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# Embankment Survey & Monitoring using Unmanned Aerial Vehicle (UAV)

**Prepared for**

Assam State Disaster Management Authority

Government of Assam

**By**

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## Introduction:

Embankment monitoring for large area may be more expensive than expected and time consuming processes in absence of thorough investigation and proper scientific approaches. However, in the last two decades with the advent of space technology and GIS, earth work estimation in any area becomes easier. For embankment survey & monitoring for Lakhimpur and Rangia of Assam state, it has been planned to use Unmanned Aerial Vehicle (UAV). The use of UAV in airborne surveys has many advantages such as Risk reduction, Better overview, Survey of inaccessible locations, Improved data density, Faster data acquisition, Higher data resolution and Lower costs.

## Study Area:

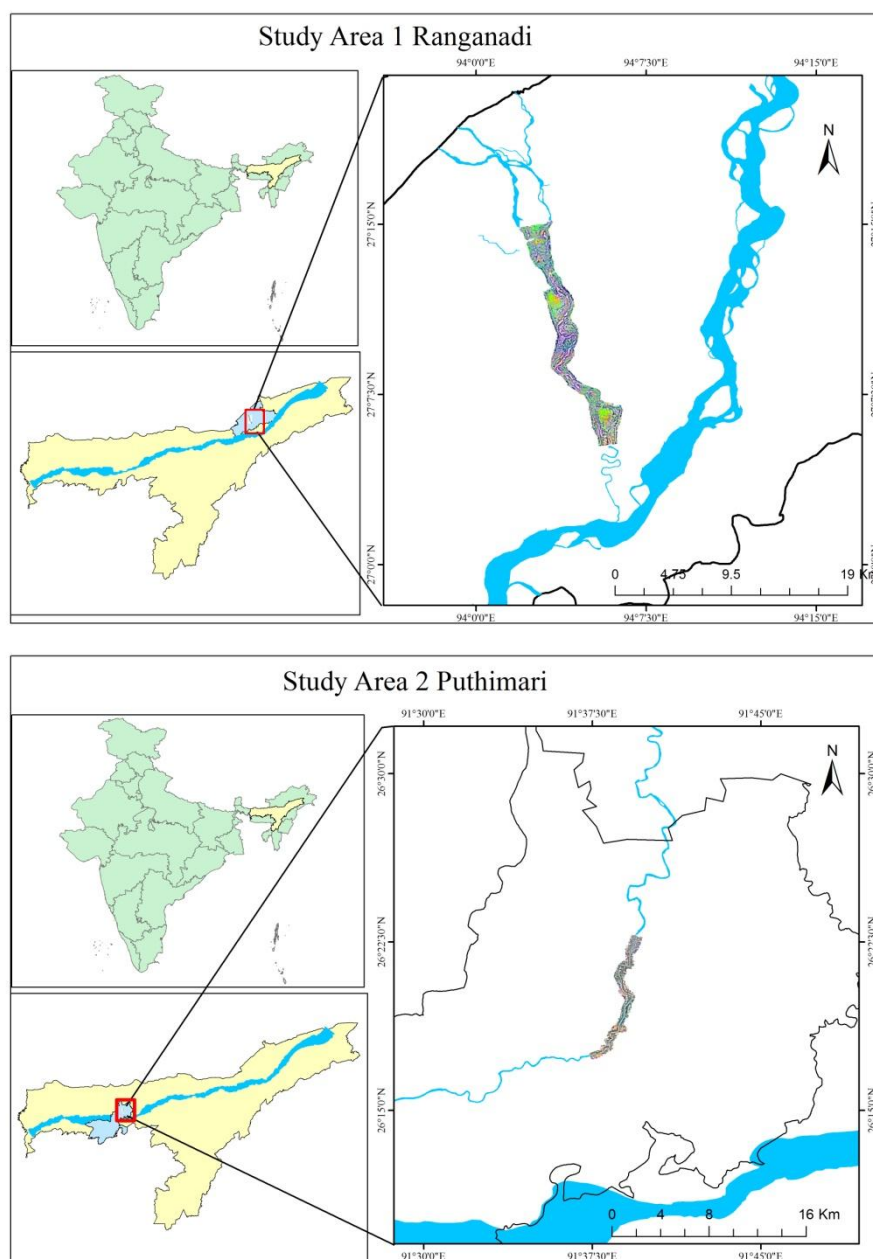


Figure 1: Study Areas

**Scope of the work:** The scope of work consists of the following tasks:

### **Task-1: Data acquisition using Unmanned Aerial Vehicle (UAV)**

A multi-rotor UAV (M600) was used. This enables vertical takeoff and landing, which are often needed in mountain sites, where there are few open wide spaces without obstacles. It is also more reliable to perform an irregular, linear, and low flight with Zenmuse X3 RGB camera. The specification of Zenmuse X3 is given in table 1. The data acquisition has been done for two different study sites, namely, Lakhimpur and Rangia of Assam State. During the data acquisition process, about 7103 images and 3305 images were recorded for Lakhimpur and Rangia respectively which cover an approx. areas of 27 Sq.Km and 7.96 Sq.km. The average flying heights above the ground for both the study areas were maintained at 145m.

*Table 1: The specification of Zenmuse X3*

<b>Camera Dimensions</b>	6.17 x 4.55 mm
<b>Optics</b>	20mm (F/2.8)
<b>Sensor</b>	CMOS
<b>Image dimensions</b>	12.4 MP
<b>Max Field of View</b>	94° (diagonal)
<b>Operating Temperature</b>	-10 to 40°C
<b>Shutter Speed</b>	8 - 1/8000s

### **Task-2: Ground Control Points collection**

Ground control points (GCPs) were collected using existing sources and DGPS survey method. The GCPs were collected in Geographic Coordinate System (GCS) and vertical reference with respect to ellipsoidal heights. A total of 29 nos of GCPs were collected for Lakhimpur and 19 nos of GCPs for Rangia. Since the area of Lakhimpur is large, the data has been processed into two parts with 12.7 Sq.Km and 14.5 Sq.Km respectively.

### **Task-3: Generation of Point Cloud, Digital Surface Model (DSM) and Ortho rectified image.**

The data is then transformed into any of the following types of products using UAV data processing software. The processing parameters are shown in table 2.

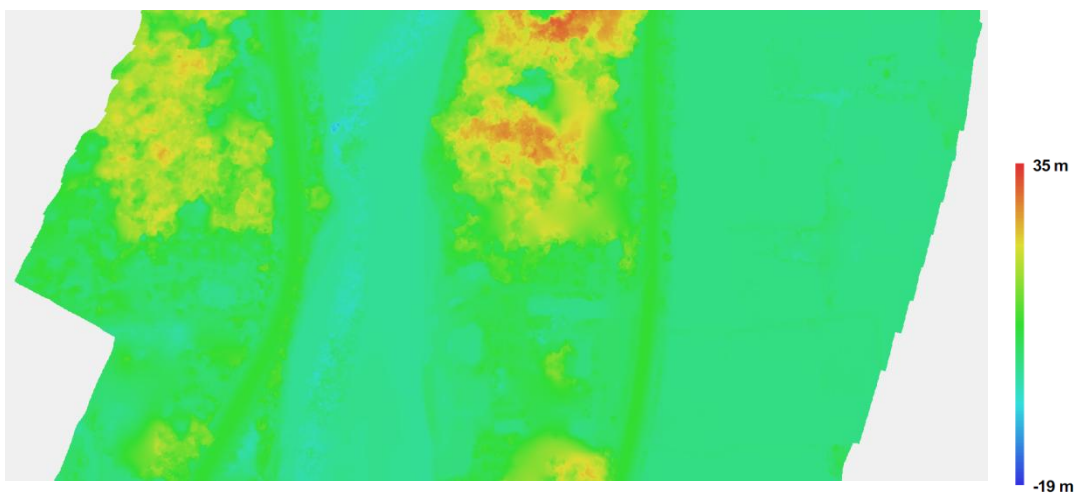
- **Point clouds:** sets of data points in a 3D coordinate system that represent the external surface of a terrain or object. (figure1)
- **Orthomosaics/Orthophotos/images:** files containing aerial photographs geometrically corrected so that the scale is uniform with ground sampling distance (GSD). (figure2)
- **Digital surface models (DSMs):** files containing elevations that include buildings, vegetation, power lines and other above-ground objects. The ground is only seen when there is nothing else on it. (figure3)

**Table 2:** Processing parameters

	<b>Lakhimpur-Part1 (12.7 Sq.Km)</b>	<b>Lakhimpur-Part2 (14.5 Sq.Km)</b>	<b>Rangia (7.96 Sq.Km)</b>
<b>No. of Images</b>	3389	3714	3305
<b>No. of GCPs</b>	18	13	19
<b>RMSE</b>	0.157307 (0.750557 pix)	0.154118 (0.71521 pix)	0.14974 (0.802148 pix)
<b>GSD</b>	5.26 cm/pix	5.33 cm/pix	4.93 cm/pix
<b>DSM</b>	10.5 cm/pix	10.7 cm/pix	19.7 cm/pix
<b>Point density</b>	90.2 points/sq m	87.9 points/sq m	25.6673 points/sq m



**Figure 2:** Orthomosaic/ orthophoto



**Figure 3:** Digital Surface Model





**Figure 4:** 3D view of Puthimari River

# RESULTS

## Longitudinal/Cross sectional profile of Ranganadi river embankment

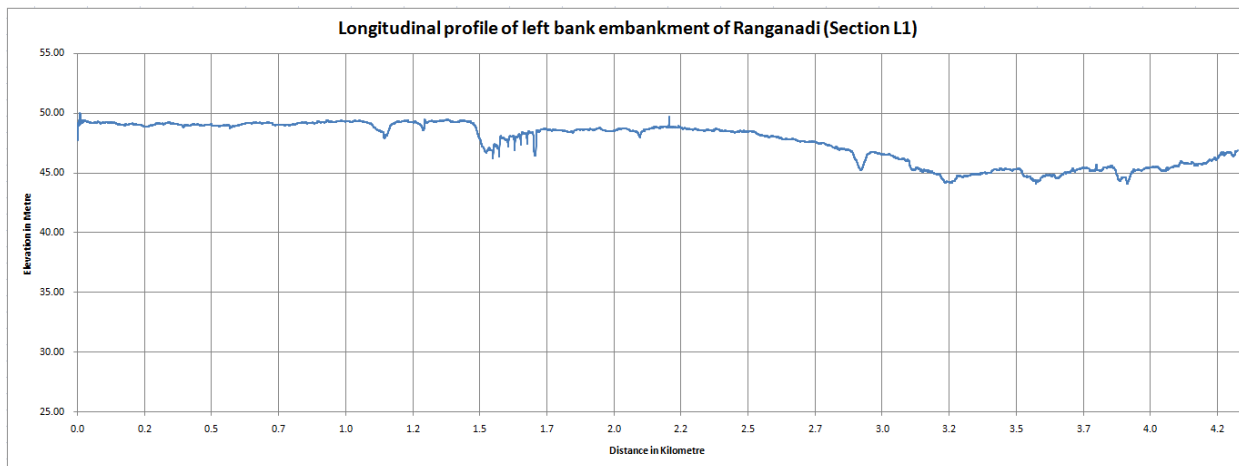
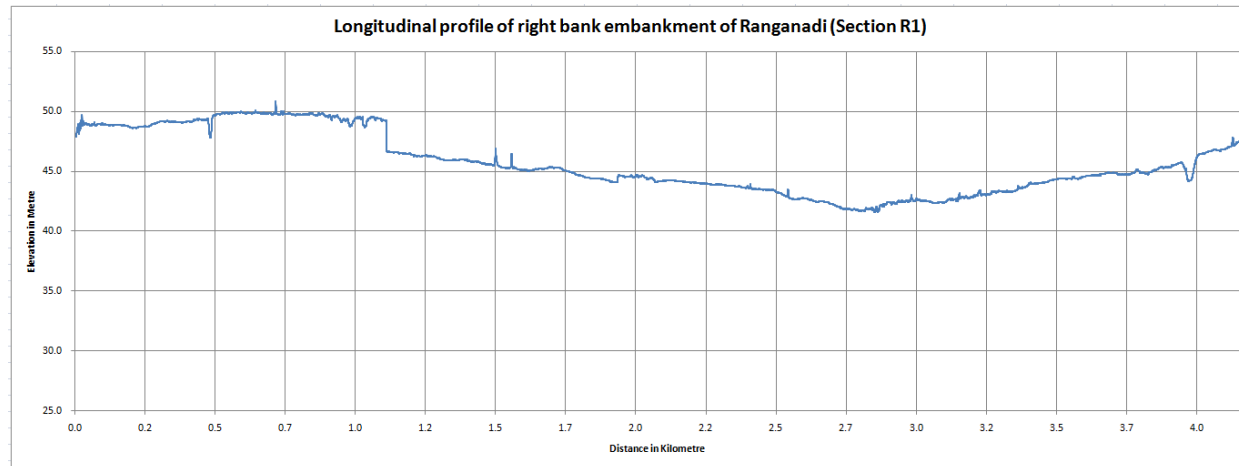


Fig: 7 Longitudinal profile of Left and right bank embankment (Section R1 & L1)

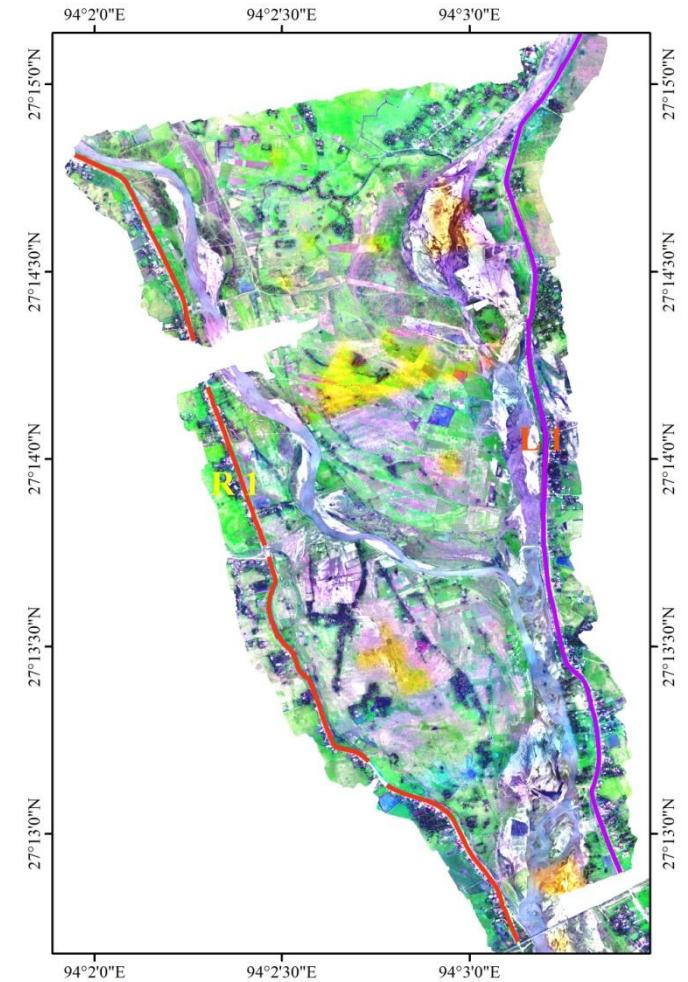


Fig: 8 UAV image of Ranganadi river and It's embankments (Section R1 & L1)



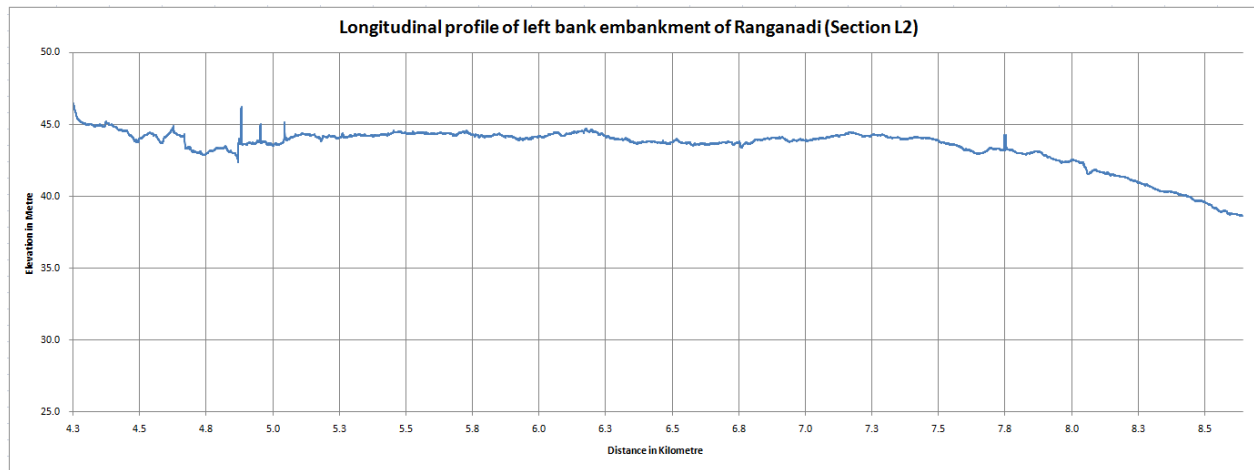
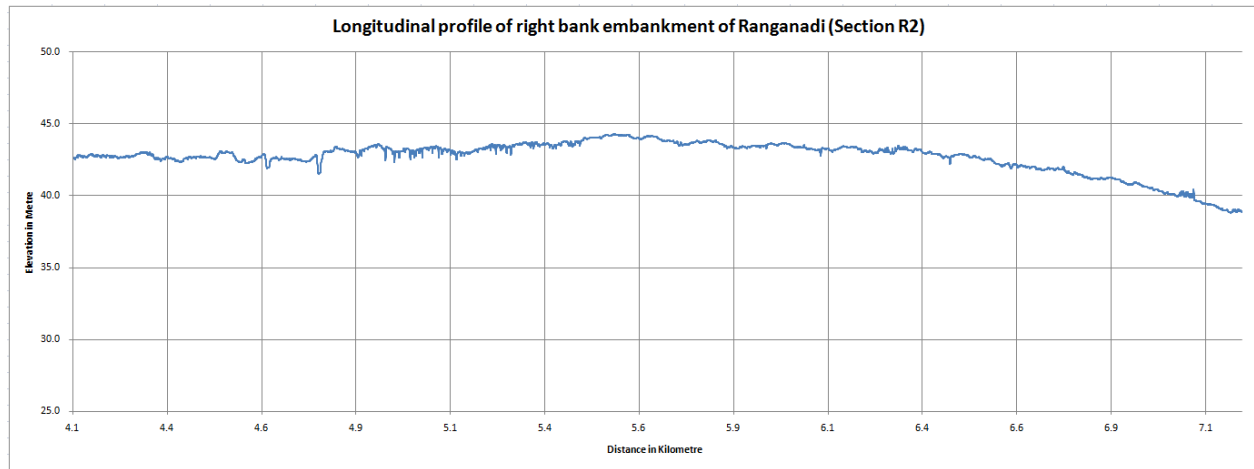


Fig: 9 Longitudinal profile of Left and right bank embankment (Section R2 & L2)

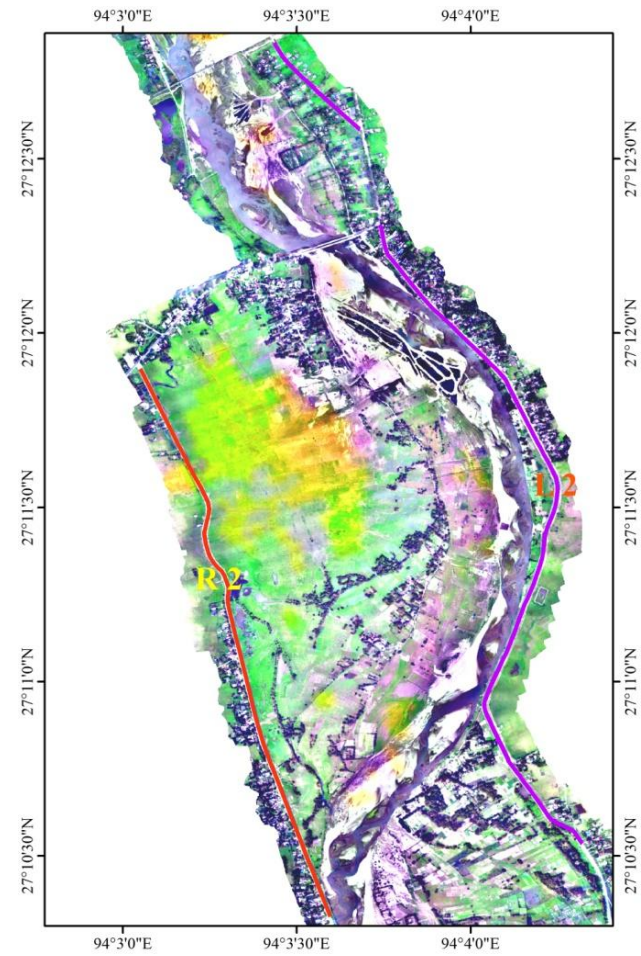


Fig: 10 UAV image of Ranganadi river and It's embankments (Section R2 & L2)



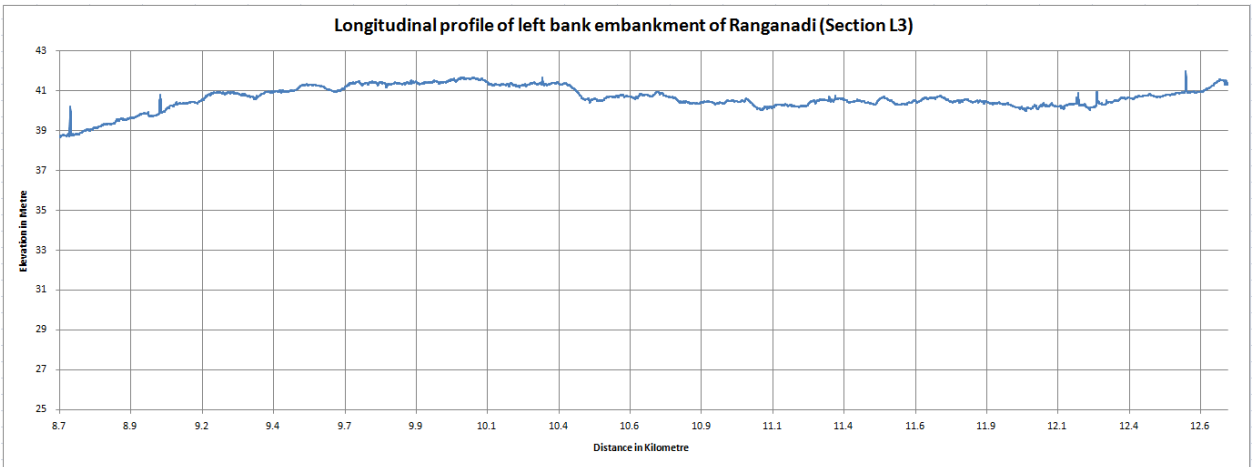
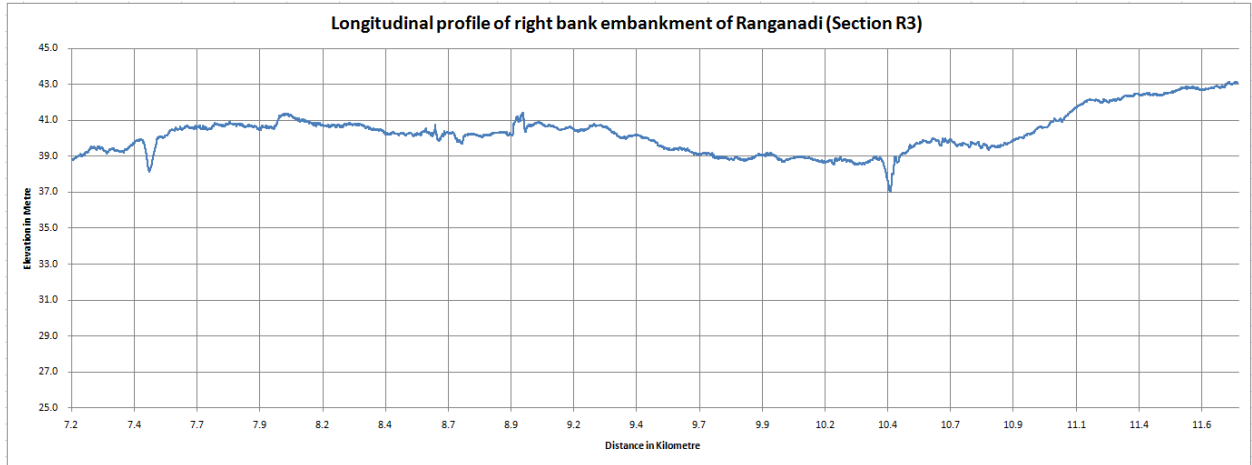


Fig: 11 Longitudinal profile of Left and right bank embankment (Section R3 & L3)

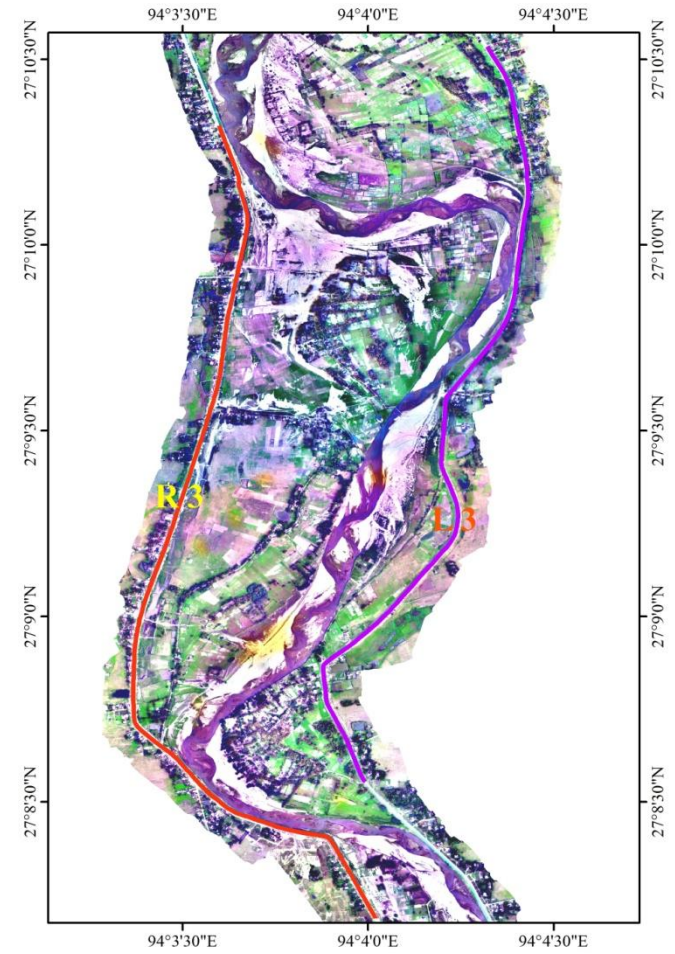


Fig: 12 UAV image of Ranganadi river and It's embankments (Section R3 & L3)

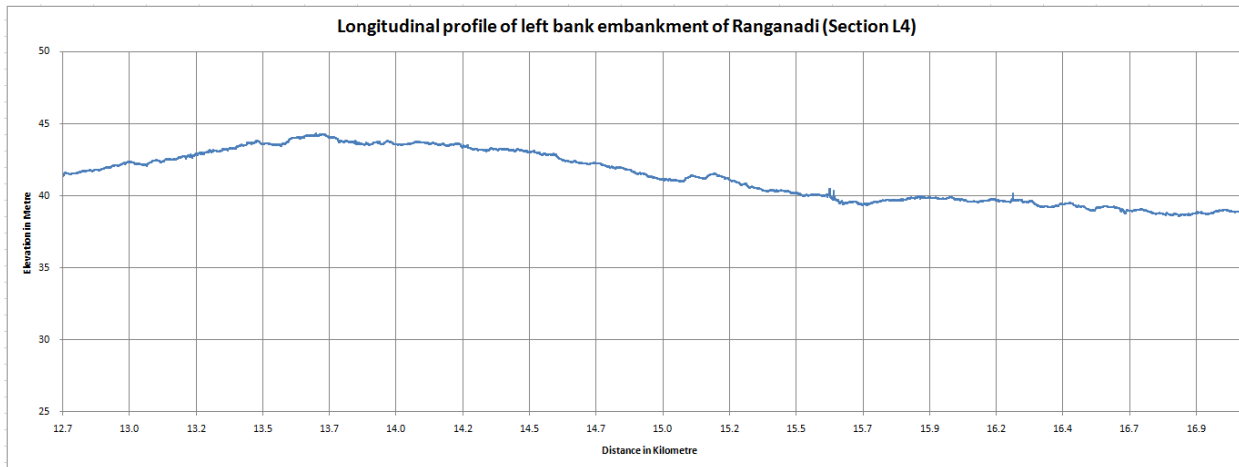
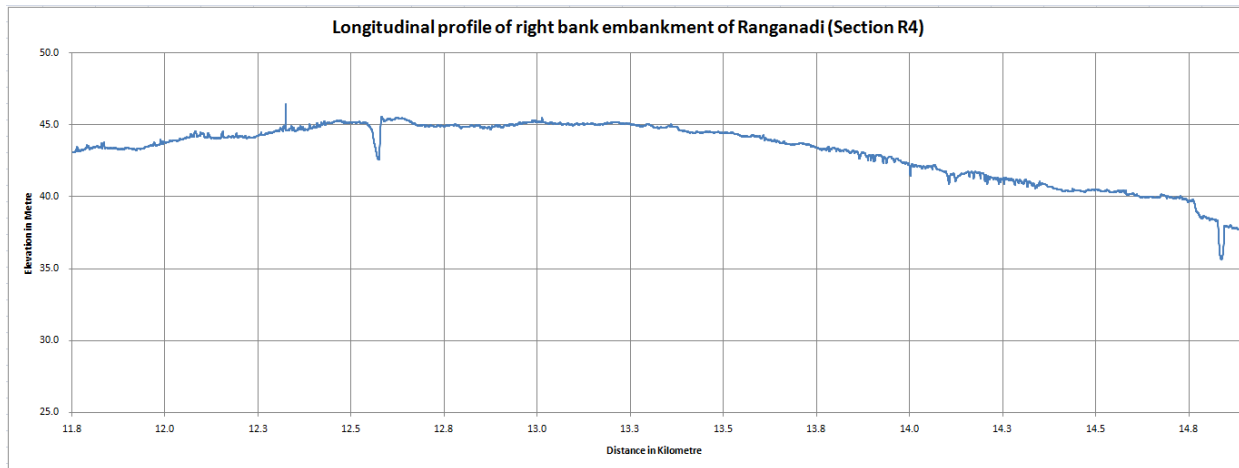


Fig: 13 Longitudinal profile of Left and right bank embankment (Section R4 & L4)

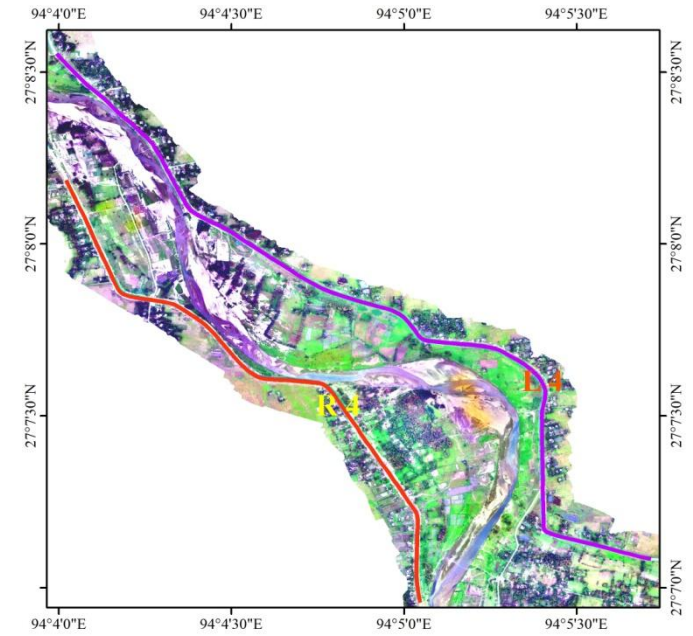


Fig: 14 UAV image of Ranganadi river and Its embankments (Section R4 & L4)

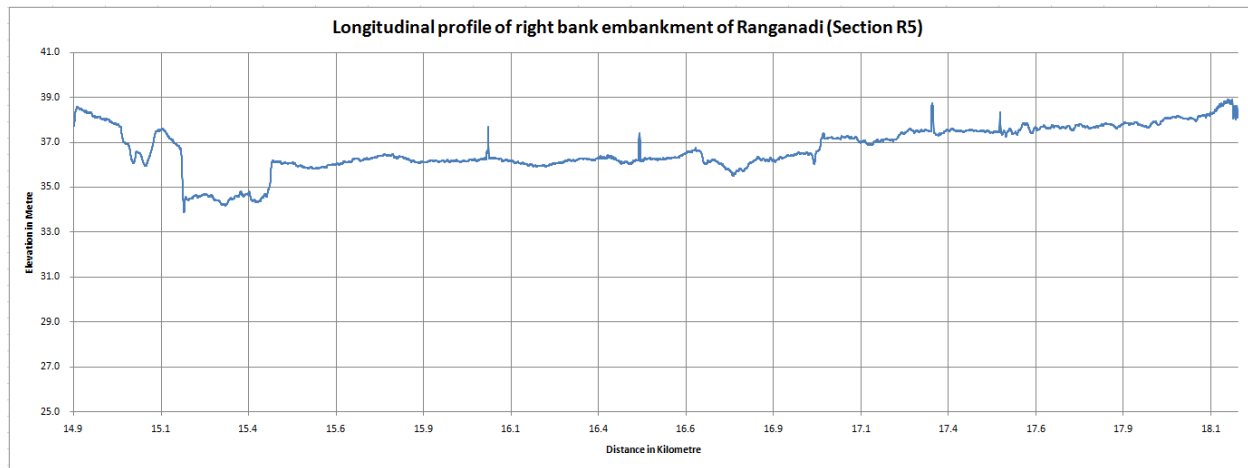
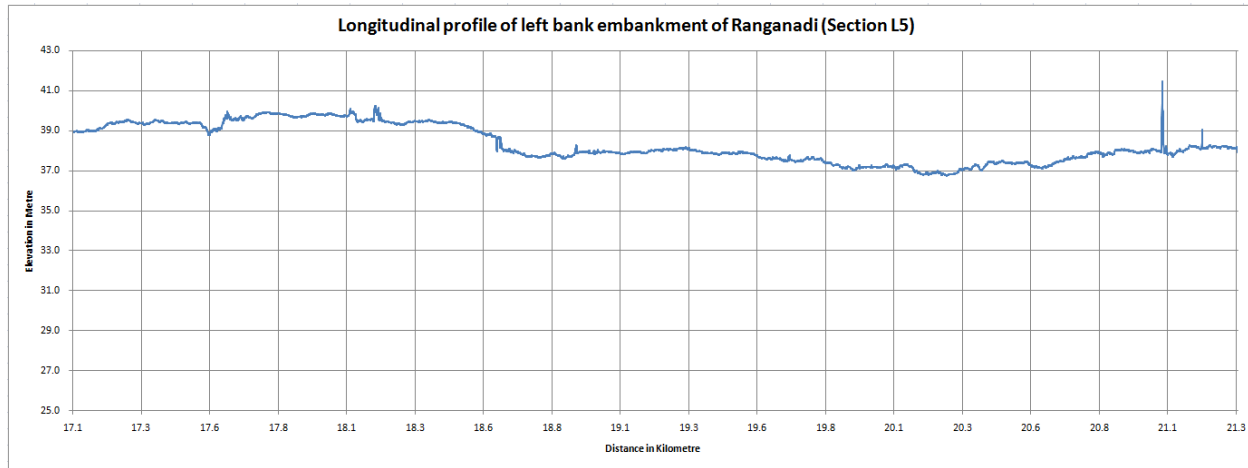


Fig: 15 Longitudinal profile of Left and right bank embankment (Section R5 & L5)

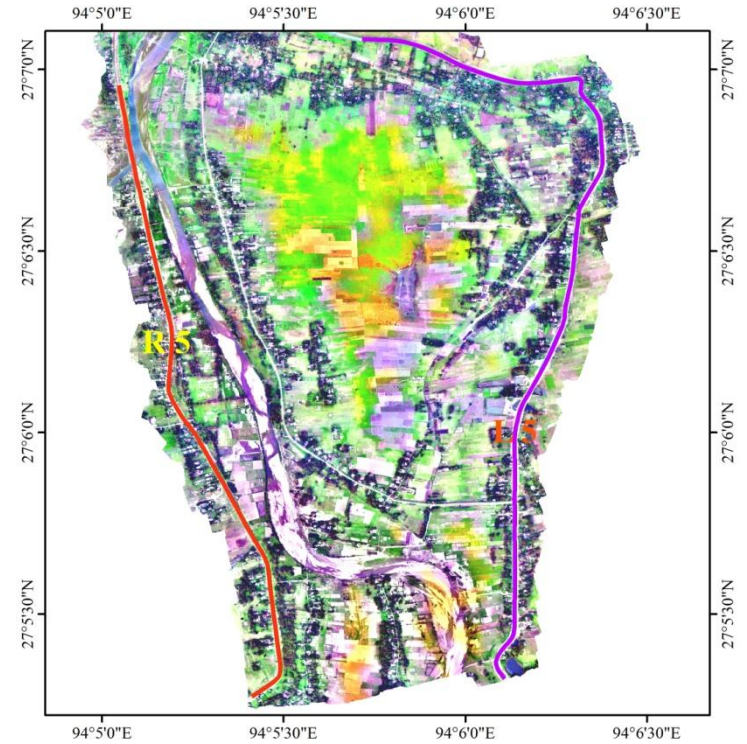


Fig: 16 UAV image of Ranganadi river and Its embankments (Section R5 & L5)

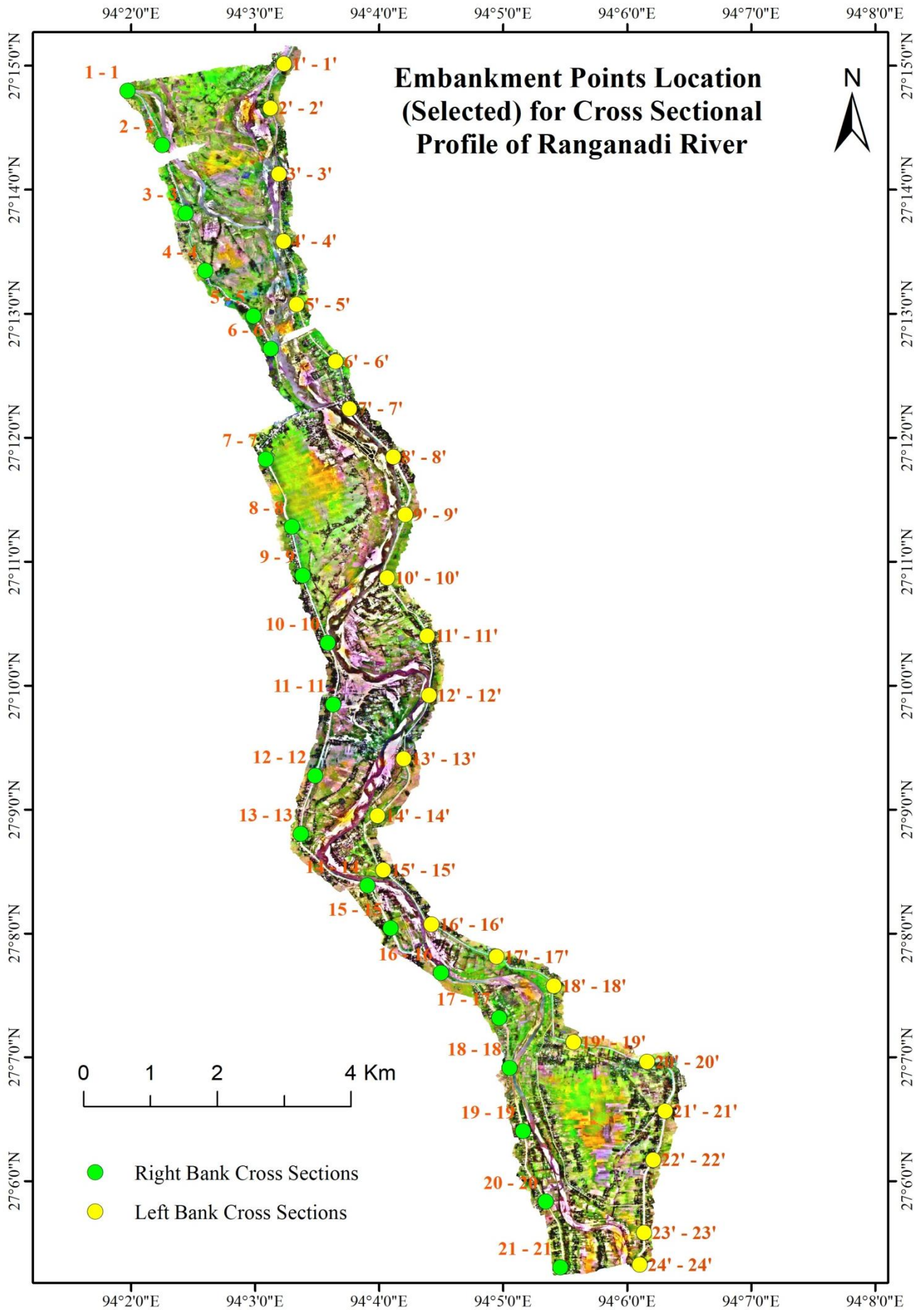


Fig: 17 Embankment Points Location (Selected) for Cross Sectional Profile of Ranganadi River

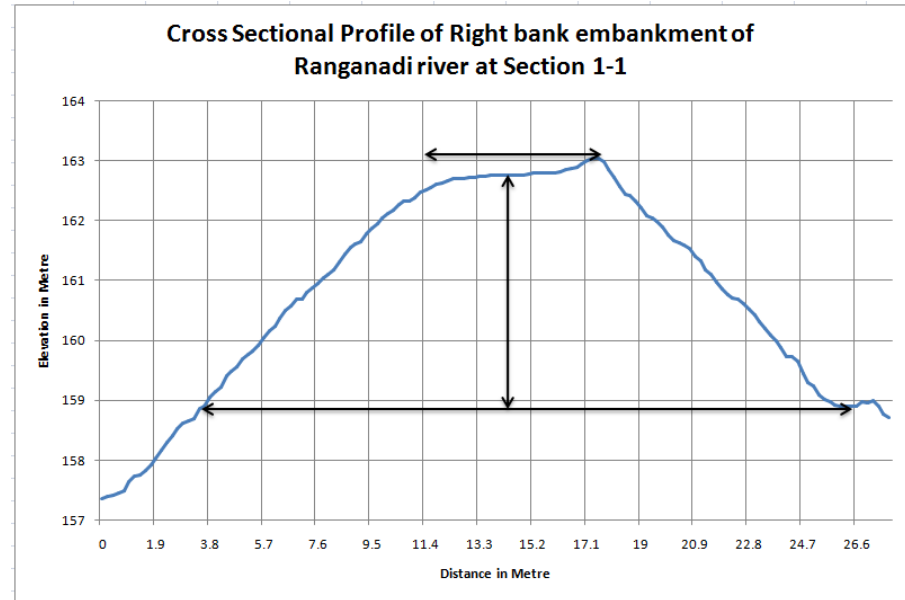


**Cross Sectional Details of Section: 1-1**

Top width : 17.5 - 11.4 = 6.1 m

Bottom width : 26.6 - 3.8 = 22.8 m

Height : 163 - 159 = 4.0 m



**Cross Sectional Details of Section: 1'-1'**

Top width : 21.4 - 9.5 = 11.9 m

Bottom width : 28.2 - 1.2 = 27.0 m

Height : 138.5 - 134.5 = 4.0 m

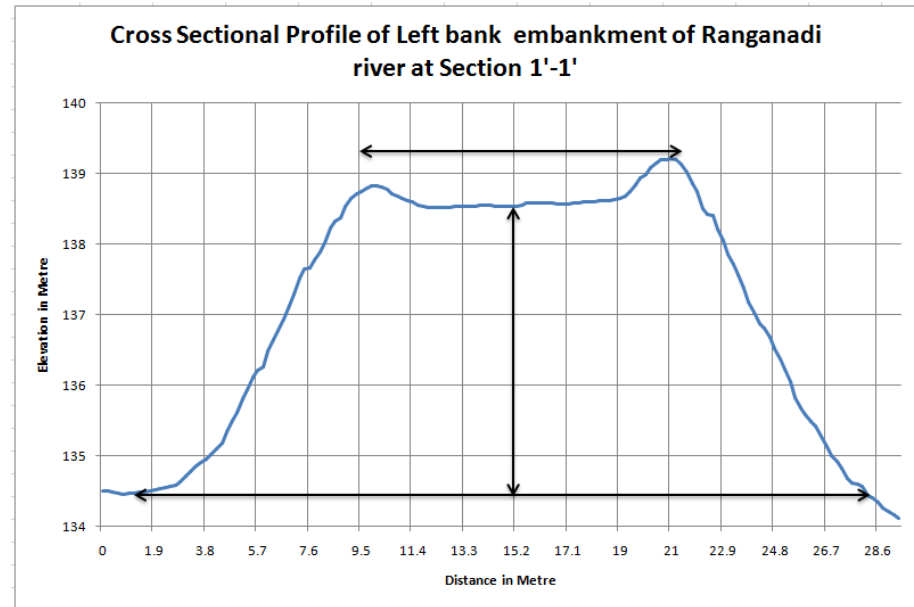
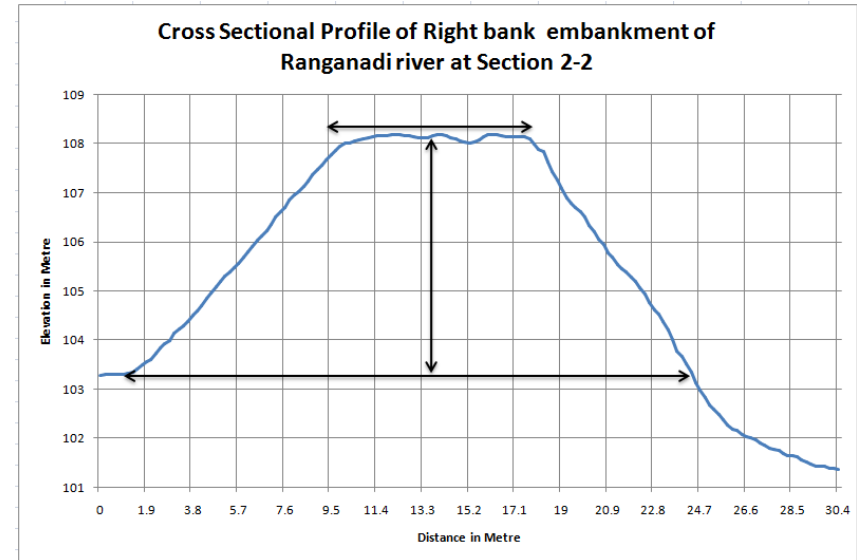


Fig: 18 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 2 - 2**

Top width : 17.5 - 9.5 = 8.0 m  
 Bottom width : 24.5 - 1.2 = 23.3 m  
 Height : 108.1 - 103.2 = 4.9 m



**Cross Sectional Details of Section: 2' - 2'**

Top width : 16.1 - 7.5 = 8.6 m  
 Bottom width : 22.8 - 0.6 = 22.2 m  
 Height : 139.2 - 135 = 4.2 m

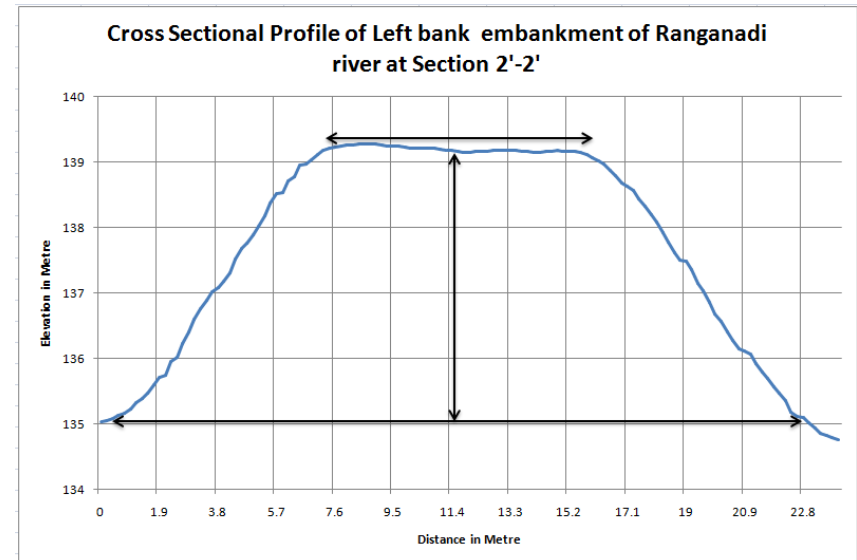
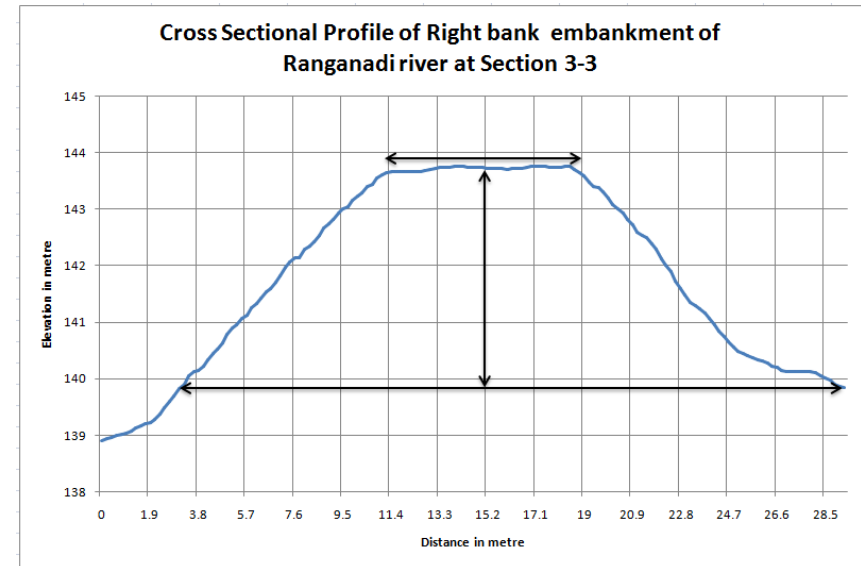


Fig: 19 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 3 - 3**

Top width : 19.0 - 11.4 = 7.6 m  
Bottom width : 29.4 - 3.4 = 26.0 m  
Height : 143.7 - 139.9 = 3.8 m



**Cross Sectional Details of Section: 3' - 3'**

Top width : 15.4 - 9.5 = 5.9 m  
Bottom width : 25.6 - 1.2 = 24.4 m  
Height : 107.6 - 103.3 = 4.3 m

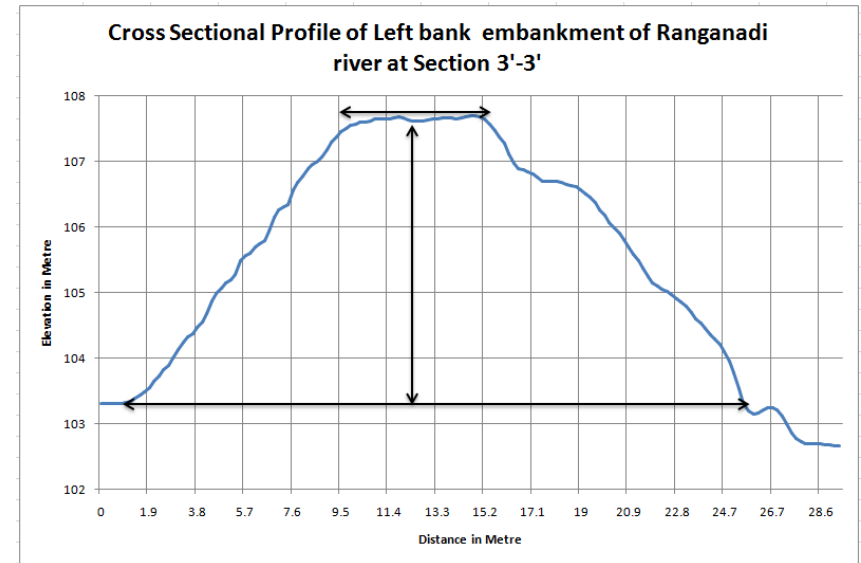
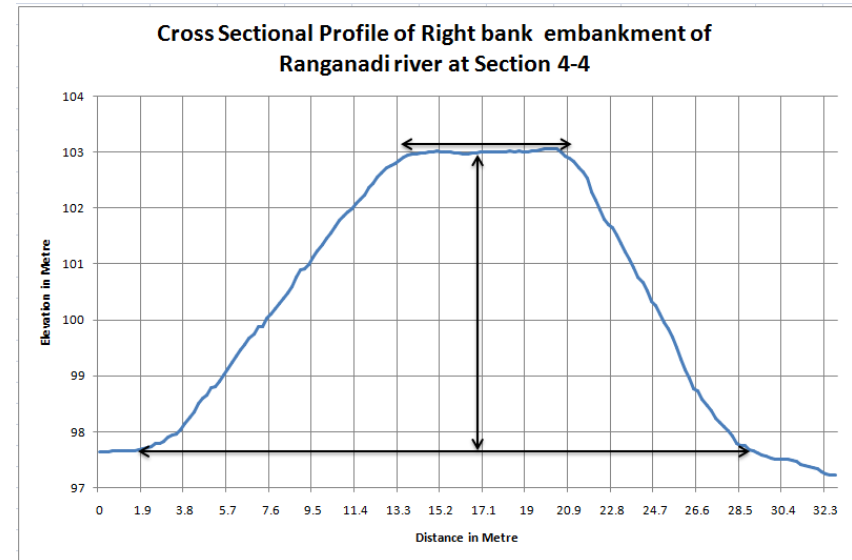


Fig: 20 Cross sectional profiles of Left and right bank embankment

### Cross Sectional Details of Section: 4 - 4

Top width : 21.0 - 13.5 = 7.5 m  
Bottom width : 28.9 - 1.9 = 27.0 m  
Height : 103 - 97.6 = 5.4 m



### Cross Sectional Details of Section: 4' - 4'

Top width : 13.5 - 8.2 = 5.3 m  
Bottom width : 22.4 - 0.0 = 22.4 m  
Height : 123.7 - 127.9 = 4.2 m

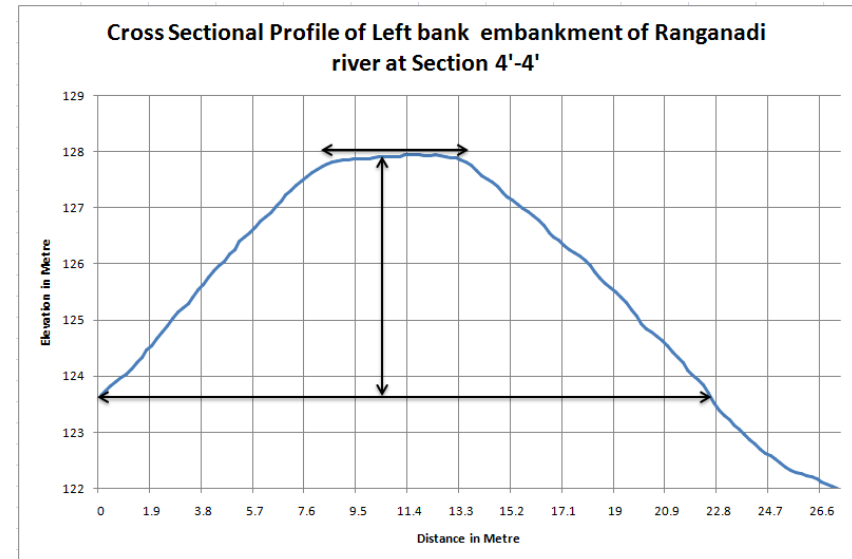


Fig: 21 Cross sectional profiles of Left and right bank embankment

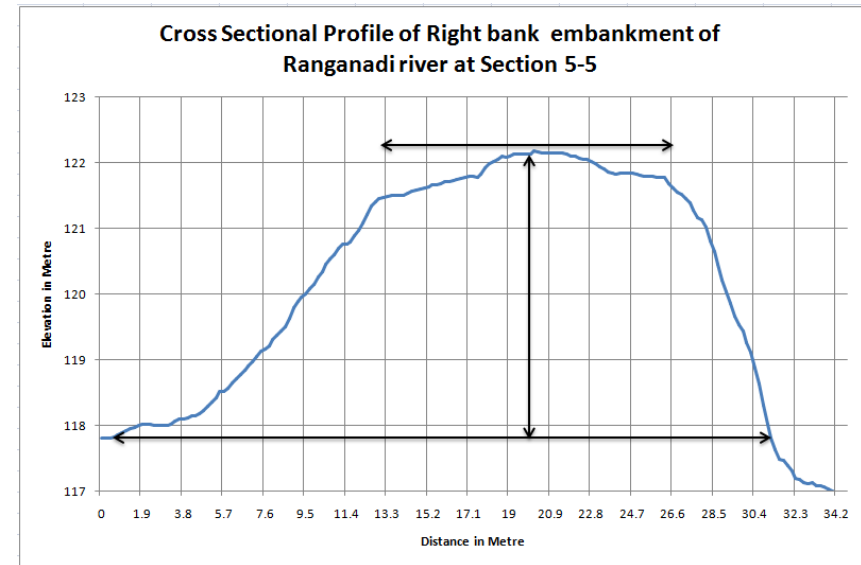


### Cross Sectional Details of Section: 5 - 5

Top width : 26.6 - 13.3 = 13.3 m

Bottom width : 31.0 - 1.0 = 30.0 m

Height : 122.1 - 117.8 = 4.3 m



### Cross Sectional Details of Section: 5' - 5'

Top width : 19.0 - 11.4 = 7.6 m

Bottom width : 29.0 - 0.8 = 28.2 m

Height : 126.2 - 121.8 = 4.4 m

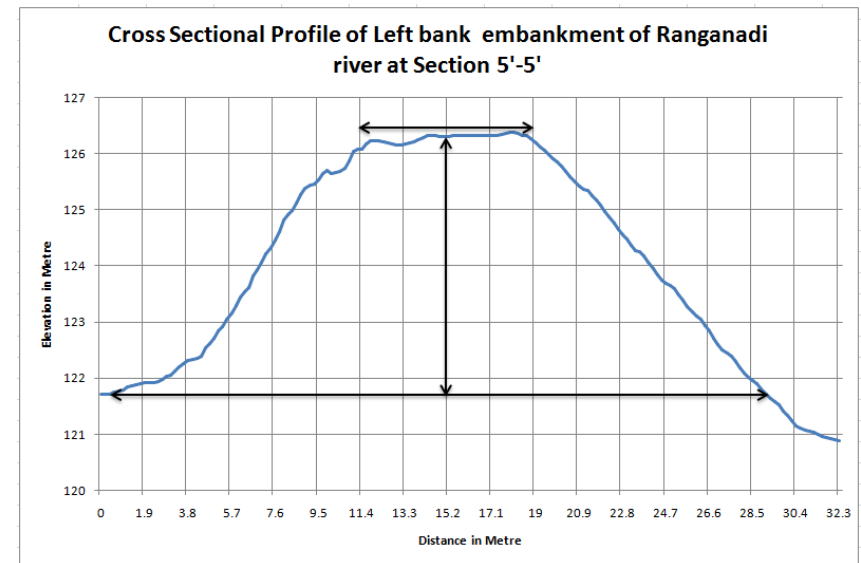
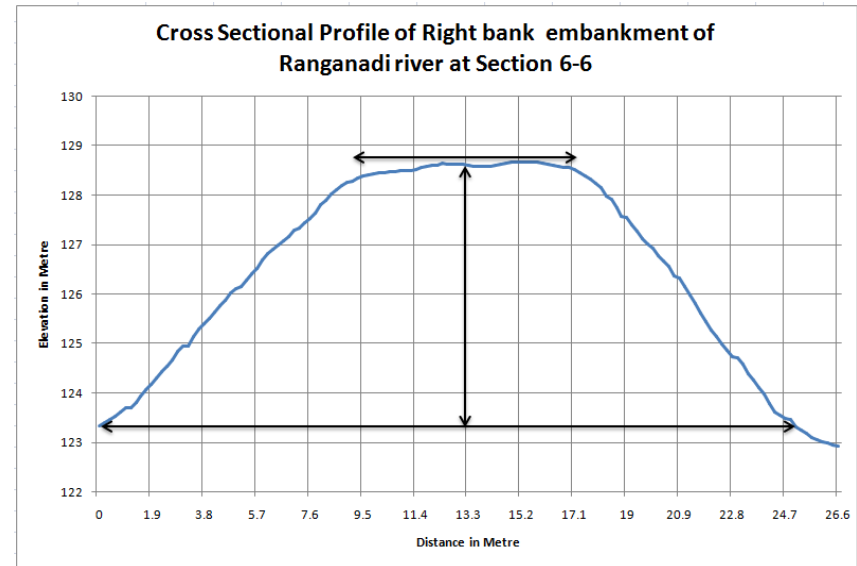


Fig: 22 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 6 - 6**

Top width : 17.3 - 9.3 = 8.0 m  
Bottom width : 25.1 - 0.4 = 24.7 m  
Height : 128.5 - 123.3 = 5.2 m



**Cross Sectional Details of Section: 6' - 6'**

Top width : 17.2 - 10.8 = 6.4 m  
Bottom width : 29.0 - 1.4 = 27.6 m  
Height : 131.6 - 126.5 = 5.1 m

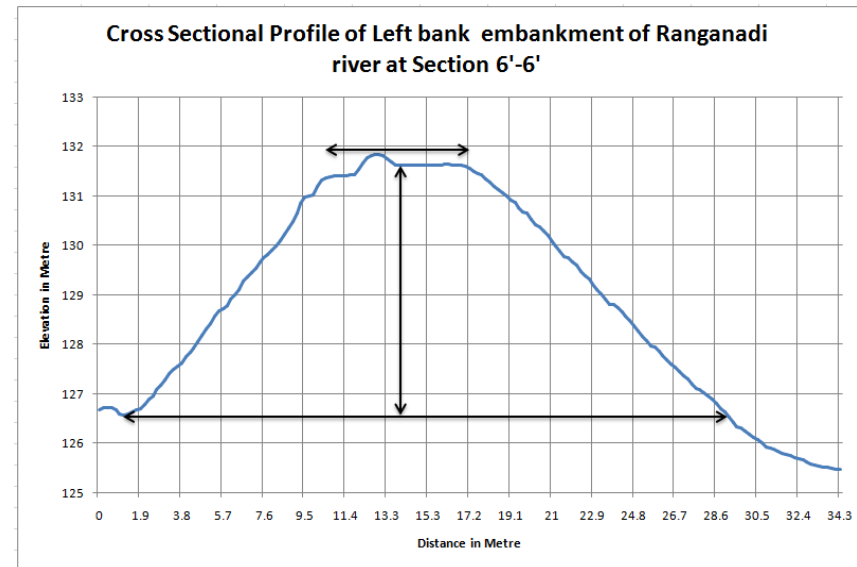
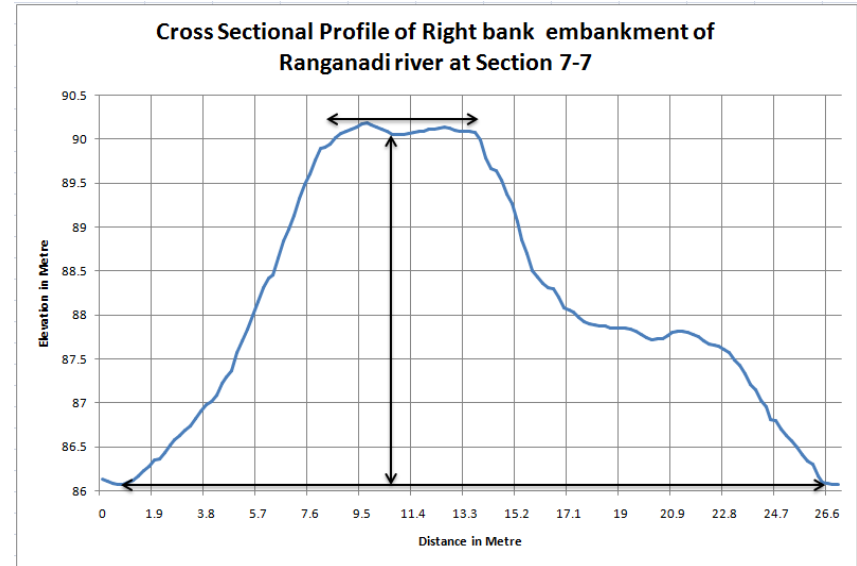


Fig: 23 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 7 - 7**

Top width : 13.7 - 8.5 = 5.2 m  
Bottom width : 26.6 - 1.2 = 25.4 m  
Height : 90.0 - 86.0 = 4.0 m



**Cross Sectional Details of Section: 7' - 7'**

Top width : 18.1 - 11.3 = 6.8 m  
Bottom width : 27.3 - 0.4 = 26.9 m  
Height : 101.9 - 98.1 = 3.8 m

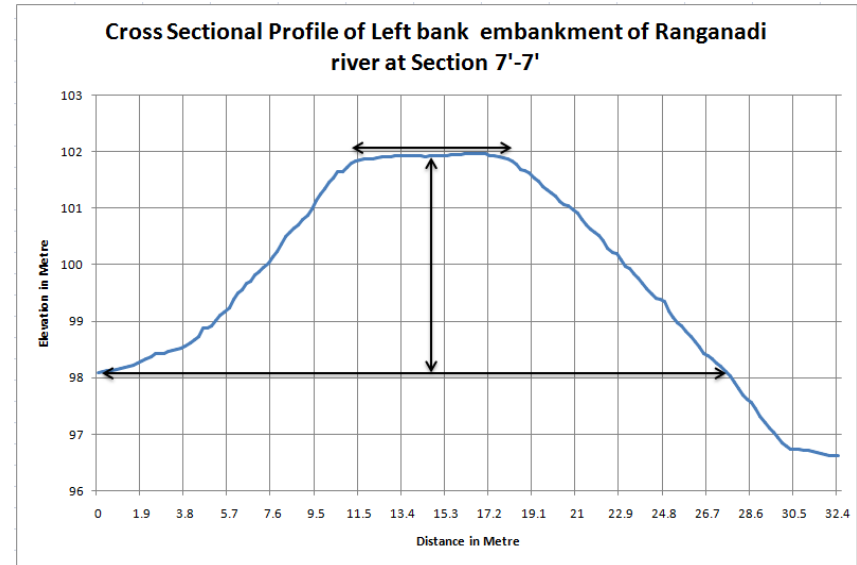
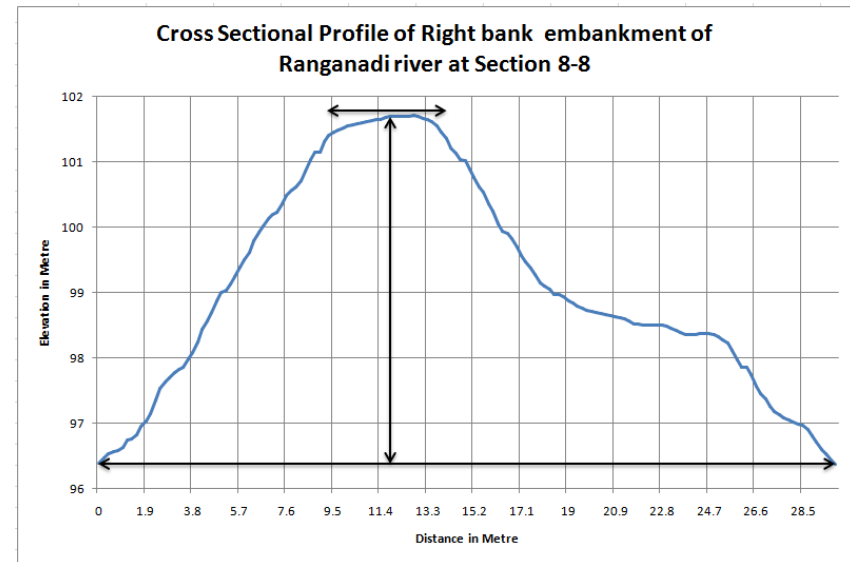


Fig: 24 Cross sectional profiles of Left and right bank embankment

### Cross Sectional Details of Section: 8 - 8

Top width : 13.9 - 9.3 = 4.6 m  
Bottom width : 29.8 - 0.0 = 29.8 m  
Height : 101.7 - 96.4 = 5.3 m



### Cross Sectional Details of Section: 8' - 8'

Top width : 19.2 - 10.5 = 9.0 m  
Bottom width : 25.7 - 1.0 = 24.7 m  
Height : 112.5 - 116.9 = 4.4 m

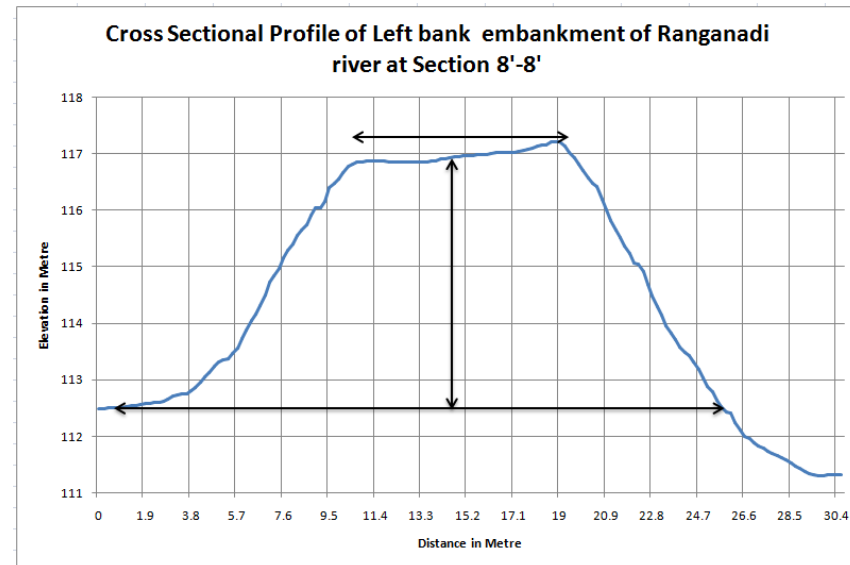
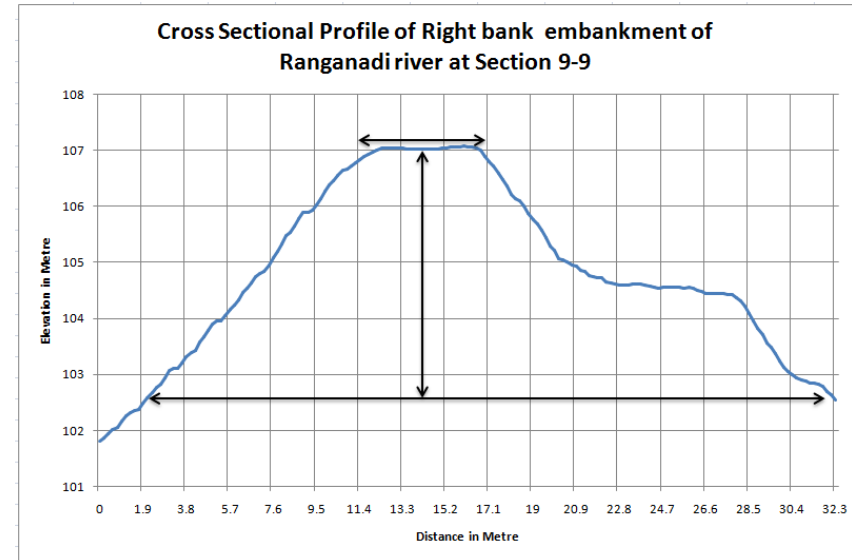


Fig: 25 Cross sectional profiles of Left and right bank embankment



**Cross Sectional Details of Section: 9 - 9**

Top width : 17.1 - 11.4 = 5.7 m  
 Bottom width : 32.3 - 2.5 = 29.8 m  
 Height : 102.6 - 107 = 4.4 m



**Cross Sectional Details of Section: 9' - 9'**

Top width : 20.9 - 14.3 = 6.6 m  
 Bottom width : 27.9 - 1.0 = 26.9 m  
 Height : 159.2 - 154.3 = 4.9 m

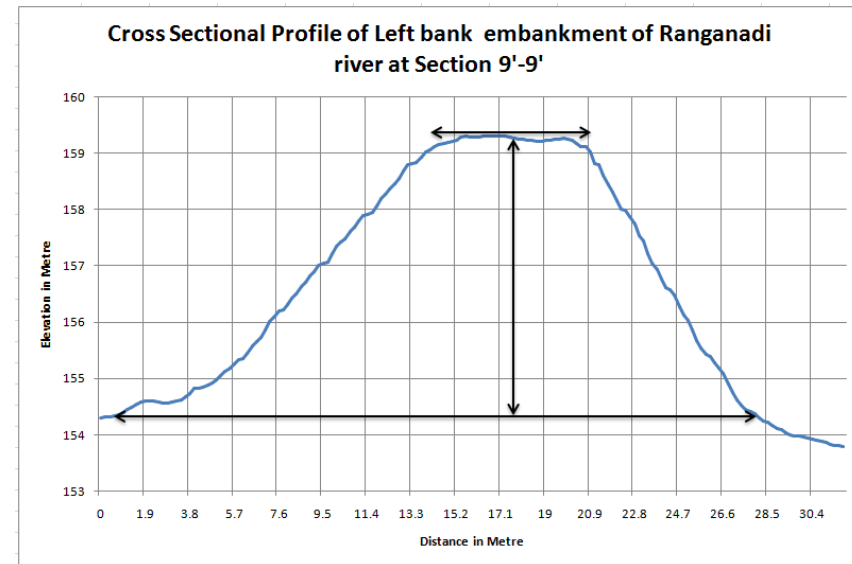
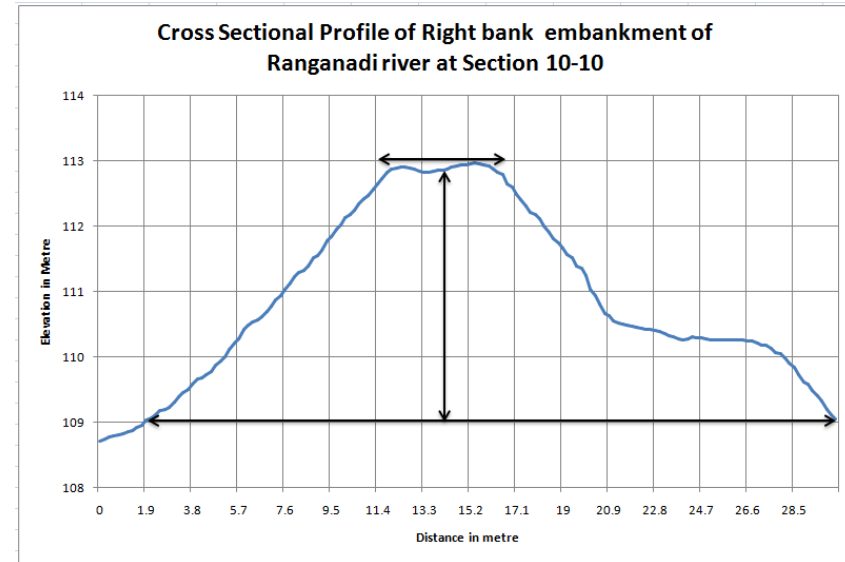


Fig: 26 Cross sectional profiles of Left and right bank embankment

### Cross Sectional Details of Section: 10 - 10

Top width : 16.7 - 11.6 = 5.1 m  
Bottom width : 30.4 - 2.1 = 28.3 m  
Height : 112.8 - 109 = 3.8 m



### Cross Sectional Details of Section: 10' - 10'

Top width : 19.1 - 11.8 = 7.3 m  
Bottom width : 27.1 - 2.3 = 24.8 m  
Height : 108 - 103.7 = 4.3 m

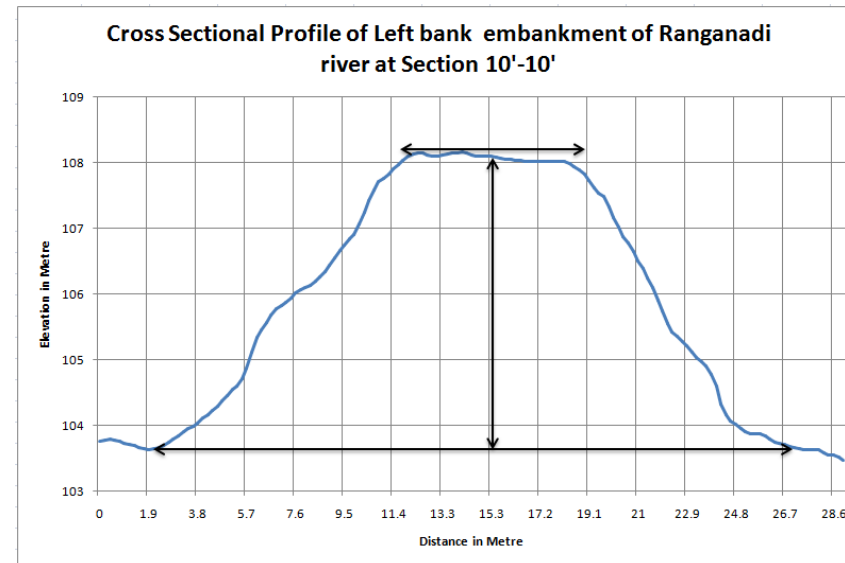
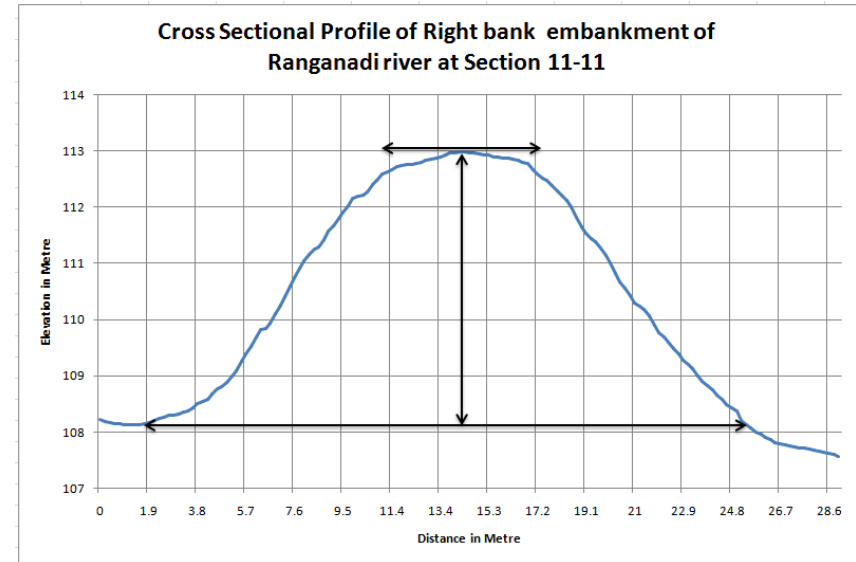


Fig: 27 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 11 - 11**

Top width : 17.4 - 11.2 = 6.2 m  
Bottom width : 25.2 - 1.9 = 23.3 m  
Height : 112.9 - 108.1 = 4.8 m



**Cross Sectional Details of Section: 11' - 11'**

Top width : 21.1 - 13.1 = 8.0 m  
Bottom width : 31.8 - 2.5 = 29.3 m  
Height : 89.7 - 86.5 = 3.2 m

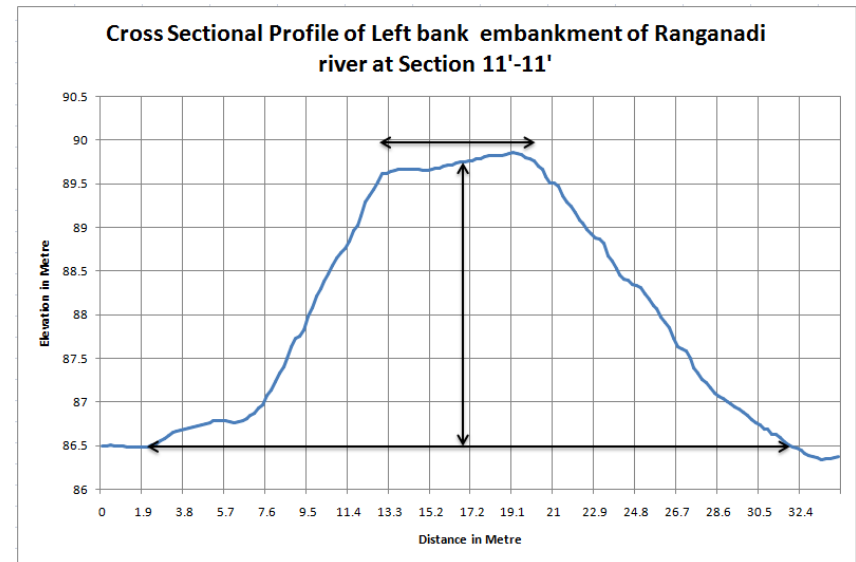
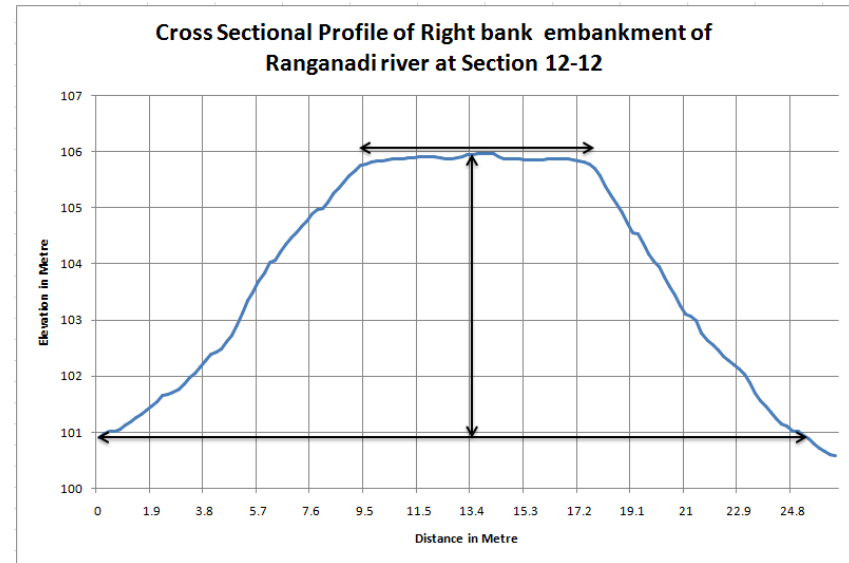


Fig: 28 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 12 - 12**

Top width : 17.6 - 9.5 = 8.1 m  
Bottom width : 25.4 - 0.0 = 25.4 m  
Height : 105.9 - 100.9 = 5.0 m



**Cross Sectional Details of Section: 12' - 12'**

Top width : 17.1 - 10.1 = 7.0 m  
Bottom width : 25.1 - 0.6 = 24.5 m  
Height : 101 - 97.3 = 3.7 m

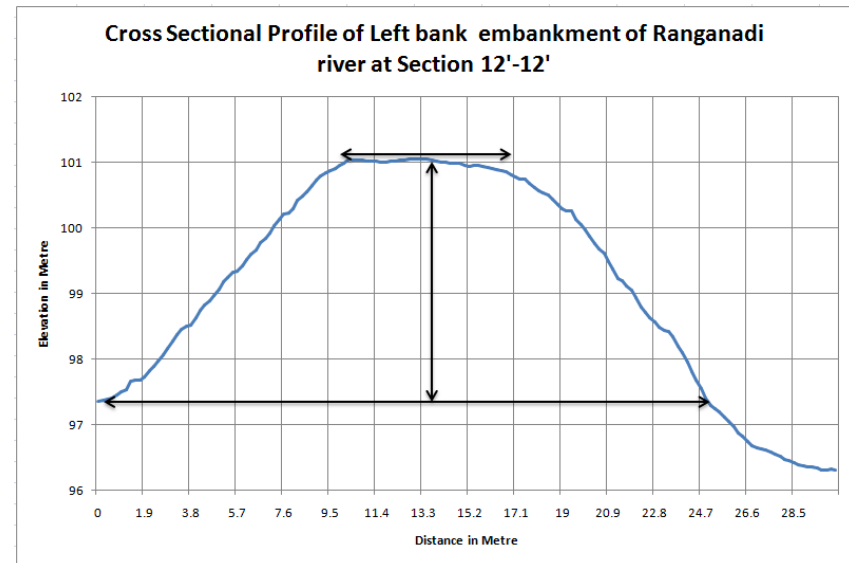


Fig: 29 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 13 - 13**

Top width : 15.4 - 9.5 = 5.9 m  
Bottom width : 23.0 - 0.0 = 23.0 m  
Height : 98.5 - 94.0 = 4.5 m

**Cross Sectional Details of Section: 13' - 13'**

Top width : 18.4 - 11.4 = 7.0 m  
Bottom width : 27.5 - 1.0 = 26.5 m  
Height : 110.3 - 105.3 = 5.0 m

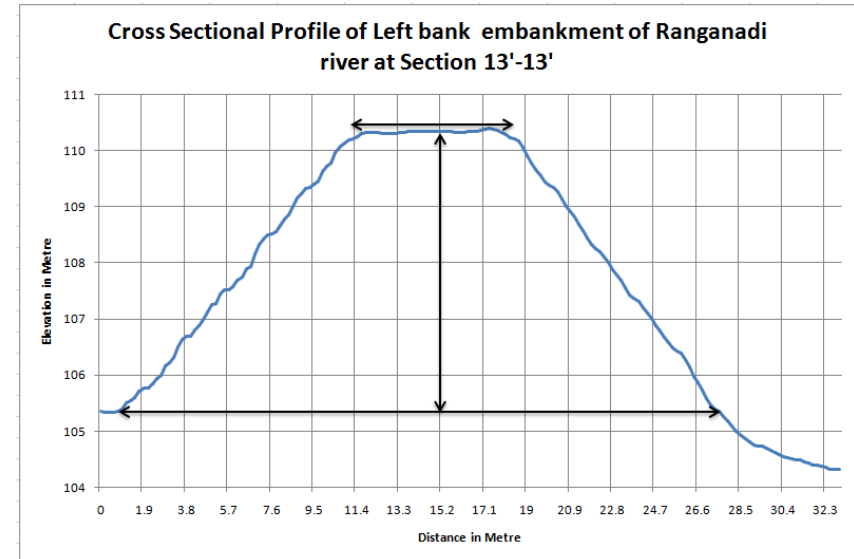
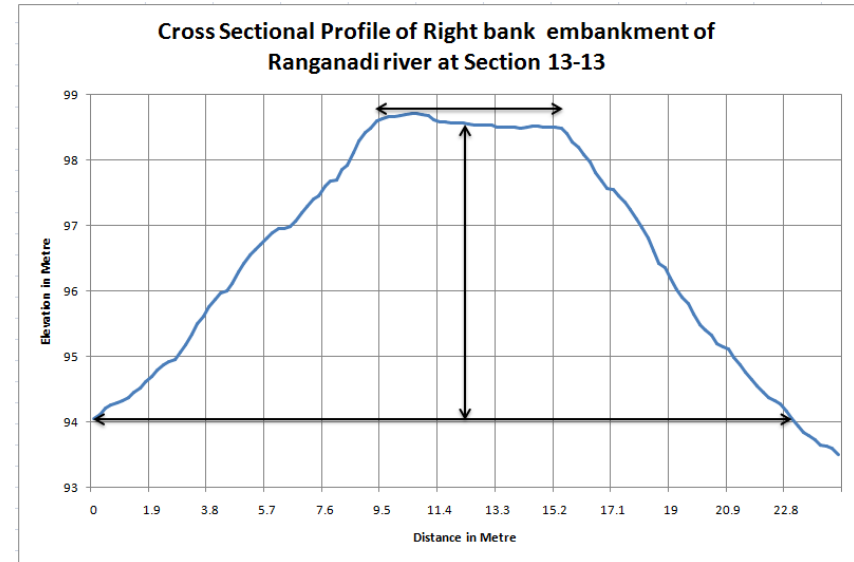
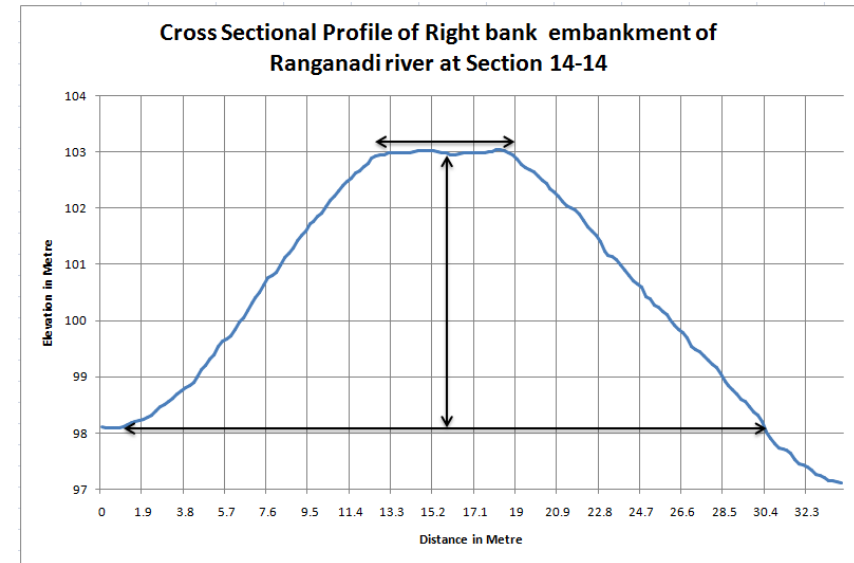


Fig: 30 Cross sectional profiles of Left and right bank embankment

### Cross Sectional Details of Section: 14 - 14

Top width :  $19.0 - 12.8 = 6.2$  m  
Bottom width :  $30.4 - 1.4 = 29.0$  m  
Height :  $103 - 98 = 5.0$  m



### Cross Sectional Details of Section: 14' - 14'

Top width :  $19.1 - 12.9 = 6.2$  m  
Bottom width :  $30.5 - 1.0 = 29.5$  m  
Height :  $115.7 - 110.5 = 5.2$  m

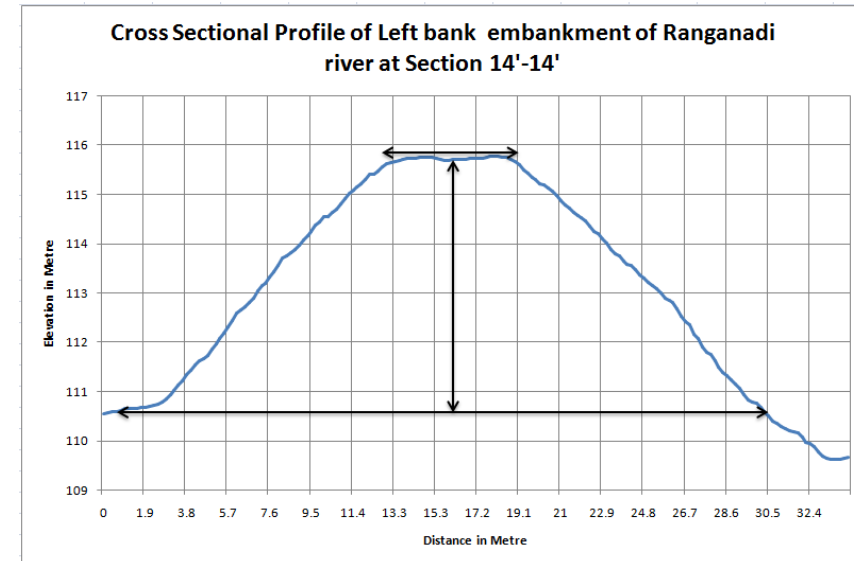
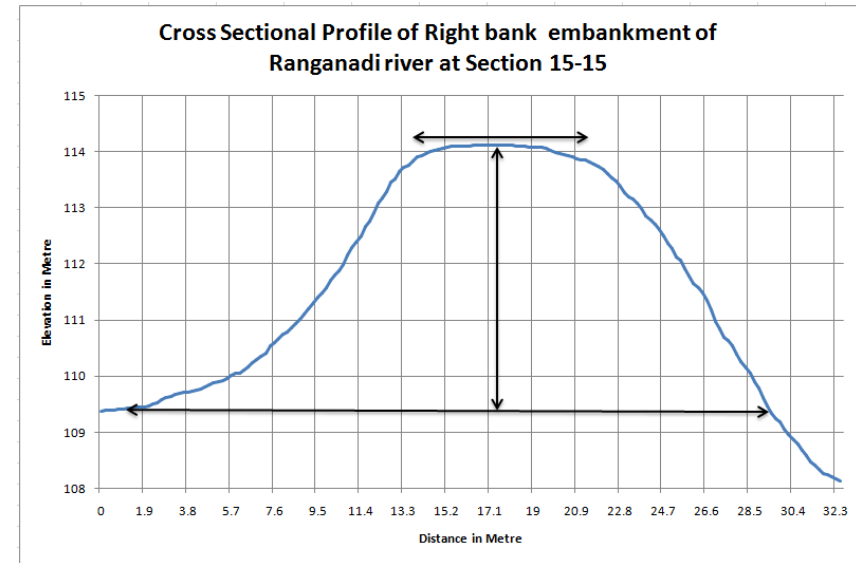


Fig: 31 Cross sectional profiles of Left and right bank embankment



**Cross Sectional Details of Section: 15 - 15**

Top width : 21.3 - 14.0 = 7.3 m  
Bottom width : 29.3 - 1.5 = 27.8 m  
Height : 114.1 - 109.3 = 4.8 m



**Cross Sectional Details of Section: 15' - 15'**

Top width : 19.0 - 11.4 = 7.6 m  
Bottom width : 32.5 - 2.3 = 30.2 m  
Height : 121.7 - 116.6 = 5.1 m

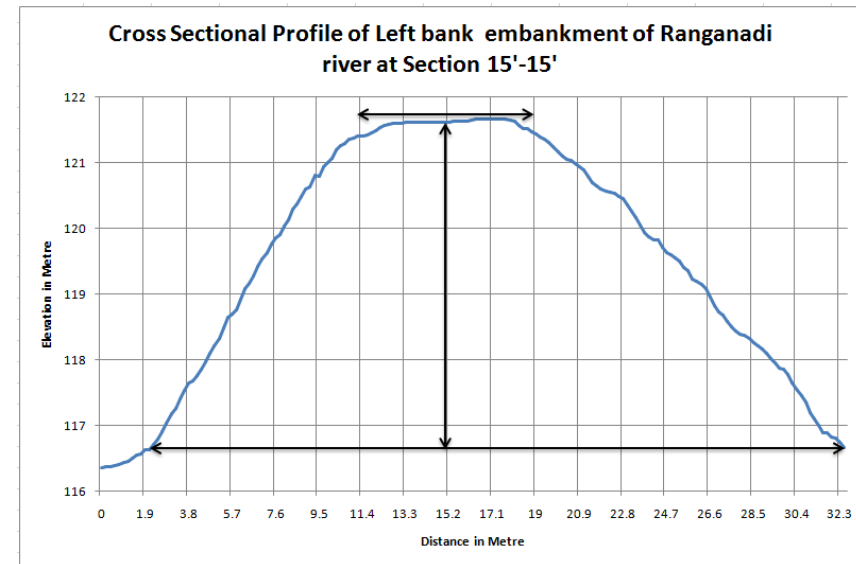


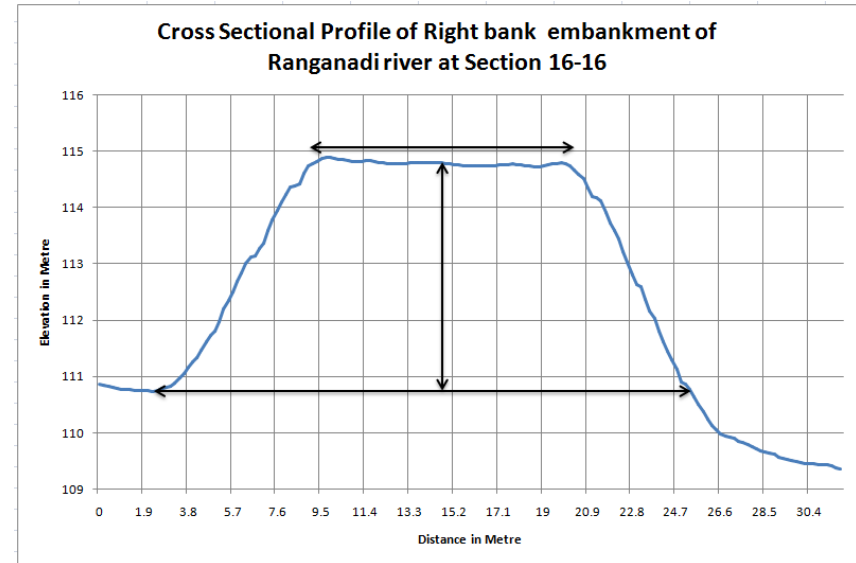
Fig: 32 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 16 - 16**

Top width : 20.3 - 9.3 = 11.0 m

Bottom width : 25.3 - 2.8 = 22.5 m

Height : 114.8 - 110.8 = 4.0 m



**Cross Sectional Details of Section: 16' - 16'**

Top width : 17.2 - 10.1 = 7.1 m

Bottom width : 28.6 - 0.2 = 28.4 m

Height : 121.8 - 116.9 = 4.9 m

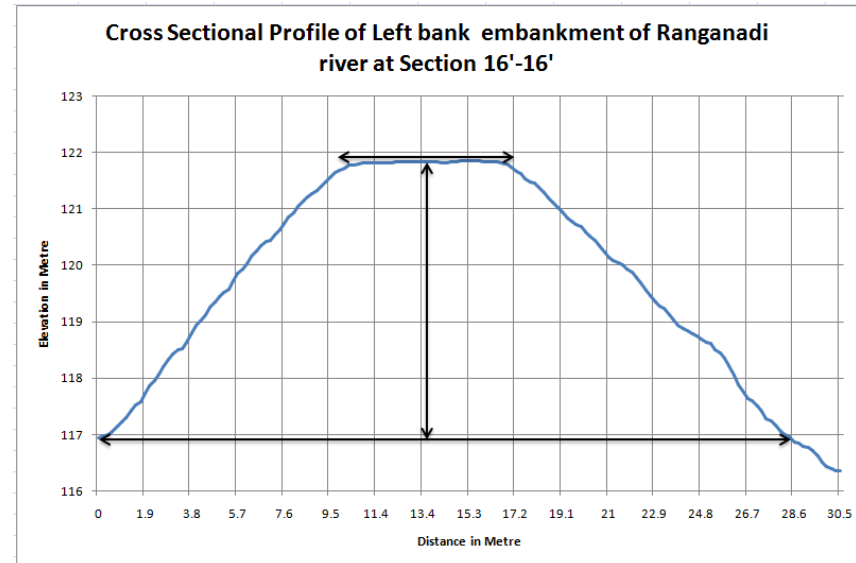
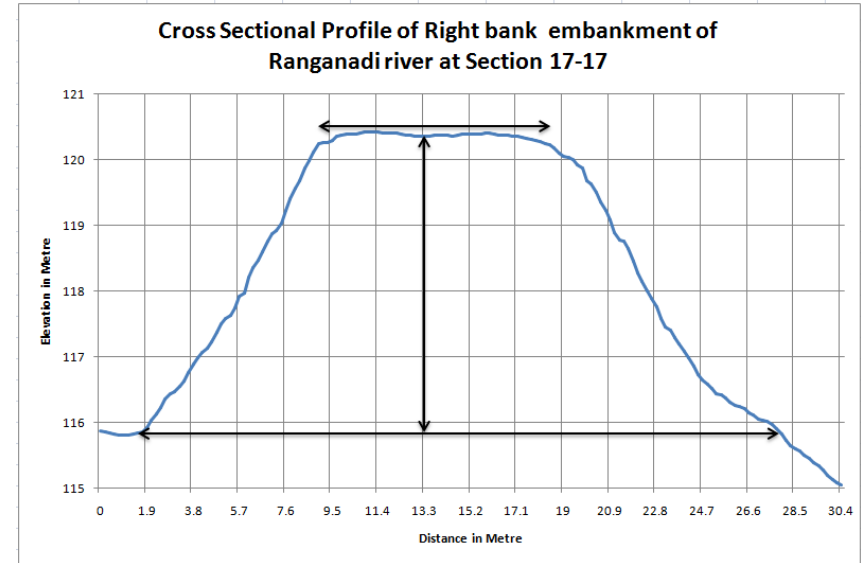


Fig: 33 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 17 - 17**

Top width : 18.5 - 9.0 = 9.5 m  
Bottom width : 27.7 - 1.7 = 26.0 m  
Height : 120.3 - 115.8 = 4.5 m



**Cross Sectional Details of Section: 17' - 17'**

Top width : 17.6 - 11.0 = 6.6 m  
Bottom width : 29.0 - 0.8 = 28.2 m  
Height : 116.2 - 111.2 = 5.0 m

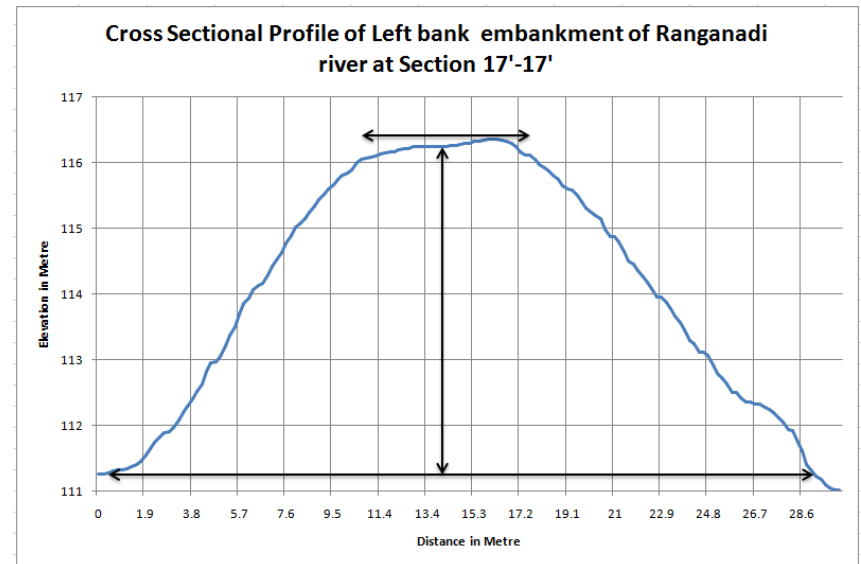
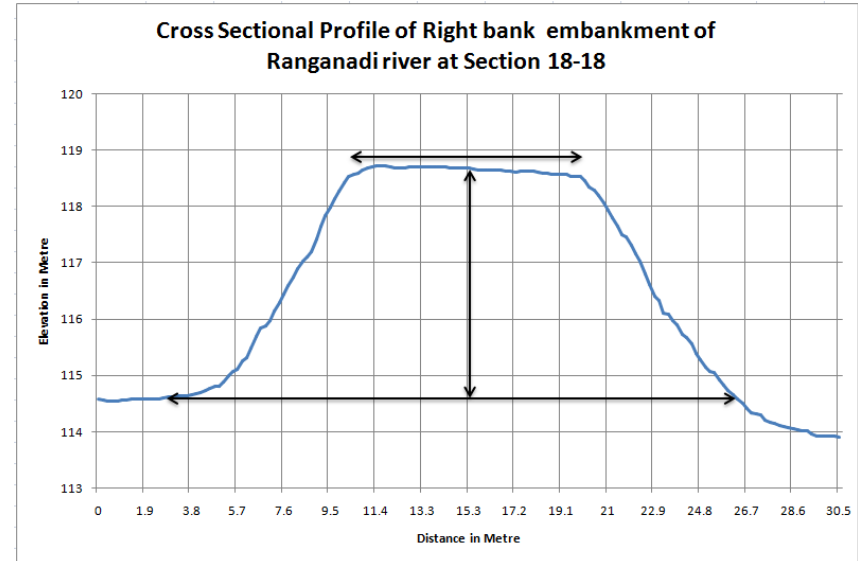


Fig: 34 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 18 - 18**

Top width : 19.9 - 10.5 = 9.4 m  
 Bottom width : 26.2 - 3.2 = 23.0 m  
 Height : 118.6 - 114.5 = 4.1 m



**Cross Sectional Details of Section: 18' - 18'**

Top width : 18.0 - 12.1 = 5.9 m  
 Bottom width : 29.0 - 0.8 = 28.2 m  
 Height : 109.2 - 104 = 5.2 m

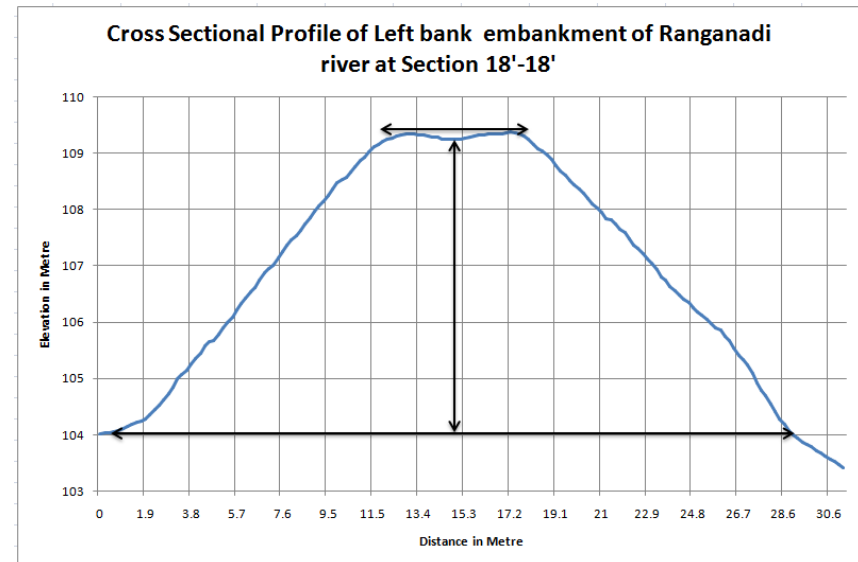


Fig: 35 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 19 - 19**

Top width : 17.7 - 12.3 = 5.4 m  
 Bottom width : 25.5 - 2.5 = 23.0 m  
 Height : 116.8 - 112.9 = 3.9 m

**Cross Sectional Details of Section: 19' - 19'**

Top width : 16.2 - 9.5 = 6.7 m  
 Bottom width : 27.6 - 0.8 = 26.8 m  
 Height : 105.4 - 101 = 4.4 m

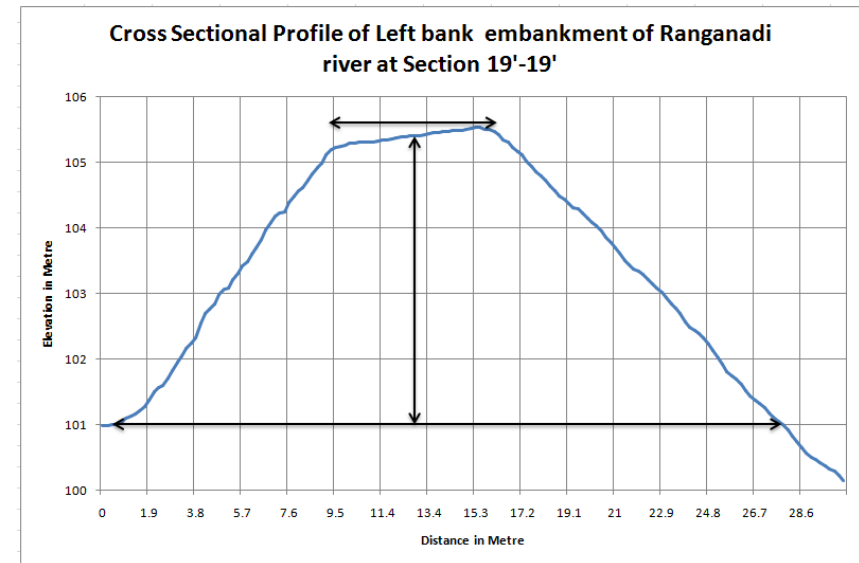
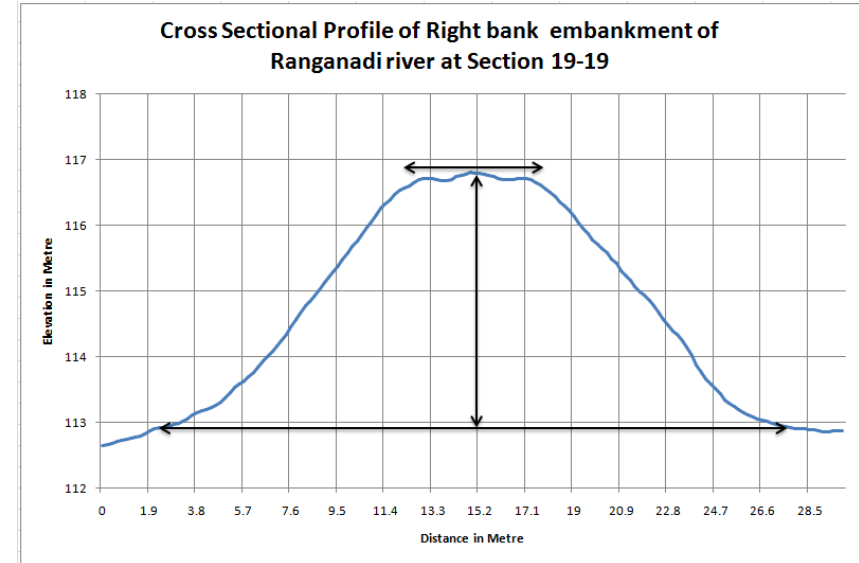


Fig: 36 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 20 - 20**

Top width : 18.5 - 11.4 = 7.1 m  
Bottom width : 27.7 - 0.0 = 27.7 m  
Height : 145.7 - 141.9 = 3.8 m

**Cross Sectional Details of Section: 20' - 20'**

Top width : 15.2 - 8.6 = 6.6 m  
Bottom width : 26.8 - 0.4 = 26.4 m  
Height : 113.8 - 109.2 = 4.6 m

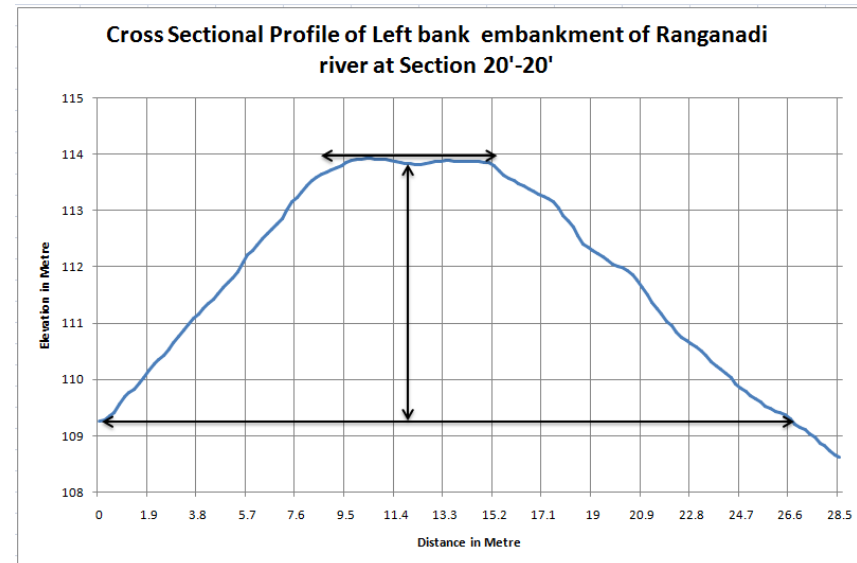
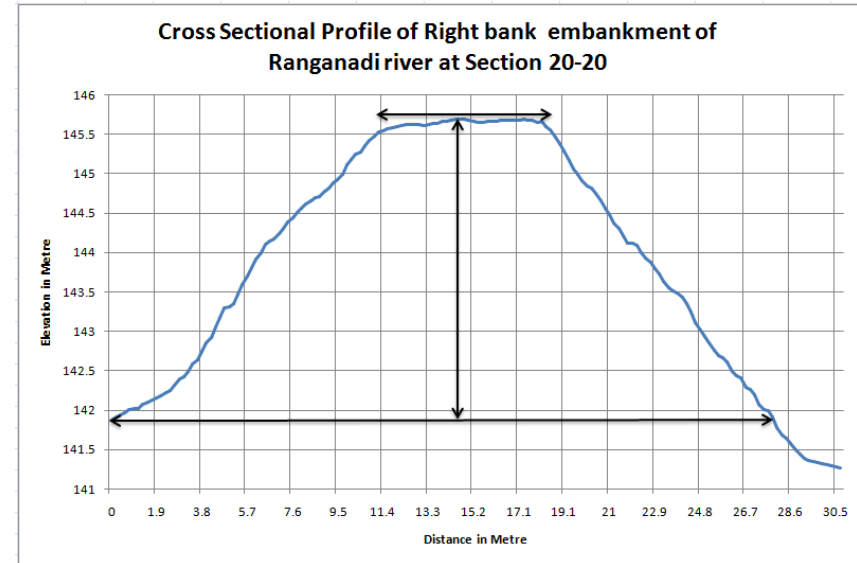
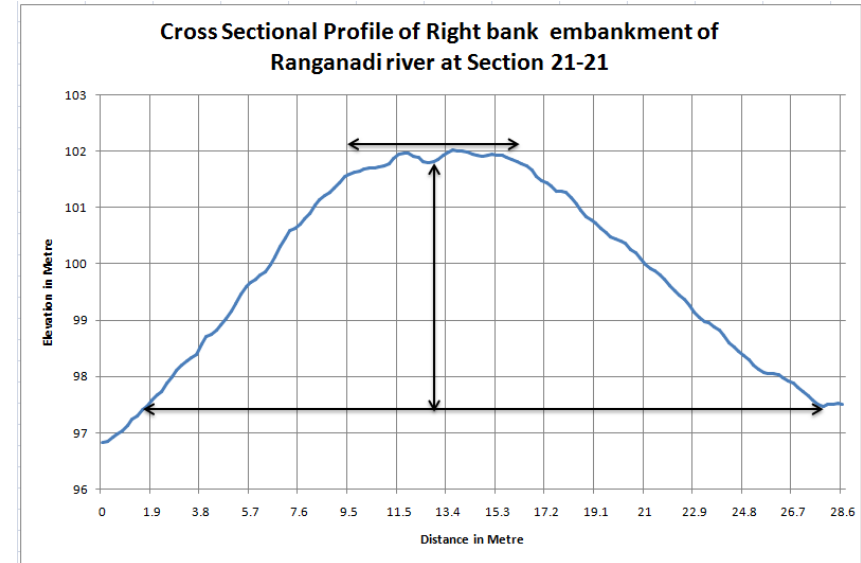


Fig: 37 Cross sectional profiles of Left and right bank embankment



**Cross Sectional Details of Section: 21 - 21**

Top width : 16.2 - 9.5 = 6.7 m  
Bottom width : 27.7 - 1.6 = 26.1 m  
Height : 101.8 - 97.4 = 4.4 m



**Cross Sectional Details of Section: 21' - 21'**

Top width : 18.2 - 12.3 = 5.9 m  
Bottom width : 32.7 - 0.8 = 31.9 m  
Height : 119.6 - 114.4 = 5.2 m

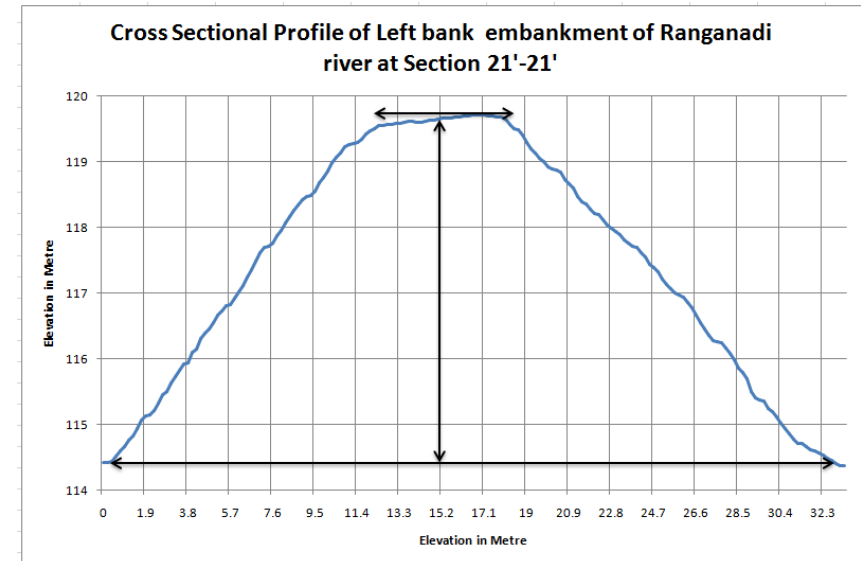
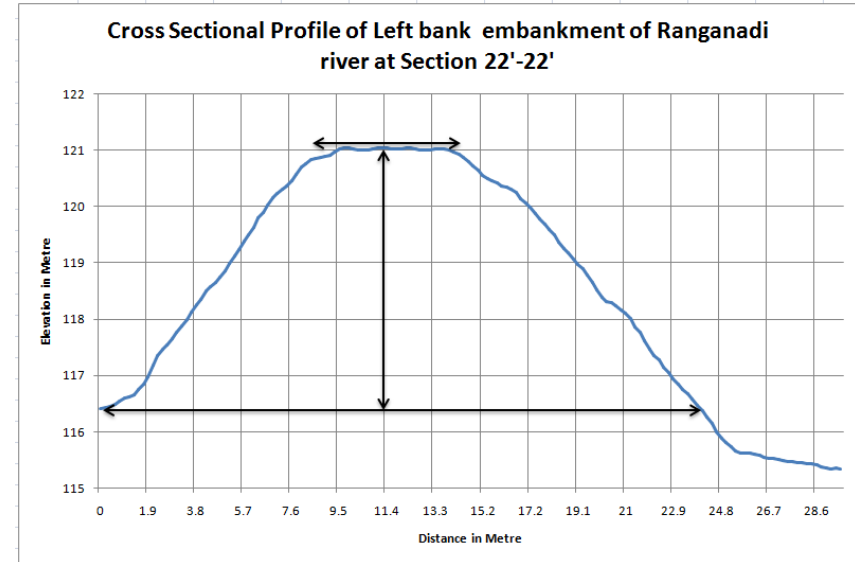


Fig: 38 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 22' - 22'**

Top width : 13.2 - 8.6 = 4.6 m  
Bottom width : 23.8 - 0.4 = 23.4 m  
Height : 121 - 116.3 = 4.7 m



**Cross Sectional Details of Section: 23' - 23'**

Top width : 16.2 - 10.3 = 5.9 m  
Bottom width : 26.3 - 0.2 = 26.1 m  
Height : 131.7 - 127 = 4.7 m

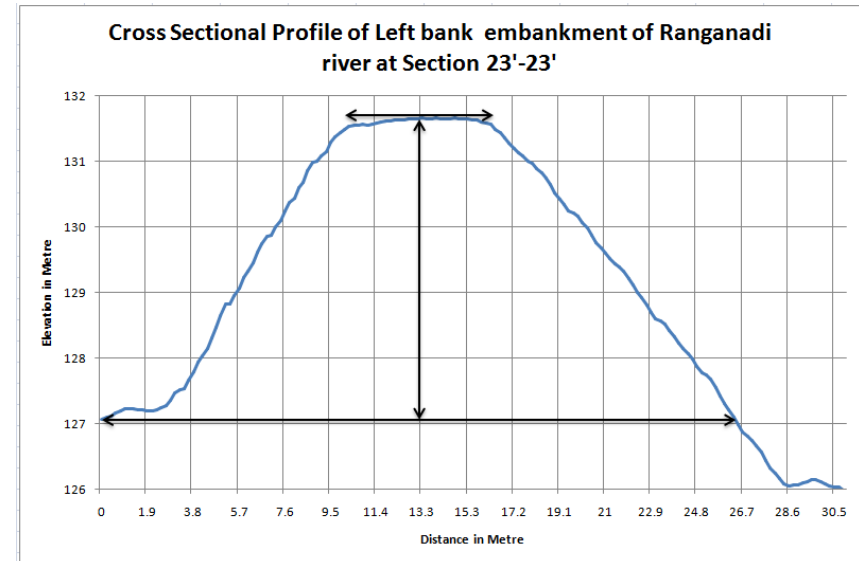


Fig: 39 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 24' - 24'**

Top width : 18.1 - 11.2 = 6.9 m  
Bottom width : 28.4 - 1.0 = 27.4 m  
Height : 128.7 - 124 = 4.7 m

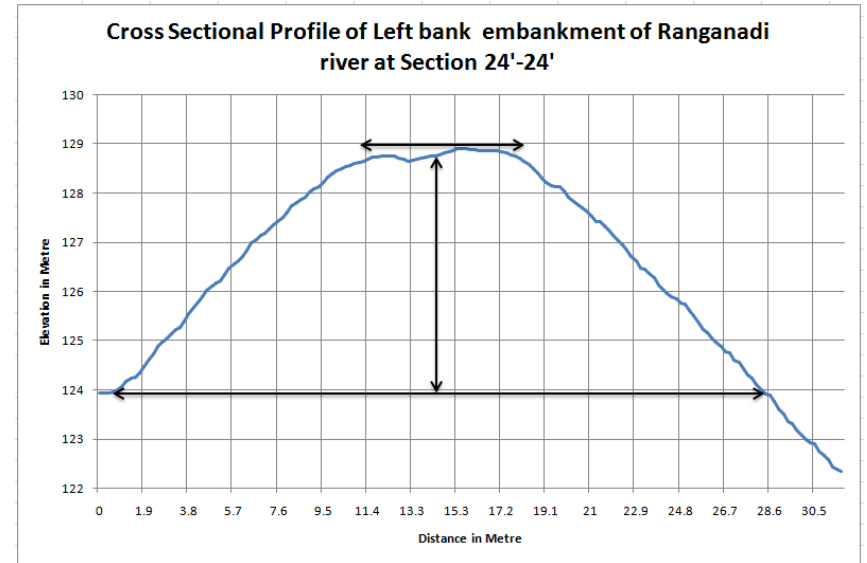


Fig: 40 Cross sectional profile of Left bank embankment

# Puthimari River embankment Longitudinal/Cross sectional profiles

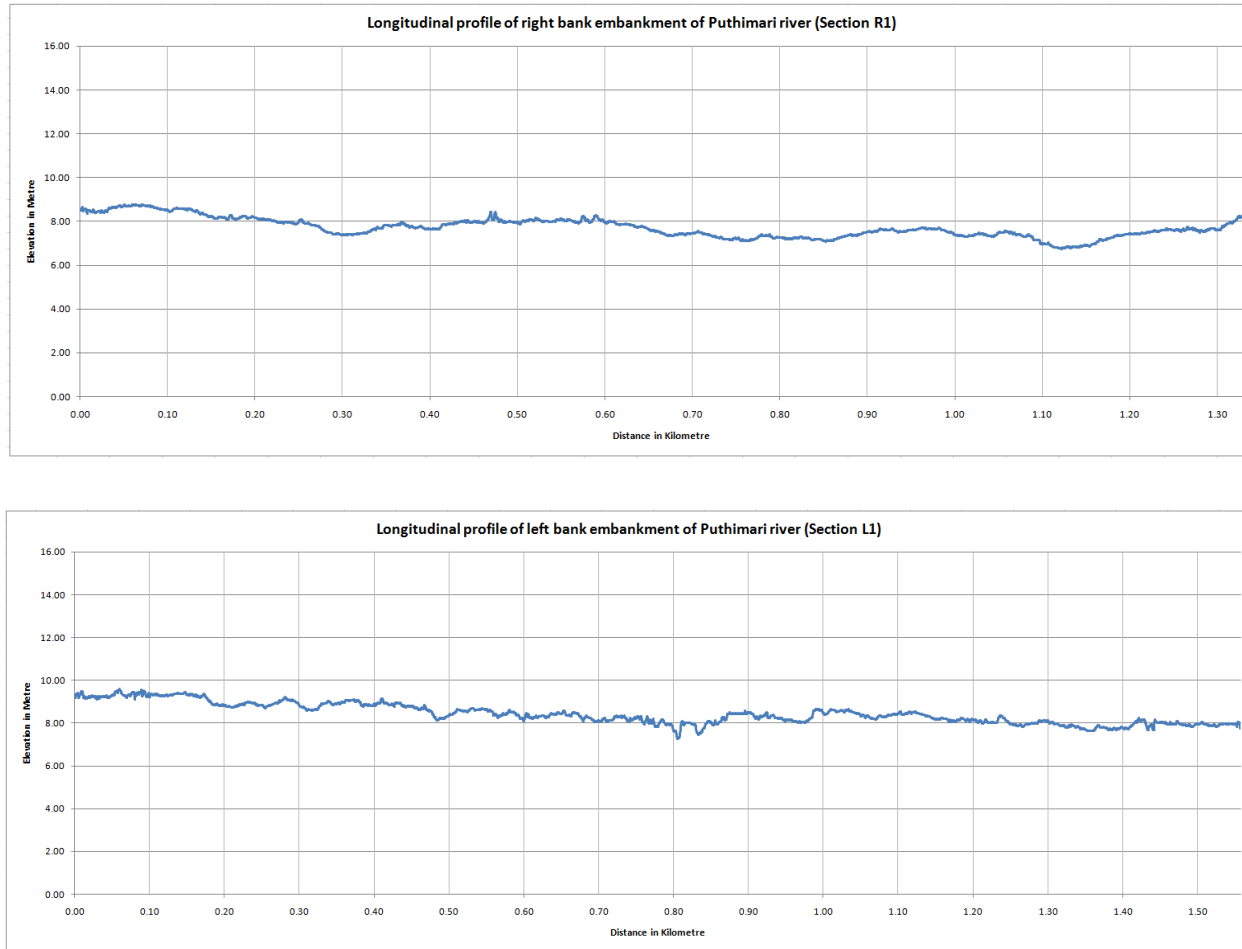


Fig: 41 Longitudinal profile of Left and right bank embankment (Section R1 & L1)

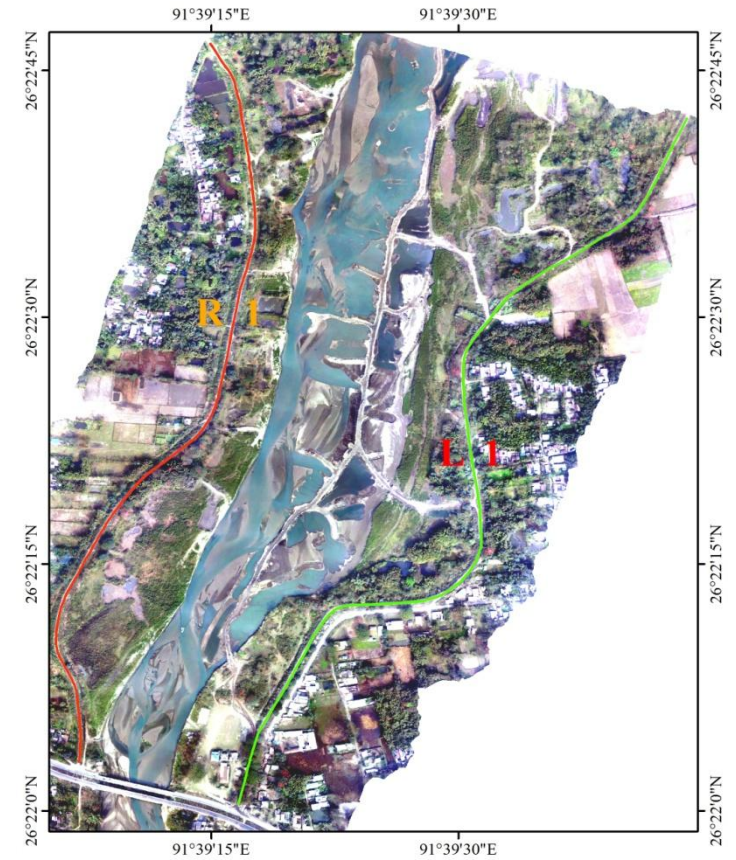


Fig: 42 UAV image of Puthimari river and It's embankments (Section R1 & L1)

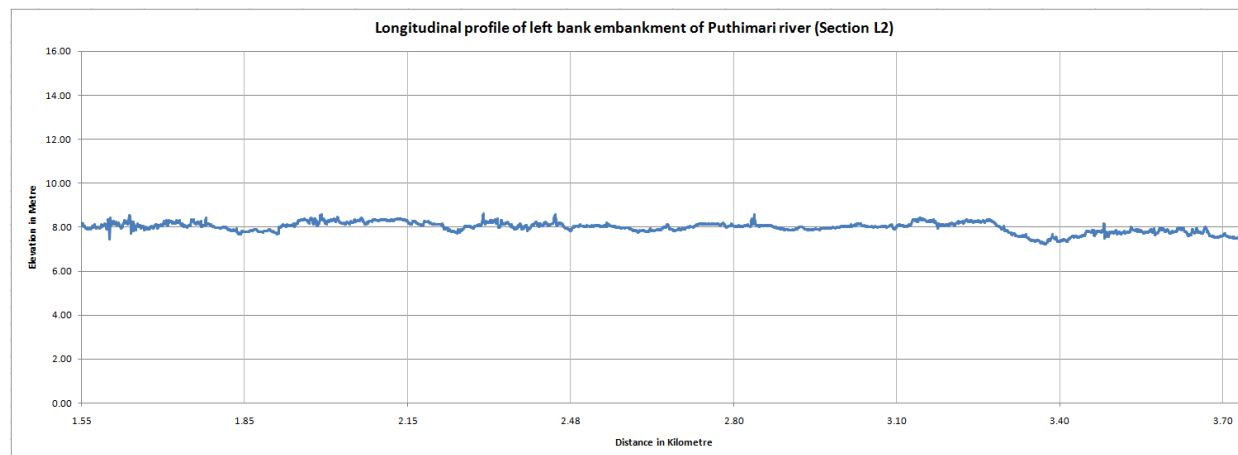
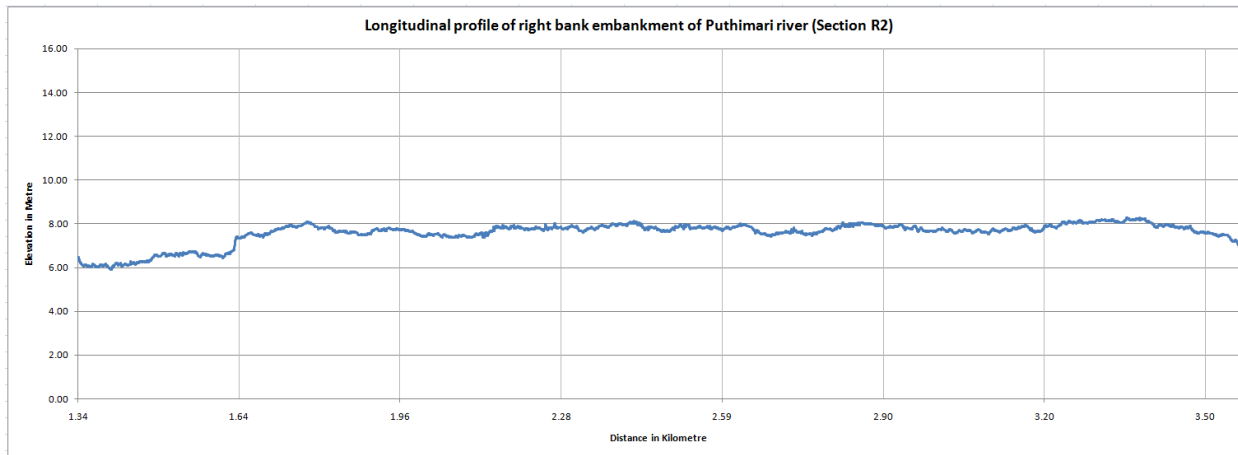


Fig: 43 Longitudinal profile of Left and right bank embankment (Section R2 & L2)

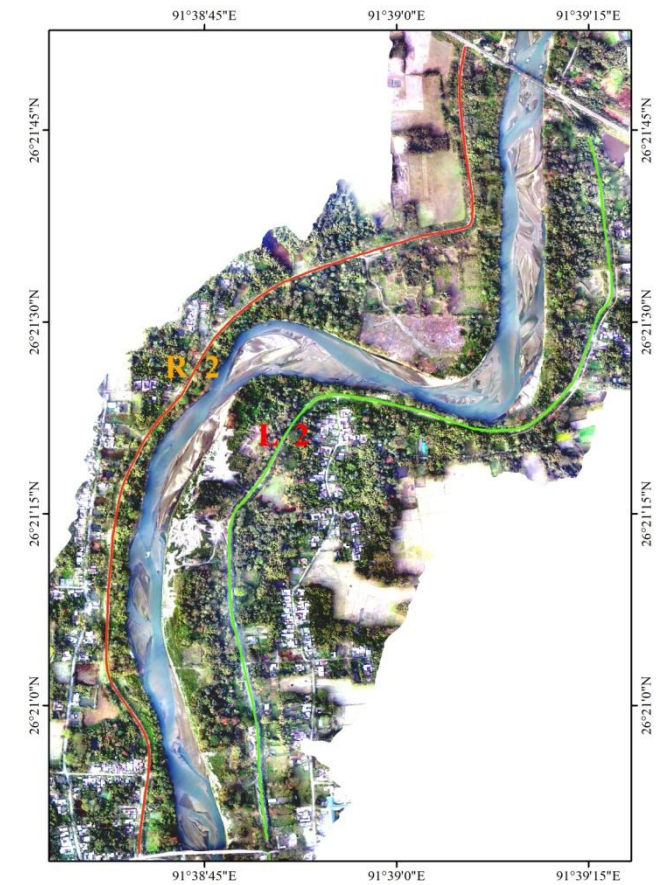


Fig: 44 UAV image of Puthimari river and Its embankments (Section R2 & L2)

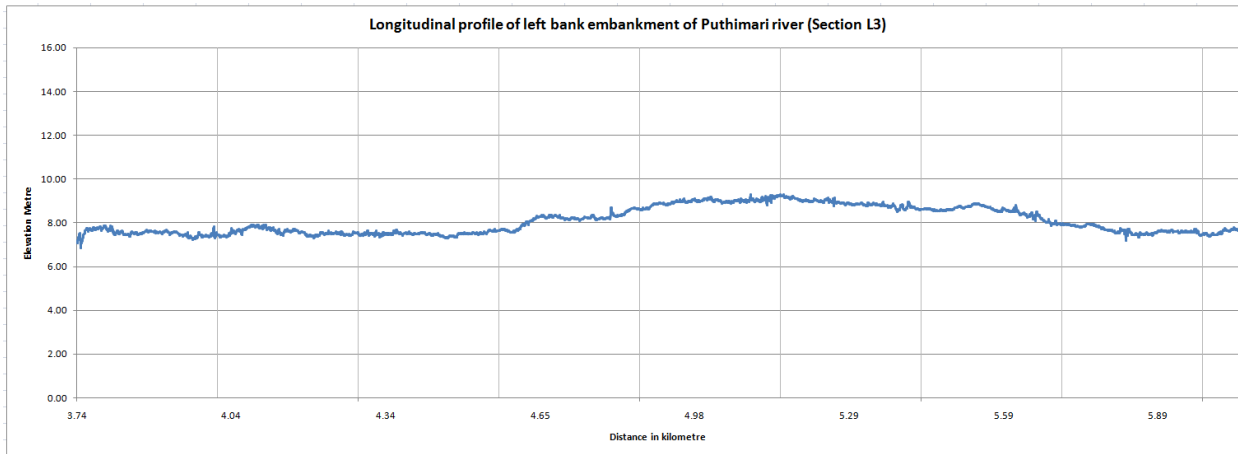
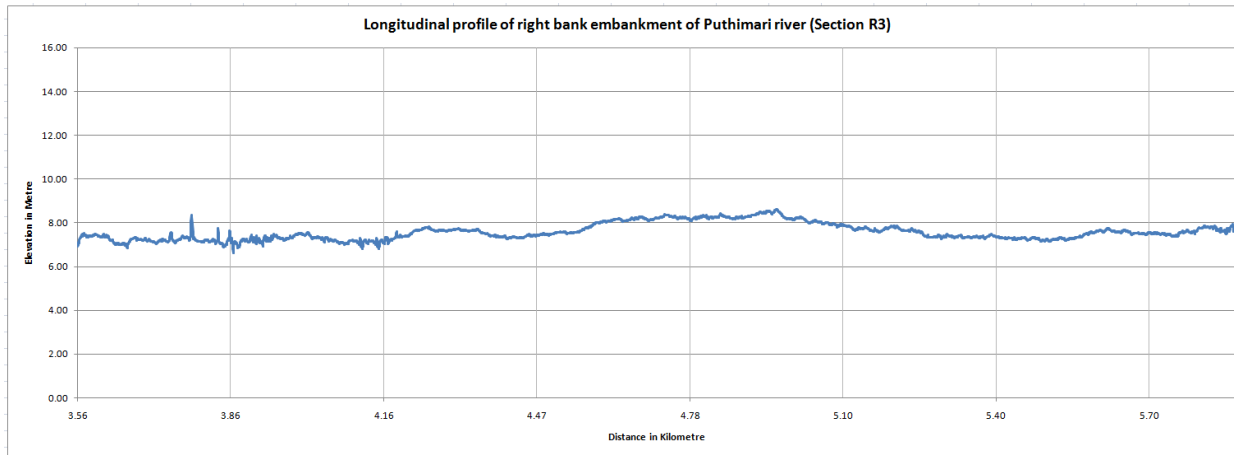


Fig: 45 Longitudinal profile of Left and right bank embankment (Section R3 & L3)

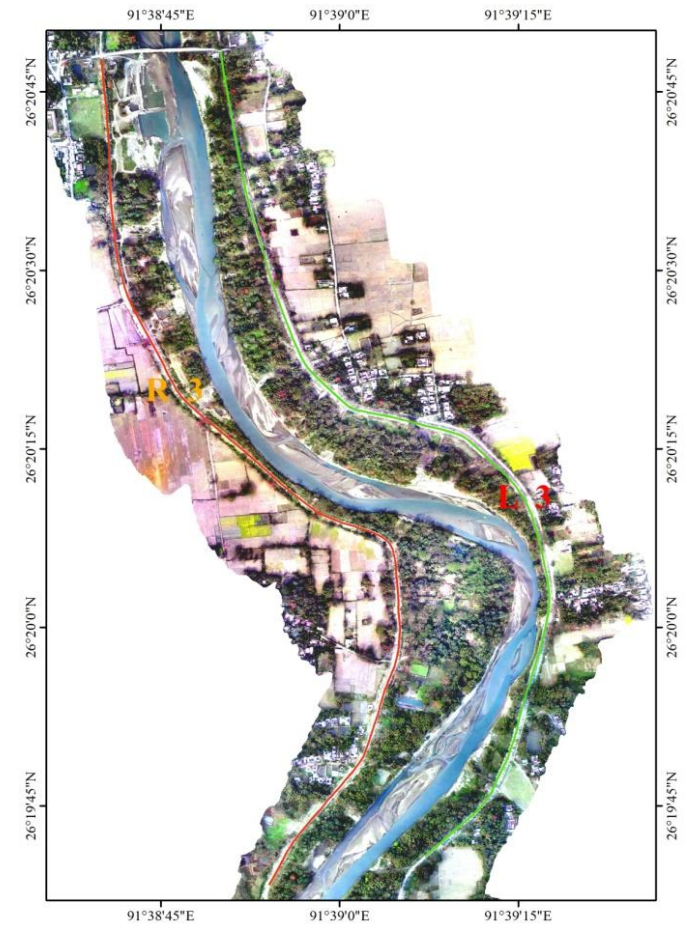


Fig: 46 UAV image of Puthimari river and It's embankments (Section R3 & L3)



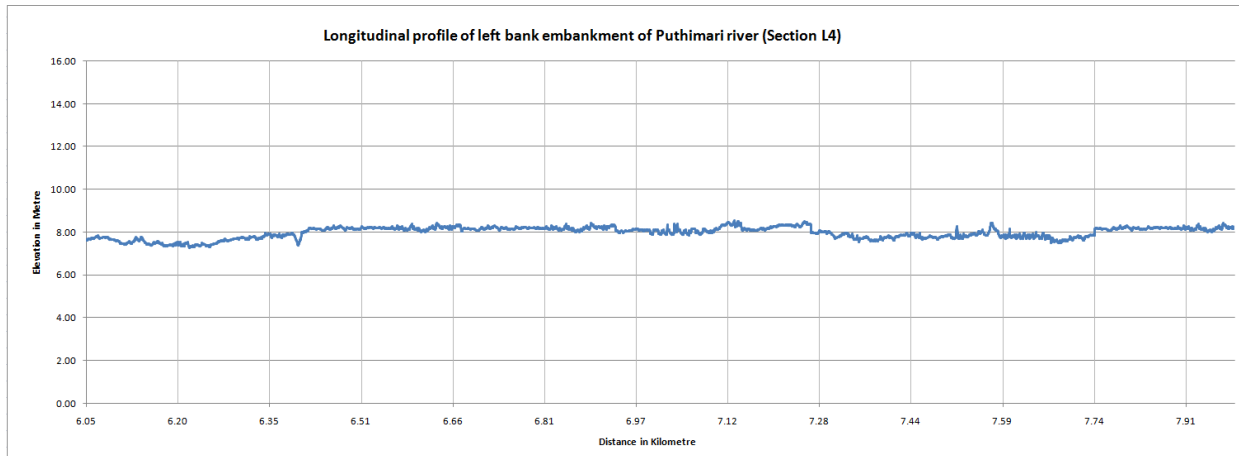
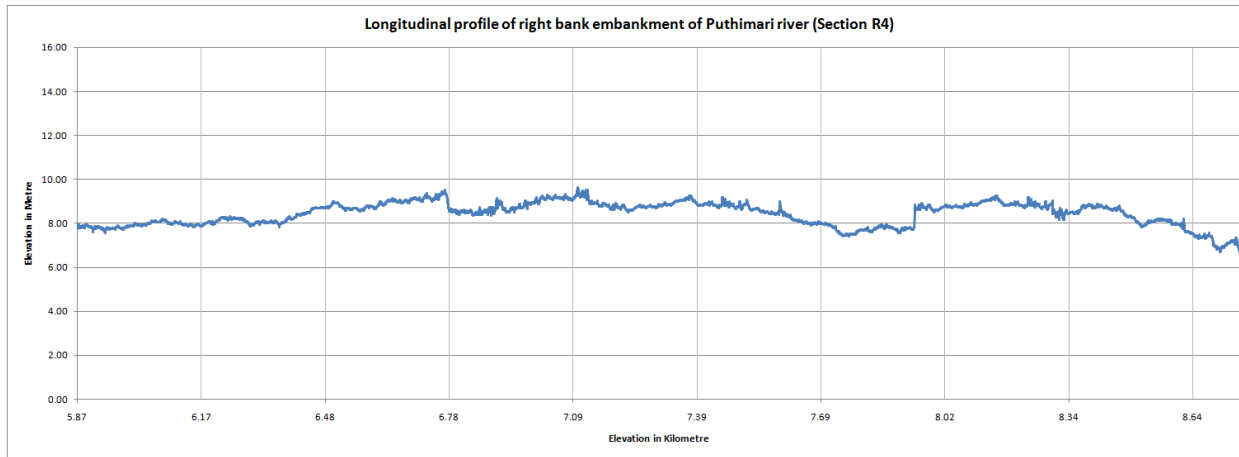


Fig: 47 Longitudinal profile of Left and right bank embankment (Section R4 & L4)

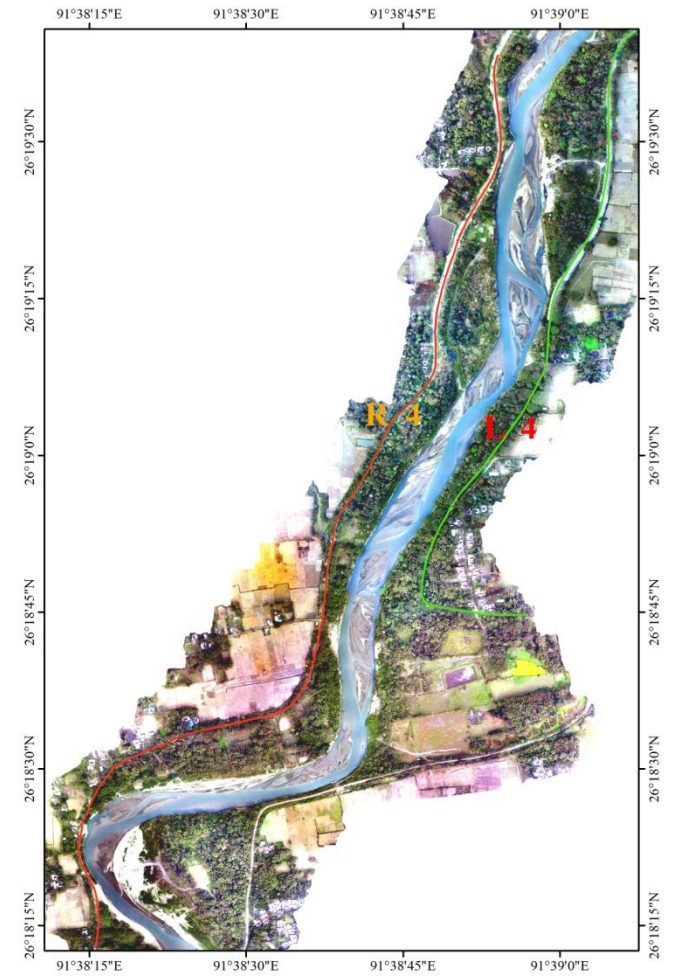


Fig: 48 UAV image of Puthimari river and It's embankments (Section R4 & L4)

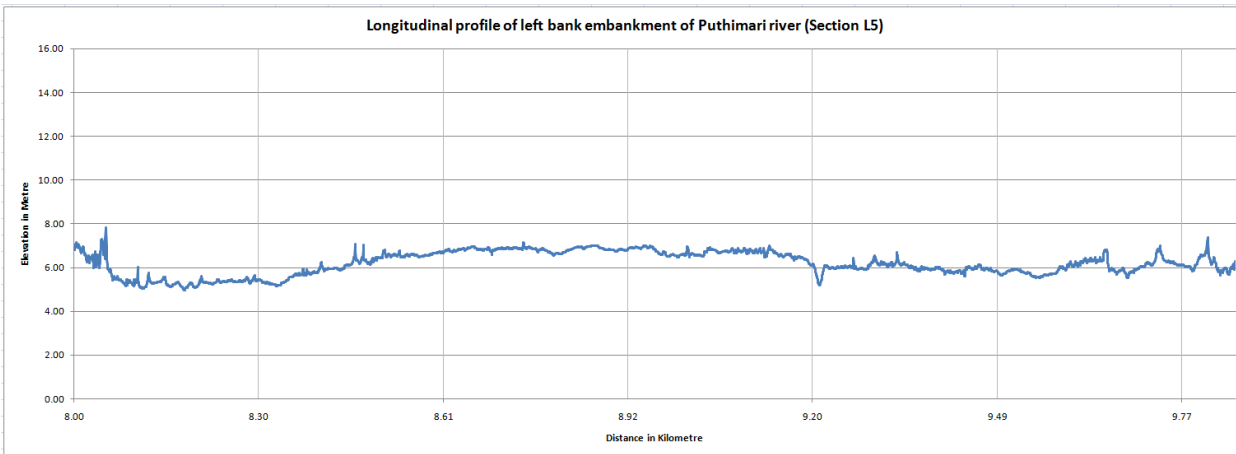
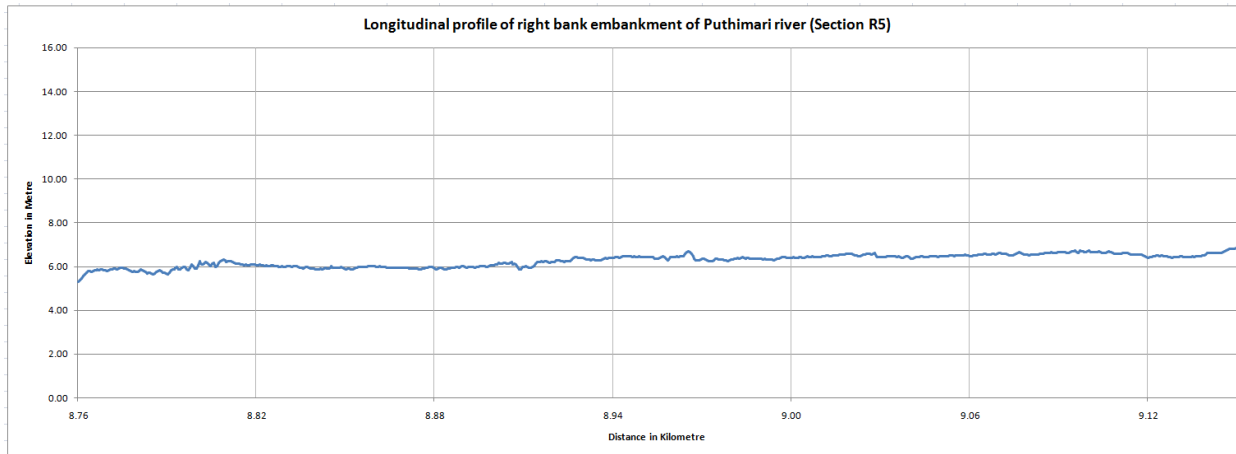


Fig: 49 Longitudinal profile of Left and right bank embankment (Section R5 & L5)

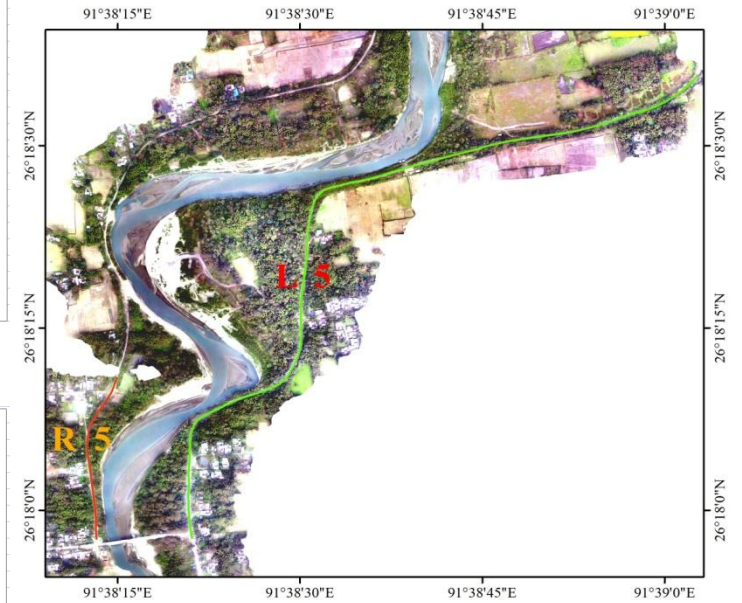


Fig: 50 UAV image of Puthimari river and It's embankments (Section R5 & L5)

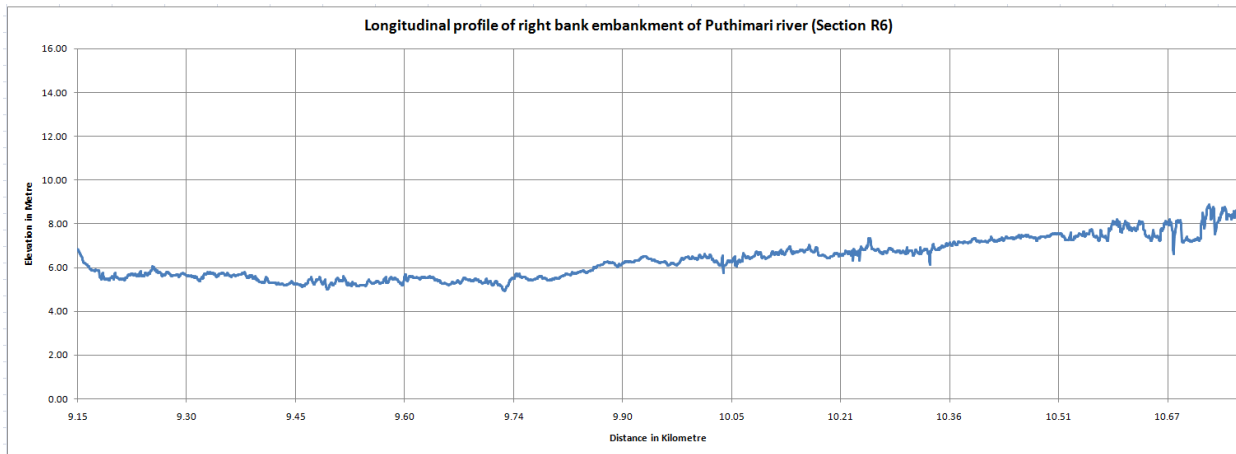
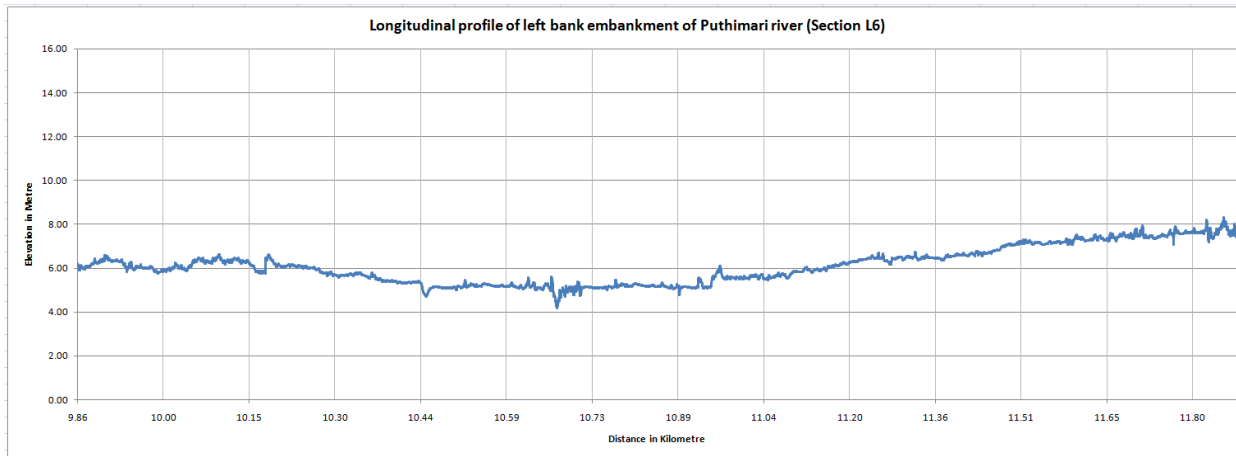


Fig: 51 Longitudinal profile of Left and right bank embankment (Section R6 & L6)

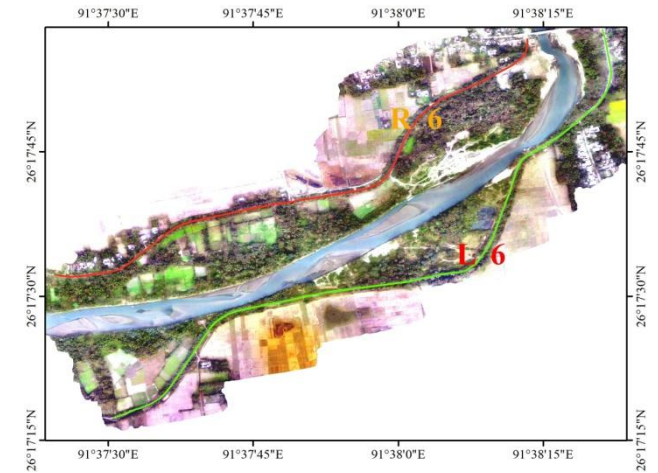


Fig: 52 UAV image of Puthimari river and It's embankments (Section R6 & L6)

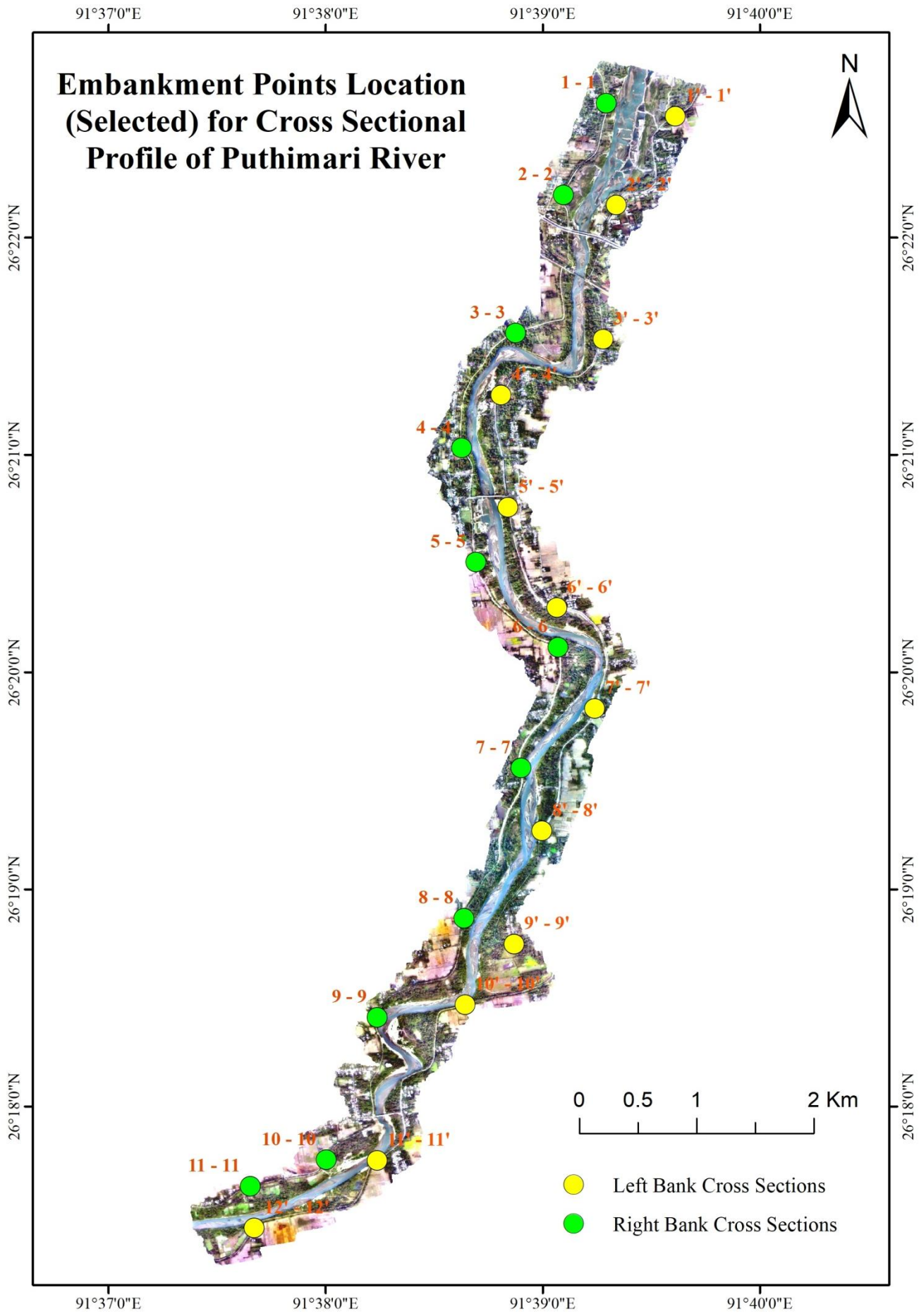


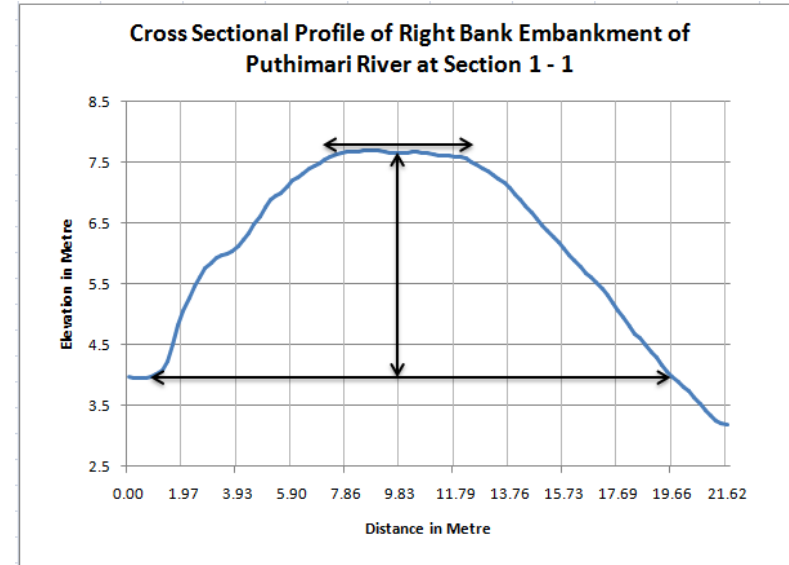
Fig: 53 Embankment Points Location (Selected) for Cross Sectional Profile of Puthimari River

### Cross Sectional Details of Section: 1 - 1

Top width :  $12.4 - 7.1 = 5.3$  m

Bottom width :  $19.66 - 1.1 = 18.56$  m

Height :  $7.7 - 3.8 = 3.9$  m



### Cross Sectional Details of Section: 1' - 1'

Top width :  $22.18 - 7.1 = 15.08$  m

Bottom width :  $35.2 - 0.0 = 35.2$  m

Height :  $8.3 - 2.5 = 5.8$  m

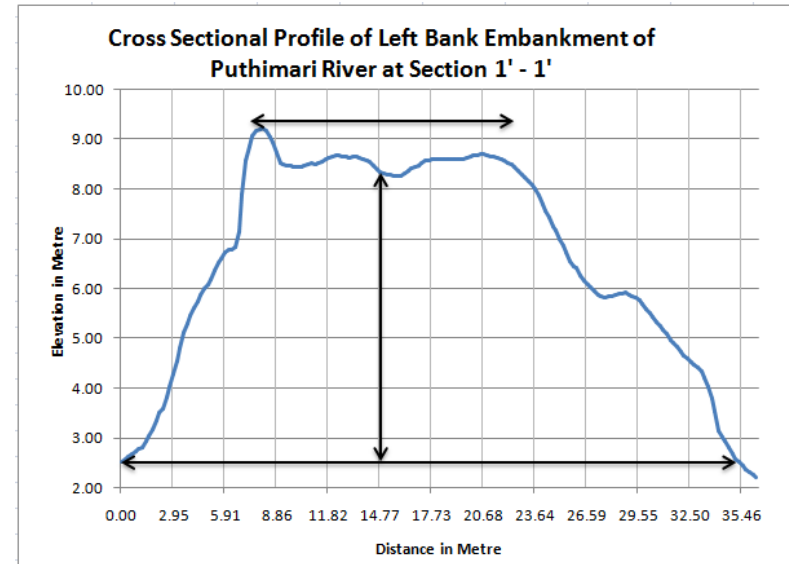


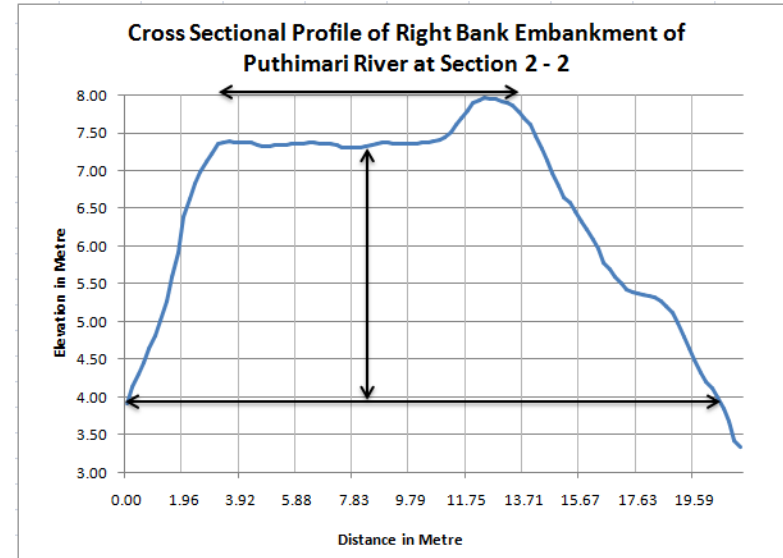
Fig: 54 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 2 - 2**

Top width : 13.71 - 3.52 = 10.19 m

Bottom width : 20.59 - 0.0 = 20.59 m

Height : 7.3 - 4.0 = 3.3 m



**Cross Sectional Details of Section: 2' - 2'**

Top width : 14.3 - 4.51 = 9.79 m

Bottom width : 19.37 - 1.0 = 18.37 m

Height : 8.0 - 5.6 = 2.4 m

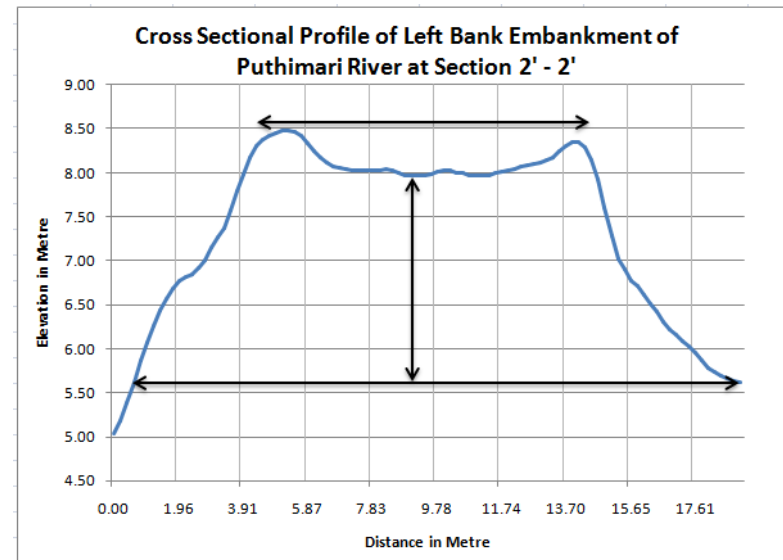


Fig: 55 Cross sectional profiles of Left and right bank embankment

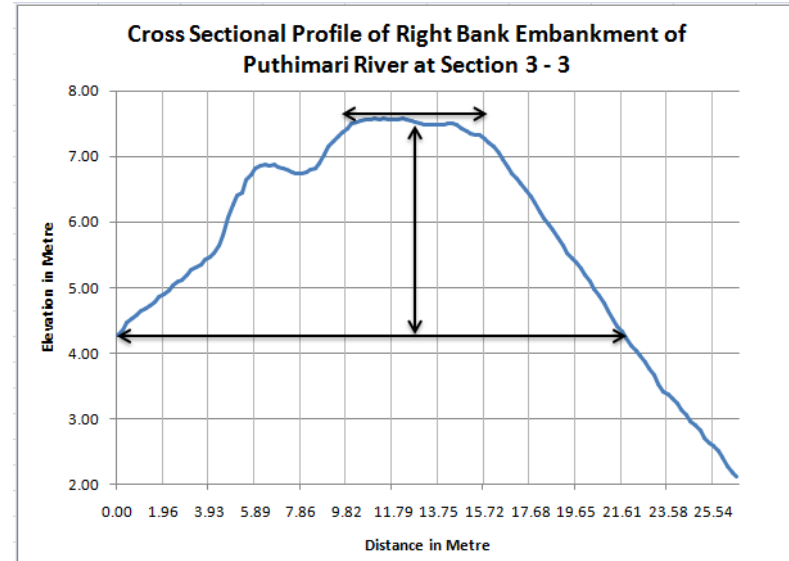


### Cross Sectional Details of Section: 3 - 3

Top width :  $15.72 - 9.82 = 5.9$  m

Bottom width :  $21.61 - 0.0 = 21.61$  m

Height :  $7.5 - 4.2 = 3.3$  m



### Cross Sectional Details of Section: 3' - 3'

Top width :  $15.76 - 10.25 = 5.51$  m

Bottom width :  $24.3 - 1.5 = 22.8$  m

Height :  $8.6 - 4.5 = 4.1$  m

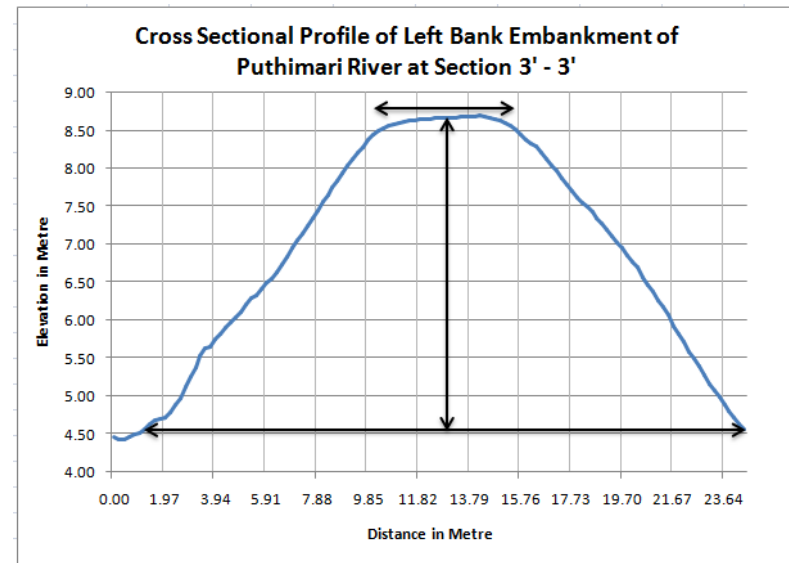
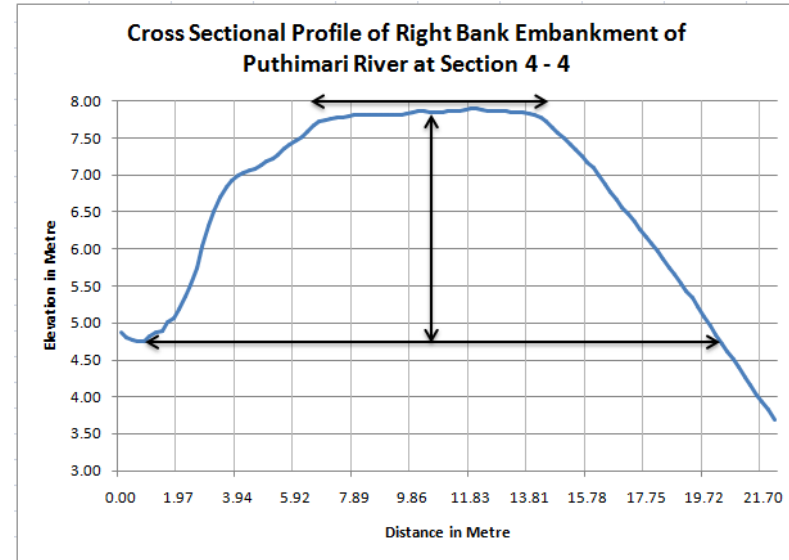


Fig: 56 Cross sectional profiles of Left and right bank embankment

### Cross Sectional Details of Section: 4 - 4

Top width :  $14.41 - 6.72 = 7.69$  m  
Bottom width :  $20.32 - 1.17 = 19.15$  m  
Height :  $7.8 - 4.7 = 3.1$  m



### Cross Sectional Details of Section: 4' - 4'

Top width :  $15.27 - 8.24 = 7.03$  m  
Bottom width :  $22.55 - 0.4 = 22.15$  m  
Height :  $8.0 - 4.5 = 3.5$  m

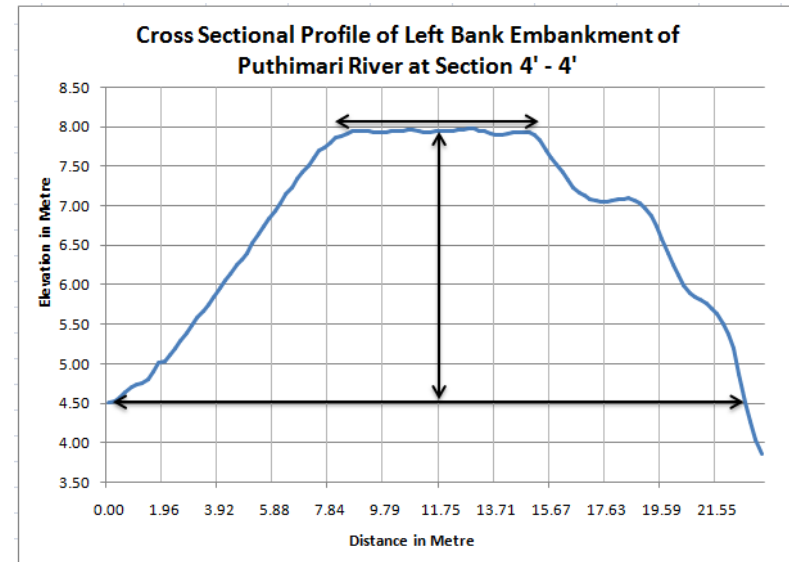


Fig: 57 Cross sectional profiles of Left and right bank embankment

### Cross Sectional Details of Section: 5 - 5

Top width :  $10.75 - 5.11 = 5.64$  m  
Bottom width :  $16.92 - 0.2 = 16.72$  m  
Height :  $7.4 - 4.0 = 3.4$  m

### Cross Sectional Details of Section: 5' - 5'

Top width :  $11.78 - 3.53 = 8.25$  m  
Bottom width :  $14.91 - 0.8 = 14.11$  m  
Height :  $7.5 - 5.6 = 1.9$  m

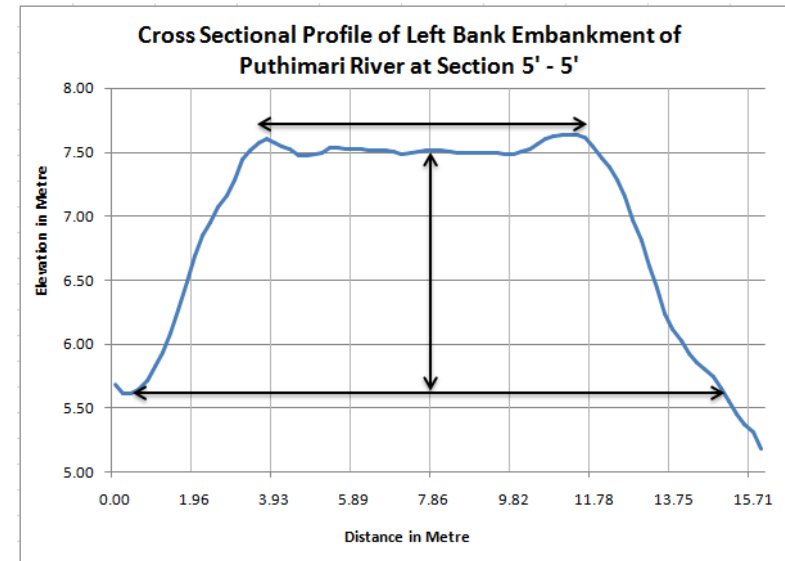
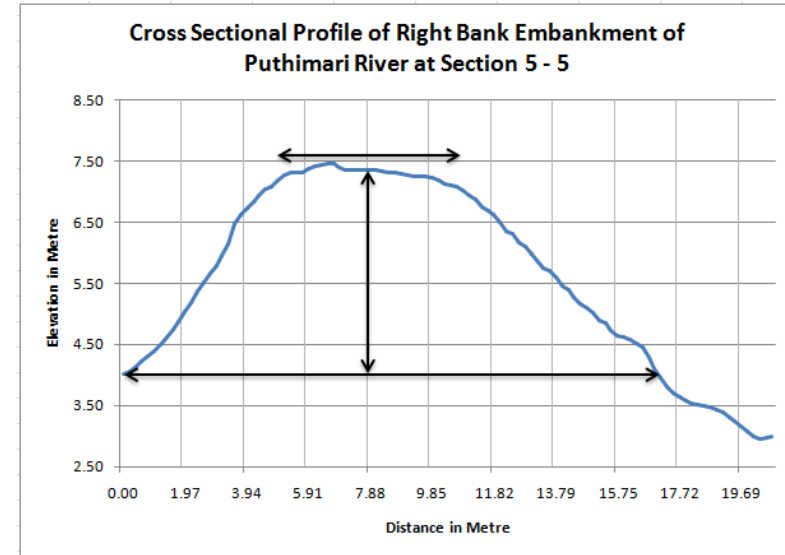
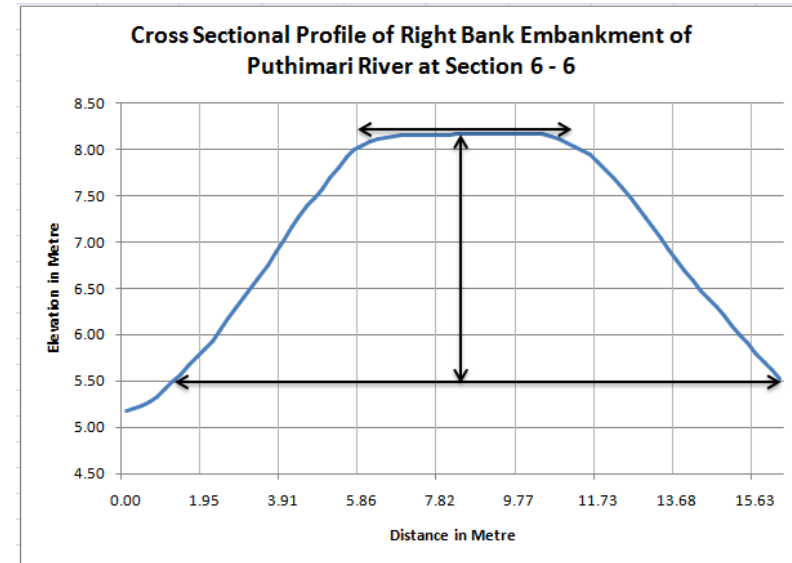


Fig: 58 Cross sectional profiles of Left and right bank embankment

### Cross Sectional Details of Section: 6 - 6

Top width :  $11.03 - 5.86 = 5.17$  m  
Bottom width :  $16.43 - 1.4 = 15.03$  m  
Height :  $8.2 - 5.5 = 2.7$  m



### Cross Sectional Details of Section: 6' - 6'

Top width :  $14.17 - 6.5 = 7.67$  m  
Bottom width :  $20.27 - 0.0 = 20.27$  m  
Height :  $8.2 - 4.4 = 3.8$  m

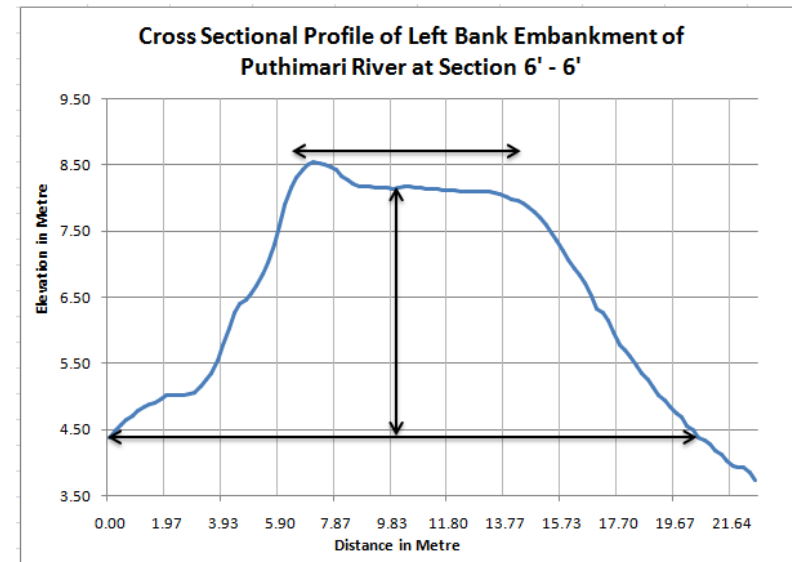
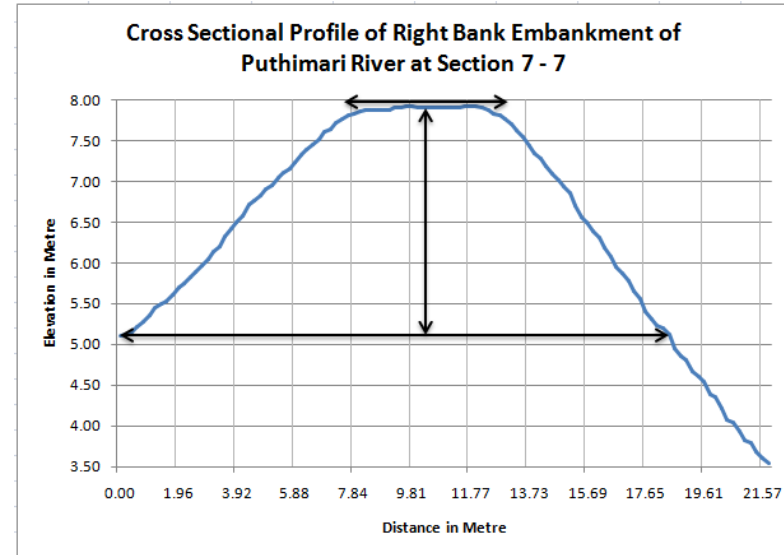


Fig: 59 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 7 - 7**

Top width :  $13.13 - 7.64 = 5.49$  m  
Bottom width :  $18.45 - 0.2 = 18.25$  m  
Height :  $7.9 - 5.1 = 2.8$  m



**Cross Sectional Details of Section: 7' - 7'**

Top width :  $7.85 - 3.0 = 4.85$  m  
Bottom width :  $12.37 - 0.0 = 12.37$  m  
Height :  $7.9 - 6.1 = 1.8$  m

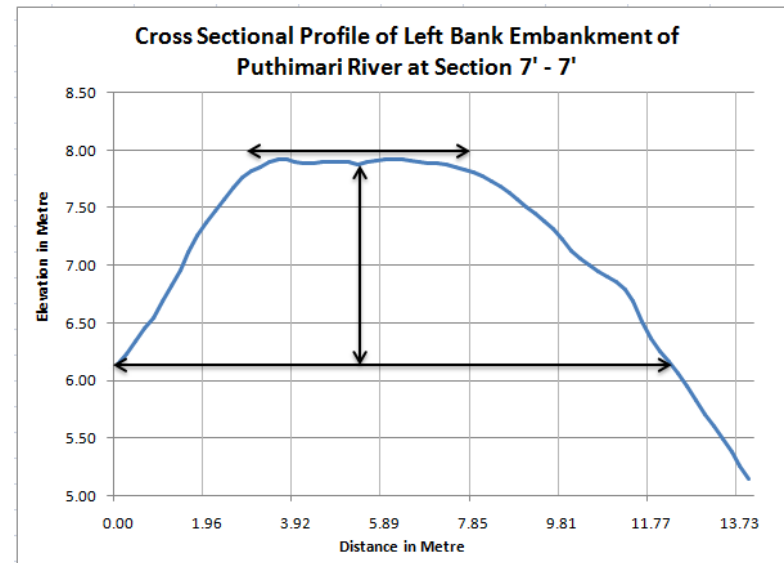


Fig: 60 Cross sectional profiles of Left and right bank embankment

### Cross Sectional Details of Section: 8 - 8

Top width : 13.73 - 9.4 = 4.33 m  
Bottom width : 23.14 - 1.2 = 21.94 m  
Height : 8.7 - 5.7 = 3.0 m

### Cross Sectional Details of Section: 8' - 8'

Top width : 12.44 - 5.72 = 6.72 m  
Bottom width : 16.58 - 0.0 = 16.58 m  
Height : 8.6 - 5.4 = 3.2 m

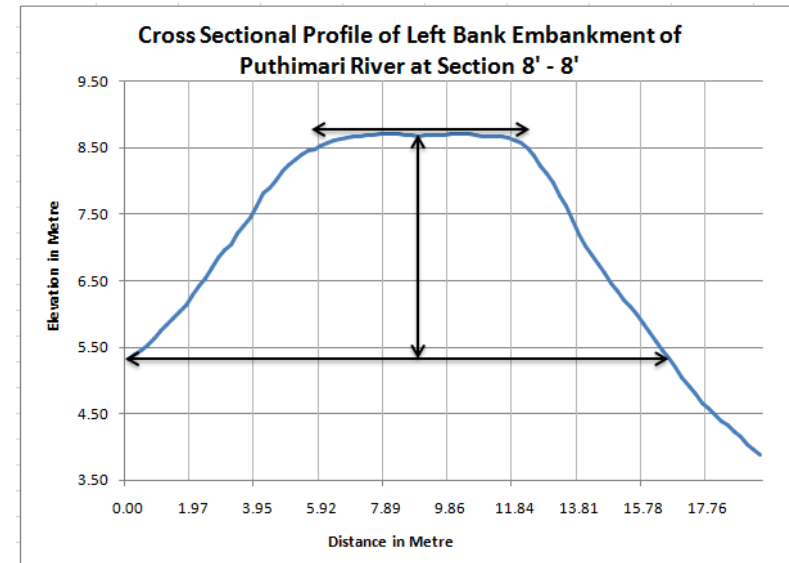
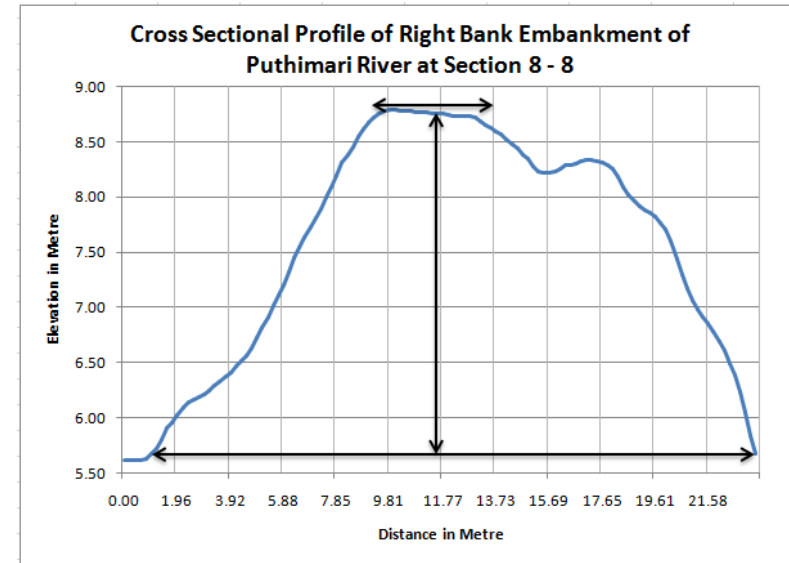
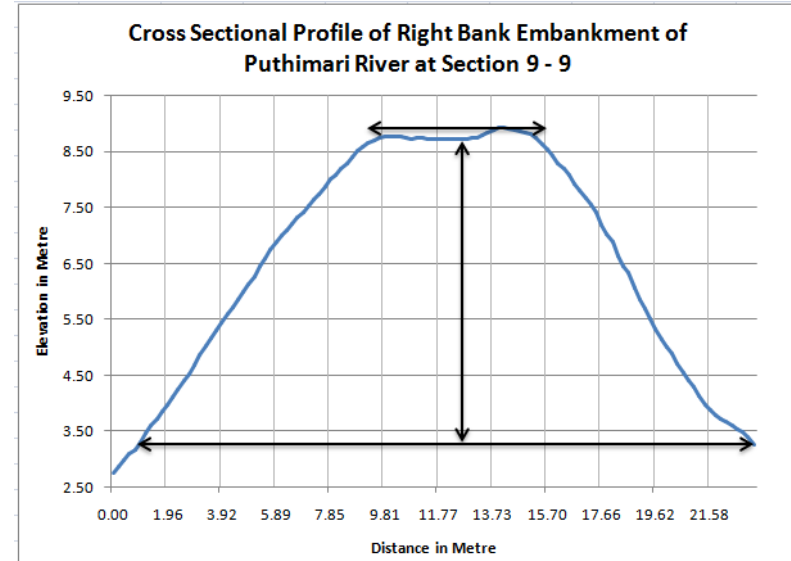


Fig: 61 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 9 - 9**

Top width : 15.7 - 9.41 = 6.29 m  
Bottom width : 23.14 - 1.1 = 22.04 m  
Height : 8.7 - 3.3 = 5.4 m



**Cross Sectional Details of Section: 9' - 9'**

Top width : 11.14 - 9.58 = 1.56 m  
Bottom width : 16.65 - 0.0 = 16.65 m  
Height : 6.15 - 4.75 = 1.4 m

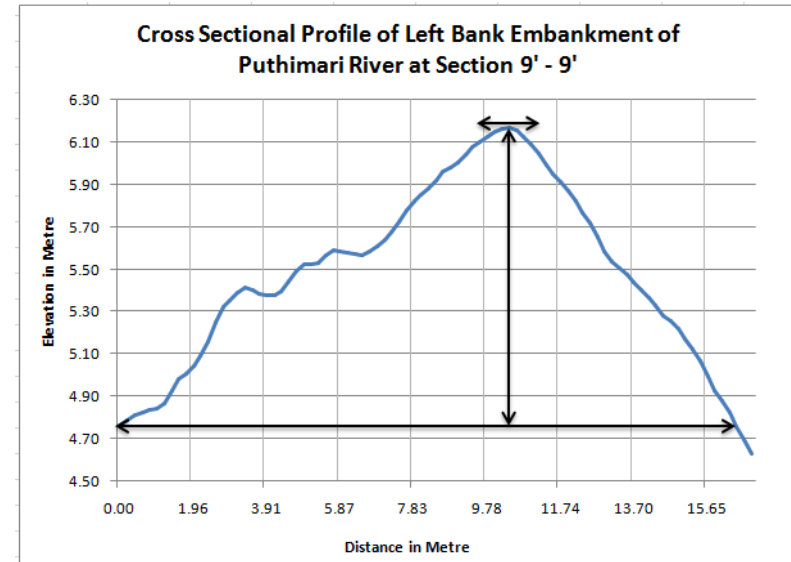
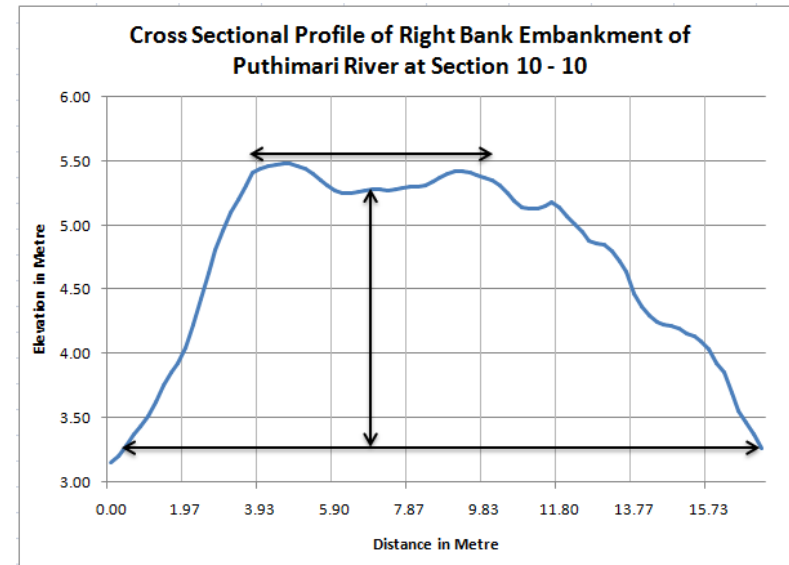


Fig: 62 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 10 - 10**

Top width :  $9.93 - 3.83 = 6.1$  m  
Bottom width :  $17.2 - 0.7 = 16.5$  m  
Height :  $5.25 - 3.25 = 2.0$  m



**Cross Sectional Details of Section: 10' - 10'**

Top width :  $19.7 - 14.1 = 5.6$  m  
Bottom width :  $29.0 - 2.94 = 26.06$  m  
Height :  $6.9 - 2.2 = 4.7$  m

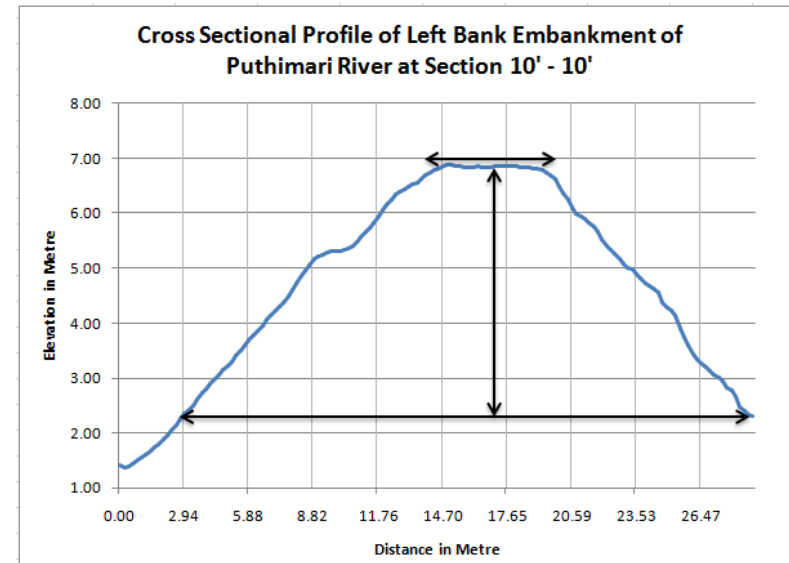


Fig: 63 Cross sectional profiles of Left and right bank embankment



**Cross Sectional Details of Section: 11 - 11**

Top width : 17.73 - 13.39 = 4.34 m  
Bottom width : 22.07 - 0.4 = 21.67 m  
Height : 6.7 - 4.2 = 2.5 m

**Cross Sectional Details of Section: 11' - 11'**

Top width : 12.15 - 6.08 = 6.07 m  
Bottom width : 20.39 - 0.2 = 20.19 m  
Height : 5.7 - 1.8 = 3.9 m

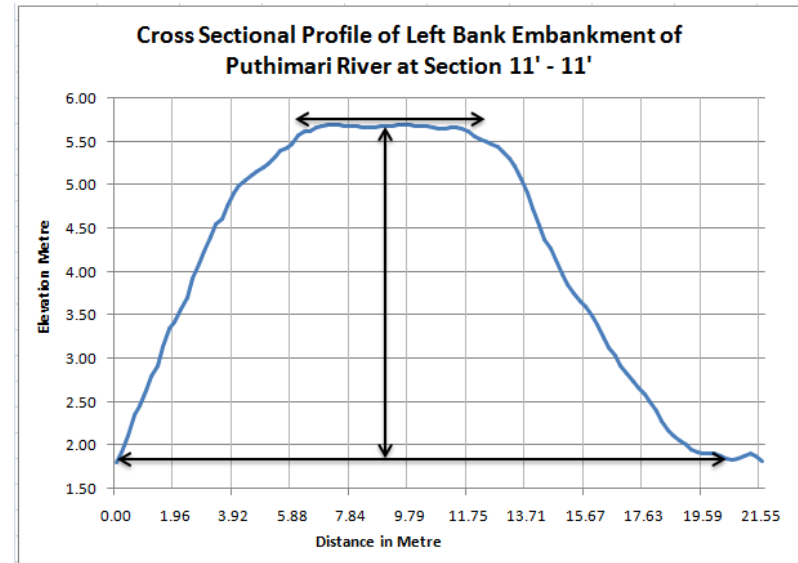
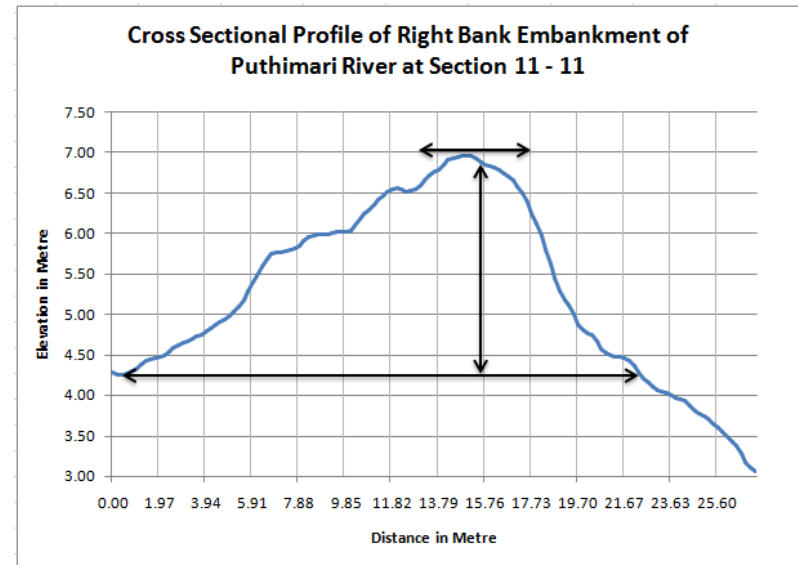


Fig: 64 Cross sectional profiles of Left and right bank embankment

**Cross Sectional Details of Section: 12' - 12'**

Top width : 9.81 - 6.08 = 3.73 m

Bottom width : 12.57 - 1.2 = 11.37 m

Height : 7.1 - 6.1 = 1.0 m

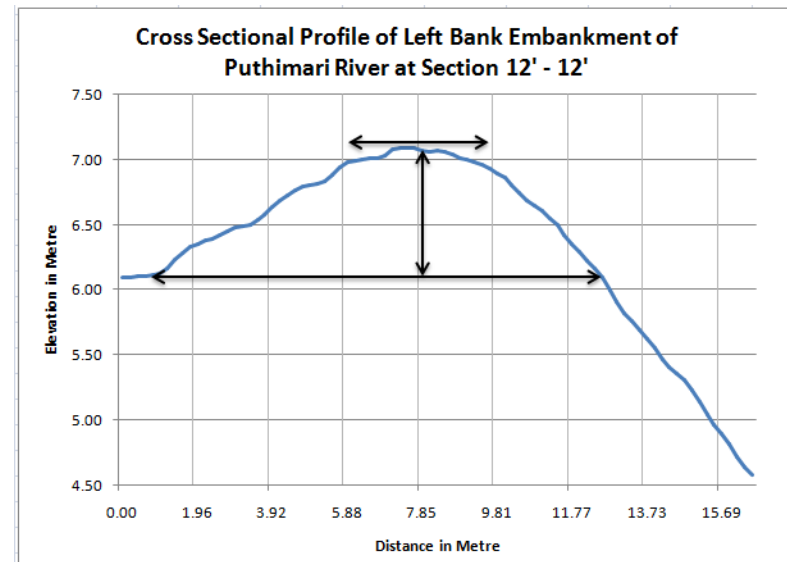


Fig: 65 Cross sectional profile of Left bank embankment

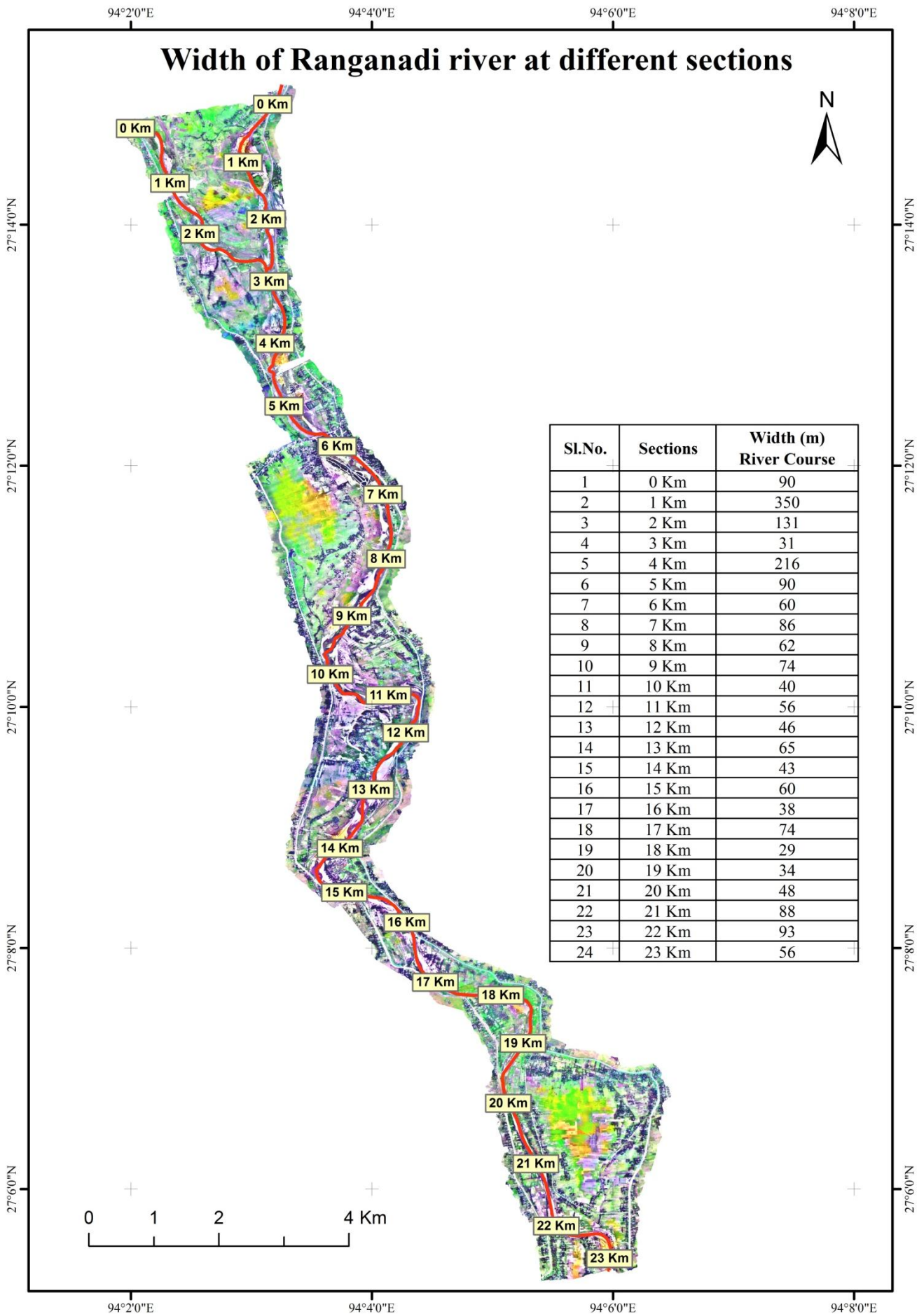


Fig: 66 Width of Ranganadi river as captured by UAV image

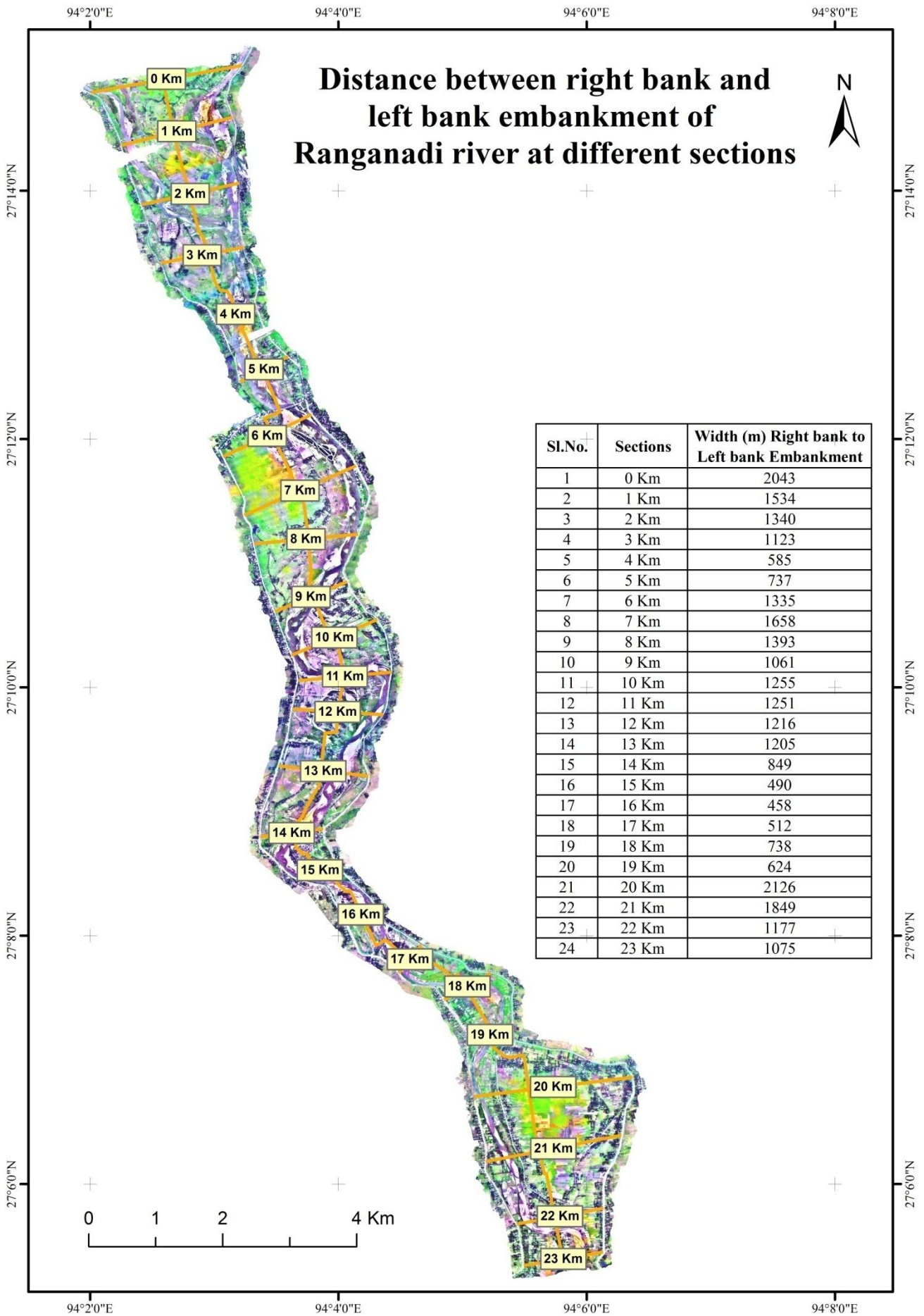


Fig: 67 Distance between right and left bank embankment as captured by UAV image

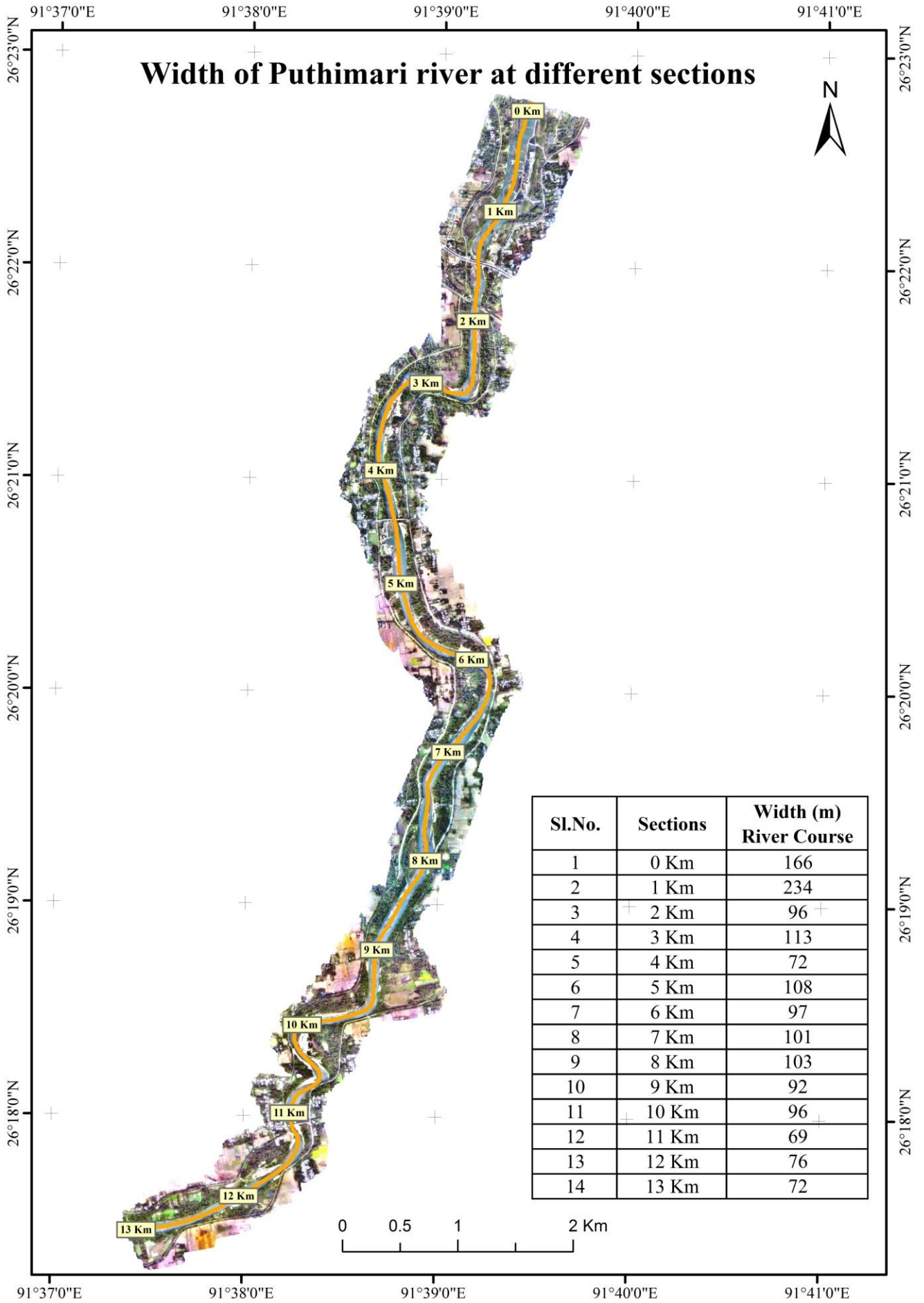


Fig: 68 Width of Puthimari river as captured by UAV image



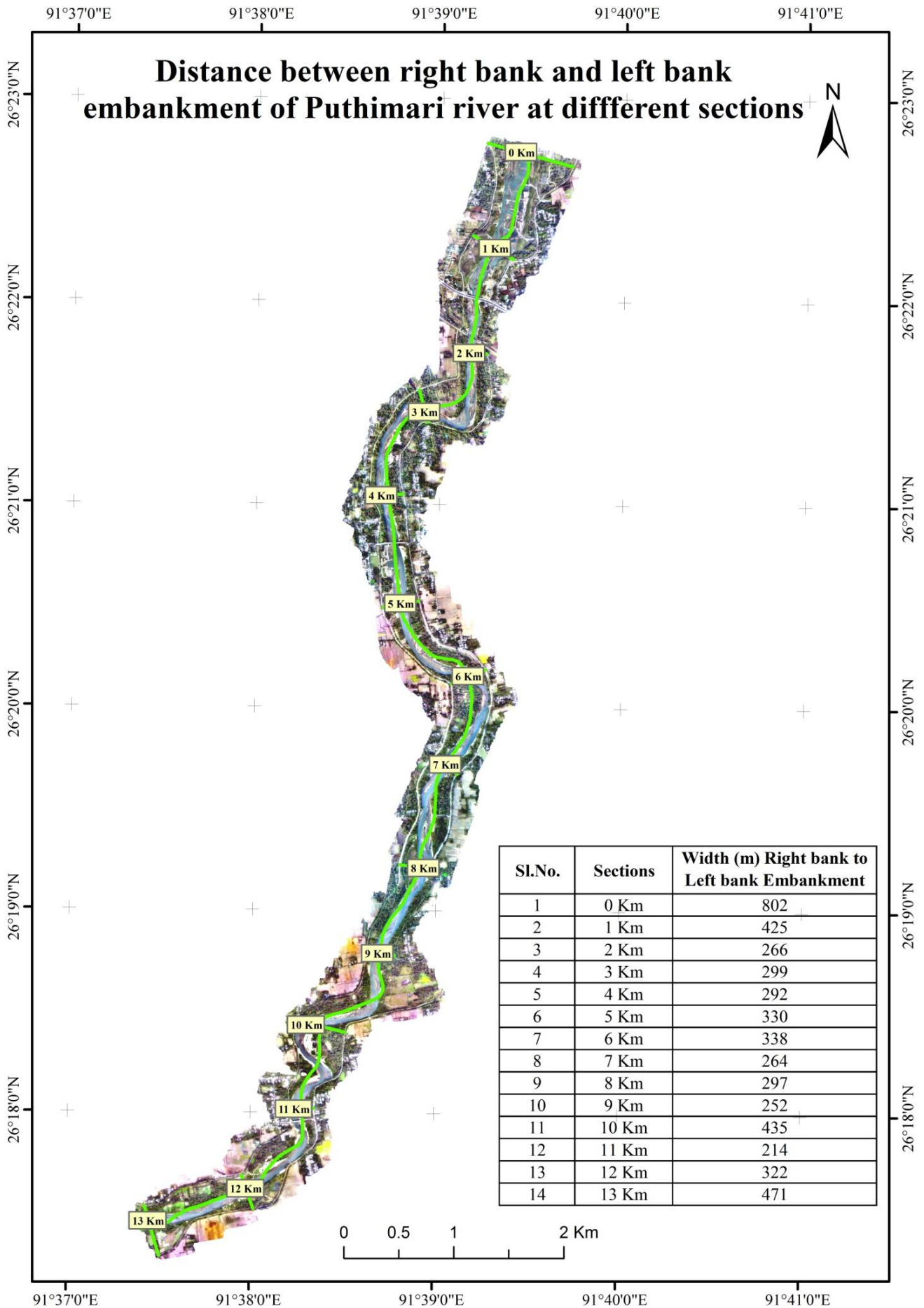


Fig: 69 Distance between right and left bank embankment as captured by UAV image

**Conclusions:** Unmanned Aerial Vehicle (UAV) utilised effectively to capture high resolution images of Ranganadi (18.5 Km) and Puthimari (12 Km) river system for monitoring of Embankment health. The horizontal resolution of the image captured is 5cm and generated a Digital Elevation Model of 20 cm vertical resolution. The Longitudinal and Cross sectional profile reflects structural deformations of the Embankments. The longitudinal profile prepared from the Digital Elevation Model created from UAV image (Fig.7 to Fig. 15) shows that the gradient of Ranganadi river embankment is not uniform. There are depressions in some places which also reveals by the cross-sectional profiles prepared in 24 locations of both of the embankments. The cross-sectional profiles (Fig.18 to Fig.40) further shows that top width, bottom width and height of Ranganadi embankment are not uniform. Sections having highest and lowest values are as below:

	Right Bank	Cross-section	Left Bank	Cross-section
Max Top width	13.3	5-5	11.9	1'-1'
Min Top Width	4.6	8-8	4.6	22'-22'
Max Bottom width	30	5-5	31.9	21'-21'
Min Bottom width	22.5	16-16	22.2	2'-2'
Max height	5.4	4-4	5.2	14'-14', 18'-18', 21'-21'
Min height	3.8	3-3, 10-10, 20-20	3.2	11'-11'

The longitudinal profile (Fig.41 to Fig.51) shows that the gradient of Puthimari River embankment mild and uniform through its length. But the top width, bottom width and height of Puthimari river embankment are also not uniform (Fig.54 to Fig.65). Sections having highest and lowest values are as below:

	Right Bank	Cross-section	Left Bank	Cross-section
Max Top width	10.19	2-2	15	1'-1'
Min Top Width	4.33	8-8	1.56	9'-9'
Max Bottom width	22	9-9	35.2	1'-1'
Min Bottom width	15	6-6	11.3	12-12
Max height	5.4	9-9	5.8	1'-1'
Min height	2	10-10	1	12'-12'