Government of India
Ministry of Water Resources,
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भारत सरकार
जल संसाधन, नदी विकास
और गंगा संरक्षण मंत्रालय

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

Technical Report No: 5384

March 2016

MATHEMATICAL MODEL STUDIES FOR THE MODIFIED LAYOUT OF PROPOSED INTERNATIONAL AIRPORT AT PANVEL, NAVI MUMBAI

Dr. Mukesh Kumar Sinha
Director

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COASTAL AND OFFSHORE ENGINEERING LABORATORY

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Dr. M.K. Sinha

Director

REPORT DOCUMENTATION SHEET

Technical Report No: 5384 **Date:** March 2016

Title:

MATHEMATICAL MODEL STUDIES FOR THE MODIFIED LAYOUT OF PROPOSED INTERNATIONAL AIRPORT AT PANVEL, NAVI MUMBAI

Officers Responsible for conducting the studies:

The studies were carried out by Shri A A Purohit, Scientist-D with the assistance of Shri M M Vaidya Scientist-B. The studies were carried out under the supervision of Shri. M. D. Kudale, Additional Director.

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Name and address of Sponsoring Authority:

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Synopsis:

M/s. CIDCO, a Govt. of Maharashtra undertaking have a ambitious proposal to develop an international airport at the confluence of five rivers meeting the Panvel Creek at Navi Mumbai. The various model studies such as 1-D, 2-D mathematical and physical were referred to CWPRS for studying the flow conditions around airport area and to determine the safe grade elevation of airport for various hydrodynamic conditions. Initial proposal of CIDCO having airport reclamation area of about 1640 ha studied using mathematical models was modified based on the guidelines given by Ministry of Environment and Forests (MoEF), Govt. of India. The modified proposal for airport consists of reclamation of about 1160 ha. This report describes the 2-D mathematical model studies carried out using Telemac-2D software for the modified layout of airport for various extreme hydrodynamic events such as simultaneous occurrence of highest spring tide from Arabian sea and peak flood discharges (100 year- RP, 6hrs storm; PMP-6Hrs storm and 26th July 2005 flooding event) from five rivers viz. Gadhi, Kalundri, Taloja, Kasadi and Ulwe meeting the proposed airport area. The maxima water levels predicted at various locations for with and without airport conditions are used to determine safe grade elevation (SGE) of airport. In order to keep SGE to minimum, optimization of channel dimensions of diversion channel of Ulwe river in to Moha creek from hydraulic design considerations was essential. The studies revealed that 120m wide (base width) Ulwe diversion channel having wider base width of 200m at the start of diversion near SH-54 bridge on Ulwe river along with removal of existing bund in Moha creek is inevitable to keep top level of 1160 ha reclamation of airport (SGE) to minimum. This will avoid inundation of airport under extreme hydrodynamic events from techno economic consideration. The clear waterway of 80 m at SH-54 bridge (Ulwe river) and 120 m at Amra Marg bridge near Moha creek for Ulwe diversion is essential with raising of soffit levels. The maxima water levels at various bridge locations as well as around the airport area predicted reveal that safe grade elevation of 11m with respect to Chart Datum of Ulwe Bunder is the minimal level. River bank protection works especially on the right bank of Gadhi River between NH-4B and SH54 bridges as well as upstream of Ulwe river diversion channel are essential to avoid inundation of low lying areas. Invert level of outfall locations around airport for discharging runoff from airport terracing are also determined to avoid inundation due to rainfall over airport area.

Key Words:
Airport, Hydrodynamics, Hydrographs, River, Rainfall, Runoff, Safe grade elevation, Tides etc

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MATHEMATICAL MODEL STUDIES FOR THE MODIFIED LAYOUT OF PROPOSED INTERNATIONAL AIRPORT AT PANVEL, NAVI MUMBAI

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1.0 PREAMBLE

India is a developing country and infrastructural developments in the country are taking place at an exponential rate. In order to cope with the demands of power, waterborne/airborne transport etc. development of power plants, harbours as well as domestic/international airports have been taken up at many places. These developments are being carried out by Governmental/Private/ Govt. Undertaking organisations. The City and Industrial Development Corporation of Maharashtra (CIDCO) is not an exception to this. The CIDCO is a Government of Maharashtra Undertaking and is carrying out infrastructural developments in Navi Mumbai for last couple of decades. These developments include construction of roads, commercial buildings, bridges, mass-housing schemes, water/sewage treatment plants, rail networks etc at Vashi, Nerul, CBD and other places in and around urban areas of Navi Mumbai. These developments are proposed in various nodes namely Kharghar, Kalamboli, New Panvel, CBD and Kamothe in Raigad district, which are on the banks of rivers/tributaries viz. Taloja, Kasadi and Gadhi meeting the Panvel Creek , wherein an International Airport is also proposed (FIG 1).

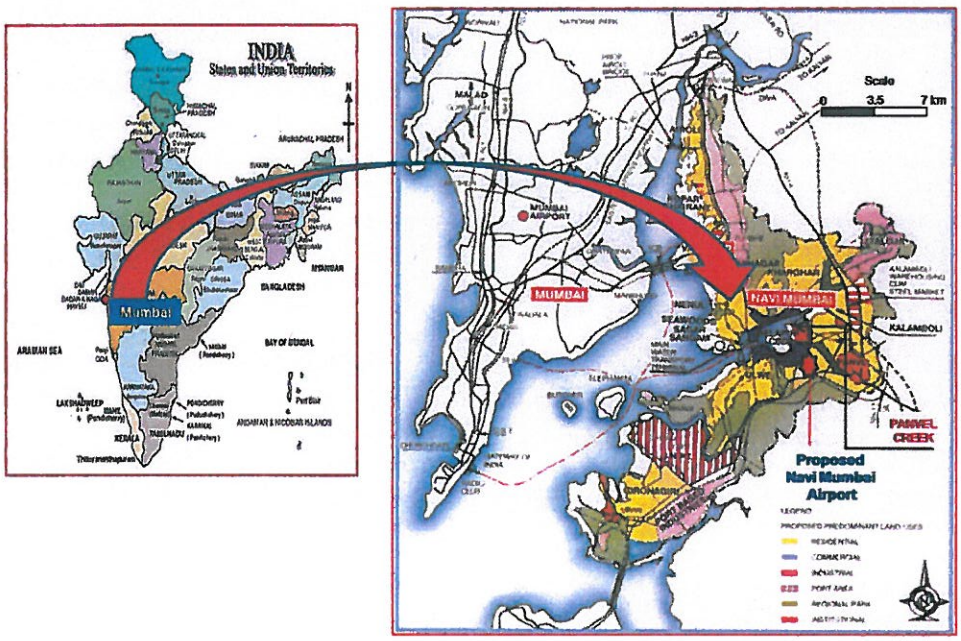

FIG 1 : LOCATION OF THE PROPOSED INTERNATIONAL AIRPORT IN PANVEL CREEK AT NAVI MUMBAI

The development at Navi Mumbai includes reclamations and developments of land in inter tidal zones for construction of roads / railways, residential and commercial nodes/townships etc.

Most of the reaches of this region is under the influence of tidal phenomenon prevailing in Thane Creek, Panvel Creek as well as flood prone reaches of Gadhi, Kalundri, Taloja, Kasadi and Ulwe Rivers. The topographic details of this region including streams, creeks, hills and high-low water lines during tidal flows are shown in FIG 2. The major part of the area earmarked for developments along creek gets submerged/ inundated either during high tide/high floods or combination of both. As such, it is essential to have information about likely changes, which may take place in the flow pattern/conditions due to the developmental works such as reclamations. This information would be useful for storm drainage systems, roads, bridges and other works related to these developments.

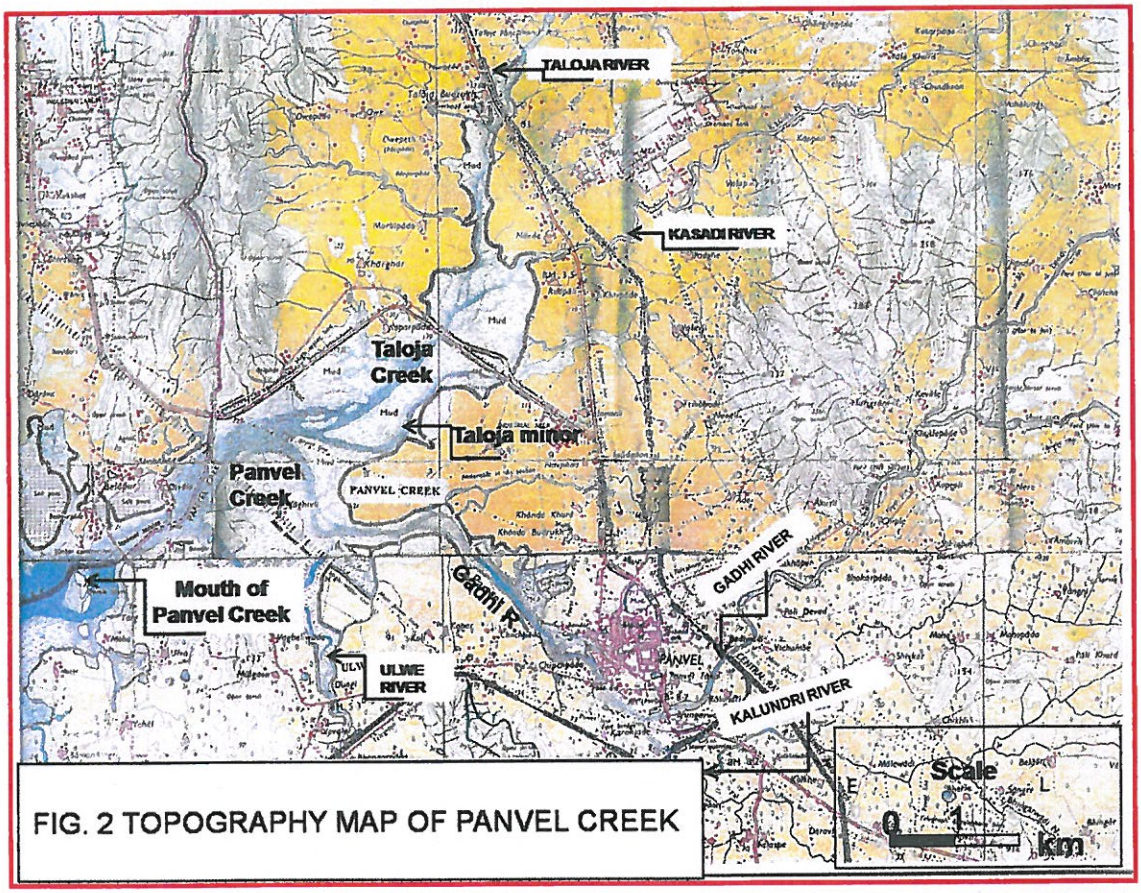

FIG. 2 TOPOGRAPHY MAP OF PANVEL CREEK

2.0 INTRODUCTION

The present airports, both domestic and international, in Mumbai, situated at Santacruz and Andheri are facing acute problem of air traffic congestion. Mumbai being financial capital of country, air traffic has increased considerably due to public /private airlines plying on domestic/international routes. In order to meet present and future demands of air traffic, M/s CIDCO have an ambitious project proposal of development of an international airport near Ulwe on the south bank of Panvel Creek between NH-4B road bridge and Ulwe Belapur road bridge as shown in FIG- 3.

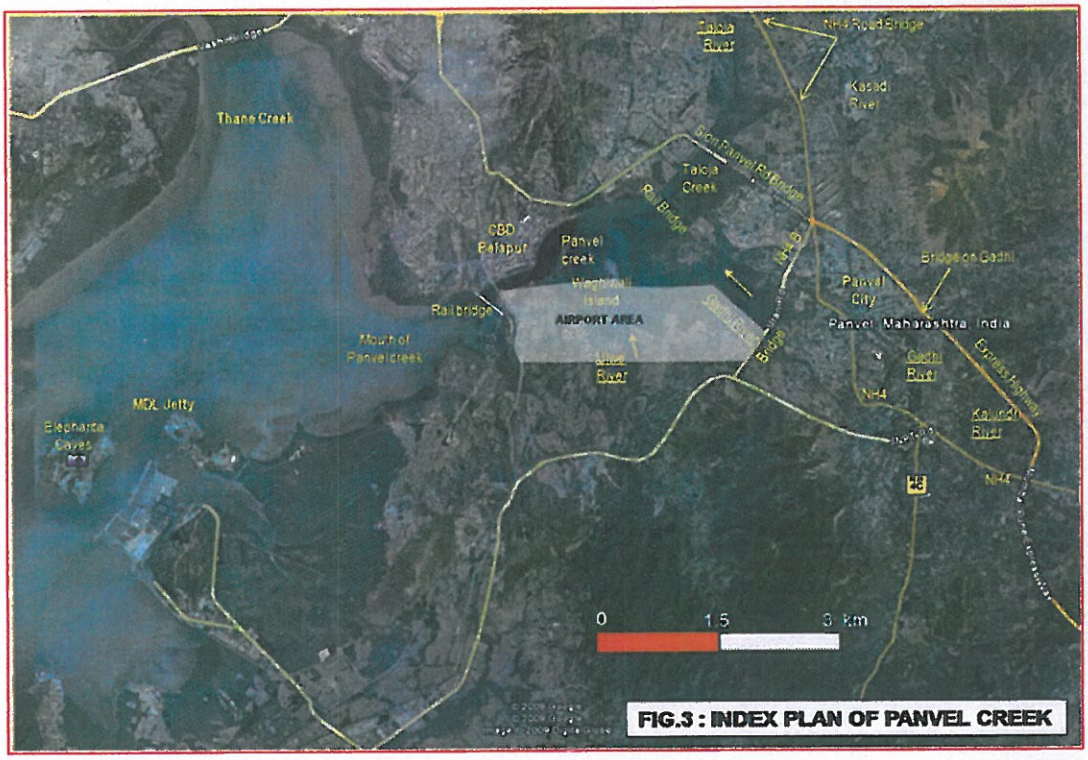

FIG 3: PLAN OF PANVEL CREEK SHOWING RIVERS CONFLUENCE & AIRPORT

The CIDCO authorities referred one dimensional mathematical model studies to CWPRS in the year 2000 to predict the changes in the flow conditions in Panvel Creek under combined influence of flood and tide after the development of various nodes and for the proposed international airport. The report on this study was submitted vide CWPRS Technical Report No.3815 of August 2001. Since many developments have taken place in the past couple of decades in and around Panvel Creek and it is being a confluence of natural channels/rivers such as Gadhi, Kalundri, Taloja, Kasadi, Ulwe which serve as drainage channels for their catchments, as well as considering the extreme rainfall event of 26th July 2005,

CIDCO authorities desired to conduct hydraulic model studies with the latest hydrographic data as well as review the hydrology based on topographical data.

The initial proposal for the development of international airport consisted of reclamation of land and some portion of Panvel Creek (total 1640 ha) with diversion of Ulwe River and channelisation of the Gadhi River as shown in FIG 4. The CIDCO authorities in this regard referred mathematical model studies to CWPRS in the year 2007 to predict the changes in the flow conditions in Panvel Creek under the combined influence of flood and tide after the development of the proposed international airport and various nodes.

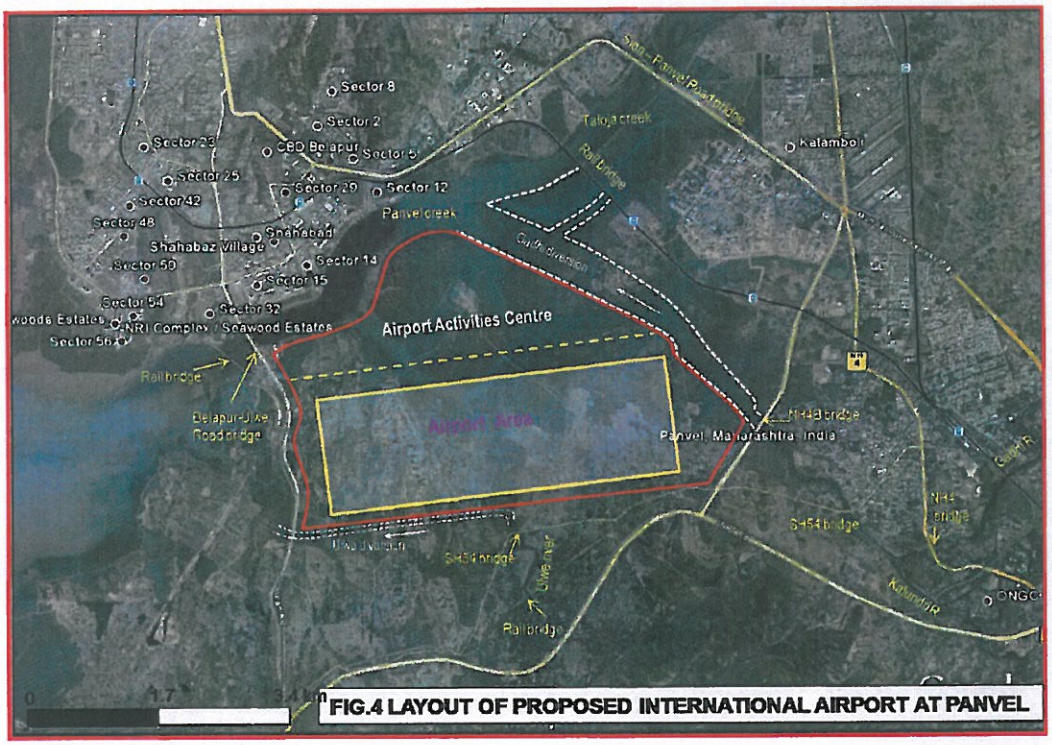

FIG 4(A): LAYOUT PLAN OF INITIAL PROPOSAL OF INTERNATIONAL AIRPORT AT PANVEL, NAVI MUMBAI

A report on these studies was submitted to M/s CIDCO vide CWPRS Technical Report No. 4665 of October 2009.

The above initial proposal for Navi Mumbai International Airport (NMIA) extending over an area of about 1640 hectare formulated by CIDCO was submitted for getting clearance from the Ministry of Environment & Forest (MoEF), Government of India. While giving the Environmental and Coastal Regulation Zone (CRZ) clearance, MoEF suggested substantial changes in the initial project proposal

submitted by CIDCO. In order to comply the conditions of MoEF, CIDCO has modified the layout plan of Airport area as shown in FIG 5.

This report describes the mathematical model studies carried out using Telemac-2D hydrodynamic software to predict the flow patterns and maxima water levels in and around Panvel creek due to development of the proposed international airport by CIDCO as per modified layout and the findings of the studies.

Note:- The levels given in the report are w.r.t Chart Datum (CD) of Ulwe Bunder. In order to obtain levels w.r.t GTS bench mark, reduce the levels by 2.94m, while to obtain levels w.r.t CD of Apollo Bunder at Mumbai, reduce the levels by 0.44m.

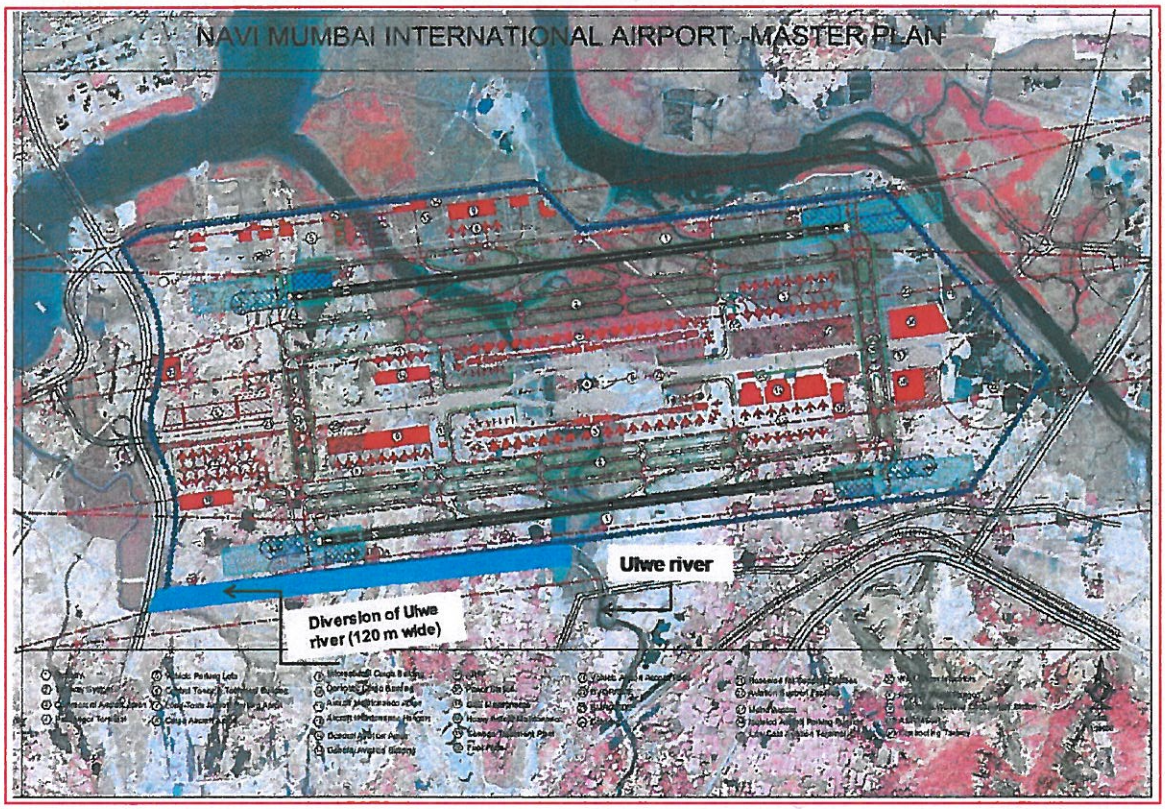

FIG 4(B): MODIFIED LAYOUT PLAN OF INTERNATIONAL AIRPORT AT NAVI MUMBAI

3.0 SCOPE OF STUDIES

Based on the modifications recommended by MoEF, the CIDCO Authorities vide their letter No: CIDCO/T&C/ACTE/2011/727 dated 10th January 2011 communicated broad scope of studies to CWPRS. In order to discuss the issues

raised by the Expert Appraisal Committee (EAC) vide letter F.No.10-53/2009-IA.III dated 22nd November 2010 and to finalize the scope of work for the additional mathematical model studies to be carried out by CWPRS with modified layout of international airport, a meeting was held at CWPRS on 19th January 2011. The scope of studies finalised and communicated vide letter No. CE/2011/35 dated 24th January 2011 for conducting 2-D mathematical model studies using Telemac-2D model is given below:

(i) Modified layout of airport , which covers an area of 1160 ha is to be reproduced in the model

(ii) Diversion of Ulwe river with 120m wide channel along with the Moha Creek is to be simulated in the model.

(iii) A shorter channel on the north of the modified airport layout, which is proposed to replace the existing secondary shallow channel flow of Gadhi river, is also to be simulated in the model.

(iv) The studies are to be carried out for the following conditions:

(a) River flow to be simulated for flood discharge of PMP with 6 hrs storm duration as an upstream boundary along with Spring tide as downstream boundary condition and shorter channel with its invert level at the bed level of Gadhi River at the upstream end.

(b) Same as in (a) with invert level of shorter channel as RL -2m at upstream end.

(c) Same as in (a) with invert level of shorter channel as RL -1m at upstream end.

(d) All above runs mentioned in (a), (b) and (c) are to be carried out also for River flood discharge corresponding to 100 year return period rainfall for 6 hours storm as upstream boundary.

Also based on letter from CIDCO dated 10th January 2011 for conducting the 2-D model studies, model runs mentioned in (a), (b) and (c) are decided to be carried out as an additional runs for River discharges corresponding to extreme rainfall event of 26th July 2005 as upstream boundary.

The data on river discharges (Hydrographs) are to be taken from the CWPRS Technical Report No. 4665 of October 2009.

The mathematical model studies for the above mentioned scope of work were carried out and based on the studies a draft technical report was submitted to M/s CIDCO on 30th October 2012. In response to the draft report submitted the

comments on above report were received vide CIDCO letter dated 16th January 2014. In order to discuss various findings of the studies the meeting was held at CWPRS on 20th January 2014 and as per opinion of CIDCO Authorities the **additional model studies** are proposed to be carried out with modifications in Moha creek bathymetry. The scope of additional studies is as follows:

I) 120 m wide diversion channel of Ulwe river with 60 m opening at Amra Marg Bridge

II) 120 m wide diversion channel of Ulwe river with 120 m opening at Amra Marg Bridge

III) 120-180 m wide diversion channel transition at Ulwe river diversion(Near SH-54 bridge at Ulwe) and

IV) Simulation of runoff discharges at various proposed locations from Airport area under neap tidal condition as well as combination of neap tide and river flood discharges.

The locations of the storm water drainage suggested by CIDCO to simulate runoff from the Airport area considered in the Technical Report No. 4665 of Oct.2009 needs to be modified as informed by CIDCO officials during the meeting held at CWPRS dated 19th January 2011 and these locations are considered to be provided by CIDCO.

4.0 PRESENT BATHYMETRIC SCENARIO OF PANVEL CREEK

The entrance to the Panvel Creek area is from Thane Creek , near Devale Island. The Devale Island, bifurcates the flow entering/leaving the Panvel Creek during flood/ebb tide. Sufficiently large depths of the order of about 10.0 m (below CD of Apollo Bandar) exists when the flood flow from Thane Creek enters the Panvel Creek. The Panvel Creek portion near Ulwe – Belapur road bridge is initially narrow (about 350 to 400 m wide with bed levels at about *-5.5 to -7.5 m* w.r.t. CD at Apollo Bandar), which subsequently thereafter gradually expands to about 3 km and the bed levels in this area are up to *-0.5 m to -2.5 m* (w.r.t. CD at Apollo Bandar). The waterway at the existing bridges at the mouth of Panvel Creek affects the total influx/out flux of the Panvel Creek. The creek channel north of Waghivali Island is relatively deeper than the south channel and carries the major discharge. The Waghivali Island is in shallow depths with the flat area having ground levels varying between 3.5 m to 6.5 m w.r.t CD at Apollo Bandar. Along Gadhi River, near Khanda and upstream of the railway bridge, the new Panvel township has been developed on the right bank. Reclamations, along the Panvel Creek near Ulwe and south of Waghiwali Island are also proposed. A large portion of the above region gets submerged during the high tide.

5.0 DATA FOR MODEL STUDIES

The data on various parameters such as bathymetry, hydrological, hydraulic and oceanographic is essential to carry out the model studies and is described in following paras.

The CIDCO authorities had supplied the following data required for the studies:

5.1 Bathymetry Data

The hydrographic survey of Panvel creek data was supplied for various stretches vide CIDCO report of August 2007 and is shown in FIG 5.

Sheet no.1 Panvel Creek –Entrance to Belapur ; Scale:1: 10,000

Sheet no.2 Panvel Creek – Belapur to Waghivali; Scale: 1:5000

Sheet no.3 Panvel Creek –Waghivali - Kharghar -Taloja; Scale: 1:5000

Sheet no.4 Panvel creek --Waghivali – Jui – Panvel; Scale: 1: 5000

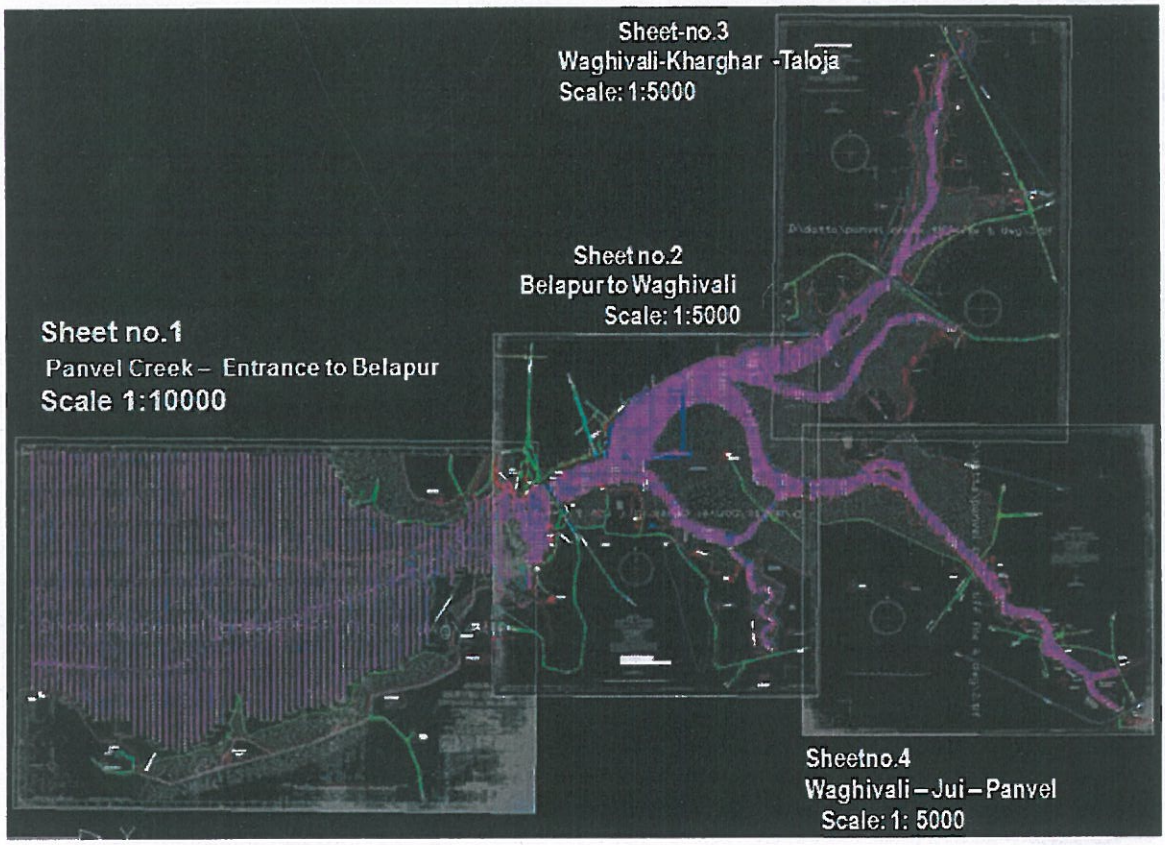

FIG 5: HYDROGRPHIC SURVEY AREA OF PANVEL CREEK FOR NMIA STUDIES

a) Cross Sectional Data: The bathymetry data in the form of cross-sections at an interval of 100 to 200 m was supplied for riverine areas in the Panvel Creek upstream of tidal reaches along the five rivers to about 2 to 8 km. The levels along the cross-sections were taken at an interval of 5 to 10 m in deep channel and cross-sections were extended on both the sides up to the high flood level (HFL) or high bank levels, where the reclamation works had been carried out.

b) Maps showing modified layout of the proposed international airport and Ulwe River diversions as shown in FIG 4(B) was also supplied.

The bathymetry survey for Thane creek area from mouth of Panvel creek extending up to Vashi bridge- BARC area and MDL jetty was taken from Admiralty Chart No. 2627

5.2 Hydrological Data

a. Yearly maximum one day rainfall for rain-gauge stations at Santacruz and Colaba are given in (Table– 1 and Table – 2 of CWPRS Technical Report No. 4665 of October 2009), while highest recorded 24 Hrs rainfall in and around Panvel Creek is given in Table-2(a), which includes rain-gauge stations at various locations such as Panvel, Karjat, Matheran, Bhivandi, Kalyan, Vada, Kurla, Murbad, Dahanu etc. Short duration data available for other stations are shown in Table – II to IV of CWPRS Technical Report No.3815 of August 2001.

b. Hourly rainfall records of rain-gauge stations at Santacruz, Powai, Panvel, Kharghar, Nerul, Vashi and CBD Belapur during the 26th July 2005 case.

c. Yearly maximum rainfall intensity (mm/hr) records of Colaba and Santacruz rain-gauge stations for the period 1969 – 2004.

5.3 Hydraulic Data

a. Recorded flood levels at different locations in Panvel Creek on 26th July 2005 (CIDCO report of Aug 2007 on Topography and Hydrographical Survey) and July 1991.

b. Gauge-discharge data for only one season on Gadhi and Kasadi river for low discharges.

5.4 Oceanographic Data

The oceanographic data such as tides, currents etc were collected by CWPRS alongwith Maharashtra Maritime Board (MMB) in consultation with CIDCO at various locations as shown in FIG 6(A) and FIG 6(B).

a. Tidal water level and velocity data at an interval of 15 minutes at five locations (MDL Jetty, Ulwe Railway bridge, Ulwe – Belapur road bridge, Kharghar and Waghivali village) for the period of one month (16th May – 15th June 2007). CWPRS and MMB had jointly collected these data with the help of CIDCO. (CIDCO report of Aug 2007 on velocity and tidal observations- Panvel creek)

b. The suspended sediment data for 3 locations in Panvel Creek indicated low concentration in the range 300 to 500 ppm. The analysis of bed samples taken in all five rivers reveal that material mainly consists of sand (60%) and silt (30%) with remaining % of gravel and clay. (CIDCO report of Aug 2007 on Topographic and Hydrographical Surveying)

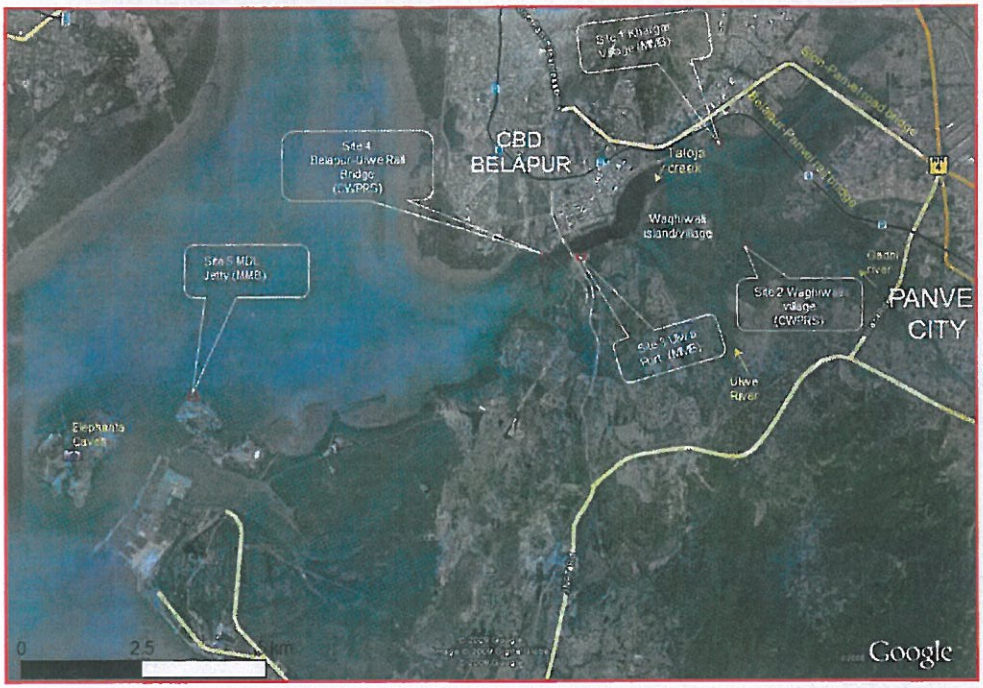

FIG 6(A): LOCATIONS OF FIELD MEASUREMENT FOR TIDE IN PANVEL CREEK

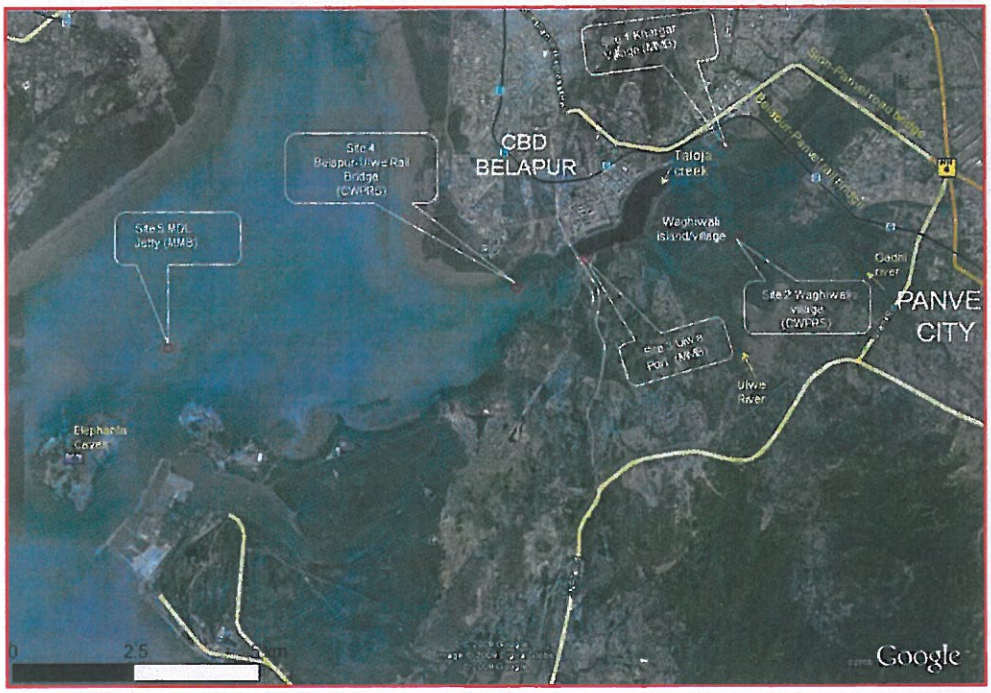

FIG 6(B): LOCATIONS OF FIELD MEASUREMENT FOR VELOCITY IN PANVEL CREEK

6.0 ANALYSIS OF TIDE AND VELOCITY DATA

The tidal data available with CWPRS at the location of Apollo Bandar, Mumbai show that tides at Mumbai are semi-diurnal in nature. The maximum tidal range is about 5.4m. The different tidal water levels observed at Apollo Bandar with respect to CD are given in Table-1.

Table-1

Tidal Levels at Apollo Bunder, Mumbai

TYPICAL TIDAL LEVELS (with respect to Chart Datum of Apollo)		
1	Highest High Water Level	5.40 m
2	Mean High Water Spring	4.36 m
3	Mean Low Water Spring	0.83 m
4	Mean High Water Neap	3.36 m
5	Mean Low Water Neap	1.82 m
6	Mean Sea Level	2.50 m
7	Lowest Low Water Level	0.0 m

The analysis of the tidal water level and velocity data collected for the studies under consideration has been reported in CWPRS Technical Report No.4627 of March 2009 and in CIDCO report on "Velocity and tidal water level observation in Panvel creek", August 2007 . FIGs.7 – 10 show continuous tidal levels measured at MDL Jetty, Ulwe rail bridge, Ulwe Bunder Jetty and Kharghar respectively and these levels reported in this report are w.r.t CD of Ulwe Bunder.

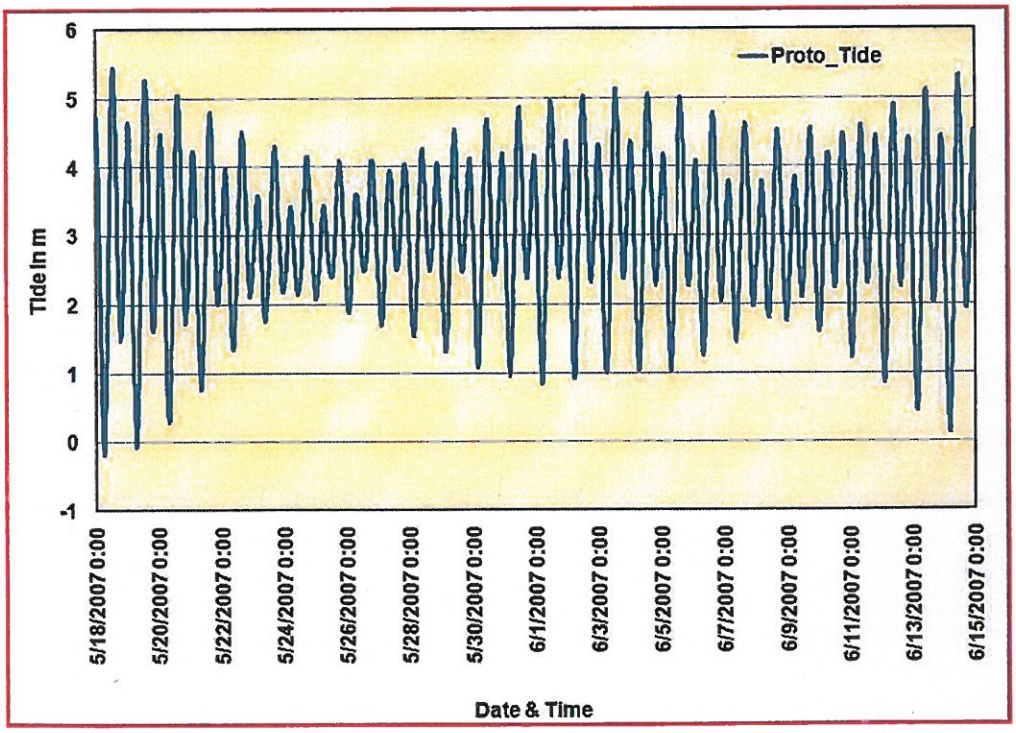

FIG 7: MEASURED TIDAL LEVELS AT MDL JETTY (NHAVA) (18TH MAY – 15TH JUNE 2007)

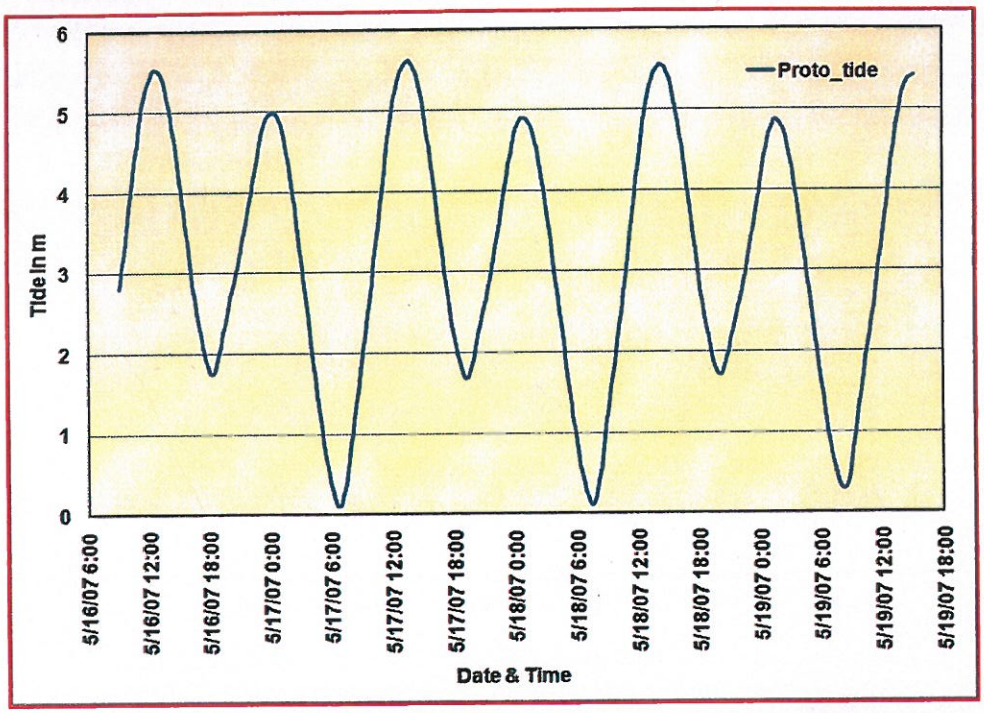

FIG 8 : MEASURED TIDAL LEVELS AT ULWE RAIL BRIDGE (16TH – 19TH MAY 2007)

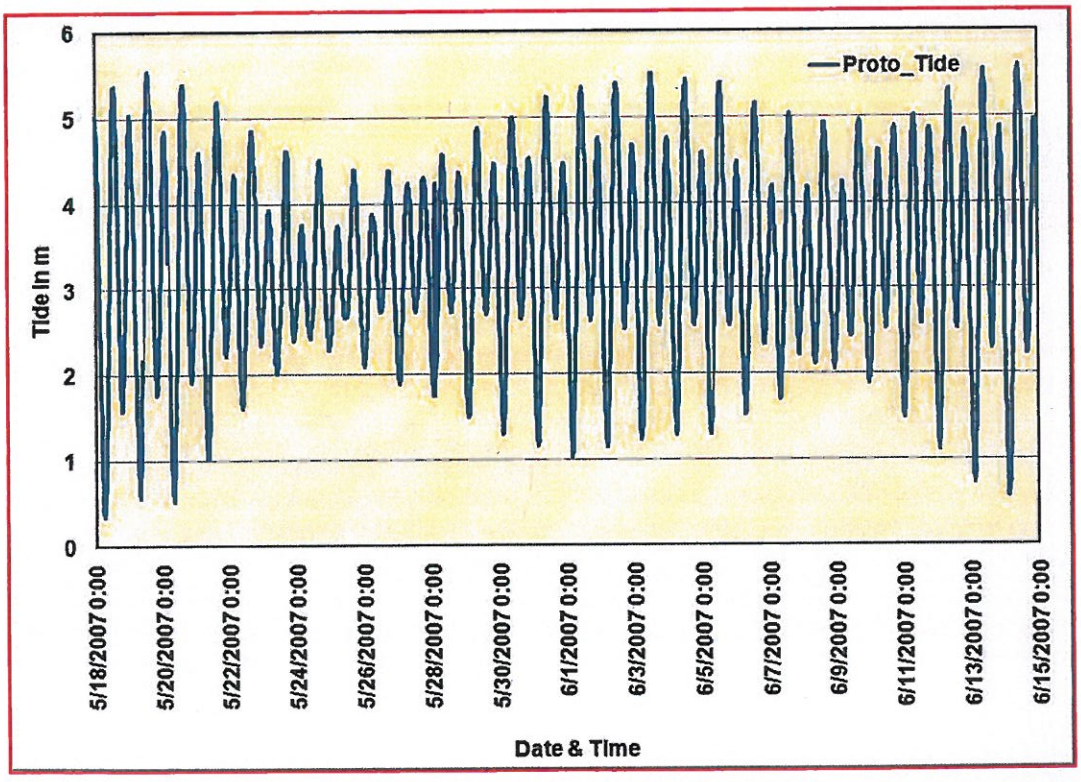

FIG 9: MEASURED TIDAL LEVELS AT ULWE BANDAR (18TH MAY – 15TH JUNE 2007)

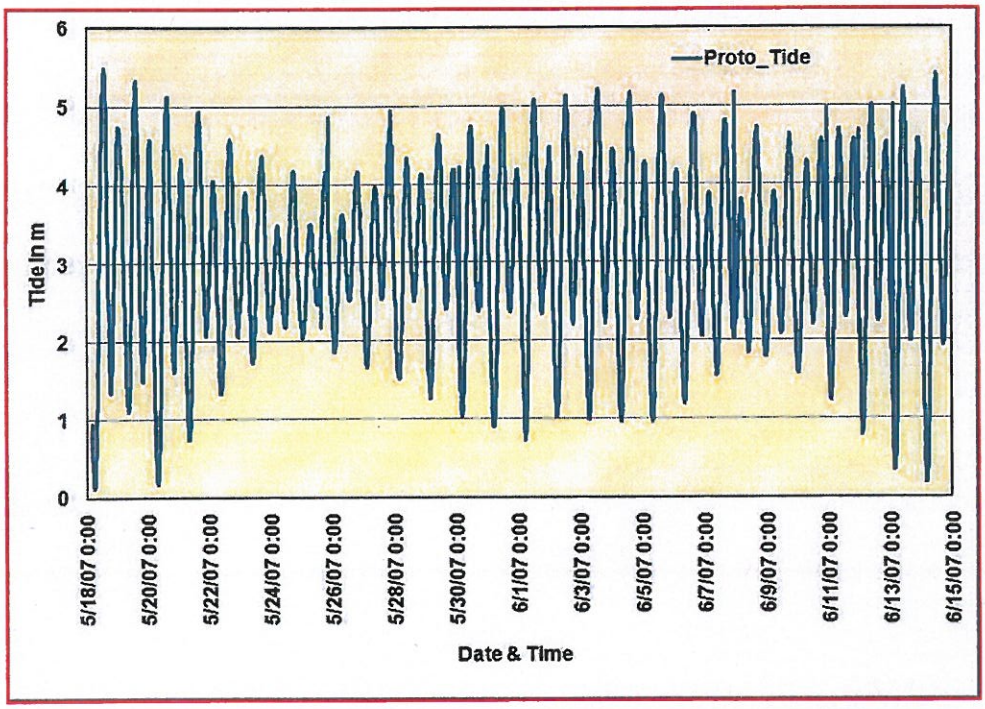

FIG 10 : MEASURED TIDAL LEVELS AT KHARGHAR (18TH MAY – 15TH JUNE 2007)

The tide levels and velocities at above four locations and near Waghivali are shown in FIGS.11 to 15 respectively, which occur during spring tidal conditions. These tidal data were utilized for calibration of mathematical model for the high water levels prevailing in Panvel Creek during no river discharge condition.

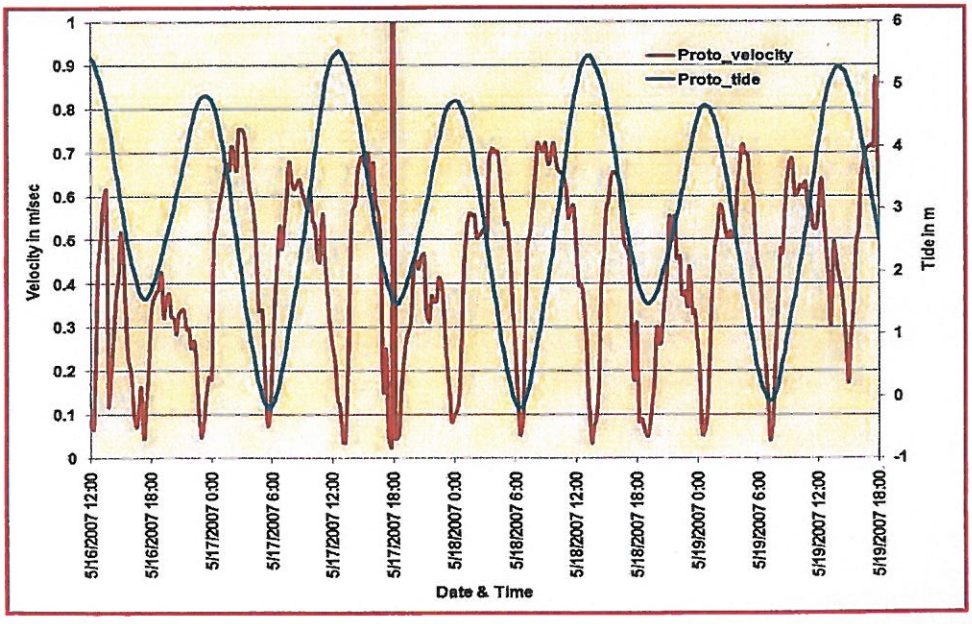

FIG 11: MEASURED TIDAL LEVELS & VELOCITIES AT MDL JETTY (NHAVA) DURING SPRING TIDE (16TH – 19TH MAY 2007)

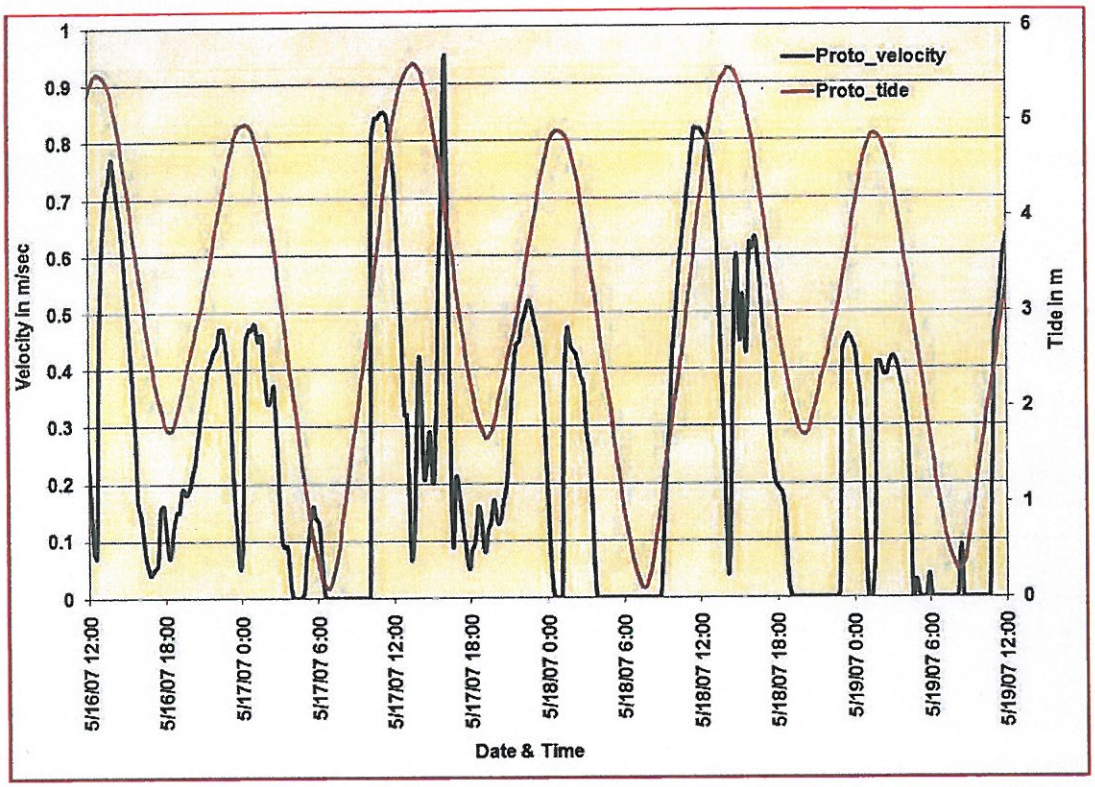

FIG 12: MEASURED TIDAL LEVELS & VELOCITIES AT ULWE RAIL BRIDGE DURING SPRING TIDE (16TH – 19TH MAY 2007)

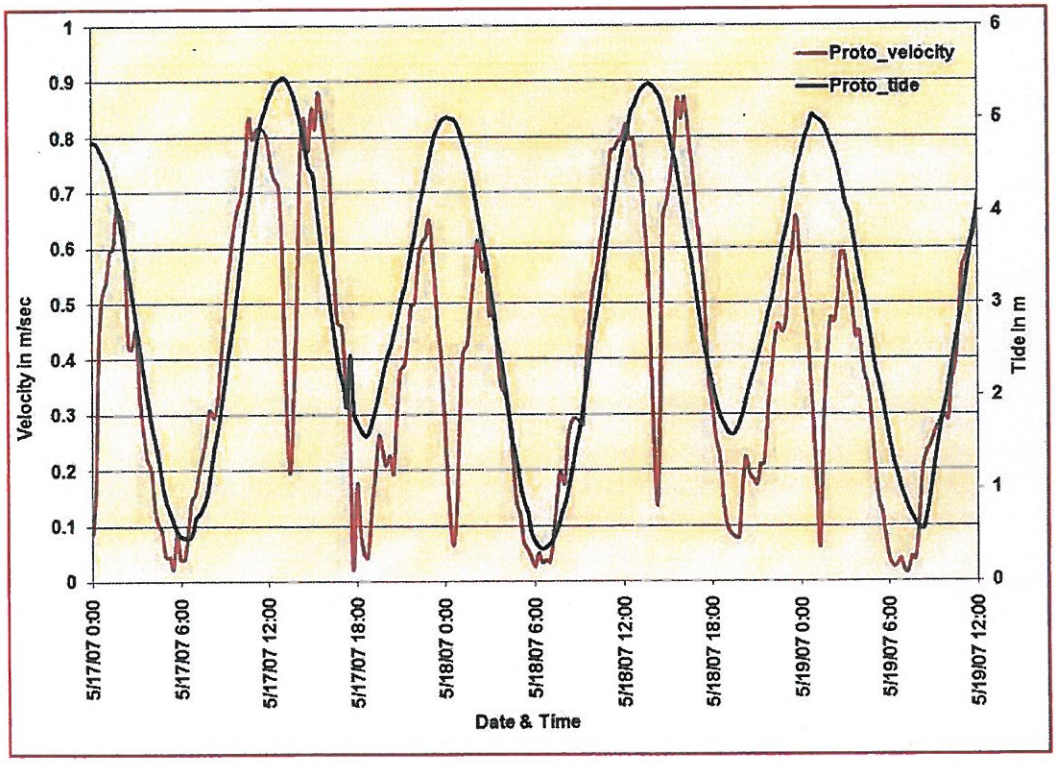

FIG 13: MEASURED TIDAL LEVELS & VELOCITIES AT ULWE BANDAR JETTY DURING SPRING TIDE (17TH – 19TH MAY 2007)

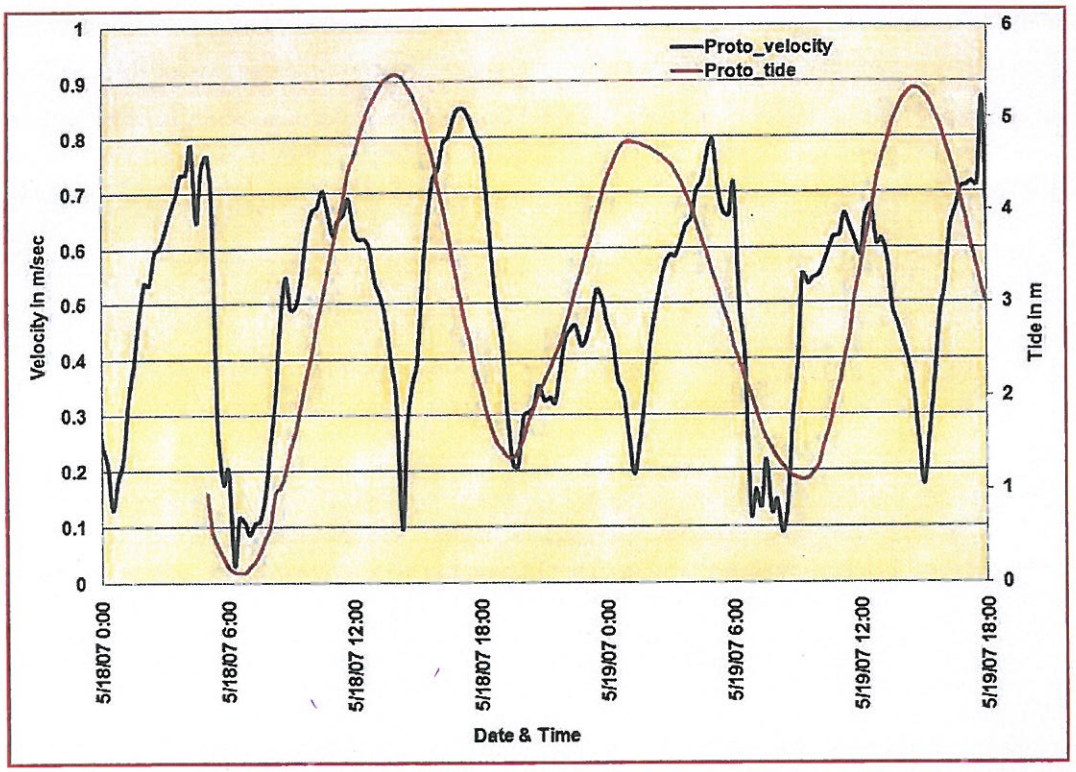

FIG 14: MEASURED TIDAL LEVELS & VELOCITIES AT KHARGHAR DURING SPRING TIDE (18TH – 19TH MAY 2007)

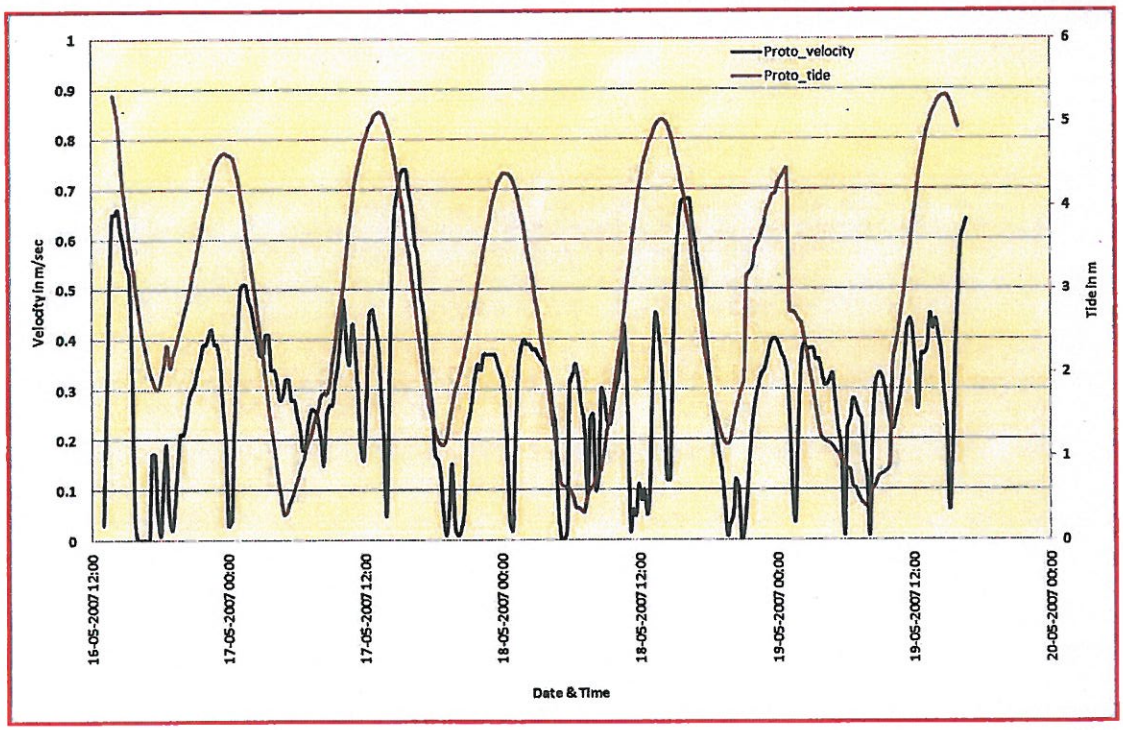

FIG 15: MEASURED TIDAL LEVELS & VELOCITIES AT WAGHIVALI DURING SPRING TIDE (16TH – 19TH MAY 2007)

Summary of analysis of tidal data collected during 16th May – 15th June 2007 is presented in Table-2:

Table-2

Tidal Levels and Flow Velocities From The Measured Data

Sr. No.	Location	Spring Tide					Neap tide				
		Tidal range	HWL	LWL	Flooding velocity	Ebbing Velocity	Tidal range	HWL	LWL	Flooding velocity	Ebbing Velocity
1.	MDL Jetty	5.74	5.54	-0.2	0.67	0.75	2.25	4.34	2.09	0.40	0.40
2.	Ulwe rail bridge	5.49	5.61	0.12	0.82	0.90	2.00	4.34	2.34	0.13	0.26
3.	Ulwe Bandar jetty	5.19	5.56	0.37	0.82	0.86	2.16	4.44	2.28	0.35	0.28
4.	Kharghar	5.44	5.58	0.1	0.70	0.90	2.50	4.14	1.64	0.37	0.37
5.	Waghivali	5.12	5.43	0.31	0.48	0.75	2.17	3.61	1.44	0.24	0.24

Note:- The tidal levels mentioned in Table-2 are with respect to CD of Ulwe Bunder in meter, while the velocities are in m/sec.

7.0 ESTIMATION OF FLOOD HYDROGRAPHS

Using the time-area relationships and hourly rainfall distribution for storms of different duration and return period, the flood hydrographs were estimated and are reported in CWPRS Technical Report No. 4665 of October 2009. The peak flood discharges for rainfall corresponding to PMP (700 mm) and 100- year return period (531 mm) for five rivers under consideration were considered for the studies. These discharges along with discharges for 50- year Return period and 26th July 2005 are also given in Table-3.

Table-3

Estimated Peak Flood Discharges

River	Estimated peak flood discharges (m^3/s) for						
	PMP		50 year Return Period		100 year Return Period		26th July 2005 rainfall
	6 hours storm	12 hours storm	6 hours storm	12 hours storm	6 hours storm	12 hours storm	
Gadhi	2082	1905	1356	1241	1580	1445	2515
Kalundri	1973	1676	1585	1091	1497	1272	1978
Kasadi	1001	927	651	603	759	703	1270
Taloja	1234	1004	803	654	936	762	1060
Ulwe	916	673	597	438	695	510	722

The plots of flood hydrographs considered for model studies are for 6 hrs duration with PMP and 100- year return periods are given in FIGS.16- 20.

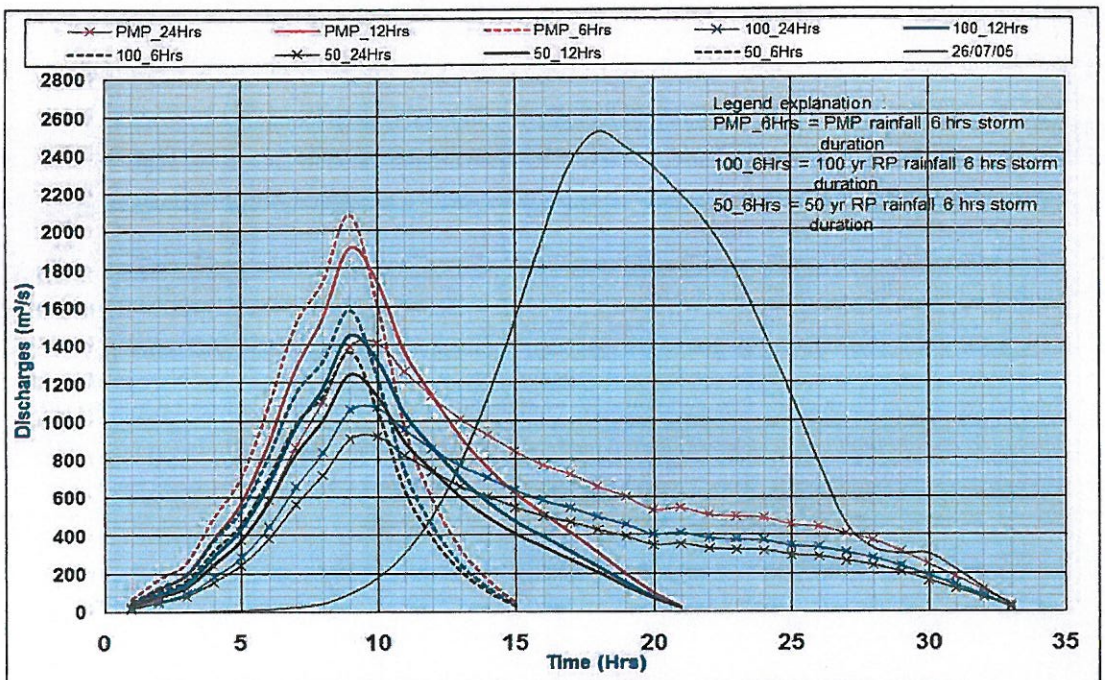

FIG.16 :FLOOD HYDROGRAPHS FOR STORMS OF DIFFERENT RETURN PERIOD AND DURATION FOR GADHI RIVER

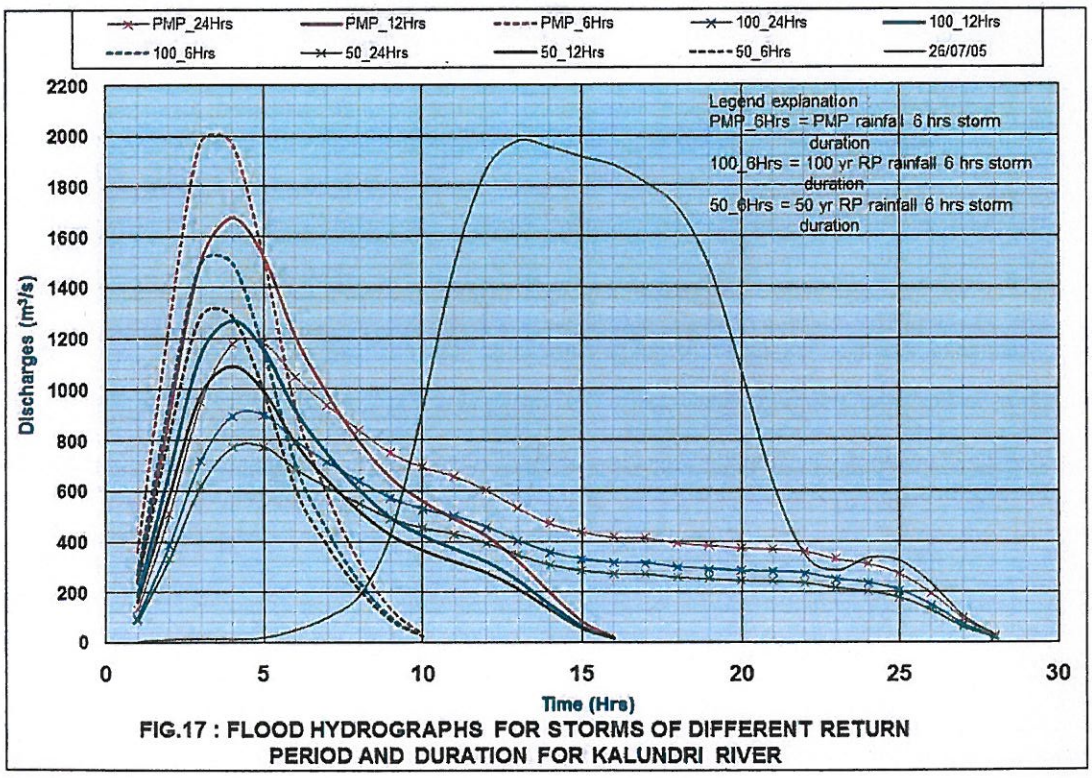

FIG.17 : FLOOD HYDROGRAPHS FOR STORMS OF DIFFERENT RETURN PERIOD AND DURATION FOR KALUNDRI RIVER

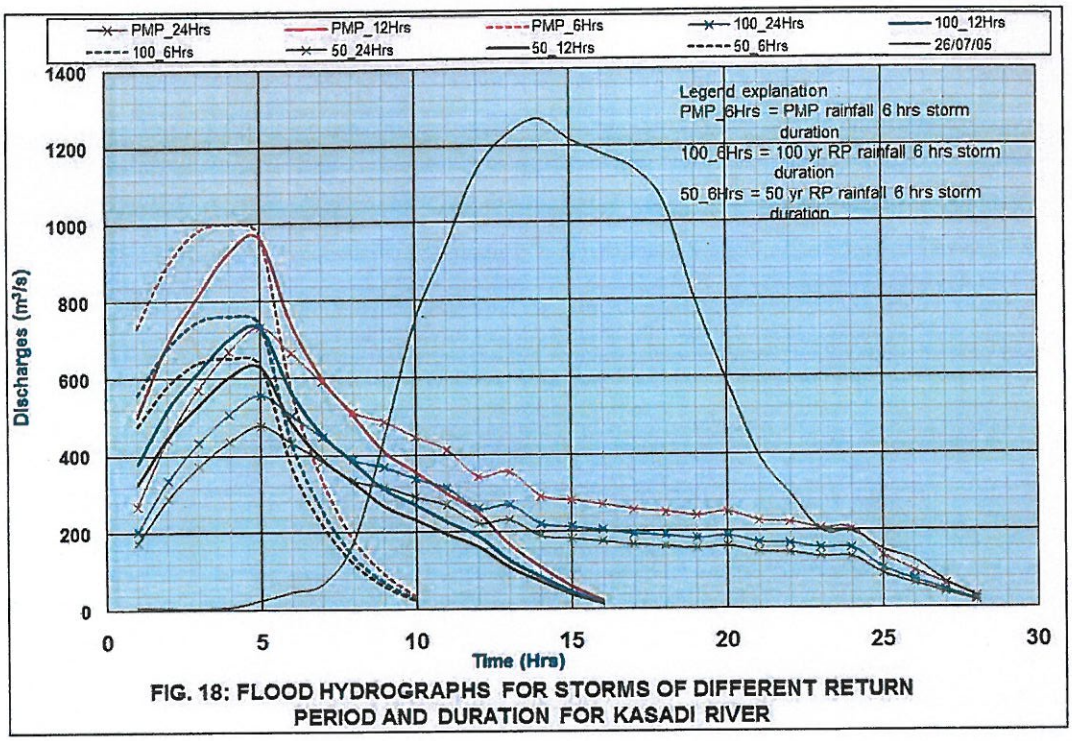

FIG. 18: FLOOD HYDROGRAPHS FOR STORMS OF DIFFERENT RETURN PERIOD AND DURATION FOR KASADI RIVER

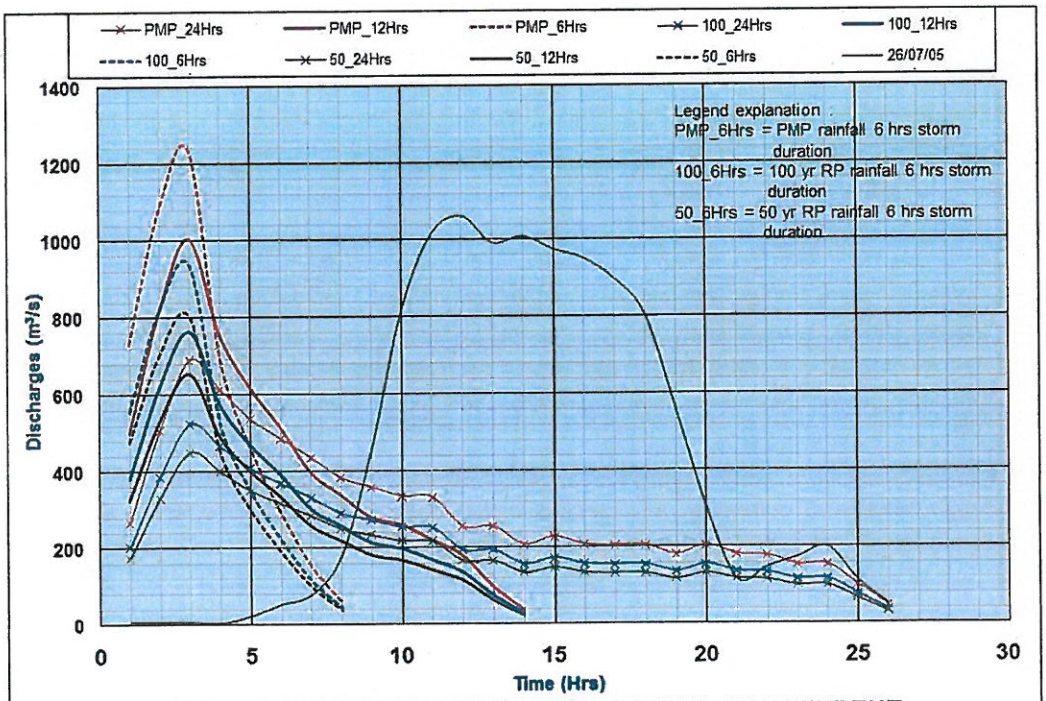

FIG.19 : FLOOD HYDROGRAPHS FOR STORMS OF DIFFERENT RETURN PERIOD AND DURATION FOR TALOJA RIVER

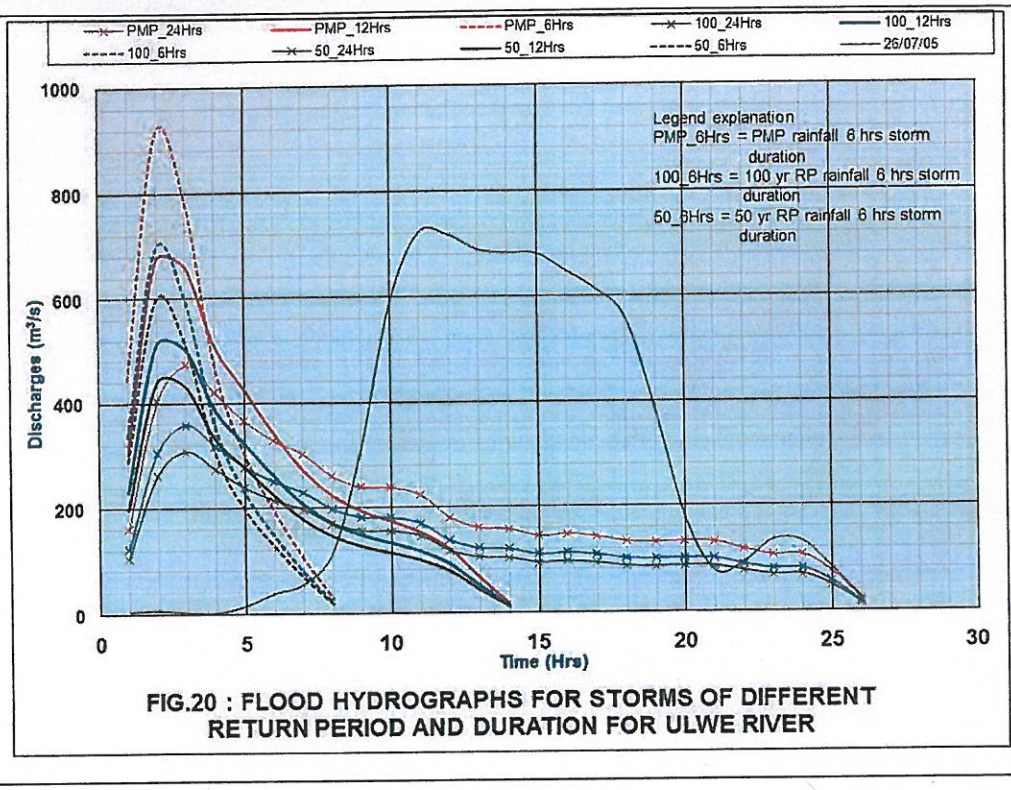

FIG.20 : FLOOD HYDROGRAPHS FOR STORMS OF DIFFERENT RETURN PERIOD AND DURATION FOR ULWE RIVER

8.0 MATHEMATICAL MODEL STUDIES

The mathematical model study covers the simulation of hydrodynamic conditions for the area, in and around the Panvel creek with and without the proposed modified layout of international airport at Navi Mumbai. The studies were carried out by using TELEMAC-2D software available at Central Water & Power Research Station (CWPRS), Pune. The TELEMAC-2D is finite element software, which considers solution of hydrodynamic equations of Saint Venant's. The model considers depth-averaged velocities. The equations are solved by solving matrices, element by element at number of nodes of finite element, which is an unstructured triangular mesh.

The TELEMAC-2D code solves the following four hydrodynamic equations simultaneously:

$$\frac{\partial h}{\partial t} + \vec{u}.\vec{\nabla}(h) + h\,div(\vec{u}) = S_h$$ ---------- **Continuity**

$$\frac{\partial u}{\partial t} + \vec{u}.\vec{\nabla}(u) = -g\frac{\partial Z}{\partial x} + S_x + \frac{1}{h}div(h\nu_t\vec{\nabla}u)$$ ---------- **Momentum along x**

$$\frac{\partial v}{\partial t} + \vec{u}.\vec{\nabla}(v) = -g\frac{\partial Z}{\partial y} + S_y + \frac{1}{h}div(h\nu_t\vec{\nabla}v)$$ ---------- **Momentum along y**

in which,

h	----------	(m)	depth of water
u, v	----------	(m/s)	velocity components
g	----------	(m/s^2)	gravitational acceleration
v_t	----------	(m^2/s)	momentum diffusion coefficients
Z	----------	(m)	free surface elevation
t	----------	(s)	time
x, y	----------	(m)	horizontal space coordinates
S_h	----------	(m/s)	source or sink of fluid
S_x, S_y	----------	(m/s^2)	source and sink terms in dynamic equations

h, u and v are the unknowns

The equations are given in Cartesian Co-ordinates. They can also be processed using spherical co-ordinates.

S_x and S_y are source terms representing the wind, Coriolis force, bottom friction, a source or sink of momentum within the domain. The different terms of these equations are processed in one or more steps (in case of advection by method of characteristics).

1. Advection of h, u ,v
2. Propagation, diffusion and source terms of the dynamic equations

8.1 Descritisation of the Domain Area

The domain area of the model for present study extends up to Vashi Bridge in Thane Creek on north and extends up to BARC area on south-west, including the area of the proposed international airport in Panvel Creek. The area of the proposed airport is on east side of Panvel Creek entrance and is immediately on downstream of the confluence of five rivers meeting the Panvel Creek. These rivers are Gadhi, Kalundri, Taloja, Kasadi and Ulwe as shown in FIG.21. The depths in the domain under consideration varies between -9 m depth contour [with respect to Chart Datum (CD) of Ulwe Bunder] to +18 m and above representing upstream bed levels in the rivers. The total area of domain is about 93 square km.

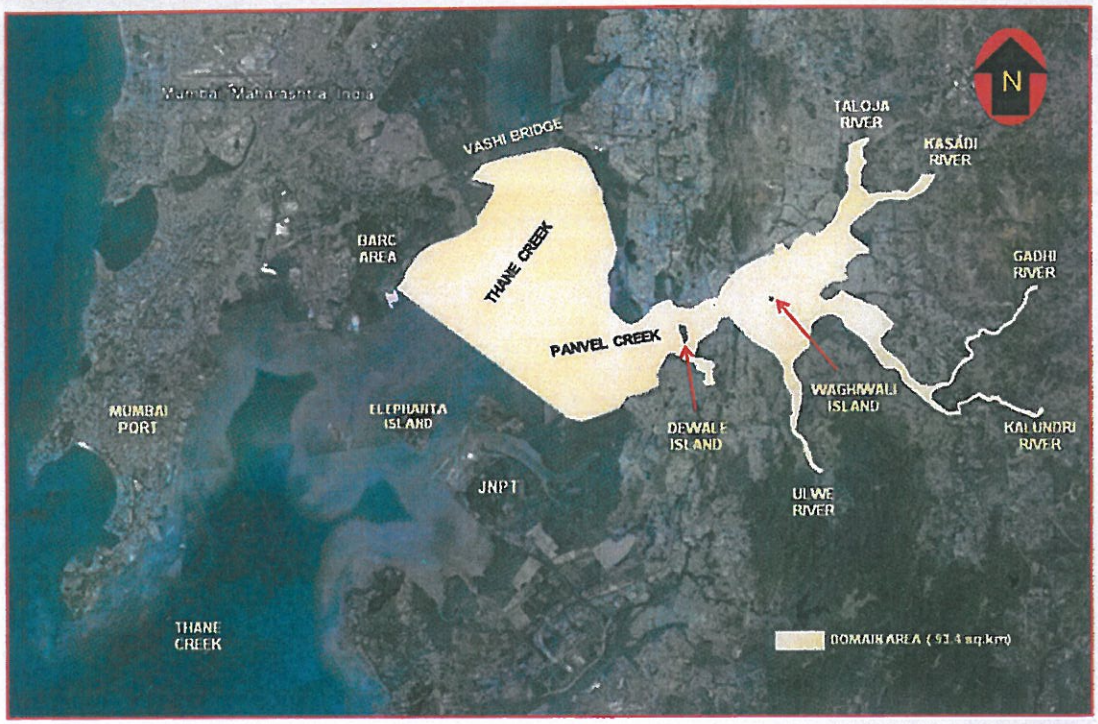

FIG 21: DOMAIN AREA CONSIDERED FOR MODEL STUDIES OF AIRPORT

The bathymetry levels in the domain area considered for reproducing the bed levels in the model area under consideration are shown in FIG.22.

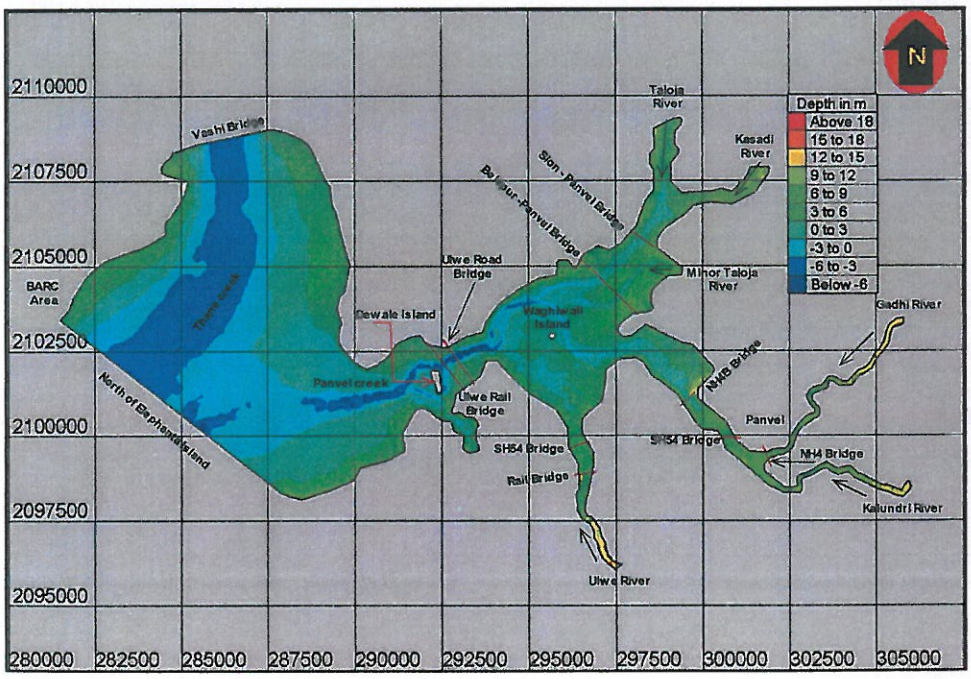

FIG 22: BATHYMETRY MAP OF MATHEMATICAL MODEL FOR THE EXISTING CONDITION (WITHOUT AIRPORT)

The simulation of about 93 sq.km area for the hydrodynamic study was essential to cover the locations of calibration and validation points as well as to determine water levels at various locations around the proposed international airport. It also includes various existing/proposed bridges. The entire domain area is descritised using triangular finite element mesh. The finite elements with fine resolution near shoreline of islands/banks/coastline and bridge piers are used for better simulation of steep slopes, while the relatively deeper areas and tidal flats are simulated with coarser elements. Thus mesh generated can effectively reproduce hydrodynamic conditions without compromising on the quality of results. The variable element size scheme adopted to schematize the deeper channels of rivers, deeper depths in Thane Creek and land boundaries is shown in FIG. 23. The interpolated depths were assigned at nodal points of finite element to represent the depths and solve hydrodynamic equations in terms of water depth and velocity.

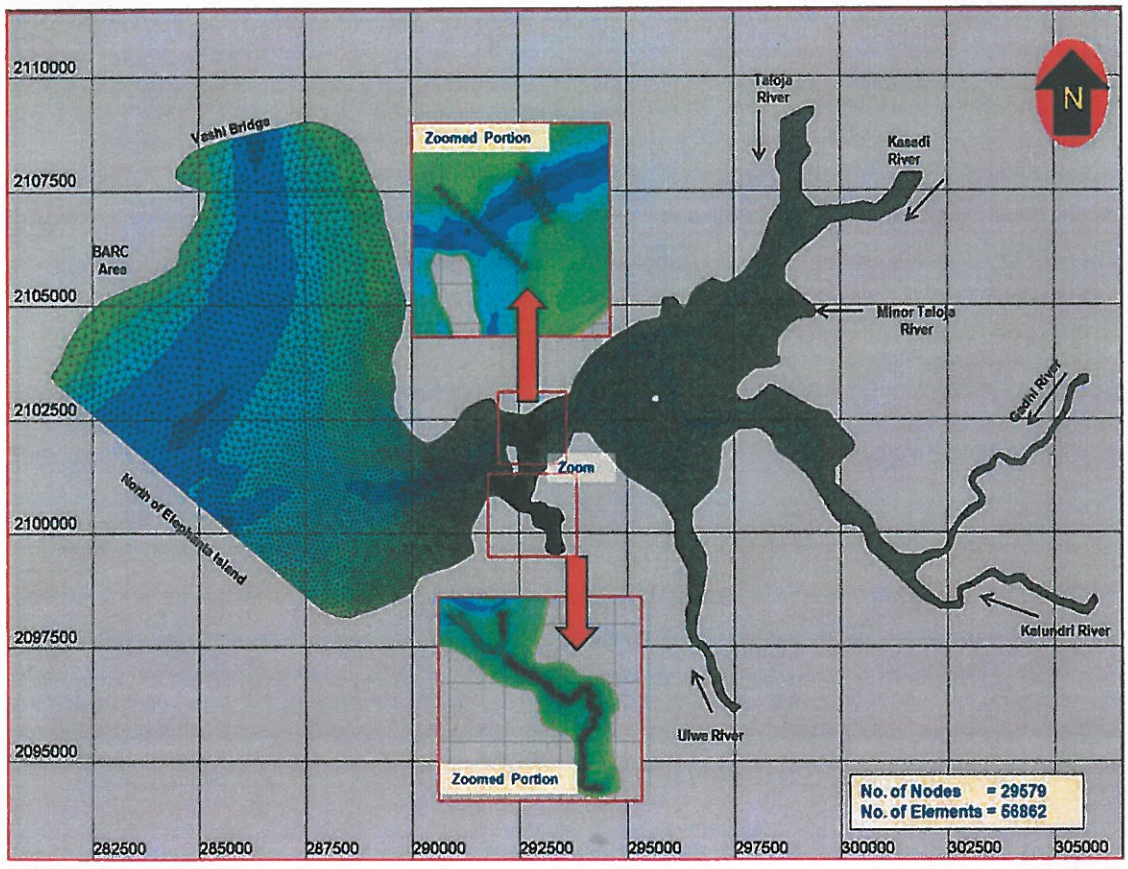

FIG 23: FINITE ELEMENT MESH DESCRITISATION FOR THE EXISTING CONDITION FOR AIRPORT STUDIES

The highest High Water level recorded at Apollo Bunder was 5.40 m (w.r.t CD of Apollo Bundar) and considering the fact that Panvel creek being a sub-creek of

Thane creek, situated at about 20 Kms inside from the Apollo Bunder, amplification of tide i.e. rise in HWL of about 0.3 m is expected during highest spring tide. Hence spring tide with high water level of 6.2 m (w.r.t CD of Ulwe Bundar) was kept as downstream boundary condition. The Natu committee report of CIDCO has also recommended highest HWL of 3.25 m (6.2 m w.r.t CD of Ulwe Bundar) for design. Hence model studies using Telemac-2D software are carried out for the modified layout of the airport ,with Spring tide as design tide (with HWL= 6.2 m and LWL= 0.94 m w.r.t CD at Ulwe Bundar). For validation of model the flood of 26th July 2005 being the worst flood scenario occurred in this region for which water levels observed/marked at various locations were available and as such it was considered. The model studies were carried out based on scope of work with the following conditions:

1) Spring tide near MDL jetty as downstream boundary condition and no flood discharge at upstream boundaries under the existing conditions (without the airport).
2) Spring tide near MDL jetty as downstream boundary condition and no flood discharge at upstream boundaries with the airport.
3) Spring tide near MDL jetty as downstream boundary and flood hydrograph of 6 hours storm of 100 year return period with peak arriving at the time of HWL as upstream boundary condition under the existing condition (without the airport).
4) Spring tide near MDL jetty as downstream boundary and flood hydrograph of 6 hours storm of 100 year return period with peak arriving at the time of HWL as upstream boundary condition with the airport and Ulwe river diversion channel having width of 120 m.
5) Spring tide near MDL jetty as downstream boundary and flood hydrograph of 6 hours storm of PMP with peak arriving at the time of HWL as upstream boundary condition under the existing condition (without the airport).
6) Spring tide near MDL jetty as above as downstream boundary and flood hydrograph of 6 hours storm of PMP with peak arriving at the time of HWL as upstream boundary condition with the airport and Ulwe river diversion channel having width of 120 m (with the existing bathymetry of Moha Creek & Moha Creek deepened to 1.0 m w.r.t CD of Ulwe Bunder).
7) The studies for northern channel with bed level as upstream bed level of Gadhi River at RL= -1m and RL= -2m with upstream boundary condition of

river discharges (flood hydrograph) of 6 hours storm for PMP and 6 hours of storm of 100 year return period with airport & Ulwe river diversion channel of 120m width.

8) The studies at Sr. 3 to 7 with 26th July 2005 case as boundary condition for river discharges were also considered as additional studies.

8.2 Calibration of Model

The oceanographic data collected as mentioned in para '6' (Analysis of tidal data) were used to derive open (liquid) boundary conditions. The data on current at an intermediate location in Ulwe Bunder area and water levels recorded at various locations in domain area were considered as 'Calibration Points' and are used for calibrating the mathematical model. The model has, in all total seven liquid boundaries consisting of two boundaries for simulating tidal flow and five boundaries representing upstream end of five rivers as shown in FIG 24.The measured tidal variation at MDL jetty location was considered as input boundary.

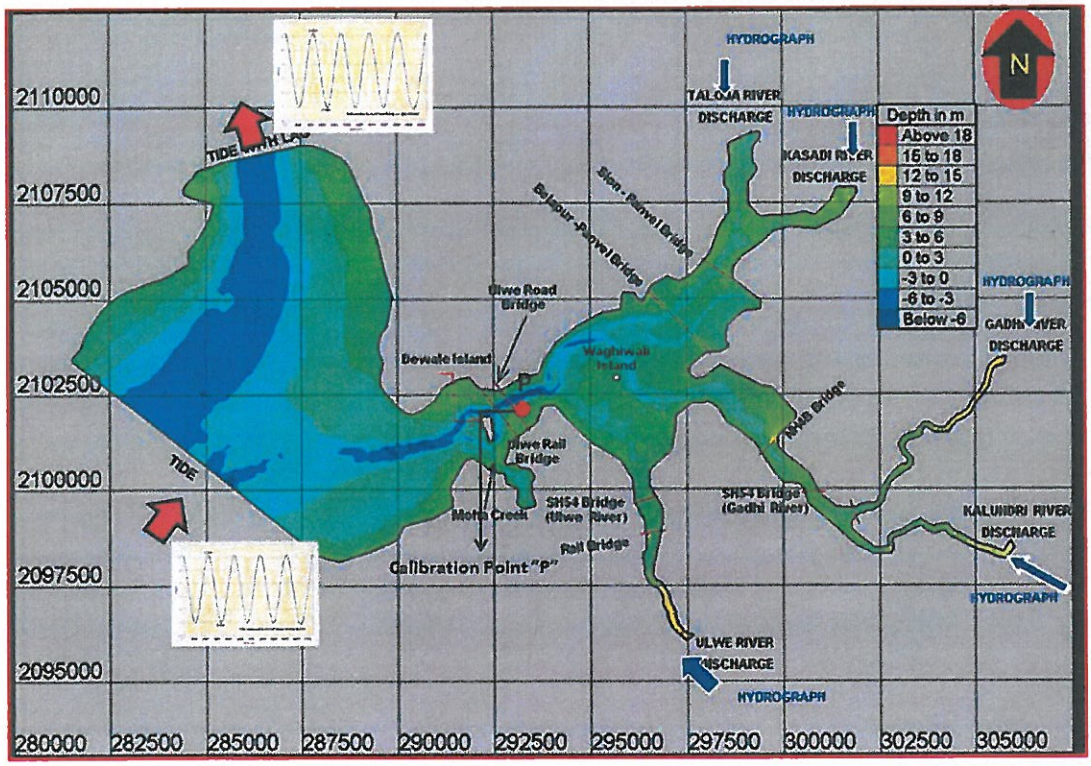

FIG 24: BOUNDARY CONDITIONS CONSIDERED FOR SIMULATING TIDE AND RIVER DISCHRGES FOR AIRPORT STUIDES

In order to represent appropriate roughness for variety of river bed condition, roughness values for different channels were adopted as per previous airport studies

carried out at CWPRS. These values are different in different region and its spatial variation is adopted and they are given in Table-4 :

Table-4
Bottom friction factors considered for model studies

Reach	Manning's roughness value
Kasadi River	0.033
Taloja River	0.030
Taloja Creek downstream of Sion – Panvel road bridge	0.030
Channels around Waghiwali island and reach downstream of Ulwe bridge	0.025
Gadhi River upstream of NH4 bridge	0.033 to 0.035
Kalundri River upstream of Gadhi confluence	0.033
Gadhi river from Kalundri confluence to Waghiwali island	0.030 to 0.033
Ulwe River	0.030

A semidiurnal tide, corresponding to the tide measured at MDL jetty was used as a prescribed input at open boundary near MDL and with a phase lag at Vashi bridge. As the data was collected during non-monsoon period while calibrating the model, discharges from all the five rivers are considered as nil for upstream boundaries. The narrow entrance of a Panvel Creek at Belapur-Ulwe Road Bridge is a controlling parameter for prevailing flow hydrodynamics, in and out of Panvel Creek. The water levels and currents were measured at Ulwe Bunder site at Panvel Creek entrance, which is considered as Calibration point for simulating the flow/ hydrodynamic conditions for the mathematical model. The comparison is shown in FIG 25(A) and 25(B).

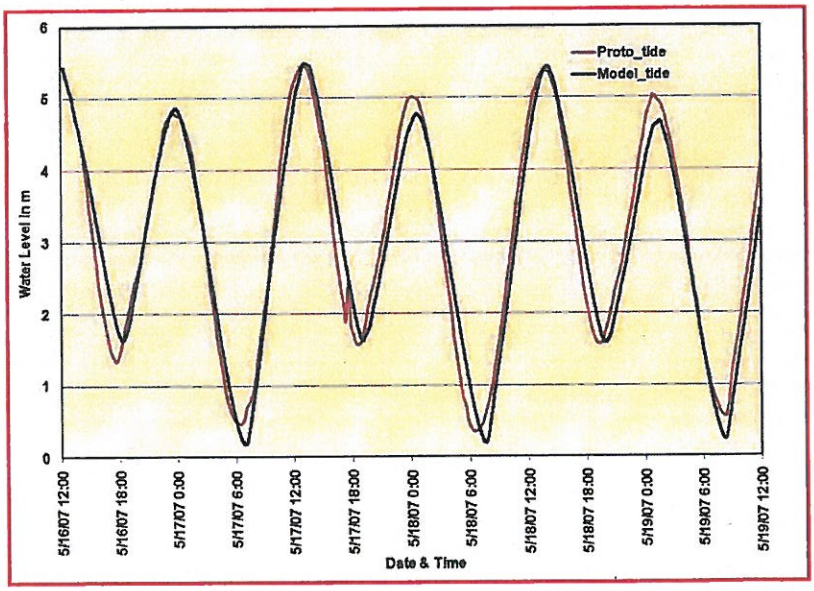

FIG 25(A): COMPARISON OF SPRING TIDE CALIBRATED AT ULWE BUNDER

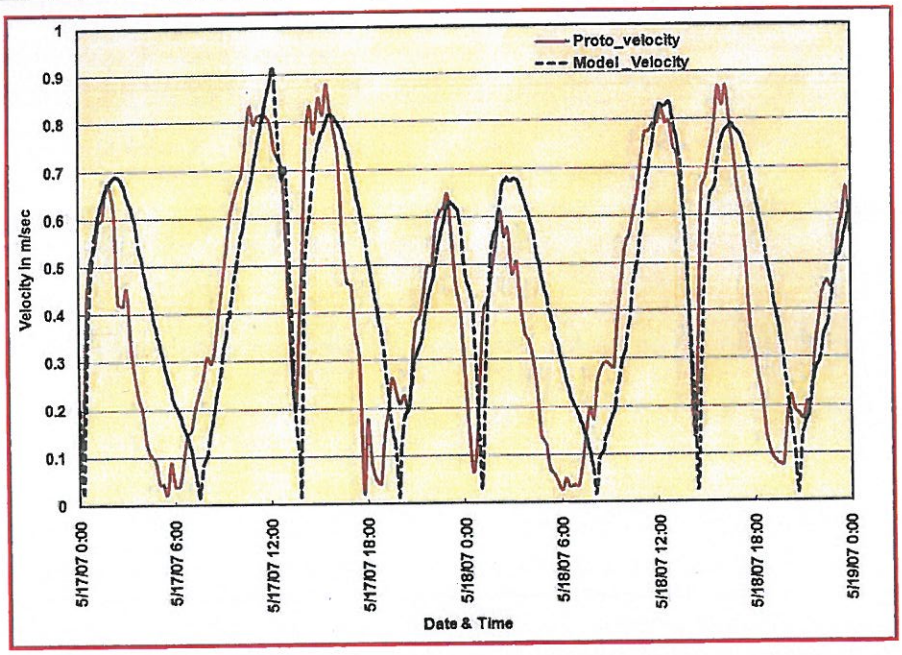

FIG 25(B): COMPARISON OF CURRENT CALIBRATED AT ULWE BUNDER

The plot of tide and current calibrated at Ulwe bunder shows reasonably acceptable match, with the actual water levels and currents at Ulwe Bunder. The water levels measured at various locations namely at Ulwe Rail bridge, Kharghar etc are also compared and are shown in FIG 26 and FIG 27.

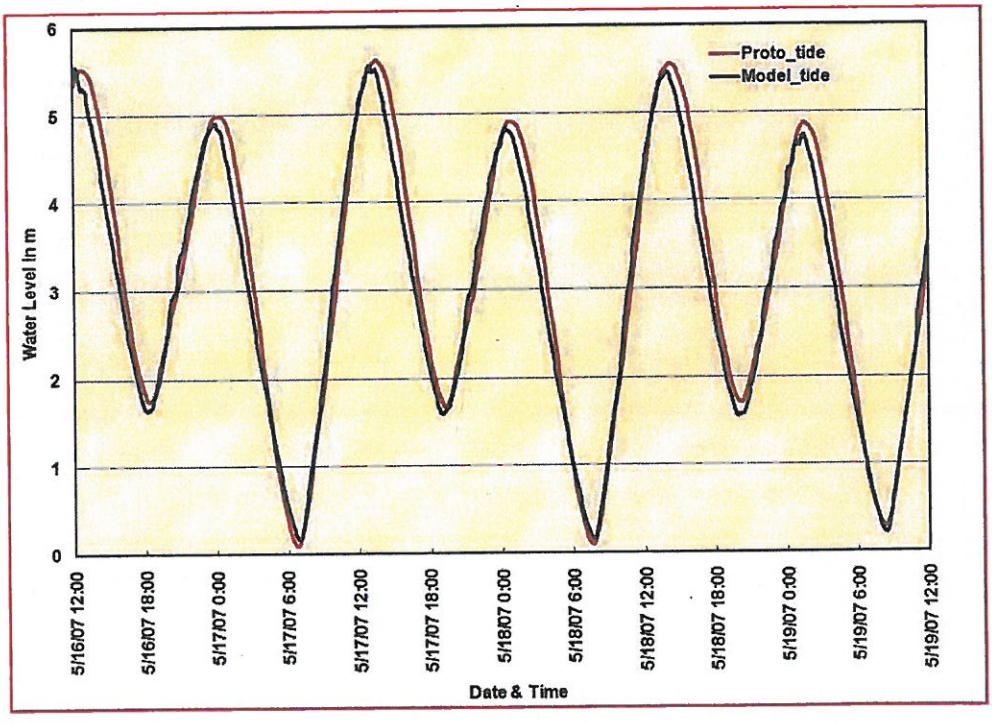

FIG 26: COMPARISON OF SPRING TIDE CALIBRATED AT ULWE RAILWAY BRIDGE

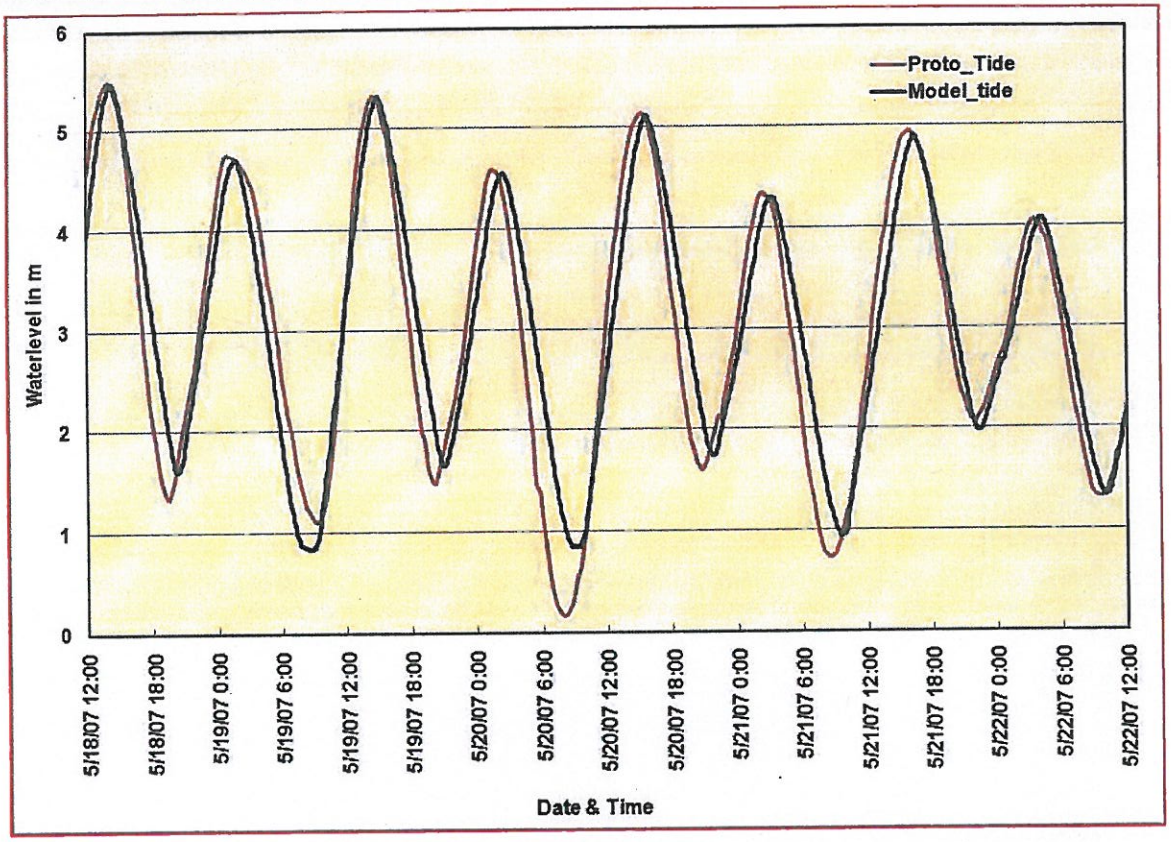

FIG 27: COMPARISON OF SPRING TIDE CALIBRATED AT KHARGAR

The flow patterns observed during flood tide and ebb tide for typical tidal cycle considered for calibrating the hydrodynamic model of airport are shown in FIGS 28(A) and 28(B).

The comparison of water level and velocity at various locations indicate that, the model is reasonably well calibrated and as such is used for the validation. On confirmation of water levels predicted from model and that observed at site for validation case, as described in para 8.3, the model is used for prediction of maxima water levels and velocities at various location for the existing as well as modified layout of the airport. The studies carried out and the results are described in para. 9.

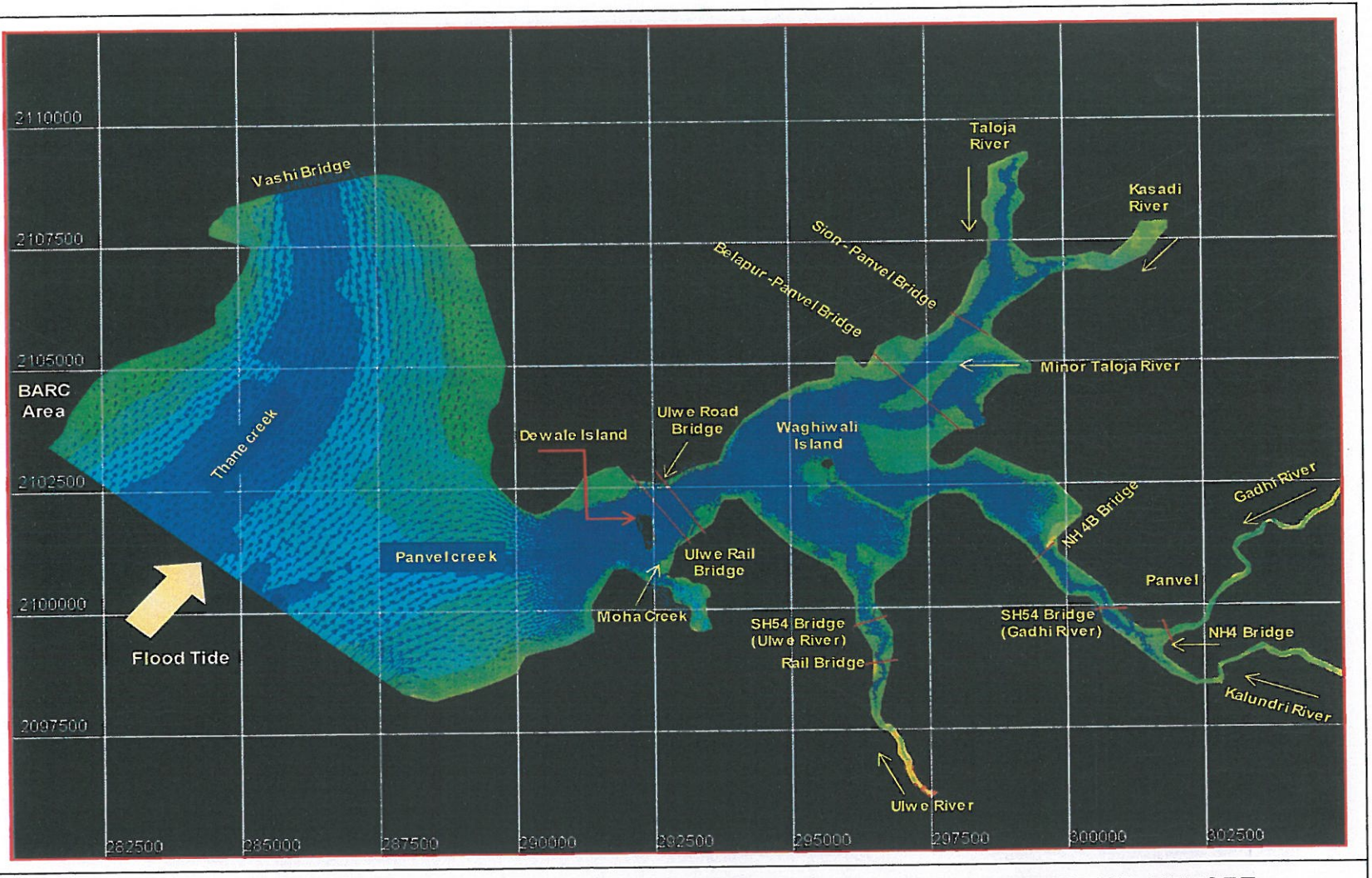

FIG 28(A): TYPICAL FLOW PATTERN OBSERVED DURING FLOOD TIDE WITHOUT THE AIRPORT (CALIBRATION CONDITION)

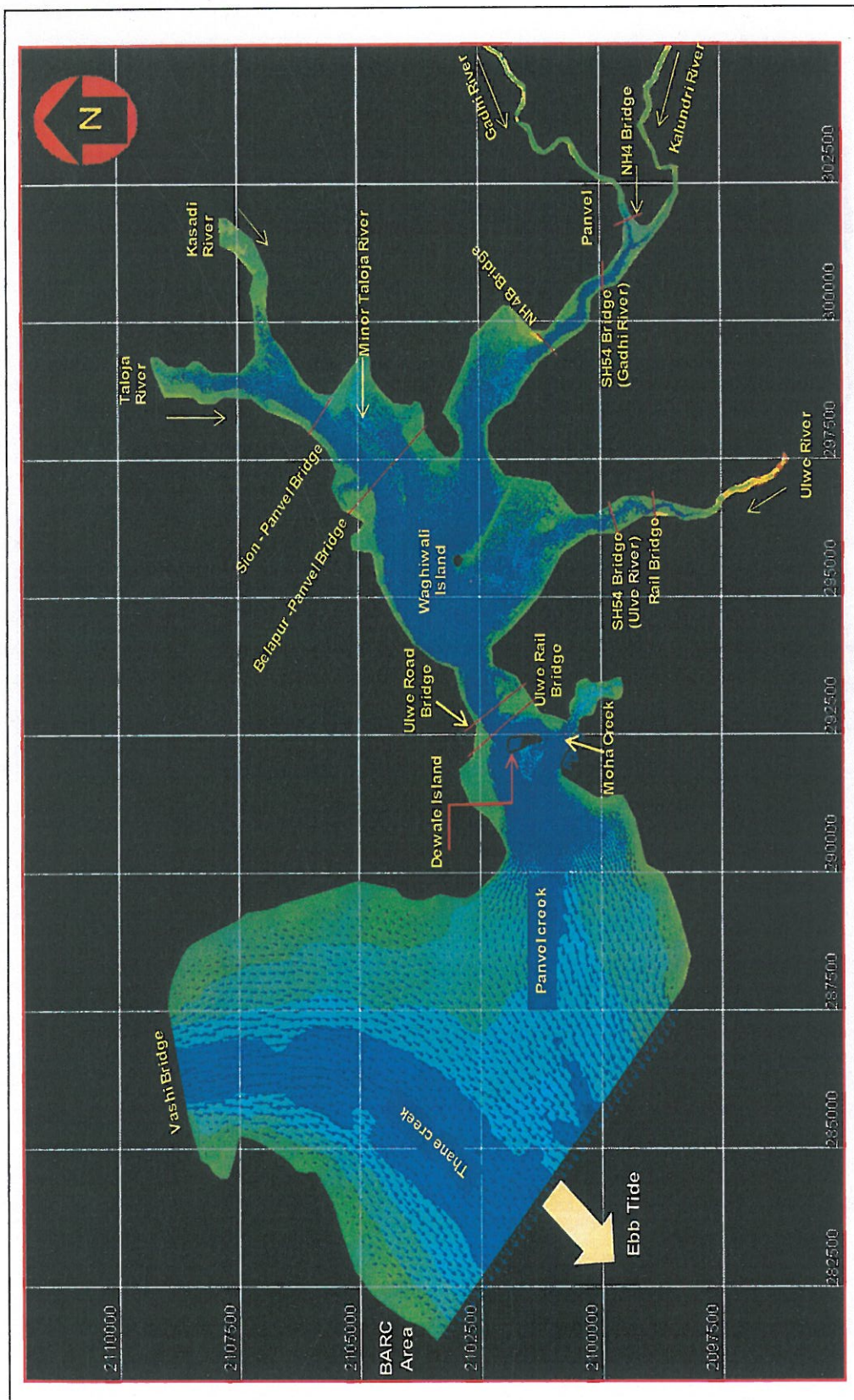

FIG 28(B): TYPICAL FLOW PATTERN OBSERVED DURING EBB TIDE WITHOUT THE AIRPORT (CALIBRATION CONDITION)

8.3 Validation of Model

The flood of 26th July 2005 being the worst flood scenario occurred in this region for which water levels observed/marked at various locations at site were considered for validation of the model. The tidal levels of 26th July 2005 as per tide table as downstream boundary and for flood conditions the hydrograph of 26th July 2005 as discharge from all five rivers as upstream boundary condition were adopted. The various parameters used for calibrating the model such as roughness co-efficient (bed friction), phase lag for tide etc. were also used to run the model for determination of the water levels observed/measured after 26th July 2005 rainfall event in Panvel creek area. The plot of water levels measured at site and predicted from model studies (Fig 29) reveal good agreement and hence model is validated and is used to estimate the water levels around modified layout of the Airport.

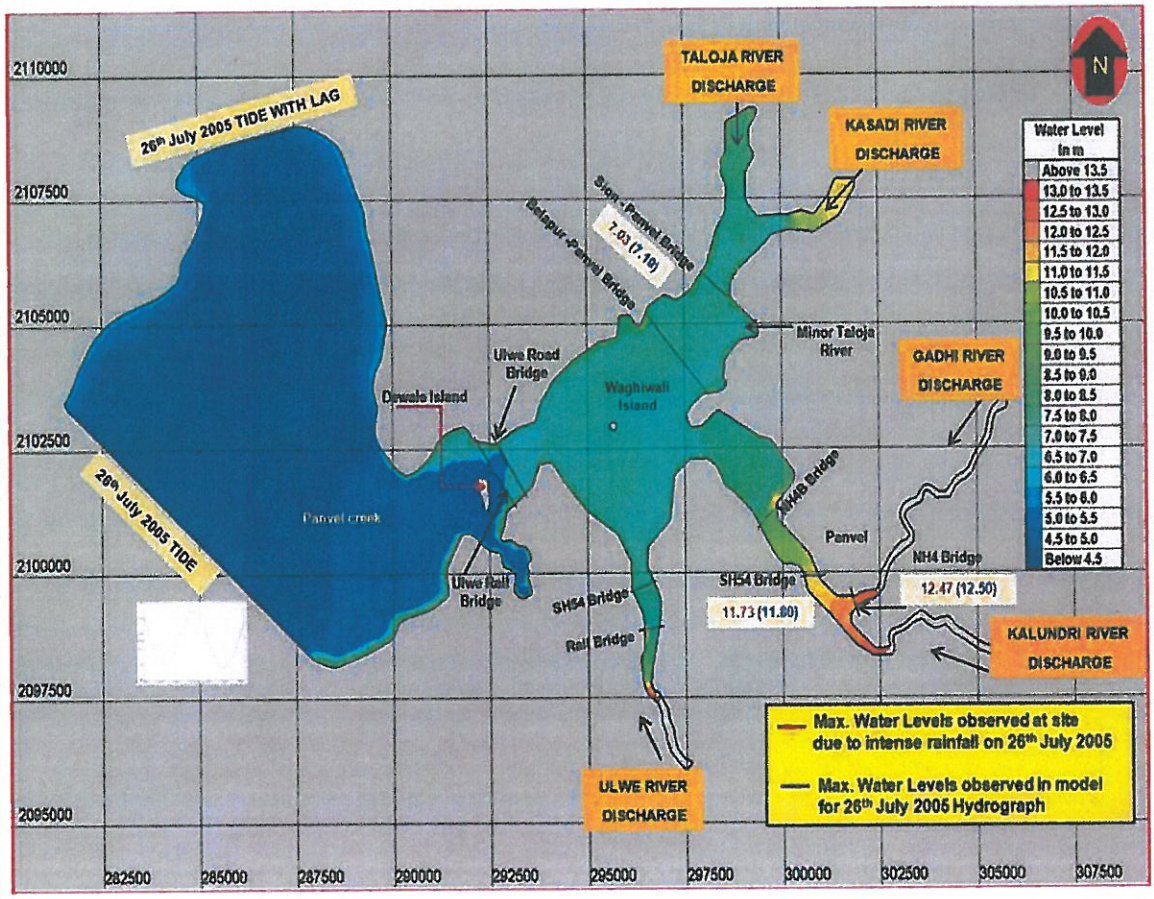

FIG 29: COMPARISON OF WATER LEVELS OBSERVED AT SITE AND IN MODEL DURING 26TH JULY 2005 EXTREME RAINFALL EVENT (VALIDATION)

9.0 MATHEMATICAL MODEL STUDIES WITH & WITHOUT AIRPORT CONDITION

The well calibrated hydrodynamic model was used to take the model runs for design conditions i.e. design tide & river discharges at open boundaries to study flow phenomena & determine maxima water levels at various locations in Panvel Creek.

The mathematical model studies carried out for the existing condition (without airport) as well as with the airport under design tide (spring) condition and with/without river discharges are described below:

The studies were carried out for design tide as seaward boundary condition with high tide level at 6.19 m (≈ 6.20 m) and low tide level at 0.94m at MDL jetty (FIG 30). This tide is considered for determination of maxima water levels in Panvel Creek area. This condition is taken from CWPRS Tech. Report No. 4665 of October 2009, wherein high tide level is considered as 3.25 m w.r.t GTS.

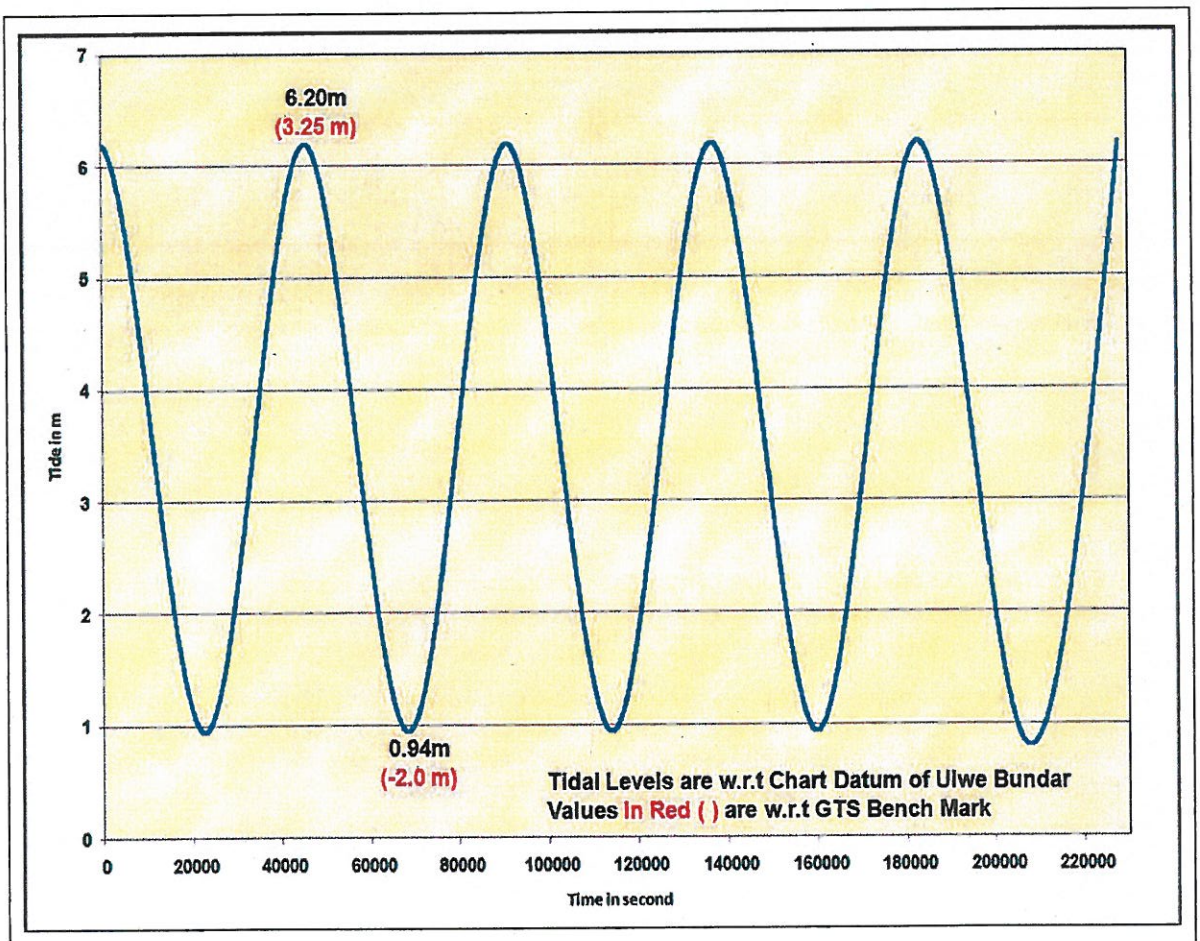

FIG 30: DESIGN TIDE CONSIDERED FOR SIMULATION OF TIDAL PROPAGATION

9.1 Studies for the Existing Condition (Without Airport)

9.1.1 Studies with spring tide and No River Discharges

The studies were carried out by applying design tide as downstream boundary condition with no river discharges as upstream boundary condition. The maxima water levels at various locations are predicted and the results are given in FIG. 31.

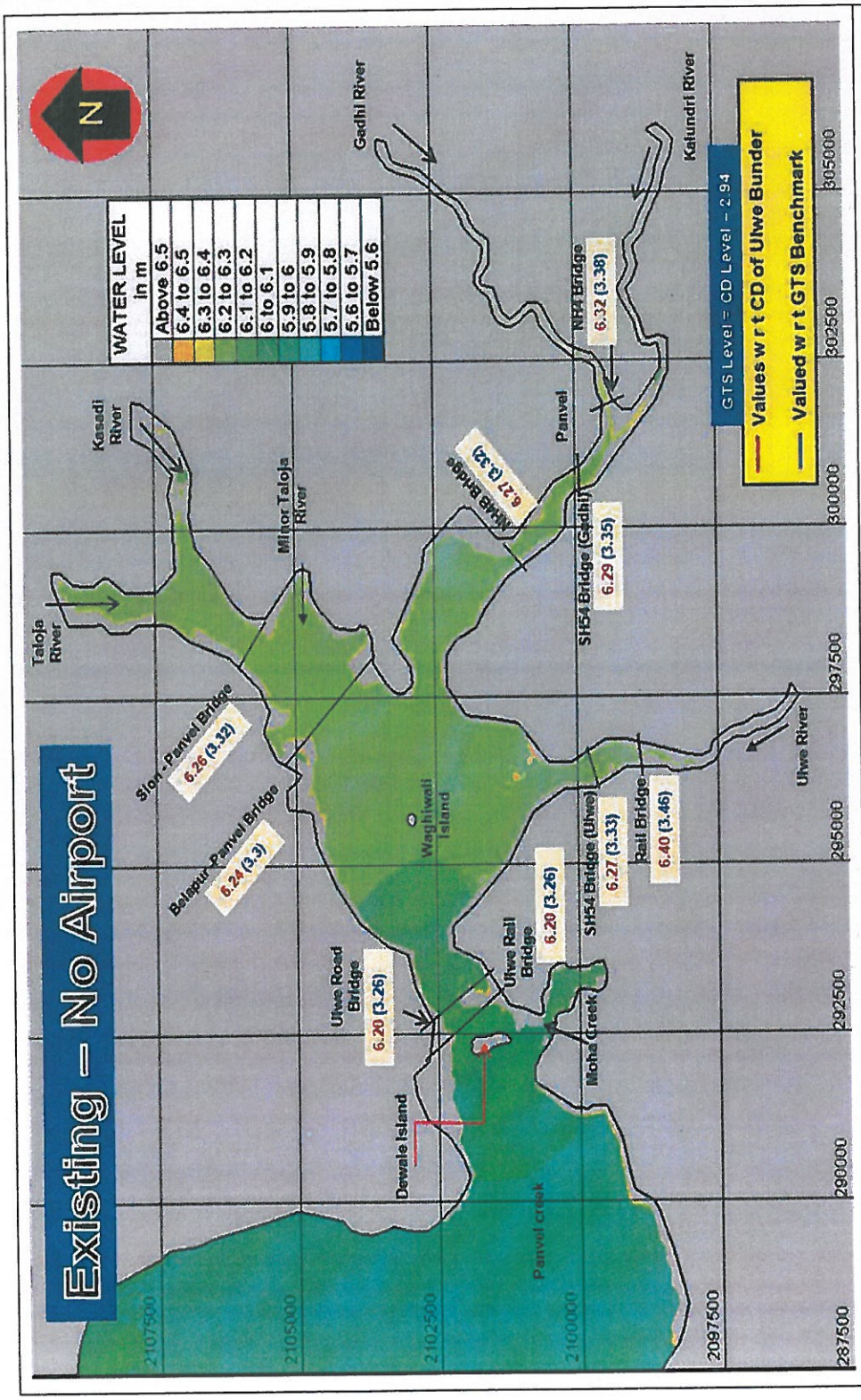

FIG 31: MAXIMA WATER LEVELS AT VARIOUS LOCATIONS FOR DESIGN TIDE AND NO RIVER DISCHRGES FOR EXISTING CONDITION (WITHOUT AIRPORT)

9.1.2 Studies with spring tide and River Discharges (Hydrograph for 100 Year RP, 6Hrs rainfall)

The studies with spring tide at MDL jetty and river discharges from all major five rivers simulated as hydrographs for 100 year RP; 6 Hrs rainfall for the existing condition were carried out. The typical flow pattern observed during flood and ebb tide are shown in FIGs 32 and 33.

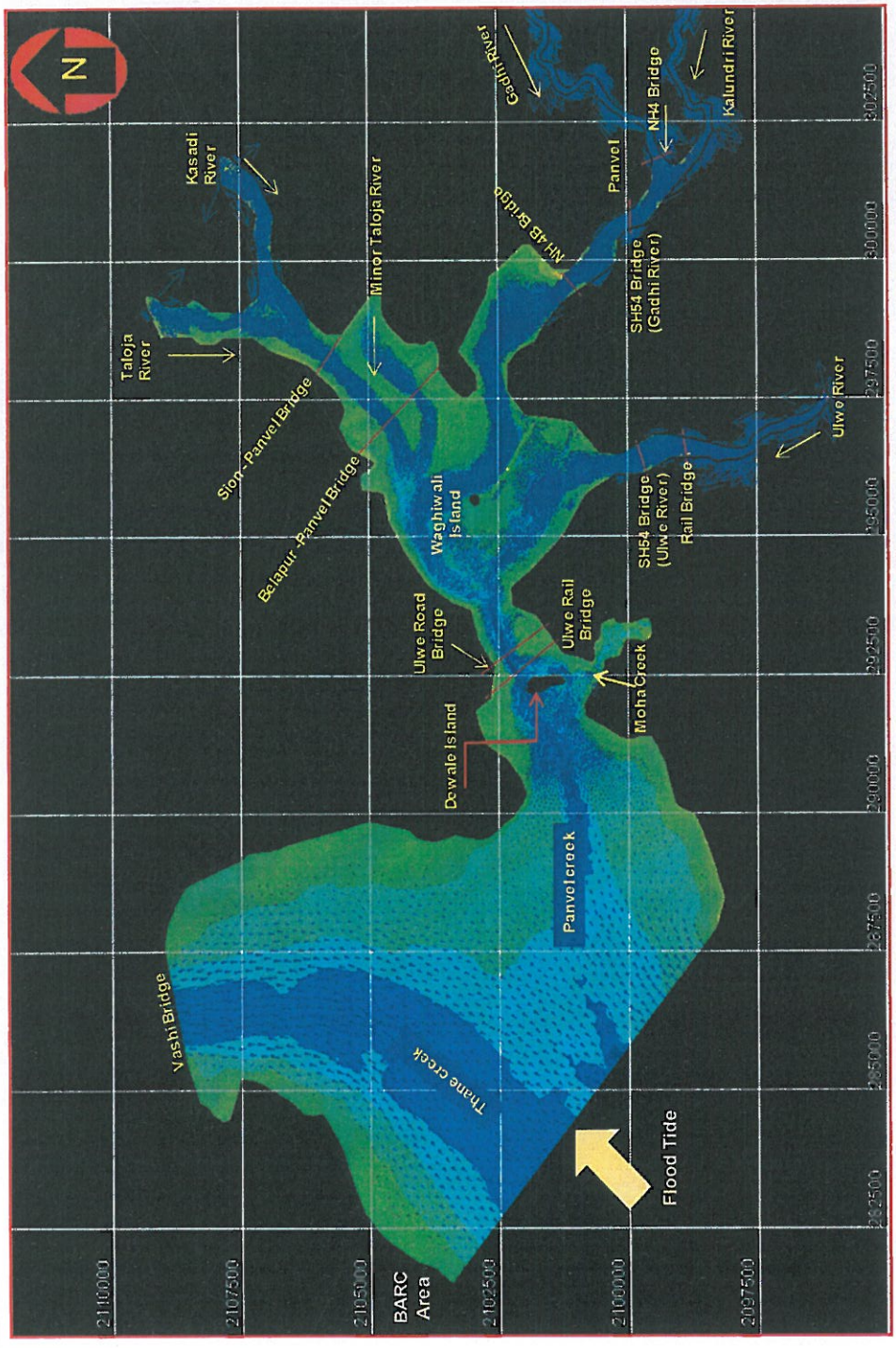

FIG 32: TYPICAL FLOW PATTERN OBSERVED DURING FLOOD TIDE AND 100 year, 6 Hrs RIVER DISCHRGES FOR EXISTING CONDITION (WITHOUT AIRPORT)

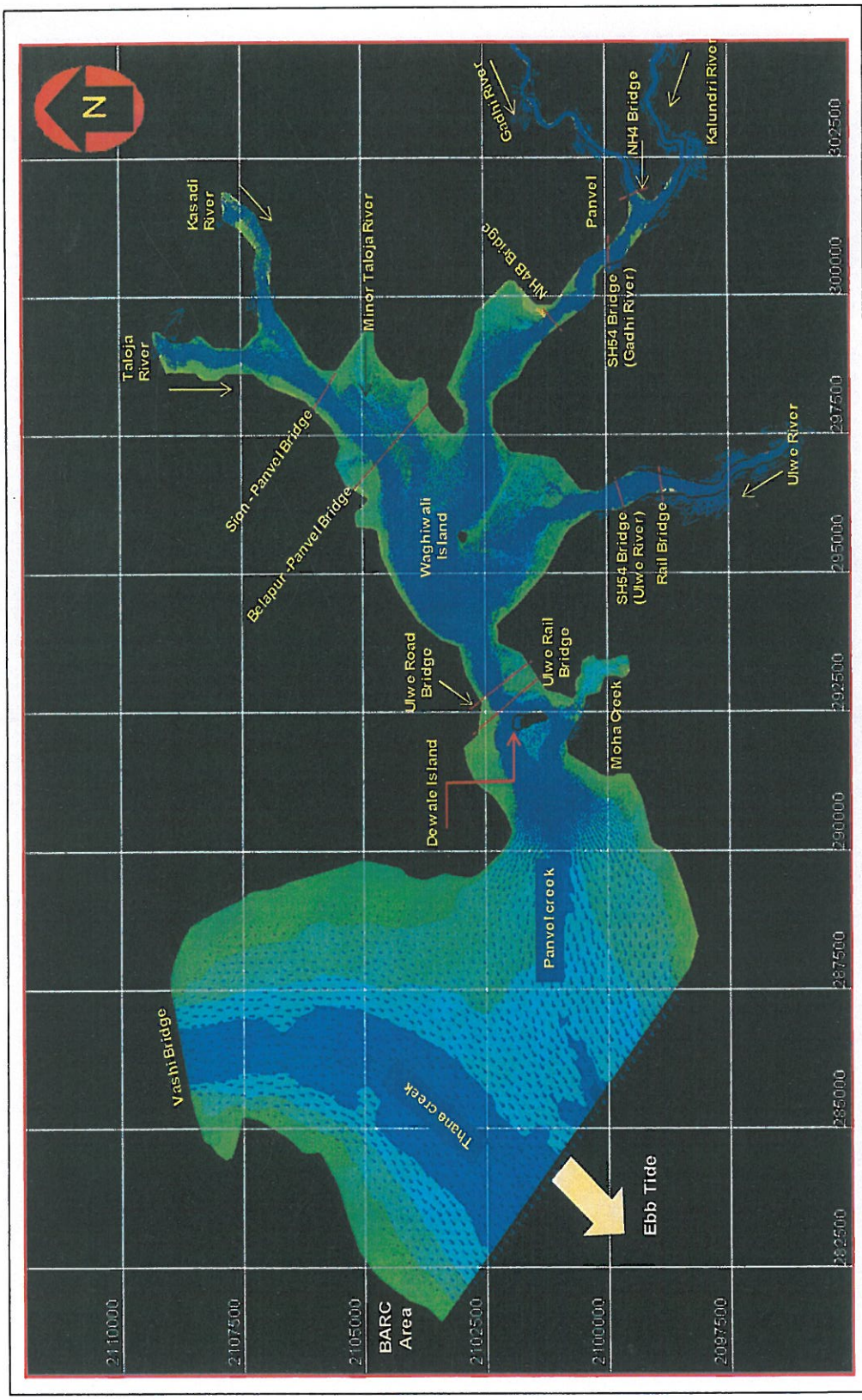

FIG 33: TYPICAL FLOW PATTERN OBSERVED DURING EBB TIDE AND 100 year, 6 Hrs RIVER DISCHRGES FOR EXISTING CONDITION (WITHOUT AIRPORT)

The maxima water levels predicted from studies are given in FIG 34.

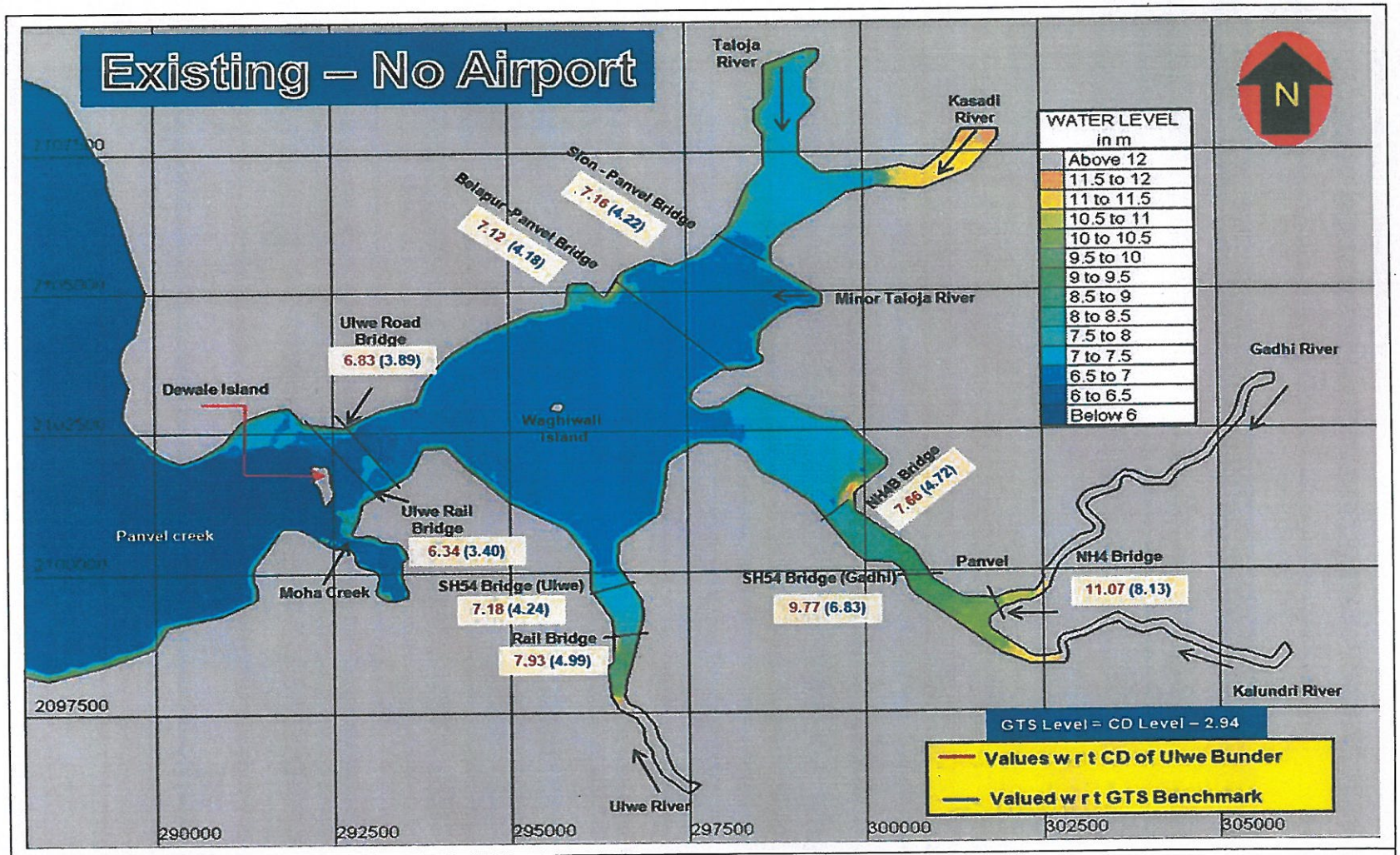

FIG.34: MAXIMA WATER LEVEL OBSERVED DURING DESIGN TIDE AND 100 year, 6 Hrs RIVER DISCHRGES FOR EXISTING CONDITION (WITHOUT AIRPORT)

9.1.3 Studies with spring tide and River Discharges (PMP, 6Hrs and 26th July 2005 extreme rainfall case)

The determination of maxima water levels under river discharges for PMP, 6 Hrs and 26th July 2005 case observed at various locations are given in FIGS 35 & 36.

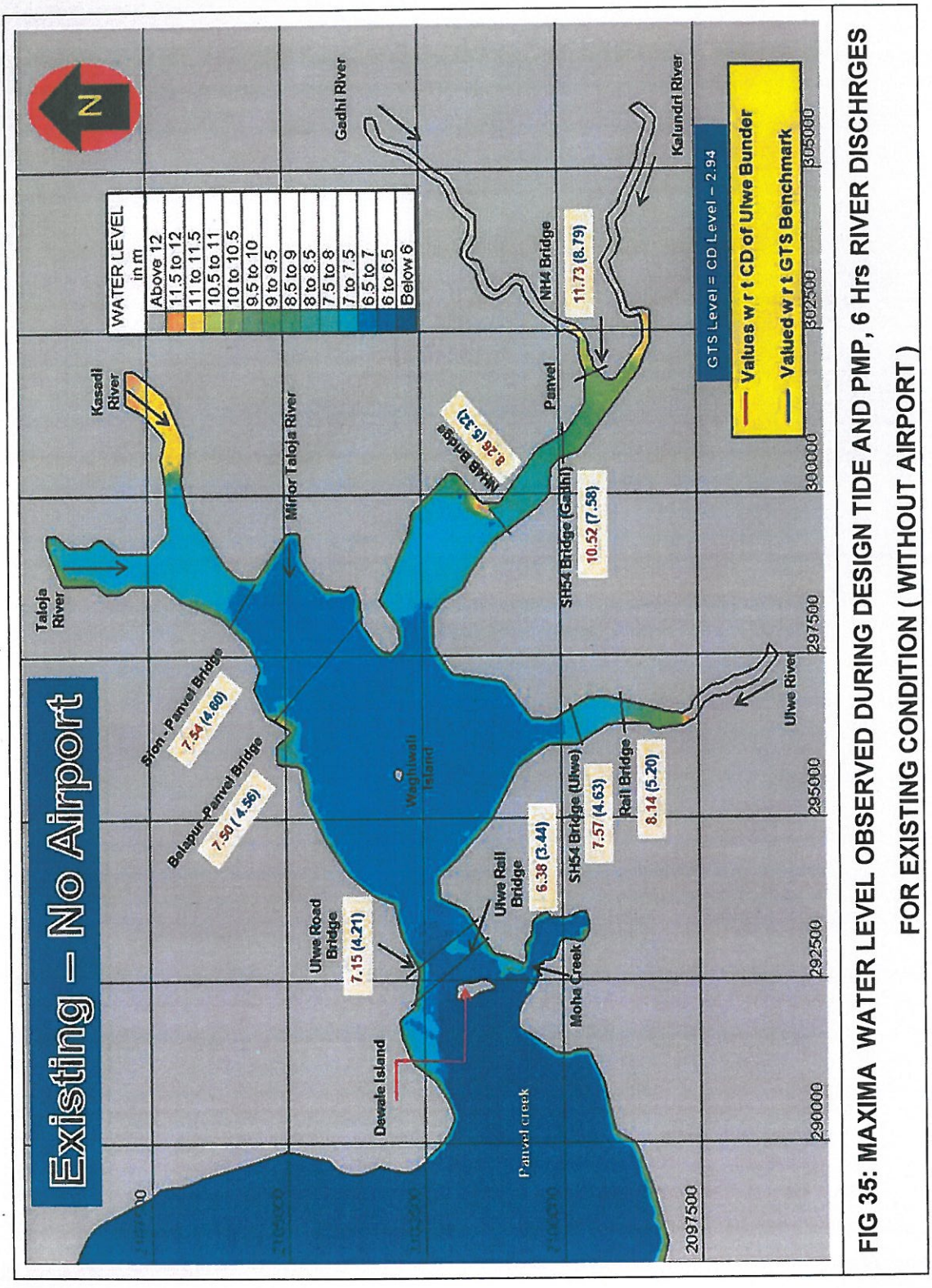

FIG 35: MAXIMA WATER LEVEL OBSERVED DURING DESIGN TIDE AND PMP, 6 Hrs RIVER DISCHRGES FOR EXISTING CONDITION (WITHOUT AIRPORT)

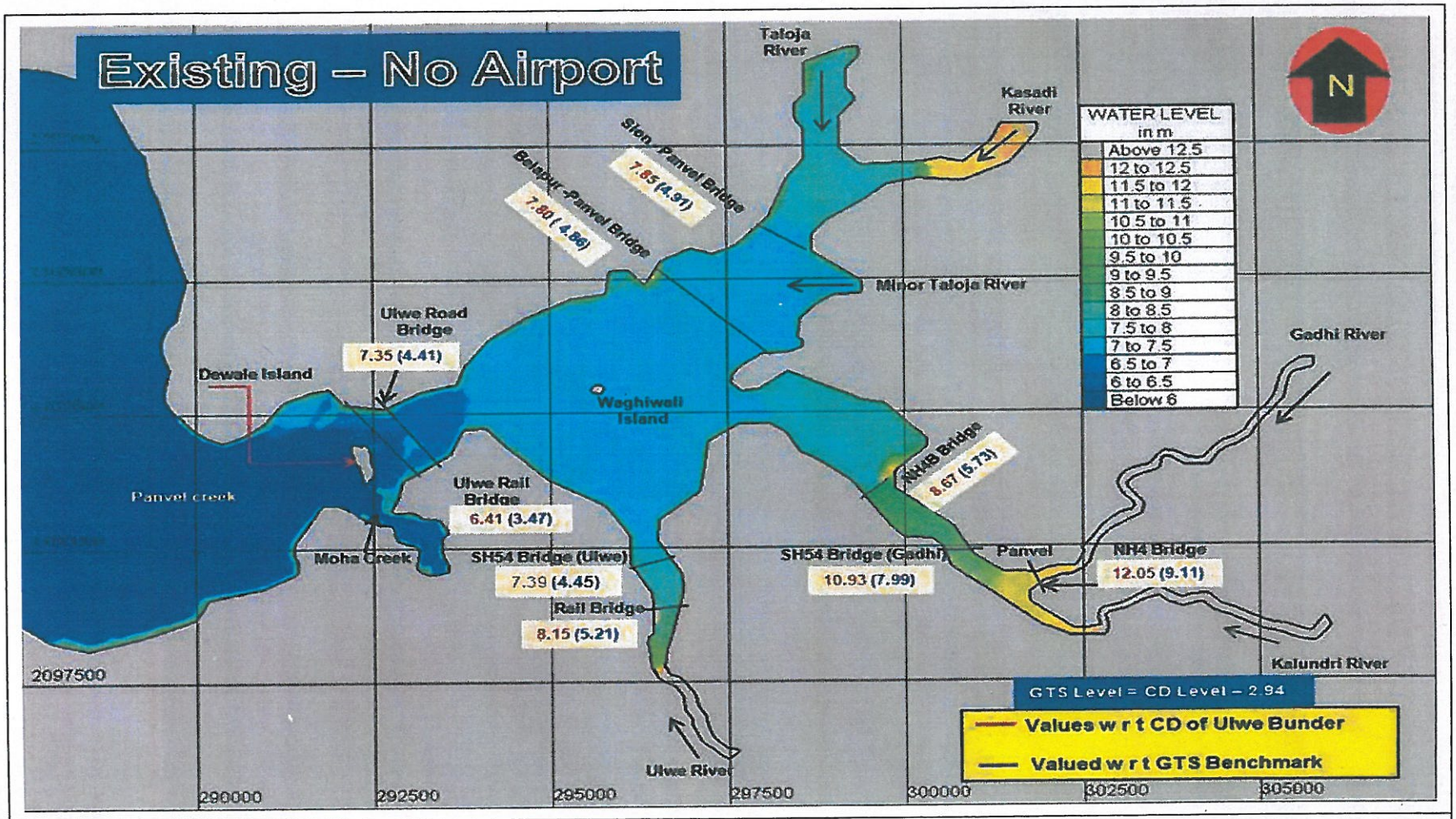

FIG 36: MAXIMA WATER LEVEL OBSERVED DURING DESIGN TIDE AND 26TH JULY 2005 RIVER DISCHRGES FOR EXISTING CONDITION (WITHOUT AIRPORT)

9.2 Studies with modified airport layout

In order to study the effect of the proposed international airport (1160 ha) on the surrounding area and corresponding rise in water level under design tide as well as design tide with hydrographs corresponding to rainfall for 6 hour storm of 100 year return period, PMP & 26 July 2005 are carried out by superimposing the area of the proposed airport on the developed mathematical model. The 120m wide diversion for Ulwe River is also simulated in order to divert the flow from Ulwe River in to Moha Creek and subsequently in to Panvel Creek. The domain area considered for the model and the bathymetry is shown in FIG 37.

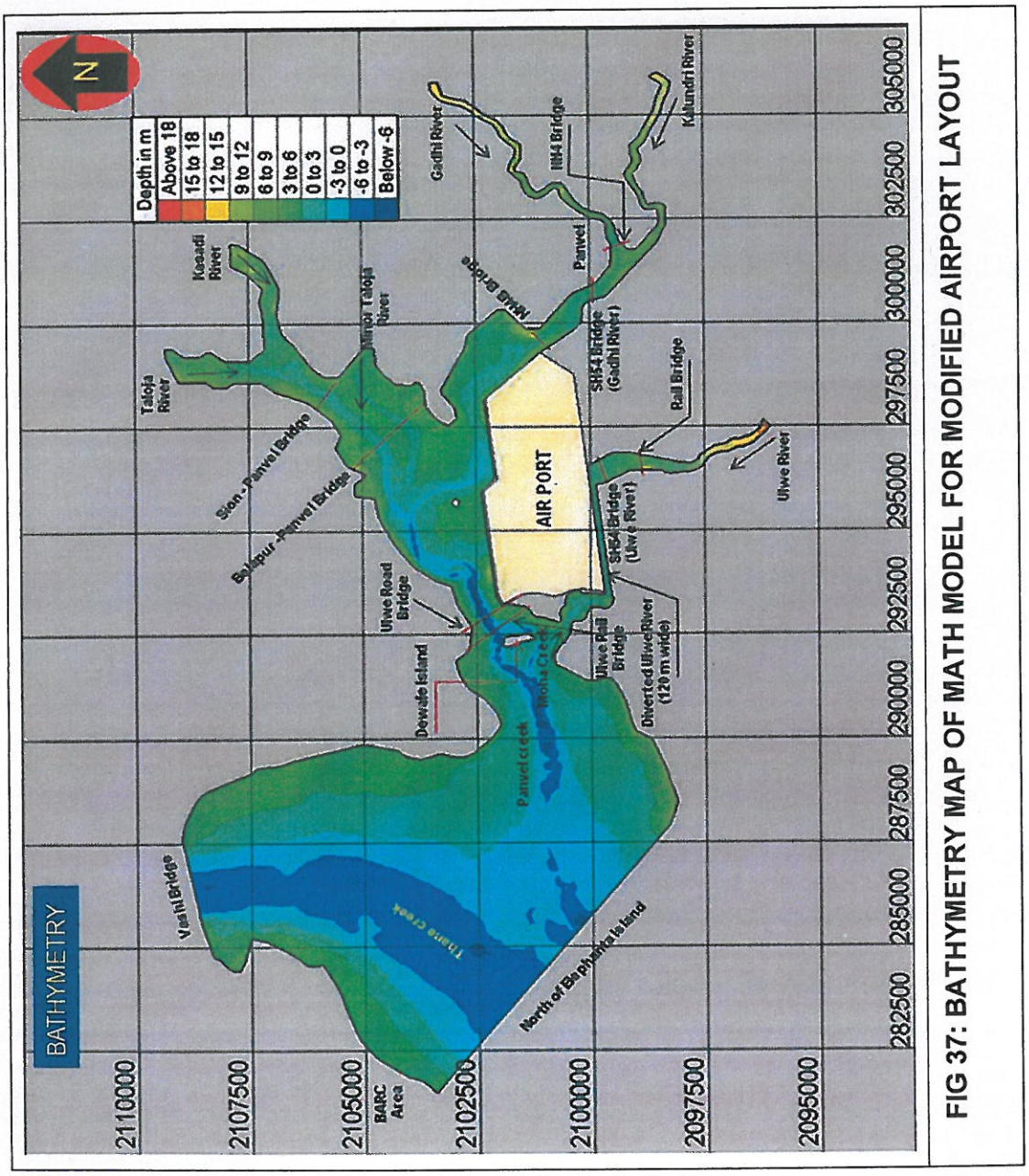

FIG 37: BATHYMETRY MAP OF MATH MODEL FOR MODIFIED AIRPORT LAYOUT

The finite element mesh generated for the modified airport layout is shown in FIG 38.

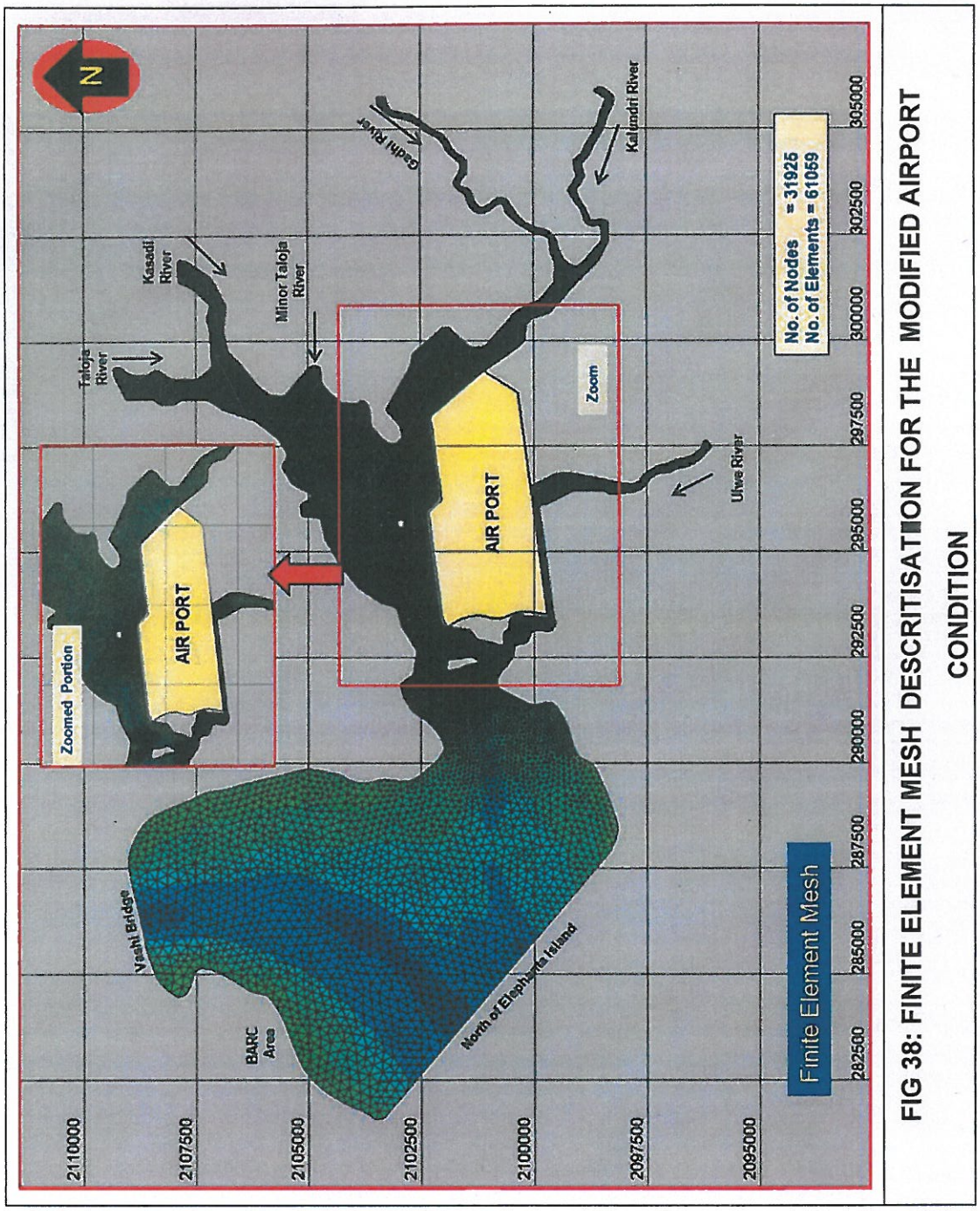

FIG 38: FINITE ELEMENT MESH DESCRITISATION FOR THE MODIFIED AIRPORT CONDITION

9.2.1 Studies with spring tide and no river discharges

The studies for modified airport layout with design tide as boundary condition were carried out to assess impact of the proposed reclamation on the surrounding area. The typical flow pattern observed during design flood and ebb tide with the proposed modified airport layout (without river discharges) are shown in FIGS 39 and 40.

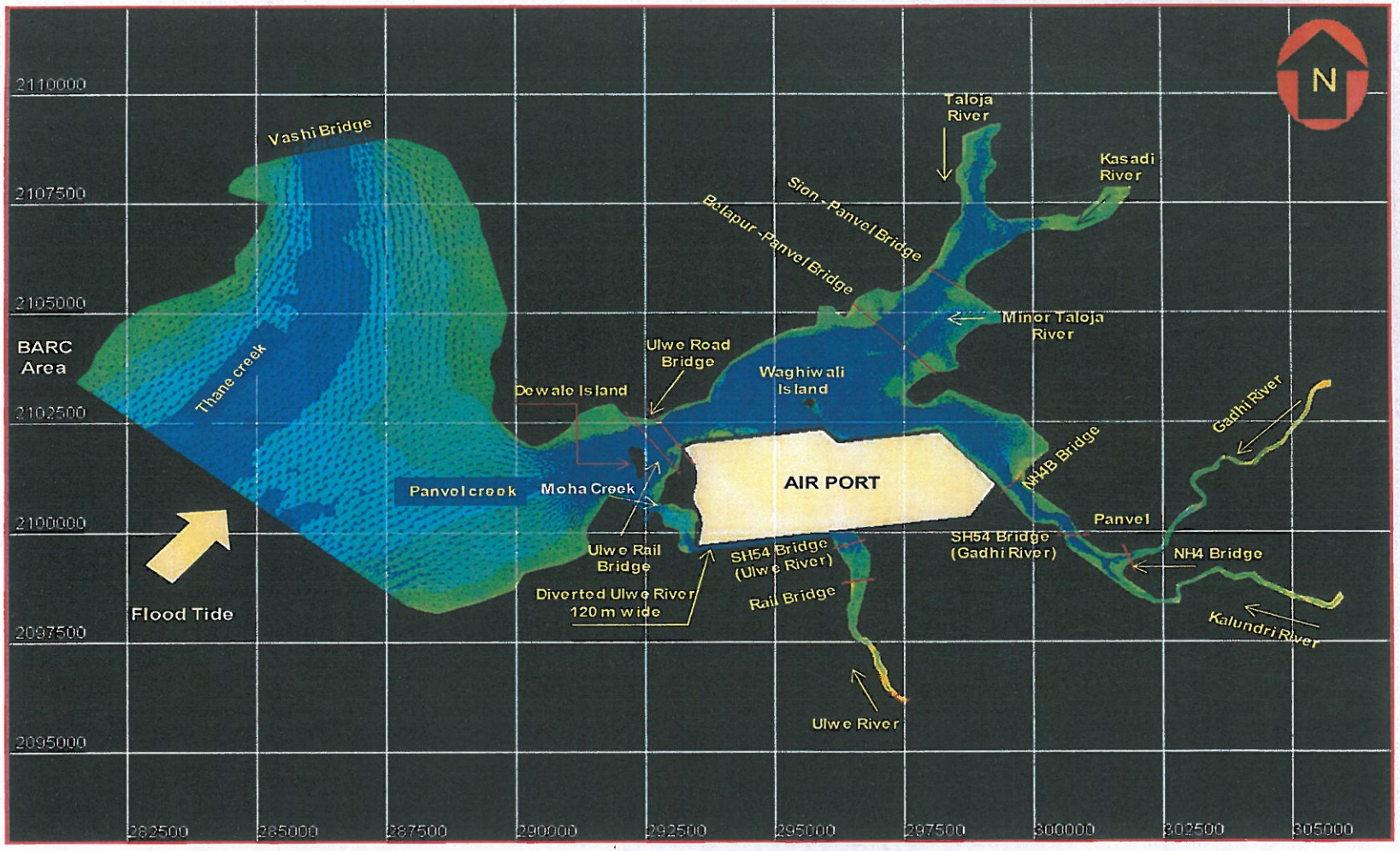

FIG 39: TYPICAL FLOW PATTERN OBSERVED DURING FLOOD TIDE WITH AIRPORT (NO RIVER DISCHARGES)

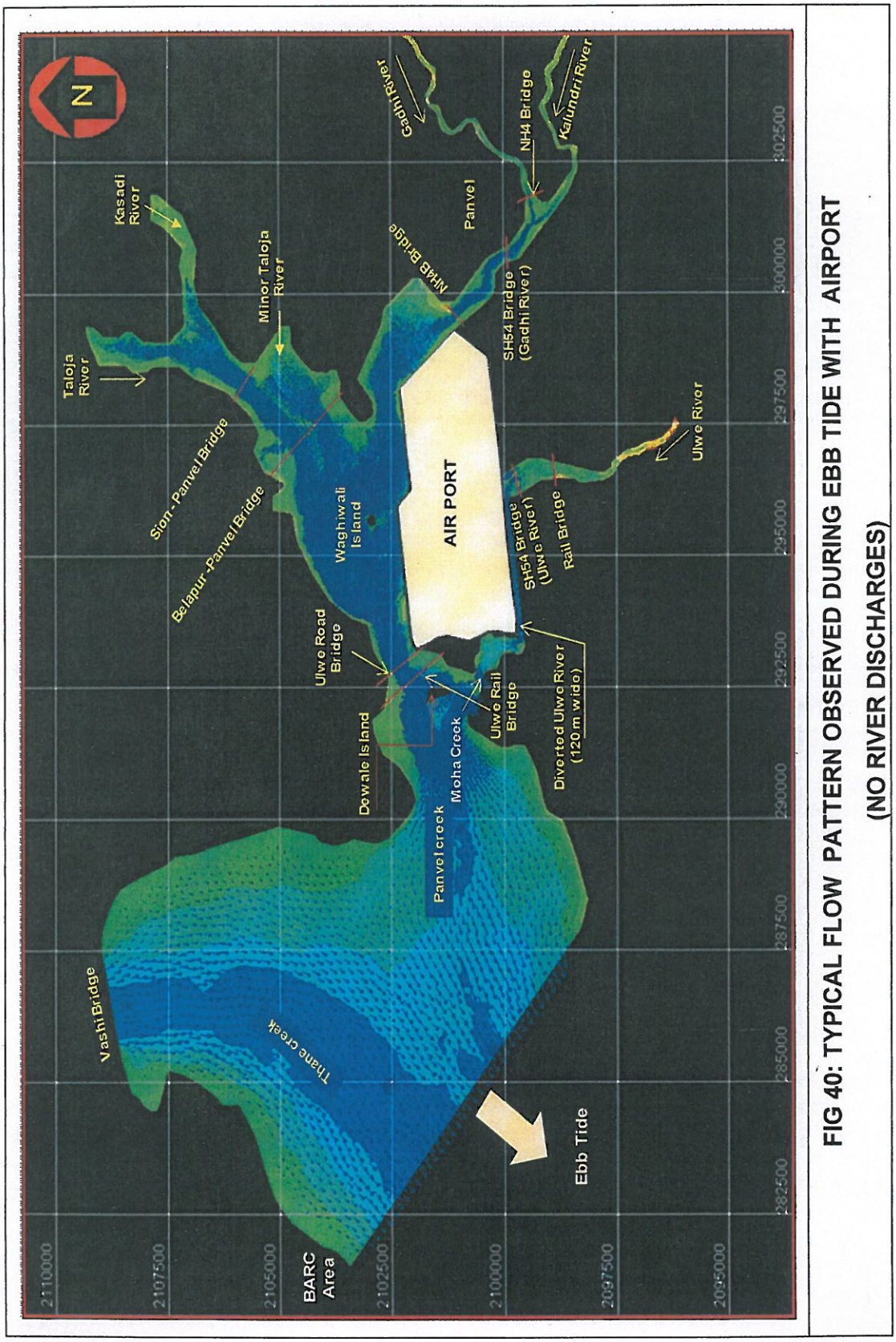

FIG 40: TYPICAL FLOW PATTERN OBSERVED DURING EBB TIDE WITH AIRPORT (NO RIVER DISCHARGES)

The maxima water levels predicted at various locations are shown in FIG 41.

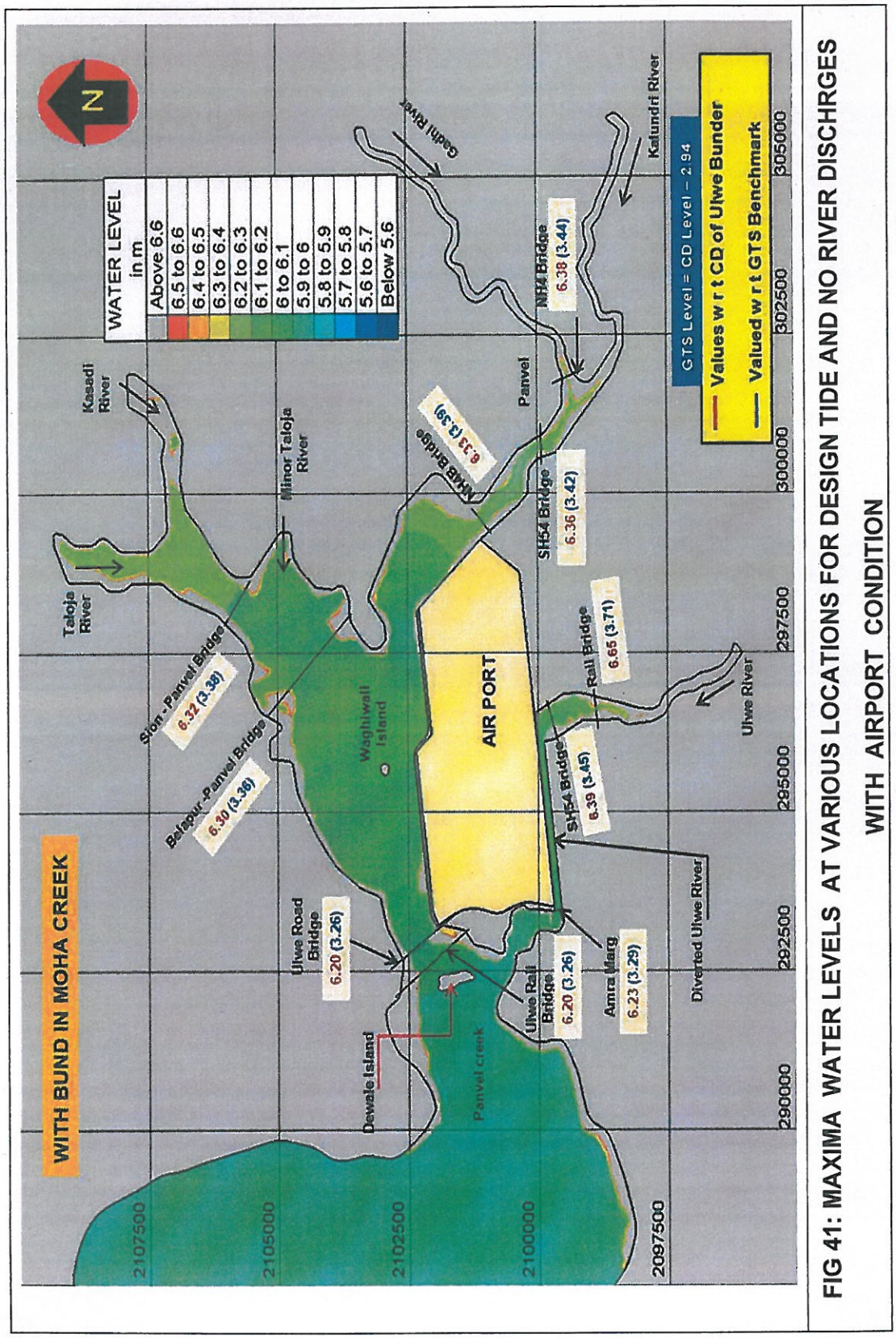

FIG 41: MAXIMA WATER LEVELS AT VARIOUS LOCATIONS FOR DESIGN TIDE AND NO RIVER DISCHRGES WITH AIRPORT CONDITION

9.2.2 Studies with spring tide and River Discharges (Hydrograph for 100 Year- RP rainfall of 6Hrs storm)

The studies for modified layout of airport with 100 year return period, 6 Hrs Hydrograph river discharges from all five rivers were carried out and the typical flow pattern during flood and ebb tide are given in FIG 42 and 43. The maxima water levels are given in FIG 44.

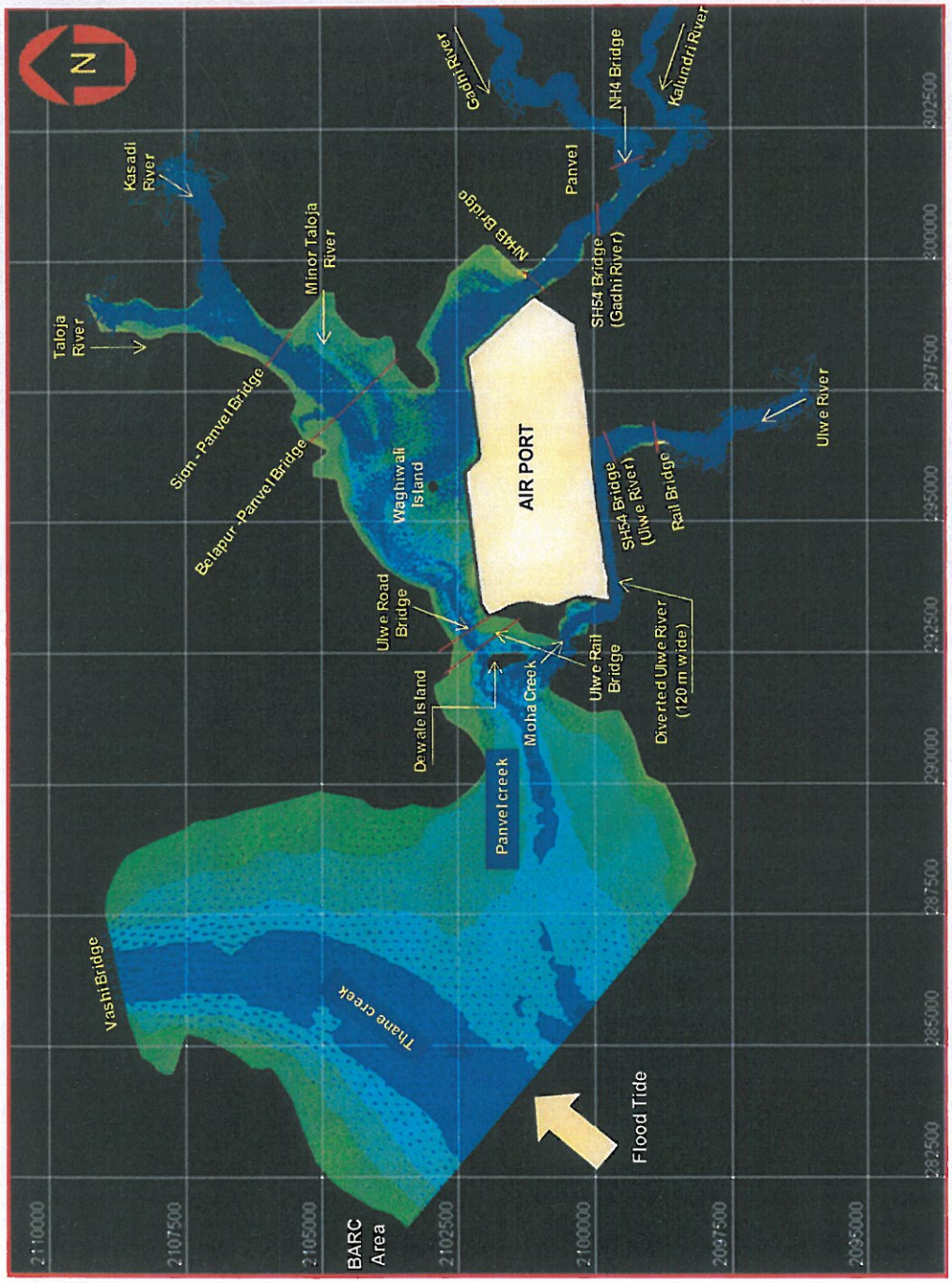

FIG 42 : TYPICAL FLOW PATTERN OBSERVED DURING FLOOD TIDE WITH AIRPORT CONDITION (100 Year , 6 Hrs Hydrograph RIVER DISCHARGES)

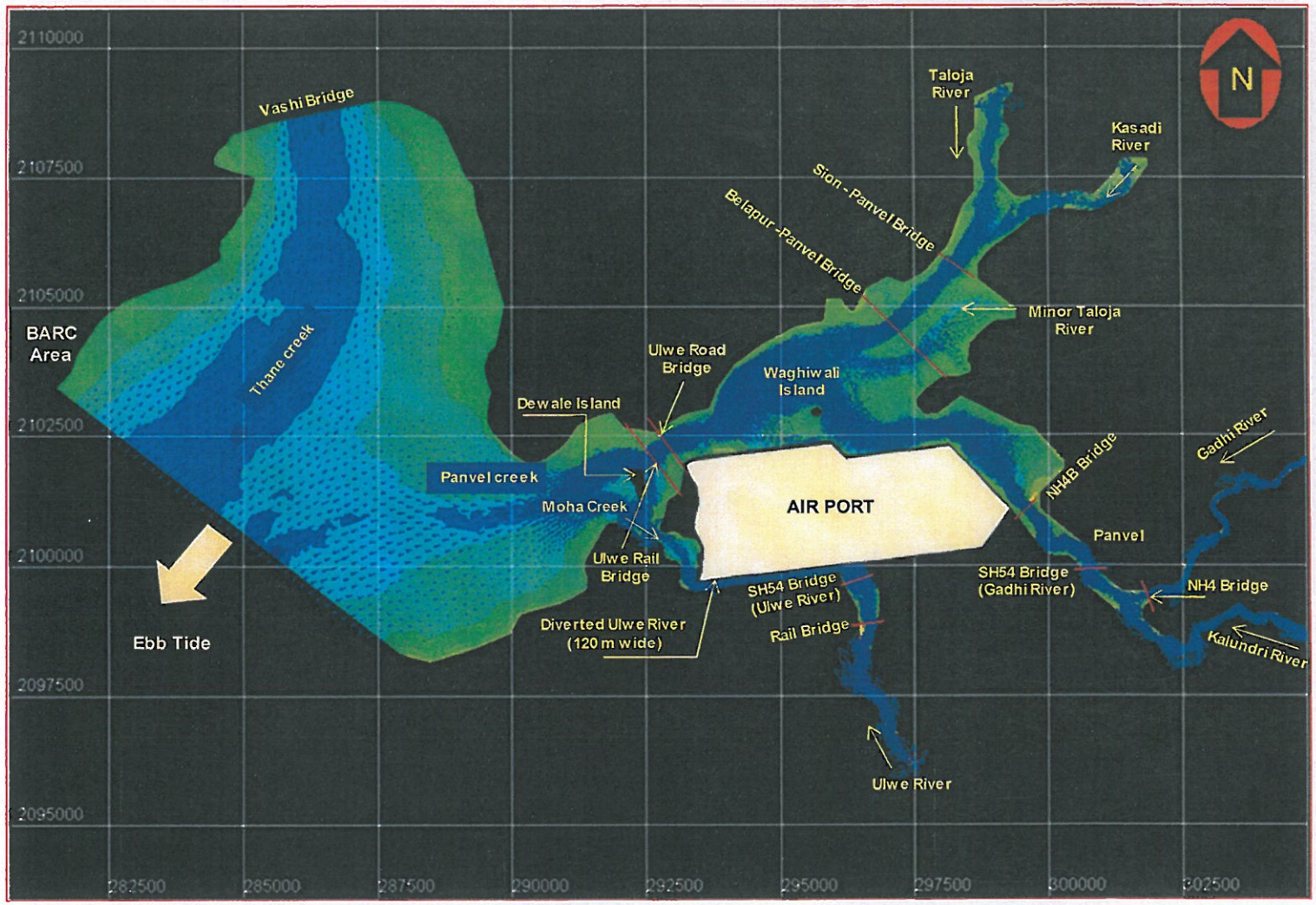

FIG 43: TYPICAL FLOW PATTERN OBSERVED DURING EBB TIDE WITH AIRPORT CONDITION (100 Year , 6 Hrs HYDROGRAPH RIVER DISCHARGES)

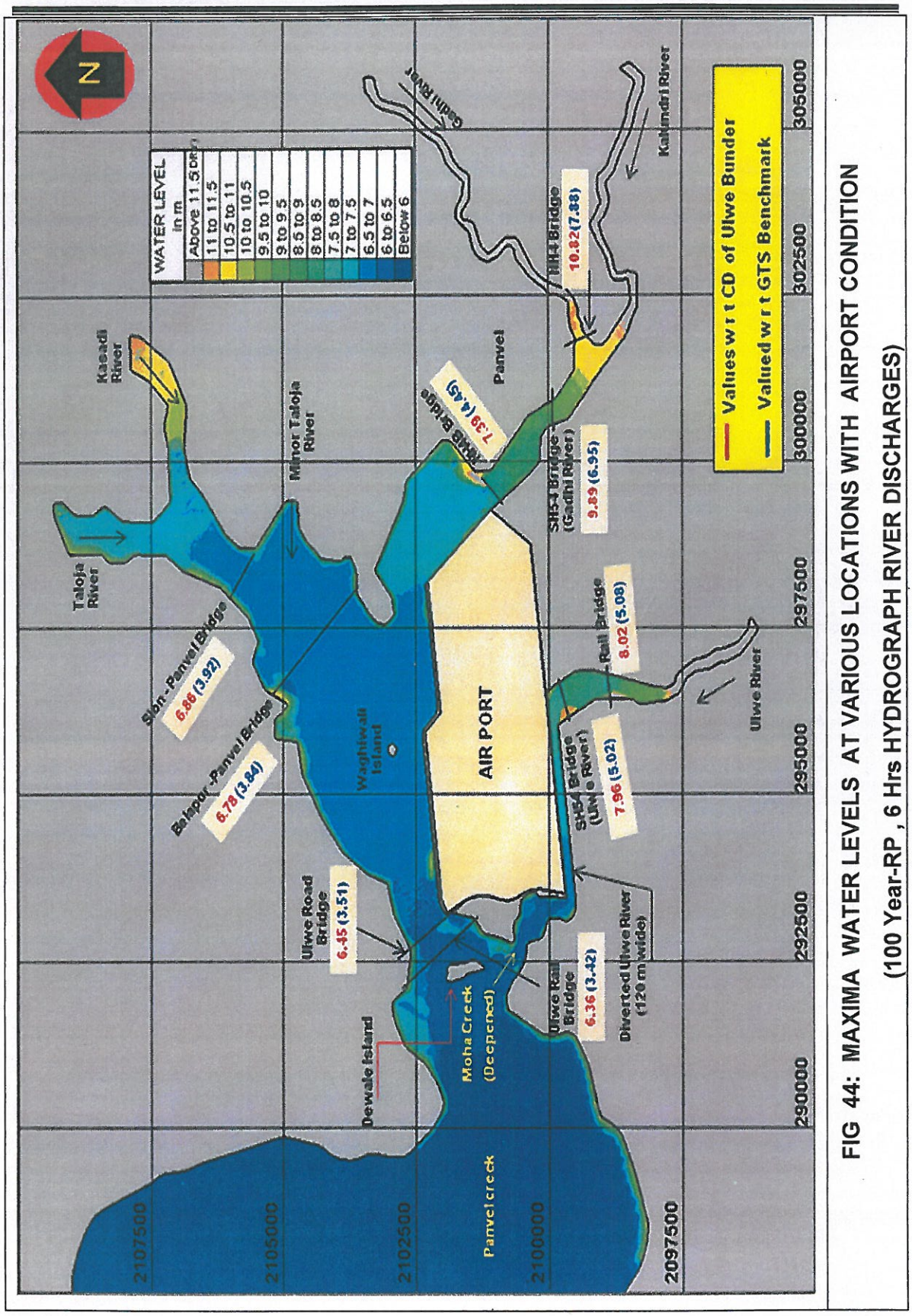

FIG 44: MAXIMA WATER LEVELS AT VARIOUS LOCATIONS WITH AIRPORT CONDITION
(100 Year-RP , 6 Hrs HYDROGRAPH RIVER DISCHARGES)

9.2.3 Studies with spring tide and River Discharges (PMP, 6Hrs storm-Hydrograph and 26th July 2005 extreme rainfall case)

In order to determine the effect of airport alongwith the Ulwe River diversion on the maxima water levels at various locations under river discharges for PMP, 6 Hrs storm and 26th July 2005 extreme rainfall case, the model for the modified airport layout was run under combined action of design tide and river discharges as reported in CWPRS Draft report of Oct. 2012. However, in view of water levels at Ulwe Diversion near SH-54 bridge being higher, in order to control the water level at this diversion deepening of Moha creek by 1m w.r.t CD of Ulwe Bundar was carried out and model was rerun for above hydrodynamic conditions. The water levels observed at various locations in the model for PMP-6 Hrs and 26th July 2005 case are given in FIG 45 & 46.

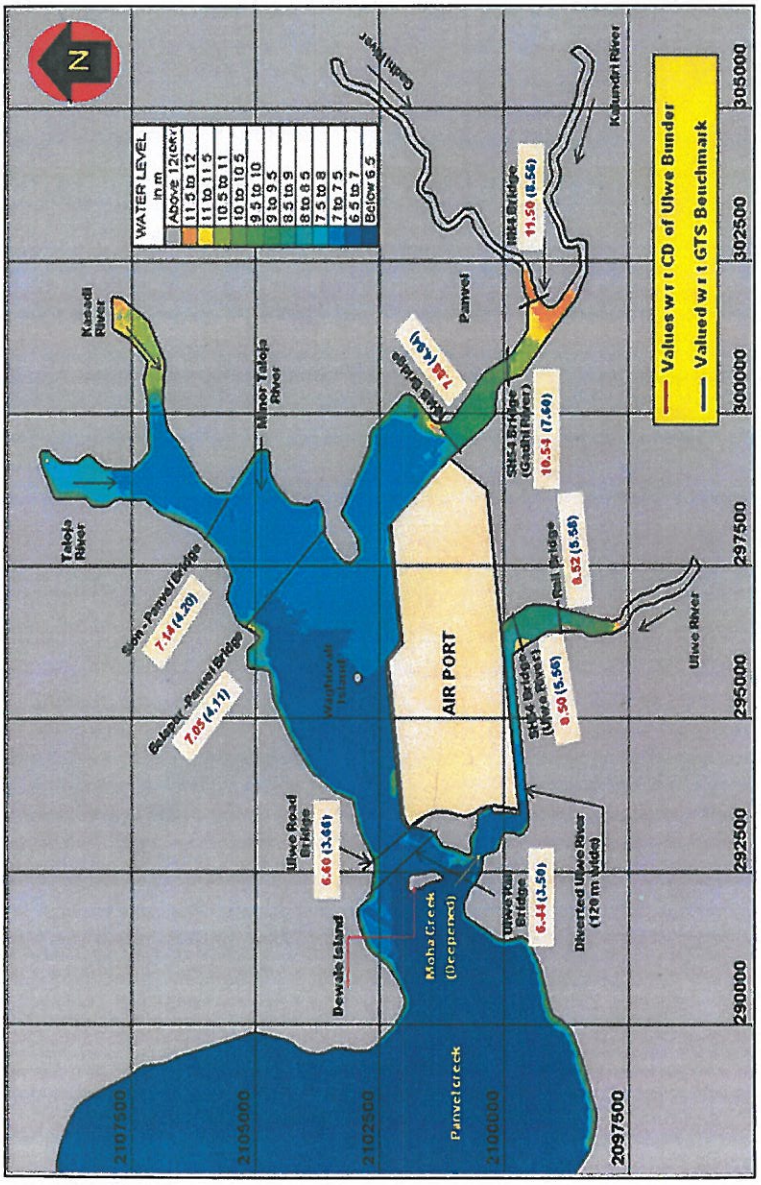

FIG 45: MAXIMA WATER LEVELS AT VARIOUS LOCATIONS WITH AIRPORT CONDITION (PMP , 6 Hrs HYDROGRAPH RIVER DISCHARGES-MOHA CREEK)

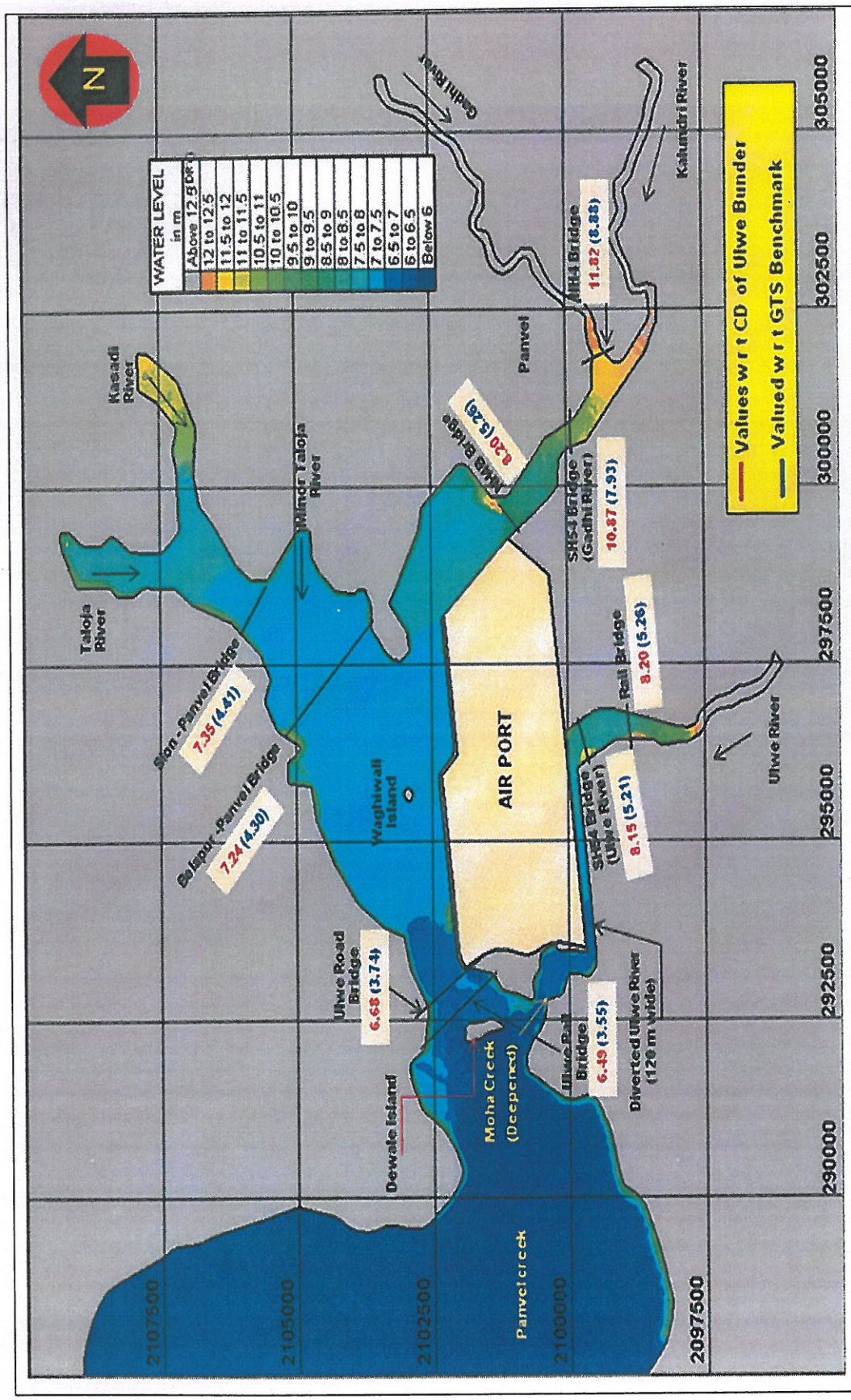

FIG 46: MAXIMA WATER LEVELS AT VARIOUS LOCATIONS WITH AIRPORT CONDITION
(26th JULY 2005 CASE HYDROGRAPH RIVER DISCHARGES-MOHA CREEK DEEPENING)

9.3 Studies for Modified Layout of Airport and River Discharges with Northern Channel (RL= -2m and RL = -1m)

The studies carried out and mentioned in subheads 9.2.1 to 9.2.3 were also repeated for northern channel having width of 75 m with its bed level at RL = -2m and RL = -1m level. The location of northern channel is shown in FIG 47.

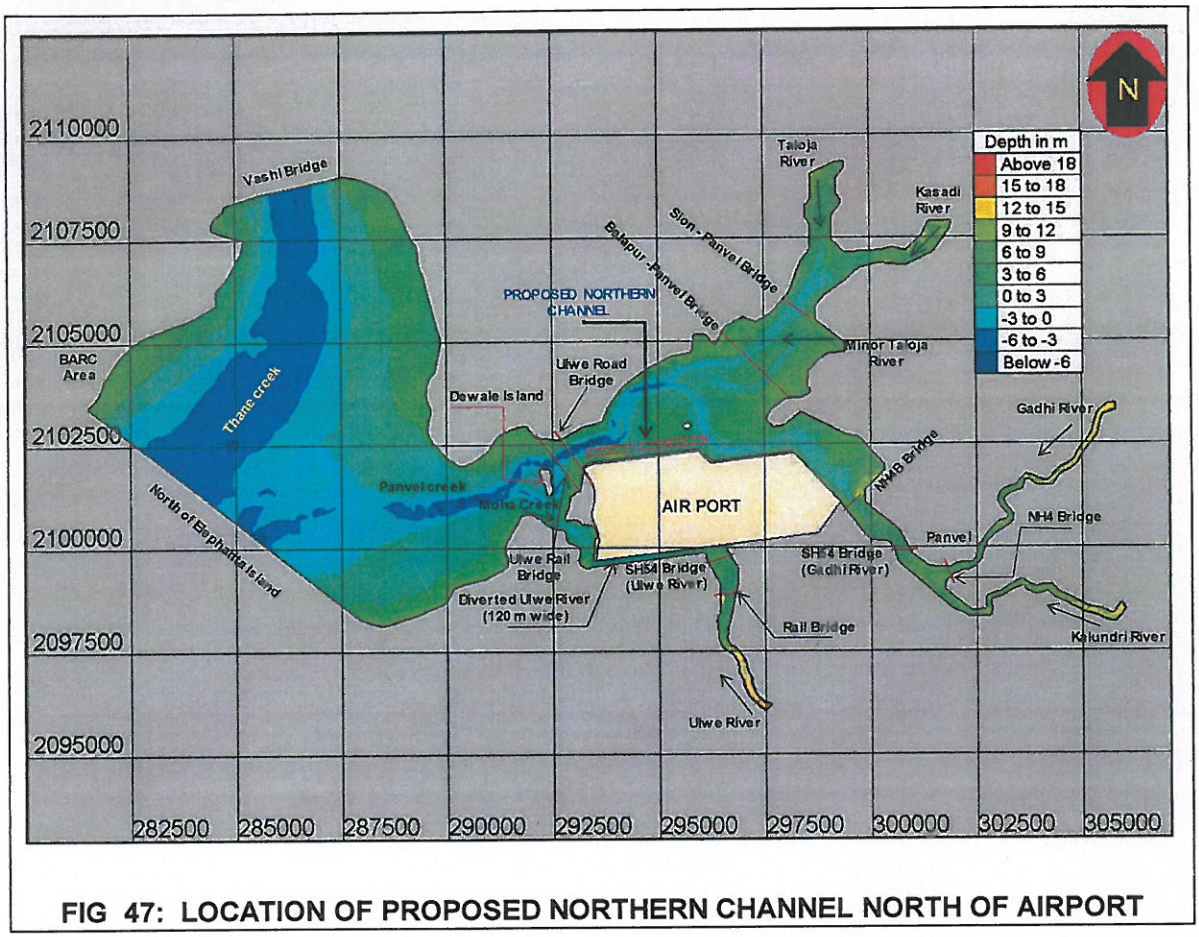

FIG 47: LOCATION OF PROPOSED NORTHERN CHANNEL NORTH OF AIRPORT

The studies carried out with northern channel reveal that there is no significant change in maxima water levels predicted with that of earlier cases mentioned in para. 9.2. Based on above results, a draft report was submitted to CIDCO in October 2012 and comments on the same were received on January 2014. A meeting was held on 20th January 2014 at CWPRS to discuss the various aspects such as deepening of Moha creek and presence of bund in Moha creek, etc. with CIDCO officials. During the meeting, CIDCO officials informed that there is considerable growth of Mangroves in Moha creek and based on environmental considerations, deepening of Moha creek will not be feasible. In addition to this it was also opined by CIDCO officials that studies with existing opening at Amra Marg bridge as 60 m in 120 m wide diversion channel near Moha creek also needs to be studied. As this case was not considered for the studies reported in draft report to

predict maxima water levels in 120 m wide diversion channel and SH-54 bridge near Ulwe diversion, additional studies as briefed in section 3 of this report were carried out and are described in following para.

9.4 Additional Model Studies for Modified Layout of Airport

The additional studies to determine maxima water levels around airport and other locations in the study area were carried out without deepening of the Moha creek. These studies involves predicting maxima water levels for 120 m wide diversion of Ulwe channel not only to decide safe grade elevation of airport but also to optimise cross section of diversion channel of Ulwe river considering various configurations such as Amra Marg bridge opening of 60m , 120m; also diversion width at Ulwe as 120m , 180m , 200 m and 240m with and without bund in Moha creek. The studies were carried out for all design hydrodynamic conditions.

9.4.1 Studies for modified layout of Airport with 120 m-120m diversion of Ulwe channel having 60 m opening at Amra Marg

The studies to determine maxima water levels at various locations around airport area were carried out for various hydrodynamic conditions such as tide only, tide with various river discharges like 100 year RP-6 hrs storm, PMP- 6 Hrs storm and 26th July 2005 extreme rainfall. The details of 120 m wide Ulwe diversion channel considered is shown in FIG 48.

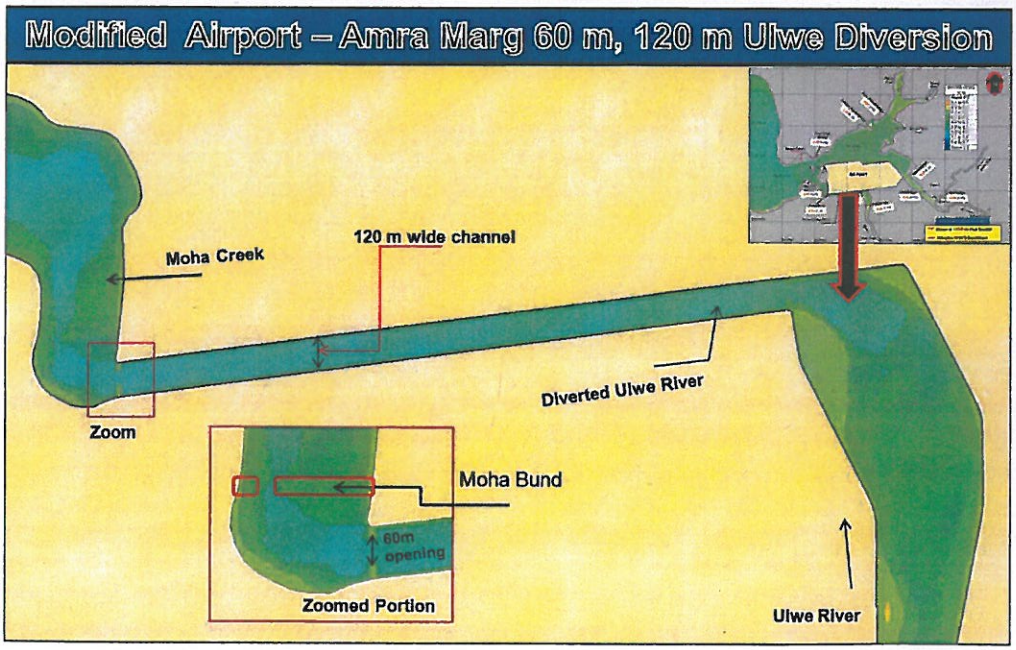

FIG 48: DETAILS OF ULWE DIVERSION WITH 60 m OPENING AT AMRA MARG AND BUND IN MOHA CRREK

The maxima water levels predicted at various locations are shown in FIG 49(A), FIG 49(B), FIG 49(C) and FIG 49(D) for the conditions mentioned above.

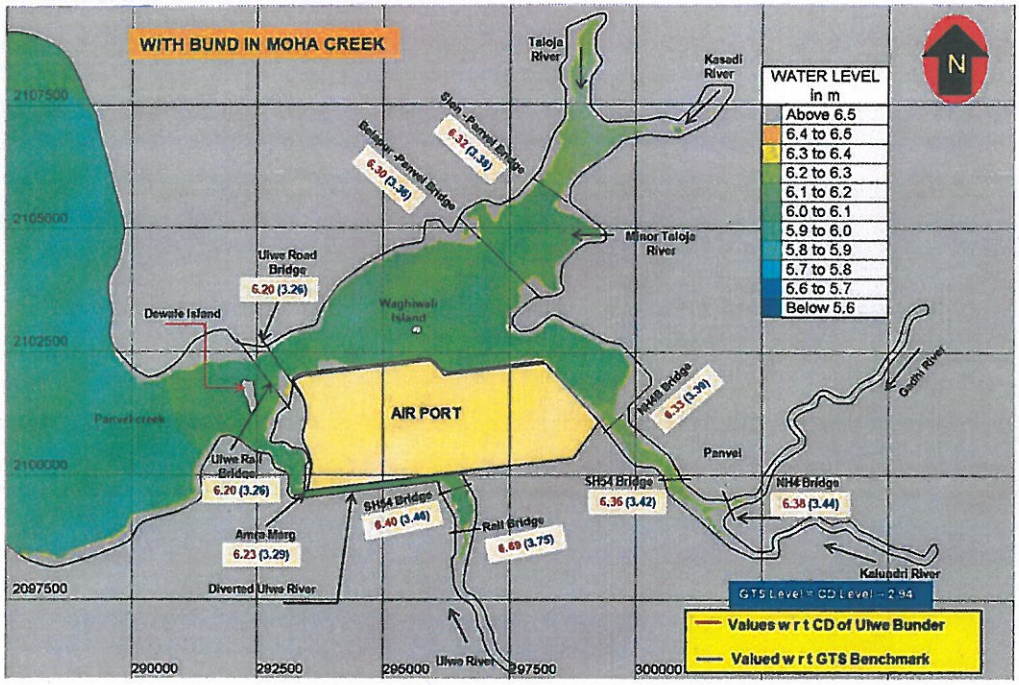

FIG 49(A): MAXIMA WATER LEVELS FOR DESIGN TIDE AND NO RIVER DISCHARGES WITH AIRPORT CONDITION (60 m OPENING AT AMRA MARG)

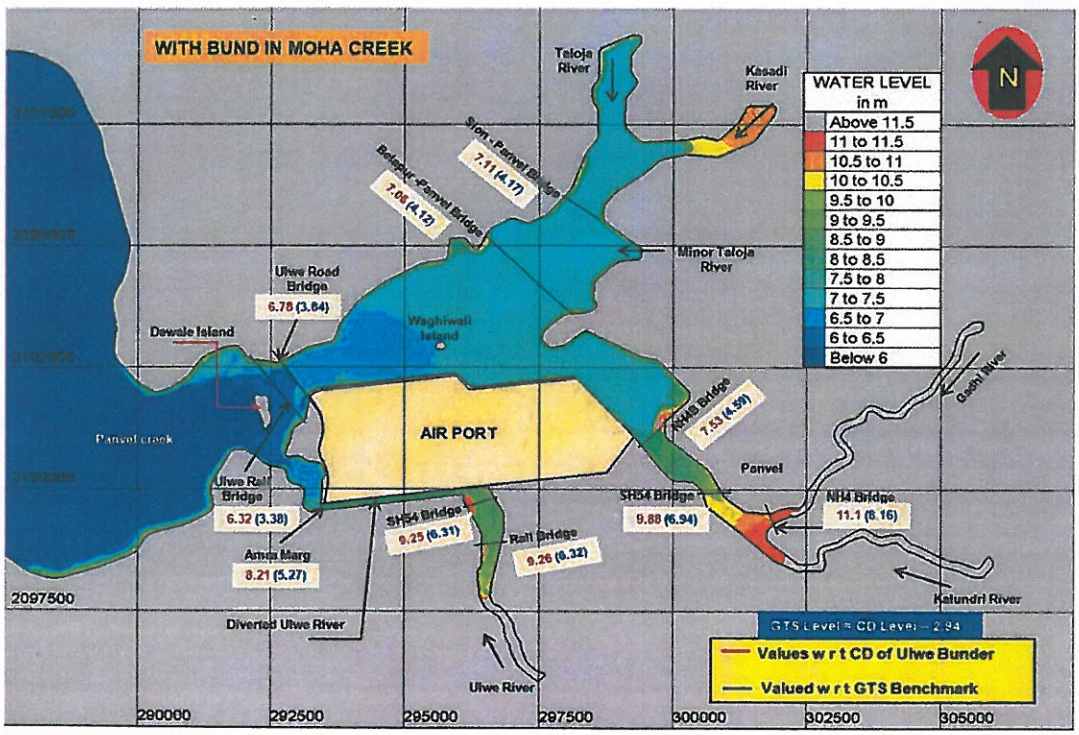

FIG 49(B): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 100 Yr-RP, 6 Hrs STORM WITH AIRPORT CONDITION (60 m OPENING AT AMRA MARG)

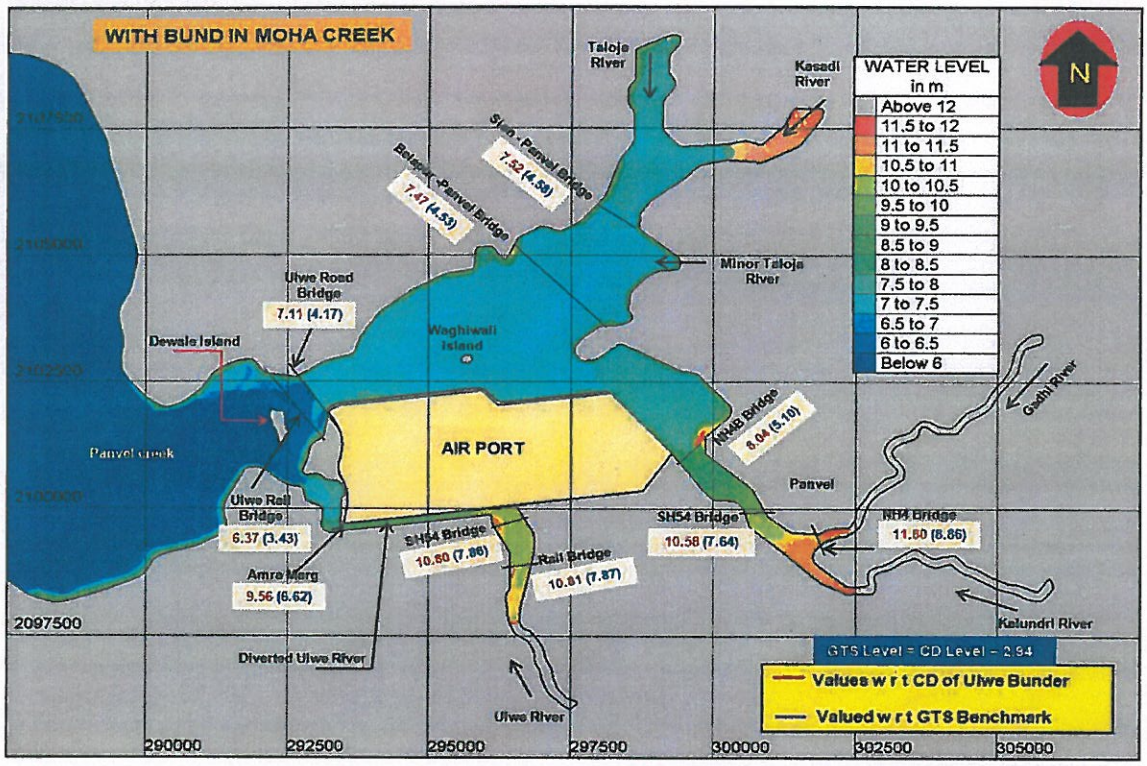

FIG 49(C): MAXIMA WATER LEVELS FOR DESIGN TIDE AND PMP, 6 Hrs STORM WITH AIRPORT CONDITION (60 m OPENING AT AMRA MARG)

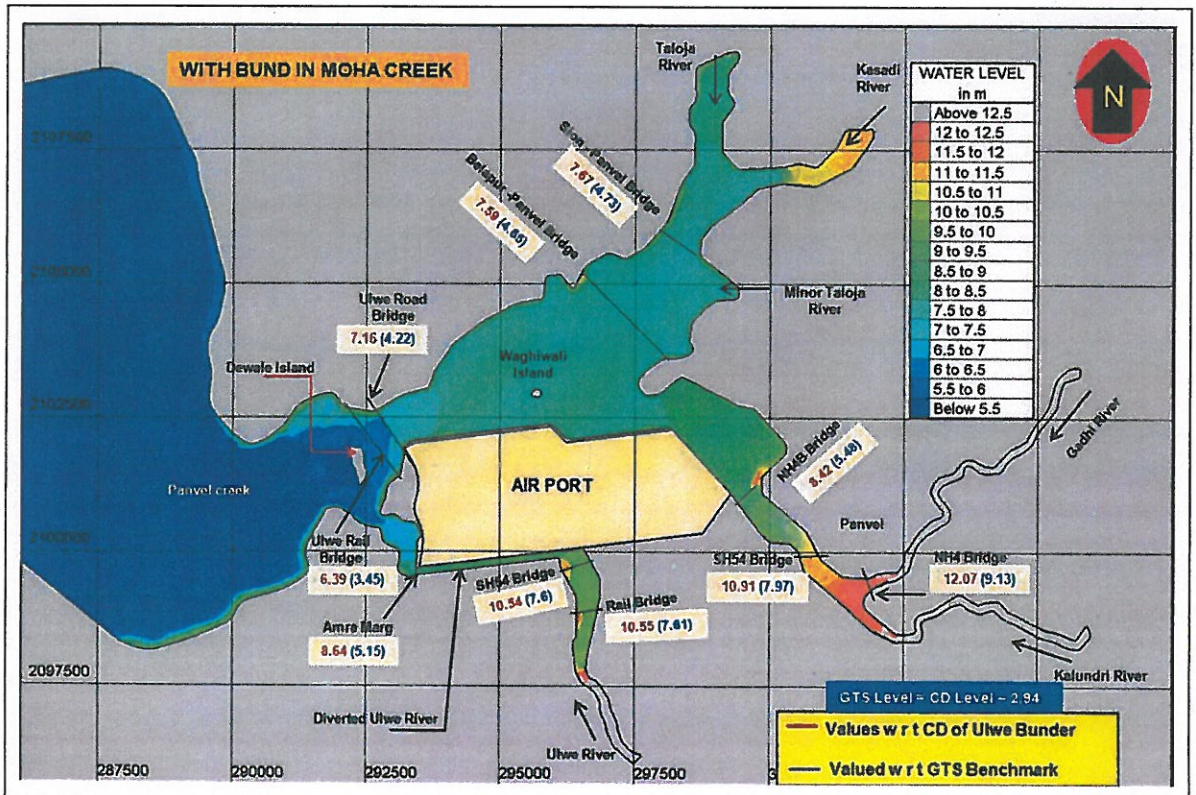

FIG 49(D): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 26th JULY 2005 STORM WITH AIRPORT CONDITION (60 m OPENING AT AMRA MARG)

9.4.2 Studies for modified layout of Airport with 120 m-120m wide diversion of Ulwe channel having 120 m opening at Amra Marg

The studies to determine maxima water levels at various locations around airport area were carried out for various hydrodynamic conditions such as tide only, tide with various river discharges like 100 year-RP, 6 hrs storm, PMP, 6 Hrs storm and 26th July 2005 extreme rainfall with bund and no bund conditions in Moha creek. The details of 120 m wide Ulwe diversion channel with bund considered is shown in FIG 50.

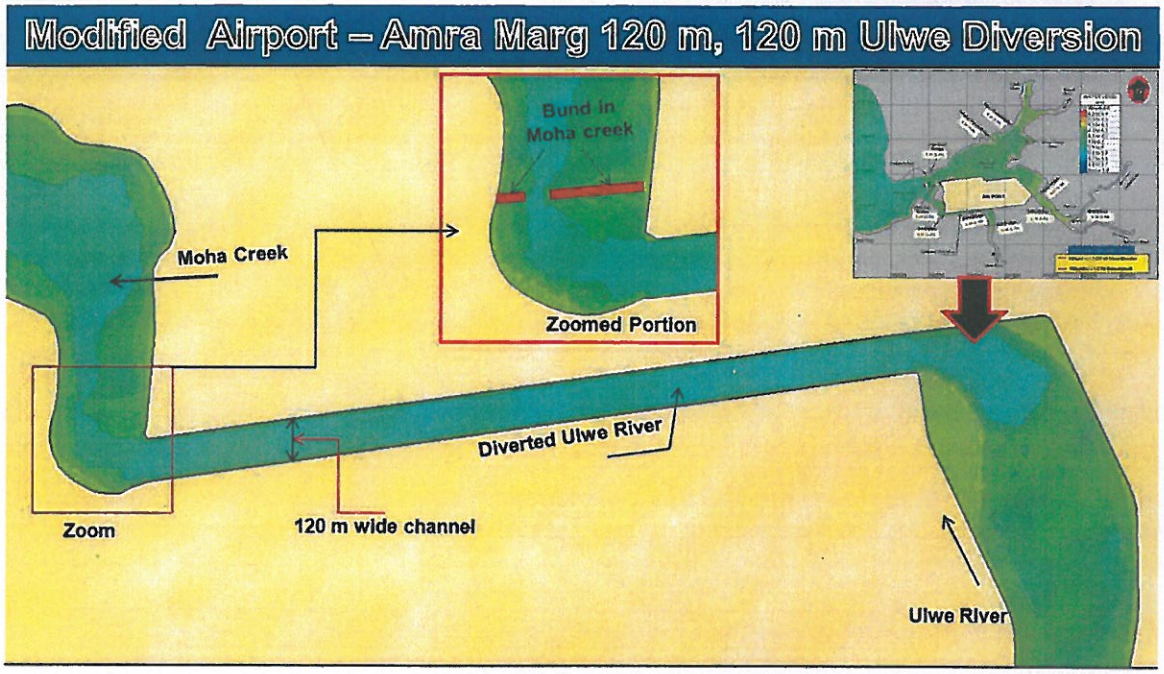

FIG 50: DETAILS OF ULWE DIVERSION WITH 120 m OPENING AT AMRA MARG AND BUND IN MOHA CREEK

The maxima water levels predicted at various locations with bund and no bund in Moha creek are shown in FIG 50(A1), FIG 50(A2); FIG 50(B1), FIG 50(B2); FIG 50(C1), FIG 50(C2) and FIG 50(D1), FIG 50(D2) respectively for the hydrodynamic conditions mentioned above.

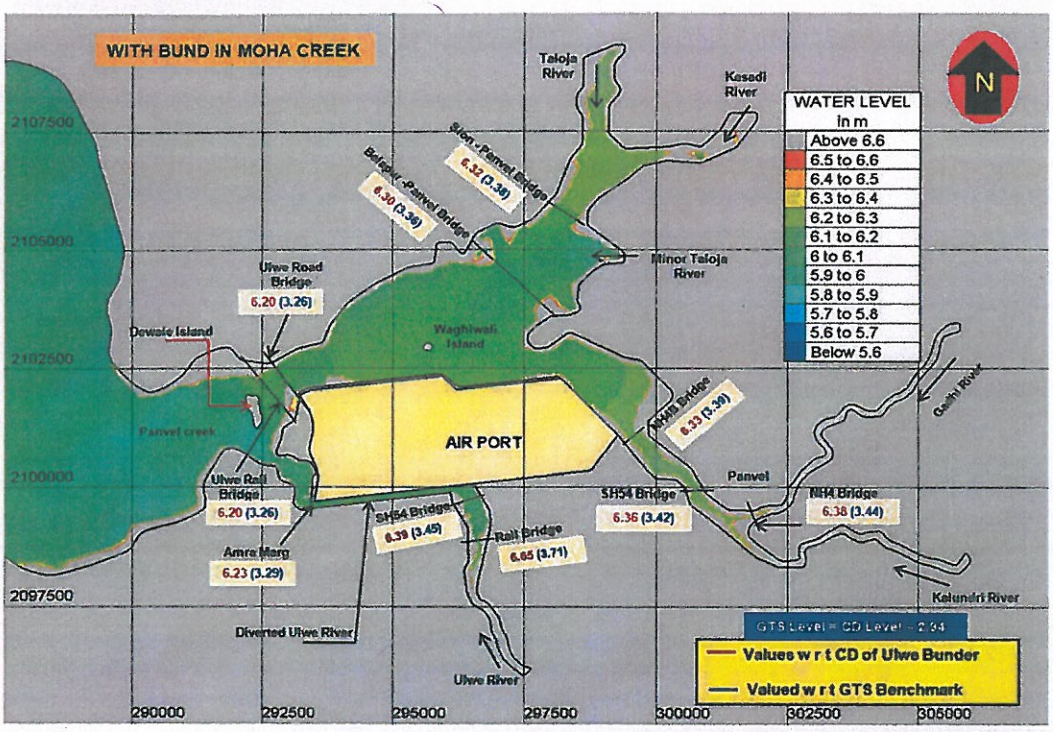

FIG 50(A1): MAXIMA WATER LEVELS FOR DESIGN TIDE AND NO RIVER DISCHARGES WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG-BUND IN MOHA CREEK)

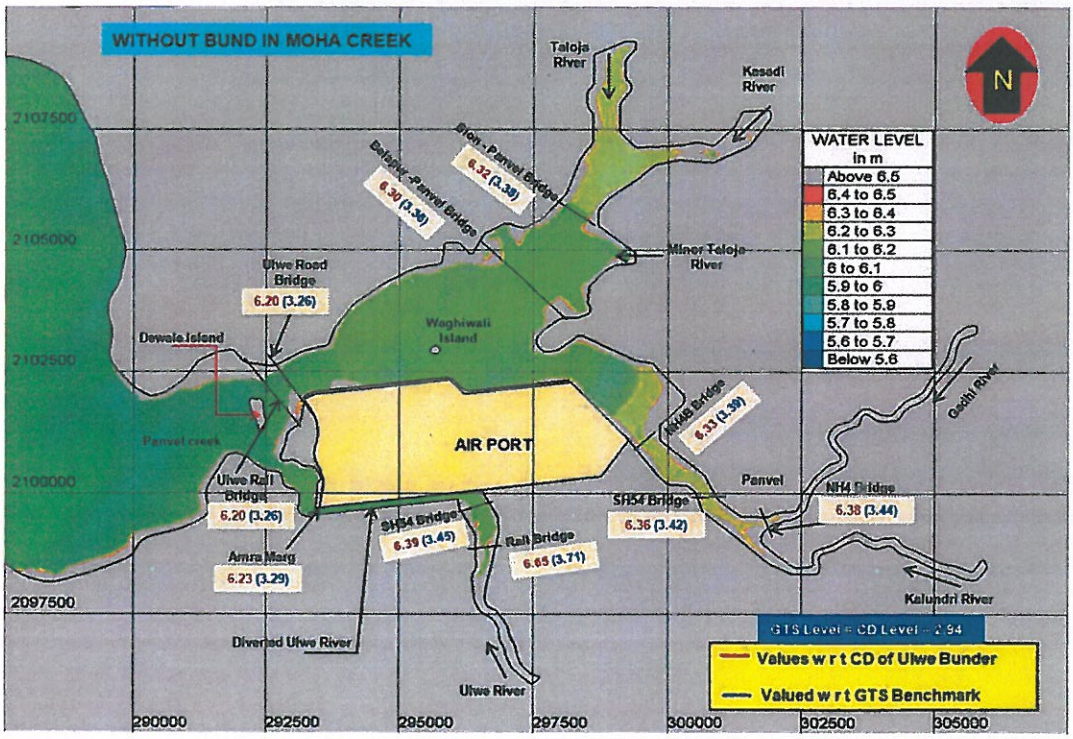

FIG 50(A2): MAXIMA WATER LEVELS FOR DESIGN TIDE AND NO RIVER DISCHARGES WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG- NO BUND IN MOHA CREEK)

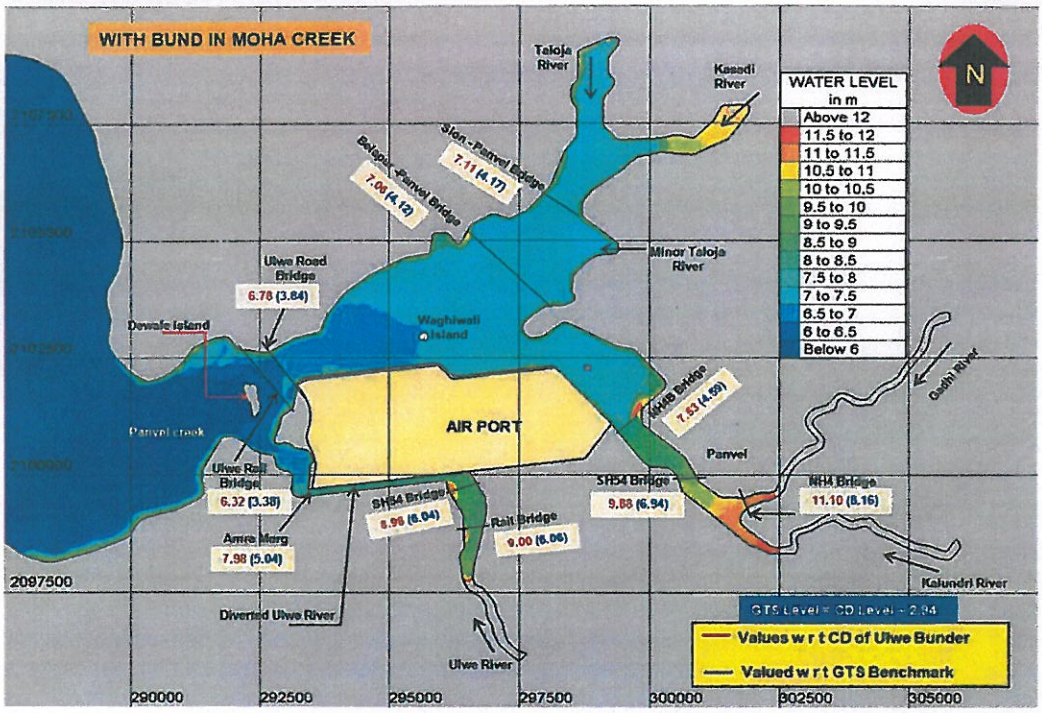

FIG 50(B1): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 100 Yr-RP, 6 Hrs STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG-BUND IN MOHA CREEK)

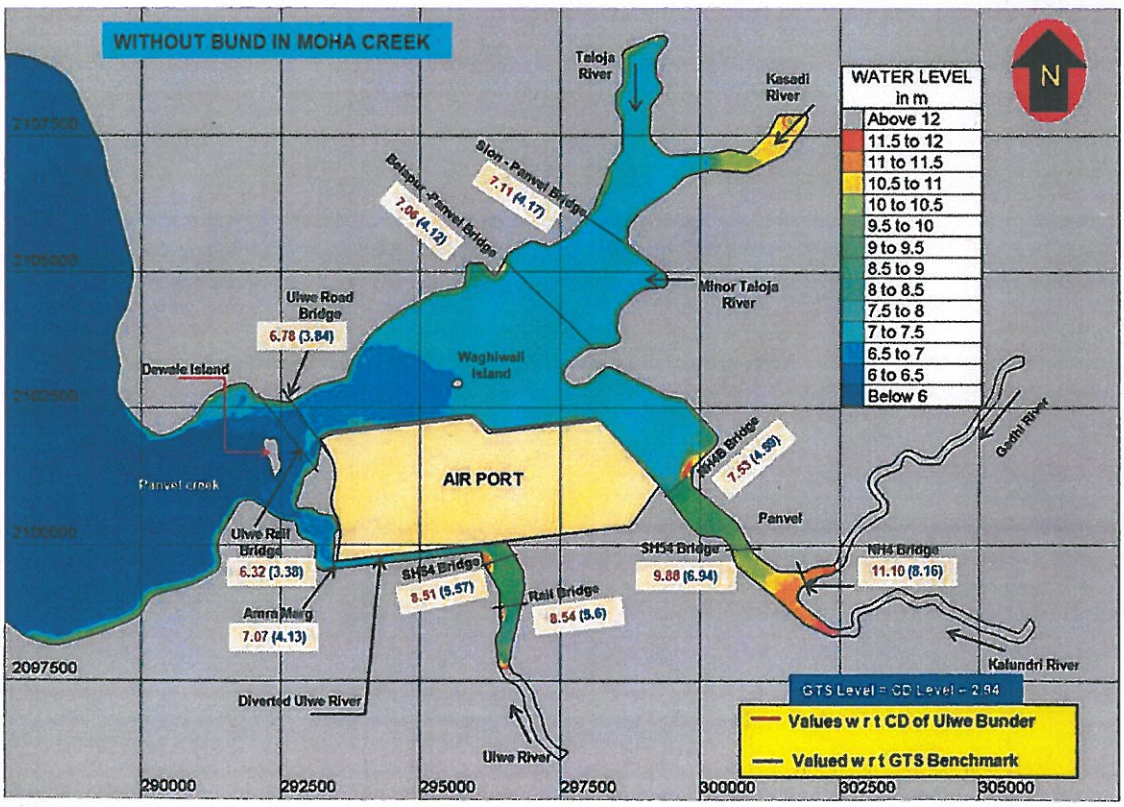

FIG 50(B2): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 100 Yr-RP, 6 Hrs STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG- NO BUND IN MOHA CREEK)

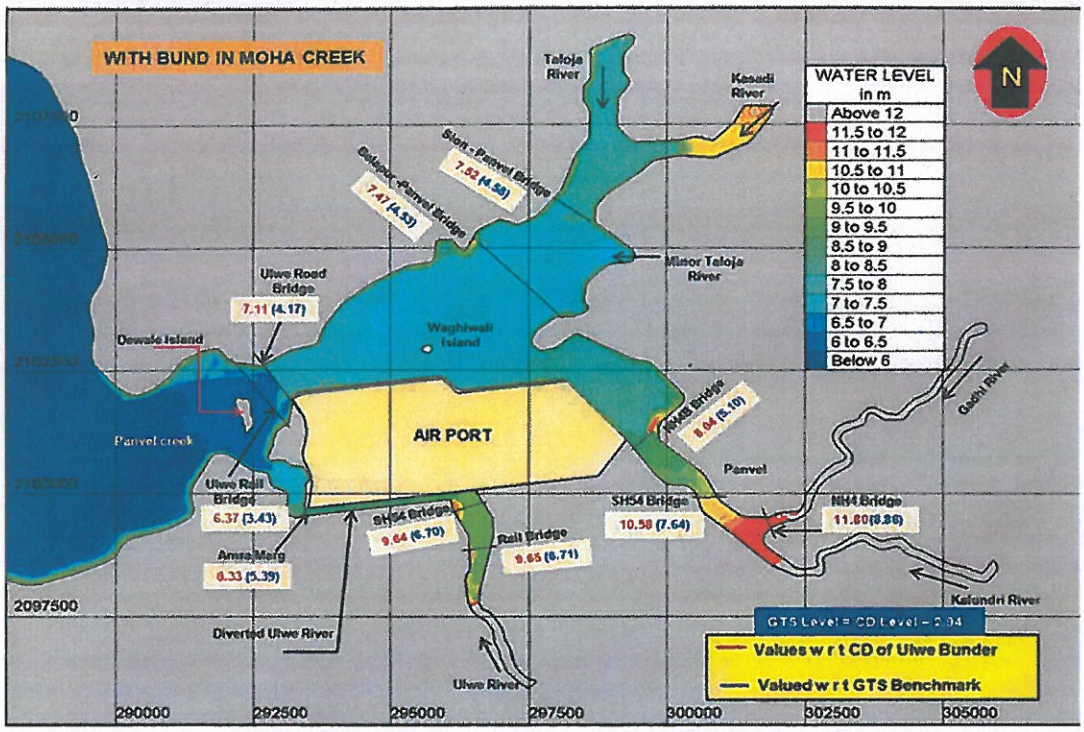

FIG 50(C1): MAXIMA WATER LEVELS FOR DESIGN TIDE AND PMP, 6 Hrs STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG-BUND IN MOHA CREEK)

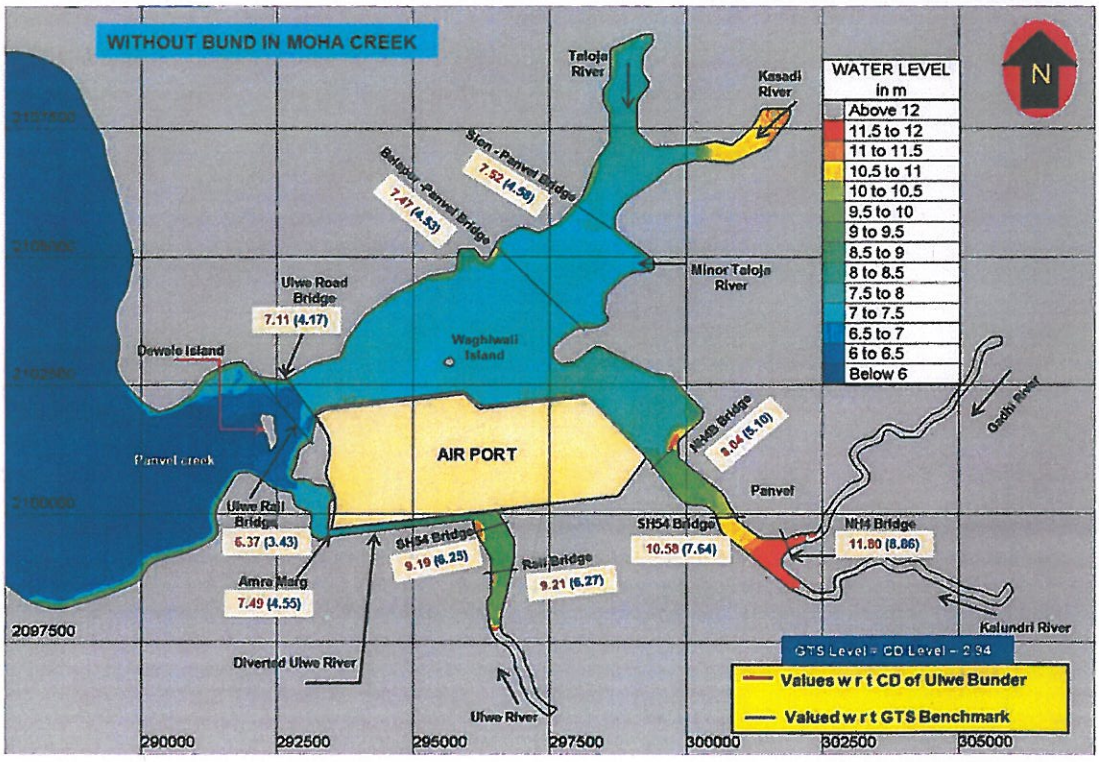

FIG 50(C2): MAXIMA WATER LEVELS FOR DESIGN TIDE AND PMP, 6 Hrs STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG- NO BUND IN MOHA CREEK)

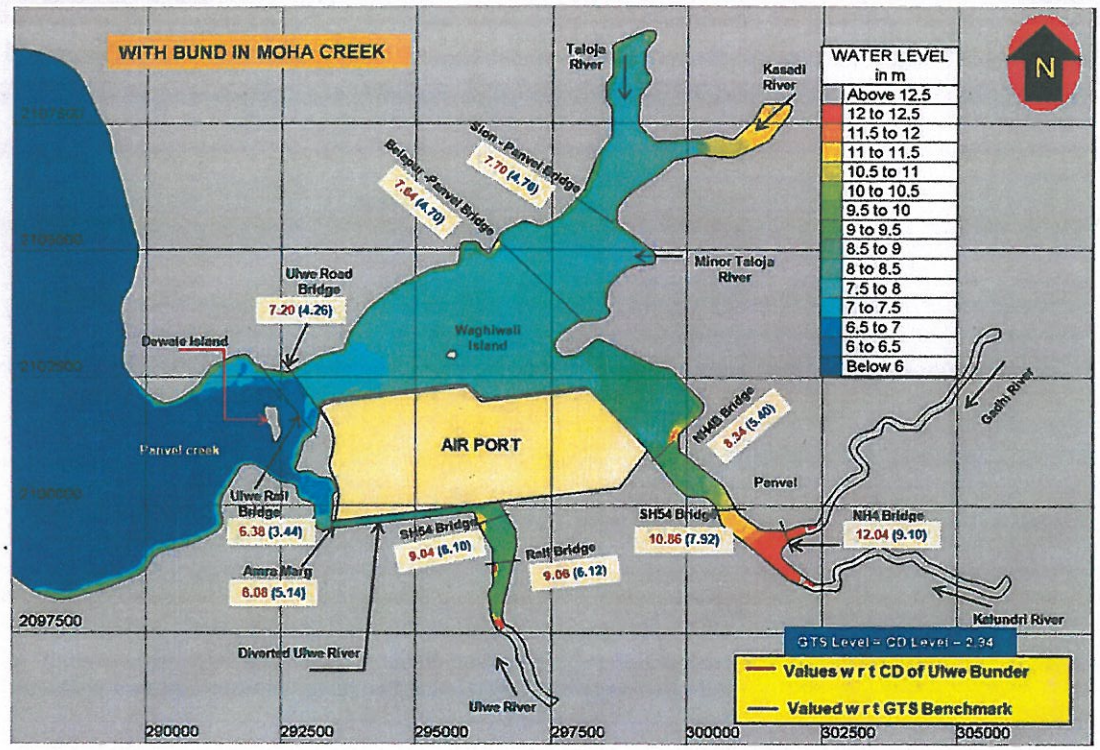

FIG 50(D1): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 26th JULY 2005 STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG-BUND IN MOHA CREEK)

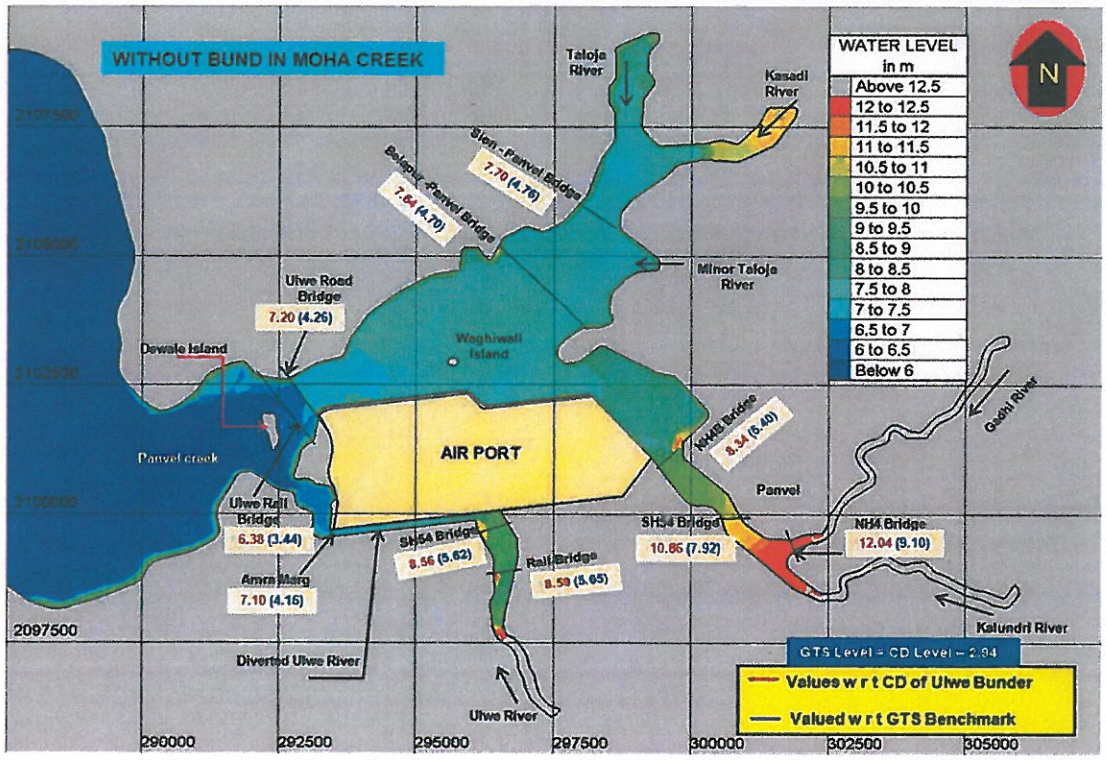

FIG 50(D2): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 26th JULY 2005 STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG- NO BUND IN MOHA CREEK)

9.4.3 Studies for modified layout of Airport with 120 m -180 m wide diversion of Ulwe channel having 120 m opening at Amra Marg

The studies to determine maxima water levels at various locations around airport area were carried out for various hydrodynamic conditions such as tide only, tide with various river discharges like 100 year- RP, 6 hrs storm, PMP, 6 Hrs storm and 26th July 2005 extreme rainfall with bund and no bund conditions in Moha creek. The details of 120 m wide Ulwe diversion with bund considered is shown in FIG 51.

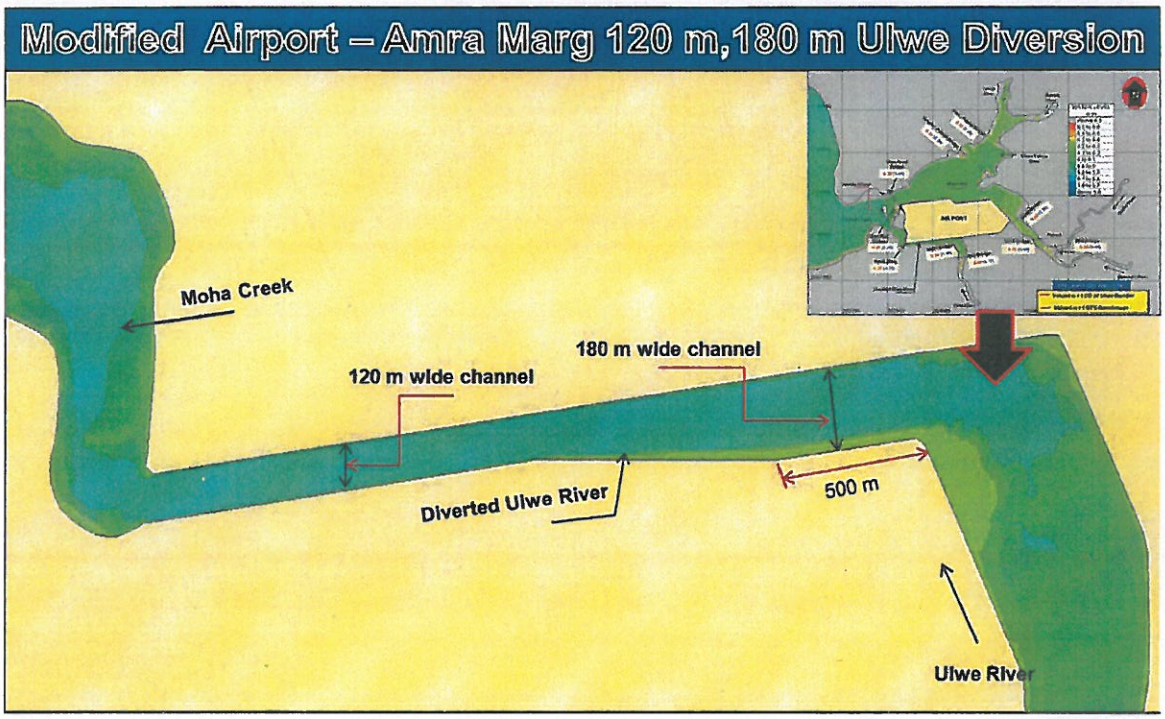

FIG 51: DETAILS OF ULWE DIVERSION WITH 120 m OPENING AT AMRA MARG AND 120 m- 180 m ULWE DIVERSION -BUND IN MOHA CREEK

The maxima water levels predicted at various locations with bund and no bund in Moha creek are shown in FIG 51(A1), FIG 51(A2); FIG 51(B1), FIG 51(B2); FIG 51(C1), FIG 51(C2) and FIG 51(D1), FIG 51(D2) respectively for the hydrodynamic conditions mentioned above.

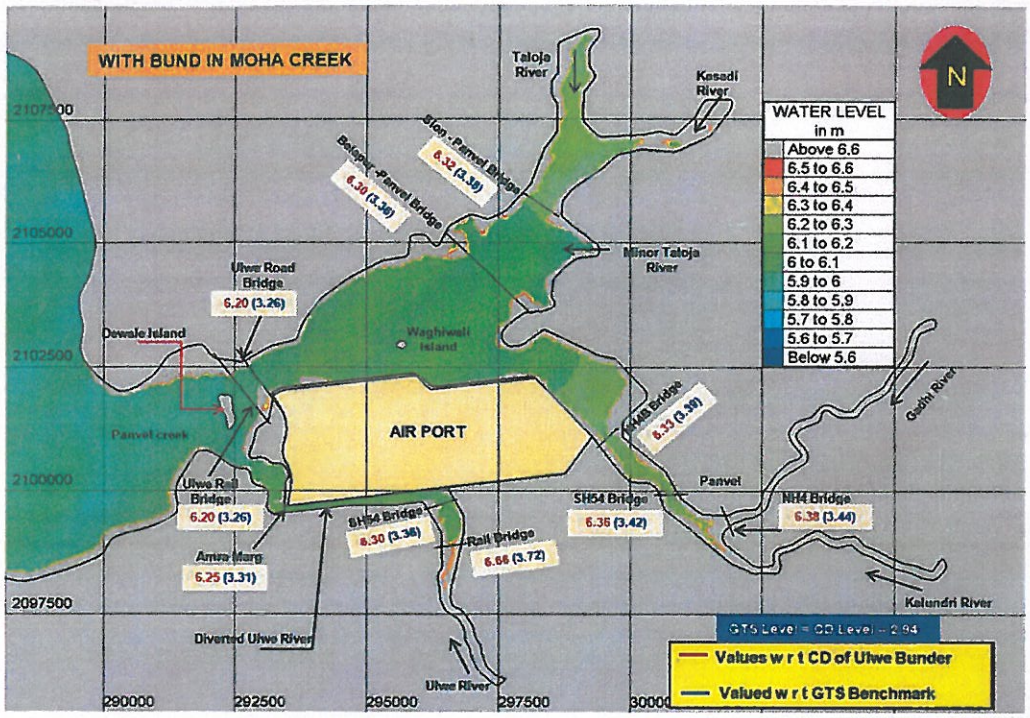

FIG 51(A1): MAXIMA WATER LEVELS FOR DESIGN TIDE AND NO RIVER DISCHARGES WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-180m ULWE DIVERSION-BUND IN MOHA CREEK)

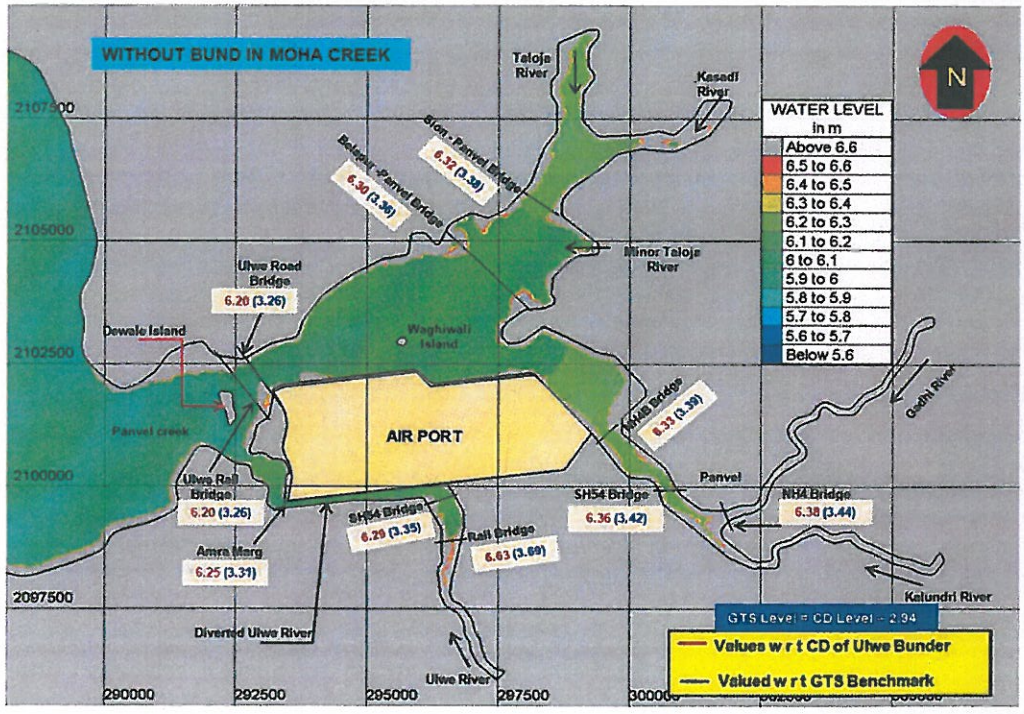

FIG 51(A2): MAXIMA WATER LEVELS FOR DESIGN TIDE AND NO RIVER DISCHARGES WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-180m ULWE DIVERSION - NO BUND IN MOHA CREEK)

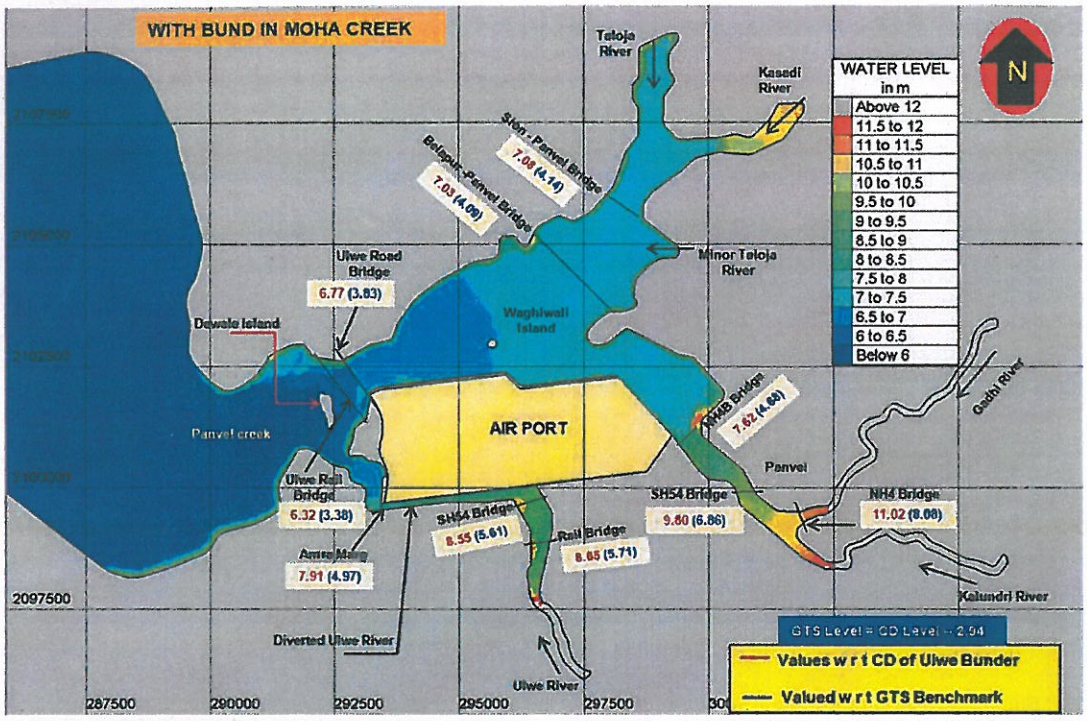

FIG 51(B1): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 100 Yr- RP, 6Hrs STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-180m ULWE DIVERSION -BUND IN MOHA CREEK)

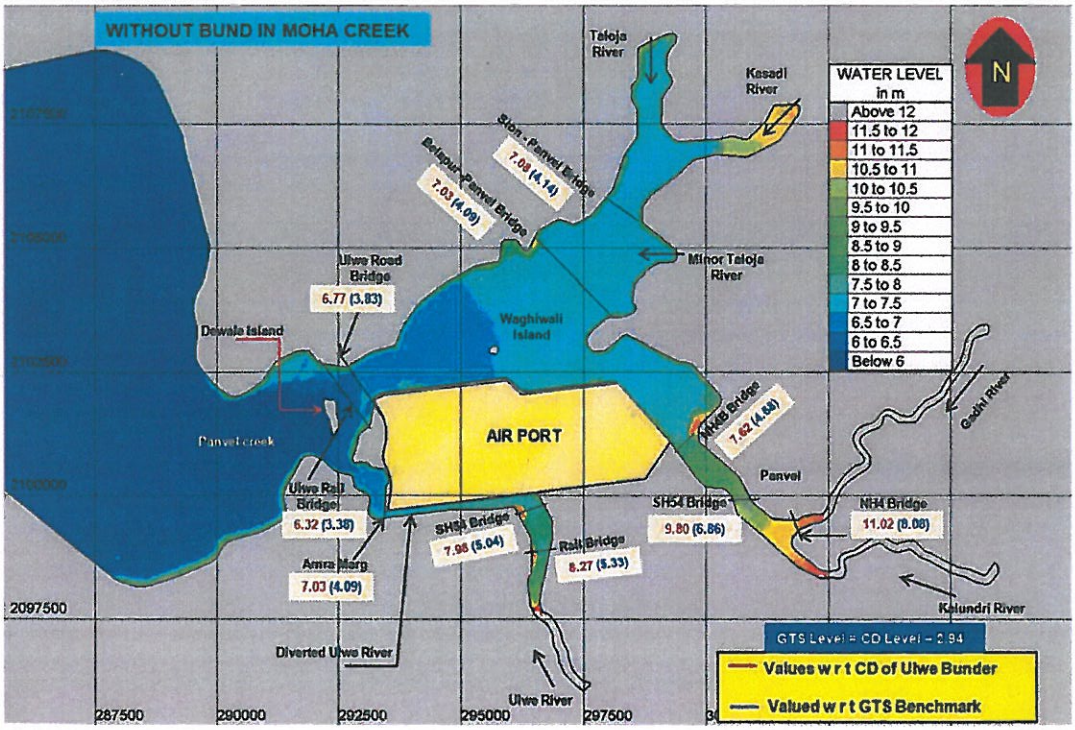

FIG 51(B2): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 100 Yr-RP, 6Hrs STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-180m ULWE DIVERSION - NO BUND IN MOHA CREEK)

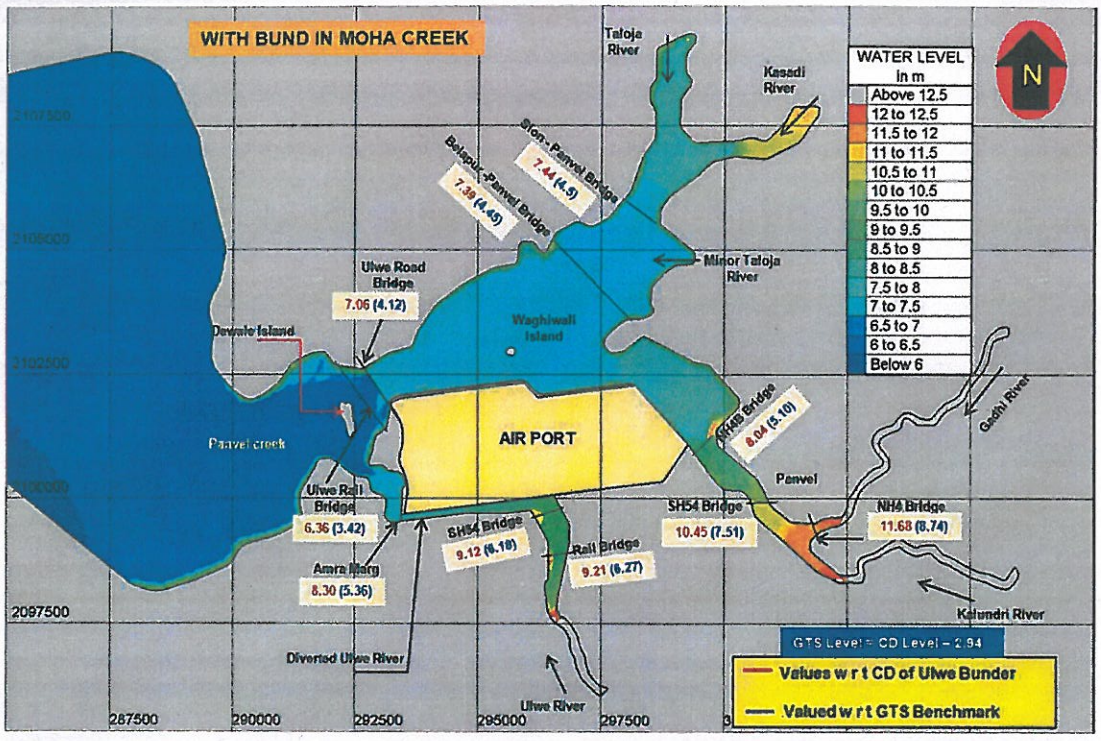

FIG 51(C1): MAXIMA WATER LEVELS FOR DESIGN TIDE AND PMP, 6Hrs STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-180m ULWE DIVERSION -BUND IN MOHA CREEK)

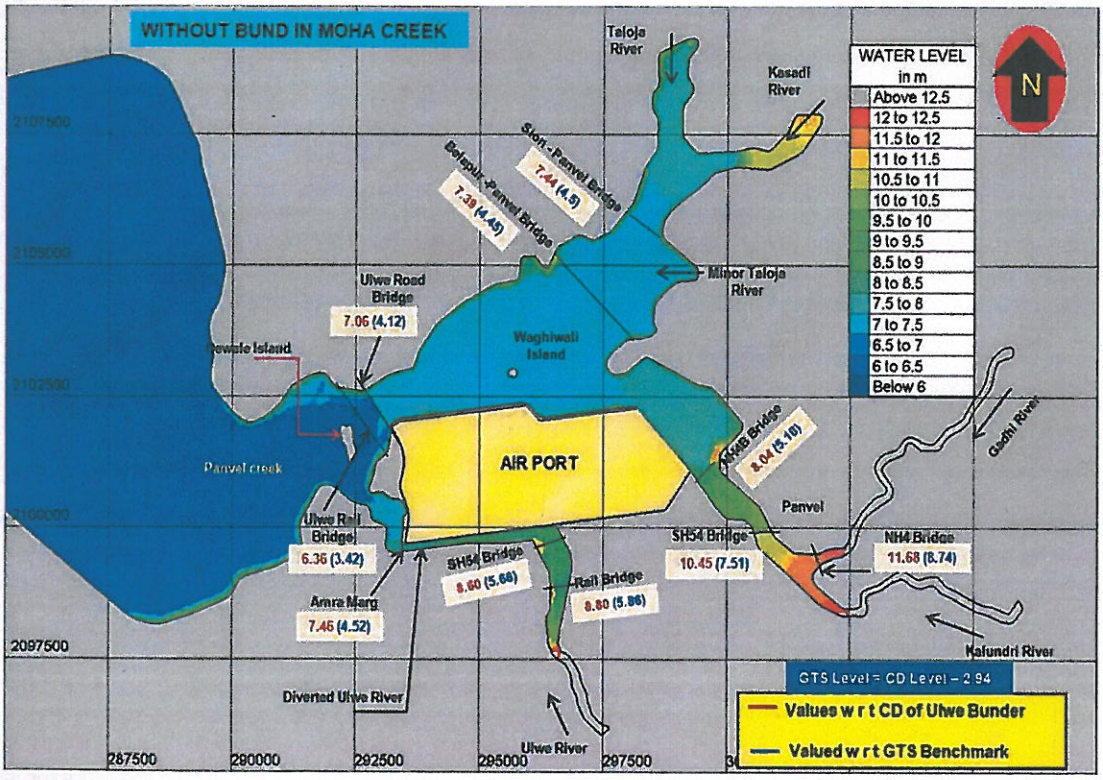

FIG 51(C2): MAXIMA WATER LEVELS FOR DESIGN TIDE AND PMP, 6Hrs STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-180m ULWE DIVERSION - NO BUND IN MOHA CREEK)

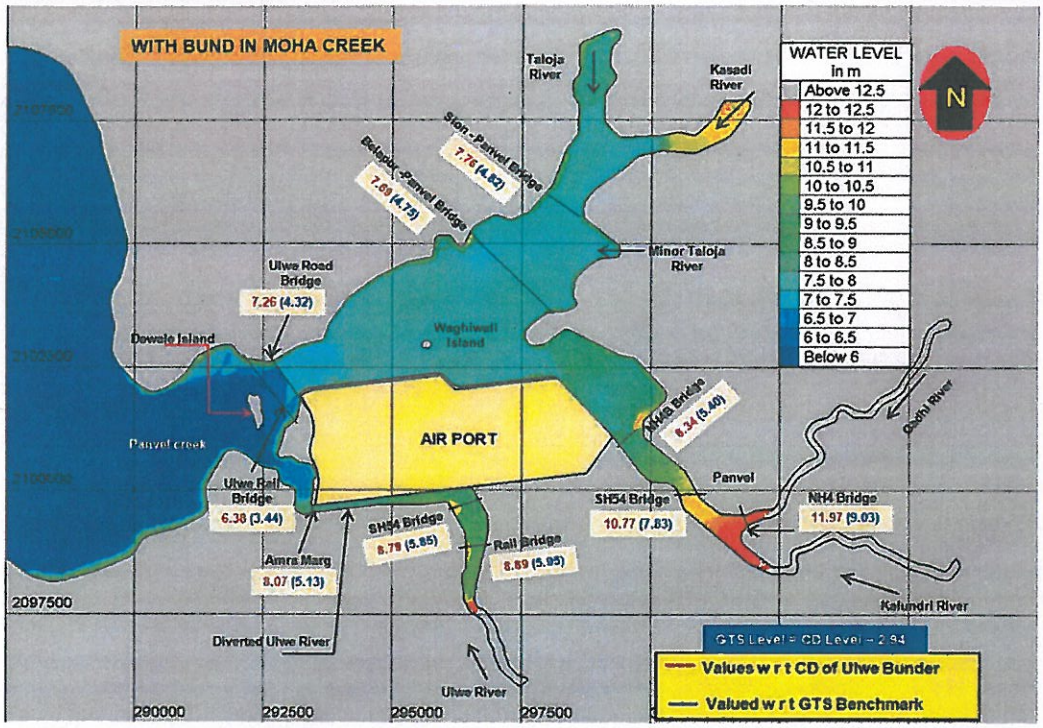

FIG 51(D1): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 26th JULY 2005 STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-180m ULWE DIVERSION -BUND IN MOHA CREEK)

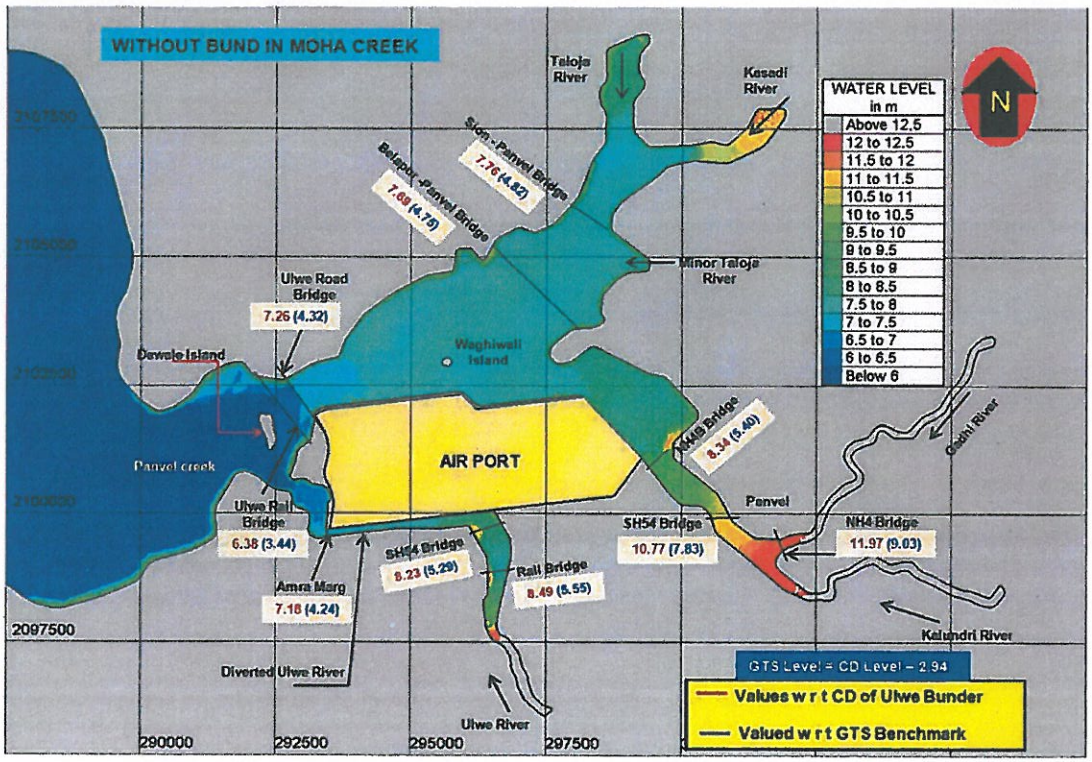

FIG 51(D2): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 26th JULY 2005 STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-180m ULWE DIVERSION - NO BUND IN MOHA CREEK)

The studies carried out as per the additional scope of work mentioned in para 3 with Ulwe diversion channel of 120-180 m width of diversion transition indicate that the maxima water level at SH-54 bridge on Ulwe river for PMP, 6 Hrs storm condition is more than the optimised water level condition of 8.5 m w.r.t CD of Ulwe Bunder. This water level was considered as the optimal maxima water level predicted when deepening of Moha creek was carried out up to 1m below CD. As such to meet the above mentioned maxima water level, it was decided to carry out the model studies by increasing the width of Ulwe diversion channel having width of 120-200m , 120-240 m etc. These studies are discussed in following para.

9.4.4 Studies for modified layout of Airport with 120 m -200 m wide diversion of Ulwe channel having 120 m opening at Amra Marg

The studies to determine maxima water levels at various locations around airport area were carried out for various hydrodynamic conditions such as tide only and no river discharge, tide with various river discharges like 100 year- RP, 6 hrs storm, PMP, 6 Hrs storm and 26th July 2005 extreme rainfall with bund and no bund conditions in Moha creek. The details of diversion channel with bund considered is shown in FIG 52.

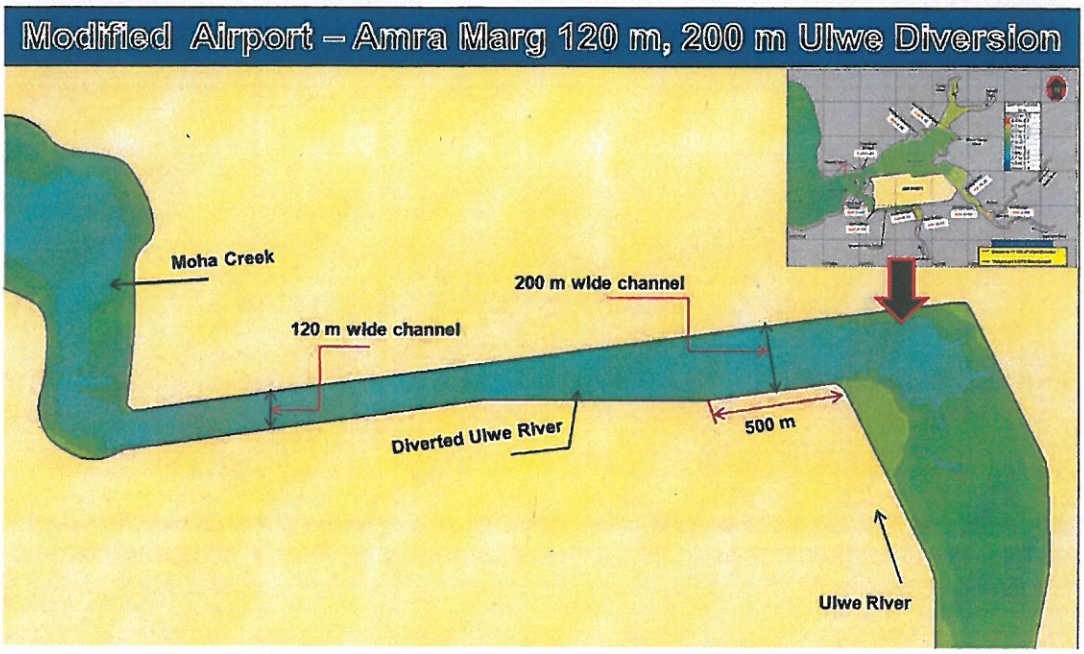

FIG 52: DETAILS OF ULWE DIVERSION WITH 120 m OPENING AT AMRA MARG AND 120 m- 200 m ULWE DIVERSION - BUND IN MOHA CREEK

The maxima water levels predicted at various locations with bund and no bund in Moha creek are shown in FIG 52(A1), FIG 52(A2); FIG 52(B1), FIG 52(B2); FIG 52(C1), FIG 52(C2) and FIG 52(D1), FIG 52(D2) respectively for the hydrodynamic conditions mentioned above.

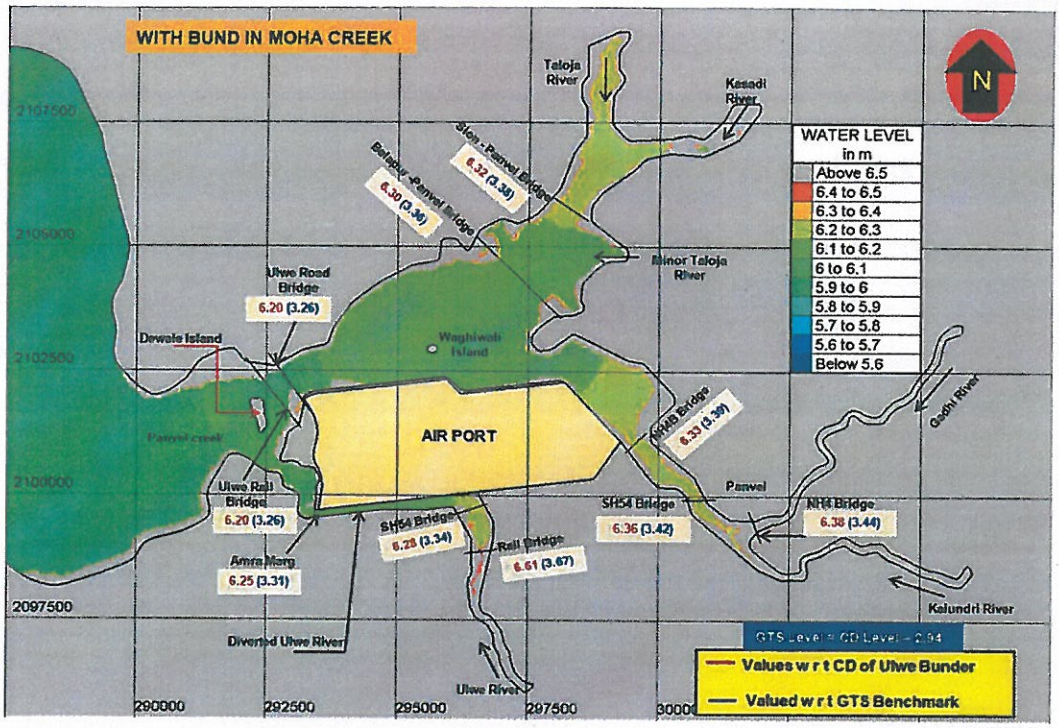

FIG 52(A1): MAXIMA WATER LEVELS FOR DESIGN TIDE AND NO RIVER DISCHARGES WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-200m ULWE DIVERSION-BUND IN MOHA CREEK)

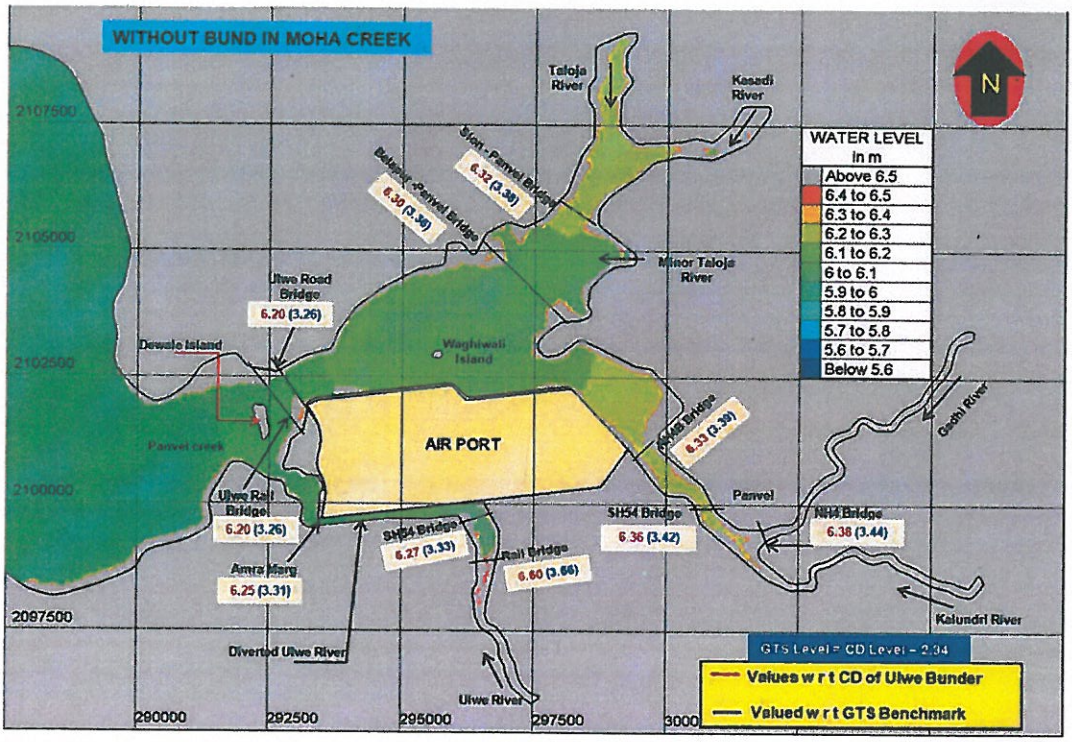

FIG 52(A2): MAXIMA WATER LEVELS FOR DESIGN TIDE AND NO RIVER DISCHARGES WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-200m ULWE DIVERSION - NO BUND IN MOHA CREEK)

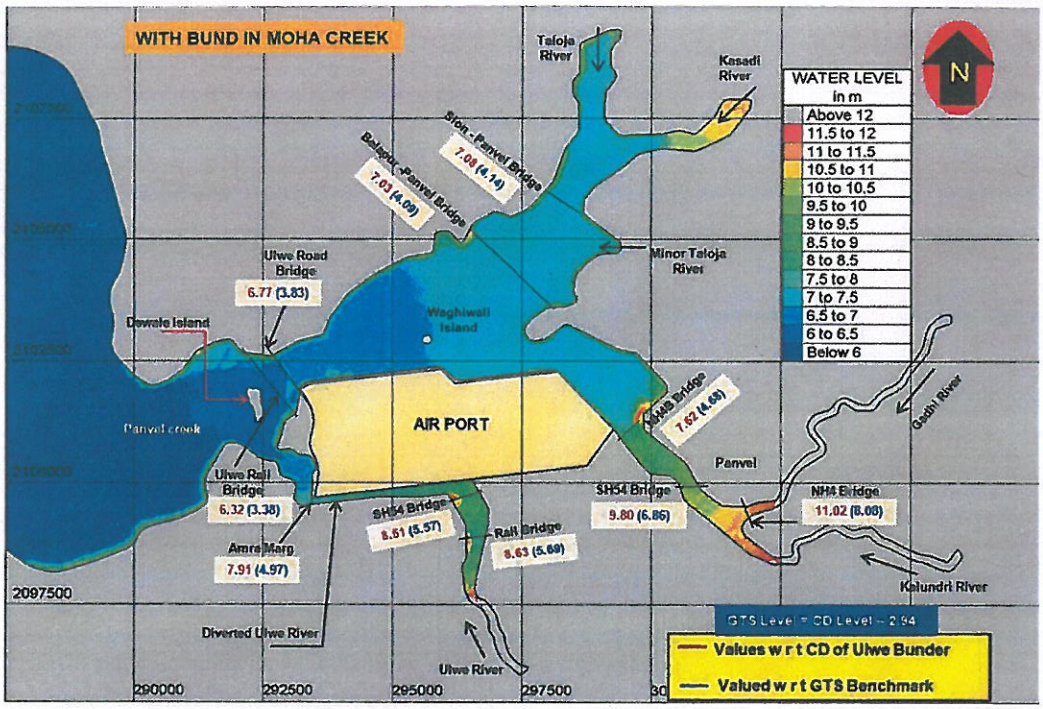

FIG 52(B1): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 100 Yr-RP, 6Hrs STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-200m ULWE DIVERSION -BUND IN MOHA CREEK)

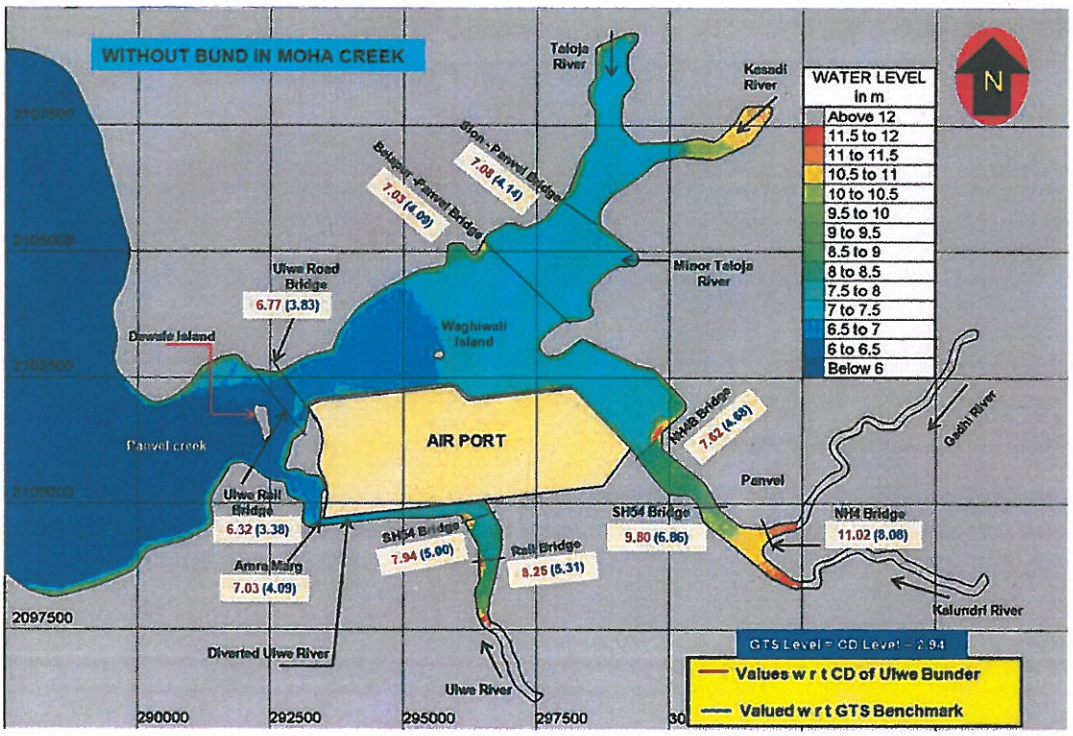

FIG 52(B2): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 100 Yr-RP, 6Hrs STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-200m ULWE DIVERSION - NO BUND IN MOHA CREEK)

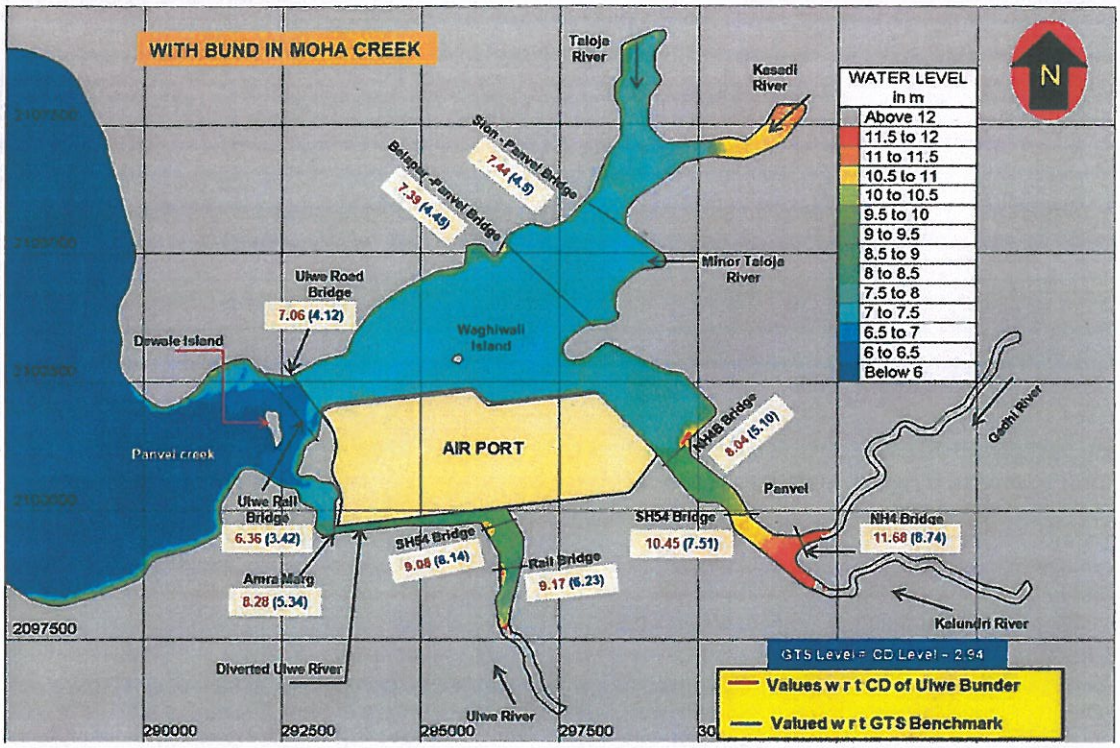

FIG 52(C1): MAXIMA WATER LEVELS FOR DESIGN TIDE AND PMP, 6Hrs STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-200m ULWE DIVERSION -BUND IN MOHA CREEK)

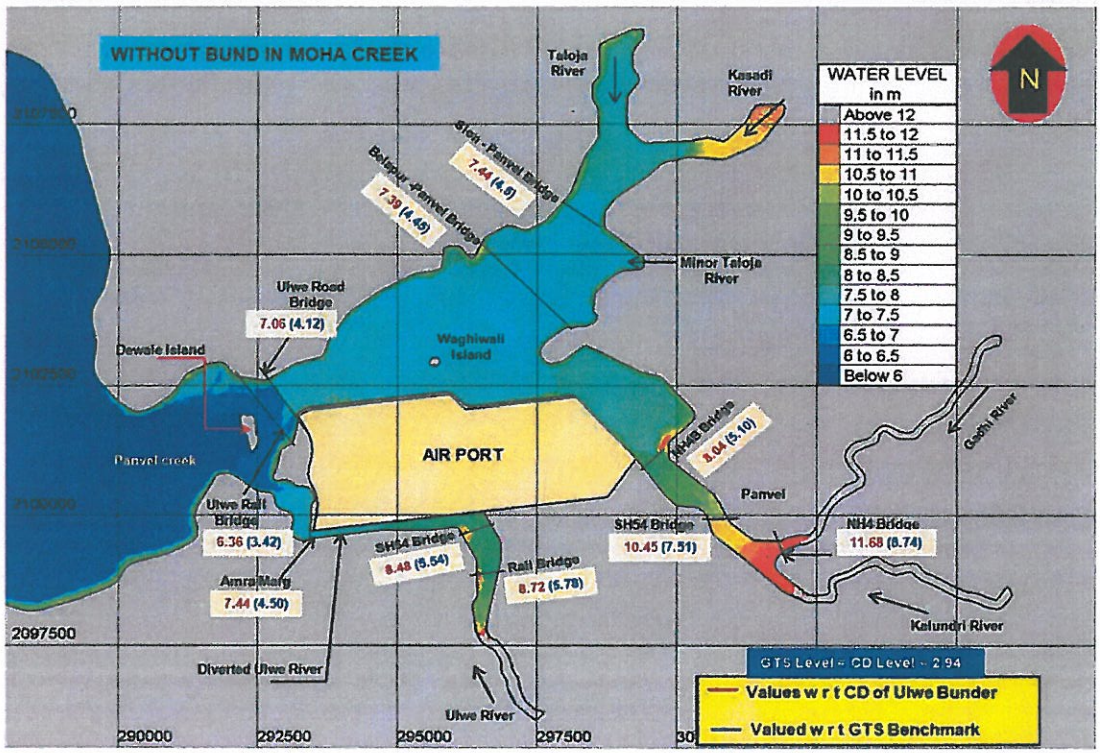

FIG 52(C2): MAXIMA WATER LEVELS FOR DESIGN TIDE AND PMP, 6Hrs STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-200m ULWE DIVERSION - NO BUND IN MOHA CREEK)

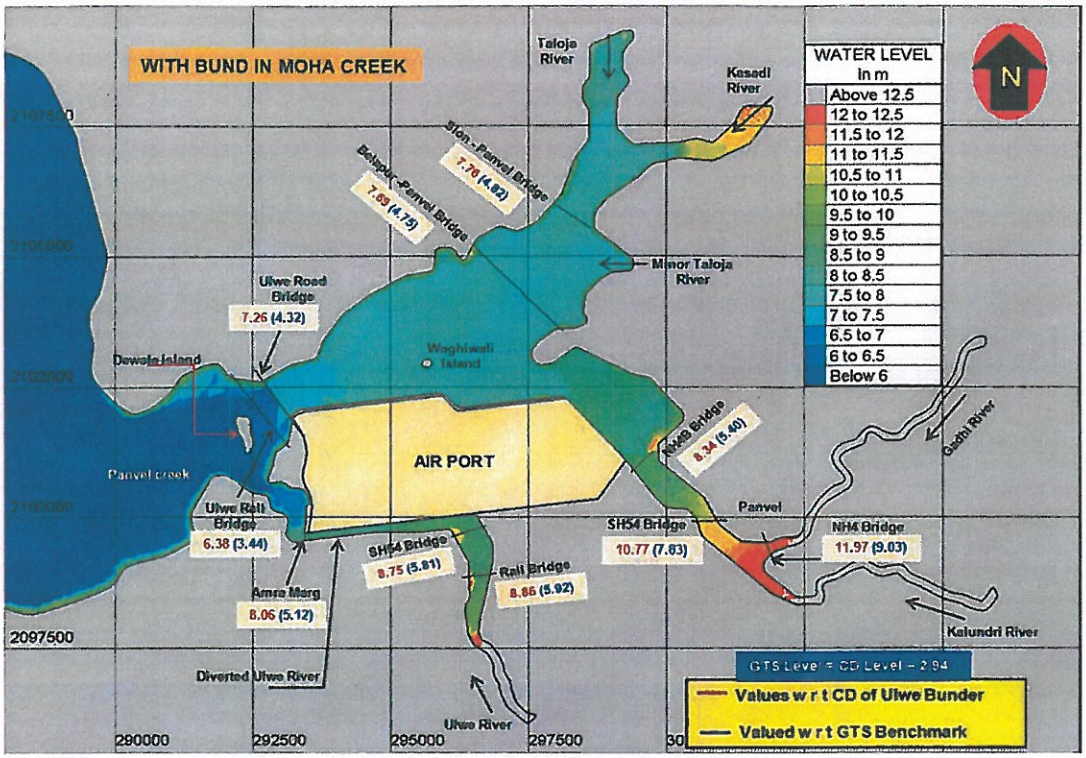

FIG 52(D1): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 26th JULY 2005 STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-200m ULWE DIVERSION -BUND IN MOHA CREEK)

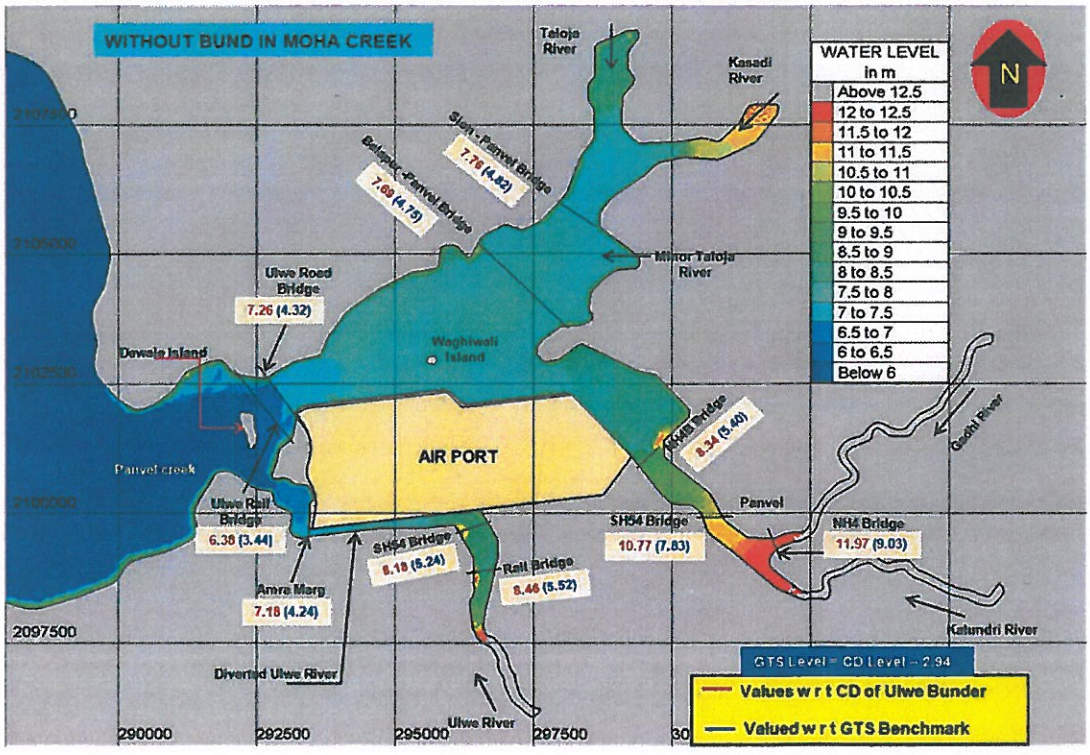

FIG 52(D2): MAXIMA WATER LEVELS FOR DESIGN TIDE AND 26th JULY 2005 STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-200m ULWE DIVERSION - NO BUND IN MOHA CREEK)

9.4.5 Studies for modified layout of Airport with 120 m -240 m wide diversion of Ulwe channel having 120 m opening at Amra Marg

The study was carried to check whether 120 -240 m configuration of diversion channel further results in any reduction in maxima water level near SH-54 Ulwe bridge so as to compare it with 120-200m diversion configuration. The maximum discharge condition of Ulwe river (PMP, 6 Hrs storm) with design tide being the worst scenario, the same was considered to predict maxima water levels at various locations. The details of Ulwe diversion channel with bund considered are shown in FIG 53.

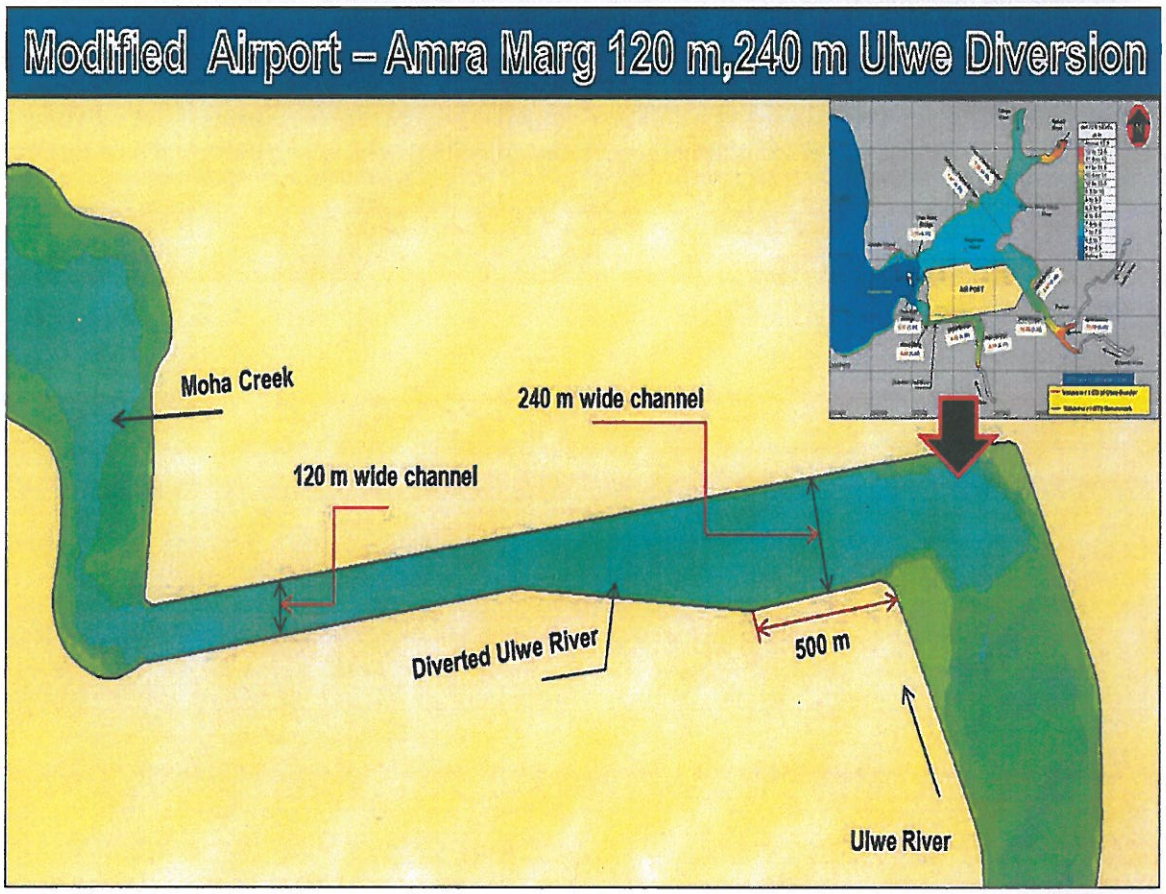

FIG 53: DETAILS OF ULWE DIVERSION WITH 120 m OPENING AT AMRA MARG AND 120 m- 240 m ULWE DIVERSION -BUND IN MOHA CREEK

The maxima water levels predicted with bund in Moha creek is shown in FIG 53(A). The study carried out reveals that, maxima water level predicted with above condition is higher as compared to 120-200 m diversion configuration. As such studies for remaining river discharge conditions were not carried out.

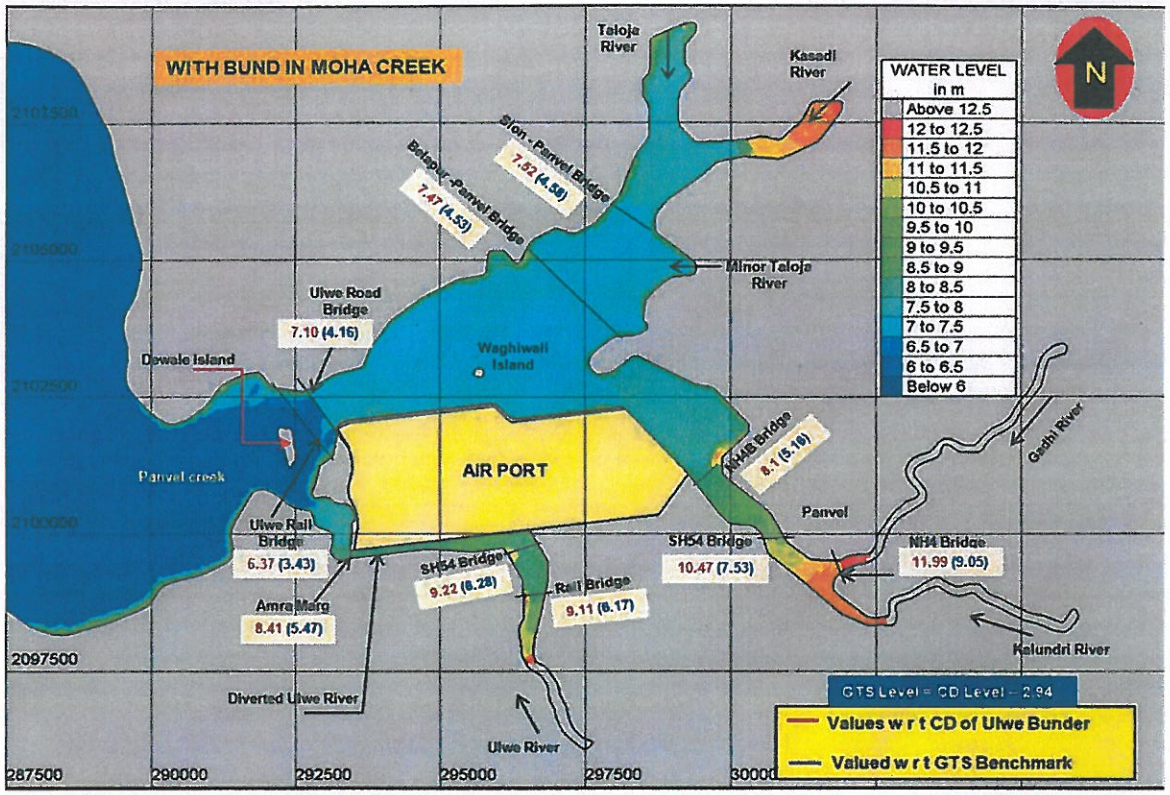

FIG 53(A): MAXIMA WATER LEVELS FOR DESIGN TIDE AND PMP, 6Hrs STORM WITH AIRPORT CONDITION (120 m OPENING AT AMRA MARG AND 120-240m ULWE DIVERSION -BUND IN MOHA CREEK)

9.5 Additional Studies for Modified Layout of Airport and River Discharges with Northern Channel (RL= -2m and RL = -1m)

The studies carried out and mentioned in subheads 9.4.1 to 9.4.5 were also repeated for northern channel having width of 75 m with its bed level at RL = -2m and RL = -1m level. The studies carried out with northern channel reveal that there is no significant change in maxima water levels predicted with that of earlier cases mentioned in para. 9.4. The results of all above test cases are given in Table-5 and following abbreviations are to be followed while reading the Table-5.

Note: - 1) Con-I = Northern channel with invert level as RL = -2m
2) Con-II = Northern channel with invert level as RL = -1m
3) Values in Underline are w.r.t GTS Bench mark

The maxima water levels predicted for all hydrodynamic conditions with various configurations of Ulwe diversion channel for the modified layout of airport as given in Table-5, inferred that Ulwe diversion channel having configuration of 120-200m with no bund in Moha creek and 120 m clear opening at Amra Marg bridge will be an optimal configuration to keep safe grade elevation of airport to a minimal level. Hence this configuration is adopted for further studies such as determination of invert levels of storm water outfall discharges from airport area.

Table - 5

Comparison of Maxima Water Levels Predicted from 2-D Mathematical Model (Telemac-2D) at Different Locations for Different Conditions.

Sr. No.	Condition	Locations																	
		Northern Channel invert level	Thana Creek MDL Jetty	Panvel Creek Mouth 4 Km u/s of MDL Jetty	Belapur Ulwe Rail Bridge	Belapur Ulwe Road Bridge	North of Waghiwali	Belapur Panvel Rail Bridge	u/s of Sion Panvel Road Bridge	d/s of Taloja NH4 Bridge	500 m d/s of Kasadi NH4 Bridge	u/s of Kasadi Rail Bridge	Gadhi NH4B Bridge	u/s of Gadhi SH54 Bridge	Gadhi Kalundri Confluence	Gadhi NH4 Bridge	u/s of Ulwe SH54 Bridge	d/s of Ulwe river Rail Bridge	Amra Marg
1	Existing condition with Spring tide and no Flood discharge	Existing	6.20	6.21	6.20	6.20	6.22	6.24	6.26	6.26	6.27	6.28	6.27	6.29	6.30	6.32	6.27	6.40	6.21
			3.25	3.27	3.25	3.25	3.28	3.3	3.32	3.32	3.33	3.34	3.33	3.35	3.36	3.38	3.33	3.46	3.27
2	Modified Airport condition with Spring tide and no Flood discharge, Ulwe Diversion channel at **Amra Marg** 120m_60m (Moha creek as existing)	Existing	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.40	6.69	6.23
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.46	3.75	3.29
		Con-I	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.40	6.69	6.23
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.46	3.75	3.29
		Con-II	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.40	6.69	6.23
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.46	3.75	3.29
3	Modified Airport condition with Spring tide and no Flood discharge, Ulwe Diversion channel at **Amra Marg** 120m_120m (Moha creek as existing)	Existing	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.39	6.65	6.23
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.45	3.71	3.29
		Con-I	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.39	6.65	6.23
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.45	3.71	3.29
		Con-II	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.39	6.65	6.23
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.45	3.71	3.29
4	Modified Airport condition with Spring tide and no Flood discharge, Ulwe Diversion channel at **Amra Marg** 120m_120m (Moha creek bund removed)	Existing	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.38	6.64	6.23
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.44	3.7	3.29
		Con-I	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.38	6.64	6.23
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.44	3.7	3.29
		Con-II	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.38	6.64	6.23
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.44	3.7	3.29

5	Modified Airport condition with Spring tide and no Flood discharge, Ulwe Diversion channel at **Amra Marg** 120m_180m (Moha creek as existing)	Existing	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.30	6.66	6.25
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.36	3.72	3.31
		Con-I	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.30	6.66	6.25
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.36	3.72	3.31
		Con-II	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.30	6.66	6.25
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.36	3.72	3.31
6	Modified Airport condition with Spring tide and no Flood discharge, Ulwe Diversion channel at **Amra Marg** 120m_180m (Moha creek bund removed)	Existing	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.29	6.63	6.25
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.35	3.69	3.31
		Con-I	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.29	6.63	6.25
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.35	3.69	3.31
		Con-II	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.29	6.63	6.25
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.35	3.69	3.31
7	Modified Airport condition with Spring tide and no Flood discharge, Ulwe Diversion channel at **Amra Marg** 120m_ 200m (Moha creek as existing)	Existing	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.28	6.61	6.25
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.34	3.67	3.31
		Con-I	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.28	6.61	6.25
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.34	3.67	3.31
		Con-II	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.28	6.61	6.25
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.34	3.67	3.31
8	Modified Airport condition with Spring tide and no Flood discharge, Ulwe Diversion channel at **Amra Marg** 120m_200m (Moha creek bund removed)	Existing	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.27	6.60	6.25
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.33	3.66	3.31
		Con-I	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.27	6.60	6.25
			3.25	3.27	3.25	3.25	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.33	3.66	3.31
		Con-II	6.20	6.21	6.20	6.20	6.28	6.30	6.32	6.33	6.34	6.44	6.33	6.36	6.37	6.38	6.27	6.60	6.25
			3.25	3.27	3.25	3.26	3.34	3.36	3.38	3.39	3.4	3.5	3.39	3.42	3.43	3.44	3.33	3.66	3.31

Sr. No.	Condition	Locations																	
		Northern Channel invert level	Thana Creek MDL Jetty	Panvel Creek Mouth 4 Km u/s of MDL Jetty	Belapur Ulwe Rail Bridge	Belapur Ulwe Road Bridge	North of Waghiwali	Belapur Panvel Rail Bridge	u/s of Sion Panvel Road Bridge	d/s of Taloja NH4 Bridge	500 m d/s of Kasadi NH4 Bridge	u/s of Kasadi Rail Bridge	Gadhi NH4B Bridge	u/s of Gadhi SH54 Bridge	Gadhi Kalundri Confluence	Gadhi NH4 Bridge	u/s Ulwe SH54 Bridge	d/s of Ulwe river Rail Bridge	Amra Marg
9	**Existing Condition** for **100 yrs** 6 Hrs Storm with peak of hydrograph at Spring tide HWL	Existing	6.20	6.23	6.34	6.83	7.10	7.12	7.16	7.51	7.30	10.53	7.66	9.77	10.87	11.07	7.18	7.93	6.28
			3.25	3.29	3.4	3.89	4.16	4.18	4.22	4.57	4.36	7.59	4.72	6.83	7.93	8.13	4.24	4.99	3.34
10	**Modified Airport** Condition for 6 Hrs Storm of **100 years** Return Period with peak of hydrograph at Spring tide HWL &Ulwe diversion channel at **Amra Marg 120 m _60m (Moha creek as existing)**	Existing	6.20	6.23	6.32	6.78	7.03	7.06	7.11	7.53	7.26	10.54	7.53	9.88	11.04	11.10	9.25	9.26	8.21
			3.25	3.29	3.38	3.84	4.09	4.12	4.17	4.59	4.32	7.6	4.59	6.94	8.1	8.16	6.31	6.32	5.27
		Con-I	6.20	6.23	6.32	6.78	7.03	7.06	7.11	7.53	7.26	10.54	7.53	9.88	11.04	11.10	9.25	9.26	8.21
			3.25	3.29	3.38	3.84	4.09	4.12	4.17	4.59	4.32	7.6	4.59	6.94	8.1	8.16	6.31	6.32	5.27
		Con-II	6.20	6.23	6.32	6.78	7.03	7.06	7.11	7.53	7.26	10.54	7.53	9.88	11.04	11.10	9.25	9.26	8.21
			3.25	3.29	3.38	3.84	4.09	4.12	4.17	4.59	4.32	7.6	4.59	6.94	8.1	8.16	6.31	6.32	5.27
11	**Modified Airport** Condition for 6 Hrs Storm of **100 years** Return Period with peak of hydrograph at Spring tide HWL &Ulwe diversion channel at **Amra Marg 120 m -120m (Moha creek as existing)**	Existing	6.20	6.23	6.32	6.78	7.03	7.06	7.11	7.53	7.26	10.54	7.53	9.88	11.03	11.10	8.98	9.00	7.98
			3.25	3.29	3.38	3.84	4.09	4.12	4.17	4.59	4.32	7.6	4.59	6.94	8.09	8.16	6.04	6.06	5.04
		Con-I	6.20	6.23	6.32	6.78	7.03	7.06	7.11	7.53	7.26	10.54	7.53	9.88	11.03	11.10	8.98	9.00	7.98
			3.25	3.29	3.38	3.84	4.09	4.12	4.17	4.59	4.32	7.6	4.59	6.94	8.09	8.16	6.04	6.06	5.04
		Con-II	6.20	6.23	6.32	6.78	7.03	7.06	7.11	7.53	7.26	10.54	7.53	9.88	11.03	11.10	8.98	9.00	7.98
			3.25	3.29	3.38	3.84	4.09	4.12	4.17	4.59	4.32	7.6	4.59	6.94	8.09	8.16	6.04	6.06	5.04
12	**Modified Airport** Condition for 6 Hrs Storm of **100 years** Return Period with peak of hydrograph at Spring tide HWL& Ulwe diversion channel at **Amra Marg 120 m -120m (Moha creek bund removed)**	Existing	6.20	6.23	6.32	6.78	7.04	7.06	7.11	7.53	7.26	10.54	7.53	9.88	11.03	11.10	8.51	8.54	7.07
			3.25	3.29	3.38	3.84	4.1	4.12	4.17	4.59	4.32	7.6	4.59	6.94	8.09	8.16	5.57	5.6	4.13
		Con-I	6.20	6.23	6.32	6.78	7.04	7.06	7.11	7.53	7.26	10.54	7.53	9.88	11.03	11.10	8.51	8.54	7.07
			3.25	3.29	3.38	3.84	4.1	4.12	4.17	4.59	4.32	7.6	4.59	6.94	8.09	8.16	5.57	5.6	4.13
		Con-II	6.20	6.23	6.32	6.78	7.04	7.06	7.11	7.53	7.26	10.54	7.53	9.88	11.03	11.10	8.51	8.54	7.07
			3.25	3.29	3.38	3.84	4.1	4.12	4.17	4.59	4.32	7.6	4.59	6.94	8.09	8.16	5.57	5.6	4.13

13	**Modified Airport** Condition for 6 Hrs. Storm of **100 years** Return Period with peak of hydrograph at Spring tide HWL& Ulwe diversion channel at **Amra Marg 120m_180m (Moha creek as existing)**	Existing	6.20	6.23	6.32	6.77	7.01	7.03	7.08	7.48	7.18	10.50	7.62	9.80	10.90	11.02	8.55	8.65	7.91
			3.25	3.29	3.38	3.83	4.07	4.09	4.14	4.54	4.24	7.56	4.68	6.86	7.96	8.08	5.61	5.71	4.97
		Con-I	6.20	6.23	6.32	6.77	7.01	7.03	7.08	7.48	7.18	10.50	7.62	9.80	10.90	11.02	8.55	8.65	7.91
			3.25	3.29	3.38	3.83	4.07	4.09	4.14	4.54	4.24	7.56	4.68	6.86	7.96	8.08	5.61	5.71	4.97
		Con-II	6.20	6.23	6.32	6.77	7.01	7.03	7.08	7.48	7.18	10.50	7.62	9.80	10.90	11.02	8.55	8.65	7.91
			3.25	3.29	3.38	3.83	4.07	4.09	4.14	4.54	4.24	7.56	4.68	6.86	7.96	8.08	5.61	5.71	4.97
14	**Modified Airport** Condition for 6 Hrs. Storm of **100 years** Return Period with peak of hydrograph at Spring tide HWL& Ulwe diversion channel at **Amra Marg 120m_180m (Moha creek bund removed)**	Existing	6.20	6.23	6.32	6.77	7.01	7.03	7.08	7.48	7.18	10.50	7.62	9.80	10.90	11.02	7.98	8.27	7.03
			3.25	3.29	3.38	3.83	4.07	4.09	4.14	4.54	4.24	7.56	4.68	6.86	7.96	8.08	5.04	5.33	4.09
		Con-I	6.20	6.23	6.32	6.77	7.01	7.03	7.08	7.48	7.18	10.50	7.62	9.80	10.90	11.02	7.98	8.27	7.03
			3.25	3.29	3.38	3.83	4.07	4.09	4.14	4.54	4.24	7.56	4.68	6.86	7.96	8.08	5.04	5.33	4.09
		Con-II	6.20	6.23	6.32	6.77	7.01	7.03	7.08	7.48	7.18	10.50	7.62	9.80	10.90	11.02	7.98	8.27	7.03
			3.25	3.29	3.38	3.83	4.07	4.09	4.14	4.54	4.24	7.56	4.68	6.86	7.96	8.08	5.04	5.33	4.09
15	**Modified Airport** Condition for 6 Hrs. Storm of **100 years** Return Period with peak of hydrograph at Spring tide HWL& Ulwe diversion channel at **Amra Marg 120m_200m (Moha creek as existing)**	Existing	6.20	6.23	6.32	6.77	7.01	7.03	7.08	7.48	7.18	10.50	7.62	9.80	10.90	11.02	8.51	8.63	7.91
			3.25	3.29	3.38	3.83	4.07	4.09	4.14	4.54	4.24	7.56	4.68	6.86	7.96	8.08	5.57	5.69	4.97
		Con-I	6.20	6.23	6.32	6.77	7.01	7.03	7.08	7.48	7.18	10.50	7.62	9.80	10.90	11.02	8.51	8.63	7.91
			3.25	3.29	3.38	3.83	4.07	4.09	4.14	4.54	4.24	7.56	4.68	6.86	7.96	8.08	5.57	5.69	4.97
		Con-II	6.20	6.23	6.32	6.77	7.01	7.03	7.08	7.48	7.18	10.50	7.62	9.80	10.90	11.02	8.51	8.63	7.91
			3.25	3.29	3.38	3.83	4.07	4.09	4.14	4.54	4.24	7.56	4.68	6.86	7.96	8.08	5.57	5.69	4.97
16	**Modified Airport** Condition for 6 Hrs. Storm of **100 years** Return Period with peak of hydrograph at Spring tide HWL& Ulwe diversion channel at **Amra Marg 120m_200m (Moha creek bund removed)**	Existing	6.20	6.23	6.32	6.77	7.01	7.03	7.08	7.48	7.18	10.50	7.62	9.80	10.90	11.02	7.94	8.25	7.03
			3.25	3.29	3.38	3.84	4.06	4.08	4.14	4.54	4.23	7.56	4.67	6.86	7.96	8.08	5	5.31	4.09
		Con-I	6.20	6.23	6.32	6.77	7.00	7.02	7.08	7.48	7.18	10.50	7.61	9.80	10.90	11.02	7.94	8.25	7.03
			3.25	3.29	3.38	3.84	4.06	4.08	4.14	4.54	4.23	7.56	4.67	6.86	7.96	8.08	5	5.31	4.09
		Con-II	6.20	6.23	6.32	6.78	7.00	7.02	7.08	7.48	7.17	10.50	7.61	9.80	10.90	11.02	7.94	8.25	7.03
			3.25	3.29	3.38	3.84	4.06	4.08	4.14	4.54	4.23	7.56	4.67	6.86	7.96	8.08	5	5.31	4.09

Sr. No.	Condition	Locations																
		Northern Channel invert level	Thana Creek MDL Jetty	Panvel Creek Mouth 4 Km u/s of MDL Jetty	Belapur Ulwe Rail Bridge	Belapur Ulwe Road Bridge	North of Waghiwali	Belapur Panvel Rail Bridge	u/s of Sion Panvel Road Bridge	d/s of Taloja NH4 Bridge	500 m d/s of Kasadi NH4 Bridge	u/s of Kasadi Rail Bridge	Gadhi NH4B Bridge	u/s of Gadhi SH54 Bridge	Gadhi Kalundri Confluence	Gadhi NH4 Bridge	u/s Ulwe SH54 Bridge	d/s of Ulwe river Rail Bridge	Amra Marg
17	Existing Condition for PMP 6 Hrs. Storm with peak of hydrograph at Spring tide HWL	Existing	6.20	6.23	6.38	7.15	7.48	7.50	7.54	7.81	7.67	10.79	8.26	10.52	11.57	11.73	7.57	8.14	6.30
			3.25	3.29	3.44	4.21	4.54	4.56	4.6	4.87	4.73	7.85	5.32	7.58	8.63	8.79	4.63	5.2	3.36
18	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at Spring tide HWL and Ulwe diversion channel at **Amra Marg** 120 m _60m (Moha creek as existing)	Existing	6.20	6.23	6.37	7.11	7.44	7.47	7.52	7.98	7.68	10.79	8.04	10.58	11.76	11.80	10.80	10.81	9.56
			3.25	3.29	3.43	4.17	4.5	4.53	4.58	5.04	4.74	7.85	5.1	7.64	8.82	8.86	7.86	7.87	6.62
		Con-I	6.20	6.23	6.37	7.11	7.44	7.47	7.52	7.98	7.68	10.79	8.04	10.58	11.76	11.80	10.80	10.81	9.56
			3.25	3.29	3.43	4.17	4.5	4.53	4.58	5.04	4.74	7.85	5.1	7.64	8.82	8.86	7.86	7.87	6.62
		Con-II	6.20	6.23	6.37	7.11	7.44	7.47	7.52	7.98	7.68	10.79	8.04	10.58	11.76	11.80	10.80	10.81	9.56
			3.25	3.29	3.43	4.17	4.5	4.53	4.58	5.04	4.74	7.85	5.1	7.64	8.82	8.86	7.86	7.87	6.62
19	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at Spring tide HWL and Ulwe diversion channel at **Amra Marg** 120 m _120m (Moha creek as existing)	Existing	6.20	6.23	6.37	7.11	7.44	7.47	7.52	7.98	7.68	10.79	8.04	10.58	11.77	11.80	9.64	9.65	8.33
			3.25	3.29	3.43	4.17	4.5	4.53	4.58	5.04	4.74	7.85	5.1	7.64	8.83	8.86	6.7	6.71	5.39
		Con-I	6.20	6.23	6.37	7.11	7.44	7.47	7.52	7.98	7.68	10.79	8.04	10.58	11.77	11.80	9.64	9.65	8.33
			3.25	3.29	3.43	4.17	4.5	4.53	4.58	5.04	4.74	7.85	5.1	7.64	8.83	8.86	6.7	6.71	5.39
		Con-II	6.20	6.23	6.37	7.11	7.44	7.47	7.52	7.98	7.68	10.79	8.04	10.58	11.77	11.80	9.64	9.65	8.33
			3.25	3.29	3.43	4.17	4.5	4.53	4.58	5.04	4.74	7.85	5.1	7.64	8.83	8.86	6.7	6.71	5.39
20	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at Spring tide HWL and Ulwe diversion channel at **Amra Marg** 120 m _120m (Moha creek bund removed)	Existing	6.20	6.23	6.37	7.11	7.44	7.47	7.52	7.98	7.68	10.79	8.04	10.58	11.76	11.80	9.19	9.21	7.49
			3.25	3.29	3.43	4.17	4.5	4.53	4.58	5.04	4.74	7.85	5.1	7.64	8.82	8.86	6.25	6.27	4.55
		Con-I	6.20	6.23	6.37	7.11	7.44	7.47	7.52	7.98	7.68	10.79	8.04	10.5	11.76	11.80	9.19	9.21	7.49
			3.25	3.29	3.43	4.17	4.5	4.53	4.58	5.04	4.74	7.85	5.1	7.64	8.82	8.86	6.25	6.27	4.55
		Con-II	6.20	6.23	6.37	7.11	7.44	7.47	7.52	7.98	7.68	10.79	8.04	10.58	11.76	11.80	9.19	9.21	7.49
			3.25	3.29	3.43	4.17	4.5	4.53	4.58	5.04	4.74	7.85	5.1	7.64	8.82	8.86	6.25	6.27	4.55

21	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at Spring tide HWL & Ulwe diversion channel at **Amra Marg 120m_ 180m** (Moha creek as existing)	Existing	6.20	6.23	6.36	7.06	7.37	7.39	7.44	7.84	7.51	10.75	8.04	10.45	11.59	11.68	9.12	9.21	8.30
			3.25	3.29	3.42	4.12	4.43	4.45	4.5	4.9	4.57	7.81	5.1	7.51	8.65	8.74	6.18	6.27	5.36
		Con-I	6.20	6.23	6.36	7.06	7.37	7.39	7.44	7.84	7.51	10.75	8.04	10.45	11.59	11.68	9.12	9.21	8.30
			3.25	3.29	3.42	4.12	4.43	4.45	4.5	4.9	4.57	7.81	5.1	7.51	8.65	8.74	6.18	6.27	5.36
		Con-II	6.20	6.23	6.36	7.06	7.37	7.39	7.44	7.84	7.51	10.75	8.04	10.45	11.59	11.68	9.12	9.21	8.30
			3.25	3.29	3.42	4.12	4.43	4.45	4.5	4.9	4.57	7.81	5.1	7.51	8.65	8.74	6.18	6.27	5.36
22	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at Spring tide HWL and Ulwe diversion channel at **Amra Marg 120m_ 180m** (Moha creek bund removed)	Existing	6.20	6.23	6.36	7.06	7.37	7.39	7.44	7.84	7.51	10.75	8.04	10.45	11.59	11.68	8.60	8.80	7.46
			3.25	3.29	3.42	4.12	4.43	4.45	4.5	4.9	4.57	7.81	5.1	7.51	8.65	8.74	5.66	5.86	4.52
		Con-I	6.20	6.23	6.36	7.06	7.37	7.39	7.44	7.84	7.51	10.75	8.04	10.45	11.59	11.68	8.60	8.80	7.46
			3.25	3.29	3.42	4.12	4.43	4.45	4.5	4.9	4.57	7.81	5.1	7.51	8.65	8.74	5.66	5.86	4.52
		Con-II	6.20	6.23	6.36	7.06	7.37	7.39	7.44	7.84	7.51	10.75	8.04	10.45	11.59	11.68	8.60	8.80	7.46
			3.25	3.29	3.42	4.12	4.43	4.45	4.5	4.9	4.57	7.81	5.1	7.51	8.65	8.74	5.66	5.86	4.52
23	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at Spring tide HWL & Ulwe diversion channel at **Amra Marg 120m_ 200m** (Moha creek as existing)	Existing	6.20	6.23	6.36	7.06	7.37	7.39	7.44	7.84	7.51	10.75	8.04	10.45	11.59	11.68	9.08	9.17	8.28
			3.25	3.29	3.42	4.12	4.43	4.45	4.5	4.9	4.57	7.81	5.1	7.51	8.65	8.74	6.14	6.23	5.34
		Con-I	6.20	6.23	6.36	7.06	7.37	7.39	7.44	7.84	7.51	10.75	8.04	10.45	11.59	11.68	9.08	9.17	8.28
			3.25	3.29	3.42	4.12	4.43	4.45	4.5	4.9	4.57	7.81	5.1	7.51	8.65	8.74	6.14	6.23	5.34
		Con-II	6.20	6.23	6.36	7.06	7.37	7.39	7.44	7.84	7.51	10.75	8.04	10.45	11.59	11.68	9.08	9.17	8.28
			3.25	3.29	3.42	4.12	4.43	4.45	4.5	4.9	4.57	7.81	5.1	7.51	8.65	8.74	6.14	6.23	5.34
24	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at Spring tide HWL and Ulwe diversion channel at **Amra Marg 120m_ 200m** (Moha creek bund removed)	Existing	6.20	6.23	6.36	7.06	7.37	7.39	7.44	7.84	7.51	10.75	8.04	10.45	11.59	11.68	8.50	8.72	7.44
			3.25	3.29	3.42	4.12	4.43	4.45	4.5	4.9	4.57	7.81	5.1	7.51	8.65	8.74	5.56	5.78	4.5
		Con-I	6.20	6.23	6.36	7.06	7.37	7.39	7.44	7.84	7.51	10.75	8.04	10.45	11.59	11.68	8.50	8.72	7.44
			3.25	3.29	3.42	4.12	4.43	4.45	4.5	4.9	4.57	7.81	5.1	7.51	8.65	8.74	5.56	5.78	4.5
		Con-II	6.20	6.23	6.36	7.06	7.37	7.39	7.44	7.84	7.51	10.75	8.04	10.45	11.59	11.68	8.50	8.72	7.44
			3.25	3.29	3.42	4.12	4.43	4.45	4.5	4.9	4.57	7.81	5.1	7.51	8.65	8.74	5.56	5.78	4.5
25	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at Spring tide HWL & Ulwe diversion channel at **Amra Marg 120m_ 240m** (Moha creek as existing)	Existing	6.20	6.23	6.37	7.10	7.44	7.47	7.52	7.86	7.63	10.74	8.10	10.47	11.58	11.99	9.11	9.22	8.41
			3.25	3.29	3.43	4.16	4.5	4.53	4.58	4.92	4.69	7.8	5.16	7.51	8.65	9.05	6.17	6.28	5.47
		Con-I	6.20	6.23	6.37	7.10	7.44	7.47	7.52	7.86	7.63	10.74	8.10	10.47	11.58	11.99	9.11	9.22	8.41
			3.25	3.29	3.43	4.16	4.5	4.53	4.58	4.92	4.69	7.8	5.16	7.51	8.65	9.05	6.17	6. 28	5.47
		Con-II	6.20	6.23	6.37	7.10	7.44	7.47	7.52	7.86	7.63	10.74	8.10	10.47	11.58	11.99	9.11	9.22	8.41
			3.25	3.29	3.43	4.16	4.5	4.53	4.58	4.92	4.69	7.8	5.16	7.51	8.65	9.05	6.17	6.28	5.47

Sr. No.	Condition	Locations																
		Northern Channel Invert level	Thana Creek MDL Jetty	Panvel Creek Mouth 4 Km u/s of MDL Jetty	Belapur Ulwe Rail Bridge	Belapur Ulwe Road Bridge	North of Waghiwali	Belapur Panvel Rail Bridge	u/s of Sion Panvel Road Bridge	d/s of Taloja NH4 Bridge	500 m d/s of Kasadi NH4 Bridge	u/s of Kasadi Rail Bridge	Gadhi NH4B Bridge	u/s of Gadhi SH54 Bridge	Gadhi Kalundri Confluence	Gadhi NH4 Bridge	u/s Ulwe SH54 Bridge	d/s of Ulwe river Rail Bridge	Amra Marg
26	**Existing Condition** for **26th July** 2005 Belapur Storm with peak of hydrograph at Spring tide HWL	Existing	6.20	6.23	6.41	7.35	7.79	7.80	7.85	8.18	8.06	11.06	8.67	10.93	11.91	12.05	7.39	8.15	6.31
			3.25	3.29	3.47	4.41	4.85	4.86	4.91	5.24	5.12	8.12	5.73	7.99	8.97	9.11	4.45	5.21	3.37
27	**Modified Airport** Condition for **26th July** Belapur Storm with peak of hydrograph at Spring tide HWL and Ulwe diversion channel at **Amra Marg 120 m - 60m (Moha creek as existing)**	Existing	6.20	6.23	6.39	7.16	7.56	7.59	7.67	8.04	7.87	11.07	8.42	10.91	12.08	12.07	10.5	10.55	8.64
			3.25	3.29	3.45	4.22	4.62	4.65	4.73	5.10	4.93	8.13	5.48	7.97	9.14	9.13	7.60	7.61	5.70
		Con-I	6.20	6.23	6.39	7.16	7.56	7.59	7.67	8.04	7.87	11.07	8.42	10.91	12.08	12.07	10.5	10.55	8.64
			3.25	3.29	3.45	4.22	4.62	4.65	4.73	5.10	4.93	8.13	5.48	7.97	9.14	9.13	7.60	7.61	5.70
		Con-II	6.20	6.23	6.39	7.16	7.56	7.59	7.67	8.04	7.87	11.07	8.42	10.91	12.08	12.07	10.5	10.55	8.64
			3.25	3.29	3.45	4.22	4.62	4.65	4.73	5.10	4.93	8.13	5.48	7.97	9.14	9.13	7.60	7.61	5.70
28	**Modified Airport** Condition for **26th July** Belapur Storm with peak of hydrograph at Spring tide HWL & Ulwe diversion channel at **Amra Marg 120 m _120m (Moha creek as existing)**	Existing	6.20	6.23	6.38	7.20	7.61	7.64	7.70	8.05	7.88	11.06	8.34	10.86	12.03	12.04	9.04	9.06	8.08
			3.25	3.29	3.44	4.26	4.67	4.7	4.76	5.11	4.94	8.12	5.4	7.92	9.09	9.1	6.1	6.12	5.14
		Con-I	6.20	6.23	6.38	7.20	7.61	7.64	7.70	8.05	7.88	11.06	8.34	10.86	12.03	12.04	9.04	9.06	8.08
			3.25	3.29	3.44	4.26	4.67	4.7	4.76	5.11	4.94	8.12	5.4	7.92	9.09	9.1	6.1	6.12	5.14
		Con-II	6.20	6.23	6.38	7.20	7.61	7.64	7.70	8.05	7.88	11.06	8.34	10.86	12.03	12.04	9.04	9.06	8.08
			3.25	3.29	3.44	4.26	4.67	4.7	4.76	5.11	4.94	8.12	5.4	7.92	9.09	9.1	6.1	6.12	5.14
29	**Modified Airport** Condition for **26th July** Belapur Storm with peak of hydrograph at Spring tide HWL &Ulwe diversion channel at **Amra Marg 120 m _120m (Moha creek bund removed)**	Existing	6.20	6.23	6.38	7.20	7.61	7.64	7.70	8.05	7.88	11.06	8.34	10.86	12.03	12.04	8.56	8.59	7.10
			3.25	3.29	3.44	4.26	4.67	4.7	4.76	5.11	4.94	8.12	5.4	7.92	9.09	9.1	5.62	5.65	4.16
		Con-I	6.20	6.23	6.38	7.20	7.61	7.64	7.70	8.05	7.88	11.06	8.34	10.86	12.03	12.04	8.56	8.59	7.10
			3.25	3.29	3.44	4.26	4.67	4.7	4.76	5.11	4.94	8.12	5.4	7.92	9.09	9.1	5.62	5.65	4.16
		Con-II	6.20	6.23	6.38	7.20	7.61	7.64	7.70	8.05	7.88	11.06	8.34	10.86	12.03	12.04	8.56	8.59	7.10
			3.25	3.29	3.44	4.26	4.67	4.7	4.76	5.11	4.94	8.12	5.4	7.92	9.09	9.1	5.62	5.65	4.16

30	**Modified Airport** Condition for **26th July** Belapur Storm with peak of hydrograph at Spring tide HWL& Ulwe diversion channel at **Amra Marg 120m- 180m (Moha creek as existing)**	Existing	6.20	6.23	6.38	7.26	7.66	7.69	7.76	8.17	7.90	11.03	8.34	10.77	11.91	11.97	8.79	8.89	8.07
			3.25	3.29	3.44	4.32	4.72	4.75	4.82	5.23	4.96	8.09	5.4	7.83	8.97	9.03	5.85	5.95	5.13
		Con-I	6.20	6.23	6.38	7.26	7.66	7.69	7.76	8.17	7.90	11.03	8.34	10.77	11.91	11.97	8.79	8.89	8.07
			3.25	3.29	3.44	4.32	4.72	4.75	4.82	5.23	4.96	8.09	5.4	7.83	8.97	9.03	5.85	5.95	5.13
		Con-II	6.20	6.23	6.38	7.26	7.66	7.69	7.76	8.17	7.90	11.03	8.34	10.77	11.91	11.97	8.79	8.89	8.07
			3.25	3.29	3.44	4.32	4.72	4.75	4.82	5.23	4.96	8.09	5.4	7.83	8.97	9.03	5.85	5.95	5.13
31	**Modified Airport** Condition for **26th July** Belapur Storm with peak of hydrograph at Spring tide HWL & Ulwe diversion channel at **Amra Marg 120m_ 180m Marg (Moha creek bund removed)**	Existing	6.20	6.23	6.38	7.26	7.66	7.69	7.76	8.17	7.90	11.03	8.34	10.77	11.91	11.97	8.23	8.49	7.18
			3.25	3.29	3.44	4.32	4.72	4.75	4.82	5.23	4.96	8.09	5.4	7.83	8.97	9.03	5.29	5.55	4.24
		Con-I	6.20	6.23	6.38	7.26	7.66	7.69	7.76	8.17	7.90	11.03	8.34	10.77	11.91	11.97	8.23	8.49	7.18
			3.25	3.29	3.44	4.32	4.72	4.75	4.82	5.23	4.96	8.09	5.4	7.83	8.97	9.03	5.29	5.55	4.24
		Con-II	6.20	6.23	6.38	7.26	7.66	7.69	7.76	8.17	7.90	11.03	8.34	10.77	11.91	11.97	8.23	8.49	7.18
			3.25	3.29	3.44	4.32	4.72	4.75	4.82	5.23	4.96	8.09	5.4	7.83	8.97	9.03	5.29	5.55	4.24
32	**Modified Airport** Condition for **26th July** Belapur Storm with peak of hydrograph at Spring tide HWL& Ulwe diversion channel at **Amra Marg 120m_ 200m (Moha creek as existing)**	Existing	6.20	6.23	6.38	7.26	7.66	7.69	7.76	8.17	7.90	11.03	8.34	10.77	11.91	11.97	8.75	8.86	8.06
			3.25	3.29	3.44	4.32	4.72	4.75	4.82	5.23	4.96	8.09	5.4	7.83	8.97	9.03	5.81	5.92	5.12
		Con-I	6.20	6.23	6.38	7.26	7.66	7.69	7.76	8.17	7.90	11.03	8.34	10.77	11.91	11.97	8.75	8.86	8.06
			3.25	3.29	3.44	4.32	4.72	4.75	4.82	5.23	4.96	8.09	5.4	7.83	8.97	9.03	5.81	5.92	5.12
		Con-II	6.20	6.23	6.38	7.26	7.66	7.69	7.76	8.17	7.90	11.03	8.34	10.77	11.91	11.97	8.75	8.86	8.06
			3.25	3.29	3.44	4.32	4.72	4.75	4.82	5.23	4.96	8.09	5.4	7.83	8.97	9.03	5.81	5.92	5.12
33	**Modified Airport** Condition for **26th July** Belapur Storm with peak of hydrograph at Spring tide HWL & Ulwe diversion channel at **Amra Marg 120m_ 200m (Moha creek bund removed)**	Existing	6.20	6.23	6.38	7.26	7.66	7.69	7.76	8.17	7.90	11.03	8.34	10.77	11.91	11.97	8.18	8.46	7.18
			3.25	3.29	3.44	4.32	4.72	4.75	4.82	5.23	4.96	8.09	5.4	7.83	8.97	9.03	5.24	5.52	4.24
		Con-I	6.20	6.23	6.38	7.26	7.66	7.69	7.76	8.17	7.90	11.03	8.34	10.77	11.91	11.97	8.18	8.46	7.18
			3.25	3.29	3.44	4.32	4.72	4.75	4.82	5.23	4.96	8.09	5.4	7.83	8.97	9.03	5.24	5.52	4.24
		Con-II	6.20	6.23	6.38	7.26	7.66	7.69	7.76	8.17	7.90	11.03	8.34	10.77	11.91	11.97	8.18	8.46	7.18
			3.25	3.29	3.44	4.32	4.72	4.75	4.82	5.23	4.96	8.09	5.4	7.83	8.97	9.03	5.24	5.52	4.24

Note: - 1) Con-I = Northern channel with invert level as RL = -2m
2) Con-II = Northern channel with invert level as RL = -1m
3) Values in Underline are w.r.t GTS Bench mark

9.6 Studies for predicting invert level of outfalls for storm water discharges around boundaries for modified layout of Airport

The area of modified airport is about 1160 ha and the water collected over the entire airport area during extreme rainfall events needs to be discharged in to creek/riverine area to avoid inundation over the airport area. In order to decide sill levels of the outfall of storm water drainage in reclaimed area of airport, the maximum water level with peak flood (100 yr-RP, 6 hrs storm; PMP, 6 Hrs storm, 26 July 2005) arriving at the time of low water level of neap tide was considered. In order to carry out these studies the Ulwe diversion channel of 120-200 m width having 120 m opening at Amra Marg and no bund in Moha creek which will be most suitable layout to keep safe grade elevation of Airport to a minimum was considered. The layout wherein the locations of outfalls for discharging storm water were provided by M/s CIDCO is as shown in FIG. 54.

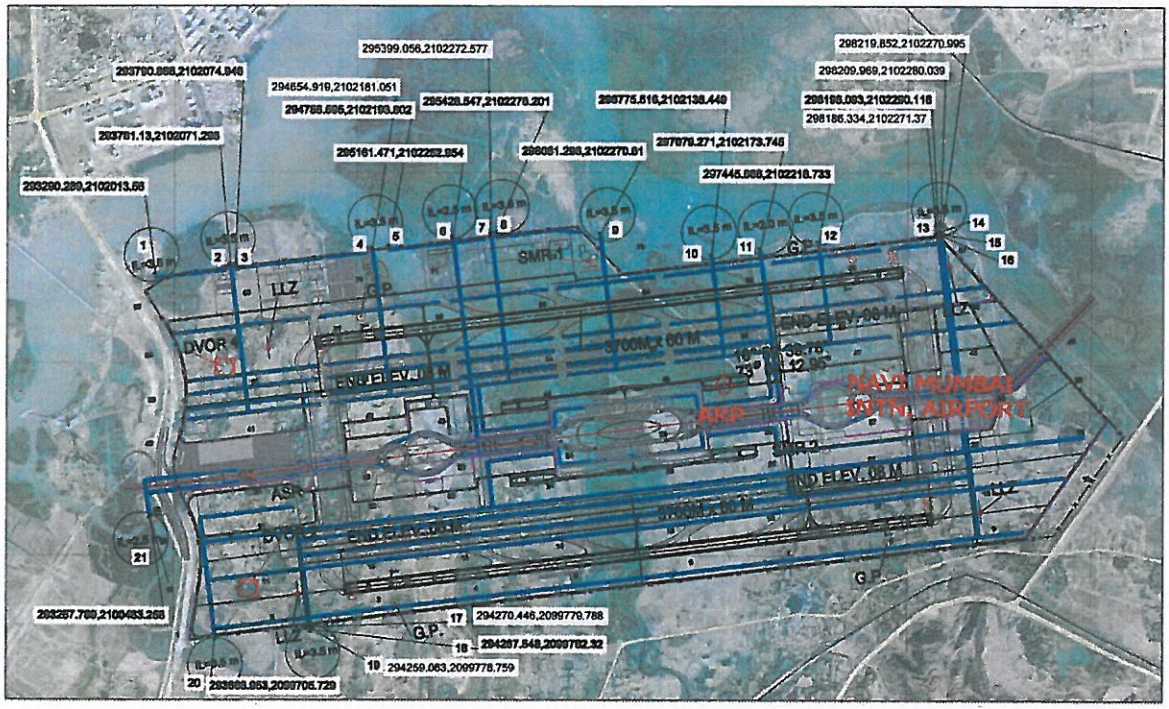

FIG. 54 LAYOUT OF AIRPORT SHOWING LOCATIONS OF OUTFALLS FOR STORM WATER DRAINAGE FROM AIRPORT AREA

The locations of outfall points and runoff discharges provided by M/s CIDCO are also given in Table- 6. The model studies were carried out for measured lowest neap tidal range (Data measured during May-June 2007 as HWL=3.42 m and LWL=2.17m with respect to CD at Ulwe Bundar). The time of occurrence of peak of Hydrograph and low water level of lowest neap tidal range was coincided and the maxima water level predicted for such configuration was used to determine the invert level of outfall points of runoff discharges from airport area.

Table -6

Details of Outlet Points for NMIA

Outlet no.	Easting in m	Northing in m	Discharge(cumec)
1	293290.29	2102013.56	9.04
2	293761.13	2102071.30	12.04
3	293790.87	2102074.95	8.88
4	294654.92	2102181.05	14.76
5	294758.60	2102193.80	13.14
6	295161.47	2102252.95	11.98
7	295399.06	2102272.58	13.52
8	295428.55	2102276.20	6.89
9	296081.30	2102270.61	12.99
10	296775.52	2102136.45	10.33
11	297079.27	2102173.75	19.37
12	297445.67	2102218.73	15.09
13	298186.33	2102271.37	8.38
14	298198.09	2102290.12	20.5
15	298209.97	2102280.04	15.24
16	298219.85	2102271.00	11.06
17	294270.45	2099779.79	16.03
18	294267.55	2099762.32	9.68
19	294259.06	2099778.76	12.38
20	293668.95	2099705.73	12.94
21	293257.79	2100483.26	9.29

The model studies were carried out under various hydrodynamic conditions and results of predicted invert levels in the vicinity of proposed storm water outfalls (Table-6) around airport are given in Table 7, while the invert levels to be adopted are given in FIG. 55.

Table-7

Predicted Water Levels around Airport for Neap tide with runoff discharges from Airport area

Water Levels around Airport in meter											
Sr. No.	Condition		Northern channel side ← Locations → Uiwe Diversion								
		Northern Channel invert level	1	2	3	4	5	6	7	8	9
1	Modified Airport condition with Neap tide and no Flood discharge, Uiwe Diver 200m_120m Amra Marg (Moha creek as existing)	Existing	4.40	3.52	3.61	3.53	4.94	3.91	4.59	4.54	3.81
		Con-I	4.40	3.52	3.61	3.53	4.94	3.91	4.59	4.54	3.81
		Con-II	4.40	3.52	3.61	3.53	4.94	3.91	4.59	4.54	3.81
2	Modified Airport condition with Neap tide and no Flood discharge, Uiwe Diver 200m_120m Amra Marg (Moha creek bund removed)	Existing	4.40	3.52	3.61	3.53	4.94	3.91	4.40	4.34	3.80
		Con-I	4.40	3.52	3.61	3.53	4.94	3.91	4.40	4.34	3.80
		Con-II	4.40	3.52	3.61	3.53	4.94	3.91	4.40	4.34	3.80
3	Modified Airport Condition for 6 Hrs. Storm of 100 years Return Period with peak of hydrograph at Neap tide HWL& Uiwe diversion channel 200 m wide 120m Amra Marg (Moha creek as existing)	Existing	5.05	5.33	5.59	5.67	6.06	6.60	8.37	7.96	6.44
		Con-I	5.05	5.33	5.59	5.67	6.06	6.60	8.37	7.96	6.44
		Con-II	5.05	5.33	5.59	5.67	6.06	6.60	8.37	7.96	6.44
4	Modified Airport Condition for 6 Hrs. Storm of 100 years Return Period with peak of hydrograph at Neap tide HWL& Uiwe diversion channel 200 m wide 120m Amra Marg (Moha creek bund removed)	Existing	5.04	5.32	5.59	5.67	6.05	6.60	7.55	6.91	6.50
		Con-I	5.04	5.32	5.59	5.67	6.05	6.60	7.55	6.91	6.50
		Con-II	5.04	5.32	5.59	5.67	6.05	6.60	7.55	6.91	6.50

Table-7-- cont.

Water Levels around Airport in meter

Sr. No.	Condition		Northern channel side ← Locations → Ulwe Diversion								
		Northern Channel invert level	1	2	3	4	5	6	7	8	9
5	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at Neap tide HWL & Ulwe diversion channel 200 m wide_120m Amra Marg (Moha creek as existing)	Existing	5.77	6.08	6.26	6.36	6.64	7.19	8.89	8.34	7.05
		Con-I	5.77	6.08	6.26	6.36	6.64	7.19	8.89	8.34	7.05
		Con-II	5.77	6.08	6.26	6.36	6.64	7.19	8.89	8.34	7.05
6	Condition for PMP 6 Hrs. Storm with peak of hydrograph at Neap tide HWL and Ulwe diversion channel 200 m wide_120m Amra Marg (Moha creek bund removed)	Existing	5.77	6.08	6.26	6.36	6.63	7.2	8.22	7.45	7.05
		Con-I	5.78	6.11	6.24	6.33	6.62	7.18	8.22	7.45	7.05
		Con-II	5.77	6.08	6.26	6.36	6.63	7.2	8.22	7.45	7.05
7	Condition for 26th July Belapur Storm with peak of hydrograph at Neap tide HWL& Ulwe diversion channel 200 m wide_120m Amra Marg (Moha creek as existing)	Existing	6.51	6.83	6.96	7.05	7.29	7.66	8.59	8.12	6.71
		Con-I	6.51	6.83	6.96	7.05	7.29	7.66	8.59	8.12	6.71
		Con-II	6.51	6.83	6.96	7.05	7.29	7.66	8.59	8.12	6.71
8	Modified Airport Condition for 26th July Belapur Storm with peak of hydrograph at Neap tide HWL & Ulwe diversion channel 200 m wide_120m Amra Marg (Moha creek bund removed)	Existing	6.52	6.83	6.96	7.06	7.29	7.66	7.85	7.15	6.73
		Con-I	6.52	6.83	6.96	7.06	7.29	7.66	7.85	7.15	6.73
		Con-II	6.52	6.83	6.96	7.06	7.29	7.66	7.85	7.15	6.73

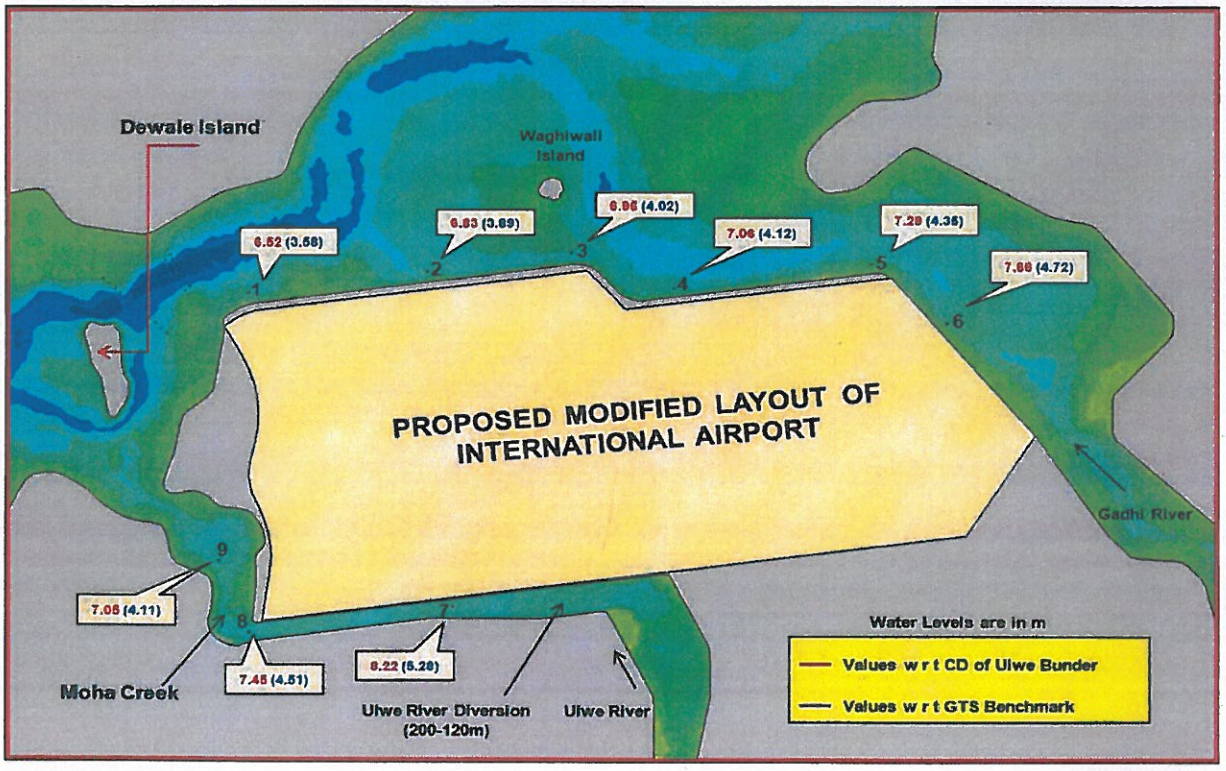

FIG.55 PREDICTED INVERT LEVELS OF STORM WATER OUTFALL AROUND MODIFIED LAYOUT OF AIRPORT

10.0 ANALYSIS OF RESULTS

The analysis of results of the studies presented in Table-5 for various hydrodynamic conditions as well as with various configurations of Ulwe diversion channel as mentioned in above para. are described in detail.

10.1 Water levels

From the comparison of maxima water levels for both the conditions i.e. with and without the airport presented vide Table 5 as obtained from FIGS 31 to 53 for different conditions, the following broad conclusions are drawn:

For design spring tides and no flood conditions

(i) Reclamation due to proposed modified airport layout do not affect the water levels at the mouth of Panvel Creek, which controls the flow in and out of Panvel Creek. The water levels further in downstream reach are also not affected.

(ii) During spring tide, the rise in the maxima water levels in the reach from Belapur – Ulwe railway bridge to NH-4 bridge on Gadhi, Kasadi, Kalundri and Taloja rivers on upstream will be less than 0.2 m after reclamation of the proposed airport for no flood condition having Ulwe diversion channel of size 120 m-200 m with no bund in Moha creek and clear opening of 120 m at Amra Marg bridge .

(iii) Along Ulwe river reach, upstream of location of proposed diversion (SH-54 bridge - Ulwe railway bridge) the maximum rise in the water levels is about 0.3m for no flood conditions having Ulwe diversion channel of size 120 m - 200 m with no bund in Moha creek and clear opening of 120 m at Amra Marg bridge.

For design spring tide with floods due to 100 year return period, 6 Hrs storm; PMP rainfall for 6 Hrs storm & 26th July 2005 case

(i) There will be no rise in flood levels at Panvel Creek mouth and the reach downstream.

(ii) The rise in the maxima water levels at different locations in Panvel Creek during design spring tide and different flood discharges are summarized in Table 8 :

TABLE-8

Rise in Maxima Water Levels due to Airport Reclamation in Comparison to Without Airport Condition

Location	Rise in maxima water level (m) due to		
	Design Spring tide with 100 year- RP, 6 hour storm	Design Spring tide with PMP- 6 hour storm	Design Spring tide with 26th July 2005 case
Mouth of Panvel Creek	Nil	Nil	Nil
Belapur – Ulwe rail bridge	Nil	Nil	Nil
Belapur – Ulwe road bridge	Nil	Nil	Nil
North of Waghiwali island	Nil	Nil	Nil
Belapur-Panvel rail bridge	Nil	Nil	Nil
Upstream of Sion-Panvel road bridge	Nil	Nil	Nil
Downstream of NH-4 bridge on Taloja river	Nil	0.03	Nil
500 m downstream of Kasadi NH-4 bridge	Nil	Nil	Nil
Upstream of Kasadi rail bridge	Nil	Nil	Nil
NH-4B bridge on Gadhi river	Nil	Nil	Nil
Upstream of SH-54 bridge on Gadhi river	0.03	Nil	Nil
Gadhi-Kalundri confluence	0.03	0.02	Nil
Gadhi NH-4 bridge	Nil	Nil	Nil
Upstream of SH-54 bridge on Ulwe river (120m-200m diversion with no bund in Moha creek)	0.76	0.91	0.79
Bridge on Amra Marg near Moha creek (120m-200m diversion with no bund in Moha creek)	0.75	1.14	0.87

(iii) It is to mention that the results presented (vide Fig. 31 - 53 and Table -5) are the maxima water levels and not the instantaneous water levels at the time of High Tide level (HTL), as the occurrence of HTL is different at different locations and time intervals.

(iv) Along Gadhi river, upstream of Gadhi Taloja confluence there is marginal relieve in the water levels. Table-5 show the water levels along the Gadhi River, Taloja River, Panvel Creek and the Waghiwali Island under the existing conditions and with the modified airport layout for 26th July 2005 extreme rainfall condition, with flood peak arriving at high water level of design spring tide. It could be seen from Table-5 that, along the boundary of the area of proposed international airport, the maxima flood levels of 7.6 to 8.4 m could be experienced at NH-4B bridge which will gradually reduce to 7.1 to 7.6 m in the northern corner of reclaimed area and then water level will further reduce to 6.8 to 7.2 m in the channel west of the reclaimed area (near Panvel Creek mouth). Also in the Ulwe river at the point of diversion (SH-54 bridge), the PMP- 6hrs storm being the governing condition for maxima water level, water level will be of the order of 9.10 m (for 120 m - 200m wide diversion channel under the existing bathymetry of Moha Creek viz. bund in Moha creek), while it reduces to about 8.50 m (for 120 m - 200 m wide diversion channel with no bund in Moha Creek). In order to arrive at above mentioned optimal water level u/s of SH-54 bridge at Ulwe river diversion, various configurations of Ulwe diversion channel with and without bund in Moha creek were studied under different hydrodynamic conditions. These conditions are briefly summarised in Table-9.

Table -9

Predicted Maxima Water Levels at Ulwe Diversion Channel (in m)

Sr. No.	Condition	u/s Ulwe SH-54 Bridge	Amra Marg
1	Existing Condition for PMP- 6 Hrs. Storm with peak of hydrograph at design Spring tide HWL	7.57	6.30
2	Modified Airport Condition for PMP-6 Hrs. Storm with peak of hydrograph at design Spring tide HWL and Ulwe diversion channel 120 m wide - 60m Amra Marg (Moha creek as existing)	10.80	9.56
3	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at design Spring tide HWL and Ulwe diversion channel 120 m -120m Amra Marg (Moha creek as existing)	9.64	8.33
4	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at design Spring tide HWL and Ulwe diversion channel 120 m -120m Amra Marg (Moha creek bund removed)	9.19	7.49
5	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at design Spring tide HWL & Ulwe diversion channel 120 m -180 m Amra Marg (Moha creek as existing)	9.12	8.30

6	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at design Spring tide HWL and Ulwe diversion channel 120 m-180 m Amra Marg (Moha creek bund removed)	8.60	7.46
7	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at design Spring tide HWL & Ulwe diversion channel 120 m - 200 m Amra Marg (Moha creek as existing)	9.08	8.28
8	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at design Spring tide HWL and Ulwe diversion channel 120 m- 200 m Amra Marg (Moha creek bund removed)	8.50	7.44
9	Modified Airport Condition for PMP 6 Hrs. Storm with peak of hydrograph at design Spring tide HWL & Ulwe diversion channel 120 m- 240 m Amra Marg (Moha creek as existing)	9.11	8.41

The values given in Table 8 are with respect to CD of Ulwe Bundar.

The maxima water levels predicted around the modified layout of international airport considering various hydrodynamic conditions are given in FIG. 56.

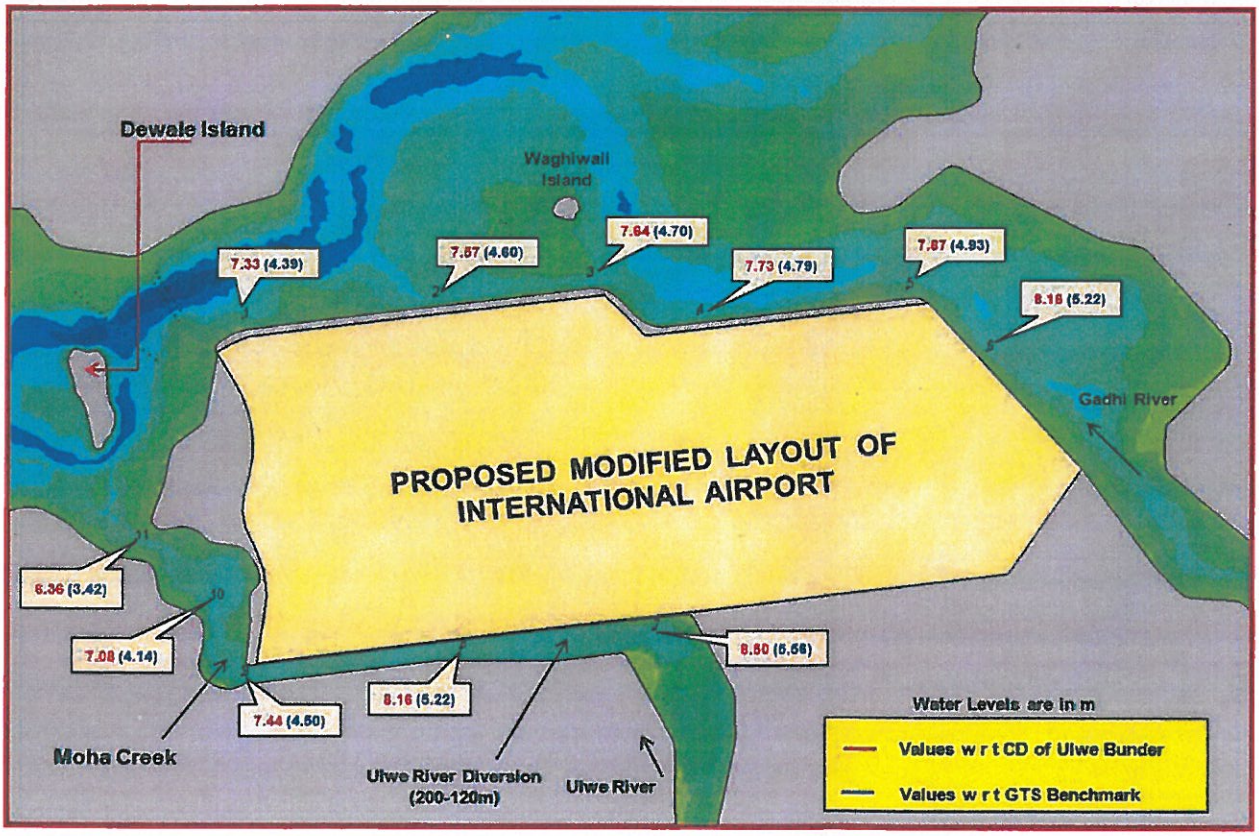

FIG. 56: LAYOUT OF AIRPORT SHOWING MAXIMA WATER LEVELS PREDICTED AROUND AIRPORT BOUNDARY

(v) Considering these flood levels and minimum free board of about 1.5 m to 1.8 m, the safe-grade elevation for the proposed international airport complex including

Airstrips, ATC towers and all buildings, hangars and roads should be kept at minimum level of 11.0 m (w.r.t CD of Ulwe Bunder). Rest of the area could also be reclaimed with the same safe-grade elevation or in slope or by terracing with finished ground levels varying along reclamation boundary.

(vi) The studies carried out by deepening the northern channel to RL = -1 m and RL = -2 m to account for discharge passing through secondary channel of Gadhi river as shown in FIG.47 reveal that, there is no effect in rise/fall of water levels predicted along boundary of modified layout of airport (Ref:- Table-5).

(vii) Based on the water levels predicted at SH-54 bridge at Ulwe diversion and bridge at Amra Marg, it is essential to provide a clear opening of about 80 m and 120 m respectively and the soffit level of these bridges also needs to be raised considering the maxima water level predicted at these locations and also allowance for free board.

10.2 Flow Velocities

The predicted velocities at different locations for following conditions as mentioned below are obtained:

1) Design Spring tide (with HWL= 6.2 m and LWL= 0.94 m) as downstream boundary condition and no flood discharge at upstream boundaries under the existing conditions (without airport).
2) Design Spring tide (with HWL= 6.2 m and LWL= 0.94 m) as downstream boundary condition and no flood discharge at upstream boundaries with airport condition and Ulwe river diversion channel width of 120 m-200 m and no bund in Moha creek.
3) Design Spring tide as above as downstream boundary and flood hydrograph of 6 hours storm of PMP and 26th July 2005 extreme rainfall with peak arriving at the time of HWL as upstream boundary conditions under the existing condition (without airport).
4) Design Spring tide as above as downstream boundary and flood hydrograph of 6 hours storm of PMP and 26th July 2005 extreme rainfall with peak arriving at the time of HWL as upstream boundary conditions with airport condition and Ulwe river diversion channel width of 120-200 m with no bund in Moha creek.

The range of maxima velocities in different channel reaches predicted for above four conditions is presented in the Table-10 :

TABLE-10
Range of Maxima Velocities in Different Reaches

Reach	Maxima velocity (m/s) for condition			
	Condition 1	Condition 2	Condition 3	Condition 4
Belapur - Ulwe rail bridge to Panvel Creek mouth	2.0	1.79	3.10	2.81
Belapur-Ulwe road bridge	1.84	1.51	2.73	2.33
North of Waghiwali	0.85	0.95	1.22	1.55
Gadhi d/s of NH-4B bridge	0.43	0.64	5.8	5.36
Gadhi from NH-4B bridge to Kalundri confluence	0.30	0.34	3.04	2.90
U/s of Ulwe SH-54 to Ulwe Railway bridge	1.36	0.57	2.48	2.56

The results in Table-10 show that with the airport development, the maximum velocities will be in the range of about 3.0 m/s to 6.0 m/s in the vicinity of NH-4B road bridge on Gadhi. At remaining locations the maximum velocities will be in the range of 1.0 m/s to 3.0 m/s. Therefore the bank protection work in these critical reaches as well as in the remaining reaches should be designed for velocities of 6.0 m/s. For most of the conditions with airport, there will be marginal decrease in velocity in the reach around airport in Panvel creek due to decreased outflow on account of Ulwe diversion and reduction in tidal prism. Without flood and only tide conditions, velocities around airport boundaries are practically not affected.

The locations of water level and velocity predicted around boundary points of modified layout of international airport are shown in FIG 57 and are summarised in Table -11 & 12.

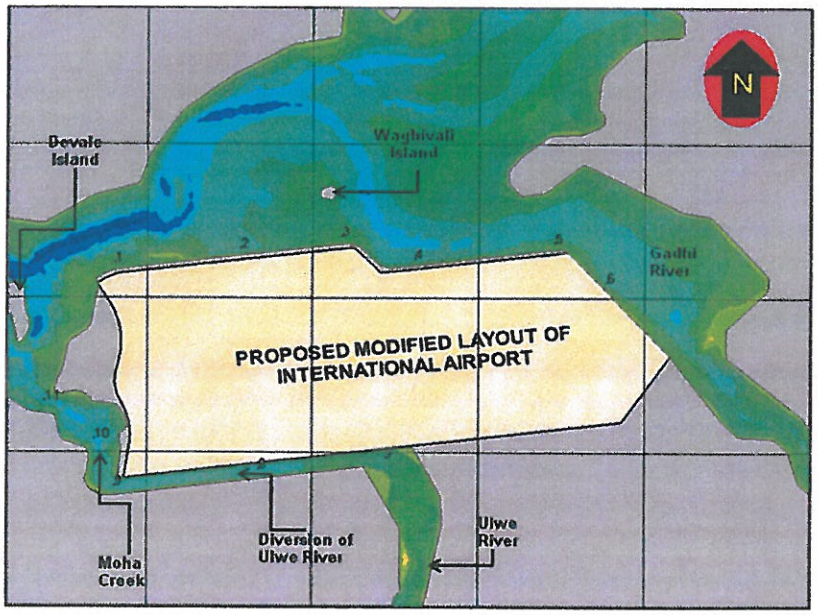

FIG 57: LOCATIONS OF WATER LEVEL / VELOCITY MEASUREMENTS AROUND AIRPORT

TABLE-11

MAXIMA WATER LEVELS PREDICTED ALONG AIRPORT BOUNDARY FOR OPTIMAL ULWE DIVERSION CHANNEL OF 120-200 m WIDTH AT BOTTOM

Water levels around Airport in m/sec												
Sr. No.	Condition	Locations										
		Northern Channel invert level	1	2	3	4	5	6	7	8	9	10	11
1	**Modified Airport** condition with **Spring tide and no Flood discharge, Ulwe Diver 120m - 200m Amra Marg (Moha creek as existing)**	Existing	6.2	6.2	6.2	6.2	6.2	6.20	6.25	6.22	6.2	6.20	6.21
		Con-I	6.2	6.2	6.2	6.2	6.2	6.20	6.25	6.22	6.2	6.20	6.21
		Con-II	6.2	6.2	6.2	6.2	6.2	6.20	6.25	6.22	6.2	6.20	6.21
2	**Modified Airport** condition with **Spring tide and no Flood discharge, Ulwe Diver 120m - 200m Amra Marg (Moha creek bund removed)**	Existing	6.2	6.2	6.2	6.2	6.2	6.20	6.25	6.22	6.2	6.20	6.21
		Con-I	6.2	6.2	6.2	6.2	6.2	6.20	6.25	6.22	6.2	6.20	6.21
		Con-II	6.2	6.2	6.2	6.2	6.2	6.20	6.25	6.22	6.2	6.20	6.21
3	**Modified Airport** Condition for 6 Hrs. Storm of **100 years** Return Period with peak of hydrograph at Spring tide HWL& Ulwe diversion channel **120m -200m Amra Marg (Moha creek as existing)**	Existing	6.81	6.94	7.00	7.05	7.19	7.38	8.49	8.28	7.91	6.63	6.30
		Con-I	6.81	6.94	7.00	7.05	7.19	7.38	8.49	8.28	7.91	6.63	6.30
		Con-II	6.81	6.94	7.00	7.05	7.19	7.38	8.49	8.28	7.91	6.63	6.30
4	**Modified Airport** Condition for 6 Hrs. Storm of **100 years** Return Period with peak of hydrograph at Spring tide HWL& Ulwe diversion channel **120m -200m Amra Marg (Moha creek bund removed)**	Existing	6.81	6.95	7.00	7.06	7.19	7.38	7.90	7.61	7.03	6.71	6.31
		Con-I	6.81	6.95	7.00	7.06	7.19	7.38	7.90	7.61	7.03	6.71	6.31
		Con-II	6.81	6.95	7.00	7.06	7.19	7.38	7.90	7.61	7.03	6.71	6.31
5	**Modified Airport** Condition for PMP 6 Hrs. Storm with peak of hydrograph at Spring tide HWL & Ulwe diversion channel 120m -200m **Amra Marg (Moha creek as existing)**	Existing	7.10	7.29	7.35	7.42	7.55	7.81	9.10	8.79	8.28	7.07	6.35
		Con-I	7.10	7.29	7.35	7.42	7.55	7.81	9.10	8.79	8.28	7.07	6.35
		Con-II	7.10	7.29	7.35	7.42	7.55	7.81	9.10	8.79	8.28	7.07	6.35
6	Condition for **PMP** 6 Hrs. Storm with peak of hydrograph at Spring tide HWL and Ulwe diversion channel **120m -200m Amra Marg (Moha creek bund removed)**	Existing	7.11	7.29	7.36	7.42	7.55	7.81	8.50	8.16	7.44	7.08	6.35
		Con-I	7.11	7.29	7.36	7.42	7.55	7.81	8.50	8.16	7.44	7.08	6.35
		Con-II	7.11	7.29	7.36	7.42	7.55	7.81	8.50	8.16	7.44	7.08	6.35
7	Condition for **26th July** Belapur Storm with peak of hydrograph at Spring tide HWL& Ulwe diversion channel **120m -200m Amra Marg (Moha creek as existing)**	Existing	7.33	7.57	7.64	7.73	7.87	8.16	8.73	8.50	8.06	6.82	6.36
		Con-I	7.33	7.57	7.64	7.73	7.87	8.16	8.73	8.50	8.06	6.82	6.36
		Con-II	7.33	7.57	7.64	7.73	7.87	8.16	8.73	8.50	8.06	6.82	6.36
8	**Modified Airport** Condition for **26th July** Belapur Storm with peak of hydrograph at Spring tide HWL & Ulwe diversion channel **120m -200m Amra Marg (Moha creek bund removed)**	Existing	7.33	7.57	7.64	7.73	7.87	8.16	8.14	7.82	7.18	6.84	6.36
		Con-I	7.33	7.57	7.64	7.73	7.87	8.16	8.14	7.82	7.18	6.84	6.36
		Con-II	7.33	7.57	7.64	7.73	7.87	8.16	8.14	7.82	7.18	6.84	6.36

TABLE-12

MAXIMA VELOCITIES PREDICTED ALONG AIRPORT BOUNDARY FOR OPTIMAL ULWE DIVERSION CHANNEL OF 120-200 M WIDTH AT BOTTOM

Velocities around Airport in m/sec												
Sr. No.	Condition	Locations										
		Northern Channel invert level	1	2	3	4	5	6	7	8	9	10	11
1	**Modified Airport** condition with **Spring tide and no Flood discharge, Ulwe Diver 120m - 200m Amra Marg (Moha creek as existing)**	Existing	0.24	0.69	0.61	0.27	0.07	0.11	0.23	0.72	1.06	0.57	1.36
		Con-I	0.24	0.69	0.61	0.27	0.07	0.11	0.23	0.72	1.06	0.57	1.36
		Con-II	0.24	0.69	0.61	0.27	0.07	0.11	0.23	0.72	1.06	0.57	1.36
2	**Modified Airport** condition with **Spring tide and no Flood discharge, Ulwe Diver 120m - 200m Amra Marg (Moha creek bund removed)**	Existing	0.24	0.70	0.61	0.27	0.07	0.11	0.28	0.85	1.14	0.60	1.35
		Con-I	0.24	0.70	0.61	0.27	0.07	0.11	0.28	0.85	1.14	0.60	1.35
		Con-II	0.24	0.70	0.61	0.27	0.07	0.11	0.28	0.85	1.14	0.60	1.35
3	**Modified Airport** Condition for 6 Hrs. Storm of **100 years** Return Period with peak of hydrograph at Spring tide HWL& Ulwe diversion channel **120m -200m Amra Marg (Moha creek as existing)**	Existing	0.23	0.73	0.83	0.35	0.29	0.32	0.72	1.32	1.41	1.76	3.26
		Con-I	0.23	1.05	1.14	0.37	0.29	0.32	0.72	1.32	1.41	1.76	3.26
		Con-II	0.23	1.03	1.14	0.38	0.29	0.32	0.72	1.32	1.41	1.76	3.26
4	**Modified Airport** Condition for 6 Hrs. Storm of **100 years** Return Period with peak of hydrograph at Spring tide HWL& Ulwe diversion channel **120m -200m Amra Marg (Moha creek bund removed)**	Existing	0.23	0.72	0.83	0.35	0.29	0.32	0.84	1.54	1.74	1.57	3.31
		Con-I	0.23	1.05	1.14	0.37	0.29	0.32	0.84	1.54	1.74	1.57	3.30
		Con-II	0.23	1.03	1.14	0.38	0.29	0.32	0.84	1.54	1.74	1.57	3.30
5	**Modified Airport** Condition for PMP 6 Hrs. Storm with peak of hydrograph at Spring tide HWL & Ulwe diversion channel **120m -200m Amra Marg (Moha creek as existing)**	Existing	0.24	0.68	0.95	0.53	0.40	0.46	0.85	1.59	1.75	2.03	3.93
		Con-I	0.24	0.97	1.14	0.39	0.40	0.46	0.85	1.59	1.75	2.03	3.93
		Con-II	0.24	0.89	1.14	0.39	0.40	0.46	0.85	1.59	1.75	2.03	3.93
6	Condition for PMP 6 Hrs. Storm with peak of hydrograph at Spring tide HWL and Ulwe diversion channel **120m -200m Amra Marg (Moha creek bund removed)**	Existing	0.17	0.62	0.95	0.37	0.40	0.37	0.96	1.76	2.01	1.77	3.79
		Con-I	0.17	0.97	1.14	0.39	0.40	0.37	0.96	1.76	2.01	1.77	3.79
		Con-II	0.17	0.89	1.14	0.39	0.40	0.37	0.96	1.76	2.01	1.77	3.79
7	Condition for **26th July** Belapur Storm with peak of hydrograph at Spring tide HWL& Ulwe diversion channel **120m -200m Amra Marg (Moha creek as existing)**	Existing	0.23	0.72	1.14	0.50	0.62	0.44	0.78	1.44	1.55	1.93	3.94
		Con-I	0.23	1.17	1.19	0.52	0.62	0.44	0.78	1.44	1.55	1.93	3.94
		Con-II	0.23	1.12	1.19	0.52	0.62	0.44	0.78	1.44	1.55	1.93	3.94
8	**Modified Airport** Condition for **26th July** Belapur Storm with peak of hydrograph at Spring tide HWL & Ulwe diversion channel **120m -200m Amra Marg (Moha creek bund removed)**	Existing	0.23	0.72	1.14	0.50	0.62	0.44	0.88	1.65	1.90	1.72	3.95
		Con-I	0.23	1.17	1.19	0.52	0.61	0.44	0.88	1.65	1.90	1.72	3.95
		Con-II	0.23	1.12	1.19	0.52	0.61	0.44	0.88	1.65	1.90	1.72	3.95

The water levels around proposed modified layout of airport indicate that in Panvel Creek area, there is insignificant change in water levels, while marginal change in velocities. However in 120 -200m wide Ulwe diversion channel, the water level near SH-54 bridge of Ulwe indicates that under the existing bathymetry of Moha Creek(with bund), the water level rises up to 9.1m, while with no bund in Moha Creek it will reduce to about 8.5 m w.r.t CD of Ulwe Bunder. This reduction in water level being significant in determining the safe grade

elevation of entire airport area, it is more appropriate to remove entire existing bund up to deepest channel level at that location in Moha Creek. In addition to this, it will also result in increase in velocities in diversion channel, thereby it will improve the flow conditions in diversion channel of 120 m - 200 m width.

11.0 SAFE-GRADE ELEVATION

The free board for deciding safe-grade elevation for any strategic installation is normally decided from various considerations, such as those mentioned in CWPRS Technical Report No 4665 of October 2009 i.e.:

a. Maximum flood level
b. Cyclone induced surges
c. Wind generated waves
d. Wind setup
e. Land subsidence natural and due to overburden
f. Embankment settlement
g. Sea level rise
h. Tsunami

In the present case, the maxima flood level is the major factor which needs consideration. The probability of occurrence of storms on west coast is less compared to east coast. This is due to the fact that majority of sever cyclones/storms are generated in Bay of Bengal and very few of them crosses Indian peninsula. The intensity of storms crossing peninsula reduces drastically and as such when it enters Arabian Sea, its strength is reduced. Also the past history of storm generated in Arabian sea indicate that most of the storm generated has been observed to move away from west coast of India. Thus storm surges are rare events on west coast of India around Mumbai. The effect of wind generated waves and wind setup is also negligible in Panvel Creek for the following reasons :

i) The Panvel Creek is situated well inside the wide estuarine entrance of Mumbai harbour which is roughly in east-west direction. The swell waves approaching Mumbai harbour are mainly from south-west direction and they cannot propagate well inside the Thane Creek due to presence of Salsette/Mumbai island or will attenuate substantially north of Elephanta Island and Panvel Creek being further inside and hence presence of swell wave is almost negligible. In addition to this, mouth of Panvel Creek is sufficiently narrow, hence such wave cannot have any significant wave run-up.

ii) Fetch within the Panvel Creek under the existing conditions is also small to generate local waves to have wave run-up. With the airport development, there will be further reduction in water body and probability of wave generation will be almost negligible.

iii) The Elephanta and Butcher (Jawahar Dweep) Islands are situated in Thane creek outside the mouth of Panvel Creek in south-west direction. These Islands provide protection from local wind generated waves coming from south-west direction.

For wind setup, sustained wind should last long at least for 3 to 4 hours in association with a large fetch. With a fetch of about 20 km, water depth of 15 m and wind speed of 100 km/hr the setup will be of the order of 0.2 to 0.3 m. The probability of simultaneous occurrence of sustained wind condition, extreme flood event due to PMP rainfall and coinciding it with HWL of spring tide all together is very less. Also during 3 to 4 hours period of sustained wind conditions, tide water level may reduce considerably. The land subsidence and embankment settlement will depend upon the type of material on the river bed and in foundation and also on type of material used for embankment. There are no well established criteria to compute the sea level rise for region under consideration. The Tsunami waves are also not common in this region to consider its effect inside the Panvel Creek on Airport area.

Considering all above factors and the estimated maximum water levels along the boundary area to be reclaimed for the proposed airport, the free board of about 1.8 m from flooding consideration (as per IRC norms the minimum free board of about 1.8 m is recommended), 0.2 m for sea level rise and 0.5 m for all other remaining factors including storm surges, embankment settlement and subsidence could be adopted. Thus total free board of 2.5 m will be quite conservative for the important establishment of international airport as also mentioned in CWPRS Technical report No. 4665 of October 2009. On the basis of this free board, the safe-grade elevation for the reclamation levels in the main airport area considering airstrips, ATC towers, administrative buildings and allied facilities could be considered as 11.0 m (w.r.t CD of Ulwe Bunder) with 120 m - 200 m wide Ulwe diversion along with no bund in Moha Creek, where 120m diversion meets the Moha Creek. The remaining area for airport could either be reclaimed with the same level or at a lower level of about 10.0 to 10.8 m considering relatively lower flood levels predicted along this region. This could be achieved by providing gradual slope or terracing. Based on the maxima water levels predicted around the airport area and considering free board, the safe grade elevation at various locations around the airport area is shown in FIG.58.

FIG 58: LAYOUT OF AIRPORT SHOWING SAFE GRADE ELEVATION PREDICTED AROUND AIRPORT BOUNDARY

12.0 DISCUSSIONS AND CONCLUSIONS

Based on the analysis of results of mathematical model studies, following conclusions / discussions are presented:

1. The review of hydrology of Panvel creek catchment and estimation of hydrographs for various return periods was already studied and described in CWPRS Technical Report No. 4665 of October 2009. This report mentions that rainfall intensities of 192 mm / hour (for PMP- 6 hour storm) and 145.8 mm / hour (100 year return period, 6 hour storm) considered for estimation of flood hydrographs are higher than statistically estimated 100 year return period intensity of 134 mm / hour at Santacruz and 145 mm / hour at Colaba. These intensities are also higher or very close to the observed maximum intensity of 153 mm at Santacruz. Also, intensity of 192 mm / hour considered for PMP, 6 hour storm duration is at par with reported intensity of 190 mm / hour at Santacruz during 26th July 2005 storm at Mumbai. The intensities considered for studies are also higher than the CIDCO and CWC norms and estimated peak discharges as given below are used for studies under consideration.

River	100 year- RP, 6 hour storm	PMP - 6 hour storm
Gadhi	1579.79 m^3/s	2082.60 m^3/s
Kasadi	759.16 m^3/s	1000.77 m^3/s
Taloja	935.94 m^3/s	1233.80 m^3/s
Kalundri	1496.52 m^3/s	1972.80 m^3/s
Ulwe	695.22 m^3/s	916.48 m^3/s

2. The studies carried out for existing bathymetry condition (without airport) and for condition of modified layout of airport, reveal that there is insignificant impact of proposed reclamation of airport on water levels at the mouth of Panvel creek for tide only as boundary condition. However the rise in water levels in Gadhi, Kalundri, Kasadi and Taloja rivers are less than 0.2 m, while in Ulwe river it is about 0.3 m.
3. The water levels predicted with modified layout of airport for extreme conditions of PMP (700 mm), 6 hour storm and 26th July 2005 storm (998 mm at Belapur) as upstream and design spring tide as downstream boundary conditions seen to vary along the different riverine channels in Panvel creek. It could be seen that the flood levels with 26th July 2005 rainfall are higher by about 0.2 to 0.4 m than the predicted water levels for PMP (700 mm), 6 hour rainfall in the region mentioned above. The levels are given with respect to Chart Datum of Ulwe Bunder.
   - Panvel Creek north channel from Ulwe port to Gadhi-Taloja confluence = 6.4 to 7.8m
   - Gadhi river reach from Kalundri confluence to NH-4B bridge= 8.4 to 12.0 m
   - Taloja Creek from Gadhi confluence to Kasadi-Taloja confluence= 7.8 to 8.20 m
4. The extreme water levels under PMP conditions along the boundary of proposed international airport will vary from 7.66 m to 8.0 m on downstream of NH-4B bridge and is about 7.36 m in northern channel. The studies carried out for Ulwe diversion channel with clear opening of bridge at Amra Marg as 60 m, 120 m wide diversion channel indicate that maxima water level at SH-54 bridge on Ulwe river is significantly higher compared to 120 m opening. The clear opening of 120 m at Amra Marg for 120 m wide diversion channel with 120 m and 180 m width near SH-54 bridge on Ulwe river indicate that the maxima water level at SH-54 bridge on Ulwe river for PMP, 6 Hrs storm condition (maximum discharge) is more than the optimised water level condition of 8.5 m w.r.t CD of Ulwe Bunder (5.5m w.r.t MSL). The level of 8.5 m was evolved in earlier studies where deepening of Moha creek up to 1m below CD was reported in CWPRS draft report of Oct. 2012. As such to avoid further increase in maxima water level, model studies by increasing the width of Ulwe diversion channel having width of 120 m - 200 m and 120 m -240 m were carried out. The flood levels in Ulwe River near point of diversion with 120 m -200 m diversion

channel (with the existing bathymetry of Moha Creek i.e. Bund in Moha creek) happens to be 9.08 m and with no bund in Moha creek, it was predicted as about 8.5 m with 120 m clear opening at Amra Marg bridge. The studies with 120 m - 240 m Ulwe diversion channel reveal that there is increase in maxima water level above 9.08 m. Hence maxima water levels predicted for all hydrodynamic conditions with various configurations of Ulwe diversion channel for the modified layout of airport as given in Table-5, it is inferred that Ulwe diversion channel having configuration of 120 -200 m with no bund in Moha creek and 120 m clear opening at Amra Marg bridge is an optimal configuration to keep safe grade elevation of airport to a minimal level.

5. The studies carried out to predict water levels at various important locations such as various bridges in Panvel creek area as well as in the diversion of Ulwe river for hydrodynamic condition of design spring tide and discharges from all five rivers with different storm conditions such as 100 Yr- RP,6 Hrs storm, PMP-6 Hrs storm and extreme storm condition of 26th July 2005 for Ulwe diversion channel of 120-200m reveal that the rise in water levels is insignificant (less than 0.03m) in major rivers like Gadhi, Kalundri, Taloja and Kasadi. However, in Ulwe river diversion, rise will be about 1.2 m maximum at Amra Marg bridge (120 m opening) compared to without airport condition.
6. Based on the Ulwe diversion channel having width of 120 m -200 m, the safe-grade elevation for the airport complex comprising Airstrips, ATC tower buildings and other important buildings and roads should be kept at an 11.0 m with respect to CD of Ulwe Bundar with consideration of predicted maxima water levels and minimum free board of 2.5 m for various reasons already discussed under para. Safe-grade Elevation. Such a high safe-grade elevation may also be beneficial from remotely possible threat of Tsunami and storm surges which are not common on west coast. For rest of the area, the reclamation levels could vary from 10.8 m to 10.0 m by providing a slope or terracing towards waterfront. Such an arrangement will be also helpful for design of storm water drainage system.
7. The invert level of outfalls around airport area were predicted considering neap tide alongwith river discharges for various storm events as open boundary conditions in association with runoff discharges at various locations provided by project Authority to discharge the collected runoff from airport area. These invert levels varies between 6.5 m and 7.7 m on northern side of airport area, while between 7.05 m and 8.22 m on southern side of airport.
8. Study of velocity variation along the different channels in Panvel Creek and predicted maximum velocities are indicated below:
    a. In general the maxima velocities in the vicinity of airport in river portion will be in the range of 3.0 to 4.0 m/s. However at some locations, e.g. near

NH-4B bridge, Kasadi bridge and in the vicinity of Ulwe bridge, high velocities of the order of 5.8 m/s could occur for short duration.

b. Along Gadhi River, high velocities of the order of 3.0 to 6.0 m/s will occur in the reach between NH-4B bridge and Gadhi Kalundri confluence.

9. Considering the local high velocities and general velocity of 3.0 to 6.0 m/s, the bank protection for the slope of the reclamation along the water edge will have to be designed for a velocity of 6.0 m/s.
10. The right bank levels along Gadhi River reach (looking at downstream) between SH-54 bridge and NH-4B bridge are much lower than predicted flood level. This region are flood prone zones, which are inundated due to over-bank flows during high floods even under the existing conditions (i.e. without airport development) as experienced during flood of July 1991 and July 2005. Retaining walls or raised banks may be necessary to reduce this inundation. The present studies have shown that the flood levels in this reach will not increase further due to airport development. These reaches need special attention from the consideration of flood protection and appropriate reclamation levels need to be adopted considering the predicted high flood levels with adequate bank protection works.
11. The areas on upstream of NH-4 bridges on Gadhi, Kalundri, Kasadi and Taloja are flood prone zones and low lying areas in these reaches got inundated during flood events of July 1991 as well as July 2005. The studies carried out for the area of proposed international airport indicate that under various flood events viz. 100 year RP, 6hrs storm; PMP- 6 hrs storm and 26 July 2005 along with design tide, there is insignificant rise in water level compared to that of without airport condition (Table - 8). As such for areas upstream of NH-4 bridges for Gadhi, Kalundri, Kasadi and Taloja rivers, appropriate bank protection works with sufficient freeboard of about 1.8 m - 2 m may be provided based on observed high flood levels during flood events of July 1991 as well as July 2005.
12. The Ulwe diversion channel of minimum 120 m - 200 m bottom width (FIG. 52) will be necessary to keep flood levels low along southern boundary of international airport with removal of existing bund up to deepest cross section level in its vicinity in Moha creek. A gradual transition between 120 m and 200 m width of Ulwe diversion channel should be provided for avoiding afflux at starting of diversion. Also smooth proper jacketing in the form of retaining walls should be provided along the high flood levels (HFL) predicted from model studies/high bank levels so as to avoid inundation of low lying area near Ulwe diversion. The bank slopes for Ulwe diversion channels should be 1V:2.5H in average soil strata without rock. Wherever rock / hard strata is encountered, steeper slopes could be adopted (CWPRS Technical report No. 4665 of Oct 2009).

13. The clear opening of 80 m and 120m should be provided to bridges on SH-54 at Ulwe river and at Amra Marg respectively. The soffit levels of these bridges also needs to be raised considering predicted maxima water levels in this report and appropriate free board as per IRC norms.
14. Along Ulwe river reach, upstream of diversion location (SH-54 bridge to Ulwe rail bridge), flood embankments of appropriate height considering freeboard etc will be necessary along high flood levels(HFL)/high bank levels) in view of rise in flood level to the tune of about 2.5m after airport development .
15. The diversion of Ulwe river for airport development is essential and water levels predicted at Ulwe diversion being the governing design condition for prediction of safe grade elevation of airport, in order to determine flood levels upstream of Ulwe Rail bridge (on Ulwe river), wherein CIDCO proposes new development and design of storm water drains, hydrodynamic model studies based on detailed bathymetry/topographic survey for this region are essential.

13.0 RECOMMENDATIONS

1. The Safe grade elevation for the proposed international Airport complex consisting of airstrips, ATC tower building and all other important structures may be kept at 11.0 m level with respect to Chart Datum of Ulwe Bundar.
2. The remaining area could be reclaimed by filling in slope or by terracing with levels varying from 11 m to 10.0 m.
3. The Ulwe diversion channel having bottom width of 120 m - 200 m with clear opening of 120 m at Amra Marg bridge and smooth transition from 200 m - 120m near SH-54 bridge diversion as well as clear opening of 80 m at SH-54 bridge on Ulwe river should be provided to keep level of water to 8.5 m at Ulwe diversion with additional free board of 2.5 m so that optimal safe grade elevation of Airport will be kept at 11 m. The bank protection work to Ulwe diversion should be provided with side slope of 1 (V): 2.5 (H). The bank protection work should be designed for maximum velocities predicted through model studies. The soffit levels of bridges at SH-54 (Ulwe) and Amra Marg at diversion channel should be raised above maxima water levels predicted with sufficient free board as mentioned in report.
4. The existing right bank levels along Gadhi river between NH-4B bridge and SH-54 bridge are very low (looking downstream) and should be raised above the predicted high flood levels with appropriate free board by providing bank protection works to avoid inundation of low lying areas. The similar type of bank protection works

should also be provided in other rivers where the maxima velocities will be about 4 m/sec $\pm$1m/sec.

5. Along Ulwe river reach upstream of Ulwe diversion channel viz. from SH-54 Ulwe Road bridge to Ulwe Rail bridge, flood bank embankments at high bank levels/high flood levels will be necessary in view of rise of flood levels to the tune of about 2.5 m after airport development. In order to determine flood levels upstream of Ulwe Rail bridge (on Ulwe river), wherein CIDCO proposes new development and design of storm water drains, hydrodynamic model studies based on detailed bathymetry/topographic survey for this region are essential.
6. The areas on upstream of NH-4 bridges on Gadhi, Kalundri, Kasadi and Taloja are flood prone zones and low lying areas in these reaches got inundated during flood events of July 1991 as well as July 2005. As such for areas upstream of NH-4 bridges for Gadhi, Kalundri, Kasadi and Taloja rivers, appropriate bank protection works with sufficient freeboard of about 1.8 m may be provided based on observed flood levels during flood events of July 1991 as well as July 2005.
7. Adequate geo-physical investigations including bore hole data collection is necessary within and along the boundary of area proposed for reclamation of airport to finalise the design of bank and bed protection works.

14.0 REFERENCES

1. Standard specifications and code of practice for road bridges, General features of design, Indian Roads Congress, IRC-5 : Section-I,1998
2. CWPRS Technical Report No. 3815 August 2001
3. CIDCO Report on "Topographic and Hydrographical Surveying for Development of Navi Mumbai International Airport" , August 2007
4. CIDCO Report on "Daily Discharge data of Rivers joining Panvel creek for Development of Navi Mumbai International Airport" , August 2007
5. CIDCO Report on "Hydrographic survey of Panvel creek for Development of Navi Mumbai International Airport" , August 2007
7. CIDCO Report on "Velocity and Tidal water level observation in Panvel creek for Development of Navi Mumbai International Airport" , August 2007
8. CWPRS Technical Report No. 4627 August 2009
9. CWPRS Technical Report No. 4665 August 2009

PHOTOGRAPHS

PHOTO-1:LOCATION OF PROPOSED INTERNATIONAL AIRPORT, NAVI MUMBAI

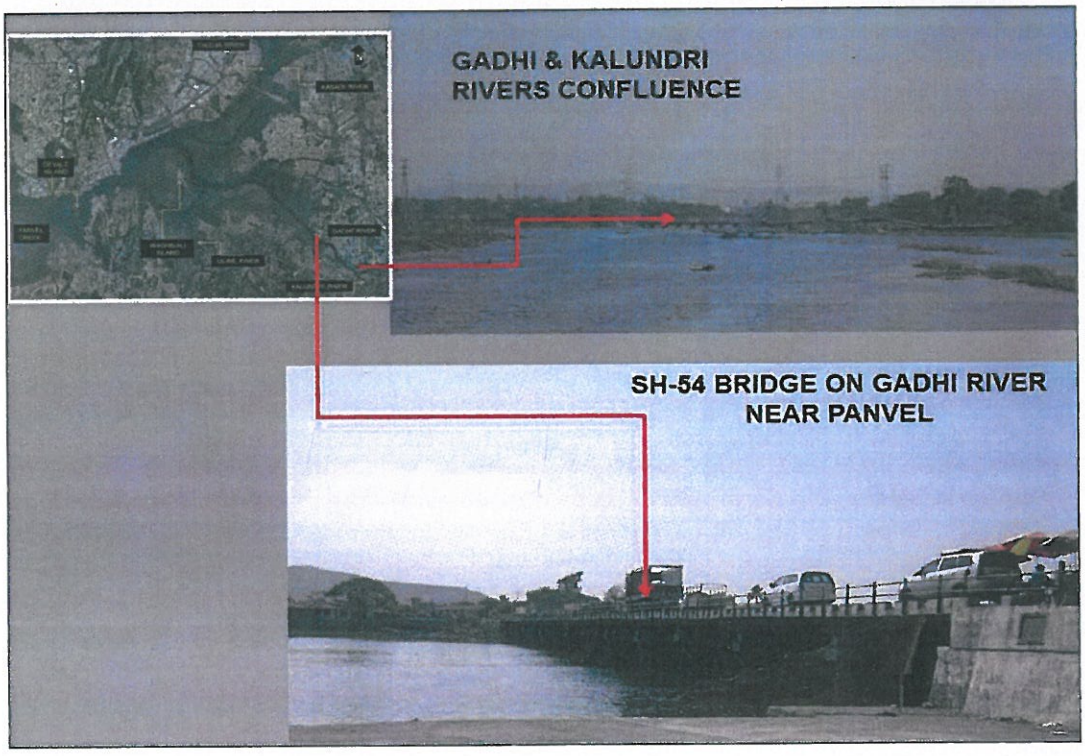

PHOTO-2:VIEW OF GADHI-KALUNDRI CONFLUENCE AND SH-54 BRIDGE ON GADHI

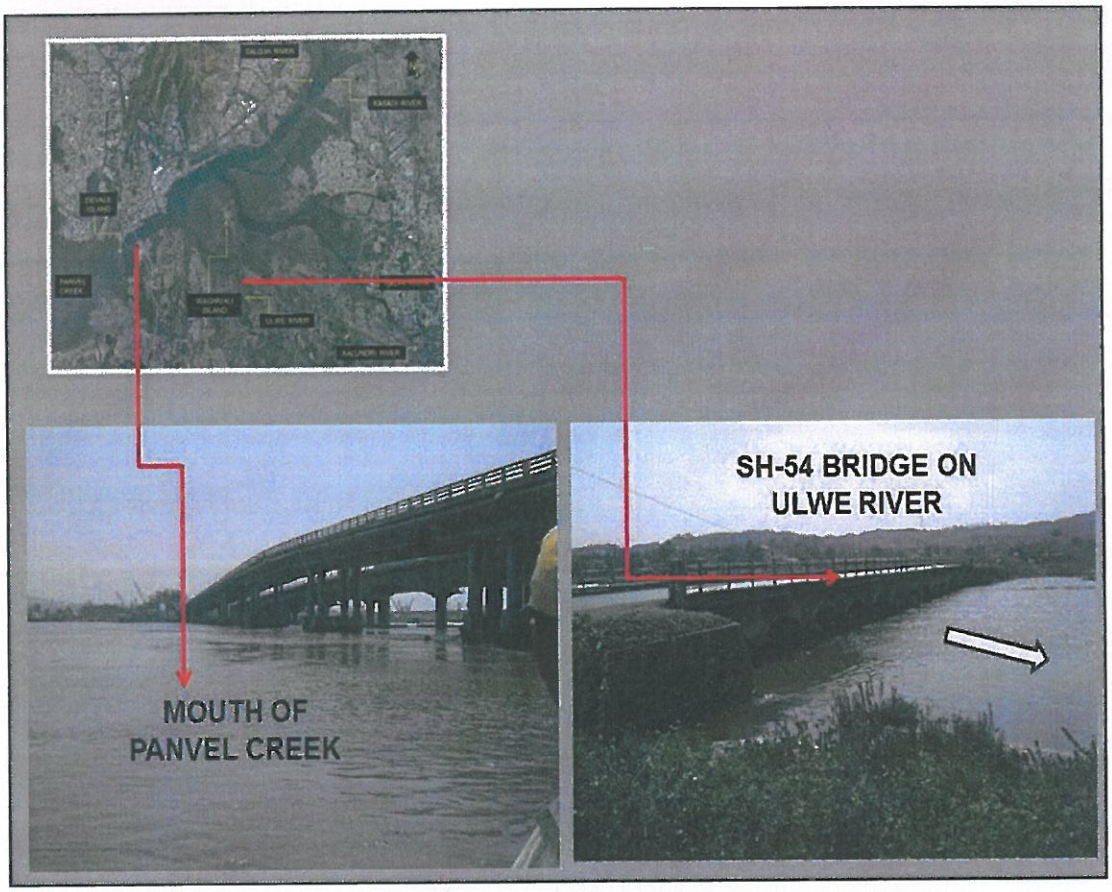

PHOTO-3: MOUTH OF PANVEL CREEK AND SH-54 BRIDGE ON ULWE RIVER

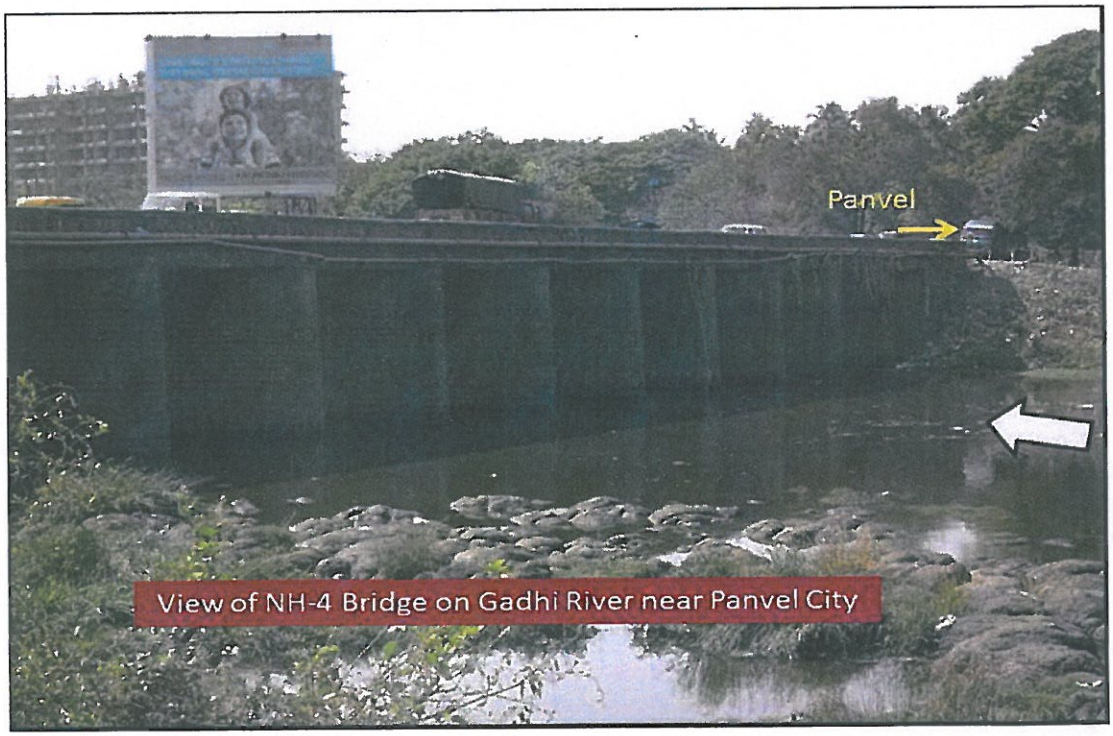

PHOTO-4:ROCKY OUTCROP AT NH-4 BRIDGE ON GADHI RIVER NEAR PANVEL TOWN

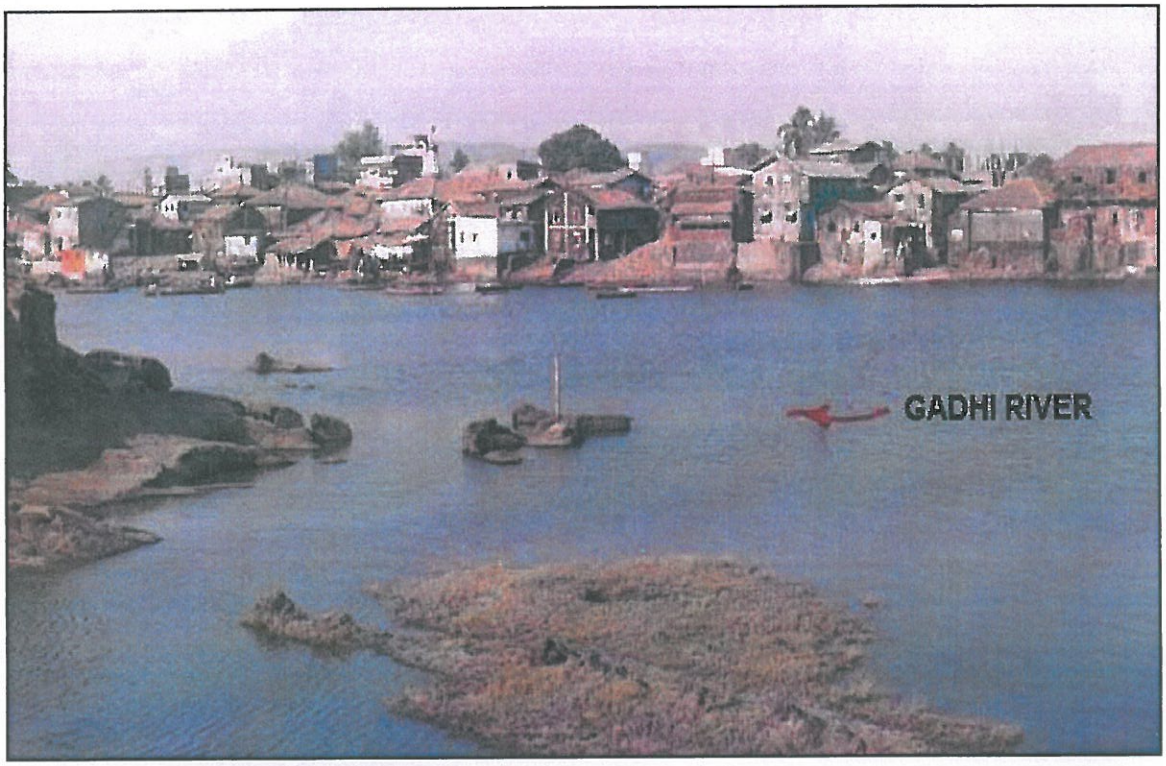

PHOTO-5: LOW LYING RIGHT BANK ALONG GADHI RIVER DOWNSTREAM OF SH54 BRIDGE AS SEEN DURING SUMMER (WITHOUT FLOODS)

PHOTO-6:VIEW OF GADHI RIVER REACH DOWNSTREAM OF SH-54 BRIDGE WITH FLOOD MARKS OF YEAR 1991

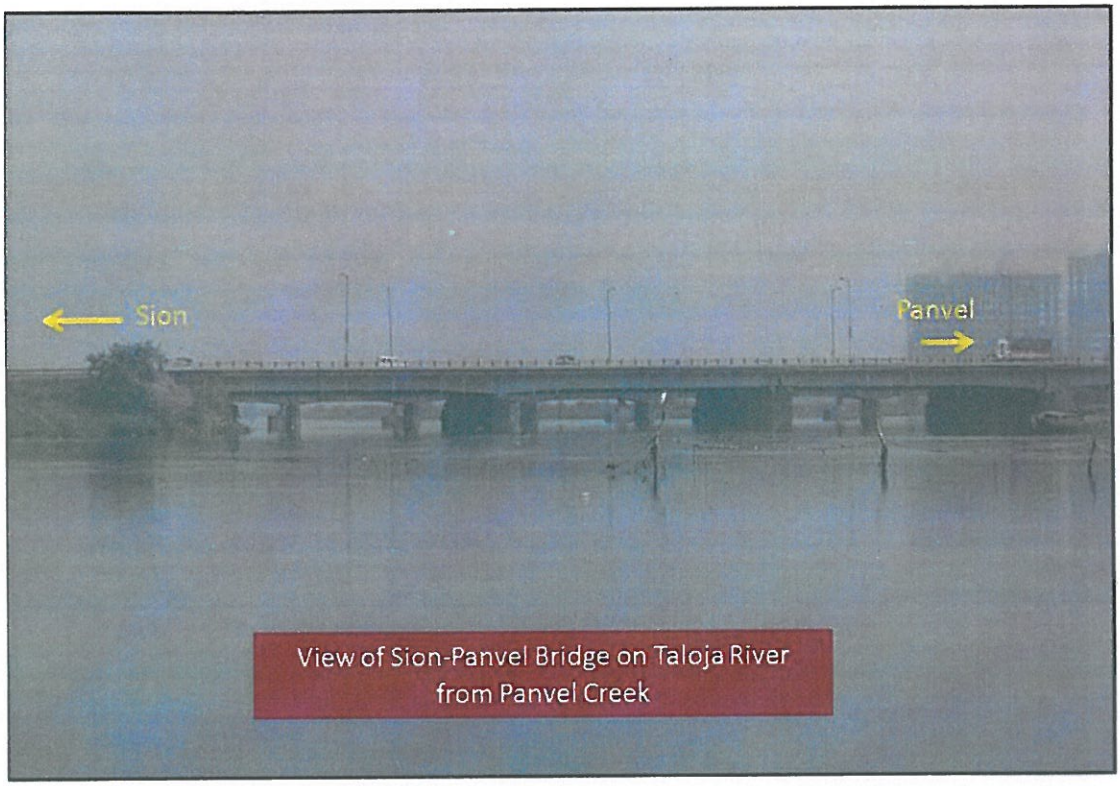

PHOTO-7: SION- PANVEL BRIDGE ON TALOJA RIVER DURING HIGH TIDE

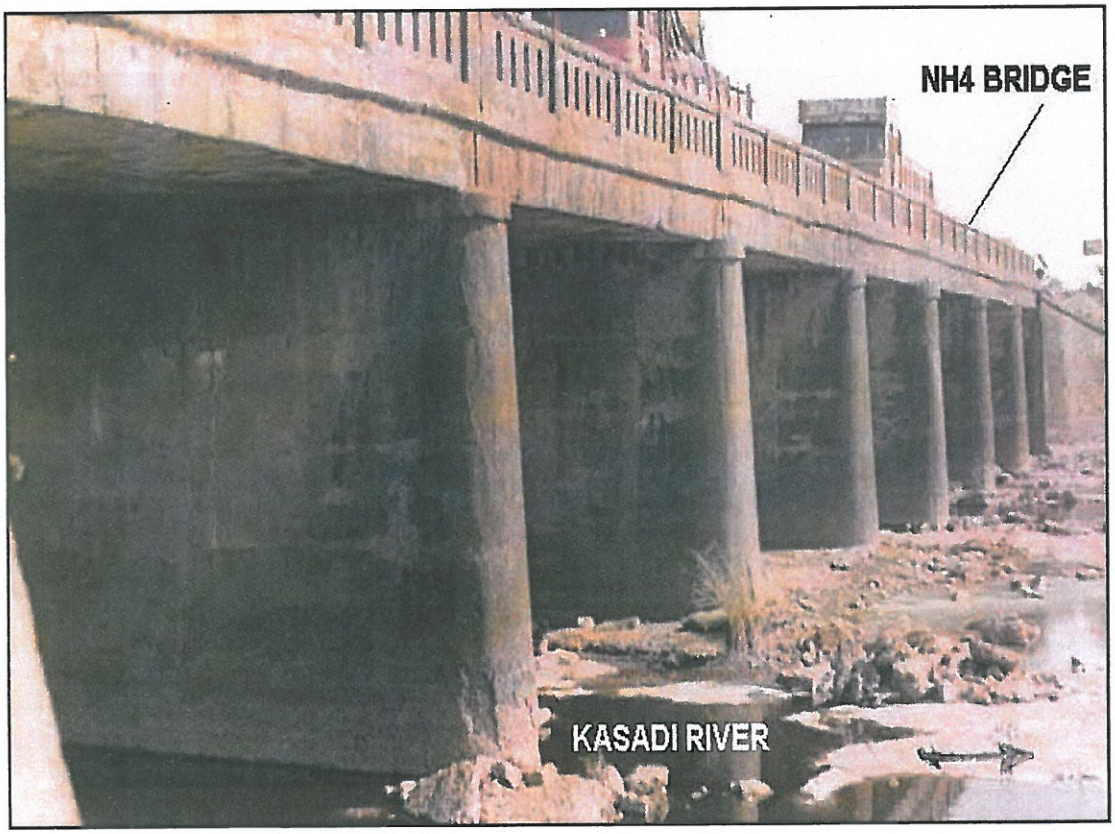

PHOTO-8: VIEW OF NH-4 BRIDGE ON KASADI RIVER DURING LOW WATER

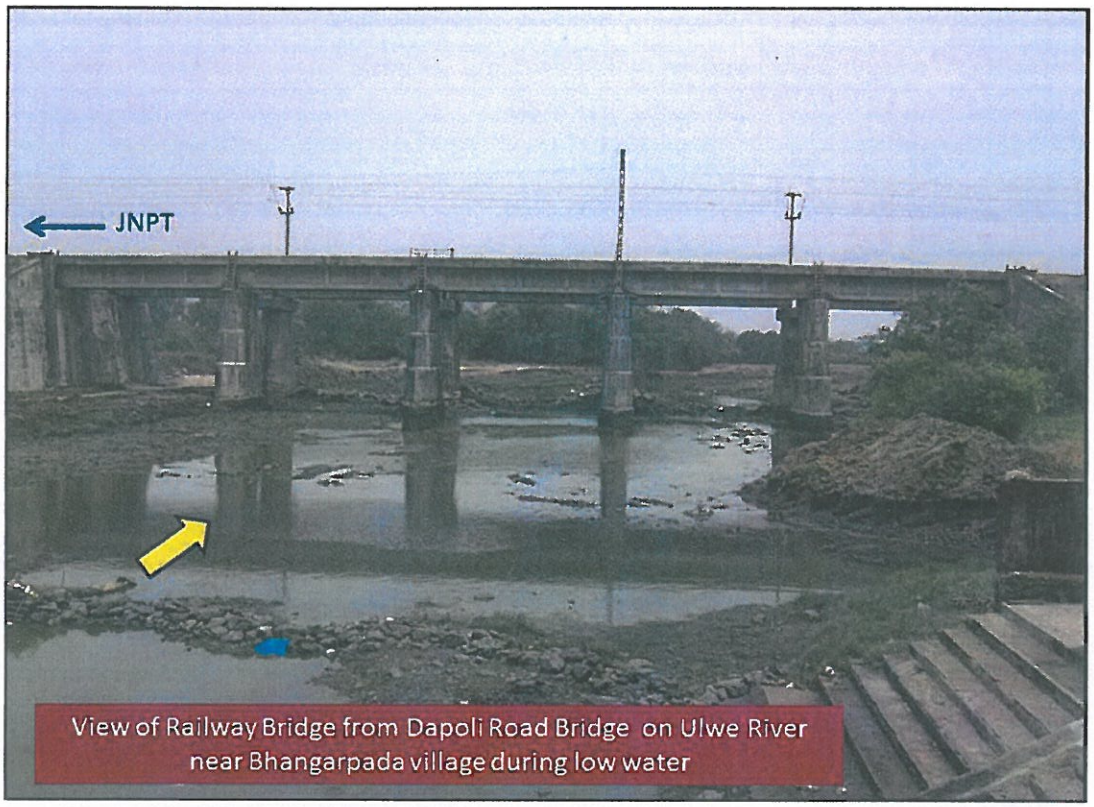

PHOTO-9: VIEW OF RAILWAY BRIDGE ON UPSTREAM OF ULWE RIVER DIVERSION

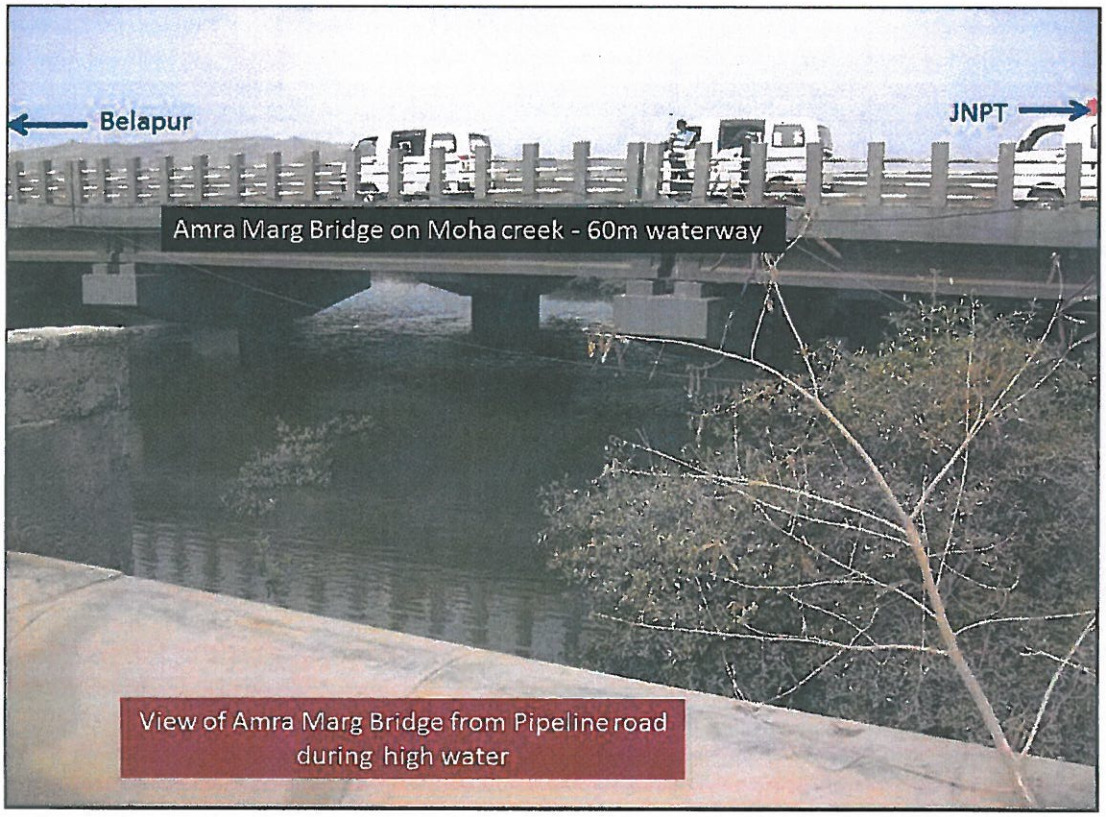

PHOTO-10: VIEW OF BRIDGE AT AMRA MARG ON MOHA CREEK DURING HIGH TIDE

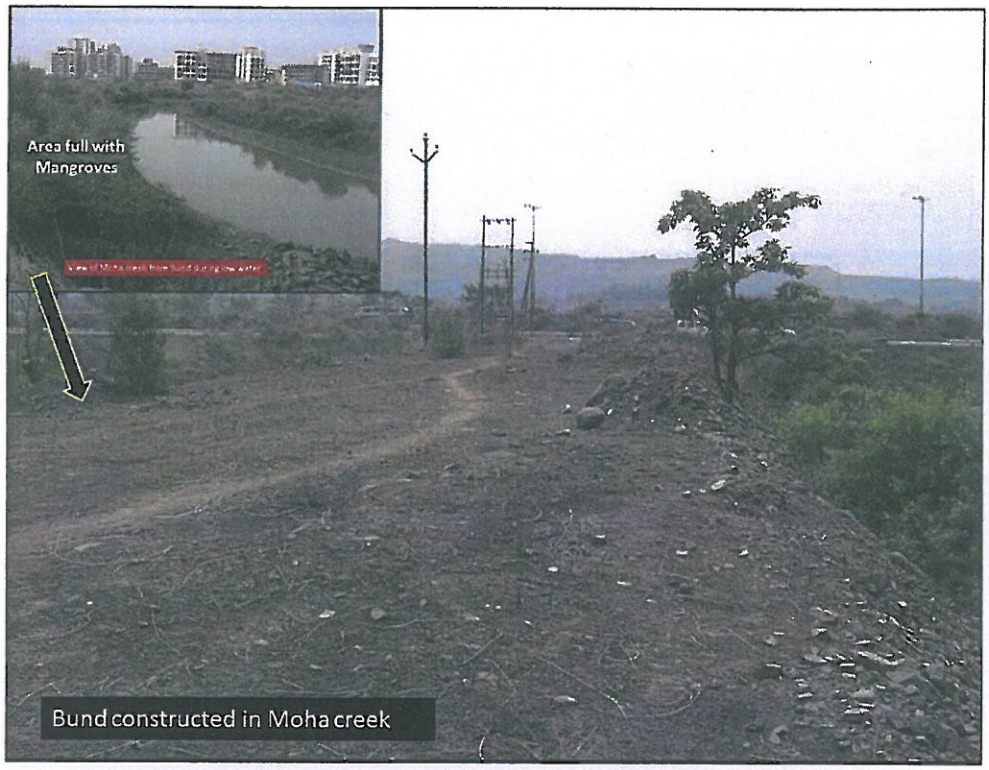

PHOTO-11: VIEW OF EXISTING BUND IN MOHA CREEK DURING LOW TIDE

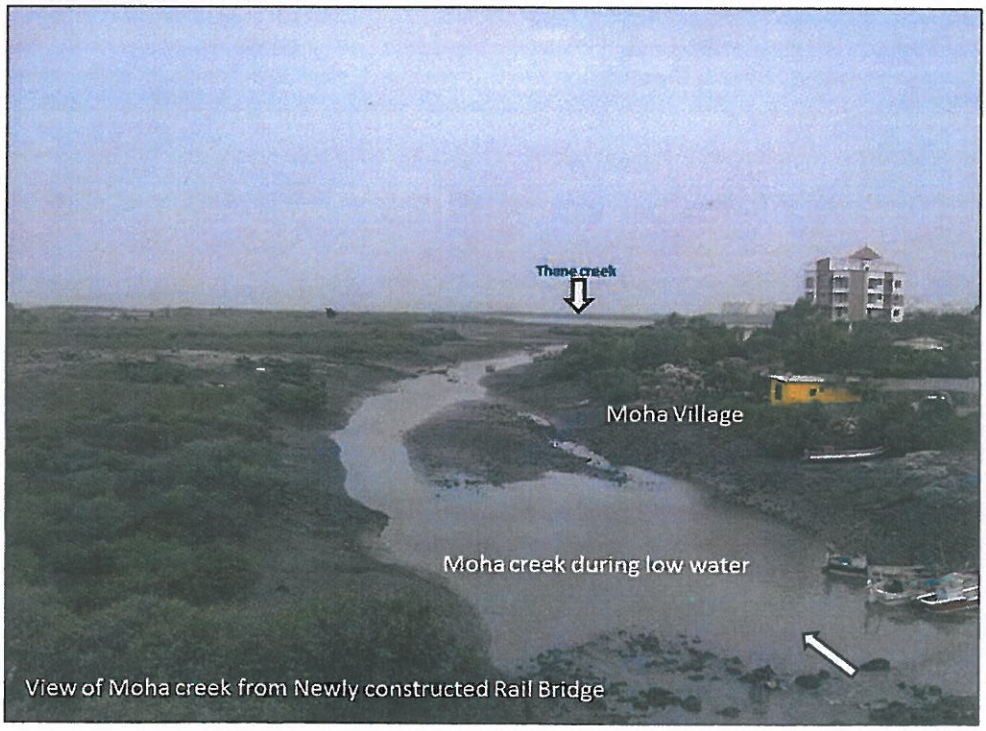

PHOTO-12:VIEW OF MOHA CREEK DURING LOW WATER FROM NEWLY CONSTRUCTED RAILWAY BRIDGE