Preface

India is the largest peninsula in the world with a coastline of about 7517 km with 12 major ports and 185 non major / intermediate ports with a very impressive water network consisting of rivers, lakes, creeks and canals.

An efficient transport sector is vital for development of the economy to stimulate optimum competitive business environment. Indian transport system comprises various modes, viz. Railways, Roadways, Inland Waterways, Coastal Shipping and Airways. Integrated development of waterways can generate waterway grid that may in future help shift cargo traffic from road transport to the cheaper and eco-friendly inland waterways.

The first national waterways were established in India in mid 1980s & 1993 with a combined length of 2,716 km:

NW 1 (1620 km): Ganga - Bhagirathi- Hooghly river system between Haldia & Allahabad declared as National waterway in 1986

NW 2 (891 Km): Brahmaputra River between Bangladesh Border and Sadiya declared as National waterway in 1988

NW 3 (205 km): West coast canal (168 km) – Udyog mandal canal (23 km) - Champakara canal (14 km) declared as National waterway in 1993

The government also declared the following two inland waterways as national waterways during 2008:

NW 4 (1095 km): Kakinada-Pondicherry canal - Godavari and Krishna rivers

NW 5 (623 km): East Coast Canal - Brahmani River and Mahanadi delta

Given the untapped potential of India's inland waterways, the Govt. of India desires to explore the commercial navigation potential on year round basis. Ministry of Shipping (MoS), Govt. of India has directed Inland Waterways Authority of India (IWAI) to identify the viable waterways in India for their phased development.

Accordingly, to make provisions for existing national waterways and to provide for the declaration of certain inland waterways to be national waterways and also to provide for the regulation and development of the said waterways for the purposes of shipping and navigation, National waterway act, 2016 has received the assent of the President on the 25th March, 2016 declaring a total of 111 National Waterways.

IWAI, a statutory body under MoS, Govt. of India, has entrusted WAPCOS with the responsibility for preparation of two stages DPR of six waterways in Tamil Nadu and Andhra Pradesh: **National waterway No's 55 (Kaveri Kollidam), 75 (Palar), 77 (Pazhyar), 79 (Pennar), 80 (Ponniyar) and 99 (Tamaraparani)** for a total length of 763 km.

This Final Feasibility report (Stage-I) covers the review of data, reconnaissance survey, preliminary traffic and market analysis and navigation development feasibility for Pazhyar river. The consultant team has physically visited the 20 km river stretch and gathered all requisite information.

Acknowledgement

This Final Feasibility report (Stage 1) is the outcome of review of existing infrastructure along the Pazhyar River, present state of affairs and the probability of development as Inland waterway. This vision is shared jointly by IWAI and WAPCOS Limited.

This report gives the present status of waterways assets, topographic features, climatic variability, land use / land cover pattern, details of all cross structures, socio-economic information of the waterways and the feasibility of its development as national waterway as per classification by Govt. of India (Gazette Notification).

We, WAPCOS project team acknowledge Shri R P Khare, Consultant, IWAI; Cdr. P. K. Srivastava, Hydrographic Chief, Inland Waterways Authority of India; Sh Rajiv Singhal, AHS for constant encouragement and guidance, technical discussions and for evincing keen interest in the project and this report.

WAPCOS Team

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List of Abbreviations

ATT	Admiralty Tide Table
BM	Bench Mark / Local Reference Level
CH	Chainage
CM	Central Meridian
CRZ	Coastal Regulation Zone
CWC	Central Water Commission
CVT	Calibration, Verification & Test
DF	Dual Frequency
DGPS	Differential Global Positioning System
DPR	Daily Progress Report
GPS	Global Positioning System
HFL	Highest Flood Level
HC	Horizontal Clearance
HSE	Health, Safety and Environment
KHz	kilohertz
Km	kilometre
m	meter
mmtpa	million metric tons per annum
MN	million
m/s	meter per second
ms	milliseconds
MSL	Mean Sea Level
PWD	Public Works Department
QA/QC	Quality Assurance / Quality Control
QMS	Quality Management System
Rev	Revision
Rep.	Representative
SBES	Single Beam Echo sounder
SD	Standard Deviation
Sr	Senior
UTM	Universal Transverse Mercator
VC	Vertical Clearance
WGS	World Geodetic System

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SUMMARY: SALIENT FEATURES AT A GLANCE

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The tidal variation between MLLW springs (0.2) and MHHW springs (0.7) is 0.5m.
Tide Source: Muttam Point Tide Data from Admiralty Tide Table (ATT Vol. 3)</td></tr>
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<tr><th colspan="6">Stretch (KM)</th></tr>
<tr><th>LAD (m)</th><th>0 - 4.56</th><th>4.56 - 10</th><th>10.0-15.0</th><th>15.0 - 20.0</th><th>Total</th></tr>
<tr><td><1.0</td><td>1.29</td><td>4.27</td><td>1.96</td><td>1.46</td><td>8.98</td></tr>
<tr><td>1.0-1.2</td><td>1.04</td><td>0.56</td><td>0.28</td><td>0.29</td><td>2.17</td></tr>
<tr><td>1.2-1.4</td><td>0.63</td><td>0.16</td><td>0.16</td><td>0.45</td><td>1.41</td></tr>
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<tr><td>1.7-2</td><td>0.47</td><td>0.08</td><td>0.43</td><td>0.08</td><td>1.06</td></tr>
<tr><td>> 2.0</td><td>0.39</td><td>0.23</td><td>2.08</td><td>1.99</td><td>4.69</td></tr>
</table>
</td></tr>
<tr><td>c)</td><td>Cross structures
i) Dams, weirs, barrages etc. (total number; with navigation locks or not)
ii) Bridges, Power Cables etc. (total number; range of horizontal and vertical clearances)</td><td>There are four weirs /barrages namely, Karkurumbathai Shutter Dam, Pillai Pethan Dam, SolanThittai Dam and Kumari Dam in the present study stretch. The present study stretch starts from D/S of Karkurumbathai Shutter Dam. Navigational lock is not provided in any of the dams/weir/ Anicuts/ Barrages in the present study stretch.

Five existing road bridges, two rail bridges and one pipeline bridge crosses Pazhyar river in this stretch.
VC from HFL for bridges varies from 1.0 m to 5.0 m.
HC for bridges varies from 6m to 30 m.

3 HT lines and 5 electric lines crosses Pazhyar River in present study</td></tr>
</table>

<table>
<tr><td></td><td></td><td>stretch.
VC from HFL for HT cables and Electric lines varies from 1.0 m to 30 m.
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HFL for tidal reach is MHHW, and for non-tidal reach is Highest Flood Level from last twenty years gauge discharge data collected from CWC.</td></tr>
<tr><td>d)</td><td>Avg discharge & no. of days</td><td>No of Gauge Stations: One at Ashramam, dist. Kanyakumari, TN (Chainage-9.55km)
Ashramam
June to August 0 to 4 m^3/s
September to November 4 to 10 m^3/s
December to May 0 to 2 m^3/s
Ashramam Gauge-discharge data analysis
The CWC data of river cross-sections at gauging site on Pazhyar River was available for number of years. The river cross sections at the gauging site for different years were compared to understand morphological changes over the longer period.</td></tr>
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<tr><th rowspan="2">River</th><th colspan="2">Reach</th><th rowspan="2">River Bed Change</th><th rowspan="2">Distance</th><th rowspan="2">Slope</th></tr>
<tr><th>From</th><th>To</th></tr>
<tr><td>Pazhyar</td><td>Ashramam
RBL 0.62 m</td><td>Mouth
RBL 0.0 m</td><td>0.62 m</td><td>9.55 km</td><td>1/15403</td></tr>
</table></td></tr>
<tr><td>f)</td><td>Consultant’s inference</td><td>Range 0-4.65 km (River mouth to Karkurumbathai Shutter Weir)
This stretch includes Tidal reach (upto 4.56 km) where raw water depths of 0.5 m to 3.1m are observed. Most of the observed water depths are about 1.5-2.0 m. This can be developed as a class I waterway with little capital dredging for round the year navigation (365 days). Kanyakumari is also very near to Pazhyar River mouth, about 8 km vide state highway 179. A beautiful beach also exists at Pazhyar river mouth which is still undeveloped. Hence this stretch has huge potential for navigation form tourism and recreation point of view.
Range 4.65-9.86 km (Karkurumbathai Shutter Barrage to SolanThittai Weir)
Reduced Water depth of the order of 1.0 – 2.0 m is observed in this reach for 365 days. This can be developed as a class I waterway with little capital dredging.</td></tr>
</table>

		Range 9.86-14.1 km (SolanThittai Weir to Kumari Barrage) Reduced Water depth of the order of 1.0 m is observed in most of this reach for 365 days. This can be developed as a class I waterway with little capital dredging. **Range 14.1-20 km (Kumari Barrage to outfall at Mankudy)** Reduced Water depths of the order of 0.5 – 1.2 m is observed in most of this reach for 365 days. This can be developed as a class I waterway with little capital dredging.
5.	<u>Traffic Potential</u>	
a)	Present IWT operations, ferry services, tourism, cargo, if any	**Cargo** The potential exists for minerals, boulder sand general cargos which are minor & fragmented segment. Mouth of the river is about 100 km from VOC port (Tuticorin) and River has substantial share of minerals products that are mostly exported to Maldives using small vessels. A large volume of stones, boulders, etc could be transported using River Sea Class ships in the Pazhyar River to VOC Port. Presently, about 1 million tonnes of these commodities are transported to VOC port using road route to Zone B of port. There exist potential to shift minor bulk cargo and general cargo using river route. **Ferry services** There are no passenger ferry services available on the proposed stretch of Pazhyar River. **Tourism** The river passes through the Kanyakumari District. It has many tourist places having potential to attract traffic through waterways like Vivekananda Rock Memorial, Thiruvallur Statue, Mahatma Gandhi Memorial, Sthanumalayan Temple, Beaches and Mathur Aqueduct.
b)	Important Industries within 50 km	Industries very close to river can transport their goods using Pazhyar River to VOC port rather than going by road. Distance difference between waterways & Roadway from industrial centers to the port is very less. Hence shifting from roadways to river is commercially viable.
c)	Distance of Rail & Road from industry	Tamarakulam, Nagercoil and SuchindramRailway stations are located in the vicinity of Pazhyar River.

		Suchindram – Kanyakumari Railway line crosses the Pazhyar River at chainage 7.2 km and Nagercoil – Thovalai Railway line crosses the Pazhyar River at chainage 14.6 km.
6.	Consultant's recommendation for going ahead with Stage-II (DPR preparation)	A large volume of stones, boulders, etc. could be transported using River Sea Class ships in the Pazhyar River to VOC Port. Presently, about 1 million tonnes of these commodities are transported to VOC port using road route to Zone B of port. Distance difference between waterways & Roadway from industrial centres to the port is very less. Hence shifting from roadways to river is commercially viable. Kanyakumari, Vivekananda rock and Tiruvalluvar statue exist very near to river mouth. The proximity to these tourist places and state highways create a lot of potential for waterway development, passenger ferry services and Tourism. Reduced Depths of about 1-2 m round the year in tidal reach of 4 km. reduced depths of about 1 m also exist in 4-20 km river stretch. **We recommend detailed studies (Stage II) for total length of 20km for Pazhyar river.**
7.	Any other information/ comment	-----

1. About the Studies

M/s Inland Waterways Authority of India (IWAI), a statutory body under ministry of shipping, Govt. of India, has entrusted WAPCOS with the responsibility for preparation of two stages DPR for 6 inland waterways of rivers Pennar, Kaveri/Kollidam, Palar, Pazhyar, Ponniyar, Tamaraparani in Tamilnadu and Andhra Pradesh. The approximate length and approx. average width of all six rivers are given in the table below:

Sl. No.	Name of the River / Canal	Description of Inland Waterway	From:	Up to:
1.	Pennar River, Andhra Pradesh	29 km length of the river from Penna Barrage, Pothireddypalem to confluence with Bay of Bengal near Kudithipalem (NATIONAL WATERWAY 79)	14°28'8.38"N, 79°59'9.31"E	14°35'36.75"N, 80°11'30.61"E
2.	Palar River, Tamilnadu	141 km length of the river from rail bridge at Virudampattu, Vellore to confluence with Bay of Bengal at Sadurangapattinam(NATIONAL WATERWAY 75)	12°56'14.07"N 79° 7'29.70"E	12°27'52.16"N, 80° 9'13.47"E
3.	Ponniyar River, Tamilnadu	125 km length of the river from Sathanur Dam to Cuddalore at confluence of Bay of Bengal (NATIONAL WATERWAY 80)	12°11'0.06"N, 78°51'1.25"E	11°46'21.76"N, 79°47'41.70"E
4.	Kaveri / Kollidam, Tamilnadu	364 km length of the river from Uratchikottai Barrage to confluence with Bay of Bengal at Pazhaiyar(NATIONAL WATERWAY 55)	11°29'3.09"N77°42'13.68"E	11°21'37.97"N79°49'53.23"E
5.	Tamaraparani River, Tamil Nadu	64 km length of the river from Sulochana Mudalir bridge, Tirunelveli to confluence with Bay of Bengal near Punnaikayal (NATIONAL WATERWAY 99)	8°43'43.17"N, 77°42'53.94"E	8°38'24.90"N, 78° 7'37.85"E
6.	**Pazhyar River, Tamilnadu**	**20 km length of the river from Bridge near Veeranarayana Mangalam village to confluence with Arabian Sea at Manakudi (NATIONAL WATERWAY 77)**	**8°13'48.97"N77°26'27.34"E**	**8°5'15.01"N77°29'7.61"E**

Table 1: National Waterways in Tamil Nadu and Andhra Pradesh

The Google Map showing all river stretches is enclosed as **Figure 1**.

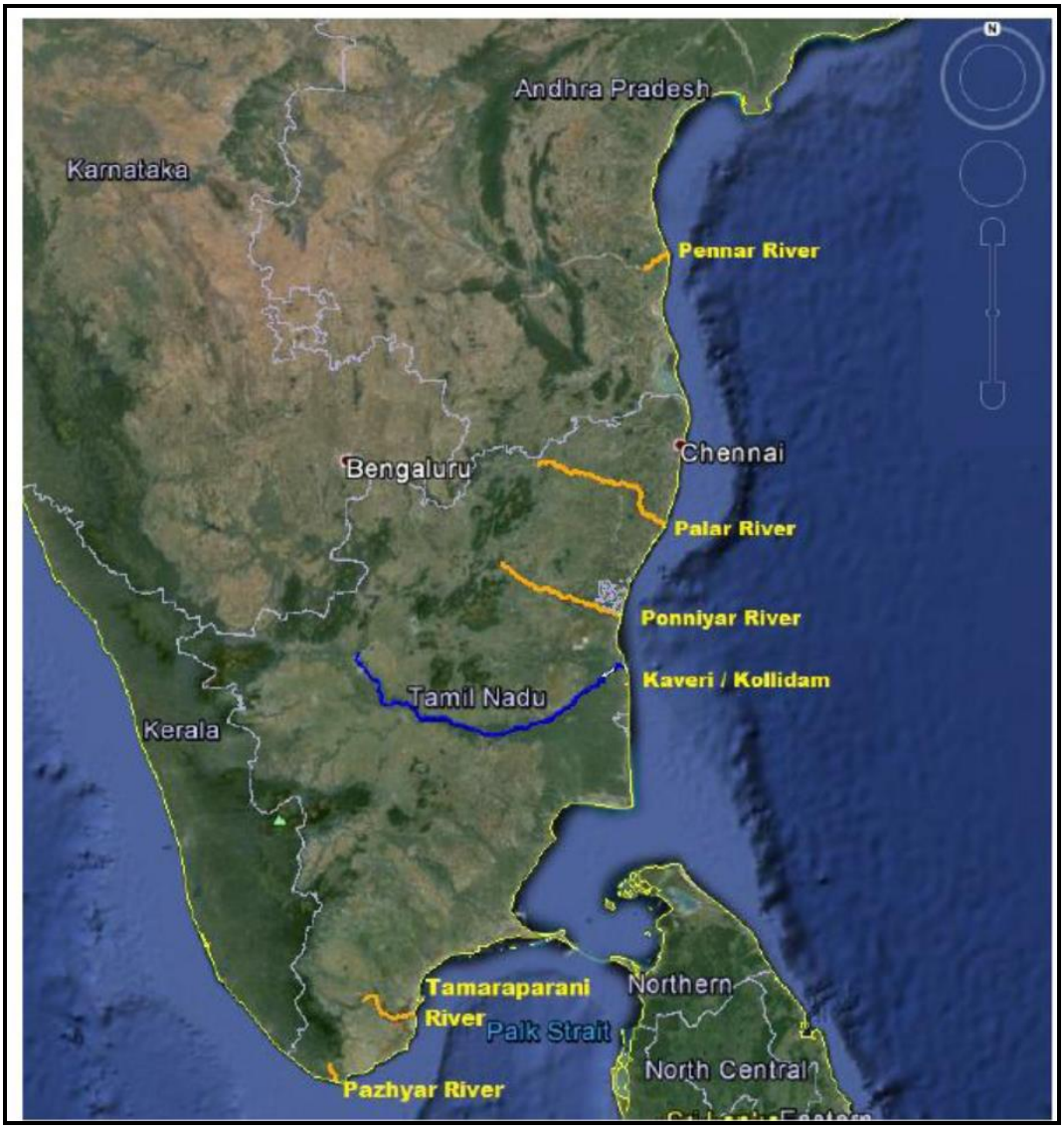


Figure 1: Google Map showing six rivers in Andhra Pradesh &Tamil Nadu

Accordingly, WAPCOS Ltd. has undertaken the studies for 6 national waterways (Pennar, Kaveri Kollidam, Palar, Pazhyar, Ponniyar and Tamaraparani) in Tamilnadu and Andhra Pradesh. The brief scope of work is depicted as under:

Stage-1

A. Reconnaissance Survey

B. Collection and Review of available data

C. Feasibility Report

Stage-2

A. Hydrographic Survey &Hydro-morphological survey

B. Traffic Survey & Techno economic feasibility

C. Preparation of Detailed Project Report

The present studies are limited to establish the feasibility of waterways for Inland navigation i.e. up to Stage 1 only**.**

The present **Final Feasibility Report** covers the review of data, reconnaissance survey, present state of affairs, traffic analysis, possible navigable stretches for Pazhyar River as detailed below:

- ✓ **Introductory Considerations**
- ✓ **Classification of waterways**
- ✓ **Details of existing structures**
- ✓ **Reconnaissance survey& site visit**
- ✓ **Single Line Longitudinal Survey**
- ✓ **Bed Profile**
- ✓ **Soil Texture**
- ✓ **Hydrological Data collection and analysis**
- ✓ **Preliminary Traffic studies and Market analysis**
- ✓ **Results and feasibility of waterways**

2. Introductory Considerations

As discussed in previous chapter, Cluster 5 consists of six rivers in the states of Tamil Nadu and Andhra Pradesh. This chapter covers the introductory considerations, origin, hydrological parameters like altitude, length, catchment area, Annual rainfall, major dams, and barrages along the river, tributaries, and major cities along their bank, historical and religious places for Pazhyar River.

2.1 Name of River: Pazhyar

2.2 Length of River

Pazhyar River is declared as National Waterway 77 as per the Gazette Notification published on 26 March 2016. The total length of the river from origin to its outfall in the Arabian Sea is 40 km. The length under present studies is detailed below:

20 km length of the river from Bridge near Veeranarayana Mangalam village to confluence with Arabian Sea at Manakudi (National Waterway 77)	**From: 8°13'48.97"N77°26'27.34"E**	**Up to: 8°5'15.01"N77°29'7.61"E**

2.3 State, District through which river passes

Pazhyar River flows through Kanyakumari, the southernmost district of Tamil Nadu. It originates from the peak of Mahendragiri hills in Surlacode. The river traverses through Mahendragiri Estate, Palkulam, Bhuttapandi, Thazhikudi, Nagercoil town, Suchindram and outfalls at sea near Manakudy.

2.4 Maps

The Map showing Present study stretch is attached as **Figure 2**.

2.5 River Characteristics

2.5.1 River Course

Pazhyar River flows through Kanyakumari, the southernmost district of Tamil Nadu. It originates from the peak of Mahendragiri hills in Surlacode. The river traverses through Mahendragiri Estate, Palkulam, Bhuttapandi, Thazhikudi, Nagercoil town, Suchindram and outfalls at sea near Manakudy.

2.5.2 River Basin (Catchment Area)

The basin contains number of water storage tanks/bunds. The catchment area of the river is 397 Sq.Km. The Tambraparni and Valliyar river basins lie on Northern side of Pazhayar River. There is no major project in Pazhayar basin.

2.5.3 Topography

The river Pazhyar originating from the slopes of Mahendragiri hills at an altitude of 800 m above M.S.L, flows towards South-Western direction through Mahendragiri Estate,

Palkulam, Bhuttapandi, Thazhikudi, Nagercoil town, Suchindram, etc. and joins the Arabian Sea near Manakudi . The total length of the river is 40 Km.

2.5.4 Climate, Temperature & Humidity

The catchment receives rainfall from both South West and the North East monsoons. The South West monsoon period starts from the month of June and ends in September, While the North East monsoon period starts from October and ends in the middle of December.

The temperature all-round the year varies from 24° C to 30° C.

2.5.5 Rainfall

The annual rainfall varies from 800 – 1450 mm. Maximum rainfall occurs during the months of October and November.

2.5.6 Demography

Kanyakumari is the main district. The main towns are Palkulam, Bhuttapandi, Thazhikudi, Nagercoil, Suchindram and Manakudy.

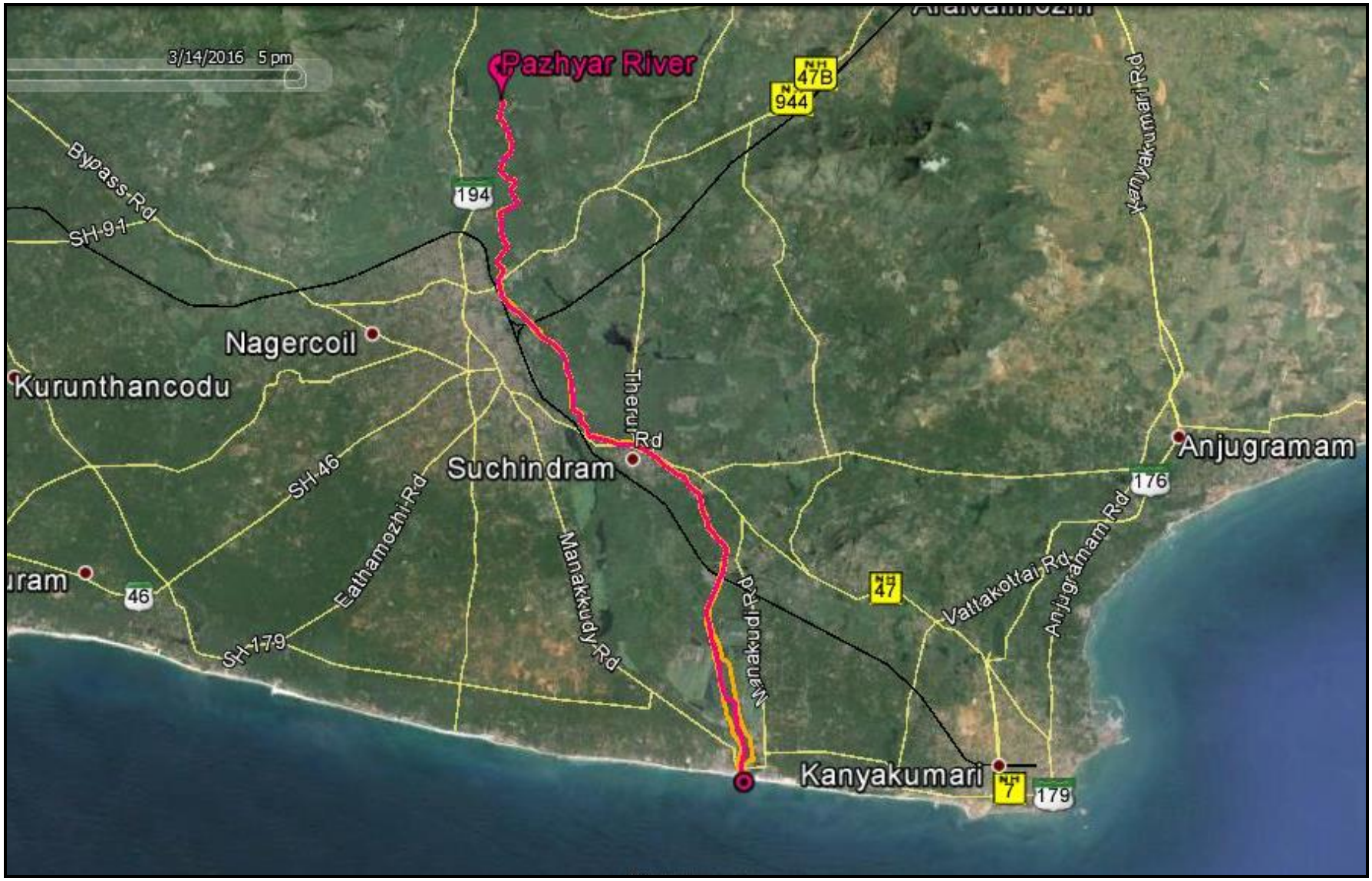


Figure 2: Google image showing stretch of Pazhyar River in present studies

2.6 Methodology and Data collection

2.6.1 Importance of Hydrological and Topographical data

Navigability of a natural river channel or tidal creek primarily depends upon hydraulic parameters like water discharge, flow depth, velocity, sediment load and width of river channel. These parameters are function of topography/bathymetry of river bed and discharge in river during different seasons. Apart from these important parameters, there are other natural factors such as tidal range and length of tidal reach, type/nature of river bed (rocky, sandy, silty, clayey), bends in river course and stability of alignment of deep channel of river over long period. Apart from above natural factors, information on other factors such as various structures across (Dams/weirs/barrages/bridges) and along the river bank (river training and bank protection works) is also required.

2.6.2 Data Requirement

The following data was required for Stage-1 feasibility report:

1. Type of crops (in different seasons) and industries along the waterway
2. Availability of passenger ferry services. Prominent towns / City along the waterway.
3. Historical and tourist places.
4. Existing water sport and recreational activities and future probability.
5. Details of cross-structures (bridges, aqueducts, electric lines, telephone lines, pipe lines, cables) and their clearances. Salient features of Dams / Barrages / Weirs.
6. Availability of water in different seasons. Also to correlate this with CWC / Irrigation datum's.
7. Ponding level and limit of Dams / Barrages / Weirs.
8. Encroachment in the waterway, width of the waterway, sharp bends.
9. Environmental impacts. CRZ or wildlife clearances.
10. Local/pronounced name of the rivers in different stretches.
11. Any Border issue with other country.
12. Incorporation of topographical features (outside survey limits) from Google Earth imageries.
13. Obstructions to the navigation and un-approachable areas.
14. Photographs of all cross-structures, gauges, obstructions - annotated with location & chainage. In report with lat/long, easting/northing, chainage details
15. Permanent structures located within this corridor.
16. All prominent shore features (locks, bridges, aqueducts, survey pillars if available etc.) and other conspicuous objects shall be fixed and indicated on the chart and included in the report.
17. Details of water intake/ structures shall be collected and shown on the charts and include in the report.
18. Availability of berthing place, existing jetty, ferry ghats, approach roads etc. in the area shall be indicated on the charts and include in the report.
19. During the survey, condition of the banks shall also be collected, whether that banks are pitched (protected) or not protected. The length of bank protection, where banks erosion is taking place shall also be estimated.
20. Positions and levels of corners of permanent structures within the corridor shall be physically surveyed and marked on survey charts.

2.6.3 Primary Data- Sources

A. Survey of India (SOI) Dehradun, during February & March 2016

Toposheets and satellite imageries are useful to obtain information such as extent of tidal reach, HTL & LTL, width of river and deep channel, important places, nature of river bed and bank along reach, channel bends, slope of river channel, and locations of various structures across and along river course and tendency of shifting of deep channel (general morphology of the deep channel of the river course).

As the coastal zone falls under restricted category, the restricted and non-restricted Toposheets of Survey of India /hydrographic charts and satellite imageries has been collected after taking approval from **Ministry of Water Resources, Govt. of India**. A total of 43 toposheets were procured from Survey of India (SOI) (39 no.'s toposheets of 1: 50000 scale and 04 No's toposheets of 1:25000 scale) and analysed to study Cluster 5 for various aspects mentioned above. The satellite imageries of different years from Google are also analysed. The details of toposheets for Pazhyar River as collected from SOI are given as under:

Pazhyar River	**58 H/8/NE, 58 H/8/SE, 58 H/8**

Table 2: SOI Toposheets

B. Data from Site Visit and Reconnaissance survey during March & April 2016

The site visit and reconnaissance survey was carried out in March and April 2016.

The details of existing cross-structures, Weirs, Barrages, Anicut, Dams, HT/ LT line, Type of Crops, Soils, shore protection along the waterway, Historical and tourist places, existing ferry services were collected. The collected data and photographs have been detailed in Chapter 3.

The details of existing industries, major commodities, production were also collected from various industries located around main industrial clusters, important towns in the vicinity of waterways and important ports near river mouth. These details have been presented in Chapter 5.

2.6.4 Secondary Data- Sources

A. Central Water Commission (CWC), Govt of India and Water Resource Division (WRD), Chennai during February, March and April 2016

These data give most vital information on water availability in river reach and sediment concentration in river water.

Gauge- discharge, sediment and river cross section data (at gauging site) were collected from CWC for one gauging station on Pazhyar River. Following Table gives details of gauging stations and data collected.

River	Gauging station	Data type	From	To	Frequency
Pazhyar	Ashramam, dist. Kanyakumari, TN $08^0\ 09'\ 33''$ N $77^0\ 27'\ 33''$ E	Gauge- discharge	1999	2013	daily
		Sediment	-	-	daily
		Cross-section	2001	2012	2 days/year

Table 3: Gauge Discharge Sediment data collected from CWC

2.6.5 Methodology

The studies were carried out as detailed below:

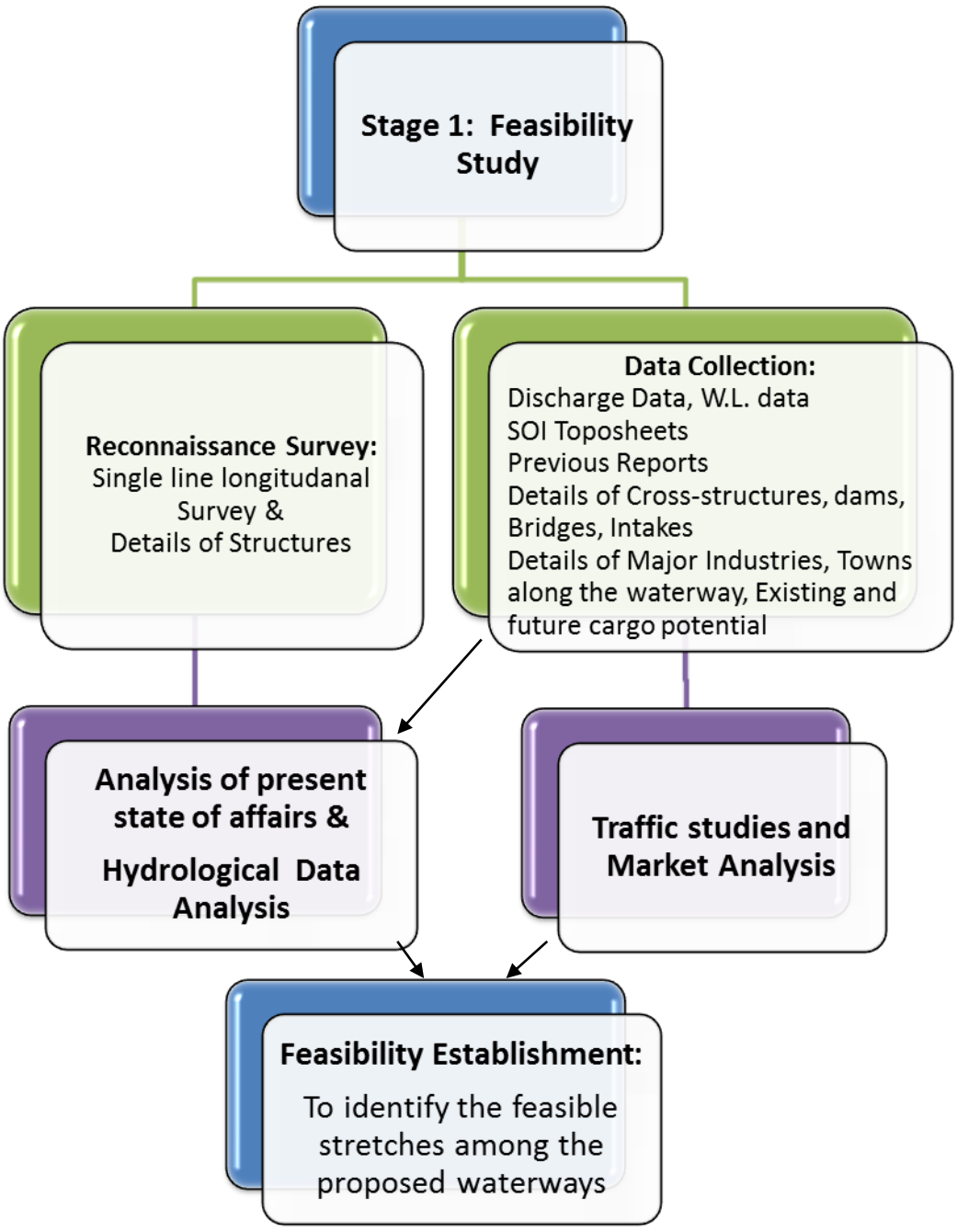


Figure 3: Feasibility Studies (Stage 1)

The detail methodology for reconnaissance survey, Hydrological data analysis and Traffic studies is given in their respective chapters. The feasibility of waterways is established after hydrological and traffic studies and analysis. Based on hydraulic conditions (depth, width, curvatures etc.) of the navigation channel, the class of the waterway are established in accordance with the classification notified by Inland Waterways Authority of India (IWAI) vide Gazette Notification dated 26 January 2007. The same has been detailed below:

2.6.6 Classification of Waterways

In India, the inland waterways are classified into seven categories for rivers as well as canals by Inland Waterways Authority of India (IWAI) vides Gazette Notification dated 26 January 2007 for safe passage of self-propelled vessels up to 2000 dead weight tonnage (DWT) and tug barge formation in push tow units of carrying capacity upto8000 tonnes.

The classification of waterways is discussed below.

A. Classification of Inland waterways for Rivers

Class of Waterway	Rivers				
	Minimum Depth	Bottom Width	Bend Radius	Vertical Clearance	Horizontal Clearance
I.	1.2 m	30 m	300 m	4 m	30 m
II.	1.4 m	40 m	500 m	5 m	40 m
III.	1.7 m	50 m	700 m	7 m	50 m
IV.	2.0 m	50 m	800 m	10 m	50 m
V.	2.0 m	80 m	800 m	10 m	80 m
VI.	2.75 m	80 m	900 m	10 m	80 m
VII.	2.75 m	100 m	900 m	10 m	100 m

Table 4: Inland Waterway classification for Rivers

B. Classification of Inland waterways for Canals

Class of Waterway	Canals				
	Minimum Depth	Bottom Width	Bend Radius	Vertical Clearance	Horizontal Clearance
I.	1.5 m	20 m	300 m	4 m	20 m
II.	1.8 m	30 m	500 m	5 m	30 m
III.	2.2 m	40 m	700 m	7 m	40 m
IV.	2.5 m	50 m	800 m	10 m	50 m
V.	-	-	-	-	-
VI.	3.50 m	60 m	900 m	10 m	60 m
VII.	-	-	-	-	-

Table 5: Inland Waterway classification for Canals

The above classification for Rivers and Canals shall be effective if:

- Minimum depth of channel should be available for about 330 days in a year (about 90% days in a year).

- Vertical clearance at cross structures over the waterway should be available at least in central 75% portion of each of the spans in entire width of the waterway.

C. *Vertical Clearance for Power Cables / Telephone Lines for all Classes*

- Telephone lines and Low Voltage lines 16.5 m
- High Voltage Transmission lines not exceeding 110 KV – 19 m
- High Voltage Transmission lines exceeding 110 KV – 19 m + 1 cm per each KV

In case of underground pipe / power lines and other cables norms to be decided as per conditions and navigational requirement

D. *Reference level for vertical clearance for different types of channels*

- For rivers – over navigational HFL which is highest flood level at frequency of 5% in any year over a period of last 20 years
- HTL for tidal channels
- For channels design FSL

E. *Type of vessels to be used in different class waterways*

Class	Self-propelled vessel	Tug with barges
I.	Self-propelled, carrying capacity 100 DWT, Size (32m X 5m), Loaded draft 1m	1 Tug + 2 barges – 200 DWT, length 80m X breadth 5m , loaded draft 1m
II.	Self-propelled, carrying capacity 300 DWT, Size (45m X 8m), Loaded draft 1.2m	1 Tug + 2 barges – 600 DWT, length 110m X breadth 8m , loaded draft 1.2m
III.	Self-propelled, carrying capacity 500 DWT, Size (58m X 9m), Loaded draft 1.5m	1 Tug + 2 barges – 1000 DWT, length 141m X breadth 9m , loaded draft 1.5m
IV.	Self-propelled, carrying capacity 1000 DWT, Size (70m X 12m), Loaded draft 1.8m	1 Tug + 2 barges – 2000 DWT, length 170m X breadth 12m , loaded draft 1.8m
V.	Self-propelled, carrying capacity 1000 DWT, Size (70m X 12m), Loaded draft 1.8m	1 Tug + 2 barges – 2000 DWT, length 170m X breadth 24m , loaded draft 1.8m (moulded with 24 m)
VI.	Self-propelled, carrying capacity 2000 DWT, Size (86m X 14m), Loaded draft 2.5m	1 Tug + 2 barges – 4000 DWT, length 210m X breadth 14m , loaded draft 2.5m
VII.	Self-propelled, carrying capacity 4000 DWT, Size (86m X 14m), Loaded draft 2.9m	1 Tug + 4 barges – 8000 DWT, length 210m X breadth 28m , loaded draft 2.5m

Table 6: Type of vessels to be used in different class of waterways

All structures to be constructed across waterway classified should conform to respective requirement of vertical clearance and horizontal clearance before construction of any structure across the national waterway.

WAPCOS has carried out hydrological studies to establish the feasibility of development of National Waterway 77 for Inland Navigation. In cases where minimum depth (of 1.2m as per Govt. of India notification) is not available round the year, the no. of days of availability and available depth is calculated and presented in chapter 4. The project authorities may review the waterway classification for navigation. The feasibility of these stretches may be established for some part of the year after detailed studies in stage 2 after the approval. Measures to improve the depth are also stressed upon.

3. Analysis of present state of affairs

This chapter identifies the existing cross-structures viz. Dams, Weirs, Barrages, Locks, Bridges, Crossings, pipelines, cables, HT/LT line, National and State highways including railway lines in the river stretch collected during the site visit and reconnaissance survey. The details of all structures are tabulated in **Annexure 1.**

3.1 Existing Dams, Weir, Barrage, Anicut and Locks

The details of existing dams/weir/barrages are given in table below. WAPCOS has tried to collect the data about each barrage from state govt. /central govt. offices. The collected data is attached at Annexure 2. It may also be noted that none of these existing Check Dams /Anicut /Barrages /Dams have navigational lock due to which through navigation in the river is not possible without constructing new lock.

Sl No	Structure Name	Chainage (km)	Location	Position (Above Survey Track)			
				WGS84 Datum; UTM Projection: Zone43N			
				Latitude [N]	Longitude [E]	Easting(m)	Northing(m)
1	Karkurumbathai Shutter Dam	4.65	Karkurumbathai	8°07'42.78" N	77°28'52.63" E	773431.996	899347.021
2	PillaiPethan Dam	5.90	PillaiPethan	8°08'15.50" N	77°28'55.21" E	773504.845	900354.856
3	SolanThittai Dam	9.87	SolanThittai	8°09'34.88" N	77°27'26.90" E	770786.958	902776.537
4	Kumari Dam	13.73	Oottuvalmdam	8°10'54.74 N	77°26'46.9916"	769548.107	905223.457
5	Local bund made of sand bags	17.11	Thiruppathisaram	8°12'25.46" N	77°26'21.52" E		

Table 7: Details of existing Dams, Weir, Barrage, Anicut, Locks

3.2 Existing Bridges and Crossing Over River

Sl No	Structure Name	Chainage (km)	Location	Position (Above vessel track)				Vertical clearance above H.F.L.* (m)	Horizontal Clearance (m)
				WGS84 Datum; UTM Projection: Zone43N					
				Latitude(N)	Longitude(E)	Easting(m)	Northing(m)		

1	Kelamanakudi old Road Bridge with pipeline (SH 179)	4.6	Manakudi	8°05'25.60"	77°29'04.70"	773828.726	895131.408	5.0	6.0
2	Manakudi new Road Bridge connecting (SH 179) on both sides	4.9	Manakudi	8°05'30.62"	77°29'05.39"	773847.949	895287.244	4.0	30
3	VadakuThamaraikulam Railway Bridge	7.2	Tamaraikulam	8°07’47.28”	77°28’56.92”	773562.572	899485.986	1.0	20
4	Vadaku Tamaraikulam Road Bridge with pipeline	7.7	Tamaraikulam	8°07’58.10”	77°29’00.30”	773664.566	899822.19	2.0	12
5	Susinderam Old Road Bridge (NH 47)	10.0	Susinderam	8°09'20.8591"	77°28'08.3751"	772058.105	902353.174	1.3	10
6	Railway Bridge	14.6	Susinderam	8°11'01.1909"	77°26'41.5094''	769379.014	905420.783	1.5	10
7	Road Bridge Connecting Thirunelveli with Nagerkovil (NH 478)	15.6	Susinderam	8°11'35.2784''	77°26'20.1753''	768719.325	906464.528	2.0	17
8	Pipeline Bridge	20.0		08 13'48.6436"	77 26'27.4911"	768918.399	910565.003	1.5	6

Table 8: Details of existing Bridges and Crossings

****VC is measured above H.F.L. HFL for tidal reach is MHHW as per ATT- Vol 3, and for non-tidal reach is calculated as maximum water level from gauge discharge data collected from CWC from year 1997-2014.***
Note: All bridges are to be considered as road bridges unless specified.

3.3 Pipelines and cables

Three pipelines are observed along the road bridges at chainage 4.6km, 7.7 km and 20.0 km. Cable bridges are not observed in the river stretch.

3.4 Details of High Tension and Electric Lines across Pazhyar River

Sl No	Structure Name	Chainage (km)	Location	Position (Above vessel track)				Vertical clearance above H.F.L.* (m)	Horizontal Clearance (m)
				WGS84 Datum; UTM Projection: Zone43N					
				Latitude(N)	Longitude(E)	Easting(m)	Northing(m)		
1	Electric Line	5.8	Manakudi	8°07'01.4689"	77°28'47.303"	773276.601	898076.077	9	250
2	Electric Line	9.3	Susinderam	8°08'52.2134"	77°28'41.375"	773074.187	901478.892	6	250
3	Electric Line	11.7	Asramam	8°09'29.578"	77°27'41.6360"	771237.544	902616.16	4	200
4	HT Line	12.1	Asramam	8°09'35.618'' 8°09'42.6307”	77°27'22.89” 77°27'19.860''	770662.295 770568.186	902798.308 903013.266	9	300
5	Electric Line	12.1	Vadiveeswaram	8°10'21.3039"	77°27'09.4763"	770242.944	904200.021	4	200
6	HT Line	13.2	Susinderam	8°10'47.941”	77°26'55.9886"	769824.904	905016.241	14	250
7	Electric Line	16.1	Susinderam	8°11'53.57”	77°26'21.4630''	768755.344	907026.977	9	250
8	HT Line	18.6	Susinderam	8°12'53.7987"	77°26'26.8358"	768908.61	908879.167	14	350

Table 9: Details of existing Bridges and Crossings

****VC is measured above H.F.L. HFL for tidal reach is MHHW as per ATT- Vol 3, and for non-tidal reach is calculated as maximum water level from gauge discharge data collected from CWC from year 1997-2014***

3.5 Hindrances in conducting the reconnaissance survey

No hindrance was encountered in the river stretch while carrying out the reconnaissance survey.

Rocky strata was not encountered during reconnaissance survey of the river stretch.

04 numbers weir/barrages in this 20 km stretch needs to be modified for developing this stretch as waterway.

3.6 Encroachment to the waterway

There is no encroachment in the waterway in the reach under consideration in this study.

3.7 Details of Protected Area, Wildlife, Defence

There are no such areas present in the vicinity of river.

3.8 NH/SH/MDR along and/or in Vicinity

Mainly two main roads are found crossing the Pazhyar River:

SH 179: Kelamanakudi old Road Bridge with pipeline

NH 47: Susinderam Old Road Bridge

NH 478: Thirunelveli – Nagerkovil Road Bridge

Apart from these, there are various major roads along both banks passing through the town of Thazhakudy, Nagercoil, Suchindram and Manakudy.

3.9 Railway Line and stations in the vicinity

Tamarakulam, Nagercoil and Suchindram Railway stations are located in the vicinity of Pazhyar River.

Suchindram – Kanyakumari Railway line crosses the Pazhyar River at chainage 7.2 km and Nagercoil – Thovalai Railway line crosses the Pazhyar River at chainage 14.6 km.

3.10 Geological sensitive areas

Rocky strata was not encountered while carrying out the reconnaissance survey.

3.11 Critical areas requiring detailed investigations

Detailed investigations shall be required at proposed ferry locations nearby temples, existing boating points and ghats.

4. Reconnaissance Survey

This chapter gives the stretch wise description (20 km stretch) of Pazhyar River and presents the observed water level during survey. This chapter also covers the Hydrological analysis of the collected data viz. Minimum and maximum water levels, discharges, average 10 daily discharges, change in cross-section over the years and establishment of sounding datum in river. The route map of Pazhyar River is given below:

Figure 4: Route map of Pazhyar River

4.1 Resources, Equipment used and Methodology adopted

4.1.1 Resources & Equipment used

Personnel Name	Function
T. Suresh Kumar	Surveyor
ArunBalaji	Asst. Surveyor

Table 10: Survey Personnel

Following equipment and systems were mobilised for the data acquisition.

Equipment / System	Description / Make / Model/Resolution /Accuracies
Software / Navigation	Starfix.Seis V. 10.1 PC based data acquisition and survey vessel navigation package and accessories
Positioning	12 Channel Single frequency (L1 & L2) DGPS System and accessories
Echo Sounder	ODOM Hydrotrac single Frequency Echo sounder, 210 KHz Transducer and accessories
Soil sample collection	Grab Sampler with accessories
Trimble Total station with accessories & Laser Distometer	

Table 11: Equipments for data acquisition

Survey Vessel

Locally Hired boat 'Arul Raj' was used for carrying out the bathymetry survey.

4.1.2 Detailed methodology adopted for survey

a) Specifications for survey: Survey Geodesy

The survey was conducted in WGS84 datum; UTM Projection (Zone 43 N, CM 075° E). The geodetic parameters to be used during the survey are as follows:

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**

Table 12: Global Positioning System Geodetic Parameters

b) Field Calibrations & Verifications

All survey equipment used for the survey was calibrated and bench tested prior to their mobilisation for this task. After installation on the survey vessel, field verification and

tests were carried out as per standard survey methods. On completion of successful Mobilization, Calibration, Verification and Testing of all equipment as per the relevant work practices, the survey task was commenced.

c) DGPS Calibrations

In order to ensure the integrity of the horizontal control of survey the DGPS system was bench checked against a known point, prior to mobilisation to site, at workshop and found to be satisfactory.

d) Single Beam Echo Sounder (SBES)

Odom Hydrotrac single frequency (210 kHz) echo sounder was used for measuring water depths. The echo sounder system was bench calibrated at workshop prior to mobilization for the survey. The echo sounder transducer was side mounted on the survey vessel and its draft below the water-line was measured and recorded. The echo sounder system was interfaced with the Starfix.Seis navigation and survey system for logging the depth vs position data.

e) Data Acquisition & Survey Run-Line Logs

The Navigation and depth data from the Starfix.HP DGPS was logged continuously and monitored using the Starfix.Seis navigation suite. A survey run-line log book was maintained where the quality of data was noted. Details such as horizontal and vertical clearances above high flood level of bridges, aqueducts, electric lines, telephone lines, pipe lines, cables en-route were assessed on the spot and recorded, and their coordinates and location were plotted on the chart and included in the report. Photographs of important structures along the route are included as part of this report.

f) Soil Sampling and Visual Analysis

Soil samples were collected from the river bed along the surveyed route at about 10 km intervals, and the nature and texture of the samples collected were visually analysed and reported.

g) On-line QC of Data Logged

Real Time Graphs and QC Plots as provided by the Starfix survey software suite were used by experienced surveyors to monitor and control the quality of sensor data on-line, before they are logged. Time stamping on all the data was done by means of Starfix Timing Module through Navigation network synchronized with the GPS (high precision) 1PPS time signal. The data / record obtained from each survey sensor such as Navigation, Heading, SBES and Motion Sensor etc. were quality checked and an extract of the same were made available for verification and confirmation to proceed further.

h) Survey of Data Processing and interpretation methods

The survey data was logged in Binary Format (BF), and processed using the Starfix.Proc software. Heading, motion and position data were processed and checked to ensure good data quality. The measured offsets for all survey sensors was entered into the navigation system and processed using Starfix.Proc to enable track charts was plotted and 'corrected' navigation files was integrated with other sensor data at a later stage. These included:

- GPS position absolute of the primary & secondary positioning systems.
- Common Reference Point.
- Single beam echo sounder.

i) Bathymetry Data Analysis and Presentation

Starfix.Proc and Starfix.Work bench was used to import and process the navigation, bathymetry, tides and sound velocity data. The data was filtered, cleaned, and combined to create geographically positioned bathymetric data set that has been corrected for tides and sound speed.

j) Equipment Layout Diagram

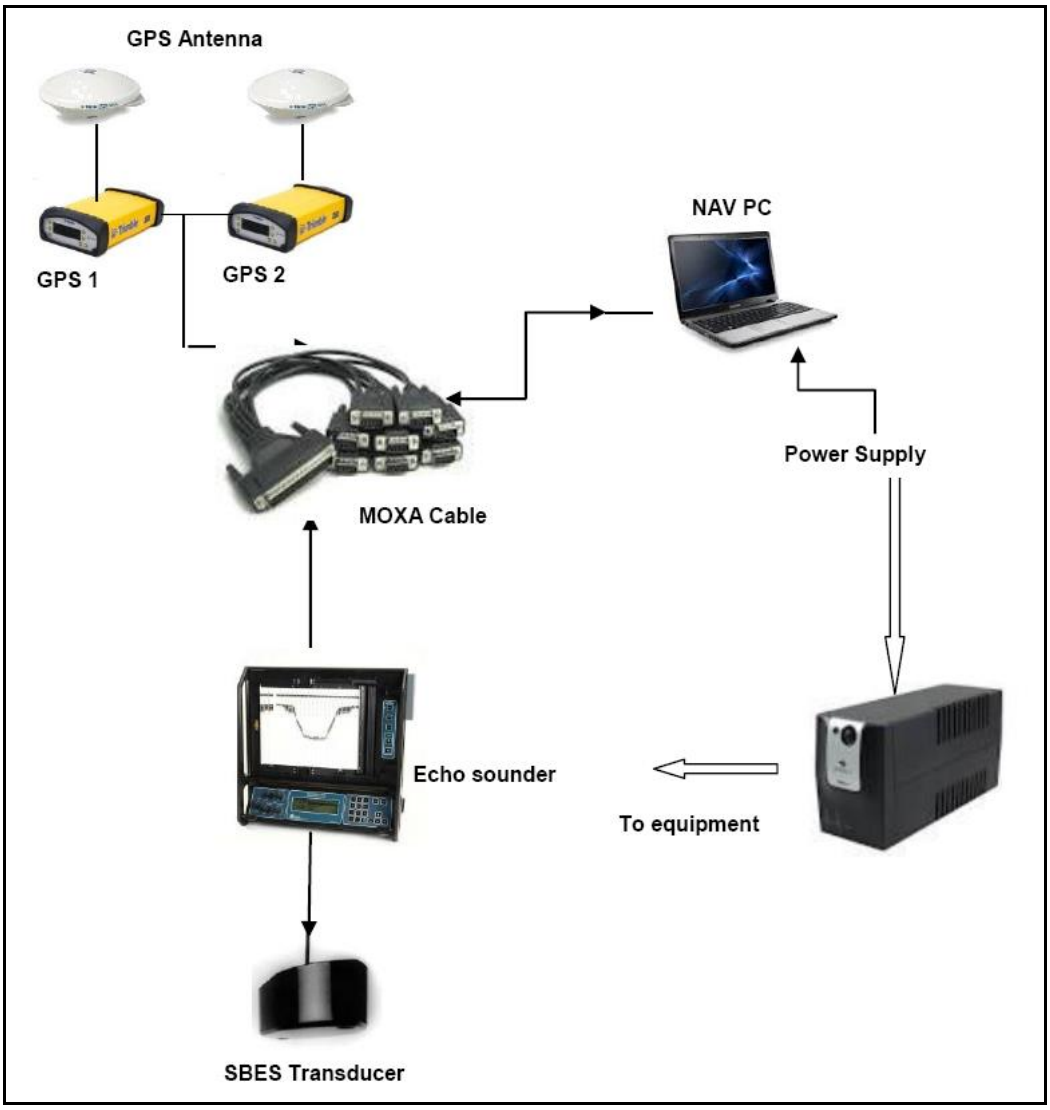


Figure 5: Equipment layout diagram

4.2 Description of bench marks (B.M.)/ authentic reference level used

A CWC Musto Type bench mark was found on the river stretch at Suchindram Ashramam, which was 6.01 m above the BM. All the heights of the riverbed in this report are referenced to this BM for obtaining their height above the MSL. The details about this BM are given below. Another GTS BM recovered by surveyor at Nagarcoil for which no height details are found.

Brief Narrative on the Recovery of the Station

a) What is the Source of Station Description Data;	CWC Site Office, Ashramam
b) Was the station recovered successfully?	Yes
c) What were the differences in Coordinates after verification using Starfix.HP?	No earlier coordinates available
d) Give Link to Starfix Mean Posn/Final Fix Report.	Mean Position Report_MTBM_ASHRAMAM.pdf

Final Coordinates in WGS84 Datum after verification using Starfix.HP

GEOGRAPHICAL COORDINATES:			UTM COORDINATES:				
LATITUDE	:	8°09'33.1833" N	EASTING:	770 943.13	m	(+/-0.04 m)	
LONGITUDE	:	77°27'32.0448" E	NORTHING:	902 725.182	m	(+/- 0.01 m)	
			Ht above MSL/CD	6.01	m		

Zone No: 43 CM: 075 °E

Describe the General Location & Access to the Station :	The station is situated on a stone inside a concrete well (1.10m x 1.10m x 0.62m). The well is filled with sand. The well is situated inside the premises (north west side) of Government High School, Suchindram Ashramam. The station is 5.7 m East of the boundary wall of the school, 4.6 m South of the CWC target post. The river Pazhyar is 15 mtrs North from the MTBM. MTBM is 40 mtrs North of the main gate of the school.The station is 5 kms south of the Nagercoil city and 20 kms north of the Kanniyakumari.
Describe how the Stn is marked on the Ground	The station is marked by a stone on ground.

Expected durability of the Station (in Years) : 10

DETAILED DIAGRAM :

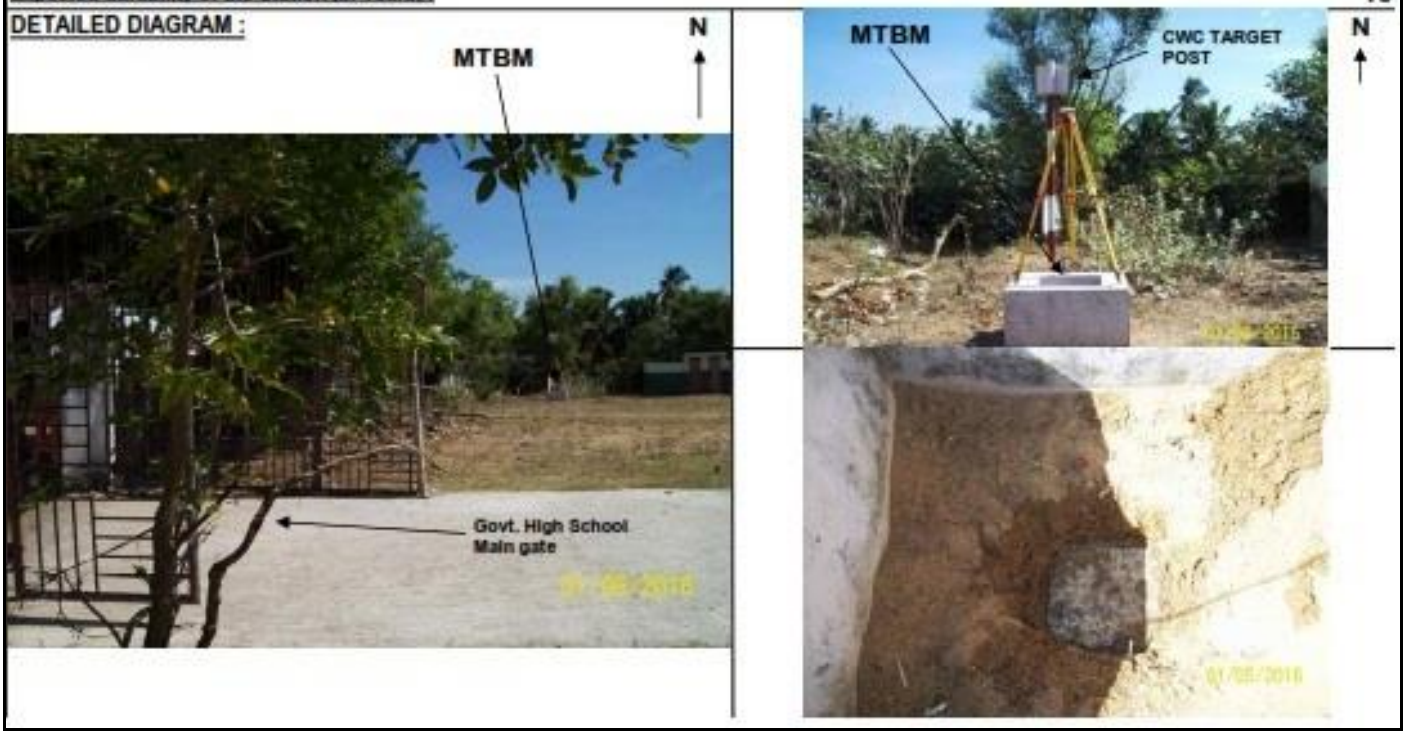


Figure 6: Details of Benchmark at Ashramam

Vessel

Vessel Name	
Project Name	**RIVER RECCEE SURVEY**
Project Number	**J_MAR_16_020**
Offset Name	**MainVessel_CRP**
Sampling Started	**01-May-2016 10:19:00 (UTC+05:30)**
Sampling Ended	**01-May-2016 10:39:07 (UTC+05:30)**
Comment	**MTBM IS SITUATED INSIDE THE PREMISES OF GOVERNMENT HIGH SCHOOL, ASHRAMAM**

Results

	Mean	Standard Deviation
Local Latitude	8°09'33.1833"N	
Local Longitude	77°27'32.0448"E	
Ellipsoidal Height	-89.31 m	
Local Easting	109686.56 m	0.04 m
Local Northing	903613.12 m	0.01 m
Orthometric Height	-89.31 m	0.03 m
WGS84 Latitude	8°09'33.1833"N	
WGS84 Longitude	77°27'32.0448"E	
Ellipsoidal Height	-89.31 m	
Quality	0.93	0.04 m
Depth	0.00 m	0.00 m
Heading	0.50°G	0.00°

Line Navigation Data

Line Name	**N/A**
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	**N/A**
Easting	N/A
Northing	N/A
Range	N/A
Bearing TO	N/A
FROM	N/A

Observations

Used 298 out of 298

Geodetic Parameters

Geodetic Datum	**WGS84**		
Ellipsoid	**WGS84**		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	**Transverse Mercator (UTM) Zone: 44**		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	81°00'00.0000"E		
False Easting	500000.000m		
False Northing	0.000m		
Convergence	- 0°30'11.5514"		
Calculation Mode	Grid		

Figure 7: Ashramam Benchmark - Fugro

SL	RIVER	POINT	DESCRIPTION	WGS 84 COORDINATES			LOCAL COORDINATES (UTM ZONE 43)		OTHER INFORMATION	REMARKS
				LATITUDE (N)	LONGITUDE (E)	ELLIPSOIDAL HEIGHT (M)	EASTING (M)	NORTHING (M)		
1	PAZHYAR	CWC MTBM, ASHRAMAM	MTBM IS ESTABLISHED BY CWC AND SITUATED ON THE WESTERN BANK OF RIVER PAZHYAR, IN THE PREMISES OF THE GOVERNMENT HIGH SCHOOL, SUCHINDRAM ASHRAMAM, NEAR NAGERCOIL.	8°09'33.1833"	77°27'32.0448"	-91.55	770 943.13	902 725.182	VALUE OF MTBM IS 06.010 MTRS ABOVE MSL. (PROVIDED BY THE EE, CWC KOCHI)	DERIVED BY STARFIX MEAN POSITION. ANTENNA HEIGHT (2.24 M) IS REDUCED TO THE OBSERVED ELLIPSOIDAL HEIGHT.
2	PAZHYAR	GTS BENCH MARK (TYPE M) (77/6, 58H)	GTS BM IS SITUATED INSIDE THE PREMISES OF THE GOVERNEMTN GUEST HOUSE (PWD), NAGERCOIL. IT IS INSIDE A CONCRETE WELL ON THE NORTH EASTERN SIDE OF THE COMPOUND.	8°11'30.7972"	77°26'00.7724"	-63.48	768 125.987	906 323.191	VALUE OF BM IS NOT AVAILABLE AT SITE	DERIVED BY STARFIX MEAN POSITION. ANTENNA HEIGHT (2.14M) IS REDUCED TO THE OBSERVED ELLIPSOIDAL HEIGHT.

Figure 8: Benchmarks details on Pazhyar River - CWC value

Brief Narrative on the Recovery of the Station	
a) What is the Source of Station Description Data;	FSINPVT, Navi Mumbai
b) Was the station recovered successfully?	Yes
c) What were the differences in Coordinates after verification using Starfix.HP?	No earlier coordinates available
d) Give Link to Starfix Mean Posn/Final Fix Report.	Mean Position Report_GTSBM_NAGERCOIL.pdf

Final Coordinates in WGS84 Datum after verification using Starfix.HP

GEOGRAPHICAL COORDINATES:				UTM COORDINATES:	Zone No:	43	CM:	075 °E
LATITUDE	:	8°11'30.7972"	N	EASTING:	766 125.967	m		(+/-0.09 m)
LONGITUDE	:	77°26'00.7724"	E	NORTHING:	906 323.191	m		(+/- 0.03 m)
				Ht above MSL/GB	Not Available	m/feet		

Describe the General Location & Access to the Station :	The GTS Type M Bench mark is situated on top of a stone, 0.3 mtrs square at base dressed to the form of a frustum of pyramid terminating in a square of a 0.1 mtrs. GTS, STD, BM & 1953 is engraved on its E,N,W & S faces respectively. This stone is surronded by a concrete well (1.53m x 1.53m x 0.70m) situated inside the premises of Government Guest House (PWD), Vadachery, Nagercoil, Tamilnadu. The station is 10 mtrs S of the northern boundary wall of the compound, 12 mtrs from the NE corner of the boundary wall, 7.3 mtrs from the Eastern boundary wall and 16 mtrs from the northern wall of the Guest House main building. This guest house is about 500 mtrs from the Nagercoil, vadachery bus stand.
Describe how the Stn is marked on the Ground	The station is on top of a stone and GTS, STD, BM & 1953 is engraved on its E,N,W & S faces respectively.
Expected durability of the Station (in Years) :	10

DETAILED DIAGRAM :

Figure 9: Details of Benchmark at Nagercoil

Vessel

Vessel Name	
Project Name	RIVER RECCEE SURVEY
Project Number	J_MAR_16_020
Offset Name	MainVessel_CRP
Sampling Started	01-May-2016 14:19:38 (UTC+05:30)
Sampling Ended	01-May-2016 14:29:38 (UTC+05:30)
Comment	GTSBM IS SITUATED INSIDE THE PREMISES OF GOVERNMENT GUEST HOUSE, PWD, NAGERCOIL

Results

	Mean	Standard Deviation
Local Latitude	8°11'30.7972"N	
Local Longitude	77°26'00.7724"E	
Ellipsoidal Height	-61.34 m	
Local Easting	106920.60 m	0.09 m
Local Northing	907256.36 m	0.03 m
Orthometric Height	-61.34 m	0.11 m
WGS84 Latitude	8°11'30.7972"N	
WGS84 Longitude	77°26'00.7724"E	
Ellipsoidal Height	-61.34 m	
Quality	0.90	0.02 m
Depth	0.00 m	0.00 m
Heading	0.51°G	0.00°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	N/A
Chainage	N/A	Easting	N/A
Cross Track	N/A	Northing	N/A
		Range	N/A
		Bearing TO	N/A
		FROM	N/A

Observations
Used 344 out of 344

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Transverse Mercator (UTM) Zone: 44		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	81°00'00.0000"E		
False Easting	500000.000m		
False Northing	0.000m		
Convergence	- 0°30'31.8107"		
Calculation Mode	Grid		

Figure 10: Nagercoil Benchmark - Fugro

4.3 Tidal Influence Zone and Tidal Variation in different stretches

From the survey of India Toposheets it was found that tidal reach is up to 4 km. However while carrying out the single line longitudinal survey at estuary, tidal influence was found up to 4.56 km.

The tidal variation between MLLW springs (0.2) and MHHW springs (0.7) is 0.5m.

{Tide Source: Muttam Point Tide Data obtained from ATT Volume-3}

4.4 Chart datum / Sounding datum and reduction details

4.4.1 Horizontal control

Worldwide Starfix.HP DGPS was used for positioning the survey vessel during this survey. The accuracy of the x, y, z position data obtained from the Starfix.HP DGPS system is +/- 10 cms at 95% assurance levels. Starfix software suite was used for navigation, data logging, and online quality control of the survey data logged.

4.4.2 Vertical control

Chart Datum at the River Estuary

From KP 0.0 to KP 4.56 which have tidal influence, the soundings obtained were reduced to Chart Datum using real time tidal observations and applying MSL~CD value of 0.488 m for the nearest port Muttam Point, obtained from ATT Volume 3. The coordinates of Chart Datum (CD) used is given below:

Sr. No.	Location	Latitude	Longitude	Z0 (m)
1	Muttam Point	8° 7' 00'' N	77° 19' 00'' E	0.488

Table 13: Details of Chart Datum Used for Reduction of Soundings

Z0: The Value of Z0 is taken below M.S.L.

Chart Datum for the upstream part of the River

The gauge discharge data of Ashramam gauging station was collected by WAPCOS. Chart datum/ Sounding Datum at this gauge station were taken as average of minimum water level of last six years for which data of maximum period was available in a year. This is detailed in Para 4.18.

4.5 Hydrographic/Topographic Survey

4.5.1 Hydrographic Survey

a) Length of stretch for which bathymetry survey has been carried out

The bathymetry survey has been carried out in the stretch of 4.56 km from Pazhyar river mouth.

b) Minimum and Maximum Depths

River Stretch (From CH 0.0 to CH 4.56)

This is the Estuary portion of the river where it meets the Bay of Bengal, and hence influenced by the tidal variations. Depths shown in the diagram are reduced to Chart Datum which is 0.488 m below the MSL. The Pazhyar River mouth is at Keelamanakudy (Lat. 08° 05' 15.01"N, Long. 77° 29' 07.61"E).

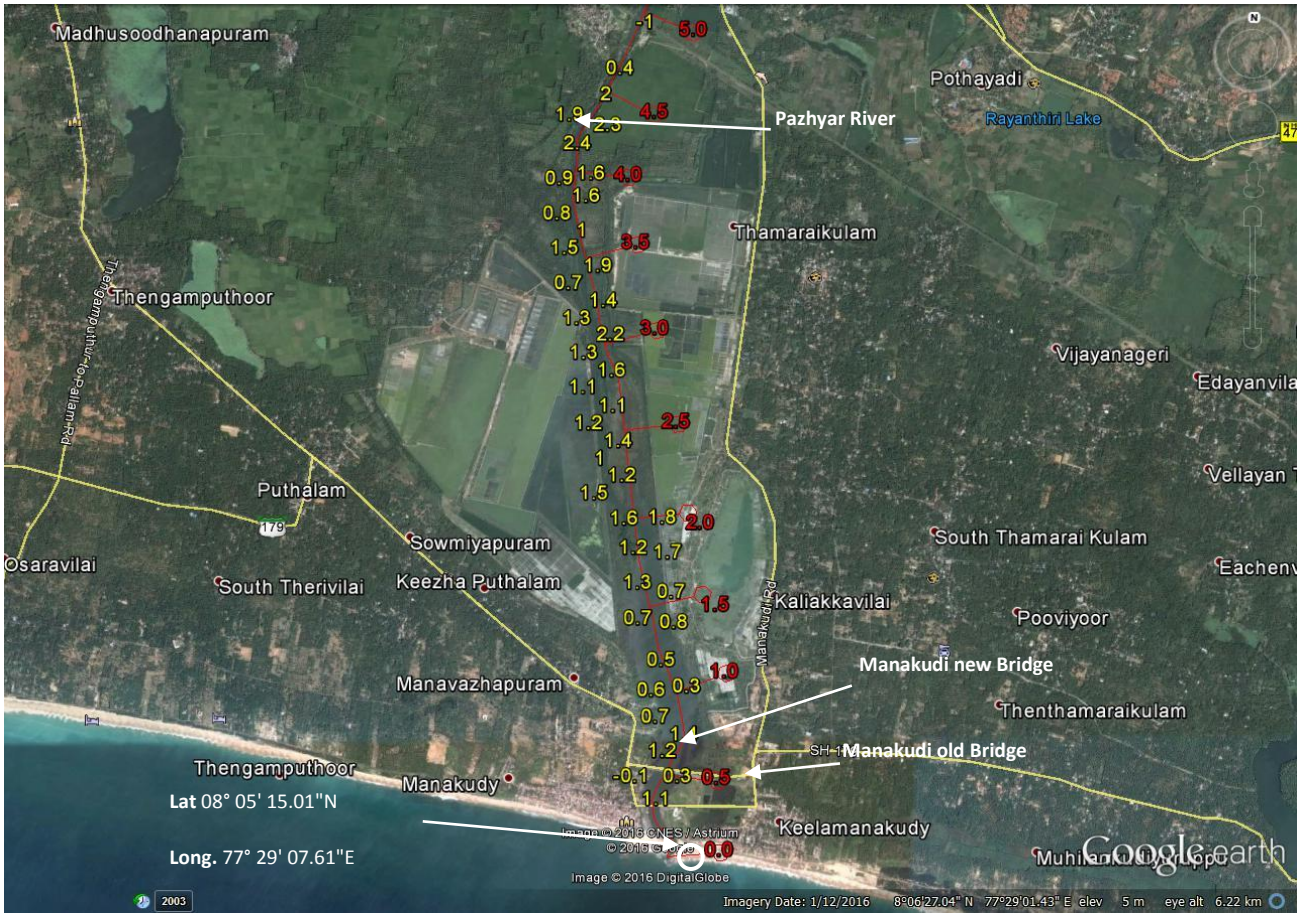


Figure 11: Pazhyar River from CH 0.0 to CH 5.0

c) Water levels Bathymetric Survey

Chainage (Km) A	Easting (m) B	Northing (m) C	Raw Depth D	Tide E	Reduced Depth w.r.t. CD (m) F = D - E
0.00	773917.88	894810.28	0.760	0.580	0.180
0.09	773929.70	894899.83	0.500	0.570	-0.070
0.19	773870.15	894972.49	0.850	0.570	0.280
0.28	773833.53	895060.05	1.200	0.580	0.620
0.37	773843.69	895127.15	1.63	0.57	1.1
0.41	773805.76	895182.31	0.49	0.57	-0.1
0.50	773874.66	895255.42	0.86	0.58	0.3
0.56	773866.07	895326.03	1.74	0.58	1.2
0.66	773901.86	895419.46	1.98	0.58	1.4
0.78	773952.83	895505.56	0.95	0.59	0.4
0.87	773895.23	895587.43	1.32	0.59	0.7
0.97	773904.89	895687.02	0.92	0.59	0.3
1.03	773862.98	895734.08	1.19	0.59	0.6
1.13	773835.48	895830.34	1.09	0.59	0.5

Chainage (Km) A	Easting (m) B	Northing (m) C	Raw Depth D	Tide E	Reduced Depth w.r.t. CD (m) F = D - E
1.22	773844.81	895929.93	1.00	0.59	0.4
1.34	773815.88	896040.64	1.40	0.60	0.8
1.44	773770.99	896130.05	1.28	0.60	0.7
1.51	773792.84	896208.59	1.31	0.60	0.7
1.63	773759.14	896328.61	1.94	0.62	1.3
1.73	773759.67	896428.67	2.30	0.62	1.7
1.83	773723.23	896521.92	1.85	0.62	1.2
1.93	773719.85	896621.91	2.42	0.62	1.8
2.00	773663.94	896683.43	2.20	0.64	1.6
2.07	773577.66	896734.20	2.62	0.64	2.0
2.16	773492.30	896815.98	2.18	0.64	1.5
2.26	773481.26	896915.40	1.84	0.64	1.2
2.35	773468.22	897008.90	1.60	0.64	1.0
2.45	773450.88	897107.43	2.10	0.66	1.4
2.55	773438.68	897206.80	1.82	0.66	1.2
2.65	773410.96	897303.06	1.79	0.66	1.1
2.76	773402.41	897408.55	1.78	0.66	1.1
2.89	773393.82	897502.52	2.26	0.66	1.6
2.97	773393.50	897602.58	1.93	0.66	1.3
3.07	773380.06	897703.97	2.82	0.66	2.2
3.16	773344.12	897793.86	2.02	0.68	1.3
3.26	773326.56	897892.32	2.10	0.68	1.4
3.37	773287.43	897989.12	1.39	0.68	0.7
3.46	773286.42	898087.42	2.61	0.68	1.9
3.57	773255.61	898186.25	2.23	0.68	1.5
3.66	773236.53	898284.45	1.65	0.69	1.0
3.76	773204.07	898379.08	1.49	0.69	0.8
3.86	773199.69	898479.06	2.33	0.69	1.6
3.96	773205.70	898578.49	1.57	0.69	0.9
4.06	773216.73	898678.33	2.32	0.71	1.6
4.16	773216.23	898777.91	3.14	0.71	2.4
4.26	773246.46	898872.58	2.60	0.71	1.9
4.36	773299.34	898957.53	3.02	0.72	2.3
4.46	773352.63	899043.29	2.84	0.72	2.1
4.56	773387.67	899136.99	2.69	0.72	2.0

Table 14: Bathymetry Water levels (Observed, Reduction factor and Reduced)

4.5.2 Topographic Survey

a) Length of stretch for which topographic survey has been carried out

Since the water depths are shallow for chainage above 4.56 km from river mouth and bathymetry survey was not possible, therefore the topography survey has been carried out from chainage 4.5 km to 20.0 km from Pazhyar river mouth.

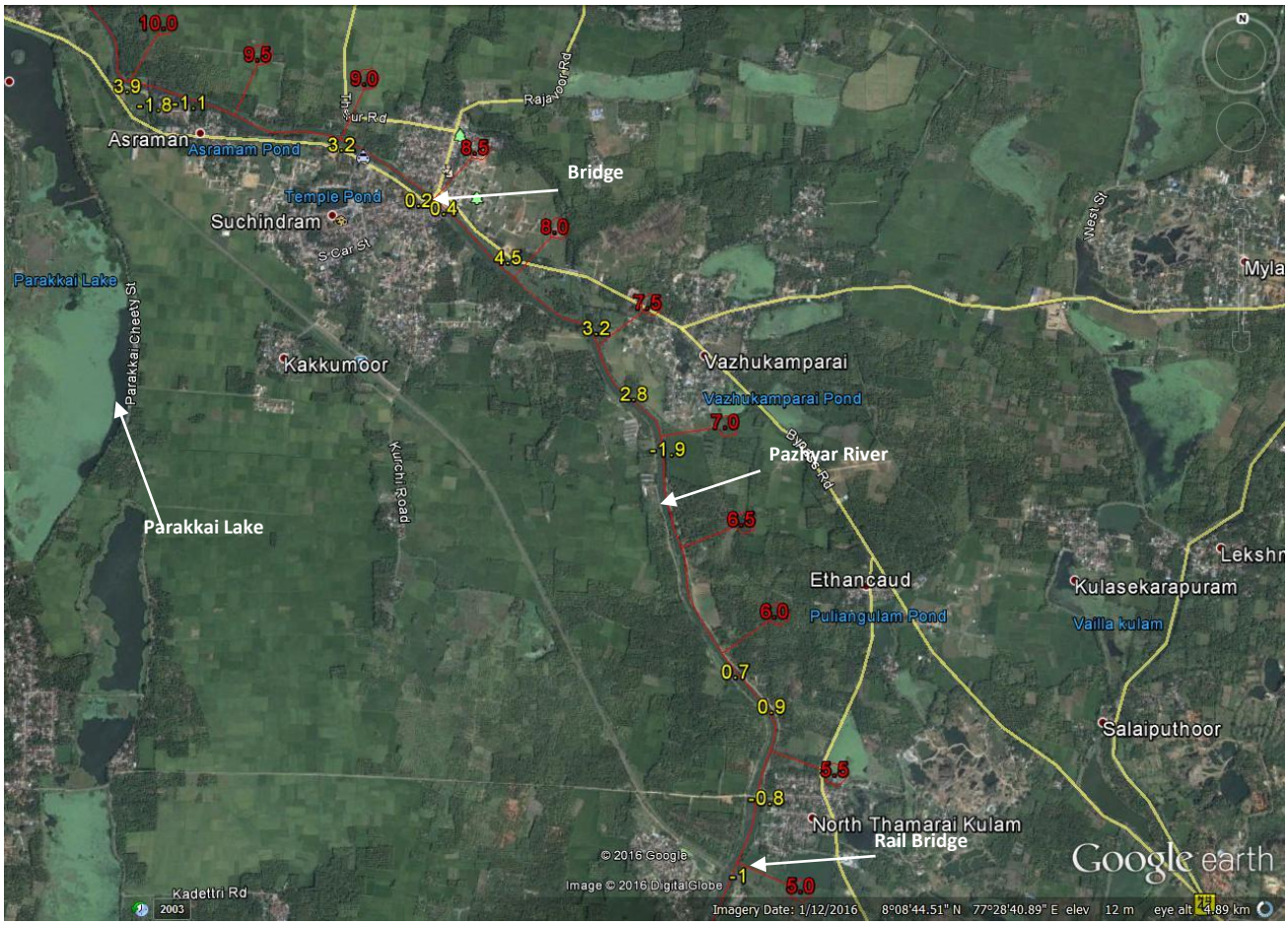
b) Minimum and Maximum Depths

As per IWAI suggestion, following sign convention is adopted

(+) : Riverbed below CD
(-) : Riverbed above CD
(+) : Water Depth below CD
(-) : Water Depth above CD

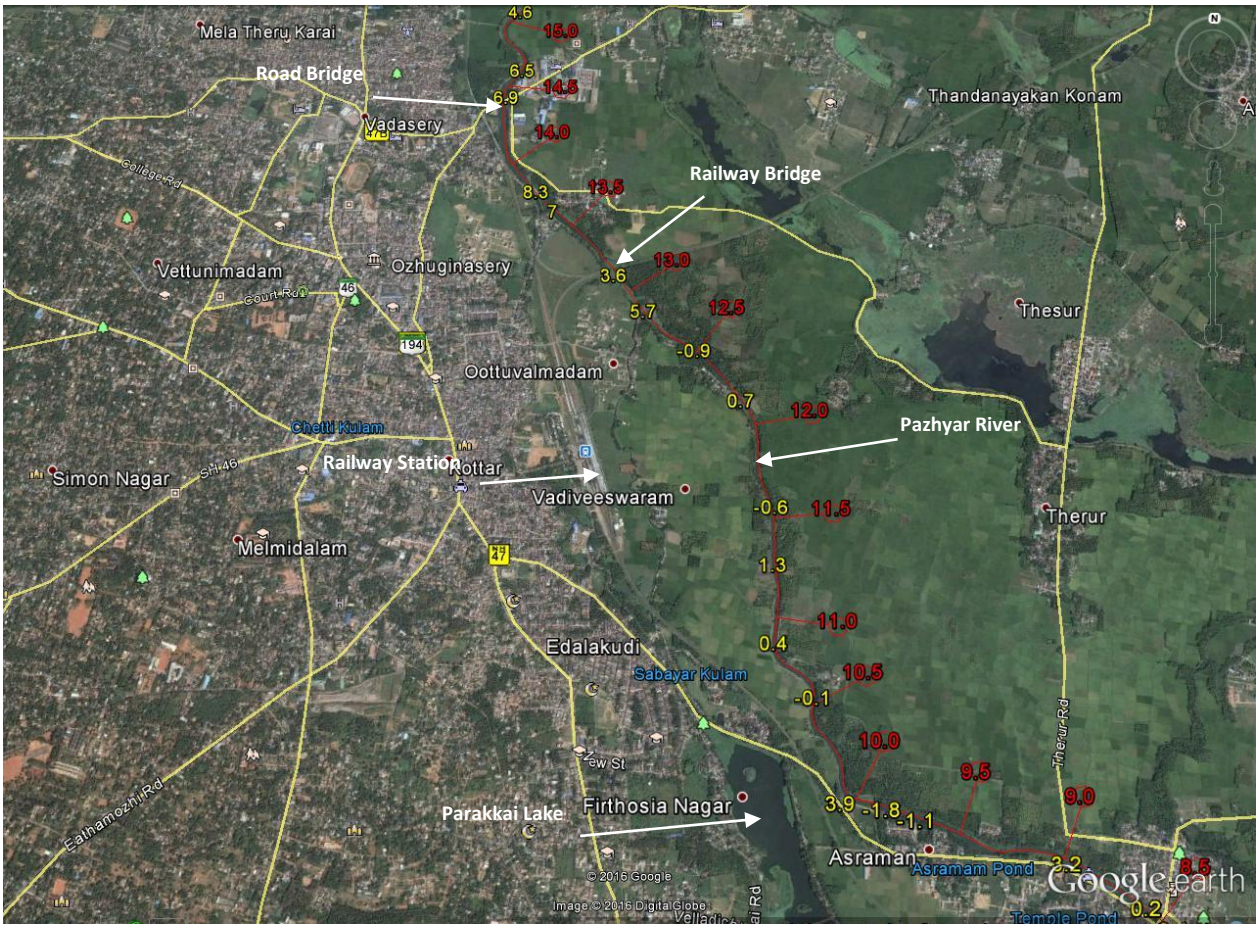
River Stretch (From CH 4.56 to CH 10.0)

The Suchindram - Akkarai Road Bridge crosses the river at CH 8.5. The Railway Bridge crosses the river at CH 4.9. The village of North Thamarai lies on the East bank at CH 5.2. The Western part of the river bank is dense populated area. The Eastern part of the river banks are covered with vegetation and open fields.



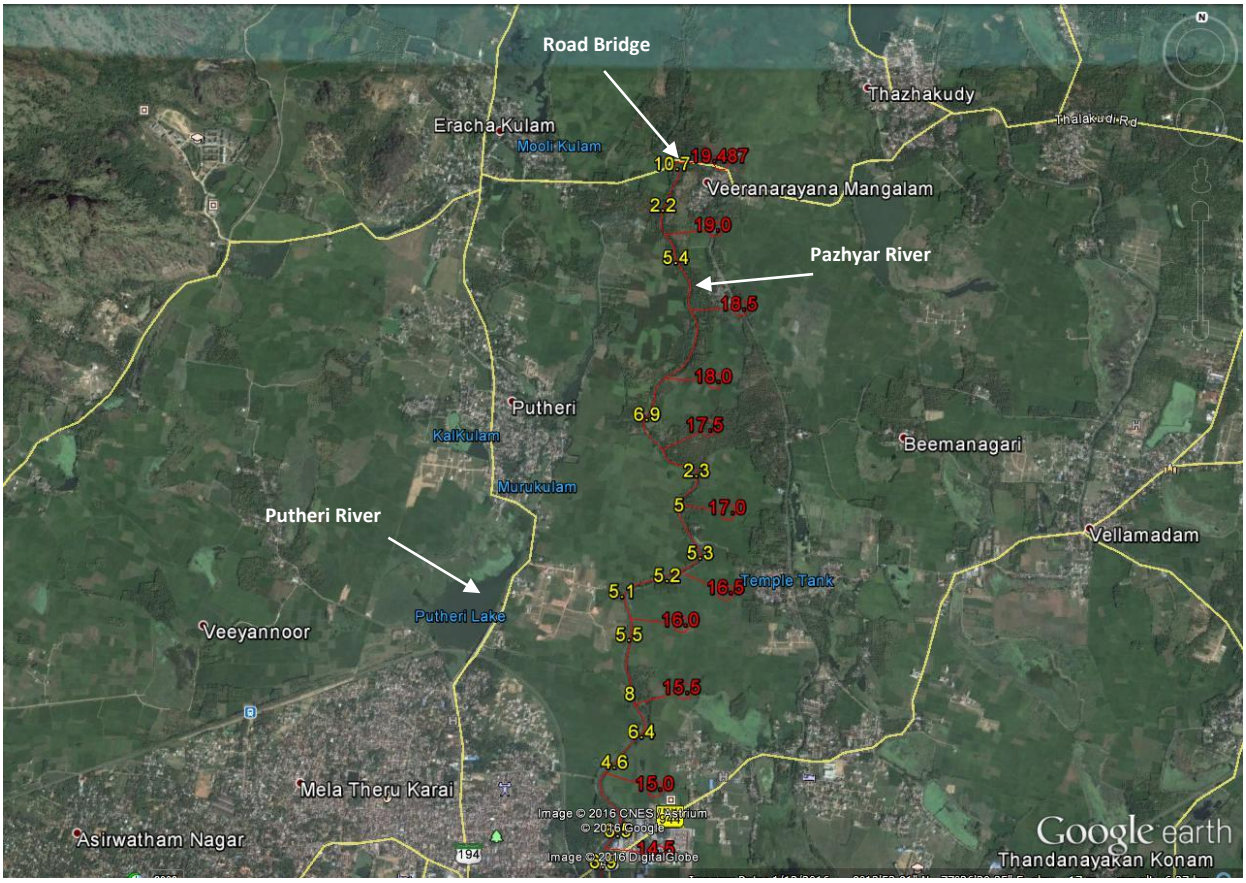
River Stretch (From CH 10.0 to CH 15.0)

The Western part of the river bank is dense populated area. The Eastern part of the river banks are covered with vegetation and open fields. Parakkai Lake is situated at western part of Pazhyar River (Approx CH 10.2). The Railway Bridge crosses the river at CH 13.1. The Road Bridge crosses the river at CH 14.4.



River Stretch (From CH 15.0 to CH 19.487)

The river banks are mostly covered with vegetation. Putheri Lake is situated at western part of the Pazhyar River (Approx. CH 16.0). The Road Bridge crosses the river at CH 19.3. The Minimum reduced depth recorded in this section is -3.81 m (CH 19.48) and the maximum reduced depth is 4.69 m (CH 19.18) w.r.t. CD.



c) Water levels Topographic survey

Chainage (km) A	River Bed Level w.r.t MSL (m) B	Observed Water Depths (m) C	Adopted C.D. D	Reduced Depth E = D - B
4.57	1.9	1.8	1.80	0.000
4.75	1.05	1.6	1.82	0.768
4.85	0.75	1.4	1.83	1.077
4.95	0.55	1.3	1.84	1.287
4.99	0.69	1.3	1.84	1.151
5.05	0.65	1.2	1.85	1.196
5.15	0.62	1.2	1.86	1.236
5.24	0.68	1.1	1.87	1.185
5.30	0.74	1.1	1.87	1.131
5.34	0.99	1.1	1.88	0.885
5.45	1.25	1.1	1.89	0.635
5.54	1.57	1	1.89	0.325
5.65	2.01	1	1.91	0.000

Chainage (km) A	River Bed Level w.r.t MSL (m) B	Observed Water Depths (m) C	Adopted C.D. D	Reduced Depth E = D - B
5.68	2.45	1	1.91	0.000
5.74	2.51	0.9	1.91	0.000
5.84	2.43	0.7	1.92	0.000
5.90	2.25	0.5	2.00	0.000
5.94	2.34	0.4	2.00	0.000
6.04	2.15	0.5	2.01	0.000
6.14	1.98	0.5	2.01	0.030
6.20	1.79	0.5	2.01	0.223
6.25	1.62	0.4	2.01	0.395
6.28	1.54	0.5	2.02	0.476
6.35	1.43	0.5	2.02	0.589
6.45	1.32	0.6	2.02	0.703
6.55	1.29	0.7	2.03	0.737
6.66	1.21	0.7	2.03	0.822
6.76	0.86	0.8	2.04	1.176
6.86	0.22	0.9	2.04	1.820
6.93	-0.06	0.9	2.04	2.103
6.94	-0.38	1	2.04	2.423
6.95	0.5	0.8	2.04	1.544
7.05	2.22	0.7	2.05	0.000
7.16	3.01	0.6	2.05	0.000
7.22	4.31	0.5	2.06	0.000
7.26	4.42	0.6	2.06	0.000
7.34	4.51	0.7	2.06	0.000
7.47	4.64	0.9	2.07	0.000
7.57	4.77	1	2.07	0.000
7.66	4.91	1	2.07	0.000
7.78	5.07	0.7	2.08	0.000
7.88	5.68	0.6	2.08	0.000
7.98	5.83	0.4	2.09	0.000
8.08	6	0.3	2.09	0.000
8.18	5.19	0.3	2.10	0.000
8.27	3.36	0.2	2.10	0.000
8.37	2.25	0.1	2.10	0.000
8.44	1.92	0.1	2.11	0.186
8.47	1.85	0.6	2.11	0.258
8.50	1.7	1	2.11	0.409
8.57	2.15	0.9	2.11	0.000
8.68	2.6	0.9	2.12	0.000
8.76	2.87	1	2.12	0.000

Chainage (km) A	River Bed Level w.r.t MSL (m) B	Observed Water Depths (m) C	Adopted C.D. D	Reduced Depth E = D - B
8.87	3.56	1	2.12	0.000
8.97	4.17	1	2.13	0.000
8.98	4.77	1	2.13	0.000
9.09	4.01	1.2	2.13	0.000
9.19	3.34	1.5	2.14	0.000
9.29	2.66	1.8	2.14	0.000
9.39	1.54	1.9	2.15	0.606
9.39	1.43	2.1	2.15	0.716
9.49	1.35	2.3	2.15	0.800
9.58	1.07	2.5	2.15	1.084
9.68	0.84	2.7	2.16	1.318
9.71	0.46	2.8	2.16	1.699
9.79	0.07	2.5	2.16	2.092
9.87	-0.29	2	5.4	5.690
9.88	1.23	1.7	5.40	4.172
9.99	3.56	1.3	5.42	1.863
10.00	5.38	1	5.43	0.046
10.04	4.96	1.1	5.43	0.474
10.08	4.06	1	5.44	1.382
10.18	4.29	1	5.46	1.172
10.28	3.74	1	5.48	1.742
10.33	3.67	1.1	5.49	1.822
10.38	3.51	1.1	5.50	1.991
10.43	3.42	1.1	5.51	2.092
10.50	3.25	1.2	5.52	2.275
10.53	3.01	1.2	5.53	2.522
10.60	3.12	1.2	5.55	2.426
10.72	3.29	1.1	5.57	2.279
10.82	3.43	1.1	5.59	2.159
10.87	3.57	1	5.60	2.030
10.92	3.41	1	5.61	2.200
11.03	3.63	1	5.63	2.001
11.12	3.91	1.1	5.65	1.740
11.20	4.23	1.1	5.67	1.435
11.26	4.42	1.1	5.68	1.257
11.32	3.92	1.1	5.69	1.770
11.42	3.61	1	5.71	2.100
11.51	3.13	1	5.73	2.597
11.55	2.53	1	5.74	3.206
11.63	2.76	1	5.75	2.991

Chainage (km) A	River Bed Level w.r.t MSL (m) B	Observed Water Depths (m) C	Adopted C.D. D	Reduced Depth E = D - B
11.72	2.89	1	5.77	2.880
11.83	3.02	1	5.79	2.772
11.85	3.12	1	5.80	2.676
11.93	3.09	1	5.81	2.722
12.03	3.27	1	5.83	2.562
12.11	3.59	1	5.85	2.257
12.14	3.85	1	5.85	2.004
12.24	3.26	1	5.87	2.613
12.34	2.97	1.1	5.89	2.924
12.44	2.61	1.1	5.91	3.304
12.51	2.24	1.2	5.93	3.688
12.54	3.65	1.2	5.93	2.284
12.64	4.92	0.8	5.95	1.034
12.74	5.7	0.7	5.97	0.274
12.82	7.33	0.6	5.99	0.000
12.86	8.78	0.5	6.13	0.000
12.95	7.41	0.4	6.43	0.000
13.05	7.03	0.3	6.78	0.000
13.12	6.74	0.3	7.04	0.302
13.15	6.93	0.2	7.13	0.202
13.25	7.29	0.2	7.48	0.186
13.34	7.21	0.2	7.81	0.601
13.46	8.69	0.1	8.21	0.000
13.56	9.1	0.1	8.55	0.000
13.63	10.13	0.1	8.81	0.000
13.67	10.57	0.1	8.94	0.000
13.73	10.93	0.1	10.5	0.000
13.85	11.21	0.1	10.52	0.000
13.97	11.03	0.1	10.55	0.000
14.04	10.96	0.1	10.56	0.000
14.15	10.67	0.1	10.58	0.000
14.28	10.61	0.2	10.61	0.001
14.36	10.36	0.2	10.63	0.267
14.42	10.02	0.2	10.64	0.619
14.50	9.98	0.6	10.66	0.675
14.59	9.73	0.8	10.67	0.943
14.62	9.67	1	10.68	1.009
14.70	9.12	1	10.69	1.574
14.80	8.82	1	10.71	1.895
14.90	8.21	1.1	10.74	2.525

Chainage (km) A	River Bed Level w.r.t MSL (m) B	Observed Water Depths (m) C	Adopted C.D. D	Reduced Depth E = D - B
15.00	7.99	1.1	10.76	2.765
15.08	7.68	1.1	10.77	3.091
15.16	8.13	1.2	10.79	2.658
15.26	9.13	1.1	10.81	1.678
15.32	9.55	1.2	10.82	1.268
15.39	10.32	1.2	10.83	0.512
15.49	10.73	1.1	10.85	0.122
15.56	11.1	1.1	10.87	0.000
15.58	11.21	1.2	10.87	0.000
15.68	11.05	1.1	10.89	0.000
15.78	10.53	1.1	10.91	0.382
15.89	9.62	1.1	10.93	1.312
15.91	8.59	1.1	10.94	2.346
15.99	8.87	1.2	10.95	2.083
16.09	8.43	1.2	10.97	2.543
16.15	8.25	1.2	10.99	2.736
16.18	8.56	0.9	10.99	2.430
16.28	8.21	0.7	11.01	2.801
16.38	8.37	0.6	11.03	2.660
16.43	8.33	0.5	11.04	2.710
16.48	8.91	0.5	11.05	2.141
16.58	8.79	0.4	11.07	2.281
16.63	9.46	0.4	11.08	1.621
16.68	10.04	0.4	11.09	1.050
16.69	10.16	0.6	11.09	0.933
16.79	9.98	0.7	11.11	1.133
16.90	9.86	0.8	11.13	1.274
16.95	9.75	0.9	11.14	1.394
16.99	9.71	1	11.15	1.443
17.00	9.99	1	11.16	1.165
17.11	8.51	0.9	11.18	2.667
17.18	7.63	1	11.19	3.562
17.24	6.99	1	11.20	4.213
17.32	7.37	0.9	11.22	3.849
17.43	7.82	0.9	11.24	3.421
17.49	8.53	0.7	11.25	2.724
17.55	8.99	0.6	11.26	2.274
17.66	9.67	0.5	11.29	1.616
17.71	10.24	0.4	11.30	1.056
17.76	11.6	0.3	11.31	0.000

Chainage (km) A	River Bed Level w.r.t MSL (m) B	Observed Water Depths (m) C	Adopted C.D. D	Reduced Depth E = D - B
17.79	11.72	0.3	11.31	0.000
17.85	11.51	0.3	11.32	0.000
17.90	11.43	0.3	11.34	0.000
17.95	11.37	0.3	11.35	0.000
18.00	11.23	0.3	11.35	0.124
18.09	11.29	0.3	11.37	0.083
18.15	11.15	0.4	11.38	0.234
18.21	11.07	0.4	11.40	0.326
18.29	10.86	0.3	11.41	0.552
18.35	10.91	0.3	11.43	0.515
18.41	10.77	0.3	11.44	0.666
18.47	10.61	0.2	11.45	0.838
18.51	10.58	0.2	11.46	0.877
18.56	10.51	0.2	11.47	0.957
18.62	10	0.3	11.48	1.478
18.67	10.16	0.3	11.49	1.328
18.72	10.11	0.2	11.50	1.389
18.83	10.41	0.2	11.52	1.110
18.84	10.13	0.2	11.52	1.393
18.88	10.26	0.5	11.53	1.271
18.95	9.61	0.7	11.54	1.935
19.03	8.78	0.9	11.56	2.780
19.14	7.96	1	11.58	3.622
19.18	6.887	1.1	11.59	4.705
19.25	7.65	1.1	11.60	3.954
19.35	7.94	1	11.62	3.685
19.39	8.65	1.2	11.63	2.982
19.48	11.21	1.2	11.65	0.440
19.48	15.45	1.2	11.65	0.000

Table 15: Topographic survey Water levels

Note: Negative (-) ive depths are reduced to zero as per discussions with project authorities.

4.6 Observed and reduced bed profile along the river

4.6.1 Observed bed profile along the river

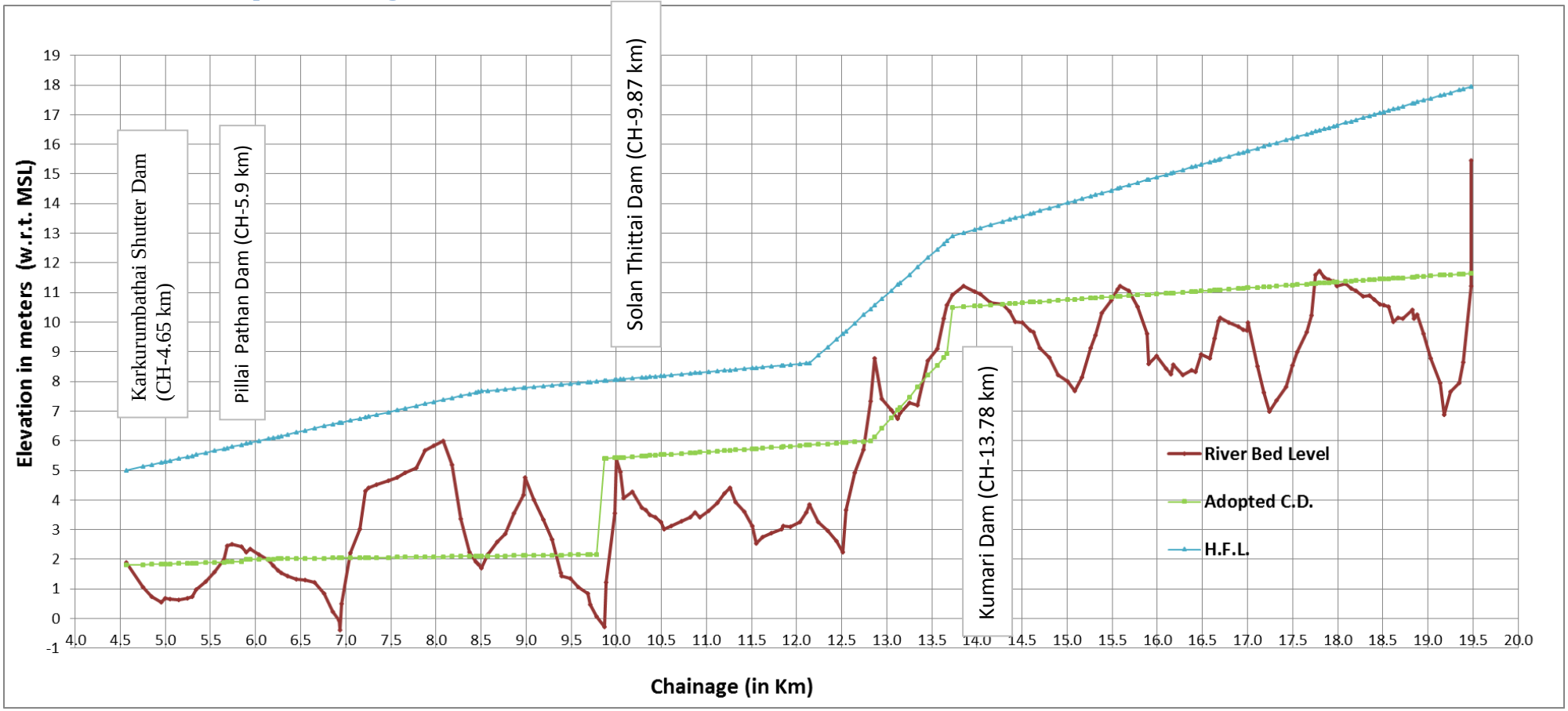


Figure 12: Riverbed profile from the end of tidal influence (Kp 4.56) till the end of 20 Km stretches.

Source: Deepest level Single line longitudinal survey carried out at site, and last twenty years gauge discharge data collected from CWC. Source data table is also attached as Annexure 4.

4.6.2 Reduced bed profile along the river

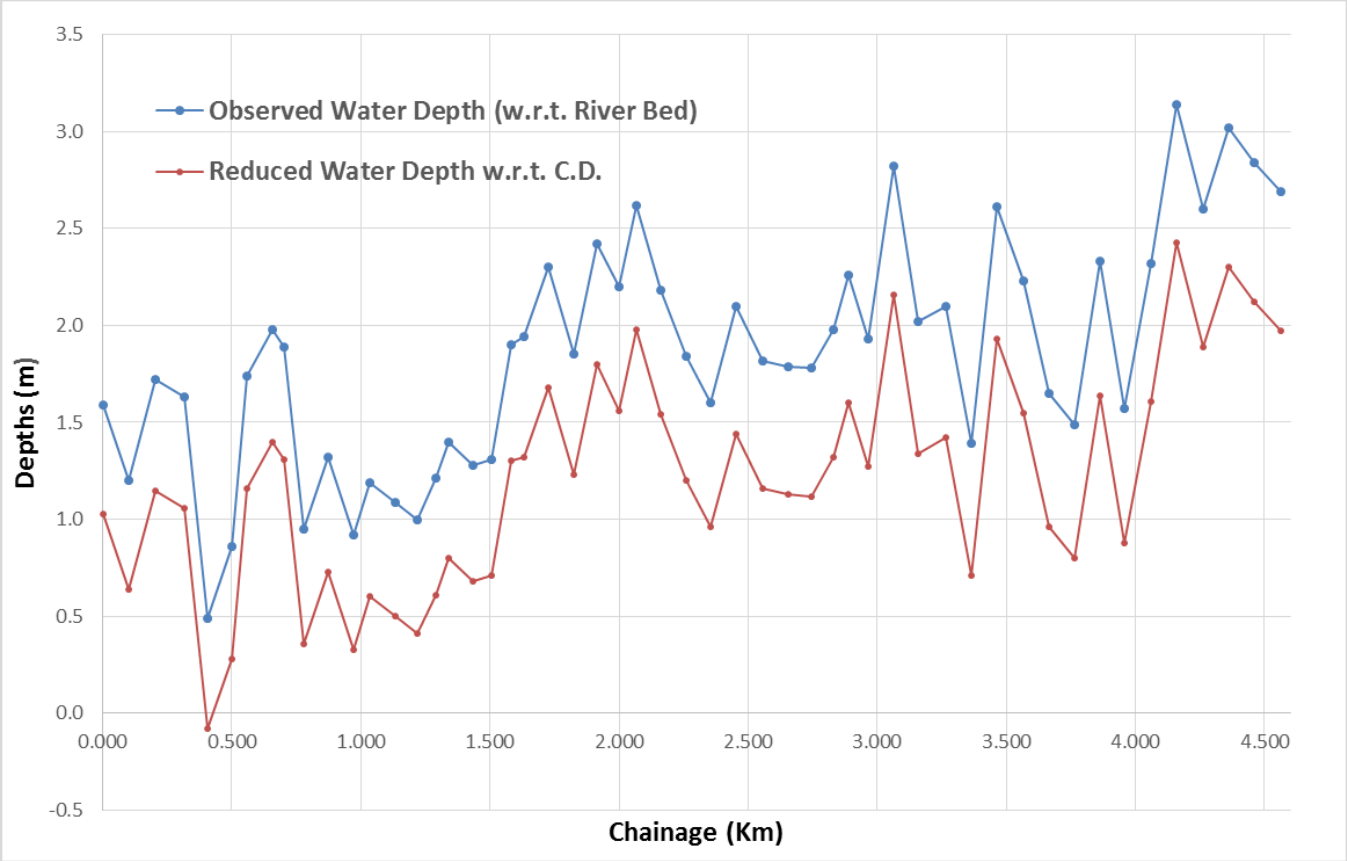


Figure 13: Depth profile at the Estuary (Kp 0 to Kp 4.56) up to tidal influence

4.7 Results from Hydrographic/Topographic Survey

- The Pazhyar River estuary up to CH 4.5 has water depths vary from -0.1 m to 2.4 m below CD.
- The extents of shallow water patches, wherever observed, are shown plotted on the Charts accompanying this Report.
- Tidal influence was found upto chainage 4.56 upto which bathymetry survey has been carried out. From 4.56 to 20 km, water depths are shallow and depths are measured manually using sounding poles.

4.8 Soil characteristics

At three (03) locations soil samples were collected and the details of CH vs soil textures are tabulated in **Annexure 1**.

From visual observation, it can be seen that sand was present in riverbed from Ch 0 to 20 km (complete stretch).

4.9 Water characteristics

From visual observation, clear water was found from chainage 0 to 4.5 km and after 4.5 km, water mixed with sand was observed at some places and clear water was observed at most of places up to 20km.

4.10 Condition of banks

Condition of banks was depicted in inventory of structures in **Annexure 2**. Natural banks were observed from chainage 0 to 20 km. The condition of banks was found to be good.

The photographs showing condition of banks along the riverduringStage-1 survey are also attached at the end.

4.11 Details of collected water level and Discharge data

The details of gauging stations and collected data as detailed in chapter 2 (refer 2.6.3 and 2.6.4):

Name	Chainage	Location	
		Lat.	Long.
Ashramam, Kanyakumari district, Tamilnadu	9.5 km	08^0 09′ 33″ N	77^0 27′ 33″ E

Table 16: Location details of Ashramam gauging station

The details of Gauge station, jurisdiction, establishment and data availability are presented in the tables below:

General Details	
Station Name	Ashramam
Station Code	KE000G2
Operational Status	Existing
Activity	HO
Station Type (Current)	GDQ
Tehsil/Taluk	Suchindrum
District	Kanyakumari
State	Tamil Nadu
Latitude (DMS)	8°9'33"N
Longitude (DMS)	77°27'32"E
Altitude (m)	6.10
Distance to Outlet (km)	-
Toposheet No.	58H8
Catchment Area (sq. km)	258.00

Table 17: Ashramam GD site-General details

Jurisdiction Details	
Owner Agency	CWC
State/Regional Office	C&S RO, Coimbatore
Circle Office	S.E.(C&SR), Bangalore
Divisional Office	SWR Division, Cochin
Sub Divisional Office	SWRSD No. 1, Trivandrum
Section Office	Ashramam
Nearest Airport	Trivendrum
Town	Suchindrum
Railway Station	Nagarcoil
Bus Stand	Ashramam
Station Bank	Right
Zero of Gauge (m)	1.00

Table 18: Ashramam GD site- Jurisdiction details

Establishment Details		
Date of establishment	12/1/1996	
Date of closure	-	
Parameters	**Start Date**	**End Date**
Gauge	1/4/1996	
Discharge	21/09/1999	
Sediment	-	
Water Quality		
Rainfall(ORG)	1/6/1987	
Rainfall(SRG)	1/9/2000	
Temperature	16/03/1971	
Wind Velocity	21/09/1999	
Evaporation	-	
Humidity	1/1/2002	
Sunshine	1/1/2002	

Table 19: Ashramam GD site- Establishment details

Parameters	Start Date	End Date
Water Level	1/4/1996	31/5/2013
Discharge	21/09/1999	31/5/2013
Sediment	Not Available	
Water Quality	2/12/2002	2/5/2013
Rainfall	1/6/2007	31/5/2008
Temperature	1/9/1999	31/5/2009
Climatic	1/12/2007	31/3/2008

Table 20: Ashramam GD site- Data availability

4.12 Methodology for analysis of Gauge- Discharge Data

The gauge-discharge data available for number of years for Ashramam gauging station was analysed in different ways as given below:

10 Daily average discharges

The ten daily average discharges in each month for each year were worked out and then the average of average 10 daily discharges over the entire period of data were worked out to get idea about availability of 10 daily average discharge during different months of the year. Based on these average 10 daily discharges it will be possible to work out available depth of flow for natural or design cross section of river. These data analysis will be helpful for navigation feasibility in given stretch of river. The outcome from this analysis will also be useful for mathematical model studies(to be carried out in stage II) to predict longitudinal water surface profiles for different discharges along given reach of river and also to design section of navigation channel on river bed.

Maximum minimum discharges and water levels

The yearly maximum discharge and water level for the entire period of data were extracted and then these data were statistically analysed using Gumbel extreme value distribution to estimate flood discharges for different return periods such as 2,5, 10,

25 ,50 and 100 years. Similarly high flood levels were analysed. The minimum flow and minimum water level data was also analysed. The estimated HFLs and Minimum water levels will be useful for planning navigation as well as for design of terminals for cargo and passenger traffic.

Gauge discharge curves

Using available gauge discharge data G-Q curves were developed for each gauge station. These will be helpful to compute water level for any discharge. Also for calibration and validation of mathematical model (studies required in stage II) this data will be very useful.

Comparison of River Cross Section Data:

The river cross sections at gauging stations on different station were available for different years. For a given gauging station the cross sections for different years including the latest cross section were superimposed to study changes in river bed levels and shifting of the deep channel if any over the period of data.

Period of availability for range of discharges

For a navigation channel to be feasible it is necessary that adequate discharge is available to maintain required depth/draft for fairly longer duration during the year. The data for each gauge station was analysed to find out period of availability for the different range of discharges. Based on past 20 to 30 years of data, % of days in a year for availability of different range of discharges were worked out. These data will be very useful to estimate number of days for which minimum discharge required to facilitate navigation will be available in different rivers.

Discharge- sediment flow data

These data was analysed to prepare discharge v/s sediment concentration plot for each gauging station. This analysis will be useful to understand sediment concentration in reach for range of discharges.

4.13 Bed Slope

The average bed slopes for Pazhyar River for the reach under consideration are given in table below:

River	Reach		River Bed Level Change	Distance	Slope
	From	To			
Pazhyar	Ashramam RBL 0.62 m	Mouth RBL 0.0 m	0.62 m	9.55 km	1/15403

Table 21: Bed Slope of Pazhyar River

RBL – River Bed Level (These are taken from CWC river cross sections at gauging sites)

4.14 River Cross sections

The CWC data of river cross-sections at gauging site on Pazhyar River was available for number of years. The river cross sections at the gauging site for different years were compared to understand morphological changes over the longer period. Figure 14 shows plots for Pazhyar river cross section at Ashramam gauging station indicating comparison of cross sections in different years. Following table shows abstract of review of these studies.

Sr	River & Gauge location	General Description & Bank to Bank width	River bed level in 2012	Bank Levels	Comments/ observations
1	Pazhyar at Ashramam	Well defined c/s width - 52 m, deep channel on left bank (Figure 14)	0.62 m	6 to 7m	Practically no change in river section during 2001 to 2012 except silting of river bed by about 0.5 m

Table 22: River cross-sections over different years

4.15 Ten- Daily average Discharges

Daily gauge- discharge data for period 2000 to 2012 was analysed in different ways as discussed above. Analysis of 10 daily average flows is presented in Table 23. Figure 15 shows bar chart indicating variation in 10 daily average flows round the year. The results of this analysis indicate range of average 10 daily flows in different period of year as following.

- ➔ June to August 0 to 4m^3/s
- ➔ September to November 4 to 10m^3/s
- ➔ December to May 0 to 2 m^3/s

The gauge- discharge curve derived from the daily flow data during periods of high floods is presented vide figure 16.

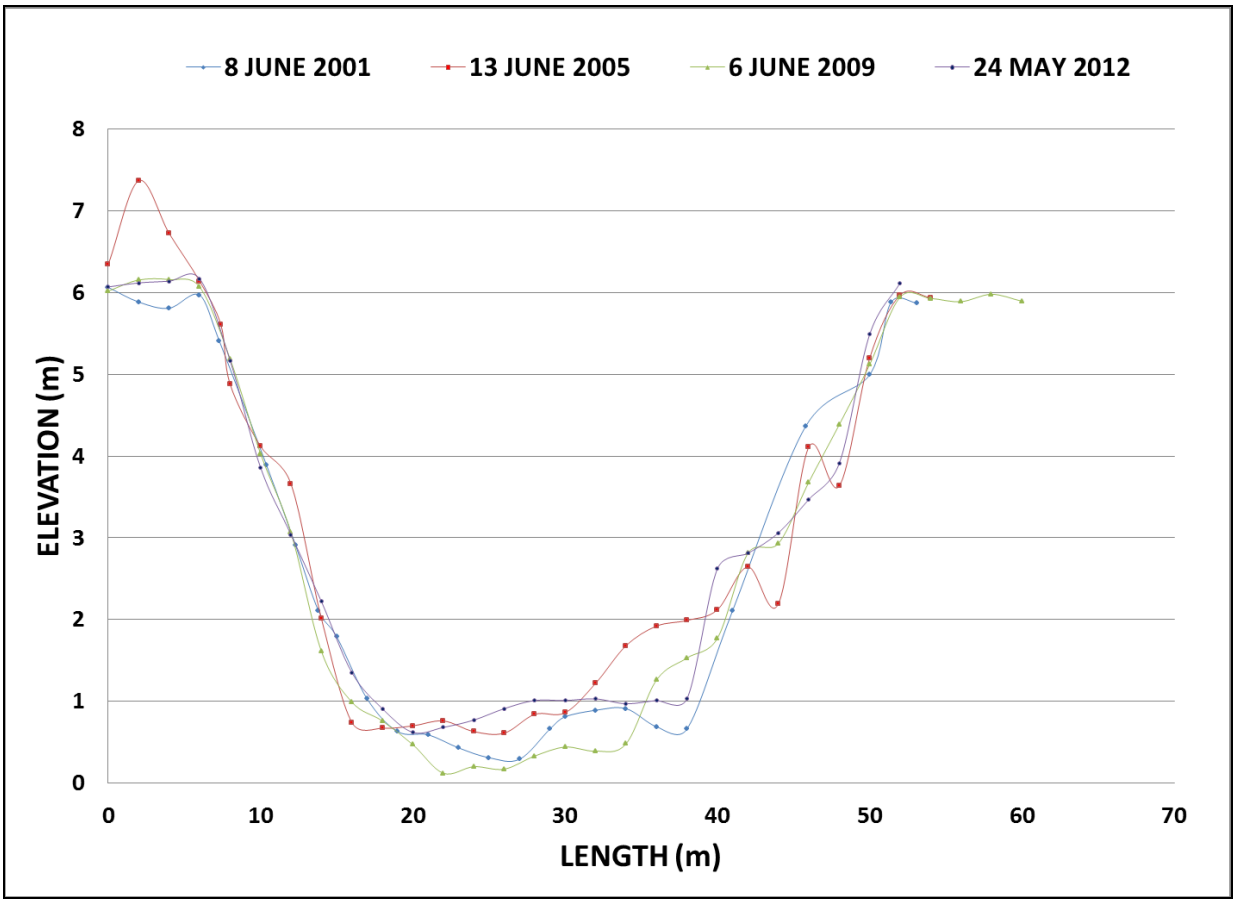


Figure 14: Comparison of Pazhyar river cross-section in different years at Ashramam gauging station

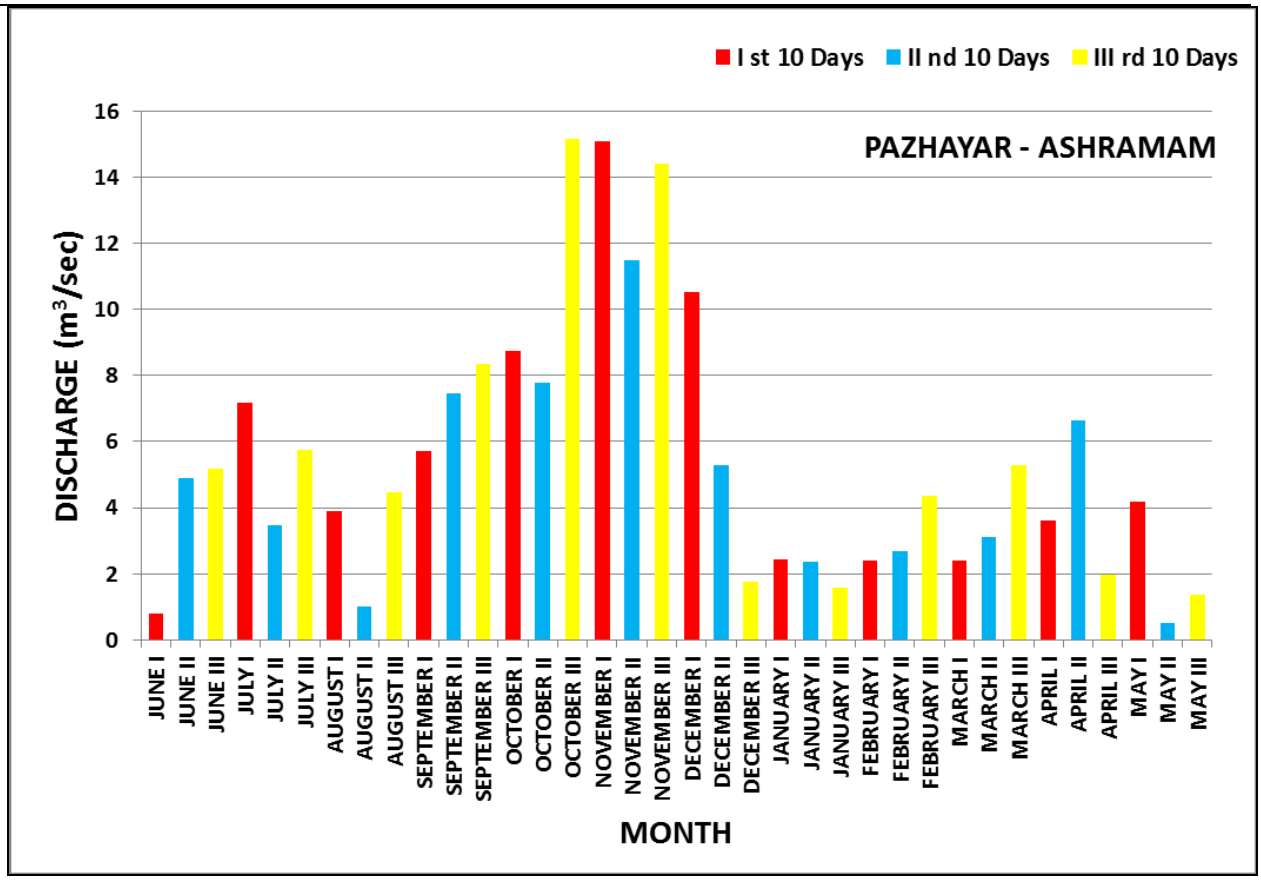


Figure 15: Average 10 daily discharges at Ashramam gauging site on Pazhyar River

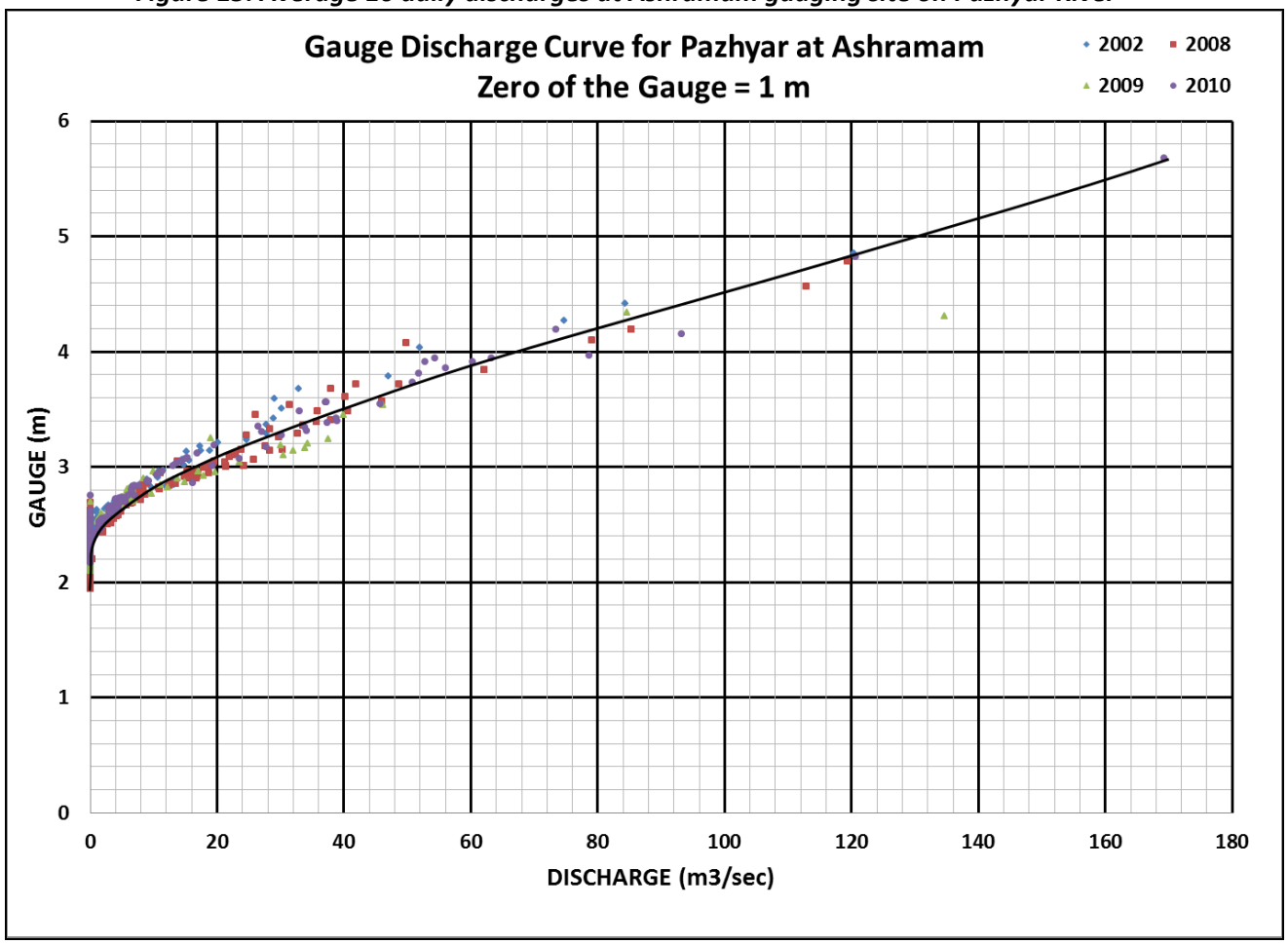


Figure 16: Gauge discharge curve for River Pazhyar at Ashramam gauge station

YEAR	JUNE			JULY			AUGUST			SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER			JANUARY			FEBRUARY			MARCH			APRIL			MAY		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1995-1996	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1996-1997	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1997-1998	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1998-1999	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1999-2000	-	-	-	-	-	-	-	-	-	-	-	1.12	3.41	7.07	10.52	2.89	4.69	3.45	3.22	-	-	-	0.16		6.53	5.66	8.03	0.16	-	-	1.65	-	-	-	-	-
2000-2001	-	-	-	-	-	-	3.13	0.90	22.35	-	0.29	6.93	10.88	3.62	0.62	2.76	1.42	10.41	0.11	-	1.45	3.03	-	0.27	1.21	0.09	-	-	-	-	0.33	8.80	4.73	2.18	-	-
2001-2002	-	-	-	9.17	2.16	0.16	0.56	0.05	0.64	-	3.65	23.63	6.76	2.06	20.20	6.64	14.48	5.64	-	-	-	-	-	0.07	1.57	0.32	0.12	-	-	-	-	-	-	4.36	0.56	-
2002-2003	-	-	-	-	-	-	-	0.04	-	-	-	-	-	0.78	20.90	31.79	11.19	22.62	0.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2003-2004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.90	0.92	0.74
2004-2005	0.05	16.46	0.92	2.39	1.52	0.81	2.41	1.04	0.39	2.83	3.47	19.78	6.34	12.34	8.24	22.27	3.70	1.14	0.06		0.84	2.18	3.40	2.08	1.83	2.81	3.63	1.72	1.43	0.05	10.11	3.39	2.20	0.30	0.05	0.24
2005-2006	1.78	2.54	9.18	8.50	5.30	31.22	11.05	0.34	0.33	10.46	8.20	0.90	3.04	13.68	14.25	15.95	31.20	15.45	8.55	11.19	1.24	4.91	6.71	5.33	4.29	7.02	8.35	7.93	10.08	0.42	-	-	0.65	-	-	0.47
2006-2007	0.23	-	5.26	7.89	1.23	-	-	3.61		0.73	16.23	12.59	4.61	16.15	27.95	27.60	8.30	9.97	2.97	1.50	-	0.91	0.81	0.22	0.32	0.29	1.84	3.67	0.71	0.12	0.18	10.67	1.22	-	-	1.66
2007-2008	-	-	8.88	13.43	1.47	1.63	2.25	-	0.37	2.86	14.50	12.22	3.10	11.64	20.26	26.07	15.10	1.78	1.23	2.51	3.43	-	-	-	0.88	2.72		1.61	1.99	20.59	5.73	3.76		-	-	-
2008-2009	-	-	-	-	-	5.32	-	0.86	7.19	25.22	17.19	-	-	14.91	50.55	15.45	13.31	19.55	10.13	3.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.63
2009-2010	0.76	0.35	-	-	6.59	0.19	-	0.24	2.73	1.99		1.88	12.91	5.48	4.74	12.83	25.92	10.37	-	-	-	-	3.00	-	-			0.15	-	-	-	-	-	-	-	-	-
2010-2011	-	-	-	-	5.49	0.84	-	1.95	1.84	1.12	1.02	2.91	34.71	3.46	4.85	2.71	6.62	45.77	60.36	8.14	-	1.42	0.14	-	-	1.68	6.55	1.69	-	-	-	-	1.06	-	-	-
2011-2012	1.08	0.28	1.64	1.72	3.84	-	-	-	-	0.67	2.51	1.65	1.65	3.74	8.34	25.36	1.99	26.81	18.05	-	-	2.09	-	-	-	3.46	2.08	2.25	1.37	-	-	-	1.90	-	-	-
2012-2013	-	-	-	-	-	-	-	-	-	-	-	-	-	6.28	5.65	4.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MAXIMUM	1.78	16.46	9.18	13.43	6.59	31.22	11.05	3.61	22.35	25.22	17.19	23.63	34.71	16.15	50.55	31.79	31.20	45.77	60.36	11.19	3.43	4.91	6.71	5.33	6.53	7.02	8.35	7.93	10.08	20.59	10.11	10.67	4.73	9.90	0.92	3.63
MINIMUM	0.05	0.28	0.92	1.72	1.23	0.16	0.56	0.04	0.33	0.67	0.29	0.90	1.65	0.78	0.62	2.71	1.42	1.14	0.06	1.50	0.84	0.91	0.14	0.07	0.32	0.09	0.12	0.15	0.71	0.05	0.18	3.39	0.65	0.30	0.05	0.24
AVERAGE	0.78	4.91	5.18	7.18	3.45	5.74	3.88	1.00	4.48	5.73	7.45	8.36	8.74	7.79	15.16	15.11	11.49	14.41	10.52	5.28	1.74	2.42	2.37	1.59	2.38	2.67	4.37	2.40	3.11	5.30	3.60	6.65	1.96	4.18	0.51	1.35

- : Data Not Available & "0" means no discharge

Table 23: Mean 10 daily discharges in cumecs

4.16 Monthly minimum and maximum Water levels

The gauge-discharge data at Pazhyar available from 1995-2012 is analysed in different ways. The monthly minimum and maximum water levels for the entire period of data were taken and are tabulated below.

YEAR	JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY	
	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN
1995-1996	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.9	0.28	0.69	0.17
1996-1997	-	-	1.20	0.29	0.75	0.49	1.08	0.49	3.85	0.52	1.22	0.44	-	-	-	-	-	-	-	-	-	-	-	-
1997-1998	1.71	1.06	1.62	1.16	1.60	1.28	3.78	1.32	1.88	1.25	3.23	1.28	1.82	1.19	1.44	1.18	1.55	1.38	1.62	1.395	1.73	1.51	1.535	1.4
1998-1999	2.12	1.17	1.68	1.26	1.98	1.34	2.25	1.39	4.67	1.29	4.08	1.24	2.45	1.48	1.67	1.33	1.51	1.32	1.45	1.1	1.33	1.01	1.935	1.01
1999-2000	3.78	1.33	2.25	1.41	1.57	1.40	1.76	1.41	2.05	1.60	2.15	1.50	2.15	1.40	1.57	1.42	2.165	1.38	1.6	1.3	1.845	1.02	1.33	1.005
2000-2001	3.13	2.05	2.50	2.20	4.53	2.32	3.09	2.36	3.28	2.33	3.36	2.42	2.79	2.32	2.94	2.39	2.77	2.36	2.47	2.13	3.175	2.12	2.875	2.115
2001-2002	2.44	2.07	3.99	2.18	2.65	2.46	3.82	2.35	3.48	2.43	3.42	2.43	2.43	2.37	2.49	2.36	2.72	2.29	2.58	2.11	2.475	2.08	2.89	2.29
2002-2003	2.36	2.16	2.33	2.22	2.49	2.14	2.36	2.21	4.27	2.11	4.86	2.67	2.57	2.20	2.31	2.19	2.44	2.21	2.38	2.255	2.285	2.18	2.63	2.155
2003-2004	2.36	2.07	2.38	1.97	2.53	1.98	2.47	2.01	2.54	2.07	2.73	2.35	2.62	2.28	2.41	2.19	2.40	2.07	2.23	2.075	2.38	2.155	3.535	2.39
2004-2005	3.76	2.29	2.69	2.34	2.79	2.34	4.19	2.25	3.545	2.5	3.56	2.27	2.57	2.28	2.78	2.53	2.88	2.53	2.69	2.34	4.15	2.35	2.65	2.22
2005-2006	2.86	2.41	4.22	2.49	3.40	2.23	3.25	2.22	3.35	2.41	4.50	2.70	3.55	2.37	2.89	2.49	2.91	2.46	3.16	2.33	2.72	2.24	2.64	2.12
2006-2007	2.98	2.19	3.19	2.27	2.76	2.39	3.60	2.40	4.30	2.45	3.94	2.39	2.76	2.24	2.66	2.32	2.61	2.36	2.74	2.27	3.095	2.19	2.84	2.17
2007-2008	3.36	2.11	3.61	2.35	2.65	2.26	3.48	2.42	3.84	2.19	3.70	2.33	2.80	2.27	2.47	2.22	2.95	2.38	4.078	2.2	2.86	2.27	2.34	2.1
2008-2009	2.26	1.95	3.27	2.04	4.10	2.30	4.19	2.33	4.78	2.24	3.57	2.38	3.14	2.31	2.45	2.37	2.44	2.25	2.5	2.14	2.7	2.13	3.45	2.1

2009-2010	2.62	2.16	3.10	2.19	2.92	2.38	2.77	2.20	4.34	2.31	4.31	2.38	2.52	2.37	2.83	2.38	2.52	2.48	2.5	2.29	2.43	2.265	2.5	2.18
2010-2011	2.49	2.17	3.19	2.23	2.73	2.32	2.83	2.31	2.83	2.31	4.16	2.34	5.68	2.20	2.66	2.30	2.84	2.34	2.52	2.16	2.78	2.11	2.4	2.035
2011-2012	2.51	2.05	2.83	2.29	2.48	2.24	2.68	2.30	3.28	2.40	5.61	2.73	3.78	2.30	3.05	2.29	2.74	2.37	2.75	2.2	2.75	2.11	2.35	2.05
2012-2013	2.28	2.04	2.36	2.19	2.42	2.20	2.43	2.24	3.90	2.27	3.20	2.43	2.51	2.43	2.54	2.27	2.45	2.27	2.38	2.265	2.38	2.2	2.43	2.1
2013-2014	2.52	2.19	2.83	2.31	2.84	2.30	2.56	2.32	2.59	2.30	4.00	2.32	2.74	2.43	2.82	2.23	2.39	2.22	2.53	2.22	2.31	2.11	4.47	2.2
MAX.	3.78	2.41	4.22	2.49	4.53	2.46	4.19	2.42	4.78	2.50	5.61	2.73	5.68	2.43	3.05	2.53	2.95	2.53	4.08	2.34	4.15	2.35	4.47	2.39
MIN.	1.71	1.06	1.20	0.29	0.75	0.49	1.08	0.49	1.88	0.52	1.22	0.44	1.82	1.19	1.44	1.18	1.51	1.32	1.45	1.10	0.90	0.28	0.69	0.17
- Stands for Data Not Available & "0" means no discharge																								

Table 24: Monthly Minimum and Maximum Water levels

4.17 Yearly minimum and maximum Water levels

Below table shows yearly maximum and minimum water levels at Ashramam gauging site.

YEAR	MAXIMUM WATER LEVEL (m)	MINIMUM WATER LEVEL (m)
1995-1996	0.900	0.17
1996-1997	2.850	0.29
1997-1998	2.780	1.06
1998-1999	3.670	1.01
1999-2000	2.165	1.01
2000-2001	4.525	2.05
2001-2002	3.990	2.07
2002-2003	4.855	2.11
2003-2004	3.535	1.97
2004-2005	4.190	2.22
2005-2006	4.500	2.12
2006-2007	4.295	2.17
2007-2008	3.700	2.10
2008-2009	4.783	1.95
2009-2010	4.310	2.16
2010-2011	5.675	2.04
2011-2012	5.610	2.05
2012-2013	3.900	2.04
2013-2014	4.47	2.11
MAXIMUM	5.68	2.22
MINIMUM	0.90	0.17

Table 25: Yearly minimum and maximum Water Levels

Yearly maximum and minimum W.L. for the year 2013-2014 was also worded out as 2.110 and 4.470 m. For calculations, the water year is considered from June to May.

4.18 Chart Datum/ Sounding Datum

As per discussion with IWAI officials, Chart Datum has been taken as following for different reaches

Tidal Reach:

C.D. is taken as C.D. of Muttam Point from Admiralty Tide Table (ATT-Vol 3)

Non Tidal Reach:

A) As per discussion with IWAI officials, Sounding datum in rivers is taken as Average of minimum yearly water level for Last six years *(for which data of maximum period was available in a year*) at Ashramam gauging site. The gauge-discharge data of Ashramam site was collected from CWC. Accordingly, the C.D. at Ashramam G.D. Site has been arrived from years 2004-05, 05-06, 06-07,07-08, 09-10 and 2013-2014:

C.D. at Ashramam G.D. Site = [2.22+2.12 + 2.17 + 2.10 + 2.16 + 2.11] / 6
= **2.147 m say 2.15**

River name	CD Value at the Ashramam Gauge Station	Gauge Station Position	
		Latitude	Longitude
Pazhyar	2.15 meters above MSL	08^0 09′ 33" N	77^0 27′ 33" E

B) In case of Dams/ Bridges/ Barrages/ Check Dam, the C.D. has been taken as Ponding level.

4.19 High Flood Levels

Tidal Reach

In Tidal reach, MHHW at Muttam Point as per Admirality Tide Table (ATT-Vol 3) has been adopted as High Flood Level.

MHHW: 0.7 (w.r.t. C.D.)

MSL : 0.49 (W.r.t. C.D.)

MHHW (w.r.t. M.S.L.) : 0.7 – 0.49 = 0.21 m (w.r.t. M.S.L.)

Non-Tidal Reach

Gauge Sites: High flood levels are computed from last twenty years Gauge discharge data collected from CWC for gauge sites. The maximum water level in last twenty years from the collected data has been adopted as H.F.L.

Maximum flood discharge & HFL (during period of data) were 169 m^3/s and 5.68 m respectively in December 2010.

Frequency Analysis of available yearly maximum flood data using Gumbel distribution indicate following flood discharges for different return periods.

Return Period in years	2	5	10	20	25	50	75	100	200
Discharge (m^3/s)	82.46	117.91	141.39	163.91	171.05	193.05	205.84	214.89	236.66

The 100 year return flood at Ashramam is calculated as 215 m^3/s

4.20 Monthly minimum and maximum Discharge at Ashramam GD site

YEAR	JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY	
	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN
1995-1996	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1996-1997	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1997-1998	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1998-1999	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1999-2000	-	-	-	-	-	-	5.27	0.09	17.49	1.69	17.14	0.53	17.44	0.00	1.57	0.00	19.09	0.00	1.639	0	10.36	0	-	-
2000-2001	-	-	-	-	91.58	0.00	16.02	0.00	24.92	0.00	29.39	0.00	8.95	0.00	12.72	0.00	8.50	0.00	-	-	18.492	0	11.427	0
2001-2002	-	-	63.65	0.00	2.50	0.00	57.42	0.00	41.41	0.00	40.79	0.00	-	-	0.39	0.00	4.55	0.00	-	-	-	-	13.25	0
2002-2003	-	-	-	-	0.39	0.00	-	-	74.77	0.00	120.38	3.41	1.50	0.00	-	-	-	-	-	-	-	-	-	-
2003-2004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2004-2005	56.65	0.00	4.08	0.00	6.79	0.00	68.80	0.00	35.703	0.928	0.00	0.00	1.46	0.00	4.68	1.14	6.53	1.11	3.205	0	44.07	0	2.614	0
2005-2006	13.02	0.00	72.37	2.17	34.28	0.00	33.11	0.00	34.42	1.17	103.90	6.95	37.17	0.00	10.23	1.87	12.61	0.00	19.77	0	6.528	0	5.183	0
2006-2007	18.61	0.00	23.29	0.00	6.87	0.00	39.76	0.00	79.28	1.01	57.43	0.48	8.18	0.00	4.42	0.00	3.73	0.00	7.504	0	20.324	0	11.752	0
2007-2008	32.53	0.00	36.99	0.00	4.83	0.00	39.18	0.42	45.87	0.00	51.73	0.00	7.70	0.70	-	-	11.16	0.00	49.798	0	9	0	-	-
2008-2009	-	-	24.61	0.00	79.06	0.00	85.28	0.00	119.32	0.00	46.02	0.00	28.30	0.00	-	-	-	-	-	-	-	-	39.88	0
2009-2010	3.84	0.00	30.46	0.00	17.91	0.00	9.69	0.00	84.65	0.00	134.60	0.00	-	-	6.73	0.00	-	-	1.545	0	-	-	-	-
2010-	-	-	19.56	0.00	5.03	0.00	6.97	0.00	73.44	0.00	93.20	0.00	169.34	0.00	5.54	0.00	10.29	0.00	2.823	0	4.09	0	-	-

2011																							
2011-2012	3.48	0.00	9.96	0.00	-	-	4.37	0.00	18.85	0.00	113.45	0.00	42.06	0.00	15.53	0.00	4.97	0.00	5.031	0	5.086	0	-	-
2012-2013	-	-	-	-	-	-	-	-	59.83	0.00	25.75	0.00	-	-	-	-	-	-	-	-	-	-	-	-
MAXIMUM	56.65	0.00	72.37	2.17	91.58	0.00	85.28	0.42	119.32	1.69	134.60	6.95	169.34	0.70	15.53	1.87	19.09	1.11	49.80	0.00	44.07	0.00	39.88	0.00
MINIMUM	3.48	0.00	4.08	0.00	0.39	0.00	4.37	0.00	17.49	0.00	0.00	0.00	1.46	0.00	0.39	0.00	3.73	0.00	1.55	0.00	4.09	0.00	2.61	0.00
- Stands for Data Not Available																								

Table 26: Monthly Minimum and Maximum Discharges in Cumecs at Ashramam GD site

4.21 Yearly minimum and maximum Discharges

YEAR	MAXIMUM DISCHARGE (m^3/sec)	MINIMUM DISCHARGE (m^3/sec)
1995-1996	-	-
1996-1997	-	-
1997-1998	-	-
1998-1999	-	-
1999-2000	19.09	0.00
2000-2001	91.58	0.00
2001-2002	63.649	0.00
2002-2003	120.379	0.00
2003-2004	-	-
2004-2005	68.797	0.00
2005-2006	103.90	0.00
2006-2007	79.277	0.00
2007-2008	51.73	0.00
2008-2009	119.32	0.00
2009-2010	134.60	0.00
2010-2011	169.335	0.00
2011-2012	113.447	0.00
2012-2013	59.829	0.00
MAXIMUM	169.34	0.00
MINIMUM	19.09	0.00

Table 27: Yearly minimum and maximum Discharges at Ashramam GD site

- ***Stands for Data not available***

5. Preliminary Traffic studies and Market Analysis

This chapter deals with the status of land use pattern, crops, agriculture existing industries, cargo, jetties and terminals, passenger ferry services along the river route.

5.1 Land use Pattern along waterway

The figure shows nearby talukas alongside Pazhyar River:

Figure 17: Pazhyar River and its nearby Talukas

5.1.1 Land Utilization Pattern along waterway

In Kanyakumari district, over 47% of the total area is net sown area. The state has more than 32% of land as forests. The forests in Kanyakumari are virgin forests and are believed to be over 75 million years old. Land for non-agriculture uses constitutes 16% of the total land in the district. Kanyakumari district has very less uncultivable barren land and fallow lands, at roughly 2% each.

Based on topographic conditions, the land in the district can be classified into three areas. The Uplands include hills and hill bases. The middle region comprises of plains and valleys. And the lowlands comprise of a coastal belt. The average size of land holdings in Kanyakumari district is 0.21.9 hectares.

	(Areas in Ha.)
District	**Kanyakumari**
Forest	54,155
Non Agriculture	26,890
Net Sown Area	79,323
Uncultivable Barren Land	3,149
Fallow lands (current & other)	2,969
Permanent and grazing land	133

Land under misc., tree crops and	581
Total Area	167,200

Table 28: Land use Pattern of District along the Pazhyar River

5.1.2 Kanyakumari

Kanyakumari district is a coastal district situated at the southernmost tip of Tamil Nadu. It has a total coastal length of 68 km. It is the smallest district in Tamil Nadu with a total geographical area of 1,684 sq. km. It is less than 2% of the total geographical area of Tamil Nadu. It is bounded by Thiruvananthapuram district of Kerala in the west. Tirunelveli district lies in north-east. Gulf of Mannar flows in the south-east and Indian Ocean forms the southern border of the district. Western Ghats are located in the west of the district. The forest area accounts for more than 30% in the district. The soil can be classified into five categories – Red Soil, Red laterite soil, Brown soil and Coastal sand.

5.2 Crops/Agriculture in the region

The annual rainfall over the district varies from 826 to 1456 mm. The area receives precipitation mostly from north-east monsoons which contributes to 44% of the total rainfall. South-west monsoons contribute 30% of the total rainfall in the district. The rest of the 26% is sparsely distributed throughout the year. The south eastern part receives the lowest precipitation. It gradually increases as we move towards west, north and northwest. Principal rivers flowing through the district are Pazhayar, Tambaraparani, Valliyar, Ponnivaikal and Paraliyar.

Kanyakumari accounts for 95% of natural rubber production of the state. Rubber is mostly grown in the hilly region of the Western Ghats. Paddy is the other major crop grown on the slopes and plains of the district. Coconut, tapioca, banana, cashew, cloves etc. are also grown in abundance. There are 1310 ago- based food industries in Kanyakumari District. Of these 933 industries are found in rural areas.

Crops	Area in hect.
Paddy	40,000
Coconut	21,000
Rubber	19,400
Tapioca	12,300
Banana	5,000
Pulses	3,000
Cashew	2,000
Mango	1,700
Palmyrah	1,600
Tamarind	900
Jackfruit	700
Cloves	500

Table 29: Major Crops cultivated in the districts

5.3 Availability of Bulk / Construction Material

River transportation would be viable for movement of bulk commodities like coal and minerals. Coal is a major import commodity from Tamil Nadu ports. Kamarajar Port and VOC Port act as gateway for import of indigenous and foreign coal to the state. Major share of the coal is consumed in the power plants located in the state. Tamil Nadu is a mineral rich state. There is abundant reserve of limestone, rough stone, silica and granite in the state. There is huge volume of export of minerals from VOC Port. The minerals are mostly sourced from the southern part of the state. They are exported to Maldives, Sri Lanka and other South East Asian countries.

5.3.1 Minerals

The map given below shows the location of minerals of Kanyakumari with respect to Pazhyar River as well as the port infrastructure of Tamil Nadu. Mines located closer to rivers would have potential for shift of minerals to river route from existing road route

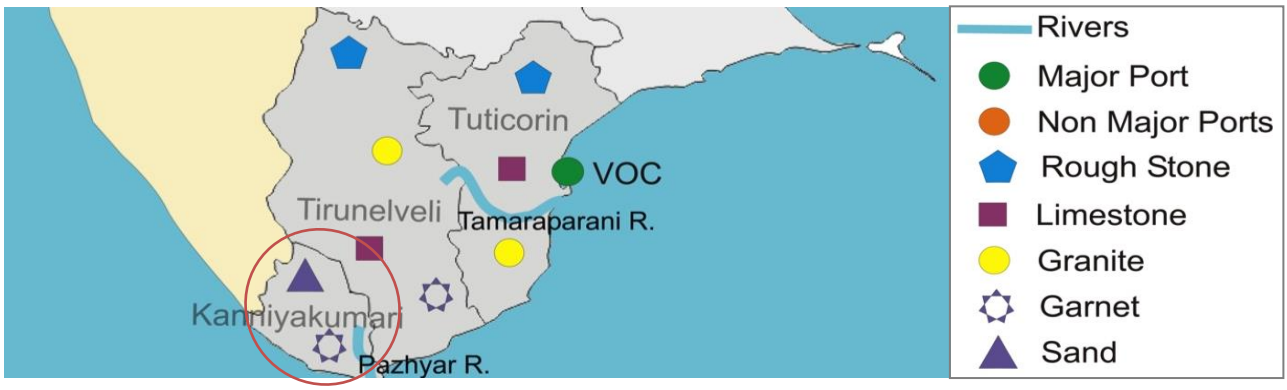


Figure 18: Minerals exported from Tamil Nadu

Major minerals found in the district are Ilmenite, gravel, rough stone and garnet. Other minerals like monazite, rutile, and granite are also found in substance.

Category	Mineral	Production in (M. T)
Major Minerals	Ilmenite	70,000
Minor Minerals	Monazite	12
	Zircon	3,300
	Rutile	960
	Garnet	35,060
	Rough stone and Jelly	6,963,586
	Granite	58
	Gravel/Earth	1,004,469

Table 30: Production of minerals in Fy'11

There is limited industrialization in the district. There are two industrial areas in the district located at Konam and Marthanda. Konam industrial area is spread in a span of 21 acres with 40 units operating in the area. Marthandam is relatively small with

mere 8 units in operation. Konam is located at a distance of 8 km from Pazhayar River while Marthandam is about 30 km from the river.

The table given below describes location of mines with respect to the VOC port exporting the commodities and the river flowing closer to VOC Port.

Minerals	Production	Distance from Industrial Area (Km)			Opportunity	Reasoning
		To River	River-Port	Direct to Port		
Sand	70,000	5	125	140	May be	High Volume, Difference between roadways and waterways is less
Garnet	35,060					
Rough Stone	6,963,586					
Granite	58					
Granite	NA					

Table 31: Minerals production and opportunity for river movement in Kanyakumari District

a) Sand

Tiruchirapalli is the major centre for sand excavation in Tamil Nadu. Kancheepuram district has a reserve of about 4.5 mntonnes of river sand. Nagapattinam district contains nearly 5 mntonnes of silica sand reserve. Most of these are transported to Maldives by sea. Kanyakumari majorly produces ilmenite sand. It accounts for about 70,000 tonnes of production every year. Ilmenite is majorly used in production of Titanium di oxide. Europe and North America are the major consumers of Titanium di oxide. China and India are growing rapidly as consumers of the compound. Ilmenite can be transported to VOC Port. The mineral can be loaded into barges in Pazhyarriver and transported via coastal waterways to VOC Port.

b) Garnet

Radhapuramtaluka is Tirunelveli district is famous for its garnet production. There are 53 mining sites located in the taluka, which produce close to 1.1 mntonnes of the mineral every year. However, it is located far from the river and hence river transportation cannot be utilised for movement of the mineral. Kanyakumari also produces substantial volume of minerals. These can be transported via Pazhyar river to VOC Port through coastal waterways.

c) Rough Stone

Rough stone is the other major mineral exported from VOC Port. This is majorly concentrated in Kanyakumari, Tuticorin and Tirunelveli districts. These are located close to VOC Ports. Tuticorin minerals cannot be transported by river as the mineral deposits are located close to the port. The rest can be transported directly to the port via roadways. Kanyakumari has huge reserves of rough stone. Coastal movement of these can be considered, as the difference between roadways and waterways is quite less.

Other places, which have deposits of rough-stone, are Namakkal, Erode, Karur, Tiruvannammalai and Tiruchirapalli. However, the volume of production from these places is quite low which does not make feasible to be transported to the ports via waterways.

5.4 Existing Industries along Waterway

The industrial areas in Tamil Nadu are located in the hinterlands far off from the ports. The industries transport their cargo via roadways to the ports in the states. The objective of the study is to show the linkage of industrial areas located on the banks of the rivers in Tamil Nadu and Andhra Pradesh with the ports in the states via waterways. In this section, we shall discuss the strategic location and infrastructural advantages of the ports in brief and analyse the amalgamation of river routes with these ports. Length of the Pazhyar river discussed in the study is too short.

Industrial Area	Land Acquired (acres)	No of Plots	No of Units
Konam	21	47	40
Marthandam	8	18	8

Table 32: Major Industrial Areas in Kanyakumari

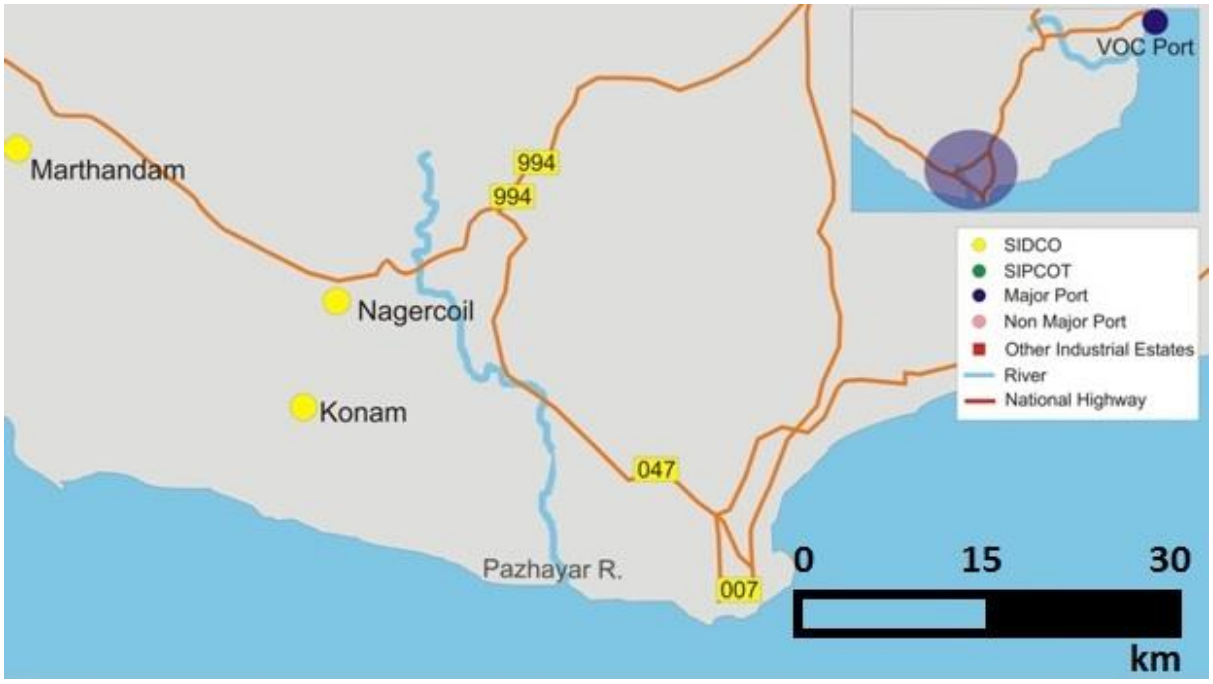


Figure 19: Port connectivity of Major Industrial Clusters via Pazhyar River

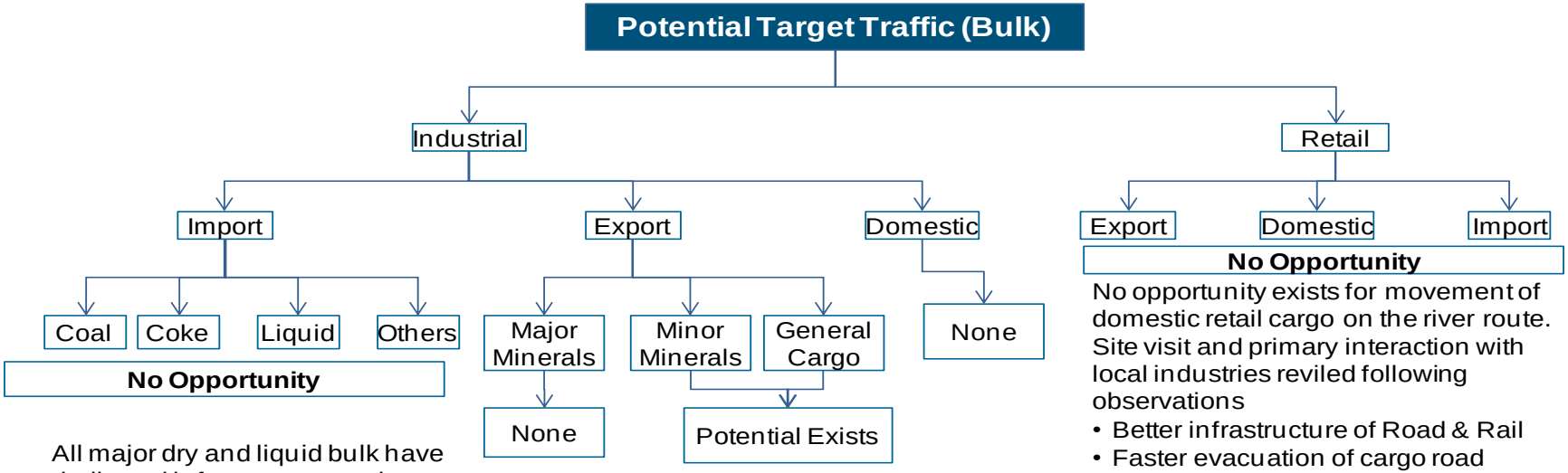
District	Industrial Area	Distance from Industrial Area (km)			Opportunity
		To River	River - Port	Direct to Port	
Kanyakumari	SIDCO, Konam	8	140	138	May be
	SIDCO, Marthandam	30	145	160	May be

Table 33: Distance Comparison between Roadways & Waterways (Pazhyar River)

The industries located on the banks of rivers in South India could have generated business potential for waterways movement. However, absence of water around the year along with well-developed road infrastructure has rendered waterways commercially less attractive for transportation. All the commodities traded on the coast as well as overseas trade was studied. It was found that the majority of trade using VOC Port uses roadways for last mile connectivity on land. One of the primary regions for this has been the development of large industrial base around Port. Following section broadly describes commodities breakup of VOC Port and evaluates their potential to use river for Inland connectivity.

Commodity	Volume (MN T)	Attractive	Reasoning
Pol & Other Products	0.6	No	Most of the consumption centers are located in surrounding areas. Liquid commodities evacuated from port using pipeline cannot be shifted
Edible Oil	0.3	No	Movement of liquid cargo is not possible, 100% goes by road
Fertilizer & FRM	1.5	No	
Coal	8.6	No	Thermal power plants are located adjacent to port. Evacuations of coal to these power plants are undertaken using Conveyors. A large volume of coal, about 3 million tonnes is evacuated to industries using railways. These industries are located away from Pazhyar River. Hence, it is not possible to transport coal using river waterway.
Containers	11	No	Containers movement on river is not viable.
Others	10.4	Yes	Potential exists for minerals & boulders which are minor & fragmented segment. A large volume of stones, boulders, etc. could be transported using River Sea Class ships in the Pazhyar River to VOC Port. Presently, about 1 million Tonnes of these commodities are transported to VOC port using road route to Zone B of port. The Zone B of VOC Port is an old port located closer to city. About 1 million Tonnes of cargo is available annually.
Total	32.4		

Table 34: Opportunity for river movement of commodities handled at VOC Port



All major dry and liquid bulk have dedicated infrastructure and evacuate imported industrial cargo to its user factories.

Import of other general cargo is not possible to shift as the volume of import is small.

- Potential exists for export of minor minerals and general cargo if water depth is maintained in Tamaraparani river. Mouth of river is close to port and river belt has substantial share of mineral products that are mostly exported to Maldives using small vessel.

No opportunity exists for movement of domestic retail cargo on the river route. Site visit and primary interaction with local industries reviled following observations

- Better infrastructure of Road & Rail
- Faster evacuation of cargo road
- No water in river
- Uncertainty over river transportation

Retail cargo is fragmented in nature. Low volume cargo, does not generate optimum mass for river movement to make it commercially viable.
The frequency of movement for retail cargo is also uncertain. River transport is commercially attractive for large volume of cargo with periodic movement.

Hence, shifting of retail cargo from Road to river is not possible.

Figure 20: Potential Trade Traffic for Bulk Commodities

5.5 Existing Jetties and Terminals (with conditions and facilities)

5.5.1 VOC Port

VO Chidambaranar Port is an artificial all weather port located in Tuticorin district. It is one of the three major ports in the state. The strategic location of the port lies close to East-west international sea route. It has an annual handling capacity of 45 million tonnes. It acts as a gateway to South India, predominantly Tamil Nadu and Kerala. The port chiefly caters Dry bulk and containerized goods. The port handles close to 0.6 million containers for its own hinterland. Most of the containers are destined to locations in south of the state. A large part of it can be diverted to the river routes.

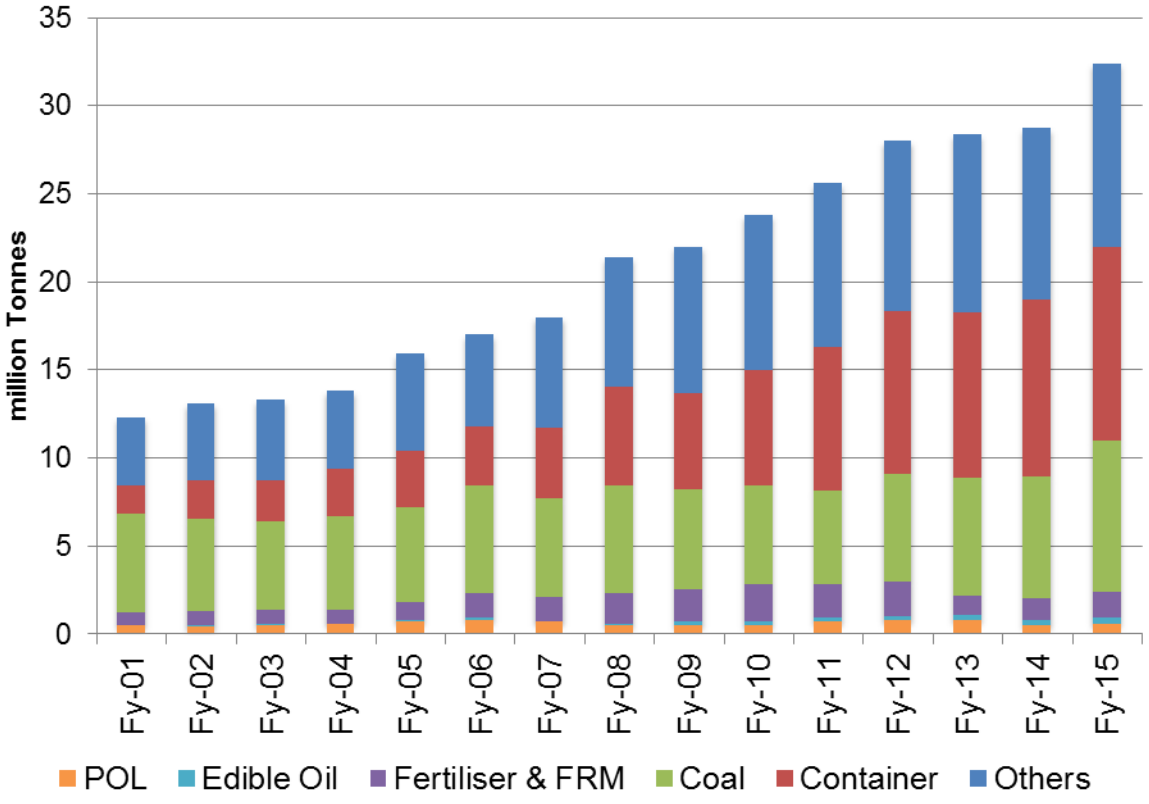
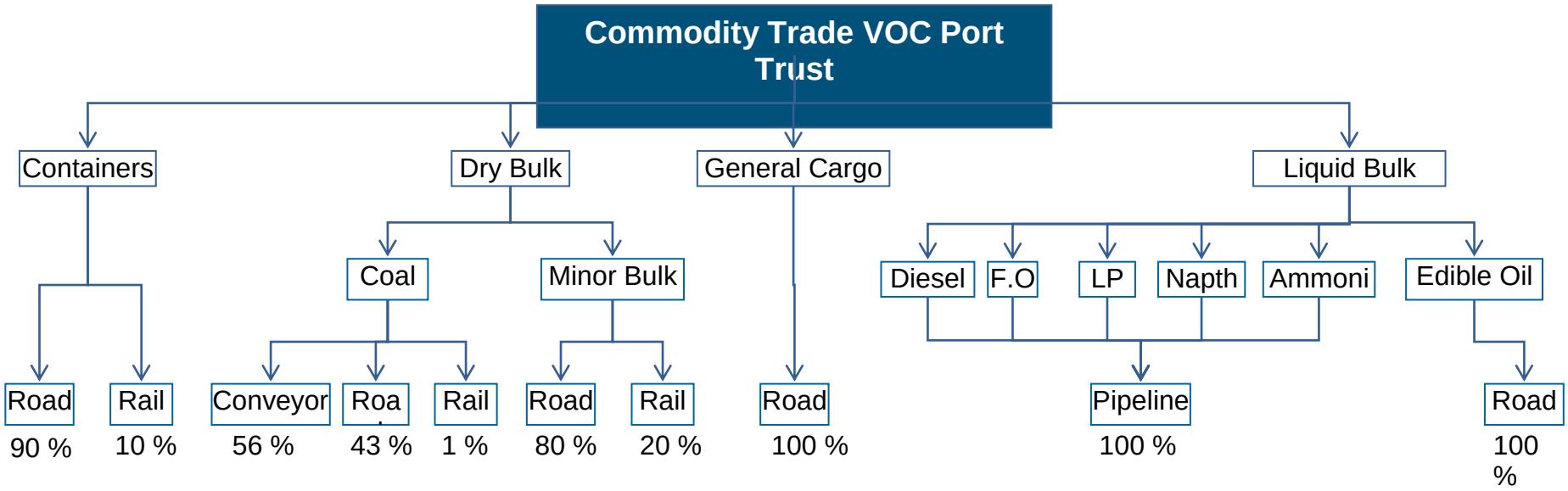


Figure 21: Commodity wise cargo growth of VOC Port



Opportunity for shifting cargo from land to waterways predominantly for commodities that are mostly carried by Road movement. Due to multiple handling involved in moving cargo using Multi-Modal route shifting cargo of Rail route to waterways becomes challenging. Especially, Railways has well developed infrastructure till the final destination. On the other hand, river does not have penetration to the final landing point for cargo.

Similarly, Cargo that are evacuated from port using conveyor mode or pipelines cannot be shifted to waterways. All liquid commodities, mostly petroleum products, are transported using pipelines. There is a set infrastructure for the same. Hence, it would not be possible to shift them.

As can be seen in the above flow chart, there exist potential to shift minor bulk cargo and general cargo using river route.

Figure 22: Commodity Wise Mode of Transportation Used

Following chart shows movement of cargo by various modes of transportation from VOC Port to the hinterland.

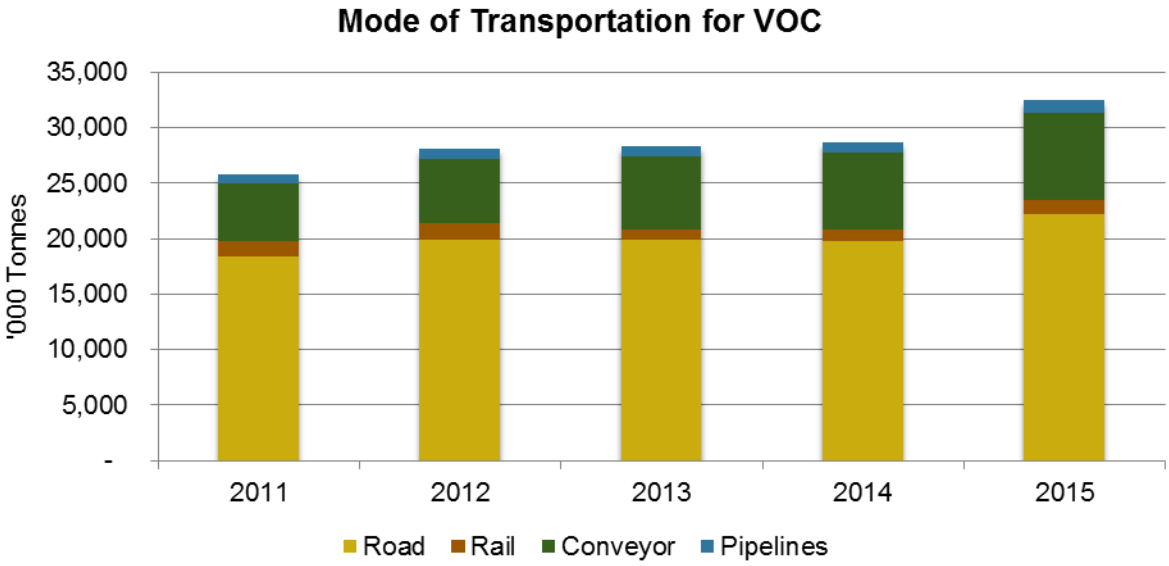


Figure 23: Various Modes of Transportation

Majority of the bulk commodities handled at VOC Port Trust is located close to port. VOC is predominantly bulk and container port with very less share of liquid cargo. There exists large power plant in port limits. Transportation of imported coal to these power plants is undertaken using conveyor belt. Hence, no opportunity exists for shift of cargo to river route.

Petroleum products are handled and later evacuated using pipelines. Most of the consumption centres for petroleum products are located in surrounding areas. Hence, it does not generate any opportunity for river transportation. The port has a well-developed pipeline infrastructure for distribution of imported petroleum products in the hinterland. The existing capacity of pipelines is adequate to accommodate future expansion and cargo growth for VOC Port Trust.

Among liquids, VOC Port imports more than 250,000 tons of edible oil annually. The distribution of edible oil to the local refineries takes place using the roadways. Most of the edible oil refineries are located on the northern side the port in the radius of 200 km. Hence, it becomes logistically challenging to use waterways for transportation of these commodities. It takes a maximum of 3 hours to 4 hours for imported edible oil to reach edible oil refineries. Use of waterways to reach last mile connectivity would deal final delivery of edible oil to the refineries. Hence, shifting of Edible oil to river route is not possible.

All the industrial zones located around rivers use containers for movement of their products. The road infrastructure for movement of containers is found to be very

efficient. Finished products for export are sent to port directly from the factory using roadways. Hence, the users of industries in the hinterland did not show any interest in shifting their products to river route. The first apprehension for them was absence of water in the river. Even if minimum depth of water available is ensured, the companies are not keen to shift to river route for container cargo.

Coal movement from VOC is either using Conveyor belt or railways. VOC port has large power plants in its port limits. Hence, Coal does not offer any opportunity for VOC. Industrial coal is transported using railway. The location of power plants is far away from VOC port Trust. Hence, movement of Coal for industrial use using Pazhyar River is not possible.

5.6 Preliminary traffic identified – within 50km

VOC Port is located at a distance of 136 km from the mouth of Pazhyar River. There are two prime industrial locations in Kanyakumari district. One of them located at Konam is at a mere distance of 8 km from the river. The other located in Marthandam is 30 km away from the river. However, the waterway transportation via river and coastal waters is less than 150 km. There is a little difference between the waterways length and road route to VOC Port which can be neglected. Coir and fishnet is majorly exported from the state. Rough stone and gravel is produced in huge amount. These can be transported to VOC port via rivers. Detailed assessment on the potential is described in the later part of section. Following chart shows reasoning behind not considering smaller rivers for transportation

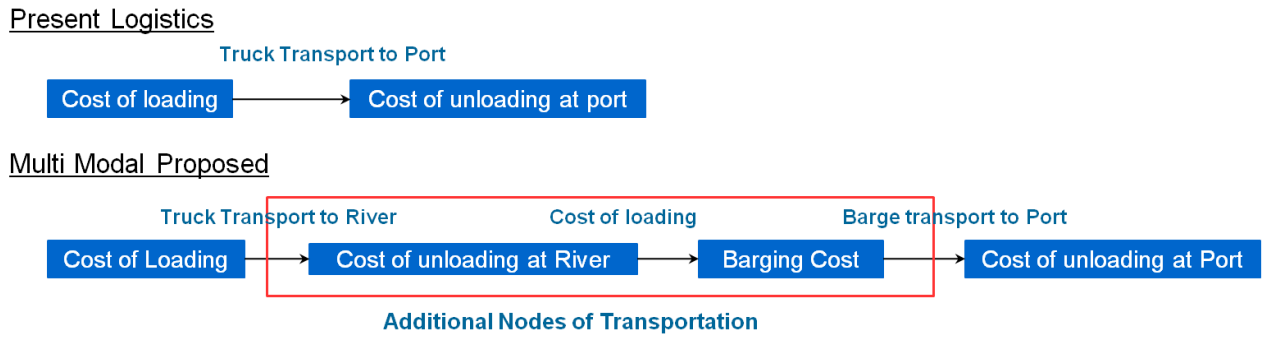


Figure 24: Present logistics and proposed Multi Modal Logistics

Shifting of trade to Pazhyar River from land route Multimodal logistics involves multiple handing at various nodes of transportation. Hence, a substantial share of cost saved by river route compared to land route gets offset by the multiple handing at additional nodes of transportation. Ideally, the shift is commercially viable when after shifting cargo from land route to waterways route, more than 75% of the cargo is moved using waterways and only 25% of the cargo is moved using roadways.

In the present case, due to smaller length of Pazhyar River, it is commercially less attractive to shift cargo to river from land route. The maximum distance travelled in

the river leg would constitute about 20 km. Additional distance of about 140 km would be travelled using waterways from river mouth to VOC Port. The total distance travel using Multimodal transportation including river would be closer to the land distance. There is no savings in the distance travelled by cargo using river route but in other case evacuation of rough stone is undertaken through land route presently. These land routes passes through congested cities. Hence, potential may exists for shift of cargo in Tamil Nadu from land to river route. River could be evaluated to compliment ports in evacuating cargo to the Port. Road is considered to be most expensive mode of transportation with uncertainty in delivery of cargo due to congestion at Road. Hence, the potential to shift cargo from Road to Rivers would be maximum in case of road.

5.7 Existing cargo movement

At present there is no Cargo movement on Pazhyar River. All the industries located near river prefer transporting their goods directly to VOC port by roadways which is time-saving.

Following table describes potential for cargo movement in the Pazhyar River of Tamil Nadu.

River	Commodity	Port	Production ('000 tonnes)	Volume ('000 Tonnes)	Reasoning
Pazhyar	Tourism	NA	NA	NA	Mineral deposits located in districts close to river
	Rough stone	VOC	6,964		

Table 35: Potential Opportunity for Pazhyar River of Tamil Nadu

However, industries very close to river can transport their goods using Pazhyar River to VOC port rather than going by road. Distance difference between waterways & Roadway from industrial centers to the port is very less. Hence shifting from roadways to river is commercially viable.

5.8 Prominent City / Town / Places of Worship / Historical places for Tourism

Pazhyar River passes through the Kanyakumari district.

Kanyakumari is a popular tourist spot, known across the world. The district is known for its clean beaches, huge hills, and pristine rivers. The district is also famous for its architectural culture, which brings together the architectural history of Tamil Nadu and neighbouring Kerala.

Some of the popular tourism spots in Kanyakumari are -

Vivekananda Rock Memorial

A highly popular tourist spot, this memorial was built to commemorate the visit of Swami Vivekananda during 1892. Even before the memorial came into existence, the rock was considered a sacred place from ancient times.

Thiruvalluvar Statue

Thiruvalluvar is a famous poet of Tamil Nadu, and this statue has been built in his honour and memory. The entire structure has a height of 133 feet, with its pedestal being 38 feet tall and the statue over it being 95 feet tall. The statue was built in the year 2000.

Mahatma Gandhi Memorial

In the year 1948, Mahatma Gandhi's ashes were immersed in the waters in Kanyakumari. This memorial, built in 1956, is a tribute to the father of the nation. The structure has a height of 79 feet.

Sthanumalayan Temple

This is a very important pilgrim centre in Kanyakumari. It's one of the only places in the country where the Trinity -- Brahma, Vishnu and Ishvara -- are worshipped.

Beaches

There are several beaches in Kanyakumari. The main beach is Kanyakumari beach, one of the most popular tourist spots in the district. The beach is famous for its sunrise and sunset. The beautiful sand at the beach makes it an ideal choice for sun bathing.

Apart from the Kanyakumari beach, the other notable beaches in the district are Sanguthurai beach, Thengapattinum beach, Shotharilal Beach, and Muttom Beach.

Padmanabhapuram Palace

This is a majestic old palace, which once used to be the capital of the rulers of old Travancore. The palace was built in around 1601 A.D. The highlights of the palace are the 17th and 18th century wall paintings, carved mahogany ceilings, and secret underground passages. The palace also has a durbar hall, a museum, granite dance hall and other attractions of the ancient era.

Our Lady of Ransom Church

This 100-year old church was built in 1914. The church has a height of 153 feet, length of 153 feet and breadth of 53 feet. People believe St. Francis Xavier visited this place in 1542.

Mathur Aqueduct

One of the highest and longest aqueducts in South Asia, Mathur Aqueduct is a popular tourist spot in the district of Tamil Nadu. It was built in 1966. It is a popular tourist attraction, because from the centre of the Aqueduct, one can see a huge expanse of greenery, with the Pahrali River flowing below.

5.9 Availability of Passenger Ferry Services

Ferry M.L. Vivekananda has been operating on the Kanyakumari Boat Jetty to Vivekananda Rock Memorial route since 2013. Each year, nearly 15 lac passengers are ferried on this route.

Apart from M.L. Vivekananda, two more ferries, M.L. Gugan and M.L. Pothigai, operate for ferrying tourists from Kanyakumari. Each of these ferries has a seating capacity of 150 seats.

Based on 2014 data, every day nearly 20,000 tourists visit Kanyakumari between November and February. However, only 3,000 tourists are able to transport from Vivekananda rock and Tiruvalluvar statue.

Development of waterway will increase the tourism and passenger ferry services.

5.10 Available and probable Water Sport Recreational Facilities

Thengapattinam Beach in Kanyakumari is a popular spot for water sports like boat riding and yachting.

In February 2016, there was a news report about the state government of Tamil Nadu developing Kanyakumari & Muttom lighthouses. According to a senior tourism official, the projects will provide recreation facilities like water sports, light and sound shows and resorts as attractions for tourists.

6. Observations, Inferences and Conclusions

6.1 Waterway

The total length of the river under present studies is detailed below:

20 km length of the river from Bridge near Veeranarayana Mangalam village to confluence with Arabian Sea at Manakudi (NATIONAL WATERWAY 77)	**From: 8°13'48.97"N77°26'27.34"E**	**Up to: 8°5'15.01"N77°29'7.61"E**

6.2 Length

The length of waterway under present studies under consideration is 20km.

6.3 LAD

Stretch (KM)					
LAD (m)	**0 - 4.56**	**4.56 - 10**	**10.0-15.0**	**15.0 - 20.0**	**Total**
<1.0	1.29	4.27	1.96	1.46	8.98
1.0-1.2	1.04	0.56	0.28	0.29	2.17
1.2-1.4	0.63	0.16	0.16	0.45	1.41
1.4-1.7	0.64	0.17	0.16	0.21	1.18
1.7-2	0.47	0.08	0.43	0.08	1.06
> 2.0	0.39	0.23	2.08	1.99	4.69

Table 36: LAD for Pazhyar River

6.4 Cross-Structures

Nos.	**Horizontal clearance**	**Vertical clearance**
Five existing road bridges, two rail bridges and one pipeline bridges crosses Pazhyar river.	Varying from 6.0 to 30 meters	Varying from 1.0 to 5.0 meters
High Tension and Electric Lines		
Nos.	**Horizontal clearance**	**Vertical clearance**
3 HT lines and 5 electric lines crosses Pazhyar River	Varying from 200 to 350 meters	Varying from 1.0 m to 30 meters

Table 37: Details of Cross Structure on River

6.5 Water availability

Results of analysis of data for assessing period of availability (% days in year) for different discharge ranges is presented in Table 36. Percentages of days in year for availability of discharge at this gauge site in excess of certain values is presented on a plot in figure 25.These results indicate the following:

Sr	Discharge (m^3/s)in excess of	Availability period in % days in year	Estimated depth from gauge and river cross section
1	5 (m^3/s)	16 % (57 days in year)	1.60 m
2	10 (m^3/s)	10 % (36 days in year)	1.80 m
3	20 (m^3/s)	4.5 %(16 days in year)	2.10m
4	40 (m^3/s)	1.3 % (5 days in year)	2.50m

Table 38: Water availability in Pazhyar River

From the above table the discharge in excess of 5 cumecs occurs for 16% days of a year, similarly the discharge in excess of 10, 20 and 40 cumecs having occurrence 10%, 4.5% and 1.3% days of a year respectively. The estimated depth from gauge and river cross-section varies from 1.60m to 2.50m. In other words, for about 300 days in a year, the discharge is less than 5 cumecs.

Table 40 represent a range of discharges occurring for a no of days in a year. As there are various gaps in the available data, therefore in above years the total days does not add up to 365. The daily gauge discharge data has been collected from CWC. The table shows the availability of ranges of discharge and their occurrence in days in each particular year.

No of Days / Years	Range of Discharge (m^3/s)												
	0 to 2	2 to 5	5 to 10	10 to 20	20 to 40	40 to 60	60 to 80	80 to 100	100 to 120	120 to 140	140 to 150	150 to 200	200 to 500
1995	-	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-	-
1997	-	-	-	-	-	-	-	-	-	-	-	-	-
1998	-	-	-	-	-	-	-	-	-	-	-	-	-
1999	51	24	16	11	0	0	0	0	0	0	0	0	0
2000	292	18	29	17	8	1	0	1	0	0	0	0	0
2001	288	15	21	24	13	3	1	0	0	0	0	0	0
2002	315	10	11	16	8	2	1	1	0	1	0	0	0
2003	365	0	0	0	0	0	0	0	0	0	0	0	0
2004	270	40	21	19	12	3	1	0	0	0	0	0	0
2005	160	81	54	41	22	4	2	0	1	0	0	0	0
2006	182	48	71	40	20	2	2	0	0	0	0	0	0
2007	233	55	24	26	22	5	0	0	0	0	0	0	0
2008	244	33	25	27	24	6	3	2	2	0	0	0	0
2009	294	28	24	8	8	1	0	1	0	1	0	0	0
2010	277	32	18	12	13	6	4	1	0	1	0	1	0
2011	266	55	22	8	8	3	1	0	2	0	0	0	0
2012	327	29	5	2	2	1	0	0	0	0	0	0	0
2013	151	0	0	0	0	0	0	0	0	0	0	0	0
N	3715	468	341	251	160	37	15	6	5	3	0	1	0
ƐN	5002												
% occurrence	74.27%	9.36%	6.82%	5.02%	3.20%	0.74%	0.30%	0.12%	0.10%	0.06%	0.00%	0.02%	0.00%

Table 39: Availability for days for discharge in different range at Ashramam gauge station on Pazhyar River

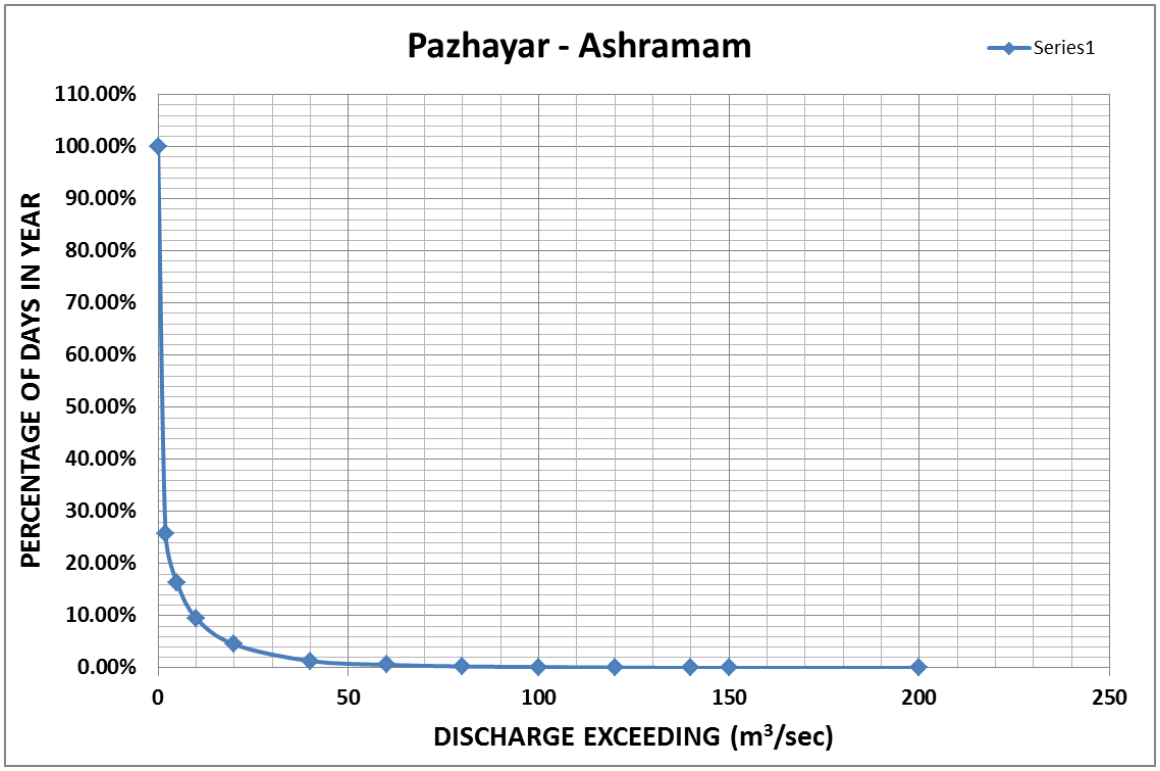


Figure 25: Period of exceedance of discharge in percentage of days in year for Pazhyar River at Ashramam gauging station

6.6 Cargo / Passenger / Tourism / Ro-Ro Facility

From figure 20, it can be seen that potential exists for minerals, boulder-sand general cargo which are minor & fragmented segment. Mouth of the river is about 100 km from VOC port (Tuticorin) and River has substantial share of minerals products that are mostly exported to Maldives using small vessels. A large volume of stones, boulders, etc. could be transported using River Sea Class ships in the Pazhyar River to VOC Port. Presently, about 1 million tonnes of these commodities are transported to VOC port using road route to Zone B of port.

There exist potential to shift minor bulk cargo and general cargo using river route. Industries very close to river can transport their goods using Pazhyar River to VOC port rather than going by road. Distance difference between waterways & Roadway from industrial centers to the port is very less. Hence shifting from roadways to river is commercially viable.

Vivekananda rock and Tiruvalluvar statue exist very close to river mouth (12km). Passenger ferry services can be developed for tourism. Three ferries operate from Kanyakumari which is very crowded. Development of waterway may create additional demand for more tourism and recreational facilities since beach near river mouth is very quiet, serene and presently used for fishing purpose only. The proximity to Kanyakumari and state highways create a lot of potential for waterway development, passenger ferry services and Tourism.

6.7 Classification of waterway: Suitable for Navigation

0-4.65km (River mouth to Karkurumbathai Shutter Weir)

This stretch is a Tidal reach where raw water depths of 0.5 m to 3.1m are observed. Most of the observed water depths are about 1.5-2.0 m. This can be developed as a class I waterway with little capital dredging for round the year navigation (365 days). Kanyakumari is also very near to Pazhyar River mouth, about 8 km vide state highway 179. A beautiful beach also exists at Pazhyar river mouth which is still undeveloped. Hence this stretch has huge potential for navigation form tourism and recreation point of view.

4.65-9.86 km (Karkurumbathai Shutter Barrage to SolanThittai Weir)

Reduced Water depth of the order of 1.0 – 2.0 m is observed in this reach for 365 days. This can be developed as a class I waterway with little capital dredging.

9.86-14.1 km (SolanThittai Weir to Kumari Barrage)

Reduced Water depth of the order of 1.0 m is observed in most of this reach for 365 days. This can be developed as a class I waterway with little capital dredging.

14.1-20 km (Kumari Barrage to outfall at Mankudy)

Reduced Water depths of the order of 0.5 – 1.2 m is observed in most of this reach for 365 days. This can be developed as a class I waterway with little capital dredging.

6.8 Proposed alternative methods for making waterway feasible

0-4.65 km (River mouth to Karkurumbathai Shutter Weir)

This stretch is a Tidal reach where raw water depths of 0.5 m to 3.1m are observed. Two breakwaters exist at river mouth. The tidal range is about 0.74 m. therefore with the provision of gated structure at river mouth; this reach can be developed as class I waterway. The details of structure and other details can only be arrived after detailed surveys and investigations in Stage II.

4.65-9.86 km (Karkurumbathai Shutter Barrage to SolanThittai Weir)

As can be seen from Karurumbathai barrage photograph (Annexure 3), it is an old barrage where the water has been stored with the help of shutters. Re-construction /Modification of this barrage are proposed to raise the water depths by about 0.5-1.2 m in entire reach. Class I Waterway may be developed by modification/reconstruction of Karkurumbathai Barrage and little dredging.

9.86-14.1 km (SolanThittai Weir to Kumari Barrage)

Re-construction/Modification of Solanthittai weir is proposed to raise the water depths by about 0.5-1.2 m in entire reach. Class I Waterway may be developed by modification/reconstruction of this weir and little dredging.

14.1-20km (Kumari Barrage to outfall at Mankudy)

Kumari barrage is an old structure. The scoring vents has the size of 5’ x 4’. The modification/reconstruction of Kumari barrage to raise its height by 1.5-2m will leads to addition in water depths by about 0.5-1.0m to develop the class I waterway.

6.9 SWOT Analysis

Strength	Weakness
• Availability of reduced depths of about 1-2 m round the year (365 days) in tidal reach of 4 km. • Low capital dredging (0.5 to 1 m) for class I waterway • With modifications of existing barrages to raise their heights, Class I waterway can be developed. • A no. of villages/roads exists along the bank.	• Existing cross-structures (7 Bridges, 4 Barrage) requiring navigation locks, modification and reconstructions • Nearby Port is Tuticorin which is 100km away.
Opportunities	**Threats**
• Cargo(Granite, Rough-stone, Garnet) • Possibility of Tourism and local ferry services • Potential exists for minerals & boulders which are minor & fragmented segment.	• Closing of river mouth due to littoral drift along east coast.

6.10 Recommendation for going into Stage-II

A large volume of stones, boulders, etc. could be transported using River Sea Class ships in the Pazhyar River to VOC Port. Presently, about 1 million tonnes of these commodities are transported to VOC port using road route to Zone B of port.

Distance difference between waterways & Roadway from industrial centres to the port is very less. Hence shifting from roadways to river is commercially viable.

Kanyakumari, Vivekananda rock and Tiruvalluvar statue exist very near to river mouth. The proximity to these tourist places and state highways create a lot of potential for waterway development, passenger ferry services and Tourism.

Reduced Depths of about 1-2 m round the year in tidal reach of 4 km. reduced depths of about 1 m also exist in 4-20 km river stretch. We recommend detailed studies (Stage II) for total length of 20km for Pazhyar River.

Annexure 1: Soil Characteristics

Soil Texture		
Sl No.	**Chainage(Km)**	**Soil texture**
1	0-10	Sandy
2	10-20	Sandy

Annexure 1: Soil Samples characteristics

Sl No	Chainage (km)	Max W.L.	Min W.L.	Types of Crops & Industry		Ferry/Prominent Towns/ City/Jetty/Terminal		Utility/Pipelines		Historical and tourist places		Bridges Name with VC & HT		HT /Electric Line		Permananent Structure in Corridor of River		Bank Condition	Critical Areas/Not approachable		Dams details		Remarks	Other Details
				Details	Position	Details	Position	Name	Position	Name	Position	Name	Position	Detail	Position	Details	Position		Details	Position		Position		
1	4.4	Batheymetric record				In between old bridge and breakwater a small mooring point for fishing boats was found												Good	river mouth is 75 meters ahead of the breakwater and not approchable due to less depth				River mouth is approximately closed due to littoral drift even if two breakwaters are present. Only a small creek is open due to water in Pazhyar River.	Open mouth on one side
2	4.6					In between old bridge and new bridge a small mooring point for fishing boats was found						kelamanakudi old bridge,	8°05'25.56"N,77°29'04.74"E					Good					Water flowing in width of 80m, Fishing boats, Dense vegetation(bushes) on one end of bridge and coconut trees, church on other side	Old Steel Bridge (3 m wide), 500 mm dia Pipleline
3	4.9											Manakudi New Bridge	8°05'30.6260"N,77°29'05.3986"E					Rockwall boundary(8°06'20.4901"N, 77°28'54.0681"E)					Water flowing in width of 200m, trees and dense bushes on both sides of bridge	Keela Munakudy to Mela Mankudy Bridge (10.5 m wide with footpaths)
4	5.1			Mangroves on west Bank	8°06'19.4353'N, 77°28'55.3193"E													River divided for salt plant 8°06'45.763'N,77°28'51.379"E	fishing nets	8°06'42.510'N, 77°28'50.950"E				
5	5.8			salt plant on the west bank	8°06'51.39N,77°28'49.40"E									electrical wire crossing	8°07'01.4689"N, 77°28'47.303"E			Good						

Sl No	Chainage (km)	Max W.L.	Min W.L.	Types of Crops & Industry		Ferry/Prominent Towns/ City/Jetty/Terminal		Utility/Pipelines		Historical and tourist places		Bridges Name with VC & HT		HT /Electric Line		Permananent Structure in Corridor of River		Bank Condition	Critical Areas/Not approachable		Dams details		Remarks	Other Details
				Details	Position	Details	Position	Name	Position	Name	Position	Name	Position	Detail	Position	Details	Position		Details	Position		Position		
6	6.4			Banana tress on the west bank coconut trees on the east Bank	8°07'07.213"N, 77°28'46.3086"E													Rock Bounday on the East Bank (8°07'14.6738"N, 77°28'44.87"E)						
7	7.0			Coconut, Banana	8°07'38.55"N, 77°28'52.609E													Good	End of Bathy Survey Rock Pathches found 10m ahed of this point navigtion not possible	8°07'38.55"N, 77°28'52.609E				
8	7.2	1	0.5	Coconut, Banana	8°07'47.2806"N, 77°28'56.921"E							Vadaku Thamaraikulam Railway bridge	8°07'47.2806"N, 77°28'56.921"E					Good			Vadaku thamaraikulam kalkuruputhai Shutter Dam	8°07'42.7857"N, 77°28'52.6302"E	Water under rly bridge, Dense forest on both sides	
9	7.74	1	0.5	Coconut, Banana	8°07'58.1198"N,77°29'00.3182"E'							Vadaku Thamaraikulam Bridge	8°07'58.1198"N,77°29'00.3182"E'					Good					Dense forest on both sides, water along the whole span, Flowers (lotus & water lilies)	Road bridge (3 m wide), Pipeline below the road
10	8.2	1.2	0.5	Paddy,coconut Banana	8°08'15.5591"N, 77°28'55.2103"E													Good			Small dam (Pillai Pethan Dam) V/c 3.8m Ht 1.76m	8°08'15.5591"N, 77°28'55.2103"		
11	8.58	1	0.5	Paddy,coconut Banana	8°08'26.0068"N,77°28'48.9433"E													Good						
12	9.32	1.5	0.5	Paddy,coconut Banana	8°08'46.5491"N, 77°28'44.1908"E									Electric wire crossing	8°08'52.2134"N, 77°28'41.375"E			Good						

Sl No	Chainage (km)	Max W.L.	Min W.L.	Types of Crops & Industry		Ferry/Prominent Towns/ City/Jetty/Terminal		Utility/Pipelines		Historical and tourist places		Bridges Name with VC & HT		HT /Electric Line		Permananent Structure in Corridor of River		Bank Condition	Critical Areas/Not approachable		Dams details		Remarks	Other Details
				Details	Position	Details	Position	Name	Position	Name	Position	Name	Position	Detail	Position	Details	Position		Details	Position		Position		
13	9.8	1.5	0.5	Paddy,coconut Banana	8°09'03.4244"N, 77°28'33.0585"E													Good						
14	10.2	1	0.3	Paddy,coconut Banana	8°09'13.0756"N, 77°28'19.8044"E											Nagerkovil Kanyakumari highway	8°09'13.0756"N, 77°28'19.8044"E	Good						
15	10.78	1.5	0.5	Paddy,coconut Banana	8°09'20.8591"N,77°28'08.3751"E							Susintheram Old Bridge	8°09'20.8591"N,77°28'08.3751"E			Culvert on the river (Construction of New bridge susitheram	8°09'19.7787"N, 77°28'10.0739"E	Good					Dry sandy bed, Coconut trees & dense vegetation on both sides	
16	11.4	1	0.5	Coconut, Banana	8°09'28.3800"N, 77°27'54.722"E									electrical Post	8°09'28.3800"N, 77°27'54.722"E			Good						
17	11.75	1	0.5	Coconut, Banana	8°09'33.5843"N, 77°27'32.2207"E									Electic wire wire crossing	8°09'29.578"N, 77°27'41.6360"E	Flood Level Markiong Buiding Govt of India Asaramam	8°09'33.5843"N, 77°27'32.2207"E	Good						
18	12.1	1.5	0.5	Coconut, Banana	8°09'35.618''N, 77°27'22.89''E									high tension wire crossing	1(8°09'35.618''N, 77°27'22.89''E),2 (8°09'42.6307N, 77°27'19.860''E)			Good			Solanthitai Dam v/c= 6.44 m Ht=8m taken 20m up the river	8°09'34.885"N, 77°27'26.956"E		
19	12.7	1.2	0.5	Coconut, Banana	8°09'51.1048"N,77°27'16.4569E													Good						
20	13.2	1.2	0.5	Coconut, Banana	8°10'21.3039"N,77°27'09.4763"E									Electic wire crossing	8°10'21.3039"N, 77°27'09.4763"E			Good						

Sl No	Chainage (km)	Max W.L.	Min W.L.	Types of Crops & Industry		Ferry/Prominent Towns/ City/Jetty/Terminal		Utility/Pipelines		Historical and tourist places		Bridges Name with VC & HT		HT /Electric Line		Permananent Structure in Corridor of River		Bank Condition	Critical Areas/Not approachable		Dams details		Remarks	Other Details
				Details	Position	Details	Position	Name	Position	Name	Position	Name	Position	Detail	Position	Details	Position		Details	Position		Position		
21	13.8	1	0.5	Coconut, Banana	8°10'30.7068"N, 77°27'07.3135"E													Good						
22	14.14	1.2	0.5	Coconut, Banana	8°10'47.9414N, 77°26'55.9886"E									HIGH TENSION WIRE CROSSING 50m away form the bridge	8°10'47.9414N, 77°26'55.9886"E			Good			Kumari Dam	8°10'54.7377N, 77°26'46.9916"E	Water on both sides, Aquatic Plants on one side, Coconut trees & dense vegetation on both sides	
23	14.6	1.2	0.5	Coconut, Banana	8°11'01.1909"N,77°26'41.5094''E							railway bridge ahead 15 mtrs from this fix	8°11'01.1909"N,77°26'41.5094''E					Good					Small creek, Aquatic Plants on one side, Coconut trees & dense vegetation on both sides	
24	15.15	0.5	0.1	Coconut, Banana	8°11'16.5520''N,77°26'26.9103''E											Purukingal olugunasery river diveded by seperation wall, center of seperation wall	8°11'16.5520''N,77°26'26.9103''E	Good						
25	15.6	0.7	0.5	Paddy,coconut Banana	8°11'35.2784''N,77°26'20.1753''E							olugunasery bridge Conntcting between Thirunelveli Nagerkovil.	8°11'35.2784"N,77°26'20.1753''E					Good					Very little water below bridge, dense vegetation on both sides, Coconut and other trees, temple nearby	Huts at right bank, Under construction storage tin shed of left bank
26	16.11	1.2	0.5	Paddy,coconut Banana	8°11'41.0637N, 77°26'22.725''E					Cremation Yard on the West bank	8°11'41.0637N, 77°26'22.725''E			Electrical Wire Crossing	8°11'53.57N, 77°26'21.4630''E			Good						

Sl No	Chainage (km)	Max W.L.	Min W.L.	Types of Crops & Industry		Ferry/Prominent Towns/ City/Jetty/Terminal		Utility/Pipelines		Historical and tourist places		Bridges Name with VC & HT		HT /Electric Line		Permananent Structure in Corridor of River		Bank Condition	Critical Areas/Not approachable		Dams details		Remarks	Other Details
				Details	Position	Details	Position	Name	Position	Name	Position	Name	Position	Detail	Position	Details	Position		Details	Position		Position		
27	16.4	1.2	0.5	Paddy,coconut Banana	8°11'59.4078''N, 77°26'26.3781''E													Good						
28	17.11	1.2	0.5	Paddy,coconut Banana	8°12'17.3850"N,77°26'23.1586"E			Drinking water pipeline	8°12'17.3850"N, 77°26'23.1586"E							Local bund made of sand bags	8°12'25.4604"N,77°26'21.5217"E	Rock Wall on the East Bank						
29	17.8	1	0.5	Paddy,coconut Banana	8°12'28.8249"N, 77°26'29.9199"E											Intake well on left bank	8°12'33.3901"N, 77°26'36.1632"E	Good					Water on both sides, vegetation on both sides	
30	18.2	1	0.5	Paddy,coconut Banana	8°12'42.2762"N, 77°26'31.7077E													Good						
31	18.6	1	0.5	Coconut, Banana	8°12'53.7987"N,77°26'26.8358"E									HT cable is crossing and itc	8°12'53.7987"N, 77°26'26.8358"E			Good						
32	19.4	1	0.2	Coconut, Banana	8°13'30.1374"N,77°26'29.0470"E													Good						
33	20.0	1.1	0.5	Coconut, Banana	08 13'48.6436"N 77 26'27.4911"E			Drinking water pipeline	08 13'48.6436"N 77 26'27.4911"E			Pipeline Bridge,	08 13'48.6436"N 77 26'27.4911"E					Good					Diversion works for offtaking canals on both banks, Pipeline crossing river on diversion works, Intake at downstream, Coconut trees both sides	

ANNEXURE 3 :- PHOTOGRAPHS OF CROSS-STRUCTURES ON PAZHYAR RIVER

1: Breakwaters at Pazhyar River Mouth

2: Breakwaters at Pazhyar River Mouth

3: Old Steel Road Bridge (SH-179) along with Pipeline at Chainage 4.6km

4: Karkurumbathai Shutter Dam

5: Keela Munakudy to Mela Mankudy Bridge at Chainage 4.9km

6: Salt Panes along left bank of Pazhyar River at Chainage 5.8km

7: Pillai Pethan Dam at Chainage 5.9km

8: Vadaku Tamaraikulam Bridge at Chainage 7.74km

9: Asharamam Regulator at Chainage 9.5km

10: Asharamam CWC G&D Station & Full Climatic Station at Chainage 9.5km

11: Solan Thittai Dam at Chainage 9.87km

12: Kumari Dam side view at Chainage 14.10km

13: Kumari Dam at Chainage 14.10km

14: Railway Bridge at Chainage 14.6km

15: Olugunasery Bridge (NH-478) at Chainage 15.6km

16: Local Bund at Chainage 17.8km

17: Water intake at Chainage 17.8km

18: Diversion Works and pipeline bridge at Chainage 20km

19: Diversion Works and pipeline bridge at Chainage 20km

Annexure 4: Source data table for *Figure 12: Riverbed profile from the end of tidal influence (Kp 4.56) till the end of 20 Km stretches.*

Chainage (km)	River Bed Level w.r.t MSL (m)	Adopted C.D. w.r.t MSL (m)	HFL w.r.t MSL (m)
4.570	1.90	1.80	5.00
4.753	1.05	1.82	5.12
4.851	0.75	1.83	5.19
4.950	0.55	1.84	5.26
4.994	0.69	1.84	5.29
5.048	0.65	1.85	5.32
5.151	0.62	1.86	5.39
5.244	0.68	1.87	5.46
5.298	0.74	1.87	5.49
5.344	0.99	1.88	5.53
5.447	1.25	1.89	5.60
5.545	1.57	1.89	5.66
5.652	2.01	1.91	5.74
5.684	2.45	1.91	5.76
5.742	2.51	1.91	5.80
5.841	2.43	1.92	5.86
5.900	2.25	2.00	5.90
5.940	2.34	2.00	5.93
6.040	2.15	2.01	6.00
6.141	1.98	2.01	6.07
6.199	1.79	2.01	6.11
6.248	1.62	2.01	6.14
6.280	1.54	2.02	6.16
6.352	1.43	2.02	6.21
6.451	1.32	2.02	6.28
6.546	1.29	2.03	6.34
6.657	1.21	2.03	6.42
6.763	0.86	2.04	6.49
6.861	0.22	2.04	6.56
6.929	-0.06	2.04	6.60
6.936	-0.38	2.04	6.61
6.954	0.50	2.04	6.62
7.049	2.22	2.05	6.68
7.156	3.01	2.05	6.76
7.219	4.31	2.06	6.80
7.257	4.42	2.06	6.83
7.344	4.51	2.06	6.88
7.471	4.64	2.07	6.97
7.569	4.77	2.07	7.04
7.661	4.91	2.07	7.10
7.782	5.07	2.08	7.18

7.879	5.68	2.08	7.25
7.977	5.83	2.09	7.31
8.077	6.00	2.09	7.38
8.176	5.19	2.10	7.45
8.274	3.36	2.10	7.52
8.372	2.25	2.10	7.58
8.439	1.92	2.11	7.63
8.472	1.85	2.11	7.65
8.500	1.70	2.11	7.67
8.572	2.15	2.11	7.69
8.682	2.60	2.12	7.72
8.765	2.87	2.12	7.74
8.869	3.56	2.12	7.77
8.973	4.17	2.13	7.79
8.985	4.77	2.13	7.80
9.088	4.01	2.13	7.82
9.191	3.34	2.14	7.85
9.292	2.66	2.14	7.88
9.389	1.54	2.15	7.90
9.393	1.43	2.15	7.90
9.487	1.35	2.15	7.93
9.581	1.07	2.15	7.95
9.684	0.84	2.16	7.98
9.707	0.46	2.16	7.98
9.785	0.07	2.16	8.00
9.873	-0.29	5.40	8.03
9.884	1.23	5.40	8.03
9.987	3.56	5.42	8.06
10.002	5.38	5.43	8.06
10.042	4.96	5.43	8.07
10.082	4.06	5.44	8.08
10.181	4.29	5.46	8.11
10.285	3.74	5.48	8.13
10.331	3.67	5.49	8.15
10.376	3.51	5.50	8.16
10.434	3.42	5.51	8.17
10.496	3.25	5.52	8.19
10.531	3.01	5.53	8.20
10.605	3.12	5.55	8.22
10.719	3.29	5.57	8.25
10.816	3.43	5.59	8.27
10.872	3.57	5.60	8.29
10.922	3.41	5.61	8.30
11.027	3.63	5.63	8.33
11.121	3.91	5.65	8.35
11.199	4.23	5.67	8.37

11.259	4.42	5.68	8.39
11.324	3.92	5.69	8.40
11.424	3.61	5.71	8.43
11.507	3.13	5.73	8.45
11.552	2.53	5.74	8.46
11.626	2.76	5.75	8.48
11.723	2.89	5.77	8.51
11.831	3.02	5.79	8.54
11.853	3.12	5.80	8.54
11.932	3.09	5.81	8.56
12.035	3.27	5.83	8.59
12.106	3.59	5.85	8.61
12.144	3.85	5.85	8.62
12.239	3.26	5.87	8.88
12.344	2.97	5.89	9.16
12.442	2.61	5.91	9.43
12.512	2.24	5.93	9.61
12.544	3.65	5.93	9.70
12.642	4.92	5.95	9.97
12.744	5.70	5.97	10.24
12.821	7.33	5.99	10.45
12.862	8.78	6.13	10.56
12.947	7.41	6.43	10.79
13.047	7.03	6.78	11.06
13.123	6.74	7.04	11.27
13.149	6.93	7.13	11.34
13.248	7.29	7.48	11.61
13.344	7.21	7.81	11.87
13.457	8.69	8.21	12.18
13.556	9.10	8.55	12.44
13.631	10.13	8.81	12.65
13.668	10.57	8.94	12.75
13.726	10.93	10.50	12.90
13.851	11.21	10.52	13.01
13.972	11.03	10.55	13.12
14.040	10.96	10.56	13.18
14.149	10.67	10.58	13.27
14.280	10.61	10.61	13.39
14.361	10.36	10.63	13.46
14.420	10.02	10.64	13.51
14.502	9.98	10.66	13.58
14.593	9.73	10.67	13.66
14.623	9.67	10.68	13.69
14.698	9.12	10.69	13.76
14.799	8.82	10.71	13.84
14.903	8.21	10.74	13.94

15.003	7.99	10.76	14.02
15.081	7.68	10.77	14.09
15.164	8.13	10.79	14.16
15.265	9.13	10.81	14.25
15.315	9.55	10.82	14.30
15.386	10.32	10.83	14.36
15.487	10.73	10.85	14.45
15.560	11.10	10.87	14.51
15.583	11.21	10.87	14.53
15.683	11.05	10.89	14.62
15.784	10.53	10.91	14.71
15.887	9.62	10.93	14.80
15.905	8.59	10.94	14.81
15.992	8.87	10.95	14.89
16.093	8.43	10.97	14.98
16.154	8.25	10.99	15.03
16.176	8.56	10.99	15.05
16.279	8.21	11.01	15.14
16.378	8.37	11.03	15.23
16.427	8.33	11.04	15.27
16.481	8.91	11.05	15.32
16.579	8.79	11.07	15.40
16.630	9.46	11.08	15.45
16.678	10.04	11.09	15.49
16.693	10.16	11.09	15.51
16.792	9.98	11.11	15.59
16.897	9.86	11.13	15.68
16.947	9.75	11.14	15.73
16.992	9.71	11.15	15.77
17.003	9.99	11.16	15.78
17.109	8.51	11.18	15.87
17.184	7.63	11.19	15.94
17.241	6.99	11.20	15.99
17.319	7.37	11.22	16.05
17.430	7.82	11.24	16.15
17.494	8.53	11.25	16.21
17.548	8.99	11.26	16.25
17.658	9.67	11.29	16.35
17.707	10.24	11.30	16.39
17.757	11.60	11.31	16.44
17.794	11.72	11.31	16.47
17.846	11.51	11.32	16.52
17.902	11.43	11.34	16.57
17.955	11.37	11.35	16.61
17.995	11.23	11.35	16.65
18.092	11.29	11.37	16.73

18.145	11.15	11.38	16.78
18.207	11.07	11.40	16.83
18.285	10.86	11.41	16.90
18.353	10.91	11.43	16.96
18.408	10.77	11.44	17.01
18.467	10.61	11.45	17.06
18.511	10.58	11.46	17.10
18.562	10.51	11.47	17.14
18.616	10.00	11.48	17.19
18.666	10.16	11.49	17.24
18.722	10.11	11.50	17.28
18.828	10.41	11.52	17.38
18.842	10.13	11.52	17.39
18.882	10.26	11.53	17.42
18.949	9.61	11.54	17.48
19.027	8.78	11.56	17.55
19.136	7.96	11.58	17.65
19.184	6.89	11.59	17.69
19.247	7.65	11.60	17.74
19.351	7.94	11.62	17.84
19.388	8.65	11.63	17.87
19.476	11.21	11.65	17.95
19.477	15.45	11.65	17.95