MINISTRY OF EDUCATION AND TRAINING
MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT

VIETNAM ACADEMY FOR WATER RESOURCES

TO VINH CUONG

RESEARCH IMPACTS OF THE GROINS SYSTEM SPATIAL LAYOUT ON TIDAL RIVER

Effects of spur dikes spatial layout

Industry: **HYDRAULIC CONSTRUCTION ENGINEERING**

Code: **9 58 02 02**

SUMMARY OF THESIS DOCTOR OF TECHNICAL

HANOI - 2022

The work was completed at **the Vietnam Academy for Water Resources**

Scientific instructor 1: Assoc. Prof. Dr. Nguyen Thanh Hung

Science instructor 2: Prof. Dr. Vu Thanh Te

Examiner 1: Assoc.Prof. Dr. Tran Ngoc Anh - VNU University of Science

Examiner 2: Assoc.Prof. Dr. Nguyen Viet Thanh - University of Transport and Communications

Examiner 3: Assoc.Prof. Dr. Le Hai Trung – Thuyloi University

The thesis will be defended before the Institute's Thesis Jury Committee

Venue: Vietnam Academy for Water Resources (VAWR)

Time: ....day.......month.......year 2023

The thesis can be found at:

- National Library;
- Library of VAWR.

INTRODUCTION

1. NEEDS OF THE SUBJECT

The coastal estuary area is a flat land, densely populated, busy roads-waterways transport as well as an important gateway for foreign exchange. Therefore, the co rrection and exploitation of the estuary area are of great significance, which received increasing attention in scientific and technological activities.

In Vietnam, the groin system is commonly used in river correction works in areas not affected by tides. However, the application of the groin system is still quite modest, mainly due to lack of a theoretical basis, standards and technical guidelines for correction works, which haves the planning or design of groin works in tidal rivers faced many difficulties.

A typical example of the difficulty in the practical application of the groin system on the river in the tidal affected area can be mentioned in the project "Construction of correction works in Cam River". Although the scope of the project is not enormous, lack of scientific basis and experience in managing rivers and tidal influence made the investor (Ministry of Transport) decide to implement the construction in 3 steps over a long period of 6 years (1991-1996) in order to reach the goals. The example proves that applying groin works in practice are still having many difficulties in tidal rivers in our country.

Those reasons mentioned above explain why the PhD student choose the thesis topic**: "Research impacts of the groins system spatial layout on tidal river".**

2. OBJECTIVES OF THE THESIS

- Clarifying the flow structure and the change of the river bed when arranging the correction groin in the condition of the interaction of the reversible flow in the river segment of the tidal affected area.
- Proposing the spatial arranging of the correctional groin system suitable for the river segment in the tidal affected area, in order to limit sedimentation and increase the efficiency of deep erosion of the river bed in order to serve navigation.

3. SUBJECTS AND SCOPE OF THE STUDY

3.1. Research subjects

The research object of the thesis is the flow structure and changes in the river bed in the vicinity of correction groin system in the tidal river.

3.2. Research scope

- The thesis studies the influence of the correctional flux system in the tidal river, the diurnal tidal regime with a regular tidal shape, without mentioning the impact of the random tidal shape.
- The thesis does not consider the influence of waves but only refers to the tidal influence flow with the reverse direction.
- The researched groin system includes 05 groins, located in the river segment with straight bed inside the estuary. The groins have a solid structure, operating in a flowing state without flooding for the purpose of limiting sedimentation and increasing deep erosion of the channel.

4. APPROACH AND METHODS

The thesis has used the following research methods: literature review; mathematical modelling; consulting experts.

5. SCIENTIFIC AND PRACTICAL MEANINGS OF THE THESIS

5.1. Scientific significance

The scientific significance of the thesis is to make clear the structure of the flow near the groin system in the tidal river, thereby making scientific proposals on the suitable spatial arrangement of the groin system, increasing the correction efficiency of the groin system on the tidal river.

5.2. Practical significance

Actual exploitation of creeks is currently facing a lot of limitations in depth due to the alluvial phenomenon. Therefore, the selection of a solution to arrange the groin system in order to prevent sedimentation, maintain the depth of the channel, save on annual maintenance and dredging costs, be a highly feasible solution and in line with the current national conditions. The research results of the thesis can be referenced in the design of the groin system preventing sedimentation of the channel, serving navigation on river sections in tidal affected areas.

6. NEW CONTRIBUTIONS OF THE THESIS

(1) Describing in detail the flow structure (water surface, flow velocity, bed shear stress and turbulence intensity) and the mechanism of interaction between the flow and the single groin in the river segment in the tidal affected area with reverse flow.

(2) The thesis has proposed a solution for spatial arrangement of concave groin system with unequal length groins to create a deep erosion effect on the channel and maintain navigation.

7. STRUCTURE AND CONTENTS OF THE THESIS

Chapter 1: Overview of research on groin works.

Chapter 2: Scientific basis and research methods.

Chapter 3: Research results on hydraulic characteristics and efficiency of the groin system in the correction of the river segment in the tidal affected area.

Chapter 4: Applying research results to reality.

CHAPTER 1. OVERVIEW OF RESEARCH ON GROIN WORKS – ORIENTATION OF THESIS RESEARCH ISSUES

1.1 INTRODUCTION

1.1.1. The concept of river areas affected by tides

Tide river area is a section of river with an estuary to the sea that is strongly influenced by tides, and flows in and out in two directions in a cyclic manner. At high tide, the flow goes against the upstream of the river. At low tide, the current flows from the river to the sea.

1.1.2. Flow, river bed changes in tidal areas

The flow in the river in the tidal affected area belongs to the type of reversible flow, which is cyclical. The process of changing water level and flow rate is shown through 4 stages of tidal flow: (a) downstream flow at high tide; (b) backflow at high tide; (c) backflow at low tide; (d) downstream flow at low tide.

1.1.3. Classification of groin works

Groin works can be classified as follows: (a) According to permeability; (b) According to the degree of flooding; (c) At the angle of deviation from the flow direction; (d) According to the shape of the work.

1.1.4. Parameters of the spatial arrangement of groin system

The layout of the groin system is related to parameters such as: groin length, distance between, angle between groin and flow (Figure 1.4).

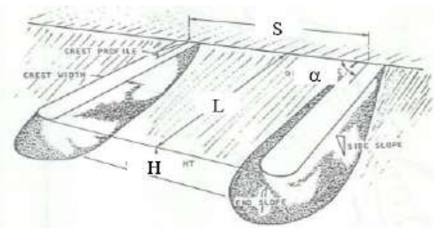


Figure 1.4: Schematic layout of the groin system.

1.2. OVERVIEW OF THE WORLD'S RESEARCH ON GROIN WORKS

1.2.1. Studies on river groin in tidal river with unidirectional flow

In the world, there have been many studies on the correction efficiency of the groin system. The recent trend has shifted to the goal of synthetic correction to promote the functions of this type of work. Author Zhang et al. have combined a pile groin and a solid groin in a solder joint. Further studies on the combined groin system of Mohammed Alauddin et al. in the laboratory to observe the hydrodynamic regime of the flow. As a result, the combined groin has a better effect of reducing the water flow, local erosion and causing accretion near the shore better than the traditional solid work. In general, research results in the world on groin system in unidirectional rivers have got remarkable achievements.

1.2.2. Studies on groin in tidal river with reversible flow

It can be said that previous studies in the world have mainly focused on the study of the groin system in rivers with the unidirectional flow, but there are still very limited studies on the system in the tidal affected area with reverse flow. Initial studies on the effect of reversible tidal currents are different from the unidirectional flow in the problem of local erosion of the tip of the single groin, but there are almost no studies on the reversible flow structure and scouring depth around the groin system.

1.3. OVERVIEW OF RESEARCH IN VIETNAM ON GROIN WORKS

1.3.1. Studies on river groin, unidirectional flow

The groin system was applied on Vietnamese rivers quite early, from the early 70s of the 20^{th} Century. The researches in this field included the works of Hoang Huu Van, Nguyen Ngoc Can, Luong Phuong Hau, Tran Xuan Thai, Le Manh Hung, Dinh Cong San, Nguyen Ngoc Quynh, Nguyen Van Phuc, Nguyen Ba Quy, Tran Van Sung, Nguyen Dang Giap, Nguyen Kien Quyet, Pham Thanh Nam, Nguyen Thanh Hung, etc.

The domestic research has achieved outstanding achievements, reflected in the in-depth research on groin works of the doctoral thesis namely Nguyen Dang Giap, Nguyen Kien Quyet, Pham Thanh Nam. However, all the studies were carried out on rivers with unidirectional current, equal groin length parameters without considering the other case. Moreover, all these pointed out the challenge direction of "***necessity to continue studying groin works on rivers in tidal affected areas"***.

1.3.2. Studies on groin in tidal rivers with reversible flow

Domestically, the research on groin works on rivers in tidal affected areas is similar to the trend of the world with the limited number of studies and modest results. Most of the research is through topics and projects associated with a specifically-designed conditions of a project area without generality. Up to now, there has not been a single in-depth study available solution to arrange the groin system to increase the efficiency of deep bed erosion for the tidal-affected river segment nationwide.

1.4. RESEARCH METHODS

At present, in-depth studies on correction works often use two basic methods, which are:

- Experimental method on physical models;
- Numerical simulation method (mathematical models).

1.4.1. Research method on physical model

1.4.1.1. Experiment in the flow conduit

Experiments on flow conduit s which are so far commonly used are mainly used for in-depth, theoretical problem studies, thereby giving the formula as well as discovering the flow states etc.

1.4.1.2. Overall model testing

Experiments on the master model are mainly used for applied studies, often conducted on models of an actual river section, with specific river conditions that need to be corrected.

1.4.2. Research methods on mathematical models

The current 3D mathematical models have been developed relatively fully, allowing detailed study of dynamic fields, adjustment and flexible change of plans for the optimal selection of design options. The results are presented diversely and effectively.

1.5. EXISTING ISSUES AND RESEARCH ORIENTATIONS

From the results of the research analysis, it was found that the research results on groin works in the world and in Vietnam mainly focus on research on the arrangement of groin systems in rivers with unidirectional flow, but no studies on spatial arrangement of groin systems in reversible flow. Therefore, it is necessary to study the impact of the spatial arrangement of the groin system in the flow and riverbed of the tidal affected area. Within the time range and conditions of a PhD thesis, the author delves into the following issues so as to:

- Clarify the theoretical basis of flow structure around the groin in the tidal river.
- Propose and select a solution for spatial arrangement of the groin system (with unequal groin length) that has the effect of deep erosion of the channel, maintains navigation in the tidal river.

1.6. CONCLUSION CHAPTER I

Studies worldwide about the impact of the spatial arrangement on the groin system on the flow structure and the depth of the channel erosion has a long history and many achievements. The studies on the spatial arrangement of the groin system have fully identified the layout parameters that have a fundamental influence on the flow structure and the scouring efficiency of the channel (length and distance between groins). However, the studies on spatial arrangement of the groin system are mostly done in conditions of unidirectional flow in the river, with very limited studies on in the reversible flow condition in the tidal river.

Domestic studies about impact the spatial arrangement on the groin system to the flow structure and the depth of the channel erosion is similar to the world trend, achieving great achievements on the river, and also lack of results on tidal river. Most of the research is through topics and projects associated with a specifically-designed conditions without generality.

Thus, the overview analysis in Chapter 1 shows that, at present, in the world and in Vietnam, studies mainly focus on the arrangement of the groin system in the river with unidirectional flow, lack of study available to determine the parameters of the arrangement of the groin system in the tidal river with reversible flow. Therefore, it is necessary to study the spatial arrangement of the groin system with unequal groin length. Because of the complexity of the research problem, this thesis limits the scope of the study to only the river segment in the tidal area of the Northern region, where there are critical alluvium-affecting sites. Regards to the flow mode and the structure of the groin, this study is aimed at flow state without flooding, impermeable structure solid groin.

CHAPTER 2. SCIENTIFIC BASIS AND METHODS

2.1. SCIENTIFIC ASSESSMENT ON EFFICIENT CORRECTION OF THE TIDAL RIVER

2.1.1. Tide transmission equation

In the research of the thesis will be interested in the tidal transmission equation (2-10) used as the basis to describe the change of water level and tidal velocity over time.

$$\eta = \hat{\eta}\, cos\, cos\, \left(\omega\left(t - \frac{x}{c}\right)\right) = \hat{\eta} cos(\omega t - kx) \qquad (2\text{-}10)$$

2.1.2. The start of the sedimentation - starting speed

To determine the starting of the sediment, two concepts are used: the starting bottom shear stress and the starting velocity.

2.1.3. Effect of sediment diameter on scour depth.

Previous studies by Gill, Ettima, Wong, Escarameia all confirmed that the influence of the uniform sediment diameter parameter d_{50} is not significant on the results of scour depth studies for both unidirectional and tidal currents are reversible. Especially in Escarameia's research, they selected the coarse-grained homogeneous sedimentation diameter (d_{50} =0.75mm) using the study of scour depth around structures on tidal-affected rivers with reversible flow. This conclusion is the scientific basis for the thesis to use for reference coarse-grained homogenized sedimentation to study and determine the depth of erosion around structures on rivers in tidal affected areas.

2.1.4. Physical processes affecting efficiency of correction groin

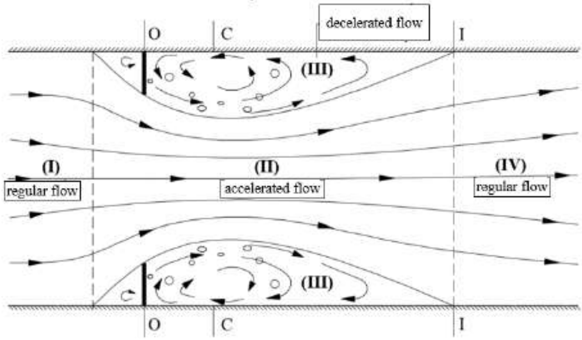


Figure 2. 6: Flow zoning.

Under the effect of the groin construction, the flow state and the erosion process around the groin work are all 3D problems, prominent as describe in Figure 2.6, in which accelerated/decelerated flow is the cause for turbulent currents, vertical eddy currents (also known as vortex zone).

The speed regulation factor Kv is defined as following:

$$K_v = \frac{u_{cu}}{u_{cs}} = \frac{1+3r_{cs}}{1+3r_{cu}} \quad (2\text{-}17)$$

It can be summed up that the scouring efficiency of the groin system evaluated through relation to layout parameters, such as: the groin's length, the distance between the groin and the interaction properties between the deceleration current of the vortex zone and the accelerating current of the mainstream area. Due to the interaction between the vortex zone and the mainstream, the impact will be strong when the large body water area narrows the width of the mainstream, increasing the flow velocity, leading to deep erosion of the channel. Therefore, it can be assumed that the vortex zone is an important dominant physical process when considering the increasing of efficient scouring in the river bed of the groin system.

2.2. MATHEMATICAL MODELLING METHODS

The thesis selects a model of the RANS family (digital conduit created by Flow 3D) which is capable of simulating well the physical processes of accelerated and decelerated flow in the vicinity of the groin work, of which the highlights are flow has 3D structure (turbulent flow, vertical eddy current) and has the same features as conduit on the physical model.

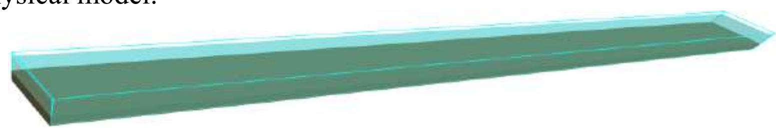


Figure 2.7: Digital Conduit - set up with Flow-3D

(1)Hydrodynamic model

Flow3D uses the Navier-Stoke equation as the dominant equations.

$$V_F \frac{\partial p}{\partial t} + \frac{\partial}{\partial x}(\rho u A_x) + R\frac{\partial}{\partial y}(\rho v A_y) + \frac{\partial}{\partial z}(\rho w A_z) = \quad (2\text{-}18)$$

$$\frac{\partial u}{\partial t} + \frac{1}{V_F}(\frac{\partial u}{\partial x} + vR\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}) - \xi\frac{v^2}{xV_F} = -\frac{1}{\rho}\frac{\partial \rho}{\partial x} + G_x + f_x \quad (2\text{-}19)$$

$$\frac{\partial v}{\partial t} + \frac{1}{V_F}\left(\frac{\partial v}{\partial x} + vR\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}\right) - \xi\frac{u\,v}{xV_F} = -\frac{R}{\rho}\frac{\partial \rho}{\partial y} + G_y + f_y \quad (2\text{-}20)$$

$$\frac{\partial w}{\partial t}+\frac{1}{V_F}\left(\frac{\partial w}{\partial x}+vR\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)=-\frac{1}{\rho}\frac{\partial \rho}{\partial z}+G_z+f_z \quad (2\text{-}21)$$

(2)Sediment transport model

Suspended and bottom sediment are calculated independently in the sediment calculation. Suspended sediment transport is determined according to the convective diffusion equation.

$$\frac{\partial c}{\partial t}+U_i\frac{\partial c}{\partial x_i}+W\frac{\partial c}{\partial z}=\frac{\partial}{\partial x_i}(\Gamma\frac{\partial c}{\partial x_i}) \quad (2\text{-}22)$$

To calculate the suspended sediment and bottom motion, the model uses 03 formulas: Van Rijn, Nielsen and Meyer-Peter & Muller.

$$\Phi_i=\beta_{VR,i}d_{*,i}^{-0.3}\left(\frac{\theta_i}{\theta_{cr,i}{}'}-1\right)^{2.1}c_{b,i} \quad (2\text{-}23)$$

$$\Phi_i=\beta_i\left(\theta_i-\theta_{cr,i}{}'\right)^{1.5}c_{b,i} \quad (2\text{-}24)$$

$$\Phi_i=\beta_{Nie,i}\theta_i^{0.5}\left(\theta_i-\theta_{cr,i}{}'\right)c_{b,i} \quad (2\text{-}25)$$

$$q_{b,i}=\Phi_i\left[\|g\|\left(\frac{\rho_i-\rho_f}{\rho_f}\right)d_i^3\right]^{1/2} \quad (2\text{-}26)$$

2.3. SETTING RESEARCH QUESTION

The thesis establishes a digital conduit using Flow 3D to realize the research objective of the flow structure and the effect of deep scouring between the spatial layout options of the groin system. The digital conduit is calibrated and verified with experimental measurements by Karami et al.

2.3.1. Experimental study on physical models of Karami et al.

The objective of the experiment Karami et al. is to study the flow structure and scour depth around the area of the groin system. The experiment was carried out on a rectangular flow chute, with 03 solid groins with a length of 0.25m and a distance of 0.5m (S=2L). Flow depth is 0.15m; uniform sediment diameter d_{50} = 0.91mm, weight S= 2.65.

Table 2-1: Results of the Karami experiment

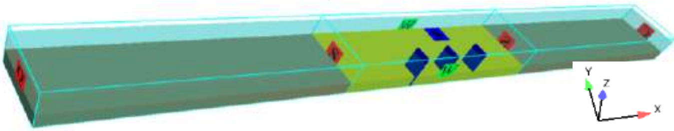
TT	Q (m^3/s)	Y (m)	U_{tb} (m/s)	U_{cr} (m/s)	U/U_{cr}	d_{s1} (m)	d_{s2} (m)	d_{s3} (m)
Q_1	0.035	0.150	0.233	0.358	0.650	0.156	0.000	0.026
Q_2	0.046	0.150	0.307	0.358	0.850	0.225	0.029	0.072

2.3.2. Build, calibrate, test 3D Flow model with experimental data of physical model of Karami et al.

(1) Building a mathematical model of FLOW 3D

Thesis builds a digital conduit on the MHT using Flow-3D software with the same setup as in MHVL through the hydraulic flow of Karami, Basser, Ardeshir and Hosseini (see Figure 2.10) .

a) Physical model

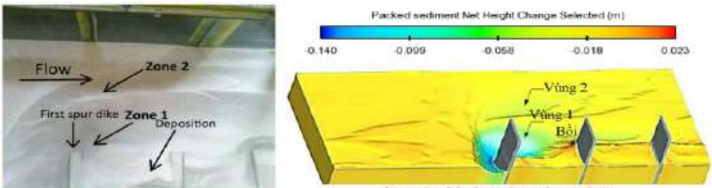


b) Mathematical model

Figure 2.10: Physical model and mathematical model.

(1) Calibrate model:

Calibrate the model with flow rate Q_1=0.035m^3/s .



a) Mô hình vật lý

b) Mô hình toán Flow-3D

- *Compare flow rates:*

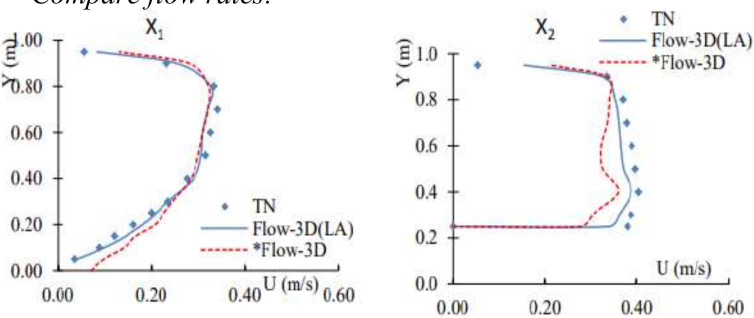


Figure 2.15: Bottom velocity at cross-sections X_1, X_2 (Q_1=0.035m^3 /s)

- *Comparison of eroding depth:*

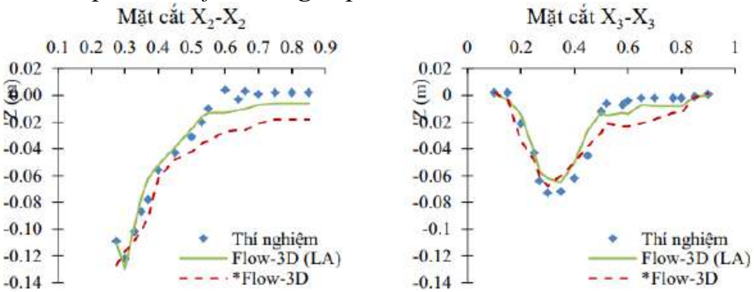


Figure 2.18: Fluctuation of conduction between experimental results ($Q_1 = 0.035m^3/s$) with Flow-3D (LA) of thesis and *Flow-3D of Hanif

(2) Model testing:

Test with flow rate $Q_2 = 0.046m^3/s$ (Table 2-1) of Krami et al.

Remarks, the 3D Flow model shows a fairly reliable prediction of the erosion depth around the groin system compared to the experimental data of Krami, with regression $R^2 = 0.891$, absolute error mean MAE is only 0.002, standard deviation RMSE is 0.022. Thus, the digital conduit set up by Flow 3D ensures the reliability used in the thesis question.

2.3.3. Set up simulation problems on digital flow conduit s

Based on the tidal transmission equation, the thesis chooses velocity and tidal level (ideal conditions) sine transform with time, the generality is expressed as following:

$$u = U_{max} \sin \sin\left(2\pi t/T\right) \quad (2\text{-}30)$$

$$H = H_0 + \frac{A}{2}\sin(2\pi t/T + \pi/2) \quad (2\text{-}31)$$

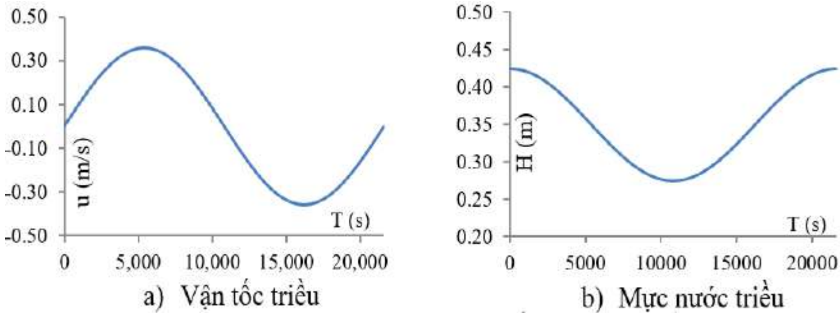


Figure 2.21: The researched tidal shape.

2.3.3.1. Setting up the problem on the number of hard-bore flow conduits

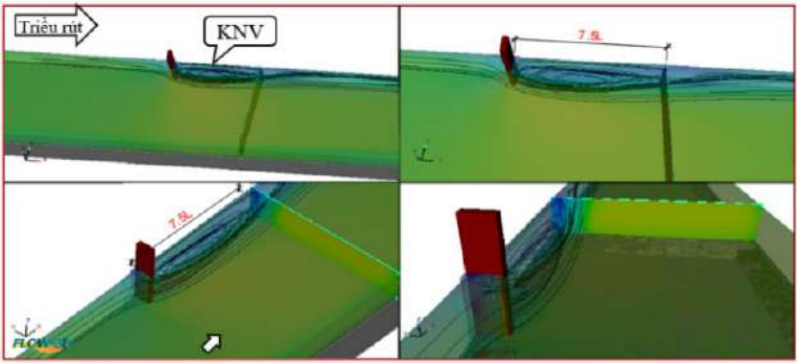


Figure 2.22: 3D flow structure around single groin.

- Case study with a single groin: to analyze the flow structure, velocity distribution and interaction mechanism between the flow and the single groin structure, thereby serving as a basis for proposing layout parameters The space of the groin groin system is suitable for the correction goal.

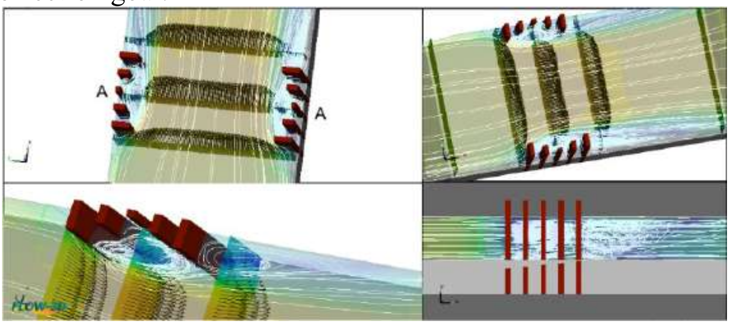


Figure 2.23: 3D flow structure around the groin system.

- Research on the groin system of unequal length: to analyze the flow structure and the mechanism of vortex zone formation covering the entire groin system and prove the superiority of the whole vortex zone comapred to local one, between the two groins through in-depth analysis of the influence of the layout parameters (angle direction, unequal groin length, distance between goins).

2.3.3.2. Set up the question on the dynamic flow

The dynamic digital conduit *(with set scour bottom material at the bed)* is used to study the effectiveness of increasing the depth of scour between the different layout options of the groin system.

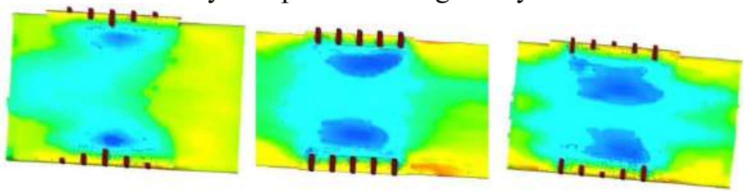


Figure 2.29: Variation of beds according to the layout options.

As we can see, the thesis has established a rigid (fixed) digital conduit to implement the goal of studying flow structure and a dynamic (deformed) digital conduit in order to study the depth of scouring of the conduit for spatial arrangement solution of the groin system under the influence of tidal river with reversible flow.

2.4. CONCLUSION CHAPTER 2

1) Scientific basis: the thesis details the tidal transmission equation and physical processes affecting the correction efficiency of the groin work. The starting conditions of sediment is determined according to the Shields graph and calculated according to the Hanco formula. From the results of previous studies with unidirectional flow and reversible flow conditions, it is shown that the influence of the parameter d_{50} on the scour depth is insignificant.

2) Regarding the research method: the thesis has studied the basic physical processes affecting the correction efficiency of the groin system. Thereby, RANS digital conduit using the Flow-3D calibrated model is chosen and tested with the experimental data of the physical model by Karami. The rigid digital conduit is used to simulate the flow structure and the dynamic cavity digital conduit is used to simulate the conduit erosion according to the spatial arrangement solutions of the groin system.

CHAPTER 3. RESEARCH RESULTS ON HYDRAULIC CHARACTERISTICS AND EFFECTIVENESS OF THE GROIN SYSTEM IN TIDAL RIVER SEGMENT

3.1. RESEARCH OF HYDRAULIC CHARACTERISTICS OF THE GROIN IN THE TIDAL RIVER SEGMENT

This thesis has referenced the existing research results, conducted a study of the hydraulic characteristics around a groin (single) under the effect of reversible flow.

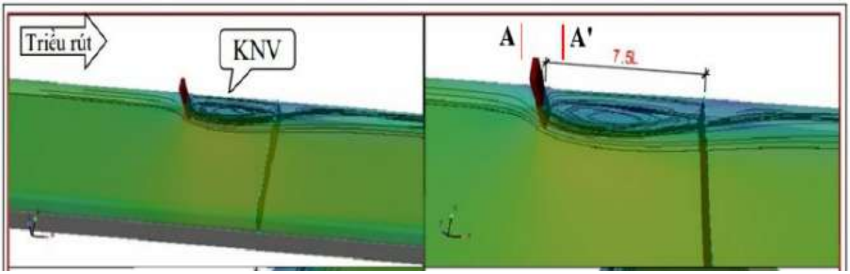


Figure 3.4: 3D flow structure of the vortex zone created by a single groin (tide receding).

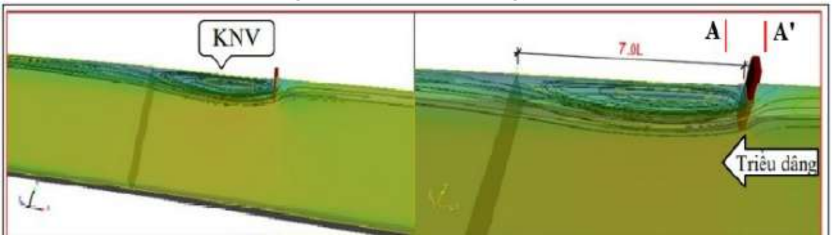
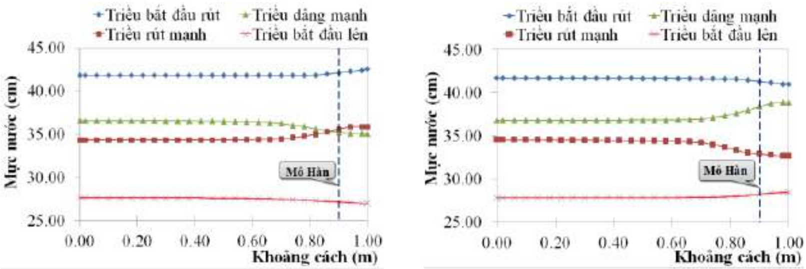


Figure 3.6: 3D flow structure of the vortex zone created by a single groin (tide ascending).



a) Section A-A b) Section A-A'

Figure 3.7: Horizontal hydraulic gradient at Sections AA and A'-A'

Comment on hydraulic characteristics of the single groin area:

Thus, the research results have described in detail the flow structure, the interaction mechanism between the flow and the single shoring works in the tidal section of the river with reversible flow.

3.2. RESEARCH IMPACTS OF SPATIAL ARRAGEMENT OF GROIN SYSTEM ON FLOW STRUCTURE

3.2.1. Case studies

Case studies: arranged on 1 bank (1B) and both sides (2B)

The plans for spatial arrangement of the groin system are as following: (1) Arrangement in the direction of the groin angle; (2) Arrangement of unequal groin length; (3) Proportional arrangement to narrow the flow width.

3.2.2. Studying the impact of groin angle direction on bed erosion

As shown in the diagrams Figures 3.16 and 3.18, the average depth in the conduit increases in the angular direction from (0^0~90^0) but decreases as the angular direction continues to increase from (90^0 ~135^0), it means that the direction Angle of 90^0 produces the largest average scour depth corresponding to the value of 6.96cm.

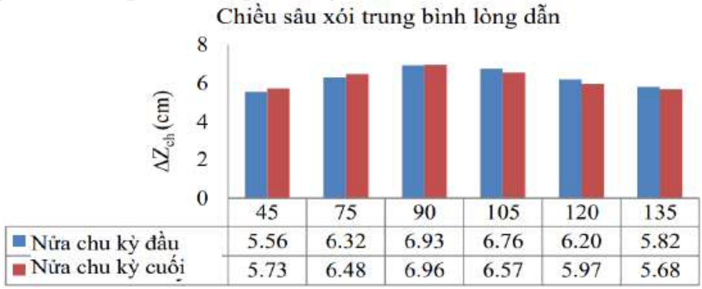


Figure 3.16: Average depth of scour in the guide bed in angular directions

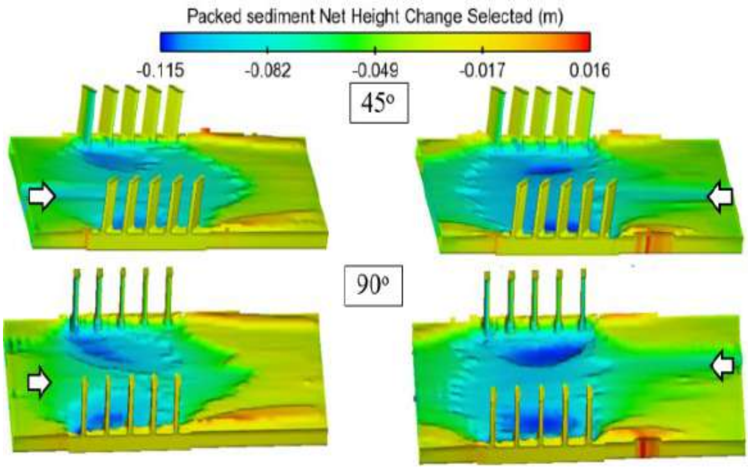


Figure 3.18: Variation of the conduits in the area where the groin system is located

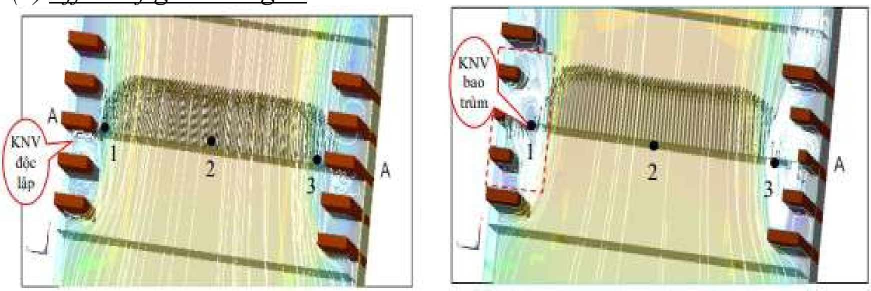
Thus, with layout plan 90^0 angle direction (A90) has increased the efficiency of deep channel erosion which is beneficial for river management for navigation. In the following, the thesis continues to study the spatial arrangement of the groin system according to the unequal groin length and fix the angle of 90^0.

3.2.3. Research on solutions to arrange groin system with unequal groin length to flow structure and channel erosion.

The thesis focuses on research in three ways to arrange the groin system convex groin system (LOI), straight groin system (THA) and concave groin system (LOM) to examine the impact of the layout parameters. position (unequal groin length, distance between groins).

3.2.3.1. Simulation results of flow structure

(1) *<u>Effect of groin length.</u>*

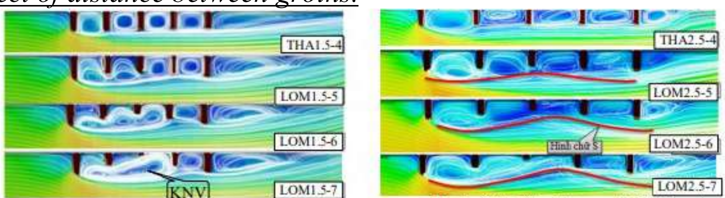


a) THA system b) LOM system

Figure 3.19: Structure of vortex zone among groin systems.

From Figure 3.19, it can be observed that the unequal groin length arrangement parameter of the LOM system has created a structure that covers the vortex zone, increases the flow velocity, and has an important influence to the effect of eroding the depth of the conduit.

(2) *<u>Effect of distance between groins.</u>*



c) S=1.5L (L=10cm và S=15cm) d) S=2.5L (L=10cm và S=25cm)

Figure 3. 22: The vortex zone created by the LOM system

From Figure 3.22 presents the distance parameter between S groins, when arranged close to each other, creates a large vortex zone structure. This confirms that there is a clear difference in the fully developed large vortex zone when the distance is close (S ≤ 2.0L) compared to the small one that is not fully developed when the distance is far from each other (S ≥ 2.5L). Thus, the distance parameter S, which affects the structure of the vortex zone, changes the velocity of the mainstream and affects the scouring efficiency of the channel bed.

(3) <u>The relationship between the width of the</u> vortex zone *<u>and the width of the mainstream.</u>*

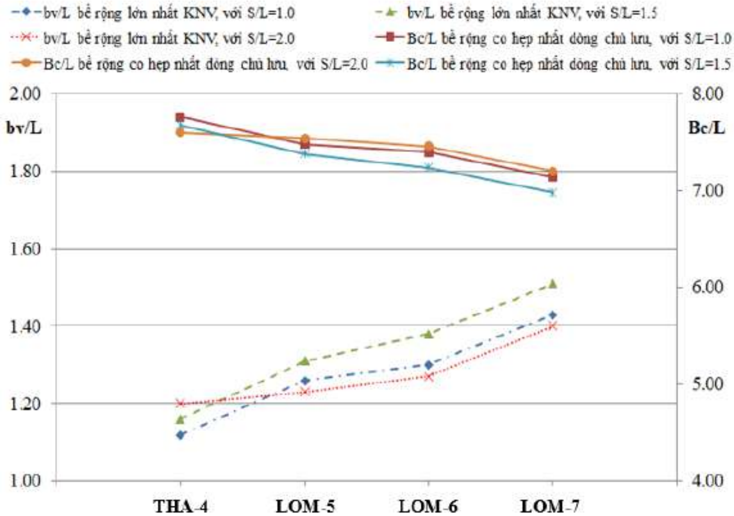


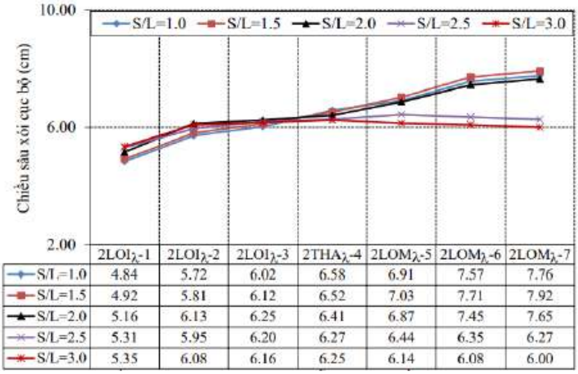
Figure 3.24: Relationship between the width of the vortex zone and the width of the mainstream of the LOM system.

From Figure 3.24 the relationship between vortex zone width and relative mainstream width (bv/L~Bc/L) is inversely proportional to each other, reflecting an increase in vortex zone width that narrows the mainstream width and vice versa.

3.2.3.2. Simulation results of fluctuating lumens

Compared with the arrangement of the straight groin system, the layout of the convex groin system and the concave groin system has a difference in the fluctuation of the conduit.

It could be remarked as the value of the average scour depth of the conduit decreases with the arrangement of the convex groin system, but increases with the concave groin system when the distance between the groins is S≤ 2.0L and maximum in case S=1.5L (LOM1.5-7).



	2LOIλ-1	2LOIλ-2	2LOIλ-3	2THAλ-4	2LOMλ-5	2LOMλ-6	2LOMλ-7
S/L=1.0	4.84	5.72	6.02	6.58	6.91	7.57	7.76
S/L=1.5	4.92	5.81	6.12	6.52	7.03	7.71	7.92
S/L=2.0	5.16	6.13	6.25	6.41	6.87	7.45	7.65
S/L=2.5	5.31	5.95	6.20	6.27	6.44	6.35	6.27
S/L=3.0	5.35	6.08	6.16	6.25	6.14	6.08	6.00

Figure 3.29: Average depth of erosion in the channel, arranged on both sides (2B)

3.2.4. Study on the effect of narrowing the river width with groin

Table 3-10: Comparison of average depth of scour channel

Erosion depth	LOM system	L/B flow narrowing (%)			
		15%	20%	25%	30%
Conduit erosion (medium)	**2LOM1.0-7**	6.58	7.76	**8.87**	**9.95**
	2LOM1.5-7	**6.71**	**7.92**	8.45	9.63
	2LOM2.0-7	6.51	7.65	8.14	9.12

According to the data in Table 3-10, with L/B ≤20%, the layout option S=1.5L (2LOM1.5-7) gives better results in depth of scouring channel. But when the L/B is increased by ≥25%, there is a shift to a closer arrangement of the groin S=1.0L (2LOM1.0-7) for better scouring depth.

3.2.5. Study to calculate the impact of the groin system on deep erosion of the channel

3.2.5.1. Criteria of eroding efficiency

The erosion effect of each construction solution is evaluated by the coefficient $\Psi_{\%L}$ which is the depth adjustment after the arrangement of the groin system. $\Psi_{\%L} = \Delta h_2 / \Delta h_1$. (3- 1)

The coefficient of variation of the groin length K_λ:

$$K_{\lfloor} = \frac{L_{đ}}{Lg} \qquad (3\text{- }2)$$

3.2.5.2. The effect of causing deep erosion in the conduit system by the groin system

Overall relationship (Ψ%L ~K λ) tends to be non-linear, covariate with the close distance to each other (S/L≤ 2.0) and the trend is nonlinear, inverse with the case of the far distance from each other (S /L ≥ 2.5). The negative relationship is most obvious when the long ($\frac{L_đ}{Lg}$≥1.33).

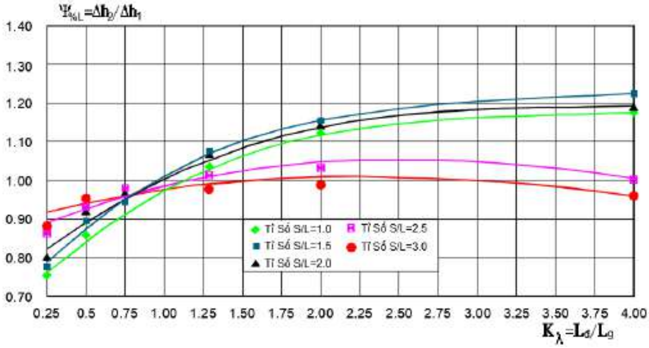


Figure 3.35: Determining the calculation depth adjustment coefficient ($\Psi_{\%L} \sim K_{\lambda}$) with different layout plans of groin system.

3.3. CONCLUSION CHAPTER 3

(1) Research results of single groin:

Thesis has described in detail the flow structure, the interaction mechanism between the flow and the single groin works in the tidal section with reversible flow. This is shown by the following results:

- Flow field: In the case of low tide, downstream of the groin, the flow velocity decreases, forming a large vortex zone with a length of 7.5L (L is the length of the groin) and shorter than the length of the vortex zone in the condition that the river flow is not affected by tides by 8.2L. As for the case of high tide, upstream of the groin appears a vortex zone with a length of 7 L.
- Variation of bottom shear stress: The variation of bottom shear stress is quite large in the vicinity of the groin area, with the maximum value in the period of receding tides at the maximum difference is between 0.1÷0.15 kg/(m.s^2).
- Turbulent current strength: Determining the increasing turbulent flow rate adjustment coefficient K_v after groin arrangement, $K_v = \frac{u_{cu}}{u_{cs}} = \frac{1+3r_{cs}}{1+3r_{cu}} = 1.23>1.0$

(2) Research results of groin system:

a) Determine the parameters of the spatial layout of the groin system

- Angular direction: determining the angular direction equal to 90^0 has increased the efficiency of deep erosion of the channel, which is beneficial for river correction for navigation.

- Unequal groin length: determine how LOM concave groin system creating a correction line with a concave curve shape that has the effect of eroding the channel.
- Distance between groins: determining the layout distance of the LOM concave groin system when placed close to each other ($S \leq 2.0L$) has created a structure that covers the entire groin system (different from the local vortex zone between equal groins) changing the velocity of the mainstream, increasing the efficiency of deep scouring serving navigation.

With narrowing ratio $L/B \leq 20\%$, the spacing arrangement ($S=1.5L$) has the best eroding effect.

In case of $L/B \geq 25\%$, a closer distance arrangement is required ($S=1L$) for the best eroding effect .

b) Efficacy criteria for erosion:

The criteria of scouring efficiency were established through different degrees of change of groin length, leading to differences of scouring efficiency of groin systems. Assuming that groin length is called L, then the corresponding groin length variations are 25%L; 50%L and 75%L are reflected by the coefficient K_λ, in different layout options, expressed by the formula (3-2): $K_\lambda = \frac{L_đ}{Lg}$

Where: K_λ- is the coefficient of variation of the groin length; $L_đ$ - is the first groin length of the system; L_g - is the groin length in the middle of the system.

c) Erosion effect:

Establishing a relationship line ($\Psi_{\%L} \sim K_\lambda$) shows that the concave groin system will give the best scouring effect when the coefficient of variation of the groin length ($K_\lambda = \frac{L_đ}{Lg} = 4$). The results of this study can be applied when designing the groin system with unequal lengths in the area of the direct channel in the tidal river with reversible flow.

CHAPTER 4. APPLICATION OF RESEARCH RESULTS TO THE PLACEMENT OF GROIN SYSTEM IN CAM RIVER

4.1. INTRODUCTION TO THE CAM RIVER

The study area is the section of the Cam River channel from KM 34+000 to KM 35+200 which is 1200m in length. This is a relatively stable straight river with the current condition of the conduit where there are often shallow passages.

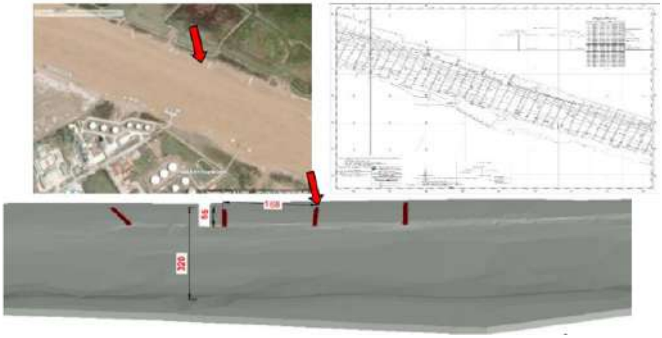


Figure 4.4: Location of groins K5, K6, K7, K8 on Cam River from KM 34+000 to KM 35+400

4.2. ESTABLISHING MODELS AND SOLUTIONS FOR GROIN SYSTEMS ON THE CAM RIVER

The thesis only focuses on considering and proposing options for arranging the layout distance between groins as (S=1.5L), this result has been confirmed in Chapter 3 to be reasonable according to the ratio (L/B≤20%) to apply to the Cam River section. The specific layout solutions are as following:

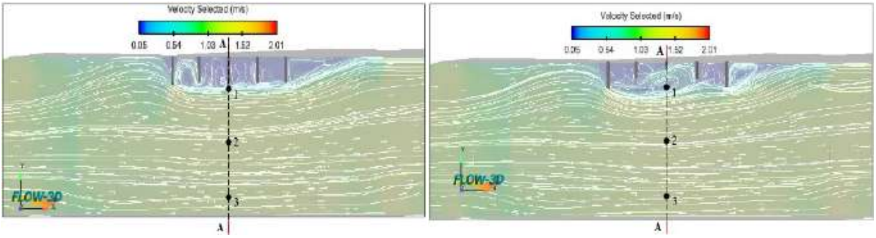
- Arrangement of straight groin system (THA1.5).
- Arrangement of concave groin system (LOM1.5).
- Arrangement of convex groin system (LOI1.5).

4.3. RESULTS OF SIMULATION OF SOME SOLUTIONS TO PLACE GROIN SYSTEM ON THE PROMISED RIVER

4.3.1. Flow field simulation results

4.3.1.1. Flow structure

Flow structure analysis Figure 4.11 indicates that the layout of the LOM concave groin system has formed a water area that covers the entire groin area wider than the layout of THA straight groin system. When the width of the vortex zone covered is large, it narrows the cross-sectional width of the mainstream leading to better intraluminal velocity increase compared to other solutions. Therefore, predicting the maximum conduction erosion rate occurs at the LOM concave groin system.



Straight groin system THA LOM concave groin system

Figure 4.11: Flow field in the area where the groin system is located

4.3.1.2. Flow velocity

The results of extracting velocity distribution data on the cross-section (AA) show that the solution of the LOM concave groin system is larger than other solutions (Figure 4.12).

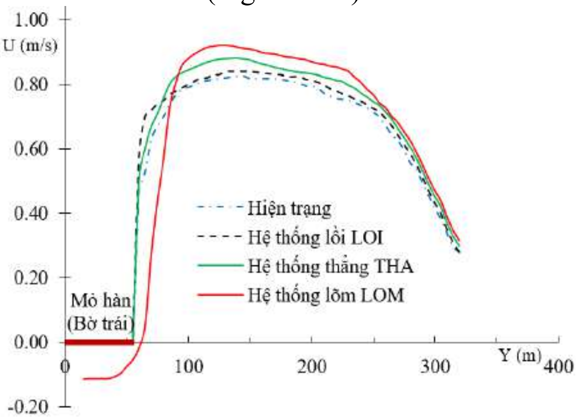


Figure 4.12: Velocity distribution in cross section AA.

Thus, the application of the cover water area of the LOM concave system solution proposed by the thesis to the Cam River segment has increased the maximum speed by about 15% compared to the current groin system.

4.3.2. Evaluate the relative effectiveness of layout solutions

Table 4-2: Changes in the bed river between the layout options (m)

Layout solution	Current groin system (basis)	Thesis solution		
		LOM concave groin system	THA Straight groin system	LOI convex groin system
Elevation of the bottom (m)	-5.23	-5.87	-5.61	-5.45

Table 4-2 describes that, according to the proposed plan of the research results, the depth of erosion of the concave groin system is 64cm larger than that of the current groin system.

Therefore, the results of comparing the velocity field, the change of the bed along with the solutions to arrange the groin system applied to the Cam River, the thesis has determined the LOM groin system effectively increases the erosion capacity against alluvium better than other solutions.

4.4. CONCLUSION CHAPTER 4

In Chapter 4, the thesis presents the application of the research results of the thesis in Chapter 3 to the actual river segment. The pratical question is to take the straight river segment on the Cam River segment in Hai Phong navigation channel to serve as basis for using topographical, hydrographic data and the current size of the current groin. Based on the current groin system, analysis of the flow structure and evaluation of the effectiveness of deep scouring of the conduit have been made to compare to the solutions of proposed groin system arrangement in the thesis.

The thesis has compared the solutions to arrange the groin system on the Cam River section, thereby determining the LOM concave groin system has the best effect against alluvial.

CONCLUSION AND CHALLENGES

A/. RESEARCH RESULTS OF THE THESIS

(1) The thesis has reviewed and selected the research approach using 3D mathematical model (Flow 3D) and Krami's physical model to build RANS digital flow conduit using Flow-3D model as a tool to study the flow structure, change of the conduction channel around the groin work.

(2) On the basis of numerical simulation by 3D mathematical model. The thesis has discovered and described in detail the flow structure, the interaction mechanism between the flow and the single groin work in the river segment in the tidal river with reversible flow, thereby serving as a basis for the study. Export the parameters of spatial arrangement of the groin system in accordance with the goal of limiting sedimentation and stabilizing the conduit above rivers in the tidal affected area have a reversible flow.

(3) With the goal of regulating rivers to serve waterway traffic then the layout plan of 90^0 angle (A90) for the best effect of increasing the depth of scour. The arrangement of the groin in the angular directions from 45^0 to 135^0 (A45~A135) creates different flow fluctuations under the action of reversible flow, in which the average scouring depth is the largest occurs when the groin system is arranged with an angle of 90^0 compared to the flow direction.

(4) On the basis of the analysis of flow structure and conduction channel deformation of 03 groin system layouts (LOI convex groin system, THA straight groin system and the LOM concave groin system), the thesis has determined the layout of the LOM concave groin system with the distance between the groins S ≤ 2.0L could increases the depth of the conduit scour larger than the other methods other layout (convex and straight groin system). Thus, the layout of the LOM concave groin system is the way proposed by the thesis due to its effectiveness in preventing sedimentation and maintaining navigation.

(5) When choosing the solution of a concave groin system with narrowing levels of the river bed L/B =15%, 20%, 25% and 30%, the reasonable layout of space between the groin has an effect on effectively increase the depth of scour. In case (L/B ≤ 20%), the layout distance S=1.5L is reasonable, while when (L/B ≥ 25%), the layout distance S=1.0L is appropriate.

(6) The thesis has established a relationship line (($\Psi_{\%L} \sim K_{\lambda}$) to determine the parameters of the layout of the groin system with unequal groin length in the condition of narrow river segment (L/B = 20 %).

(7) The thesis has applied the layout of the groin system proposed from the research results to the Cam River segment - Hai Phong with the aim of improving the depth of the channel and maintaining navigation.

B/. FURTHER RESEARCH

1) Continue to study the groin system in the overflow state, under the impact of waves in the estuary.

2) Continue to study the shape of the tip of the groin, the groin system for water to pass through (pile groin) etc. on the tidal river section.

3) Continue to study the groin by physical with tidal generated system.

4) Conduct experimental application of solutions proposed by the thesis author to the actual river, in order to increase the efficiency of deep-bed erosion on the maritime channels in the estuary of the Red River Delta.

C/. LIMITATIONS AND CHALLENGES

1) The 3D Flow model is limited to large time simulations provided that the current computer should be run on a highly configurable computer.

2) Due to the limited model building conditions for accurate fabrication of sedimentary materials for dynamic bed models, therefore experimental studies on physical model are required.

3) The thesis problem only stops at studying the effect of regular tidal shape without considering the impact of random tidal shape, so the calculated results in the study may be different from reality.

PUBLICATIONS RELATED TO THE THESIS

1. **To Vinh Cuong,** (2021). Studying the hydraulic characteristics of the groin groin work area in the estuary section with reversible flow. Journal of Irrigation Science and Technology No. 66 in 2021.
2. **T. Vinh Cuong,** NT Hung, V.Thanh Te, P. Anh Tuan (2019) . Analysis of spur dikes spatial layout to river bed degradation under reversing tidal flow. International Conference on Asian and Pacific Coasts in Hanoi, Vietnam, September 25-28, 2019 (APAC 2019).
3. **T. Vinh Cuong**, NT Hung, V.Thanh Te, Ward Anh Tuan (2018). Effects of spur dikes spatial layout to river bed evolution in tidal river. International Symposium on Lowland Technology Sept. 26 – 28, 2018, Hanoi, Vietnam (ISLT 2018).
4. Nguyen Ngoc Quynh, B.H. Hieu, N.N. Dang, N.H. Quang, **To Vinh Cuong**, (2020). Variation in morphology of the Red River and Duong river near Hanoi from 2000 to 2018. Vietnam Journal of Science, Technology Engineering.
5. Nguyen Thanh Hung, Vu Dinh Cuong, Yoshimitsu Tajima, **To Vinh Cuong** (2014). Numerical modeling of Hydrodynamics and sediment transport processes in Ma river estuary, Vietnam, Proceedings of the 19th IAHR-APD Congress 2014, Hanoi, Vietnam.