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Problems of river degradation in the Kathmandu Valley

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ABSTRACT

The speedy degradation of rivers in the Kathmandu Valley has led to the failure of bridges, historical sites, and riverbanks. The present *ad hoc* practice of constructing protection measures has to be given a second thought. An integrated approach including engineering, legal, and social aspects can stop the speedy degradation of rivers. The proposed engineering measures include short-, medium-, and long-term stabilisation of the Chobhar Gorge including the construction of a series of check dams at a regular interval. The legal and other measures include banning sand extraction, construction of riverside road, preventing encroachment of floodplain, reducing sand demand, controlling the discharge of acidic effluents into the river, and creating awareness.

INTRODUCTION

The Kathmandu Valley (Fig. 1) was a big lake long time ago (Sharma 1990). Subsequently, it was filled up with a thick pile of sand, silt, and clay. At present, many rivers and rivulets drain the valley through the Chobhar Gorge as the main outlet. Some of the rivers were in existence before the outburst of greater (older) lake and cutting down of remaining smaller lakes.

The river degradation in the Kathmandu Valley dates back to prehistoric period after the outburst of the greater Kathmandu Lake. But the speedy degradation began recently due mainly to human factors. The degradation has caused severe damage to the bridges, historical sites, and riverbanks. The recent development of settlement pattern encroaching even low-lying areas along the riverbanks is accelerating the speedy degradation of rivers in the Kathmandu Valley.

The main objective of the paper is to analyse the nature of river degradation in the Kathmandu Valley. Taking into account the severity of the problem, instead of *ad hoc* decision-making practices, an integrated approach including engineering, legal, and social aspects is also proposed.

SOILS IN THE KATHMANDU VALLEY

The Kathmandu Valley is filled up with lacustrine and fluvial sediments. Up to 20 m thick fluvio- lacustrine deposits forming terraces are found at the centre of the valley underlain by thick lacustrine black clay (called *Kalimati* in Nepali). The southern part of the valley is made up of fluvial deposits of clay, silt, sand, and gravel. In the Chapagaon, Sainbu, Bungamati, Lagankhel, Jawalakhel, Sanepa, and the Chobhar Gorge areas, alluvial clayey gravel with boulders is found, especially around the Nakhu Khola. It was deposited prior to the outburst of the greater Kathmandu Lake. In Jhaukhel (Phikhel), at the leeward southern side of the Changu Hills, sandy beds were deposited by the Manohara River (Fig. 2). Soils observed in various locations in the valley are shown in Fig. 3.

RIVER DEGRADATION IN THE KATHMANDU VALLEY

The extent of river degradation in the Kathmandu Valley varies spatially as well as temporally. During the last 2,500–3,000 years, the degradation of the Bagmati River was about 20 m at Thapathali (Pradhananga 1991). The rate of downcutting by rivers depends on the erosion of bed level at the Chobhar Gorge to some extent. Before 1950, the degradation rate was not so high, but it increased rapidly after intensive sand extraction from the Bagmati River and its tributaries at various places in the valley. The degradation was about 1 m at the Hanumante Bridge in Bhaktapur during 1970–1990 before the sand extraction. The alarming rate of degradation started from 1990 with the exposure of black clay bed by over-extraction of sand. The bed level at the Thapathali Bridge went down by 1.7 m between 1950 and 1989 (Fig. 4) (Table 1). During the process of downcutting in the black clay, at first

Table1: Rate of degradation before the construction of protection measures

S. N.	Reference location	Period	Years	Degradation		Remarks
				Depth (m)	Rate (mm/year)	
1.	Thapathali Bridge	1950–1968	18	0.3 m	16.7	After construction of truss bridge (already dismantled)
2.	Thapathali Bridge	1968–1989	21	1.4 m	66.7	Excessive sand extraction period
3.	Thapathali Bridge	1989–1991	2	0.9 m	450.0	River flow in black clay bed

Source: Author's observations

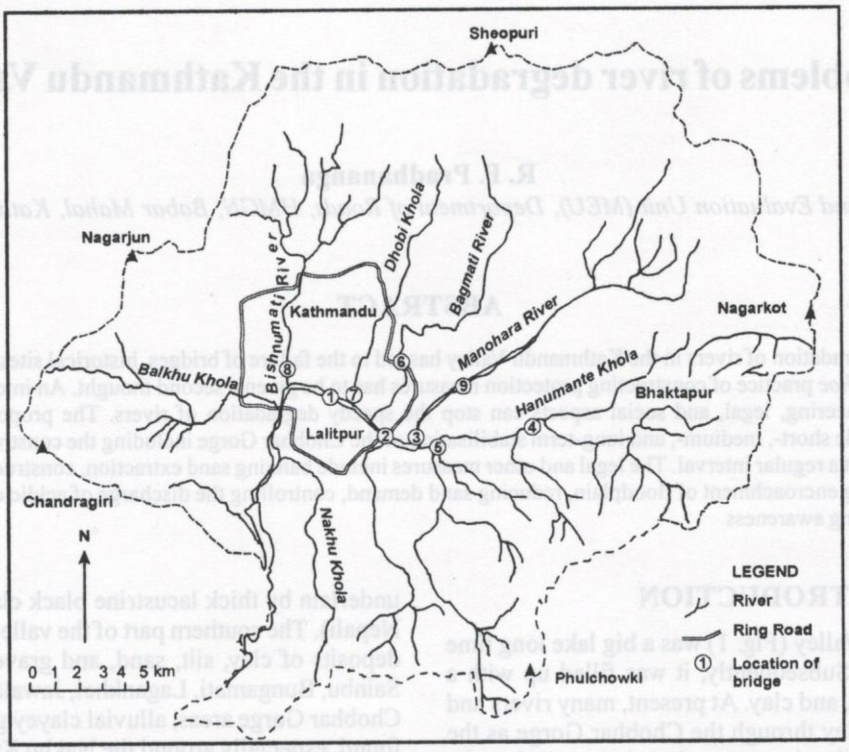

Fig. 1: Map showing the location of investigated bridges in the Kathmandu Valley. 1: Bagmati Bridge (Failed on 16 September 1991); 2: Manohara Bridge (Ring Road); 3: Manohara Bridge; 4: Hanumante Bridge; 5: Hanumante Bridge; 6: Bagmati Bridge; 7: Dhobi Khola Bridge; 8: Bishnumati Bridge; and 9: Manohara Bridge (Failed in 1997)

Fig. 2: Investigation of sand deposits along riverbanks

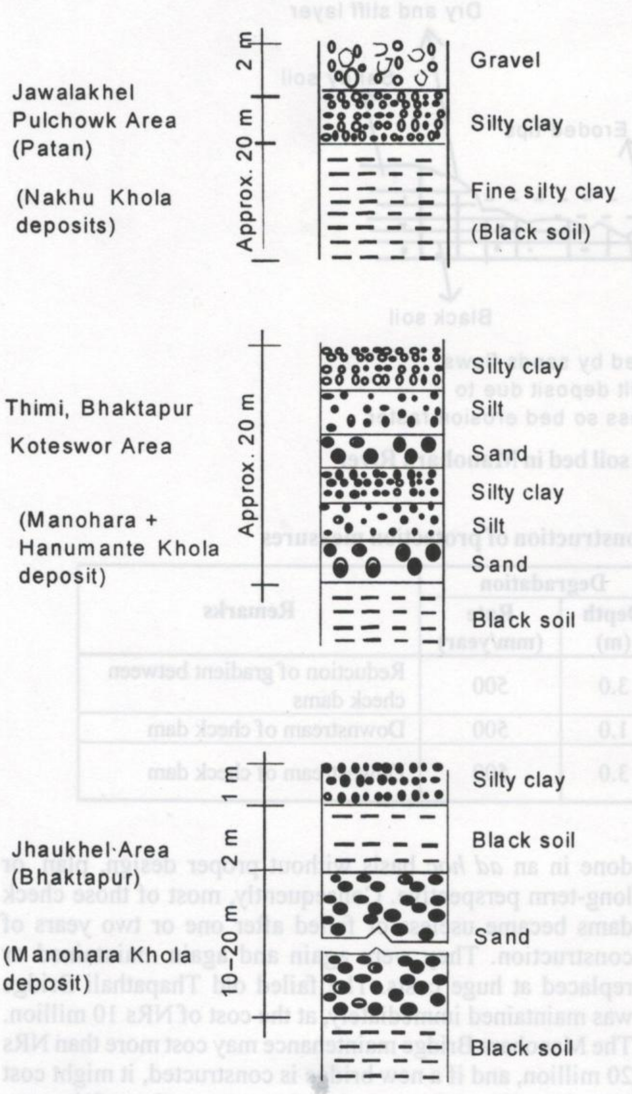

Fig. 3: Soil section at various location in Kathmandu Valley

rills are formed. Subsequently, they become deeper and wider, forming gullies with steep banks, where the riverbed is ultimately confined (Fig. 5). The average flow width of the Bagmati River is 120 m, but in the dry season its flow is just 10 m in the black clay bed. The bed level of the Bagmati River at the Thapathali Bridge and that of the Manohara River at the bridge south of Koteshwar went down by 3 m between 1991 and 1997 even after gabion check dams were constructed (Table 2).

The bed level difference between the Manohara River at the bridge south of Koteshwar and that of the Bagmati River at the Chobhar Gorge is 15 m. The rivers flow through the black clay deposits between the two locations. If left unprotected, the clay layer might be eroded away up to the depth of 14.5 m between the two locations in the long run. The river degradation in the south beyond the Chobhar Gorge also will be greater in future, as the river flows there also in the black clay bed (Plate 1).

CAUSES AND CONSEQUENCES OF RIVER DEGRADATION

The main cause of recent river degradation in the Kathmandu Valley is the excessive sand extraction from the riverbed for construction activities. The sand demand for construction of houses in the three major cities of the Kathmandu Valley in 1997 was 270,000 m³ (Pradhananga 1991). Similarly, population explosion in the Kathmandu Valley and settlement of people in low-lying areas encroaching riverbanks have helped directly or indirectly in narrowing and degrading the rivers (Plate 2). The construction of guide bunds and riverbank protection works without proper planning has also contributed to the degradation. Erosion of the limestone (bed rock) at the Chobhar Gorge due to rapid weathering as well as reaction with acidic effluents has also added to the speedy river degradation north of it (Fig. 6a and 6b).

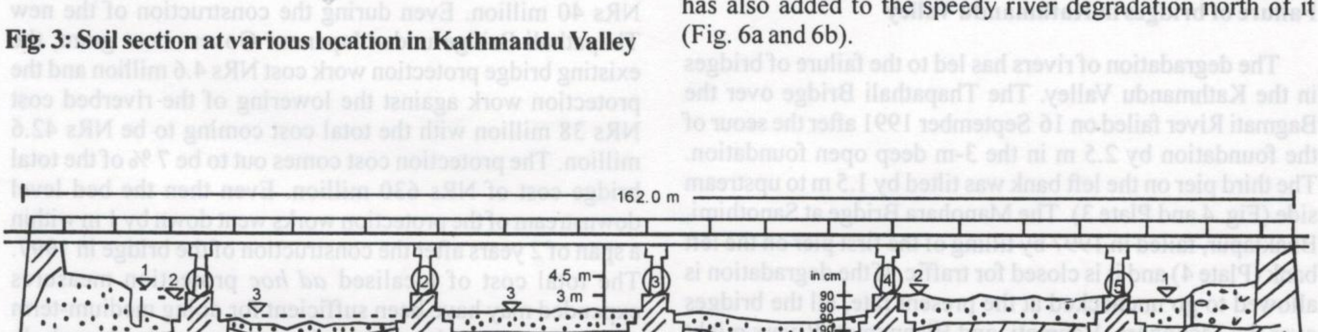

Fig. 4: Section with riverbed in September 1989 (Bagmati Bridge, Thapathali)

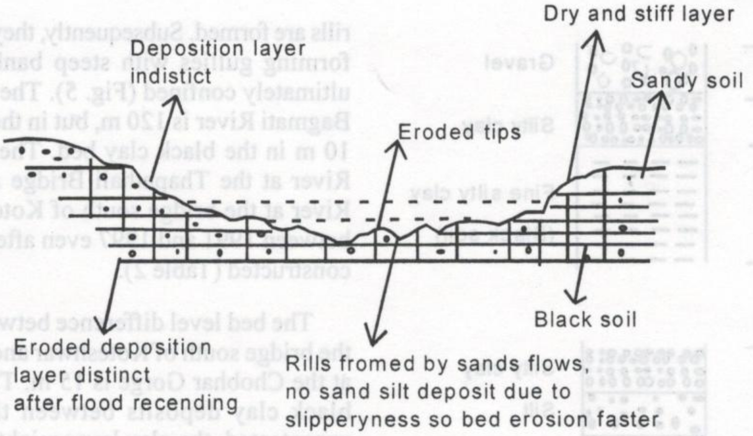

Fig. 5: Erosion process in black soil bed in Manohara River

Table 2: Rate of degradation after the construction of protection measures

S. N.	Reference location	Period	Years	Degradation: Depth (m)	Degradation: Rate (mm/year)	Remarks
1.	Thapathali Bridge	1991–1997	6	3.0	500	Reduction of gradient between check dams
2.	Thapathali Bridge	1997–1999	2	1.0	500	Downstream of check dam
3.	Manohara Bridge, South of Koteshwar	1991–1997	6	3.0	500	Downstream of check dam

Source: Author's observations

One of the main consequences of speedy river degradation is the failure of existing bridges and probable danger to the bridges to be constructed in the future. Some of the cultural and historic sites along the riverbanks are completely damaged or washed away. Others are left far behind the banks leading to less cultural and religious activities in those areas.

Failure of bridges in Kathmandu Valley

The degradation of rivers has led to the failure of bridges in the Kathmandu Valley. The Thapathali Bridge over the Bagmati River failed on 16 September 1991 after the scour of the foundation by 2.5 m in the 3-m deep open foundation. The third pier on the left bank was tilted by 1.5 m to upstream side (Fig. 4 and Plate 3). The Manohara Bridge at Sanothimi, Bhaktapur, failed in 1997 by tilling of the first pier on the left bank (Plate 4) and it is closed for traffic. If the degradation is allowed to go unchecked at the present rate, all the bridges over the Manohara, Bagmati, and Bishnumati Rivers might fail one day including the bridges with pile foundation (Plate 5).

PRESENT PROTECTION PRACTICES AND COSTS INVOLVED

After the failure of the Thapathali Bridge in 1991, heavy gabion check dams but without proper apron (Plate 4) were constructed at huge costs at most of the bridge locations where foundations were exposed. The protection works were done in an *ad hoc* basis without proper design, plan, or long-term perspective. Consequently, most of those check dams became useless or failed after one or two years of construction. They were again and again maintained or replaced at huge costs. The failed old Thapathali Bridge was maintained immediately, at the cost of NRs 10 million. The Manohara Bridge maintenance may cost more than NRs 20 million, and if a new bridge is constructed, it might cost NRs 40 million. Even during the construction of the new Thapathali Bridge under Japanese Government grant, the existing bridge protection work cost NRs 4.6 million and the protection work against the lowering of the riverbed cost NRs 38 million with the total cost coming to be NRs 42.6 million. The protection cost comes out to be 7 % of the total bridge cost of NRs 630 million. Even then the bed level downstream of the protection works went down by 1 m within a span of 2 years after the construction of the bridge in 1997. The total cost of localised *ad hoc* protection measures expended may have been sufficient for doing medium-term planned engineering protection measures in the whole effected stretch of the rivers. If the present practice of doing *ad hoc* solution is not changed, it will be very difficult to solve the problems.

PROPOSED PROTECTION MEASURES

The present practice of *ad hoc* protection work has not helped to prevent river degradation leading to the failure of bridges and cultural sites along the riverbanks. Hence, planned and integrated protection measures are required,

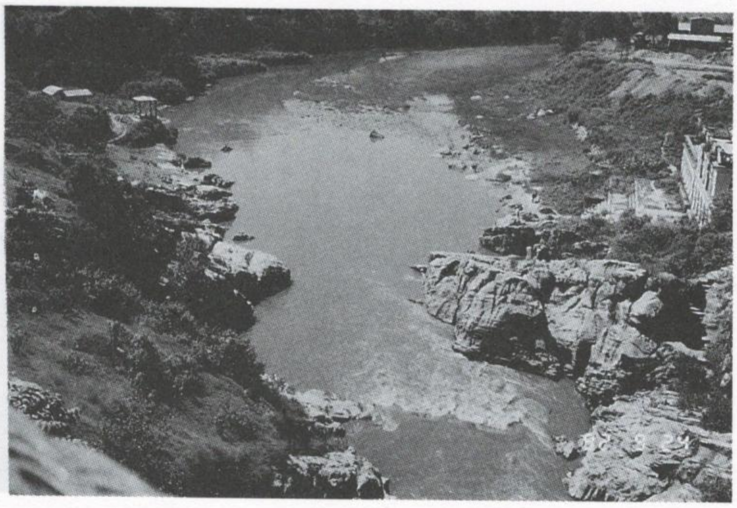

Plate 1: River degradation beyond Chobhar Gorge in the Bagmati River

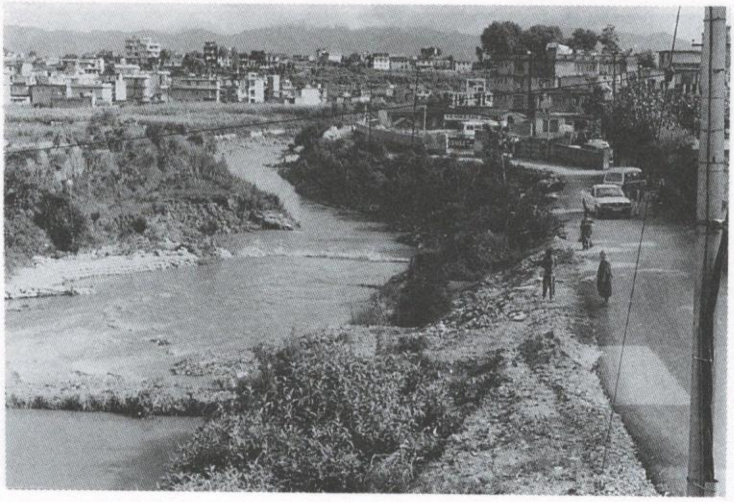

Plate 2: River degradation, narrowing and encroachment along the Bagmati River

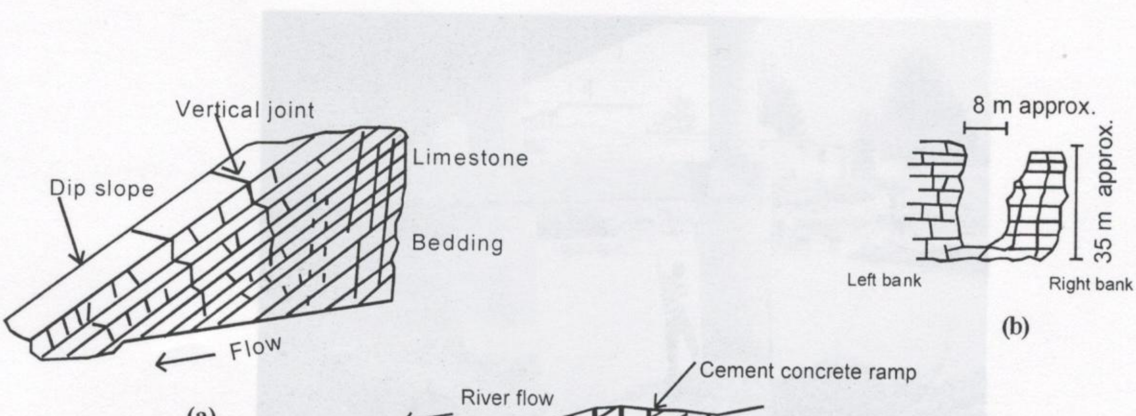

Fig. 6: (a) Rock structure, (b) cross section, and (c) probable stabilisation method for river gorge at Chobhar

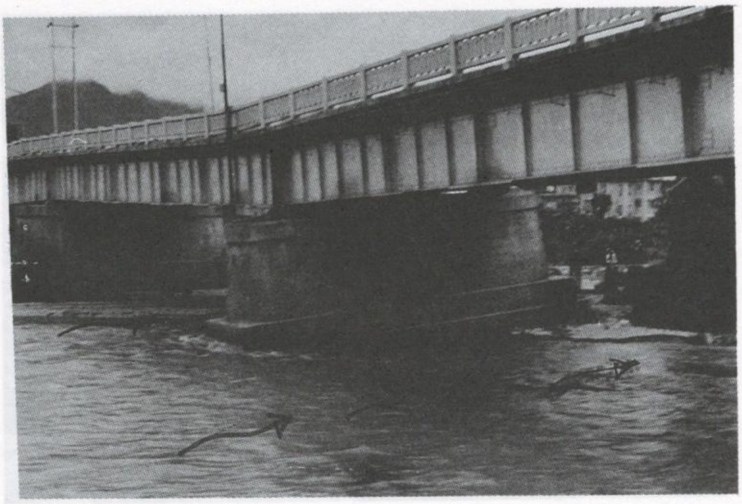

Plate 3: Failure of Pier No. 3, Bagmati Bridge Thapathali on 16 September 1991

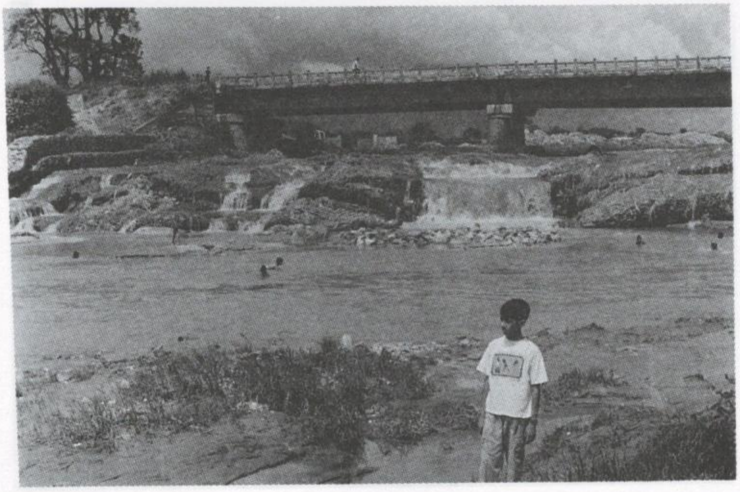

Plate 4: Failure of protection work and bridge, Manohara Bridge, Sanothimi in 1997

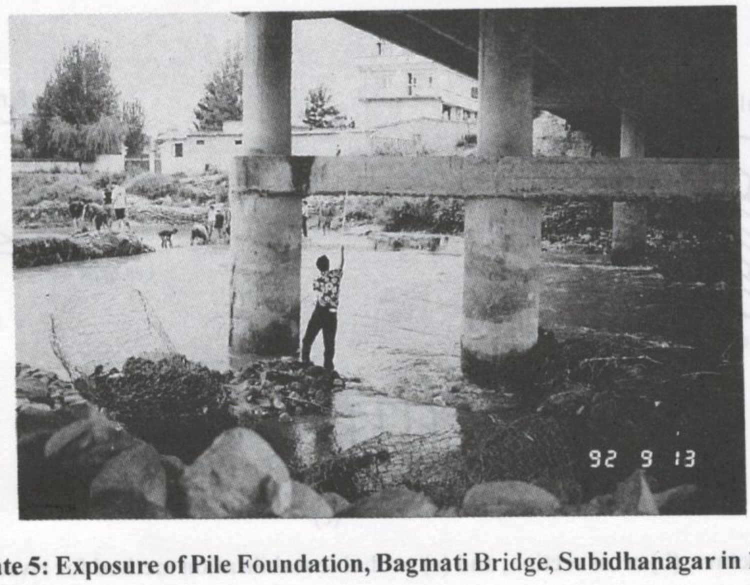

Plate 5: Exposure of Pile Foundation, Bagmati Bridge, Subidhanagar in 1992

which can take care of river degradation inside and beyond the Chobhar Gorge as well as prevent the sand extraction, encroachment of riverbanks, and narrowing of riverbed. Such types of protection measure include planned integrated engineering, legal, social, and other measures.

Engineering solutions

Proposed engineering safety measures for the protection of valley bridges and river degradation consist of the following three stages: short-term (immediate i.e. 3 years); medium-term (3–10 years); and long-term (10–20 years).

The short-term solutions include a localised approach for effected areas, such as construction of pier protection walls, spare tier check dams with primary and secondary check dams supported by gabion mattress at bridge locations and highly degraded areas (Fig. 7).

The medium-term solution is based on an integrated approach consisting of construction of check dams with apron, natural covering of black clay bed by sand, and stabilisation works at the Chobhar Gorge. It is proposed to construct a series of check dams along the affected stretches at a regular interval to prevent failure of existing check dams and stabilise black clay bed, and they should be slightly higher than the present black clay bed height. After covering the black clay bed by sand, again the height of these check dams needs to be raised by adding more gabion boxes above them. Gabion mattress aprons are provided both upstream and downstream of the check dams to prevent scouring (Fig. 7). Formation of cascade should be avoided as far as possible to prevent scouring by water jet effect. It is proposed to stabilise the Chobhar Gorge with rock dowel bars and cement concrete to bond and cover the fractures favourable for bed erosion (Fig. 6c).

Long-term engineering measures include the stabilisation of the Bagmati riverbed beyond the Chobhar Gorge up to the limit of the Kathmandu Valley (i.e. Duku) by constructing a series of check dams with apron (Fig. 7).

Legal measures

The legal provisions for the prevention of taking out sand from the riverbed are week and insufficient. After the failure of the Thapathali Bridge in 1991, government banned for taking out sand up to 200 m upstream and downstream of the existing bridges in the valley, but the regulations were not followed effectively. The Village Development Committee and District Development Committee authorise private firms to extract sands by levying nominal charges. Therefore, strict legal measures are needed to prevent further river degradation. This should include banning of sand extraction from riverbanks and riverbeds by imposing sever punitive measures and by restricting the District Development Committee and Village Development Committee to allow sand mining from the riverbed and riverbanks inside the Kathmandu Valley. It also should include provisions for severe punishment to encroachers and those who help in encroachment of the riverbanks. The registration of riverbank lands should be completely stopped. A separate 'Government Policy' may be required in this aspect.

Other measures

Other measures such as construction of roads along riverbanks, reducing sand demand, controlling acidic industrial and domestic effluents, controlling increase of population, and awareness-building campaign have to be taken up.

It is also required to construct the riverside roads. They should be at a safe distance from the riverbed, and should not contribute to further narrowing of river courses.

The construction methods requiring less sand have to be developed and encouraged. The construction of a house with tile, CGI sheet roof, brick walls (they alone will reduce the sand demand by 1/8 to 1/10 per house), walls without cement and sand, and walls with mud masonry or lime-brick mortar has to be encouraged in the Kathmandu Valley. Besides

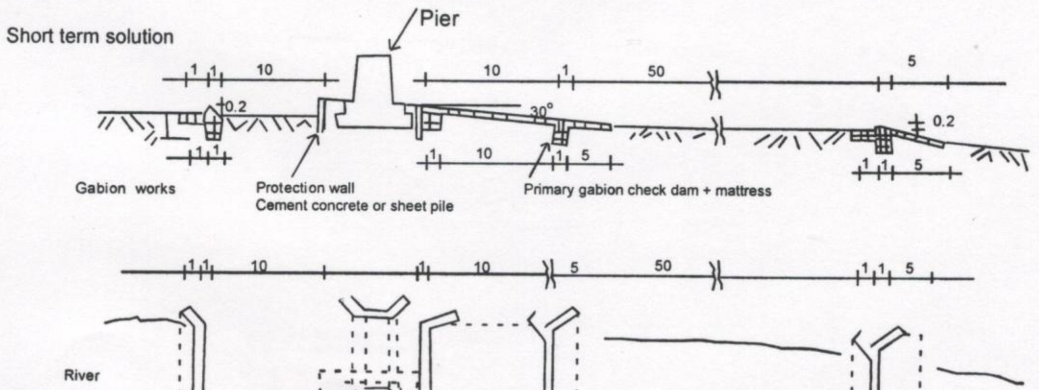

Fig. 7: Typical proposed engineering safety measures for protection of valley bridges and river degradation in Kathmandu Valley

the reduction of sand demand, new sources of sand should also be explored.

The industries producing acidic waste should be controlled and shifted from the valley. The industrial wastes, effluents, and public sewerage should be discharged into the river only after treatment. There should be a septic tank and a soak pit in every new building.

CONCLUSIONS

The river degradation in the Kathmandu Valley has reached an alarming stage, and some bold and drastic measures are required to prevent bed erosion, and failure of bridges and cultural sites. Until now, only *ad hoc* measures are practiced for localised protection works. Neither integrated approach nor long-term solution is executed. The resource, technology, and capability are available in Nepal itself. However, a commitment is required on the part of government, non-governmental organisations, and general public for the long-term protection. It should be supported by necessary legal, restrictive and punitive measures, and awareness campaign. A separate integrated project is also required for this purpose.

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