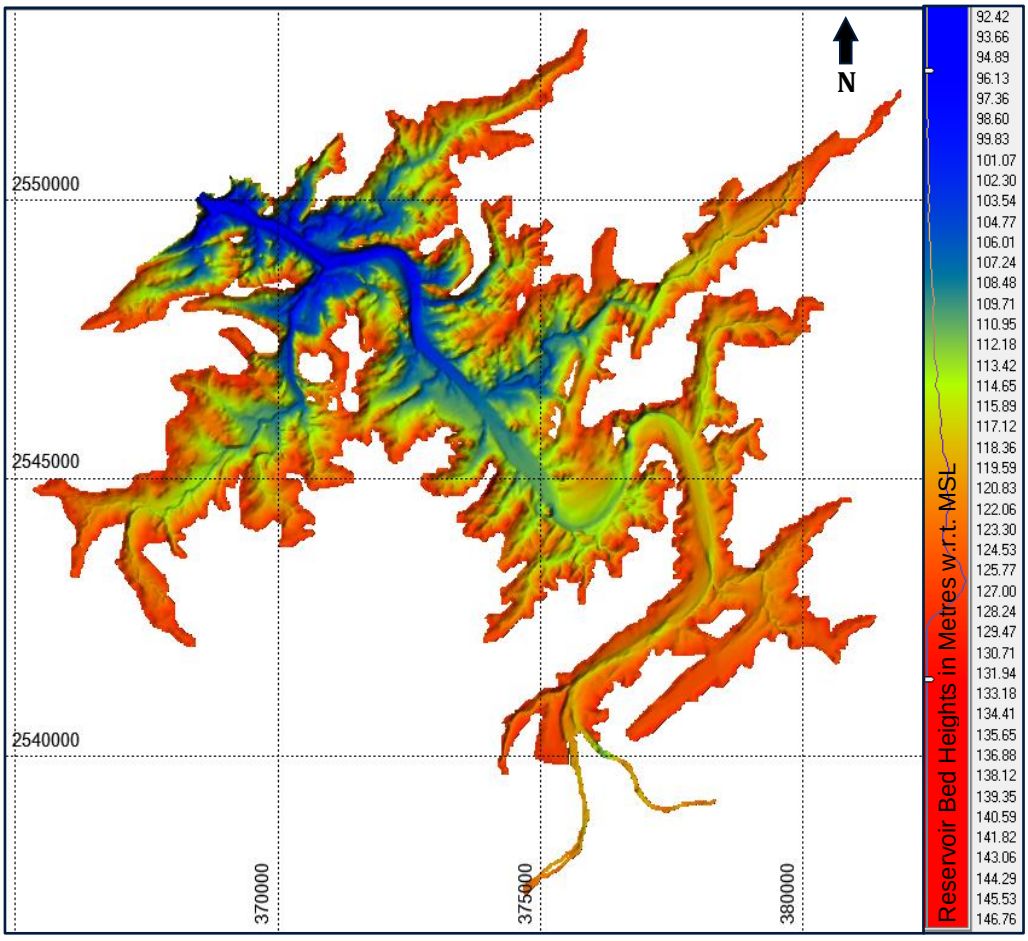

Providing Services for Conducting Bathymetric Survey of Reservoirs of Central Gujarat Under National Hydrology Project

Survey Results of Panam Reservoir Location | Central Gujarat

JHYD20-174630-Volume 1-Panam Reservoir/R3 [03] | 22 September 2021

Final Report

(Final Issue)

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

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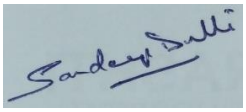
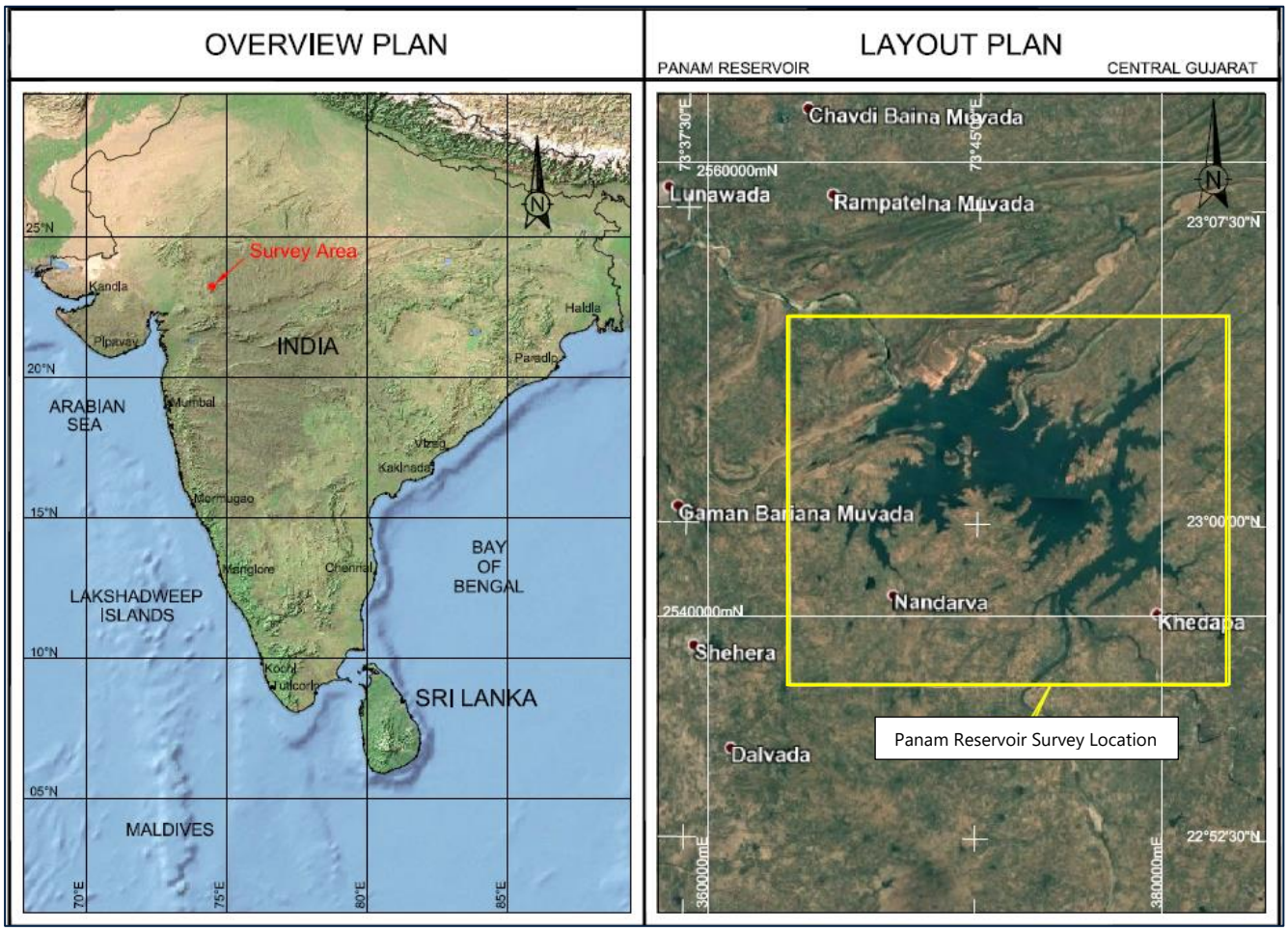
[03]	22 September 2021	Final Report (Final Issue)			
			Sandeep Dutta	G.N. Hariharan	Rahul Patkar

LOCATION MAP



EXECUTIVE SUMMARY

Survey Overview – Panam Reservoir

Preamble:	The Gujarat State Government is implementing World Bank assisted national hydrology project. This project aims to improve the planning, development, and management of water resources, as well as flood forecasting and reservoir operations in real-time. Various activities, including Sediment survey, Water Quality monitoring have been planned under this project. Water Resources department have evolved a comprehensive plan for periodic assessment of reservoir storage capacity and sedimentation of eleven (11) reservoirs. In this regard, **Narmada Water Resources, Water Supply and Kalpsar Department/ Government of Gujarat** contracted **Fugro Survey (India) Pvt. Ltd. (FSINPVT)** to carry out the Bathymetry and Topography survey. Fugro's scope of work consist of Bathymetry and Topography survey at the eleven (11) reservoirs. In order to complete the scope, the survey was carried out in two passes; • Pass 1: Bathymetry / Hydrographic Survey. • Pass 2: Topographical Survey
Data Acquisition:	**FSINPVT** mobilised their topographical and bathymetry survey team and equipment along with survey boat Fugro Zodiac 1 and Polaris' which was deployed from the month of December 2020 to February 2021 in order to acquire survey data as per mutually agreed scope and relevant survey specifications.
Survey Location	Panam Reservoir, Keldezar village, Shehera Taluka, District – Panchmahal, Gujarat.
Survey Geodesy:	The survey was conducted in WGS 84 datum, Universal Transverse Mercator (UTM) Projection, Zone 43 N, CM 075°E.
Scope Compliance & Meets Client's objectives:	FSINPVT performed this survey methodically as per the scope of work defined in the contract and the results obtained have met the client's objectives in following areas: ■ To assess the reservoir storage capacity; ■ To assess the variations in the reservoir capacity; ■ To estimate and study sedimentation behaviour in horizontal zones and vertical zones, namely dead storage, live storage and flood storage; ■ To upgrade Elevation–Area-Capacity tables / curves of reservoir at regular intervals; ■ To create historical database for further water resources usage planning.
Accuracy and Reliability	The accuracy of the data logged was ensured by calibrating each and every sensor deployed in the current survey. Statistical techniques were applied during the execution of the survey to ensure that the results of survey conform to the agreed levels of accuracy and precision.
Reservoir water level correction	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 – Panam Reservoir Location	
Reservoir Bed levels	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 92.5 m w.r.t. MSL (368 624 mE, 2 550 008 mN) and highest reservoir bed elevation mapped during topography survey was FRL 127.44 m w.r.t. MSL (369 087 mE, 2 549 351mN) within the survey area.
Capacity Survey (2020-2021)	Elevation Area Capacity table and curve of Panam 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 to FRL 127.44 m was calculated using GIS software.
Revised elevation area capacity details	In comparison with 2011 survey results, the present survey results indicate that the gross storage capacity has increased. However, in comparison with 1977 Original Project data, there is a loss in gross storage capacity. As per the revised elevation area capacity curve for the year 2020, the storage capacity is found to be close to year 2004.
Annual loss in storage capacity	As per 2020 survey results, the annual loss in Gross storage capacity w.r.t. 1977 or volume of sediment deposited in the Panam reservoir is 75 Mm^3.
Trap efficiency & Sedimentation Index	Trap Efficiency and sedimentation Index calculated for Panam reservoir as per methodology give in IS-12182 (1987) is 95% and 1.58 x 10^{11} s^2/m respectively
Sedimentation rate	The rate of siltation in Panam reservoir is 1.705 Mm^3/year
Observed rate of siltation	The observed rate of siltation in the Panam reservoir during the 44 year life span (1977 – 2020), works out to 7.366 Ham/100 km^2/year.
Annual % loss	The annual % loss in gross storage capacity for Panam reservoir during the 44 year life span is 0.23% and hence, the reservoir is classified as “Significant category” as per IS-12182 (1987).

CONTENTS

APPENDICES

TABLES

FIGURES

LIST OF ABBREVATIONS

BM	Benchmark
Ch	Channel
CM	Central Meridian
CVT	Calibration, Verification & Test
DF	Dual Frequency
DGNSS	Differential Global Navigation Satellite System
DPR	Daily Progress Report
FBF	Fugro Binary Format
FRL	Full Reservoir Level
FSINPVT	Fugro Survey (India) Private Limited
GLONASS	Global Navigation Satellite System
GPS	Global Positioning System
HSE	Health, Safety and Environment
km	kilometre
m	metre
MCM	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
RTK	Real Time Kinematic
SBES	Single beam Echosounder
Sr	Senior
SoW	Scope of Work
TBM	Temporary Benchmark
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 01 December 2020”

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 Anton J., 2016).

Reservoir sedimentation is a process of erosion, transportation, deposition and compaction of sediment 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 (Greg 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) reservoirs (for details of reservoirs, refer table 1.2), 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;

Pass 1: Bathymetry / Hydrographic Survey;

Pass 2: Topographical Survey.

The bathymetry survey work was performed from the shallow draft boat 'Fugro Zodiac 1' and 'Polaris'.

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

1.2 Study Area

The present study area falls under 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 River and its tributaries constitute an inter-state river system flowing through the states of Madhya Pradesh, Rajasthan and Gujarat. Mahi river is comprised of several tributaries on both the banks, viz. Som, Anas, Panam and others.

The Mahi basin covers an area of 15,474 km^2 (40.36%) in Gujarat accounting to 41.73% of the total basin area.

Mahi is the major inter-state west flowing river of India, rising from the northern slopes of Vindhyas in Madhya Pradesh at an elevation of about 500 m and draining into the Gulf of Khambhat. The Mahi River flows for about 538 km through Dhar, Jhabua and Ratlam districts of Madhya Pradesh, Banswara in Rajasthan and Panchmahal district of Gujarat before falling into the Arabian Sea through the Gulf of Khambhat in Kheda district of Gujarat. The principal tributaries of the Mahi River are the Som, a right bank tributary, which rises on eastern slopes of Aravalli in Udaipur district of Rajasthan and Anas, a left bank tributary, which rises from Jhabua district of Madhya Pradesh joining Mahi in Dungarpur district of Rajasthan. The Panam rises near Bhabra in Jhabua district of Madhya Pradesh joining Mahi from left in Panchmahal district of Gujarat.

Panam is a left bank tributary of Mahi River. Panam river rises near Bhadra on the northern slopes of Vindhyas near Jhabua district of Madhya Pradesh at an elevation of about 300 m above m.s.l. It flows in the north-west direction and joins the Mahi River on its left bank in the Panchmahal district of Gujarat. It has a total length of about 136 km and drainage area of about 2470 km^2.

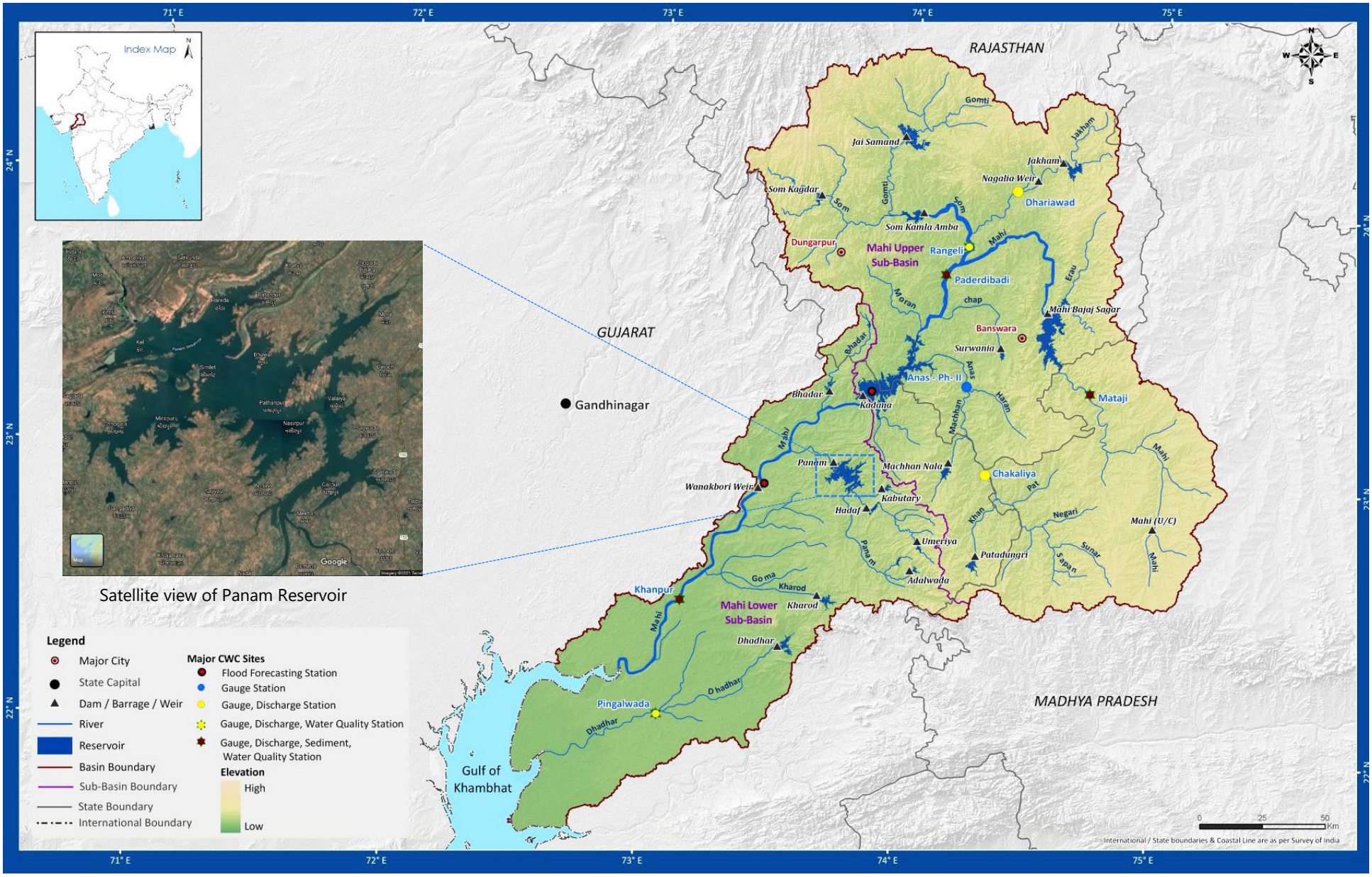


Figure 1.1: Mahi basin showing major tributaries – Drainage and sub-basin (Courtesy: India-WRIS)

1.3 Geology of Study Area

The available information on soil survey (Source: Irrigation Commission Report-1972) conducted in the Mahi basin indicates that the basin consists mainly of red and black soils. Panchmahal district has soils that are somewhat different from those in the other districts, in that they are residual soils, formed by the decomposition of granites and gneisses. Geologically, Panchmahal district is the manifestation of diverse geological extension from Lower Proterozoic to Holocene with different rock types such as granite to basalt and limestone to alluvium. Soils of the Panam river and its catchment are derived from rocks like quartzites, schists and phyllites.

The oldest formation in the area is Aravallis Supergroup comprising of various meta-sediments belonging to Lower Proterozoic. Godhra granite and gneisses were intruded into older Aravalli. Aravallis and granite-gneiss have undergone many orogenic movements. 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. Alluvial deposits occur in the vicinity of the river and in intermittent valleys. The thickness and extent of alluvial formation is however very limited (Nayak K.M., 2014).

1.4 Panam Reservoir Characteristics

The Panam reservoir for Panam dam is constructed over the perennial Panam river in India. It is located near Keldezar village, in Shehera taluka, Panchmahal District in State of Gujarat. The Panchmahal district in Gujarat comes under heavy rainfall areas in Gujarat, having sub-tropical climate with moderately low humidity.

The Panam dam is masonry type dam and its reservoir's catchment area are 2314 km^2. The catchment is mostly hilly and covered with forest except near the dam site where it is relatively flatter. The Full Reservoir Level (FRL) is 127.44 m and Minimum Draw Down Level (MDDL) is 108.20 m. The gross storage capacity is 735.80 Mm^3. The gross storage included dead storage of 56.60 Mm^3 and live storage of 679.20 Mm^3. Salient features of the Panam reservoir are tabulated below:

Table 1.1: Panam Reservoir Specifications

Characteristics	Value for reservoir (client provided)
Reservoir name	Panam
Location	Keldezar village, Shehera Taluka, District – Panchmahal, Gujarat
River	Panam
Total catchment area in Gujarat	2314 km^2
Mean annual rainfall	940 mm
Mean annual runoff at the dam site	26 Mm^3

Characteristics	Value for reservoir (client provided)
Year of impounding	1977
Dam Type	Masonry
Length of dam	182 m
Spillway Type	Ogee
Spillway length	182 m
Maximum discharge	10090 m^3/sec
Type and No. of gates	Radial, 10
Reservoir Crest Level	116.70 m
FRL	127.44 m
Dead R.L.	108.20 m
Area at FRL	89.80 km^2
Gross storage capacity	735.80 Mm^3
Effective Storage Capacity	679.2 Mm^3
Area under submergence	5827.3 Ha
Length of canal	99.725 km
Canal Capacity	27.95 m^3/s
Gross command Area	5827.3 Ha

1.5 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 the details of area covered as part of bathymetry and topography survey.

Table 1.2: Reservoir details for Bathymetry and Topography Survey

SL No.	Name of Dam	Area (km^2) covered under Bathymetry Survey	Area (km^2) covered under Topography Survey
1	Panam	53	18

1.6 Scope of Work

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

1.6.1 Pass 1: Bathymetry / Hydrographic Survey

The scope of work for bathymetry survey conforms bathymetry survey for total area of approximately 53 km^2.

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

- Bathymetry / Hydrographic survey work was conducted using echosounder for assessment of reservoir capacity and sedimentation at Panam reservoir of Central Gujarat.
- Survey lines were run at 25 m segment line spacing and along the survey line continuous data of 25 m x 25 m grid point were captured so that each and every point is included. Additional survey lines were executed as and when required.
- DGNSS positioning system, Dual frequency single beam echosounder system along with associated Navigational system were deployed on all the survey lines.

1.6.2 Pass 2: Topographical Survey

Topographical survey was carried out using Total station and equivalent levelling instruments. The total area covered in Topographical survey is 18 km^2. Following scope of work was undertaken in order to achieve client objectives:

- Topographical survey was conducted to facilitate hydrographic survey so as to fill up the gaps between MWL area and reservoir submergence area till current water level for assessment of reservoir capacity and sedimentation at the reservoir locations.
- Topographical survey was carried out from FRL 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 up to 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).

1.7 Survey Execution

The survey boat ‘Fugro Zodiac 1’ and ‘Polaris’ was mobilized at Panam reservoir location to carry out the survey. Survey operations were executed as per the mutually agreed survey execution schedule.

1.8 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

1.9 Deliverables

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

2. Survey Specifications and Resources

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

2.1 Survey Geodesy

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

Table 2.1: Geodetic Datum, Projection Parameters

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

2.2 Horizontal Control

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

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

2.3 Vertical Control / Water Level Corrections

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

Table 2.2: Observed Reservoir Water Level w.r.t. MSL

Date	Observed Reservoir Water Level w.r.t. MSL [m]	Date	Observed Reservoir Water Level w.r.t. MSL [m]	Date	Observed Reservoir Water Level w.r.t. MSL [m]
06/12/2020	125.10	10/01/2021	124.33	10/02/2021	123.43
07/12/2020	125.10	11/01/2021	124.31	11/02/2021	123.43
08/12/2020	125.05	14/01/2021	124.26	12/02/2021	123.39
09/12/2020	125.05	15/01/2021	124.25	13/2/2021	123.39
10/12/2020	125.00	16/01/2021	124.23	14/2/2021	123.34
12/12/2020	124.95	17/01/2021	124.20	15/2/2021	123.32
13/12/2020	124.95	18/01/2021	124.17		
14/12/2020	124.95	19/01/2021	124.13		
15/12/2020	124.90	20/01/2021	124.10		
16/12/2020	124.90	21/01/2021	124.08		
17/12/2020	124.87	22/01/2021	124.06		
18/12/2020	124.85	23/01/2021	124.05		
19/12/2020	124.83	24/01/2021	124.04		
21/12/2020	124.81	25/01/2021	124.04		
24/12/2020	124.74	26/01/2021	124.02		
25/12/2020	124.72	27/01/2021	124.01		
28/12/2020	124.68	28/01/2021	124.00		
29/12/2020	124.64	29/01/2021	124.00		
30/12/2020	124.60	30/01/2021	123.90		
31/12/2020	124.56	31/01/2021	123.88		
01/01/2021	124.53	01/02/2021	123.75		
02/01/2021	124.50	02/02/2021	123.71		
03/01/2021	124.47	03/02/2021	123.69		
04/01/2021	124.45	04/02/2021	123.67		
05/01/2021	124.45	05/02/2021	123.65		
06/01/2021	124.42	06/02/2021	123.60		
07/01/2021	124.40	07/02/2021	123.50		
08/01/2021	124.38	08/02/2021	123.50		
09/01/2021	124.35	09/02/2021	123.48		

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 'Zodiac 1'

Bathymetry Survey Personnel	
Personnel Name	**Function**
Pritam Seth	Party Chief / Surveyor
Arpit Bose	Party Chief / Surveyor
Sai Kiran A.	Engineer
Sunil Singh	Zodiac 1 Operator

Table 2.4: List of Survey Personnel – Bathymetry Survey 'Polaris'

Bathymetry Survey Personnel	
Personnel Name	**Function**
Mathiyazhagan V.	Engineer
Vishal Kumar	Polaris Operator

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

Table 2.5: List of Survey Personnel – Topography Survey

Topography Survey Personnel	
Personnel Name	**Function**
Pritam Seth + 2 Survey Assistant	Topographic Survey Team

Following onshore FSINPVT staffs were associated to this project.

Table 2.6: 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

Onshore Project Management and Data QC	
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 Zodiac 1 and Polaris is placed at Appendix C to this document.

Table 2.7: Survey Equipment / Systems Deployed for Bathymetry Survey in Zodiac 1

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	Midas & Echotrac CV100 Dual Frequency Single Beam Echosounder
Tide Measurement	Veleport Tide Master

Table 2.8: Survey Equipment / Systems Deployed for Bathymetry Survey in Polaris

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

Table 2.9: Survey Equipment / Systems Deployed for Topographical Survey

Equipment / System	Description / Make / Model/Resolution /Accuracies
Land Survey	GNSS RTK System E-600 along with accessories and consumables.

2.7 Survey Vessel

Shallow draft boat 'Fugro Zodiac 1' and 'Polaris' was used to carry out the bathymetry / hydrographic survey.

Figure 2.1: Survey boat Fugro Zodiac

Figure 2.2: Survey boat Polaris

2.8 Survey Database Used

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

- Client Supplied BM – 132.412 m.
- High Flood Level – 128.015 m.
- Water Line @ - 124.00 m (approx.).

3. Survey Data Acquisition

3.1 Survey Planning, Preparation & Transportation to Site

The bathymetry survey equipment and personnel for 'Fugro Zodiac 1' arrived at Panam reservoir location on 04 December 2020 and equipment was mobilised on-board the survey boat 'Fugro Zodiac 1' on 05 December 2020.

Bathymetry survey equipment and personnel for 'Polaris' arrived at Panam reservoir location on 12 January 2021 and equipment was mobilised on-board the survey boat on 13 January 2021.

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

The topography survey equipment and personnel arrived at Panam reservoir location on 27 December 2020 and commenced survey on 28 December 2020. The topography survey was completed on 28 January 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 boats 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'. Station description for client supplied Benchmark and TBM is placed at Appendix E.

3.3.1 Heading Sensor Alignment

Vessel heading was obtained onboard 'Fugro Zodiac 1' and 'Polaris' from Spatial Dual. Spatial dual features dual antenna moving baseline RTK. This enables it to provide extremely accurate heading both at rest and at movement. It's a great option for situations where magnetic heading isn't possible due to interference or where extra precision is required. The system was tested at FSINPVT workshop prior to mobilization for the survey. The performance of the system was found to be satisfactory during the period of survey.

3.3.2 Navigation System

The Positioning System on board 'Fugro Zodiac 1' and 'Polaris' was Spatial Dual.

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

Table 3.1: Results of Positioning System Verification

Sensor	Serial No.	Easting (mE)	Northing (mN)	Latitude	Longitude	Ellipsoidal Height (m)
Positioning System Verification Results With BX-992 and Spatial Dual Receiver (Fugro Zodiac 1)						
Trimble BX-992	025-00009601	368442.10	2550006.133	23°03'12.162" N	073°42'57.047" E	76.118
Spatial Dual	025-00006405	368441.84	2550006.218	23°03'12.164" N	073°42'57.038" E	76.201
Difference		**0.260**	**-0.085**	--	--	**-0.083**
Positioning System Verification Results With BX-992 and Spatial Dual Receiver (Fugro Zodiac 1)						
Trimble BX-992	025-00009601	368442.100	2550006.133	23°03'12.162" N	073°42'57.047" E	76.118
Spatial Dual	025-272968	368441.893	2550006.175	23°03'12.163" N	073°42'57.040" E	76.353
Difference		**0.207**	**-0.042**	--	--	**-0.235**

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 Single Beam Echosounder

Midas, Echotrac CV100 and Echotrac E20 single beam dual frequency 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. The echo sounder system was interfaced with the Starfix NG navigation and survey system for logging the depth vs position data. Sound velocity within water column was measured on a regular basis using sound velocity profiler and average sound velocity was entered in the top side unit of the echo sounder.

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

Date	SBES Sensor Type	Average (m)	Standard Deviation
Summary of SBES Calibration Results on-board 'Fugro Zodiac 1'			
06 December 2020	Midas DF SBES	-0.02	0.0172
Summary of SBES Calibration Results on-board 'Polaris'			
12 January 2021	Echotrac E20	0.00	0.00

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 were quality checked and an extract of the same were made available for verification and confirmation to proceed further.

3.5 Topography Survey

3.5.1 RTK Verification

The RTK system verification was carried out by 'Static Observations' for 30 minutes at Permanent Benchmark (Panam Dam BM) and Temporary Benchmark locations (TBM P01).

3.5.2 RTK Position Comparison

The RTK observed position at Permanent Benchmark and Temporary Benchmark location was compared to that of Trimble BX992 Receiver position. Details of the comparison is tabulated below:

Table 3.3: Results of RTK Position Comparison

Sensor	Serial No.	Easting (mE)	Northing (mN)
Panam Dam BM (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	368442.100	2550006.130
RTK Rover	--	368441.948	2550006.157
Difference		**-0.165**	**0.028**
TBM P-01 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	368490.850	2550059.290
RTK Rover	--	368491.015	2550059.262
Difference		**0.152**	**-0.027**

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 FRL 127.44 m is carried out by topography survey method.

The topography survey was carried out using GNSS RTK E600 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., the benchmark location (Panam dam BM) and thereafter the tripod was levelled and the base receiver was configured.

- The rover receiver along with RTK pole was installed at TBM-01 (created by Fugro) location. Static observation was carried out subsequently as part of verification.
- The Base receiver is installed at Base station (BM) and configured the system with Known coordinates with elevation. The rover receiver position and elevation are verified by setting up the system at TBM P-01.
- 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.

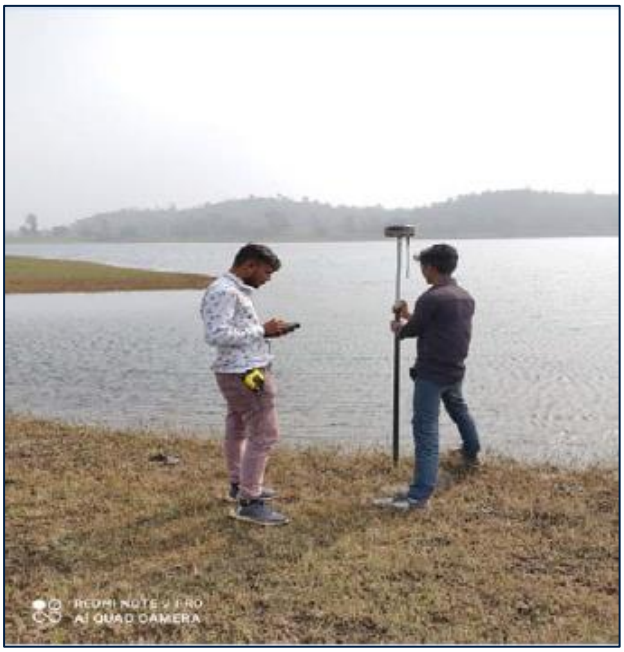


Figure 3.1: Existing water line being picked up by RTK Rover

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 FRL 127.44 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 Mean Sea Level (MSL), applying observed Reservoir Water Level / Height heights recorded at Dam. (Refer Figure 4.1)
- The data was filtered, cleaned, and combined to create geographically positioned bathymetric data set that has been corrected for MSL and sound speed.
- Starfix.Workbench & Mproc was used to quality check the data.

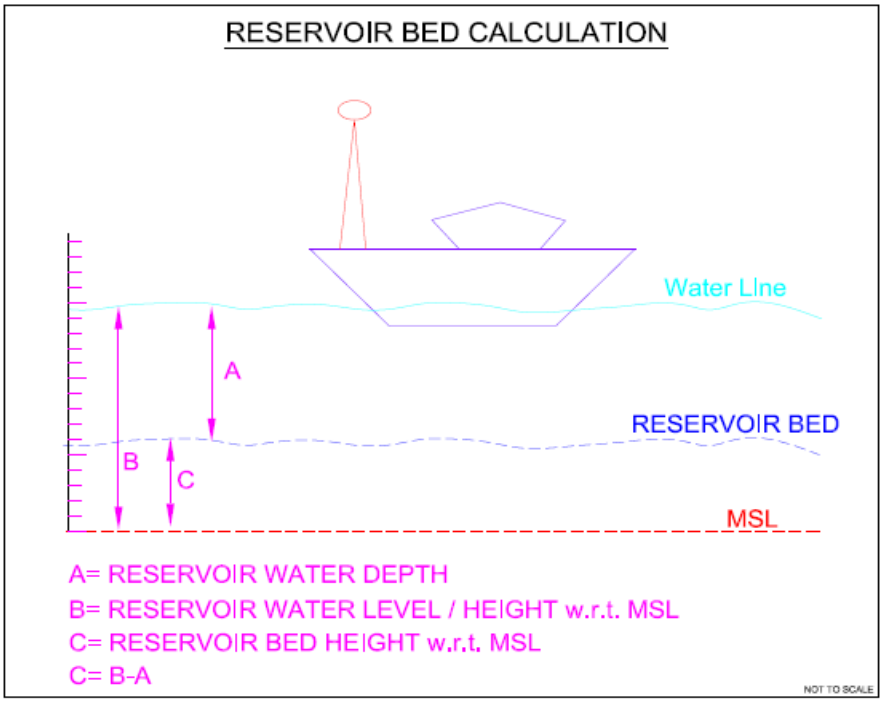


Figure 4.1: Reservoir Bed Height Calculation w.r.t. MSL

4.3 Creating Digital Terrain Model (DTM)

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

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

Where:

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

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

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

4.4 Development of Area Capacity Curves

Area Capacity curves are useful tools for operational and planning purposes such as water management and sediment monitoring. By comparing the area capacity curves at different times, the rate of sedimentation in the reservoirs can be determined. These curves show the capacity and surface area of the reservoir at an indicated elevation above the reference elevation level. The elevation area capacity curves are prepared using the DTM for the reservoir site. For, this study the reference elevation level used for the preparation of Area capacity curve is 92.5 m which is the lowest bottom level for the reservoir and the maximum level considered is 129.72 m. The incremental value for elevation used for developing these curves is kept at 0.1 m. The surface area at the successive intervals was obtained in GIS software by intersecting the DTM with horizontal planes at an interval of 0.1 m starting from the zero bed elevation till the MWL. The incremental volume (ΔV_i)between two contours was then calculated and integrated from bottom to specified elevation to obtain the required capacity at specified elevation.

The method and formula used for volume calculation is the cone formula given by the equation 2.

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

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

4.5 Sedimentation in Different Zones of Reservoir

The sediment entering into the reservoir carried by the flowing river from the upstream catchments get deposited in the reservoir with the passage of time and reduces the live as well as dead storage capacity of the reservoir. 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.

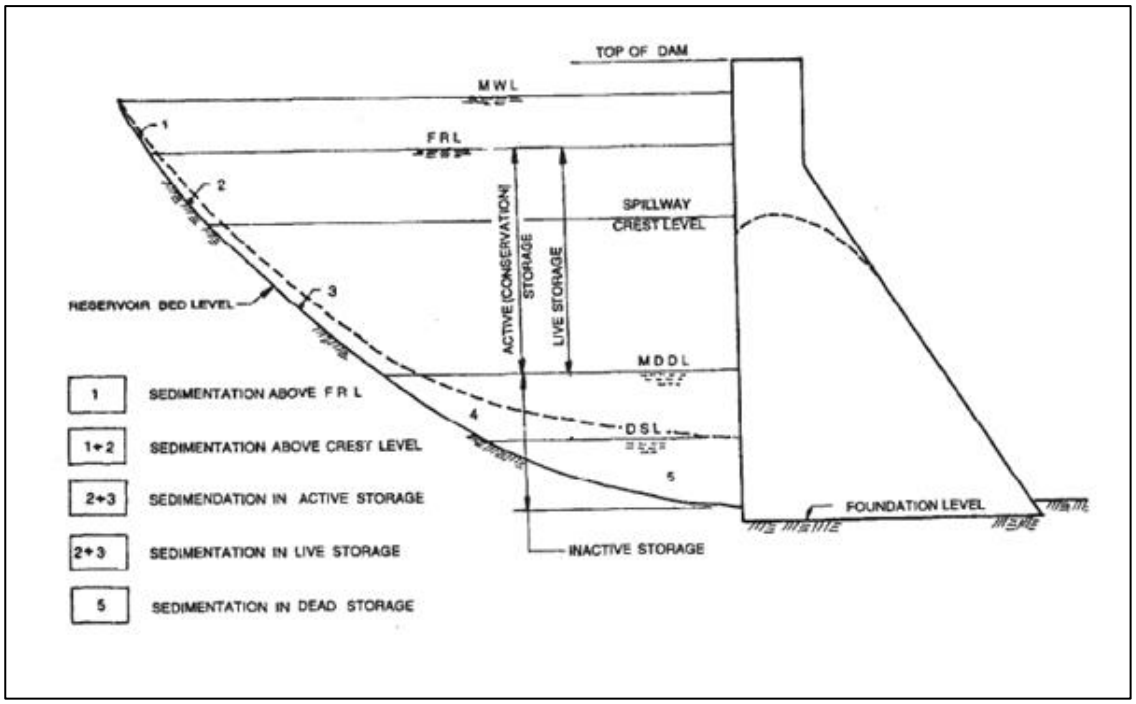


Figure 4.2: Sedimentation in different zones of reservoir (Ref: IS-5477 (Part 1): 1999)

This causes the bed level near the dam to rise and the new elevation is called zero bed elevation. Therefore, the first step for computing the sedimentation in different zones of reservoir begins with predicting the new zero bed elevation. The initial guess of the value is calculated using Moody's Method as shown in standard code, IS-5477 (Part 2): 1994. The Moody's method takes into account the two parameters, f(p) and f'(p) for doing the calculations. To determine, new zero elevation (NZE) these two parameters must be equal. These two parameters are explained below.

$$f(p) = (1\text{-}V(p))/a(p) \quad (3)$$

$$f'(p) = (S\text{-}V(pH))/HA(pH) \quad (4)$$

Where,

f(p)	-	A function of relative depth of reservoir for one of the four types of theoretical design curves
V(p)	-	Relative Volume at given elevation
a(p)	-	Relative Area at given elevation
f'(p)	-	A function of relative depth of reservoir for a particular reservoir and its anticipated sediment storage
S	-	Total volume of sediment in the reservoir
V(pH)	-	Reservoir capacity at given elevation
H	-	Total depth of reservoir
A(pH)	-	Reservoir area at given elevation

However, the final value is fixed based on the trial and error method only. There are several methods available for predicting the sediment distribution for design purpose. However, two methods- Empirical Area method and Area Increment method are widely used. Among these two methods, the empirical area method is more exact while area increment method is not only approximate but is only valid when the ratio of sediment deposited over the period of 100 years and the reservoir capacity is less than 15%. Therefore, in this study Empirical Area method has been used. The method was developed by Borland and Miller (1958) from analysis of sediment distribution data obtained from surveys of 30 reservoirs. They prepared area design curves for the four standard types of reservoirs with relative sediment area as ordinate and relative depth as abscissa, the area under the curve being unity in each case. The curve given by the equation (5).

$$Ap = Cp^{m}(1-p)^{n} \quad (5)$$

Where,

Ap	-	Non-dimensional area
P	-	Relative depth of reservoir.

Where, m and n are constants whose values depend on type of reservoir and their respective values can be obtained from IS-5477 (Part 2): 1994.

The stepwise procedure for computation is as below.

- Determine the type of reservoir by determining the value of M. Determine the relative depth for each increment at each value of h.
- Select as a first approximation a NZE (an elevation upto which the reservoir is expected to be filled up completely by sediment). Sediment area at and below this elevation will be equal to the original reservoir area. Sediment areas for each depth increment above the assumed NZE would be obtained by finding, K = Ao/Ap and multiplying K by the Ap value at each h, where A_o is the original area at the new zero elevation.

- After computing the sediment areas, the incremental sediment volumes can be computed as explained earlier. If the cumulative sediment volume does not tally with the anticipated sediment accumulation in the reservoir, the second approximation for the NZE would have to be made.

After selecting the method for predicting the sediment distribution, it is essential to determine the category of reservoir under which the reservoir under study falls. These categories are decided based on the inverse of slope (M) of graph of reservoir depth vs Capacity plotted on a log-log graph paper (refer Figure 4.3). There are four categories of reservoir stated in IS-5477 (Part 2): 1994 (refer Table 4.1).

Table 4.1: Types of Reservoirs

Type	Type of Reservoir	Range of M
1	Lake	3.5-4.5
2	Flood plain Foot Hill	2.5-3.5
3	Hill	1.5-2.5
4	Gorge	1-1.5

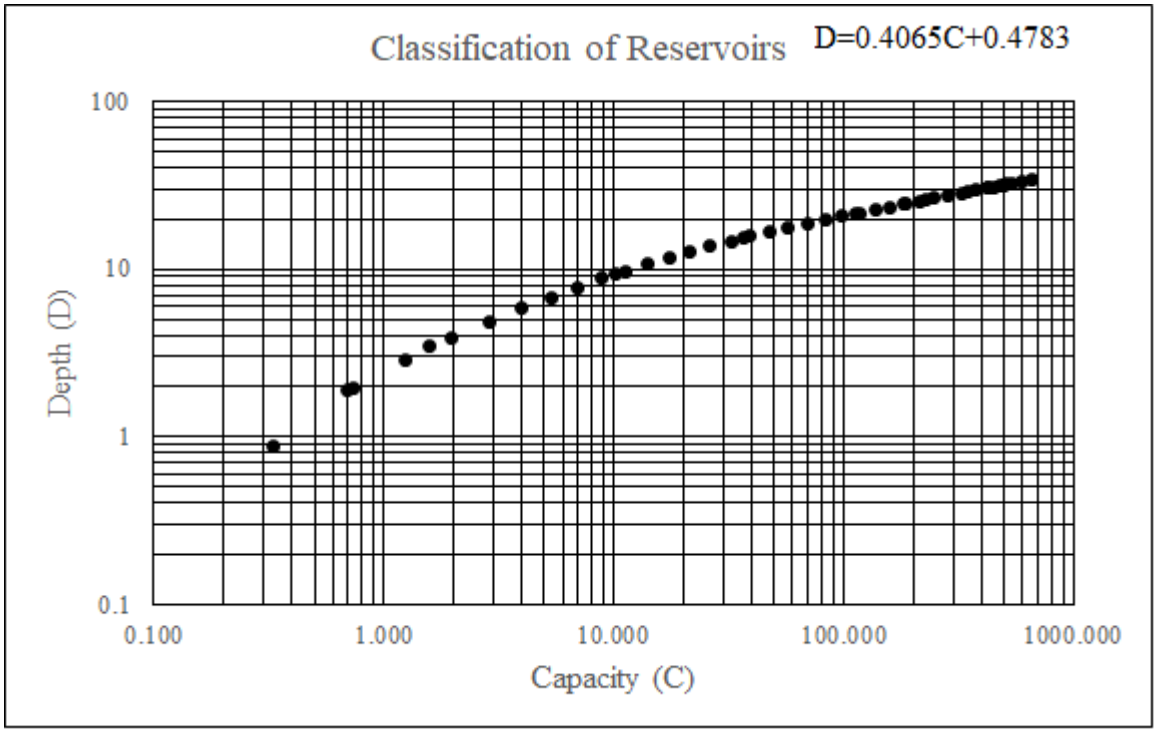


Figure 4.3: Classification of Reservoirs

As per the Figure 4.3, the equation of the best fit line is given in equation (6)

$$D = 0.4065C + 0.4783 \quad (6)$$

and the coefficient of correlation (R^2) of the best fit line with the actual values is 0.95. From, equation (6), the slope of line is 0.4065. Therefore, the inverse of the slope (m) has the value of 2.5, hence the Panam reservoir is Type II (Flood Plain Foot Hill Type).

Moreover, it is essential to calculate the trap efficiency and the silt index which will be useful in further calculations. The capacity of reservoir at FRL is 660.799 Mm^3 and mean annual inflow is 357.96 Mm^3. Therefore, capacity inflow ratio is 1.846. The values of trap efficiency are 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 calculation of period of retention and flow velocity are given in standard codes such as IS-12182, 1987. The values are shown in Table 4.2.

At last, sedimentation volumes are compared with sedimentation volumes from previous year surveys and rate of sedimentation, loss of capacity as well as annual loss percentage is computed and compared with the values of previous years to arrive at meaningful conclusions. The sedimentation quantities as well as loss of storage capacities, rate of siltation are shown in Table 5.3 whereas trap efficiency and sedimentation index are shown in Table 4.2.

The Sedimentation rate and Annual % loss is calculated using the equations (7) and (8)

$$\text{Sedimentation rate (Ha m/ 100 sq km/year)} = \frac{100 * \text{loss of gross capacity}}{\text{Catchment Area} * \text{Number of years between the surveys}} \quad (7)$$

$$Annual\ \%\ loss = \frac{\text{Annual Sedimentation rate (M cu m)}}{\text{Original Gross capacity of reservoir (M cu m)}}\ x\ 100 \quad (8)$$

Table 4.2: Initial Data for Sedimentation in Different Zones if Reservoir

Type of Reservoir	New Zero Bed Elevation	Trap Efficiency	Sedimentation Index
Floodplain Foot Hill	100.8 m	95%	1.58 x 10^{11} s^2/m

4.6 Charting the Results of Bathymetry and Topography Data

- Chart showing reservoir bed heights are provided for the current survey at 1:20000 scale.
- Chart showing contour map of Panam reservoir is also provided at 1:20000 scale.
- Chart showing seabed relief image prepared from SBES data is provided at 1:20000 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 – Panam 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.

5.1 Reservoir Bed Heights

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

The reservoir topography was uneven with reservoir bed level ranging from 92.5 m to 127.44 m w.r.t. MSL.

The reservoir bed tends to get shallower as we go further towards east, west & south away from the reservoir centre within the survey area. At some of the places shallow patches/islands/isolated land bodies were observed within the survey area.

Lowest reservoir bed level recorded was 92.5 m w.r.t. MSL (368 624 mE, 2 550 008 mN), within the survey area.

Highest reservoir bed level recorded was 127.44 m w.r.t. MSL (369 087 mE, 2 549 351mN) within the survey area.

Figure 5.1 shows the gridded SBES and bathymetry and topography data for the Panam reservoir. Figure 5.2 shows the 3D view of the Panam reservoir.

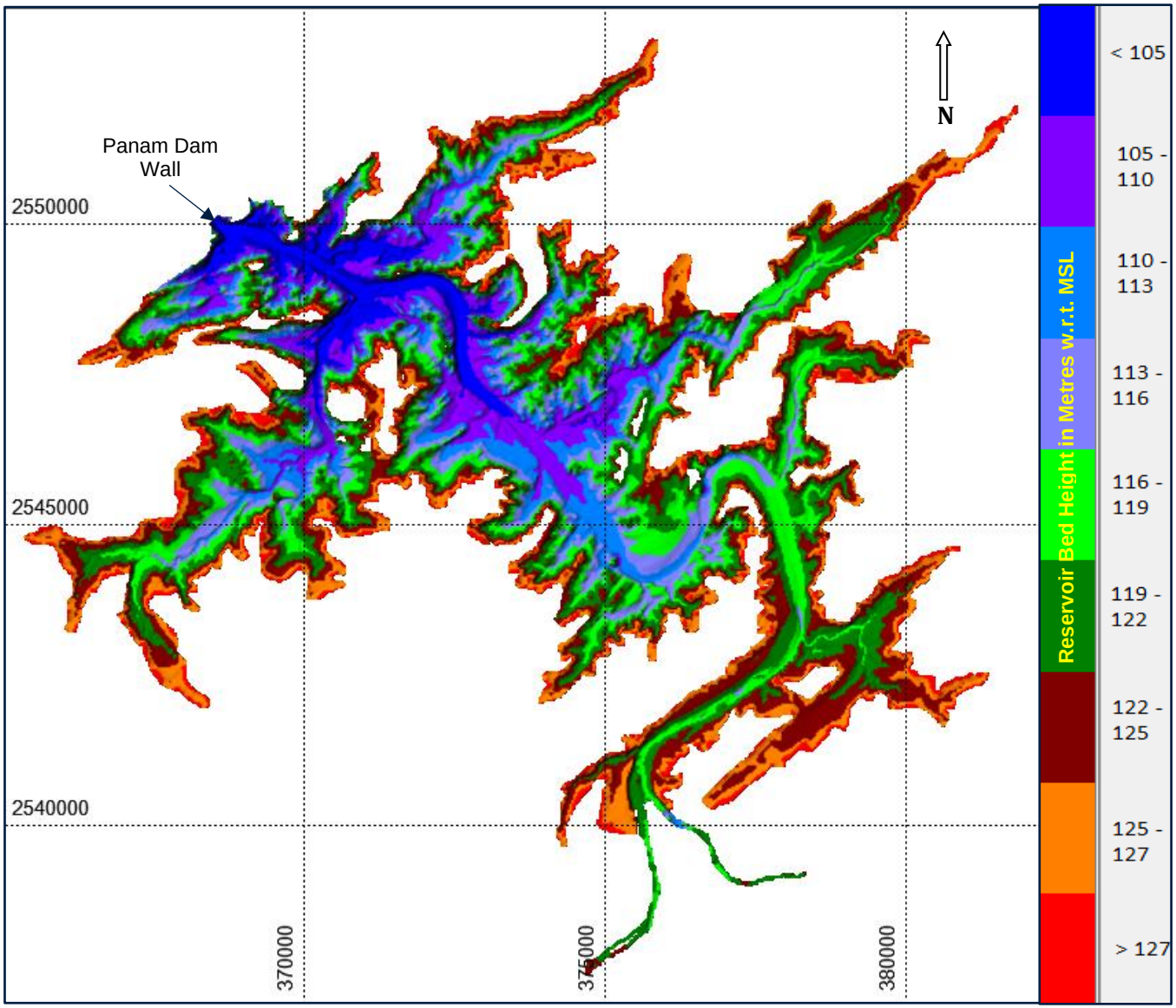


Figure 5.1: Image showing grided SBES bathymetry and topography data of Reservoir Bed Heights from lowest bed level to FRL in Metres (w.r.t. MSL)

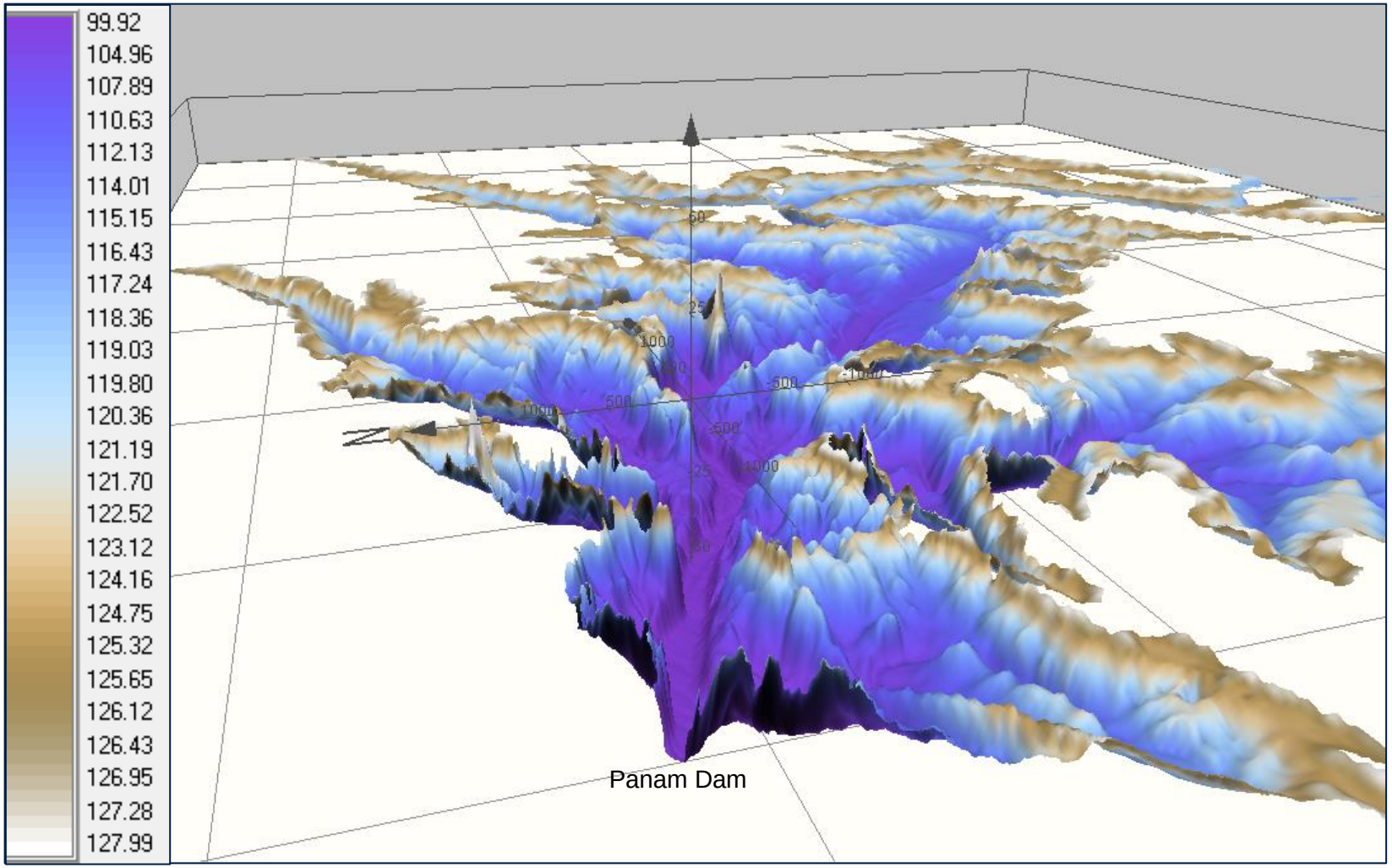


Figure 5.2: 3D View of the Panam Reservoir Area

5.2 Elevation Area Capacity Curve (2020-2021)

The area and capacity of the reservoir was tabulated against the respective increasing elevation starting from zero bed elevation up to MWL at an increment of 0.1 m as shown in Table 5.1.

Table 5.1: Revised Elevation Area Capacity table at every 0.1 m interval starting from Lowest bed level to MWL for the Survey Year 2020-2021

Sr. No.	Elevation [m] wrt MSL	Area [km^2]	Capacity [Mm^3]	Sr. No.	Elevation [m] wrt MSL	Area [km^2]	Capacity [Mm^3]
1	92.5	0.172	0.121	37	96.1	0.771	1.696
2	92.6	0.187	0.139	38	96.2	0.792	1.774
3	92.7	0.201	0.159	39	96.3	0.813	1.855
4	92.8	0.214	0.179	40	96.4	0.830	1.937
5	92.9	0.222	0.201	41	96.5	0.853	2.021
6	93.0	0.230	0.224	42	96.6	0.870	2.107
7	93.1	0.241	0.247	43	96.7	0.888	2.195
8	93.2	0.252	0.272	44	96.8	0.904	2.285
9	93.3	0.265	0.298	45	96.9	0.920	2.376
10	93.4	0.281	0.325	46	97.0	0.938	2.469
11	93.5	0.295	0.354	47	97.1	0.955	2.563
12	93.6	0.313	0.384	48	97.2	0.973	2.660
13	93.7	0.333	0.417	49	97.3	0.993	2.758
14	93.8	0.350	0.451	50	97.4	1.014	2.858
15	93.9	0.364	0.486	51	97.5	1.032	2.961
16	94.0	0.380	0.524	52	97.6	1.051	3.065
17	94.1	0.401	0.563	53	97.7	1.068	3.171
18	94.2	0.422	0.604	54	97.8	1.085	3.279
19	94.3	0.445	0.647	55	97.9	1.102	3.388
20	94.4	0.469	0.693	56	98.0	1.123	3.499
21	94.5	0.489	0.741	57	98.1	1.150	3.613
22	94.6	0.503	0.790	58	98.2	1.178	3.729
23	94.7	0.514	0.841	59	98.3	1.200	3.848
24	94.8	0.526	0.893	60	98.4	1.221	3.969
25	94.9	0.537	0.946	61	98.5	1.242	4.092
26	95.0	0.548	1.001	62	98.6	1.263	4.217
27	95.1	0.559	1.056	63	98.7	1.283	4.345
28	95.2	0.569	1.112	64	98.8	1.304	4.474
29	95.3	0.581	1.170	65	98.9	1.325	4.606
30	95.4	0.594	1.229	66	99.0	1.346	4.739
31	95.5	0.609	1.289	67	99.1	1.369	4.875
32	95.6	0.628	1.351	68	99.2	1.391	5.013
33	95.7	0.646	1.414	69	99.3	1.416	5.153
34	95.8	0.669	1.480	70	99.4	1.441	5.296
35	95.9	0.702	1.548	71	99.5	1.469	5.442
36	96.0	0.739	1.621	72	99.6	1.502	5.590

Sr. No.	Elevation [m] wrt MSL	Area [km^2]	Capacity [Mm^3]
73	99.7	1.535	5.742
74	99.8	1.568	5.897
75	99.9	1.598	6.055
76	100.0	1.626	6.217
77	100.1	1.652	6.381
78	100.2	1.682	6.547
79	100.3	1.708	6.717
80	100.4	1.738	6.889
81	100.5	1.769	7.065
82	100.6	1.801	7.243
83	100.7	1.835	7.425
84	100.8	1.868	7.610
85	100.9	1.901	7.798
86	101.0	1.934	7.990
87	101.1	1.966	8.185
88	101.2	2.001	8.384
89	101.3	2.037	8.585
90	101.4	2.073	8.791
91	101.5	2.107	9.000
92	101.6	2.146	9.212
93	101.7	2.184	9.429
94	101.8	2.227	9.649
95	101.9	2.268	9.874
96	102.0	2.308	10.103
97	102.1	2.350	10.336
98	102.2	2.392	10.573
99	102.3	2.440	10.814
100	102.4	2.488	11.061
101	102.5	2.538	11.312
102	102.6	2.593	11.569
103	102.7	2.646	11.830
104	102.8	2.696	12.098
105	102.9	2.746	12.370
106	103.0	2.798	12.647
107	103.1	2.859	12.930
108	103.2	2.914	13.219
109	103.3	2.977	13.513
110	103.4	3.049	13.814
111	103.5	3.128	14.123
112	103.6	3.198	14.440
113	103.7	3.267	14.763
114	103.8	3.330	15.093
115	103.9	3.392	15.429
116	104.0	3.457	15.771
117	104.1	3.525	16.120
118	104.2	3.598	16.477
119	104.3	3.667	16.840
120	104.4	3.733	17.210
121	104.5	3.805	17.587
122	104.6	3.868	17.970
123	104.7	3.934	18.360
124	104.8	4.004	18.757
125	104.9	4.072	19.161
126	105.0	4.142	19.572
127	105.1	4.212	19.990
128	105.2	4.283	20.414
129	105.3	4.353	20.846
130	105.4	4.427	21.285
131	105.5	4.506	21.732
132	105.6	4.585	22.186
133	105.7	4.665	22.649
134	105.8	4.751	23.120
135	105.9	4.839	23.599
136	106.0	4.932	24.088
137	106.1	5.023	24.585
138	106.2	5.121	25.092
139	106.3	5.229	25.610
140	106.4	5.330	26.138
141	106.5	5.426	26.676
142	106.6	5.518	27.223
143	106.7	5.615	27.780
144	106.8	5.719	28.346
145	106.9	5.825	28.923
146	107.0	5.933	29.511
147	107.1	6.047	30.110
148	107.2	6.162	30.720
149	107.3	6.274	31.342
150	107.4	6.392	31.976
151	107.5	6.502	32.620
152	107.6	6.616	33.276
153	107.7	6.727	33.943
154	107.8	6.837	34.621
155	107.9	6.950	35.311
156	108.0	7.063	36.011

Sr. No.	Elevation [m] wrt MSL	Area [km^2]	Capacity [Mm^3]
157	108.1	7.176	36.723
158	108.2	7.296	37.447
159	108.3	7.416	38.182
160	108.4	7.546	38.930
161	108.5	7.682	39.692
162	108.6	7.819	40.467
163	108.7	7.972	41.256
164	108.8	8.121	42.061
165	108.9	8.279	42.881
166	109.0	8.432	43.717
167	109.1	8.579	44.567
168	109.2	8.729	45.432
169	109.3	8.878	46.313
170	109.4	9.029	47.208
171	109.5	9.181	48.119
172	109.6	9.338	49.044
173	109.7	9.506	49.986
174	109.8	9.676	50.946
175	109.9	9.837	51.921
176	110.0	10.011	52.914
177	110.1	10.191	53.924
178	110.2	10.371	54.952
179	110.3	10.586	55.999
180	110.4	10.784	57.068
181	110.5	10.995	58.157
182	110.6	11.189	59.266
183	110.7	11.369	60.394
184	110.8	11.553	61.540
185	110.9	11.742	62.705
186	111.0	11.922	63.888
187	111.1	12.109	65.089
188	111.2	12.292	66.310
189	111.3	12.465	67.548
190	111.4	12.644	68.803
191	111.5	12.823	70.076
192	111.6	12.998	71.367
193	111.7	13.184	72.676
194	111.8	13.365	74.004
195	111.9	13.557	75.350
196	112.0	13.746	76.715
197	112.1	13.937	78.099
198	112.2	14.121	79.502
199	112.3	14.308	80.924
200	112.4	14.494	82.364
201	112.5	14.679	83.822
202	112.6	14.871	85.300
203	112.7	15.063	86.797
204	112.8	15.262	88.313
205	112.9	15.460	89.849
206	113.0	15.671	91.405
207	113.1	15.882	92.983
208	113.2	16.092	94.582
209	113.3	16.310	96.202
210	113.4	16.530	97.844
211	113.5	16.743	99.508
212	113.6	16.961	101.193
213	113.7	17.178	102.900
214	113.8	17.403	104.629
215	113.9	17.626	106.380
216	114.0	17.856	108.154
217	114.1	18.088	109.952
218	114.2	18.313	111.771
219	114.3	18.544	113.614
220	114.4	18.783	115.481
221	114.5	19.025	117.371
222	114.6	19.268	119.286
223	114.7	19.522	121.225
224	114.8	19.766	123.190
225	114.9	20.014	125.179
226	115.0	20.260	127.192
227	115.1	20.509	129.231
228	115.2	20.769	131.294
229	115.3	21.034	133.385
230	115.4	21.290	135.501
231	115.5	21.552	137.643
232	115.6	21.819	139.811
233	115.7	22.086	142.007
234	115.8	22.360	144.229
235	115.9	22.638	146.479
236	116.0	22.930	148.757
237	116.1	23.225	151.065
238	116.2	23.528	153.402
239	116.3	23.838	155.771
240	116.4	24.144	158.170

Sr. No.	Elevation [m] wrt MSL	Area [km^2]	Capacity [Mm^3]
241	116.5	24.456	160.600
242	116.6	24.765	163.061
243	116.7	25.073	165.553
244	116.8	25.386	168.076
245	116.9	25.703	170.630
246	117.0	26.022	173.216
247	117.1	26.354	175.835
248	117.2	26.687	178.487
249	117.3	27.024	181.173
250	117.4	27.370	183.892
251	117.5	27.727	186.647
252	117.6	28.098	189.438
253	117.7	28.461	192.266
254	117.8	28.819	195.130
255	117.9	29.184	198.030
256	118.0	29.539	200.966
257	118.1	29.890	203.938
258	118.2	30.244	206.944
259	118.3	30.605	209.987
260	118.4	30.978	213.066
261	118.5	31.358	216.183
262	118.6	31.740	219.337
263	118.7	32.124	222.530
264	118.8	32.511	225.762
265	118.9	32.899	229.033
266	119.0	33.295	232.342
267	119.1	33.688	235.692
268	119.2	34.083	239.080
269	119.3	34.457	242.508
270	119.4	34.831	245.972
271	119.5	35.217	249.474
272	119.6	35.599	253.015
273	119.7	35.968	256.593
274	119.8	36.335	260.209
275	119.9	36.699	263.861
276	120.0	37.067	267.549
277	120.1	37.448	271.274
278	120.2	37.855	275.039
279	120.3	38.265	278.846
280	120.4	38.675	282.693
281	120.5	39.083	286.581
282	120.6	39.488	290.509

Sr. No.	Elevation [m] wrt MSL	Area [km^2]	Capacity [Mm^3]
283	120.7	39.900	294.478
284	120.8	40.337	298.491
285	120.9	40.771	302.546
286	121.0	41.190	306.644
287	121.1	41.607	310.784
288	121.2	42.038	314.966
289	121.3	42.461	319.192
290	121.4	42.895	323.459
291	121.5	43.348	327.771
292	121.6	43.807	332.129
293	121.7	44.263	336.532
294	121.8	44.721	340.982
295	121.9	45.182	345.477
296	122.0	45.640	350.018
297	122.1	46.109	354.605
298	122.2	46.585	359.239
299	122.3	47.060	363.922
300	122.4	47.535	368.652
301	122.5	48.021	373.429
302	122.6	48.515	378.256
303	122.7	48.997	383.132
304	122.8	49.484	388.056
305	122.9	49.959	393.029
306	123.0	50.389	398.046
307	123.1	50.773	403.105
308	123.2	51.132	408.200
309	123.3	51.471	413.331
310	123.4	51.787	418.494
311	123.5	52.090	423.687
312	123.6	52.384	428.911
313	123.7	52.671	434.164
314	123.8	52.968	439.446
315	123.9	53.281	444.758
316	124.0	53.593	450.102
317	124.1	53.910	455.477
318	124.2	54.219	460.883
319	124.3	54.524	466.321
320	124.4	54.838	471.789
321	124.5	55.167	477.289
322	124.6	55.543	482.824
323	124.7	56.016	488.400
324	124.8	56.774	494.039

Sr. No.	Elevation [m] wrt MSL	Area [km^2]	Capacity [Mm^3]
325	124.9	57.573	499.757
326	125.0	58.331	505.553
327	125.1	59.009	511.420
328	125.2	59.606	517.351
329	125.3	60.146	523.340
330	125.4	60.646	529.379
331	125.5	61.125	535.468
332	125.6	61.577	541.603
333	125.7	61.997	547.782
334	125.8	62.394	554.002
335	125.9	62.775	560.261
336	126.0	63.152	566.557
337	126.1	63.513	572.890
338	126.2	63.874	579.260
339	126.3	64.238	585.666
340	126.4	64.572	592.106
341	126.5	64.892	598.579
342	126.6	65.199	605.084
343	126.7	65.483	611.618
344	126.8	65.758	618.181
345	126.9	66.027	624.770
346	127.0	66.290	631.386
347	127.1	66.552	638.028
348	127.2	66.803	644.695
349	127.3	67.043	651.388
350	127.4	67.268	658.104
351	127.44 (FRL)	67.356	660.799
352	127.5	67.489	664.842
353	127.6	67.705	671.601
354	127.7	67.917	678.382
355	127.8	68.120	685.185
356	127.9	68.314	692.006
357	128.0	68.500	698.847
358	128.1	68.679	705.706
359	128.2	68.842	712.582
360	128.3	68.971	719.474
361	128.4	69.070	726.375
362	128.5	69.141	733.287
363	128.6	69.195	740.204
364	128.7	69.238	747.125
365	128.8	69.271	754.051
366	128.9	69.300	760.979
367	129.0	69.322	767.911
368	129.1	69.339	774.844
369	129.2	69.353	781.778
370	129.3	69.364	788.714
371	129.4	69.372	795.650
372	129.5	69.380	802.588
373	129.6	69.386	809.527
374	129.7	69.392	816.465
375	129.72	69.393	817.853

Comparison table between the elevation area capacity for the year 2020-21 with the elevation area capacity for the previous survey years of 2004 and 2011 as well as the original project capacity, was also prepared as shown in Table 5.2. Also, the comparison plots of capacity curve for the year 2020-2021, 2011, 2004 and original project capacity are shown in Figure 5.3.

Table 5.2: Comparison of Elevation Area Capacity details of 2020-21, 2011, 2004 and Original Project data

Sr. No	Elevation (wrt MSL) [m]	Original		Survey in year 2004		Survey in year 2011		Survey in year 2020-21	
		Gross Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]
1	93.4	0	0	0.034	0.092	0.062	0.045	0.325	0.281
2	94.4	0	0	0.204	0.228	0.132	0.1	0.693	0.469
3	94.5	0	0	0.226	0.239	0.142	0.107	0.730	0.487
4	95.4	4.61	0.862	0.5	0.349	0.275	0.188	1.229	0.594
5	96.01	--	--	0.741	0.424	0.408	0.247	1.558	0.666
6	96.4	6.12	1.124	0.919	0.472	0.511	0.287	1.937	0.830
7	97.4	--	--	1.471	0.619	0.866	0.426	2.858	1.014
8	98.4	--	--	2.207	0.83	1.362	0.568	3.969	1.221
9	99.4	--	--	3.157	1.049	2.014	0.737	5.296	1.441
10	100.4	--	--	4.359	1.358	2.879	0.98	6.889	1.738
11	101.4	--	--	5.969	1.86	4.021	1.281	8.791	2.073
12	102.11	19.44	3.254	7.441	2.225	5.034	1.543	10.142	2.310
13	102.4	--	--	8.115	2.371	5.505	1.668	11.061	2.488
14	103.4	--	--	10.793	2.926	7.443	2.173	13.814	3.049
15	104.4	--	--	14.051	3.527	9.909	2.735	17.210	3.733
16	105.4	--	--	17.957	4.2	13.004	3.409	21.285	4.427
17	106.4	--	--	22.581	5.004	16.738	4.026	26.138	5.330
18	107.4	--	--	26.934	5.825	21.142	4.754	31.976	6.392
19	108.2	56.06	9.436	33.483	7.216	25.219	5.434	37.447	7.296
20	108.4	--	--	34.963	7.486	26.33	5.639	38.930	7.546
21	109.4	--	--	43.208	8.926	32.603	6.932	47.208	9.029
22	110.4	--	--	52.989	10.547	40.315	8.377	57.068	10.784
23	111.4	--	--	64.403	12.157	49.404	9.762	68.803	12.644
24	112.4	--	--	77.466	13.875	59.96	11.369	82.364	14.494
25	113.4	--	--	92.418	15.89	72.204	13.057	97.844	16.530
26	114.3	153.33	21.87	107.673	17.884	84.684	14.643	111.795	18.363

Sr. No	Elevation (wrt MSL) [m]	Original		Survey in year 2004		Survey in year 2011		Survey in year 2020-21	
		Gross Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]
27	114.4	--	--	109.484	18.137	86.161	14.83	115.481	18.783
28	115.4	--	--	129.146	21.068	102.043	16.971	135.501	21.290
29	116.4	--	--	151.986	24.408	120.331	19.553	158.170	24.144
30	117.35	232.59	30.376	176.926	27.852	140.15	22.139	179.737	26.855
31	117.4	--	--	178.331	28.038	141.263	22.284	183.892	27.370
32	118.4	--	--	208.543	32.222	165.113	25.387	213.066	30.978
33	118.87	281.32	33.618	224.302	34.42	177.434	26.964	226.769	32.673
34	119.4	--	--	243.324	36.982	192.245	28.844	245.972	34.831
35	120.4	336.44	38.524	282.852	41.443	223.145	32.964	282.693	38.675
36	121.4	--	--	326.576	45.186	258.534	37.696	323.459	42.895
37	121.92	401.68	46.896	350.834	47.112	278.845	40.22	344.658	45.089
38	122.4	--	--	374.159	48.883	298.792	42.589	368.652	47.535
39	123.4	--	--	425.708	52.691	343.978	47.373	418.494	51.787
40	123.44	477.92	53.213	427.856	52.848	345.887	47.565	420.480	51.957
41	123.85	479	54.98	450.284	54.49	365.913	49.528	443.822	53.700
42	124.4	--	--	481.604	56.824	394.078	52.159	471.789	54.838
43	124.75	--	--	--	--	412.782	53.862	490.783	55.563
44	124.97	565.87	61.538	515.755	59.563	424.859	54.951	502.927	56.019
45	125.43	615	63	544.953	62.579	450.923	57.272	529.379	60.646
46	126.49	666.81	71.783	--	--	515.537	63.185	592.106	64.572
47	127.44	735.8	89.8	--	--	580.378	70.740	660.799	67.356

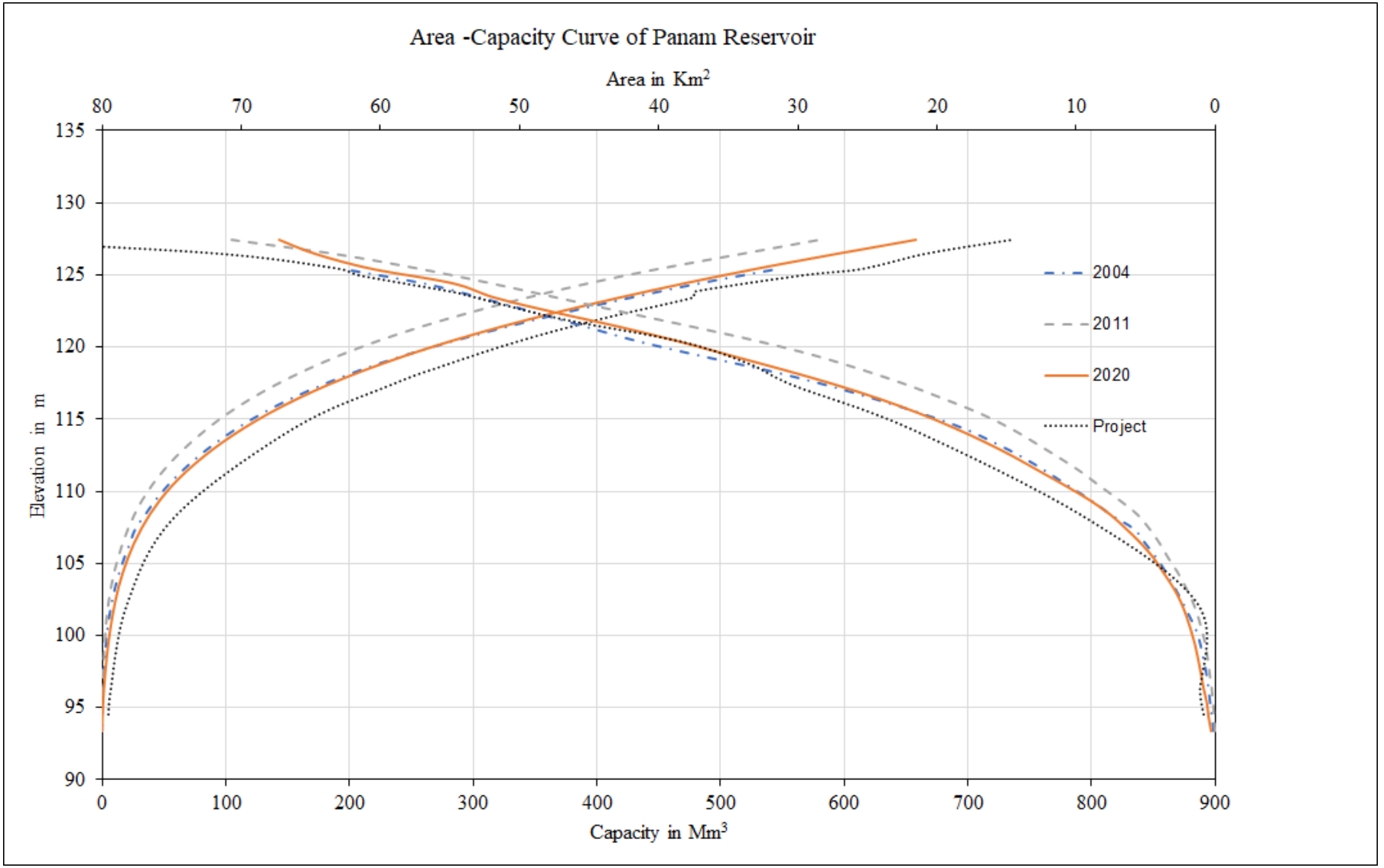


Figure 5.3: Comparison of Area Capacity Curve

5.3 Sedimentation in Reservoir

The present survey of Panam reservoir was carried out between December 2020 and February 2021. Previous survey was carried out in the year 2011. The catchment area considered for sedimentation studies is 2314 km^2. In the present study, the age of the reservoir is considered as 44 years (1977 – 2020). As per 2020-2021 survey, the total area at reservoir FRL 127.44 m is 67.356 km^2 and the corresponding storage capacity is 660.799 Mm^3. Table 5.3 details the capacity loss, rate of sedimentation and annual % loss in gross storage capacity w.r.t. original project capacity (1977) and 2011 capacity survey results.

Table 5.3: Sedimentation in Different Zones of Reservoir

Year	1977	2011	2020-21	2020-21
Storage Capacity in Mm^3				
Dead	56.6	25.219	37.45	37.45
Live	679.2	555.159	623.349	623.349
Gross	735.8	580.378	660.799	660.799
Loss of Storage Capacity in Mm^3		(wrt 1977)	(wrt 2011)	(wrt 1977)
Dead	NA	31.381	-12.231	19.15
Live	NA	124.041	-68.19	55.85
Gross	NA	155.422	-80.421	75
Sedimentation Rate in Ham/100 km^2/Year		(wrt 1977)	(wrt 2011)	(wrt 1977)
Dead	NA	3.875	-5.286	1.881
Live	NA	15.316	-29.468	5.485
Gross	3.57	19.190	-34.754	7.366
Annual % loss		(wrt 1977)	(wrt 2011)	(wrt 1977)
Dead		0.1	-0.2	0.06
Live		0.5	-1.2	0.17
Gross		0.6	-1.4	0.23
Remarks	As per design	Serious	Desiltation	Significant
Volume of sediment (wrt 1977) deposited on bed in 2020-21= Loss of storage capacity= 75 Mm^3				
Note: Sign Convention: -ve sign shows desiltation and +ve sign shows siltation				

- As per 2020-2021 survey results, the volume of sediment deposited or the annual loss in gross storage capacity w.r.t. 1977 (Original Project data) is 75 Mm^3.
- The rate of siltation in Panam reservoir is 1.705 Mm^3/year.
- The observed rate of siltation in the Panam reservoir during the 44 years life span (1977 – 2020), works out to 7.366 Ham/100 km^2/year.
- The annual % loss in Panam reservoir during the 44 years life span is 0.23% and hence, the reservoir is classified as "Significant category" as per IS-12182 (1987).

In Table 5.4, the siltation data for year 1984 and 1990 has been obtained from CWC report on Indian Reservoirs (CWC, 2020). It may be observed that there is a cyclic trend of siltation and desiltation process happening over the lifespan of the reservoir. For the year 2020, there is desiltation as compared to the 2012 survey. Also, in 2012 survey, it was observed that the reservoir desilted as compared to 2004 survey. The reason behind desiltation could be change of upstream catchment characteristics. Also, there could be some anthropogenic activity of desiltation of reservoir, which might be the cause of the desiltation.

Table 5.4: 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 1977 survey (Ha m / 100 km^2/Yr)
				Gross	Live	Dead	Since 1977 Survey	% Cumulative	Remarks	
1	1977 (FRL)			735.8	679.2	56.6				
2	1977 (RL-125.43)			615	600.8	14.2				
3	1984	St Govt (HS)	7	697.55	624.85	72.7	38.25	5.2	Siltation	23.61
4	1990	St Govt (HS)	6	720.19	671.95	48.24	15.61	2.12	Desiltation	5.19
5	2004 (RL-125.44)	St Govt (HS)	14	544.95	511.47	33.48	70.05	11.39	Siltation	11.21
6	2012 (FRL)	St Govt (HS)	8	580.378	555.159	25.219	155.42	21.12	Desiltation	19.19
7	2020 (FRL)	Current survey	8	660.799	623.349	37.45	75	10.19	Desiltation	7.366

Table 5.5 gives the details of revised gross capacity for Panam reservoir at every 0.1 m interval starting from FRL (127.44 m) to lowest bed level (RL 92.5)

Table 5.5: Gross Capacity of Reservoir at every 0.1 m interval starting from FRL (127.44 m) to lowest bed level (RL 92.5 m)

Sr. No	Elevation [m]	Gross Capacity [Mm^3]	Remarks
1	127.44	660.799	FRL
2	127.4	658.104	
3	127.3	651.39	
4	127.2	644.70	
5	127.1	638.03	
6	127.0	631.39	
7	126.9	624.77	
8	126.8	618.18	
9	126.7	611.62	
10	126.6	605.08	
11	126.5	598.58	
12	126.4	592.11	
13	126.3	585.67	
14	126.2	579.26	
15	126.1	572.89	
16	126.0	566.56	
17	125.9	560.26	
18	125.8	554.00	
19	125.7	547.78	
20	125.6	541.60	
21	125.5	535.47	
22	125.4	529.38	
23	125.3	523.34	
24	125.2	517.35	
25	125.1	511.42	
26	125.0	505.55	
27	124.9	499.76	
28	124.8	494.04	
29	124.7	488.40	
30	124.6	482.82	
31	124.5	477.29	
32	124.4	471.79	
33	124.3	466.32	
34	124.2	460.88	
35	124.1	455.48	
36	124.0	450.10	
37	123.9	444.76	
38	123.8	439.45	
39	123.7	434.16	
40	123.6	428.91	
41	123.5	423.69	
42	123.4	418.49	
43	123.3	413.33	
44	123.2	408.20	
45	123.1	403.11	
46	123.0	398.05	
47	122.9	393.03	
48	122.8	388.06	
49	122.7	383.13	
50	122.6	378.26	
51	122.5	373.43	
52	122.4	368.65	
53	122.3	363.92	
54	122.2	359.24	
55	122.1	354.61	
56	122.0	350.02	
57	121.9	345.48	
58	121.8	340.98	
59	121.7	336.53	
60	121.6	332.13	
61	121.5	327.77	
62	121.4	323.46	
63	121.3	319.19	
64	121.2	314.97	
65	121.1	310.78	
66	121.0	306.64	
67	120.9	302.55	
68	120.8	298.49	
69	120.7	294.48	
70	120.6	290.51	
71	120.5	286.58	
72	120.4	282.69	
73	120.3	278.85	
74	120.2	275.04	
75	120.1	271.27	
76	120.0	267.55	

Sr. No	Elevation [m]	Gross Capacity [Mm^3]	Remarks
77	119.9	263.86	
78	119.8	260.21	
79	119.7	256.59	
80	119.6	253.02	
81	119.5	249.47	
82	119.4	245.97	
83	119.3	242.51	
84	119.2	239.08	
85	119.1	235.69	
86	119.0	232.34	
87	118.9	229.03	
88	118.8	225.76	
89	118.7	222.53	
90	118.6	219.34	
91	118.5	216.18	
92	118.4	213.07	
93	118.3	209.99	
94	118.2	206.94	
95	118.1	203.94	
96	118.0	200.97	
97	117.9	198.03	
98	117.8	195.13	
99	117.7	192.27	
100	117.6	189.44	
101	117.5	186.65	
102	117.4	183.89	
103	117.3	181.17	
104	117.2	178.49	
105	117.1	175.84	
106	117.0	173.22	
107	116.9	170.63	
108	116.8	168.08	
109	116.7	165.55	
110	116.6	163.06	
111	116.5	160.60	
112	116.4	158.17	
113	116.3	155.77	
114	116.2	153.40	
115	116.1	151.07	
116	116.0	148.76	

Sr. No	Elevation [m]	Gross Capacity [Mm^3]	Remarks
117	115.9	146.48	
118	115.8	144.23	
119	115.7	142.01	
120	115.6	139.81	
121	115.5	137.64	
122	115.4	135.50	
123	115.3	133.39	
124	115.2	131.29	
125	115.1	129.23	
126	115.0	127.19	
127	114.9	125.18	
128	114.8	123.19	
129	114.7	121.23	
130	114.6	119.29	
131	114.5	117.37	
132	114.4	115.48	
133	114.3	113.61	
134	114.2	111.77	
135	114.1	109.95	
136	114.0	108.15	
137	113.9	106.38	
138	113.8	104.63	
139	113.7	102.90	
140	113.6	101.19	
141	113.5	99.51	
142	113.4	97.84	
143	113.3	96.20	
144	113.2	94.58	
145	113.1	92.98	
146	113.0	91.41	
147	112.9	89.85	
148	112.8	88.31	
149	112.7	86.80	
150	112.6	85.30	
151	112.5	83.82	
152	112.4	82.36	
153	112.3	80.92	
154	112.2	79.50	
155	112.1	78.10	
156	112.0	76.72	

Sr. No	Elevation [m]	Gross Capacity [Mm^3]	Remarks
157	111.9	75.35	
158	111.8	74.00	
159	111.7	72.68	
160	111.6	71.37	
161	111.5	70.08	
162	111.4	68.80	
163	111.3	67.55	
164	111.2	66.31	
165	111.1	65.09	
166	111.0	63.89	
167	110.9	62.71	
168	110.8	61.54	
169	110.7	60.39	
170	110.6	59.27	
171	110.5	58.16	
172	110.4	57.07	
173	110.3	56.00	
174	110.2	54.95	
175	110.1	53.92	
176	110.0	52.91	
177	109.9	51.92	
178	109.8	50.95	
179	109.7	49.99	
180	109.6	49.04	
181	109.5	48.12	
182	109.4	47.21	
183	109.3	46.31	
184	109.2	45.43	
185	109.1	44.57	
186	109.0	43.72	
187	108.9	42.88	
188	108.8	42.06	
189	108.7	41.26	
190	108.6	40.47	
191	108.5	39.69	
192	108.4	38.93	
193	108.3	38.18	
194	108.2	37.45	MDDL
195	108.1	36.72	
196	108.0	36.01	

Sr. No	Elevation [m]	Gross Capacity [Mm^3]	Remarks
197	107.9	35.31	
198	107.8	34.62	
199	107.7	33.94	
200	107.6	33.28	
201	107.5	32.62	
202	107.4	31.98	
203	107.3	31.34	
204	107.2	30.72	
205	107.1	30.11	
206	107.0	29.51	
207	106.9	28.92	
208	106.8	28.35	
209	106.7	27.78	
210	106.6	27.22	
211	106.5	26.68	
212	106.4	26.14	
213	106.3	25.61	
214	106.2	25.09	
215	106.1	24.59	
216	106.0	24.09	
217	105.9	23.60	
218	105.8	23.12	
219	105.7	22.65	
220	105.6	22.19	
221	105.5	21.73	
222	105.4	21.29	
223	105.3	20.85	
224	105.2	20.41	
225	105.1	19.99	
226	105.0	19.57	
227	104.9	19.16	
228	104.8	18.76	
229	104.7	18.36	
230	104.6	17.97	
231	104.5	17.59	
232	104.4	17.21	
233	104.3	16.84	
234	104.2	16.48	
235	104.1	16.12	
236	104.0	15.77	

Sr. No	Elevation [m]	Gross Capacity [Mm^3]	Remarks
237	103.9	15.43	
238	103.8	15.09	
239	103.7	14.76	
240	103.6	14.44	
241	103.5	14.12	
242	103.4	13.81	
243	103.3	13.51	
244	103.2	13.22	
245	103.1	12.93	
246	103.0	12.65	
247	102.9	12.37	
248	102.8	12.10	
249	102.7	11.83	
250	102.6	11.57	
251	102.5	11.31	
252	102.4	11.06	
253	102.3	10.81	
254	102.2	10.57	
255	102.1	10.34	
256	102.0	10.10	
257	101.9	9.87	
258	101.8	9.65	
259	101.7	9.43	
260	101.6	9.21	
261	101.5	9.00	
262	101.4	8.79	
263	101.3	8.59	
264	101.2	8.38	
265	101.1	8.19	
266	101.0	7.99	
267	100.9	7.80	
268	100.8	7.61	
269	100.7	7.43	
270	100.6	7.24	
271	100.5	7.07	
272	100.4	6.89	
273	100.3	6.72	
274	100.2	6.55	
275	100.1	6.38	
276	100.0	6.22	

Sr. No	Elevation [m]	Gross Capacity [Mm^3]	Remarks
277	99.9	6.06	
278	99.8	5.90	
279	99.7	5.74	
280	99.6	5.59	
281	99.5	5.44	
282	99.4	5.30	
283	99.3	5.15	
284	99.2	5.01	
285	99.1	4.88	
286	99.0	4.74	
287	98.9	4.61	
288	98.8	4.47	
289	98.7	4.35	
290	98.6	4.22	
291	98.5	4.09	
292	98.4	3.97	
293	98.3	3.85	
294	98.2	3.73	
295	98.1	3.61	
296	98.0	3.50	
297	97.9	3.39	
298	97.8	3.28	
299	97.7	3.17	
300	97.6	3.07	
301	97.5	2.96	
302	97.4	2.86	
303	97.3	2.76	
304	97.2	2.66	
305	97.1	2.56	
306	97.0	2.47	
307	96.9	2.38	
308	96.8	2.29	
309	96.7	2.20	
310	96.6	2.11	
311	96.5	2.02	
312	96.4	1.94	
313	96.3	1.86	
314	96.2	1.77	
315	96.1	1.70	
316	96.0	1.62	

Sr. No	Elevation [m]	Gross Capacity [Mm^3]	Remarks
317	95.9	1.55	
318	95.8	1.48	
319	95.7	1.41	
320	95.6	1.35	
321	95.5	1.29	
322	95.4	1.23	
323	95.3	1.17	
324	95.2	1.11	
325	95.1	1.06	
326	95.0	1.00	
327	94.9	0.95	
328	94.8	0.89	
329	94.7	0.84	
330	94.6	0.79	
331	94.5	0.74	
332	94.4	0.69	
333	94.3	0.65	
334	94.2	0.60	
335	94.1	0.56	
336	94.0	0.52	
337	93.9	0.49	
338	93.8	0.45	
339	93.7	0.42	
340	93.6	0.38	
341	93.5	0.35	
342	93.4	0.33	
343	93.3	0.30	
344	93.2	0.27	
345	93.1	0.25	
346	93.0	0.22	
347	92.9	0.20	
348	92.8	0.18	
349	92.7	0.16	
350	92.6	0.14	
351	92.5	0.12	Bed Level

Table 5.6 gives the details of revised Gross, Live and Dead storage capacity of Panam reservoir at every 0.1 m interval starting from FRL (127.44 m)

Table 5.6: Gross, Live and Dead Storage Capacity of Reservoir at every 0.1 m interval starting from FRL (127.44 m)

Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity Mm^3]	Dead Capacity [Mm^3]	Remarks
1	127.44	660.799	623.349	37.45	FRL
2	127.40	658.104	620.654	37.45	--
3	127.30	651.39	613.94	37.45	--
4	127.20	644.70	607.25	37.45	--
5	127.10	638.03	600.58	37.45	--
6	127.00	631.39	593.94	37.45	--
7	126.90	624.77	587.32	37.45	--
8	126.80	618.18	580.73	37.45	--
9	126.70	611.62	574.17	37.45	--
10	126.60	605.08	567.63	37.45	--
11	126.50	598.58	561.13	37.45	--
12	126.40	592.11	554.66	37.45	--
13	126.30	585.67	548.22	37.45	--
14	126.20	579.26	541.81	37.45	--
15	126.10	572.89	535.44	37.45	--
16	126.00	566.56	529.11	37.45	--
17	125.90	560.26	522.81	37.45	--
18	125.80	554.00	516.55	37.45	--
19	125.70	547.78	510.33	37.45	--
20	125.60	541.60	504.15	37.45	--
21	125.50	535.47	498.02	37.45	--
22	125.40	529.38	491.93	37.45	--
23	125.30	523.34	485.89	37.45	--
24	125.20	517.35	479.90	37.45	--
25	125.10	511.42	473.97	37.45	--
26	125.00	505.55	468.10	37.45	--
27	124.90	499.76	462.31	37.45	--
28	124.80	494.04	456.59	37.45	--
29	124.70	488.40	450.95	37.45	--
30	124.60	482.82	445.37	37.45	--
31	124.50	477.29	439.84	37.45	--
32	124.40	471.79	434.34	37.45	--
33	124.30	466.32	428.87	37.45	--
34	124.20	460.88	423.43	37.45	--
35	124.10	455.48	418.03	37.45	--

Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity Mm^3]	Dead Capacity [Mm^3]	Remarks
36	124.00	450.10	412.65	37.45	--
37	123.90	444.76	407.31	37.45	--
38	123.80	439.45	402.00	37.45	--
39	123.70	434.16	396.71	37.45	--
40	123.60	428.91	391.46	37.45	--
41	123.50	423.69	386.24	37.45	--
42	123.40	418.49	381.04	37.45	--
43	123.30	413.33	375.88	37.45	--
44	123.20	408.20	370.75	37.45	--
45	123.10	403.11	365.66	37.45	--
46	123.00	398.05	360.60	37.45	--
47	122.90	393.03	355.58	37.45	--
48	122.80	388.06	350.61	37.45	--
49	122.70	383.13	345.68	37.45	--
50	122.60	378.26	340.81	37.45	--
51	122.50	373.43	335.98	37.45	--
52	122.40	368.65	331.20	37.45	--
53	122.30	363.92	326.47	37.45	--
54	122.20	359.24	321.79	37.45	--
55	122.10	354.61	317.16	37.45	--
56	122.00	350.02	312.57	37.45	--
57	121.90	345.48	308.03	37.45	--
58	121.80	340.98	303.53	37.45	--
59	121.70	336.53	299.08	37.45	--
60	121.60	332.13	294.68	37.45	--
61	121.50	327.77	290.32	37.45	--
62	121.40	323.46	286.01	37.45	--
63	121.30	319.19	281.74	37.45	--
64	121.20	314.97	277.52	37.45	--
65	121.10	310.78	273.33	37.45	--
66	121.00	306.64	269.19	37.45	--
67	120.90	302.55	265.10	37.45	--
68	120.80	298.49	261.04	37.45	--
69	120.70	294.48	257.03	37.45	--
70	120.60	290.51	253.06	37.45	--
71	120.50	286.58	249.13	37.45	--
72	120.40	282.69	245.24	37.45	--
73	120.30	278.85	241.40	37.45	--

Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity Mm^3]	Dead Capacity [Mm^3]	Remarks
74	120.20	275.04	237.59	37.45	--
75	120.10	271.27	233.82	37.45	--
76	120.00	267.55	230.10	37.45	--
77	119.90	263.86	226.41	37.45	--
78	119.80	260.21	222.76	37.45	--
79	119.70	256.59	219.14	37.45	--
80	119.60	253.02	215.57	37.45	--
81	119.50	249.47	212.02	37.45	--
82	119.40	245.97	208.52	37.45	--
83	119.30	242.51	205.06	37.45	--
84	119.20	239.08	201.63	37.45	--
85	119.10	235.69	198.24	37.45	--
86	119.00	232.34	194.89	37.45	--
87	118.90	229.03	191.58	37.45	--
88	118.80	225.76	188.31	37.45	--
89	118.70	222.53	185.08	37.45	--
90	118.60	219.34	181.89	37.45	--
91	118.50	216.18	178.73	37.45	--
92	118.40	213.07	175.62	37.45	--
93	118.30	209.99	172.54	37.45	--
94	118.20	206.94	169.49	37.45	--
95	118.10	203.94	166.49	37.45	--
96	118.00	200.97	163.52	37.45	--
97	117.90	198.03	160.58	37.45	--
98	117.80	195.13	157.68	37.45	--
99	117.70	192.27	154.82	37.45	--
100	117.60	189.44	151.99	37.45	--
101	117.50	186.65	149.20	37.45	--
102	117.40	183.89	146.44	37.45	--
103	117.30	181.17	143.72	37.45	--
104	117.20	178.49	141.04	37.45	--
105	117.10	175.84	138.39	37.45	--
106	117.00	173.22	135.77	37.45	--
107	116.90	170.63	133.18	37.45	--
108	116.80	168.08	130.63	37.45	--
109	116.70	165.55	128.10	37.45	--
110	116.60	163.06	125.61	37.45	--
111	116.50	160.60	123.15	37.45	--

Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity Mm^3]	Dead Capacity [Mm^3]	Remarks
112	116.40	158.17	120.72	37.45	--
113	116.30	155.77	118.32	37.45	--
114	116.20	153.40	115.95	37.45	--
115	116.10	151.07	113.62	37.45	--
116	116.00	148.76	111.31	37.45	--
117	115.90	146.48	109.03	37.45	--
118	115.80	144.23	106.78	37.45	--
119	115.70	142.01	104.56	37.45	--
120	115.60	139.81	102.36	37.45	--
121	115.50	137.64	100.19	37.45	--
122	115.40	135.50	98.05	37.45	--
123	115.30	133.39	95.94	37.45	--
124	115.20	131.29	93.84	37.45	--
125	115.10	129.23	91.78	37.45	--
126	115.00	127.19	89.74	37.45	--
127	114.90	125.18	87.73	37.45	--
128	114.80	123.19	85.74	37.45	--
129	114.70	121.23	83.78	37.45	--
130	114.60	119.29	81.84	37.45	--
131	114.50	117.37	79.92	37.45	--
132	114.40	115.48	78.03	37.45	--
133	114.30	113.61	76.16	37.45	--
134	114.20	111.77	74.32	37.45	--
135	114.10	109.95	72.50	37.45	--
136	114.00	108.15	70.70	37.45	--
137	113.90	106.38	68.93	37.45	--
138	113.80	104.63	67.18	37.45	--
139	113.70	102.90	65.45	37.45	--
140	113.60	101.19	63.74	37.45	--
141	113.50	99.51	62.06	37.45	--
142	113.40	97.84	60.39	37.45	--
143	113.30	96.20	58.75	37.45	--
144	113.20	94.58	57.13	37.45	--
145	113.10	92.98	55.53	37.45	--
146	113.00	91.41	53.96	37.45	--
147	112.90	89.85	52.40	37.45	--
148	112.80	88.31	50.86	37.45	--
149	112.70	86.80	49.35	37.45	--

Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity Mm^3]	Dead Capacity [Mm^3]	Remarks
150	112.60	85.30	47.85	37.45	--
151	112.50	83.82	46.37	37.45	--
152	112.40	82.36	44.91	37.45	--
153	112.30	80.92	43.47	37.45	--
154	112.20	79.50	42.05	37.45	--
155	112.10	78.10	40.65	37.45	--
156	112.00	76.72	39.27	37.45	--
157	111.90	75.35	37.90	37.45	--
158	111.80	74.00	36.55	37.45	--
159	111.70	72.68	35.23	37.45	--
160	111.60	71.37	33.92	37.45	--
161	111.50	70.08	32.63	37.45	--
162	111.40	68.80	31.35	37.45	--
163	111.30	67.55	30.10	37.45	--
164	111.20	66.31	28.86	37.45	--
165	111.10	65.09	27.64	37.45	--
166	111.00	63.89	26.44	37.45	--
167	110.90	62.71	25.26	37.45	--
168	110.80	61.54	24.09	37.45	--
169	110.70	60.39	22.94	37.45	--
170	110.60	59.27	21.82	37.45	--
171	110.50	58.16	20.71	37.45	--
172	110.40	57.07	19.62	37.45	--
173	110.30	56.00	18.55	37.45	--
174	110.20	54.95	17.50	37.45	--
175	110.10	53.92	16.47	37.45	--
176	110.00	52.91	15.46	37.45	--
177	109.90	51.92	14.47	37.45	--
178	109.80	50.95	13.50	37.45	--
179	109.70	49.99	12.54	37.45	--
180	109.60	49.04	11.59	37.45	--
181	109.50	48.12	10.67	37.45	--
182	109.40	47.21	9.76	37.45	--
183	109.30	46.31	8.86	37.45	--
184	109.20	45.43	7.98	37.45	--
185	109.10	44.57	7.12	37.45	--
186	109.00	43.72	6.27	37.45	--
187	108.90	42.88	5.43	37.45	--

Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity Mm^3]	Dead Capacity [Mm^3]	Remarks
188	108.80	42.06	4.61	37.45	--
189	108.70	41.26	3.81	37.45	--
190	108.60	40.47	3.02	37.45	--
191	108.50	39.69	2.24	37.45	--
192	108.40	38.93	1.48	37.45	--
193	108.30	38.18	0.73	37.45	--
194	108.20	37.45	0.00	37.45	MDDL
195	108.10	36.72	--	36.72	--
196	108.00	36.01	--	36.01	--
197	107.90	35.31	--	35.31	--
198	107.80	34.62	--	34.62	--
199	107.70	33.94	--	33.94	--
200	107.60	33.28	--	33.28	--
201	107.50	32.62	--	32.62	--
202	107.40	31.98	--	31.98	--
203	107.30	31.34	--	31.34	--
204	107.20	30.72	--	30.72	--
205	107.10	30.11	--	30.11	--
206	107.00	29.51	--	29.51	--
207	106.90	28.92	--	28.92	--
208	106.80	28.35	--	28.35	--
209	106.70	27.78	--	27.78	--
210	106.60	27.22	--	27.22	--
211	106.50	26.68	--	26.68	--
212	106.40	26.14	--	26.14	--
213	106.30	25.61	--	25.61	--
214	106.20	25.09	--	25.09	--
215	106.10	24.59	--	24.59	--
216	106.00	24.09	--	24.09	--
217	105.90	23.60	--	23.60	--
218	105.80	23.12	--	23.12	--
219	105.70	22.65	--	22.65	--
220	105.60	22.19	--	22.19	--
221	105.50	21.73	--	21.73	--
222	105.40	21.29	--	21.29	--
223	105.30	20.85	--	20.85	--
224	105.20	20.41	--	20.41	--
225	105.10	19.99	--	19.99	--

Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity Mm^3]	Dead Capacity [Mm^3]	Remarks
226	105.00	19.57	--	19.57	--
227	104.90	19.16	--	19.16	--
228	104.80	18.76	--	18.76	--
229	104.70	18.36	--	18.36	--
230	104.60	17.97	--	17.97	--
231	104.50	17.59	--	17.59	--
232	104.40	17.21	--	17.21	--
233	104.30	16.84	--	16.84	--
234	104.20	16.48	--	16.48	--
235	104.10	16.12	--	16.12	--
236	104.00	15.77	--	15.77	--
237	103.90	15.43	--	15.43	--
238	103.80	15.09	--	15.09	--
239	103.70	14.76	--	14.76	--
240	103.60	14.44	--	14.44	--
241	103.50	14.12	--	14.12	--
242	103.40	13.81	--	13.81	--
243	103.30	13.51	--	13.51	--
244	103.20	13.22	--	13.22	--
245	103.10	12.93	--	12.93	--
246	103.00	12.65	--	12.65	--
247	102.90	12.37	--	12.37	--
248	102.80	12.10	--	12.10	--
249	102.70	11.83	--	11.83	--
250	102.60	11.57	--	11.57	--
251	102.50	11.31	--	11.31	--
252	102.40	11.06	--	11.06	--
253	102.30	10.81	--	10.81	--
254	102.20	10.57	--	10.57	--
255	102.10	10.34	--	10.34	--
256	102.00	10.10	--	10.10	--
257	101.90	9.87	--	9.87	--
258	101.80	9.65	--	9.65	--
259	101.70	9.43	--	9.43	--
260	101.60	9.21	--	9.21	--
261	101.50	9.00	--	9.00	--
262	101.40	8.79	--	8.79	--
263	101.30	8.59	--	8.59	--

Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity Mm^3]	Dead Capacity [Mm^3]	Remarks
264	101.20	8.38	--	8.38	--
265	101.10	8.19	--	8.19	--
266	101.00	7.99	--	7.99	--
267	100.90	7.80	--	7.80	--
268	100.80	7.61	--	7.61	--
269	100.70	7.43	--	7.43	--
270	100.60	7.24	--	7.24	--
271	100.50	7.07	--	7.07	--
272	100.40	6.89	--	6.89	--
273	100.30	6.72	--	6.72	--
274	100.20	6.55	--	6.55	--
275	100.10	6.38	--	6.38	--
276	100.00	6.22	--	6.22	--
277	99.90	6.06	--	6.06	--
278	99.80	5.90	--	5.90	--
279	99.70	5.74	--	5.74	--
280	99.60	5.59	--	5.59	--
281	99.50	5.44	--	5.44	--
282	99.40	5.30	--	5.30	--
283	99.30	5.15	--	5.15	--
284	99.20	5.01	--	5.01	--
285	99.10	4.88	--	4.88	--
286	99.00	4.74	--	4.74	--
287	98.90	4.61	--	4.61	--
288	98.80	4.47	--	4.47	--
289	98.70	4.35	--	4.35	--
290	98.60	4.22	--	4.22	--
291	98.50	4.09	--	4.09	--
292	98.40	3.97	--	3.97	--
293	98.30	3.85	--	3.85	--
294	98.20	3.73	--	3.73	--
295	98.10	3.61	--	3.61	--
296	98.00	3.50	--	3.50	--
297	97.90	3.39	--	3.39	--
298	97.80	3.28	--	3.28	--
299	97.70	3.17	--	3.17	--
300	97.60	3.07	--	3.07	--
301	97.50	2.96	--	2.96	--

Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity Mm^3]	Dead Capacity [Mm^3]	Remarks
302	97.40	2.86	--	2.86	--
303	97.30	2.76	--	2.76	--
304	97.20	2.66	--	2.66	--
305	97.10	2.56	--	2.56	--
306	97.00	2.47	--	2.47	--
307	96.90	2.38	--	2.38	--
308	96.80	2.29	--	2.29	--
309	96.70	2.20	--	2.20	--
310	96.60	2.11	--	2.11	--
311	96.50	2.02	--	2.02	--
312	96.40	1.94	--	1.94	--
313	96.30	1.86	--	1.86	--
314	96.20	1.77	--	1.77	--
315	96.10	1.70	--	1.70	--
316	96.00	1.62	--	1.62	--
317	95.90	1.55	--	1.55	--
318	95.80	1.48	--	1.48	--
319	95.70	1.41	--	1.41	--
320	95.60	1.35	--	1.35	--
321	95.50	1.29	--	1.29	--
322	95.40	1.23	--	1.23	--
323	95.30	1.17	--	1.17	--
324	95.20	1.11	--	1.11	--
325	95.10	1.06	--	1.06	--
326	95.00	1.00	--	1.00	--
327	94.90	0.95	--	0.95	--
328	94.80	0.89	--	0.89	--
329	94.70	0.84	--	0.84	--
330	94.60	0.79	--	0.79	--
331	94.50	0.74	--	0.74	--
332	94.40	0.69	--	0.69	--
333	94.30	0.65	--	0.65	--
334	94.20	0.60	--	0.60	--
335	94.10	0.56	--	0.56	--
336	94.00	0.52	--	0.52	--
337	93.90	0.49	--	0.49	--
338	93.80	0.45	--	0.45	--
339	93.70	0.42	--	0.42	--

Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity Mm^3]	Dead Capacity [Mm^3]	Remarks
340	93.60	0.38	--	0.38	--
341	93.50	0.35	--	0.35	--
342	93.40	0.33	--	0.33	--
343	93.30	0.30	--	0.30	--
344	93.20	0.27	--	0.27	--
345	93.10	0.25	--	0.25	--
346	93.00	0.22	--	0.22	--
347	92.90	0.20	--	0.20	--
348	92.80	0.18	--	0.18	--
349	92.70	0.16	--	0.16	--
350	92.60	0.14	--	0.14	--
351	92.50	0.12	--	0.12	Bed Level

6. Discussion

Though the current survey results indicate desiltation (w.r.t. 2011 survey results) of the reservoir, dam authorities have confirmed that desiltation process is not performed after the 2011 survey. Hence, to better understand the reason for the increased gross storage capacity in the 2021 survey results, the present survey data was analysed in detail and outcome of the same has been presented in this section. For this, area and capacity (i.e. gross, live and dead storage capacity given in Table 6.2 and Table 6.3) was calculated by considering bathymetry and topography data (above water line) at 200 m line interval and compared with capacity and area calculated as per the SoW defined for the present survey (Refer Table 6.1, Table 6.2 and Table 6.3 given below). Comparison table for Original, 2004, 2011 and 2021 survey is given in Table 6.1 (for year 2021, area and capacity at 25 m and 200 m line spacing data has been considered for analysis).

Table 6.1: Comparison of Elevation Area Capacity details of 2020-21 (25 m and 200 m data), 2011, 2004 and Original Project data

Sr. No	Elevation (wrt MSL) [m]	Original		Survey in year 2004		Survey in year 2011		Survey in year 2020-21 (@25 m)		Survey in year 2020-21 (@200m)		Surface area difference	Capacity difference	Capacity difference
		Gross Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	25 m vs 200 m (2021) [km^2]	25 m vs 200 m (2021) [Mm^3]	2011 vs 2021 @200 m [Mm^3]
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	93.4	0	0	0.034	0.092	0.062	0.045	0.325	0.281	0.047	0.105	0.176	0.278	0.015
2	94.4	0	0	0.204	0.228	0.132	0.1	0.693	0.469	0.191	0.187	0.282	0.502	-0.059
3	94.5	0	0	0.226	0.239	0.142	0.107	0.73	0.487	0.211	0.196	0.291	0.519	-0.069
4	95.4	4.61	0.862	0.5	0.349	0.275	0.188	1.229	0.594	0.441	0.328	0.266	0.788	-0.166
5	96.01	--	--	0.741	0.424	0.408	0.247	1.558	0.666	0.673	0.446	0.220	0.885	-0.265
6	96.4	6.12	1.124	0.919	0.472	0.511	0.287	1.937	0.83	0.867	0.533	0.297	1.070	-0.356
7	97.4	--	--	1.471	0.619	0.866	0.426	2.858	1.014	1.502	0.740	0.274	1.356	-0.636
8	98.4	--	--	2.207	0.83	1.362	0.568	3.969	1.221	2.351	0.956	0.265	1.618	-0.989
9	99.4	--	--	3.157	1.049	2.014	0.737	5.296	1.441	3.429	1.218	0.223	1.867	-1.415
10	100.4	--	--	4.359	1.358	2.879	0.98	6.889	1.738	4.816	1.568	0.170	2.073	-1.937

Sr. No	Elevation (wrt MSL) [m]	Original		Survey in year 2004		Survey in year 2011		Survey in year 2020-21 (@25 m)		Survey in year 2020-21 (@200m)		Surface area difference	Capacity difference	Capacity difference
		Gross Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	25 m vs 200 m (2021) [km^2]	25 m vs 200 m (2021) [Mm^3]	2011 vs 2021 @200 m [Mm^3]
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
11	101.4	--	--	5.969	1.86	4.021	1.281	8.791	2.073	6.591	1.986	0.087	2.200	-2.570
12	102.11	19.44	3.254	7.441	2.225	5.034	1.543	10.142	2.310	8.089	2.295	0.015	2.053	-3.055
13	102.4	--	--	8.115	2.371	5.505	1.668	11.061	2.488	8.799	2.447	0.041	2.262	-3.294
14	103.4	--	--	10.793	2.926	7.443	2.173	13.814	3.049	11.528	3.003	0.046	2.286	-4.085
15	104.4	--	--	14.051	3.527	9.909	2.735	17.21	3.733	14.793	3.544	0.189	2.417	-4.884
16	105.4	--	--	17.957	4.2	13.004	3.409	21.285	4.427	18.654	4.206	0.221	2.631	-5.650
17	106.4	--	--	22.581	5.004	16.738	4.026	26.138	5.330	23.272	5.050	0.280	2.866	-6.534
18	107.4	--	--	26.934	5.825	21.142	4.754	31.976	6.392	28.775	5.975	0.417	3.201	-7.633
19	108.2	56.06	9.436	33.483	7.216	25.219	5.434	37.447	7.296	33.911	6.886	0.410	3.536	-8.692
20	108.4	--	--	34.963	7.486	26.33	5.639	38.93	7.546	35.315	7.168	0.378	3.615	-8.985
21	109.4	--	--	43.208	8.926	32.603	6.932	47.208	9.029	43.246	8.707	0.322	3.962	-10.643
22	110.4	--	--	52.989	10.547	40.315	8.377	57.068	10.784	52.729	10.324	0.460	4.339	-12.414
23	111.4	--	--	64.403	12.157	49.404	9.762	68.803	12.644	63.943	12.111	0.533	4.860	-14.539
24	112.4	--	--	77.466	13.875	59.96	11.369	82.364	14.494	76.991	14.008	0.486	5.373	-17.031
25	113.4	--	--	92.418	15.89	72.204	13.057	97.844	16.53	91.963	15.947	0.583	5.881	-19.759
26	114.3	153.33	21.87	107.673	17.884	84.684	14.643	111.795	18.363	107.211	17.972	0.391	4.584	-22.527
27	114.4	--	--	109.484	18.137	86.161	14.83	115.481	18.783	109.020	18.213	0.570	6.461	-22.859
28	115.4	--	--	129.146	21.068	102.043	16.971	135.501	21.29	128.493	20.824	0.466	7.008	-26.450
29	116.4	--	--	151.986	24.408	120.331	19.553	158.17	24.144	150.922	24.163	-0.019	7.248	-30.591
30	117.35	232.59	30.376	176.926	27.852	140.15	22.139	179.737	26.855	175.320	27.569	-0.714	4.417	-35.170

Sr. No	Elevation (wrt MSL) [m]	Original		Survey in year 2004		Survey in year 2011		Survey in year 2020-21 (@25 m)		Survey in year 2020-21 (@200m)		Surface area difference	Capacity difference	Capacity difference
		Gross Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	Capacity [Mm^3]	Area [km^2]	25 m vs 200 m (2021) [km^2]	25 m vs 200 m (2021) [Mm^3]	2011 vs 2021 @200 m [Mm^3]
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
31	117.4	--	--	178.331	28.038	141.263	22.284	183.892	27.37	176.881	27.809	-0.439	7.011	-35.618
32	118.4	--	--	208.543	32.222	165.113	25.387	213.066	30.978	206.689	31.908	-0.930	6.377	-41.576
33	118.87	281.32	33.618	224.302	34.42	177.434	26.964	226.769	32.673	222.548	34.165	-1.492	4.221	-45.114
34	119.4	--	--	243.324	36.982	192.245	28.844	245.972	34.831	241.014	36.977	-2.146	4.958	-48.769
35	120.4	336.44	38.524	282.852	41.443	223.145	32.964	282.693	38.675	280.758	42.437	-3.762	1.935	-57.613
36	121.4	--	--	326.576	45.186	258.534	37.696	323.459	42.895	325.960	48.075	-5.180	-2.501	-67.426
37	121.92	401.68	46.896	350.834	47.112	278.845	40.22	344.658	45.089	351.423	51.024	-5.935	-6.765	-72.578
38	122.4	--	--	374.159	48.883	298.792	42.589	368.652	47.535	376.870	53.626	-6.091	-8.218	-78.078
39	123.4	--	--	425.708	52.691	343.978	47.373	418.494	51.787	432.769	57.865	-6.078	-14.275	-88.791
40	123.44	477.92	53.213	427.856	52.848	345.887	47.565	420.48	51.957	435.095	57.980	-6.023	-14.615	-89.208
41	123.85	479	54.98	450.284	54.49	365.913	49.528	443.822	53.7	459.451	59.401	-5.701	-15.629	-93.538
42	124.4	--	--	481.604	56.824	394.078	52.159	471.789	54.838	492.307	61.161	-6.323	-20.518	-98.229
43	124.75	--	--	--	--	412.782	53.862	490.783	55.563	513.861	62.203	-6.640	-23.078	-101.079
44	124.97	565.87	61.538	515.755	59.563	424.859	54.951	502.927	56.019	528.310	63.092	-7.073	-25.383	-103.451
45	125.43	615	63	544.953	62.579	450.923	57.272	529.379	60.646	557.152	64.855	-4.209	-27.773	-106.229
46	126.49	666.81	71.783	--	--	515.537	63.185	592.106	64.572	626.549	67.669	-3.097	-34.443	-111.012
47	127.44	735.8	89.8	--	--	580.378	70.74	660.799	67.356	692.925	68.425	-1.069	-32.126	-112.547
2004 - RL 125.43 m														
Original, 2011, 2021 - FRL 127.44 m														

Table 6.2: Sedimentation in different zones w.r.t. FRL 127.44 m (using 25 m and 200 m data)

Year	1977	2011	2020-21	2020-21	2021
Storage Capacity in Mm^3			(@25 m)	(@25 m)	(@200 m)
Dead	56.6	25.219	37.45	37.45	33.911
Live	679.2	555.159	623.349	623.349	659.014
Gross	735.8	580.378	660.799	660.799	692.925
Loss of Storage Capacity in Mm^3		(wrt 1977)	(wrt 2011)	(wrt 1977)	(wrt 1977)
Dead	NA	31.381	-12.231	19.15	22.689
Live	NA	124.041	-68.19	55.85	20.186
Gross	NA	155.422	-80.421	75.00	42.875
Sedimentation Rate in Ha m/100 Km^2/Year		(wrt 1977)	(wrt 2011)	(wrt 1977)	(wrt 1977)
Dead	NA	3.875	-5.286	1.881	2.228
Live	NA	15.316	-29.468	5.485	1.983
Gross	3.57	19.190	-34.754	7.366	4.211
Annual % loss		(wrt 1977)	(wrt 2011)	(wrt 1977)	(wrt 1977)
Dead		0.1	-0.2	0.059	0.070
Live		0.5	-1.2	0.173	0.062
Gross		0.6	-1.4	0.232	0.132
Remarks	As per design	Serious	Desiltation	Significant	Significant
Volume of sediment (wrt 1977) deposited on bed in 2020-21 = Loss of storage capacity= 75 Mm^3					
Note: Sign Convention: -ve sign shows desiltation and +ve sign shows siltation					

Table 6.3: Sedimentation in different zones w.r.t. RL 125.43 m (using 25 m and 200 m data)

Year	1977	2004	2020-21	2020-21	2020-2021	2020-21
Storage Capacity in Mm^3		(@200 m)	(@200 m)	(@200 m)	(@25 m)	(@25 m)
Dead	56.6	33.483	33.911	33.911	37.447	37.447
Live	558.4	511.470	523.241	523.241	491.932	491.932
Gross	615	544.953	557.152	557.152	529.379	529.379
Loss of Storage Capacity in Mm^3		(wrt 1977)	(wrt 2004)	(wrt 1977)	(w.r.t. 2004)	(wrt 1977)
Dead	NA	23.117	-0.428	22.689	-3.964	19.153
Live	NA	46.93	-11.771	35.16	19.538	66.47
Gross	NA	70.047	-12.199	57.85	15.574	85.62
Sedimentation Rate in Ha m/100 Km^2/Year		(wrt 1977)	(wrt 2004)	(wrt 1977)	(wrt 2004)	(wrt 1977)
Dead	NA	3.700	-0.109	2.228	-1.008	1.881
Live	NA	7.511	-2.992	3.453	4.967	6.528
Gross	3.57	11.211	-3.101	5.682	3.959	8.409
Annual % loss		(wrt 1977)	(wrt 2004)	(wrt 1977)	(wrt 2004)	(wrt 1977)
Dead		0.14	-0.005	0.084	-0.043	0.071
Live		0.28	-0.127	0.130	0.211	0.246
Gross		0.42	-0.132	0.214	0.168	0.316
Remarks	As per design	Significant	Desiltation	Significant	Significant	Significant
Volume of sediment (wrt 1977) deposited on bed in 2020-21 = Loss of storage capacity= 85.62 Mm^3						
Note: Sign Convention: -ve sign shows desiltation and +ve sign shows siltation						

Based on the above analysis following points can be deduced:

1) At any elevation up to FRL, when comparing surface areas of Original, 2004 and 2021 it is more or less same (Refer comparison Table 6.1). This implies that surface area at any given elevation is more or less uniform as that of previous years, except in 2011 survey, where there is significant reduction in surface area, which in turn also resulted in the loss of storage capacity (as per 2011 survey the annual % loss is 0.6% and reservoir classified as serious category).
2) Since the surface area of 2021 survey is more or less agreeing with Original and 2004, the data seems to be more reliable (Refer comparison Table 6.1: rows highlighted in orange and area column). As per this analysis, the surface area for 2011 survey ideally should remain more or less same which is not the case.
3) It is to be noted that the previous surveys (2004 and 2011) were carried out with 200 m line spacing specification whereas current survey is carried out with 25 m line spacing specification (bathymetry and topography), and hence there will be some percentage of inherent error in the results (i.e., in terms of surface area and storage capacity). In addition to this, the 2011 and 2004 data above waterline is acquired using remote sensing technique/satellite imageries whereas in 2021, the data above water line was acquired using topography survey.
4) Hence, we compared and analysed the 2021 data which is acquired at 25 m line spacing with 2021 data at 200 m line spacing results.
5) It is noticed that at lower elevations, surface areas of 25 m line spacing are more or less matching with 200 m line spacing. In other words, not much difference noticed in surface areas at lower elevation, as the data interpolation is less due to less surface area (Refer Table 6.1, column "M").
6) However, with increasing elevations, surface area increases and consequently data interpolation becomes more and hence there is over estimate of the surface area at each elevations in the 200 m line spacing result as compared to 25 m line spacing result (Refer Table 6.1, column "M").
7) Thus, surface area generated using 25 m line spacing will be more accurate due to less degree of data interpolation especially at higher elevations.
8) In turn as the capacity is based on the surface area (Refer cone formula or Equation 2 given in Section 4.4) the capacity computed using 25 m line spacing data will be more reliable and with less error.

In addition to the above, sedimentation in different zones (FRL 127.44 m and RL 125.43 m) was also compared with 25 m and 200 m line spacing data and is given in Table 6.2 and Table 6.3. The sedimentation in different zones of reservoir table provides how the annual % loss changes/varies if we compare data from 25 m and 200 m line spacing with previous survey results.

Further to the above, it is observed that at FRL 127.44 m the surface area for the 2021 survey is decreased as compared to 2011 survey. This could be due to multiple reasons as explained below.

i) The area at FRL is surface area at the elevation 127.44 m, however the capacity at that elevation is the cumulative of all incremental volumes at different elevations calculated using the Cone formula as stated in the report. Since the deposition of sediment in the

reservoir is normally varies non-linearly in the different parts of the reservoir, it is quite possible to have higher incremental volume at a particular elevation and lower incremental volume at some other elevation. This is the reason that the rate of variation of capacity with depth is not same as the rate of variation of surface area.

ii) When we compare the surface area of 2011 with that of 2021, there is a decrease in the surface area at FRL in the 2021 survey. The reason for the decrease is given in point no. 1 and 2 given above.

iii) Secondly, the difference/decrease in surface area (w.r.t. year 2011) could be due to the methodology adopted during 2004 and 2011 survey where data acquired/surface area calculated above water line up to FRL is using remote sensing technique/satellite imageries whereas the 2021 data acquired/surface area was calculated using topography survey data (Refer point no. 3 given above).

iv) Also consider the following example of capacity and area at RL 125.43 m (highest elevation considered during 2004 survey)

Elevation (wrt MSL) [m]	Original		Survey in year 2004		Survey in year 2011		Survey in year 2020-21 (@25 m)		Survey in year 2020-21 (@200m)	
	Gross Capacity	Area	Capacity	Area	Capacity	Area	Capacity	Area	Capacity	Area
	[Mm^3]	[km^2]	[Mm^3]	[km^2]	[Mm^3]	[km^2]	[Mm^3]	[km^2]	[Mm^3]	[km^2]
125.43	615	63	544.953	62.579	450.923	57.272	529.379	60.646	557.152	64.855
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**

a) As expected, the area and capacity keep on reducing from Original to 2004 and 2021. Compare area column C, E & I and corresponding capacity for Original, 2004 and 2021 (@25 m).

b) However, when we compare the Original, 2004 and 2021 (@200 m), there is an increase in surface area at RL 125.43 m for the year 2021 and hence a corresponding increase in the capacity. The difference / increase in the surface area in the year 2021 could be due to change in survey methodology adopted in previous survey (satellite imageries used for recording elevations above water line) and current survey (topography survey carried out for recording elevations above water line).

7. Conclusions

- The reservoir topography was uneven, with reservoir bed level ranging from 92.5 m to 127.44 m w.r.t. MSL. The lowest reservoir bed level (92.5 m) was found at 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 east, west & south from the reservoir center.
- Through the elevation area capacity curves, it was found that the capacity has increased in year 2020-21 as compared to 2011. The capacity is close to that of the year 2004. The probable reasons for the increase of capacity could be change in hydrodynamics due to change of upstream discharges as sediment carrying capacity of the river and its tributaries. Also, there is a cyclic trend of siltation and desiltation of the reservoir as observed from survey data of previous years. More detailed analysis of present data with previous years has been discussed in section 6.
- However, w.r.t. 1977 Project Capacity data, siltation of Panam reservoir has taken place and the annual % loss in gross storage capacity is 0.23 % and hence, the reservoir is classified as “Significant category” as per IS-2182 (1987).
- The sedimentation volumes, sedimentation rates, loss of storage capacity have been reported zone wise in the study. Moreover, the tables for gross and live storage capacity of reservoir at every 0.1 m interval have been provided.

8. References

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Appendix A

Diary of Events

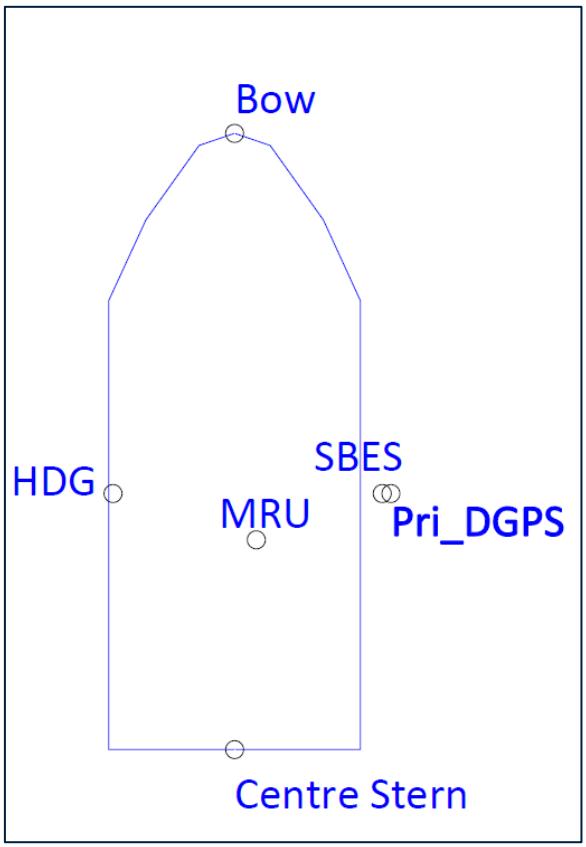
(01 page)

Diary of Events	
Date	**Events**
4 December 2020	Fugro personnel for 'Zodiac 1' reached Panam Dam location
5 December 2020	Mobilization of equipment commenced.
6 December 2020	Equipment calibration / verification carried out.
7 December 2020	Bathymetry and Topography survey started.
8 December 2020 – 11 January 2021	Bathymetry and Topography survey continued.
12 January 2021	Bathymetry and Topography survey continued by 'Zodiac 1'. Personnel and survey boat 'Polaris' reached survey location.
13 January 2021	Bathymetry and Topography survey continued by 'Zodiac 1'. Mobilization of 'Polaris' started.
14 January 2021	Bathymetry and Topography survey continued through 'Zodiac 1'. Mobilization of 'Polaris' completed and calibration / verification commenced.
15 January 2021 – 14 February 2021	Bathymetry and Topography survey continued by 'Zodiac 1' & 'Polaris'. Topography survey completed on 28 January 2021.
15 February 2021	Bathymetry survey completed.

Appendix B

Survey Vessel Sensor Offsets

(01 page)

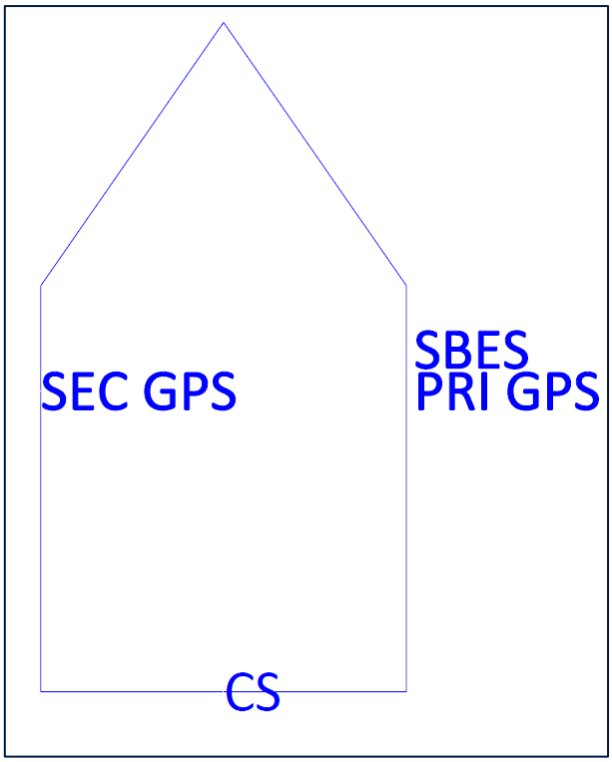


Outline | Offsets | Fairleads

Show

Name	X	Y	Z
Centre Stern	0.000	0.000	0.000
Bow	0.000	4.260	0.000
Pri_DGPS	1.080	1.770	1.740
HDG	-0.840	1.770	1.740
SBES	1.020	1.770	-0.220
MRU	0.150	1.450	0.170

Survey Vessel 'Polaris'



Outline | Offsets | Fairleads

Show

Name	X	Y	Z
PRI GPS	1.010	1.600	1.900
SBES	1.010	1.820	-0.320
SEC GPS	-0.970	1.600	1.900
CS	0.000	0.000	0.000

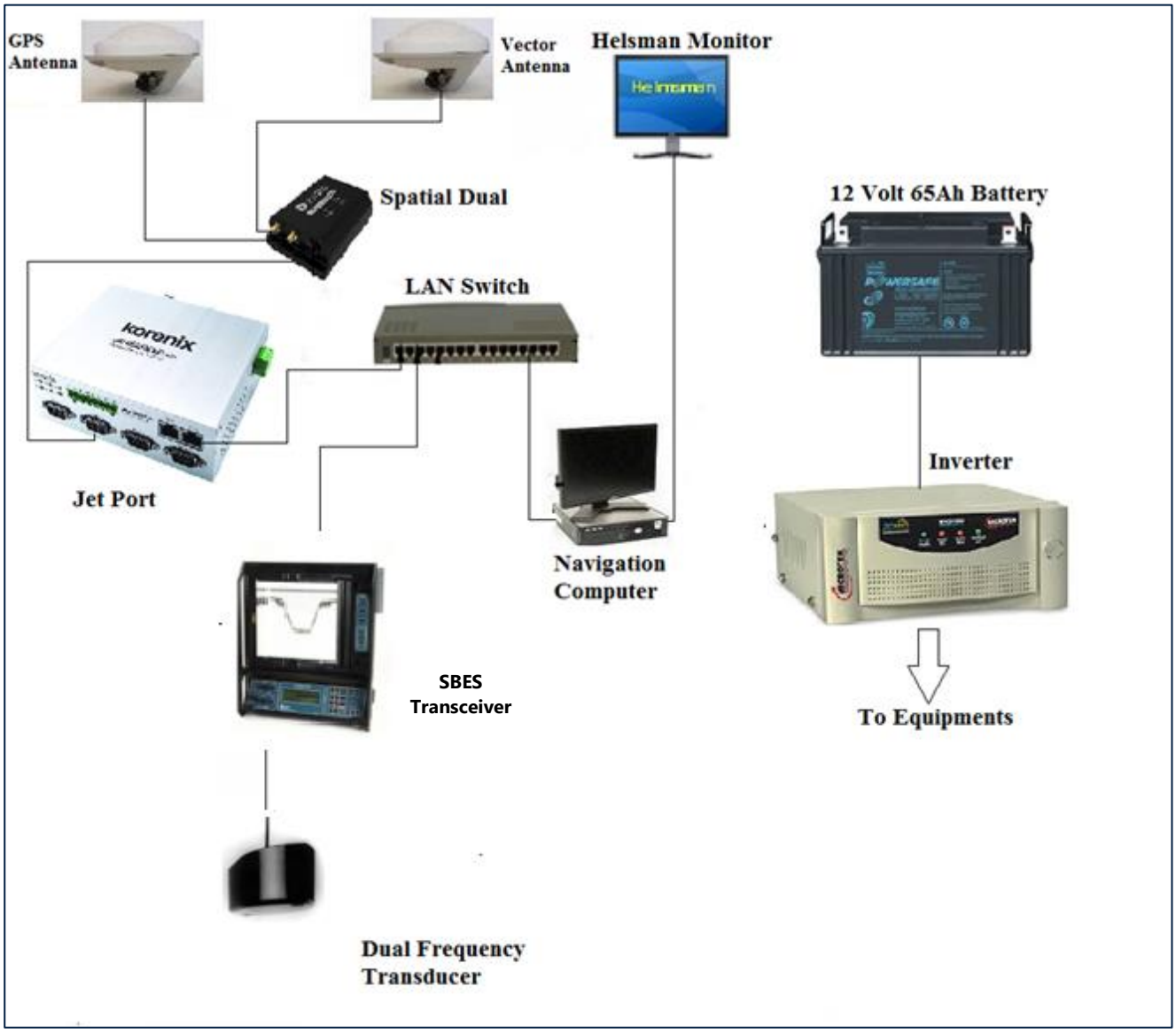
Survey Vessel 'Zodiac 1'

Appendix C

Equipment Layout Diagrams

(01 page)

Equipment Layout Diagram for 'Fugro Zodiac 1' & 'Polaris'



Appendix D

Results of Field Calibrations / Verifications

(14 pages)

FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of Panam Dam BM

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	Panam Dam	**Location:**	Gujarat, West Coast of India
Party Chief :	Arpit Bose	**Job Engineer/Surveyor :**	Mathiyazhagan.V
Date of Observation: (Date & Time)	11-02-2021 & 18:34hrs	**End of Observation: (Date & Time)**	11-02-2021 & 19:04

1. Station Name: Panam Dam BM.

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**
SPATIAL DUAL RECIEVER	025-00006405	PRI_DGPS	Mean position report	FBF	NA	0.01

A= BM Height of Panam Dam from MSL 132.412m (Client provided)

B= Antenna Height from center of BM 1.410m (Measured by Tape)

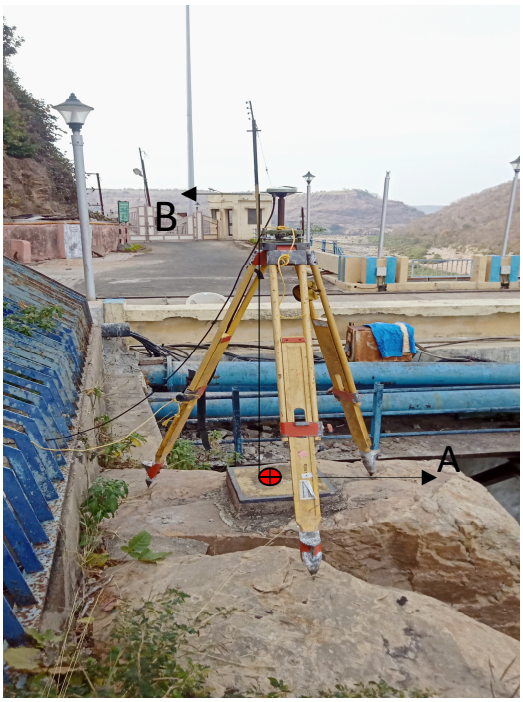
Ellipsoidal height of Antenna= 77.611m

Ellipsoidal Height of BM 77.611m-1.410m=76.201m

Position Of Antenna:-

Latitude: 23°03’12.164”N, **Longitude:** 73°42’57.038”E

Easting: 3,68,441.840m E, **Northing:** 25,50,006.218m N



Prepared By: Arpit Bose.

BATHYMETRIC SURVEY FOR RESERVOIRS
MEAN POSITION REPORT

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

Session Name: MPR-20210211130323-v3 Records Used: 1084 of 1762

Start Time: 11 Feb 2021, 18:34:59+05:30 End Time: 11 Feb 2021, 19:04:57+05:30 Session Length: 00:29:59

Mean Position for Tripod CentreOfGravity		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	23°03’12.16484”N	23°03’12.16484”N
Longitude	73°42’57.03814”E	73°42’57.03814”E
Height	77.611m Ell.	77.611m Ell.
Easting	3,68,441.840m E (SD: ±0.01m)	
Northing	25,50,006.218m N (SD: ±0.01m)	
Height	134.264m 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

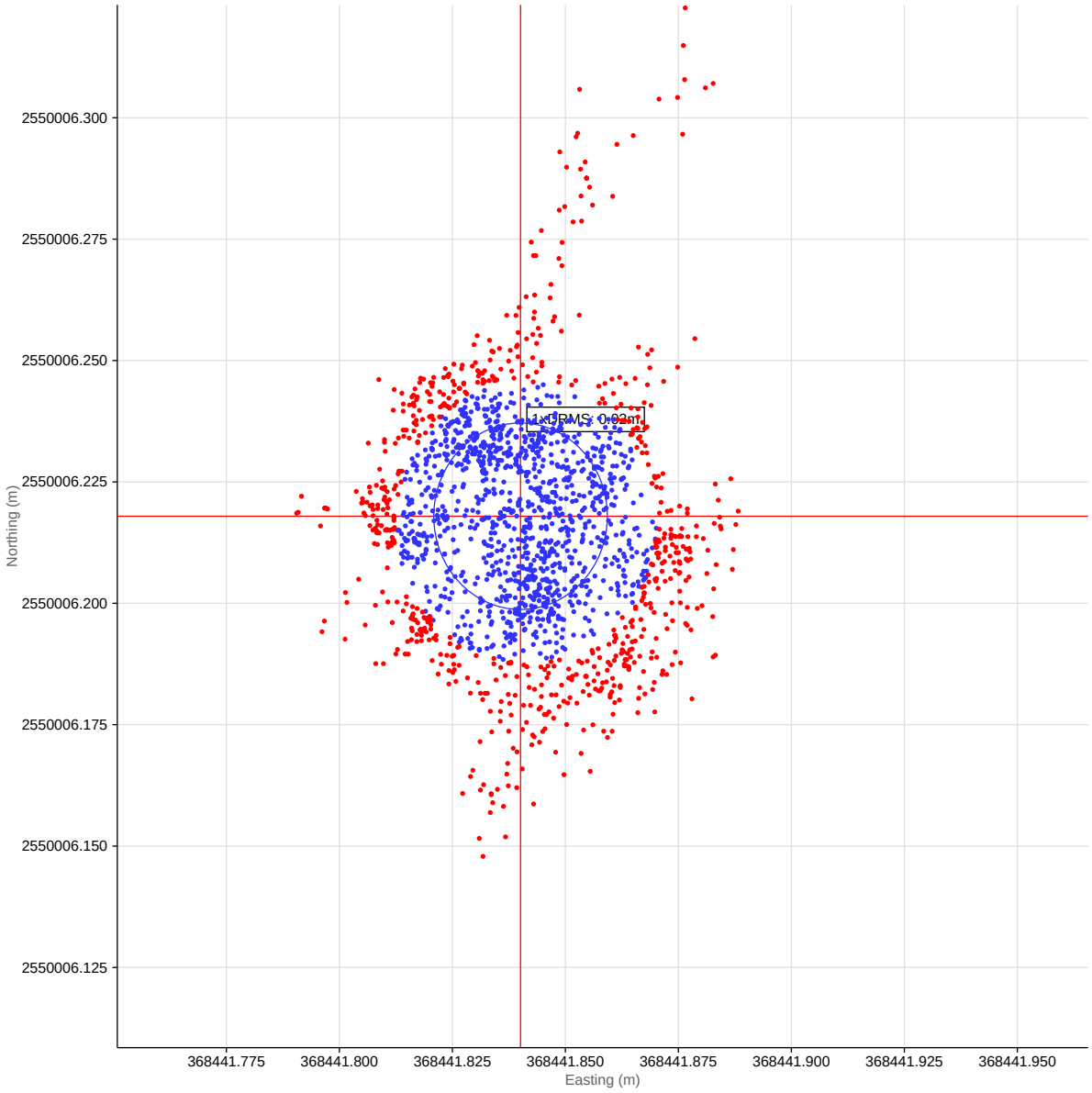
Arpit Bose
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

U C.SHAH
End Client Representative
Narmada Water Resources Govt. of Gujarat

Geodetic Parameters

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

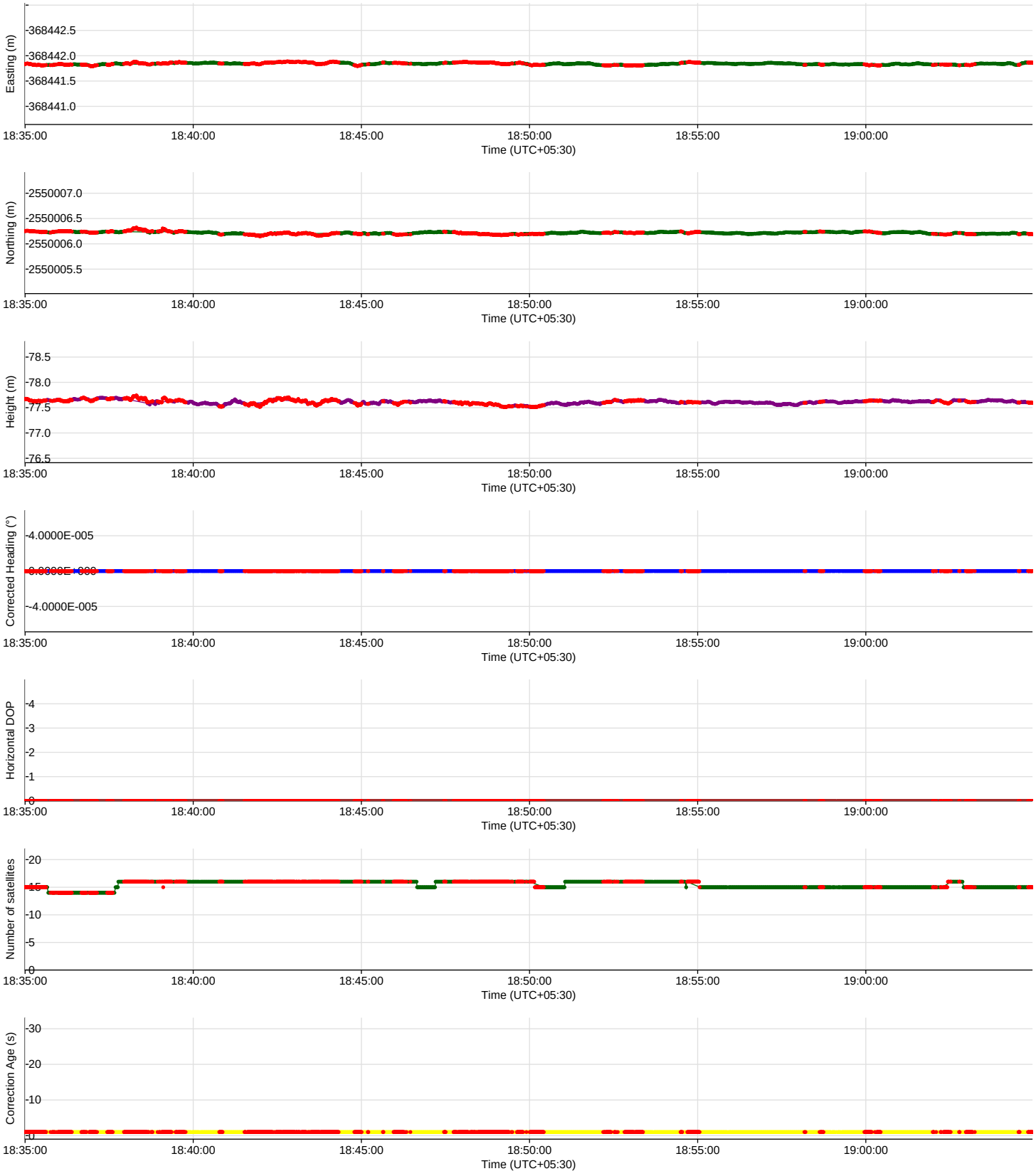
Scatter Plot



Mean Position

	Easting	Northing
Tripod	3,68,441.840m E	25,50,006.218m N

Time Series Plots for Tripod



FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of Panam Dam BM

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	Panam Dam	**Location:**	Gujarat, West Coast of India
Party Chief :	Arpit Bose	**Job Engineer/Surveyor :**	Mathiyazhagan.V
Date of Observation: (Date & Time)	12-02-2021 & 14:02hrs	**End of Observation: (Date & Time)**	12-02-2021 & 14:47hrs

1. Station Name: Panam Dam BM.

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**
SPATIAL DUAL RECIEVER	025-272968	PRI_DGPS	Mean position report	FBF	NA	0.01

A= BM Height of Panam Dam from MSL 132.412m (Client provided)

B= Antenna Height from center of BM is 1.452m (Measured by Tape)

Ellipsoidal height of Antenna= 77.805m

Ellipsoidal Height of BM 77.805m-1.452m=76.353m

Position Of Antenna:-

Latitude: 23°03'12.163"N, **Longitude:** 73°42'57.040"E

Easting: 3,68,441.893m E, **Northing:** 25,50,006.175m N

Prepared By: Arpit Bose.

BATHYMETRIC SURVEY FOR RESERVOIRS
MEAN POSITION REPORT

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

Session Name: MPR-20210212063924-polaris spatial dual-v2

Records Used: 1668 of 2700

Start Time: 12 Feb 2021, 14:02:27+05:30 End Time: 12 Feb 2021, 14:47:26+05:30 Session Length: 00:44:59

Mean Position for Tripod CentreOfGravity		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	23°03’12.16347”N	23°03’12.16347”N
Longitude	73°42’57.04001”E	73°42’57.04001”E
Height	77.805m Ell.	77.805m Ell.
Easting	3,68,441.893m E (SD: ±0.01m)	
Northing	25,50,006.175m N (SD: ±0.01m)	
Height	134.458m Ort. (SD: ±0.05m Ort.)	

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

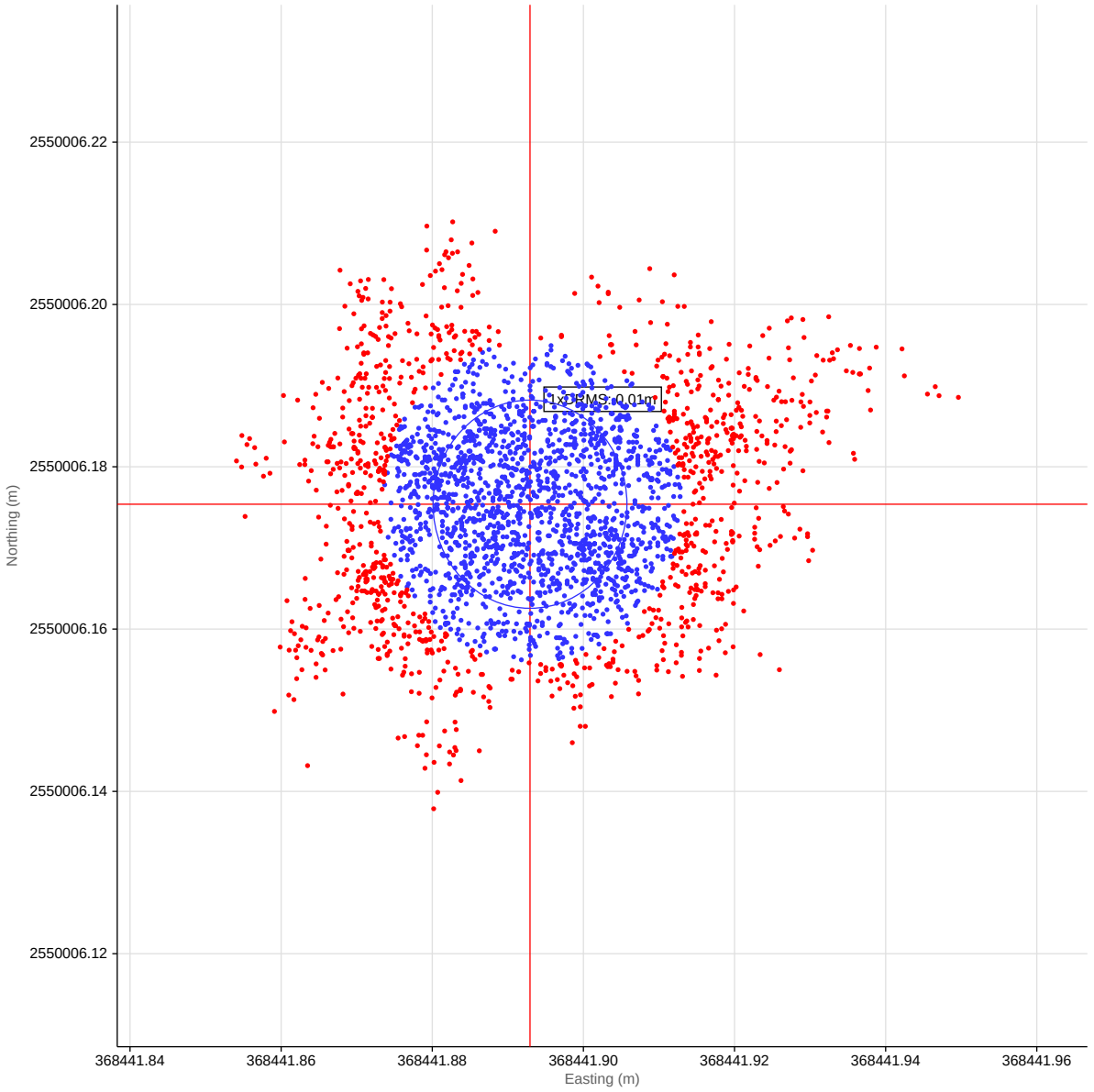
Arpit Bose
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

U C.SHAH
End Client Representative
Narmada Water Resources Govt. of Gujarat

Geodetic Parameters

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

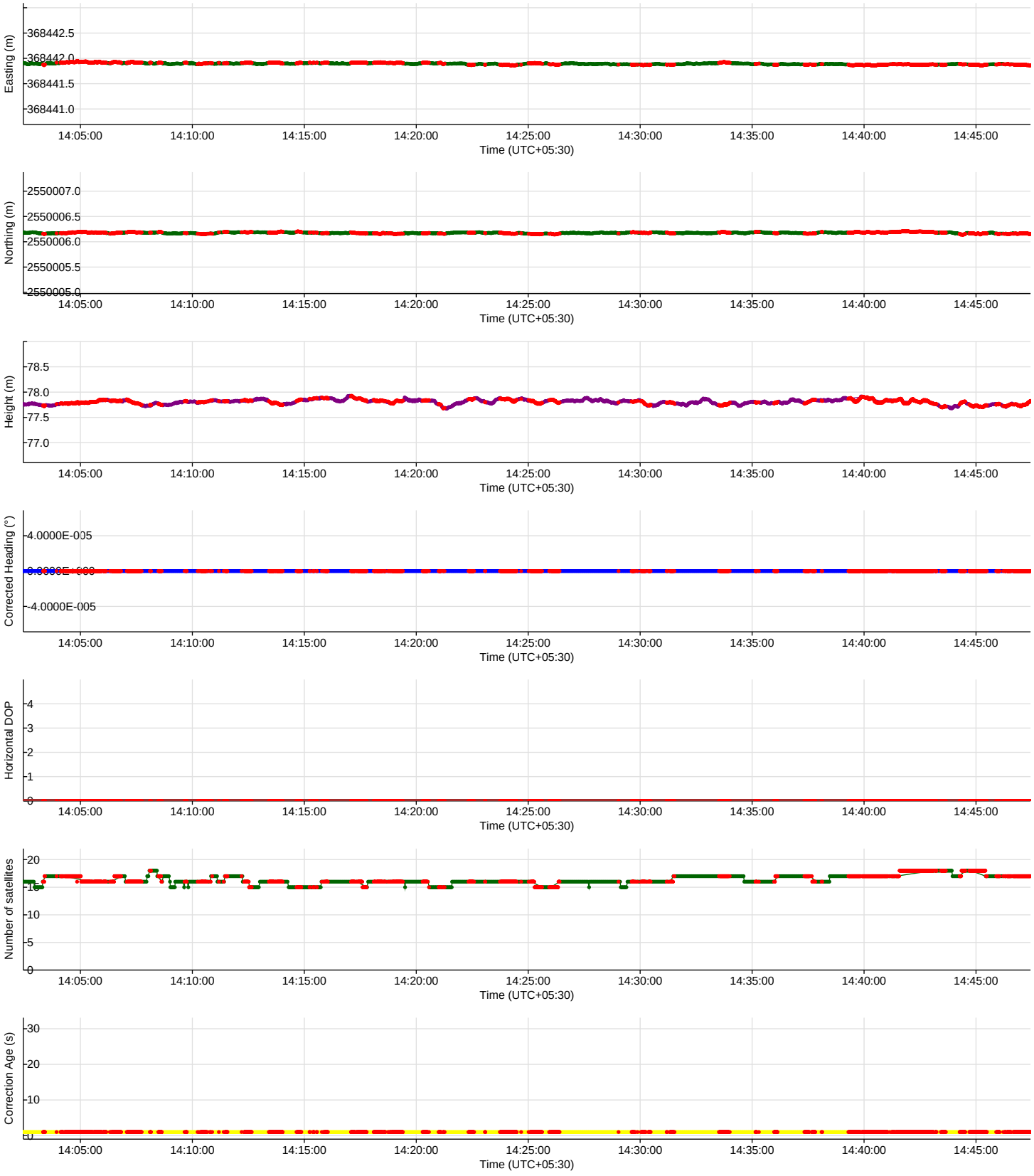
Scatter Plot



Mean Position

	Easting	Northing
Tripod	3,68,441.893m E	25,50,006.175m N

Time Series Plots for Tripod



SBES Calibration

SBES Barcheck Correction Table

Project No.	Project Title:	Vessel:	Place:
J-HYD-20-174630	**Bathymetry Survey**	**FUGRO ZODIAC 1**	**PANAM DAM**
Date:	Time:	Client:	
06-May-09	**15:00**	**GOV. OF GUJRAT**	
Observed By: PRITAM SETH		Echo Sounder Model and SL. No.	Area Depth
Project No. J-HYD-20-174630		**MIDAS**	**30**

Echo Sounder Settings

Draft HI	Draft LO	Sound Velocity	
		Average	**Upto Depth**
0.32	**0.32**	**1497**	**16**
Barcheck Frequency selected	**Survey Frequency:**	Manufacturer's Accuracy	
High 210 KHz	**33 and 210 KHz**	0.10 % of Depth	0.03 m

Observations while lowering			Observations while hoisting		
Bar Depth (m)	ES Reading (m)	Difference (m)	Bar Depth (m)	ES Reading (m)	Difference (m)
1	1.01	-0.01	7	7.02	-0.02
2	2	0	6	6.02	-0.02
3	3.02	-0.02	5	5.04	-0.04
4	4.04	-0.04	4	4	0
5	4.99	0.01	3	2.99	0.01
6	6	0	2	2.03	-0.03
7	7.02	-0.02	1	1.01	-0.01

Average	-0.01	Average	-0.02
Std. Dev	0.0168	Std. Deviation	0.0172
		Cumulative Average	-0.01
		Cumulative Std. Deviation	0.0003

PRITAM SETH
FSINPVT Party Chief

For Client

SBES Calibration

SBES Barcheck Correction Table

Project No.	Project Title:	Vessel:	Place:
J-HYD-20-174630	**Bathymetry Survey**	**POLARIS**	**PANAM DAM**
Date:	Time:	Client:	
12-Jan-21	**10:49**	**GOV. OF GUJRAT**	
Observed By: PRITAM SETH		Echo Sounder Model and SL. No.	Area Depth
Project No. J-HYD-20-174630		**E20 ECHOTRAC**	**30**

Echo Sounder Settings

Draft HI	Draft LO	Sound Velocity	
		Average	**Upto Depth**
0.2	**0.2**	**1497**	**20**
Barcheck Frequency selected	**Survey Frequency:**	Manufacturer's Accuracy	
High 200 KHz	**33 and 200 KHz**	0.10 % of Depth	0.03 m

Observations while lowering			Observations while hoisting		
Bar Depth (m)	ES Reading (m)	Difference (m)	Bar Depth (m)	ES Reading (m)	Difference (m)
1	1	0	10	10	0
2	2	0	9	9	0
3	3	0	8	8	0
4	4	0	7	7	0
5	5	0	6	6	0
6	6	0	5	5	0
7	7	0	4	4	0
8	8	0	3	3	0
9	9	0	2	2	0
10	10	0	1	1	0

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

PRITAM SETH

FSINPVT Party Chief

For Client

Station Name: Panam Dam BM.

Positioning System Verification With BX-992 Reciever and Spatial Dual						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Easting mE**	**Northing mN**	**Latitude**	**Longitude**	**Ellipsoidal height (m)**
TRIMBLE BX992 RECEIVER	025-00009601	368442.10	2550006.133	23°03'12.162"N	073°42'57.047"E	76.118
Spatial Dual (Zodiac)	025-00006405	368441.84	2550006.218	23°03'12.164"N	073°42'57.038"E	76.201
	Difference	**0.260**	**-0.085**	**--**	**--**	**-0.083**
Positioning System Verification With BX-992 Reciever and Spatial Dual						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Easting mE**	**Northing mN**	**Latitude**	**Longitude**	**Ellipsoidal height (m)**
TRIMBLE BX992 RECEIVER	025-00009601	368442.100	2550006.133	23°03'12.162"N	073°42'57.047"E	76.118
Spatial Dual (Polaris)	025-272968	368441.893	2550006.175	23°03'12.163"N	073°42'57.040"E	76.353
	Difference	**0.207**	**-0.042**	**--**	**--**	**-0.235**

Location Name:	PANAM DAM	Date:	06-04-2021	Instrument Name	LYNX
Work:	RTK Observation by Topography Team			Model no.	H6

Station Name	Observation Duration	Easting (mE)	Northing (mN)	MSL Height (m)	Remarks
Panam Dam BM	14:40-15:10 (30min)	368440.627	2550007.620	132.678	XYZ Value generated by RTK of Topography Team
TBM P01	15:58-16:28 (33min)	368490.351	2550060.994	131.769	XYZ Value generated by RTK of Topography Team

		30min Observation by RTK XYZ value								Difference With RTK XYZ Value		
Station Name	Remarks	Easting mE	Northing (mN)	MSL Height (m)	Station Name	Remarks	Easting (mE)	Northing (mN)	MSL Height (m)	Easting (mE)	Northing (mN)	MSL Height (m)
Panam Dam BM	Base station Setup	368440.627	2550007.620	132.678	TBM P01	Check by Rover	368489.539	2550060.742	131.787	0.812	0.252	-0.018
TBM P01	Base station Setup	368490.351	2550060.994	131.769	Panam Dam BM	Check by Rover	368441.444	2550007.871	132.647	-0.817	-0.251	0.031

		Fugro Provided XYZ Value								Difference With Fugro Provided XYZ Value		
Station Name	Remarks	Easting (mE)	Northing (mN)	MSL Height (m)	Station Name	Remarks	Easting (mE)	Northing (mN)	MSL Height (m)	Easting (mE)	Northing (mN)	MSL Height (m)
Panam Dam BM	Base station Setup	368442.100	2550006.130	132.412	TBM P01	Check by Rover	368491.015	2550059.262	131.541	0.152	-0.027	0.002
TBM P01	Base station Setup	368490.850	2550059.290	131.533	Panam Dam BM	Check by Rover	368441.948	2550006.157	132.41	-0.165	0.028	-0.008

Prepared by Pritam Seth

Appendix E

Benchmark Descriptions

(4 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 :	Panam Dam	**PANAM DAM BM**
Observed By:	Pritam Seth, Sai Kiran	
Date:	20-12-2020	

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

GEOGRAPHICAL COORDINATES: **UTM COORDINATES:** Zone No: 43N CM: 75° E

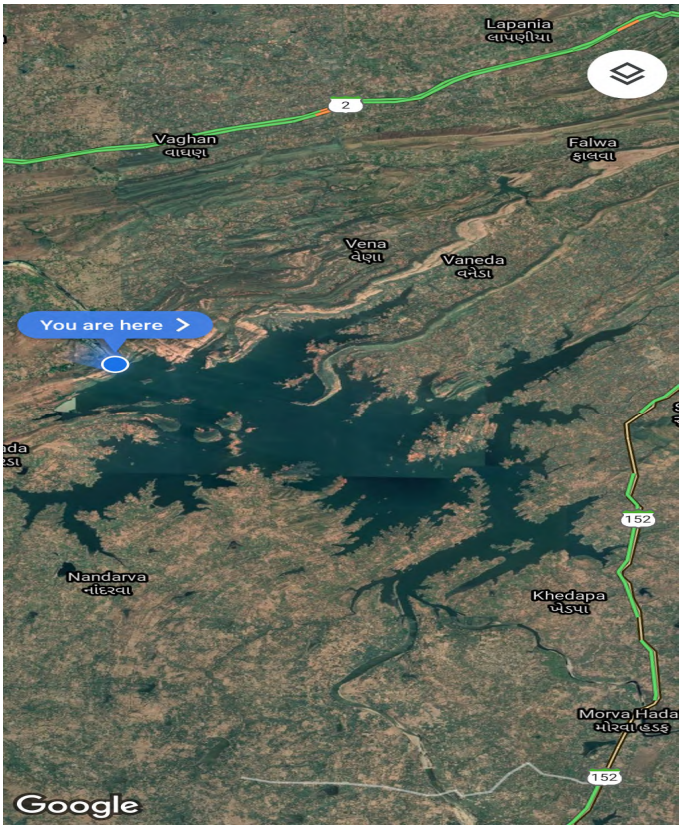
LATITUDE:	23°03'12.16214"	N	EASTING:	368,442.10 m	σ = +/- 0.01 m
LONGITUDE :	073°42'57.04729"	E	NORTHING:	2,550,006.13 m	σ = +/- 0.01 m
ELLIPSOIDAL HEIGHT:	76.118	m	CONVERGENCE :	-0.50293	Degrees
HEIGHT ABOVE LAT/CD:		m	Ht above Local MSL:	132.412	m

LOCATION & ACCESS : Beside Control house of Panam Dam(Near Lockgate). 100m from Panam Dam Main Gate.

STATION MARKING : It's a Concrete Piller (Yellow colour) establised by Gov of Gujarat Panam Dam.

Expected durability of the Station (Years) : 10years

DETAILED DIAGRAM :



Pritam Seth
Party chief (FSINPVT)

Upendrakumar C. Shah
Client Rep.(Govt. Of Gujarat)

FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of Panam Dam BM

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	Panam Dam	**Location:**	Gujarat, West Coast of India
Party Chief :	Pritam Seth	**Job Engineer/Surveyor :**	Sai Kiran
Date of Observation: (Date & Time)	20-12-2020 & 12:58hrs	**End of Observation: (Date & Time)**	20-12-2020 & 13:28

1. Station Name: Panam Dam BM.

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	025-000096 01	PRI_DGPS	Mean position report	FBF	NA	0.01

A= Panam Dam BM.Height from MSL 132.412m

B= Antenna Height from BM 1.352m (Measure by Tape)

Ellipsoidal height of Antenna= 77.470m

Ellipsoidal Height of BM 77.470m-1.352m=76.118m

C is the center point of BM.

(Antenna is top of Center point Of BM)

Position Of Antenna:-

Latitude: 23°03'12.16214"N, **Longitude:** 073°42'57.04729"E

Easting: 3,68,442.100m E, **Northing:** 25,50,006.133m N

Prepared By: Pritam Seth.

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 :	Panam Dam	**TBM P-01**
Observed By:	Pritam Seth, Sai Kiran	
Date:	27-12-2020	

Brief Description of the Method Adopted

1. Purpose of Establishing the station :- Ref. Station and cross check purpose of 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

GEOGRAPHICAL COORDINATES: **UTM COORDINATES:** Zone No: 43N CM: 75° E

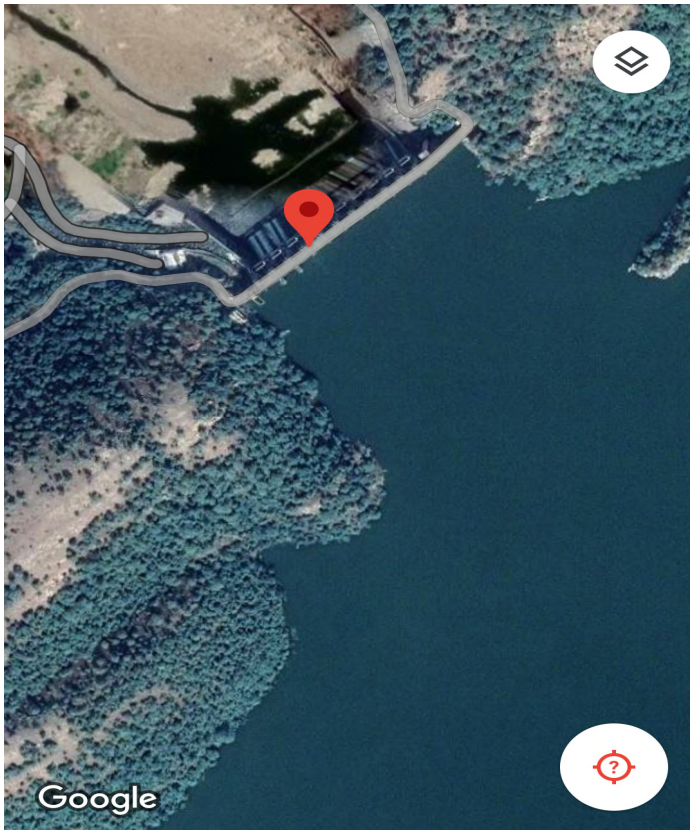
LATITUDE:	23°03'13.90413" N		EASTING:	368,490.85 m	σ = +/- 0.02 m
LONGITUDE :	073°42'58.74363" E		NORTHING:	2,550,059.29 m	σ = +/- 0.02 m
ELLIPSOIDAL HEIGHT:	75.251 m		CONVERGENCE :	-0.50276 Degrees	
HEIGHT ABOVE LAT/CD:	NA m		Ht above Local MSL:	131.533 m	

LOCATION & ACCESS : 150m from Panam Dam Main Gate near 3no. Lock Gate. This TBM point established on Top of Dam.

STATION MARKING : This station marked by red colour on Top of Dam near 3no. Lock gate.

Expected durability of the Station (Years) : 2years

DETAILED DIAGRAM :



Pritam Seth
Party Chief (FSINPVT)

Upendrakumar C. Shah
Client Rep. (Govt. Of Gujarat)

FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of TBM P-01

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	TBM P-01	**Location:**	Gujarat, West Coast of India
Party Chief :	Pritam Seth	**Job Engineer/Surveyor :**	Sai Kiran
Date of Observation: (Date & Time)	27-12-2020 & 11:26hrs	**End of Observation: (Date & Time)**	27-12-2020 & 11:56hrs

1. Station Name: TBM P-01.

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 TBM P-01. Height from MSL 131.533m

B= Antenna Height from TBM 1.574m (Measure by Tape)

Ellipsoidal height of Antenna= 76.821m

Ellipsoidal Height of TBM P-01 76.821m-1.574m=75.251m

Position Of Antenna:-

Latitude: 23°03'13.90413"N, **Longitude:** 073°42'58.74363"E

Easting: 3,68,490.849m E, **Northing:** 25,50,059.285m N

(Antenna is top of Center point Of TBM)

Prepared By: Pritam Seth.

Appendix F

List of Deliverables

(01 page)

Details of Reports				
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						
Sl. No.	Charts showing	Sheet No.	Encl. No.	Drawing No.:	Rev. No	HS
1	Reservoir Bed and Topography Heights	01 of 01	01 of 03	J-HYD-20-174630/WRD/GUJARAT/B/B/01/9508	0	1:20000
2	Contour Map of Panam Reservoir	01 of 01	02 of 03	JHYD-20-174630/WRD/GUJARAT/B/B/01/9636	0	1:20000
3	Seabed Relief Image Prepared from SBES Data	01 of 01	03 of 03	JHYD-20-174630/WRD/GUJARAT/B/I/01/9630	0	1:20000
Details of Other Deliverables						
1	L-section	Soft copy				
2	C-section at every 100 m	Soft copy				