BEFORE THE NATIONAL GREEN TRIBUNAL

WESTERN ZONE BENCH AT PUNE

I.A. No. 83 of 2020

IN

ORIGINAL APPLICATION NO. 28 OF 2020

INDEX

NOTARY ANIL VITTHAL HORANE PUNE CITY REGD NO. ...92 EXPIRED ON 19/10/2023 GOVERNMENT OF INDIA

BEFORE THE NATIONAL GREEN TRIBUNAL
WESTERN ZONE BENCH AT PUNE
I.A. No. 83 of 2020
IN
ORIGINAL APPLICATION NO. 28 OF 2020

Sarang Yadwakar & Ors. ...Applicants

Versus

Pune Municipal Corporation and Ors. ...Respondents

AFFIDAVIT OF COMPLIANCE ON BEHALF OF THE COMIITTEE APPOINTED BY THIS HON'BLE COURT

I, Mr. Saurabh Rao, Divisional Commissioner, Pune Division, Pune having my office at Council Hall Pune 411 001 do hereby state on solemn affirmation as under :

1. I say that the in compliance with the order of this Hon'ble Tribunal dated 28 September 2020, I am submitting herewith a copy of the Final Report submitted by Central Water and Power Research Station (CWPRS) Pune, dated 12 February 2021. Hereto annexed and marked as **Exhibit 'A'** is a copy of the Final CWPRS Report.

2. I say that to discuss the said Report, a 7th meeting under my Chairmanship was held on 8 March 2021. The meeting was attended by representatives of CWPRS as also Dr Ritesh Vijay - Principal Scientist NEERI and convenor of the Expert Committee, Dr A Benniamin – Scientist State Biodiversity board, member of the Expert Committee, Dr Y B Sontakke – Joint Director, Maharashtra Pollution Control Board and members of Maharashtra Metro Rail Corporation. The Expert Committee under the Chairmanship of the Divisional Commissioner has considered that the CWPRS has given its report based on simulations studies to estimate afflux due to construction of metro piers along the Mutha river bank. The Expert Committee also considered the study on the extended cross section based on drone survey for discharges of 1,00,000 and 60,000 cusecs.

3. The Expert Committee has considered in its minutes that the CWPRS Scientist has pointed out that in the last 56 years the discharge of 60,000 cusecs has only breached four

times and the discharge of 1,00,000 cusecs has not been breached even once. The Expert Committee has also noted that the Irrigation Department and the Smart city Project have a robust flood alarm and evacuation system to avoid loss of life and property. The Smart City project has identified the flood prone locations and areas where people will be moved in case of floods. The committee observed that Maha metro is taking utmost care during construction of the project and complying all the guidelines issued by the Expert Committee. Hereto annexed and marked as **Exhibit 'B'** is a copy of the Minutes of Meeting dated 8 March 2021 along with the comments of the Expert Committee as forwarded.

verification

I Saurabh Avadh Rao, age: 46 years, Occupation: Service, serving as Divisional Commissioner, Pune, Division. Pune, do hereby state on solemn affirmation that contents of this affidavit are true and correct to best of my knowledge. I have signed hereunder at Pune on this day 22 June 2021.

Solemnly affirmed at Pune

Dated this 22 June 2021

NOTARY
ANIL VITTHAL HORANE
PUNE CITY
REGD. NO. 2492
EXPIRED ON 19/10/2023
GOVERNMENT OF INDIA

Deponent

(Saurabh Rao)
Divisional Commissioner, Pune
Division Pune.
Pune Division, Pune

BEFORE ME
A V HORANE
NOTARY GOVT OF INDIA
PUNE

REGISTERED & NOTED
S. No. 355/2021

23 JUN 2021

I know the deponent

(Advocate Swati Vaidya-Pandit)

NOTARIAL NOTARIAL NOTARIAL NOTARIAL NOTARIAL
CANCELLED CANCELLED

Government of India
Ministry of Jal Shakti
Department of Water Resources,
River Development and
Ganga Rejuvenation

सत्यमेव जयते

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास
और गंगा संरक्षण विभाग

TECHNICAL REPORT NO.5886
JANUARY, 2021

MATHEMATICAL MODEL STUDIES OF RIVER MUTHA FOR MAHA – METRO RAIL CORPORATION LTD. PUNE

केन्द्रीय जल और विद्युत अनुसंधान शाला, पुणे
CENTRAL WATER AND POWER RESEARCH STATION, PUNE

A. K. Agrawal
Director

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और
गंगा संरक्षण विभाग
केन्द्रीय जल और विद्युत अनुसंधान शाला
खड़कवासला, पुणे-411 024

सत्यमेव जयते

Government of India
Ministry of Jal Shakti
Department of Water Resources
River Development and Ganga Rejuvenation
CENTRAL WATER & POWER RESEARCH STATION
Khadakwasla, Pune – 411 024

संख्या: ज.वि.आ.प./ महा मेट्रो/ 2021- 46 |23

दिनांक: 11.01.2021

22 JAN 2021

श्री रत्नाकर पांडे
उप महाप्रबंधक (पर्यावरण)
महाराष्ट्र मेट्रो रेल कोर्प लि।
प्रथम तल, द ओरियन बिल्डिंग, अर्जुन मनसुखानी मार्ग,
पुणे -411001

विषय : महा-मेट्रो रेल कॉर्पोरेशन लिमिटेड, पुणे के लिए मुठा नदी के गणितीय प्रतिमान का अध्ययन ।

महोदय,

"महा-मेट्रो रेल कॉर्पोरेशन लिमिटेड, पुणे के लिए मुठा नदी का गणितीय प्रतिमान अध्ययन के लिए" शीर्षक की तकनिकी रिपोर्ट संख्या 5886, जनवरी 2021 की दो प्रतियाँ आपकी जानकारी और अभिलेख हेतु संलग्न है ।

कृपया तकनिकी रिपोर्ट के प्राप्ति की सूचना दे।

धन्यवाद,

भवदीया,

Neena Isaac
11/01/2021

डॉ.(श्रीमती) नीना आयझॉक
वैज्ञानिक- ई

संलग्न: तकनिकी रिपोर्ट की दो प्रतियाँ।

दूरभाष / Telephone: +91-20-24103331; फैक्स/Fax: +91-20-24381004; ईमेल / Email : neena.isaac@gov.in / n_isaac@rediffmail.com
वेबसाइट/ Website : http://jalshakti-mowr.gov.in, www.cwprs.gov.in

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और
गंगा संरक्षण विभाग
केन्द्रीय जल और विद्युत अनुसंधान शाला
खड़कवासला, पुणे-411 024

सत्यमेव जयते

Government of India
Ministry of Jal Shakti
Department of Water Resources
River Development and Ganga Rejuvenation
CENTRAL WATER & POWER RESEARCH STATION
Khadakwasla, Pune – 411 024

No.HAPT/Maha-Metro/2021 - 46/23

Date : 11.01.2021
22 JAN 2021

Shri Ratnakar Pandey
Deputy General Manager (Environment)
Maharashtra Metro Rail Corporation Ltd.
1st floor, The Orion Building, Arjun Mansukhani Marg,
Pune-411001

Sub : Mathematical Model Studies of River Mutha for Maha-Metro Rail Corporation Ltd. Pune.

Sir,

A Technical Report No. 5886 of January 2021 entitled "Mathematical Model Studies of River Mutha for Maha-Metro Rail Corporation Ltd. Pune" is enclosed in duplicate, for reference and record.

Kindly acknowledge the receipt of report alongwith the feedback in the format attached herewith.

Thanking you,

Yours faithfully,

Neena Isaac 11/01/2021

(Dr. (Mrs) Neena Isaac)
Scientist 'E'

Encl: Two copies of Technical report

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और
गंगा संरक्षण विभाग
केन्द्रीय जल और विद्युत अनुसंधान शाला
खड़कवासला, पुणे-411 024

सत्यमेव जयते

Government of India
Ministry of Jal Shakti
Department of Water Resources
River Development and Ganga Rejuvenation
CENTRAL WATER & POWER RESEARCH STATION
Khadakwasla, Pune – 411 024

No.HAPT/Maha-Metro/2021 -

Date :

Shri Ratnakar Pandey
Deputy General Manager (Environment)
Maharashtra Metro Rail Corporation Ltd.
1st floor, The Orion Building, Arjun Mansukhani Marg,
Pune-411001

Sub : Corrigenda (Errata) for "Mathematical Model Studies of River Mutha for Maha-Metro Rail Corporation Ltd. Pune".

Sir,

The Corrigenda (Errata) for the technical report no. 5886 of January 2021 entitled "Mathematical Model Studies of River Mutha for Maha-Metro Rail Corporation Ltd. Pune" is enclosed , for reference and record.

Kindly acknowledge the receipt.

Thanking you,

Yours faithfully,

Neena Isaac
23/02/2021

(Dr. (Mrs) Neena Isaac)
Scientist 'E'

Encl: As above

CORRIGENDA (Errata)

to

CWPRS Technical report No. 5886 of January 2021 Titled "Mathematical model studies of River Mutha for Maha Metro Rail Corporation Ltd. Pune"

1. Page 27, Table 7, Column 2: title,

for "Water Surface Elevation after Metro Pier "
read "Water Spread after Metro Pier"

2. Page 27, Table 7, Column 3: title,

for "Water Surface Elevation before Metro Pier "
read "Water Spread before Metro Pier"

3. Page 30, Table 8, Column 2: title,

for "Water Surface Elevation after Metro Pier "
read "Water Spread after Metro Pier"

4. Page 30, Table 8, Column 3: title,

for "Water Surface Elevation before Metro Pier "
read "Water Spread before Metro Pier"

PUNE;

February 23, 2021

GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION
CENTRAL WATER AND POWER RESEARCH STATION
PUNE - 411 024

Reservoirs and Appurtenant Structures

TECHNICAL REPORT NO. 5886
JANUARY 2021

MATHEMATICAL MODEL STUDIES OF RIVER MUTHA FOR MAHA – METRO RAIL CORPORATION LTD. PUNE

A.K. Agrawal
Director

REPORT DOCUMENTATION SHEET

Technical Report No. 5886 **Month: January 2021**

TITLE: MATHEMATICAL MODEL STUDIES OF RIVER MUTHA FOR MAHA – METRO RAIL CORPORATION LTD. PUNE

Officers Responsible for Conducting the Studies
Shri P. S. Kunjeer, Scientist 'C', Mrs. H. P. Chaudhary, Shri P. D. Patil, Scientist 'B', Mrs. S. B. Tayade, Assistant Research Officer, Mrs. S. A. Shinde, Shri V. R. Medhe Research Assistants, Shri U. K. Kanthali, Shri P. M. Mehatar Lab Assistants-II under the supervision of Dr. (Mrs) Neena Isaac, Scientist 'E'

Name and Address of Organization Conducting the Studies
Reservoirs and Appurtenant Structures
Central Water and Power Research Station, Khadakwasla, Pune-411 024

Name and Address of the Authority Sponsoring the Studies
Shri Ratnakar Pandey, Deputy General Manager (Environment), Maharashtra Metro Rail Corporation Ltd. 1st floor, The Orion Building, Arjun Mansukhani Marg, Pune-411001

Synopsis:
Maharashtra Metro Rail Corporation Limited (MMRCL) is a joint venture company of Govt. of India and Govt. of Maharashtra, established for the purpose of implementation of Pune Metro Rail Project. The total length of Pune Metro Rail Project is 31.25 km of which a stretch of 1.45 km passes along the left bank of Mutha River. As per the design, 61 Piers of Metro Rail line will be constructed along the left bank of Mutha River. MMRCL approached Central Water and Power Research Station (CWPRS) to conduct hydrodynamic model studies to estimate the afflux in Mutha River due to the construction of metro pier and allied structures. One dimensional mathematical model studies for river Mutha were carried out. The numerical model of river Mutha covering a reach of about 15.0 km from Khadakwasla dam to Sangam near confluence of Mutha River with Mula River was developed using HEC-RAS software. Simulations were carried out for Mutha River in the study reach considering the existing bridges without Metro piers and then including Metro piers to find out the afflux for the discharges of 60,000 ft^3/s and 1,00,000 ft^3/s. Further, same set of experiments were carried out using Aerial Survey data. The maximum afflux for the discharge of 1,00,000 ft^3/s in the reach near Sambhaji bridge reduces to 216 from 380 mm when the extended cross sections from the Aerial survey the afflux in same reach are taken into account. For discharge of 60,000 ft^3/s reduces to 193 mm from 290 mm. Inundation depths and the extent of inundation were also computed considering SRTM DEM. Subsequently the inundation depths were computed based on the DEM data collected by aerial survey for limited reach of 2.5 Km. Flood extent was overlaid on Google image.

Key words: Afflux, Bridges, Piers, Mutha River, One dimensional model, HEC-RAS, RAS Mapper

TABLE OF CONTENTS

NUMERICAL MODEL STUDIES FOR RIVER MUTHA FOR MAHA METRO RAIL CORPORTION LTD. (MMRCL), PUNE

Technical Report No.: 5886 **Month: January 2021**

1.0 INTRODUCTION

Maharashtra Metro Rail Corporation Limited (MMRCL) is a joint venture company of Govt. of India and Govt. of Maharashtra, established for the purpose of implementation of Pune Metro Rail Project. The total length of Pune Metro Rail Project is 31.25 km of which a stretch of 1.45 km passes along the left bank of Mutha river. As per the design, 61 Piers will be constructed along the left bank of Mutha river. MMRCL approached Central Water and Power Research Station (CWPRS) to conduct hydrodynamic model studies to estimate the afflux in Mutha river due to the construction of Metro Pier and allied structures. This technical report describes the numerical model studies conducted to determine the afflux along Mutha river due to the construction of Metro Piers. Numerical model simulations were conducted for various discharge conditions.

2.0 STUDY AREA

The study area is a reach of Mutha river passing through Pune city. The Mutha river is a part of Bhima basin which is a sub-basin of river Krishna. The Mutha river originates from the Sahyadri ranges and flows in the South-East direction. The flows in the Mutha river is controlled by the releases from the Khadakwasla dam located about 10 km upstream of Pune city area. River Mutha is flowing through the heart of Pune city and have confluence with river Mula about 15 km downstream of Khadakwasla dam. The river is known as Mula-Mutha downstream of this confluence. The river Mula-Mutha continues to flow in South-East direction and have confluence with river Bhima near village Pargaon at about 80 km downstream of Khadakwasla dam. The 15 km reach of Mutha river from Khadakwasla dam to its confluence with Mula river in Pune city is considered in the present study (Figure 1a). Pune city is spread along both the banks of Mutha river and there are about 16 bridges across the river in the study reach. MMRCL proposes to construct Pune Metro Rail Project for a length of about 31.25 km out of which a stretch of about 1.45 km length is passing along the left bank flood plain of Mutha river in the city area (Figure 1b).

3.0 TERMS OF REFERENCE

1. Estimation of afflux at each bridge for two river discharges of 60,000 ft^3/s and 1,00,000 ft^3/s.
2. Inundation of riverbanks caused by afflux

4.0 DATA REQUIRED FOR THE STUDIES

The basic data required for the studies include

(i) Topographic data in the form of river plan and cross sections

(ii) Hydraulic data in the form of discharge and water level/rating curve

(iii) Structural data of the bridges, causeways and Metro Piers in the form of plan, elevation and sections

The data received from the project were reviewed and observations along with data used in the studies are given below.

4.1 Topographic Data

Geometric data of the river in the form of river plan, cross sections and L-section were provided by MMRCL. The cross sections of river Mutha covering a reach of about 15.0 km from Khadakwasla dam to Sangam near confluence of Mutha river with Mula river were made available. The cross sections of the river were taken at an interval of 30 m in the study reach. The representative cross sections in the study reach are shown in Figure 2.

4.2 Hydraulic Data

The MMRCL provided the water surface profiles for Mutha river published by Water Resource Department, Government of Maharashtra in the study reach for the two river discharges of 60,000 ft^3/s (Blue line) and 1,00,000 ft^3/s (Red line).

4.3 Structural Data

The MMRCL provided the details of the bridges across the Mutha river in the study reach. Project Authorities also provided the structural details of Metro Pier and pier cap along with the alignment of Metro line passing through the Mutha river flood plain.

5.0 MATHEMATICAL MODEL

A number of commercial or free numerical models are available which can simulate hydrodynamic flow routing along with the structural operations. The selection of the model depends on the objectives of the study, availability of data and computational resources. HEC-RAS 5.0.7 developed by the U.S. Army Corps of Engineers at the Army's Hydrologic Engineering Centre is extensively used all over world for simulating hydrodynamic flow routing. Hence, the same software was selected for hydrodynamic simulations in the present studies. The main input data required for HEC-RAS model include cross-sections of the river reach, gauge-discharge data, structural data etc.

The numerical model of river Mutha covering a reach of about 15.0 km from Khadakwasla dam to Sangam near confluence of Mutha river with Mula river was developed using HEC-RAS software. The river geometry was reproduced in the model using the cross section data supplied by the Project Authorities (Figure 3). The steady state simulations were performed by imposing the discharge as the upstream boundary and water levels obtained from the Irrigation data as the downstream boundary. The Manning 'n' of 0.021 was used in simulations studies based on the existing river condition. Details of the simulations performed along with the results are described in the following paragraphs.

5.1 Simulation studies without Metro Piers

Initial simulation studies were conducted to obtain water surface elevations without the Metro Piers. The existing bridges in the river Mutha were incorporated in the model. The studies were conducted for two river discharges of 60,000 ft^3/s and 1,00,000 ft^3/s corresponding to blue and red line respectively. The results presented in the report are restricted to the study reach of river Mutha between Garware bridge and Shivaji bridge covering the Metro Piers and infrastructure. The computed water surface elevations were compared with blue line and red line provided by the Irrigation department. The results are plotted in the Figure 4. The simulated water surface elevations are above the red line in the reach between Sambhaji bridge and Shivaji bridge for the discharge of 1,00,000 ft^3/s. This may be attributed to the restricted cross section data. The cross sections may not be covering the entire flood plain where the water is likely to spread for larger area along both the banks thereby reducing the flood levels in actual site conditions. The representation of some of the bridge data in the model may also be incorrect. It was observed that the computed water surface elevation is about 0.74 m above the red line near/in the vicinity of Shinde bridge. The results obtained were also compared with the blue line. Similar trend as described above is observed for this condition also, wherein simulated water surface elevations are above the blue line provided by the Irrigation Department. The computed water surface profile is about 1.5 m above the blue line near/in the vicinity of Shinde Bridge.

5.2 Simulation studies with Metro Piers

The Metro Pier and related infrastructure works were also incorporated in the model. These simulations indicate the afflux induced due to construction of the Metro Piers. Figure 5 shows the Metro Pier near the Sambhaji Bridge and Figure 6 shows Metro Pier with the cap protruding above the ground surface near Gadgil (Z) Bridge incorporated in the model. The simulations were conducted for two river discharges of 60,000 and 1,00,000 ft^3/s. The computed water surfaces from these simulations were compared with the previously simulated water surface elevations.

The results are plotted in the Figure 7(a) and (b) for the discharge of 1,00,000 ft^3/s. The water surface elevations and afflux are given in Table 1. It was observed that in the study reach, afflux varies from 50 to 100 mm in the reach between Shivaji and Shinde bridges. Further in the upstream reach between Shinde bridge and Metro Pier DE 8, afflux varies between 150 to 250 mm. The afflux upstream of the Baba Bhide bridge is in the range of 340 to 350 mm with the maximum afflux of 380 mm observed at pier No. P152.

The results for the discharge of 60,000 ft^3/s are also plotted in the Figure 8(a) and (b). The water surface elevations and afflux are given in Table 2. It was observed that in the study reach, afflux is the range of 60 to 100 mm in the reach between Shivaji and Shinde bridges. Further in the upstream reach between Shinde bridge and Metro Pier DE 8 afflux varies between 150 to 240 mm. The afflux upstream of the Baba Bhide bridge is in the range of 200 to 250 mm with the maximum afflux of 290 mm observed at pier No. P153.

5.3 Additional simulations with aerial survey data

The results of the initial simulations with available data were discussed in the meeting held at Divisional Commissioner Office on 24.09.2020. The issue of the restricted cross sections was discussed during the meeting. The cross section data used in the studies were cross verified with the Irrigation Department to check the width of cross sections. It was found that the data used in the model is in agreement with the Irrigation data. It was decided to conduct additional survey covering both the banks of river Mutha to overcome the problem of restricted cross section data. Owing to time restriction, aerial survey using the drone was conducted by MMRCL. This data was provided to CWPRS to utilize in further studies. The data was provided in the cross section (Figure 9) and Digital Elevation Model (DEM) format.

5.3.1 Simulation studies using aerial survey data and existing bridges

The cross sections obtained from the aerial survey was incorporated in the model. The old cross sections provided by the Irrigation Department in the reach between the chainage 11430 m to 13800 m were replaced with cross sections obtained from the aerial survey. The simulations were performed for the discharges of 60000 ft^3/s and 1,00,000 ft^3/s corresponding to blue and red line respectively. The results are plotted in Figure 10 and given in Table 3 and Table 4. The water level in the Metro Pier reach varies from 546.13 m to 547.50 m for the discharge of 60000 ft^3/s and from 548.67 m to 549.68 m for the discharge of 1,00,000 ft^3/s.

5.3.2 Simulation studies using aerial survey data along with Metro Piers

The cross sections obtained from the aerial survey was incorporated in the model. The old cross section data provided by the Irrigation Department in the reach between the chainage 11430 m to 13800 m was replaced with cross sections obtained from the aerial survey. The simulations were performed for the discharges of 60000 ft^3/s and 1,00,000 ft^3/s corresponding to blue and red line respectively. The results are plotted in Figure 11 and given in Table 3 and Table 4. The water level in the Metro Pier reach varies from 546.13 m to 547.70 m for the discharge of 60000 ft^3/s and from 548.67 m to 549.90 m for the discharge of 1,00,000 ft^3/s.

The water surface profiles for the discharge of 1,00,000 ft^3/s with and without the Metro Piers are plotted in the Figure 11(a) and Figure 11(b). The water surface elevations and afflux at bridges and Metro Piers are given in Table 5. The results indicate that there is reduction in the afflux in the study reach because of the extended cross sections obtained from aerial survey. The afflux is lowered by an average of about 50 mm in the reach between Shivaji and Shinde bridge and the afflux at present with extended cross sections is in the range of 0 to 30 mm. In the reach between Shinde bridge and Metro Pier DE 8, the afflux is reduced by an average of about 80 mm and afflux at present is in the range of 30 to 180 mm. The afflux is reduced by about 120 mm in the reach upstream of Baba Bhide bridge. The afflux observed at P152 with extended cross sections is 216 mm which is less than previously computed value of 380 mm.

The water surface profiles for the discharge of 60,000 ft^3/s with and without the Metro Piers are plotted in the Figure 12(a) and Figure 12(b). The water surface elevations and afflux at bridges and Metro Piers are given in Table 6. The results indicate that there is reduction in the afflux in the study reach because of the extended cross sections obtained from aerial survey. The afflux is lowered by an average of about 60 mm in the reach between Shivaji and Shinde bridge and the afflux at present with extended cross sections is in the range of 0 to 23 mm. In the reach between Shinde bridge and Metro Pier DE 8, the afflux is reduced by an average of about 50 mm and afflux at present is in the range of 23 to 202 mm. The afflux is reduced by about 40 mm in the reach upstream of Baba Bhide bridge. The afflux observed at P152 with extended cross sections is 193 mm which is less than previously computed value of 270 mm.

5.4 Flood inundation mapping

Water surface profiles were computed for the discharges of 60,000 ft^3/s (Blue line) and 1,00,000 ft^3/s (Red line) using the numerical model. The inundation depths were computed based on the STRM DEM (30 m grid) downloaded from the USGS website. The inundation map generated is presented in Figure 13 to Figure 24. The inundation map overlaid on Google Map covering the entire study reach and for different stretches are presented in Figure 13 to Figure 18. The inundation map overlaid on SRTM terrain map covering the entire study reach and for different stretches are presented in Figure 19 to Figure 24.

Subsequently, the inundation depths were computed based on the DEM generated from the aerial survey data. The aerial survey data were provided for a reach of about 2.5 km covering the reach between S M Joshi bridge and Shivaji bridge (reach where Metro Piers are located along the river flood plain).

The inundation area for the flood discharge of 1,00,000 ft^3/s with and without the Metro Piers are plotted in the Figure 25. The inundation area at bridges and Metro Piers are given in Table 7. The results indicate that the inundation area in the reach between Shivaji and Shinde bridge in the range of 0 to 0.02 m. In the reach between Shinde bridge and Metro Pier DE 8, the inundation area varies from 0.02 m to 10.01 m. The inundation area in the reach between Metro Pier DE 8 and Baba Bhide bridge is in the range of 3.06 m to 10.94 m. The inundation area in the reach upstream of Baba Bhide bridge varies from 10.94 m to 2.66 m. In the reach near the Metro Piers P159, P160 and Z bridge, inundation area is higher and is in the range of 20 m to 30 m.

Numerical model studies for river Mutha for Maha Metro Rail Corporation Ltd. (MMRCL), Pune

The inundation area for the flood discharge of 60,000 ft^3/s with and without the Metro Piers are plotted in the Figure 26. The inundation area at bridges and Metro Piers are given in Table 8. The results indicate that the inundation area in the reach between Shivaji and Shinde bridge in the range of 0 to 0.01 m. In the reach between Shinde bridge and Metro Pier DE 8, the inundation area varies from 0.01 m to 2.27 m. The inundation area in the reach between Metro Pier DE 8 and Baba Bhide bridge is in the range of 2.27 m to 11.44 m. The inundation area in the reach upstream of Baba Bhide bridge varies from 11.44 m to 0.79 m. In the reach near Bhide bridge and Metro Piers P162 and P163 inundation area is higher and is in the range of about 10 m to 12 m.

The extent of inundation and its accuracy is dependent on the underlying DEM data. Hence, the extent of inundation may vary depending on the underlying DEM.

6.0 CONCLUSIONS

The numerical model of river Mutha covering a reach of about 15.0 km from Khadakwasla dam to Sangam near confluence of Mutha river with Mula river was developed using HEC-RAS 5.0.7. Simulations were carried out for the discharges of 60,000 ft^3/s and 1,00,000 ft^3/s to compute the water surface profiles under existing conditions and also by incorporating the Metro Piers to estimate the afflux.

- It was observed that the maximum afflux for the discharge of 1,00,000 ft^3/s is about 380 mm in the reach near Sambhaji bridge. This afflux is reduced to 216 mm when the extended cross sections are taken into account.
- It was observed that the maximum afflux for the discharge of 60,000 ft^3/s is about 290 mm in the reach upstream of Sambhaji bridge near pier number P153. This afflux is reduced to 198 mm when the extended cross sections are taken into account.
- The inundation depths were computed based on the STRM DEM (30 m grid) downloaded from the USGS website and inundation maps were prepared for the entire study reach. The extent of inundation and its accuracy is dependent on the underlying DEM data. Hence, the extent of inundation may vary depending on the underlying DEM.
- Subsequently the inundation depths were computed based on the DEM data collected by aerial survey for limited reach of 2.5 Km. Flood extent was overlaid on Google image.

ACKNOWLEDGEMENTS

Central Water and Power Research Station, Pune (CWPRS) is thankful to M/s MMRCL, Pune for referring the studies. We wish to express our sincere gratitude to Shri A.K. Agrawal, Director CWPRS, Pune for his constant encouragement and continuous guidance during execution of studies. The help and efforts of Shri S.A Kamble, Scientist B, Shri S D. Pingale, Research Assistant and other staff members are acknowledged with thanks. Shri Ratnakar Pandey, Deputy General Manager (Environment), Ms Renu Gera, Consultant visited CWPRS during the studies and discussed various aspects of model studies in details. Their valuable contribution and support during the course of studies is gratefully acknowledged.

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Table 1: Water Surface Elevations for the discharge of 1,00,000 ft^3/s

[redacted]			
	(m)	(m)	(mm)
Nanded Shivne	559.90	559.90	0
NH 4 Vadgaon	555.23	555.27	40
Rajaram	553.10	553.21	110
Mhatre	551.13	551.38	250
SM Joshi	550.56	550.93	370
YB Chavan	550.47	550.83	360
P152	550.36	550.74	380
P153	550.39	550.70	310
P154	550.16	550.49	330
P155	550.14	550.47	330
Sambhaji/ Lakadi	550.12	550.45	330
P156	550.12	550.45	330
P157	550.06	550.39	330
P158	550.02	550.35	330
P159	549.99	550.33	340
P160	550.00	550.33	330
Z bridge	549.97	550.30	330
P161	549.93	550.27	340
P162	549.91	550.24	330
P163	549.80	550.14	340
Bhide	549.79	550.13	340
DE1	549.78	550.13	350
DE2	549.78	550.12	340
DE3	549.75	550.08	330
DE4	549.76	550.09	330
DE5	549.71	550.04	330
DE6	549.77	550.08	310

DE7	549.79	550.04	250
DE8	549.65	549.90	250
DE9	549.67	549.90	230
DE10	549.62	549.86	240
P164	549.67	549.89	220
P165	549.65	549.88	230
P166	549.42	549.67	250
P167	549.43	549.68	250
P168	549.46	549.70	240
P169	549.29	549.55	260
P170	549.27	549.53	260
P171	549.38	549.61	230
P172	549.16	549.39	230
P173	549.02	549.26	240
P174	549.10	549.32	220
P175	549.13	549.35	220
P176	549.06	549.28	220
SP1	549.11	549.31	200
SP2	549.10	549.30	200
SP3	548.99	549.19	200
SP4	549.06	549.24	180
SP5	549.07	549.24	170
SP6	549.03	549.19	160
SP7	549.08	549.23	150
SP8	549.10	549.24	140
SP9	549.11	549.25	140
SP10	548.98	549.12	140
P177	549.03	549.15	120
P178	548.96	549.08	120
P179	548.97	549.08	110
P180	549.01	549.12	110
P181	548.82	548.93	110
P182	548.84	548.96	120

Shinde	548.81	548.91	100
P183	548.74	548.85	110
P184	548.63	548.74	110
P185	548.52	548.63	110
P186	548.54	548.63	90
P186a	548.53	548.61	80
Causeway	548.60	548.67	70
P187	548.62	548.68	60
P188	548.30	548.35	50
P189	548.53	548.55	20
P190	548.48	548.49	10
P191	548.33	548.34	10
Shivaji	548.34	548.34	0
Dengale	547.91	547.91	0
Wellesely	547.07	547.07	0
Railway	547.02	547.02	0
Sangam/RTO	546.86	546.86	0

Table 2: Water Surface Elevations for the discharge of 60,000 ft^3/s

[redacted]			
	(m)	(m)	(mm)
Nanded Shivne	558.18	558.18	0
NH 4 Vadgaon	553.35	553.35	0
Rajaram	550.70	550.75	50
Mhatre	549.19	549.31	120
SM Joshi	548.48	548.71	230
YB Chavan	548.41	548.67	260
P152	548.31	548.58	270
P153	548.29	548.58	290
P154	548.33	548.55	220
P155	548.12	548.36	240
Sambhaji/ Lakadi	548.11	548.35	240
P156	548.08	548.32	240
P157	548.06	548.31	250
P158	548.03	548.28	250
P159	548.00	548.25	250
P160	547.98	548.23	250
Z bridge	547.99	548.23	240
P161	547.97	548.22	250
P162	547.93	548.18	250
P163	547.91	548.16	250
Bhide	547.85	548.10	250
DE1	547.83	548.09	260
DE2	547.80	548.06	260
DE3	547.78	548.04	260
DE4	547.77	548.02	250
DE5	547.77	548.02	250
DE6	547.73	547.98	250
DE7	547.74	547.99	250

DE8	547.77	547.97	200
DE9	547.66	547.87	210
DE10	547.68	547.88	200
P164	547.66	547.86	200
P165	547.67	547.86	190
P166	547.64	547.84	200
P167	547.43	547.66	230
P168	547.46	547.67	210
P169	547.49	547.69	200
P170	547.26	547.50	240
P171	547.23	547.46	230
P172	547.34	547.54	200
P173	547.23	547.42	190
P174	547.07	547.27	200
P175	547.12	547.31	190
P176	547.16	547.34	180
SP1	547.15	547.32	170
SP2	547.17	547.33	160
SP3	547.17	547.32	150
SP4	547.09	547.24	150
SP5	547.05	547.21	160
SP6	547.10	547.25	150
SP7	547.05	547.19	140
SP8	547.11	547.24	130
SP9	547.10	547.23	130
SP10	547.11	547.24	130
P177	546.98	547.09	110
P178	547.03	547.14	110
P179	546.98	547.09	110
P180	546.99	547.09	100
P181	547.00	547.09	90
P182	546.89	546.98	90
Shinde	546.88	546.97	90

P183	546.86	546.94	80
P184	546.78	546.87	90
P185	546.72	546.81	90
P186	546.62	546.72	100
P186a	546.64	546.73	90
Causeway	546.63	546.71	80
P187	546.68	546.74	60
P188	546.67	546.73	60
P189	546.28	546.35	70
P190	546.54	546.54	0
P191	546.37	546.37	0
Shivaji	546.24	546.24	0
Dengale	545.74	545.74	0
Wellesely	544.57	544.57	0
Railway	544.56	544.56	0
Sangam/RTO	544.33	544.33	0

Table 3: Water Surface Elevations for the discharge of 1,00,000 ft³/s EXTENDED CS

[redacted]

	(m)	(m)	(mm)
Nanded shivne bridge	559.936	559.936	0
NH4 1	555.268	555.279	11
Rajaram	553.206	553.243	37
Mhatre	550.514	550.654	140
SM Joshi	549.924	550.132	208
YB Chavan	549.840	550.045	205
P152	549.683	549.899	216
P153	549.613	549.831	218
P154	549.585	549.802	217
P155	549.583	549.795	212
Sambhaji/ Lakadi	549.471	549.691	220
P156	549.458	549.677	219
P157	549.466	549.683	217
P158	549.457	549.672	215
P159	549.470	549.681	211
P160	549.464	549.671	207
Z bridge	549.408	549.624	216
P161	549.423	549.635	212
P162	549.432	549.641	209
P163	549.423	549.634	211
Bhide	549.419	549.629	210
DE1	549.347	549.562	215
DE2	549.345	549.557	212
DE3	549.343	549.550	207
DE4	549.270	549.466	196
DE5	549.283	549.476	193
DE6	549.278	549.468	190

DE7	549.281	549.467	186
DE8	549.269	549.452	183
DE9	549.265	549.445	180
DE10	549.237	549.418	181
P164	549.229	549.407	178
P165	549.195	549.372	177
P166	549.186	549.360	174
P167	549.164	549.340	176
P168	549.138	549.307	169
P169	549.052	549.208	156
P170	549.053	549.201	148
P171	549.046	549.191	145
P172	549.031	549.173	142
P173	549.021	549.160	139
P174	549.014	549.142	128
P175	548.993	549.116	123
P176	548.964	549.081	117
SP1	548.94	549.053	113
SP2	548.943	549.044	101
SP3	548.933	549.030	97
SP4	548.940	549.031	91
SP5	548.936	549.017	81
SP6	548.893	548.97	77
SP7	548.883	548.957	74
SP8	548.885	548.953	68
SP9	548.875	548.939	64
SP10	548.918	548.973	55
P177	548.912	548.963	51
P178	548.909	548.958	49
P179	548.900	548.946	46
P180	548.822	548.865	43
P181	548.844	548.882	38
P182	548.808	548.842	34

Table 4: Water Surface Elevations for the discharge of 60,000 ft^3/s EXTENDED CS

[redacted]			
	(m)	(m)	(mm)
Nanded shivne bridge	558.278	558.278	0
NH4 1	553.330	553.331	1
Rajaram	550.764	550.778	14
Mhatre	548.548	548.615	67
SM Joshi	547.791	547.947	156
YB Chavan	547.677	547.849	172
P152	547.504	547.697	193
P153	547.434	547.635	201
P154	547.407	547.609	202
P155	547.405	547.603	198
Sambhaji/ Lakadi	547.319	547.529	210
P156	547.287	547.500	213
P157	547.253	547.468	215
P158	547.254	547.464	210
P159	547.256	547.462	206
P160	547.250	547.452	202
Z bridge	547.183	547.395	212
P161	547.160	547.377	217
P162	547.129	547.354	225
P163	547.115	547.341	226
Bhide	547.107	547.332	225
DE1	547.031	547.272	241
DE2	547.028	547.266	238
DE3	547.023	547.255	232
DE4	547.006	547.215	209
DE5	547.008	547.214	206

Table 4: Water Surface Elevations for the discharge of 60,000 ft³/s EXTENDED CS

[redacted]			
	(m)	(m)	(mm)
Nanded shivne bridge	558.278	558.278	0
NH4 1	553.330	553.331	1
Rajaram	550.764	550.778	14
Mhatre	548.548	548.615	67
SM Joshi	547.791	547.947	156
YB Chavan	547.677	547.849	172
P152	547.504	547.697	193
P153	547.434	547.635	201
P154	547.407	547.609	202
P155	547.405	547.603	198
Sambhaji/ Lakadi	547.319	547.529	210
P156	547.287	547.500	213
P157	547.253	547.468	215
P158	547.254	547.464	210
P159	547.256	547.462	206
P160	547.250	547.452	202
Z bridge	547.183	547.395	212
P161	547.160	547.377	217
P162	547.129	547.354	225
P163	547.115	547.341	226
Bhide	547.107	547.332	225
DE1	547.031	547.272	241
DE2	547.028	547.266	238
DE3	547.023	547.255	232
DE4	547.006	547.215	209
DE5	547.008	547.214	206

DE6	547.002	547.204	202
DE7	547.002	547.201	199
DE8	546.958	547.160	202
DE9	546.950	547.150	200
DE10	546.935	547.129	194
P164	546.926	547.117	191
P165	546.845	547.036	191
P166	546.833	547.020	187
P167	546.837	547.015	178
P168	546.819	546.985	166
P169	546.763	546.915	152
P170	546.752	546.901	149
P171	546.705	546.855	150
P172	546.676	546.824	148
P173	546.662	546.808	146
P174	546.587	546.739	152
P175	546.597	546.741	144
P176	546.601	546.737	136
SP1	546.524	546.657	133
SP2	546.520	546.633	113
SP3	546.507	546.617	110
SP4	546.500	546.599	99
SP5	546.500	546.581	81
SP6	546.387	546.467	80
SP7	546.371	546.448	77
SP8	546.375	546.446	71
SP9	546.356	546.422	66
SP10	546.424	546.475	51
P177	546.410	546.456	46
P178	546.406	546.450	44
P179	546.409	546.448	39
P180	546.394	546.430	36
P181	546.396	546.428	32

P182	546.358	546.386	28
Shinde	546.352	546.375	23
P183	546.291	546.316	25
P184	546.285	546.305	20
P185	546.303	546.315	12
P186	546.288	546.296	8
P186a	546.281	546.286	5
Causeway	546.200	546.205	5
P187	546.133	546.140	7
P188	546.104	546.111	7
P189	546.124	546.128	4
P190	546.138	546.140	2
P191	546.131	546.131	0
Tilak	546.066	546.066	0
Shivaji	545.984	545.984	0
Dengle/ Kumbharwada new	545.370	545.370	0
Wellesely	544.685	544.685	0
Railway	544.585	544.585	0
Sangam/RTO	544.396	544.396	0

Table 5: Water Surface Elevations and comparison of afflux for the discharge of 1,00,000 ft^3/s

[redacted]						
	(m)	(m)	(mm)	(m)	(m)	(mm)
Nanded shivne bridge	559.90	559.90	0	559.936	559.936	0
NH4 1	555.23	555.27	40	555.268	555.279	11
Rajaram	553.10	553.21	110	553.206	553.243	37
Mhatre	551.13	551.38	250	550.514	550.654	140
SM Joshi	550.56	550.93	370	549.924	550.132	208
YB Chavan	550.47	550.83	360	549.840	550.045	205
P152	550.36	550.74	380	549.683	549.899	216
P153	550.39	550.70	310	549.613	549.831	218
P154	550.16	550.49	330	549.585	549.802	217
P155	550.14	550.47	330	549.583	549.795	212
Sambhaji/ Lakadi	550.12	550.45	330	549.471	549.691	220
P156	550.12	550.45	330	549.458	549.677	219
P157	550.06	550.39	330	549.466	549.683	217
P158	550.02	550.35	330	549.457	549.672	215
P159	549.99	550.33	340	549.470	549.681	211
P160	550.00	550.33	330	549.464	549.671	207
Z bridge	549.97	550.30	330	549.408	549.624	216
P161	549.93	550.27	340	549.423	549.635	212
P162	549.91	550.24	330	549.432	549.641	209
P163	549.80	550.14	340	549.423	549.634	211
Bhide	549.79	550.13	340	549.419	549.629	210
DE1	549.78	550.13	350	549.347	549.562	215
DE2	549.78	550.12	340	549.345	549.557	212
DE3	549.75	550.08	330	549.343	549.550	207

DE4	549.76	550.09	330	549.270	549.466	196
DE5	549.71	550.04	330	549.283	549.476	193
DE6	549.77	550.08	310	549.278	549.468	190
DE7	549.79	550.04	250	549.281	549.467	186
DE8	549.65	549.90	250	549.269	549.452	183
DE9	549.67	549.90	230	549.265	549.445	180
DE10	549.62	549.86	240	549.237	549.418	181
P164	549.67	549.89	220	549.229	549.407	178
P165	549.65	549.88	230	549.195	549.372	177
P166	549.42	549.67	250	549.186	549.360	174
P167	549.43	549.68	250	549.164	549.340	176
P168	549.46	549.70	240	549.138	549.307	169
P169	549.29	549.55	260	549.052	549.208	156
P170	549.27	549.53	260	549.053	549.201	148
P171	549.38	549.61	230	549.046	549.191	145
P172	549.16	549.39	230	549.031	549.173	142
P173	549.02	549.26	240	549.021	549.160	139
P174	549.10	549.32	220	549.014	549.142	128
P175	549.13	549.35	220	548.993	549.116	123
P176	549.06	549.28	220	548.964	549.081	117
SP1	549.11	549.31	200	548.940	549.053	113
SP2	549.10	549.30	200	548.943	549.044	101
SP3	548.99	549.19	200	548.933	549.030	97
SP4	549.06	549.24	180	548.940	549.031	91
SP5	549.07	549.24	170	548.936	549.017	81
SP6	549.03	549.19	160	548.893	548.970	77
SP7	549.08	549.23	150	548.883	548.957	74
SP8	549.10	549.24	140	548.885	548.953	68
SP9	549.11	549.25	140	548.875	548.939	64
SP10	548.98	549.12	140	548.918	548.973	55
P177	549.03	549.15	120	548.912	548.963	51
P178	548.96	549.08	120	548.909	548.958	49
P179	548.97	549.08	110	548.900	548.946	46

P180	549.01	549.12	110	548.822	548.865	43
P181	548.82	548.93	110	548.844	548.882	38
P182	548.84	548.96	120	548.808	548.842	34
Shinde	548.81	548.91	100	548.804	548.834	30
P183	548.74	548.85	110	548.755	548.785	30
P184	548.63	548.74	110	548.751	548.777	26
P185	548.52	548.63	110	548.778	548.798	20
P186	548.54	548.63	90	548.762	548.779	17
P186a	548.53	548.61	80	548.756	548.770	14
Causeway	548.60	548.67	70	548.722	548.735	13
P187	548.62	548.68	60	548.693	548.707	14
P188	548.30	548.35	50	548.636	548.647	11
P189	548.53	548.55	20	548.675	548.682	7
P190	548.48	548.49	10	548.67	548.673	3
P191	548.33	548.34	10	548.665	548.666	1
Tilak				548.560	548.560	0
Shivaji	548.34	548.34	0	548.076	548.076	0
Dengle/ Kumbharwada new	547.91	547.91	0	547.598	547.598	0
Wellesely	547.07	547.07	0	547.190	547.190	0
Railway	547.02	547.02	0	547.054	547.054	0
Sangam/RTO	546.86	546.86	0	546.956	546.956	0

Table 6: Water Surface Elevations and comparison of afflux for the discharge of 60,000 ft^3/s

[redacted]						
	(m)	(m)	(mm)	(m)	(m)	(mm)
Nanded shivne bridge	558.18	558.18	0	558.278	558.278	0
NH4 1	553.35	553.35	0	553.33	553.331	1
Rajaram	550.70	550.75	50	550.764	550.778	14
Mhatre	549.19	549.31	120	548.548	548.615	67
SM Joshi	548.48	548.71	230	547.791	547.947	156
YB Chavan	548.41	548.67	260	547.677	547.849	172
P152	548.31	548.58	270	547.504	547.697	193
P153	548.29	548.58	290	547.434	547.635	201
P154	548.33	548.55	220	547.407	547.609	202
P155	548.12	548.36	240	547.405	547.603	198
Sambhaji/ Lakadi	548.11	548.35	240	547.319	547.529	210
P156	548.08	548.32	240	547.287	547.500	213
P157	548.06	548.31	250	547.253	547.468	215
P158	548.03	548.28	250	547.254	547.464	210
P159	548.00	548.25	250	547.256	547.462	206
P160	547.98	548.23	250	547.25	547.452	202
Z bridge	547.99	548.23	240	547.183	547.395	212
P161	547.97	548.22	250	547.16	547.377	217
P162	547.93	548.18	250	547.129	547.354	225
P163	547.91	548.16	250	547.115	547.341	226
Bhide	547.85	548.10	250	547.107	547.332	225
DE1	547.83	548.09	260	547.031	547.272	241
DE2	547.80	548.06	260	547.028	547.266	238
DE3	547.78	548.04	260	547.023	547.255	232

DE4	547.77	548.02	250	547.006	547.215	209
DE5	547.77	548.02	250	547.008	547.214	206
DE6	547.73	547.98	250	547.002	547.204	202
DE7	547.74	547.99	250	547.002	547.201	199
DE8	547.77	547.97	200	546.958	547.160	202
DE9	547.66	547.87	210	546.950	547.150	200
DE10	547.68	547.88	200	546.935	547.129	194
P164	547.66	547.86	200	546.926	547.117	191
P165	547.67	547.86	190	546.845	547.036	191
P166	547.64	547.84	200	546.833	547.020	187
P167	547.43	547.66	230	546.837	547.015	178
P168	547.46	547.67	210	546.819	546.985	166
P169	547.49	547.69	200	546.763	546.915	152
P170	547.26	547.5	240	546.752	546.901	149
P171	547.23	547.46	230	546.705	546.855	150
P172	547.34	547.54	200	546.676	546.824	148
P173	547.23	547.42	190	546.662	546.808	146
P174	547.07	547.27	200	546.587	546.739	152
P175	547.12	547.31	190	546.597	546.741	144
P176	547.16	547.34	180	546.601	546.737	136
SP1	547.15	547.32	170	546.524	546.657	133
SP2	547.17	547.33	160	546.520	546.633	113
SP3	547.17	547.32	150	546.507	546.617	110
SP4	547.09	547.24	150	546.500	546.599	99
SP5	547.05	547.21	160	546.5	546.581	81
SP6	547.10	547.25	150	546.387	546.467	80
SP7	547.05	547.19	140	546.371	546.448	77
SP8	547.11	547.24	130	546.375	546.446	71
SP9	547.10	547.23	130	546.356	546.422	66
SP10	547.11	547.24	130	546.424	546.475	51
P177	546.98	547.09	110	546.410	546.456	46
P178	547.03	547.14	110	546.406	546.450	44
P179	546.98	547.09	110	546.409	546.448	39

P180	546.99	547.09	100	546.394	546.430	36
P181	547.00	547.09	90	546.396	546.428	32
P182	546.89	546.98	90	546.358	546.386	28
Shinde	546.88	546.97	90	546.352	546.375	23
P183	546.86	546.94	80	546.291	546.316	25
P184	546.78	546.87	90	546.285	546.305	20
P185	546.72	546.81	90	546.303	546.315	12
P186	546.62	546.72	100	546.288	546.296	8
P186a	546.64	546.73	90	546.281	546.286	5
Causeway	546.63	546.71	80	546.200	546.205	5
P187	546.68	546.74	60	546.133	546.140	7
P188	546.67	546.73	60	546.104	546.111	7
P189	546.28	546.35	70	546.124	546.128	4
P190	546.54	546.54	0	546.138	546.140	2
P191	546.37	546.37	0	546.131	546.131	0
Tilak				546.066	546.066	0
Shivaji	546.24	546.24	0	545.984	545.984	0
Dengle/ Kumbharwada new	545.74	545.74	0	545.370	545.370	0
Wellesely	544.57	544.57	0	544.685	544.685	0
Railway	544.56	544.56	0	544.585	544.585	0
Sangam/RTO	544.33	544.33	0	544.396	544.396	0

Table :7 Flood inundation extent for the discharge of 1,00,000 ft³/s

[redacted]			
Nanded shivne bridge	462.49	462.49	0.00
NH4 1	186.43	186.29	0.14
NH4 2	185.18	185.03	0.15
Rajaram	306.00	304.95	1.05
Mhatre	159.77	158.42	1.35
SM Joshi	206.82	206.63	0.19
YB Chavan	214.08	206.82	7.26
P152	205.34	202.68	2.66
P153	180.12	180.05	0.07
P154	174.26	174.16	0.10
P155	174.26	174.16	0.10
Sambhaji/ Lakadi	161.72	161.44	0.28
P156	167.20	166.77	0.43
P157	204.24	203.97	0.27
P158	196.30	194.76	1.54
P159	285.24	263.04	22.20
P160	283.31	262.70	20.61
Z bridge	325.40	295.56	29.84
P161	340.00	330.37	9.63
P162	364.56	354.80	9.76
P163	364.38	353.79	10.59
Bhide	364.25	353.31	10.94
DE1	283.27	280.68	2.59
DE2	283.21	280.66	2.55
DE3	283.13	280.63	2.50
DE4	213.90	211.13	2.77
DE5	256.41	250.16	6.25
DE6	256.31	250.01	6.30

DE7	254.78	249.61	5.17
DE8	252.16	249.10	3.06
DE9	252.05	249.03	3.02
DE10	264.80	261.69	3.11
P164	264.65	261.54	3.11
P165	230.42	227.18	3.24
P166	230.21	227.05	3.16
P167	278.39	222.63	55.76
P168	260.85	259.62	1.23
P169	223.19	218.10	5.09
P170	211.00	208.03	2.97
P171	230.95	230.48	0.47
P172	251.21	245.52	5.69
P173	250.60	245.21	5.39
P174	240.65	239.33	1.32
P175	225.95	224.23	1.72
P176	191.05	189.55	1.50
SP1	249.56	242.07	7.49
SP2	268.92	258.91	10.01
SP3	267.31	258.00	9.31
SP4	266.18	263.51	2.67
SP5	265.88	263.39	2.49
SP6	261.90	257.24	4.66
SP7	261.59	255.58	6.01
SP8	258.62	254.65	3.97
SP9	257.78	254.28	3.50
SP10	249.73	249.70	0.03
P177	249.73	249.70	0.03
P178	248.82	248.39	0.43
P179	243.08	242.56	0.52
P180	168.39	168.38	0.01
P181	183.53	183.51	0.02
P182	174.06	174.04	0.02

Shinde	174.06	174.04	0.02
P183	172.40	172.36	0.04
P184	172.39	172.36	0.03
P185	211.42	210.62	0.80
P186	184.98	184.85	0.13
P186a	184.92	184.82	0.10
Causeway	247.44	247.00	0.44
P187	246.59	246.14	0.45
P188	195.94	195.62	0.32
P189	225.04	224.87	0.17
P190	198.59	198.37	0.22
P191	175.54	175.53	0.01
Tilak	203.36	203.36	0.00
Shivaji	209.62	209.62	0.00
Dengle/ Kumbharwada new	164.18	164.18	0.00
Wellesely	196.25	196.25	0.00
Railway	164.63	164.63	0.00
Sangam/RTO	174.98	174.98	0.00

Table :8 Flood inundation extent for the discharge of 60,000 ft³/s

[redacted]			
Nanded shivne bridge	201.66	201.66	0.00
NH4 1	155.83	155.82	0.01
NH4 2	155.48	155.47	0.01
Rajaram	172.42	172.31	0.11
Mhatre	144.11	143.62	0.49
SM Joshi	204.90	204.76	0.14
YB Chavan	202.63	202.50	0.13
P152	190.75	189.96	0.79
P153	179.42	179.36	0.06
P154	172.19	171.49	0.70
P155	172.17	171.48	0.69
Sambhaji/ Lakadi	158.08	157.76	0.32
P156	163.14	162.99	0.15
P157	160.50	160.40	0.10
P158	162.76	161.98	0.78
P159	160.74	160.63	0.11
P160	160.74	160.63	0.11
Z bridge	164.67	164.36	0.31
P161	189.08	184.14	4.94
P162	209.98	199.57	10.41
P163	209.42	198.90	10.52
Bhide	209.00	197.56	11.44
DE1	192.63	187.43	5.20
DE2	192.46	187.36	5.10
DE3	192.19	187.27	4.92
DE4	170.58	168.38	2.20
DE5	175.23	173.16	2.07
DE6	175.13	173.10	2.03

DE7	180.25	178.73	1.52
DE8	184.39	182.12	2.27
DE9	184.29	182.03	2.26
DE10	169.12	166.41	2.71
P164	168.94	166.28	2.66
P165	174.08	173.43	0.65
P166	174.03	173.39	0.64
P167	169.89	169.12	0.77
P168	161.30	159.86	1.44
P169	150.13	149.41	0.72
P170	160.05	159.31	0.74
P171	158.23	157.60	0.63
P172	158.16	156.38	1.78
P173	157.93	156.23	1.70
P174	158.13	153.52	4.61
P175	157.97	156.36	1.61
P176	160.19	159.82	0.37
SP1	146.80	143.96	2.84
SP2	147.87	146.09	1.78
SP3	147.63	145.90	1.73
SP4	150.41	147.54	2.87
SP5	149.87	147.56	2.31
SP6	149.22	148.56	0.66
SP7	149.06	148.42	0.64
SP8	163.86	163.30	0.56
SP9	163.67	163.14	0.53
SP10	195.45	195.30	0.15
P177	195.39	195.26	0.13
P178	190.83	190.82	0.01
P179	183.24	183.21	0.03
P180	163.47	163.08	0.39
P181	182.45	182.44	0.01
P182	172.99	172.98	0.01

Shinde	172.98	172.97	0.01
P183	169.83	169.81	0.02
P184	169.82	169.80	0.02
P185	177.33	177.31	0.02
P186	162.95	162.94	0.01
P186a	162.94	162.94	0.00
Causeway	150.08	150.08	0.00
P187	150.02	150.02	0.00
P188	147.50	147.47	0.03
P189	165.21	165.20	0.01
P190	167.83	167.83	0.00
P191	167.42	167.42	0.00
Tilak	159.83	159.83	0.00
Shivaji	172.83	172.83	0.00
Dengle/ Kumbharwada new	157.44	157.44	0.00
Wellesely	175.69	175.69	0.00
Railway	156.63	156.63	0.00
Sangam/RTO	165.41	165.41	0.00

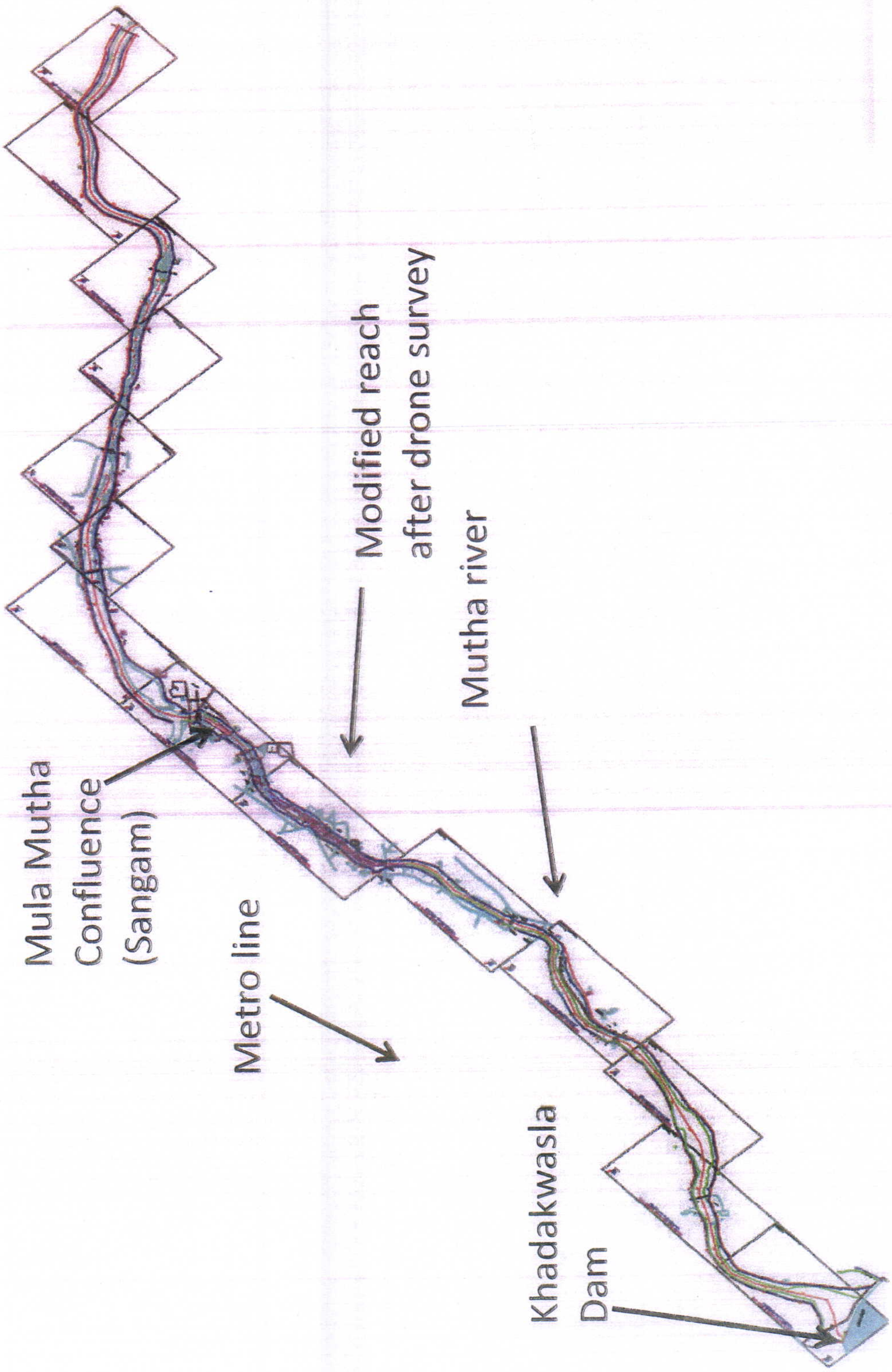

Figure 1(a): Study Reach

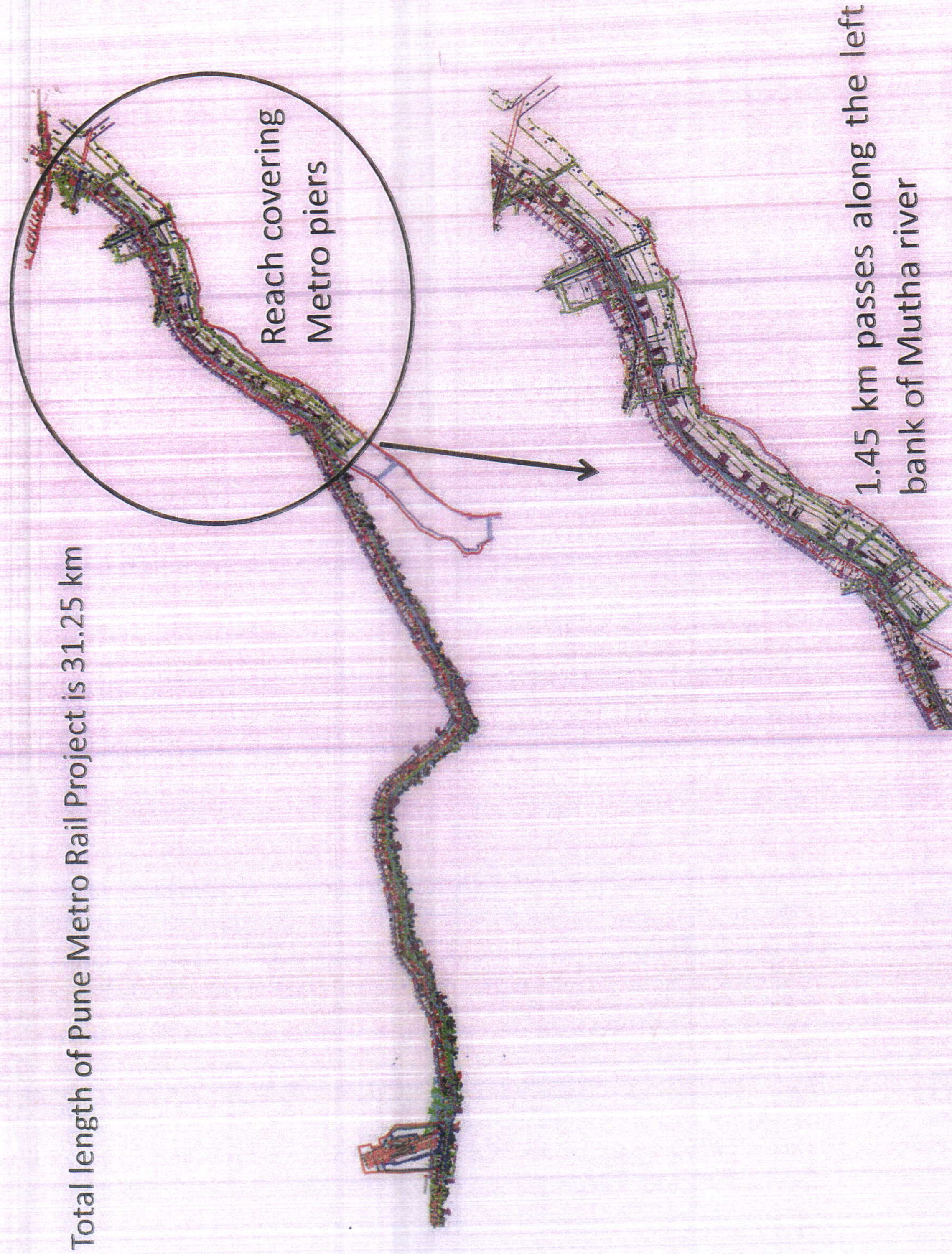

Figure 1(b): Study Reach highlighting area of metro pier in river flood plain

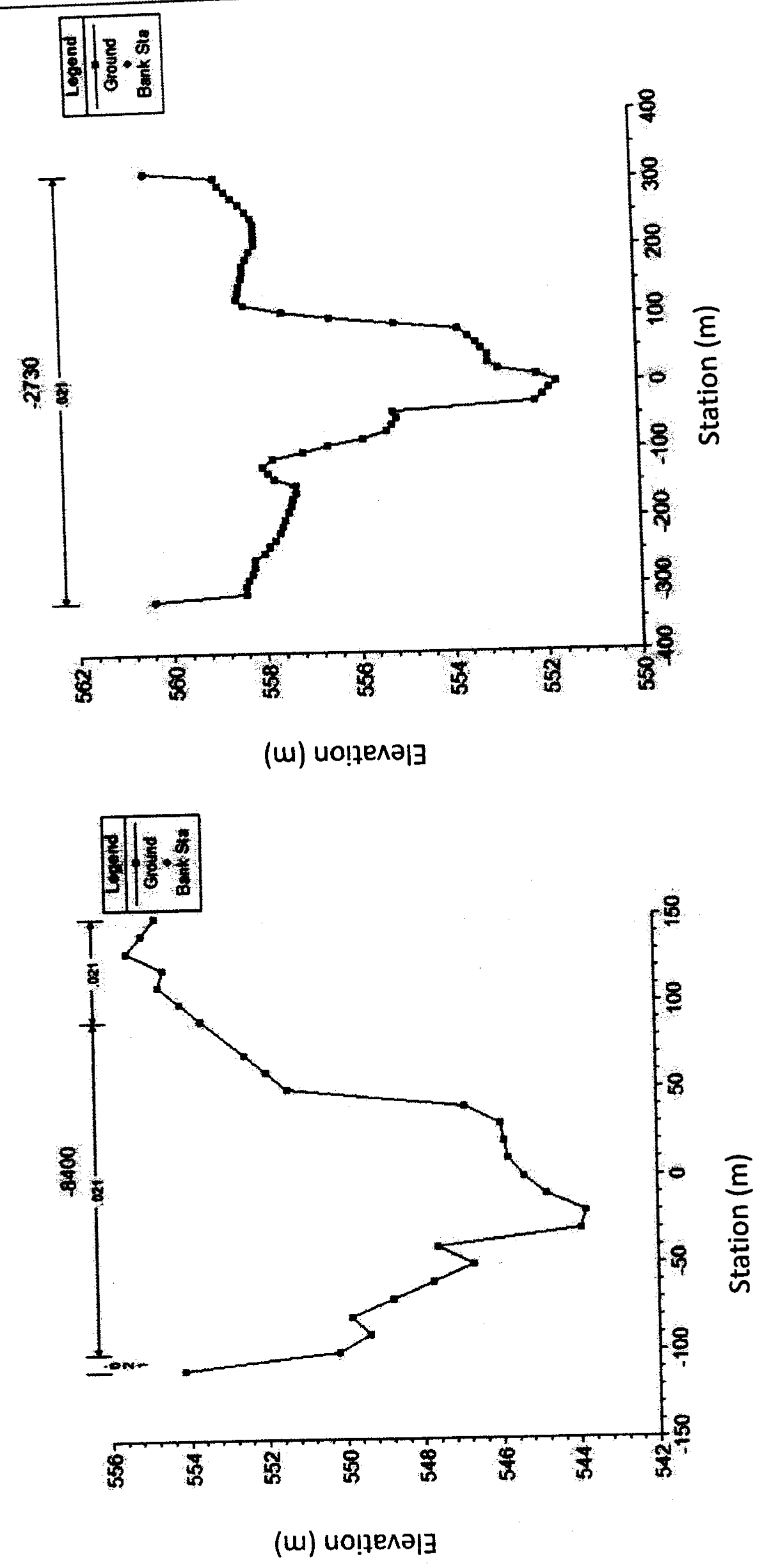

Figure 2: Representative cross sections of Mutha river in the study reach

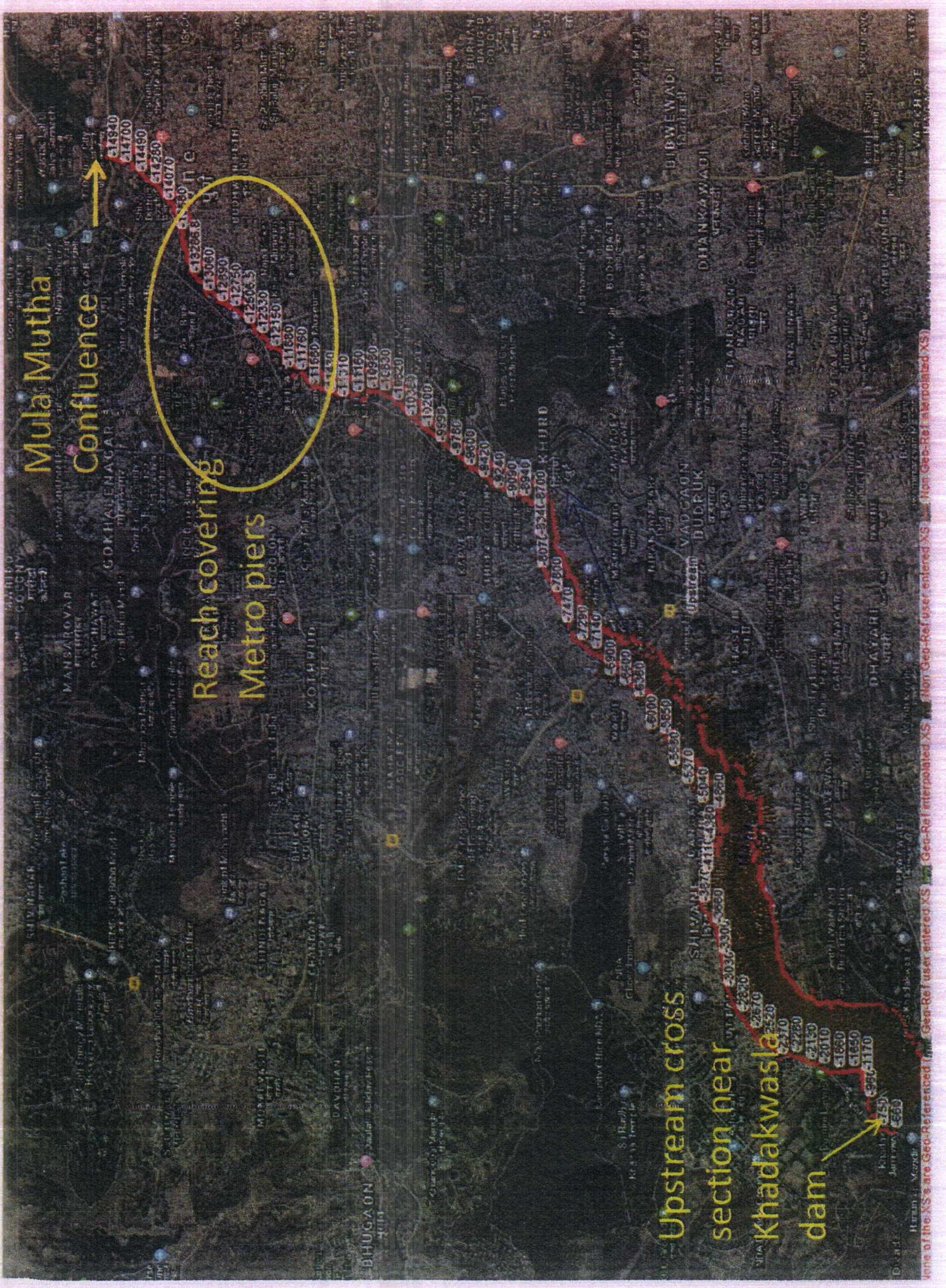

Figure 3: River schematic in HEC-RAS

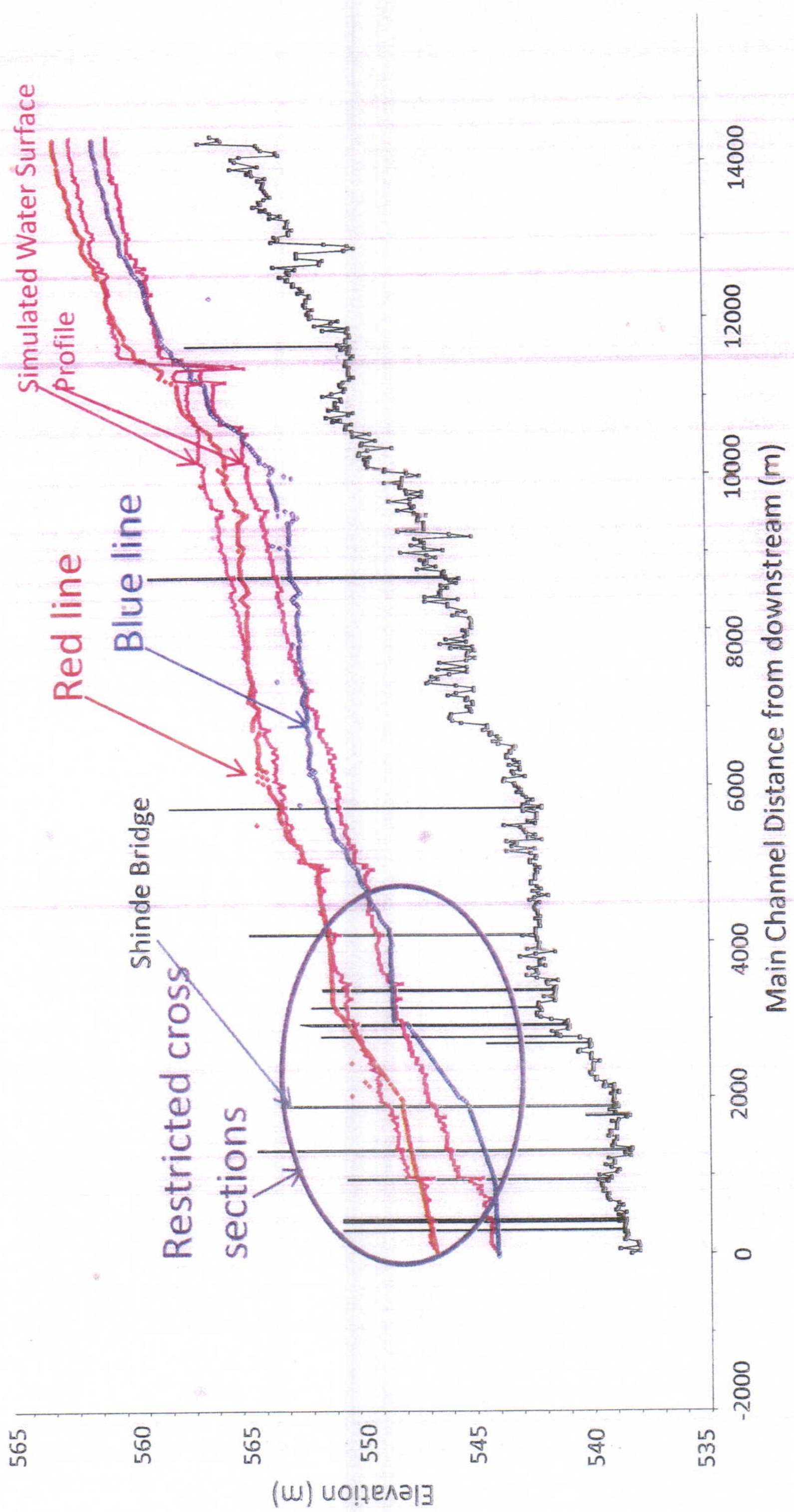

Figure 4: Water surface profiles incorporating existing bridges without metro piers alongwith blue line (60,000 ft^3/s) and red line (1,00,000 ft^3/s)

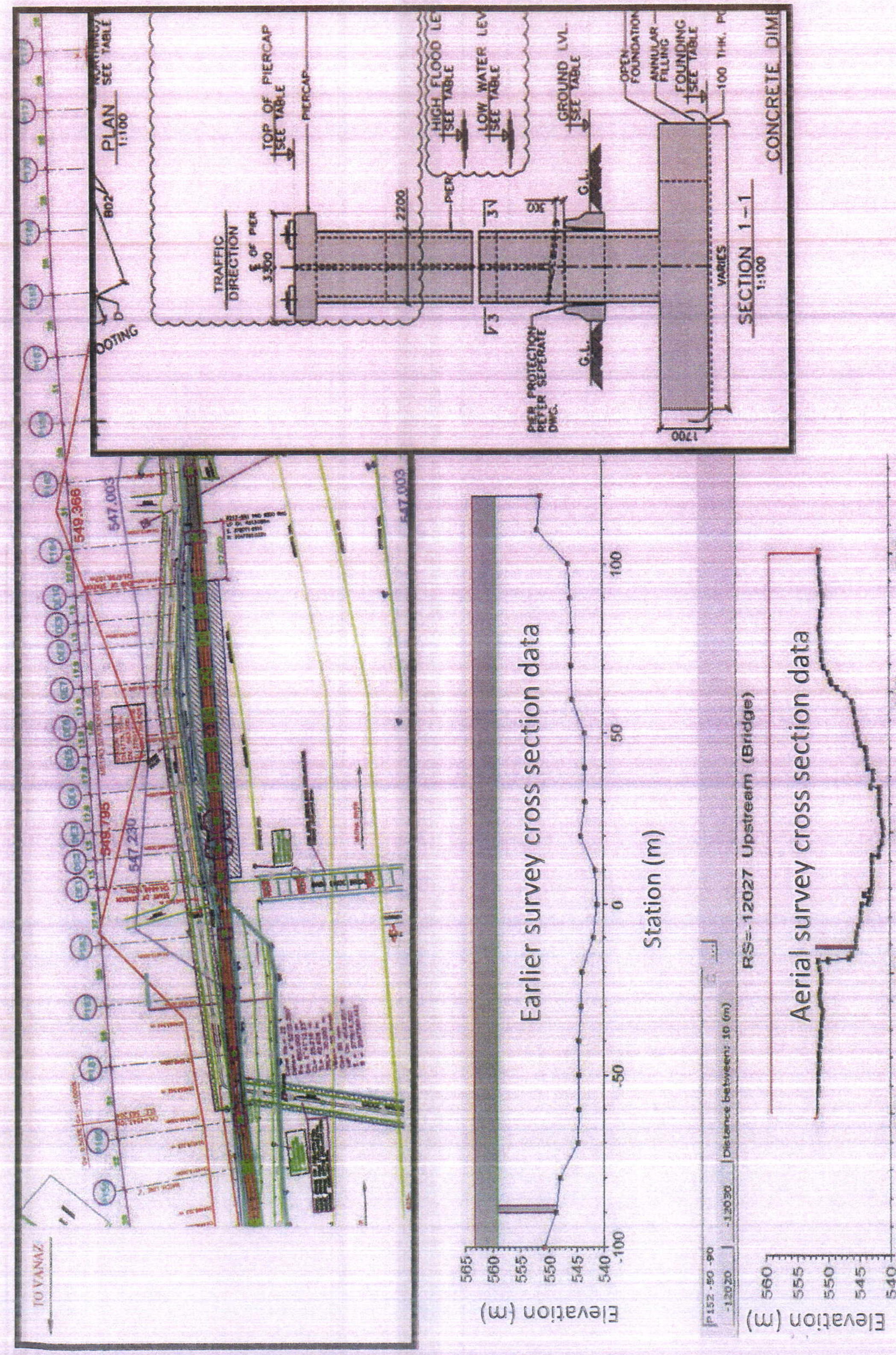

Figure 5: Sample Data Metro pier (P152) near Sambhaji Bridge

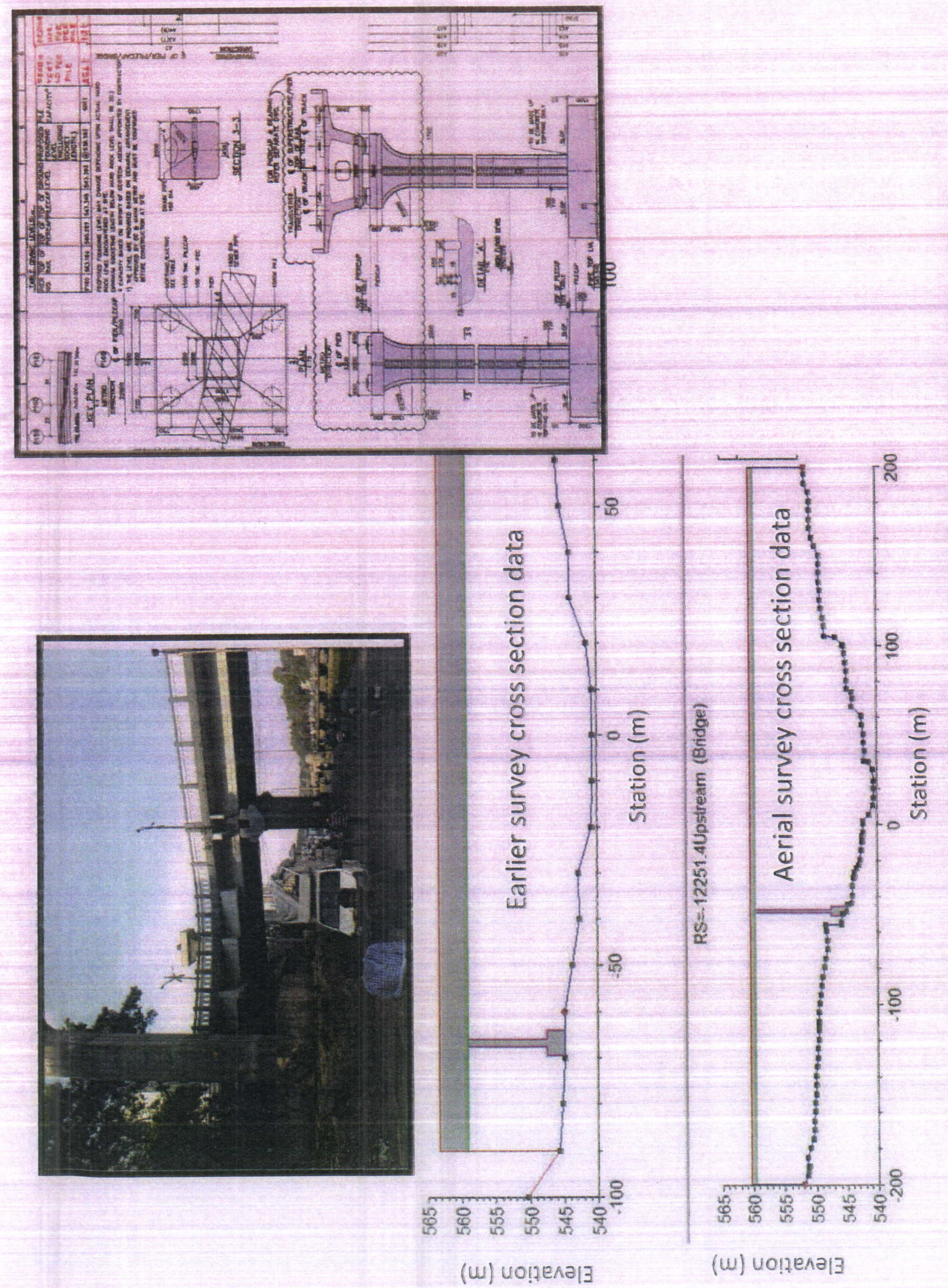

Figure 6: Sample Data Metro pier (P160) near Gadgil (Z) Bridge

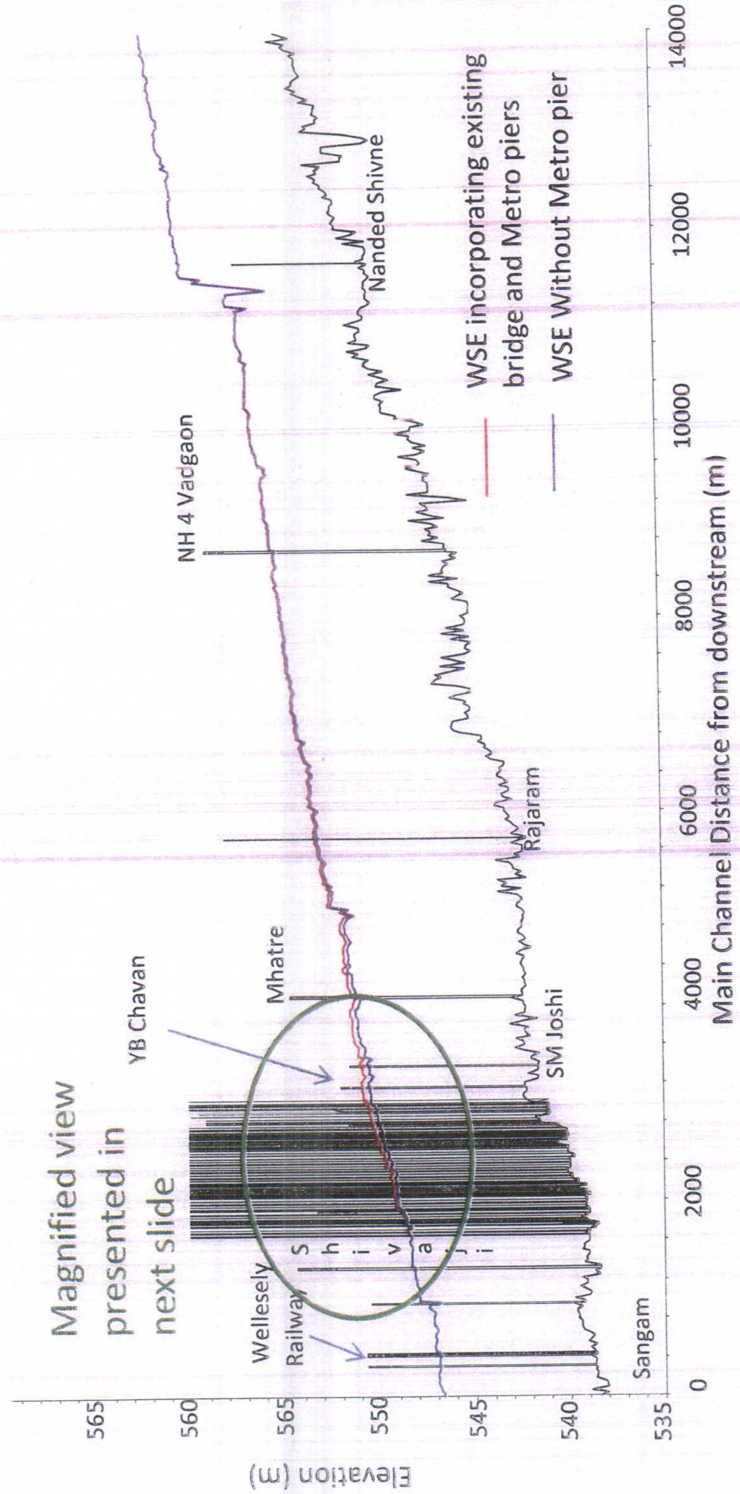

Figure 7(a): Water surface elevation for the discharge of 1,00,000 ft^3/s (incorporating existing bridge and Metro piers)

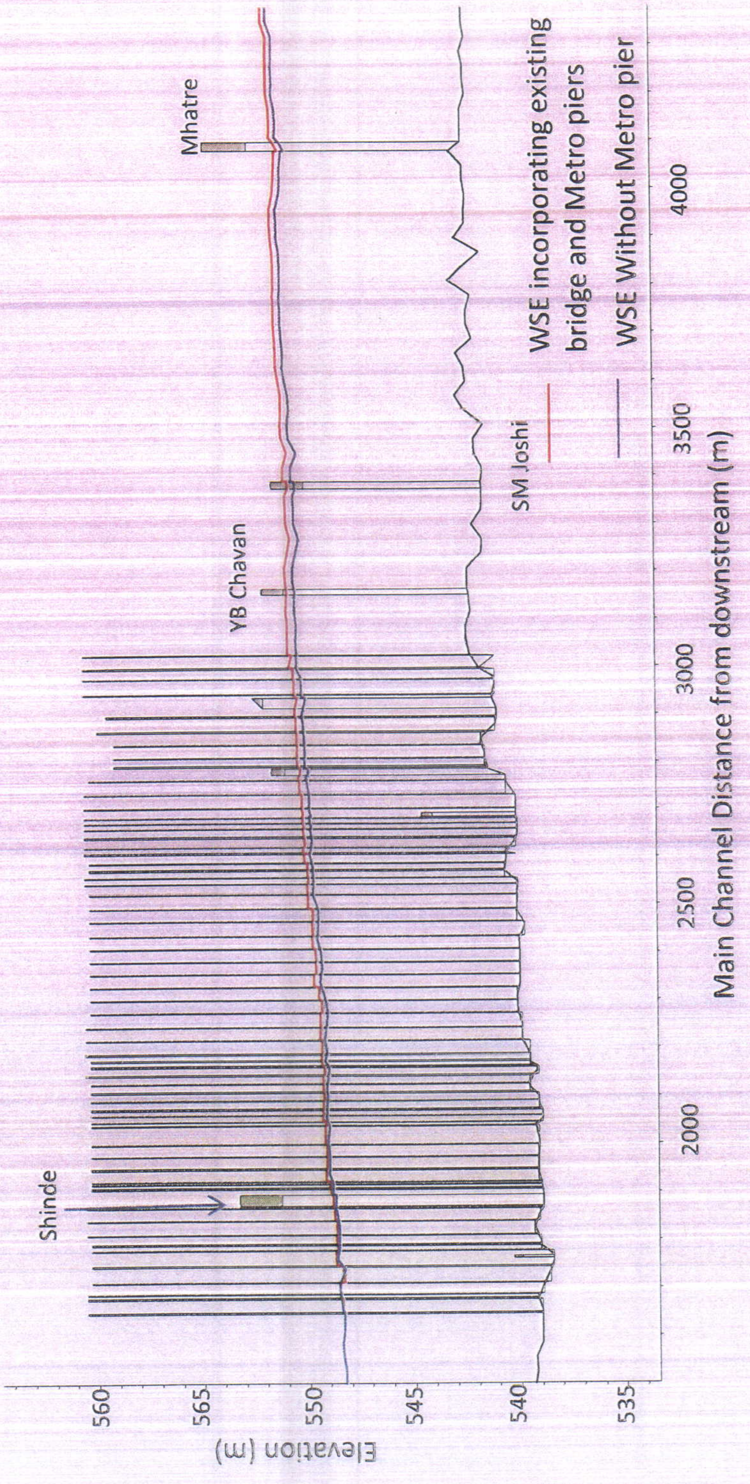

Figure 7(b) : Zoomed view of Water Surface Elevations for the discharge of 1,00,000 ft^3/s

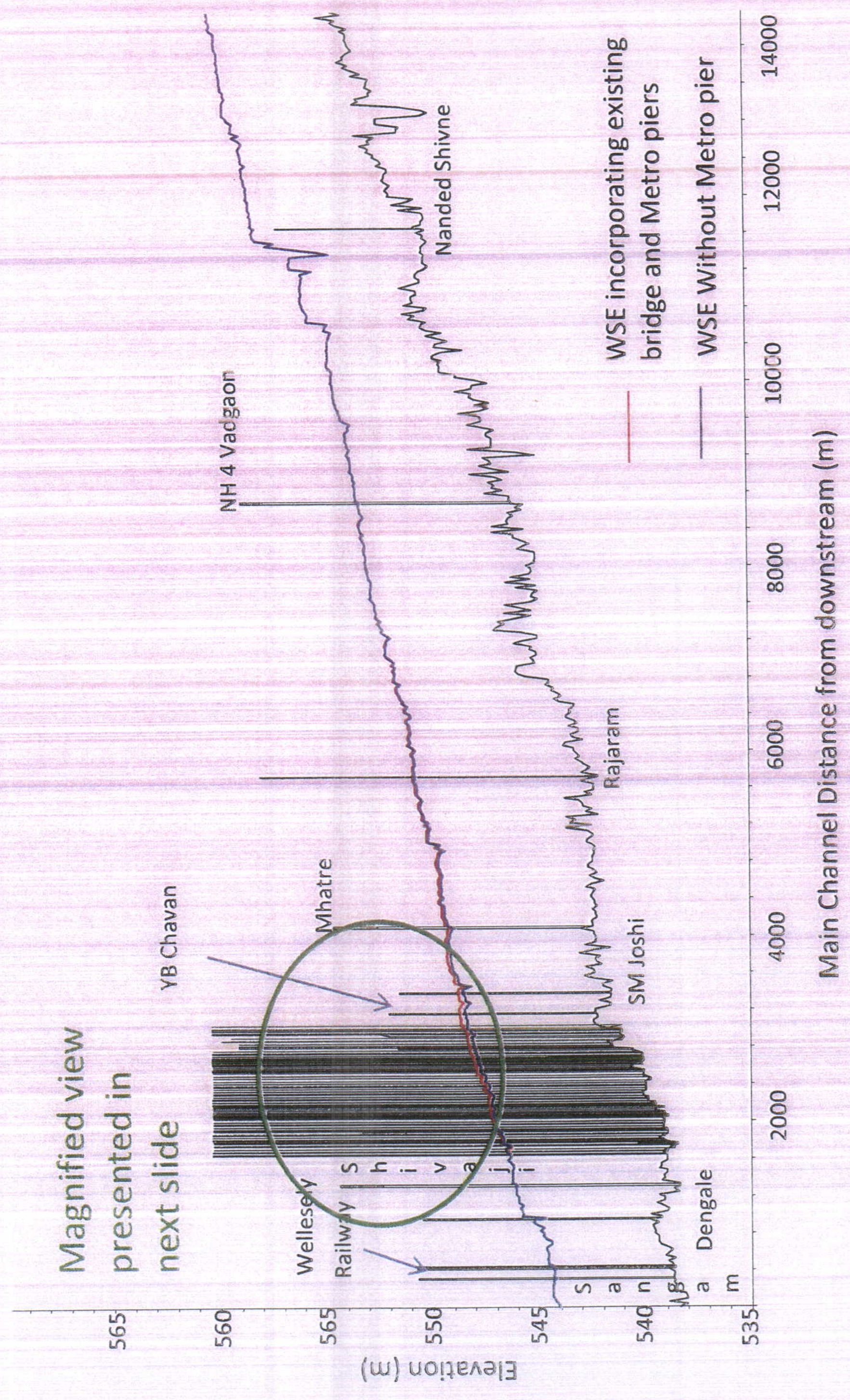

Figure 8(a): Water surface elevation for the discharge of 60,000 ft^3/s (incorporating existing bridge and Metro piers)

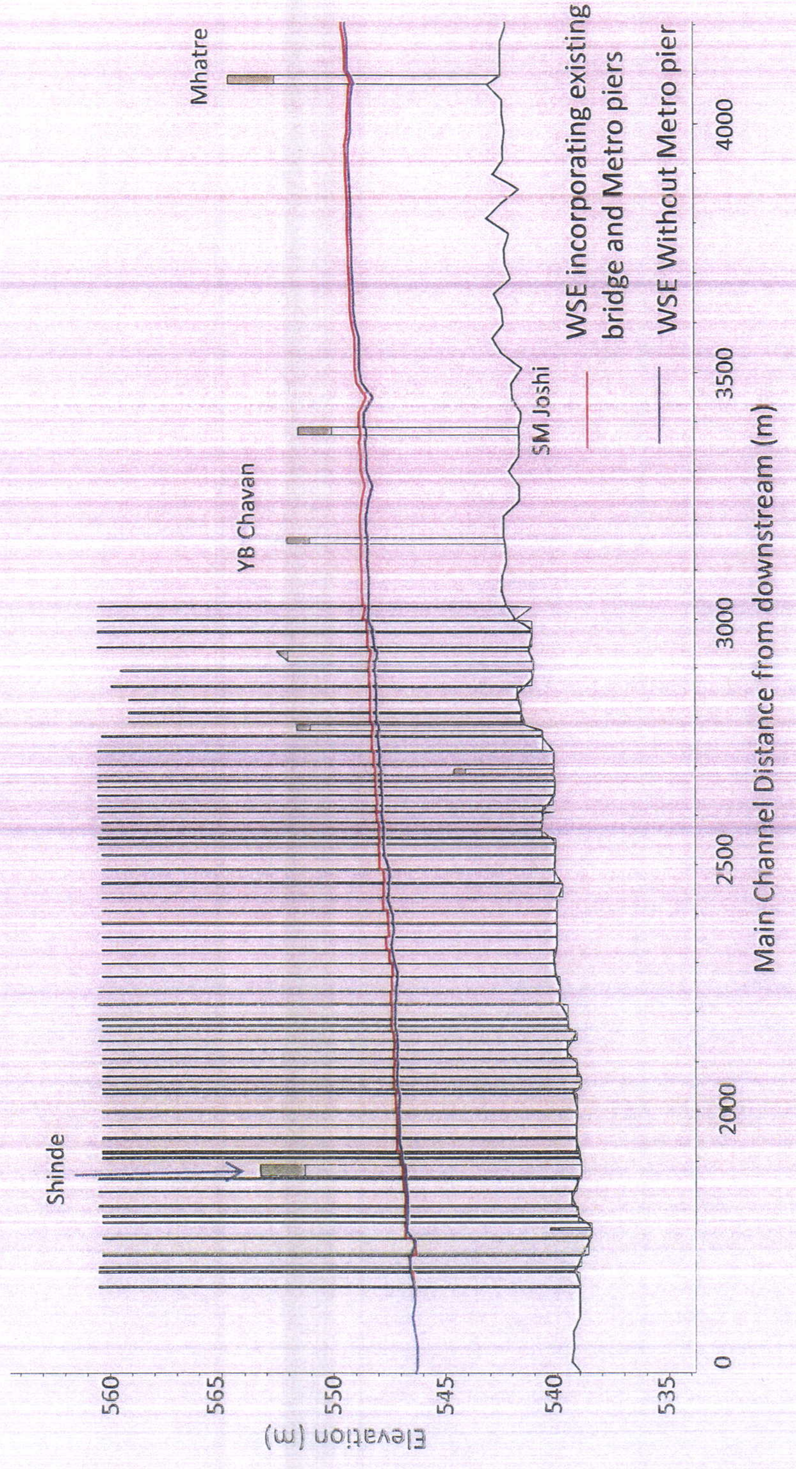

Figure 8(b) : Zoomed view of Water Surface Elevations for the discharge of 60,000 ft^3/s

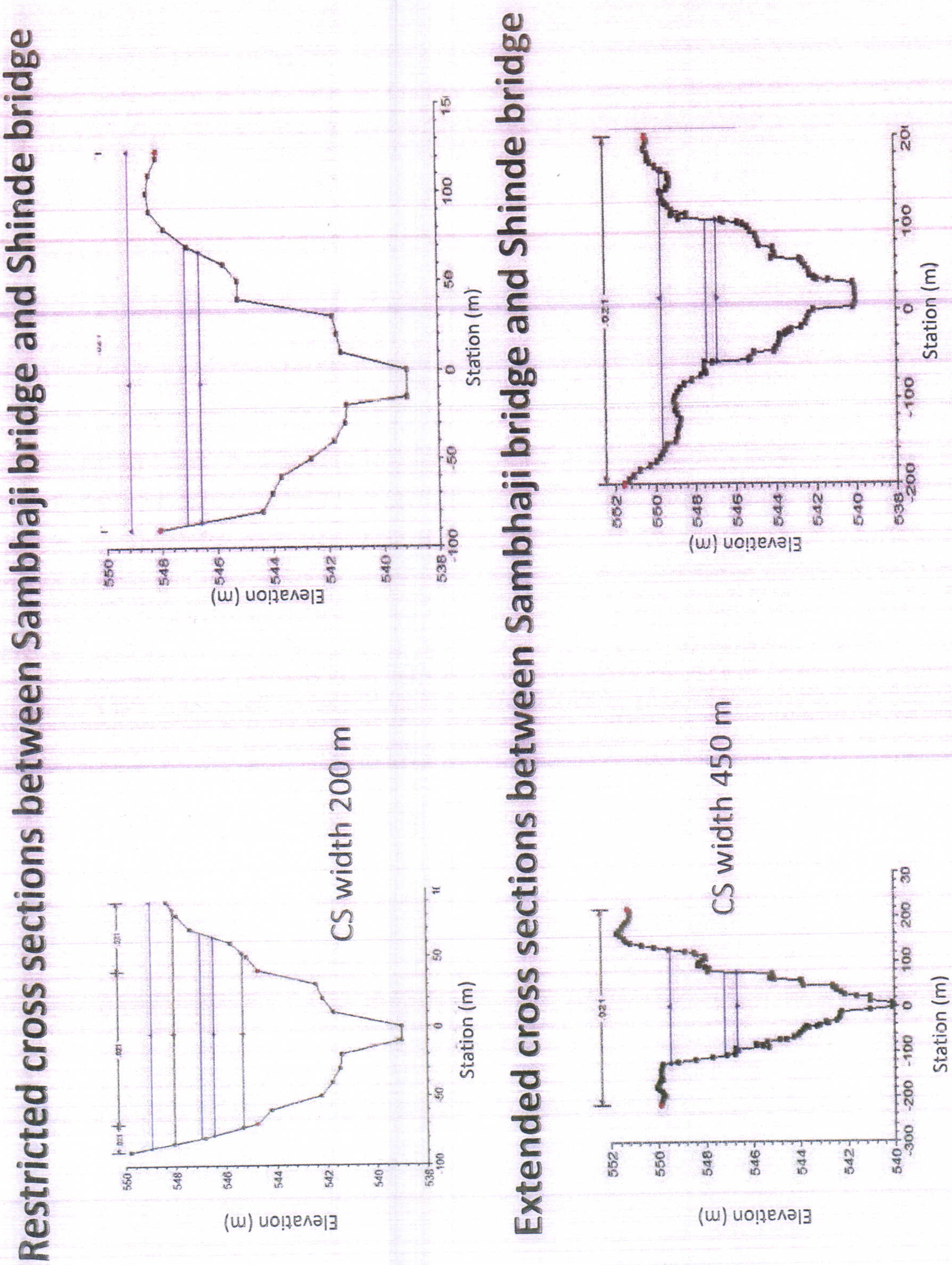

Figure 9: Restricted and extended cross section near Sambhaji bridge

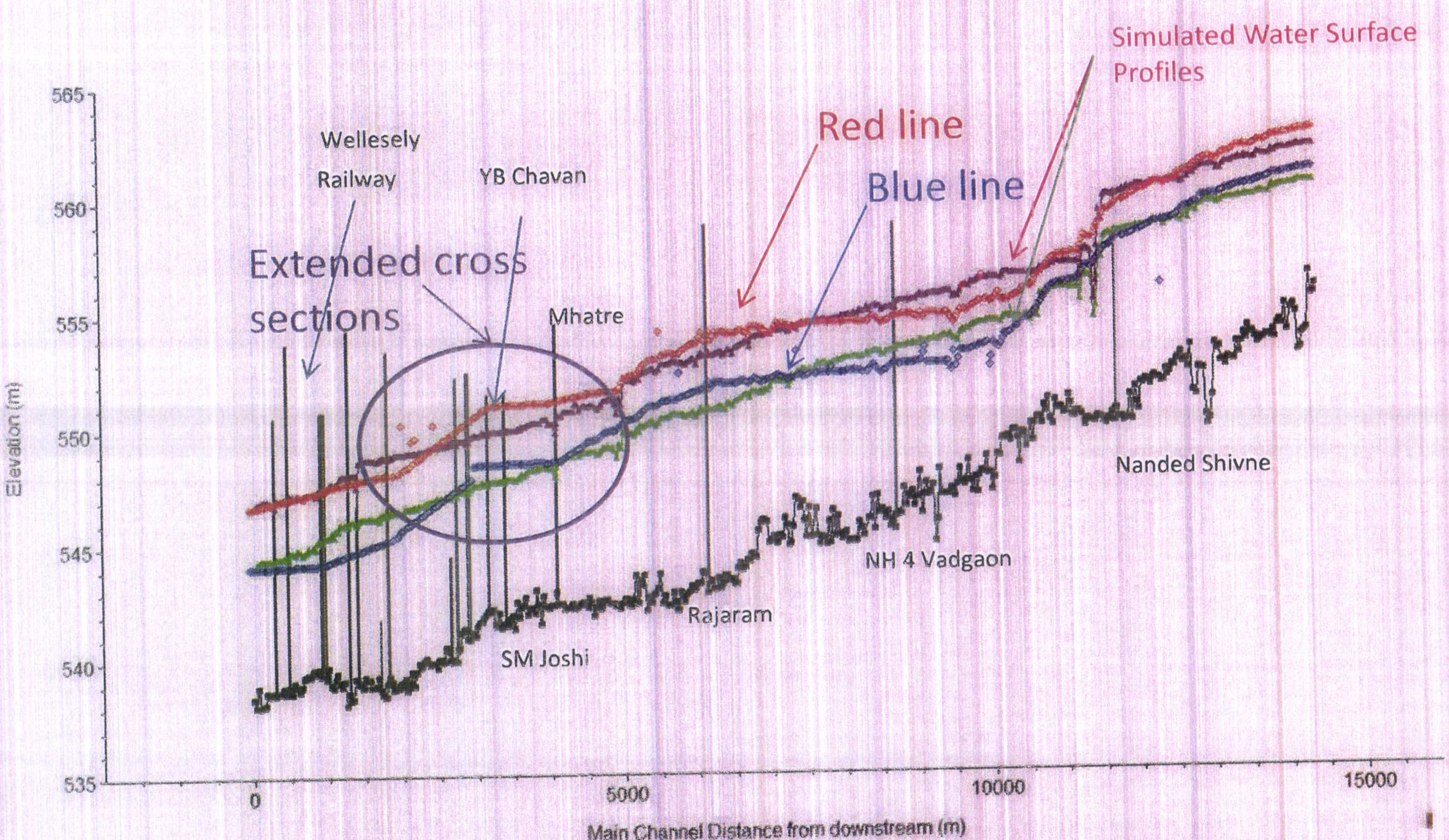

Figure 10: Water surface profiles using aerial survey data incorporating existing bridges alongwith blue line (60,000 ft^3/s) and red line (1,00,000 ft^3/s)

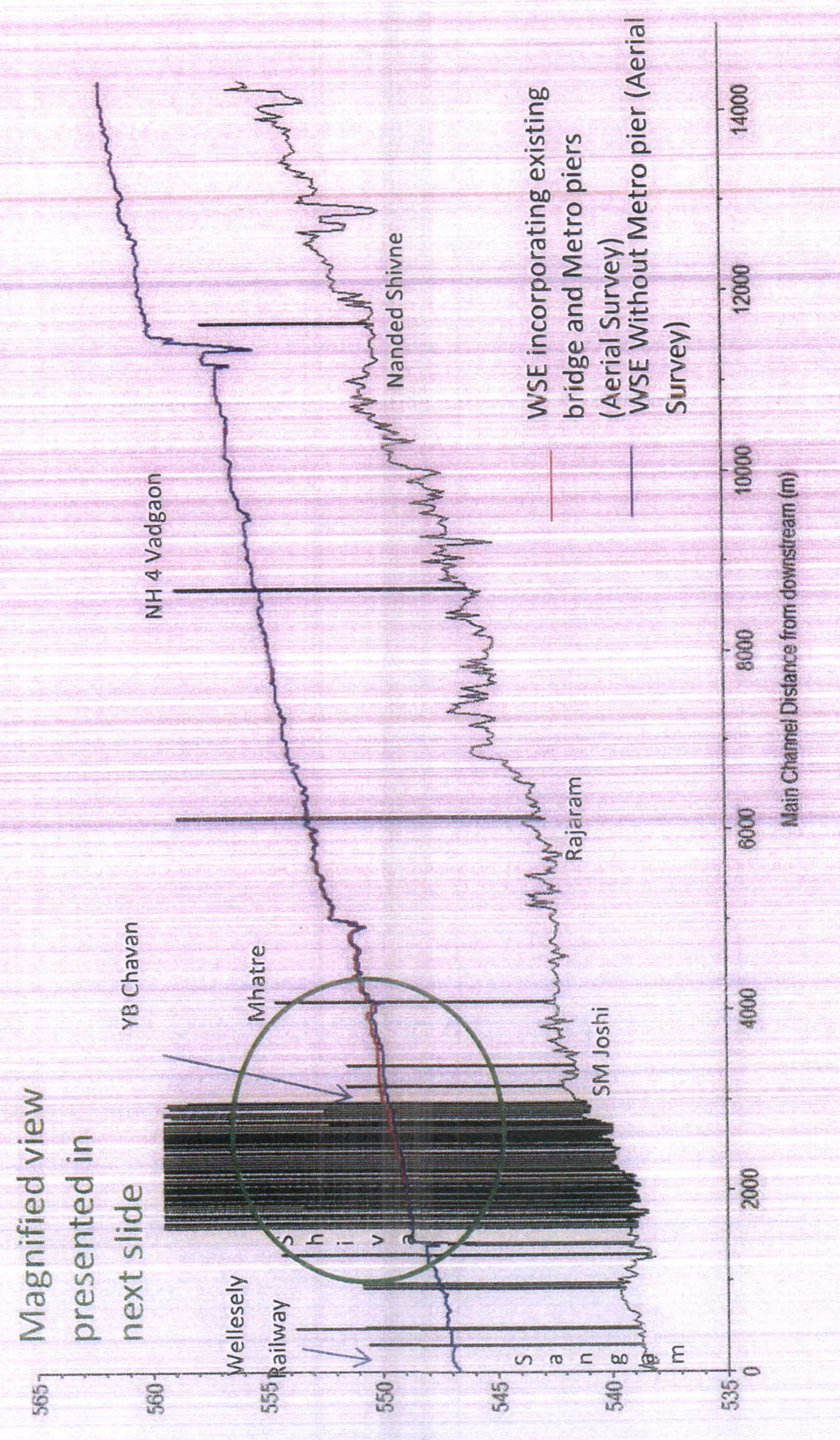

Figure 11(a): Water surface profiles using aerial survey data incorporating existing bridges and Metro piers for discharge of 1,00,000 ft^3/s

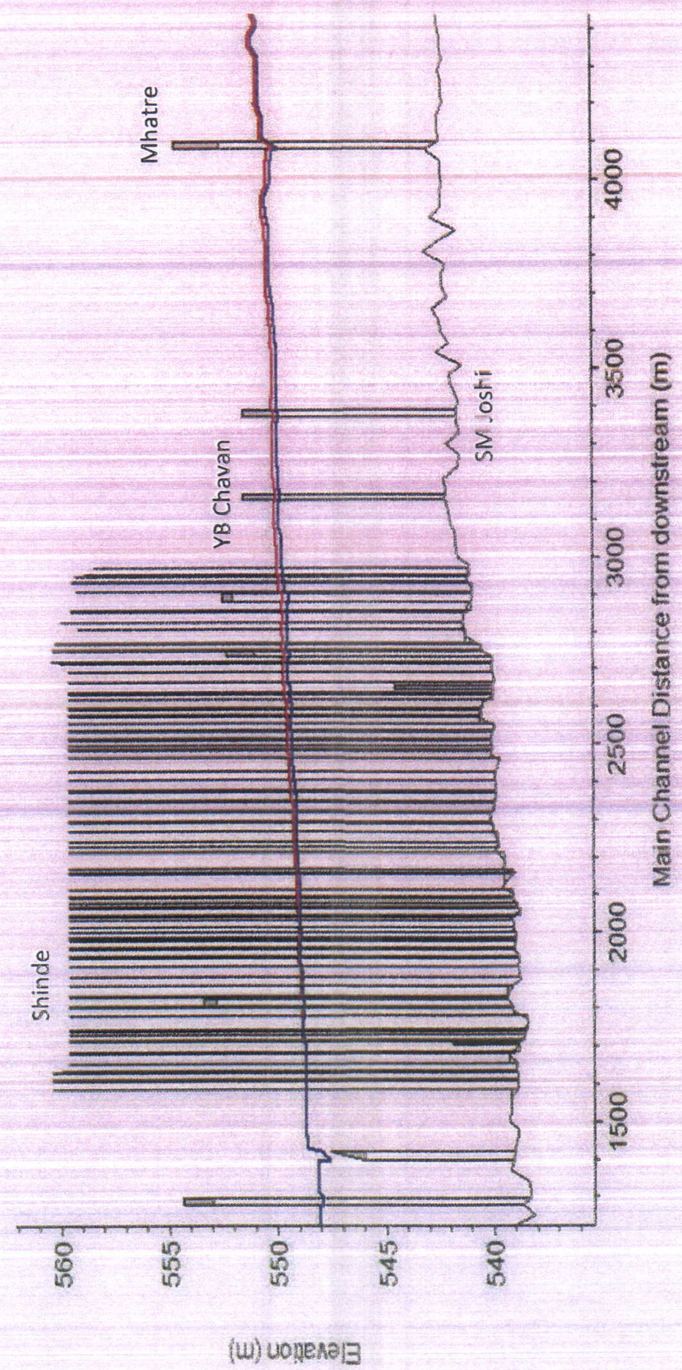

Figure 11(b): Zoomed view of water surface profiles using aerial survey data incorporating existing bridges and Metro piers for discharge of 1,00,000 ft^3/s

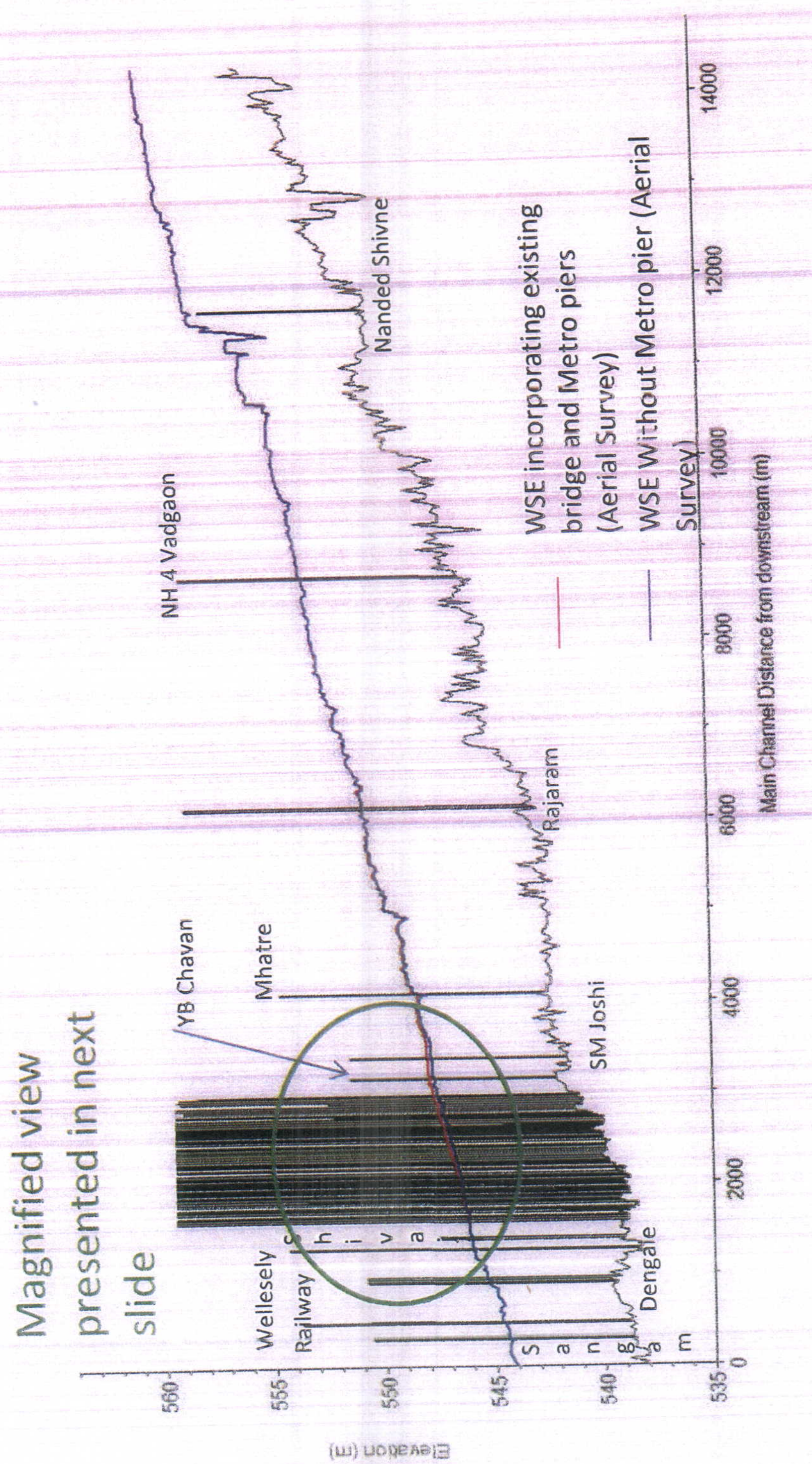

Figure 12(a): Water surface profiles using aerial survey data incorporating existing bridges and Metro piers for discharge of 60,000 ft^3/s

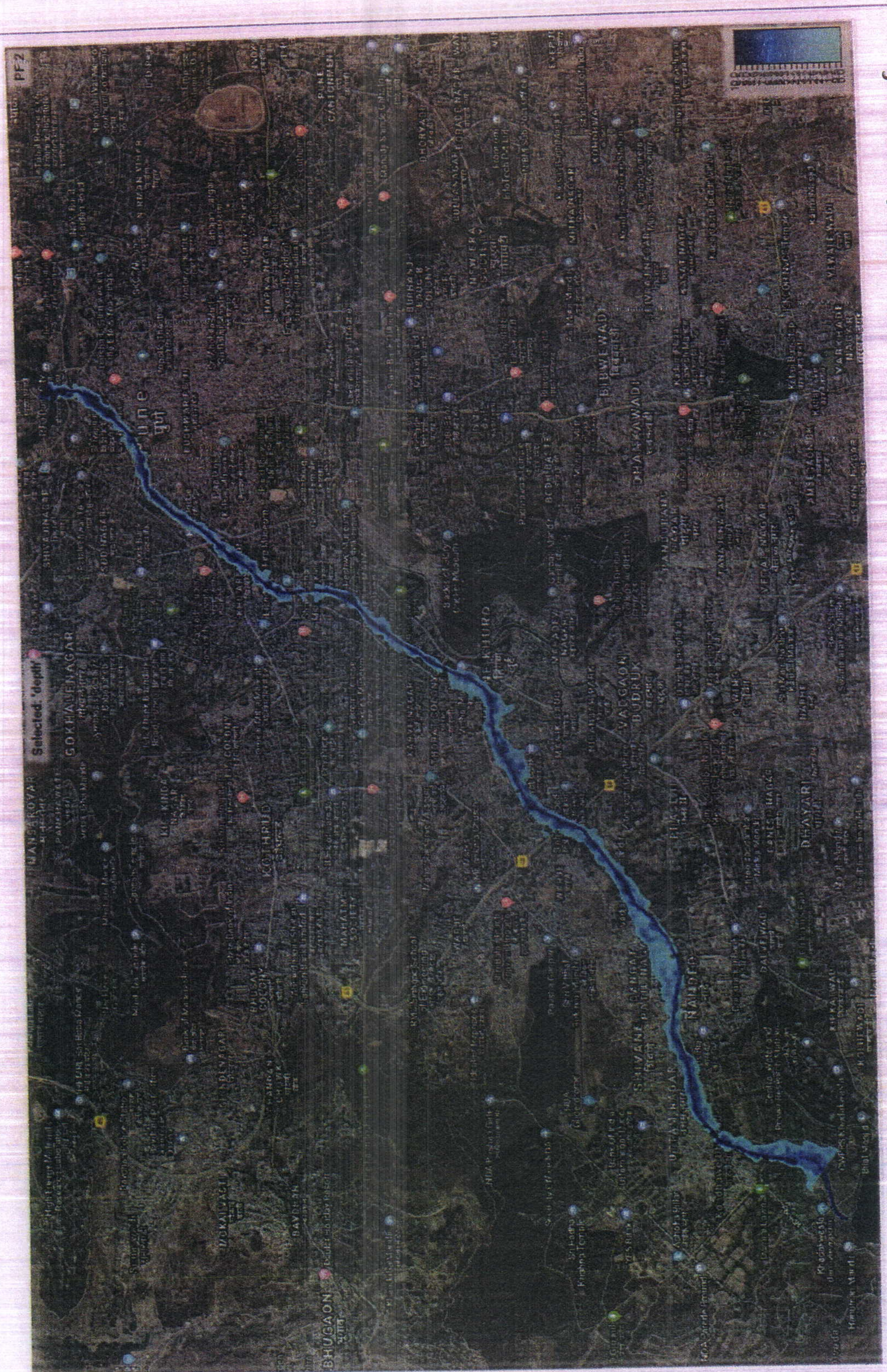

Figure 13: Flood inundation map overlaid on Google map for the discharge of 1,00,000 ft^3/s covering the entire study reach

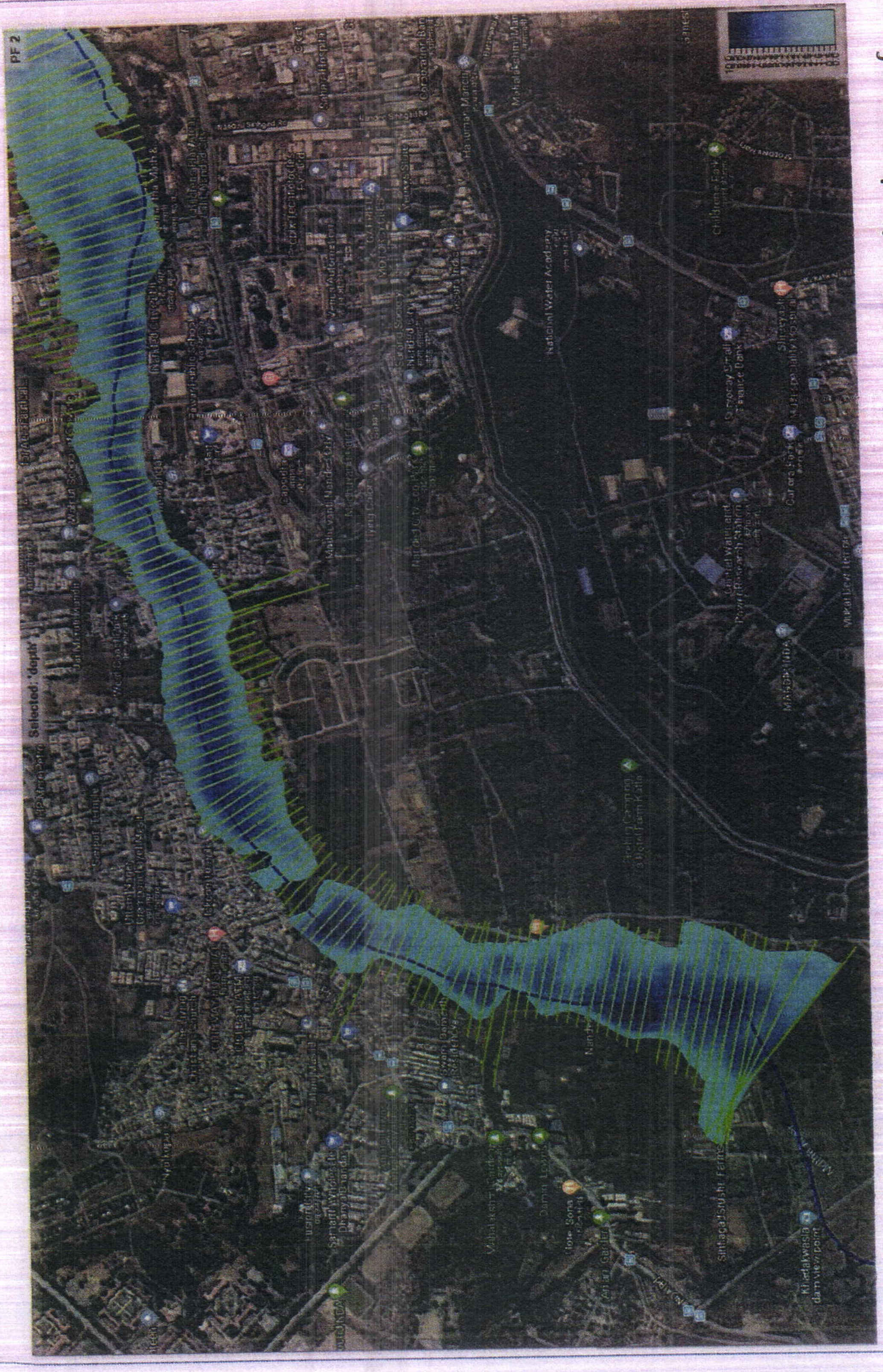

Figure 14: Flood inundation map overlaid on Google map for the discharge of 1,00,000 ft^3/s covering reach from Khadakwasla dam to Nanded city

Figure 15: Flood inundation map overlaid on Google map for the discharge of 1,00,000 ft^3/s covering reach from Nanded city to Anand nagar

Figure 16: Flood inundation map overlaid on Google map for the discharge of 1,00,000 ft^3/s covering reach from Anand nagar to Mhatre bridge

Figure 17: Flood inundation map overlaid on Google map for the discharge of 1,00,000 ft^3/s covering reach from Mhatre bridge to Tilak bridge

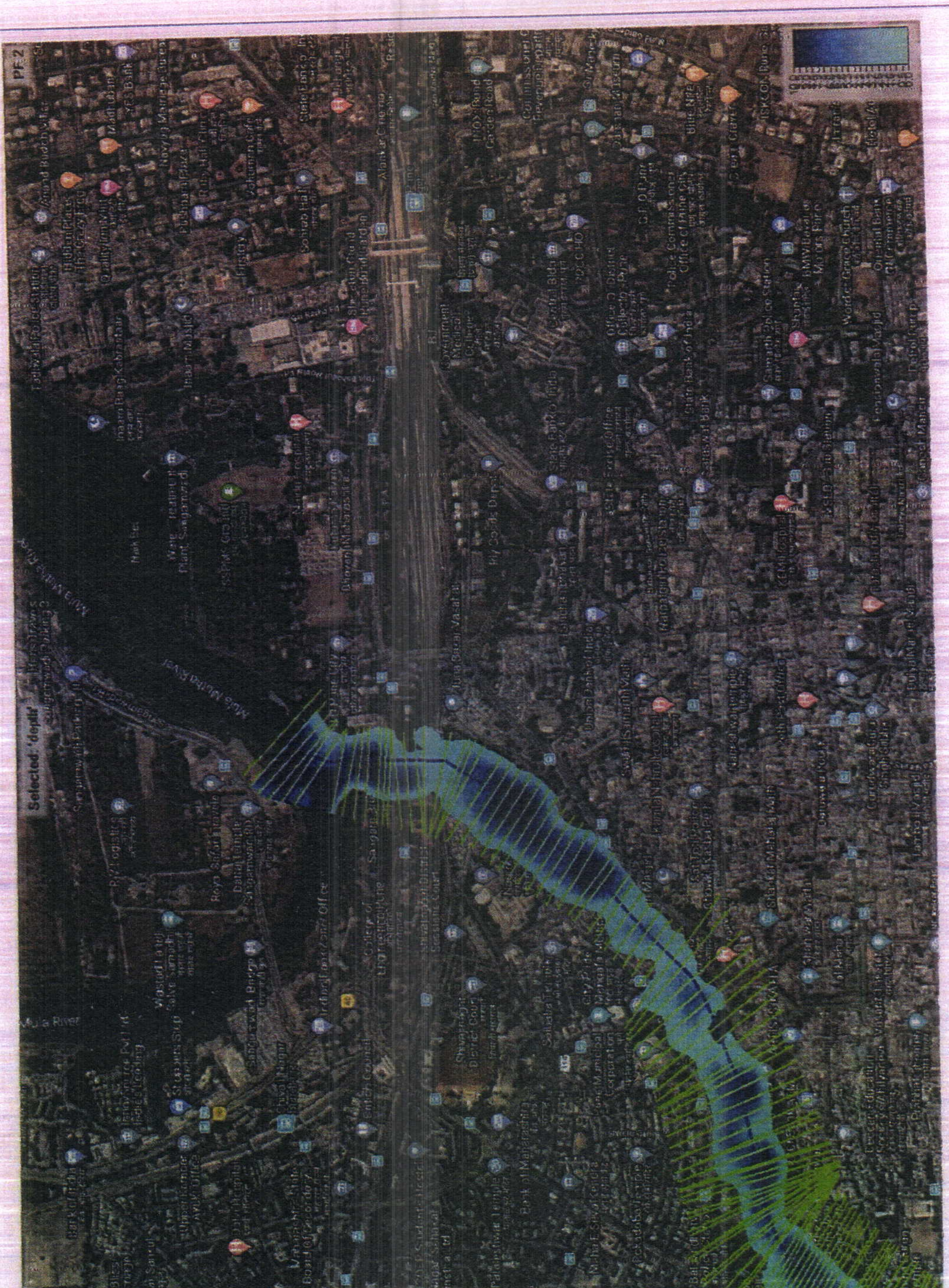

Figure 18: Flood inundation map overlaid on Google map for the discharge of 1,00,000 ft^3/s covering reach from Tilak bridge to Sangam

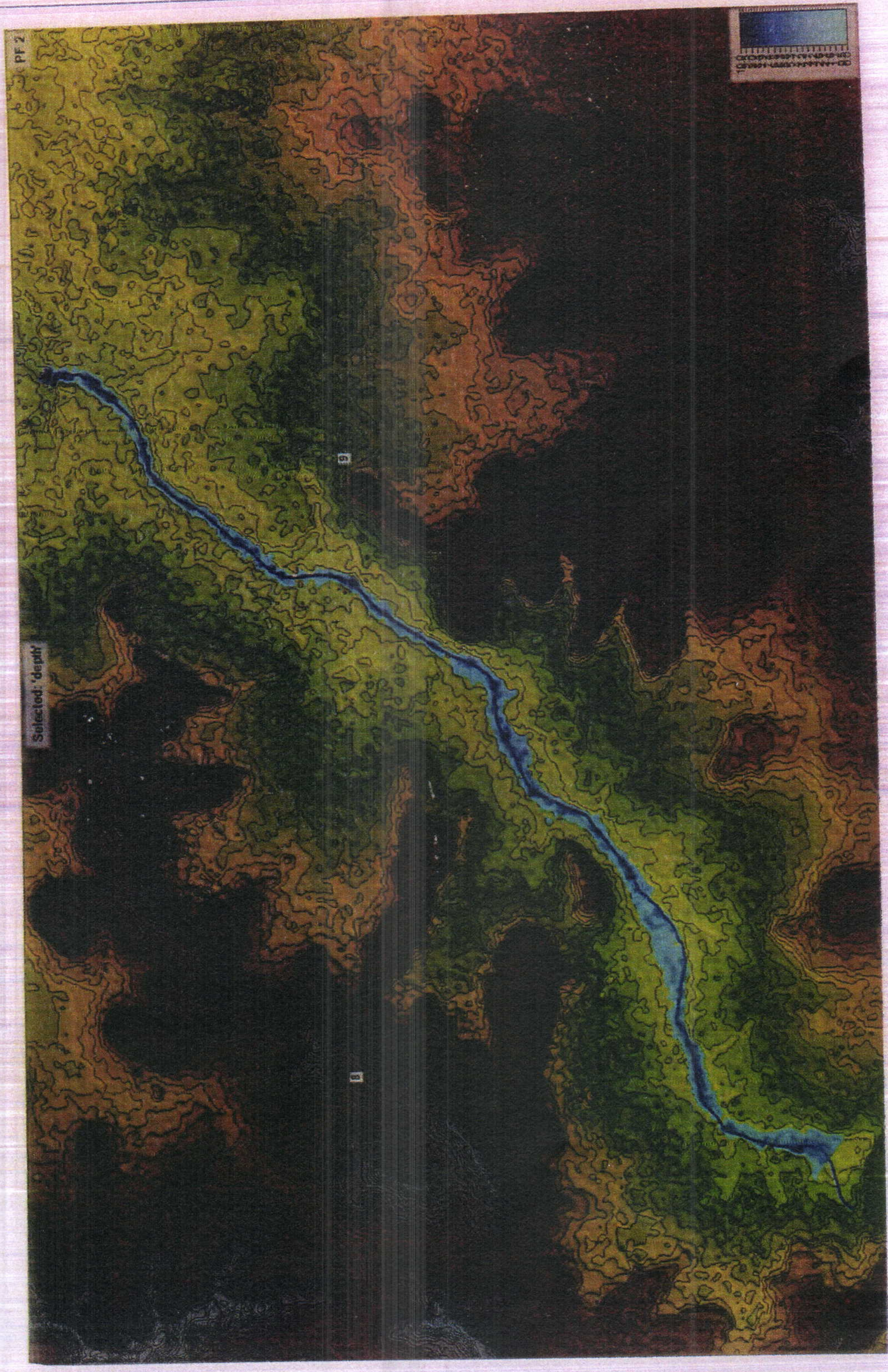

Figure 19: Flood inundation map overlaid on SRTM terrain map for the discharge of 1,00,000 ft^3/s covering the entire study reach

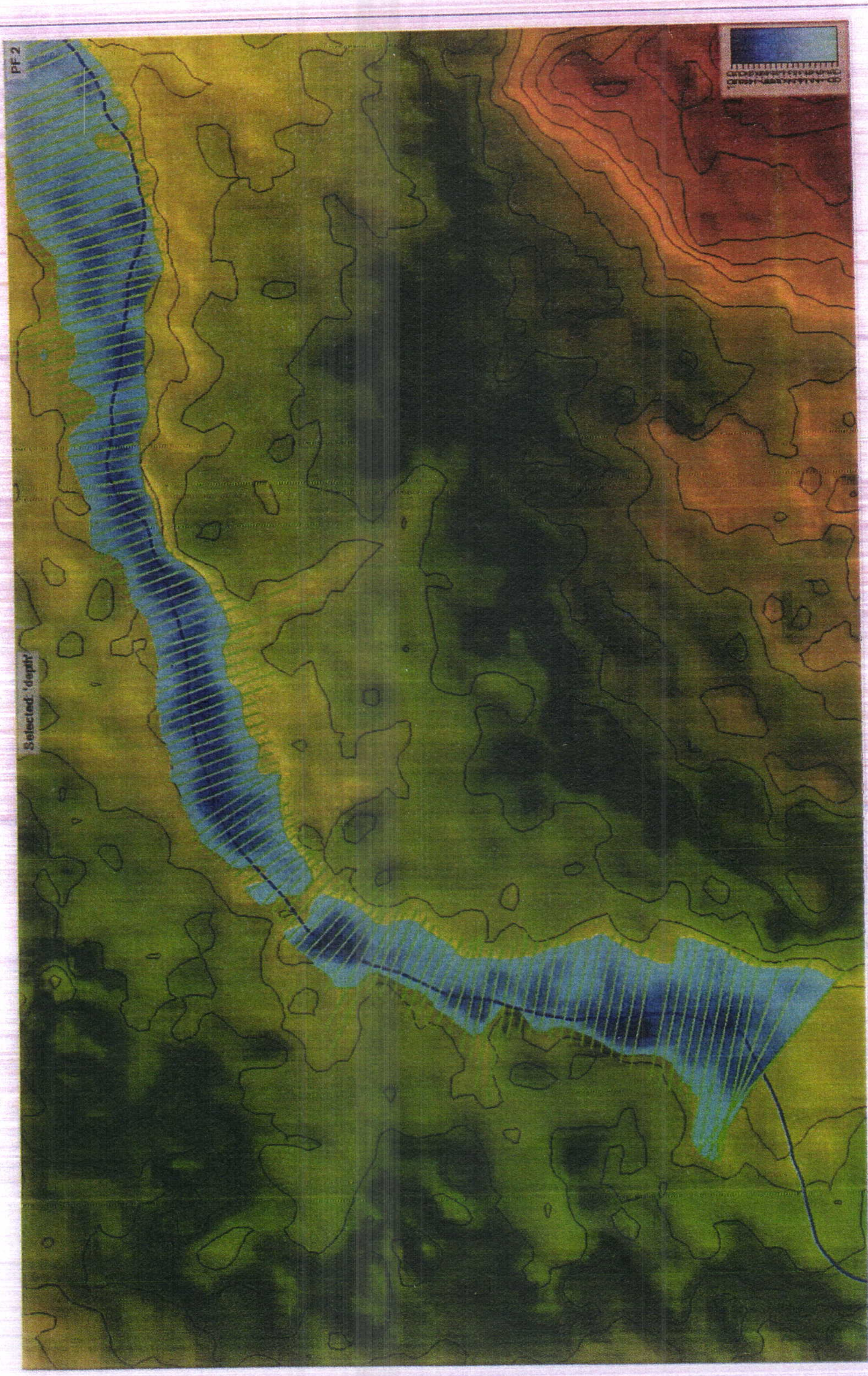

Figure 20: Flood inundation map overlaid SRTM terrain map for the discharge of 1,00,000 ft^3/s covering reach from Khadakwasla dam to Nanded city

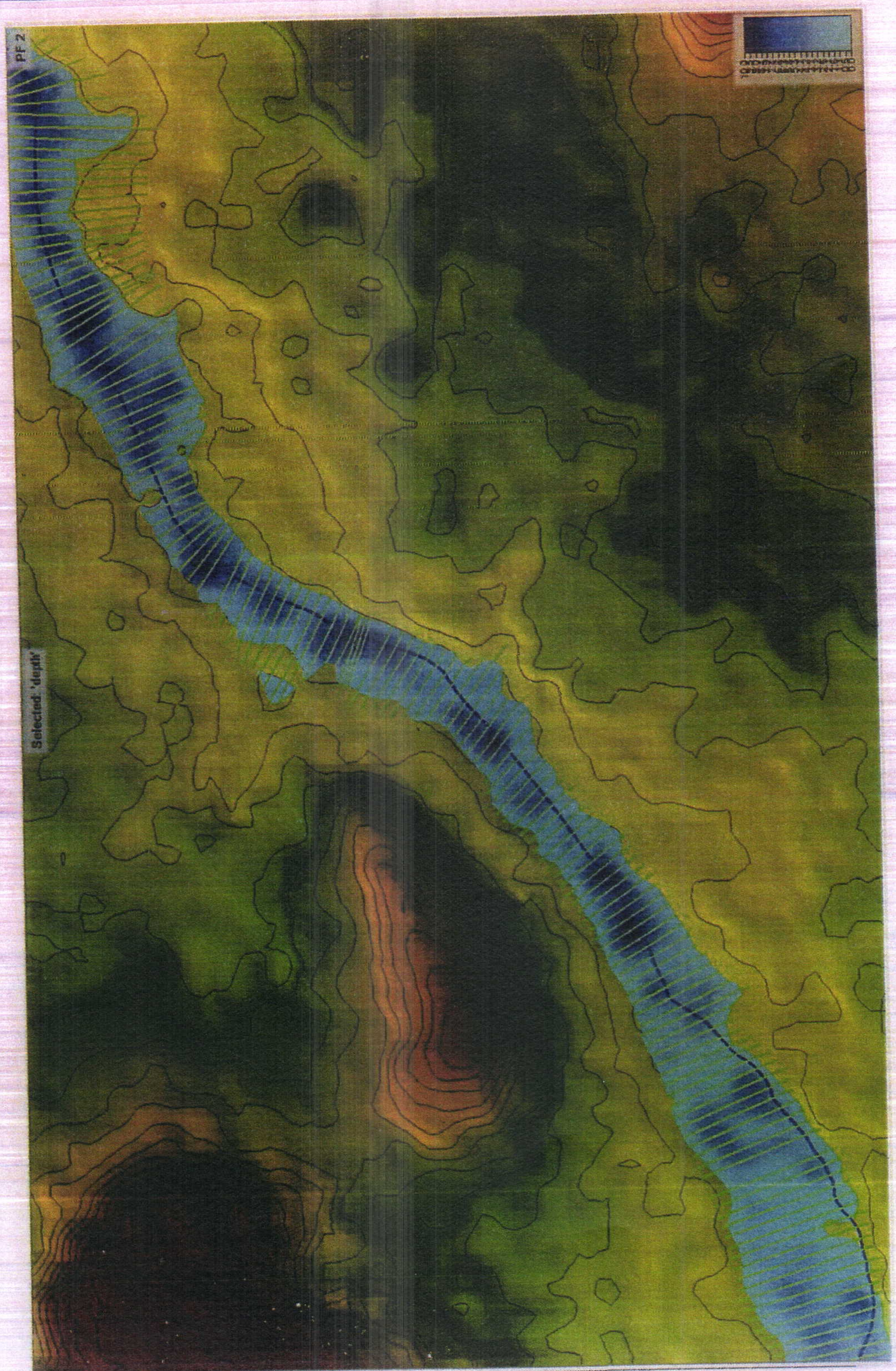

Figure 21: Flood inundation map overlaid SRTM terrain map for the discharge of 1,00,000 ft^3/s covering reach from Nanded city to Anand nagar

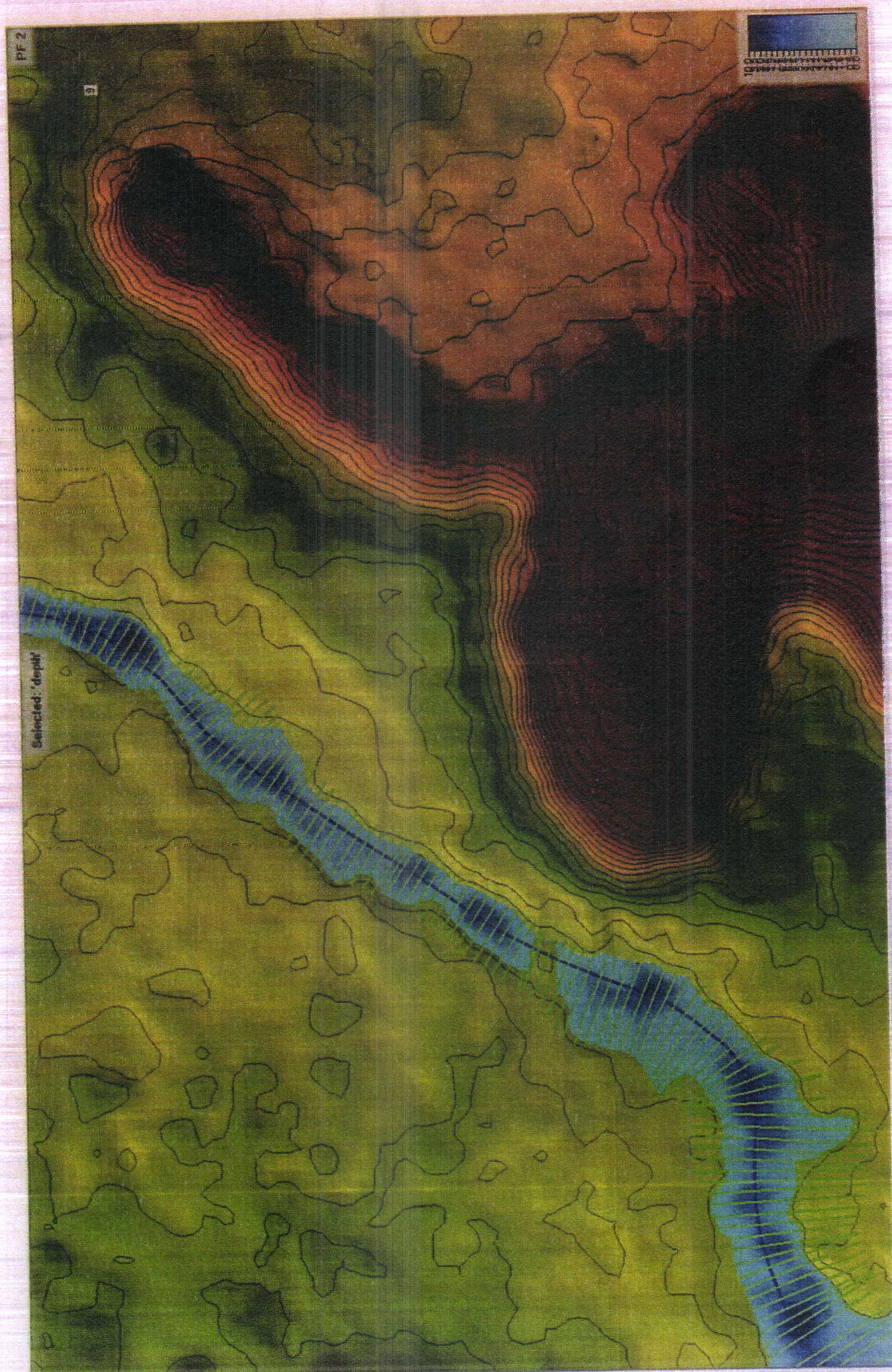

Figure 22: Flood inundation map overlaid on SRTM terrain map for the discharge of 1,00,000 ft^3/s covering reach from Anand nagar to Mhatre bridge

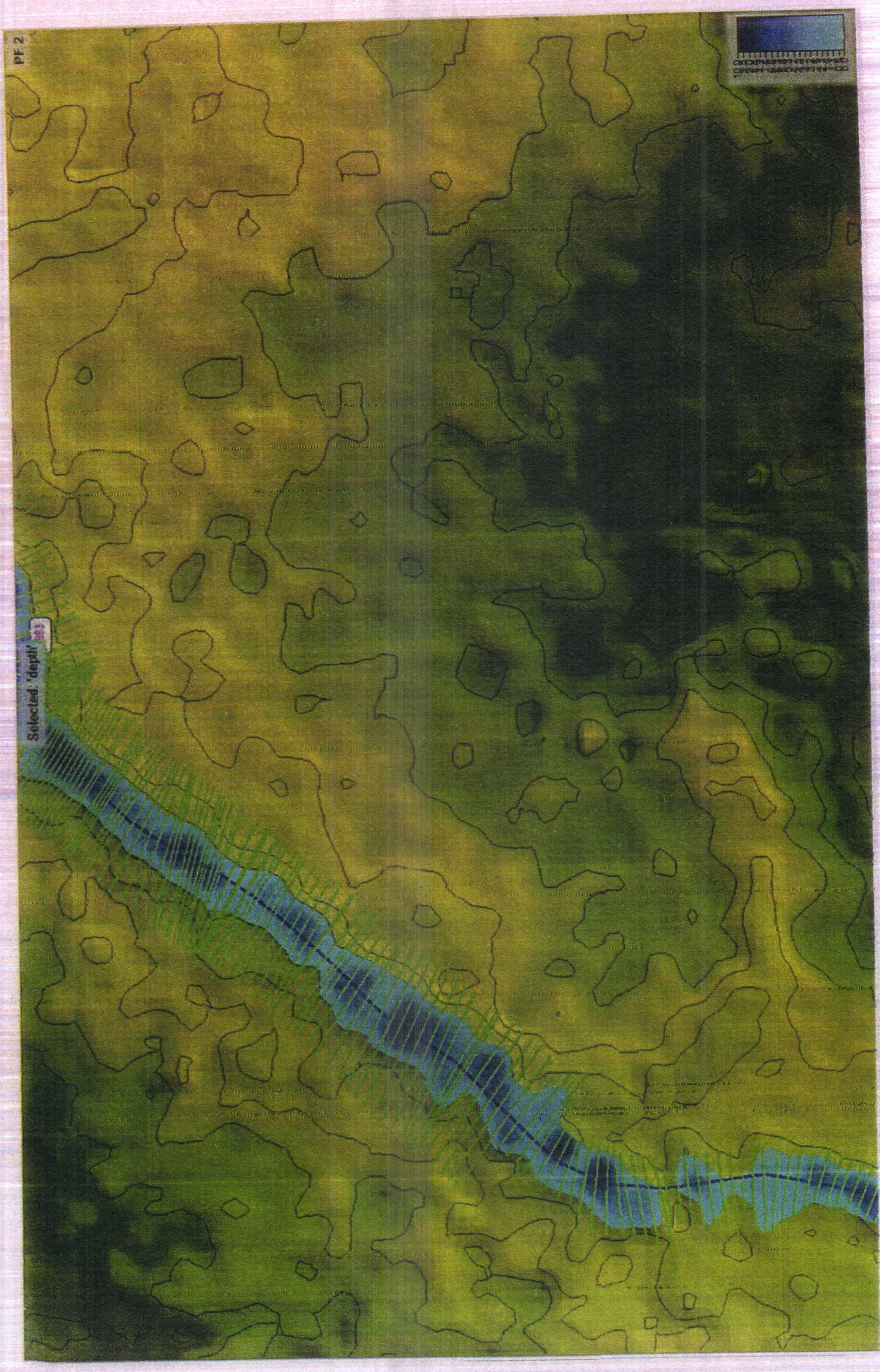

Figure 23: Flood inundation map overlaid on SRTM terrain map for the discharge of 1,00,000 ft^3/s covering reach from Mhatre bridge to Tilak bridge

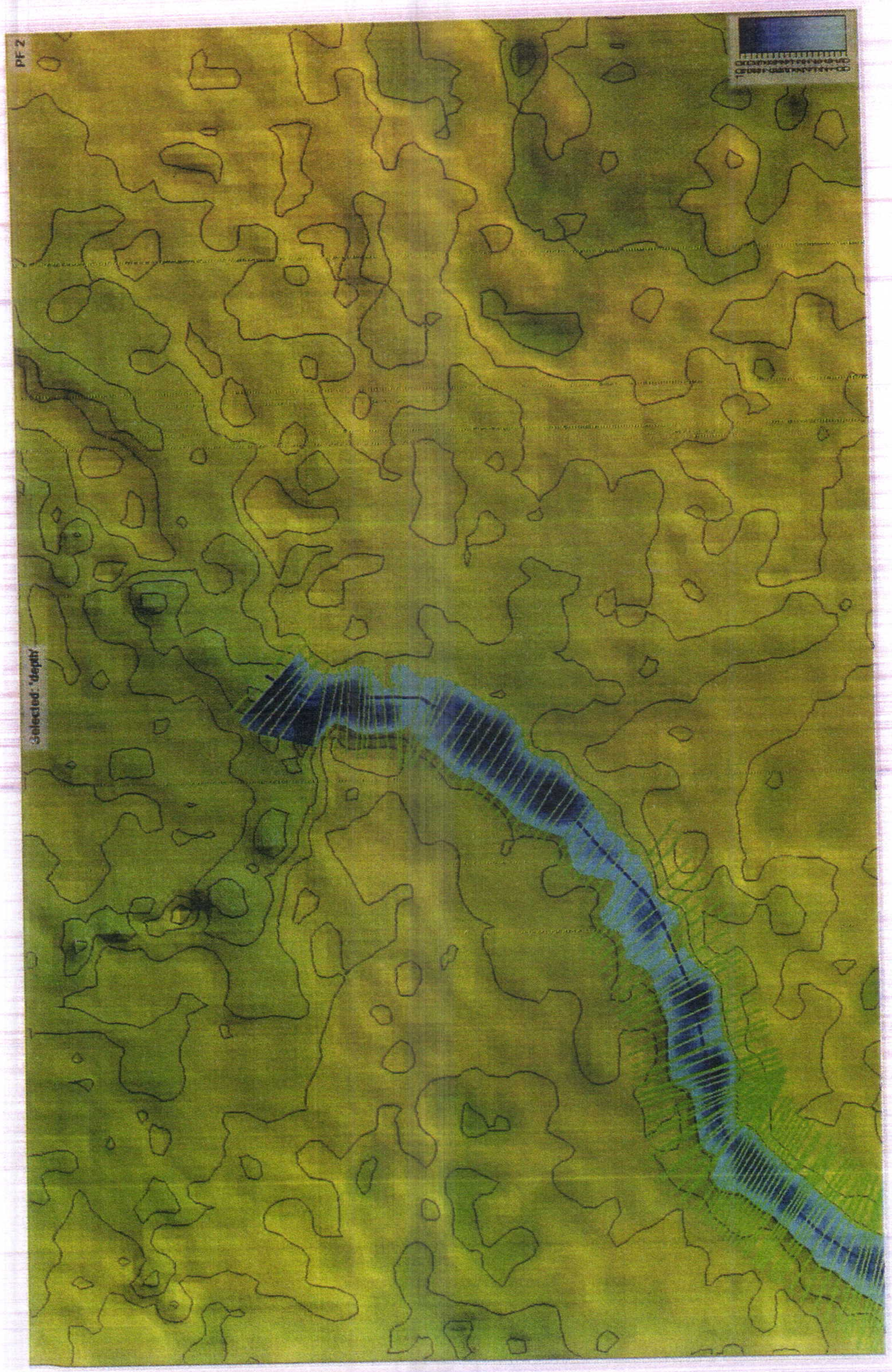

Figure 24: Flood inundation map overlaid on SRTM terrain map for the discharge of 1,00,000 ft^3/s covering reach from Tilak bridge to Sangam

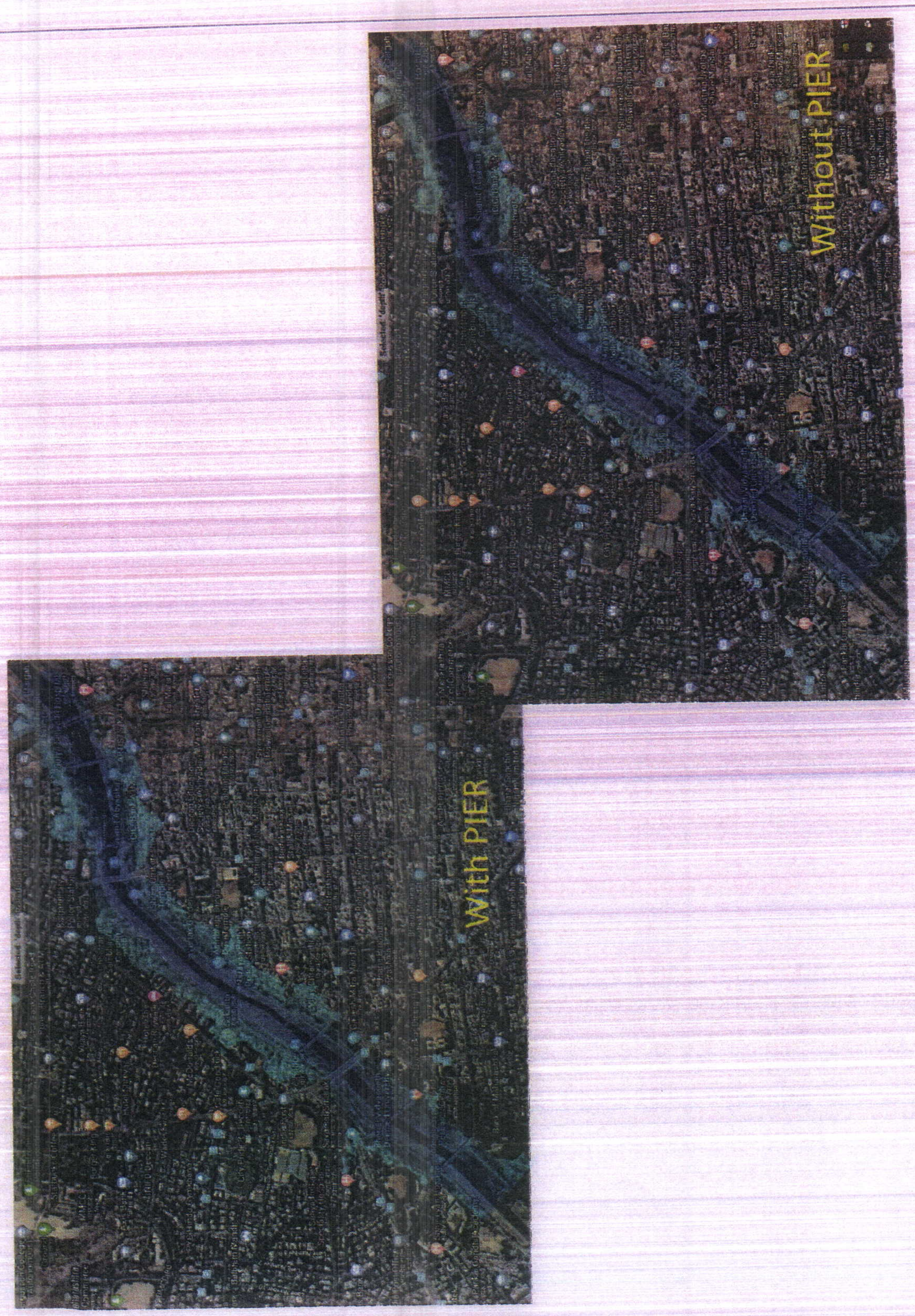

Figure 25: The inundation area for the flood discharge of 1,00,000 ft^3/s with and without the Metro piers between Joshi and Shivaji bridge

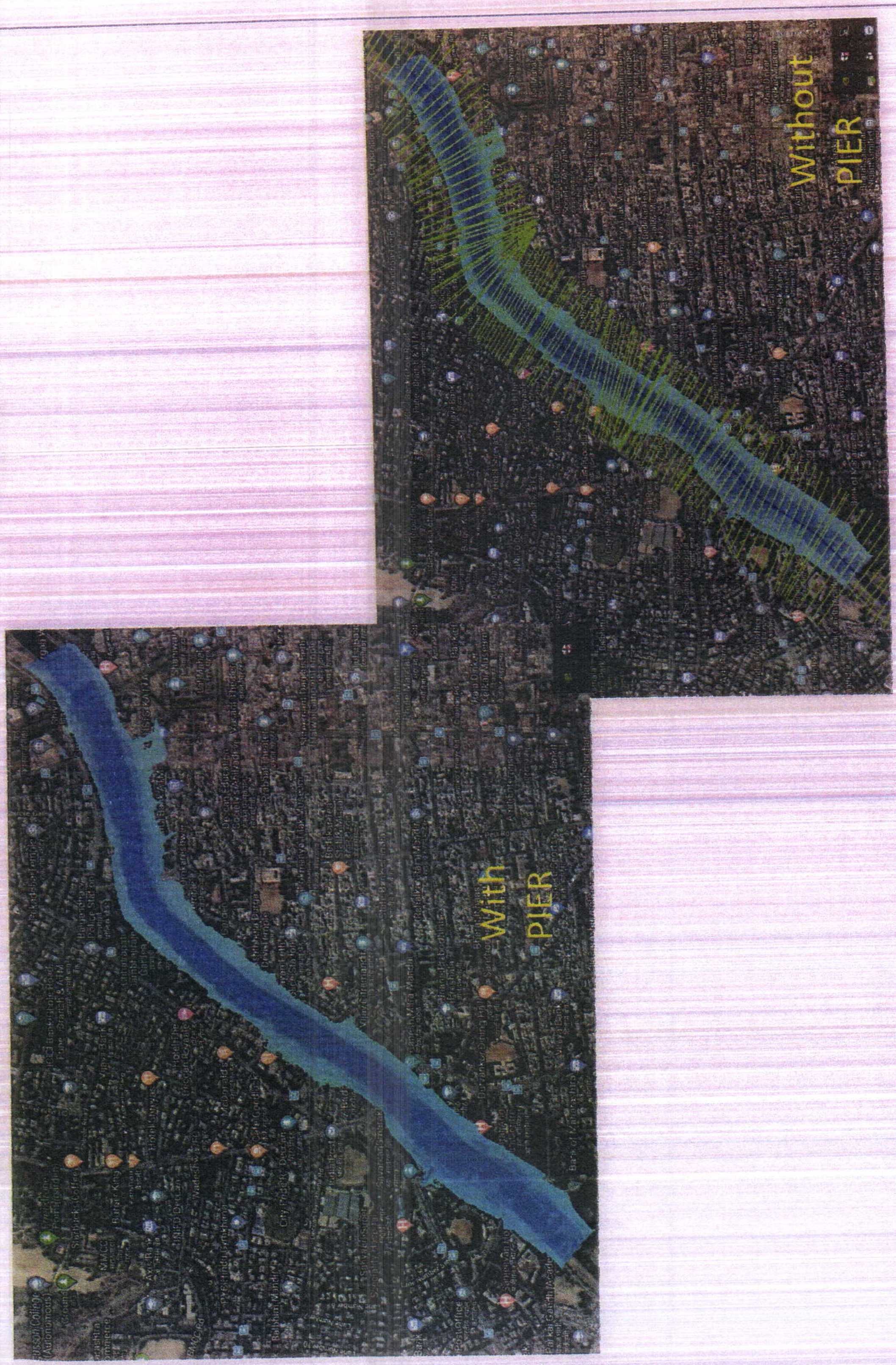

Figure 26: The inundation area for the flood discharge of 60,000 ft^3/s with and without the Metro piers between Joshi and Shivaji bridge

Annexure-1

HEC-RAS: Model Capabilities

HEC-RAS is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. The following is a description of the major capabilities of HEC-RAS.

- User interface
- Hydraulic Analysis Components
- Data Storage and Management
- Graphics and Reporting
- RAS Mapper

User Interface

The user interacts with HEC-RAS through a graphical user interface (GUI). The interface provides for the following functions:

File Management
Data Entry and Editing
Hydraulic Analyses
Tabulation and Graphical Displays of Input and Output Data
Reporting Facilities
Context Sensitive Help

Hydraulic Analysis Components

The HEC-RAS system contains four one-dimensional river analysis components for: (1) steady flow water surface profile computations; (2) unsteady flow simulation; (3) movable boundary sediment transport computations; and (4) water quality analysis. A key element is that all four components use a common geometric data representation and common geometric and hydraulic computation routines. In addition to the four river analysis components, the system contains several hydraulic design features that can be invoked once the basic water surface profiles are computed.

Steady Flow Water Surface Profiles

This component of the modeling system is intended for calculating water surface profiles for steady gradually varied flow. The system can handle a full network of channels, a dendritic system, or a single river reach. The steady flow component is capable of modeling subcritical, supercritical, and mixed flow regimes water surface profiles.

The basic computational procedure is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head). The momentum equation may be used in situations where the water surface profile is rapidly varied. These situations include mixed flow regime calculations (i.e. hydraulic jumps), hydraulics of bridges, and evaluating profiles at river confluences (stream junctions).

The effects of various obstructions such as bridges, culverts, weirs, etc. in the flood plain may be considered in the computations. The steady flow system is designed for application in flood plain management and flood insurance studies to evaluate floodway encroachments. Also, capabilities are available for assessing the change in water surface profiles due to channel improvements, and levees.

Special features of the steady flow component include: multiple plan analyses; multiple profile computations; multiple bridge and/or culvert opening analyses; and split flow optimization.

Unsteady Flow Simulation.

This component of the HEC-RAS modeling system is capable of simulating one-dimensional unsteady flow through a full network of open channels. The unsteady flow equation solver was adapted from Dr. Robert L. Barkau's UNET model (Barkau, 1992 and HEC, 1997). The unsteady flow component was developed primarily for subcritical flow regime calculations. However, with the release of further Versions, the model can now performed mixed flow regime (subcritical, supercritical, hydraulic jumps, and draw downs) calculations in the unsteady flow computations module.

The hydraulic calculations for cross-sections, bridges, culverts, and other hydraulic structures that were developed for the steady flow component were incorporated into the unsteady flow module.
Special features of the unsteady flow component include: Dam break analysis; levee breaching and overtopping; Pumping stations; navigation dam operations; and pressurized pipe systems.

Sediment Transport/Movable Boundary Computations

This component of the modeling system is intended for the simulation of one-dimensional sediment transport/movable boundary calculations resulting from scour and deposition over moderate time periods (typically years, although applications to single flood events are possible).

The sediment transport potential is computed by grain size fraction, thereby allowing the simulation of hydraulic sorting and armoring. Major features include the ability to model a full network of streams, channel dredging, various levee and encroachment alternatives, and the use of several different equations for the computation of sediment transport. The model is designed to simulate long-term trends of scour and deposition in a stream channel that might result from modifying the frequency and duration of the water discharge and stage, or modifying the channel geometry. This system can be used to evaluate deposition in reservoirs, design channel contractions required to maintain navigation depths, predict the influence of dredging on the rate of deposition, estimate maximum possible scour during large flood events, and evaluate sedimentation in fixed channels.

Water Quality Analysis

This component of the modeling system is intended to allow the user to perform riverine water quality analyses. An advection-dispersion module is included with this version of HEC–RAS, adding the capability to model water temperature. This new module uses the QUICKEST-ULTIMATE explicit numerical scheme to solve the one-dimensional advection-dispersion equation using a control volume approach with a fully implemented heat energy budget. Transport and Fate of a limited set of water quality constituents is now also available in HEC-RAS. The currently available water quality constituents are: Dissolved Nitrogen (NO3-N, NO2-N, NH4-N, and Org-N); Dissolved Phosphorus (PO4-P and Org-P); Algae; Dissolved Oxygen (DO); and Carbonaceous Biological Oxygen Demand (CBOD).

Data Storage and Management

Data Storage is accomplished through the use of "flat" files (ASCII and binary), as well as the HEC-DSS. User input data are stored in flow files under separate categories of project, plan, geometry, steady flow, unsteady flow, and sediment data. Output data is predominantly stored in separate binary files. Data can be transferred between HEC-RAS and other programs by utilizing the HEC-DSS. Data management is accomplished through the user interface. The modeler is required to enter a single filename for the project being developed. Once the project filename is entered, all other files are automatically created and named by the interface as needed. The interface provides for renaming, mobbing, and deletion of files on a project-by-project basis.

Graphics and Reporting

Graphics include X-Y plots of the river system schematic, cross-sections, profiles, rating curves, hydrographs, and many other hydraulic variables. A three-dimensional plot of multiple cross-sections is also provided. Tabular output is available. Users can select from pre-defined tables or develop their own customized tables. All graphical and tabular output can be displayed on the screen, sent directly to a printer (or plotter), or passed through the Windows Clipboard to other software, as a word-processor or spreadsheet.

Reporting facilities allow for printed output of input data as well as output data. Reports can be customized as to the amount and type of information desired.

RAS Mapper

HEC-RAS has the capability to perform inundation mapping of water surface profile results directly from HEC-RAS. Using the HEC-RAS geometry and computed water surface profiles, inundation depth and floodplain boundary datasets are created through the RAS Mapper. Additional geospatial data can be generated for analysis of velocity, shear stress, stream power, ice thickness, and floodway encroachment data. In order to use the RAS Mapper for for analysis, you must have a terrain model in the binary raster floating-point format (.flt). The resultant depth grid is stored in the .flt format while the boundary dataset is store in ESRI's Shapefile format for use with geospatial software.

VISION

To be a world-class centre of excellence in hydraulic engineering research and allied areas; which is responsive to changing global scenario, and need for sustaining and enhancing excellence in providing technological solutions for optimal and safe design of water resources structures.

MISSION

- To meet the country's need for basic & applied research in water resources, power sector and coastal engineering with world-class standards
- To develop competence in deployment of latest technologies by networking with the top institutions globally, to meet the future needs for development of water resources projects in the country effectively
- To disseminate information, build skills and knowledge for capacity-building and mass awareness for optimization of available water resources

MAJOR FUNCTIONS

- Undertaking specific research studies relating to development of water resources, power and coastal projects
- Consultancy and advisory services to Central and State Governments, private sector and other countries
- Disseminating research findings and promoting/assisting research activities in other organizations concerned with water resources projects
- Contributions to Bureau of Indian Standards and International Standards Organization
- Carrying out basic and applied research to support the specific studies
- Contribution towards advancements in technology through participation in various committees at National and State Levels

The Director,
Central Water and Power Research Station
Khadakwasala, Sinhgad Road, Pune 411 024. Maharashtra

Telephone : +91-20-24103400/ 24103500
Fax : +91-20-24381004
Web : www.cwprs.gov.in

Minutes of the 7th meeting dated 08.03.2021 under the chairmanship of Shri Saurabh Rao Divisional Commissioner, Pune.

Sub: NATIONAL GREEN TRIBUNAL, PRINCIPAL BENCH, NEW DELHI
SARANG YADWADKAR & ORS Vs. PMC & ORS

Quorum (Through Video Conferencing).

1. Dr. Ritesh Vijay -Principal Scientist, NEERI and convener of the Expert Committee
2. Dr. A.Benniamin -Scientist. State Biodiversity Board. Member of the Expert Committee.
3. Dr. Y. B. Sonetakke – Joint Director, Maharashtra Pollution Control Board
4. Mr. Raghunath Mahabal -Advocate, Office of Divisional Commissioner.

Quorum (Physical Presence)

1. Mr. Atul Gadgil - Director (works), Maha Metro Pune
2. Dr Nina Isaac - Scientist E. CWPRS
3. Mr. Prasad Kunjeer - Scientist C, CWPRS
4. Ms Harsha Chaudhary - Scientist B, CWPRS.
5. Mr. Mangesh Dighe - Environment Officer, PMC
6. Ms Renu Gera - Environmental Expert, GC
7. Mr Ratnakar Pandey - DGM Environment, Maharashtra Metro Rail Corporation
8. Mr. Santosh Patil - Manager Maharashtra Metro Rail Corporation
9. Ms. Swati Pandit, Adv. for office of Divisional Commissionar, Pune.

Purpose: Review of the compliance made in accordance with the order dated 03.08.2018 of the Hon'ble NGT wherein, Divisional Commissioner, Pune has been directed to associate with the committee and supervise the project with respect to environmental aspect. It has been kept open for the applicant or any stakeholders to continue to give their suggestions to the committee so that damage to the environment can be prevented or minimized. In case it is found that the project Proponent is not complying with the directions of the committee, the committee will be at liberty to bring the same to the notice of this Tribunal by moving an appropriate application.

Proceedings: This is the 7th Meeting of the Expert Committee Members on Environmental compliance of River front .The last meeting was held on 6.11.2020 wherein the committee was informed that CWPRS Scientist Mr. Prasad Kunjeer who is the lead scientist for the study had been infected by COVID -19 and was hospitalized from 11th -18th October and subsequently on home quarantine till 25th October, hence the study progress was severely hampered, the request for time extension was placed to the court accordingly NGT has granted the time extension till 12th March 2021.

The meeting commenced with a presentation by CWPRS to the expert committee of the study undertaken is limited to 2.5 km stretch between Khadakwasla dam to Sangam Bridge. At the onset the Expert Committee sought confirmation that the roads and other structure have been considered in study, The CWPRS confirmed the same. The simulations studies to estimate afflux due to construction of Metro piers along the Mutha river bank. This study was carried out on the extended cross section based on drone survey for two discharges of 100,000 cusecs and 60,000 cusecs corresponding to red line and blue line defined by the irrigation department respectively. In addition, inundation depth was also computed and maps were prepared to show inundation depth and extent on both banks.

The major findings from the studies are as below:

1. The maximum afflux (rise in water level) for the 100.000 cusecs and 60,000 cusecs due to introduction of Metro piers have been estimated as 216 mm at Metro pier no. P152 and 241 mm at pier no. DE 1 respectively.
2. This increase in water level results in incremental increase in inundation. Inundation is the spread of the water along both banks (i.e. left bank + right Bank).
3. For the discharge of 100, 000 cusecs the incremental increase in inundation would be insignificant (0.02 m) in the reach between Shivaji Bridge and Shinde Bridge. In the reach between Shinde Bridge and Metro pier DE 8 incremental increase inundation varies between 0.02 to 10 m. Further from DE 8 to Baba Bhide bridge the incremental inundation varies from 2.6 to 10.94 m. (i.e. about 5m on either bank.)
4. At three locations i.e. P159, P160 and Z Bridge the inundation is 22.2 m 20.6 and 29. 8 m respectively. The incremental inundation extent 55.76 m at pier no P167 due to specific topography at this location. There is a low level cross road connecting the river front road and Kelkar road at this location. Water is spreading along this road and hence the higher inundation extent at this particular location was observed.
5. The incremental increase in inundation extent for 60,000 cusecs in the reach between Shivaji Bridge and Shinde Bridge is insignificant (0 to 0.01 m). In the reach between Shinde Bridge and Metro pier DE 8 varies between 0 to 2.27 m. From DE 8 to upstream of Baba Bhide bridge is 2.27 to 11.44 m. At two locations i.e. P162 and P 163 is 10 to 11.4 m. (i.e. 5 to 5.6 m on either bank.)
6. Appropriate mitigation measures to be adopted to reduce the inundation extent at critical points.
7. The Irrigation Department has demarcated the redline for a discharge of 100,000 cusecs and blue line for discharge of 60.000 cusecs in year 2011.The expert committee is of the opinion that the Red line and Blue line to be redefined by the competent authority taking into account the recent developments along the river reach.
8. The CWPRS scientist highlighted in their presentation that the contribution of discharge from the local catchment downstream of the Khadakwasla dam to Sangam Bridge will only

yield about 8,500 cusecs corresponding to the discharge of 90,000 cusecs. Therefore, in the worst-case scenario the total discharge will not breach 100,000 cusecs. Also, the spillway design capacity of Khadakwasla dam is 97,000 cusecs only.

9. The CWPRS scientist has also pointed out that in the last 56 years the discharge of 60,000 cusecs has only been breached four times and the 100,000 cusecs has not been breached even once, so scenario for breaching the 100,000 cusec discharge would be a rare.
10. It was referred that the Irrigation Department and the Smart City project both have robust flood alarm and evacuation system to avoid loss of life and property. The Smart City Project has already identified the flood prone locations and areas to where people will be moved in case of floods. This has been tested during the floods of 2019.
11. The CWPRS has stated that they have submitted their final report based on the available data. If there would be any further requirement, CWPRS can take up additional studies.

The expert committee has pursued that Maharshtra Metro Rail Corporation through Central Water and Power Research Station (CWPRS) have conducted all studies and submitted reports as directed by the committee. Maha Metro is taking utmost care during construction of Project and complying all the guidelines issued by Expert Committee. There is no impediments in proceeding with work by Maha Metro.

The meeting concluded formally with a vote of thanks.

NO/NP-4/WS/२८० /2021
Date:30/3/2021

(Saurabh Rao)
Divisional Commissioner, Pune,
Division Pune.

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