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Studies to Determine Dimensions for River Training Works in the Hanoi Segment of the Red River

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Based on the natural laws and adverse impacts of the human activities on the Red River, this Paper will present applied studies as a basis for determining dimensions of river training works in the Hanoi segment of the Red River.

I. INTRODUCTION

The Red River plays an important role in the multi-faceted sustainable development of the Red River Delta in general, and the capital city of Hanoi in particular. The Red River's segment running through Hanoi has the length of about 40 km and is a factor causing direct effects on every economic, social and environmental activities of the city. This factor is becoming more crucial in the context that the Red Rivermailto:cora.hoogeveen@cur.nl will soon run through the center of the city, as a result of the city development planning until 2020.

The Red River is considered the cradle of the Vietnam nation. It brings up the Vietnam people and helps to enlarge the territory. It also created the ancient capital city of the country, Thang Long (or "ascending dragon" citadel), which has become Hanoi nowadays. But, on the other hand, it is a source of many unexpected and unwanted disasters, the most dangerous of which possibly is flooding. The flood water level in the Red River may reach up to 14 m while the landside elevation is only 6.5 m. Therefore, the whole city of Hanoi will be under deep water if the dyke is broken. Another kind of disasters that may happen in the Red River is landslide. Due to the instability of the flow, the floodplain of the Red River is usually eroded, causing frequent landslide and endangering the safety of local people and structures. Sedimentation and erosion also cause a lot of obstructions to water supply and drainage as well as navigation. Thus, to have the Red River running at the center of the city, we must ensure that its morphology is stable and any changes of the flow are kept under control (see Fig. 1).

The Red River segment in Hanoi has very complicated features as if there are so many channels and effluent. Such the complicatedness is exacerbated by the human unplanned and strong impact on the river, making the river under coercive rater than natural, factor. However, in spite of these complicated developments of the Red River, it still keeps its original spatial position; its width and water depth are still within certain limits and even sedimentation and erosion follow some certain cycle and a cause - and - effect relation. This is the issue that needs to be studied further for determining dimensions for the river training works. Within the frameworks of this Paper, the author will only focus on one of the basic aspect of river dynamics, which is, in particular, the law of applied morphology. This law itself is determined by other component laws, namely the law of flow, the law of sediment transport in natural conditions and in the "with river training works" conditions.

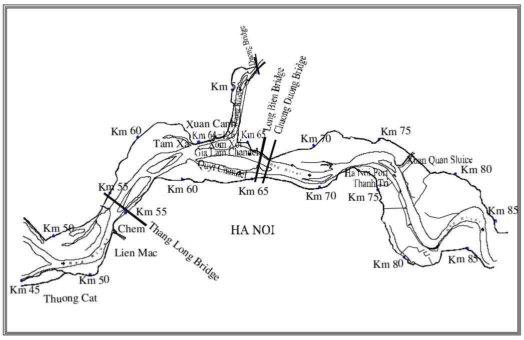

Figure 1. The Hanoi Segment of the Red River

II. GENERAL STUDIES AND REQUIREMENT ON RIVER TRAINING WORKS IN THE HANOI SEGMENT OF THE RED RIVER

A. *Requirements*

The Red River channel must ensure safe flood discharge through Hanoi city at the designed dyke water level of 13.40 m in Hanoi, according to the national elevation system.

As a matter of fact, the Red River has an effluent on its left, which is Duong River. The Duong River dike is rather weak, therefore the river training solution must maintain the current regime of flow distribution between the Red River and Duong River in the flood season so as no additional water goes into the Duong River.

In addition, it is necessary to maintain stable conditions for navigation, avoid sedimentation at Hanoi Port and other new port and berths already specified in the city master plan.

Good planning of the flood plain is also required for proper use of land on the flood plain, for development of the city and "beatification" of the riverside landscape.

B. *General Studies*

Sediment Transport Capacity: In Vietnam, the well-known formula of Truong Thuy Can is usually used for this purpose. Other authors, namely Vi Van Vy, Hoang Huu Van, Luong Phuong Hau, etc., have defined coefficients and powers for this formula when applied for the rivers in the northern delta of Vietnam [5].

Stability and morphological relation: this aspect was analyzed by many authors in their studies in the 1970s-1980s, e.g. the ones carried Nguyen Thoi Giap, Le Ngoc Bich and Luong Phuong Hau. Luong Phuong Hau assuming that the morphology of the river channel would follow the principle of "minimum channel variation", has suggested a formula to determine the morphological relation of the cross section [1], [5].

Channel stabilization: Since the 1980s, the Ministry of Transport has launched a number of projects on channel stabilization and sedimentation prevention at Hanoi Port. In three years 2001-2003, JICA also conducted a study on the Red River Inland Waterway Transport System [2], [3].

Flood discharge Capacity: Since 1971, there have been many projects and research programs studying the issue of flood discharge for the Red River in general, and for its Hanoi segment in particular. However, there has not been yet any answer to the question due to its complexity. This issue is becoming more pressing now as the law on dike management is being drafted.

Achievements and outstanding issues: The dyke system has been safely protected for a long time and so far. The river training works have appeared to be effective for preventing sedimentation at Hanoi Port [2].

Apart from these achievements, however, there are still outstanding issues on this river segment, such as unstable channels, unplanned arrangements of structures, uncontrollable river channel alignment, and unreasonable dimensions of structures.

III. Main Bases in the Studies Methods

A. Hydrological data

Data on daily mean discharge and water level are the real values measured at Son Tay and Hanoi Stations on the Red River and Thuong Cat station on the Duong River during the period 1960-1998. There are also data showing high water level and discharge, reflecting the extreme values of maximum floods. These data on discharge and water level are used to analyze the water level rising. Data on suspended sedimentation, hourly water level and discharge from 1993 to 2001 are also available and data on sedimentation are used to calculate the volume of sediment transport in the Red River.

B. Methodology

This study combines, in a reasonable manner, the method of analyzing the real data series and method of examining the physical model. Subjects of the study are also combined with the national level research project on "Development of river training plan to increase the flood discharge capacity and stabilize the river channel in the critical Hanoi segment of the Red River," conducted by the author himself. For the purpose of the study, 2 models have been developed:

Rigid-bed model, length scale 1/400 and depth scale 1/80: its coverage includes the whole studied area, i.e. the Red River in the Hanoi segment and the Duong River from the Duong River mouth to Duong Bridge. The model has been designed with similar characteristics of the flow, Froude and Reynolds numbers in order to ensure the hydraulic regime in the area of rough and turbulent flow.

Movable-bed model, length scale 1/200 and depth scale 1/100: the function of this model is limited by the requirement of studying the bed transformation in the area of critical works. Therefore the coverage of the model is defined from Chem to Long Bien Bridge, including the Duong River mouth. This model design follows the method of M. De. Vries [9], using light material Keramzit, and ensures similar transport and flow parameters and sediment load.

IV. Analyzing and Determining Dynamic Factor Effecting the Morphology Development in the Red River Through Hanoi

A. Bankfull discharge

Of the hydrological data series from 1990 to 1998, the year 1997 has been chosen as the base year for calculating the bank full discharge corresponding to the water level 9.50 m in Hanoi. The bank full discharge, calculated according to Makkaveep method [6], is 10,750 m^3/s on the Red River segment, upstream of the Duong River mouth, and 7,650 m^3/s on the segment downstream of the Duong River mouth.

B. Changes of flow distribution between effluents

The flow distribution to the Duong River has calculated for different periods of time in comparison with the discharge at Son Tay and on the basis of hydrological data of Son Tay and Hanoi stations on the Red River and Thuong Cat Station on the Duong River from 1960 to 1998. Calculations show that during the period 1961-1969, the flow in the Duong River accounted for about 24.9 % of the discharge of at Son Tay which was 20,000m^3/s. It was 29.5 % during the period 1991-1998.

C. Discharge and stage relation in Hanoi

Analyses of discharge and stage relations show that, at the same water level, the river channel cannot discharge the same discharge as in the past. This situation reflects the decreased discharge capacity of the river channel, which is dangerous for flood control. Particularly in Hanoi, with the same flood discharge as 30 years ago, the water level during the period 1991-1998 was increased by 63 cm.

D. Total sediment transport formulas

Introduction: Total sediment transport formulas of Rottner, Meyer - Peter Muller, Engelund and Hansen, Van Rijn, Ackers and White can put in the form of two parameter relations as follow [7]:

Transport parameter (dimensionless):

$$\psi_t = X = \frac{s_t}{\sqrt{g\Delta D_{50}^{\ 3}}} \tag{1}$$

Flow parameter (dimensionless):

$$\theta = \frac{h.i}{\Delta D_{50}} \tag{2}$$

In which:

s_t: volumetric total transport of bed ($m^3/m/s$)

g: gravitational acceleration (m/s^2)

Δ: relative density $(\rho_s - \rho)/\rho$ (-)

ρ: density of water (kg/m^3).

ρ_s: density of sediment (kg/m^3).

D_{50}: Mean grain size of bed material (m)

h: average water depth (m)

i: average water-surface slope (-).

The total sediment transport (s_t) is a sum of the bed-load transport (s_b) and the suspended-load transport (s_s). In the case that the bed load is unknown, it can be calculated using Meyer-Peter Muller formula. Suspended-load transport can be determined from measured data at hydrographical stations

$$s_t = s_b + s_s \tag{3}$$

In general, the form of Englund - Hansen formula:

$$\psi_t = \alpha \frac{C^2}{g} \theta^{\beta} \tag{4}$$

In which: α is the coefficient and β is the power determined from measured data.

Formula (4) in the actual condition of the Red River: For the Red River (4) can be adapted by adjusting the coefficient (α) and the power (β). Based on the measured data of Son Tay, Thuong Cat and Hanoi Stations in the period 1993-2001, it can be determined the coefficient and power of (4) for transport of solid material:

$$s_t = \alpha \sqrt{g \Delta D_{50}{}^3} \frac{C^2}{g} \left(\frac{hi}{\Delta D_{50}} \right)^{\beta} \tag{5}$$

The results on the total sediment transport (3), then ψ_t and θ are basis to plot the Engelund - Hansen relation for the Red River (see Fig. 2). After that, the coefficient and the power have been determined:

$\alpha = 0.284$ and $\beta = 2.18$

Substituting α and β into (5), the total sediment transport formula for the Red River for solid material can be written:

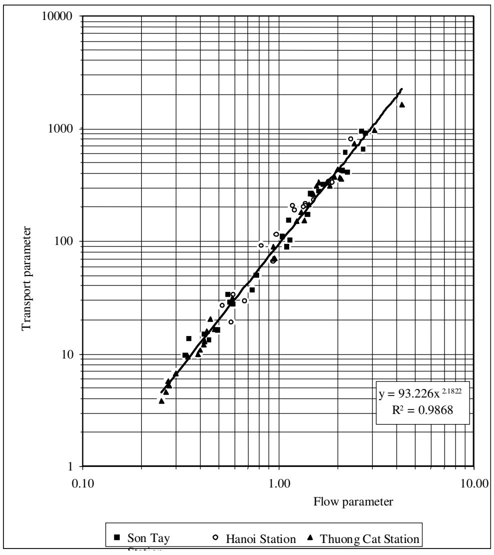

Figure 2. Relationship between Ψ_t and θ for the Red River

$$s_t = 0{,}284 \sqrt{g \Delta D_{50}{}^3} \frac{C^2}{g} \left(\frac{hi}{\Delta D_{50}} \right)^{2{,}18} \tag{6}$$

Formula (6) is basic to determine dimensions for the proper alignment of the river training works for the Red River in general and the Hanoi Segment of the Red River in particular.

V. Evolutions of river Channel and Mechanism to control the Morphology Development of River Channels of the Studies River Segment

The Red River segment in Hanoi has had a lot of changes. Since the XI century, when this place was selected to be the capital city of the country, nearly one thousand years have been over, and the human being, during that long period time, have a lot of impacts (of different levels) on the Red River, for the sake of their livelihood. As a result, the river has lost many of its movements and developments, which should have followed the natural laws. Nevertheless, studying the historical evolution of this river segment, we still find basic characteristics of the semi-natural laws (i.e. with the presence of coercive factors such as dyke, river training works etc.)

A. Evolutions on plan

Stable factors on the river plan: Though there have been very complicated evolutions, affected by many natural and man-made factors, the studied river segment still maintains quite stable features on its plan, in particular:

- The river - bank configuration in the season of medium water level is hardly changed.

- The river sections determining the river channel alignments are quite stable, such as the sections Lien Mac - Chem, Tam Xa - Xom Xoi and the section from Hanoi Port to Thanh Tri.

- The Duong River mouth: Analyzing the river site plan since 1958, we can see that the position of the Duong river mouth has not been changed at all, as this river mouth is located in the area of good geological conditions, formed of layers of inerodible clay materials.

- There are controlling "bottlenecks" on this river segment, such as Chem, Chuong Duong and Thanh Tri. The River channel with is 960 m at Chem, 880 m at Chuong Duong and 800 m Thanh Tri. With these bottlenecks, transversal changes are limited.

Transversal fluctuations of channels: According to the analyses of river evolutions, we see that the main channel of the section from Chem to the Duong River mouth has very strong fluctuations, from being very close to the left side dyke to being close to the right side dyke and vice - versa, with the fluctuation amplitude of about 3,800 m. These fluctuations endanger the both dykes and make navigation become difficult. Furthermore, these unwanted and uncontrolled movements even go further to the downstream part of the Duong River mouth, causing sedimentation at the Hanoi port and Xuan Quan sluice.

Major river channel alignments: Based on the changes of the main channel from 1986 until now, it can be noted that in general, the Hanoi segment of the Red River has 3 major channel alignments, of which Alignment A as described in Fig. 3 [2], [3] is a favorable curve, desirable for the purposes of irrigation /drainage, navigation and

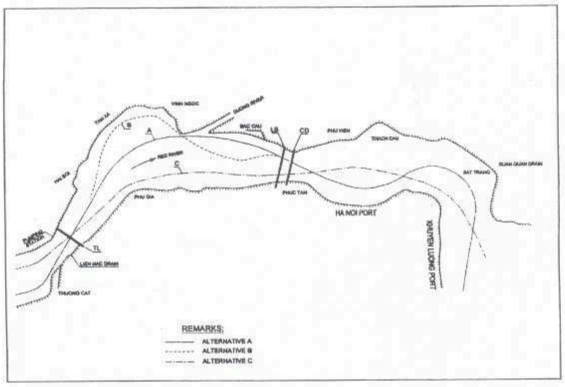

Figure 3. Historical Evolution of Channel Alignment and Alternatives

urban development. The channel alignment A has been noted in the two periods of time, 1959-1964 and more recently 1995-2005.

B. Changes of the flood plain

Comparing the elevation of the river floodplain in 2000 with that in 1976, we see that the Hanoi segment of the Red River has had elevation of the flood plain increased by 0.86 m. This is one of the causes making the flood water level become higher.

C. Relationship between transverse and vertical factors of the channel

On the river longitudinal profile, there usually deep scour holes where the river width is narrowing and abrupt curve is formed [4]. The depth of the scour hole has correlation with the configuration of the river plan, represented by the ratio of the minimum radius of curvature to the river width. This is a typical feature reflecting the relations between the transverse and vertical factors of a river. Data on the scour hole - depth (h_{max}) and the ratio of the minimum radius of curvature to river width (R_{min}/B) on the Red River are topographical data in 1997.

The graph shows the depth of the scour hole in the Hanoi segment of the Red River in a general broad picture governed by a quite clear law. According to this relation (h_{max}-R_{min}/B), the Red River can be divided into 2 sections - ahead and behind river mouth.

- The sections ahead of the Duong River mouth often have large width and small depth. Corresponding to the bank full water level, the river width (B) is within the range of 960-2,000 m. The smallest radius of curvature (R_{min}) is within the range of 4,000-8,000 m. The maximum depth (h_{max}) varies between 12.85 m and 21.36 m.

- The sections behind of the Duong River mouth often have small width and high depth. With typical features as with the bank full water level, the width of water surface is within the range of 443-1,243 m. The radius of curvature (R_{min}) is within the range of 900-5,000 m. The maximum depth (h_{max}) varies between 10.60 m and 30.24 m.

On the Red River, the most abrupt curves are the 2 sections at Duong Tao, corresponding to the bed elevation - 22.22 m, and at Quang Lang, corresponding to the deepest bed elevation - 23.73 m. The radius of curvature at this location is only 900 m. These are also 2 positions where the ratio R_{min}/B is smallest on the Red River. From the topographical data in 1997, the relation between h_{max} and R_{min}/B is shown on Fig. 4 and in accordance with the approximate relation as follow:

$$h_{max} = 47.26\left(\frac{R_{min}}{B}\right)^{-0.762} \quad (7)$$

Relation (7) correlates to the elevation of the foundation of training works, bank protection works, groins, bridge piers, berths, etc., and to the stability of the structures on the river.

D. Relation between B and h

The Channel of narrow river section will be stable when a relative balance is achieved, which is expressed by the following basic equations [9]:

For the water flow: $Q_0=Q_1$ (8)

$Q=BCh^{3/2}i^{1/2}$ (9)

For sediment: $S_1=S$ (10)

$S=Bau^b$ (11)

In which: values of the original parameters corresponding to the natural status have the indicator '0', and those of the new parameters corresponding to the "with river training works" conditions have the indicator '1', a represents coefficient, b represents the power.

The current balancing status and the final future balancing status, assuming: $C_1 \approx C_0$ and $D_1 \approx D_0$

a and b do not change in the both balancing situations.

The equations (8)-(11) bring the following results:

$$\frac{h_1}{h_0} = \left(\frac{B_0}{B_1}\right)^{\frac{b-1}{b}} \quad (12)$$

and

$$\frac{i_1}{i_0} = \left(\frac{B_1}{B_0}\right)^{1-\frac{3}{b}} \quad (13)$$

Using (11), the power b doubles the power β in (5). For the Red River in particular, Using (6) has determined β equal to 2.18 therefore b is 4.36. Put this value of b in (12) and (13), we have the following formulas:

$$\frac{h_1}{h_0} = \left(\frac{B_0}{B_1}\right)^{0,771} \quad (14)$$

and

$$\frac{i_1}{i_0} = \left(\frac{B_1}{B_0}\right)^{0,312} \quad (15)$$

Then, using (14) and (15), we can predict the average depth of the flow (h) and slope (i) within the context of narrowing river channel by river training works.

E. Impacts of structures and construction works

Dykes: The Hanoi dyke was constructed in the XI century and further developed throughout the period of nearly one thousand years. Apart from the Hanoi dyke, there are also many layers of ring levees surrounding the residential zones. The smallest and largest distance has the gap of 3.2 times.

Bridges across river, and river training works: On the studied river segment, there are 3 bridges: Long Bien (built in 1902), Thang Long (built in 1984), and Chuong

Duong (built in 1985). The bridge piers occupy the area for water drainage, diminish the flow in the main channel and the flood plain, marking the water level increase and causing local erosion. Experiments done on the physical model with the discharge of 29,000 m^3/s have identified that the difference water levels upstream and downstream of Thang Long Bridge is 12 cm; that between water levels at Long Bien is 26 cm, and at Chuong Duong 16 cm.

E. Analysis of flood plain impacts on flood discharge capacity

General analysis: To analyze the flood plain impacts on the stage-discharge relations, we have made reference to studies by Myers and Brennan (1990), Wormleaton and Merrett (1990) in experimental flumes (Fig. 5A and Fig. 5B). There is difference in the stage-discharge relations in the "main channel" and the "flood plain". Fig. 5A indicates that when the flood plain is narrow the stage-discharge relation is line 4 in the case of smooth tests, which has the "main channel" in the "stretched out" form though the stage-discharge relation is in the "flood plain". Similarly, in Fig. 5B, when there is no the flood plain, the depth-discharge relation curve is line 4 in the case of smooth tests too. In both cases, corresponding to the same water level, the discharge is the smallest, or in other words, the flood discharge is the lowest.

Impacts from residential zones: Impacts from the residential zones on the flood plain have made the water level increase. The rise of the water level has been determined on the rigid-bed model. After removing all the residential zones on the flood plain and with the total discharge of 29,000m^3/s, the water level has been decreased by 20 cm.

Impacts of the rise of flood plain elevation: (see Fig. 6)

To determine the level impacts by the rise of the flood plain elevation (ΔZ) on the water level, we have made reference to studies by Bray [8] and start from the stage-discharge relations (H-Q) in the "main channel" and the "flood plain" as follows:

- In the "main channel": $Q_1=a_1H_1^{\alpha 1}$ (16)
- In the "flood plain": $Q_2=a_2H_2^{\alpha 2}$ (17)

In which: a_1, a_2, α_1, α_2 are the coefficients and powers determined from real measurement data or from experiments on the physical model. The B-D_1 line illustrates the relations in the "flood plain" at present, i.e. with impacts from the residential zones. The B-D_2 line represents the relations in the "flood plain" after the removal of all the residential zones on the flood plain. Using the real measurement data, we can only define the B-D_1 line and the point (Z^*, Q_2) on it. The B-D_2 line must be based on the model. The rise of the water level (ΔH) determined according to the B-D_2 line is completely due to the rise of the flood plain elevation, and corresponds to the point (Z^{**}, Q_2) on the line.

Equations (16) and (17) have the intersection at coordinates (Z_0, Q_0), where $Q_1=Q_2=Q_0$; $H_1=H_2=Z_0 \Rightarrow a_1Z_0^{\alpha 1}= a_2Z_o^{\alpha 2}$, therefore:

$$Z_o = \left(\frac{a_1}{a_2}\right)^{\frac{1}{(\alpha 2-\alpha 1)}} \quad (18)$$

When the flood plain elevation rises by ΔZ, use (16) at the point ($Z_0+\Delta Z$, Q_1), we have:

$$Q_1= a_1 (Z_0 +\Delta Z)^{\alpha 1} \quad (19)$$

When the flood plain does not yet rise up and the discharge is the same ($Q_1=Q_2$), use (17) at the point (Z^*, Q_2) we have:

$$Q_2 = a_2Z^{*\alpha 2} \quad (20)$$

Use (19) and (20) calculate the elevation Z^*:

$$Z^* = \left\{\frac{a_1(Z_0+\Delta Z)^{\alpha 1}}{a_2}\right\}^{\frac{1}{\alpha 2}} \quad (21)$$

So, with the same discharge, the water level rise (ΔH) when the flood plain elevation rises (ΔZ) is:

$$\Delta H = (Z_0+\Delta Z)-Z^*$$

$$\Delta H = (Z_0+\Delta Z) - \left\{\frac{a_1(Z_0+\Delta Z)^{\alpha 1}}{a_2}\right\}^{\frac{1}{\alpha 2}} \quad (22)$$

In which: Z_0 is calculated according to (18)

From hydrological data in 1996, in the period 1991-1998 and experiments on the model, we can determine (16) and (17), and relevant coefficients and powers a_1, a_2, $\alpha 1$, $\alpha 2$.

Calculate the flood plain elevation with ΔZ equal to 86 cm, use (18) and (22) to identify the rise of the water level due to the rise of the flood plain elevation. For example, Fig 7 is drawn to identify a_1, a_2, $\alpha 1$ and $\alpha 2$ according to 1996 data. Use (18) and (22), we can identify the rise of the water level being 25 cm. Similarly, if the hydrological data of the 1991-1998 period are used, the rise of the water level will be 24 cm, and if the data from experiments on the physical model are used (in case of removal of all houses in the residential zones), such value will be 27 cm.

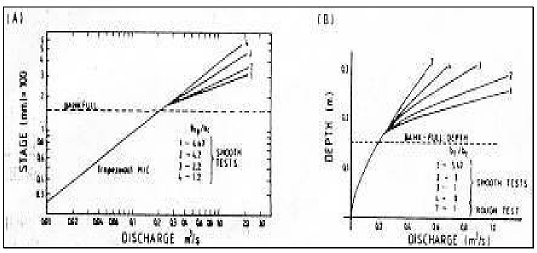

Figure 5. Depth - discharge curves for different geometric of the compound cross-sections. (A)- After Myers' and Brennan's flume experiments (B) - After Wormleaton's and Merrett's flume experiments (1990)

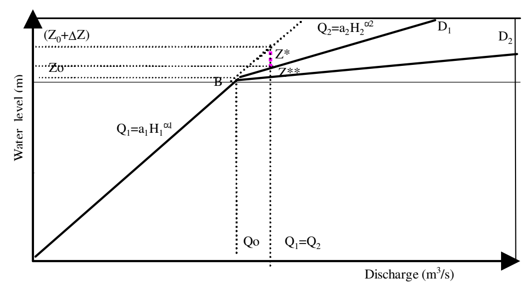

Figure 6. The rise of the water level due to the rise of flood

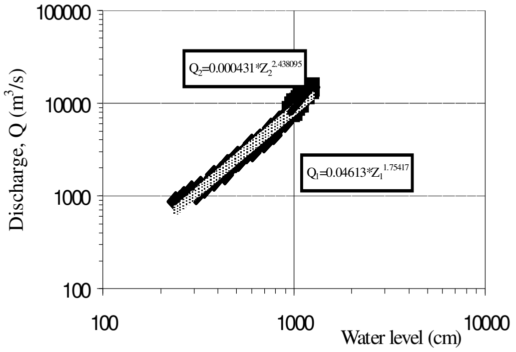

Figure 7. Stage - discharge relation in 1996 at Hanoi Hydrological Station

The flood plain elevation has risen due to the impacts of the human activities, such as raising the ground elevation to build up houses or construct roads, etc. This in turn makes the water level go up. If the flood plain continues to rise up by 1 or 2 m, the flood water level will become 30-60 cm higher. Therefore, the river training solution absolutely needs to refer to the elevation of the flood plain, and any bank protection or groin works must be designed in such a way to have an adequate crest elevation.

VI. Application of Studied Results to Determine Dimensions for Alignment and River Training Work in Hanoi Segment of th Red River

The major objective of river training in Hanoi Segment of the Red River is, first of all, to increase the flood discharge capacity, overcome constraints to navigation and beatify the environmental landscape and build up a modern and civilized urban appearance. From the studied results, we see that premise for regulating this river segment is to stabilize the channel alignment in the season of medium water level, stabilize the flow distribution to the Duong River and remove man-made obstructions on the flood plain. For this purpose, the first thing to do is determine specific dimensions of the river training works on a scientific basis.

A. *Objects of river training and objects of impact*

For the Hanoi segment of the Red River, there are two objects of the river training works, which are objects of training works for flood discharge, and the object of training works for channel stabilization.

For effective flood discharge, it is necessary to make impacts on obstructions in the main channel and flood plain. However, the bridge piers are un-removable obstructions. The objects of the training works for flood discharge therefore will be mainly the obstructions in the flood plain, such as the ring levees, houses and the parts of flood plain where the elevation has risen. For the immediate purpose, it is essential to clear away obstruction within the 50 m - wide belt along the banks, and remove houses at the bottles necks, as well as avoid, raising the flood plain elevation.

To stabilize the river segment, it is necessary to focus the flow on the main channel under the desirable alignment and guide the flow to the direction of Gia Lam channel.

B. *Dimensions of alignment and Training works*

Use (12) to calculate the dimensions of the training alignment - see results in Table1, then draw out the alignment and locate the groins - After that, carry out experiments on the physical model to determine specific dimensions for each groin.

There are 2 alternatives to arrange the works: CT1 (B_1=940 m) and CT2 (B_2=880 m). Both alternatives have the same alignment width in the downstream of the Duong River mouth.

The two alternatives are tested on the models in terms of the velocity distribution and flow distribution in Gia Lam and Quyt channels as well as in the effluent to the Duong River. On this basic, analyses are done to choose the suitable alternative.

CT2 alternative: This alternative can be the best to stabilize the channel as desired. However, the flow distribution to the Duong River will increase by a small volume, compared to the current situation. At the discharge levels of 27,500 and 29,000 m ^{3}/s, the increased flow entering the Duong River will account for about 1.8-1.9 % of the total flow.

CT1 alternative: This alternative can ensure quite good stability for the channel alignment A, and stability for new port at Tam Xa, and more important, it will meet requirement of not increasing the flow in to Duong River during the flood season. Therefore, CT1 alternative has been selected.

VII. Conclusions and Recommendations

A. *Conclusions*

1. This study has been conducted on basis of materials and basic data collected from reliable sources and edited according to consistent criteria.
2. Specific values have been determined for the Red River conditions for coefficients and powers in the Engelund-Hansen formula to calculate the sediment load (6), as the basic to determine dimensions for the river training works (14), (15).
3. The author has suggested formula (22) to calculate the rise of water level during the flood season due to the rise of flood plain elevation. Therefore, the river training solution absolutely needs to refer to the elevation of the flood plain, and any bank protection or groin works must be designed in such a way to have an adequate crest elevation.
4. The author has analyzed the effect of channel stabilization of controlling bottlenecks and guiding bank sections. On this basis, the channel alignment A, which is the current alignment for river training

TABLE I.
Long- Term Widths and Depths

River section	B_0 (m)	h_0 (m)	B_1 (m)	h_1 (m)
The Red River, upstream of Duong River mouth	1520	5.82	940	8.40
	1520	5.82	880	8.90
The Red River, the downstream of Duong River mouth	1150	6.12	709	8.90

works, as well as calculate the dimensions of the alignment and training works for maintaining the stable flow distribution for the Hanoi segment of the Red River.

B. Recommendations

1. It is recommended that the flood plain elevation should be decreased to increase the flood discharge capacity of the channel. This solution is worth of considering and will certainly bring about obvious effects.
2. Along with the requirements on the main channel, the food plain and urban management in Hanoi city, there should be a consistent guidance among the sectors in order to study and work out a river training master plan for the Hanoi segment of the Red River.
3. For the immediate time, it is necessary to remove soon houses at the bottlenecks and remove the obstructions within the 50 m - wide belt along the banks to facilitate the current measures of channel stabilization.

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