V. Plan for Channel Stabilization in Hanoi Segment

A. Purposes of Channel Stabilization

97. The purposes of the channel stabilization in this Study are as follows, under the overall purposes such as to contribute **social and economic development** through development/good usage of inland waterways in the Hanoi Segment of the Red River and to ameliorate environmental impacts, such as decrease in air **pollution** by COx, through usage of inland waterways.

(1) Basic direct purposes

1) To stabilize the **channel alignment**, or to maintain the route of **Alternative A**,
2) To secure the requirements for **channel dimensions**, or planned minimum width of 150m, depth of 2.5m, and curvature radius of 700 m for the Low Water Level, or water level with 95% occurrence possibility. Particularly, planned water depth shall be secured in the channel and at important infrastructure such as Hanoi Port, Khuyen Luong Port, and new North Port; To enhance **self-scouring** at shallow channels, to stop undesirable **sedimentation** at shallow portions of the River, and to stop **sediment supply** by unnecessary erosion of the riverbanks, sand bars and riverbed.
3) To ascertain **safe navigation** by stabilized channel and aids-to-navigation.
4) Not to render **navigation/berthing** impossible by modified current field, or current speed at a berth of a port shall be less than 3 knots.
5) To contribute improvement of **appearance** and **scenery** of the Red River through construction of channel stabilization facilities.

(2) Other purposes from required hydraulic criteria

1) To avoid undesirable adverse effects on **flood**, especially increase in **water level** and **inundation area** during floods, and decrease in **flood discharge capacity**.
2) To avoid undesirable adverse effects on **irrigation** from the Red River, especially closure of water intakes at Lien Mac, Ap Bac, Xuan Quang and Yen So.
3) To maintain **flow distribution** between the Red River and the Duong River.
4) To avoid undesirable adverse effect on **city planning**, especially usage of

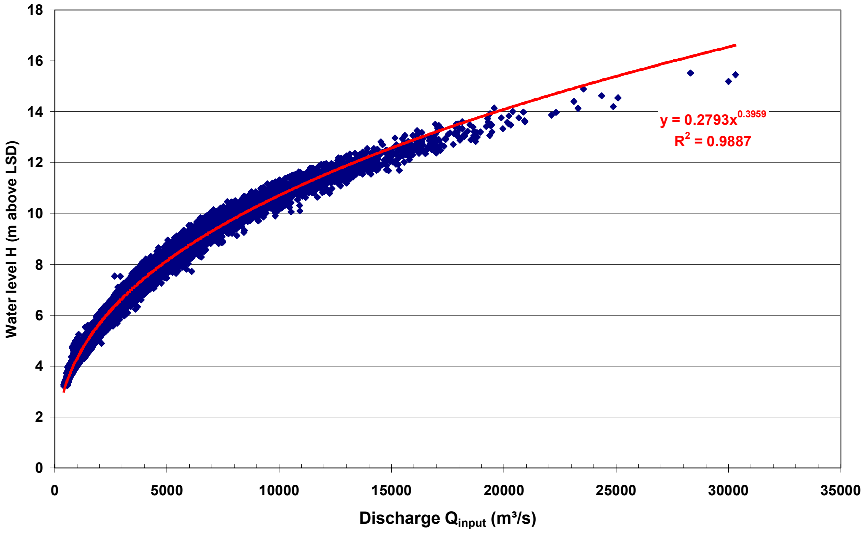
riverbanks, or no induced adverse **bank instability**.

5) Not to affect the **bridge pile stability**, i.e. Thang Long, Long Bien, Chuong Duong, and Thanh Tri Bridges, or no significant increase in current velocity.
6) To avoid adverse effects on natural and social **environment** such as water quality, air quality, bio-diversity, convenience and safety of people's life, etc.

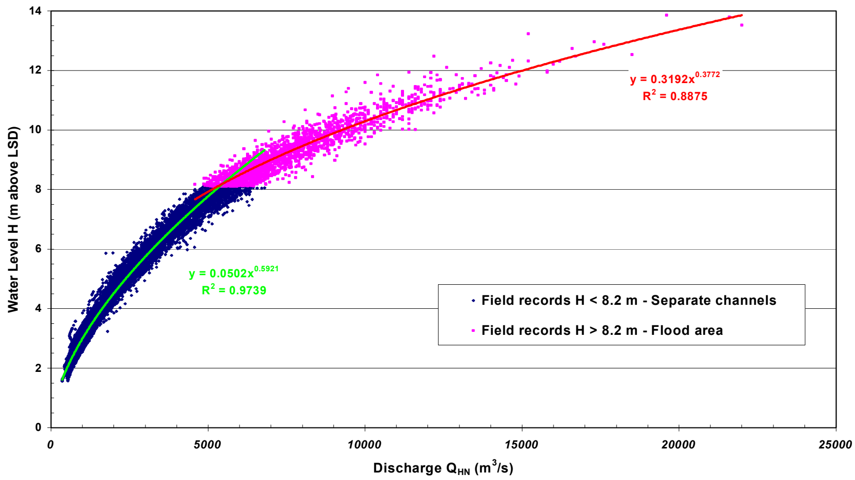
B. Natural Conditions of Hanoi Segment

98. The hydrological Red River Basin can be sub-divided into its upstream part - upstream of Viet Tri, where there is a confluence of the three major tributaries, the Thao, Lo, and Da Rivers - and its downstream part, where the braided river flows, via six affluent through the alluvial and coastal plain towards the sea. The Red River IWT System is nowadays developed within two hydrological river basins: the Red River Basin and the Thai Bin River Basin. The two basins are interconnected via two rivers, the Duong River (Hanoi - Pha Lai) and the Luoc River.

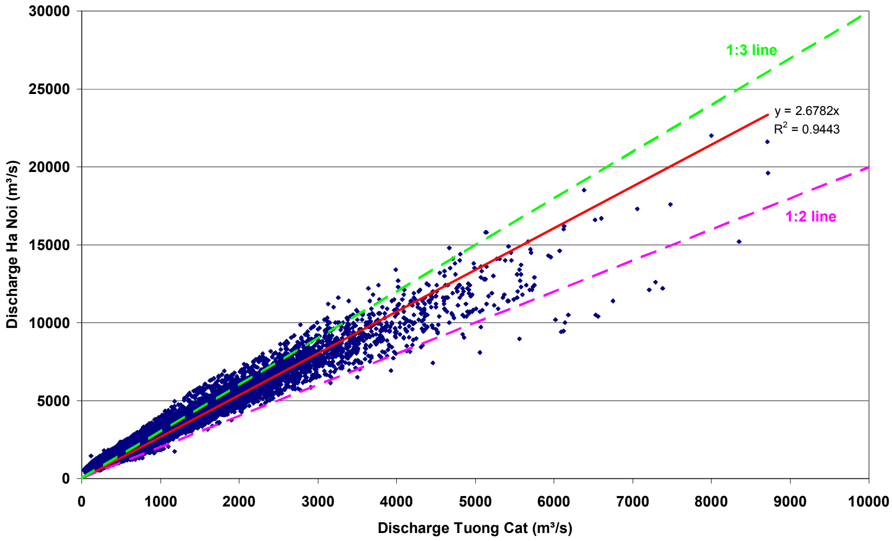
99. Water levels and discharges are fluctuating within broad ranges, due to seasonal (two monsoon climatic regime) and/or hydrological -meteorological conditions: in Hanoi, the average seasonal fluctuations between the flood season and the dry season are typically around 9m, with discharge-fluctuations of 10 to 20 times. A summary table of typical water levels at Hanoi Hydro-meteorological Station is shown in **Table V-1**. The water level-discharge rating curve, or H=f (Q), is shown in **Figure V-1** at above Thang Long Bridge, at Hanoi H-M Station, and distribution of discharge between the Red River and the Duong. About 27% of the discharge in the Red River flows into the Duong River on the average.



(1) Water Level-Discharge at above Thang Long Bridge



(2) Water Level-Discharge at Hanoi H-M Station



(3) Discharge Ratio between the Red River and the Duong River

Figure V-1 Water Level and Discharge

Table V-1 Water Levels at Hanoi H-M Station for Design Purposes (1956-2001)

Name of Water Level	Water level (m above LSD)
Highest Water Level (1971)	+13.97 *
Water Level for Design of Hanoi Dyke (Special Class)**	+13.4
Mean Annual Highest Water Level	+10.96
5% Occurrence Water Level (1995-2001)	+9.52
Mean Water Level in the Flood Season (May to October)	+7.34
Mean Water Level	+5.04
Mean Water Level in the Dry Season (November to April)	+3.47
95% Occurrence Level (1995-2001)	+2.58
Mean Annual Lowest Water Level	+2.20
Lowest Water Level (1960)	+1.55

Note) LSD = Land Survey Datum (equal to the National Elevation System)
= CDL (Chart Datum Level at Hon Dau) +1.86m;
* By Hanoi HM Station * * Defined by MARD in July 2002
Source) TEDI-port and Study Team

100. Current speed measurements were carried out in January 2002 during the dry season and August 2002 in the flood season. The former result is shown in **Figure V-2**. The current speeds observed are mostly less than 1.0m/sec in the dry season and 1.0 to1.8 m/sec in the rainy season.

101. Moreover, the Red River hydrological basin is characterized by proportionally high sediment-loads (average 1 gds/l) and huge sediment transport rates. Surveys in August 2002 revealed that the bed-load in Hanoi Segment could be the order of 100-200 tons/hour, which is considerable and considered as the main agent governing the morphological dynamics in the Hanoi Segment.

102. Riverbed sediments consist mainly out of fine well-sorted sand (d_{50} between 0.100 mm and 0.235 mm) in the deeper channels, and mixtures of fine sand (20-40%), silt (40-70%) and clay (10 - 20%) prevail on the shoals and banks. Under the observed current-velocities, it appears that these fine sediments are quite mobile and susceptible to be easily transported as bed-load or as suspension-load transport. A diagram of measured current speed vs. particle size is shown in **Figure V-3**.

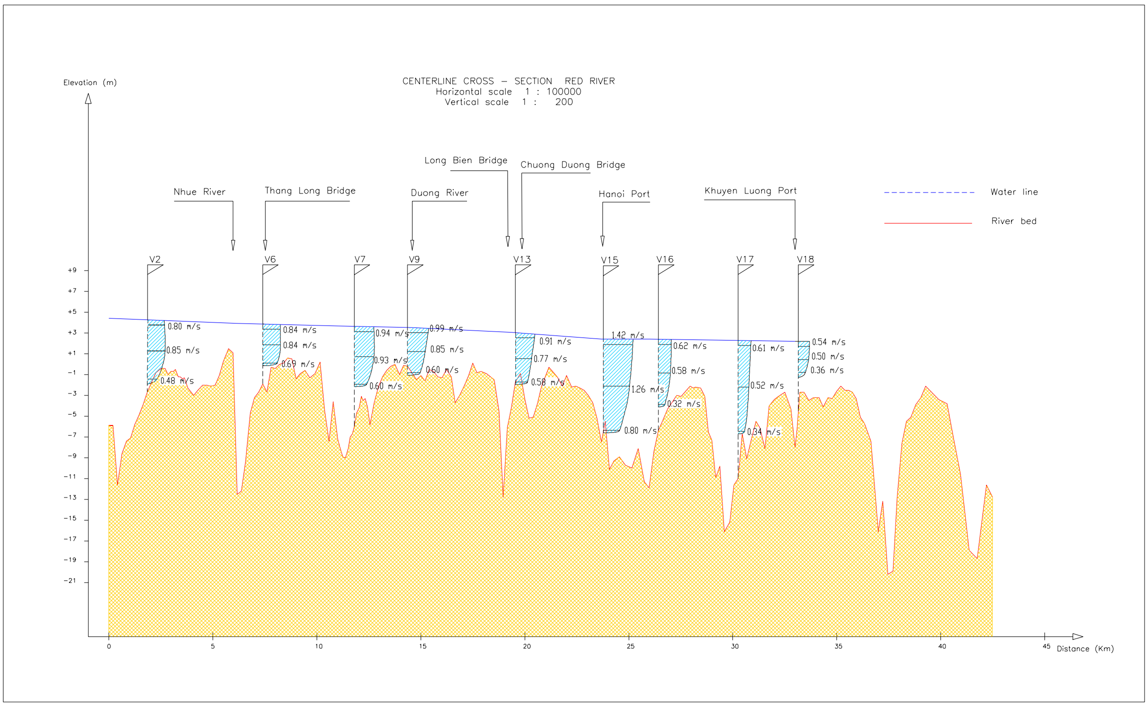


Figure V-2 Observed Current in the Dry Season (January 2002)

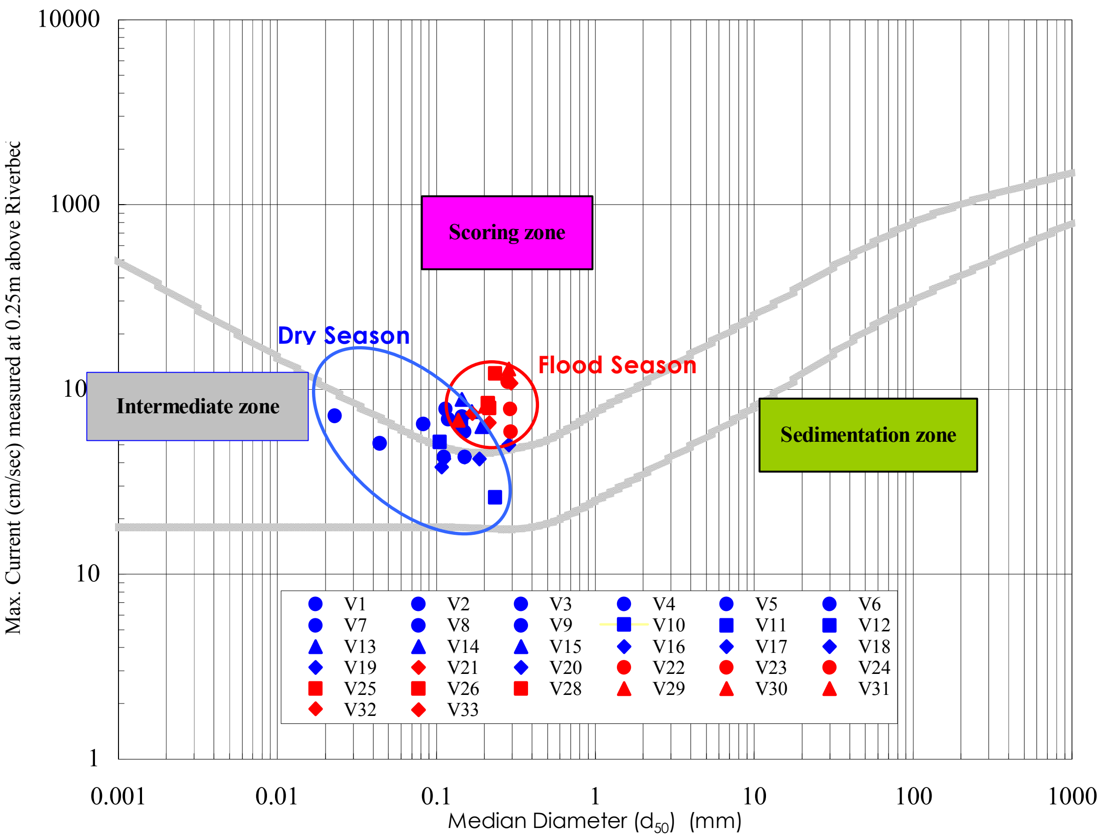


Figure V-3 Critical Erosion and Sedimentation Velocities (after Gilully, 1968)

103. The above-mentioned characteristics of the river-system constitute the basis for two major threats: on one hand, the risk for flooding of the riverine alluvial plain, and, on the other hand, the sedimentation/erosion features affecting both bank stability and navigation. Regarding these threats, Vietnam has since long initiated a series of civil and fluvial works, including earth dikes and dike strengthening, weirs, rubble-mound and pile groins, bank (slope) protections, training walls, maintenance dredging, etc. Large-scale dams for hydraulic power plants, including Hoa Binh Dam and Thac Ba Dam, have been playing a role of peek-shaving, stoppage of sediments, and prolonging the high water level. The effect of construction of Na Hang and Son La dams in the near future can be considered rather favorable for channel stabilization to reduce peak flood discharge and sediment discharge, and as a result to develop somewhat stable floodplains and possible bed degradation.

104. Undesired sedimentation occurs also in other specific segments of the IWT-network, and regular maintenance dredging is to be carried out in order to ascertain safe navigation, and compliant navigation channels. Sand mining by dredging is also executed on a regular basis and especially in the dynamic 'Hanoi Segment'. The amount of extraction reaches an order of 3 million m^3 per year.

105. The locations of stranded ships are identified as of January 2002, which provides information on navigationally difficult places and snags in the Red River Basin.

C. River Alignments and Profiles

106. In this Hanoi segment, three different alternatives for the alignment of the main stream proposed by TEDI are considered as shown in **Figure IV-3**. At this stage of the Study, preference is given to Alternative A as it ascertains an open access to the flow-discharge into the Duong River which ensures not only inland transport to/from Hai Phong, but also an evacuation of approximately 27 % of the flood-discharge of the Red River. Moreover, Alternative A is supposed to prevent siltation at the quays of Hanoi Port and other planned ports, or a major facility to be considered in the IWT development. The Alternative A also has advantages to maintain major water intakes, existing along the Segment.

107. In this JICA Study it is revealed that, in the Hanoi segment of the river - a 40 km stretch of the Red River between upstream of Thang Long Bridge and downstream of Khuyen Luong Port, the river adopts a multi-channel character with strong lateral shifts of channels and banks, and erosion/sedimentation patterns. In

two-year time between Dec. 1999 and Jan. 2002, erosions and sedimentations of 1 to 5m and lateral shifts more than 100m could be observed. Historical data were processed, and dedicated erosion/sedimentation surveys were executed in the dry and flood seasons to substantiate this Study. By comparing the measured depths in January and August 2002, it is found that, generally speaking, accretion occurred along the straight portions and erosion developed at the corners of meandering in front of Tam Xa, Trung Ha Sand bar, and Hanoi Port. The latter can be understood by the effects of increased currents caused by inertial force and secondary near-bed currents due to lateral hydraulic gradient by centrifugal force.

108. Detailed plane evolutions of river channels are analyzed for 1999 and 2002 and the results are shown in **Figure V-4**. Cross sections are analyzed based on the past bathymetries from 1987. The cross section at Thang Long Bridge shows quite stable features. They revealed that the significant dynamic change of riverbed, or the order of 10m differences in elevations, has been occurring as shown in **Figure V-5** for Trun Ha Sand Bar. This is mainly because of instability of the Talweg.

109. Very recently, there is a sign of change in the main stream from Alternative A to Alternative C, which is observed after the flood season in 2002, and to be stopped.

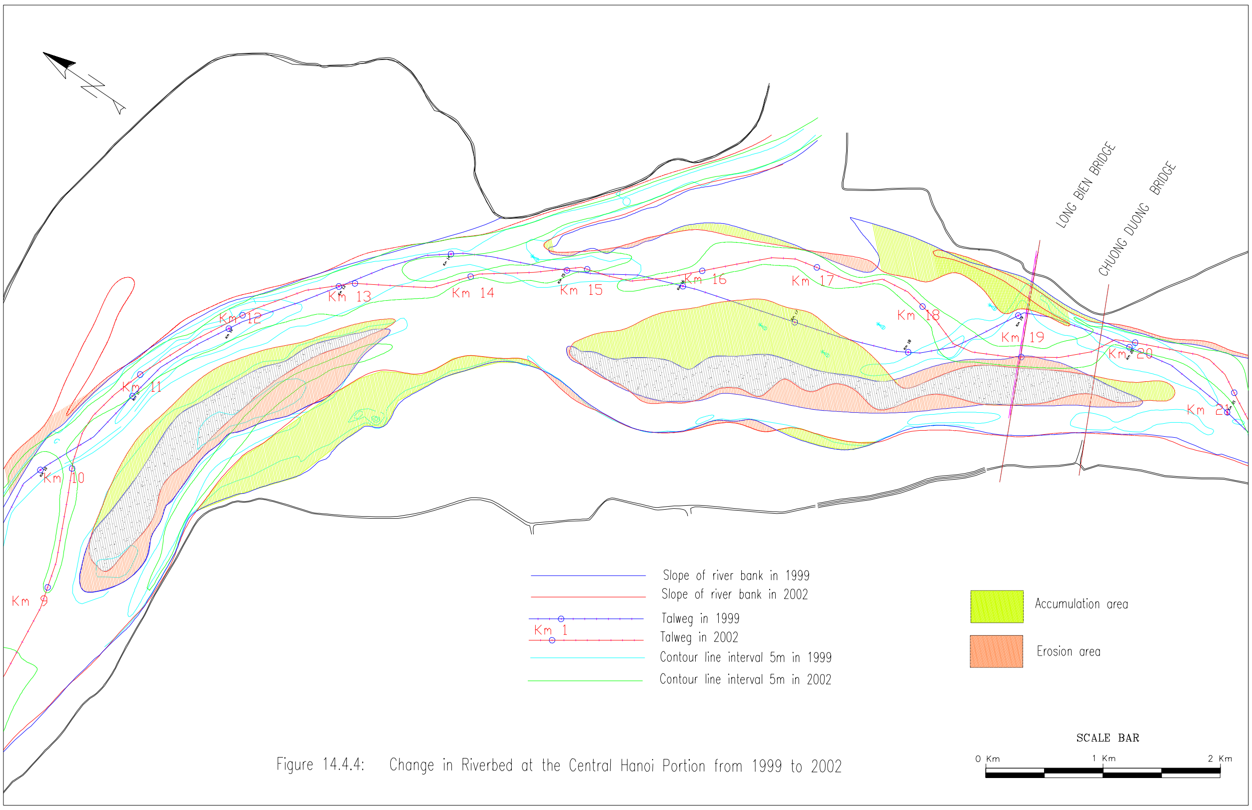


Figure V-4 Recent Change in Channel Morphology (Enlarged)

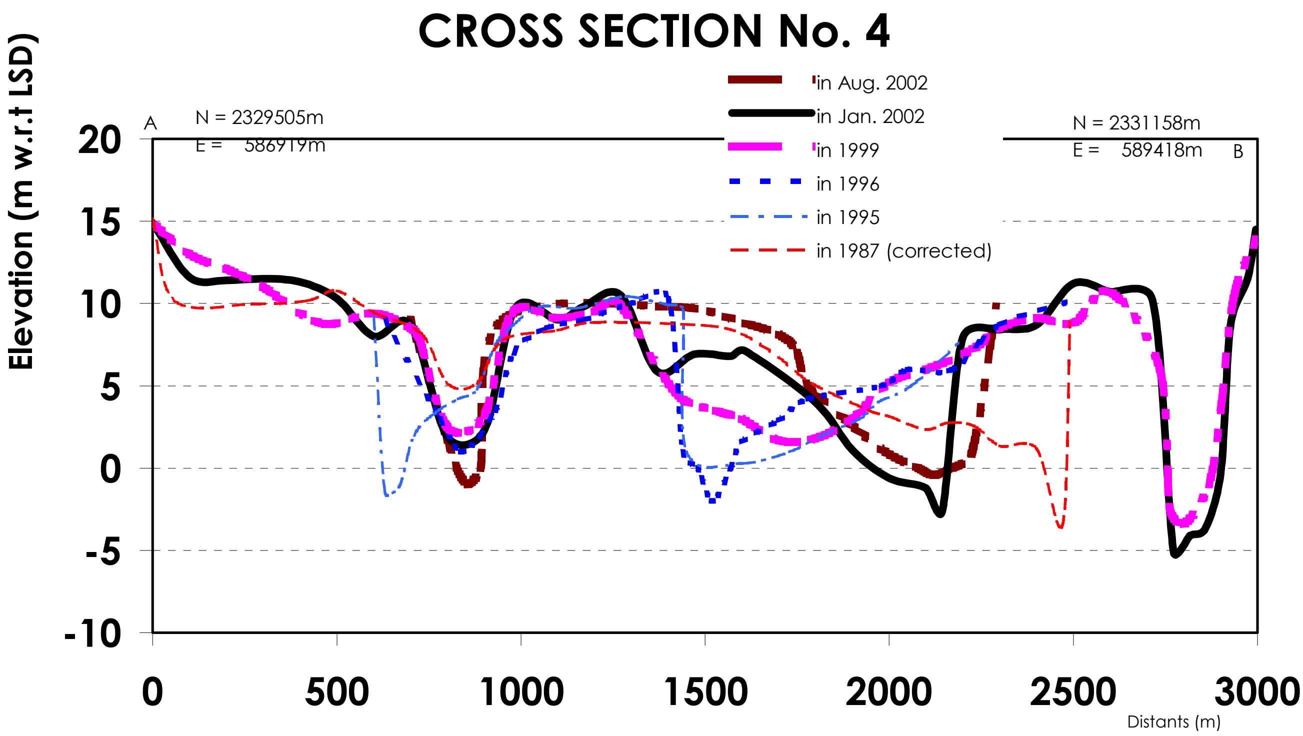


Figure V-5 Change in Cross Section at Trung Ha Sand Bar (Section at Km 18)

D. Channel Stabilization Measures

110. **Channel stabilization plan** is discussed in terms of basic policy, intention of countermeasures, general description of river regulation works (groins, training walls, sills and weirs), and hydraulic characteristics of river training philosophy. Taking account of the purposes of the channel stabilization plan, first the **basic sinuosity** is assumed as shown in **Figure V-6**.

111. As the **measures for river and channel stabilization,** three basic alternative plans (**Alternative 1, 2** and **3**) are selected and divided into the Priority Project (until 2010) and Long-term Plan (until 2020), which are shown in **Figure V-7**. It is considered that the existing groin fields at Tam Xa and Thach Cau Banks and around Tu Lien-Trung Ha Sand Bars are effective and prerequisite for planning of the new channel stabilization facilities.

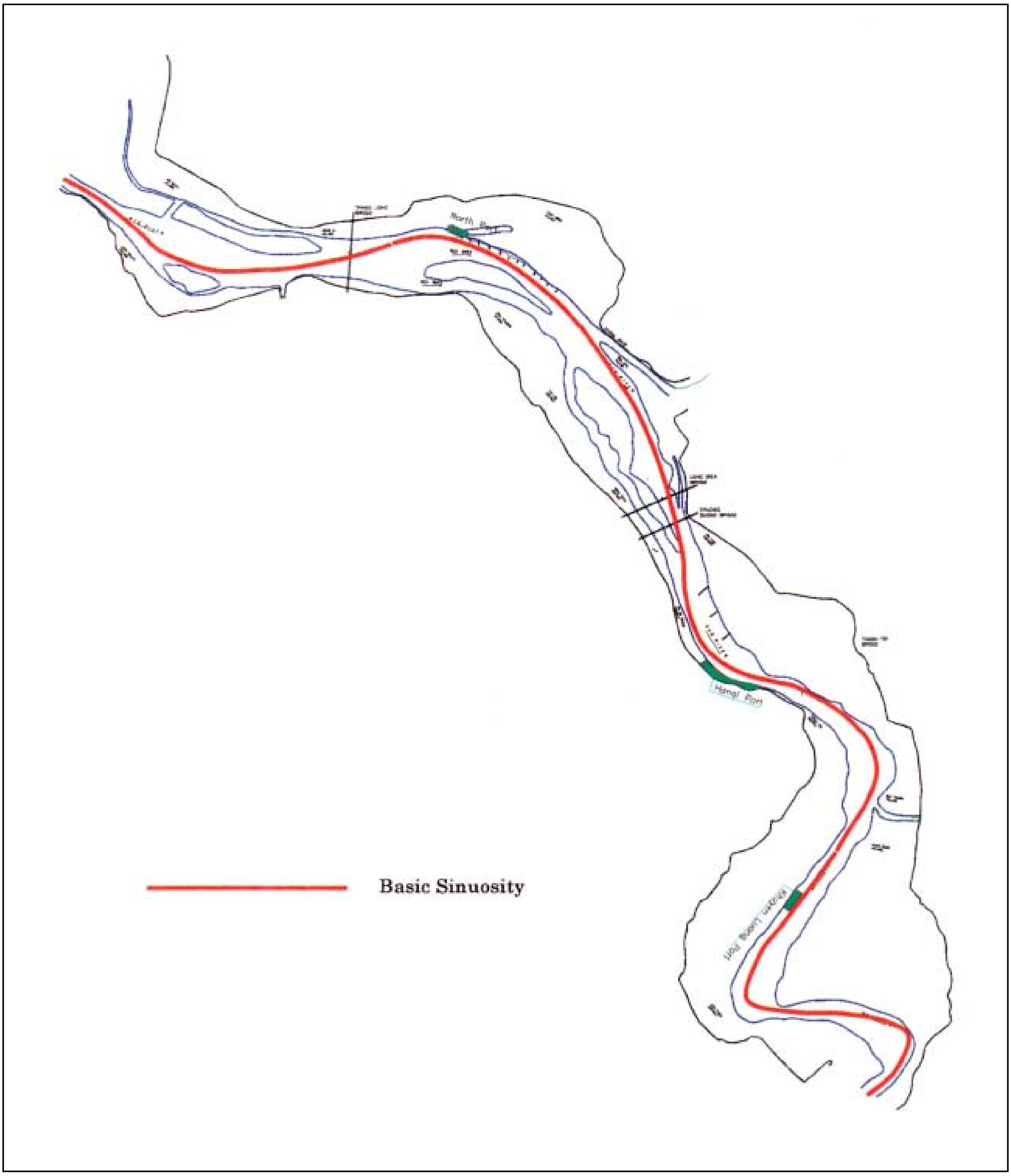


Figure V-6 Basic Sinuosity of the Main Flow in Hanoi Segment

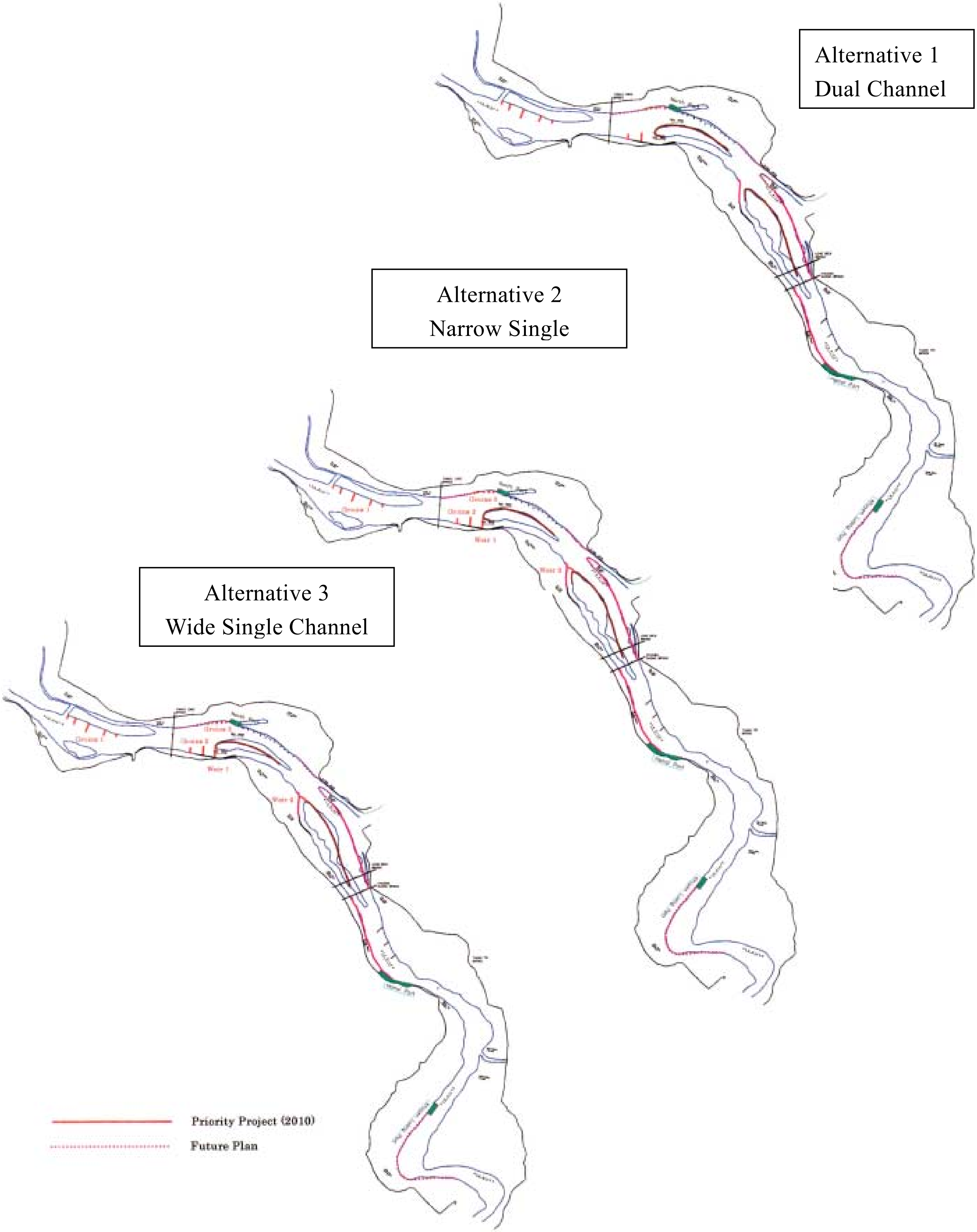


Figure V-7 Three Basic Alternatives of Arrangement of Channel Stabilization Facilities

112. **Alternative 1** aims at stabilization and maintenance of the present alignment of the channel, not to change the primary features of the *dual channels*. In **Alternative 2**, the waterway becomes a *single channel* by means of two weirs at the mouths of the second channel in order to close the secondary channel and to make the main channel stable and deep enough. **Alternative 3** is a modified plan of Alternative 2 by widening the main channel to ameliorate the excessive increase in velocity, discharge and water level, taking account of hydraulic cross sections, or Sh/Q ratio. They include the following facilities and locations:

1) Group of Groins (Structure: Permeable pile groins with varied length)
   - **Groin-1 (Vong La**): Along the Vong La Sand Bar to deviate the Talweg to the right side, and to guide the flow to the left bank at Hai Boi.
   - **Groin-2 (Dong Ngoc):** Right side downstream of Thang Long Bridge to guide the Talweg to the new Hanoi North Port at Hai Boi and constrict flow into and development of the second channel.
   - **Groin-3 (Nhat Tan):** Upper head portion of Nhat Tan Sand Bar to streamline the flow to the main channel, in case of need in the future.
2) Training Wall (Structure: Continuous walls)
   - **Training Wall-1 (Nhat Tan):** Along the head and the left side of Nhat Tan Sand Bar to maintain the bar and to control the flow in the main channel, the location of which is determined based on dynamic equilibrium analysis.
   - **Training Wall –2 (Tu lien-Trung Ha):** Along the left side of Tu Lien and Trung Ha Sand Bars to control the flow in the main channel and to prevent a cut of the bars, location of which is determined based on dynamic equilibrium analysis.
3) Bank Slope Protection (Structure: Stone and/or concrete covering, sheet piles, etc.)
   - **Bank Protection-1 (Thuong Cat):** Right bank at the opposite side of Vong La Sand Bar to protect the right bank from excessive bank erosion due to the effect of Groin-1 (To be considered in the Long-term Plan).
   - **Bank Protection-2 and 3 (North Port at Hai Boi):** Left Bank at Hai Boi at up and down portions of New North Port to protect the erosion of the bank due to the effect of Groin 1, 2, and 3, and the new port itself.
   - **Bank Protection-4 (Tam Xa):** Left bank of Tam Xa to strengthen the bank and prevent erosion (Long-term Plan).
   - **Bank Protection-5 (An Ninh):** Right bank at An Ninh to strengthen the entrance and secure flow into the secondary channel.

- **Bank Protection-6 (Bac Cau-Bo De):** Along the left bank of Bac Cau-Bo De Communes to streamline the flow, to prevent erosion and sedimentation, and ameliorate the side effect to Tu Lien-Trung Ha Sand Bar. The head of Bac Cau (Long-term) to prevent erosion and to maintain the entrance of the Duong River (Long-term Plan).
- **Bank Protection-7 (Ly Thai To- Bach Dang):** Right bank at the upstream portion of Hanoi Port to prevent erosion of the slope beside the channel and sedimentation in front of the Port (Upstream portion in Long-term Plan).
- **Bank Protection-8 (Duyen Ha):** Along concave corners at Duyen Ha to secure the channel and to stop developing of meandering (Long-term Plan).

4) Weirs (**Alternatives 2** and **3**, Structure: Submerged gravel and stone mound)

- **Weirs-1 and 2:** At the two mouths of the secondary channels at Nhat Tan Sand Bar and Tu Lien-Trung Ha Sand Bar for **Alternatives 2** and **3**.

113. The structure and permeability of the groins is discussed, and pile structure is selected with the top level of 3 to 4m and the crown level of group piles of LSD+9m, taking account of a permeability of 0.5 to 0.7 under the flood condition. The diagram to show the permeability is presented in **Figure V-8**.

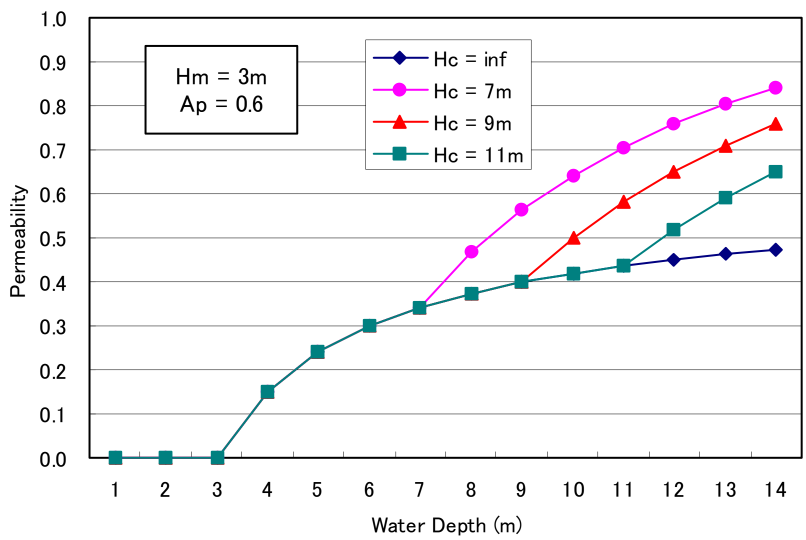


Figure V-8 Permeability of Groins (Mound height: 3m, Permeability of Piles: 0.6)

E. Justification and Evaluation of Channel Stabilization Measures

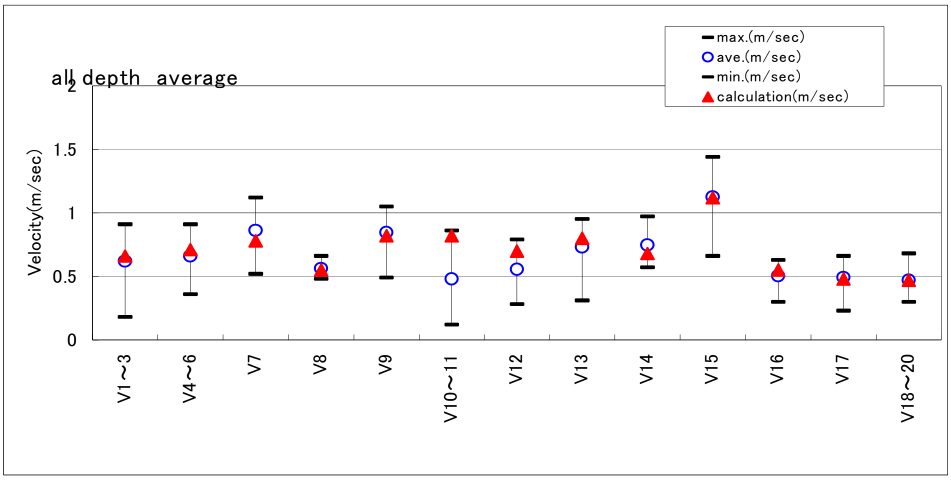
114. As a tool for analyzing hydraulic and morphological phenomena and predicting the effect of channel development, a **computer simulation model** is introduced in this Study. The model is two-dimensional shallow water model with the cylindrical coordinate system, which is suitable to represent curved river configurations.

115. The model is first calibrated in terms of velocity and SS between the simulated and the measured values in dry and flood seasons in January and August 2002. The calibration results on current are shown in **Figure V-9.** They agree with each other very well, which proves the model's reliability as far as the present river configuration is concerned.

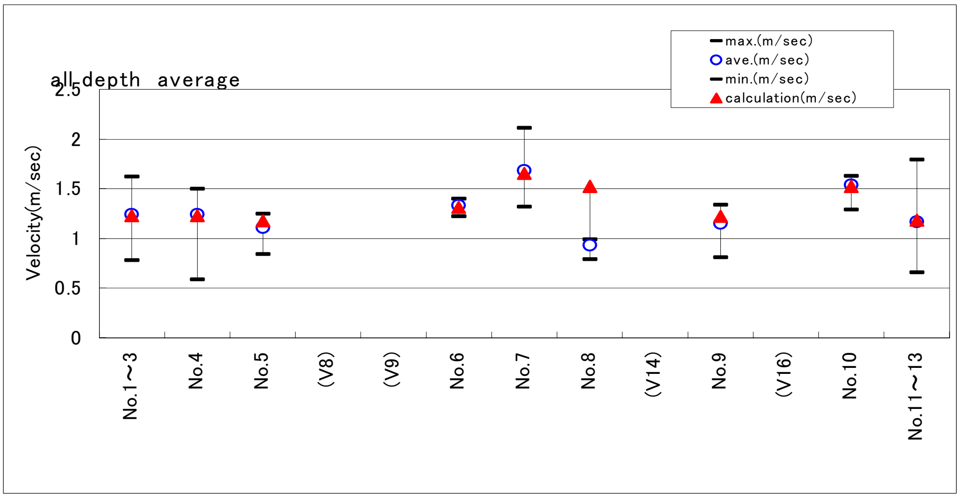
116. **Stability of the present river channel** at 40km segment of the Red River in the dry season is analyzed by means of computer simulations of the current and the riverbed for the following three cases:

1) The present flow and morphology as the base case (two cases with and without the existing groins).
2) Imaginary deviations of current direction at Thang Long Bridge from the present direction to extremely north and south directions (two cases).

117. With regard to 1), the pattern and magnitude of flow vectors coincide with the measured velocity and the route of Talweg. The riverbed varies insignificantly. It is considered that the present state of the river configuration and flow is stable and no significant change is expected during the dry season (water level at Hanoi H-M Station = LSD +3.1m). For the case 2), the flow condition changes drastically, which prevails in all the areas of the river. Erosion of riverbed and banks at the deviated direction and accretion at the opposite direction are anticipated. The conditions of 2) cause instability in flow and discharge in both the Red River and the Duong River. It may develop a large-scale change in river morphology, although the change is maintained small in the dry season.



(1) Dry Season



(2) Flood Season

Figure V-9 Calibration of Numerical 2-D Hydraulic Simulation Model

118. After the flood season, in October 2002, there is a sign of the above item 2) where the main stream is going to change to the secondary channel on the right at Nhat Tan Sand Bar.

119. For the flood season (water level at Hanoi H-M Station = LSD +9.3m), the degree of difference in current speed of the Alternatives is compared with the current speed of the present condition. The ratios of current speeds are shown in **Figure V-10 (1)** and **(2)** for **Alternative 1** and **2**, respectively. The major characteristics can be summarized as follows:

1) **Alternative 2** indicates strong effects of Weir 1 on increase in the water level of 18 cm in the Location A. Even **Alternative 3** has an increase in water level of 6 cm. Whereas **Alternative 1** has a limited increase of 3.5 cm.

Water level in the Duong River does not change significantly for the all Alternatives, or maximum 3cm.

2) Increase in current velocity at Locations A and E, and decrease at Location B are significant in the cases of **Alternative 2** and **3**, and the maximum speed exceeds 1.5 m/sec at Location A. **Alternative 1** has moderate increase at the same Location.
3) Water discharge shows the same tendency as the current. It is noted that the discharge in the Duong River decreases slightly in the case of **Alternative 3.**
4) Cross-section/Discharge ratios of **Alternative 1** show relatively stable values along the river sections compared with those of **Alternatives 2** and **3**.

120. Thus, **Alternative 1** is chosen as the most preferable case of the river stabilization measures.

121. In order to confirm the appropriate width of the channels, surveyed hydraulic parameters are examined in terms of hydraulic section; *A*, water surface width; *B*, and average water depth; *H*. **Figure V-11** is the case of the transitional season, in which water level is LSD +6.00 m at Hanoi H-M Station. It is derived from this Figure that the existing channels have the following dimensional characteristics:

At Nhat Tan Sand Bar,

Main Channel:	B 600m x H 6m = A 3,600 m^2
Secondary Channel:	B 300m x H 5m = A 1,500 m^2
Total:	B 900m A 5,100 m^2

At Tu Lien- Trung Ha Sand Bar,

Main Channel:	B 500m x H 6m = A 3,000 m^2
Secondary Channel:	B 200m x H 3m = A 600 m^2
Total:	B 700m A 3,600 m^2

122. Another examination is made based on a theoretical relationship between width and depth of a rectangular channel under dynamic equilibrium state:

$$y = a\, x^{-b} \qquad (1)$$

where $y = B/B_0$ and $x = H/H_0$. The actual data are applied to this equation by the least squares method. The result is shown in **Figure V-12**, or a = 1.0624 and b = 0.8218. Then, the optimum main channel widths are confirmed to be about 600m for Nhat Than Sand Bar and about 500m for Tu Lien- Trung Ha Sand Bar as shown in **Table V-2**.

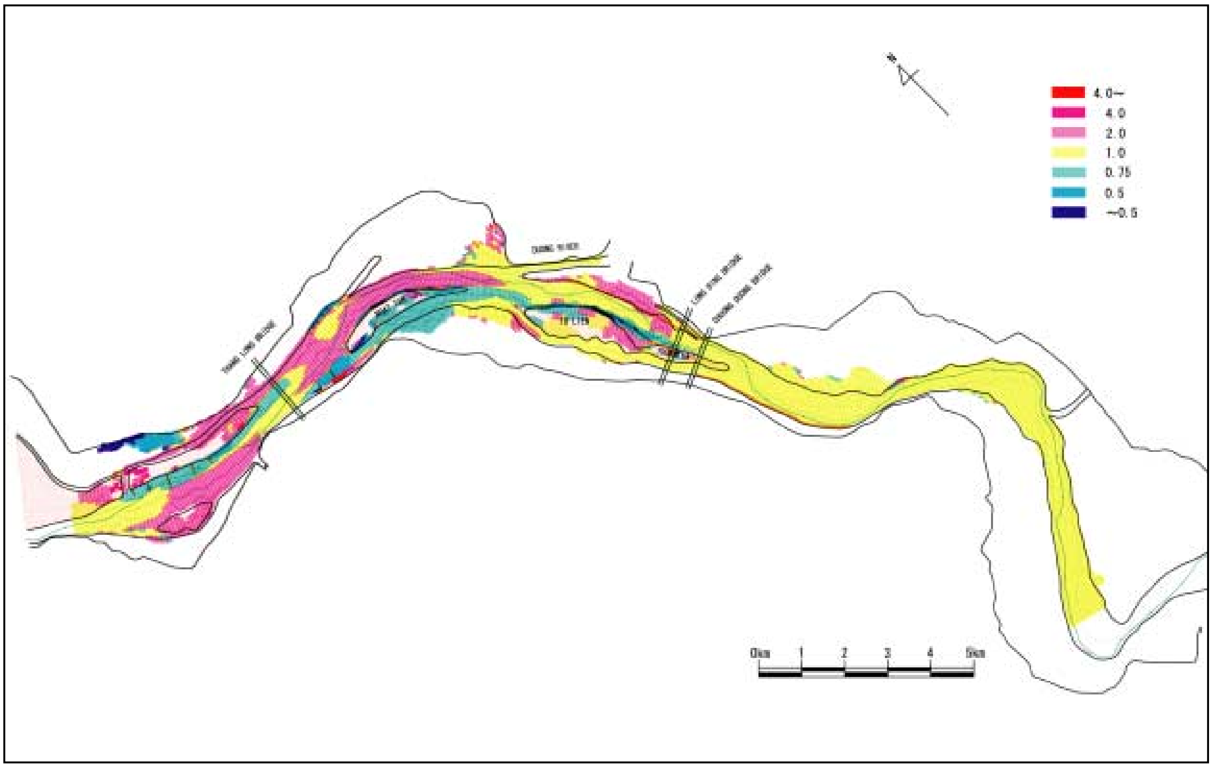


Figure V-10 (1) Ratio of Current Speed (Flood Season: Alt. 1 / Present Condition)

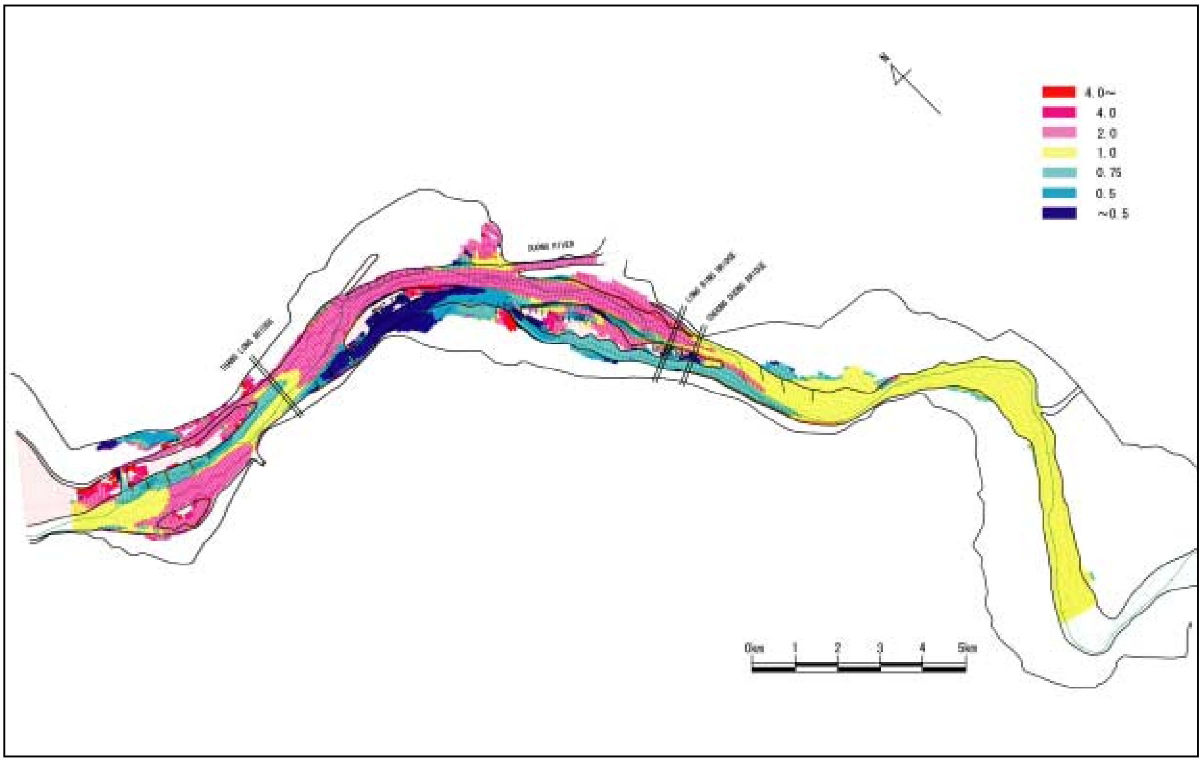


Figure V-10 (2) Ratio of Current Speed (Flood Season: Alt. 2 / Present Condition)

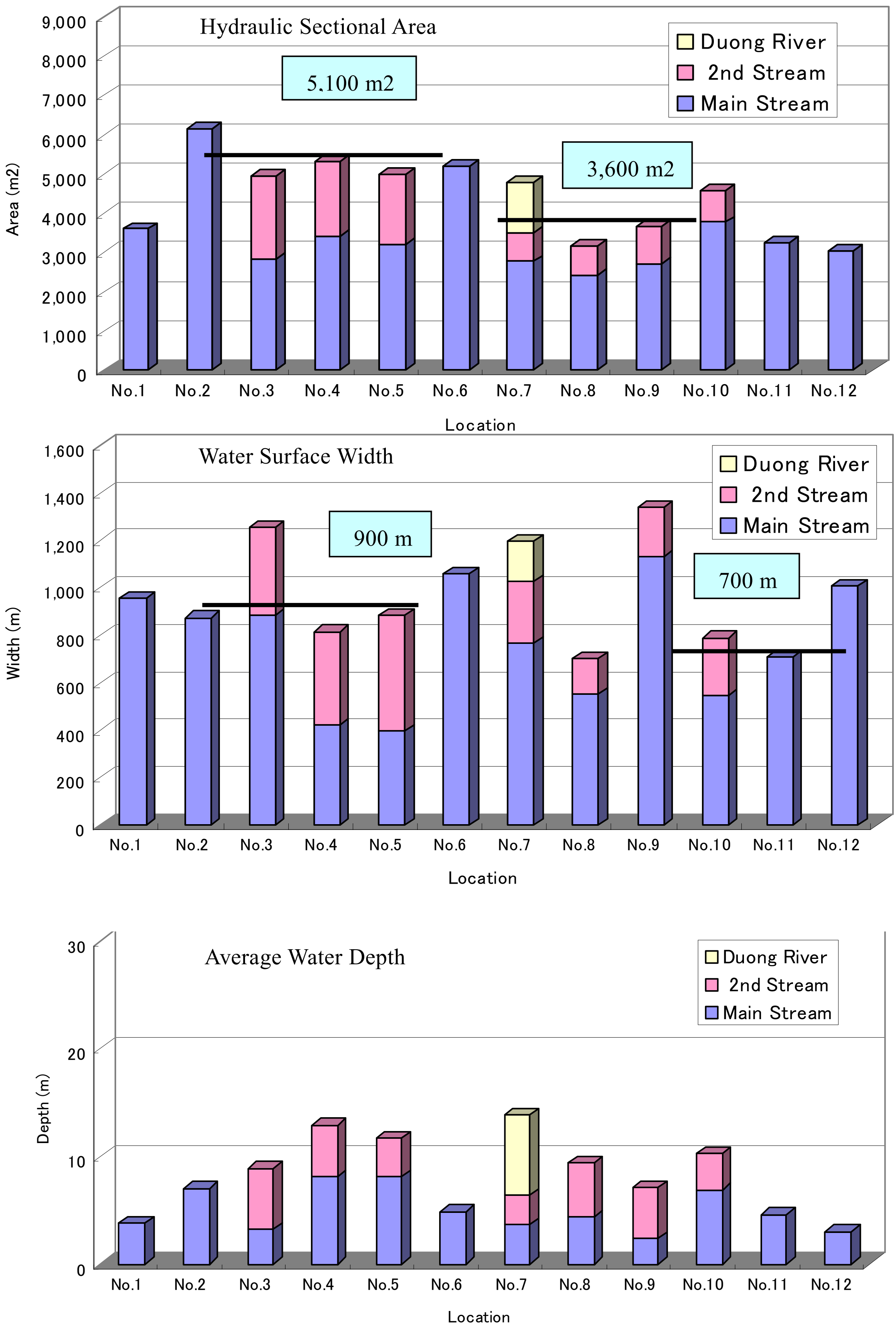


Figure V-11 Dimensional Characteristics of the Existing Channels in the Transitional Season (Water level: CDL +6.00m)

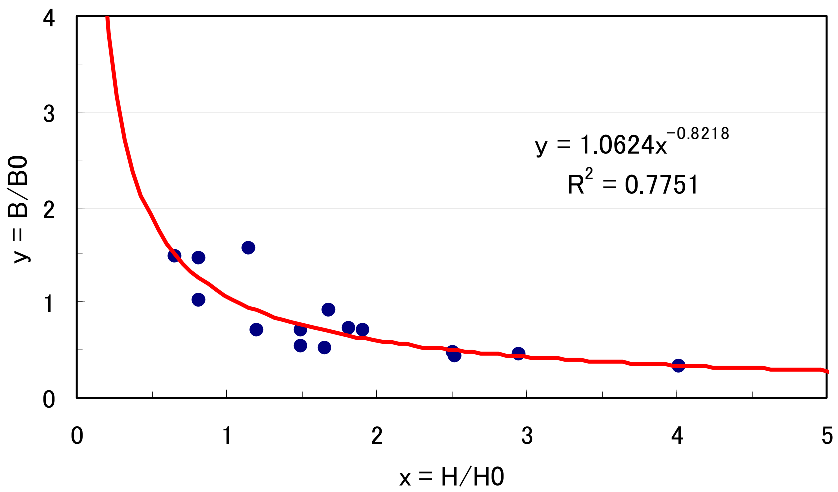


Figure V-12　Relationship between Channel Width and Depth

Table V-2　Required Channel Width based on Theoretical Balance Equation

(Unit: m)

Location	Percentage Occurrence	Water Depth		Channel Width	
		H	*H₀*	*B₀*	*B*
Nhat Tan Sand Bar	7%	9	6.18	891	695
	27%	6	3.22	883	563
	95%	2.5	1.56	794	573
	Average				610
Tu Lien-Trung Ha Sand Bar	7%	9	6.46	794	642
	27%	6	3.63	766	539
	95%	2.5	1.74	362	286
	Average				490

123.　Lastly, the **flood drainage capacity** is examined by the simulation model for a very high water level of 12.5 m (Water discharge at the upper boundary = 22,700 m^3/sec) and an extremely high water level of 13.4 m (Water discharge at the upper boundary = 32,400 m^3/sec). The result of flow vector is shown in **Figure V-13** for the case of extremely high water level with consideration of self-scouring effect by channel stabilization facilities. The bank is inundated in the both sides of the dikes. Comparing with the result of simulation for **Alternative-1**, it is confirmed that the channel stabilization facilities have little effects on the flood discharge. A slight decrease in flow into the Duong River is expected. The anticipated **change in water levels** at major points in the segment is summarized in **Table V-3** for the case of extremely high water level. The water level is expected to be reduced at the upper river portions owing to self-scouring effect due to flood. The increase due to construction of channel stabilization facilities occurs at downstream of Choung Duong Bridge, which is an order of few cm or minimal. It is noted that, in the above analysis, the **flood drainage corridor** is maintained as same as that of the present conditions, or the area between the existing dikes. Thus, the effect of the facilities can be neglected on flood conditions.

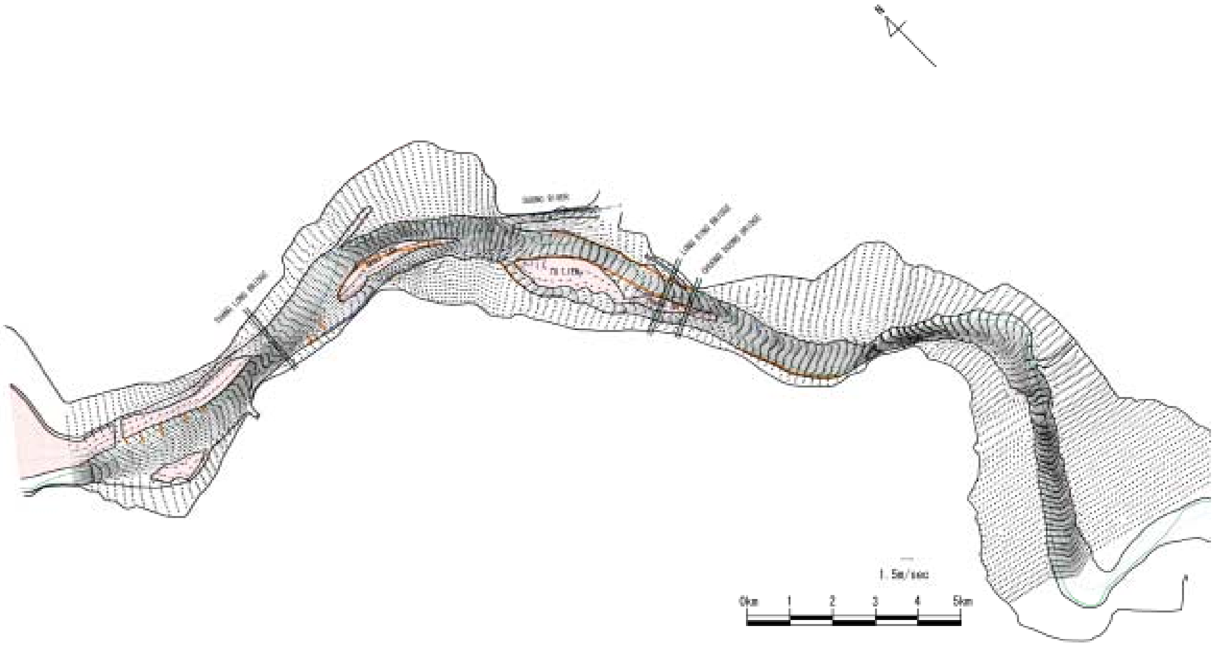


Figure V-13 Flow Vectors of Very High Flood (H=13.4m, Alternative 5s)

Table V-3 Change in Flood Water Level due to Channel Stabilization Facilities

(Water depth: 13.4m at Hanoi H-M Station)

Location	Increase in Water Level	Remarks
Thang Long Bridge	- 2 cm	
New North Port	- 12 cm	Hai Boi Commune
Duong River	- 1 cm	
Hanoi H-M Station	- 3 cm	
Hanoi Port	+ 2 cm	

F. Considerations on Implementation

124. The plane alignment of the channel stabilization facilities is summarized in **Figure V-14**. It is noted that, in order to stabilize the secondary channel at Lach Quyt, the mouth of which is fixed by the extended training wall, T2, and the bank slope protection works, B5. The construction sequence is presented in **Table V-4,** which takes account of completion of the Short-term Plan by the end of 2009. The groins are proposed to be built one by one, and the training walls to be constructed, in principle, from upstream to downstream.

125. It is recommended that, in consideration of the recent trend of changes of the main channel into the secondary channel, the proposed stabilization measures should be undertaken as soon as possible. In the detailed design stage before construction the above plan shall be further examined and confirmed by additional simulations by means of numerical and physical models with movable riverbed. The above facilities for channel stabilization should be constructed step by step with careful monitoring on the effects of the facilities by follow up surveys, at least twice a year in the dry and the flood seasons, including bathymetric, topographic, and hydraulic surveys, and review of the plan taking account of the expected and realized effects, priority, timing, and scale of the facilities. Flexible and mobile operations of dredging should be incorporated in addition to construction of hard facilities. The capital dredging could amount to an order of 3 million m^3. Even though self-scouring effect is expected owing to the channel stabilization facilities, a certain amount of periodical maintenance dredging should be taken into account to secure the planned channel depth at sedimentation areas during the dry season.

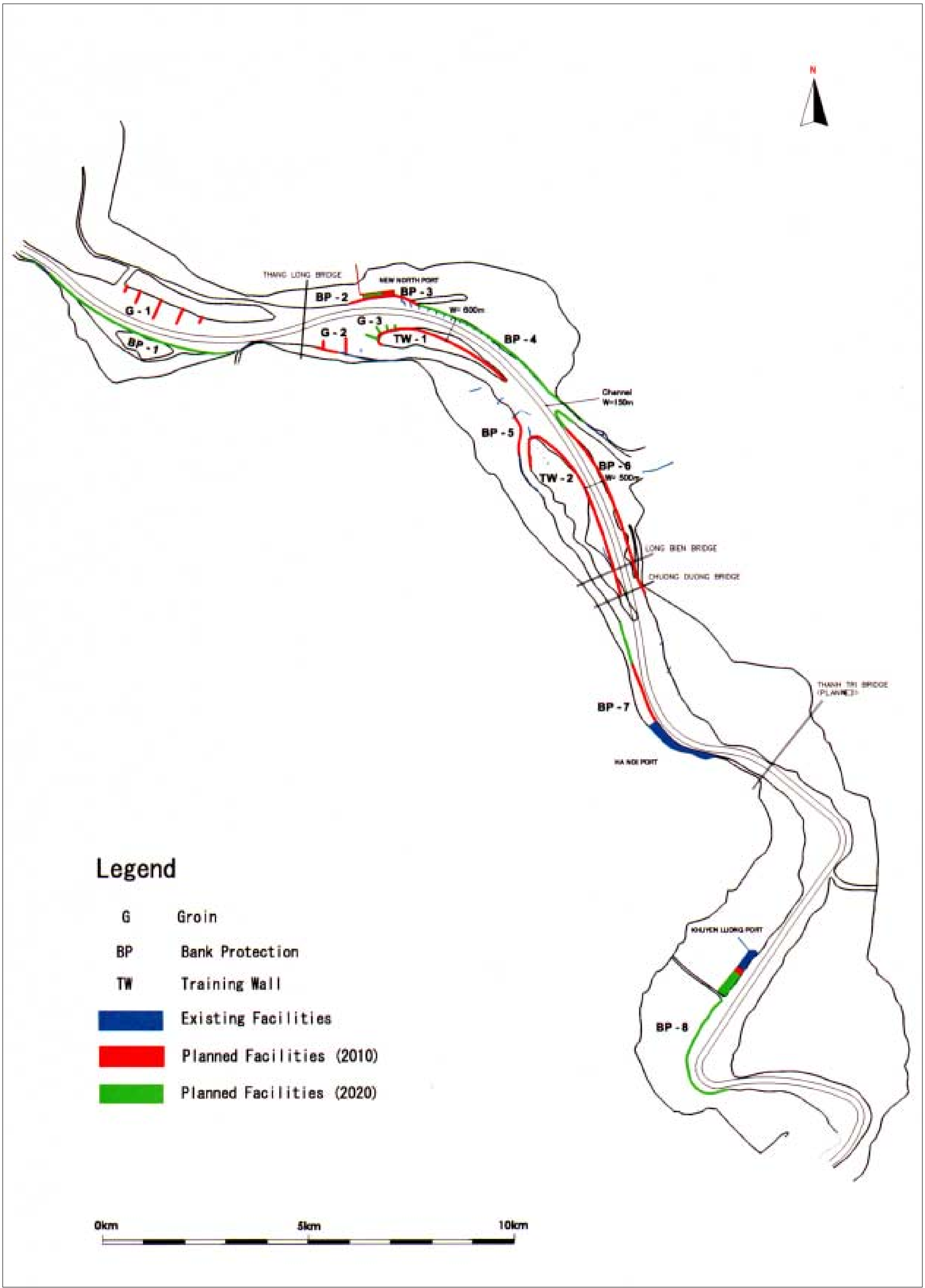


Figure V-14 Proposed Alignment of Channel Stabilization Facilities

Table V-4 Construction Sequences of Channel Stabilization Facilities

Unit: m

Facilities	Location	Short Term (2010)					Long Term
		1st period	2 nd period	3 rd period	4 th period	Total	-(2020)
Groin - 1	①	150				150	
(Vong La)	②	300				300	
	③	500				500	
	④		400			400	
	⑤		150			150	
	Total	950	550			***1,500***	
Groin - 2	①	200				200	
(Dong Ngoc)	②		400			400	
	Total	200	400			***600***	
	Foot Protecion	500				500	
Groin - 3 (Nhat Tan)	① – ④						***900***
Training Wall - 1	Head		800			800	
(Nhat Tan)	Side		500	1,500	1,500	3,500	
	Total		1,300	1,500	1,500	***4,300***	
Training Wall - 2	Head		1,000			1,000	
(Tu Lien-Trung Ha)	Side (upstream)		1,500			1,500	
	Side (downstream)			1,500	1,500	3,000	
	Total		2,500	1,500	1,500	***5,500***	
Bank Protection - 1 (Thuong Cat)							***5,200***
Bank Protection - 2 (Hai Boi, N-Port)					800	**800**	
Bank Protection - 3 (Hai Boi、N-Port)					500	**500**	
Bank Protection - 4 (Tam Xa)							***4,300***
Bank Protection - 5 (An Ninh)		1,000				**1,000**	
Bank Protection - 6	Head						1,000
(Bac Cau-Bo De)	Side (upstream)		1,500			1,500	
	Side (downstream)			1,500	1,500	3,000	
	Total		1,500	1,500	1,500	***4,500***	***1,000***
Bank Protection - 7	Upstream						1,000
(Ly Thai To-Bach Dang)	Middle			1,500		1,500	
	Downstream (H.N port)				800	800	
	Total			1,500	800	***2,300***	***1,000***
Bank Protection - 8 (Duyen Ha)							***2,500***