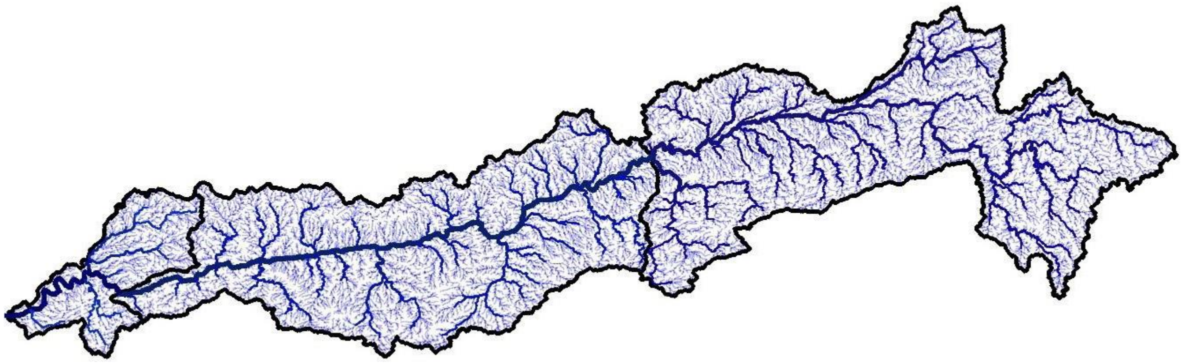
National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

Hydraulic Status of Narmada River Basin



December 2024

Hydraulic Status of Narmada River Basin

National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development & Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

www.nrcd.nic.in

Centres for Narmada River Basin Management and Studies (cNarmada)

The Center for Narmada River Basin Management and Studies (cNarmada) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by IIT Gandhinagar and IIT Indore, under the supervision of cGanga at IIT Kanpur, the center serves as a knowledge wing of the National River Conservation Directorate (NRCD). cNarmada is committed to restoring and conserving the Narmada River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

www.cnarmada.org

Centres for Ganga River Basin Management and Studies (cGanga)

cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.

www.cganga.org

Acknowledgment

This report is a comprehensive outcome of the project jointly executed by IIT Gandhinagar (Lead Institute) and IIT Indore (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

Team Members

Pranab Kumar Mohapatra, cNarmada, IIT Gandhinagar
Bhanu Parmar, cNarmada, IIT Gandhinagar
Sunil Kumar, cNarmada, IIT Gandhinagar
Sushil Kumar Jaiswal, cNarmada, IIT Gandhinagar
Jitendra Poddar, cNarmada, IIT Gandhinagar
Ashok Kumar Parmar, cNarmada, IIT Gandhinagar
Rajesh Kumar, cNarmada, IIT Gandhinagar
Vinod Tare, cGanga, IIT Kanpur
Shahrukh Ahmad, cGanga, IIT Kanpur

PREFACE

The Narmada River, with its vast hydrological significance and rich ecological diversity, continues to serve as a lifeline for central and western India. Its extensive basin is not only a source of sustenance for countless communities but also a critical resource for agricultural, industrial, and cultural activities. However, this vital water system faces mounting challenges from anthropogenic pressures and environmental changes, necessitating a deeper understanding of its dynamics and a robust approach to its management.

This report, focused on the hydraulic characteristics and infrastructure of the Narmada River, is an endeavour to consolidate and present key insights drawn from meticulous data collection and analysis. By exploring cross-sectional and longitudinal profiles, as well as examining the river's interaction with major infrastructure elements like dams, canals, and bridges, this report aims to provide a holistic perspective on the river's functioning and the factors influencing its health.

Throughout this study, emphasis has been placed on delivering actionable findings to guide sustainable management strategies for the Narmada Basin. This report aims to serve as a cornerstone for future initiatives, offering valuable insights to researchers, policymakers, and practitioners seeking to balance ecological preservation with developmental goals. The recommendations outlined herein aspire to encourage informed decision-making and foster collaborative efforts to ensure the long-term health and resilience of the Narmada River.

We extend our heartfelt gratitude to the numerous contributors, including project staff, government agencies, research institutions, and individuals who provided data, insights, and support. Their contributions have been invaluable in shaping this report. We hope that this report will inspire thoughtful engagement with the challenges and opportunities facing the Narmada River Basin, ultimately contributing to a brighter future for the region and its inhabitants.

Centre for Narmada River Basin
Management and Studies (cNarmada)
IIT Gandhinagar, IIT Indore

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

cGanga	Centres for Ganga River Basin Management and Studies
cNarmada	Centres for Narmada River Basin Management and Studies
CWC	Central Water Commission
HE	Hydroelectric
IR	Irrigation
ISP	Indira Sagar Project
MCM	Million Cubic Meters
NHDC	Narmada Hydro Development Corporation
NMCG	National Mission for Clean Ganga
NRCP	National River Conservation Plan
NRCD	National River Conservation Directorate
PS	Potable Supply
WRIS	Water Resources Information System

Chapter 1: Introduction

1.1 BACKGROUND AND SIGNIFICANCE OF THE NARMADA RIVER

The Narmada River, originating from the Amarkantak Plateau in Madhya Pradesh, is one of India's most significant west-flowing rivers, spanning approximately 1,312 kilometers before draining into the Arabian Sea. Its basin, covering 95,959.7 square kilometers, exhibits diverse geomorphological features, including steep gradients in the upper reaches, basaltic formations in the middle basin, and expansive alluvial plains downstream.

The river's hydraulic profile is shaped by its unique physiography and tectonic settings, particularly the Narmada Rift Valley flanked by the Vindhya and Satpura ranges. This geological framework influences the flow regime, sediment dynamics, and discharge patterns, making the river a vital case study for hydraulic research and water resource management.

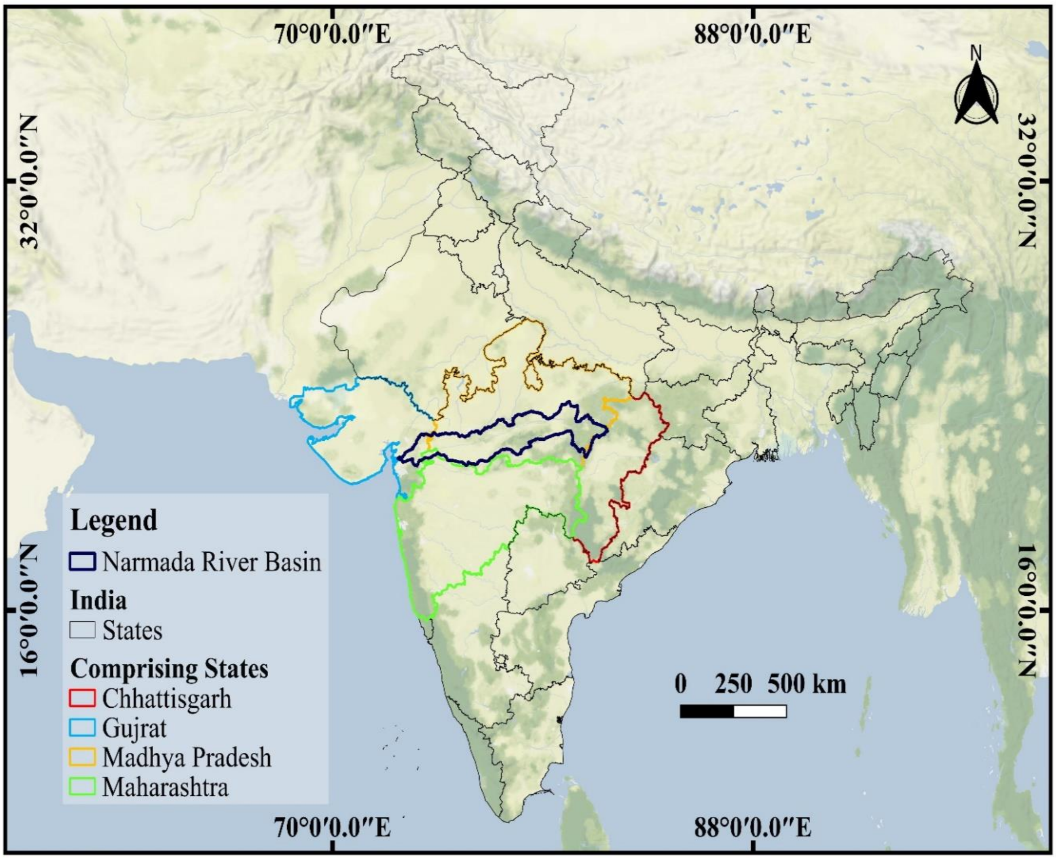


Figure 1: Geographical location map

1.1.1 Geographic Profile of the Narmada River

Originating from the Amarkantak Plateau in Madhya Pradesh, the Narmada River flows westward for 1,312 km before emptying into the Arabian Sea through the Gulf of Khambhat. Its basin extends from 21° 40' 12" to 23° 41' 24" N latitudes and 72° 48' 36" to 81° 45' 36" E longitudes, covering 95,959.70 sq. km—approximately 3% of India's total geographical area. The basin's elongated shape spans 915.65 km from east to west and 236 km from north to south.

The river's physiography is defined by three distinct zones: the upper, middle, and lower reaches. The upper Narmada flows through rugged and forested terrain, characterized by steep slopes and narrow valleys. Notable topographical features include the Kapildhara Falls near the river's origin and the Marble Rocks gorge at Bhedaghat near Jabalpur. The middle Narmada is marked by wider valleys and fertile plains, with prominent basaltic formations from ancient volcanic activity. This region is ideal for agriculture and supports several large irrigation projects. The lower Narmada basin transitions into the Gujarat plains, featuring alluvial deposits and a gentler gradient as it approaches the Arabian Sea.

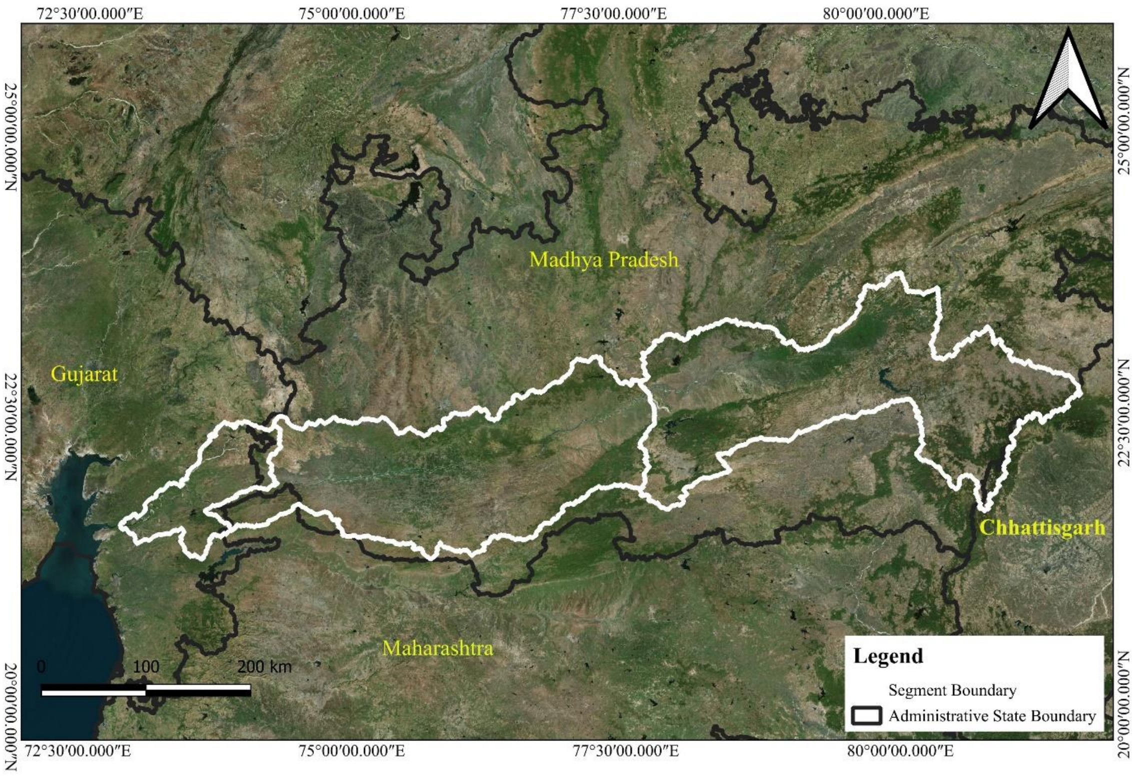


Figure 2: Drainage area of the Narmada River with its three segments

The Narmada Rift Valley, a tectonic feature, significantly influences the river's course. Flanked by the Vindhya Range to the north and the Satpura Range to the south, this valley provides a unique geological setting. The river's flow is further augmented by its 41 tributaries, including the Tawa, Hiran, and Shakkar Rivers, which contribute to the hydraulics, hydrological and ecological diversity of the basin.

1.1.2 Sub-Divisions of the Basin

The Narmada River basin is divided into three sub-basins based on geomorphology, hydrology, and hydraulics, each with unique characteristics and challenges:

Upper Narmada Sub-Basin: Extending from Amarkantak to Hoshangabad (~720 km), this region encompasses the river's origin at the Amarkantak Plateau and its flow through rugged, forested terrain. The area is characterized by steep gradients and narrow valleys, making it ideal for hydropower projects such as the Bargi Dam. However, these steep slopes and high rainfall levels also make the sub-basin prone to soil erosion and sedimentation issues, affecting downstream water quality and reservoir capacity.

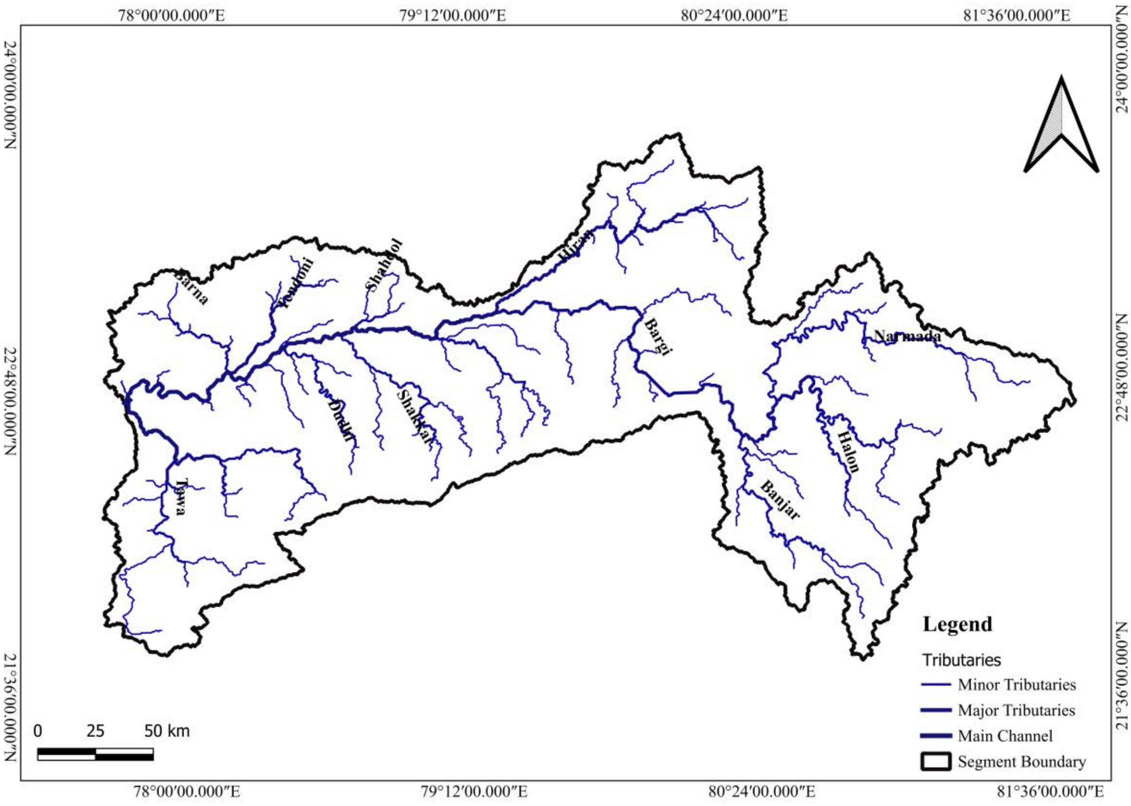


Figure 3: Tributaries of Upper Narmada River segment

Middle Narmada Sub-Basin: Spanning Hoshangabad to Navagam (~485 km), the middle sub-basin is marked by wider valleys, fertile plains, and basaltic rock formations. This region supports extensive agricultural activity, thanks to irrigation systems fed by major projects like the Indira Sagar and Omkareshwar Dams. Despite its agricultural productivity, the middle Narmada faces challenges such as deforestation in the surrounding uplands, leading to increased siltation, and pollution from untreated urban and industrial effluents.

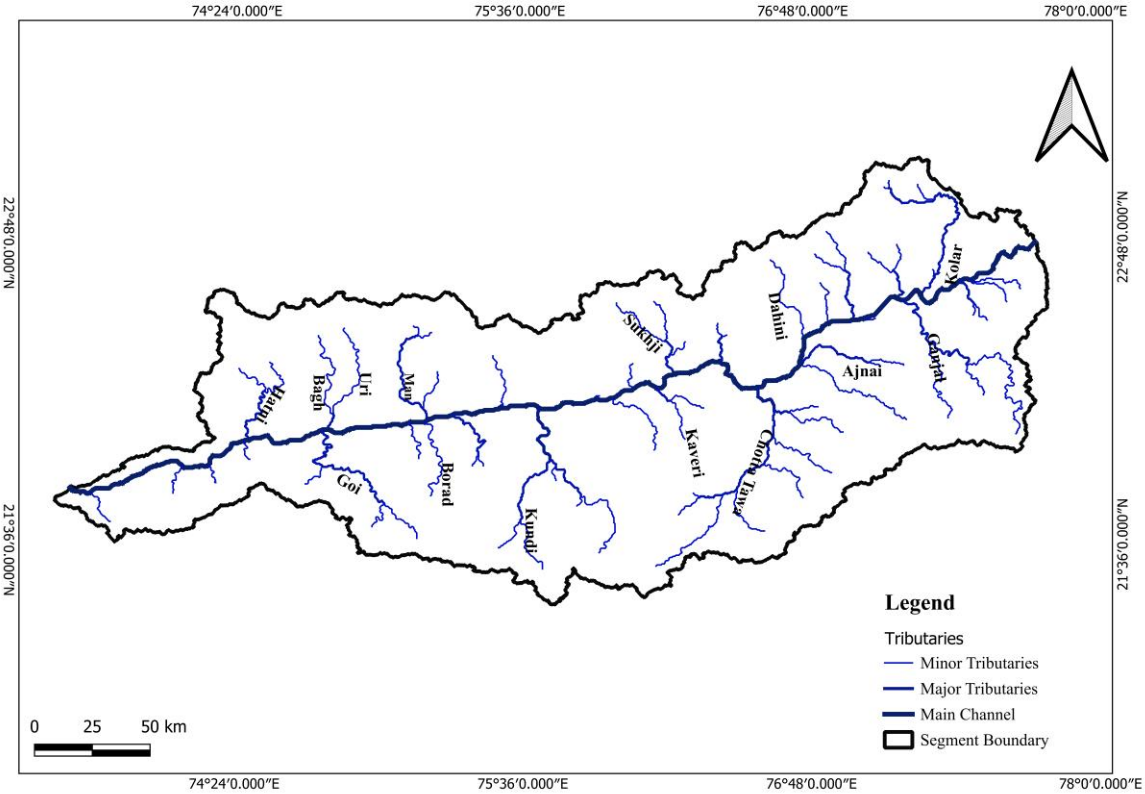


Figure 4: Tributaries of the Middle Narmada River segment

Lower Narmada Sub-Basin: Covering the area from Navagam to the Gulf of Khambhat (~145 km), the lower sub-basin transitions into the flat alluvial plains of Gujarat. Here, the river slows down, creating rich floodplains that support diverse ecosystems and fertile agricultural lands. This region includes the Sardar Sarovar Dam, a critical infrastructure for irrigation, water supply, and power generation. However, the lower Narmada is heavily impacted by industrial discharges, sand mining, and changes in sediment flow due to upstream damming, leading to coastal erosion near the river's mouth.

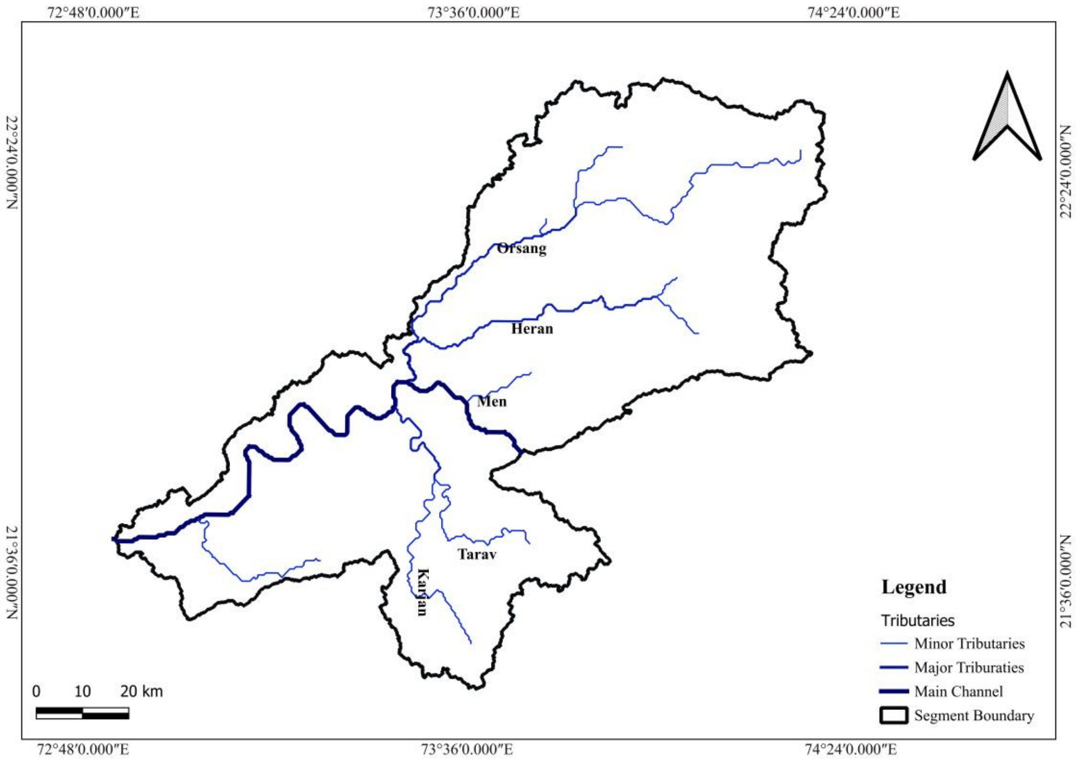


Figure 5: Tributaries of Lower Narmada River segment

1.2 REPORT OBJECTIVES

This report provides a detailed analysis of the hydraulic parameters and infrastructure of the Narmada River system. It offers cross-sectional data of the Narmada River, enabling researchers to determine critical hydraulic parameters such as bed slope, water surface slope, surface roughness, and channel velocity. This data serves as a valuable resource for future hydraulic studies and modelling efforts. The report also analyzes longitudinal sections of the Narmada River and its major tributaries to understand how the river profile influences flow dynamics. Additionally, it examines riverine infrastructure like bridges, dams, canals, and ghats, assessing their potential impacts on hydraulic processes and the overall health of the Narmada River ecosystem. By providing this comprehensive analysis, the report aims to enhance understanding of Narmada River hydraulics and offer valuable insights for researchers and policymakers working in sustainable river basin management, infrastructure planning, and environmental conservation.

This report sets the stage for a comprehensive analysis of the hydraulic systems and infrastructure associated with the Narmada River. Following the objectives outlined in Chapter 1, the upcoming chapters will delve deeper into the intricacies of data acquisition, analysis of hydraulic characteristics, and the impacts of infrastructure on the river's ecosystem.

Chapter 2 will detail the methodologies employed in this study, focusing on data sources such as the India-WRIS platform, Central Water Commission records, and field data collection. The chapter will also discuss the rigorous quality control measures applied to ensure the reliability of the data used in subsequent analyses.

Chapter 3 will provide a detailed exploration of the river’s hydraulic characteristics, including cross-sectional geometries, discharge patterns, and longitudinal profiles. This chapter aims to unravel the river’s flow dynamics, sediment transport, and other critical parameters that influence its overall functionality.

In Chapter 4, the focus will shift to riverine infrastructure. Key structures such as dams, canals, bridges, and ghats will be examined for their roles in water management, transportation, and cultural significance. This chapter will also highlight the challenges posed by these structures to the river’s ecological balance.

Finally, Chapter 5 will synthesize the findings, offering actionable conclusions and recommendations for sustainable river basin management. By addressing these areas comprehensively, this report serves as a vital resource for researchers, policymakers, and planners.

Chapter 2: Data Acquisition and Methodology

2.1 DATA SOURCES

Accurate and comprehensive data collection is crucial for analyzing the hydraulic characteristics of the Narmada River. This study utilized multiple reliable sources to ensure the robustness of the dataset:

1. **India Water Resources Information System (India-WRIS):** This platform provided detailed data on dams, canals, and the Narmada River basin, including shape files and figures such as tributary details.
2. **Central Water Commission (CWC) Office:** Cross-sectional, discharge, and stage data were collected directly from CWC offices, ensuring access to reliable and authoritative information.

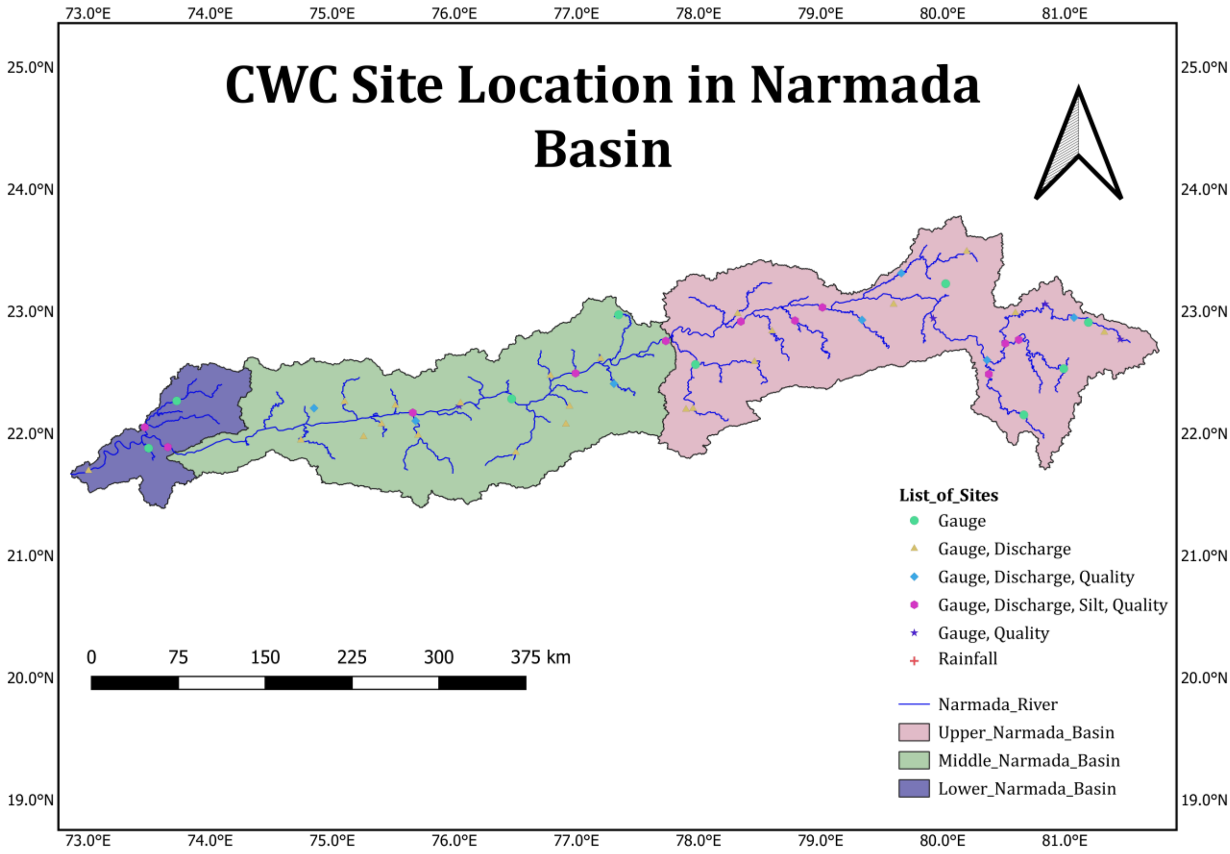


Figure 6: Distribution of CWC Monitoring Sites Along the Narmada River Basin

3. **Google Earth and GIS Tools:** Spatial analysis was conducted to identify and map bridges and ghats along the river and its tributaries using satellite imagery.
4. **SSNNL and Government Websites:** Additional data, particularly related to infrastructure and water resource management, were sourced from official government platforms to complement the primary datasets.

These data sources ensured a comprehensive understanding of the river's hydraulic characteristics and infrastructure.

2.2 DATA COLLECTION PROCEDURES

The methodology for data collection was focused on aggregating existing data from reliable sources rather than direct field measurements. Key procedures included:

1. **Compilation from CWC and SSNNL:** Cross-sectional profiles, discharge, and stage data were collected from CWC offices and the Sardar Sarovar Narmada Nigam Limited (SSNNL).
2. **Analysis of India-WRIS Data:** The platform provided dam-related information, canal networks, and tributary details, which were used for hydraulic assessments.
3. **Google Earth Mapping:** High-resolution satellite imagery was utilized to locate and map bridges and ghats, adding spatial context to the dataset.
4. **Validation Against Historical Records:** Data from various sources were cross-verified to ensure consistency and reliability.

This approach ensured that the study leveraged existing datasets effectively, reducing the need for direct measurement.

2.3 METHODOLOGICAL FRAMEWORK

The methodological framework integrated the collected data into a coherent analysis structure. This involved:

1. **Data Preprocessing:** Organizing and standardizing data formats for seamless integration.

2. **Hydraulic Data Analysis:** Using available datasets from government reports and reliable sources to analyze river flow, velocity profiles, and discharge patterns.
3. **Comparative Analysis:** Reviewing and consolidating data from available government reports and websites to ensure consistency and reliability.

Reporting: Synthesizing the results into actionable insights for river basin management.

This comprehensive methodology provided a solid foundation for the subsequent analysis of the Narmada River's hydraulic characteristics.

Chapter 3: Hydraulic Characteristics

3.1 CROSS-SECTIONAL GEOMETRY

Cross-sectional data of rivers provide critical insights into the hydraulic and geomorphic characteristics of river systems, which are essential for understanding water flow, sediment transport, and floodplain dynamics. This report analyzes cross-sectional measurements from three sites in the lower Narmada Basin, provided by the Central Water Commission (CWC). These sites include two locations on the main Narmada River—Bharuch and Garudeshwar—and one on its tributary, the Orsang River, at Chanwada. Each cross-section represents a snapshot of the river's geometry and flow characteristics, enabling assessments of riverine processes, bank stability, and the potential impact of hydrological changes.

Cross-sections reveal the interplay of natural and anthropogenic factors shaping river morphology. Variations in channel width, depth, and slope at different locations result from processes such as erosion, deposition, and flow velocity changes. Bharuch, located near the estuarine zone, reflects the dynamic interactions of tidal forces, sediment deposition, and upstream discharges. Garudeshwar, positioned in a transitional zone upstream, highlights the influence of dam operations and flow regulation on channel geometry. The Chanwada section on the Orsang River illustrates tributary-specific characteristics, such as lower flow velocities and sediment transport compared to the main river.

These cross-sectional profiles are crucial for applications like flood modeling, sediment management, and ecological restoration. Understanding the hydraulic parameters at each location can help in designing effective management strategies, such as optimizing reservoir operations or mitigating flood risks. The data also contribute to a broader understanding of riverine ecosystems, enabling a sustainable approach to river basin management. By examining the cross-sectional geometry of these sites, this report provides foundational data to support hydrological studies, infrastructure planning, and environmental conservation within the Narmada River Basin. A site location map is presented for spatial context (Figure).

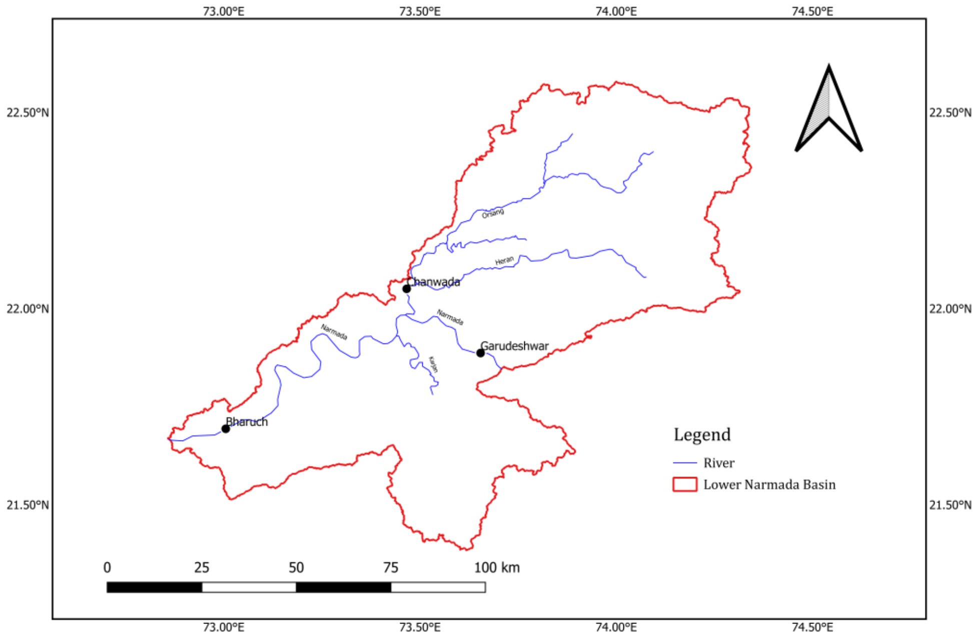
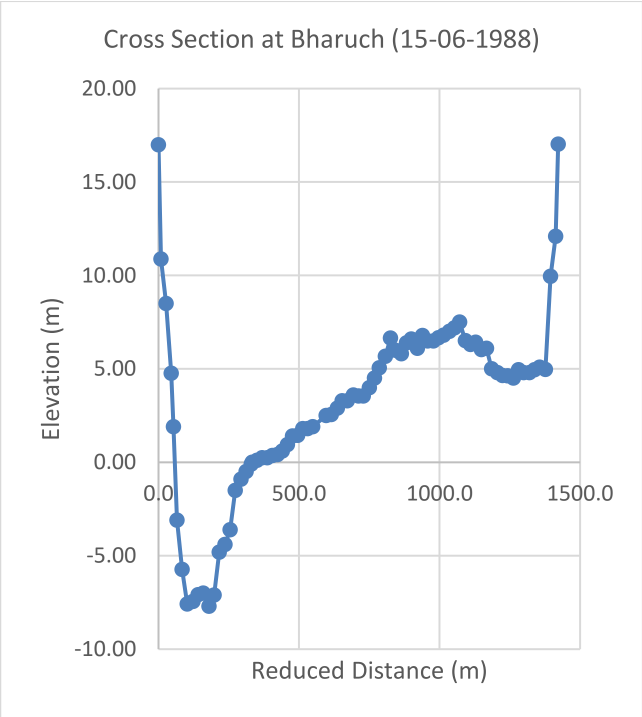


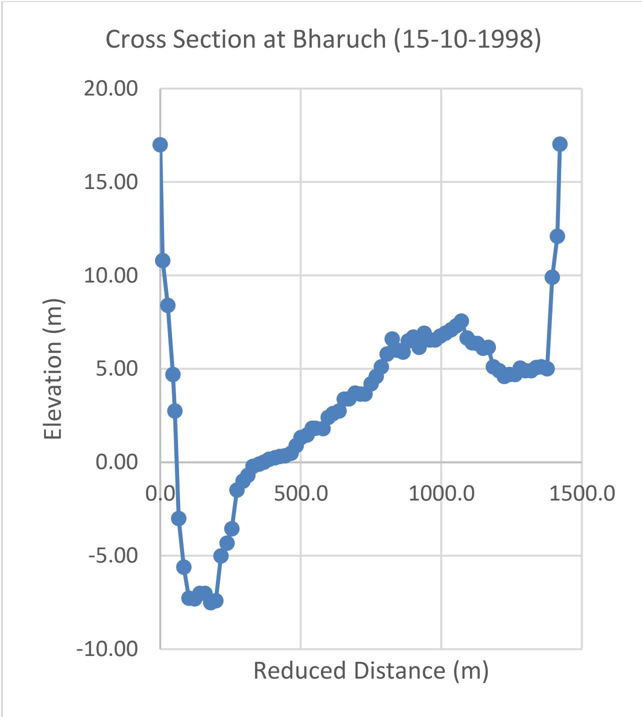
Figure 7: Measurement Sites for Cross-Sections along the Narmada River Basin by CWC

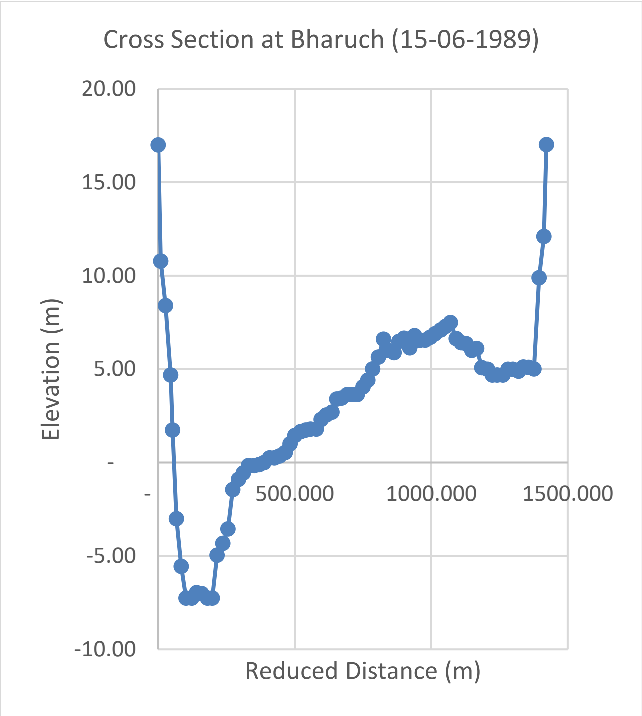
3.1.1 Cross Sections at Bharuch

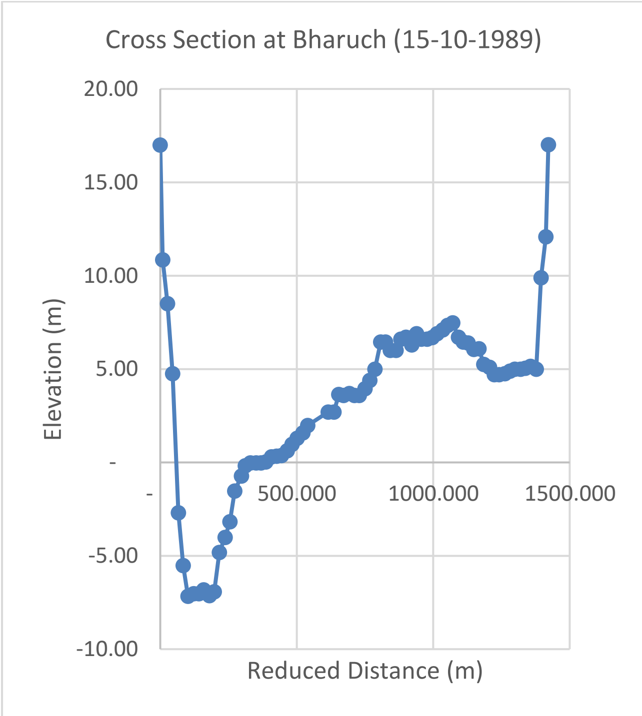
The Bharuch cross-section, located in the downstream reaches of the Narmada River, is characterized by a wide channel influenced by tidal forces and sedimentary processes. This section exhibits significant asymmetry, with one bank showing greater depths due to erosion from high-velocity flows, while the opposite side shows signs of sediment deposition. These features highlight the dynamic interplay between fluvial processes and anthropogenic factors, as Bharuch is a region of significant human activity and urbanization.

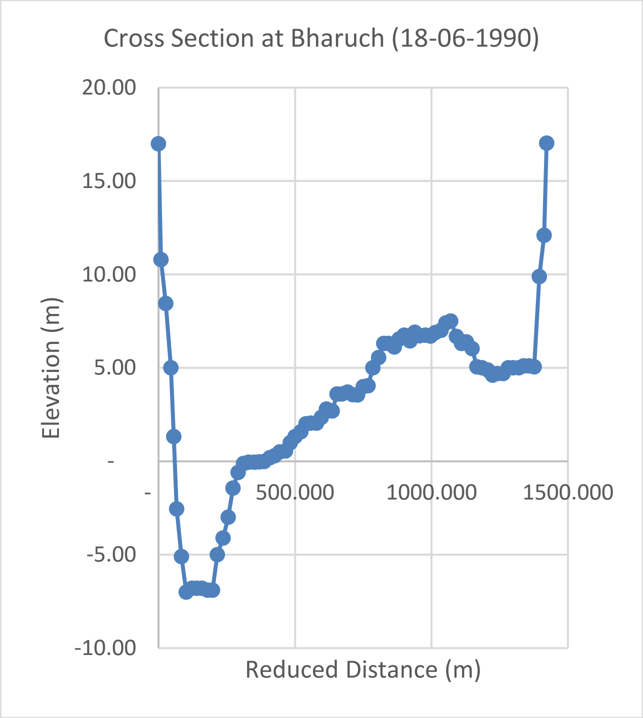
The cross-sectional profile suggests a gradual slope with considerable variability in depth, indicative of a mixed flow regime influenced by upstream discharges and tidal backwater effects. The section's width and depth variations reflect ongoing sediment transport and deposition, which can impact floodplain dynamics and channel stability. Vegetative cover and local land use likely contribute to hydraulic resistance, further affecting flow patterns.

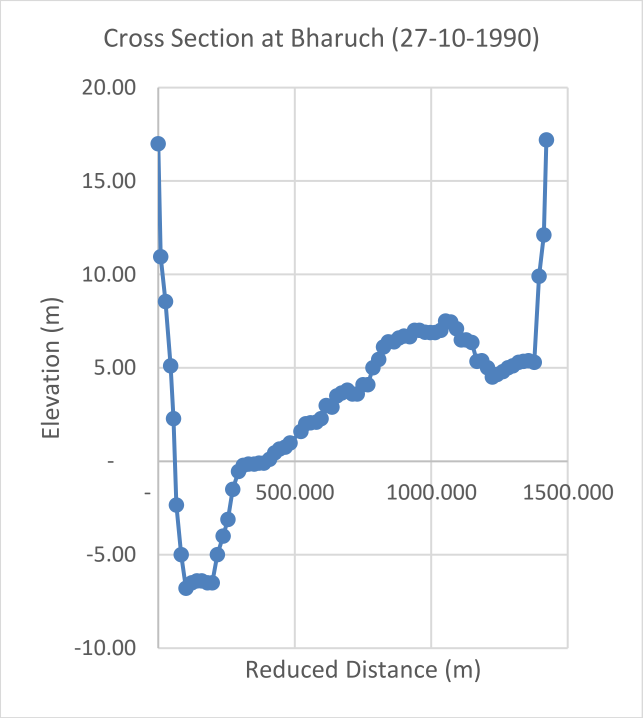

Cross Section at Bharuch (15-06-1988)
Elevation (m)
Reduced Distance (m)

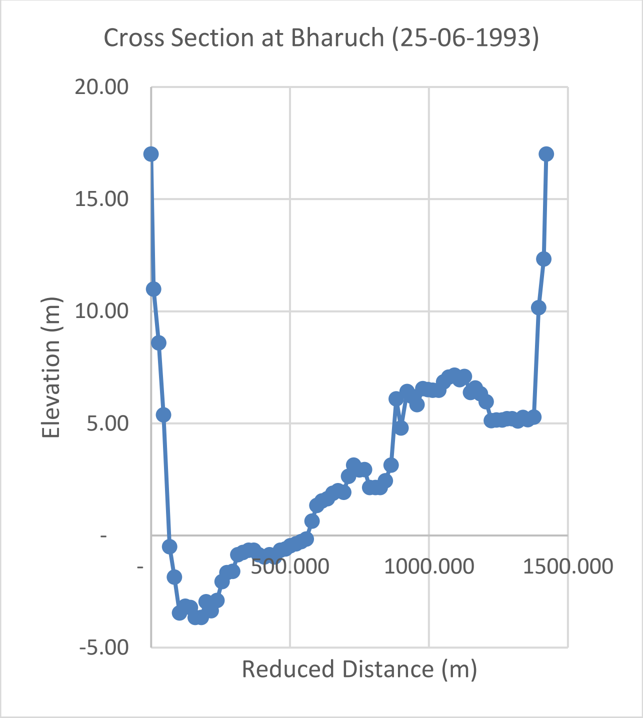

Cross Section at Bharuch (15-10-1998)
Elevation (m)
Reduced Distance (m)

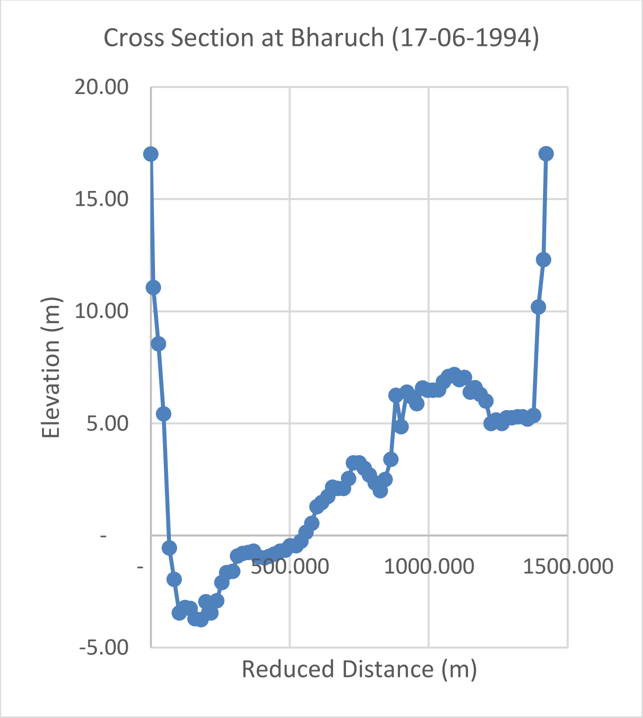

Cross Section at Bharuch (15-06-1989)
Elevation (m)
Reduced Distance (m)

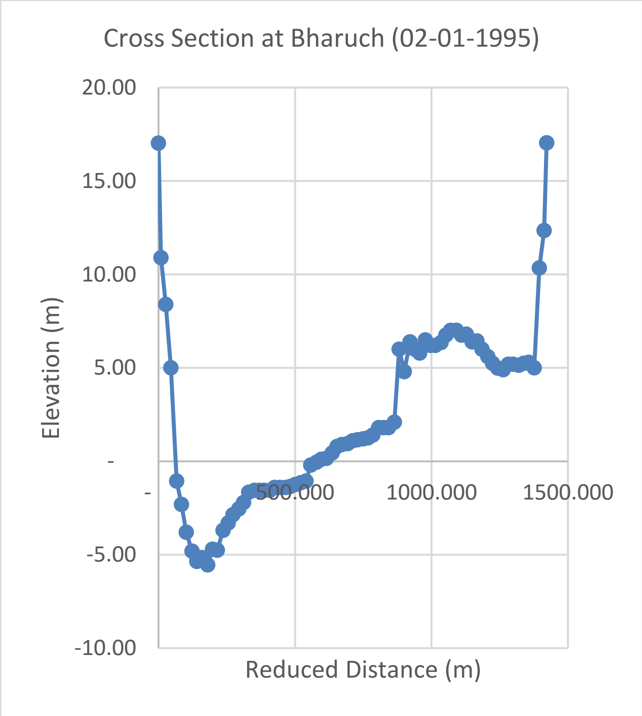

Cross Section at Bharuch (15-10-1989)
Elevation (m)
Reduced Distance (m)

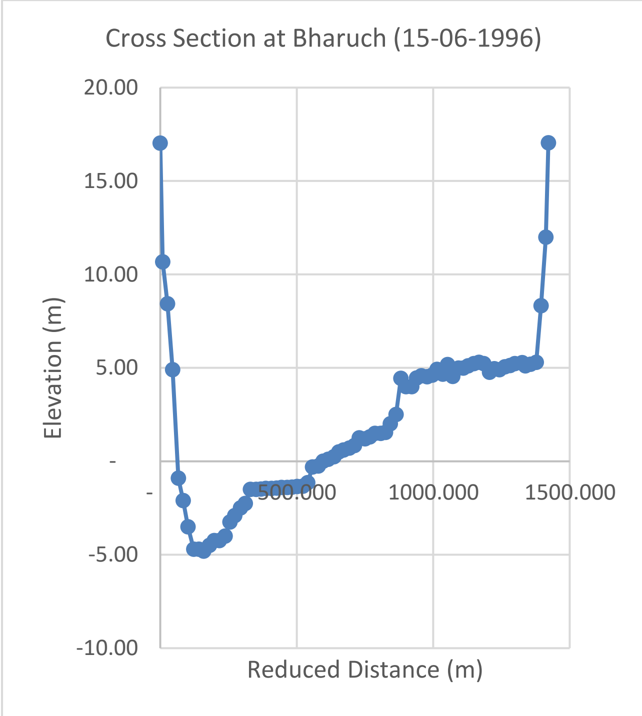

Cross Section at Bharuch (18-06-1990)
20.00
15.00
10.00
5.00
-
-5.00
-10.00
-
500.000
1000.000
1500.000
Elevation (m)
Reduced Distance (m)

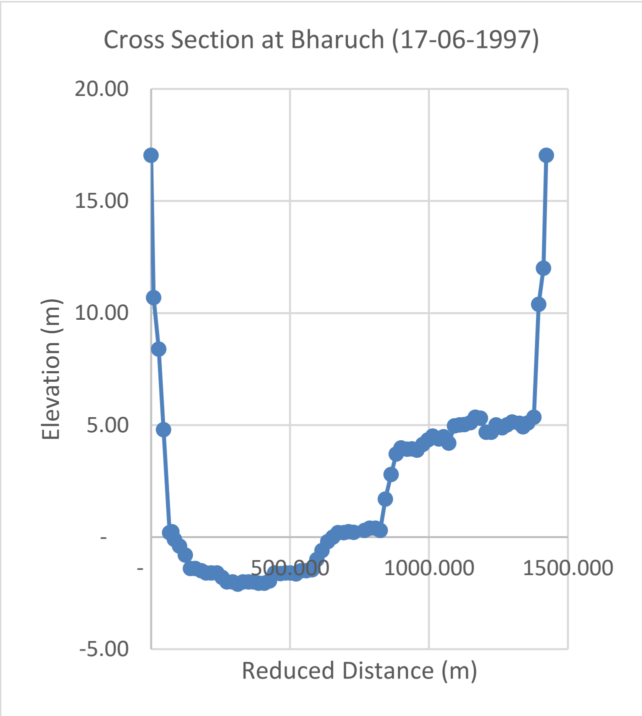

Cross Section at Bharuch (27-10-1990)
20.00
15.00
10.00
5.00
-
-5.00
-10.00
-
500.000
1000.000
1500.000
Elevation (m)
Reduced Distance (m)

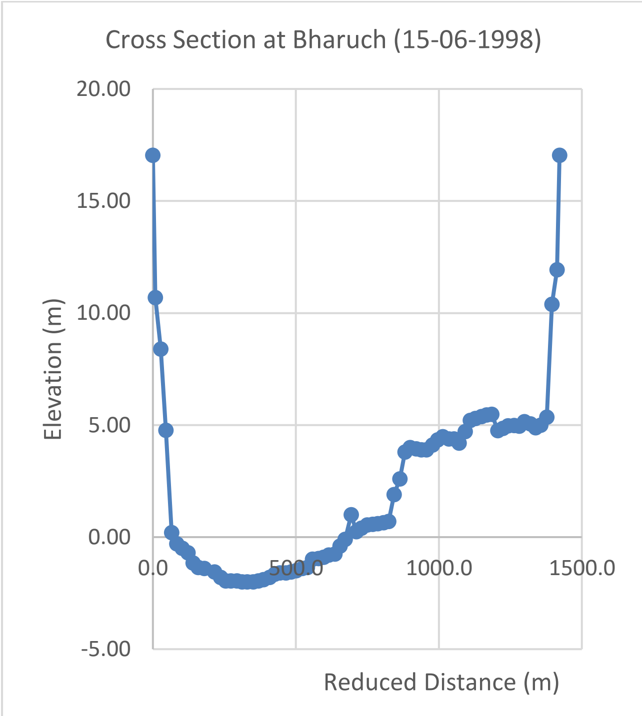

Cross Section at Bharuch (25-06-1993)
20.00
15.00
10.00
5.00
-
-5.00
-
500.000
1000.000
1500.000
Elevation (m)
Reduced Distance (m)

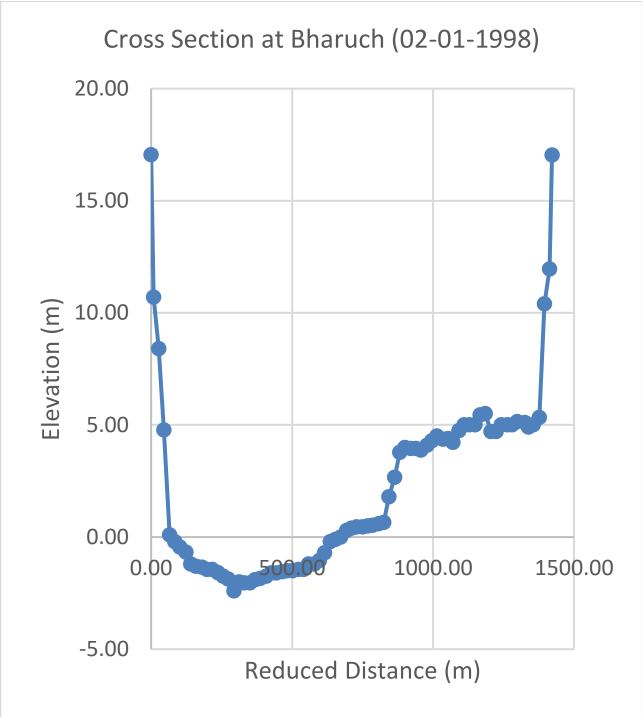

Cross Section at Bharuch (17-06-1994)
20.00
15.00
10.00
5.00
-
-5.00
-
500.000
1000.000
1500.000
Elevation (m)
Reduced Distance (m)

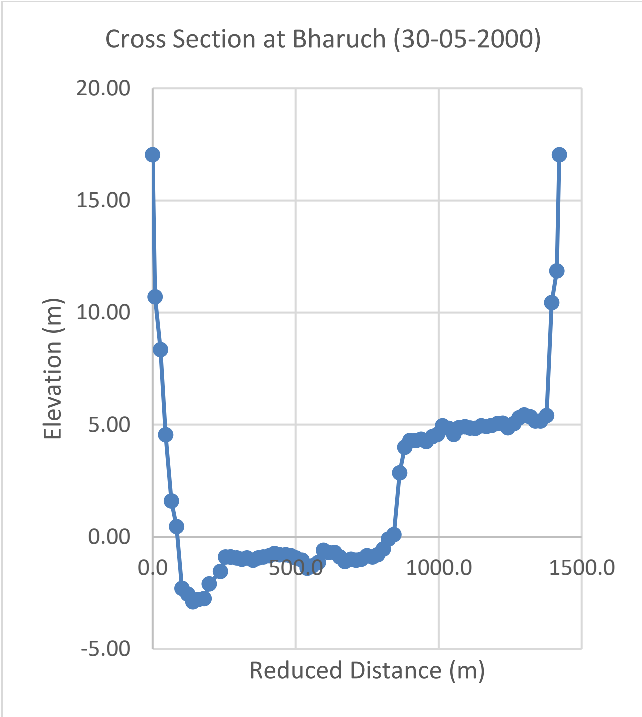

Cross Section at Bharuch (02-01-1995)
20.00
15.00
10.00
5.00
-
-
-5.00
-10.00
500.000
1000.000
1500.000
Elevation (m)
Reduced Distance (m)


Cross Section at Bharuch (15-06-1996)
20.00
15.00
10.00
5.00
-
-
-5.00
-10.00
500.000
1000.000
1500.000
Elevation (m)
Reduced Distance (m)


Cross Section at Bharuch (17-06-1997)
20.00
15.00
10.00
5.00
-
-
-5.00
500.000
1000.000
1500.000
Elevation (m)
Reduced Distance (m)


Cross Section at Bharuch (15-06-1998)
20.00
15.00
10.00
5.00
0.00
-5.00
0.0
500.0
1000.0
1500.0
Elevation (m)
Reduced Distance (m)





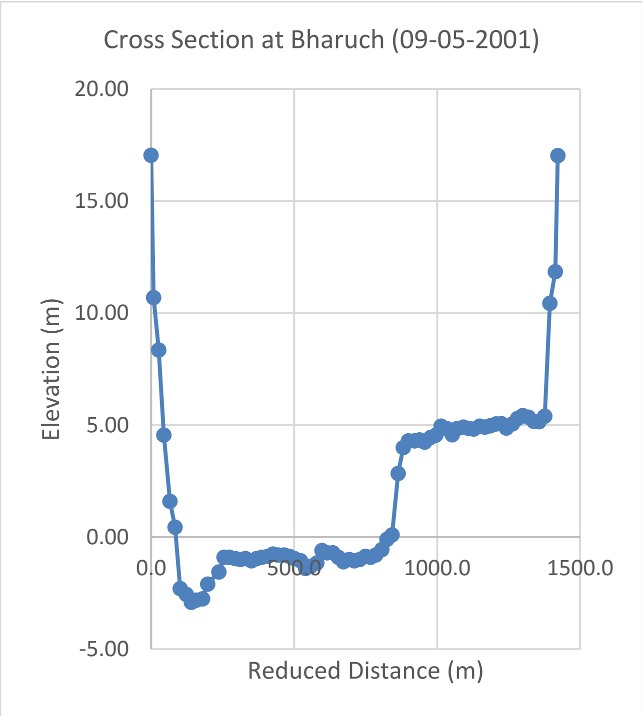


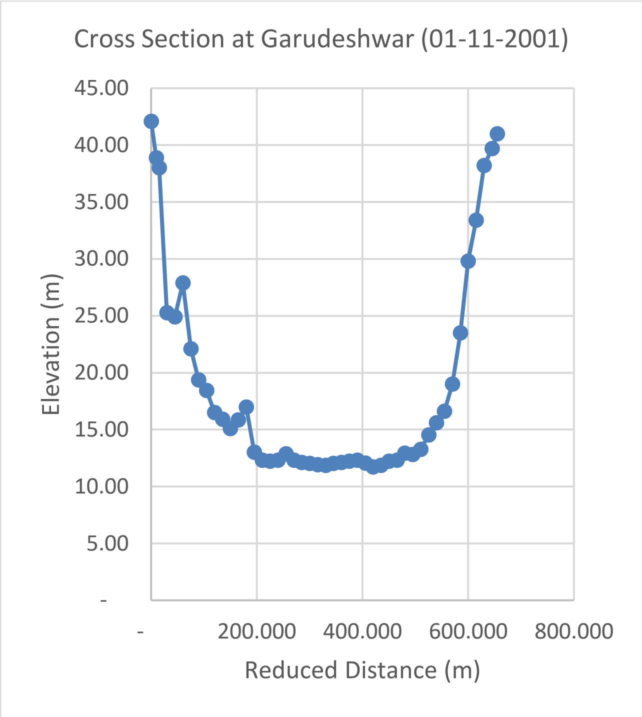
Figure 8: Temporal Variations in Cross-Sectional Profiles at Bharuch

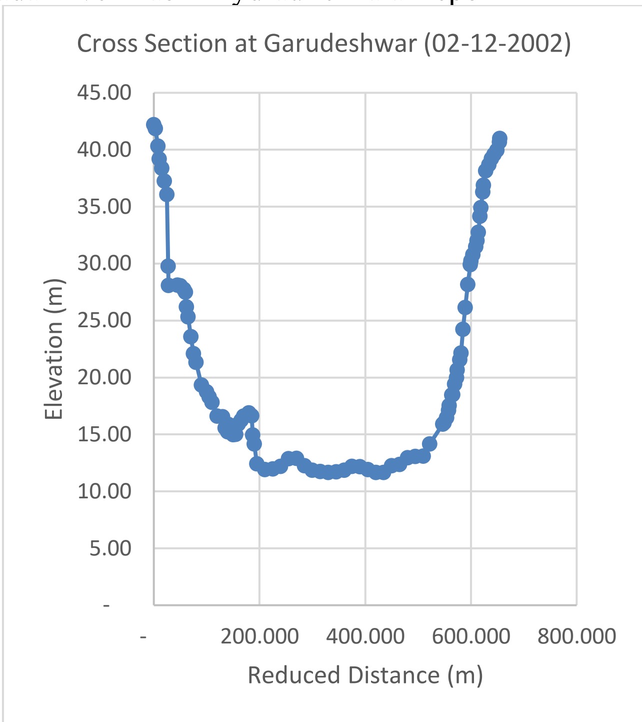
3.1.2 Cross Sections at Garudeshwar

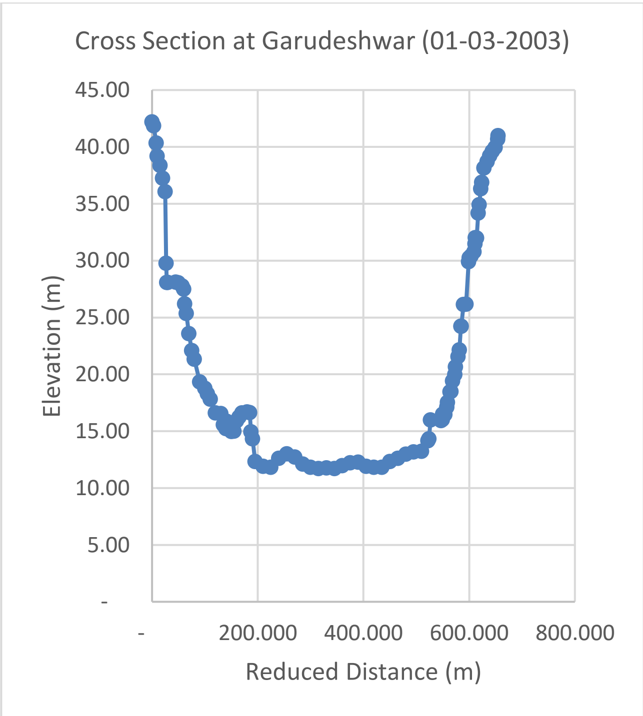
The Garudeshwar cross-section, situated upstream in the Narmada River, offers insights into a narrower and well-defined channel geometry. This section lies within a transitional zone influenced by upstream reservoir releases and natural flow variations. The channel here demonstrates moderate asymmetry, with depth variations along the cross-section reflecting the influence of regulated discharges and sediment transport.

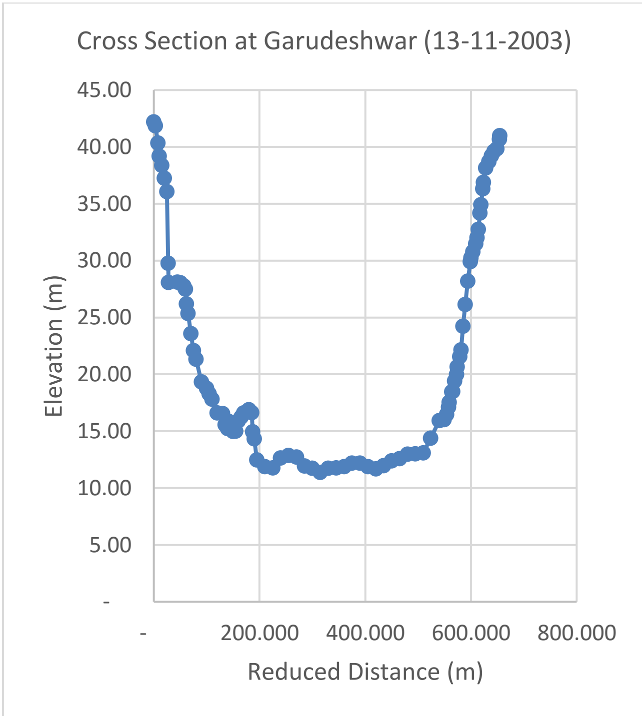
Compared to Bharuch, the Garudeshwar section has steeper banks and a narrower width, highlighting the localized hydraulic effects of dam operations upstream. Seasonal flow fluctuations, particularly during the monsoon, amplify erosion and deposition dynamics, shaping the channel's morphology. The cross-section data reveal patterns of sediment redistribution, with deeper zones near the banks suggesting areas of active scouring, while mid-channel areas exhibit relatively stable depths.

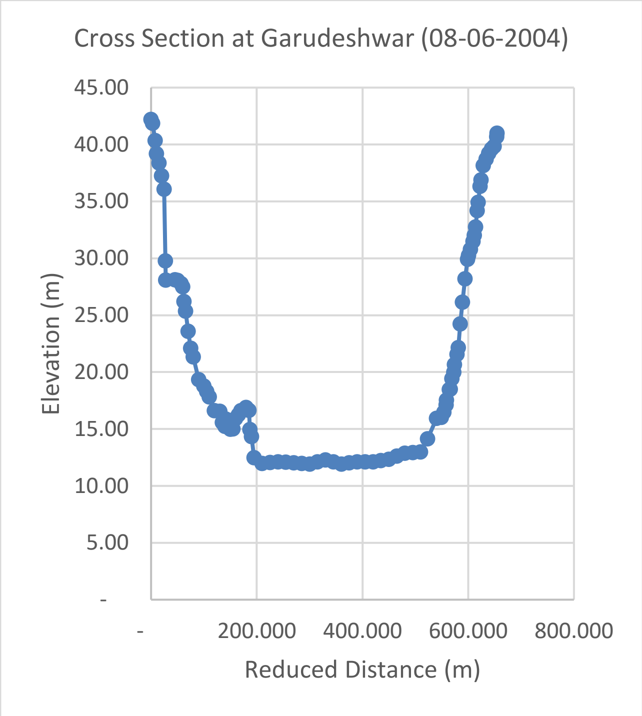
This location is crucial for understanding the downstream impacts of reservoir operations, including flow regulation and sediment trapping. The data from Garudeshwar provide a basis for managing water releases to maintain channel stability and prevent excessive sedimentation downstream.


Cross Section at Garudeshwar (01-11-2001)
Elevation (m)
Reduced Distance (m)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
-
200.000
400.000
600.000
800.000

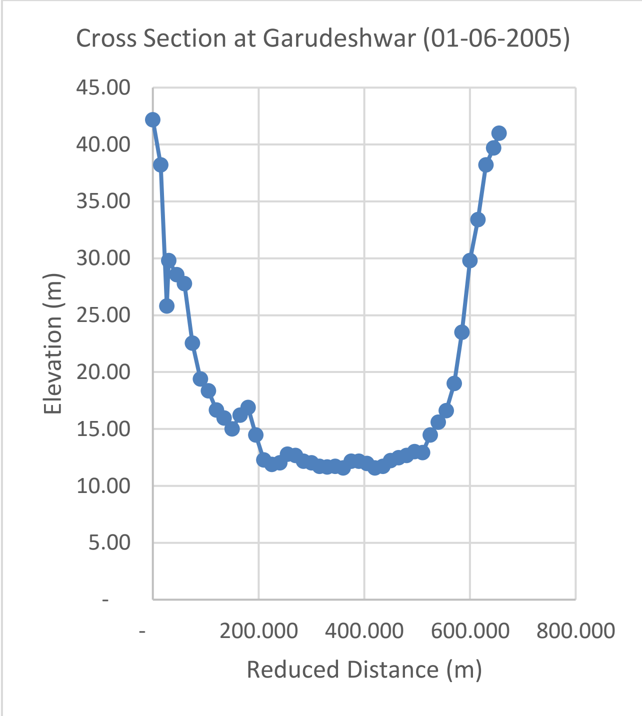

Cross Section at Garudeshwar (02-12-2002)
Elevation (m)
Reduced Distance (m)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
-
200.000
400.000
600.000
800.000


Cross Section at Garudeshwar (01-03-2003)
Elevation (m)
Reduced Distance (m)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
-
200.000
400.000
600.000
800.000

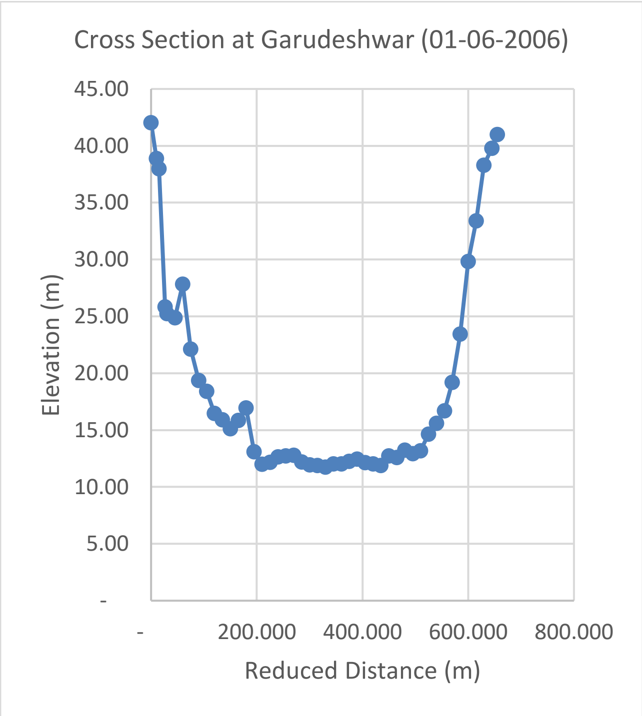

Cross Section at Garudeshwar (13-11-2003)
Elevation (m)
Reduced Distance (m)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
-
200.000
400.000
600.000
800.000



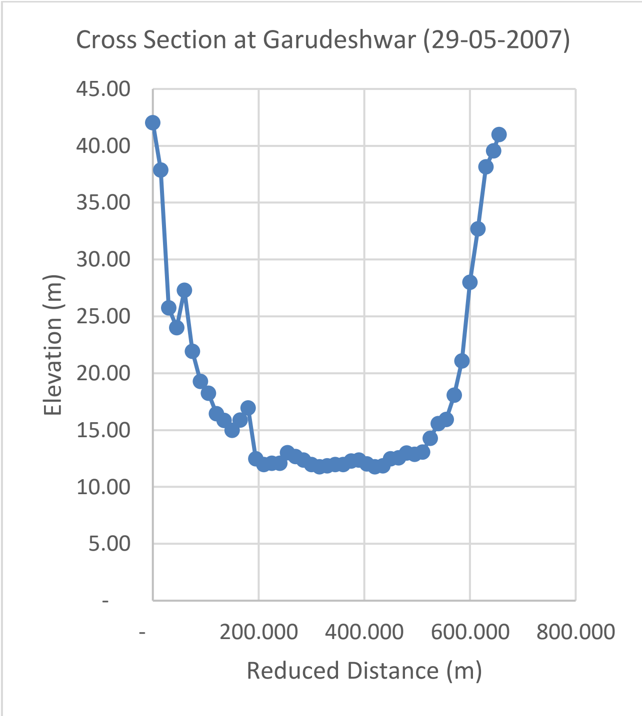
Cross Section at Garudeshwar (08-06-2004)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Elevation (m)
-
200.000
400.000
600.000
800.000
Reduced Distance (m)



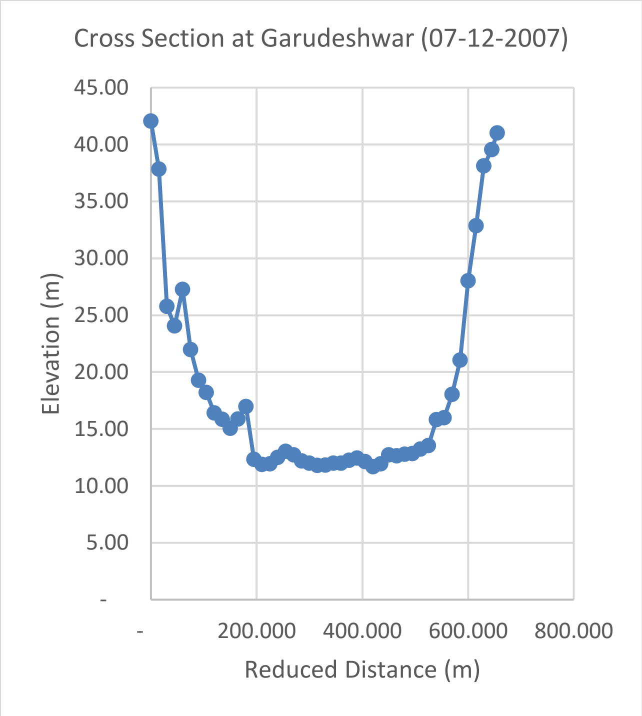
Cross Section at Garudeshwar (01-06-2005)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Elevation (m)
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

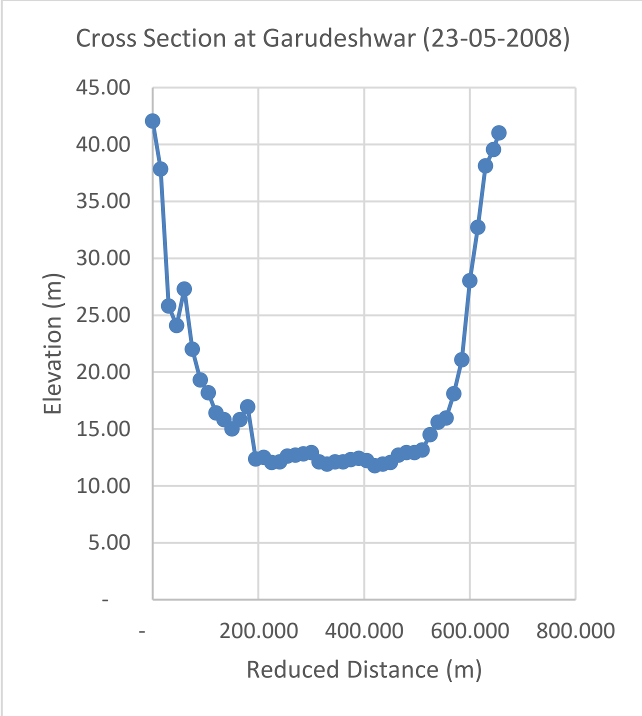


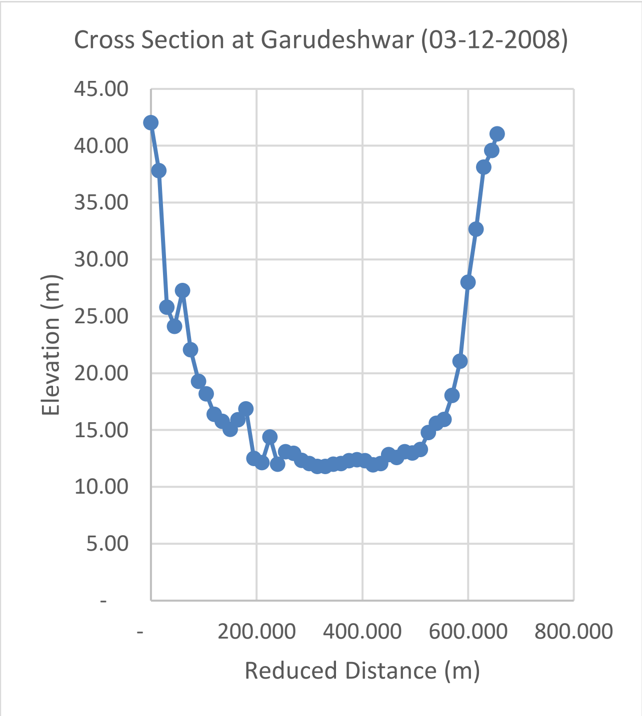
Cross Section at Garudeshwar (01-06-2006)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Elevation (m)
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

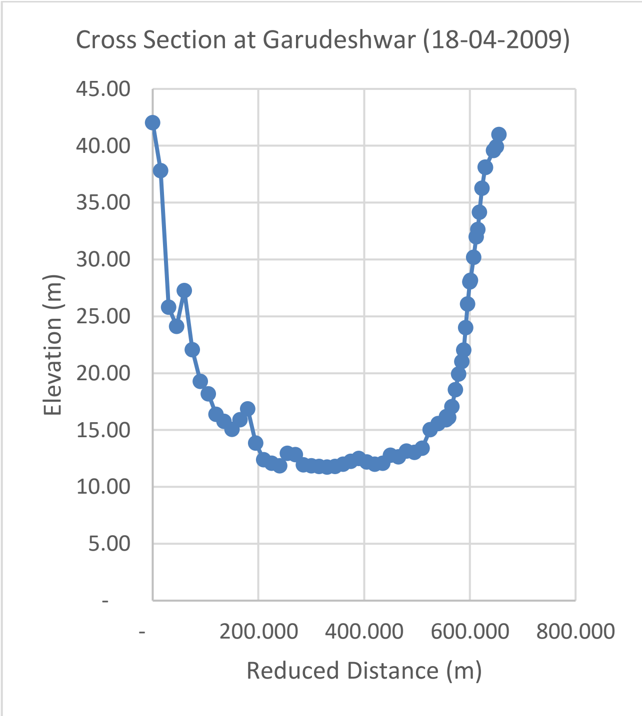


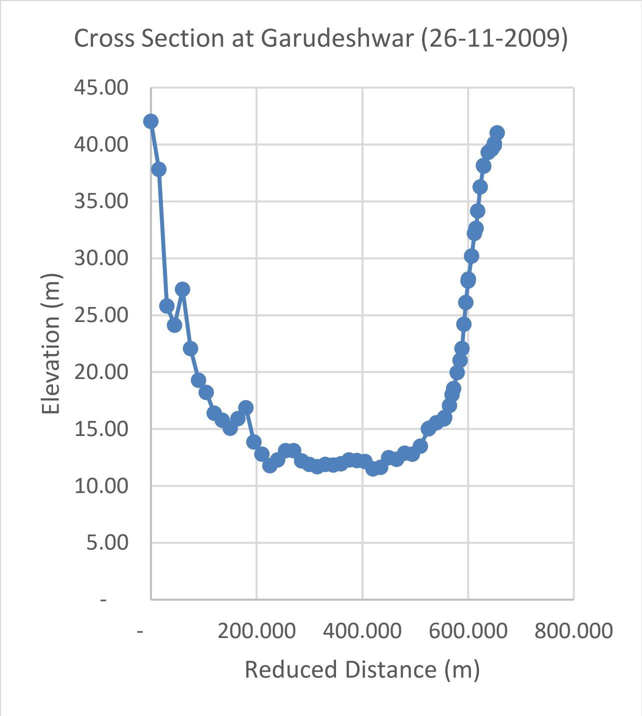
Cross Section at Garudeshwar (29-05-2007)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Elevation (m)
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

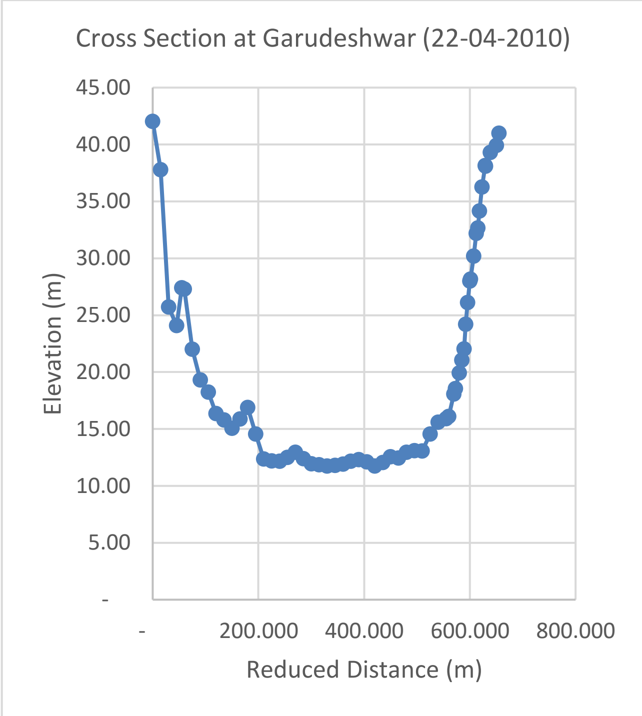

Cross Section at Garudeshwar (07-12-2007)
Elevation (m)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

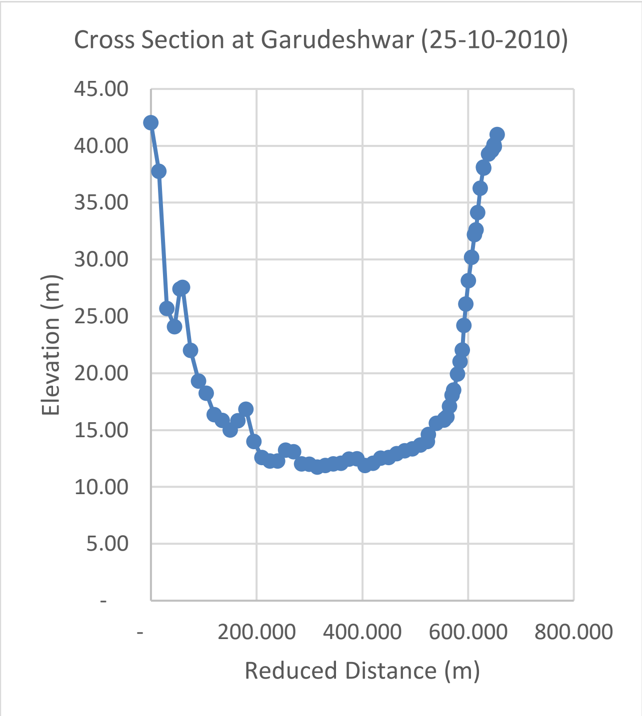

Cross Section at Garudeshwar (23-05-2008)
Elevation (m)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

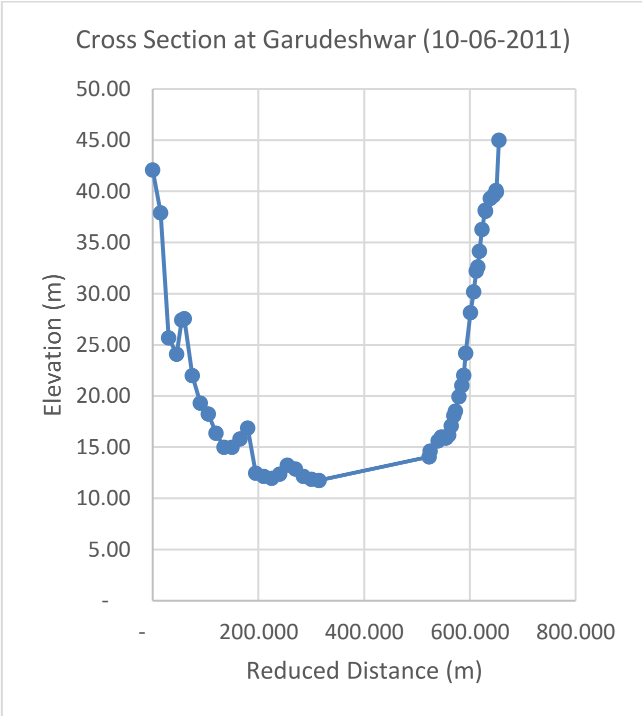

Cross Section at Garudeshwar (03-12-2008)
Elevation (m)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

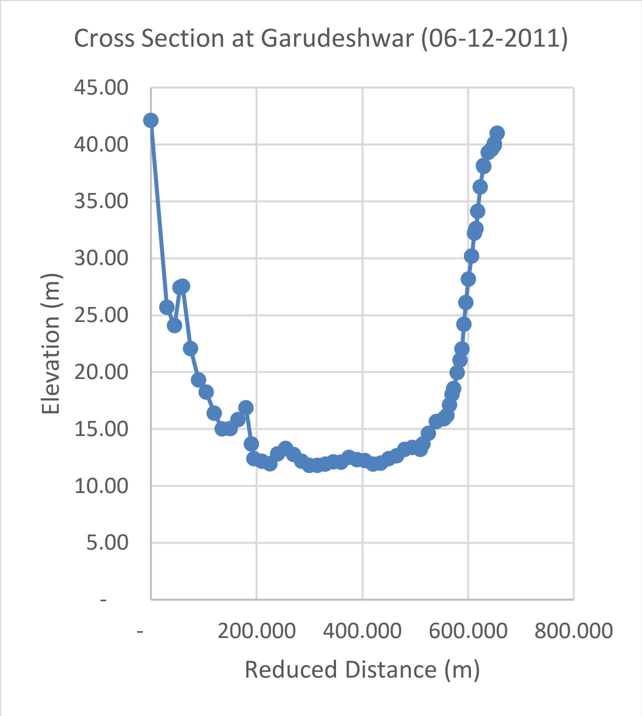

Cross Section at Garudeshwar (18-04-2009)
Elevation (m)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
-
200.000
400.000
600.000
800.000
Reduced Distance (m)


Cross Section at Garudeshwar (26-11-2009)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Elevation (m)
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

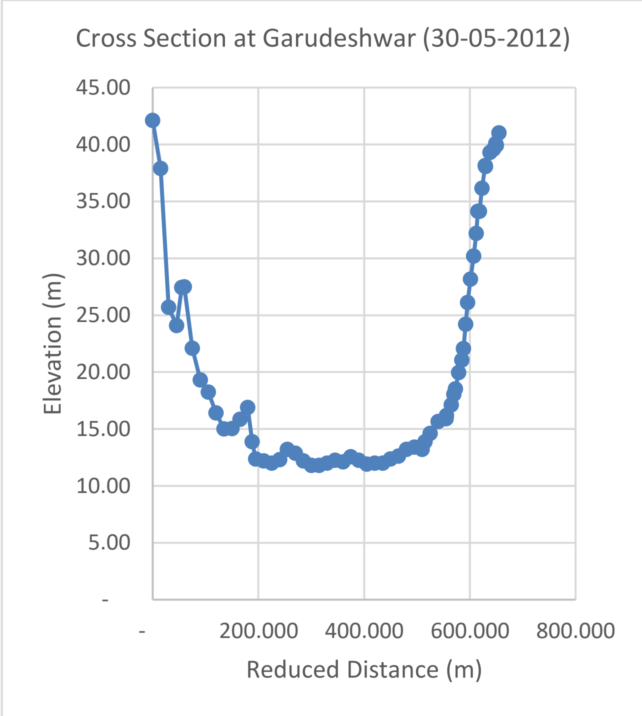

Cross Section at Garudeshwar (22-04-2010)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Elevation (m)
-
200.000
400.000
600.000
800.000
Reduced Distance (m)


Cross Section at Garudeshwar (25-10-2010)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Elevation (m)
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

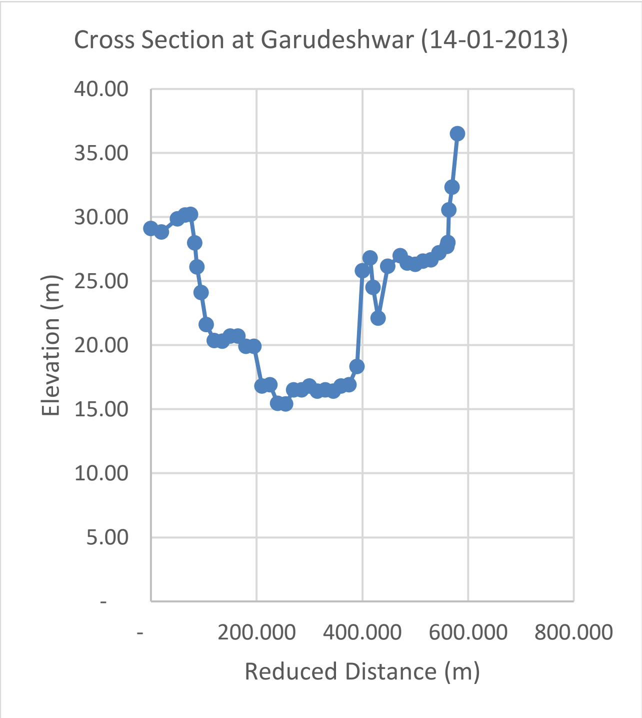

Cross Section at Garudeshwar (10-06-2011)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Elevation (m)
-
200.000
400.000
600.000
800.000
Reduced Distance (m)



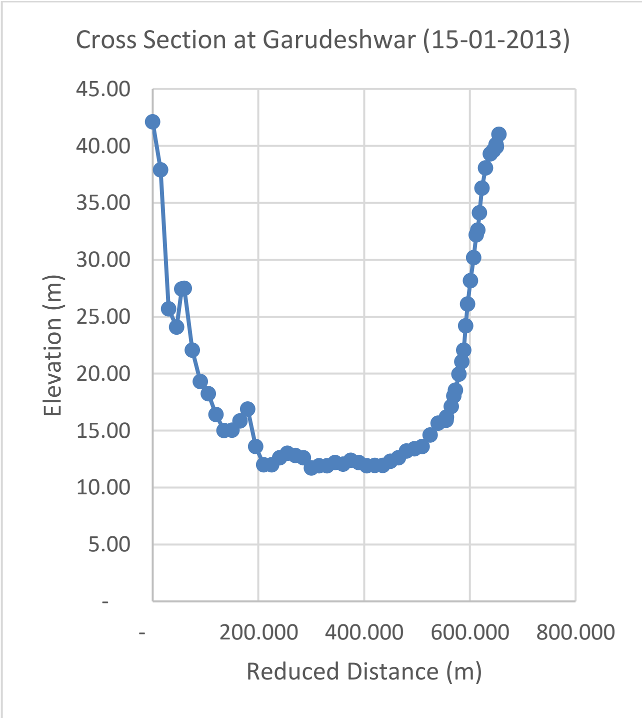
Cross Section at Garudeshwar (06-12-2011)
Elevation (m)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
-
200.000
400.000
600.000
800.000
Reduced Distance (m)



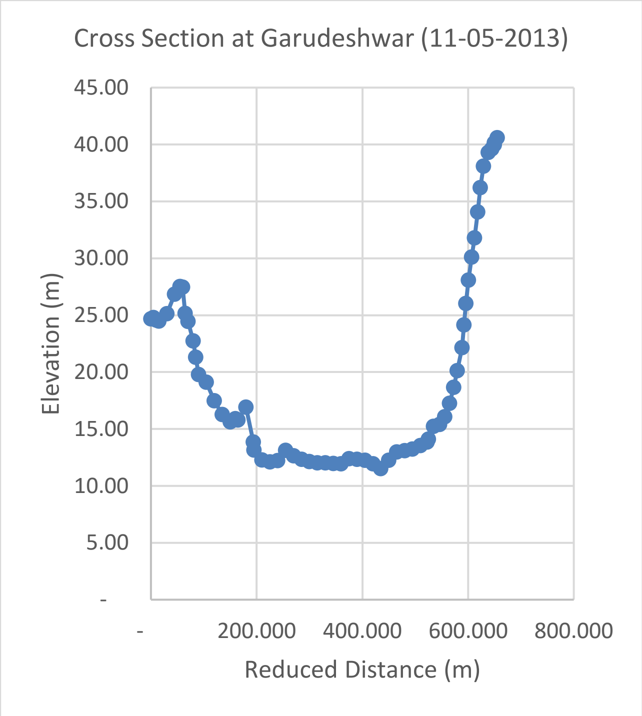
Cross Section at Garudeshwar (30-05-2012)
Elevation (m)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

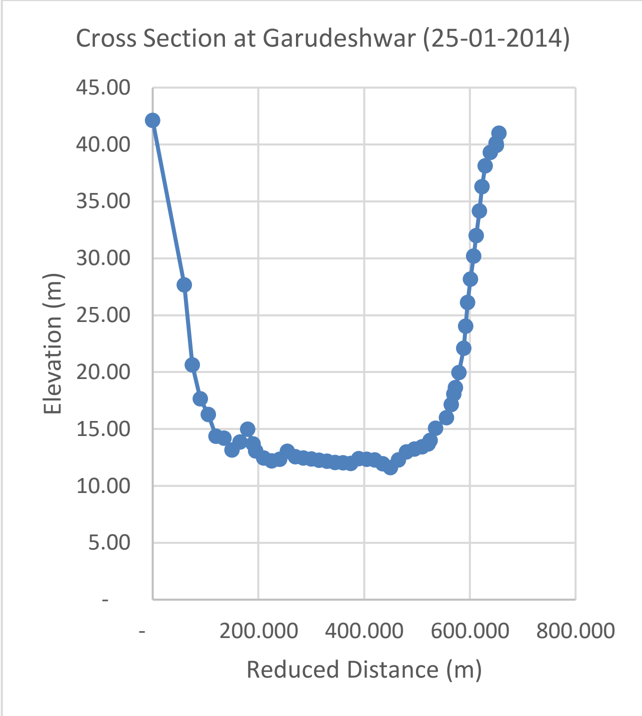


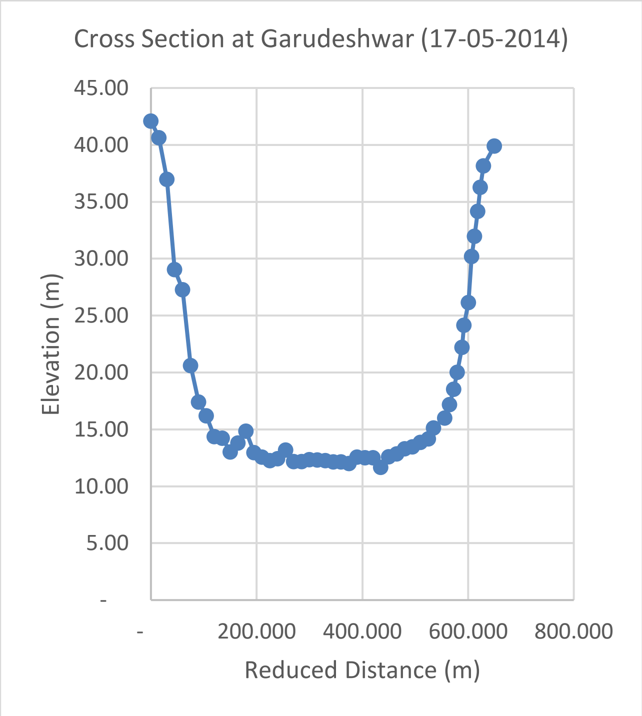
Cross Section at Garudeshwar (14-01-2013)
Elevation (m)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

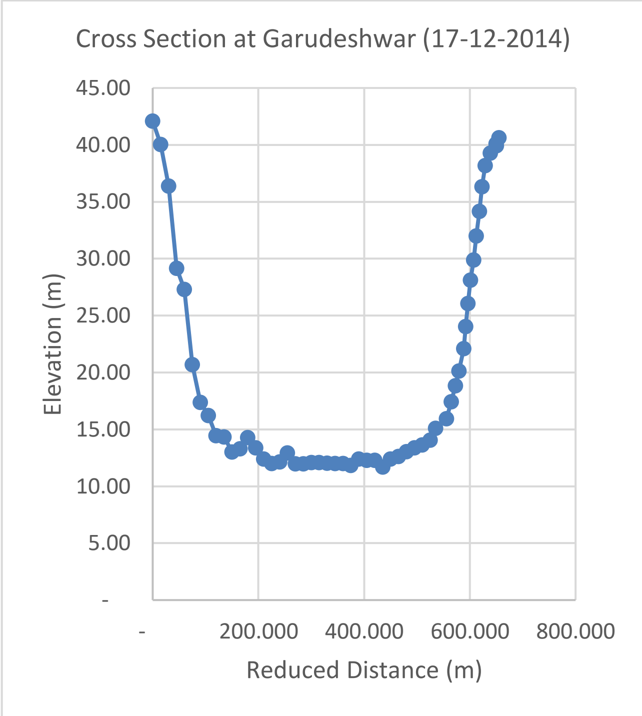


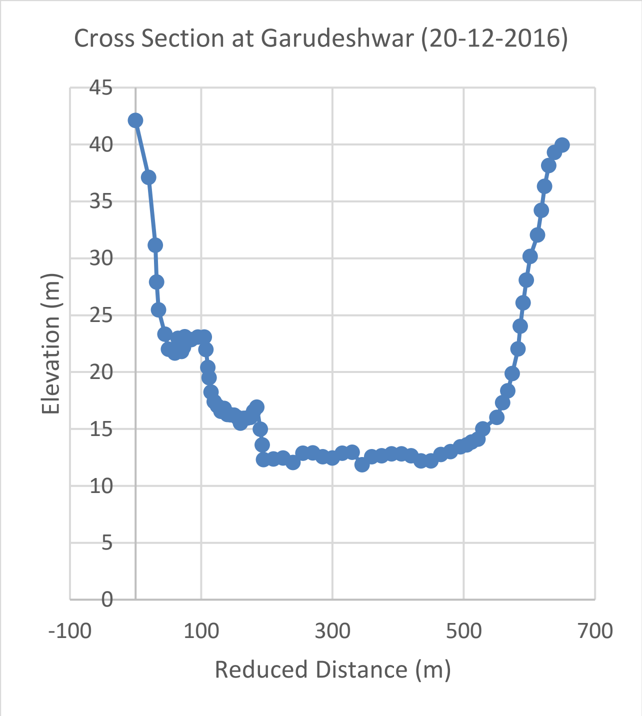
Cross Section at Garudeshwar (15-01-2013)
Elevation (m)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

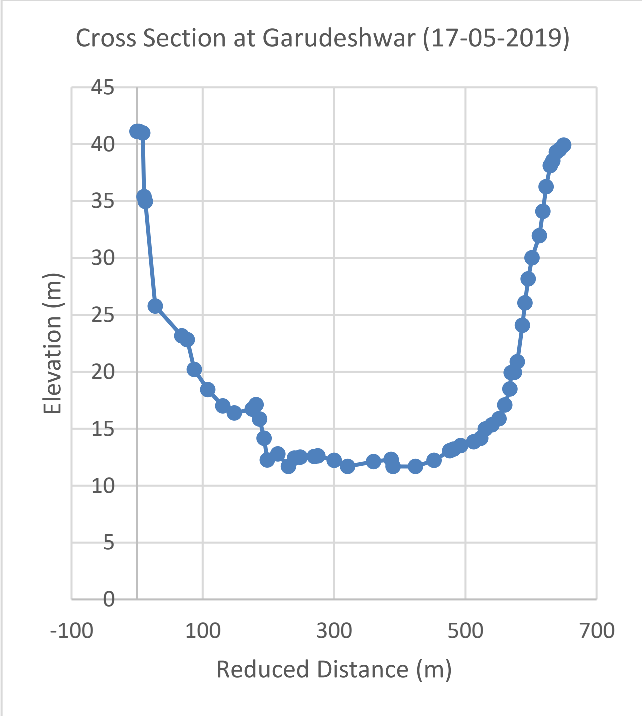

Cross Section at Garudeshwar (11-05-2013)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Elevation (m)
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

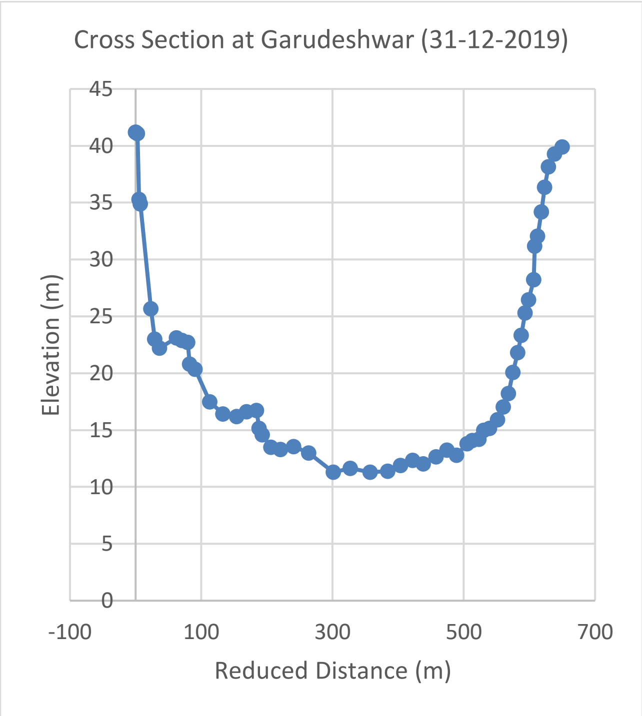

Cross Section at Garudeshwar (25-01-2014)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Elevation (m)
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

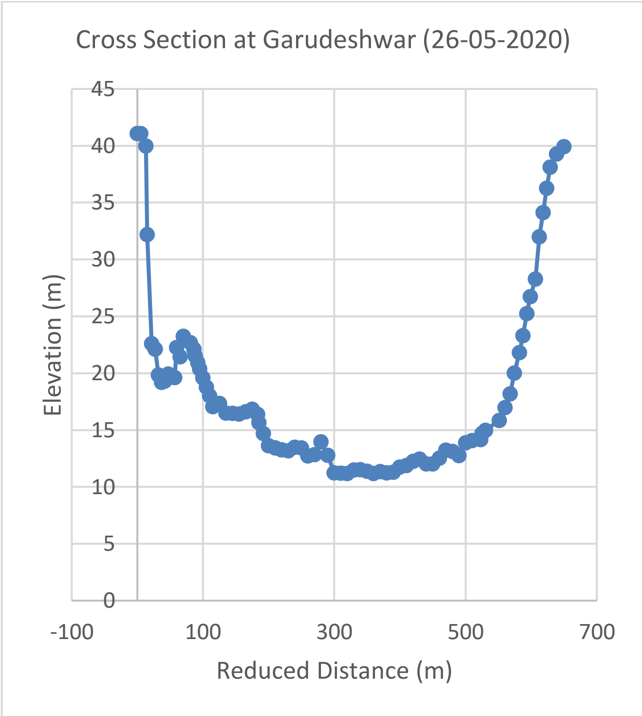

Cross Section at Garudeshwar (17-05-2014)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Elevation (m)
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

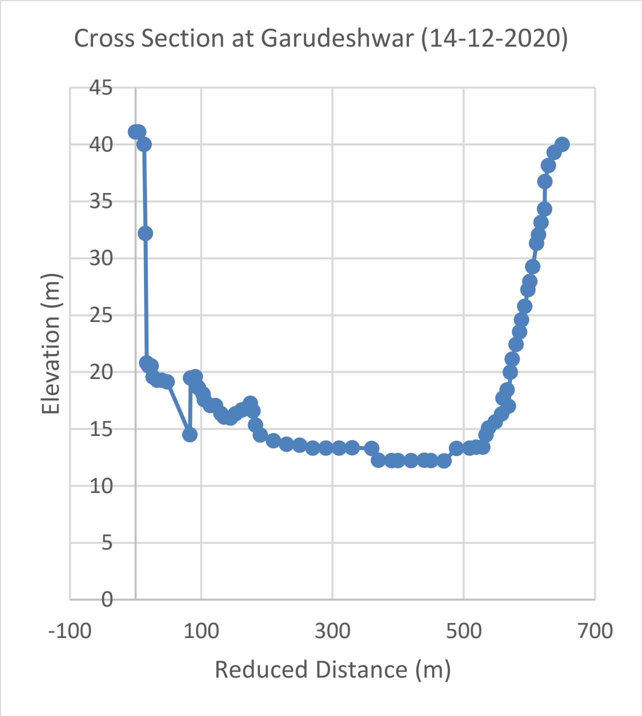

Cross Section at Garudeshwar (17-12-2014)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Elevation (m)
-
200.000
400.000
600.000
800.000
Reduced Distance (m)

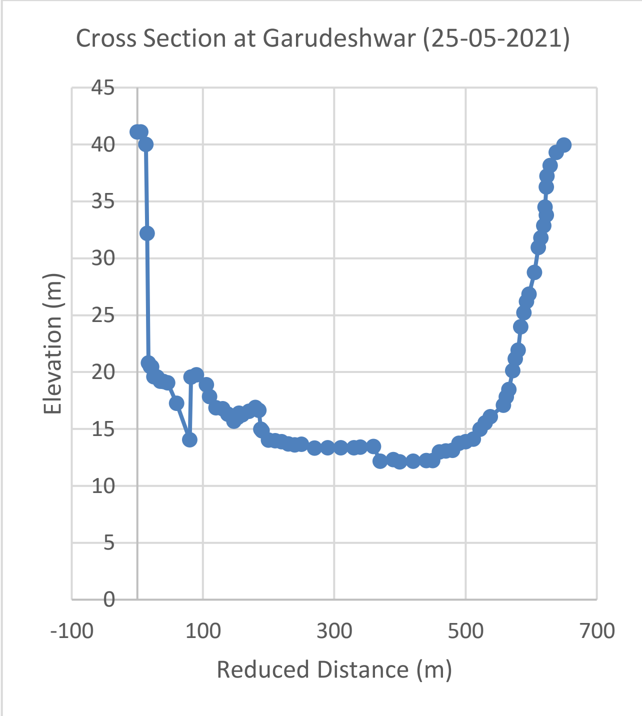

Cross Section at Garudeshwar (20-12-2016)
Elevation (m)
Reduced Distance (m)
45
40
35
30
25
20
15
10
5
0
-100
100
300
500
700

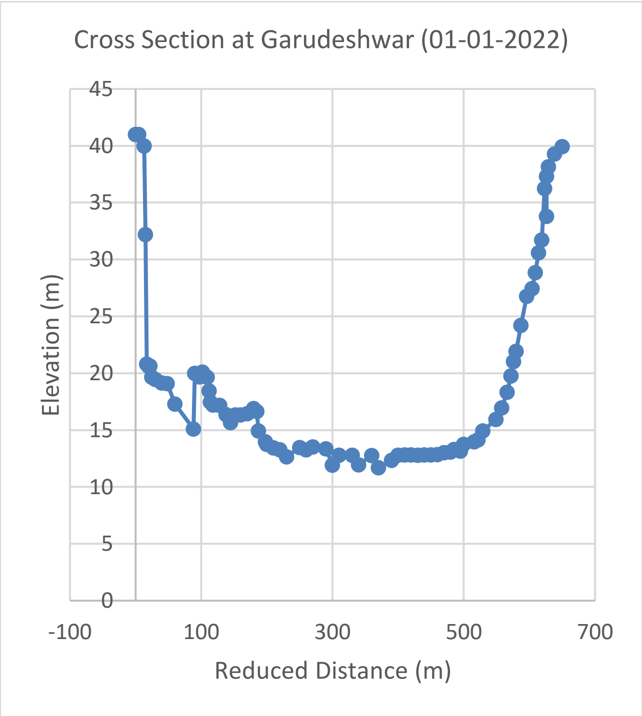

Cross Section at Garudeshwar (17-05-2019)
Elevation (m)
Reduced Distance (m)
45
40
35
30
25
20
15
10
5
0
-100
100
300
500
700

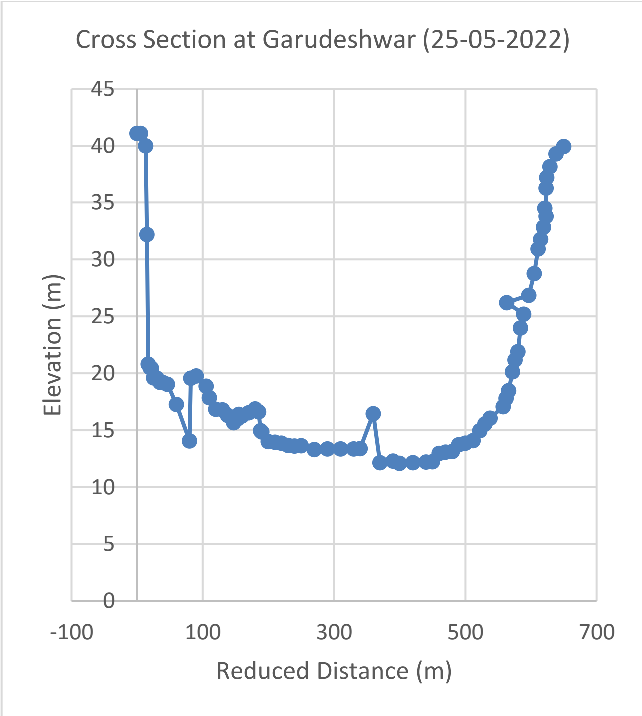

Cross Section at Garudeshwar (31-12-2019)
Elevation (m)
Reduced Distance (m)
45
40
35
30
25
20
15
10
5
0
-100
100
300
500
700

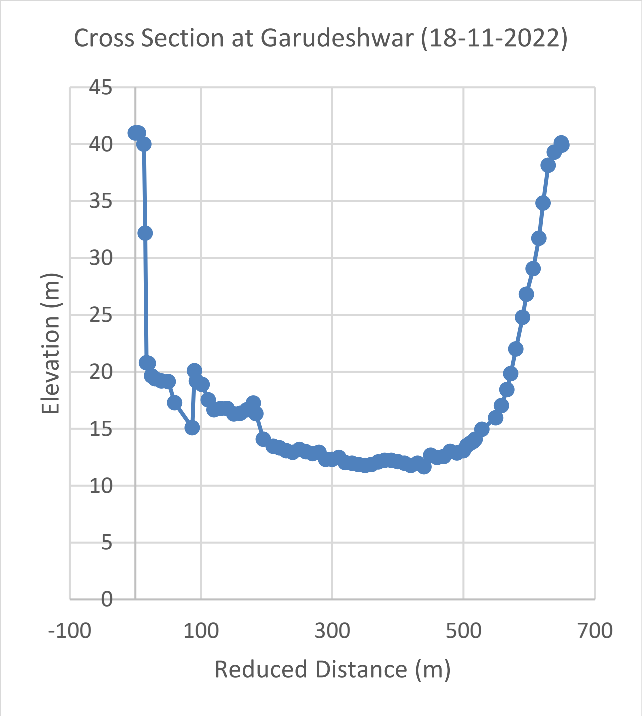

Cross Section at Garudeshwar (26-05-2020)
Elevation (m)
Reduced Distance (m)
45
40
35
30
25
20
15
10
5
0
-100
100
300
500
700

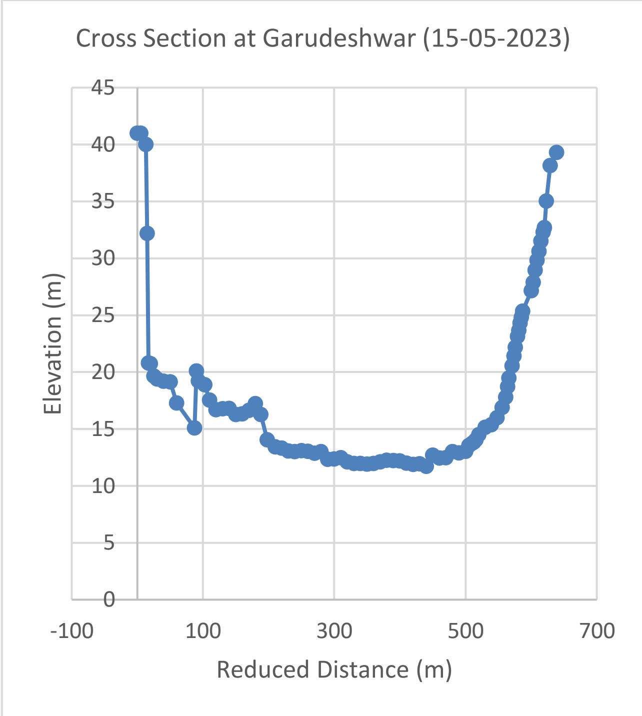

Cross Section at Garudeshwar (14-12-2020)
Elevation (m)
Reduced Distance (m)
0
5
10
15
20
25
30
35
40
45
-100
100
300
500
700


Cross Section at Garudeshwar (25-05-2021)
Elevation (m)
Reduced Distance (m)
0
5
10
15
20
25
30
35
40
45
-100
100
300
500
700


Cross Section at Garudeshwar (01-01-2022)
Elevation (m)
Reduced Distance (m)
0
5
10
15
20
25
30
35
40
45
-100
100
300
500
700


Cross Section at Garudeshwar (25-05-2022)
Elevation (m)
Reduced Distance (m)
0
5
10
15
20
25
30
35
40
45
-100
100
300
500
700





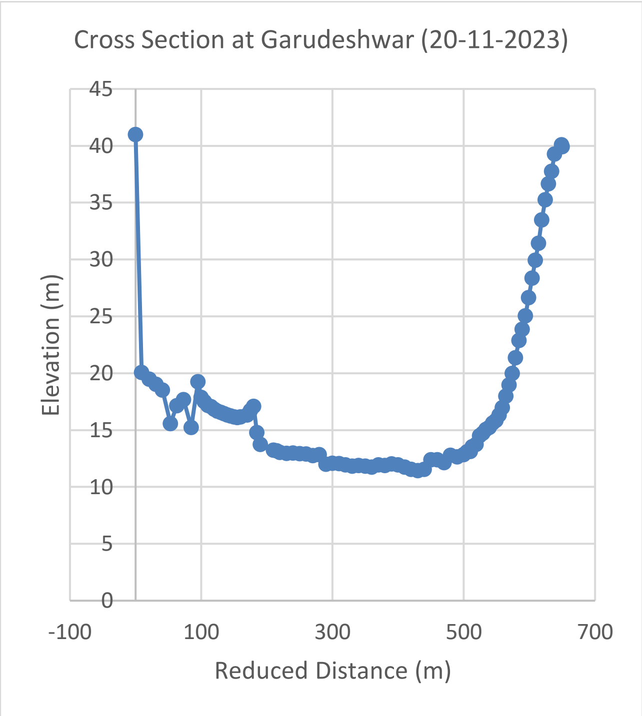
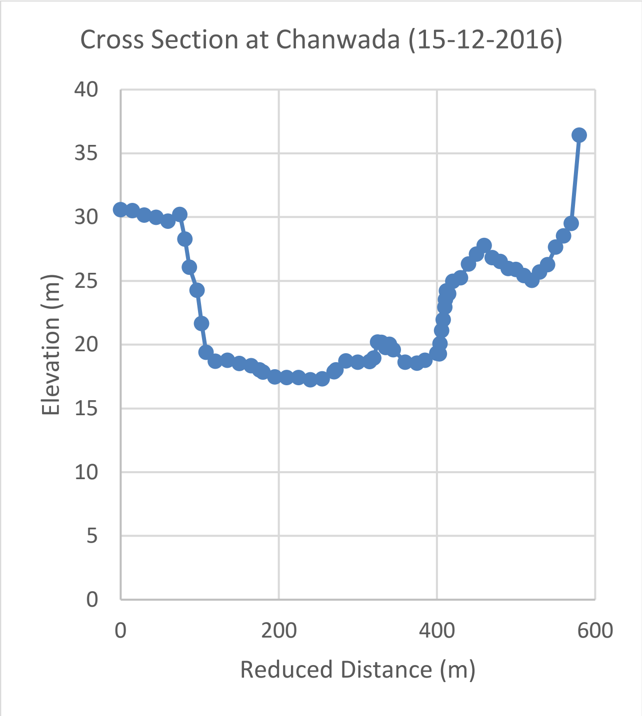


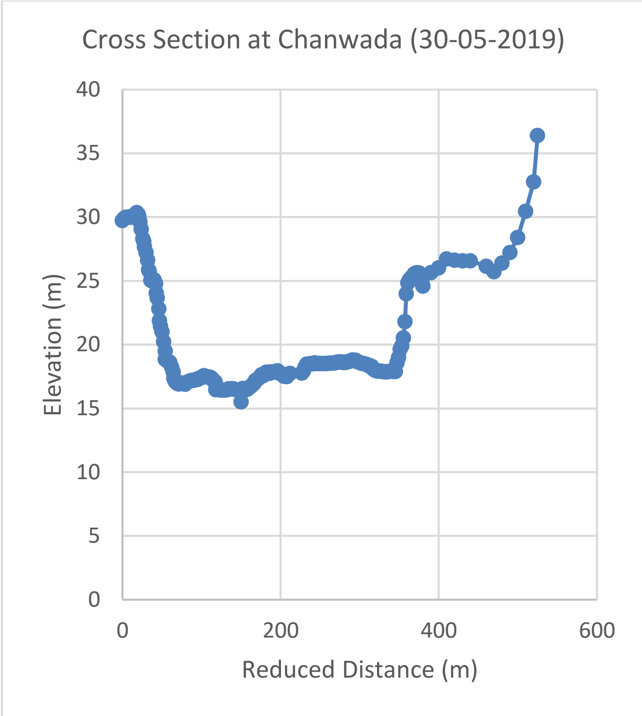
Figure 9: Evolution of Cross-Sectional Geometry at Garudeshwar Over Time

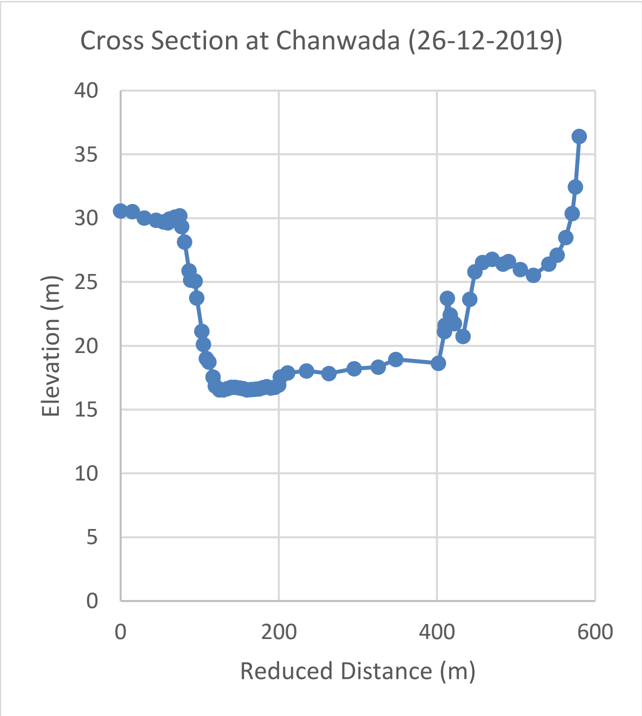
3.1.3 Cross Sections at Chanwada

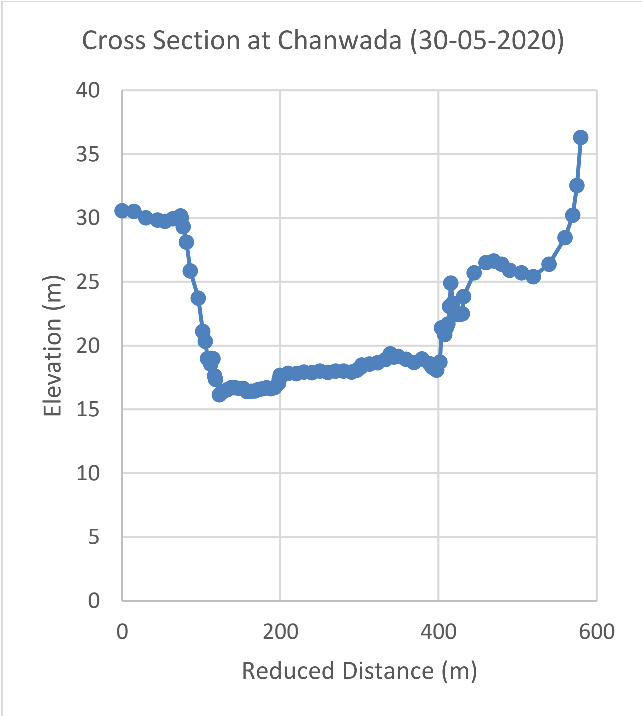
The Chanwada cross-section represents the Orsang River, a tributary of the Narmada, and provides a contrast to the main river's dynamics. This section reveals a narrower channel with relatively uniform depths, indicative of stable flow conditions and limited sediment transport capacity. The reduced variability in depth and width suggests lower flow velocities, typical of tributary systems with smaller discharges.

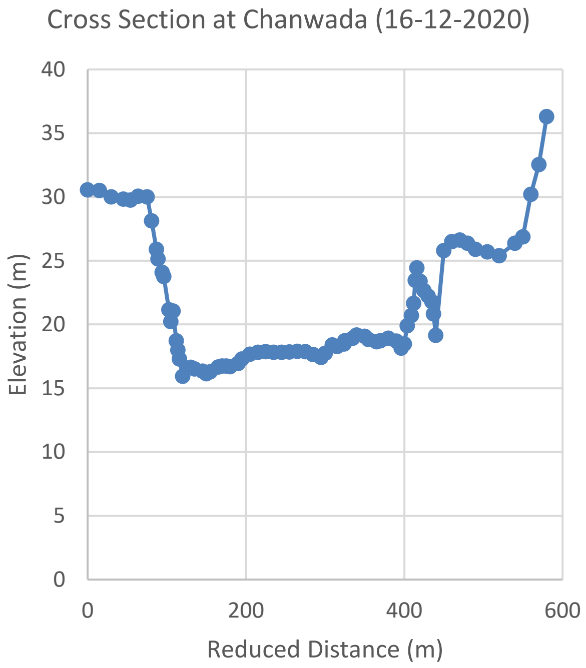
The cross-sectional profile at Chanwada reflects minimal bank erosion and deposition, likely due to reduced anthropogenic pressures and the tributary’s smaller catchment area. This stability provides an essential baseline for understanding sediment inputs from the Orsang River into the Narmada. The section’s geometry suggests that it primarily acts as a conduit for sediment and water transfer without significant channel alterations.

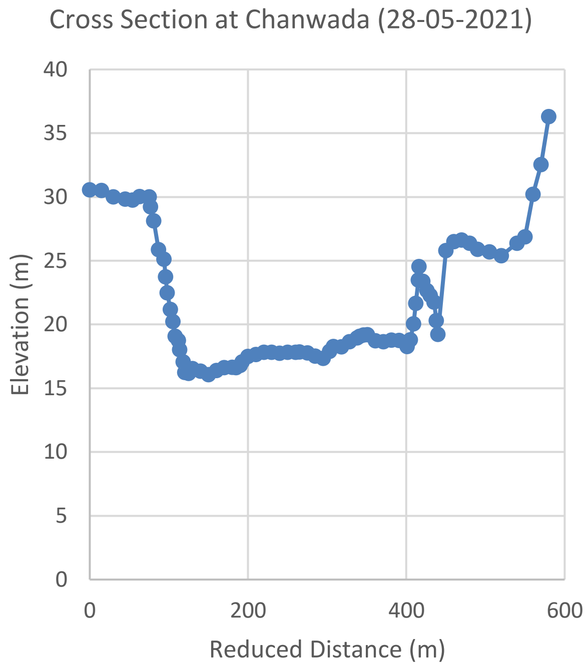

Cross Section at Chanwada (15-12-2016)
Elevation (m)
Reduced Distance (m)
0
5
10
15
20
25
30
35
40
0
200
400
600

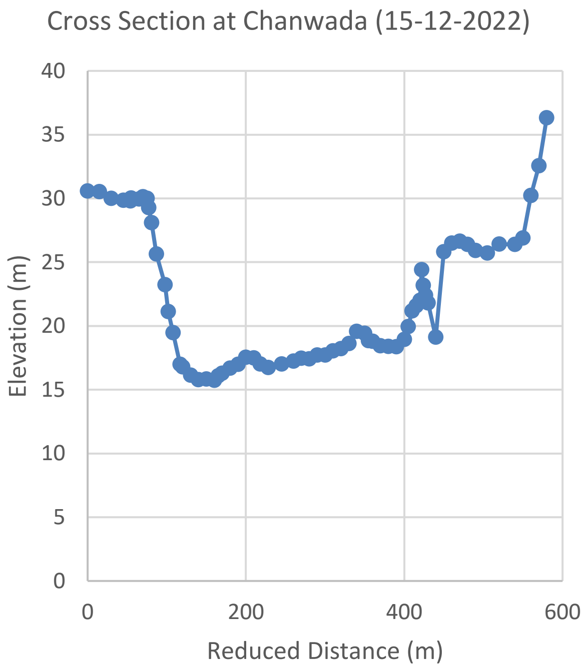

Cross Section at Chanwada (30-05-2019)
Elevation (m)
Reduced Distance (m)
0
5
10
15
20
25
30
35
40
0
200
400
600

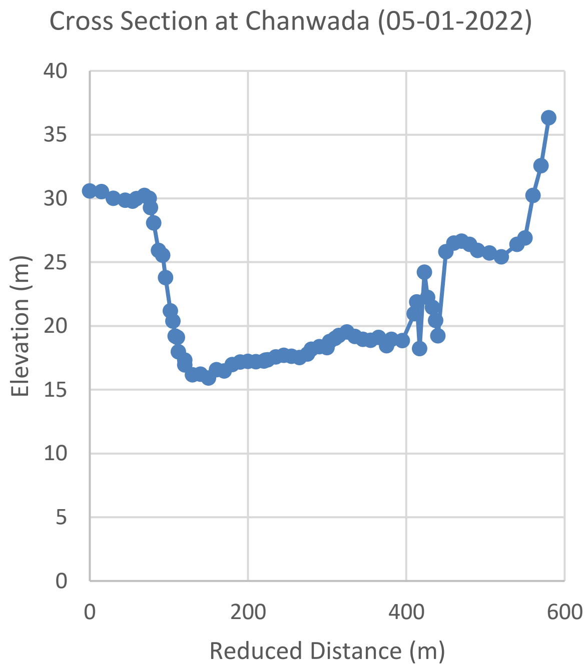

Cross Section at Chanwada (26-12-2019)
Elevation (m)
Reduced Distance (m)
0
5
10
15
20
25
30
35
40
0
200
400
600


Cross Section at Chanwada (30-05-2020)
Elevation (m)
Reduced Distance (m)
0
5
10
15
20
25
30
35
40
0
200
400
600


Cross Section at Chanwada (16-12-2020)
Elevation (m)
Reduced Distance (m)
0
5
10
15
20
25
30
35
40
0
200
400
600


Cross Section at Chanwada (28-05-2021)
Elevation (m)
Reduced Distance (m)
0
5
10
15
20
25
30
35
40
0
200
400
600


Cross Section at Chanwada (15-12-2022)
Elevation (m)
Reduced Distance (m)
0
5
10
15
20
25
30
35
40
0
200
400
600


Cross Section at Chanwada (05-01-2022)
Elevation (m)
Reduced Distance (m)
0
5
10
15
20
25
30
35
40
0
200
400
600

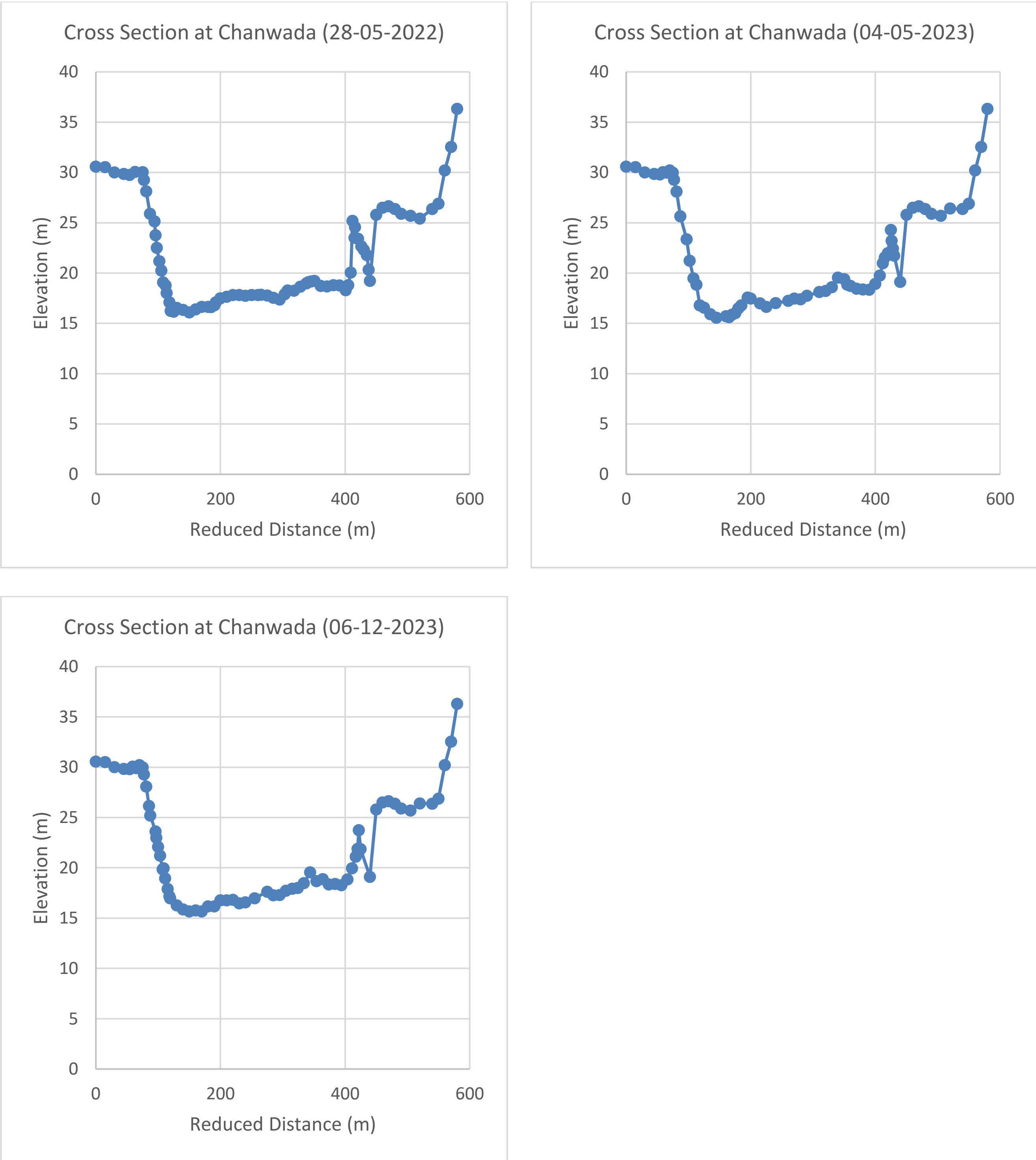


Figure 10: Temporal Analysis of Cross-Sectional Profiles at Chanwada

3.2 LONGITUDINAL PROFILE OF NARMADA RIVER

The longitudinal profile of the Narmada River provides a comprehensive view of its gradient, flow characteristics, and elevation changes from its origin to its mouth. Originating from the Amarkantak Plateau in Madhya Pradesh at an elevation of approximately 1,048 meters, the Narmada flows westward over a length of about 1,312 km before draining into the Arabian Sea. The profile reveals a distinct gradient variation across three major segments: the upper, middle, and lower courses, each characterized by unique geomorphological and hydrological features.

The longitudinal profile of the Narmada River reflects its journey from its origin to its mouth, showcasing distinct variations in gradient and flow characteristics. The river begins with a steep gradient, indicating a youthful stage where the elevation drops rapidly. This upper segment is marked by features such as waterfalls, rapids, and gorges, with significant erosion dominating the landscape. The high energy in this section facilitates the transportation of sediments and carving of deep valleys.

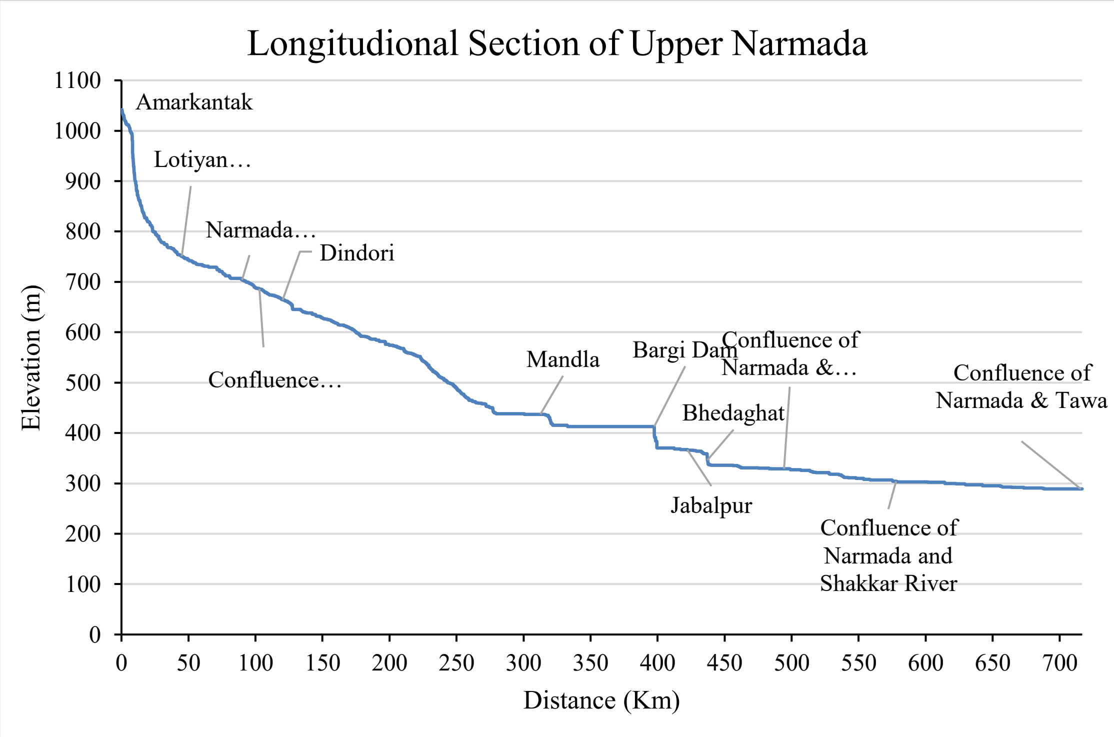


Figure 11: Longitudinal Section of Upper Narmada

As the river transitions to its middle segment, the gradient becomes moderate, and the flow begins to meander. The river widens considerably, and sediment deposition becomes more evident. This segment is characterized by fertile plains, where the slower flow supports agricultural activities and the construction of dams and reservoirs regulates the water. The middle portion also displays a balance between erosion and deposition, shaping the riverbed and surrounding areas.

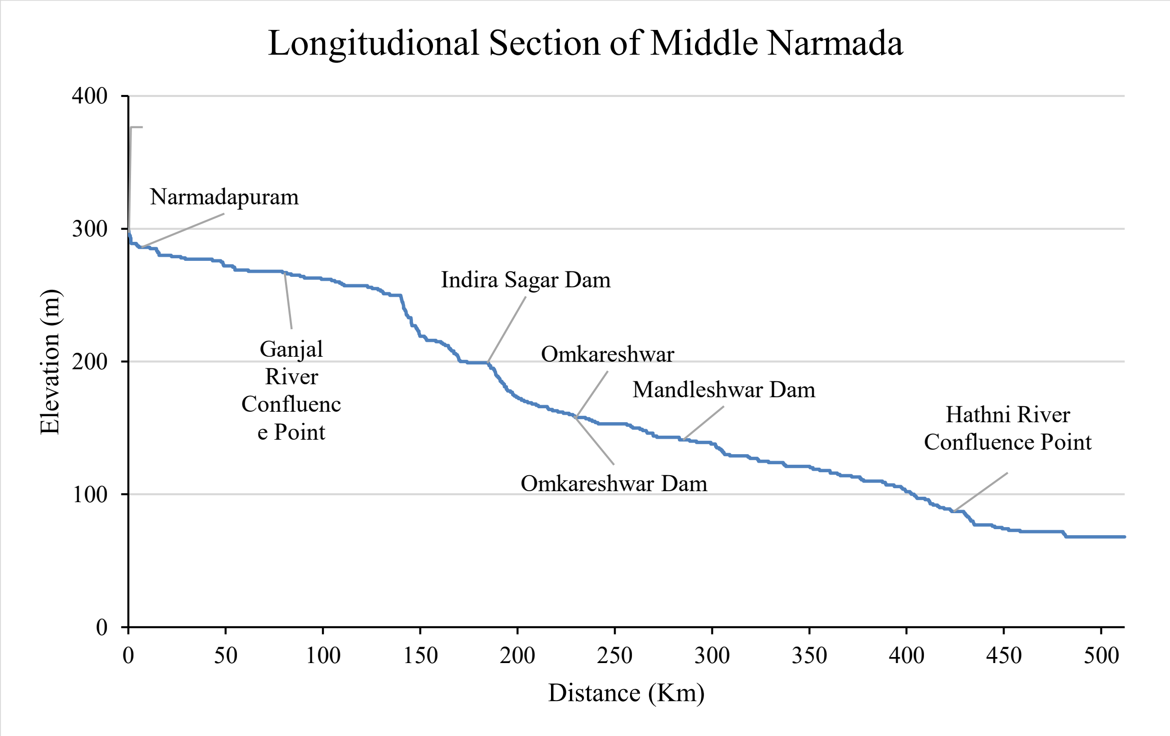


Figure 12: Longitudinal Section of Middle Narmada

In its lower segment, the Narmada exhibits an almost flat gradient, with minimal elevation changes. The flow slows significantly, leading to extensive sediment deposition near the river's mouth. This part of the river supports irrigation and fosters unique estuarine ecosystems due to its sediment-rich waters. The longitudinal profile, as a whole, illustrates the river's transition from a youthful, energetic stage to a mature, depositional phase, demonstrating its vital role in shaping the regional landscape and supporting ecological and human activities.

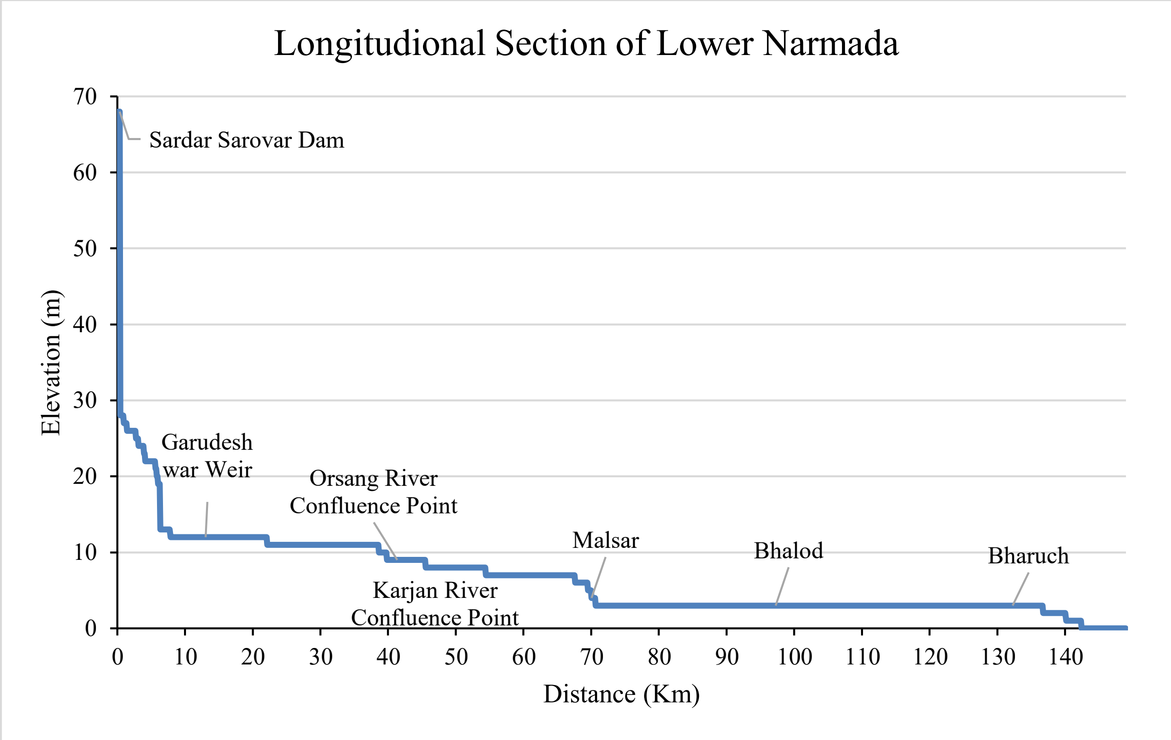


Figure 13: Longitudinal Section of Lower Narmada

Chapter 4: Riverine Infrastructure

This chapter marks a pivotal point in our comprehensive investigation of the Narmada River. Building upon the foundational understanding of the river's hydraulics and the methodologies employed in our data collection (Chapter 2), we now turn our attention to the network of human-made structures that interact with this vital waterway. The Narmada River, one of India's most vital waterways, supports a diverse range of infrastructure that plays a crucial role in the region's economic development and social well-being. This chapter provides an overview of the key infrastructure present on the Narmada, focusing on dams, canals, bridges, and ghats. These structures serve various purposes, including water storage, irrigation, hydropower generation, transportation, and cultural practices. While each type of infrastructure offers significant benefits, it is essential to consider their potential impacts on the river's natural flow regime, sediment transport, and ecosystem health. Specifically, this chapter will delve into the following key infrastructure categories:

- **Dams and Reservoirs:** A detailed examination of the major dams along Narmada river, including their physical characteristics, purposes, and potential impacts.
- **Canals:** An overview of the extensive canal network, highlighting its role in irrigation and water resource distribution.
- **Bridges:** Documentation of significant bridges that facilitate transportation across the river, particularly those associated with major roadways.
- **Ghats:** A survey of these culturally and practically important riverbank structures, emphasizing their distribution and purposes.

By providing this meticulously compiled dataset, this chapter aims to empower researchers, planners, and policymakers with the information necessary to make informed decisions regarding the sustainable management and development of the Narmada River basin.

4.1 DAMS AND RESERVOIRS

Dams and reservoirs are pivotal components of riverine infrastructure, serving a multitude of purposes such as water storage, irrigation, hydropower generation, and flood control. The Narmada River, with its significant water resources and potential, has been harnessed through the construction of numerous dams and reservoirs along its course. These structures play a crucial role in managing the river's flow, ensuring water availability for various needs, and mitigating the impacts of floods.

This section provides a comprehensive overview of the dams and reservoirs on the Narmada River, based on a meticulously compiled dataset. The dataset encompasses a variety of attributes, including the type of dam, year of construction, length, maximum height, design flood, spillway type, and total dam volume. This information enables a thorough analysis of these structures' physical characteristics and functionalities, facilitating a deeper understanding of their role in the Narmada River basin.

The India-WRIS dataset reveals a significant presence of dams within the Narmada River basin, with 324 recorded structures. These dams are distributed across the basin, with 142 located in the upper reaches, 153 in the middle basin, and 29 in the lower basin. This distribution highlights the extensive utilization of the Narmada's water resources for various purposes, including irrigation, hydropower generation, and water supply.

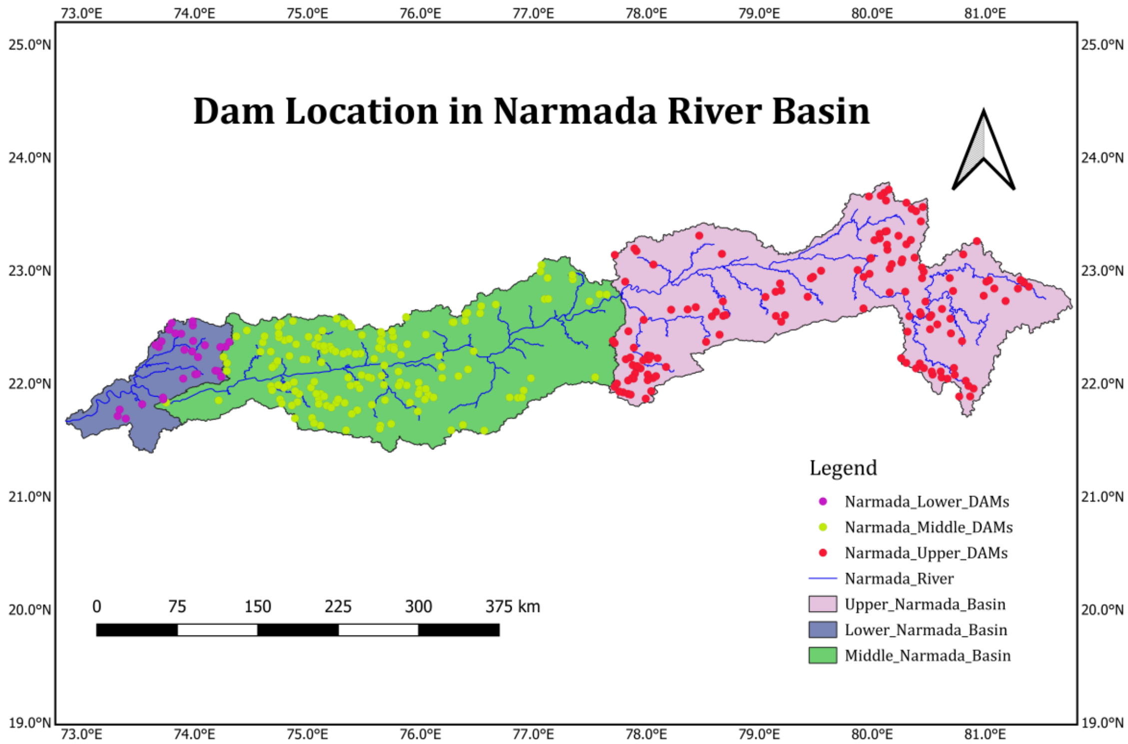


Figure 14: Spatial Distribution of Dams in the Narmada River Basin

Sardar Sarovar Dam

The Sardar Sarovar Dam, an imposing concrete gravity structure, stands as a testament to India's ambition in water resource management. Located on the Narmada River in Gujarat, this colossal dam stretches 1,210 meters in length and towers 163 meters high, making it the third-highest concrete dam in India. The dam's reservoir, with a gross storage capacity of 0.95 million hectares meter, is a sprawling expanse of water covering 37,000 hectares. The dam's catchment area upstream spans a vast 88,000 square kilometres, and its spillway has a remarkable discharge capacity of 87,000 cubic meters per second.

Indira Sagar Dam

The Indira Sagar Dam, a concrete gravity dam with a slightly curved alignment, holds a prominent position among India's water resource projects. Located on the Narmada River in the Khandwa district of Madhya Pradesh, it is the largest dam in India in terms of the volume of water stored in its reservoir. The dam, standing tall at 92 meters and stretching 653 meters in length, was envisioned by Prime Minister Indira Gandhi, who laid the foundation stone for the project in 1984. The dam's construction, which commenced in 1992, involved the displacement of a town of 22,000 people and 100 villages, underscoring the social and environmental challenges associated with large dam projects.

Indra Sagar Dam Details:

- Type of dam: Concrete Gravity dam with a slightly curved alignment
- Height: 92 m (302 ft)
- Length: 653 m (2,142 ft)
- Spillways: 20 (Chute spillway (auxiliary) – 8 : 20 m x 17 m, Main (service) Spillway – 12 : 20 m x 17 m)
- Spillway type: Ogee
- Spillway capacity: 83,400 m3/s (2,950,000 cu ft/s)

Reservoir Details

- Creates: Indira Sagar Reservoir
- Total capacity: 12.220 km^3 (9,907,000 acre·ft) (432 Tmcft)
- Active capacity: 9.750 km^3 (7,904,000 acre·ft) (344.37 tmcft)
- Inactive capacity: 2.470 km^3 (2,002,000 acre·ft)
- Catchment area: 62,000 km^2

- Surface area: 913.48 km2 (352.70 sq mi)

Power Station Details

- Operator(s): NHDC
- Turbines: Dam: 8 × 125 MW Francis pump-turbine. Canal: 15 MW Kaplan-type.
- Installed capacity: 1,000 MW

Omkareshwar Dam

The Omkareshwar Dam, a gravity dam on the Narmada River in Madhya Pradesh, is an integral part of the Narmada Valley Development Project. Completed in 2007, this multipurpose dam stands 64 meters tall and has a length of 949 meters. The dam serves a variety of needs, including irrigation, power generation, and flood control. With an installed capacity of 520 MW, generated through eight 65 MW Francis turbines, the Omkareshwar Dam plays a significant role in meeting the region's energy demands. Its reservoir has a live storage capacity of 987 MCM, providing a substantial water resource for various uses.

Maheshwar Dam

The Maheshwar Dam, a run-of-the-river hydropower project on the Narmada River in Madhya Pradesh, is a key contributor to the region's energy supply. Completed in 2013 after a construction period that began in 1992, the dam stands 36 meters high and stretches 3123 meters in length. With an installed capacity of 400 MW, generated through ten 40 MW Kaplan turbines, the Maheshwar Dam primarily focuses on power generation, playing a vital role in meeting the energy needs of Madhya Pradesh.

Bargi Dam

The Bargi Dam, a gravity dam built on the Narmada River in Madhya Pradesh, holds a significant place in the history of dam construction in the Narmada basin. Completed in 1988, it was one of the first major dams to be built on the river. The dam, with a length of 5,357 meters and a height of 69.8 meters, created a reservoir with a total capacity of 3,920,000,000 cubic meters.

Bhadbhut Barrage

The Bhadbhut Barrage, currently under construction on the Narmada River in Gujarat, is a unique project with a focus on mitigating the downstream impacts of upstream dams, particularly the Sardar Sarovar Dam. Expected to be completed by October 2026, the barrage is located 25 km upstream of the river mouth where it enters the Gulf of Khambhat and 125 km downstream of the Sardar Sarovar dam. The barrage, with a length of 1.663 km, will create a reservoir with a capacity of 599 MCM, and it will feature 90 gates to regulate water flow. A notable feature of the barrage is the inclusion of a six-lane bridge that will connect Dahej and Hazira, reducing the travel distance between these locations by 18 km.

The construction of the barrage involves land acquisition from 14 villages, totaling 131.53 hectares, to accommodate flood protection embankments on both banks of the river.

Adampura Dam

The Adampura Dam, an earthen dam completed in 2001, is located on a local tributary of the Narmada River in the West Nimar district of Madhya Pradesh. With a length of 2,070 meters and a height of 21.95 meters, the dam is situated near a significant stone deposit, highlighting the potential for resource extraction in the vicinity.

Agar Dam

The Agar Dam, an earthen dam completed in 1981, is located on a local tributary of the Narmada River in the Dhar district of Madhya Pradesh. With a length of 210 meters and a height of 16.79 meters, the dam plays a role in providing irrigation to the surrounding agricultural areas. The Agar Dam is also connected to the Kundalia major irrigation project on the Kalisindh River, a significant water resource development initiative in the region.

Ahirkheda Dam

The Ahirkheda Dam, an earthen dam completed in 2001, is located on a local tributary of the Narmada River in the West Nimar district of Madhya Pradesh. With a length of 460 meters and a height of 12.35 meters, the dam serves the purpose of providing irrigation to the surrounding agricultural lands.

Ahmadpur Dam

The Ahmadpur Dam, an earthen dam completed in 1916, is located on a local tributary of the Narmada River in the Balaghat district of Madhya Pradesh. With a length of 1,007 meters and a height of 14.12 meters, the dam serves the purpose of providing irrigation to the surrounding agricultural lands.

Ama (Old) Dam

The Ama (Old) Dam, an earthen dam completed in 1916, is located on the Pongar Nala, a tributary of the Narmada River, in the Balaghat district of Madhya Pradesh. With a length of 762 meters and a height of 10.24 meters, the dam serves the purpose of providing irrigation to the surrounding agricultural lands. Interestingly, the dam has an association with a music publisher, as mentioned in a source related to the dam.

Fifty Major Dams on the Narmada River

The following table presents details of 50 major dams on the Narmada River, including their name, river, type, year of completion, catchment area, length.

Table 1: Major Dams in Narmada River Basin with Catchment Area

Sl. No.	Name of Dam	River	Type of Dam	Year of completion	Catchment Area (Sq.km)	Length of dam (m)	Max height above foundation (m)	Gross storage capacity (MCM)	Purpose
1	Indira Sagar (NHDC) Dam	Narmada	Earthen / Gravity / Masonry	2006	62000	654	91.4	12200	HE, IR
2	Sardar Sarover Dam	Narmada	Gravity / Masonry		88000	1210	163	9500	HE, IR
3	Rani Avanti Bai Sagar (Bargi (Nvda) Dam	Narmada	Gravity / Masonry	1988	15000	5357	69.8	3924.8	HE, WS ,IR
4	Tawa Dam	Tawa	Earthen / Gravity / Masonry	1978	6000	1944. 92	57.91	2312	HE, IR
5	Omkareshwar (NHPC) Dam	Narmada	Gravity / Masonry	2007	65000	949	64	987	HE, WS ,IR
6	Karjan Dam	Karjan	Earthen / Gravity / Masonry	1987	1404	903	100	630	IR
7	Barna Dam	Barna	Gravity / Masonry	1977	1200	432	47.7	539	IR, PS

Sl. No.	Name of Dam	River	Type of Dam	Year of completion	Catchment Area (Sq.km)	Length of dam (m)	Max height above foundation (m)	Gross storage capacity (MCM)	Purpose
8	Maheshwar Dam	Narmada	Earthen / Gravity / Masonry		69184	3123	36	483.0	HE
9	Kolar Dam	Kolar	Gravity / Masonry	1990	508	1242	45	270	IR, WS
10	Upper Narmada Dam	Narmada	Earthen / Gravity / Masonry		12	2120	33.8	206.26	IR
11	Sukhi Dam	Sukhi	Earthen / Gravity / Masonry	1986	412	4271	38	178.47	IR
12	Halon (Nvda) Dam	Halon	Gravity / Masonry		715	993	35	146.08	IR
13	Man (NVDA) Dam	Man	Gravity / Masonry		690	633	53	145.0	IR
14	Lower Goi Dam	Goi	Earthen / Gravity / Masonry		1100	2400	44.2	143.18	IR
15	Satpura (Mpseb) Dam	Tawa	Earthen / Gravity / Masonry	1967	553.13	513.58	33.52	110.44	WS
16	Upper Beda Dam	Kundi	Gravity / Masonry	2010	520	2431	23.93	91.82	IR
17	Sukta Dam	Sukta	Earthen	1984	468.79	2219	32	89.5	IR
18	Jobat (NVDA) Dam	Hatni	Gravity / Masonry	2007	790	462.55	34.6	77.84	IR
19	Dejla Dewada Dam	Dejla	Earthen	1988	340	1560	35.2	56.35	IR, PS
20	Matiyari Dam	Matiyari	Earthen	1986	158.75	1131.42	28.1	46.87	IR
21	Bohribund Dam	Bhuta Nalla	Earthen	1927	108.8	518.8	22.25	36.98	IR
22	Chandrakeshar Dam	Chandrakeshar	Earthen	1976	110	2450	21.1	30.07	IR
23	Satak Dam	Satak	Earthen	1960	28.37	1650	25	25.61	IR
24	Choral Dam	Choral	Earthen	1988	64.75	620	28.04	23.92	IR
25	Ambak Dam	Local Nala	Earthen	2001	151	1250	25.05	22.05	IR
26	Pariat (Corporation) Dam	Pariat Nalla	Earthen	1927		1182	22.74	20.06	WS
27	Sampana Dam	Sampna	Earthen	1956	44.75	1790	21.95	16.9	IR

Sl. No.	Name of Dam	River	Type of Dam	Year of completion	Catchment Area (Sq.km)	Length of dam (m)	Max height above foundation (m)	Gross storage capacity (MCM)	Purpose
28	Beherakhar (Banjar) Dam	Kuru Behrakhara nalla	Earthen / Gravity / Masonry		36	670.73	21.81	15.7	IR, WS
29	Sakalda Dam	Chiri and Khuj Nalla	Earthen	1981	84.17	539.5	22	15.66	IR
30	Gadigaltar Dam	Undri Nadi	Earthen	1990	9.9	873	23.19	15.55	IR
31	Dholi Dam	Madhumati	Earthen	1995	34	1280	36	14.17	IR
32	Lower Palakmati Dam		Earthen	1936	85.45	990	15.24	13.87	IR
33	Dukrikheda Dam	Ghoghara Nallla	Earthen	1956	22.5	1981	18.67	12.23	IR
34	Upper Palakmati Dam	Palakmati	Earthen	2002	50.29	210	22.71	11.04	IR
35	Bhikarkhedi Dam	Borad	Earthen	1985	43.86	613	20.85	10.39	IR
36	Ranipur Dam	Local Nala	Earthen	1992	25.8	774	23.86	9.65	IR
37	Madai Dam		Earthen	1966	27.2	307	18.9	8.7	IR
38	Moga Dam		Earthen	1997	25.9	210	20.7	8.62	IR
39	Bichhia Dam	Kathar Nalla	Earthen	1975	19.42	1579	26.53	8.51	IR, WS
40	Kunda Nala Dam	Buti Nalla	Earthen	1963	31.75	2500	15.6	8.5	IR
41	Gagan Dam	Local Nala	Earthen	1959	41	880	18.28	8.34	IR
42	Utawad Dam	Local Nala	Earthen	1987	36.6	450	22.39	8.05	IR
43	Banganga Dam	Rohini Nadi	Earthen	1988	46.6	539	23.8	7.58	IR
44	Paras Dam	Paras	Earthen	1982	24.05	660	26.94	7.54	IR
45	Padliya Dam	Local Nala	Earthen	1984	38.23	825	16.02	7.39	IR
46	Rami Dam	Rami	Earthen	1980	24.68	485	26.52	7.08	IR
47	Jhirbhar Dam	Local Nala	Earthen	1980	51.56	327	21.33	5.66	IR
48	Dhuandhar Dam	Dhuandhar Nalla	Earthen	1962	13.2	1240.5	27.19	5.46	IR
49	Harwant Dam	T- Narmada	Earthen	1982		279	23.11	4.92	IR
50	Samaldo Dam	Local Nala	Earthen	1960	18.45	823	12.9	4.88	IR

***Source**: India Water Resources Information System (https://indiawris.gov.in/wris/)*

For a comprehensive list of all dams in the Narmada River basin, please refer to the supplementary table [Dam_Narmada_River]. This resource provides detailed information on each dam, including location coordinates, physical characteristics, and operational details.

4.2 CANALS

Approximately 30% of the Narmada basin area falls under command areas, comprising major and medium irrigation projects. Of this, 27.6% is classified as major command and 3.3% as medium command. The major command areas in the basin include the Indira Sagar, Bargi (Rani Avanti Bai Sagar), Bargi Diversion, Sardar Sarovar, and Tawa projects. These systems serve districts in Madhya Pradesh such as Jabalpur, Narsimhapur, Raisen, Hoshangabad, Harda, Sehore, and West Nimar, as well as Gujarat districts including Bharuch, Narmada, and Vadodara. Medium command areas include projects such as Upper Beda, Matiyari Chandrakeshar, Uri, Machak, Bohari Bund, Madai, and Heran.

Waterlogging is a significant issue in the lower part of the basin, particularly in command areas under Sardar Sarovar, Ukai, and Karjan projects. The Narmada basin features an extensive canal network that not only irrigates the basin but also facilitates inter-basin water transfer. The Narmada Canal, part of the Sardar Sarovar Project, is the longest lined irrigation canal in the world, stretching approximately 459 km from its headworks at the Sardar Sarovar Dam in Gujarat to the Gujarat-Rajasthan border. Beyond this point, it extends into Rajasthan, irrigating areas in Barmer and Jalore districts. The canal system also supports inter-basin transfers to the Mahi, Sabarmati, and west-flowing rivers in the Kutch and Saurashtra basins. Projects such as Bargi and Tawa also have extensive canal networks. In total, the canal systems across various irrigation projects in the basin span an impressive 6637.8 km. The command areas and their corresponding canal networks are depicted in the accompanying map.

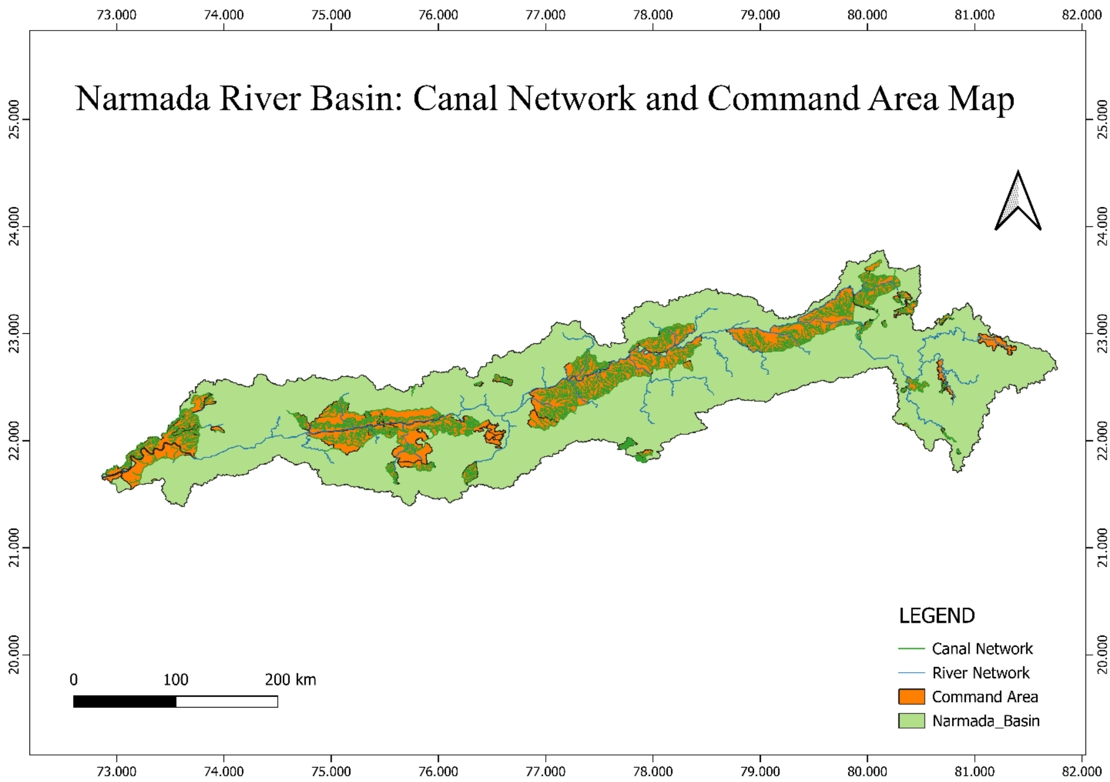


Figure 15: Canal Network and Command Areas in the Narmada River Basin

4.2.1 Narmada Main Canal

Narmada Main Canal is a contour canal. It is the biggest lined irrigation canal in the world. It is about 458 km. long up to Gujarat -Rajasthan border. It has a capacity to flow 1133 cumecs (40000 cusecs) at its head-at kevadia and reducing to 71 cumecs (2500 cusecs) at the Gujarat -Rajasthan border. The canal extends further in the state of Rajasthan to irrigate areas in Barmer and Jhalore districts of Rajasthan. The Main Canal is lined with plain cement concrete to minimise seepage losses to attain higher velocity and to control the water logging in future. The lining work is carried out with the mechanized pavers. Such a large scale paving of concrete lining is done for the first time in India.

Table 2: Hydraulic Data Summary for the Narmada Main Canal

Sr. No.	Chainage From	Chainage To	Bed Width (B)	Full Supply Depth (D)	Inner Slope	Bed Gradient	Discharge	
	km	km	m	m	H:V		Cusec	Cumec
1	0.000	17.250	73.10	7.60	2:1	1 in 12500	40037	1133.550
2	17.250	21.390	72.10	7.60	2.25:1	1 in 12500	40037	1133.550
3	21.390	48.086	73.10	7.60	2:1	1 in 12500	40037	1133.550
4	48.086	51.553	72.80	7.60	2:1	1 in 12500	39885	1129.250
5	51.553	67.153	72.60	7.60	2:1	1 in 12500	39784	1126.380
6	67.153	82.040	68.70	7.60	2:1	1 in 12500	37810	1070.510
7	82.040	95.234	66.40	7.60	2:1	1 in 12500	36648	1037.600
8	95.234	105.344	66.10	7.60	2:1	1 in 12500	36496	1033.310
9	105.344	129.305	65.30	7.60	2:1	1 in 12500	36092	1021.870
10	129.305	144.500	64.40	7.60	2:1	1 in 12500	35638	1009.010
11	144.500	184.926	72.00	7.60	2:1	1 in 15500	35454	1003.796
12	184.926	196.188	75.20	7.30	2:1	1 in 15500	34415	974.377
13	196.188	210.936	72.70	7.30	2:1	1 in 15500	33350	944.239
14	210.936	229.920	71.30	7.30	2:1	1 in 15500	32755	927.372
15	229.920	246.477	67.50	7.30	2:1	1 in 15500	31139	881.634
16	246.477	263.265	62.60	7.30	2:1	1 in 15500	29060	822.757
17	263.265	277.800	53.70	6.50	2:1	1 in 15500	20612	583.574
18	277.800	293.501	51.20	6.50	2:1	1 in 15500	20799	588.889
19	293.501	310.256	46.60	6.50	2:1	1 in 15500	18139	513.571
20	310.256	314.696	40.60	6.50	2:1	1 in 15500	16060	454.696
21	314.696	321.115	40.60	6.50	2:1	1 in 15500	16060	454.696
22	321.115	333.589	40.60	6.50	2:1	1 in 15500	16060	454.696
23	333.589	348.577	38.20	6.50	2:1	1 in 15500	15231	431.236
24	348.577	356.422	35.80	6.50	2:1	1 in 15500	14405	407.835
25	356.422	362.011	33.70	6.50	2:1	1 in 15500	13683	387.415
26	362.011	375.881	33.70	6.50	2:1	1 in 15500	13683	387.415
27	375.881	388.164	33.90	6.10	2:1	1 in 15500	12254	346.950
28	388.164	406.162	20.30	5.20	2:1	1 in 15500	5985	169.449
29	406.162	424.467	17.30	5.20	2:1	1 in 15500	5288	149.721
30	424.467	442.452	14.10	4.90	2:1	1 in 15500	4054	114.772
31	442.452	458.318	14.60	4.40	2:1	1 in 15500	3380	95.700

4.2.2 Branch Canals

Forty four (44) canals are off taking from Narmada Main Canal. Seven Sub Branch Canals from Saurashtra Branch Canal. Major branch canals are Saurashtra Branch Canal and Kachchh Branch Canal:

Saurashtra Branch Canal off takes at Ch. 263.20 km of Narmada Main Canal near Kadi . It has a peculiar feature in its 104 km long alignment . It falls down through 40.71 m upto

Ch 68.480 km and raises by 70.85 m before tailing into Bhogavo reservoir. It is proposed to generate hydro power at 3 fall locations and then pump the water in five stages from the lowest point in to the canal . Seven Sub Branch Canals- Narsinhpur , Vallabhipur , Maliya , Dhrangadhra , Limbdi, Botad and Morbi offtakes from SBC and are also executed completely and flowing with Water for irrigation, drinking & industrial usage in Saurashtra region.

Kachchh Branch Canal is 358 km long and off takes from NMC with designed enhanced discharge of 220 cumecs and serves net CCA of 175811 hectors in Banaskantha, Patan & Kachchh districts. It crosses Little Run and Great Run of Kachchh. There are three pumping stations on KBC. The works of these pumping stations are completed. The canal works beyond 190 km is divided into 23 slices (IR-O to IR-22). Kachchh Branch Canal is already in operation up to Tapar Dam and beyond which, it is partially completed and under progress. Gagodhar, Wandhiya & Dudhai Sub Branch Canal off takes from KBC. Gagodhar & Wandhiya Sub Branch Canal is almost completed & Dudhai sub branch canal is in progress.

Table 3: Narmada Main Canal Section Characteristics

Sr. No	Name of Canal	Chainage of NMC (km)	Sr. No	Name of Canal	Chainage of NMC (km)	Sr. No	Name of Canal	Chainage of NMC (km)
1.	Wadia	9.931	2.	Tilakwada	17.871	3.	Mandwa	25.263
4.	Bhilodia	32.694	5.	Timbi	38.523	6.	Sankheda	45.109
7.	Miyagam	62.916	8.	Gojali	70.236	9.	Vadodara	81.834
10.	Dena	88.77	11.	Dumad	100.026	12.	Sakarda	102.953
13.	Zumkha	106.905	14.	Nahra	111.645	15.	Desar	126.645
16.	Sanali	171.961	17.	Mehmdabad	187.074	18.	Ghodasar	202.368
19.	Vehlal	212.546	20.	Daskroi	223.667	21.	Dholka	246.286
22.	Sanand	258.632	23.	Saurashtra	263.2	24.	Viramgam-I	267.063
25.	Viramgam-II	277.166	26.	Goriya	290.605	27.	Kharaghoda	292.398
28.	Zinzuwada	301.041	29.	Bolera	326.389	30.	Rajpura	344.772
31.	Amarapura	354	32.	Radhanpur	374.486	33.	Kachchh	385.814

34.	Vejpur	405.722	35.	Madka	417.792	36.	Malsan	423.732
37.	Dhima	438.552	38.	Godasisar	453.837			

The Main Canal in its journey has to negotiate several water streams, rivers, roads, railways etc. This is possible by constructing appropriate structure on the canal. In all, there are 598 Structures on the Narmada Main canal. Out of this 236 structures are cross drainage structures, comprising of 5 Aqueducts, 15 canal syphons, 182 drainage syphons, 33 canal crossing and one super passage. There are 89 Regulating structures comprising of 1 Main HR, 44 Branch HR, 32 Cross Regulators and 12 Escapes. There are total 274 nos. of Road Bridge including national Highway, State Highway, MDRB, ODRB, VRB, and UVRB etc. Narmada Main Canal as on today is almost completed up to 458 km. and water has flown through it and has reached the state of Rajasthan.

4.2.3 Other Major Irrigation Projects

In addition to this other major irrigation projects are:

4.2.3.1 Bargi Project

The Bargi Project, located on the Narmada River near Bargi village in Jabalpur district, was completed in June 1988. It is a multipurpose project aimed at irrigation, hydropower generation, and drinking water supply.

Irrigation: Covers a Culturable Command Area (CCA) of 2.198 lakh hectares, providing irrigation to 1.57 lakh hectares in Jabalpur and Narsinghpur districts.

4.2.3.2 Tawa Project

The Tawa Project is an irrigation initiative built on the Tawa River, a left-bank tributary of the Narmada, near Ranipur village in Hoshangabad district. Completed in 1992-93, the project supports agriculture and hydropower generation in the region.

Irrigation: CCA of 2.468 lakh hectares in Hoshangabad and Harda districts.

4.2.3.3 Omkareshwar Project

The Omkareshwar Project is located downstream of the Indira Sagar Project near Omkareshwar Jyotirlinga in Khandwa district. The project was completed in November 2007 by NHDC, a joint venture of the Government of Madhya Pradesh and NHPC.

Irrigation: Envisaged to irrigate 1.47 lakh hectares in Khargone, Dhar, and Khandwa districts upon completion of the canal network.

4.2.3.4 Indira Sagar Project (ISP)

The Indira Sagar Project, located near Punasa village in Khandwa district, is a multipurpose river valley project that plays a vital role in water resource development in the Narmada Basin. It is notable for having the largest storage capacity in the country.

Irrigation: Provides an annual irrigation potential of 1.69 lakh hectares in Khandwa and surrounding districts.

These major projects collectively contribute significantly to irrigation, power generation, and water resource management in the Narmada Basin.

4.3 BRIDGES AND CROSSINGS

Bridges are essential components of riverine infrastructure, providing vital connections across waterways and facilitating transportation and communication. The Narmada River, with its numerous tributaries and extensive network of roads and railways, is traversed by a variety of bridges, each with its unique characteristics and significance.

This section provides a comprehensive overview of the bridges and crossings on the Narmada River and its tributaries. The data presented here includes the names of the bridges, their locations, the rivers they cross, and other relevant details. This information is crucial for transportation planning, infrastructure development, and assessing the connectivity provided by these crossings. By integrating this data with hydrological and topographical information, researchers can analyze potential vulnerabilities to flooding or identify areas where new bridges might be needed.

A detailed inventory of bridges and crossings on the Narmada River and its tributaries is provided in Annexure III. This annexure includes a comprehensive table with information on the name, location, river, and other relevant details of each bridge. This information can be used for a variety of purposes, including transportation planning, infrastructure management, and research.

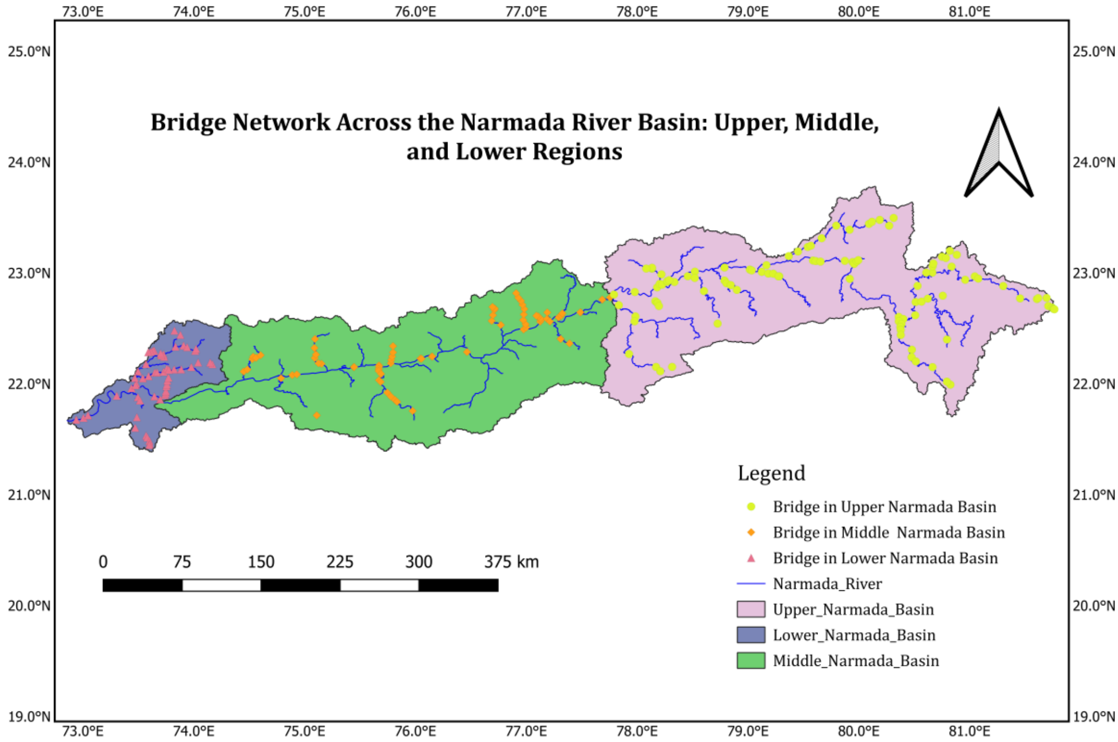


Figure 16:Comprehensive Mapping of Bridge Locations in the Narmada River Basin

4.4 GHATS AND RIVERBANK STRUCTURES

Ghats are sets of steps leading down to a body of water, often a river. They are essential components of riverine infrastructure in India, serving a variety of cultural, religious, and practical purposes. The Narmada River, with its rich cultural and spiritual significance, is dotted with numerous ghats along its banks.

This section provides a comprehensive overview of the ghats and riverbank structures on the Narmada River. The data presented here includes the names of the ghats, their locations, and other relevant details. This information is crucial for understanding the cultural and social significance of these structures, as well as their potential impacts on the riverbank and water quality.

A detailed inventory of ghats and riverbank structures on the Narmada River is provided in Annexure IV. This annexure includes a comprehensive table with information on the name, location, and other relevant details of each ghat. This information can be used for a variety of purposes, including cultural heritage studies, tourism planning, and environmental management.

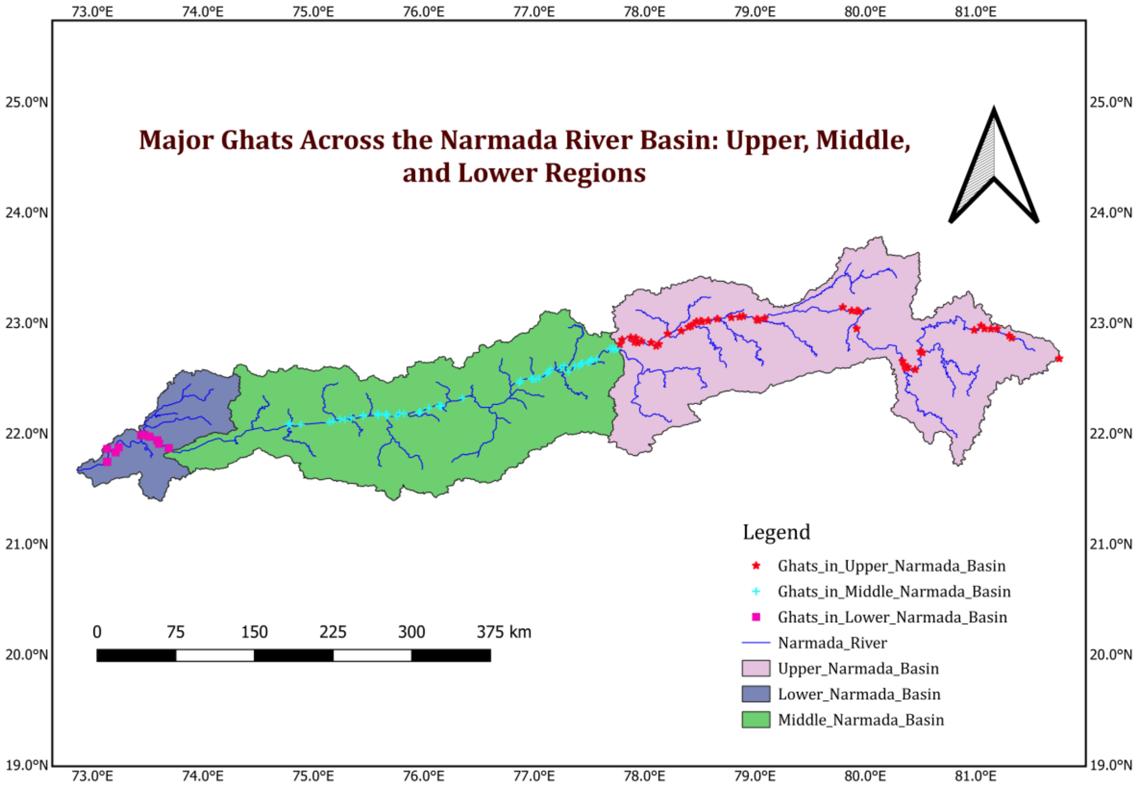


Figure 17: Comprehensive Mapping of Ghat Locations in the Narmada River Basin

Chapter 5: Conclusions and Recommendations

5.1 SUMMARY OF FINDINGS

The Narmada River, with its diverse physiography and substantial hydraulic significance, has been extensively analyzed in this report to understand its hydraulic parameters, infrastructure, and challenges. The study highlighted the unique characteristics of the Narmada River basin, including its three physiographic zones – upper, middle, and lower – and their respective contributions to flow dynamics. Data collected from sources like the India Water Resources Information System (India-WRIS), Central Water Commission (CWC), and Google Earth have been instrumental in deriving critical insights.

Key findings include:

1. Hydraulic Characteristics: Cross-sectional data revealed variations in channel geometry influenced by natural and anthropogenic factors. For example, the cross-section at Bharuch reflected tidal influences, while Garudeshwar displayed impacts of upstream dam operations.
2. Discharge Characteristics: Seasonal fluctuations were evident across all studied segments, significantly affecting reservoir operations and downstream flow. This has implications for flood control, irrigation, and water storage.
3. Infrastructure Impacts: The presence of major dams, such as the Sardar Sarovar and Indira Sagar, has transformed the river's flow regime. While these structures support irrigation, hydropower, and water supply, they also present challenges such as altered flow patterns and management complexities.

The findings emphasize the need for integrated river basin management that balances development goals with sustainable water resource utilization.

5.2 CONCLUSIONS

The Narmada River serves as a lifeline for central and western India, fulfilling diverse needs ranging from irrigation and hydropower to cultural significance. This study underscores the interplay between the river's natural hydraulics and human interventions, highlighting areas of both achievement and concern.

Key Conclusions:

1. Hydraulic Dynamics: The river's hydraulic behavior varies significantly across its segments. The upper reaches are dominated by steep gradients conducive to hydropower, while the middle and lower basins support agriculture and floodplain systems.
2. Infrastructure Contributions and Challenges: While infrastructure like dams and canals boosts economic growth, it also disrupts natural flow regimes. Efficient dam operations and flow management strategies are essential to mitigate these impacts.
3. Data Utilization: Reliable hydraulic data is pivotal for effective water resource management. This report's cross-sectional and longitudinal data provide a foundation for modeling efforts and future research.

Overall, the Narmada River's management demands a holistic approach that integrates hydraulic insights and infrastructure planning.

5.3 DATASET USAGE

The dataset compiled and analyzed in this report is a valuable resource for researchers, planners, and policymakers. It provides a robust foundation for understanding the Narmada River's hydraulics and planning sustainable interventions.

Applications of the Dataset:

1. Hydraulic Modeling: The cross-sectional and longitudinal profiles can be used to simulate river flow, discharge characteristics, and flood scenarios. This can assist in designing infrastructure and flood mitigation strategies.
2. Reservoir Operations: Data on discharge characteristics can optimize dam operations, balancing water storage, hydropower generation, and downstream flow requirements.

3. Infrastructure Planning: Engineers and planners can utilize the data to design bridges, canals, and other structures that align with the river's hydraulic dynamics and minimize operational challenges.
4. Policy Formulation: Policymakers can leverage the findings to draft regulations on water usage and river basin management.

The dataset is intended to be a living resource, continuously enriched through future studies and monitoring efforts. Open access to this data can foster collaboration and innovation in the sustainable management of the Narmada River basin.