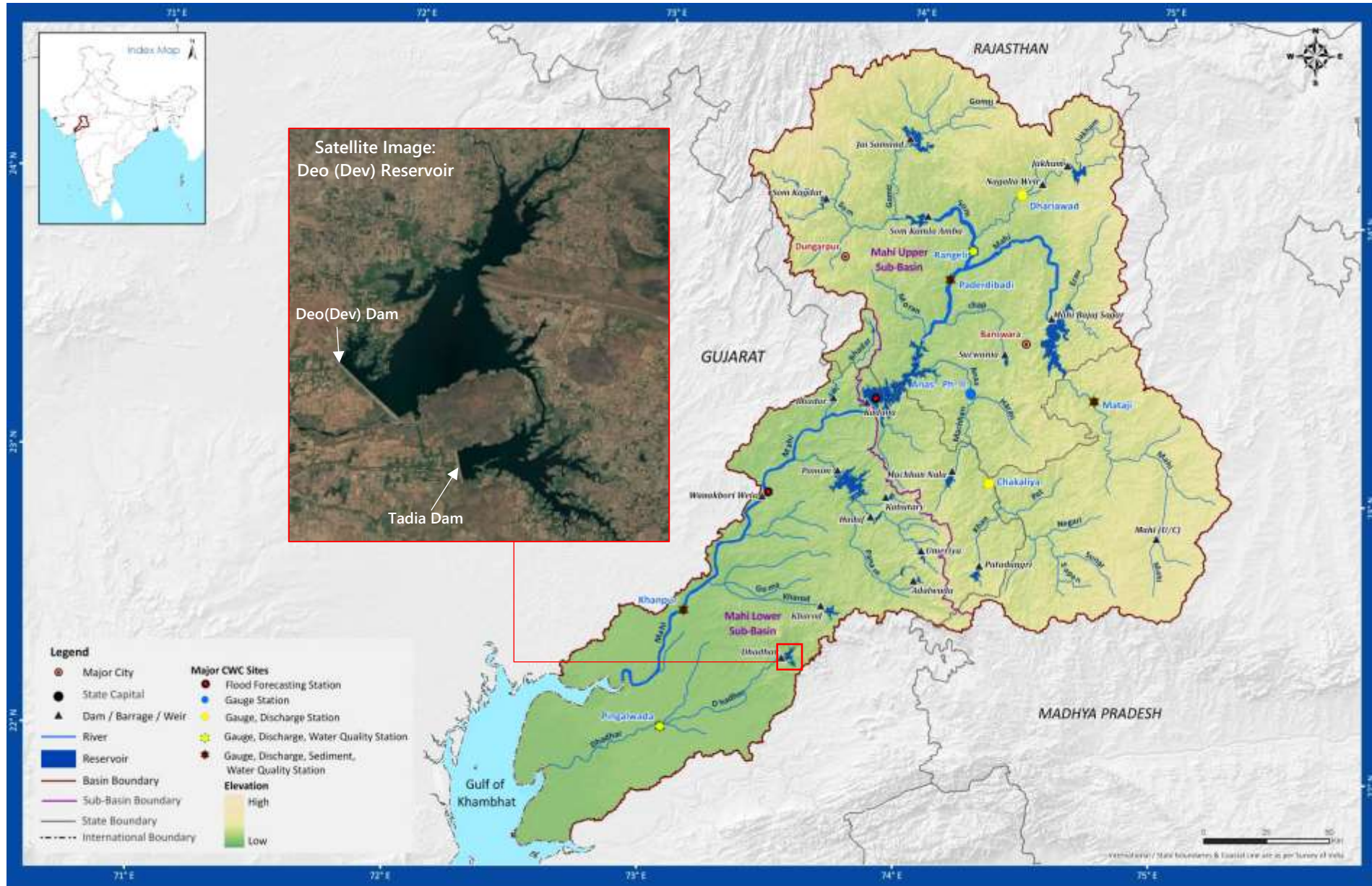


Figure 1.1: Mahi basin showing major tributaries – Drainage and sub- basins (India-WRIS, 2014) and Satellite Image of Deo (Dev) Reservoir (Google Earth).

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 comprises of various meta-sediments belongs to Lower Proterozoic. The post-Delhi intrusive, Godhra granite and gneisses were intruded into older Aravalli. Both Aravallis and granite-gneiss have undergone many orogenic movement. They are overlain at places by Lower cretaceous fluvial and marine sequences, namely Bagh beds and Lametas. Lower Cretaceous rocks are overlain by Deccan basalts, extrusive rock formation; 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 present study area is located in the Halol taluka of the Panchmahal district which exhibits a varied geology and comprises of alluvium, sandstone, sandy phyllite-mica schist, granite and basalt with intertrappean (Nayak, 2014).

1.4 Soil Types

The soil of the Panchmahal district can be divided broadly into three categories depending upon the source rock, viz. 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 produce light soil with splinters of *morum* where as 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).

The Halol taluka of the Panchmahal district is mainly covered by either deep black or shallow black type of soil. The northern part of the taluka is having a soil of interfluves, (i.e. The region of higher land between two rivers that are in the same drainage system) whereas the southern part has regions with hill slope or slight to moderate erosion. The eastern part of the area exhibits excessively drained loamy soil (Tyagi, 2008)

1.5 Land use patten

The total geographical area of the Panchmahal district (as per state territory) is 5210 km² (Directorate of Census Operations, 2011a), which comprises 685.76 km² of forest area, 375 km² area under non-agricultural uses , 255 km² of barren and unculturable land, 152 km² of permanent pasture & grazing land, 110 km² of culturable waste land, 12 km² of fallow land, 257 km² of current fallow land and net area sown of 2807 km² (Monitoring Branch, PCCF & Head Forest Force, Gujarat State, 2017).

1.6 Deo (Dev) Reservoir Characteristics

The Deo (Dev) medium irrigation project is constructed on the Deo river and its tributary, near Kuberpura of Halol taluka in Panchmahal district, Gujarat State. The scheme envisages construction of two Earth dams across Deo river and its tributary Tariamba and an ogee shaped gated masonry spillway with eight radial gates located in the saddle on the left side of Deo river. Both the reservoir linked together with an open cut channel (Govt. of Gujarat , Deo Irrigation Scheme, 1984).

Salient features of the Deo (Dev) reservoir are tabulated below:

Table 1.1: Client Supplied Deo (Dev) Reservoir Salient Features

Characteristics	Feature
Reservoir name	Deo Reservoir
Name of Dam	Deo (Dev) Dam
Deo (Dev) Dam Location	
Latitude	22° 22' 22" N
Longitude	73° 33' 0" E
Purpose	Irrigation
Name of River	Deo and its tributary Tariamba
River Basin	Mahi Lower Sub-Basin
Village	Kuberpura, Tariamba
Taluka	Halol
District	Panchmahal
State	Gujarat
Hydrology	
Total Catchment Area	259 km ²
Peak Designed Flood	5438 cumecs
Routed Flood	4118 cumecs
Mean annual rainfall	1072 mm
Annual Yield	84.00 Mm ³ at 73% reliability
Reservoir Details	
F.R.L.	89.65 m
H.F.L.	90.15 m
LWL / MDDL R.L.	80.0 m
Gross storage capacity	84.09 Mm ³
Live storage capacity	76.33 Mm ³
Dead storage capacity	7.76 Mm ³
D/s Tail Water Level	76.80 m
Area at Full Reservoir Level	16.68 km ²
Commencement of work (Masonry dam)	1979

Characteristics	Feature
Year of impounding	1986
Masonry Dam (Non-overflow section)	
Total length of non-over flow section (except key)	15.486 m
R.L. of non-over flow section	93.33 m
Maximum height of dam from deepest foundation	17.33 m
Width at top	5.638 m
Width at base	14.569 m
Overflow Section (Spillway)	
Total length of overflow section	99.976 m
Maximum height above deepest foundation	12.00 m
Width at base including bucket	30.583 m
Crest elevation	81.40 m
Bridge width (clear)	4.888 m
Number and size of radial gates	8 Nos. (12.496 x 8.23 m)
No. of piers	7 intermediate and 2 end piers
Pier width	2.743 m
Top of D/s retaining wall	88.50 m
Bucket invert elevation	70.40 m
D/s end sill elevation	73.27 m
Trunnion Level	83.997 m
Earth Dam	
Top width of dam	6 m
Top elevation	93.65 m
Maximum height above deepest G.L.	26.35 m
Length of the left flank earth dam (Tadia dam)	650 m
Length of the Right flank earth dam (Deo dam)	1770 m
Slope U/s 2.5:1 Slope U/s <u>2.17:1</u> 2.5: 1	Upto R.L. 88.30 m
Length of dam on Deo river	1.77 km
Length of dam on Tadiamba Kotar	0.65 km
Key	
Length of right key	5.0 m
Length of left key	5.0 m
Top of key	93.33 m
Head Regulator	

Characteristics	Feature
U/s sill R.L.	(Right) 80.00 m, (Left) 80.00 m
D/s sill R.L.	(Right) 79.82 m, (Left) 79.872 m
Conduit size	1.5 m x 1.8 m (Right) 1.2 m x 1.5 m (Left)
Capacity of canal at head	Right: 4.50 cumecs, Left: 1.70 cumecs
Irrigation	
Gross command area	11017 Ha,
Total Culturable command area	7207 Ha.

1.7 Project Objectives

Primarily the main objective of the survey was to:

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

Table 1.2 provides bathymetry and topography survey area details for Deo (Dev) reservoir.

Table 1.2: Deo (Dev) Reservoir details for Bathymetry and Topography Survey

Name of Dam / Reservoir	Actual Area (km ²) surveyed	
	Bathymetry Survey	Topography Survey
Deo (Dev)	5.41	6.84

1.8 Scope of Work

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

1.8.1 Pass 1: Bathymetry / Hydrographic Survey

The scope of work for bathymetry survey conforms bathymetry survey for total area of approximately 5.41 km².

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 Deo (Dev) 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.
- DGNS positioning system, Dual frequency singlebeam echosounder system along with associated Navigational system were deployed on all the survey lines.

1.8.2 Pass 2: Topographical Survey

Topographical survey was carried out using Total station and equivalent levelling instruments. The total area covered in Topographical survey is 6.84 km². Following scope of work was undertaken in order to achieve client objectives:

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

1.9 Survey Execution

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

1.10 Reference Documents

Table 1.3: Reference Documentation

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

1.11 Deliverables

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

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
<u>Notes:</u> <ul style="list-style-type: none"> 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 Deo (Dev) Reservoir

Date	Observed Reservoir Water Level Heights w.r.t. MSL at Deo (Dev) Reservoir [m]
07-05-2021	86.20
08-05-2021	86.20
09-05-2021	86.15
10-05-2021	86.11
11-05-2021	86.09
12-05-2021	86.08
13-05-2021	86.07
14-05-2021	86.05
15-05-2021	86.04
16-05-2021	86.01
20-05-2021	86.08
21-05-2021	86.06
22-05-2021	86.00
23-05-2021	85.99
24-05-2021	85.98
25-05-2021	85.92
26-05-2021	85.87
27-05-2021	85.80
28-05-2021	85.78
29-05-2021	85.71
30-05-2021	85.66
31-05-2021	85.65
01-06-2021	85.60
02-06-2021	85.59
03-06-2021	85.59
05-06-2021	85.60

2.4 Accuracy and Precision of Results

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

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

2.5 Survey Personnel Deployed

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

Table 2.3: List of Survey Personnel – Bathymetry Survey 'Fugro Zodiac'

Bathymetry Survey Personnel	
Personnel Name	Function
Pritam Seth	Party Chief / Surveyor
Atul Bhoyte	Engineer
MD Salman Khan	Fugro Zodiac Operator

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

Table 2.4: List of Survey Personnel – Topography Survey

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

Following onshore FSINPVT staffs were associated to this project.

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

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

2.6 Equipment Deployed

Following equipment and systems were deployed for the survey work. The equipment setup and configuration diagram on the survey boat Fugro Zodiac is placed at [Appendix C](#) to this document.

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

Equipment / System	Description / Make / Model/Resolution /Accuracies
Software / Navigation	Starfix.NG PC based data acquisition and survey vessel navigation package.
Positioning	Trimble BX-992 & Spatial Dual Receivers
Heading Sensor	Spatial Dual
Motion Sensor	Spatial Dual
Sound Velocity	Odom DigiBar Pro
Single beam Echosounder	Echotrac CV100 Dual Frequency_Single Beam Echosounder

Table 2.7: Survey Equipment / Systems Deployed for Topographical Survey

Equipment / System	Description / Make / Model/Resolution /Accuracies
Land Survey	GNSS RTK CHC I 80 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 – 89.65 m w.r.t. MSL
- Full Reservoir Level (FRL) – 89.65 m w.r.t. MSL
- Approximate Water line during survey– 85.92 m

3. Survey Data Acquisition

3.1 Survey planning, Preparation & Transportation to Site

The bathymetry survey equipment and personnel with survey boat 'Fugro Zodiac' arrived at Deo (Dev) reservoir location on 4 May 2021 and equipment was mobilised on-board the survey boat on 5th - 6th May 2021.

After field testing / verification / calibration of all survey equipment bathymetry survey was carried out and completed on 06 June 2021. Refer [Appendix A](#) to this document for diary of events.

The topography survey equipment and personnel arrived at Deo (Dev) reservoir location and commenced survey on 28 July 2021. The topography survey was completed on 7 August 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 Deo (Dev) 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	350616.13	2474,907.72	22°22'25.20221"N	073°32'56.59068"E	36.439
Spatial Dual	025-00006405	350616.105	2474907.765	22°22'25.20354"N	073°32'56.58964"E	36.664
Difference		0.029	-0.042	--	--	-0.225

3.3.3 Sound Velocity Measurements

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

3.3.4 Heave Compensator

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

3.3.5 Single Beam Echosounder

Echotrac CV100 dual frequency single beam echosounder was used for measuring water depths within the survey corridor. The echo sounder system was bench tested at FSINPVT workshop prior to mobilization for the survey. The echo sounder transducer was vertically side mounted on the survey boat and its draft below the waterline was measured and recorded. Heave compensator was connected to the echo sounder receiver. The echo sounder system was interfaced with the Starfix NG navigation and survey system for logging the depth vs position data. Sound velocity within water column was measured on a regular basis using sound velocity profiler and average sound velocity was entered in the top side unit of the echo sounder.

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

Date	SBES SensorType	Average (m)	Standard Deviation
Summary of SBES Calibration Results on-board 'Fugro Zodiac'			
6 May 2021	Echotrac CV100 SBES	0.01	0.0053

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 Deo (Dev) Dam Temporary Benchmark (TBM1) and Temporary Benchmark location (TBM2).

3.5.2 RTK Position Comparison

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

Table 3.3: Results of RTK Position Comparison

Sensor	Model No.	Easting (mE)	Northing (mN)
TBM2 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	350616.134	2474907.723
RTK Rover 1	CHC I 80	350616.138	2474907.718
Difference		-0.004	0.005
TBM2 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	350616.134	2474907.723
RTK Rover 2	CHC I 80	350616.145	2474907.719
Difference		-0.011	0.004
TBM2 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	350616.134	2474907.723
RTK Rover 3	CHC I 80	350616.135	2474907.720
Difference		-0.001	0.003

Refer [Appendix D](#) for RTK comparison details.

3.5.3 Topographical Survey Methodology

The area not covered under hydrographic survey i.e., between the existing water level at the time of survey up to Full Reservoir Level (FRL)- 89.65 m has been carried out by topography survey method.

The topography survey was carried out using GNSS RTK CHC I 80 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 (TBM1) 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 TBM2 location. Static observation was carried out subsequently as part of verification.
- The Base receiver is installed at TBM1 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 TBM2.
- The level or height transfer for temporary Bench Mark 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: Temporary Benchmark 1 (TBM1)



Figure 3.2: Temporary Benchmark (TBM2)

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)- 89.65 m, was achieved by undertaking topography survey.

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

4. Data Processing and Interpretation

4.1 Navigation and Positioning

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

4.2 Bathymetry Data Processing

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

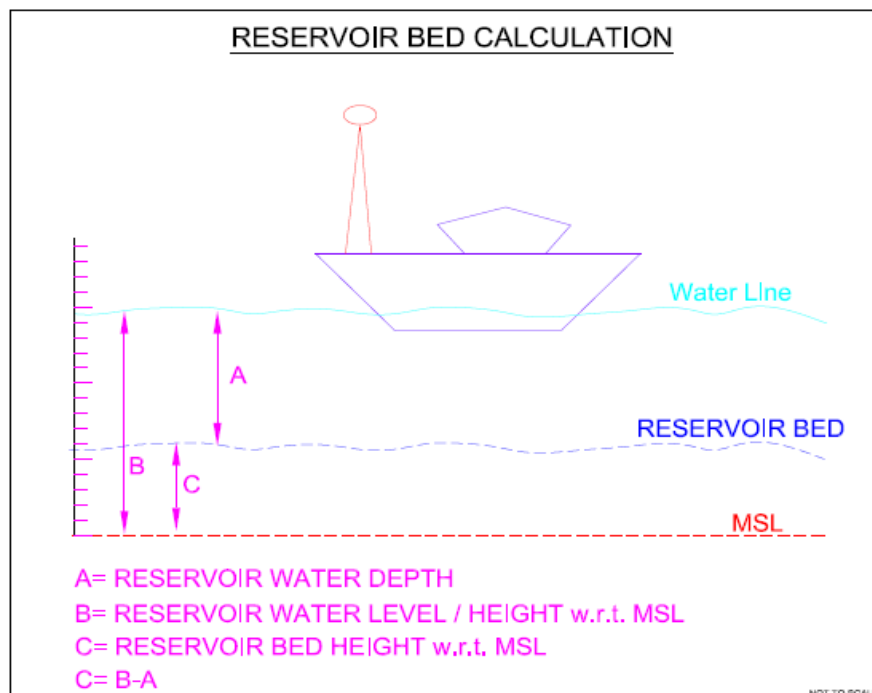


Figure 4.1: Reservoir Bed Height Calculation w.r.t. MSL

4.3 Creating Digital Terrain Model (DTM)

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

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

Where:

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

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

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

4.4 Development of Area Capacity Curves

Area Capacity curves are useful tools for operational and planning purposes such as water management and sediment monitoring. By comparing the area capacity curves at different times, the rate of sedimentation in the reservoirs can be determined. These curves show the capacity and surface area of the reservoir at an indicated elevation above the reference elevation level. The elevation area capacity curves are prepared using the DTM for the reservoir site. For, this study the reference elevation level used for the preparation of Area capacity curve is 70.3 m which is the lowest bed level for the reservoir and the maximum level considered is 89.65 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.

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

Where, ΔV is the incremental volume between two successive elevations; h is the incremental height between two successive elevations; A_1 and A_2 are the areas of two successive elevations.

4.5 Sedimentation in Different Zones of Reservoir

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

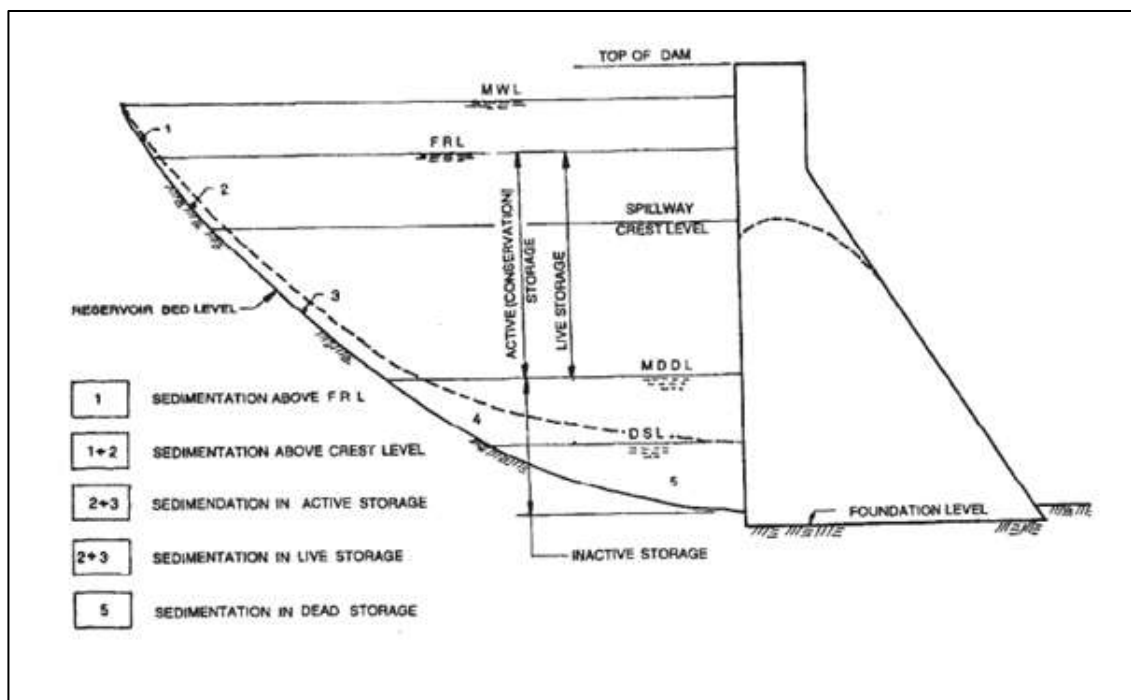


Figure 4.2: Sedimentation in different zones of reservoir (Ref: IS 5477-Part 1,1999)

The trap efficiency and the silt index has been calculated based on the methodology given in IS 12182, 1987. The gross capacity of reservoir as per present survey at FSL is 61.440 Mm³ and client supplied Mean Annual inflow is 84 Mm³. 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 Deo (Dev) 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)

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

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

4.6 Charting the Results of Bathymetry and Topography Data

- Chart showing reservoir bed heights are provided for the current survey at 1:10000 scale.
- Chart showing contour map at 1 m interval for Deo (Dev) reservoir is also provided at 1:10000 scale.
- Chart showing reservoir bed relief image prepared from bathymetry and topography survey data is provided at 1:10000 scale.
- L-section of the reservoir and C-section at 100 m interval are provided as soft copy.

The results of the survey were submitted as per the documents in the 'List of Deliverables' placed at [Appendix F](#).

5. Survey Results – Deo (Dev) Reservoir

Survey results are detailed in the following sections. The following text should be read in conjunction with the Charts as listed in [Appendix F](#) to this document.

Data acquisition for Deo (Dev) reservoir was carried out up to Full Reservoir Level (FRL) of 89.65 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 70.3 m to 89.65 m w.r.t. MSL.

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

Lowest reservoir bed level recorded was 70.3 m (350 720.mE, 2 475 064 mN) w.r.t. MSL, within the survey area.

The following figures show the gridded bathymetry and topography data for the Deo (Dev) reservoir.

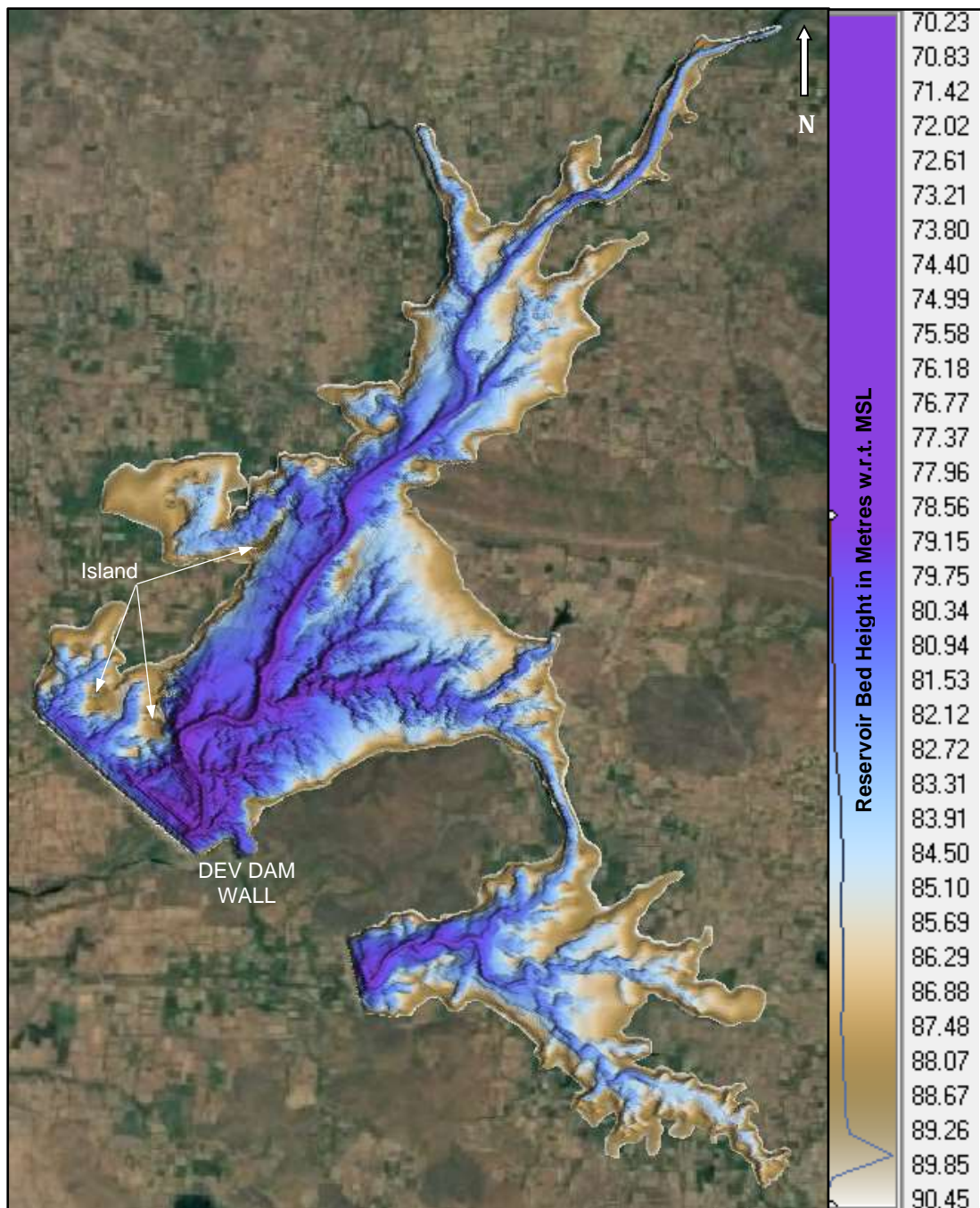


Figure 5.1: Image showing gridded SBES Bathymetry and topography data (superimposed with satellite imagery) of reservoir bed heights in metres from lowest bed level to FRL

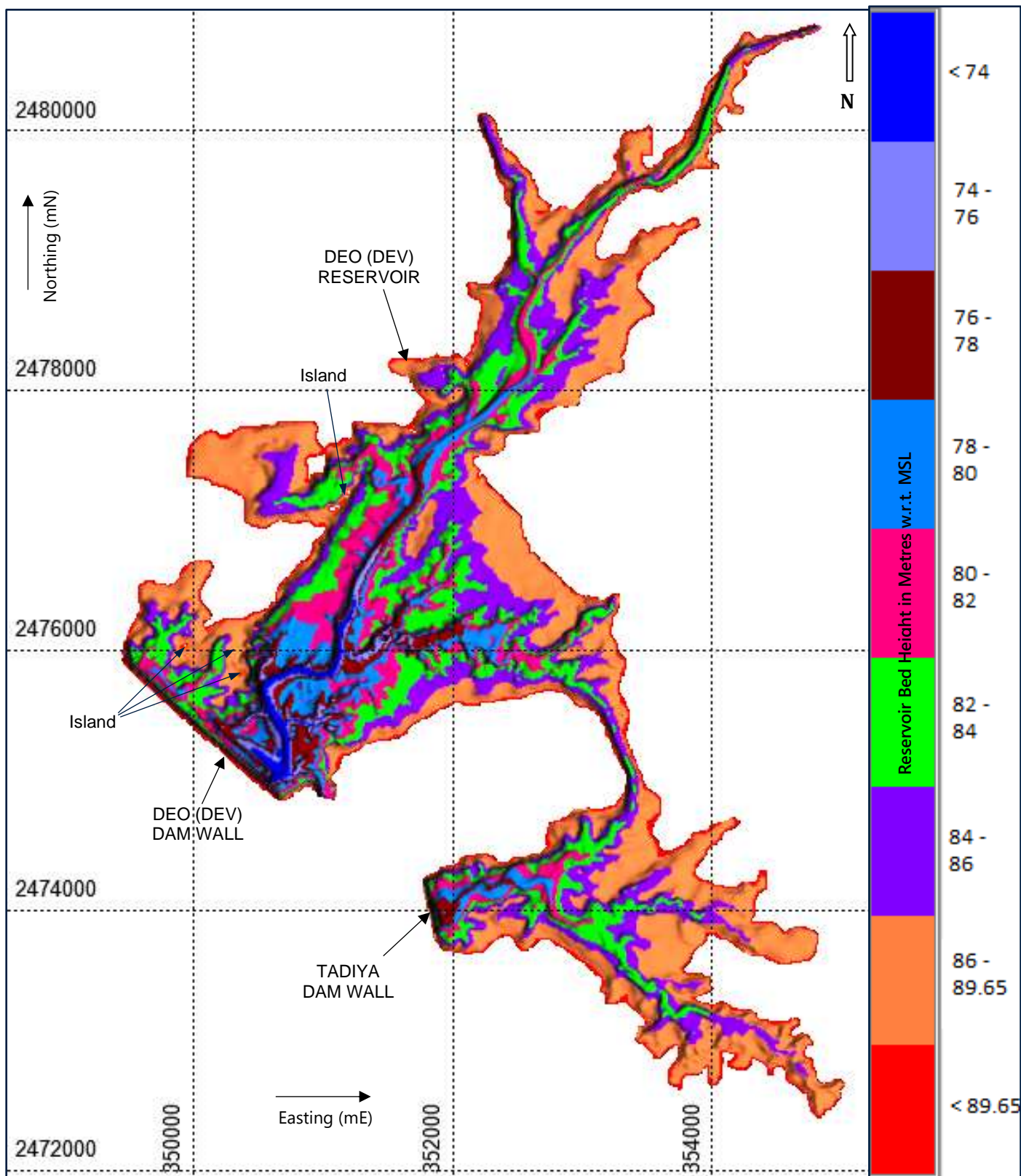


Figure 5.2: Shaded Relief image showing gridded SBES Bathymetry and topography data of reservoir bed heights in metres from lowest bed level to FRL.

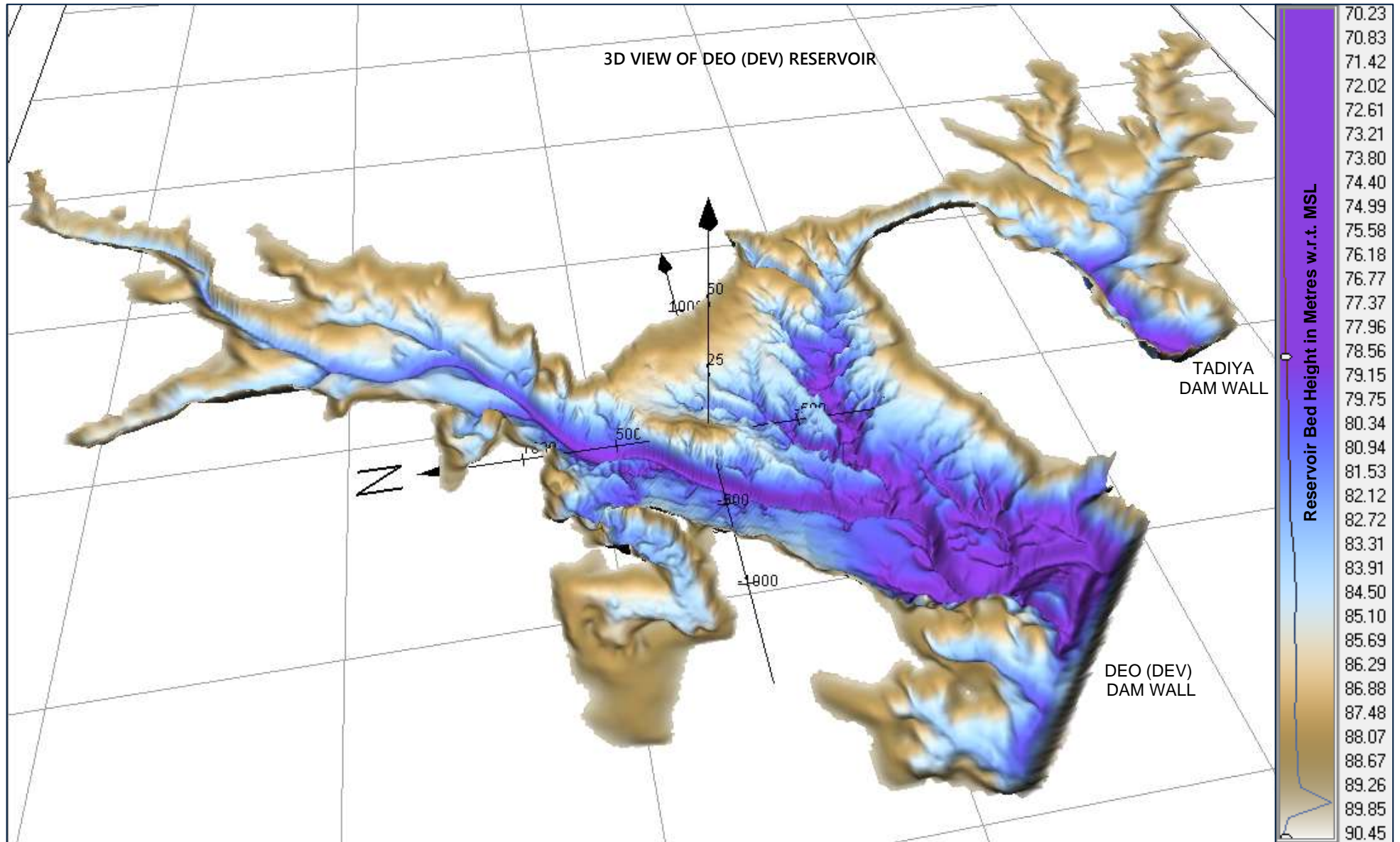


Figure 5.3: 3D view of Deo (Dev) Reservoir

Photograph A



Photograph A: Northern part of Dev (Deo) Reservoir (353164 mE, 2479559 mN) with shallow water depth.

Photograph B



Photograph B: Easternmost approachable part of Dev (Deo) Reservoir near the Deo- Tadiya interconnecting canal (353040 mE, 2476136 mN) with shallow water depth.

Photograph C



Photograph C: South-eastern part of Dev (Deo) Reservoir [Tadiya Lake] (354004 mE, 2474016 mN) with shallow water depth and submerged construction work.

Photograph D



Photograph D: Rock outcrop in the south-west part of the Dev (Deo) reservoir near the dam wall (350152 mE, 2475971 mN)

Figure 5.4: Photographs A, B, C and D showing the northern, eastern, south-eastern and south-western areas within Deo (Dev) Reservoir respectively

5.2 Elevation Area Capacity Curve (2021)

The area and capacity of the Deo (Dev) reservoir was tabulated against the respective increasing elevation starting from lowest bed elevation (i.e., 70.3 m) up to 93.40 m at an increment of 0.1 m as shown in Table 5.1. Area capacity curve for Deo (Dev) reservoir is shown in [Figure 5.5](#).

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

Elevation Area Capacity Table (2021): Deo (Dev) Dam				
Sr. No.	Elevation [m]	Area [km ²]	Capacity [Mm ³]	Remarks
1	70.30	0.0000	0.00000	Bed level
2	70.40	0.0002	0.00001	-
3	70.50	0.0008	0.00007	-
4	70.60	0.0020	0.0002	-
5	70.70	0.0033	0.0005	-
6	70.80	0.0043	0.0008	-
7	70.90	0.006	0.001	-
8	71.00	0.007	0.002	-
9	71.10	0.009	0.003	-
10	71.20	0.011	0.004	-
11	71.30	0.014	0.005	-
12	71.40	0.018	0.006	-
13	71.50	0.021	0.008	-
14	71.60	0.025	0.011	-
15	71.70	0.028	0.013	-
16	71.80	0.032	0.016	-
17	71.90	0.036	0.020	-
18	72.00	0.039	0.023	-
19	72.10	0.043	0.027	-
20	72.20	0.046	0.032	-
21	72.30	0.050	0.037	-
22	72.40	0.053	0.042	-
23	72.50	0.057	0.047	-
24	72.60	0.062	0.053	-
25	72.70	0.067	0.060	-
26	72.80	0.071	0.067	-
27	72.90	0.075	0.074	-
28	73.00	0.080	0.082	-
29	73.10	0.085	0.090	-
30	73.20	0.089	0.099	-
31	73.30	0.094	0.108	-
32	73.40	0.100	0.117	-
33	73.50	0.105	0.128	-

Elevation Area Capacity Table (2021): Deo (Dev) Dam				
Sr. No.	Elevation [m]	Area [km ²]	Capacity [Mm ³]	Remarks
34	73.60	0.111	0.138	-
35	73.70	0.117	0.150	-
36	73.80	0.124	0.162	-
37	73.90	0.131	0.175	-
38	74.00	0.137	0.188	-
39	74.10	0.143	0.202	-
40	74.20	0.150	0.217	-
41	74.30	0.157	0.232	-
42	74.40	0.164	0.248	-
43	74.50	0.172	0.265	-
44	74.60	0.179	0.283	-
45	74.70	0.187	0.301	-
46	74.80	0.194	0.320	-
47	74.90	0.201	0.340	-
48	75.00	0.209	0.360	-
49	75.10	0.218	0.382	-
50	75.20	0.226	0.404	-
51	75.30	0.235	0.427	-
52	75.40	0.245	0.451	-
53	75.50	0.254	0.476	-
54	75.60	0.264	0.502	-
55	75.70	0.274	0.529	-
56	75.80	0.285	0.557	-
57	75.90	0.297	0.586	-
58	76.00	0.309	0.616	-
59	76.10	0.323	0.648	-
60	76.20	0.338	0.681	-
61	76.30	0.353	0.715	-
62	76.40	0.369	0.751	-
63	76.50	0.386	0.789	-
64	76.60	0.405	0.829	-
65	76.70	0.425	0.870	-
66	76.80	0.446	0.914	-



Elevation Area Capacity Table (2021): Deo (Dev) Dam				
Sr. No.	Elevation [m]	Area [km ²]	Capacity [Mm ³]	Remarks
67	76.90	0.470	0.960	-
68	77.00	0.493	1.008	-
69	77.10	0.516	1.058	-
70	77.20	0.542	1.111	-
71	77.30	0.566	1.166	-
72	77.40	0.590	1.224	-
73	77.50	0.616	1.285	-
74	77.60	0.644	1.348	-
75	77.70	0.672	1.413	-
76	77.80	0.698	1.482	-
77	77.90	0.726	1.553	-
78	78.00	0.753	1.627	-
79	78.10	0.779	1.704	-
80	78.20	0.807	1.783	-
81	78.30	0.834	1.865	-
82	78.40	0.861	1.950	-
83	78.50	0.889	2.037	-
84	78.60	0.920	2.128	-
85	78.70	0.952	2.221	-
86	78.80	0.985	2.318	-
87	78.90	1.018	2.418	-
88	79.00	1.054	2.522	-
89	79.10	1.093	2.629	-
90	79.20	1.134	2.740	-
91	79.30	1.177	2.856	-
92	79.40	1.221	2.976	-
93	79.50	1.267	3.100	-
94	79.60	1.316	3.229	-
95	79.70	1.369	3.364	-
96	79.80	1.425	3.503	-
97	79.90	1.480	3.648	-
98	80.00	1.533	3.799	MDDL
99	80.10	1.586	3.955	-
100	80.20	1.638	4.116	-
101	80.30	1.691	4.283	-
102	80.40	1.746	4.455	-
103	80.50	1.798	4.632	-
104	80.60	1.851	4.814	-
105	80.70	1.903	5.002	-
106	80.80	1.957	5.195	-
107	80.90	2.013	5.393	-

Elevation Area Capacity Table (2021): Deo (Dev) Dam				
Sr. No.	Elevation [m]	Area [km ²]	Capacity [Mm ³]	Remarks
108	81.00	2.071	5.598	-
109	81.10	2.130	5.808	-
110	81.20	2.190	6.024	-
111	81.30	2.254	6.246	-
112	81.40	2.320	6.475	-
113	81.50	2.391	6.710	-
114	81.60	2.464	6.953	-
115	81.70	2.537	7.203	-
116	81.80	2.609	7.460	-
117	81.90	2.679	7.725	-
118	82.00	2.749	7.996	-
119	82.10	2.823	8.275	-
120	82.20	2.899	8.561	-
121	82.30	2.974	8.854	-
122	82.40	3.052	9.156	-
123	82.50	3.134	9.465	-
124	82.60	3.220	9.782	-
125	82.70	3.305	10.109	-
126	82.80	3.389	10.443	-
127	82.90	3.475	10.787	-
128	83.00	3.566	11.139	-
129	83.10	3.665	11.500	-
130	83.20	3.764	11.872	-
131	83.30	3.867	12.253	-
132	83.40	3.973	12.645	-
133	83.50	4.082	13.048	-
134	83.60	4.191	13.461	-
135	83.70	4.308	13.886	-
136	83.80	4.429	14.323	-
137	83.90	4.557	14.773	-
138	84.00	4.691	15.235	-
139	84.10	4.825	15.711	-
140	84.20	4.955	16.200	-
141	84.30	5.088	16.702	-
142	84.40	5.227	17.218	-
143	84.50	5.369	17.747	-
144	84.60	5.512	18.291	-
145	84.70	5.654	18.850	-
146	84.80	5.796	19.422	-
147	84.90	5.932	20.008	-
148	85.00	6.060	20.608	-



Elevation Area Capacity Table (2021): Deo (Dev) Dam				
Sr. No.	Elevation [m]	Area [km ²]	Capacity [Mm ³]	Remarks
149	85.10	6.179	21.220	-
150	85.20	6.287	21.843	-
151	85.30	6.384	22.477	-
152	85.40	6.479	23.120	-
153	85.50	6.580	23.773	-
154	85.60	6.697	24.437	-
155	85.70	6.813	25.112	-
156	85.80	6.932	25.799	-
157	85.90	7.059	26.499	-
158	86.00	7.177	27.211	-
159	86.10	7.288	27.934	-
160	86.20	7.400	28.668	-
161	86.30	7.510	29.414	-
162	86.40	7.625	30.171	-
163	86.50	7.736	30.939	-
164	86.60	7.855	31.718	-
165	86.70	7.977	32.510	-
166	86.80	8.102	33.314	-
167	86.90	8.229	34.130	-
168	87.00	8.357	34.960	-
169	87.10	8.486	35.802	-
170	87.20	8.612	36.657	-
171	87.30	8.734	37.524	-
172	87.40	8.856	38.403	-
173	87.50	8.981	39.295	-
174	87.60	9.109	40.200	-
175	87.70	9.232	41.117	-
176	87.80	9.353	42.046	-
177	87.90	9.470	42.987	-
178	88.00	9.584	43.940	-
179	88.10	9.705	44.904	-
180	88.20	9.839	45.881	-
181	88.30	9.970	46.872	-
182	88.40	10.095	47.875	-
183	88.50	10.209	48.890	-
184	88.60	10.329	49.917	-
185	88.70	10.445	50.956	-
186	88.80	10.559	52.006	-
187	88.90	10.676	53.068	-
188	89.00	10.796	54.141	-
189	89.10	10.917	55.227	-

Elevation Area Capacity Table (2021): Deo (Dev) Dam				
Sr. No.	Elevation [m]	Area [km ²]	Capacity [Mm ³]	Remarks
190	89.20	11.044	56.325	-
191	89.30	11.178	57.436	-
192	89.40	11.319	58.561	-
193	89.50	11.477	59.701	-
194	89.60	11.655	60.857	-
195	89.65	11.760	61.440	FRL
196	89.70	11.873	62.034	-
197	89.80	12.081	63.232	-
198	89.90	12.171	64.444	-
199	90.00	12.194	65.662	-
200	90.10	12.203	66.882	-
201	90.20	12.208	68.103	-
202	90.30	12.212	69.324	-
203	90.40	12.216	70.545	-
204	90.50	12.218	71.767	-
205	90.60	12.220	72.989	-
206	90.70	12.221	74.211	-
207	90.80	12.223	75.433	-
208	90.90	12.224	76.655	-
209	91.00	12.225	77.878	-
210	91.10	12.227	79.100	-
211	91.20	12.229	80.323	-
212	91.30	12.230	81.546	-
213	91.40	12.231	82.769	-
214	91.50	12.232	83.992	-
215	91.60	12.233	85.215	-
216	91.70	12.234	86.439	-
217	91.80	12.235	87.662	-
218	91.90	12.236	88.886	-
219	92.00	12.236	90.109	-
220	92.10	12.237	91.333	-
221	92.20	12.238	92.557	-
222	92.30	12.239	93.781	-
223	92.40	12.239	95.004	-
224	92.50	12.240	96.228	-
225	92.60	12.241	97.453	-
226	92.70	12.241	98.677	-
227	92.80	12.242	99.901	-
228	92.90	12.242	101.125	-
229	93.00	12.243	102.349	-
230	93.10	12.243	103.574	-

Elevation Area Capacity Table (2021): Deo (Dev) Dam				
Sr. No.	Elevation [m]	Area [km ²]	Capacity [Mm ³]	Remarks
231	93.20	12.243	104.798	-
232	93.30	12.243	106.022	-
233	93.40	12.243	107.246	-

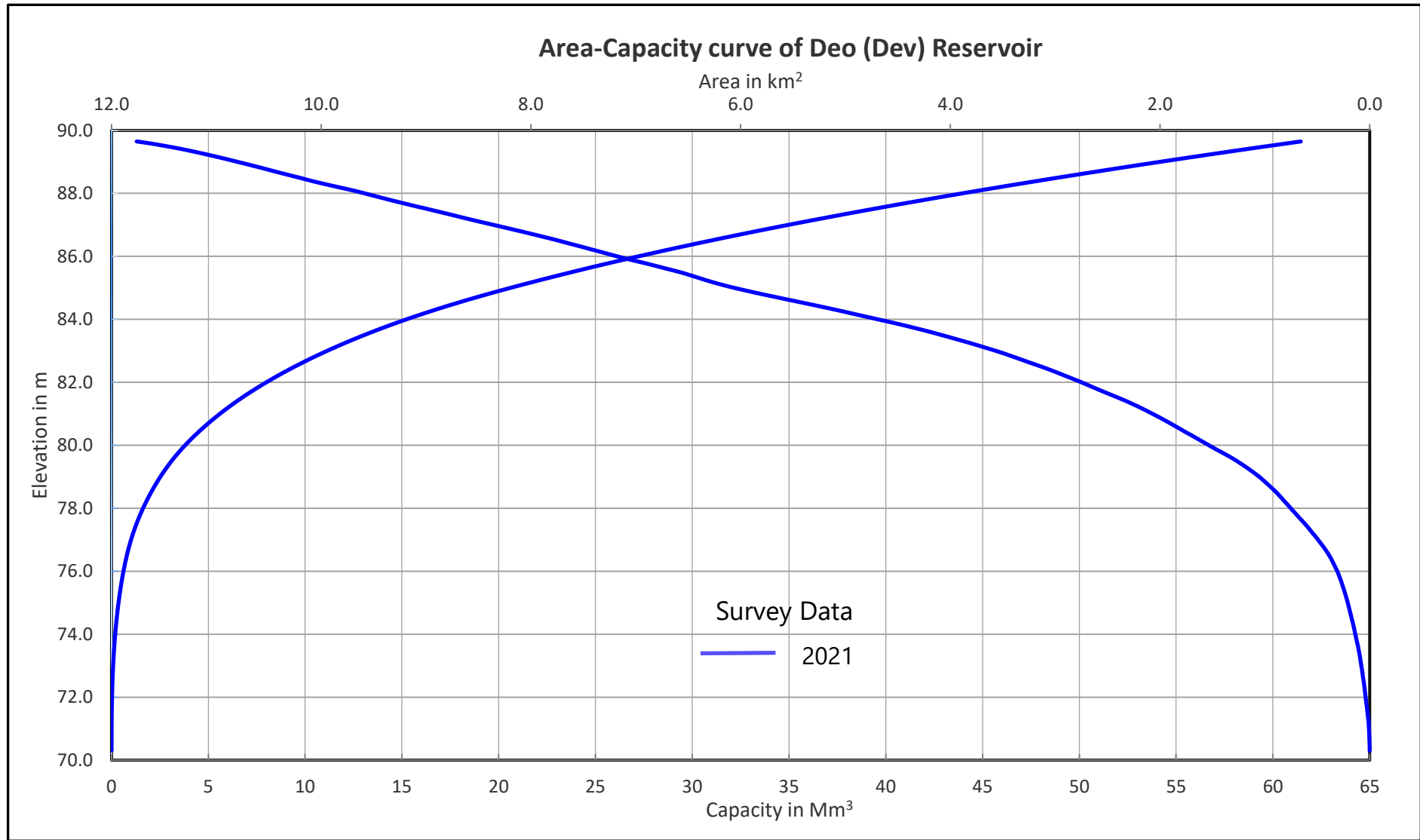


Figure 5.5: Area capacity curve for 2021 survey for Deo (Dev) Reservoir

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 2005 are shown in Table 5.2. In addition, the comparison plots of capacity curve for the year 2021, 2005 and 1986 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. 1982 survey. The capacity curve of 2021 is found close to that of year 2005.

Table 5.2: Comparison of Elevation Capacity details of 2021, 2005 and 1986 data for Deo (Dev) Reservoir

Sr. No	Elevation (wrt MSL) [m]	1986 Survey		2005 Survey		2021 Survey	
		Gross Capacity [Mm ³]	Area [km ²]	Gross Capacity [Mm ³]	Area [km ²]	Gross Capacity [Mm ³]	Area [km ²]
1	67.30	0.000	0.000	0.000	0.000	--	--
2	68.65	0.040	--	0.313	0.077	--	--
3	69.65	0.080	--	0.398	0.097	--	--
4	70.65	0.110	--	0.504	0.122	0.0004	0.003
5	71.65	0.150	--	0.642	0.161	0.013	0.026
6	72.00	0.173	0.11	0.701	0.185	0.023	0.039
7	72.65	0.300	--	0.832	0.230	0.056	0.064
8	73.65	0.450	--	1.097	0.308	0.145	0.114
9	74.00	0.577	0.320	1.209	0.340	0.188	0.137
10	74.65	0.840	--	1.449	0.411	0.292	0.183
11	75.65	1.130	--	1.925	0.556	0.516	0.269
12	76.00	1.394	0.690	2.128	0.618	0.616	0.309
13	76.65	2.130	--	2.567	0.751	0.855	0.415
14	77.65	3.230	--	3.433	0.994	1.387	0.658
15	78.00	3.655	1.630	3.794	1.085	1.627	0.753
16	78.65	4.980	--	4.556	1.278	2.180	0.936
17	79.65	7.040	--	5.998	1.642	3.313	1.342
18	80.00	7.764	2.500	6.594	1.779	3.799	1.533
19	80.65	9.770	--	7.829	2.044	4.915	1.877
20	81.65	12.930	--	10.111	2.575	7.096	2.501
21	82.00	14.025	3.800	11.047	2.796	7.996	2.749
22	82.65	16.780	--	13.009	3.276	9.970	3.262
23	83.65	22.290	--	17.708	4.179	13.714	4.248



Sr. No	Elevation (wrt MSL) [m]	1986 Survey		2005 Survey		2021 Survey	
		Gross Capacity [Mm ³]	Area [km ²]	Gross Capacity [Mm ³]	Area [km ²]	Gross Capacity [Mm ³]	Area [km ²]
24	84.00	24.039	6.310	18.225	4.514	15.235	4.691
25	84.65	28.940	--	21.383	5.249	18.614	5.583
26	85.65	36.490	--	27.287	6.485	24.774	6.756
27	86.00	39.132	8.840	29.633	6.875	27.211	7.177
28	86.65	45.870	--	34.364	7.586	32.103	7.917
29	87.53	55.100	--	41.543	8.570	39.747	9.045
30	87.65	56.360	--	42.597	8.791	40.640	9.171
31	88.00	60.021	12.120	45.791	9.203	43.940	9.584
32	88.32	65.160	13.000	49.016	10.043	47.173	10.008
33	88.65	69.500	13.920	53.356	10.963	50.413	10.387
34	89.65	84.090	16.680	67.946	13.723	61.440	11.760

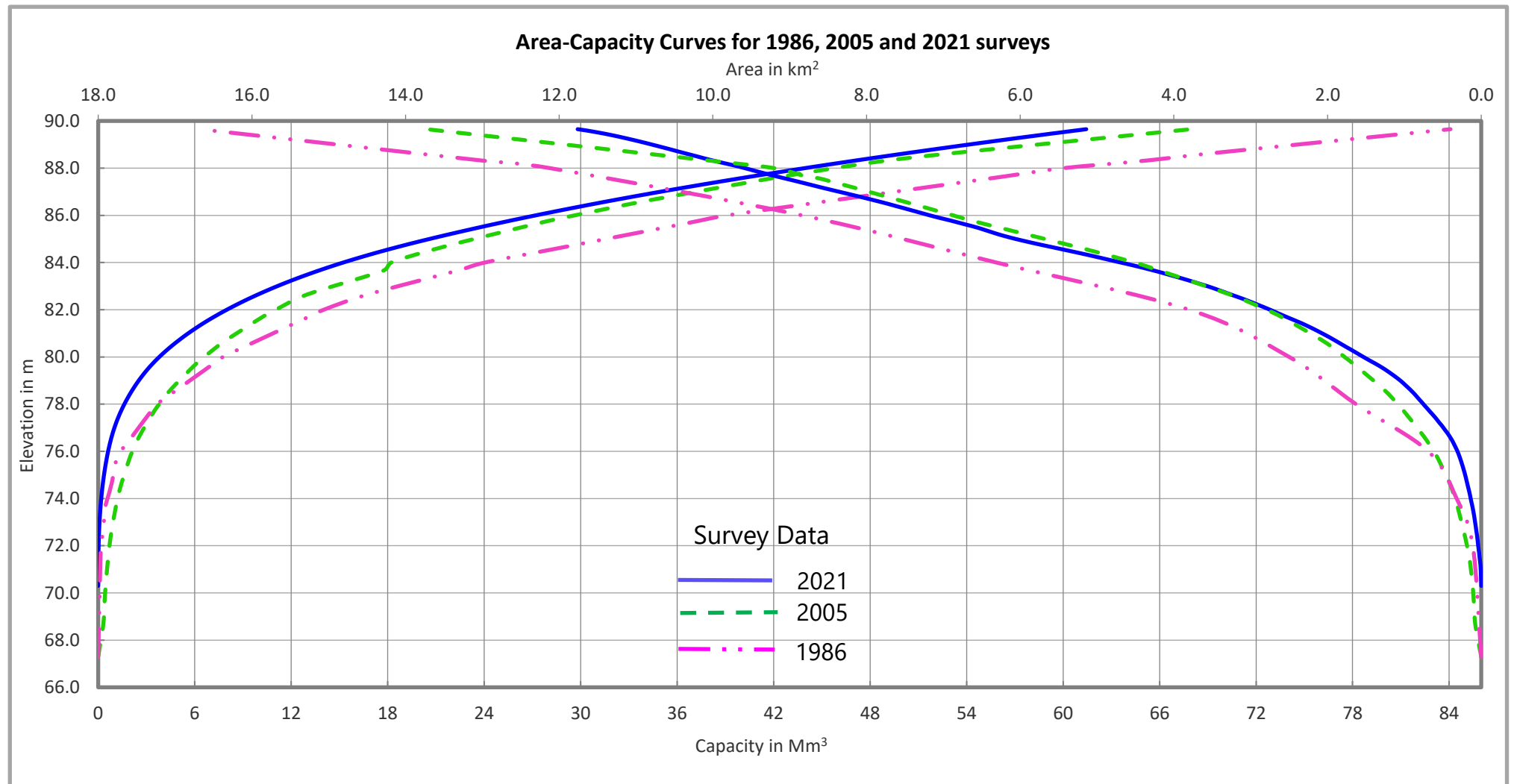


Figure 5.6: Area capacity curve for 2021 survey compared with elevation capacity details of 1986 and 2005 for Deo (Dev) Reservoir

5.4 Sedimentation in Reservoir

The present survey of Deo (Dev) reservoir was carried out between May -August 2021. Previous survey was carried out in the year 2005. The catchment area considered for sedimentation studies is 259 km². In the present study, the age of the reservoir is considered as 35 years (1986 – 2021). As per 2020-2021 survey, the total area of reservoir at FRL 89.65 m is 11.760 km² and the corresponding gross storage capacity is 61.44 Mm³. Table 5.3 details the gross capacity loss, rate of sedimentation and annual % loss in gross storage capacity w.r.t. original project capacity (1986).

Table 5.3: Sedimentation in Deo (Dev) Reservoir

Year	1986	2005	2021	2021
Storage Capacity in Mm³				
Dead	7.76	6.594	3.799	3.799
Live	76.33	61.352	57.641	57.641
Gross	84.09	67.946	61.440	61.440
Loss of Storage Capacity in Mm³				
		(wrt 1986)	(wrt 2005)	(wrt 1986)
Dead	NA	1.166	2.795	3.961
Live	NA	14.978	3.711	18.689
Gross	NA	16.144	6.506	22.650
Sedimentation Rate in Ham/100 km²/Year				
		(wrt 1986)	(wrt 2005)	(wrt 1986)
Dead	NA	2.369	6.745	4.369
Live	NA	30.437	8.955	20.617
Gross	NA	32.806	15.700	24.986
Annual % loss				
		(wrt 1986)	(wrt 2005)	(wrt 1986)
Dead	NA	0.073	0.257	0.135
Live	NA	0.937	0.341	0.635
Gross	NA	1.010	0.598	0.770
Class of reservoir as per IS - 12182 (1987)	As per design	Serious	Serious	Serious
Volume of sediment (w.r.t. 1986) deposited on bed in 2021= Loss of storage capacity= 22.650 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 Deo (Dev) reservoir as per the methodology given in IS 12182-1987.

Table 5.4: Trap Efficiency and Sedimentation Index for Deo (Dev) Reservoir

Trap Efficiency	Sedimentation Index
96%	6.218 x 10 ¹⁰ sec ² /m

In Table 5.3, the Project data of 1986 has been compared with 2021 survey results to understand the sedimentation in Deo (Dev) reservoir. It may be observed that there is a reduction in the storage capacity of the reservoir due to siltation.

In comparison with 1986 and 2005 surveys, the present survey results indicate continuous siltation process in the reservoir. The reason behind the present survey results showing siltation w.r.t. 1982 and 2005 survey results could be due to change of upstream catchment characteristics. Also, there could be some anthropogenic activities in the catchment area which might result in siltation in the reservoir.

Table 5.5: Sedimentation Volumes from Surveys of Previous Year

Sr. No.	Year of Survey	Source of Data	Period (years)	Reservoir Capacity (Mm ³)	Loss of Gross Capacity (Mm ³)			Observed Rate of Sedimentation Since 1986 survey (Ha m / 100 Sq km/Yr)
					Since 1986 survey	% Cumulative	Remark	
1	1986	Govt.	-	84.090				
2	2005	Govt.	19	67.946	16.144	19.198	Siltation	32.806
3	2021	Present survey	35	61.440	22.650	26.935	Siltation	24.986

- As per 2021 survey results, the volume of sediment deposited or the loss in gross storage capacity w.r.t. 1986 survey data is 22.650 Mm³.
- The rate of siltation in Deo (Dev) reservoir is 0.647 Mm³/year.
- The average rate of siltation in the Deo (Dev) reservoir during the 35 years life span (1986 – 2021), works out to 24.986 Ha m/100 sq km/year.
- The annual % loss in Deo (Dev) reservoir during the 35 years life span is 0.770 % and hence, the reservoir is classified as “Serious” category as per IS 12182 (1987).

1. Trap Efficiency and sedimentation Index calculated for Deo (Dev) reservoir as per methodology give in IS 12182-1987 is 96% and $6.218 \times 10^{10} \text{ sec}^2/\text{m}$ respectively.

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

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

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Deo (Dev) reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm ³]	Live Capacity [Mm ³]	Dead Capacity [Mm ³]	Remarks
1	70.30	0.00000	--	0.00000	Bed level
2	70.40	0.00001	--	0.00001	--
3	70.50	0.0001	--	0.0001	--
4	70.60	0.0002	--	0.0002	--
5	70.70	0.0005	--	0.0005	--
6	70.80	0.0008	--	0.0008	--
7	70.90	0.001	--	0.001	--
8	71.00	0.002	--	0.002	--
9	71.10	0.003	--	0.003	--
10	71.20	0.004	--	0.004	--
11	71.30	0.005	--	0.005	--
12	71.40	0.006	--	0.006	--
13	71.50	0.008	--	0.008	--
14	71.60	0.011	--	0.011	--
15	71.70	0.013	--	0.013	--
16	71.80	0.016	--	0.016	--
17	71.90	0.020	--	0.020	--
18	72.00	0.023	--	0.023	--
19	72.10	0.027	--	0.027	--
20	72.20	0.032	--	0.032	--
21	72.30	0.037	--	0.037	--
22	72.40	0.042	--	0.042	--
23	72.50	0.047	--	0.047	--
24	72.60	0.053	--	0.053	--
25	72.70	0.060	--	0.060	--
26	72.80	0.067	--	0.067	--
27	72.90	0.074	--	0.074	--
28	73.00	0.082	--	0.082	--
29	73.10	0.090	--	0.090	--
30	73.20	0.099	--	0.099	--
31	73.30	0.108	--	0.108	--
32	73.40	0.117	--	0.117	--
33	73.50	0.128	--	0.128	--
34	73.60	0.138	--	0.138	--
35	73.70	0.150	--	0.150	--
36	73.80	0.162	--	0.162	--
37	73.90	0.175	--	0.175	--
38	74.00	0.188	--	0.188	--
39	74.10	0.202	--	0.202	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Deo (Dev) reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm ³]	Live Capacity [Mm ³]	Dead Capacity [Mm ³]	Remarks
40	74.20	0.217	--	0.217	--
41	74.30	0.232	--	0.232	--
42	74.40	0.248	--	0.248	--
43	74.50	0.265	--	0.265	--
44	74.60	0.283	--	0.283	--
45	74.70	0.301	--	0.301	--
46	74.80	0.320	--	0.320	--
47	74.90	0.340	--	0.340	--
48	75.00	0.360	--	0.360	--
49	75.10	0.382	--	0.382	--
50	75.20	0.404	--	0.404	--
51	75.30	0.427	--	0.427	--
52	75.40	0.451	--	0.451	--
53	75.50	0.476	--	0.476	--
54	75.60	0.502	--	0.502	--
55	75.70	0.529	--	0.529	--
56	75.80	0.557	--	0.557	--
57	75.90	0.586	--	0.586	--
58	76.00	0.616	--	0.616	--
59	76.10	0.648	--	0.648	--
60	76.20	0.681	--	0.681	--
61	76.30	0.715	--	0.715	--
62	76.40	0.751	--	0.751	--
63	76.50	0.789	--	0.789	--
64	76.60	0.829	--	0.829	--
65	76.70	0.870	--	0.870	--
66	76.80	0.914	--	0.914	--
67	76.90	0.960	--	0.960	--
68	77.00	1.008	--	1.008	--
69	77.10	1.058	--	1.058	--
70	77.20	1.111	--	1.111	--
71	77.30	1.166	--	1.166	--
72	77.40	1.224	--	1.224	--
73	77.50	1.285	--	1.285	--
74	77.60	1.348	--	1.348	--
75	77.70	1.413	--	1.413	--
76	77.80	1.482	--	1.482	--
77	77.90	1.553	--	1.553	--
78	78.00	1.627	--	1.627	--
79	78.10	1.704	--	1.704	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Deo (Dev) reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm ³]	Live Capacity [Mm ³]	Dead Capacity [Mm ³]	Remarks
80	78.20	1.783	--	1.783	--
81	78.30	1.865	--	1.865	--
82	78.40	1.950	--	1.950	--
83	78.50	2.037	--	2.037	--
84	78.60	2.128	--	2.128	--
85	78.70	2.221	--	2.221	--
86	78.80	2.318	--	2.318	--
87	78.90	2.418	--	2.418	--
88	79.00	2.522	--	2.522	--
89	79.10	2.629	--	2.629	--
90	79.20	2.740	--	2.740	--
91	79.30	2.856	--	2.856	--
92	79.40	2.976	--	2.976	--
93	79.50	3.100	--	3.100	--
94	79.60	3.229	--	3.229	--
95	79.70	3.364	--	3.364	--
96	79.80	3.503	--	3.503	--
97	79.90	3.648	--	3.648	--
98	80.00	3.799	--	3.799	MDDL
99	80.10	3.955	0.156	3.799	--
100	80.20	4.116	0.317	3.799	--
101	80.30	4.283	0.484	3.799	--
102	80.40	4.455	0.655	3.799	--
103	80.50	4.632	0.833	3.799	--
104	80.60	4.814	1.015	3.799	--
105	80.70	5.002	1.203	3.799	--
106	80.80	5.195	1.396	3.799	--
107	80.90	5.393	1.594	3.799	--
108	81.00	5.598	1.799	3.799	--
109	81.10	5.808	2.009	3.799	--
110	81.20	6.024	2.225	3.799	--
111	81.30	6.246	2.447	3.799	--
112	81.40	6.475	2.676	3.799	--
113	81.50	6.710	2.911	3.799	--
114	81.60	6.953	3.154	3.799	--
115	81.70	7.203	3.404	3.799	--
116	81.80	7.460	3.661	3.799	--
117	81.90	7.725	3.926	3.799	--
118	82.00	7.996	4.197	3.799	--
119	82.10	8.275	4.475	3.799	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Deo (Dev) reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm ³]	Live Capacity [Mm ³]	Dead Capacity [Mm ³]	Remarks
120	82.20	8.561	4.762	3.799	--
121	82.30	8.854	5.055	3.799	--
122	82.40	9.156	5.356	3.799	--
123	82.50	9.465	5.666	3.799	--
124	82.60	9.782	5.983	3.799	--
125	82.70	10.109	6.310	3.799	--
126	82.80	10.443	6.644	3.799	--
127	82.90	10.787	6.988	3.799	--
128	83.00	11.139	7.340	3.799	--
129	83.10	11.500	7.701	3.799	--
130	83.20	11.872	8.073	3.799	--
131	83.30	12.253	8.454	3.799	--
132	83.40	12.645	8.846	3.799	--
133	83.50	13.048	9.249	3.799	--
134	83.60	13.461	9.662	3.799	--
135	83.70	13.886	10.087	3.799	--
136	83.80	14.323	10.524	3.799	--
137	83.90	14.773	10.974	3.799	--
138	84.00	15.235	11.436	3.799	--
139	84.10	15.711	11.912	3.799	--
140	84.20	16.200	12.401	3.799	--
141	84.30	16.702	12.903	3.799	--
142	84.40	17.218	13.418	3.799	--
143	84.50	17.747	13.948	3.799	--
144	84.60	18.291	14.492	3.799	--
145	84.70	18.850	15.050	3.799	--
146	84.80	19.422	15.623	3.799	--
147	84.90	20.008	16.209	3.799	--
148	85.00	20.608	16.809	3.799	--
149	85.10	21.220	17.421	3.799	--
150	85.20	21.843	18.044	3.799	--
151	85.30	22.477	18.678	3.799	--
152	85.40	23.120	19.321	3.799	--
153	85.50	23.773	19.974	3.799	--
154	85.60	24.437	20.638	3.799	--
155	85.70	25.112	21.313	3.799	--
156	85.80	25.799	22.000	3.799	--
157	85.90	26.499	22.700	3.799	--
158	86.00	27.211	23.412	3.799	--
159	86.10	27.934	24.135	3.799	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Deo (Dev) reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm ³]	Live Capacity [Mm ³]	Dead Capacity [Mm ³]	Remarks
160	86.20	28.668	24.869	3.799	--
161	86.30	29.414	25.615	3.799	--
162	86.40	30.171	26.372	3.799	--
163	86.50	30.939	27.140	3.799	--
164	86.60	31.718	27.919	3.799	--
165	86.70	32.510	28.711	3.799	--
166	86.80	33.314	29.515	3.799	--
167	86.90	34.130	30.331	3.799	--
168	87.00	34.960	31.160	3.799	--
169	87.10	35.802	32.003	3.799	--
170	87.20	36.657	32.858	3.799	--
171	87.30	37.524	33.725	3.799	--
172	87.40	38.403	34.604	3.799	--
173	87.50	39.295	35.496	3.799	--
174	87.60	40.200	36.401	3.799	--
175	87.70	41.117	37.318	3.799	--
176	87.80	42.046	38.247	3.799	--
177	87.90	42.987	39.188	3.799	--
178	88.00	43.940	40.141	3.799	--
179	88.10	44.904	41.105	3.799	--
180	88.20	45.881	42.082	3.799	--
181	88.30	46.872	43.073	3.799	--
182	88.40	47.875	44.076	3.799	--
183	88.50	48.890	45.091	3.799	--
184	88.60	49.917	46.118	3.799	--
185	88.70	50.956	47.157	3.799	--
186	88.80	52.006	48.207	3.799	--
187	88.90	53.068	49.269	3.799	--
188	89.00	54.141	50.342	3.799	--
189	89.10	55.227	51.428	3.799	--
190	89.20	56.325	52.526	3.799	--
191	89.30	57.436	53.637	3.799	--
192	89.40	58.561	54.762	3.799	--
193	89.50	59.701	55.902	3.799	--
194	89.60	60.857	57.058	3.799	--
195	89.65	61.440	57.641	3.799	FRL

6. Conclusions

- The reservoir topography was uneven, with reservoir bed level ranging from 70.3 m to 89.65 m w.r.t. MSL. The lowest reservoir bed level 70.3 m was found near the upstream face of the dam boundary and it becomes shallower as we go further upstream from the dam face. Also, the reservoir bed tends to get shallower as we go further in northeast, east and southeast directions away from the dam wall within the survey area.
- Current survey results indicate that the loss of gross storage capacity (w.r.t. 1986 project data) due to siltation in Deo (Dev) reservoir is 22.650 Mm³. The capacity is close to that of the year 2005. 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 results, 2021 results indicate decrease in storage capacity due to siltation. The annual % loss in gross storage capacity is 0.770 % and hence, the reservoir is classified as "Serious" category as per IS 12182 (1987).
- The sedimentation volumes, sedimentation rates, loss of storage capacity, trap efficiency, sedimentation index have been reported in the study. Moreover, the tables for gross, live and dead storage capacity of reservoir at every 0.1 m interval from lowest bed level to FRL have been provided.

7. References

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Appendix A

Diary of Events

(01 page)

Diary of Events (Bathymetry and Topography Survey)	
Date	Events
Bathymetry Survey	
04 May 2021	Survey personnel and equipment with survey boat 'Fugro Zodiac' reached Deo (Dev) reservoir. Fugro Zodiac deployed on Deo (Dev) reservoir
05 May 2021	Mobilization
06 May 2021	Mobilization completed. Calibration/verification commenced.
07 May 2021	Calibration/verification completed, and bathymetry survey started.
08 May to 03 June 2021	Bathymetry Survey continued.
04 June 2021	Bathymetry Survey completed
05 June 2021	Demobilization started.
06 June 2021	Demobilization completed.
Topography Survey	
28 July 2021	Topography survey team with equipment reached Deo (Dev) Dam. Mobilisation and calibration commenced and completed. Topography survey commenced
29 July to 6 August 2021	Topography survey continued.
7 August 2021	Topography survey completed. Demobilization commenced and completed.

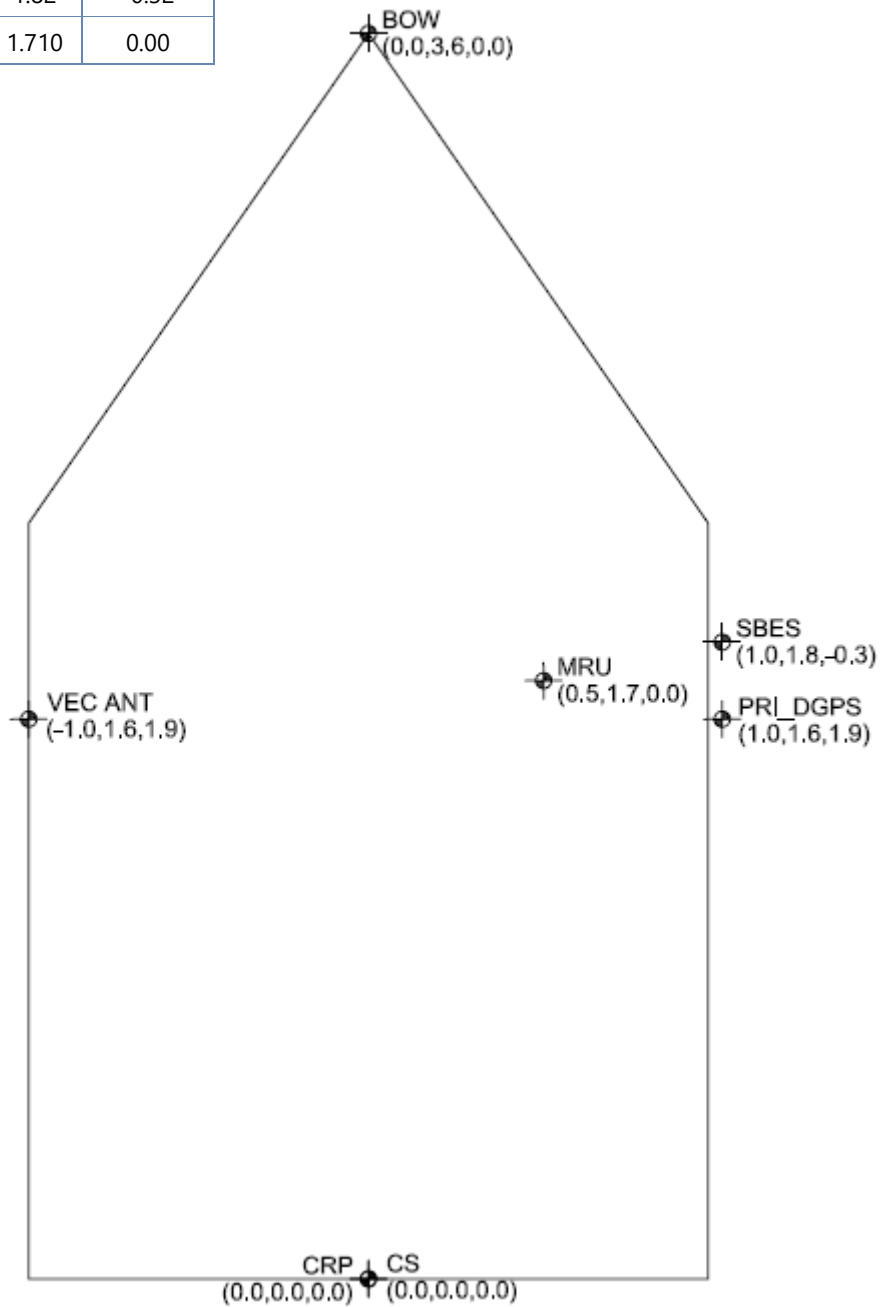
Appendix B

Survey Vessel Sensor Offsets

(01 Page)

Survey Vessel 'Fugro Zodiac' Sensor Offset Diagram

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



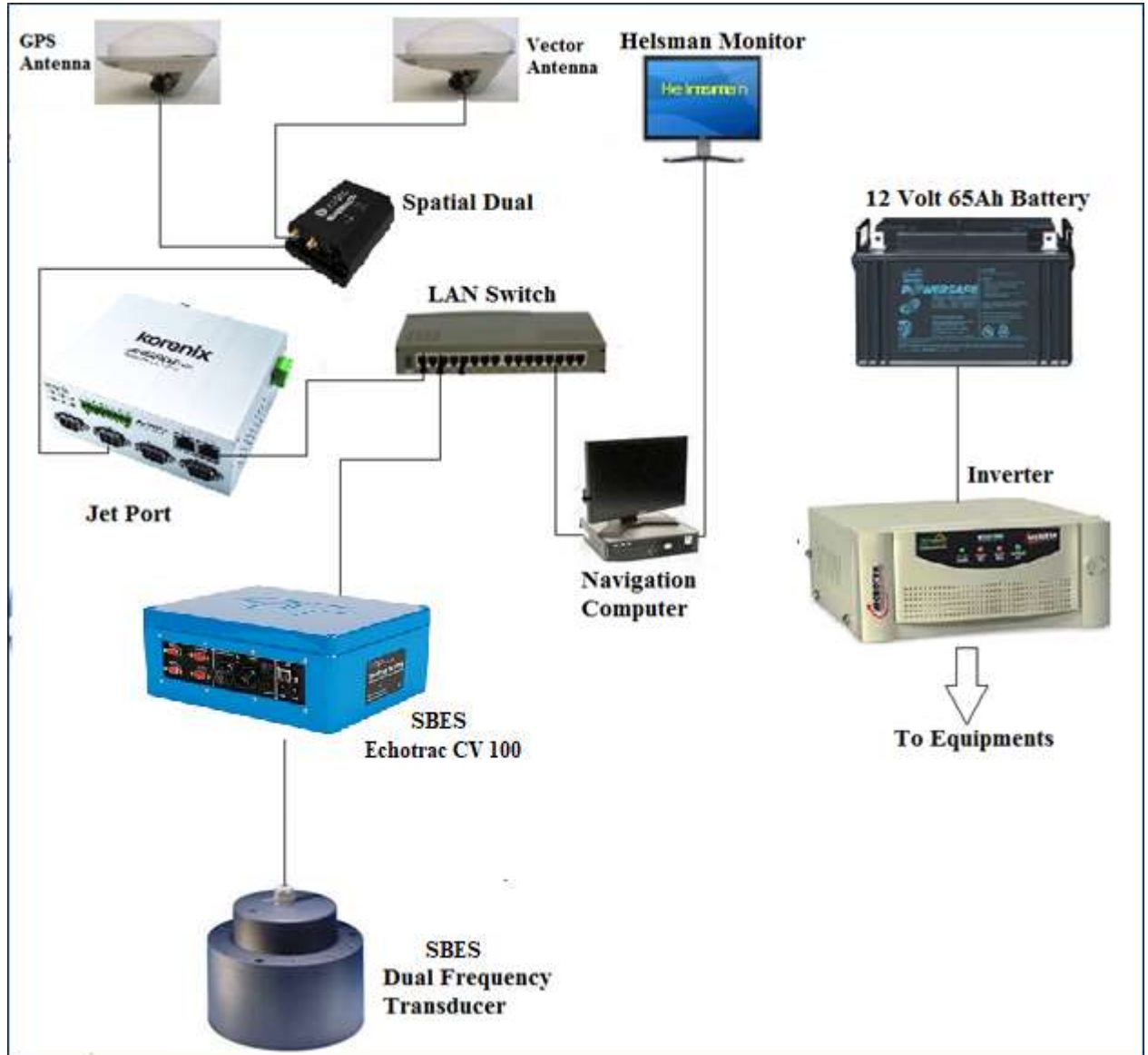
Appendix C

Equipment Layout Diagram

(01 Page)



Equipment Layout Diagram onboard Fugro Zodiac



Appendix D

Results of Field Calibrations / Verifications

(20 pages)



Diagram Report of DEV DAM TBM1

Job No. :	J-HYD-20-174630	Job Name:	Bathymetric Survey
Station Name:	DEV DAM TBM1	Location:	DEV DAM, Gujarat
Party Chief :	Pritam Seth	Job Engineer/Surveyor :	Atul Bhojte.
Date of Observation: (Date & Time)	05-05-2021 & 12:53hrs	End of Observation: (Date & Time)	05-05-2021 & 13:23hrs

1. Station Name: DEV DAM TBM1.

Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075° 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 DEV DAM TBM1 Height from MSL 94.128m

B= Antenna Height from BM 1.169m (Measure by Tape)

Ellipsoidal height of Antenna= 36.781

Ellipsoidal Height of BM 36.781m - 1.169m=35.612m

Position Of Antenna:-

Latitude: 22°22'24.252"N, Longitude: 073°32'57.787"E

Easting: 3,50,650.092m E, Northing: 24,74,878.187m N



Prepared By: Pritam Seth.

**BATHYMETRIC SURVEY
MEAN POSITION REPORT**



Project ID	J-HYD-20-174630-DEV DAM		
Location	DEV DAM, CENTRAL GUJRAT		
Client	GOVERMENT OF GUJRAT	Vessel	Tripod
Comment	DEV DAM TBM1 STN HT 1.169m		

Session Name: MPR-20210505071940-v1

Records Used: 1688 of 1799

Start Time: 05 May 2021, 12:53:54+05:30

End Time: 05 May 2021, 13:23:52+05:30

Session Length: 00:29:59

Mean Position for Tripod CommonReferencePoint		
	WGS 84 / UTM zone 43N	WGS 84(2D)
Latitude	22°22'24.25256"N	22°22'24.25256"N
Longitude	073°32'57.78771"E	073°32'57.78771"E
Height	36.781m Ell.	36.781m Ell.
Easting	3,50,650.092m E (SD: ±0.02m)	
Northing	24,74,878.187m N (SD: ±0.02m)	
Height	95.608m Ort. (SD: ±0.04m Ort.)	

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

DEV DAM TBM1 STN HT 1.169m

PRITAM SETH

Party Chief

FSINPVT (Fugro Survey (India) Pvt Ltd.)

Deputy Executive Engineer

DEV DAM

GOVERNMENT OF GUJRAT

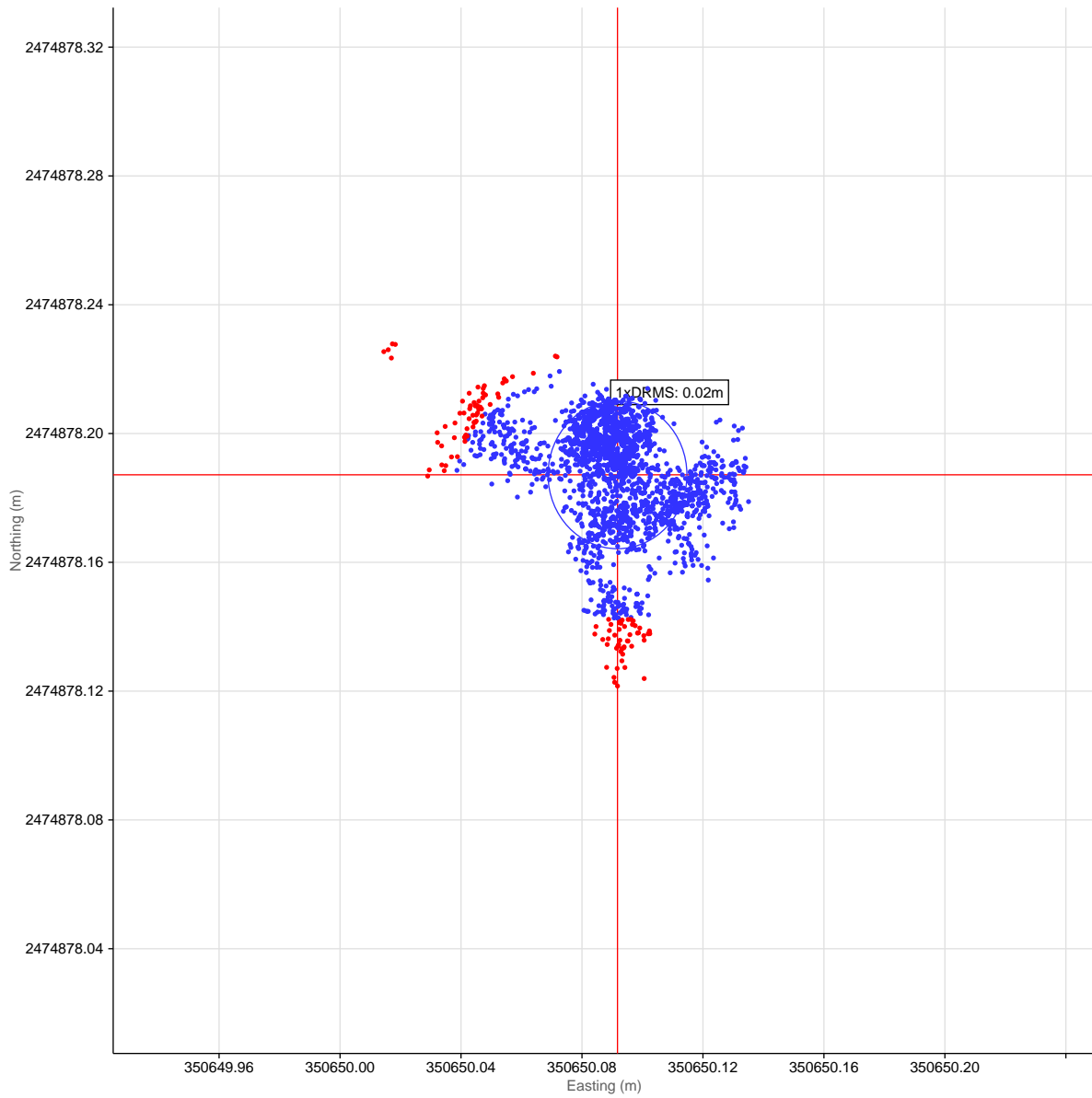
BATHYMETRIC SURVEY MEAN POSITION REPORT



Geodetic Parameters

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

Scatter Plot



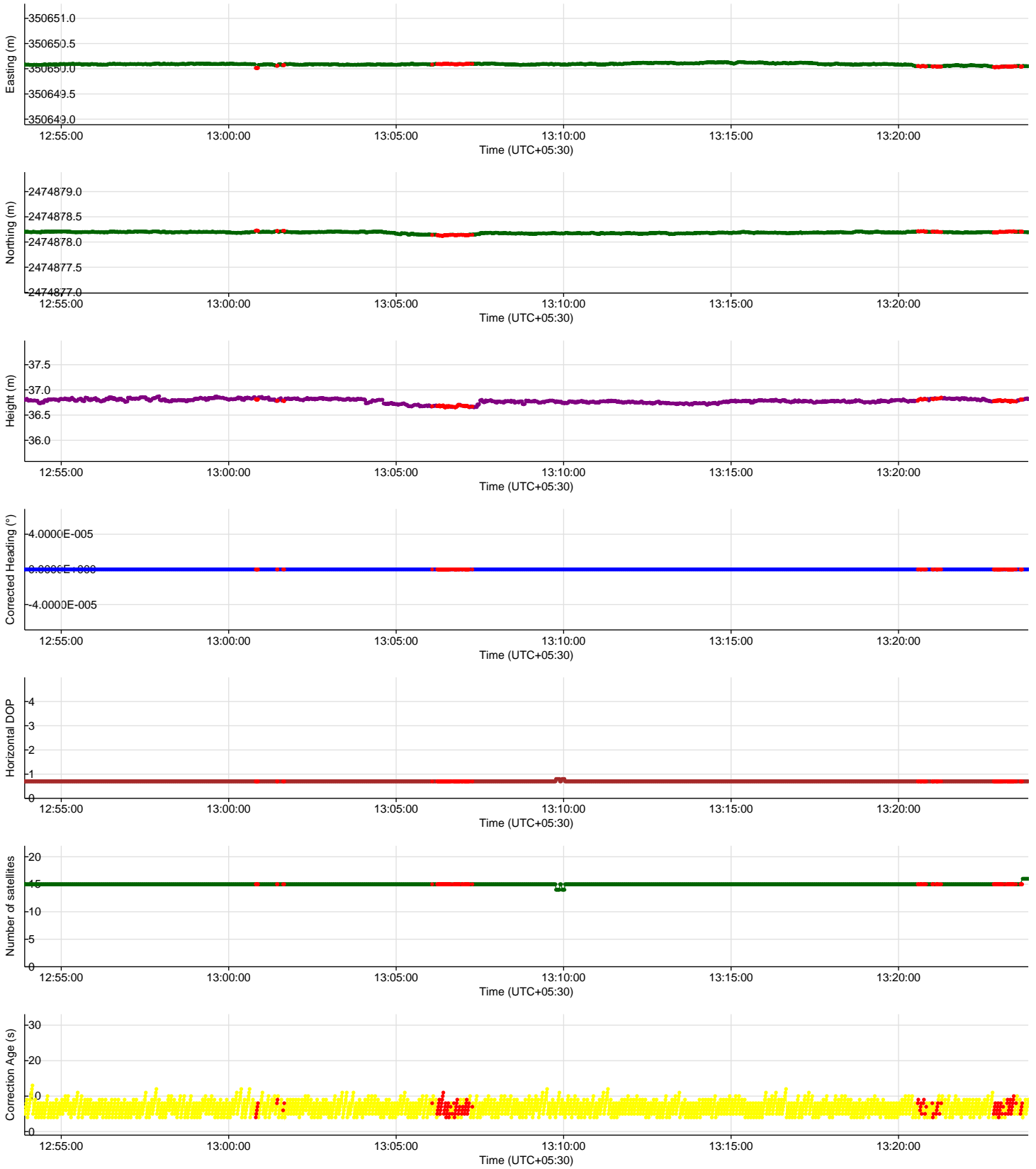
Mean Position

	Easting	Northing
Tripod	3,50,650.092m E	24,74,878.187m N

BATHYMETRIC SURVEY MEAN POSITION REPORT



Time Series Plots for Tripod



FUGRO SURVEY (INDIA) PVT. LTD.



Diagram Report of DEV DAM TBM2

Job No. :	J-HYD-20-174630	Job Name:	Bathymetric Survey
Station Name:	DEV DAM TBM2	Location:	DEV DAM, Gujarat
Party Chief :	Pritam Seth	Job Engineer/Surveyor :	Atul Bhojte.
Date of Observation: (Date & Time)	05-05-2021 & 15:00hrs	End of Observation: (Date & Time)	05-05-2021 & 15:30hrs

1. Station Name: DEV DAM TBM2.

Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075° 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 DEV DAM TBM2 Height from MSL 94.063m

B= Antenna Height from BM 0.885m (Measure by Tape)

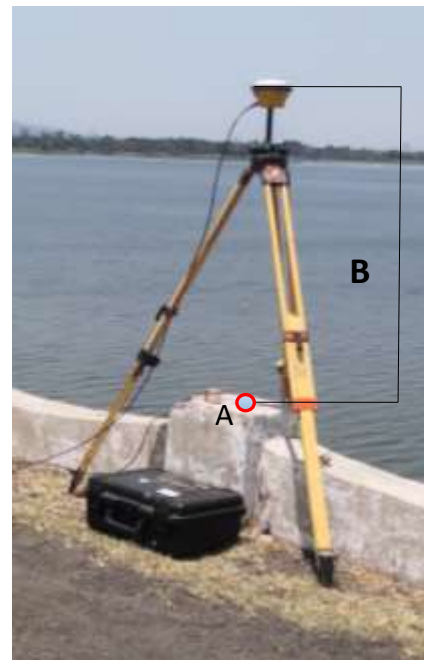
Ellipsoidal height of Antenna= 36.439m

Ellipsoidal Height of BM 36.439m - 0.885m=35.554m

Position Of Antenna:-

Latitude: 22°22'25.202"N, **Longitude:** 073°32'56.590"E

Easting: 3,50,616.134m E, **Northing:** 24,74,907.723m N



Prepared By: Pritam Seth.

**BATHYMETRIC SURVEY
MEAN POSITION REPORT**



Project ID	J-HYD-20-174630-DEV DAM		
Location	DEV DAM, CENTRAL GUJRAT		
Client	GOVERNMENT OF GUJRAT	Vessel	Tripod
Comment	DEV DAM TBM2 STN HT 0.885m		

Session Name: MPR-20210505082737-v1

Records Used: 1651 of 1800

Start Time: 05 May 2021, 14:59:58+05:30

End Time: 05 May 2021, 15:29:57+05:30

Session Length: 00:29:59

Mean Position for Tripod CommonReferencePoint		
	WGS 84 / UTM zone 43N	WGS 84(2D)
Latitude	22°22'25.20221"N	22°22'25.20221"N
Longitude	073°32'56.59068"E	073°32'56.59068"E
Height	36.439m Ell.	36.439m Ell.
Easting	3,50,616.134m E (SD: ±0.02m)	
Northing	24,74,907.723m N (SD: ±0.01m)	
Height	95.265m Ort. (SD: ±0.09m Ort.)	

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

DEV DAM TBM2 STN HT 0.885m

PRITAM SETH

Party Chief

FSINPVT (Fugro Survey (India) Pvt Ltd.)

Deputy Executive Engineer

DEV DAM

GOVERNMENT OF GUJRAT

BATHYMETRIC SURVEY MEAN POSITION REPORT



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	

**BATHYMETRIC SURVEY
MEAN POSITION REPORT**



Scatter Plot



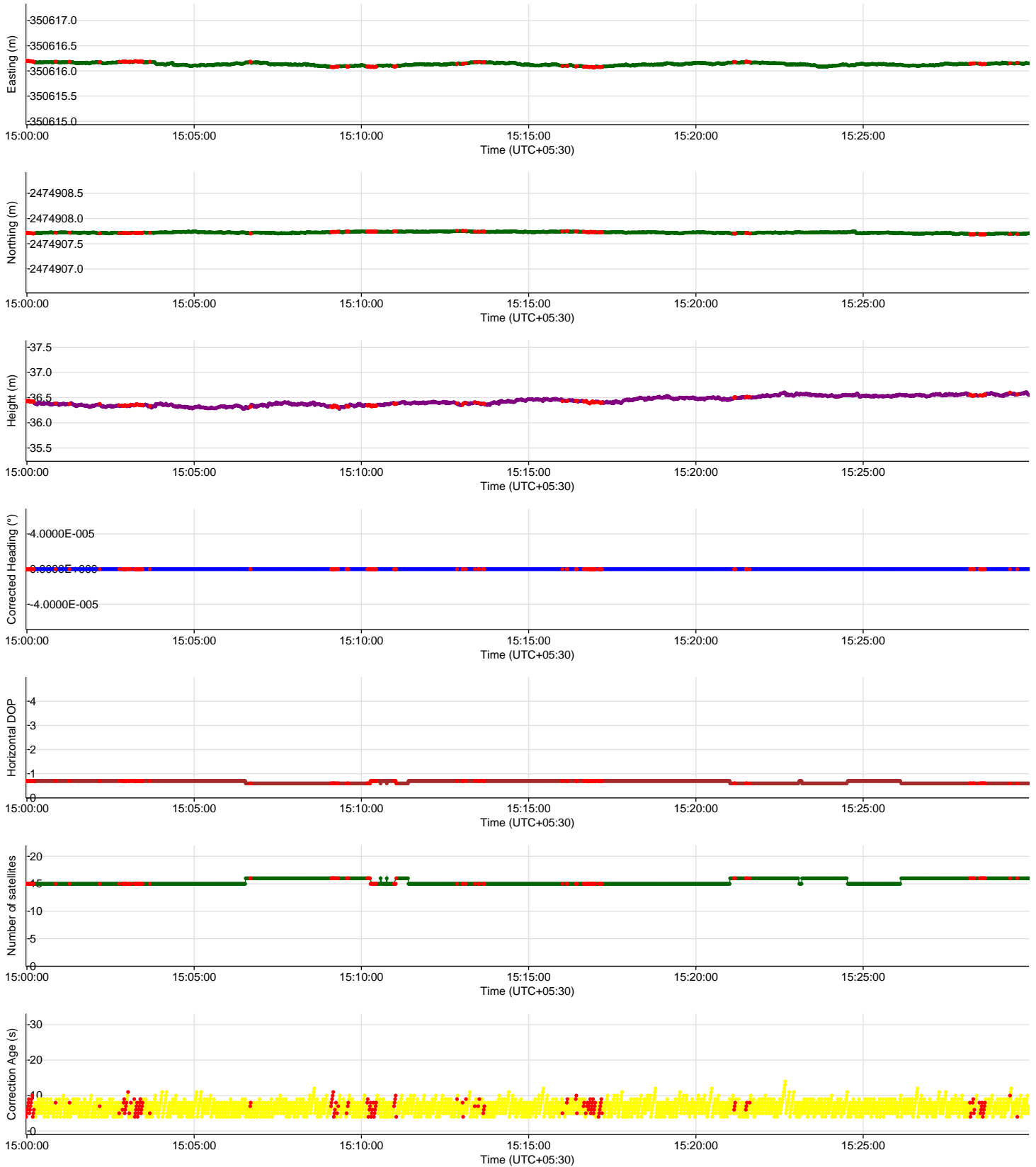
Mean Position

	Easting	Northing
Tripod	3,50,616.134m E	24,74,907.723m N

BATHYMETRIC SURVEY MEAN POSITION REPORT



Time Series Plots for Tripod



FUGRO SURVEY (INDIA) PVT. LTD.



Diagram Report of DEV DAM TBM2

Job No. :	J-HYD-20-174630	Job Name:	Bathymetric Survey
Station Name:	DEV DAM TBM2	Location:	DEV DAM, Gujarat
Party Chief :	Pritam Seth	Job Engineer/Surveyor :	Atul Bhoyte.
Date of Observation: (Date & Time)	05-05-2021 & 16:41hrs	End of Observation: (Date & Time)	05-05-2021 & 17:11hrs

1. Station Name: DEV DAM TBM2.

Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075° 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	0.03

A=Center Point of **DEV DAM TBM2** Height from MSL 94.063m

B= Antenna Height from BM 0.845m (Measure by Tape)

Ellipsoidal height of Antenna= 36.664m

Ellipsoidal Height of BM 36.664 - 0.845m=35.819m

Position Of Antenna:-

Latitude: 22°22'25.203"N, **Longitude:** 073°32'56.589"E

Easting: 3,50,616.105m E, **Northing:** 24,74,907.765m N



Prepared By: Pritam Seth.

**BATHYMETRIC SURVEY
MEAN POSITION REPORT**



Project ID	J-HYD-20-174630-DEV DAM		
Location	DEV DAM, CENTRAL GUJRAT		
Client	GOVERMENT OF GUJRAT	Vessel	Tripod
Comment	DEV DAM TBM2 STN HT 0.845m SD		

Session Name: MPR-20210505102809-v1

Records Used: 1685 of 1799

Start Time: 05 May 2021, 16:41:32+05:30

End Time: 05 May 2021, 17:11:30+05:30

Session Length: 00:29:59

Mean Position for Tripod CommonReferencePoint		
	WGS 84 / UTM zone 43N	WGS 84(2D)
Latitude	22°22'25.20354"N	22°22'25.20354"N
Longitude	073°32'56.58964"E	073°32'56.58964"E
Height	36.664m Ell.	36.664m Ell.
Easting	3,50,616.105m E (SD: ±0.03m)	
Northing	24,74,907.765m N (SD: ±0.01m)	
Height	95.490m Ort. (SD: ±0.03m Ort.)	

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

DEV DAM TBM2 STN HT 0.845m SD

Mean Position to Waypoint	
Waypoint	TBM2
Easting	3,50,616.134m E
Northing	24,74,907.723m N
Range	0.05m Geodetic
Bearing TO	144.21°True
Bearing FROM	324.21°True

PRITAM SETH

Party Chief

FSINPVT (Fugro Survey (India) Pvt Ltd.)

Deputy Executive Engineer

DEV DAM

GOVERNMENT OF GUJRAT

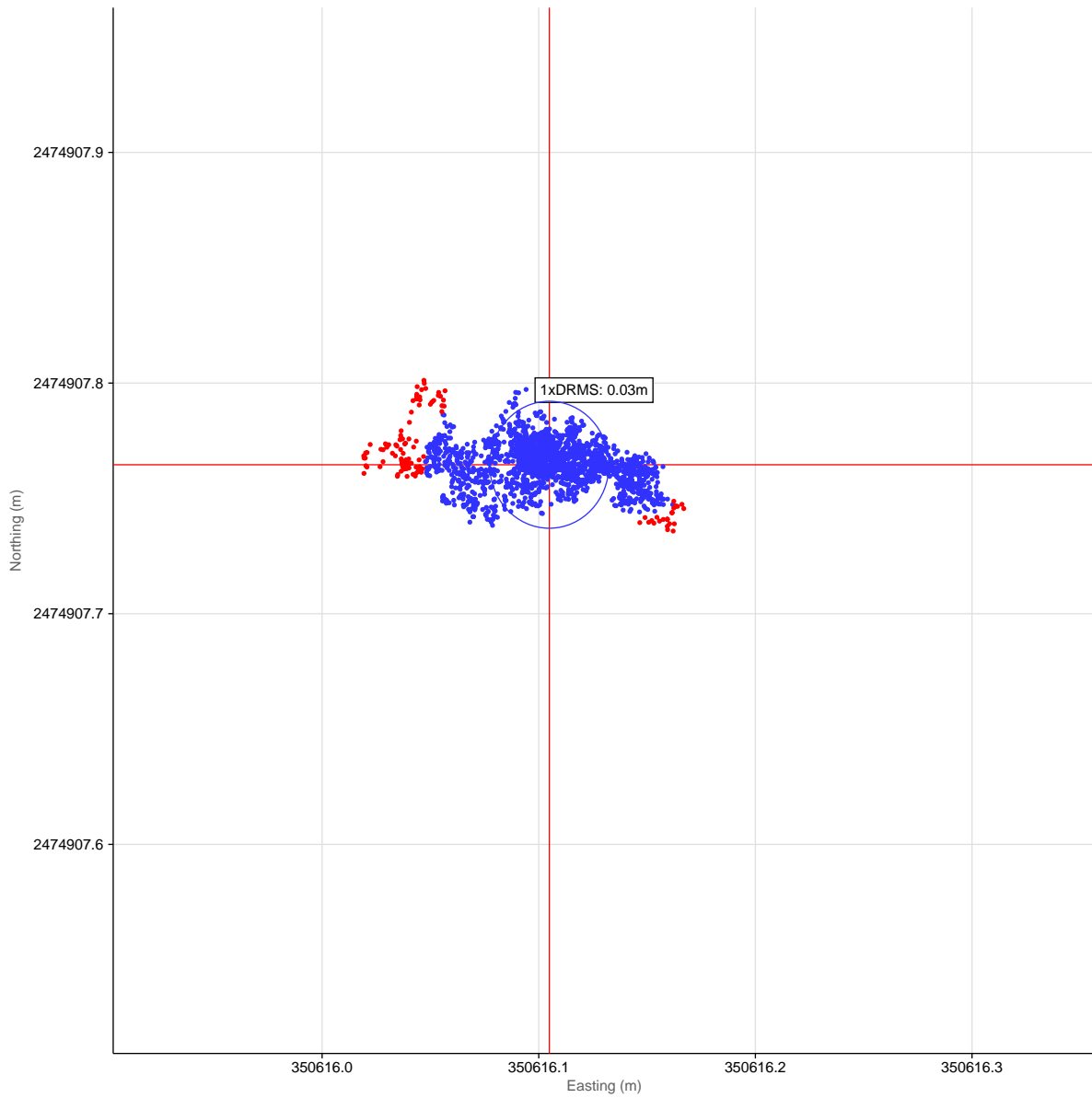
BATHYMETRIC SURVEY MEAN POSITION REPORT



Geodetic Parameters

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

Scatter Plot



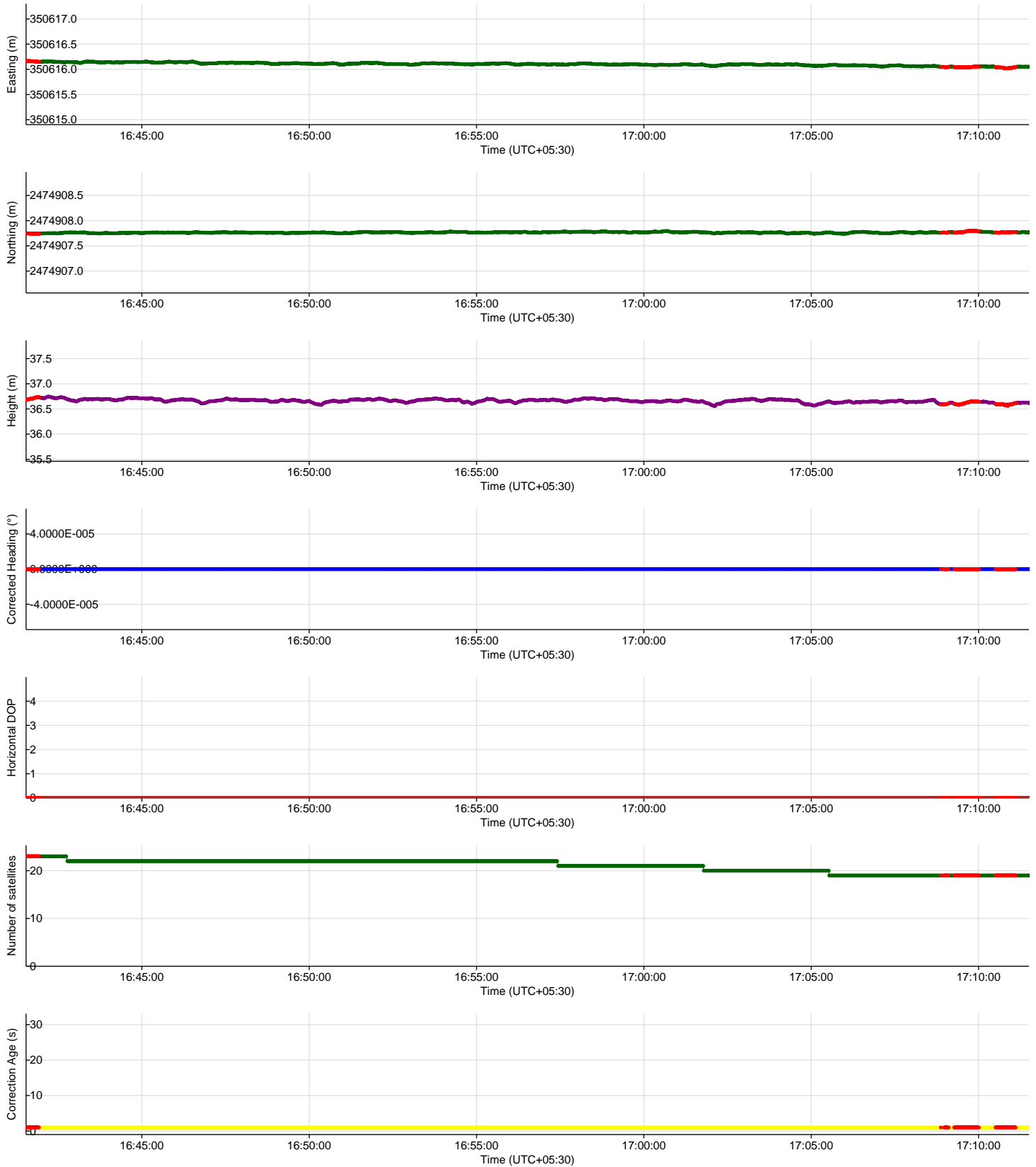
Mean Position

	Easting	Northing
Tripod	3,50,616.105m E	24,74,907.765m N

BATHYMETRIC SURVEY MEAN POSITION REPORT



Time Series Plots for Tripod



Station Name: DEV DAM

Positioning System Verification With BX-992 Receiver and Spatial Dual In Dev Dam TBM2						
World Geodetic System 84, UTM Projection, CM 075° East, Zone 43 North						
Sensor	Serial No.	Easting mE	Northing mN	Latitude	Longitude	Ellipsoidal height (m)
TRIMBLE BX992 RECEIVER	025-00009601	350,616.13	2,474,907.72	22°22'25.20221"N	073°32'56.59068"E	36.439
Spatial Dual	025-00006405	350,616.105	2,474,907.765	22°22'25.20354"N	073°32'56.58964"E	36.664
	Difference	0.029	-0.042	--	--	-0.225

Report No: ###	Rev No: 0	Prepared	Checked	Client Rep.
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Report on Motion Sensor Calibration at sea by ‘Free-Float’ Method

Job No:	J-HYD-20-174630
Job Title:	Bathymetric Survey
Vessel Name:	Fugro Zodiac
Client Name:	Govt. Of Gujarat

Spatial Dual Set up:-

The instrument was placed on a plain surface Near Single beam Echosunder of the vessel and secured firmly in place.

Instrument has kept for 5 minutes to acquire accurate solution. Spatial Dual’s Motion is always on fully automatic.

Screen Shot of Spatial Dual Manager software

Reference Position Offset

Primary Reference Point Offset

X Offset: 0.000 Metres

Y Offset: 0.000 Metres

Z Offset: 0.000 Metres

Heave Point 2 Offset

X Offset: 0.000 Metres

Y Offset: 0.000 Metres

Z Offset: 0.000 Metres

Heave Point 3 Offset

X Offset: 0.000 Metres

Y Offset: 0.000 Metres

Z Offset: 0.000 Metres

Heave Point 4 Offset

X Offset: 0.000 Metres

Y Offset: 0.000 Metres

Z Offset: 0.000 Metres

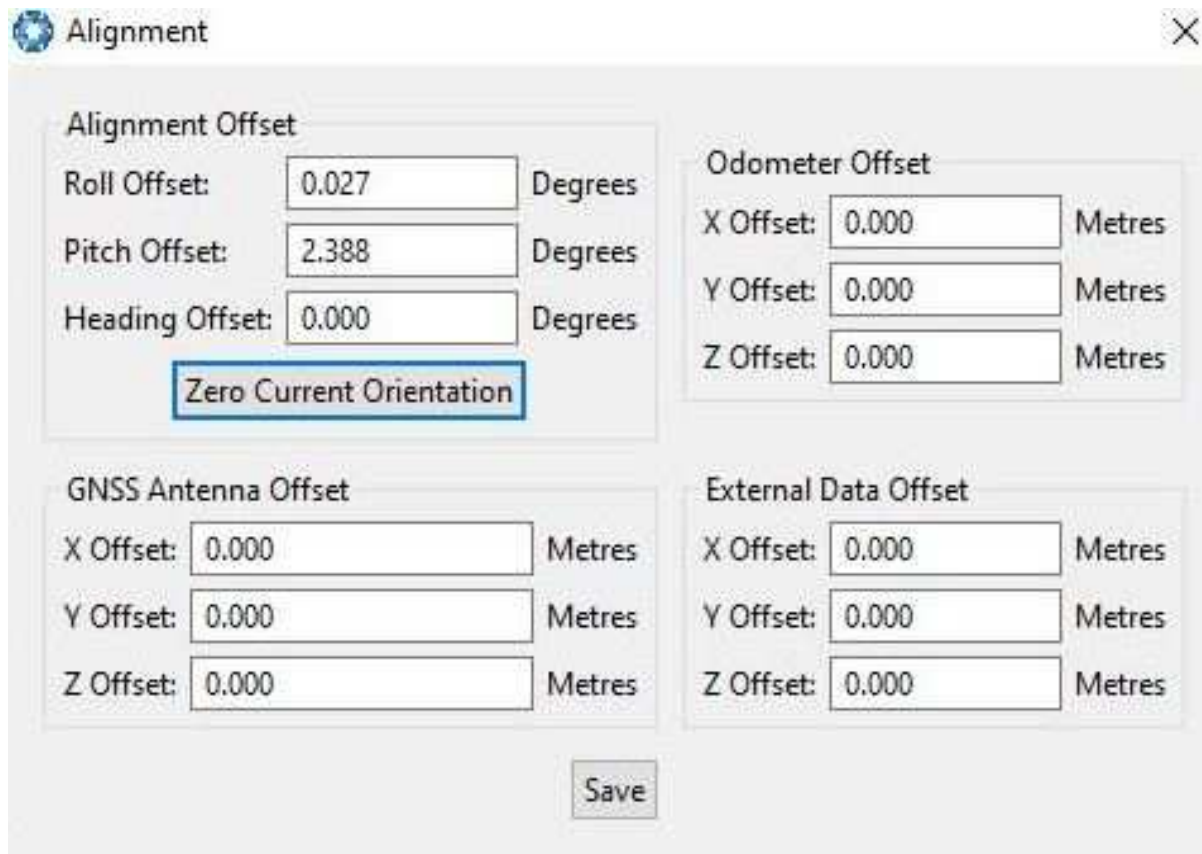
Save

Calibration by ‘Free-Float’ Method:-

Spatial Dual Manager Terminal program was chosen to observe the sensor.

The vessel was then allowed to float freely for 15 minutes and the data output by the motion sensor was observed.

Pre Zero-Orientation Screen Shot of the Spatial Dual Alignment



Spatial Dual Motion has been “Zero-Oriented” by clicking “Zero current Orientation” Option in Spatial Dual manager software.

Pritam Seth
FSINPVT Party Chief
Date: 06/05/2021

Atul Bhoite
Engineer
Date: 06/05/2021

SBES Calibration
SBES Barcheck Correction Table



Project No. J-HYD-20-174630	Project Title: Bathymetry Survey	Vessel: FUGRO ZODIAC	Place: DEV DAM
Date: 06-May-21	Time: 17:50	Client: GOV. OF GUJRAT	
Observed By: PRITAM SETH Project No. J-HYD-20-174630		Echo Sounder Model and SL. No. ODOM ECHOTRAC CV 100/ 007169	Area Depth 6

Echo Sounder Settings

Draft HI	Draft LO	Sound Velocity	
0.32	0.32	Average	Upto Depth
		1506	4.3
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	1.02	-0.02	4	3.98	0.02
2	1.99	0.01	3	2.98	0.02
3	2.97	0.03	2	1.99	0.01
4	3.98	0.02	1	1.01	-0.01
Average	0.01	Average	0.01	Average	0.01
Std. Dev	0.0216	Std. Deviation	0.0141	Cumulative Average	0.01
		Cumulative Std. Deviation	0.0053		

Partychief
Pritam Seth
FSINPVT


Deputy Executive Engineer
DEV DAM
Govt. of Gujrat

Location Name:	Dev Dam	Date:	28/07/2021		Instrument Name	CHC						
Work:	RTK Observation by Topography Team				Model no.	I 80						
Station Name	Observation Duration	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)	Remarks							
TBM-2	By rover 1	2 sec	350616.138	2474907.718	94.064	XYZ Value generated by RTK of Topography Team, Base station was on Dev Dam TBM-1 (Fugro provided XYZ value)						
TBM-2	By rover 2	2 sec	350616.1452	2474907.719	94.018	XYZ Value generated by RTK of Topography Team, Base station was on Dev Dam TBM-1 (Fugro provided XYZ value)						
TBM-2	By rover 3	2 sec	350616.1346	2474907.72	94.022	XYZ Value generated by RTK of Topography Team, Base station was on Dev Dam TBM-1 (Fugro provided XYZ value)						
Fugro Provided XYZ Value					Difference With Fugro Provided XYZ Value							
Station Name	Remarks	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)	Station Name	Remarks	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)
TBM-2	Fugro Provided Value	350616.134	2474907.723	94.063	TBM-2	Check by Rover 1	350616.138	2474907.718	94.064	-0.004	0.005	-0.001
					TBM-2	Check by Rover 2	350616.145	2474907.719	94.018	-0.011	0.004	0.045
					TBM-2	Check by Rover 3	350616.135	2474907.720	94.022	-0.001	0.003	0.041
<p>Note: Client has confirmed that Dev Dam the FRL value(89.65qm) is from Mean Sea Level, TBM-1 RL value is shifted from FRL(Full Reservoir Level) of the Dam Note: Base station was on Dev Dam TBM-1, TBM-1 value used to setup base (Fugro provided XYZ value), 3 reading taken for 2 sec each on TBM-2 by 3 rovers on pole mounted.</p>												
Prepared by Rambabu Sah												

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 :	DEV DAM	DEV DAM TBM1
	Observed By:	Pritam Seth, Atul Bhoite	
Date:	05-04-2021		

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

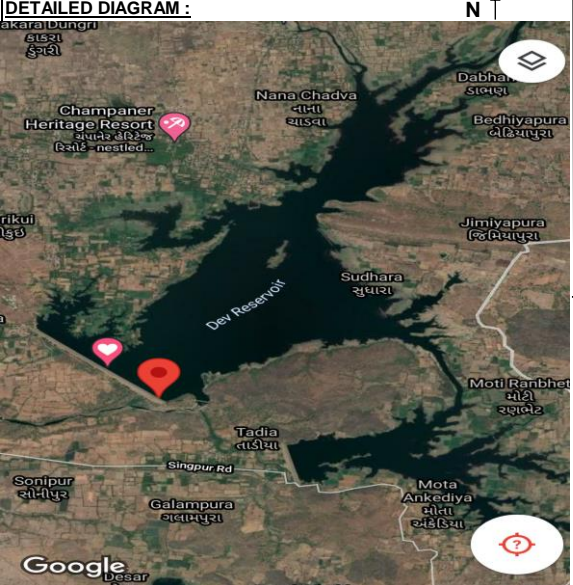
Final Coordinates in WGS84 Datum/UTM zone-43N			
GEOGRAPHICAL COORDINATES:		UTM COORDINATES:	
LATITUDE:	22°22'24.25256"N	EASTING:	3,50,650.092m E $\sigma = +/- 0.02$ m
LONGITUDE :	073°32'57.78771"E	NORTHING:	24,74,878.187m N $\sigma = +/- 0.02$ m
ELLIPSOIDAL HEIGHT:	35.612m Ell	CONVERGENCE :	-0.55227 Degrees
HEIGHT ABOVE LAT/CD:	NA	TBM VALUE:	94.128m w.r.t MSL


LOCATION & ACCESS : DEV DAM TBM1 established beside DEV dam road near Rest house Gate.

STATION MARKING : DEV DAM TBM1 established by Fugro. And point is marked with Yellow paint in a White concrete Piller.

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 DEV DAM GOVT. OF GUJRAT
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 Fugro Survey (India) Pvt. Ltd. D-222/30, TTC Industrial Area, MIDC, Nerul, Navi Mumbai Pin - 400 075 (India)	Station / Bench Mark Description	
	Job No. :	J_HYD_20_174630
	Client :	Govt. Of Gujarat
	Location :	DEV DAM
	Observed By:	Pritam Seth, Atul Bhoite
Date:	05-05-2021	
Station Name:		
DEV 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

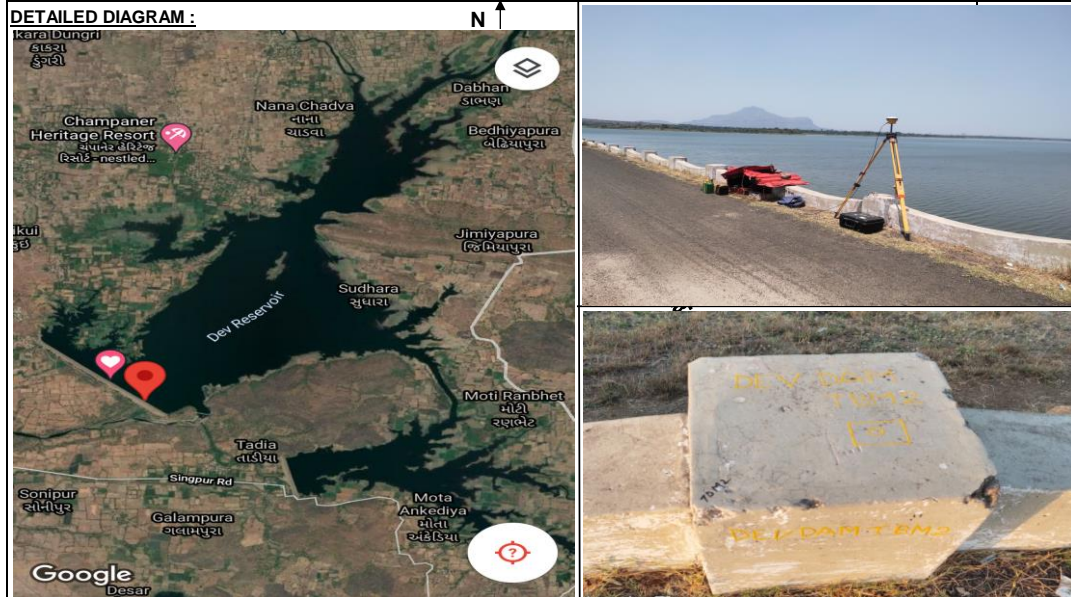
GEOGRAPHICAL COORDINATES:		UTM COORDINATES:		CM: 75° E
LATITUDE:	22°22'25.20221"N	EASTING:	3,50,616.134m E	$\sigma = +/- 0.02 m$
LONGITUDE :	073°32'56.59068"E	NORTHING:	24,74,907.723m N	$\sigma = +/- 0.01 m$
ELLIPSOIDAL HEIGHT:	35.554m	CONVERGENCE :	-0.5524 Degrees	
HEIGHT ABOVE LAT/CD:	NA	TBM VALUE:	94.063m w.r.t MSL	

LOCATION & ACCESS : DEV DAM TBM2 Established beside DEV Dam road. 50m from DEV DAM TBM1.

STATION MARKING : DEV DAM TBM2 established by Fugro. And point is marked with Yellow paint in a White Concrete Piller..

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
DEV DAM
GOVT. OF GUJRAT

LEVELLING RECORD FROM TOP OF DAM AND HFL of DEV 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:	DEV DAM	Date of Observation:	06/05/2021
Observer's Name:	Pritam Seth	Staff Holder's Name:	Atul Bhojte

TOP OF DAM TBM TO DEV DAM TBM1			
BACK SIGHT	FORE SIGHT	RL Value	Point Name
		93.65	TOP OF DAM
1.367	0.889	94.128	DEV DAM TBM1
0.893	1.371	93.65	TOP OF DAM
Miscloser value	0		

HFL TO ATG TBM	
Point Name	RL Value(m)
HFL	90.15
Tape Measurement	1.945
ATG TBM	92.095
Adjusted Tide Gauge Height	92.095
TBM to ATG Sensor	9.855
The Zero of Tide Gauge	82.24

DEV DAM TBM1 TO DEV DAM TBM2			
BACK SIGHT	FORE SIGHT	RL Value	Point Name
		94.128	DEV DAM TBM1
0.95	1.015	94.063	DEV DAM TBM2
1.045	0.98	94.128	DEV DAM TBM1
Miscloser value	0		

NOTE- FRL Value 89.65m, HFL Value 90.15m, TOP OF DAM 93.65 w.r.t MSL Provided by Client.
 HFL to ATG TBM measured by Measuring Tape manually = 1.945m. So, ATG TBM= 90.15m + 1.945m = **92.095m W.R.T MSL.**
 DEV Dam TBM1 and DEV Dam TBM2 established by Fugro for Topography purpose. ATG TBM used for Setup ATG and Mesure Daily Water Level.



Photograph showing the Water Level Measurement Pillar at Dev Dam with HFL and FRL values

PRITAM SETH
 PARTY CHIEF
 FSINPVT

 Deputy Executive Engineer
 DEV DAM
 GOVT. OF GUJRAT

Appendix F

List of Charts

(1 page)

List of Reports / Documents to be Submitted

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

Details of Charts Accompanying this Report

Details of Charts							
Sl. No.	Charts showing Results of Bathymetry and Topography Survey at Deo (Dev) Reservoir	Sheet No.	Encl. No.	Drawing No.: JHYD-20-174630/WRD/GUJARAT/BS/	Rev. No	HS	VS
1	Reservoir Bed and Topographic Heights	01 of 01	01 of 03	B/01/9511	R0/Rev.0	1:10000	-
2	Contour Map of Deo (Dev) Reservoir	01 of 01	02 of 03	B/01/9671	R0/Rev.0	1:10000	-
3	Shaded Relief Image Prepared from SBES Data	01 of 01	03 of 03	I/01/9672	R0/Rev.0	1:10000	-
Details of Other Deliverables							
1	L-section	Soft copy					
2	C-section at every 100 m	Soft copy					