IMPACT OF URBAN DEVELOPMENTS ALONG PANVEL CREEK ON THE FLOOD LEVELS

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ABSTRACT

The flow in the tidal reach of the river is governed by the tide levels at the mouth of river creek, the upland flood discharge and the topography of the river reach. Any topographical changes in the tidal flats and flood plains along the river banks will result in changes in the water levels along the river reach. As a part of urbanisation project around Navi Mumbai, the City and Industrial Developement Corporation of Maharashtra Limited (CIDCO) is developing townships on the land reclaimed on tidal flats along rivers discharging into Panvel creek. The commercial and residential nodes are being developed alongwith the infrastructural development such as roads, railways, bridges and storm water drainage. The mathematical model studies were carried out at CWPRS to assess the rise in flood levels due to reclamations along the different river channels of the Panvel creek river network. The appropriate tide and flood hydrographs were considered as boundary conditions. The mathematical model was first validated for observed floods under existing conditions and then applied for further predictions with reclamation. Based on predicted flood levels, the levels for reclamation and for storm water drainage channel outfalls into creek were proposed.

1.0 INTRODUCTION

The City and Industrial Development Corporation of Maharashtra Limited (CIDCO) is executing an ambitious Urban development plan on an area of about 350 sq.km. spread from Vashi (Navi Mumbai) to Panvel in Raigarh district of Maharashtra. These works are being carried out along the coast of Thana creek as well as along the banks of various river channels discharging in to Panvel creek (Fig.1). The urban developments include land reclamations along banks on tidal flats for construction of residential and commercial nodes / townships. So called Navi Mumbai area near Belapur and Panvel comprise such townships developed around Panvel creek. As a part of these developments some of these nodes namely Kharghar, Kalamboli, Kamothe, New Panvel and CBD are being developed along Gadhi, Kasadi, Taloja, Kalundri and Ulwe rivers discharging into Panvel creek (Fig.1). The region proposed for developments is inundated during high tides and high floods under existing situations. The knowledge of the expected rise in flood levels after developments is necessary for the designs of reclamation works, storm water drainage systems, roads, bridges and other works related to these developments. A mathematical model capable of handling unsteady flows in river channel netowrk in Panvel creek was developed at CWPRS to predict the water levels with and without developments under combined influence of tide and flood.

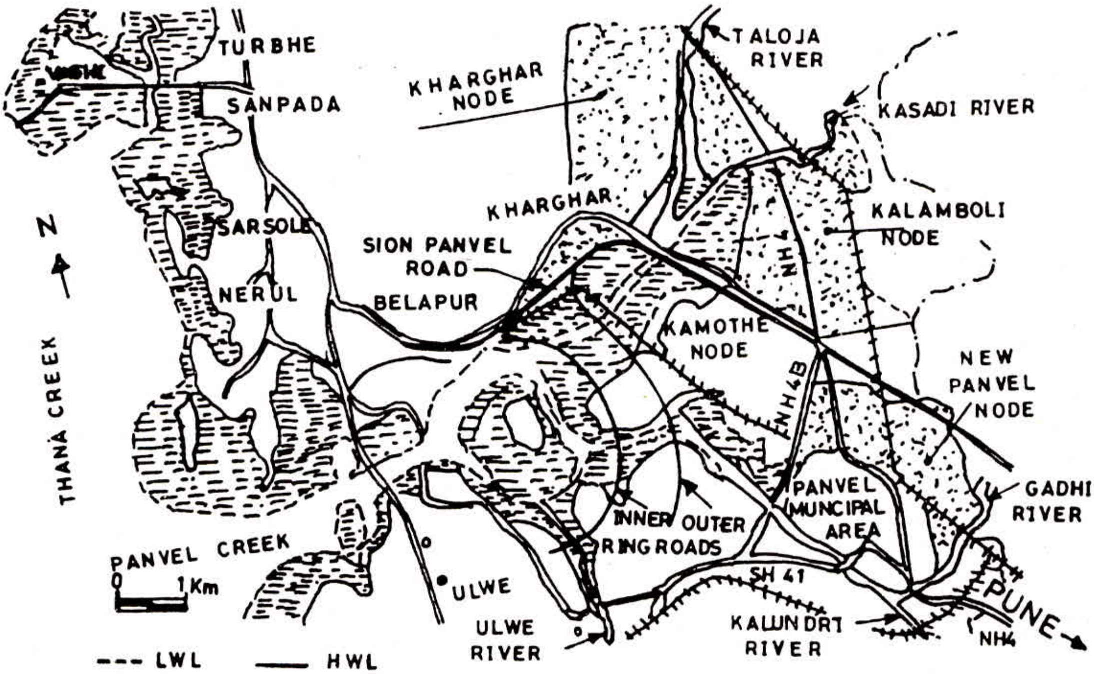


Fig.1 : River Network in Panvel Creek

2.0 RIVERS IN PANVEL CREEK

Gadhi, Kasadi, Taloja, Kalundri and Ulwe are the main rivers discharging into Panvel creek. All these rivers originate in hilly region of western ghat and flow towards west to merge into Panvel creek (Fig.1). Following are the independent catchment areas of these rivers till they join Panvel creek.

River	Gadhi	Kasadi	Kalundri	Taloja	Ulwe
Catchment area (km^2)	116	60	93	30	33

As seen from Fig.1 Gadhi river flows along eastern and southern boundary of Panvel city and Kalundri joins Gadhi just downstream of bridge on National Highway No.4 (NH4). The river further flows along west of Panvel city till it joins Panvel creek near Waghiwali island. Rivers Kasadi and Taloja flow on north of Panvel and both merge upstream of the bridge on Sion Panvel road. Further part of river is called Taloja creek which merges with Gadhi near Waghiwali island. At about 5 kms downstream of Waghiwali island the river merges into Thana creek. The entire river network is called as Panvel creek. The Ulwe river joins from south near Waghiwali island.

The 100 year return period (24 hour) rainfall in the catchment area of these rivers is about 400 mm as per IMD records. Heavy storm of total rainfall of 350 mm to 400 mm on 27 - 28 July 1991 resulted into heavy flooding of this area (especially Panvel city) which was never experienced before.

3.0 MATHEMATICAL MODEL

The model CHARIMA developed at IOWA Institute of Hydraulic Research, USA, by Prof. F.M.Holly was used for the purpose of prediction of water levels in Vasai Creek. The model is capable of handling unsteady flows in multiple connected channels.

3.1 Governing Equations and their solutions

One dimensional unsteady water flow is represented by Saint Venant equations

Continuity Equation

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0$$

Momentum Equations

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\frac{\alpha Q^2}{A}\right) + gA\left(\frac{\partial y}{\partial x}\right) + gA\left(\frac{Q|Q|}{K^2}\right) = 0$$

Where
- Q - Water Discharge
- A - Cross Section Area
- y - Water Surface Elevation
- α - Momentum Correction Factor
- k - Conveyance
- X - Distance Along Channel
- t - Time

These equations are nonlinear partial differential equations with Q and y as dependent variables and x and t as independent variables. The exact solutions of these equations are not possible since these equations are not in standard forms. Therefore, approximate solutions are obtained using numerical methods such as finite difference, finite element etc. The CHARIMA model uses widely applied Preissman 4 point weighted implicit finite difference scheme for solution of these equations. Using the Preissman 4 point implicit filnite difference scheme, the terms in the equation are discretised in x-t plane and a system of linearised simultaneous difference equations is obtained. This system of equations has banded structure (i.e. coefficient matrix is a banded matrix). This set of linearised equations is solved by double sweep alogorithm which is relatively faster technique. The entire network of channels is schematised into Links (Channels) and Nodes (i.e. junctions or bifurcation points or end or begining of the channels) so that each link has one node at each end and each node has at least one link (channel) starting from it or ending at it. Formulation of set of linearised difference equations for each link, carryingout forward and backward sweep in each channel, formulation and solution of node matrix to obtain the water levels at each node and computing the water level and discharge at each grid point in each channel are the broad steps involved in solution procedure. During these computations the values of various numerical parameters involved were adopted as follows :

Time weighting coefficient (θ) = 0.55, Space weighting coefficient (Ψ) = 0.5,

Time step (Δt) = 10 minutes, distance step (Δx) = variable as per grid point spacing.

3.2 Input Data Requirements for Model

The model needs following type of input data :

1. Topographical data i.e. river channel cross sections and channel network layout and their connectivity.
2. Hydrological / Hydraulic data which include inflow flood hydrographs to be used as upstream boundary and water level data or gauge discharge relation at downstream boundary.
3. Observed water level / velocity data for Model Calibration and Validation.

3.3 Schematisation of Panvel Creek

The mathematical model was developed for the entire Panvel creek reach from mouth to about 10 to 15 kms upstream including five major rives namely Gadhi, Kalundri, Kasadi, Taloja and Ulwe. Fig.2 shows the Panvel creek reach considered in the model alongwith the locations of the cross sections used to reproduce topography of Panvel creek river ntework. These cross sections were extended above High Flood levels with the help of toposheets. The structures such as bridges, reclamations works, road / railway embankments were reproducted by providing appropriate river channel width at relevant cross sections. The entire river network is schematised into links (channels) and nodes. Fig.3 shows schematisation for the mathematical model of Panvel creek network.

3.4 Boundary Conditions

The spring tide with HWL of 3.25 m and LWL of -2.00 m (Fig.4) was used as downstream boundary condition at the mouth of Panvel creek for the model runs for predicting high flood levels. During validation run for simulation of high flood on 27th July 1991, the actual tide on these day was used as downstream boundary condition.

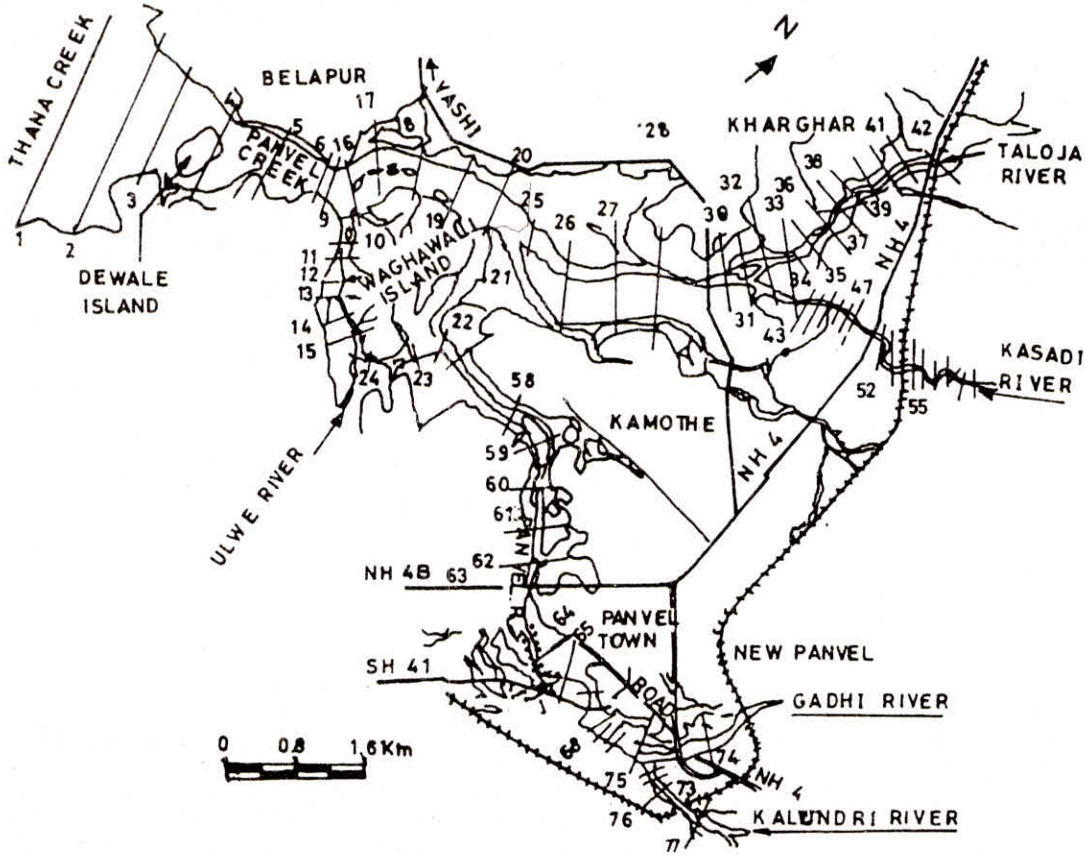


Fig.2 : Locations of cross sections in model reach

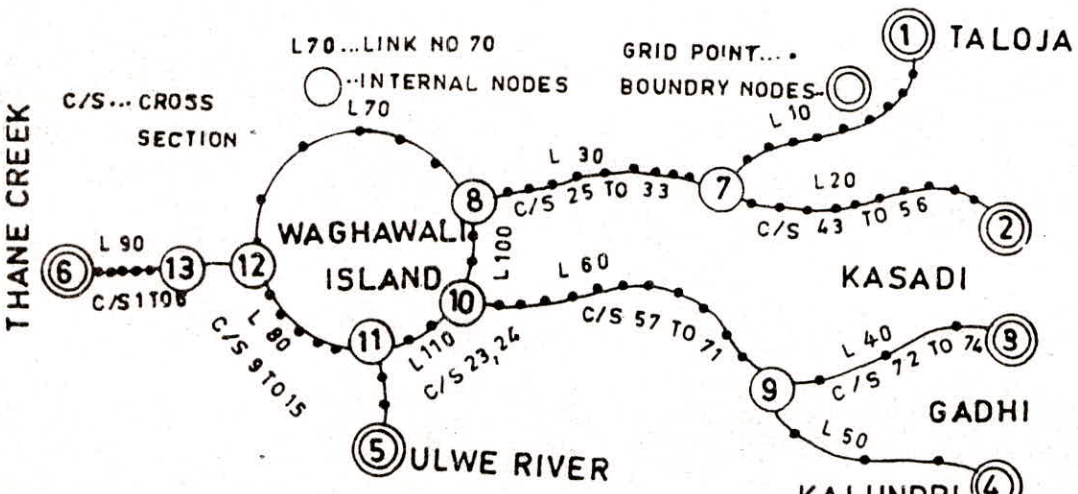
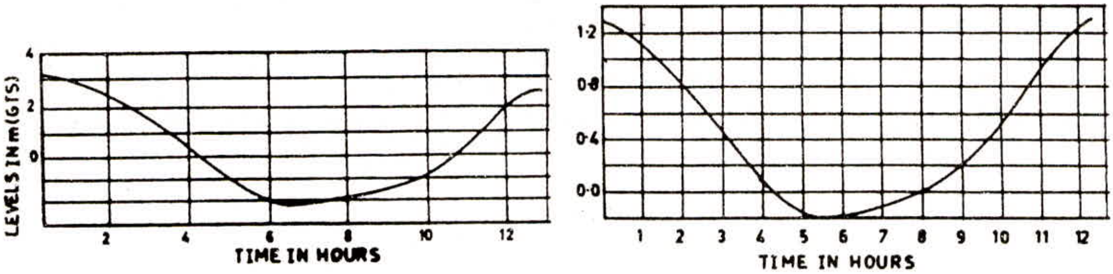


Fig.3 : Schematisation of Panvel Creek



'Spring Tide *Neap Tide*

Fig. 4 : Spring Tide and Neap Tide as D/S Boundary

For the upstream boundary conditions the peak flood discharges (for the major five rivers) computed from rational formula using 100 year return period 24 hour rainfall intensity of 80 mm/hour were used. These discharges are given below :

Sr.No.	River	Catchment area (km^2)	Runoff coefficient	Peak discharge (m^3/s)
1	Gadhi	116	0.6	1647
2	Kalundri	93	0.6	1320
3	Kasadi	60	0.8	1130
4	Taloja	30	0.8	570
5	Ulwe	33	0.8	470

4.0 MODEL CALIBRATION AND VALIDATION

Using gauge discharge data of September 1992 flood the model was calibrated using bed roughness coefficient varying from 0.035 for upstream rocky reach to 0.025 for the downstream reach near Wagiwali island. Using these values of bed roughness the model was run for simulation of high flood experienced on 27 July (when rainfall of about 350 mm to 400 mm occured) by using appropriate tidal levels as downstream boundary and peak discharges in all five rivers as mentioned in para 3.5. Fig.5 and Fig.6 show that the water surface profile predicted by the mathematical model for the 100 year return period flood in Taloja and Kasadi rivers is in good agreement with the observed high flood levels in both these rivers at the bridge on NH4 and at the railway bridge on Kasadi. Fig.7 shows comparison of predicted water surface profile along Gadhi river reach (from Waghiwali island to New Panvel) with the observed HFLs along Gadhi river on 27th July 1991.

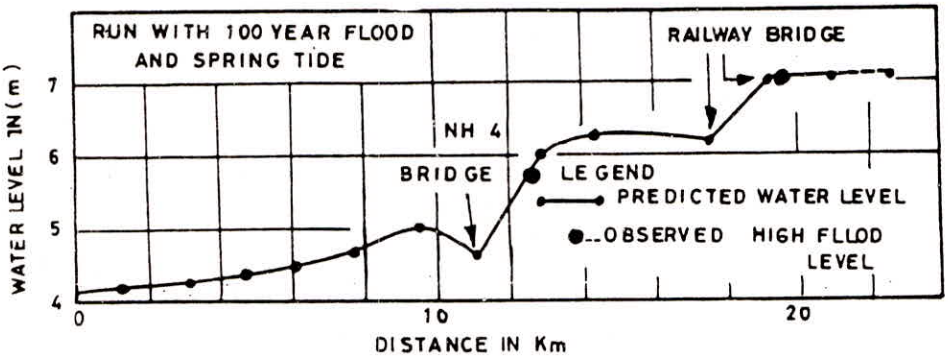


Fig. 5 : Kasadi River U/s of Taloja confluence validation run

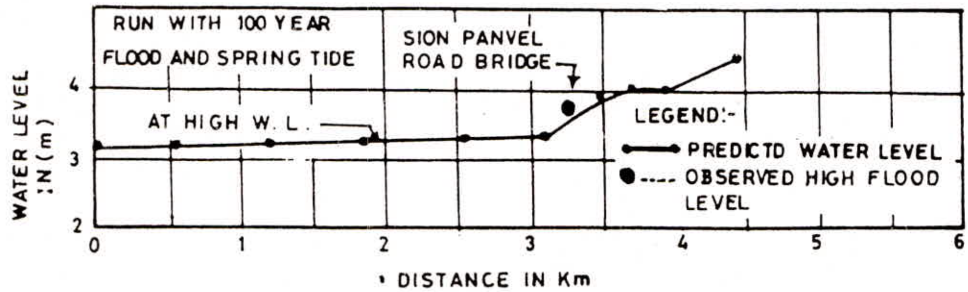


Fig. 6 : Taloja Creek from Kasadi confluence to Waghiwali Island - validation run

It could be seen that the observed HFLs at Panvel port (5.5 m), at the bridge on SH41 (6.0 m), at NH4 bridge (7.75 m) and at New Panvel (10.75 m) are well in agreement with the predicted water surface profile. Fig.7 also indicates that due to construction of NH4B bridge (with contricted waterway of 180 m) there was rise in HFL on upsteram by about 0.5 m. Thus Fig.5, Fig.6 and Fig.7 clearly indicate that the mathematical model is adequately validated.

5.0 MODEL RUNS WITH AND WITHOUT RECLAMATION IN PANVEL CREEK

For these runs the spring tide with HWL of 3.25 m and LWL of -2.00 m (Fig.4) was adopted as downstream boundary condition. The peak flood discharges mentioned in para 3 were adopted as

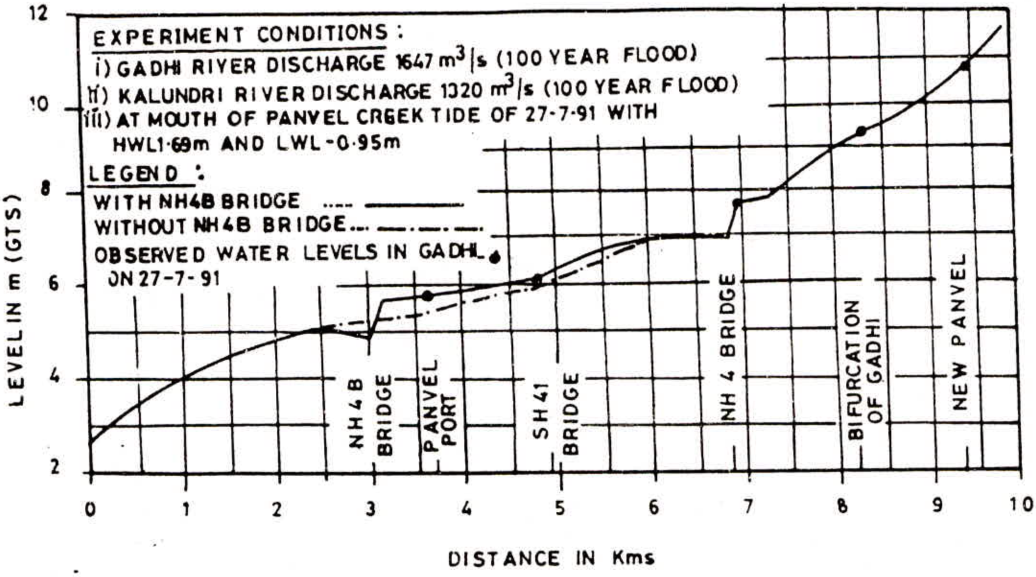


Fig. 7: Model Validation for Gadhi river water levels during high flood on 27.7.91

upstream boundary conditions for various river channels. The original river cross sections were used for simulation flow under predevelopment situation. For the post development situation, the river widths were constricted at different cross sections as per the development plan. For example the maximum widht of Taloja was restricted to 200 m. For Kasadi river upstream of Taloja confluence the constricted width varied from 300 m to 150 m. Waterways of existing and proposed road and railway bridges were adopted as per design. Fig.8 to Fig.11 show the comparison of water surface profiles without and with reclamation in different reaches of Panvel creek under the conditions mentioned above.

It could be seen that the predicted rise in the flood levels due to urban developments vary from 0.2 m to 1.5 m in different channels as follows :

Channel No.	Reach	rise in HFLs
30	Taloja creek from Waghiwali island to Kasadi confluence	0.2 m to 0.5 m
20	Kasadi river upstream of Taloja confluence	0.0 m to 0.5 m
10	Taloja river upstream of Kasadi confluence	0.4 m to 0.5 m
60	Gadhi river from Waghiwali island to New Panvel	0.5 m to 1.5 m

The above water level rise in different channels is at the time of HWL of spring tide. The rise in water levels at the time of low water level of spring tide varies from 1.0 m at Waghiwali island to about 0.1 m at Sion Panvel road bridge downstream of Kasadi and Taloja river confluence.

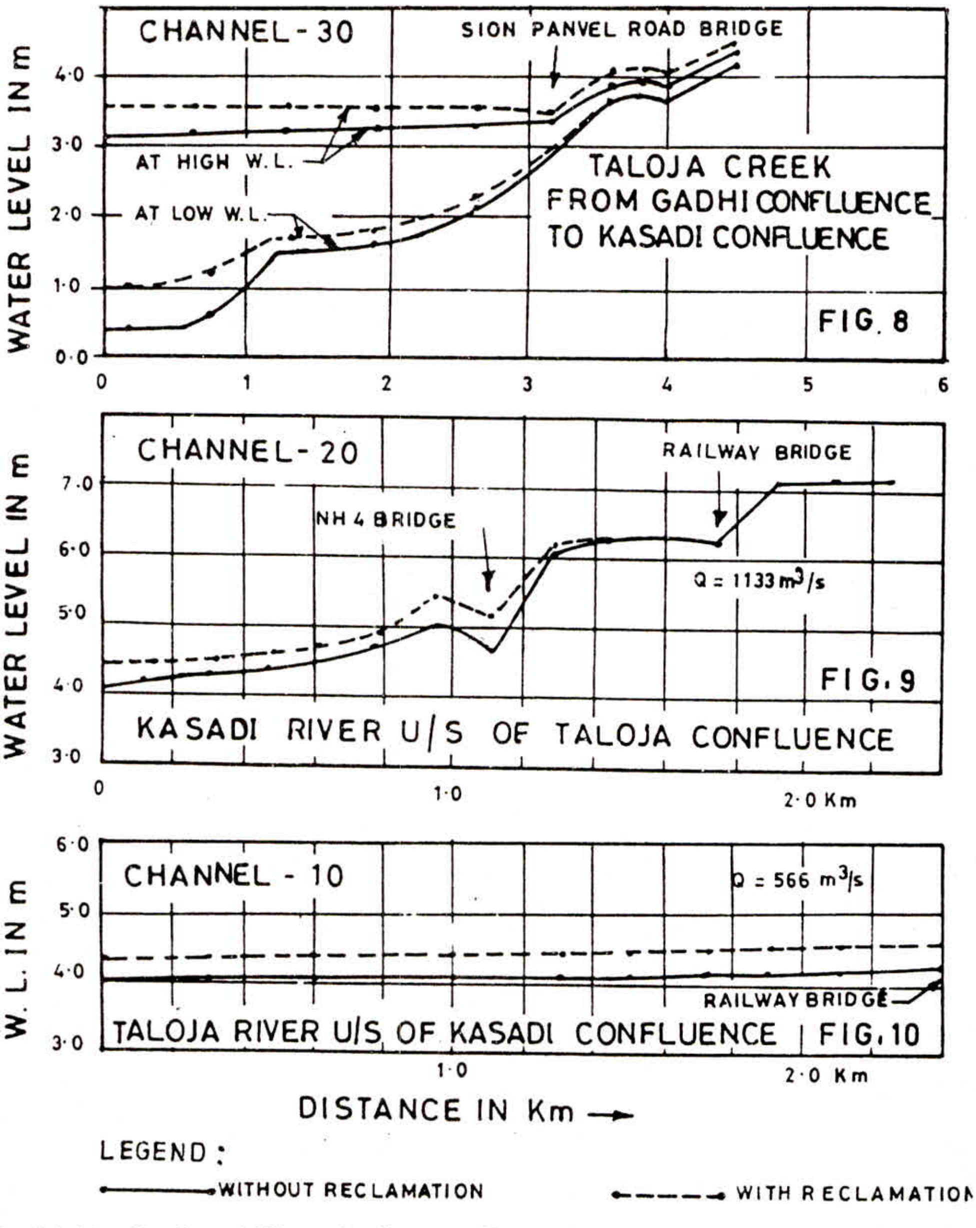


Fig.8,9,10 : Predicted Water Surface Profiles with Spring Tide and 100 year Flood

As far as flooding is considered the combination of spring tide with flood gave the maximum possible flood levels as seen from earlier para. In view of storm water drainage system the rise in low water levels is also important. Therefore, runs with 100 year return period flood with neap tide with HWL of 1.30 m and LWL of 0.0 m (Fig.4) were also taken. The predicted water levels under this condition in the Taloja creek (channel No.30) reach between ring road to Sion-Panvel road bridge downstream of Kasadi - Taloja rivers are as follows :

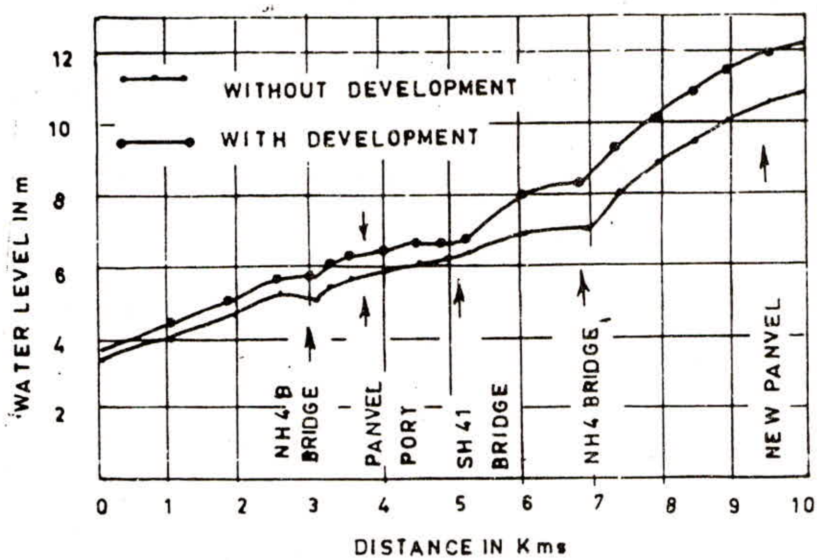


Fig. 11 : Predicted Water Surface Profile along Gadhi River

Location	Water level (m) at H.W.	Water level (m) at L.W.
Inner ring road bridge	2.02	1.24
Railway bridge	2.20	1.63
Sion - Panvel road bridge	2.78	2.74
Taloja - Kasadi confluence	4.12	4.12

The water levels upstream of Taloja - Kasadi confluence are not affected by tidal conditions and are governed by only floods. Also the low water levels varying between 1.284 m and 4.12 m need to be kept in view while designing the outfalls of storm water systems in Taloja creek. The invert levels at the outfalls must not be lower than the low water levels mentioned above.

6.0 DISCUSSIONS AND CONCLUSIONS

1. The rise in the high flood levels at the time of spring tide will be above 0.2 m to 0.5 m in the Panvel creek reach between Waghiwali island to Taloja - Kasadi confluence and also on upstream along Taloja and Kasadi (Fig.8, 9 and 10)

2. The rise in high flood levels along Gadhi river will vary from 0.5 m at the bridge on proposed ring road to 1.5 m at New Panvel (Fig.11).

3. The high flood levels along Taloja creek from Waghiwali island to the bridge on Sion - Panvel road will be about 3.70 m.

4. The water levels in Kasadi river upstream of NH4 bridge will not be affected by development as well as by tide. These levels will be about 6.3 m between NH4 bridge to railway bridge and about 7.2 m upstream of railway bridge (Fig.9). The adequate protection along left bank of Kasadi need to be provided to avoid flooding of proposed townships.

5. The water levels along Taloja river upstream of Kasadi confluence will be about 4.50 m.

6. Keeping in view the predicted maximum flood levels along different river channels the finished ground levels of reclaimed land should not be lower than the levels prescribed below :

   a) Developments along Taloja creek for Kamothe and Kharghar - 4.50 m

   b) Developments for Kharghar node along Taloja river upstream of Sion - Panvel road bridge - 5.50 m

   c) Developments for Kalamboli node along Kasadi river between Sion - Panvel road bridge and NH4 bridge - 6.50 m

7. The invert levels of outfalls of the storm water drainage systems should as far as possible be higher than the low water levels predicted for the condition of flood at the time of neap tide.

8. Keeping in view the high flood levels along Gadhi river reach from NH4B bridge to New Panvel appropriate flood protection need to be provided along right bank to avoid flooding of Panvel city.

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