Conference Paper, Published Version

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Bank Erosion Mitigation Red River Vietnam, Towards an Anticipating River Training Strategy

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I. INTRODUCTION

Bank protection, as a means of mitigation of bank erosion along rivers, may serve different goals and may take different forms. The different goals are not always addressed well in bank protection design. In addition, bank protection works may themselves induce more severe erosion, when not properly designed within the total concept of river training. These issues will be dealt with in this paper. The ideas are illustrated for the Red River system in Vietnam, for which the authors analyzed the erosion problems and reviewed the current practices regarding planning, implementation and monitoring of bank protection works.

II. BACKGROUND

One of the most prominent issues in current river training is the control of bank erosion. Bank erosion may cause major loss of land and property and may endanger the stability of structures such as embankments. Apart from the settlements at the river banks that need to be protected, flood plains may be inhabited or used economically. In the latter case severe bank erosion has to be controlled there as well. At the other hand, bank erosion is a natural manifestation of river dynamics. By introducing extensive bank protection works, the natural dynamics of rivers is suppressed and adverse effects may arise, such as the creation of very sharp bends, as shown in Fig. 1 below.

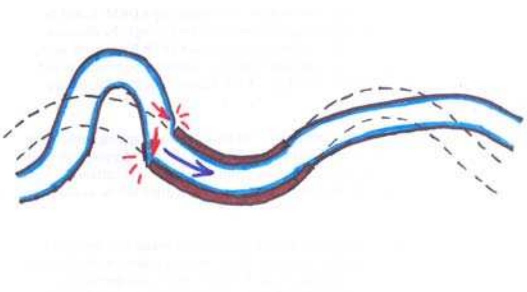

FIGURE 1. EFFECT OF LOCAL FIXATION OF MEANDER BEND

Man-made bank protection works may even change the course of the main channel, such as in Pakistan where spurs built in Punjabi rivers are attracting head-on attack during floods. These examples show that bank protection works should be considered within the total framework of river training. Such a framework, as presented hereafter, may help river managers in placing bank protection in the wider context of integrated river management and to formulate an anticipating river training strategy.

III. OBJECTIVES AND FUNCTIONS

The objectives and functions of bank protection works show a hierarchy:

Type A = first type of protection: protection of higher grounds from erosion and to provide safety against flooding. In addition, critical infrastructure can be protected, i.e. bridge abutments and pipeline crossings.

Type B = second type of protection: protection of flood plains to mitigate erosion and to provide safety against erosion and (frequent) flooding of the floodplain.

Type C = third type of protection: promotion of navigation by fixation/constriction of the main channel.

The spatial appearance of these types of protection levels is illustrated in Fig. 2 below.

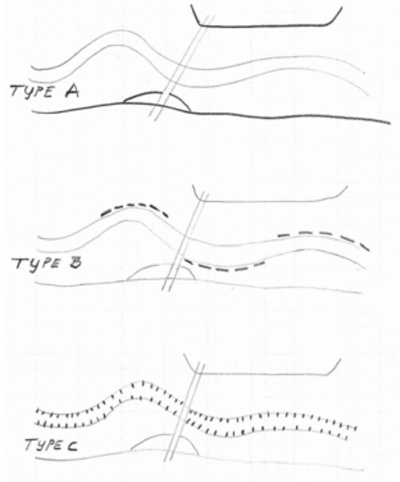

FIGURE 2. ILLUSTRATION OF DIFFERENT TYPES OF PROTECTION

The different types of protection can be combined, e.g. starting from Type A, proceeding with Type B and ending up with Type C, as was the case in the Netherlands' Rhine river system. As a result, the whole river system has gradually been trained and controlled. In contrast, Type A will leave maximum river dynamics and maximum natural development. The three types are sometimes three successive stages in the training of the river, but not necessarily because they serve different purposes: flood protection, erosion protection and navigation. Hence, e.g. combinations of Types A and C, without Type B are also possible. Type C, serving the development of inland navigation can also be applied in absence of Types A and B, e.g. in natural river systems with minor interventions, such as seasonal training works to influence the sediment distribution. At present there is a strong tendency for the Rhine rivers to allow the river more space and dynamics and to restore natural assets. This implies reducing Type B protection, while maintaining Types A and C.

The different protection levels require different types of bank protection structures:

Type A requires high structures and high safety levels → massive and solid bank protection works.

Type B requires intermediate structures and intermediate safety levels

→ less massive and less solid bank protection works.

Type C requires low structures and minor safety levels

→ (usually) modest or provisional bank protection works, focused on constriction of the fairway and/or sediment management.

It should be remarked that only in case of extreme navigational demands, e.g. at the Waal river in the Netherlands, the protection works of Type C will have to be extensive, such as a continuous groyne system in the Waal river, shown in Fig. 3.

IV. Overall Situation of Bank protections along the Red River

The authors of this paper participated in a mission for evaluation of bank erosion and current protection works in the Red River in Vietnam [1]. The location was upstream of Hanoi (up to Viet Tri) and downstream of Hanoi (up to Hung Yen). In addition distributaries, the Duong River, the Thai Binh and the Luoc, have been surveyed.

The protection levels of these river stretches are typically of Types A and B. Training works for navigation are in a premature stage yet. Type A is evident from the high flood embankments surrounding the meander belt and the densely populated areas to be protected. These embankments have to be protected from outflanking of the main channel during high river flows. At many locations, the main channel approaches the primary embankments and there the focal point is laid on the bank protection works. However, the flood plains are also widely occupied: large and small settlements and intensive economic activities (e.g. sand mining, agriculture). At the larger villages Type A protection is used, leading to encroachments of the flood plains. Generally, however, Type B protection applies, mainly concentrated near sharp outer bends.

FIGURE 3. AREAL VIEW OF GOYNES AT THE WAAL RIVER

The encroachment of the natural flood plains can have adverse effects, with effects comparable to Fig. 1, as shown in Fig. 4. This will, together with the other occupation in and usage of the flood plains, increase flooding risk. From this example, it can be seen that river management should in the first place be spatially oriented with due consideration of the dynamic character of the river. Given the situation as it is now, with a strongly utilized and tamed river, the Type A and Type B protections may need to be continued. This is acknowledged and practiced in present bank protection design for the Red River.

In spite of the river training works already applied, the Red River locally still has some dynamic character. This can be seen from Fig. 5. Herein the plan form upstream of Hanoi is shown in 1990 as well as in 2000 (white lines) from satellite images. In recent years and in the years to come, however, more and more bank protection works do contribute to further fixation of the main channel. Yet after every flood season, new endangered locations arise which have to be urgently protected.

Some of the river authorities showed an inclination towards full protection of the main channel by means of groynes. It should be kept in mind, however, that this protection is of Type C, which would not be justified from navigational point-of-view at present. Navigation is coming up as an economical factor, but is still modest. Another item arises here: the large difference in low water levels and flood levels. As a consequence, it would suffice to keep the protection works (e.g. groynes) of Type C modest, which is also important from an economical point-of-view. In that case, however, these works will not provide sufficient protection for the flood plains (Type B), let alone for the higher grounds (Type A). The sparse groynes that have already been constructed near the primary embankments do not seem to be very effective up to now. Groyne construction, as compared to direct strengthening of the banks is not economical, as the material usage increases strongly with increasing heights. Hence, groynes should not be applied as a protection for the primary embankments.

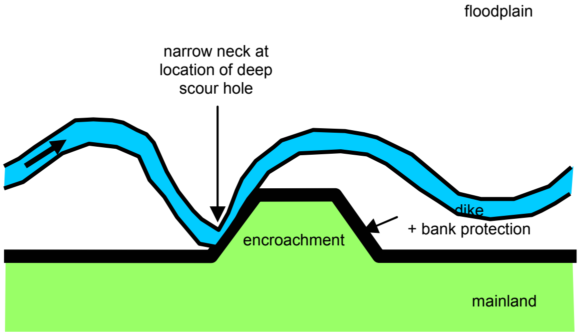

FIGURE 4. 'FOLDING' OF CHANNEL NEAR ENCROACHMENT

The planning and execution of bank protection works is mainly reactive-based, i.e. as an instant reaction upon the observation of strong bank erosion after the flood season. At those locations, the bathymetry is measured and a decision is made on the necessity for bank protection works. If deemed necessary, these works are initiated shortly after a positive decision. The respective departments are dealing with this approach effectively. This approach is also highly cost-effective on the short-term, which is inevitable with the limited funds available at present.

V. Review of locations already protected

Bank erosion has been intense along the Red River. Over the years, the reactive response resulted in relatively long stretches of protected banks of the main channel. This followed from an inventory, including field visits, during the mission of the authors. A typical illustration is shown in Fig. 6 for the section of the Red River upstream of Hanoi.

This example shows that the dynamics of the Red River near Ha Noi is strongly reduced nowadays by the presence of these protection works. Also in other stretches nearly every outer bend is provided with some protection. This can be well-understood from the demand for Type B protection (floodplains). However, some dynamics still remains and in future new critical bank sections will certainly continue to appear.

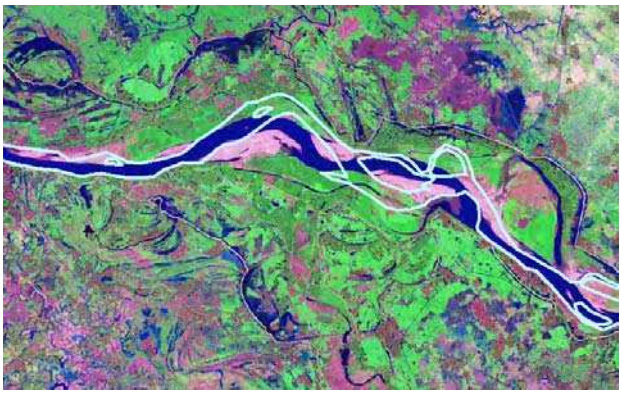

FIGURE 5. PLAN FORM CHANGES FROM SATELLITE IMAGES

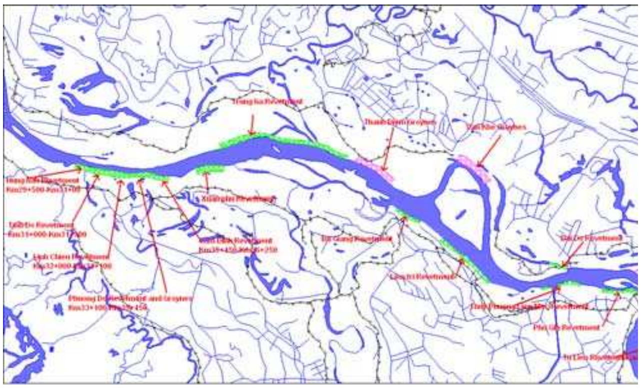

FIGURE 6. ILLUSTRATION OF BANK PROTECTION WORKS

VI. Structural design of bank protection

During floods the flow velocities in the Red River are large and, as a consequence, the tractive forces on the slopes are large as well. Hence, the banks need to be protected in a robust way. To cope with this requirement, the Red River authority developed a special type of protection: concrete or masonry grids, filled up with a neatly placed rockfill stone pitching. This type of protection is called 'Tsu Phan' and is shown in Fig. 7 below. This rockfill layer is provided with a filter layer underneath of crushed gravel. The use of geotextiles, as separation between gravel layer and soil, was observed at some places, but was absent at other places.

Below the waterline, rubble is dumped to fill up the slope to the desired angle or gabions or bamboo-packed stone sausages ('dragons') are applied. Before placing the stabilization, the slope above the waterline is re-adjusted to the desired slope angle (usually around 1: 2.5) by removing or replenishing the soil.

There are quite some advantages to this method, such as easy visual construction without measuring equipment after the grids have been installed. Another advantage is that the stone pitching is enclosed by the concrete or masonry grids, what adds to the stiffness of the pitching. Initially, drainage ditches can be made first. They are accurately positioned and provide a reference position for the subsequent construction of the grids.

The stone pitching is able to withstand large flow velocities, in spite of the small stones used, and is far more preferable than a loose rockfill revetment in this situation (scarcity of large rockfill scarce, abundant relatively cheap labour).

FIGURE 7. STONE PITCHING GRID ('TSU PHAN')

VII. Discussion

Bank erosion is a major threat to safety and occupied areas in the floodplains of the Red River. Hence, the efforts and costs of bank protection works is substantial. The mission team felt that the approach of the Red River authorities (Dike Departments) to combat bank erosion is highly cost-effective and adequate. The reactive strategy is fitting well into the present budget framework.

Additional budget, however, may give the opportunity to arrive at a more anticipating river training strategy. Such a strategy would allow a more preventive approach and would possibly minimize bank protection works in future.

Bank erosion is just one phenomenon of the complex morphodynamic behaviour of the river. A better understanding of the morphodynamics is important for a sustainable long-term river management strategy. This is especially important while at present hydraulic and morphological data are scarce. At the same time, the Red River experiences large changes, e.g. a strong decrease of the forest cover of the Da River (a major upstream tributary) [2] over the last decades, excessive sand mining from the river (poorly recorded) and ongoing occupation of flood plain areas. In addition, the morphodynamic behaviour of the river is complicated by the large difference between discharges in the flood and in the dry season (factor 20).

It is very important to maintain safety levels against flooding in future. This requires a better understanding, a better monitoring of plan form changes and improved predictions on the morphodynamic development of the Red River system.

Such knowledge can be used very well for introducing a more anticipating bank protection strategy, which will also contribute to safety and cost-effectiveness.

For the short-term the mission team recommended to monitor plan form changes by satellite image analysis, to increase bathymetric monitoring and to perform 1-D morphodynamic modeling, so as to anticipate better on bed and bank erosion. A second recommendation is to set-up a Best Practice Guide on bank protections, so as to unify and improve, where necessary, current bank protection design. Another issue is to study the changing morphology of the bifurcation of the Red River and Duon River at Hanoi.

Acknowledgment

The authors thank the Vietnam Ministry of Agriculture and Rural Development for their invitation and hospitality and the Asian Development Bank for their funding. Thanks are also due to the Second Red River Basin Sector Project, that identified this mission [3] and hosted our mission team. The Dutch authors are especially grateful for the pleasant cooperation with the counterpart experts: the co-authors of this article.

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