*Proceedings of the 5th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020), 7~9 February 2020, KUET, Khulna, Bangladesh (ISBN-978-984-34-8764-3)*

# NUMERICAL MODELLING FOR PLANNING AND HYDRAULIC DESIGN OF ROAD AND ASSOCIATED ROAD STRUCTURES IN COMPLEX PHYSICAL AND HYDROLOGICAL SETTINGS

**Kanungoe Pintu*[1], Al Imran Abdullah[2] and Uddin Md. Alim[3]**

[1]*Chief Scientific Officer, River Research Institute, Bangladesh, e-mail: pintu_kanungoe@yahoo.com*
[2]*Scientific Officer, River Research Institute, Bangladesh, e-mail: imran0301086@gmail.com*
[3]*Director General, River Research Institute, Bangladesh, e-mail: rribd@yahoo.com*

***Corresponding Author**

## ABSTRACT

Sunamganj-Netrokona-Mymensingh road is a regional road of the Roads and Highways Department of Bangladesh. The road is indented to establish smooth roadway communication facility between the northeast and the northcentral regions of the country. However, because of complex physical and hydrological settings of the low-lying haor (wetland) area from Sachna Bazar to Golakpur Bazar of the Jamalganj upazila under Sunamganj district, the intended road communication could not be established yet. People of this region do not have easy access to national road network and largely depend on waterway communication. However, establishment of this road link is the most challenging task as it will run through an environmentally and hydrologically sensitive area. The river Surma flows along the likely road alignment and the road alignment has to cross either the Surma river or the Baulai river together with many other drainage routes. There is also distinct connectivity between rivers and haors. Since rainfall on the adjacent Indian state Meghalaya largely affects flooding in the study area, the rainfall pattern of the upstream catchment has great influence here. The Surma-Kushiyara basin receives water from the transboundary catchments of the Meghalaya, the Barak and the Tripura situated to the north, east and southeast respectively across the border in India. In view of the above mentioned facts a number of hydro-morphological and environmental aspects related to the proposed road project have been crucial for investigation.River Research Institute has conducted a comprehensive hydro-morphological study and EIA for construction of the road with appropriate alignment and road structures to minimize the adverse impacts of the road project on natural flooding, drainage and sedimentation. The study is based on extensive field survey data that include cross-sections of rivers and drainage routes, topographic data, data on infrastructure, surface and subsurface soil data, environmental data etc. The secondary data include historical hydrological data of the rivers, maps, time series satellite images etc. A two-dimensional model covering an extent of about 31km of the Surma river and parts of the Baulai and the Rakti rivers together with parts of their floodplains has been developed using modelling software MIKE21C. Flood frequency analysis has been done with historical hydrological data using General Extreme Value distribution and Extreme Value Type-1 distribution to determine different probable discharges and water levels at different gauge stations on the rivers. Based on the analyzed data two hydrological scenarios have been identified that are critical for the road project. Baseline hydrological and hydraulic conditions in the study area have been investigated for the selected critical hydrological scenarios. Based on baseline hydro-morphological and environmental conditions three alternative options of the proposed road alignment have been devised and assessed against a set of criteria. A standard screening process has been followed for selection of the preferred option. Hydraulic and hydrological assessment of the preferred option have been made for the two preselected critical hydrological scenarios and location and dimension of the road structures have been fixed following trial and error method. The study has come up with some important outcomes namely type, location and dimension of the road structures, locations and extents of road embankment slope protection works and their hydrologic and hydraulic design variables, design flood level, wave runup, road formation level, through bridge velocity, bridge scour etc.

***Keywords:*** *Haor, Drainage, Scour, Wave runup, Flooding.*

## 1. INTRODUCTION

The study area is located in the North East Region (NER) of Bangladesh (Fig. 1). This region comprises an area about 22,000 km$^2$ which can be further subdivided into six distinct sub regions. The project area belongs to the Baulai sub region (5000 km$^2$) and the Surma sub region (4500 km$^2$). It means the total a result of excessive rainfall. The local and cross border flows and the internal rainfall influence the water level in the rivers and floodplains of the area. This is an interactive zone where flow area covered by these two sub regions is about 43% of the total area covered by the NER. These sub-regions are located in one of the depressed portions of the country. The topography of the study area along with other parts of the NER had undergone structural transformation creating depression in the remote past. The bowl-shaped depression is popularly known as haor and remains inundated for 6-7 months during the monsoon. Within the haor there are perennial and seasonal water bodies. Most of the rivers in these areas are originated from nearby hilly areas of India. These rivers are extremely flashy that is characterized by sudden and wide variation in flow as characteristics change with the rise and fall of water levels. The floodplain flows in the study area occur due to overflow of Surma, Baulai, Jadukata-Rakti and other small rivers. Therefore, during monsoon the study area remains deeply flooded. The flood water drains out with the fall of water level in the Surma-Baulai system. During normal flood period the rainwater is drained to the adjoining rivers through the link channels and small rivers following the flow directions. The average annual rainfall in the study area is 4000mm. One of the functions of flash floodwater is to carry sediments, which are eroded from the hilly catchment area. The sediments carried by the rivers are also deposited along the river banks resulting in an increase in the land elevation there compared to the surrounding low-lying areas. These elevated lands are inhabited by people. Therefore, patches of small villages almost all along the rivers and channels are visible in the study area. These village areas are densely vegetated with well grown trees.

Roads and Highways Department (RHD) of Bangladesh has decided to construct the missing stretch of the Sunamgonj-Netrokona-Mymensingh-Dhaka road by establishing road link between Sachna Bazar and Golakpur Bazar of Sunamganj district. If this road link can be established it would be easy to connect this road with existing Netrokona-Mymensingh-Dhaka road because establishment of this road link is the most challenging task as it will run through an environmentally and hydrologically sensitive low-lying haor (wetland) area. The river Surma flows along the likely road alignment and the road alignment has to cross either the Surma river or the Baulai river together with many other drainage routes. Understanding of the prevailing hydrological regime is of utmost importance to decide about appropriate road alignment and road structures

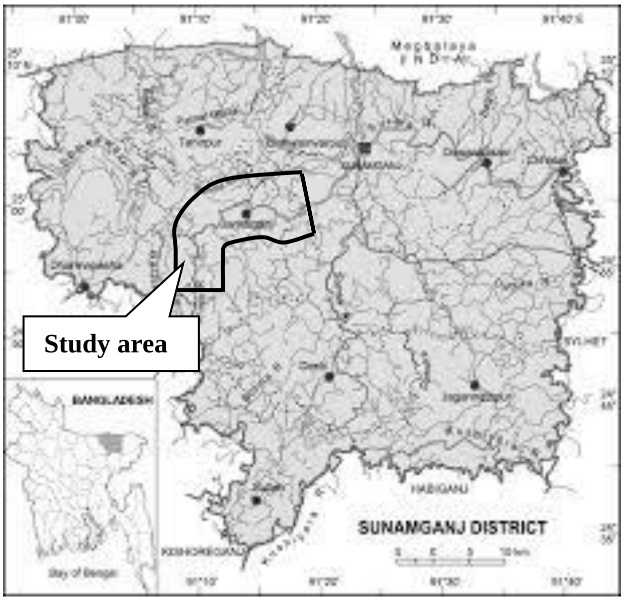



Figure 1: Location of the study area in the Sunamganj district

The Surma is the major river in the study area and there is distinct connectivity between rivers and surrounding haors. The connectivity between the Surma river and the haor area is a major issue for fixing the proper road alignment and road structure locations for establishing the proposed Sachna-Golakpur road link. Since rainfall on the adjacent Indian state Magalaya largely affects flooding in the study area, the rainfall pattern of the upstream catchment has great influence here. The Surma-Kushiyara basin receives water from the transboundary catchments of the Meghalaya, the Barak and the Tripura situated to the north, east and southeast respectively across the border in India.

Road embankment through the haors creates obstruction to natural flow of water and is subjected to wave actions. Also bridges and its accessory structures in general often constrict the flow area under the bridge and the bridge piers enhance this constriction resulting in increase of speed, acceleration of scouring process, backwatering of stage etc. Mathematical modeling is state-of-the-art technology applicable in planning and design and construction stages of the road embankment and road structures to ensure safe and economic design of the same. The technology can also be applied for devising suitable mitigation measures to counteract any negative impact of the road project.

Under this circumstance RHD has envisaged a comprehensive hydro-morphological study and EIA for construction of Sancha-Golakpur road with appropriate alignment to minimize the adverse impacts of the road project on natural flooding, drainage and sedimentation. The Surma is a sinuous river at and around the study reach. Since the structures like bridges across the river and road embankment in a hydrologically complex region (haor areas) will be constructed, a number of issues are there to be addressed properly before constructing the bridges/culverts and road embankment. The bridges/culverts and road embankment might have significant impacts on existing hydrological regime as well as environmental quality of the project area if not properly planned and designed.

River Research Institute (RRI), Faridpur, Bangladesh has conducted hydro-morphological study and EIA to support planning and hydraulic design of the road project. Necessary topographical, hydrological, hydrographic and sediment data have been collected through a field survey campaign. Historical hydrological data of the rivers concerned and satellite images of the study area have been collected from available sources.

The collected data have been processed and analysed to the extent of deriving necessary inputs for the MIKE21C model that has been developed for reproducing baseline hydrological and hydraulic conditions in the study area as well as for hydrological assessment and hydraulic analysis of the selected road alignment and road structures. The two-dimensional model covers the whole study area (rivers and floodplains). The tool (MIKE21C) is suited for river and floodplain hydro-morphological studies and includes modules to describe flow hydrodynamics, sediment transport, alluvial resistance, scour and deposition, bank erosion and planform changes (DHI, 2006). This paper highlights the application of the model in gaining understanding of the flow conditions in the study area for two critical hydrological scenarios and in deciding about appropriate road alignment and location, type and dimension of the road structures and their hydrological and hydraulic design parameters.

## 2. METHODOLOGY

In order to conduct the study needed primary and secondary data and other relevant information have been collected. The collected data include historical hydrological data (discharge and water level), digital elevation model (DEM) of the study area, cross-sections of the rivers, information on existing metalled and unmetalled roads and road structures, physical features on both sides of the Surma river in the project area, sediment samples, satellite images, maps, photographs etc. The secondary data have been collected from available sources whereas the primary data have been collected through field reconnaissance and field survey campaign (River Research Institute, 2017). A final road alignment survey has been conducted along the proposed road alignment covering a 100m corridor. Sub-soil investigation has been carried out at all proposed road structure locations. The collected data have been processed and analyzed to the extent of gaining understanding of the present physical conditions of the rivers and the low-lying land surrounding the rivers in terms of their vertical and lateral stability and physical settings of the study area and also deriving information to use as model inputs. A two-dimensional model covering an extent of about 31km of the Surma river and parts of the Baulai and the Rakti rivers has been developed using modelling software MIKE21C. The initial bathymetry of the model is formed by use of the recently surveyed bathymetric and topographic data as well as DEM of the study area. The computational grid and initial bathymetry of the model is shown in Fig. 2 and Fig. 3 respectively. Practically flow enters into the model domain through two boundaries and leaves model domain through another two boundaries. The flow of the Surma river enters into the model domain through upstream boundary whereas flow from Meghalaya Hills enter into the same through right boundary. Water leaves the model domain through downstream boundary (Surma-Baulai river) as well as through left boundary into the haor. Since haors act as storage reservoir during monsoon, majority of the flow leaves the model domain through downstream boundary.

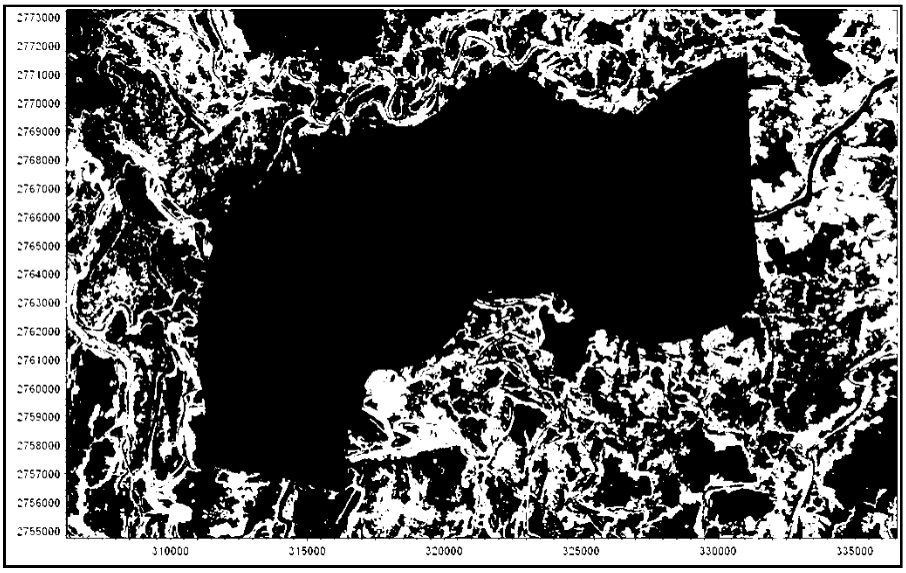



Figure 2: Curvilinear computational grid of the model


Figure 3: Initial bathymetry of the model

Downstream boundary data of the model are obtained from the recorded historical water level data at Sukdevpur, which is located at just downstream from the model downstream boundary. On the other hand, upstream boundary data of the model are obtained from the recorded historical discharge data at Sunamganj. It is to be noted here that the discharge gauge station at Sunamganj town is situated at about 12.5km (along the river) upstream of the model upstream boundary. During monsoon water enters into and leaves the river almost throughout this 12.5km stretch. There is no other discharge gauge station between Sunamganj town and model upstream boundary. Therefore, the discharge records at Sunamganj town have been used to determine the model upstream boundary. The right open boundary data of the model have been determined from historical discharge records of the Jadukata river at Laurerghar. Upon entering the Sunamganj plain from the Meghalaya Hills, the Jadukata river gets divided into a number of rivers. During monsoon flow enters into the model domain through these rivers as well as through overspill from these rivers. During generation of right boundary of the model this fact is taken into account.

Flood frequency analysis with available historical discharge and water level data at different gauge stations on the rivers that are hydrologically connected with the study area has been made for determination of different return period discharges and water levels. The GEV and EVI methods have been employed for frequency analysis of water level and discharge data. At first, the annual maximum water level and discharge is determined for each gauge station for the available years. It is found from the plots of the fitted GEV and EVI distributions together with 95% confidence limits for the water level and rated discharge data at Sunamganj, Sukdevpur and Laurerghar that GEV distribution fits the annual maximum water level and discharge data well relative to EVI distribution. Therefore, the water level and discharge obtained from GEV distribution for various return periods have been accepted. Since there is no water level or discharge gauge station in the model domain, the water level along the proposed road for different return period discharges including the design discharge have been determined from model simulation results. The water level at different road structures and discharges through them for different return period discharges have also been determined from model simulation results with structures in place.

As the flow conditions in the study area are very complex and depend on a number of factors namely magnitude of discharge and water level in the Surma river, magnitude of flash flood discharge from the Meghalaya Hills and water level of the Meghna river at the outfall of the Suma river. The extreme flow conditions result from the combination of these factors. But it is less likely that the peak discharges of the Surma river and the Jadukata river and peak water level of the Meghna river may occur at the same time. It is found from the hydrological data that simultaneous occurrence of an extreme event in the Surma river and large discharge from the Meghalaya Hills result in severe flood condition in the study area. During a flood event when flood stage goes up flow occurs not only through the rivers but also over the floodplain. Generally floodplain flow occurs in a direction more or less parallel to the Surma river flow direction. Therefore, such an occurrence has been considered as one critical hydrological scenario for the road project. Another critical hydrological scenario for the road project to decide about appropriate type, location and dimension of the road structures occurs if flash flood water from the Meghalaya Hills arrives in the study area during falling stage of Surma river flood or low stage of the Surma river. Based on these facts two critical hydrological scenarios have been developed for model simulation in base condition and with road and road structures in place.

On the basis of base line flow conditions in the study area, relevant factors controlling road alignment selection and identified issues and constraints three feasible alignment options of the road have been devised (Fig. 4). Alternative road alignment options are then assesses under a set of criteria and sub-criteria taking into account community and agency concerns. A two-step screening process namely advantages and disadvantages matrix and evaluation criteria matrix has been conducted for elimination and selection of options. Among the three road alignment alternatives, two options (Option-2 and Option-3) have been eliminated stating the reasons and Option-1 has been retained for further assessment as it provides a number of advantages and community attitude towards this road alignment is very positive.

Hydrological and hydraulic analysis of the selected road alignment is made for two pre-selected critical hydrological scenarios and type, location and dimension of the road structures have been selected following trial and error method. Four different arrangements of road structures have been tested to arrive at final decision as to appropriate type, location and dimension of the road structures. Based on model results wave runup, design water level and formation level of the road, design water level, discharge and maximum velocity for each road structure, scour depth at bridge piers and abutments, road stretches where road embankment slope protection works are needed etc. have been determined.

## 3. RESULTS AND DISCUSSIONS

The base line flow conditions in the study area have been investigated for two critical hydrological scenarios as mentioned earlier. Scenario one represents conditions when 50 year event (design event) occurs simultaneously in the Surma and the Jadukata rivers. On the other hand, scenario two represents conditions when a flash flood of 50 year return period suddenly occurs from the Meghalaya Hills during recession period of the Surma river. Both scenarios have been obtained by synthesizing recorded events. It is found that 50 year discharge of the Surma and the Jadukata river is 3567m3/s and 3184m3/s at Sunamganj town and Laurerghar respectively. On the other hand, 50 year water level of the Surma-Baulai system at Sukdevpur is 8.66mPWD;

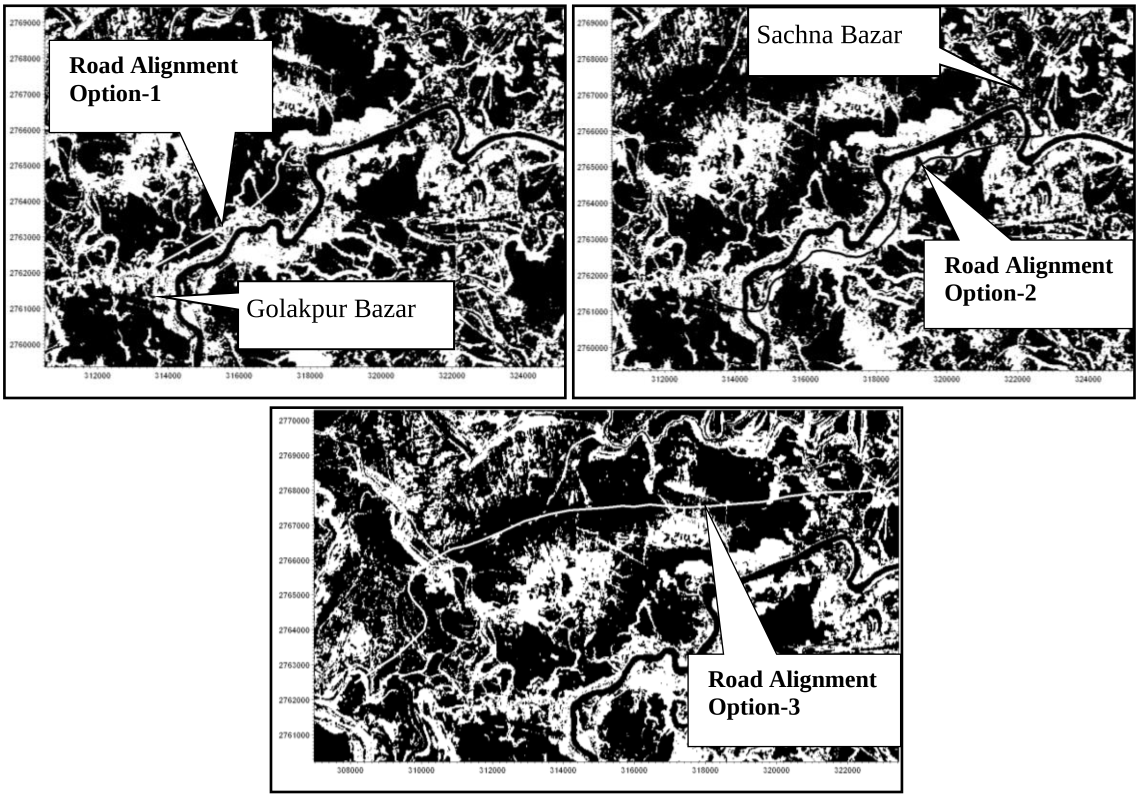



Figure 4: Devised road alignment options

### 3.1 Baseline Conditions

Velocity field and water depth in the study area for hydrological scenario one have been shown in Fig. 5 and Fig. 6 respectively. It is evident from the Fig. 5 that during an extreme event flow occurs both in the rivers and over the floodplain with a low velocity (<0.5m/s) and there is no noticeable difference between the magnitude of flow velocity in the river and over the floodplain. It is also noticeable from Fig. 5 that floodplain flow occurs more or less parallel to the Surma river. Since the selected road alignment runs more or less along the right bank of the Surma river it is less likely that the cross-flow will occur through the road openings except for the upstream part of the road link where water from the river flows out over the river bank towards the low-lying floodplain. However, this is not the case for hydrological scenario two. A flash flood from the Meghalaya Hills during falling stage of the Surma river causes flow concentration at Baulai outfall as the river drains the north floodplain (haor area). As a result, flow velocity of the Surma river downstream of the outfall becomes higher than that upstream of the same. This occurrence is reported afterwards with road and road structures in place condition. It is found from the simulated water levels that the design water level (for 50 year discharge) of the proposed road varies from 8.52mPWD to 8.55mPWD from Golakpur end to Sachna Bazar end respectively. It is evident from the Fig. 6 that low water depth occurs over a narrow strip of land on both sides of the Surma river almost all along the river in the study area. The water depth along these strips of land having relatively higher elevation varies from 0m to 3m. On the other hand, relatively higher water depth occurs in the low-lying haor areas to the south, south-east and north-east of the Surma-Baulai confluence.

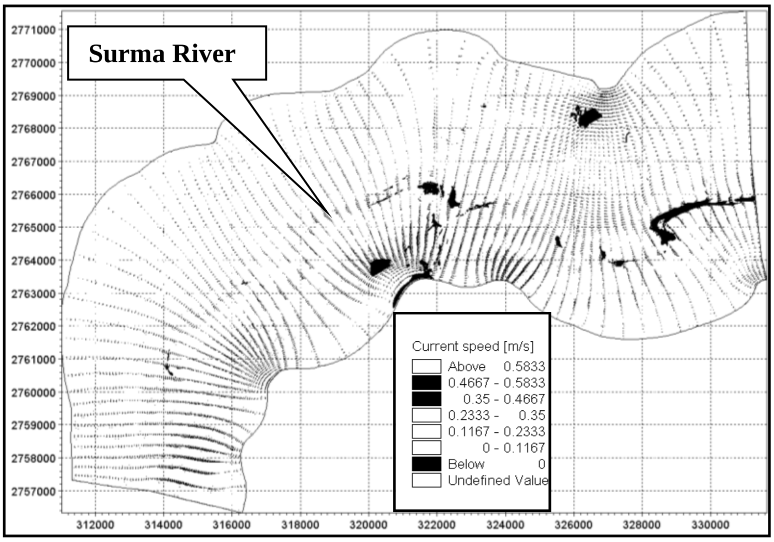



Figure 5: Velocity field in the study area for hydrological scenario one

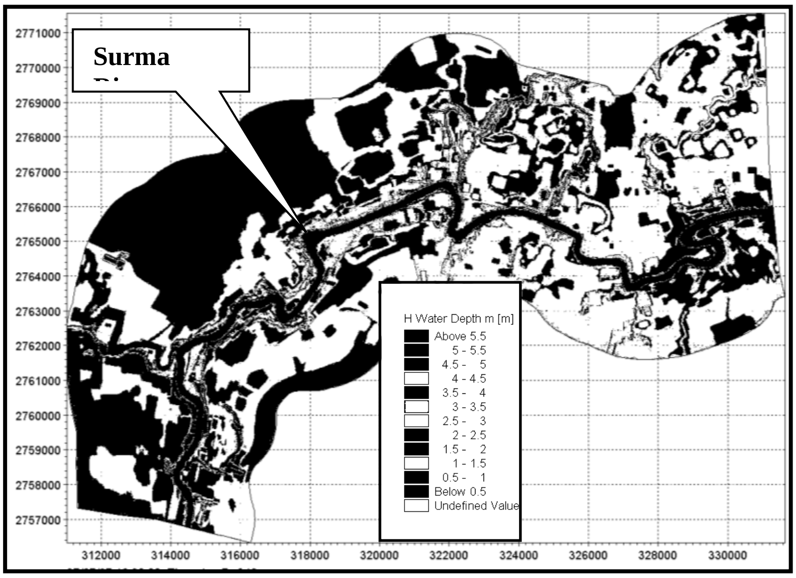
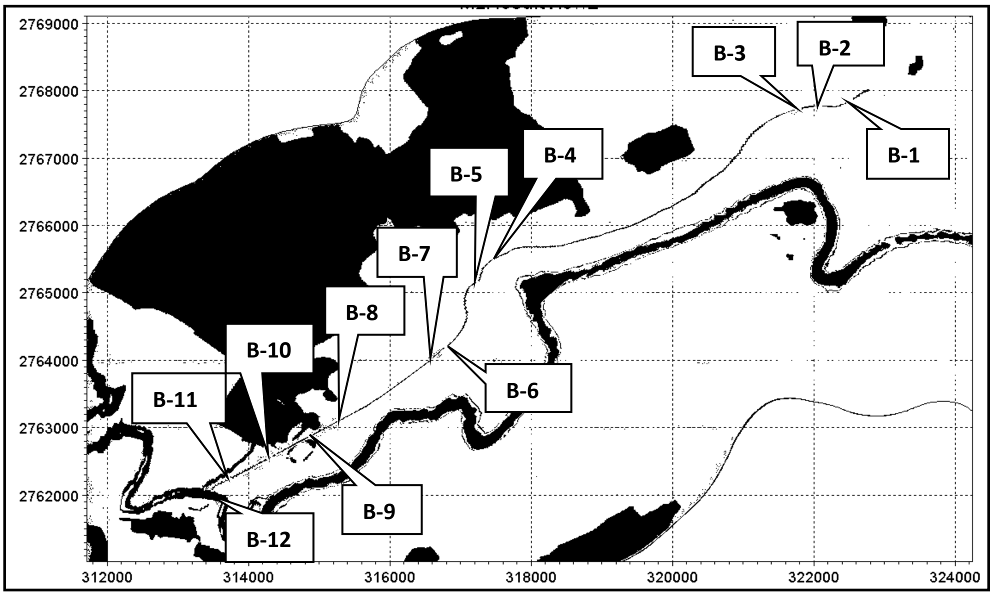



Figure 6: Water depth in the study area for hydrological scenario one

The Sachna-Golakpur road alignment is, therefore, selected in such a way so that the areas of high flood depth can be avoided. There are small villages and other community facilities and private properties on the elevated land (levee) along the Surma river. Therefore, the selected road alignment creates fewer disturbances to wetland biodiversity and ecosystem and integrates well with the existing community facilities. However, in order to ensure minimum disturbance to existing hydrological regime sufficient number of road openings have to be provided at appropriate locations.

### 3.2 Project Conditions

Based on the model simulation results in base condition and field information the type, location and dimension of the needed road structures have been determined and introduced in the model to assess their hydraulic performance. Hydrological assessment and hydraulic analysis of the road and road structures have been conducted for the two critical hydrological scenarios as is done in base condition. Initially 12 road structure (bridge) locations have been fixed to allow for smooth passage of flood flow as shown in Fig. 7. The length of the bridges varies from 25m to 190m. It is to be noted here that initially a total of 686m bridge opening throughout the road having length of about 12.2km has been considered. The percentage of considered road opening is about 5.62% of the total length of the road. Based on the performance of the structure's necessary modifications in the structure locations and dimensions have been made for reassessment of their performance. In this way after fourth trial the required type, location and dimension of the road structures have been determined. The effect of the road and road structures on existing hydrologic and hydraulic conditions has been assessed by




comparing the model results with that under base (without project) condition.

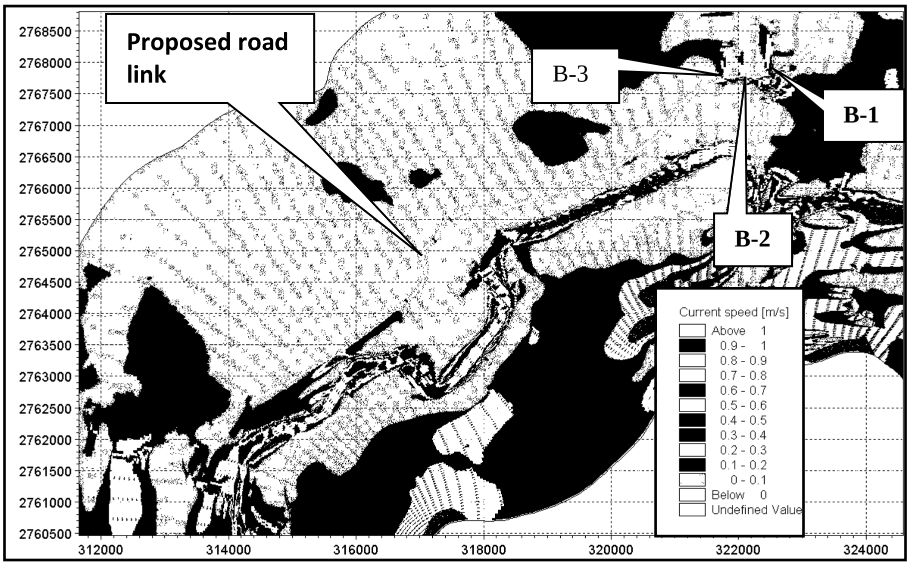



Figure 7: Location of initially considered bridges on the proposed road

The velocity field in the study area for hydrological scenario one and with initially considered bridges has been shown in Fig. 8. It is evident from the figure that under this hydrological scenario cross-flow occurs only through Bridge-1 to Bridge-3 (B-1 to B-3). There is very little or no cross flow through other considered bridges. However, exactly opposite condition is found for hydrological scenario two (Fig. 9). In this case, cross flow does occur through B-4 to B-12.

Bridge-12 (B-12) is situated over the Baulai which drains the haor area. Under hydrological scenario two substantial flood flows will enter into the Surma river through the Baulai river as well as over the nearby low-lying land. Since the proposed road obstructs this flow there should be sufficient road opening there. It is to be noted here that beyond southwest end of the proposed road link there is submersible road over the floodplain that has to be upgraded with sufficient road openings to establish the Sunamganj-Netrokona-Mymensingh road communication. It is found from the hydrological scenario one simulation results that about 3000$m^3$/s discharge may pass over the floodplain. Addressing this issue is beyond the scope of this study.

Figure 8: Velocity field for hydrological scenario one and initial arrangement of road structures

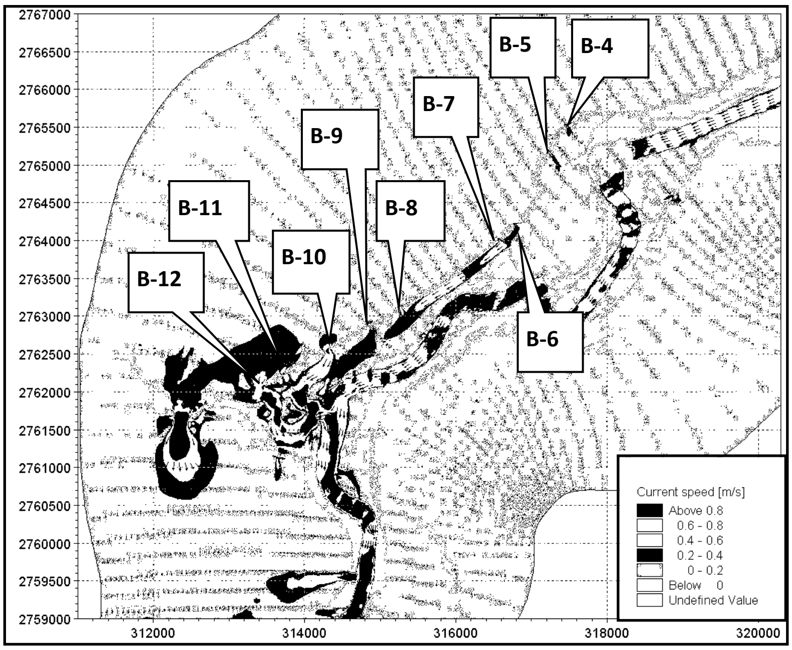



Figure 9: Velocity field for hydrological scenario two and initial arrangement of road structures

Based on the outcomes of the hydrological and hydraulic assessment of the initially considered arrangement of road structures, the number, location and dimension of the road structures have been changed for assessment, which is termed as first trial. In this way, four trials have been made to arrive at a decision as to appropriate number of road structures and their locations and dimensions. Analysis of model results shows that hydraulic performance of the road structures under fourth trial is satisfactory. The number and location of road structures under fourth trial are shown in Fig. 10.

The velocity field in the study area for hydrological scenario one and two is shown in Fig. 11. The discharge through each bridge has been determined from the model results and appropriate bridge length has been determined using Lacey's formula as shown in Equation (1).

$$W = 1.811C\sqrt{Q} \tag{1}$$

Where, W is effective width of waterway for the bridge (m), C is a co-efficient and Q is the design discharge ($m^3/s$).

Total length of road opening for finally decided ten bridges is 539m which is about 4.42% of the total length of the proposed road. It is found that one side of the road could be subjected to wave action at a number of locations. Therefore, wave runup has been calculated based on available wind speed record and information on average water depth, fetch length, angle of wave attack and slope of road embankment. Standard chart and formula have been used for wave runup computation. It is found that wave runup is 1.06m which is slightly higher than standard free board (1m). Therefore, formation level of the road has been computed by adding wave runup with design flood level.

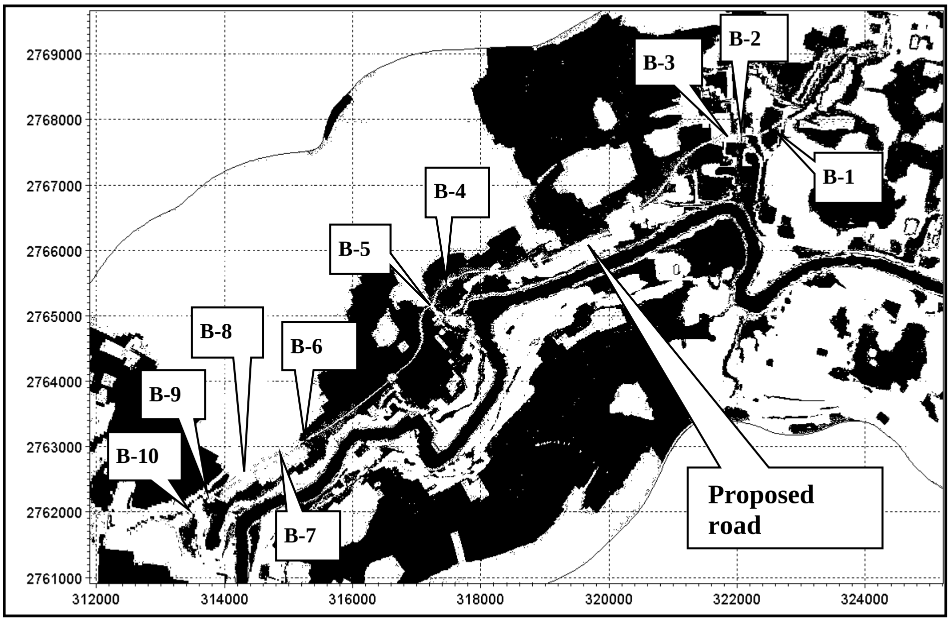



Figure 10: Final location of the road structures (bridges)

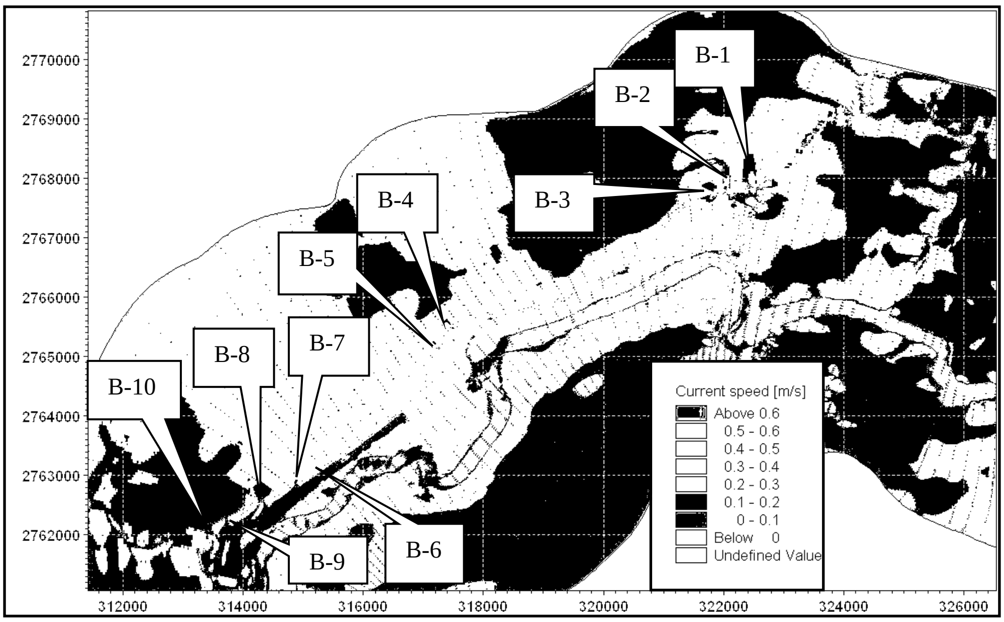



Figure 11: Velocity field for hydrological scenario one and final arrangement of road structures

Formation level of the road varies from 9.58mPWD at Golakpur end to 9.61mPWD at Sachna Bazar end. The expected minimum scour level at bridge piers and abutments for each bridge has been determined by using standard empirical formula and model generated hydraulic parameters. The hydrological and hydraulic design parameters of the bridges have been shown in Table 1. The chainages are from the starting point of the road at Sachna Bazar end (northeast end).

Table 1: Hydrologic and hydraulic design parameters of the road structures (bridges)

| Road Structure description | Chainage (km) | Length (m) | Design discharge (m3/s) | Design water level (mPWD) | Maximum velocity (m/s) | Pier Scour level (mPWD) | Abutment scour level (mPWD) |
|---|---|---|---|---|---|---|---|
| Bridge-1 | 0.305 | 50 | 103 | 8.55 | 0.76 | -2.59 | -3.86 |
| Bridge-2 | 0.725 | 50 | 88 | 8.55 | 0.56 | -3.57 | -3.26 |
| Bridge-3 | 0.911 | 50 | 85 | 8.55 | 0.40 | -4.50 | -0.92 |
| Bridge-4 | 6.092 | 31 | 26 | 8.54 | 0.63 | -2.09 | -2.70 |
| Bridge-5 | 6.586 | 37.5 | 56 | 8.54 | 0.60 | -4.25 | -6.51 |
| Bridge-6 | 9.554 | 28 | 33 | 8.54 | 0.76 | -3.20 | -3.87 |
| Bridge-7 | 10.01 | 43.5 | 82 | 8.53 | 0.78 | -4.95 | -6.15 |
| Bridge-8 | 10.65 | 93 | 245 | 8.53 | 0.97 | -6.45 | -7.50 |
| Bridge-9 | 11.30 | 81 | 191 | 8.53 | 1.20 | -6.78 | -7.11 |
| Bridge-10 | 11.722 | 75 | 168 | 8.53 | 0.88 | -6.38 | -1.16 |

It is found from the model result that during an extreme event water surface slope in the study area gets very mild. Maximum water level in the study area at and around the proposed Sachna-Golakpur road under hydrological scenario one has been shown in Fig. 12. It can be inferred from Fig. 12 that with proposed bridges in place afflux is negligible. It is also found from the model results that slope protection works along both sides of the road will be needed at some road stretches particularly where water depth is very high during the monsoon season.

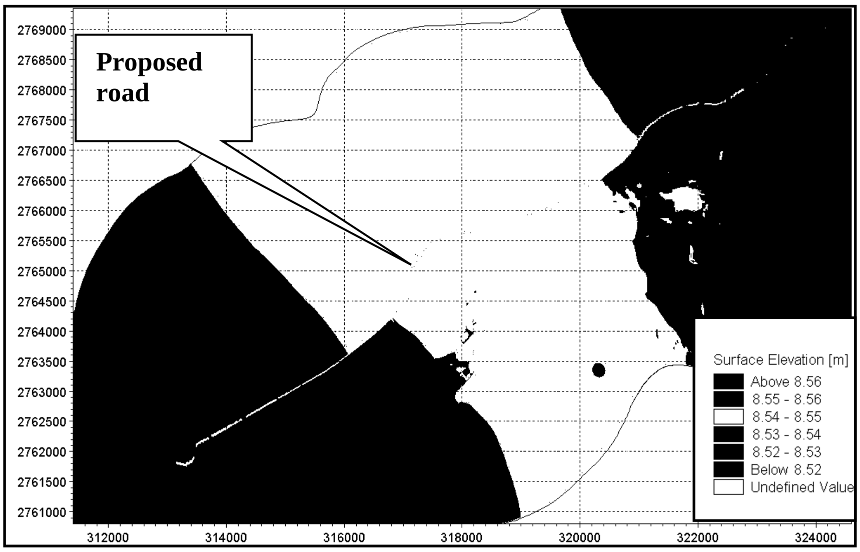



Figure 12: Design water level along the proposed road

The identified locations have been reported for taking necessary road embankment slope protection measures. It is revealed from the examination that all road approaches have to be protected from damage against parallel current by constructing slope protection works.

## 4. COCLUSIONS

The following key conclusions have been drawn from the study.

In order to establish the proposed Sachna-Golakpur road link in the low-lying haor area where hydrology is very much complex due to a number of factors, all relevant issues have to be taken into account. The Surma is the main river in the study area whereas the Baulai and the Rakti are important tributaries of the Surma. These rivers drain the haor area during recession period of the Surma river flood. The rivers are flashy in nature. 50 year return period discharge of the Surma and the Jadukata river is $3567m^3/s$ and $3184m^3/s$ at Sunamgonj town and Laurerghar respectively. On the other hand, 50 year return period water level of the Surma-Baulai system at Sukdevpur is 8.66mPWD.

The existing connectivity between the rivers and floodplain is very important for maintaining existing rich terrestrial and aquatic biodiversity in the haor region. Model results show that under hydrological scenario one Surma river water enters into the surrounding floodplain and flow occurs through the river as well as over the floodplain. During such an event, with a few exceptions flow velocity over the floodplain ranges from 0.1m/s to 0.2m/s. Flow velocity through the river also decreases in magnitude compared to that in bankfull discharge condition. Large inflow from the Meghalaya Hills during this time may cause an increase in the floodplain as well as river flow velocity to some extent. Model results under scenario two show that flash flood flow from the Meghalaya Hills will enter into the Surma river both through the Baulai and the Rakti rivers as well as over the floodplain. As a result, flow velocity at the outfall of these rivers will increase sharply. Flow velocity in the river downstream of the outfalls will also increase compared to that in the upstream of the same. Among three developed road alignment alternatives Option-1 is selected as preferred road alignment. The total length of the Sachna-Golakpur road link is about 12.2km. A number 10(ten) bridges on the proposed road link are needed to keep the existing hydrological regime undisturbed. The wave runup is 1.06m considering road embankment slope of 1:2. The design water level of the proposed road varies from 8.52mPWD to 8.55mPWD from Golakpur Bazar end to Sachna Bazar end respectively. Road embankment slope protection works will be needed at all road approaches and at some stretches of the road against parallel current and wave action.

## ACKNOWLEDGEMENTS

The authors like to pay gratitude to Road Division, Sunamganj, Roads and Highways Department, Bangladesh for providing financial support and data and information available with them for successful completion of the study.

## REFERENCES

River Research Institute. (2018). *Hydrological and Morphological Study Using Mathematical Model for the Proposed New Sachna-Golakpur Road under Sunamgonj Road Division*, Final Report, Faridpur.

DHI Water and Environment. (2006). MIKE21C, River Hydrodynamics and Morphology, User Guide.