ASSESSMENT OF THE IMPACTS OF PLANNING TRAFFIC BRIDGES SYSTEM ACROSS RED RIVER ON HA NOI REACH TO THE RIVER BANK EROSION AND RIVER BED CHANGES FOR PERIOD FROM 2020 TO 2030

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Abstracts: *The article presents some results of research and evaluation about the influence of planning traffic bridges system across Red River on Ha Noi reach to the river bank erosion and river bed changes for period from 2020 to 2030. On the basis of simulation results on hydraulic models, MIKE 21FM HD-ST two-dimensional morphology simulated for the Red River section from Son Tay to Hung Yen and Duong River to Thuong Cat. Bridge piers are simulated in the model using a combination of both meshing and pier simulations. The evaluation results include topographic changes in the cross-section, longitudinal section, changes in the riverbank, and deep creeks on the studied river section before and after the construction of the bridge.*
Keywords: *Red River, hydraulic model, MIKE 21FM HD-ST, traffic bridges, river bed evolution*

1. INTRODUCTION

River bed evolution is the change in shape, size on the ground, longitudinal section, cross-section of the river bed under the action of water flow, in natural conditions or under the influence of other factors, weak natural or man-made factors. The basic cause of river bed change is the imbalance of sand transportation. The evolution is maily affected by: influence on the historical process of river bed formation including the movement of the earth's crust; the influence of currents flow; the influence of climate and weather in which the influence of the flow is predominant; impacts on existing riverbed changes include: incoming water and its distribution mode; the amount of sand arriving and its mode of distribution; valley slopes; geology and human activity. Human activities including all activities of exploiting and using the river and the construction of bridges across the river, are one of the activities that affect the bed river's changes.

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The Red River is an important flood drainage route. The construction of works on rivers and riverbanks requires an assessment of the impact on flood drainage, changes in riverbed. Among the construction works on the river, the traffic bridge is the one that has been, is and is being built more and more. The section of the Red River through Hanoi currently has 6 traffic bridges built across the river. According to Hanoi's transport planning from now to 2030, on the river section, 8 more bridges will continue to be built. Therefore, it is necessary to consider and assess the overall impact of the existing and upcoming bridge works on riverbank erosion and river bed changes.

There are many methods to evaluate the influence of traffic bridge construction on hydraulic regime and erosion changes such as empirical method, mathematical model method, and physical model method [1],[2],[4],[4]. This paper presents the calculation results of the 2-D morphological hydraulic model MIKE 21 FM HD-ST to evaluate the impacts of the traffic bridge system construction on riverbank erosion and river bed evolution.

2. MODEL SETUP

2.1. MIKE 21 FM HD-ST model

MIKE 21 is a specialized technical software built and developed by the Danish Hydraulic Institute (DHI) [5], which is applied to simulate 2-dimensional fluctuations of water level and flow in rivers, lakes, estuaries, bays, coastal areas and in the sea. MIKE 21 software suite includes many component modules, suitable for different calculation purposes such as: MIKE 21 Flow Model; MIKE 21 Flow Model FM; MIKE 21 Spectral Wave FM, and so forth.

The MIKE 21 Flow Model FM model incorporates new modeling techniques using an unstructured mesh approach, which can accurately simulate contours and use flexible meshes. MIKE 21FM creates flexible meshes in computational area simulations. The use of a flexible mesh compared to using a rectangular grid has less number of grid points because the grid cell can be resized according to the topography of the calculation area. Better contour simulation and therefore better calculation results with higher accuracy. In the flexible mesh model, a longer time step can be used and the resolution of the flow path is further improved because the grid always follows the flow line. Finally, when running the flexible mesh model, because the number of points defined and stored is small, the storage capacity is limited. This is the strength of MIKE 21FM when studying river hydrodynamics. MIKE 21 Flow Model FM includes the following modules: Hydraulic Module (HD); Transport module (ST); Ecological Module (EL), Morphological Module (MT).

2.2. Model setting

- Documents and data used

The documents and input data using in the calculation include the topographic documents, hydrological data, sediment data and works on the river. The topographic documents include the map of the Red River - Duong River at the scale of 1/2000, 1/5000 in 2016, 2017, 2018, 2022. Most of the documents are from the topic KC08.10/16-20 survey in 2018 provided by the Key Laboratory [6]. The documents and hydrological data was used to establish boundary conditions. Observed water level and flow data was used to calibrate and validate the model. For the sediment data (Table 1), the mud and sand documents used in calculation include: actual suspended sediment flow measured at the stations; analysis of sediments along the river at the sections from SH1 to SH56 along the Red River and division 1 to 24 in the Duong River (shown in Figure 1 by the Key Laboratory in 2013). One of the important input data is documentation of works on the river include all embankment works, river correction works, existing traffic bridges, bridges planned to be built by 2030, residential areas and infrastructure on the riverbanks.

Table 1: Characteristics of sand particles in the study area

No.	Sample	>10 (mm)	10-7 (mm)	7-5 (mm)	5-3 (mm)	3-2 (mm)	2-1 (mm)	1-0.5 (mm)	0.5-0.25 (mm)	0.25-0.1 (mm)	0.1-0.063 (mm)	0.063-0.02 (mm)	0.02-0.006 (mm)	0.006-0.002 (mm)	<0.002 (mm)
1	SH1	0	0	0	0	0	0.82	7.77	38.8	51.55	1.02	0	0	0	0
2	SH10	0	0	0	0	0	2.08	13.85	84.1	0.00	0	0	0	0	0
3	SH20	0	0	0	0	0	0	0	11.9	83.49	4.65	0	0	0	0
4	SH30	0	0	0	0	2.69	1.88	5.56	36.9	51.65	1.34	0	0	0	0
5	SH40	0	0	0	0	0.00	3.34	1.17	5.16	33.84	56.49	0	0	0	0
6	SH56	0	0	0	0	0	0	0	8.24	90.76	0.99	0	0	0	0
7	SĐ 1	0	0	0	0	0	0	0	3.85	81.61	8.88	3.66	2.00	0	0
8	SĐ 24	0	0	0	0	0	0	0	0	75.70	15.29	5.29	2.89	0.82	0

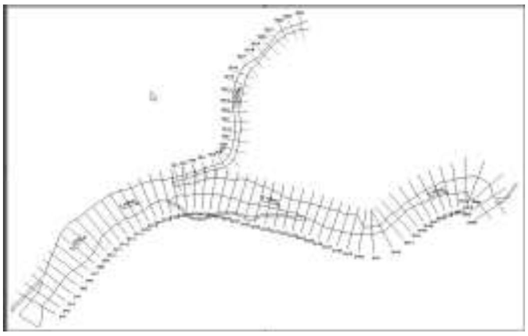


Figure 1: Location map of the sampling cross-sections for bottom sediment analysis

- Model setup

The two-dimensional model was built covering the section of Red River from Son Tay hydrological station to Hung Yen and Duong river to Thuong Cat hydrological station. The hard boundary of the model is controlled by the left and right dykes of the Red and Duong rivers. The total length of the river is about 108.38 km and the calculated area is 323 km^2. Figure 2 illustrates the establishment of grid. The calculation grid is divided on the basis of topographical characteristics of the study area, including main channel area, riverbank area, works on river. With the flexibility of the mesh in the MIKE 21 FM model, the project has divided the mesh into two parts: the main canal area and the riverside area. Traffic bridge works are simulated by 2 methods, including simulation of pier grid at the main channel area and simulation of piers at riverbank area.

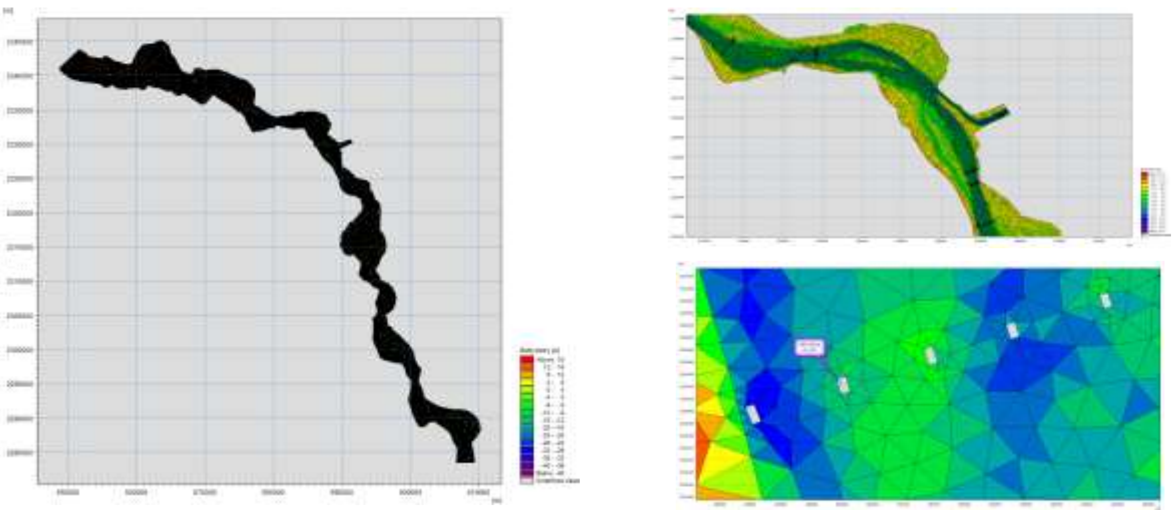
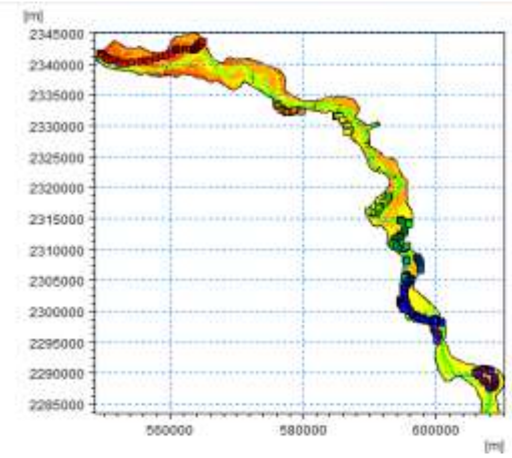
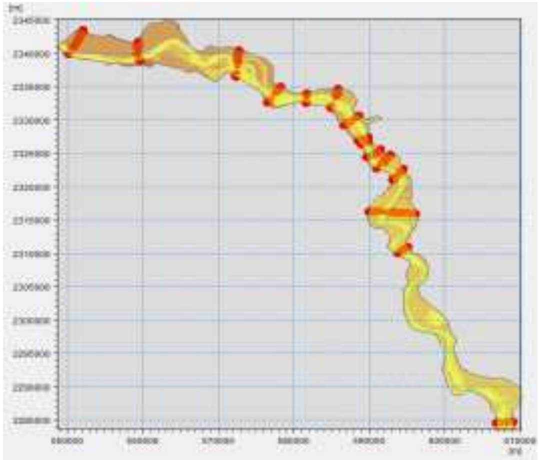


Figure 2: Grid and overall topography, details of the study area

Figure 3 shows the simulation of constructions on the river include the bridge over the river, the embankment of the welding mine, the dike and the road on the beach. After establishing the construction, the hydraulic parameters and morphology for the model are setup. The main hydraulic parameter is the Manning roughness coefficient for the river section. The roughness coefficient can be determined as 40-45 for the main channel and 32-35 on the riverbank. For the sediment parameters, observed suspended sediment data was measured at Son Tay, Thuong Cat and Hung Yen stations using empirical formulas pre-installed in the model. Bottom sediment simulated as simply non-cohesive sand with the same size over the entire model represented by the mean grain diameter d50. Through the analysis results of the grain composition as shown in Table 1, select the characteristics of bottom sediment grains on the river section from 0.15mm to 0.25mm (average d50 = 0.20mm).



Dike works and traffic on the beach



The system of traffic bridges across the river

Figure 3: Simulation of constructions on the river

2.3. Model calibration and validation

Calibration and validation of the hydraulic model were carried out simultaneously with the sediment transport model. The model is calibrated with the flood data of October 2017, the flood of July and August, 2018 and tested with the flood of August 1996. The results of calibration and verification with real data measured at the Hanoi station are similar in both flow and water level in terms of value and phase of oscillation (Figure 4-6).

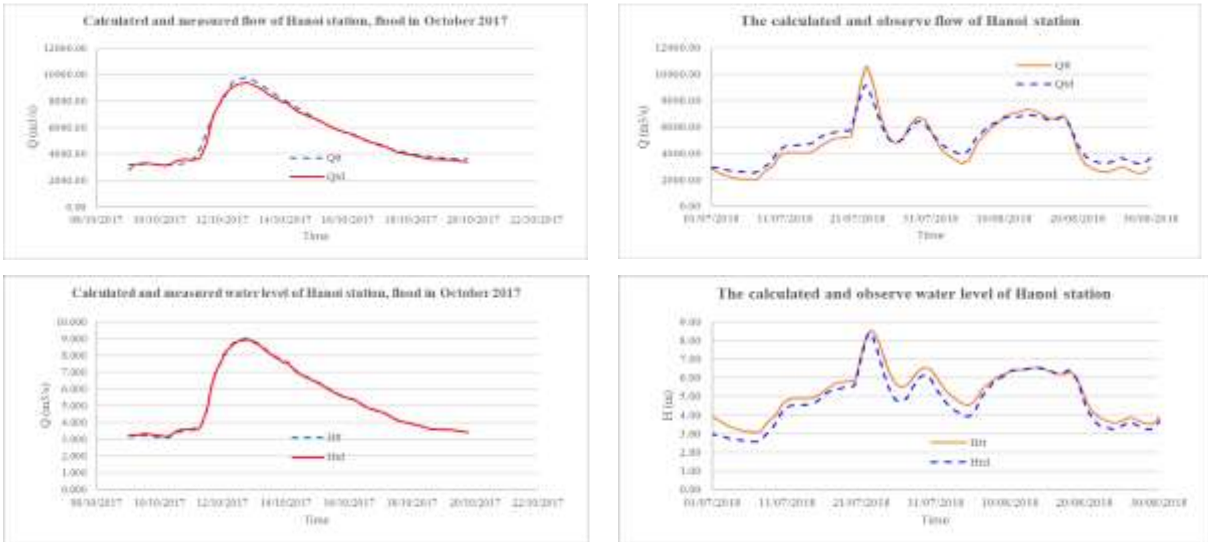


Figure 4: Results of model calibration with floods in October 2017, July and August 2018

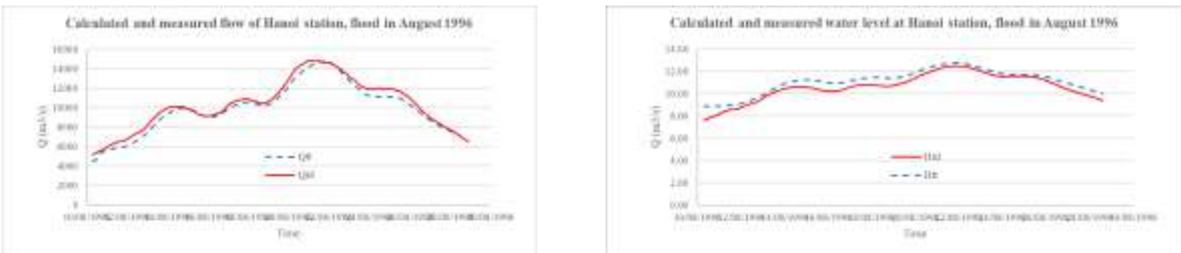
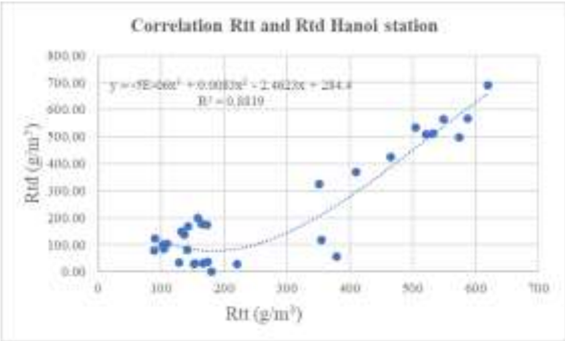
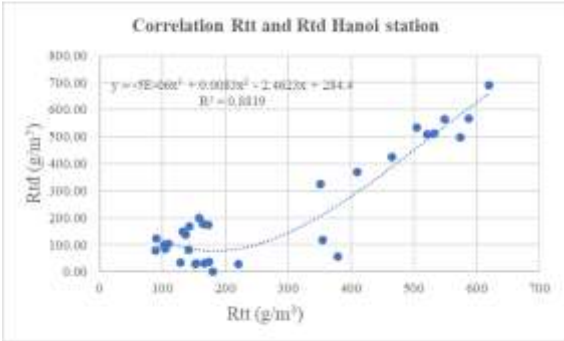


Figure 5: Results of model testing with floods in August 1996



Result of sand and mud calibration in October 2017



Results of sand and mud testing in July and October 2018

Figure 6: Results of calibration and verification of the sediment transport model

3. EVALUATION RESULTS

3.1. Scenario and calculation objective

The calculated flood scenario with the designed flood for the section through Hanoi in the period up to 2030 is according to the master plan on flood control and dike planning in the Red River and Thai Binh river basins. The center area of Hanoi city on the right bank of the Red River (within the ring road 4) ensures safety with the design flood with a 500-year return period (0.2% frequency) equivalent to the flood volume at Son Tay hydrological station is 28,000m^3/s with water level of 16.4m; flow and water level at Hanoi hydrological station is 20,000m^3/s and 13.4m respectively; flow and water level at Hung Yen hydrological station is 19,900m^3/s and 8.4m respectively. In this calculation, the plans for construction of traffic requirements include the location and design plan requirements taken from the general layout drawings according to the steps of Project Study and Feasibility Study of the Ministry of Transport. The current situation on the Red River under the study area has 8 bridges include Vinh Thinh Bridge, Thang Long Bridge, Nhat Tan Bridge, Long Bien Bridge, Chuong Duong Bridge, Vinh Tuy 1 Bridge, Thanh Tri Bridge and Yen Lenh Bridge. Until 2025, it is planned to build 02 more bridges including Vinh Tuy 2 and Tu Lien bridge. Up to 2030, 6 more bridges are planned including Van Phuc, Hong Ha, Thuong Cat, Tran Hung Dao, Ngoc Hoi and Me So bridge. Thus, by 2030 on the Red River within the scope of the study, there will be a total of 16 bridges. The calculation tasks follow this process. First step is the calculation of hydraulics and morphology in current conditions and planning to 2025, 2030. Then going with the assessment of changes in the riverbed of the Red River, including changes in the cross-section, longitudinal section of the river, changes in the shoreline, deep creek and in the whole river section due to the influence of the construction of traffic bridges.

3.2. Evaluation results

The evolution of conduction is assessed through the analysis and assessment of changes in conduction on cross sections, shoreline changes, deep creek changes and evaluate changes on the ground.

- *Cross-section variation*

On the bridge cross-section, fewer fluctuations occurred on the riverbank compared with the main channel. The river bank part, depending on the position of the bridge over the river section, the shape of the river section where the bridge is built, changes on the riverbank. Van Phuc bridge tends to accumulate on the left bank and erode on the right bank. For Hong Ha, Tran Hung Dao and Vinh Tuy 2 Bridge, the trend of accretion prevails on both the left and right banks (Figure 7). Erosion trend dominates both parts of the riverbank in Thuong Cat Bridge and Tu Lien Bridge. The river banks on both sides of Ngoc Hoi Bridge are quite stable. While in Me So Bridge, the trend of accretion on the riverbank on the left and erosion on the riverbank on the right. Due to the influence of the bridge pier construction, the trend of deep erosion of the main channel between the two bridge piers in all cross sections of the bridge. The depth of erosion depends on the distance between the bridge piers and the shape of the river cross section at the bridge pier area. The largest erosion trend is assessed at Tran Hung Dao bridge with the scouring depth of -3.66m (Table 2).

Table 2: Maximum level of erosion on bridge cross-sections

Serial	Location	When building a bridge	
		Maximum Erosion (m)	Maximum Compensation (m)
1	Van Phuc bridge	-2.11	2.37
2	Hong Ha bridge	-0.52	-0.52
3	Thuong Cat bridge	-1.50	1.88
4	Tu Lien bridge	-2.65	3.31
5	Tran Hung Đ ao bridge	-3.66	2.69
6	Vinh Tuy 1,2 bridge	-1.96	0.72
7	Ngoc Hoi bridge	-0.77	0.65
8	Me So bridge	-2.34	3.12

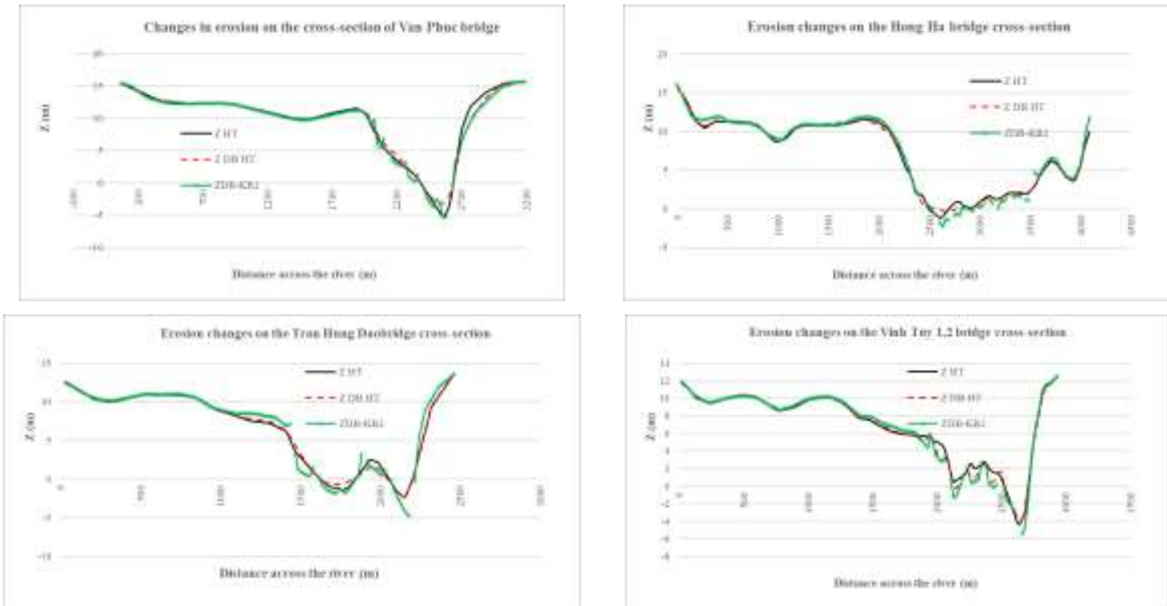


Figure 7: Erosion variation on bridge cross-section

- Changes in riverbank

Due to sediment transportation, the accretions happened in the right bank line. From downstream of Vinh Thinh bridge to Hong - Duong junction (Figure 8-9), the trend of accretion on the right bank will prevail on this river both in present and when building 2 more bridges by 2025 and 6 bridges by 2030. The degree of shoreline change is greatest in the downstream area of Van Phuc and Hong Ha bridges. The level of accretion has increased by more than 2m compared to the current situation. In the section from Hong Duong junction to Me So bridge downstream, the number of bridges is built with a higher density, so the variation in shoreline of this area is also higher than that in the upstream section of this area. From Long Bien bridge to

Vinh Tuy bridge 1,2 in the 4.5km long river section, 4 bridges have been built by 2030, so there is an influence between bridges on riverbank changes. For the trend of change in left bank line, the trend of accretion and erosion is alternating in the whole river section, but in general, the trend of erosion is more dominant than that of accretion. For bridge construction sites, the trend of left-bank change is also different. Erosion trend occurred for Hong Ha, Tran Hung Dao, Vinh Tuy 2, Ngoc Hoi and Me So Bridge while accretion trend happened to Van Phuc, Thuong Cat and Tu Lien Bridge.

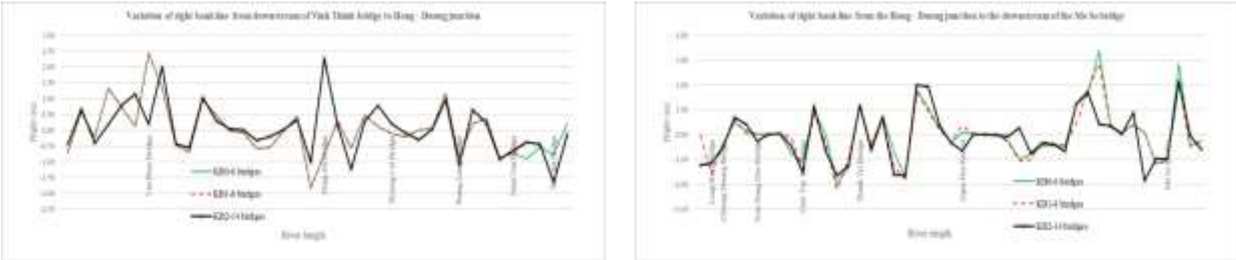


Figure 8: Changes of right bank under bridge construction scenarios

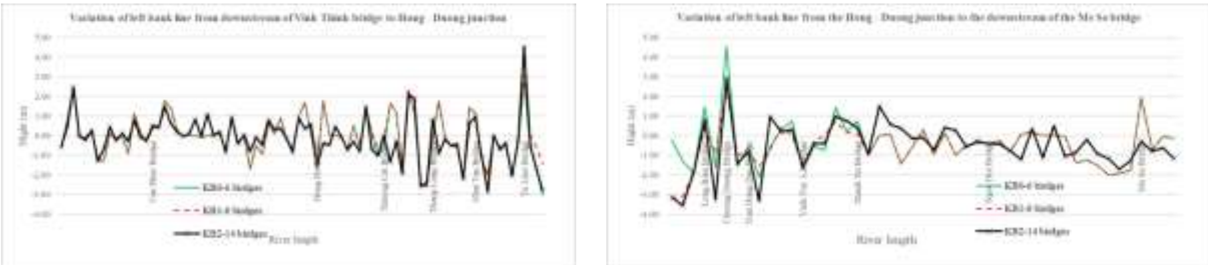


Figure 9: Changes of the left bank of the study area

- Deep creek variation

Considering the whole river section, the deep creek has an alternating accretion/erosion trend, the maximum level of deep creek accretion is +3.91m and the maximum erosion is -4.02m. At the bridge cross-sections, the erosion of the creek is deep compared to the current situation, the largest erosion is at the Tu Lien bridge, the deep creek part on the distributary branch to the Duong river with the erosion rate is -2.61m compared to the current situation (Figure 10).

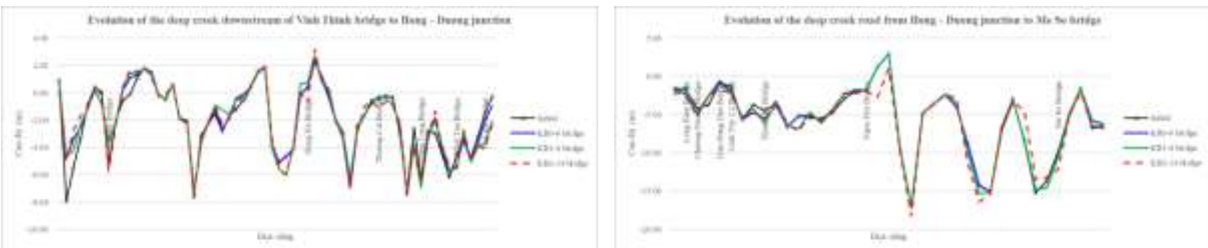


Figure 10: Evolution of deep creek with bridge construction scenarios

- Morphology variation

On the whole river section, the trend of accretion and erosion alternates on the beach and the main channel. The maximum level of accretion is about +5m, the largest erosion is about -4m. The degree of common sedimentation and erosion on the riverbank is from -0.2m ÷ +0.2m, with the main channel, the level of common erosion is from -2.2m ÷ +2.2m. The largest locality is in the area of the mouth of the Duong River (Figure 11-14).

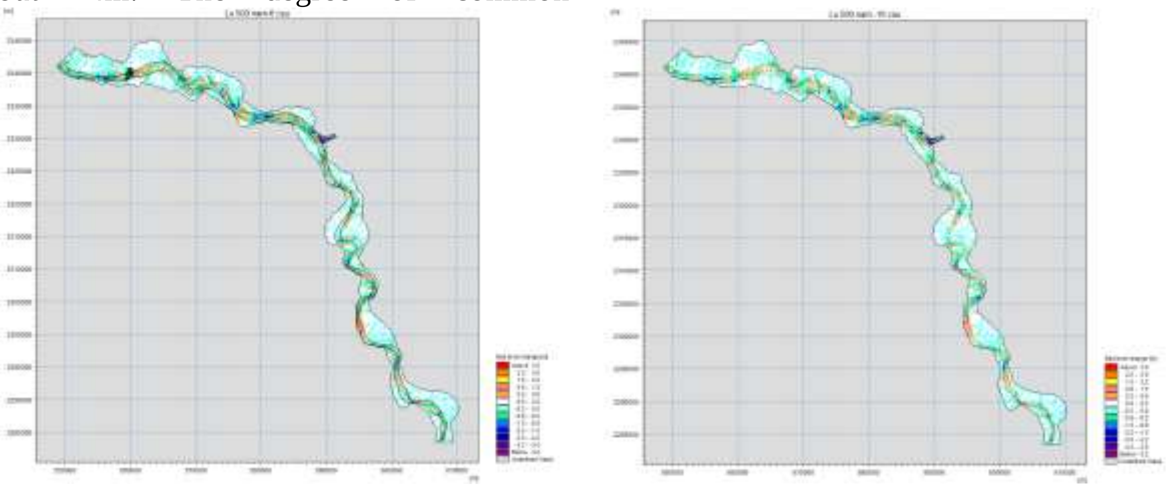


Figure 11: Erosion changes in the whole river section of the scenario 6 bridges and 14 bridges

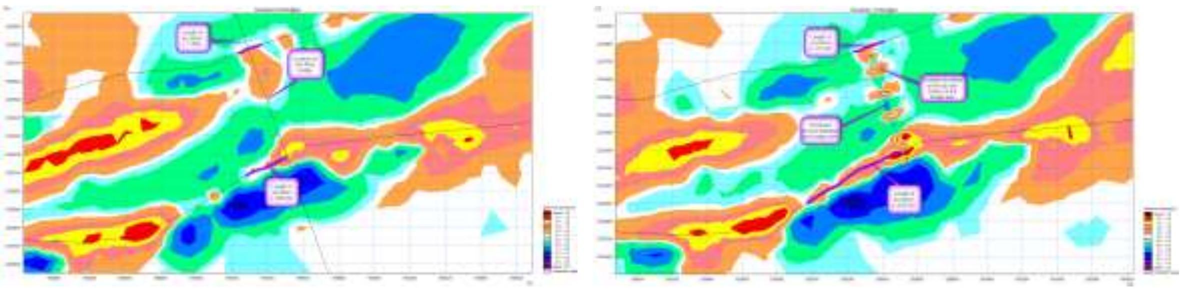


Figure 12: Changes in sedimentation/erosion in Thuong Cat bridge area in current condition and during bridge construction

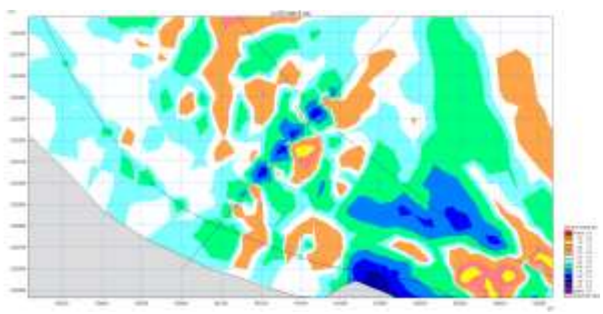


Figure 13: Changes in sedimentation/erosion in Vinh Tuy bridge area 1 current status

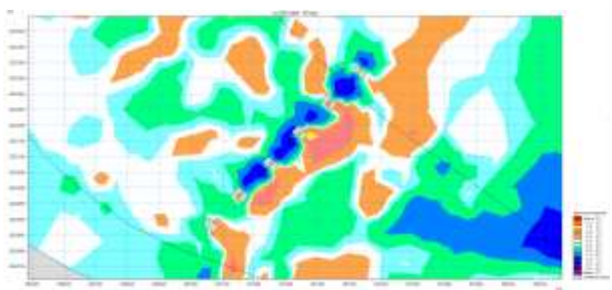


Figure 14: Changes in sedimentation/erosion in Vinh Tuy 1 bridge area when adding Vinh Tuy 2 bridge

4. DISCUSSION AND CONCLUSION

The paper presents the assessment of changes in the river bed on the Red River section passing through Hanoi in the current condition and when building traffic bridges across the river in the period up to 2025 (2 bridges including Vinh Tuy 2 and Tu Lien), by 2030 (6 bridges including Van Phuc, Hong Ha, Thuong Cat, Tran Hung Dao, Ngoc Hoi, Me So). The results show that the construction of traffic bridges across the river has had significant impacts on the river bed and riverbank changes in the bridge construction area, including changes in shoreline, deep creek and changes in accretion or erosion of river beds and banks of the construction area.

The calculation results are based on the use of collected topographic documents, mainly in 2018, so they cannot update all the topographic changes of the river bed in the present; The design parameters, the overall layout of the bridge project to be built are based on the project formulation and feasibility studies. So when the actual construction works, there will be adjustments to the documents used. In this study, the calculation uses commercial models, so that the methodology and coefficients in the hydrodynamic and sediment equations are not interfered or edited. Therefore, the calculation results will have elements that are not really suitable with the actual conditions of the study area. Accordingly, the results will need to be updated when there are more completed documents on topography, construction layout design and simulation calculation methods in the future.

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