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Impact of Silt Excavation on River Morphology and Bed Material: A Study of Tarali Channel, Maharashtra, India

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Abstract :- River channels, being the container of the moving water and also the product of the movement of the same, become the most dynamic component of a river basin. Variations in the discharges reflect the variations in energy available and hence such variations immediately get reflected in the alterations in the channel morphology. Bank-full discharges are often considered to be the channel forming discharges. However, it does not mean that the flows below this condition do not have any role in shaping the channels. The changes caused by the discharge variations can be understood through the detailed study of the channel morphology. Any variation in the discharge is immediately reflected in channel geometry both in plan and profile. This is particularly true for the segment of channel, which is characteristically 'mobile' in nature, as the erodible materials often respond to flow variations with slightest provocation. In the present day context, an intervention in natural processes at varied levels by man has also resulted in serious ramifications that may range from micro level to macro level. The alluvium excavation for brick making activities have occurring on a massive scale in the area at Umbraj along River Tarali, therefore, the present study aims to analyses the effect of alluvium excavation on channel morphology, bed material and flow lines.

Keywords: - Alluvium Excavation, Bed material, Cross-sections, flow lines, Geomorphic map

I. INTRODUCTION

The dynamism of channel geometry and channel morphology is a product of natural process as well as anthropogenic intervention. A continued repetitive attack by flow along a river bank eventually leads to change in the channel location and different variables of hydraulic geometry. Any catastrophic event like large flood would also bring about change in location of the channel bed and bed material. The natural processes leading to change or shift in the location of channel bed are sometimes aided by human interventions too. A number of cases can be cited of such changes, at times not necessarily deliberate ones. When the interventions are of high magnitude the effects also can be quite serious. Thus channel alteration leads to severe ecological and economic consequences. If the channel becomes deep and narrow then excess river discharge with tremendous hydraulic energy erodes the channel bed and banks, also leading to channel widening. Although under the influence of flow action over a long time, such type may be strike a balanced condition through the self-adjusting action of the channel. At the same time some functional relationships exist between the river morphology, including longitudinal profile and cross sectional geometry. These morphological relationships show the interrelationships between the river's capacity to adjust the incoming runoff and sediment load. However, human interventions also cause some kind of changes in the morphological characteristics of the channel. Human activities, like construction of bridges, roads, dams are non-recurrent in nature and hence over a time lapse, the channel adjusts itself form to the new environment. However, in case of repetitive activities like alluvium mining, sand extraction, etc., the channel is not able to assimilate the modulations in the available time span and hence, such activities create serious environmental problem of stability of the channel. Osterkamp has also observes that environmental impacts of mining sand, gravel and other building materials from stream beds lead to modifications in stream regime [1]. The complications due to variations in river discharge and sediment characteristics on channel morphology have also précised by Schumm in 1977 [2]. At the same, increasing or decreasing rate of sediment in river channel also influences on fluvial processes. Study by Boccardy and Spaulding in 1968, revealed that the sediment load due to surface mining may resulting for aggradation of channel and causes reduction in the volume of flow that tends to increase the rate of flooding [3].

Considering above discussion, the present study aims to analyses the impact of alluvium excavation on river bed material and flow lines of River Tarali, a tributary of River Krishna. Generally alluvium of many rivers is considered as a good building material, particularly for brick making. Such activity is observed almost at all rivers with varying magnitude. In the absence of alternative materials, bricks continue to be in high demand. In most of the cases, annual yield of the alluvium brought by river is being used in such activities and hence one finds many brick kilns along river channels, mostly located close to major urban centers. The observation of such condition at Umbraj along River Tarali indicates serious signs of alarming environmental problems. Therefore, it is necessary to study the variation in river bed material and morphological characteristics of the channel in response to human intervention [4], [5].

II. DATA BASE AND METHODOLOGY

A stretch of River Tarali, extending for about 4.325 km in direction upstream from its confluence with River Krishna forms the focus of the study area for the present work.

2.1 Field Survey

In preliminary visits it was realized that the alluvium deposition is restricted to a length of about 4.3 km from the confluence. Hence it was decided to carryout field surveys in Nov/Dec and April/May and prepared block contour maps for the entire stretch of 4.3 km of the river channel. The surveying has been carried with the help of transit theodolite using tacheometric method. In order to understand the details of micro relief detailed maps on scale 1:1000 with contour interval of 1 m have been prepared for each survey session from 1994 to 1997.

2.2 Geomorphic map/Material map

Flow line(s) and Material maps of the channel (presented in five stretches for three years) have prepared which reveals the variation in bed material and shifts in flow lines.

III. RESULTS AND DISCUSSIONS

Morphology of a channel can best be understood through the study of channel in plan and channel in section. The channel in plan is explained with the help of flow line and material maps given in figures 1- 5. The natures of variations in terms of the location of post monsoon flow line as well as the nature of material along the channel have been mapped and the same is presented in the form of set of maps for each of the stretch (I to V).

3.1 Identification of stretches

The entire length of the channel under consideration has been divided into five stretches. These are identified on the basis of fall along the channel and the intensity of excavation activity.

The stretch I, from KT Weir at village Hingnole, extends in downstream direction for a distance of 910 metres. At least for the period from April 94 to June 97 the excavation was almost absent in this stretch. The stretch is free from the effect of piling up of the water during the monsoon flood.

Stretch II extends from 910 to 1700m where the extraction activity is of very low order but its presence can be unmistakably identified. There are a few excavation sites along this stretch and these are of recent origin.

Stretch III and IV

From 1700m till 3250 m one finds intensive extraction activity and hence this portion is identified as a separate stretch. However, this portion of the channel has been divided into two separate stretches as stretch III and IV. At about 1900 – 2000 m there exists a major break. The effect of the nick that exists around 1900-2000m has a direct impact till 2500m and the later portion appears to be relatively free from the effect of this nick. Hence the portion is divided into two different stretches as 1700 to 2485m (stretch III) and 2485 to 3250m (stretch IV).

The stretch V, extending from 3250 till the confluence of Tarali with Krishna, was initially not a favoured stretch so far as extraction activity is concerned. However, 95 onwards we find that the extraction activity extended in this section. Hence this has been identified as a separate stretch.

3.2 Details of flow lines and material maps

Morphological characteristics and the micro relief of the channel under consideration have been depicted stretch wise for three years survey and these are shown in fig 1 to 5, The details are as follows:-

3.2.1 Stretch I (Fig.1 a, b, c distance from 0 to 910 m; CS No. 1– 11)

Within this stretch, in all 11 cross section (CS) have been surveyed. The extraction activity is very less in this stretch. Near CS 1 the bed material was coarser with a diameter of 25 cm in the year 95 & 96 as compare to the bed material of year 97. A central bar was developed for a length of 110 metres during the 1997 near

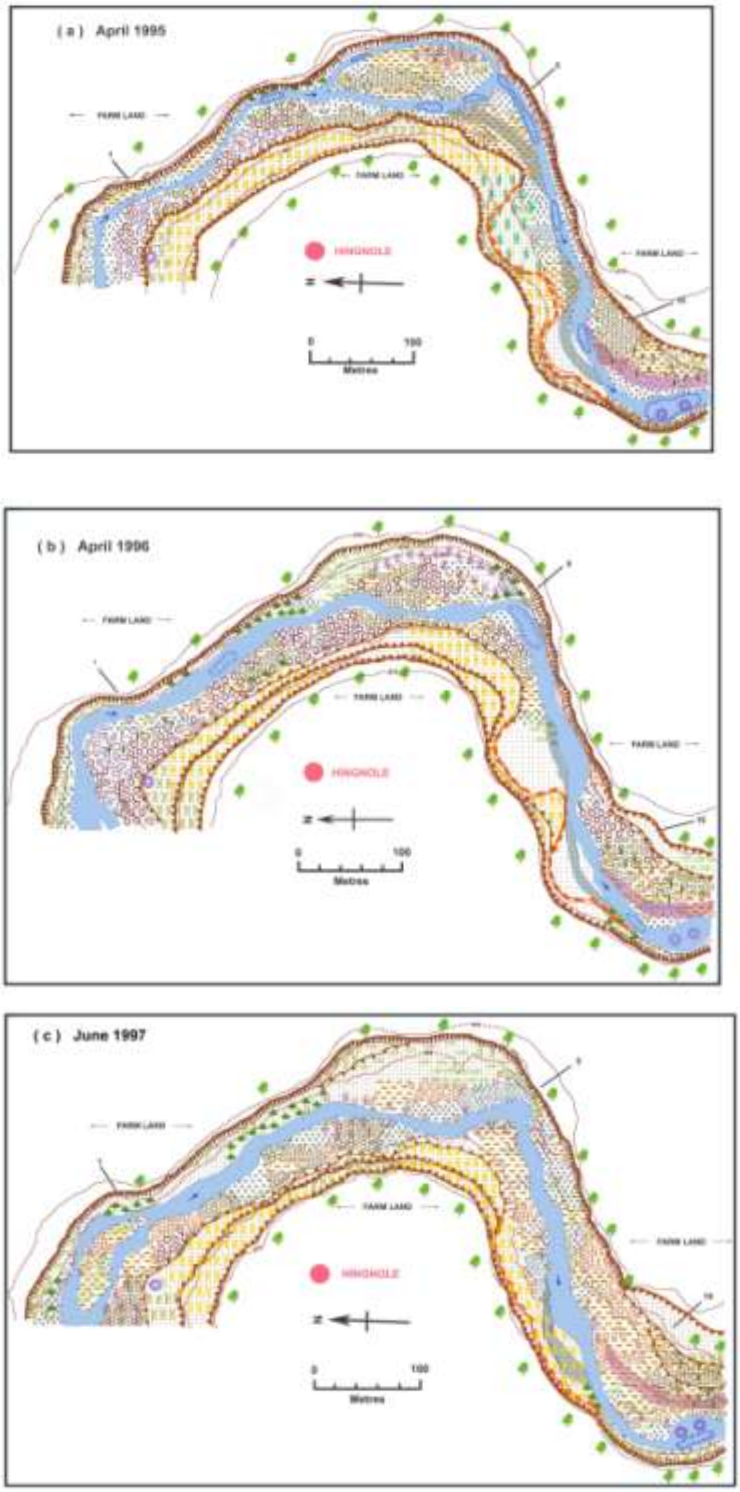

Fig. 1 Stretch No. 1: Flow lines and material along Tarali channel (Distance - 0 to 910 metres) surveyed in (a) April 1995, (b) April 1996 & (c) June 1997

Starting point. Between cross section no. 5-10 for a distance of 300 metres the channel was fairly straight and only towards the downstream ends it turns southward. Normally the piling up effect is not observed in this area, though the flooding is commonly observed, the flood water recedes within a short period of time. The main flow is well maintained. The banks along this stretch are near vertical particularly on the left side where rock exposures are observed, whereas the relief along right bank is contributed by terrace wall. For first 200 metres from starting point (Hingnole), mixed bed material with large size cobble with 15 – 16 cm diameter and pebbles with various sizes was found in April 1995. In the same manner distributed material is found in April 96, but during June 97 the bed material for the same track was totally changed, mostly the finer material with a size of 0.5- 0.6 cm diameter was spread over the coarser bed material, due to the reduced velocities of the flow. There is a large pool along the left bank, and it was followed by a central bar in downstream direction in December 95. The bar was developed due to deposition of coarser material with a mean size of 5-10 cm diameter. This central bar was nearly 150 m long and 45 m wide, although at its widest it was 55 m. In the next post monsoon survey during 96 the central bar disappeared, it was covered with small size pebbles and a thin layer of finer material mostly fine to coarse sand with some silt. Next to this bar, there exists a pool at the turn of the river. The size of material downstream the pool is reduced drastically and the largest size of the bed material were found to be 1 – 2 cm while the mean size was around 0.5cm. Generally bank erosion is dominant. However it was observed that there was no major change in flow line locations. Near C S 4 the flow bifurcation has lead to formation of a new central bar. This was observed during I and II survey of 94 - 95. In the next year post monsoon survey in Jan 96, central bar was covered with fine bed material. The flow line shifted along the central bar giving way to the development of a lateral bar along left side. Strip of vegetation with pinkish coloured flower was observed. This shows the signs of previous channel path in left side of the bar. On the same bar the cobbles with a diameter of 15 cm which were observed in 94-95 had disappeared and replaced by the small size pebbles with a diameter of 2-4 cm during Jun 97(Fig. 1 c). During same period deposition of fine sand (khaswa) also increased near the end of the bar which covered an area of 1600 sq. metres and a veneer of silt was also spread over the same bar and surrounding portion covering an area of 6000 sq. metres. At CS 5 there is a major bend; flow line deviated towards right in an old excavated block during 96-97. At the bend, the channel strikes a spur. The first site of alluvium extraction is noticed on right bank near CS 7. This extraction site observed in last two surveys i.e. 94-95 had a dimension of 20 m x 20 m and it is located along the right bank. This caused shift of the channel during June 97. There is a point bar on left side of the flow line near wells. Uneven size of bed material is uneven in range and ranges from coarse sand to cobbles of 10 cm. The point bar has very steep slope. Even this bar has been subjected to change in bed material size and in 97 it was found to have been covered by pebbles with maximum diameter of 5 cm. The major changes in the stretch can be summarised as follows. Of the two flow lines on either side of the central bar, the one on the left side has been abandoned by the river. It was the major flow line till April 1995. There has been continuous reduction in the size of bed material suggesting either reduction in flow velocity or trapping of the coarser material upstream. The latter interpretation appears to be more plausible. At Hingnole a K.T. weir has been recently constructed. It is more than likely that it has acted as a sink for coarser material and hence in subsequent years in stretch from the weir records lower size of bed material.

3.2.2 Stretch II (Fig. 2 a, b, c; distance from 900 to 1700 m; CS No. 12 – 24)

It is from this section onwards one can finds increasing number of locations where from agricultural fields are being used as sites for alluvium extraction. 4 – 5 locations of extraction have been noticed for all three years survey. The bed material in this section is reduced from cobbles to small size pebbles and coarse sand at various patches of the bed. The width of the channel increases from 60 m to 120 m. A number of lateral bars are developed, and channel of low flow condition meanders through these bars. As per the information provided by local people the main flow line was more or less confined to left bank for quite some time. However, during survey period it was found to be shifting towards right bank. Three tributary streams two from right bank and one from left bank enter in the channel within this stretch. A number of bars are covered with grasses and short shrubs, thorny type vegetation which indicates the stability of bars as a form. The tops of the bar show large and small size bed material, whereas the bar further to CS 20 is covered by fine sand and silt. The detailed

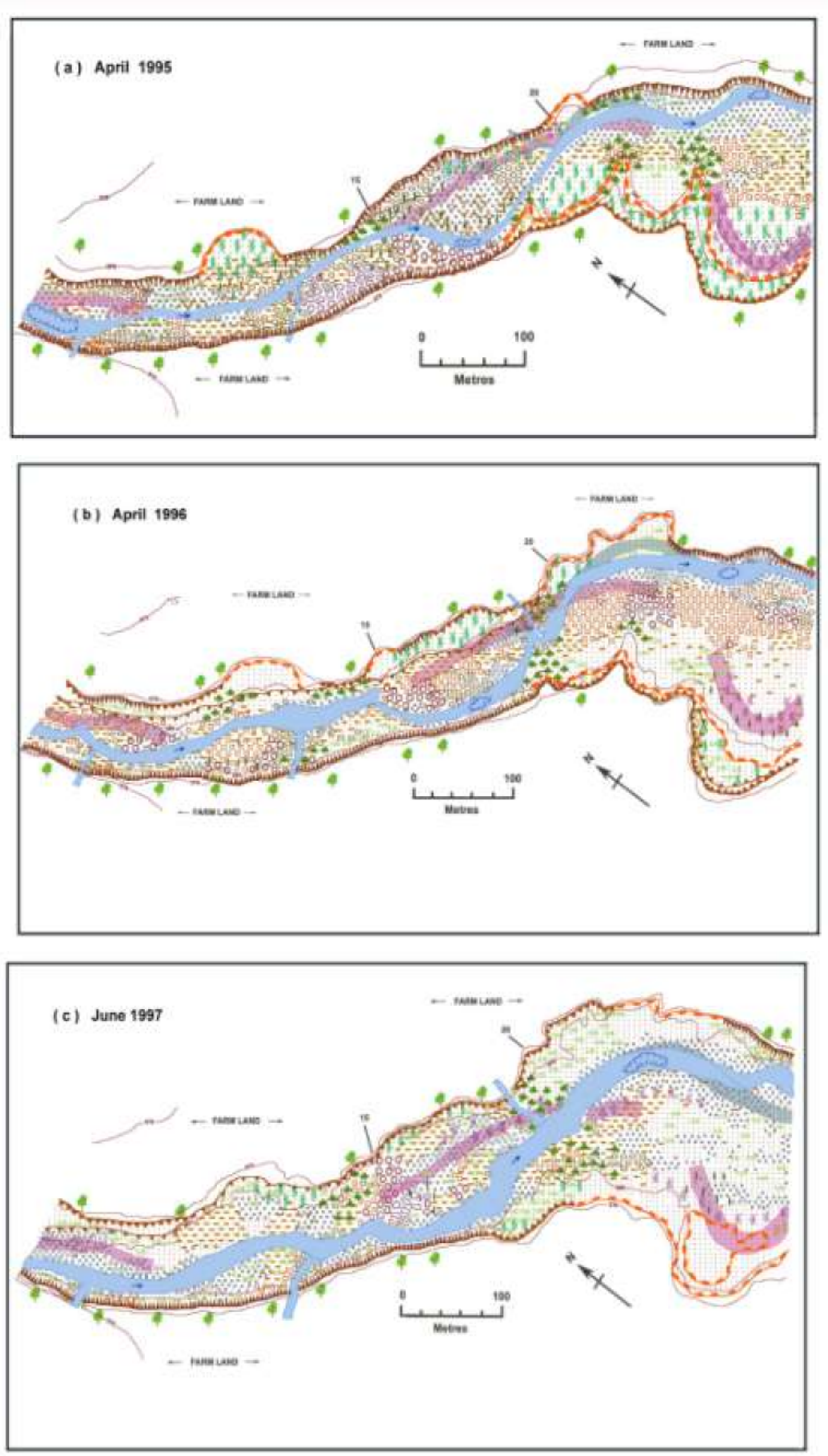

Fig. 2 Stretch No. 2: Flow lines and material along Tarali channel (Distance - 910 to 1700 metres) surveyed in (a) April 1995, (b) April 1996 & (c) June 1997

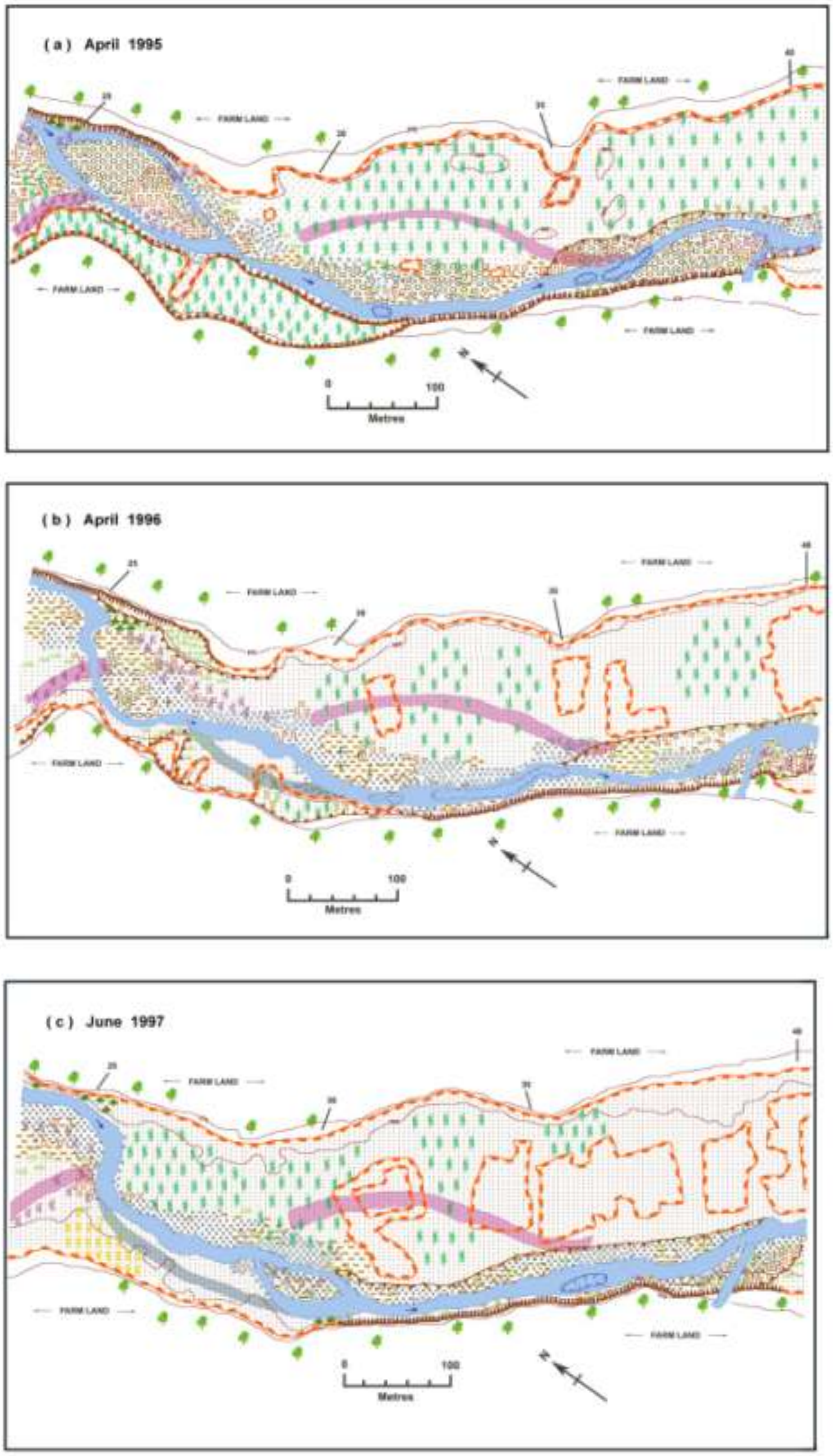

Fig. 3 Stretch No. 3: Flow lines and material along Tarali channel (Distance - 1700 to 2485 metres) surveyed in (a) April 1995, (b) April 1996 & (c) June 1997

Observations of the bed material helped in identifying locations of old channels and these are shown in the map. Looking at the map of this section it is noticed that channel width increase to 200-230 metres from its original width, of 60 metres. It may be because of heavy bank cutting in right side. Ipomea carnea was planted to protect the bank from further natural erosion. The channel in this section is quite meandering and has sinuosity index of 1.32.This is mainly due to the formation of numerous lateral bars through which the channel finds its path. In these sections it is also noticed that right bank is near vertical, bank failure and slump are major form of erosion. At CS 15, large scale dumping of the material was noticed. This has caused increase in the bed elevation of the order of the metre. It is in this stretch one notices heavy excavation of material. Most of the excavation sites are located beyond the bank. A plot of suitable size in selected depending on the demand. The material is extracted from the plots at times to the extent of 3 to 3.5 metres. The side walls of the plot are retained (left unaltered). The plot always has an elevation of 2 to 5 m on its channel ward side and extends to a distance of 25 to 30 metres, in some cases even beyond. In subsequent monsoon period water moves in these plots and remains stagnant for quite some time and this leads to fresh silt deposition. The steps like structures retained in channel ward direction arrests the coarser bed material and allows finer suspended material to get into the block. The loosening of the bank material during excavation activity, attack of the flood discharges, movement of water into excavated plots etc. lead to bank failure and increase in the material supplied to monsoon floods.

The changes observed in the bed material in this stretch are as follows.

Keen examination of this patch of the stretch shows the variation in bed material. On every convex side of the flow line, there has been accumulation of the material in the form of point bar with a mix of coarser bed material carried by the high discharges of the river and finer material mostly removed from excavated sites. During 95 and 96 up to the half portion of this section, large grain size material with a thin veneer of small grain sized pebbles was found at various locations. But during Jun 97 the grain size of bed material was considerably and coarse sand became the dominating material size. Large sized cobbles were present only near CS 15.

3.2.3 Stretch III (Fig. 3 a b c; Distance 1700 – 2485m C S NO.25 - 41)

This stretch is quite different than the previous two in terms of the intensity of excavation. The width in this stretch has increased to the extent of 500 m firstly due to lowering of stream gradient and more probably due to excavation carried out along both the banks. Large portion of the channel are used for cultivation of Shevari (sesbania agyptiaca). This cultivation appears to have two definite purposes. In first place the plant is cultivated with high density. It grows fast and acts as a sieve for the land passing through the channel. The plant provides the fodder and fuel requirements of local population. Moreover it does not have to be sown every year. Once planted, it can be continuously used for 2-3 years. Besides Shevari, local farmers also take a crop of corn and sorghum mostly on the elevated portion of the channel along the banks. The bed material being fairly loose it does not require ploughing. This agrarian activity at times extends into excavated plots where mostly shevari is cultivated.

The stretch is characterized by formation of large central bar having a width of 160 m. The channel shows a definite tendency to shift towards right bank. This is mainly due to the fact that along right bank excavation is highly concentrated. The monsoon discharges rushing into these excavated blocks lead to such shift of flow line. In river Tarali, during the survey period, sand dredging was not noticed. However, in order to collect recently deposited silt material for brick some plots in the bed are dug out. Such digging lowers the bed elevation, allows the water get stagnated during post monsoon period and helps the shifting of the flow lines. Numbers of such plot were traced in this stretch particularly during 97 survey session.

The material in stretch III onwards changes drastically, the cobble size bed material is rarely seen in this stretch and most dominant size appears to be that of pebbles with large proportion of coarse to fine sand. Most of the coarser material get deposited in the central bars which repeatedly gets covered by coarse to fine sand and silt.

3.2.4 Stretch IV (Fig. 4 a b c Distance 2485 to 3250m C S NO.42- 61)

This stretch evidenced massive extraction activity along the right bank as compared to its left bank during the survey period. Undisturbed large terrace on left bank during 95 & 96 near Bhonslewadi village was scooped out during the year 1997. Silt deposition for 0.8 m was seen in the right bank extracted block in Jan 96. Deposition of fine sand and silt up to 1.5-2.0 m was also seen on the bar. Alluvium extraction is highly concentrated in this stretch as well. Large meander of channel and lateral bars is observed in this section, and in

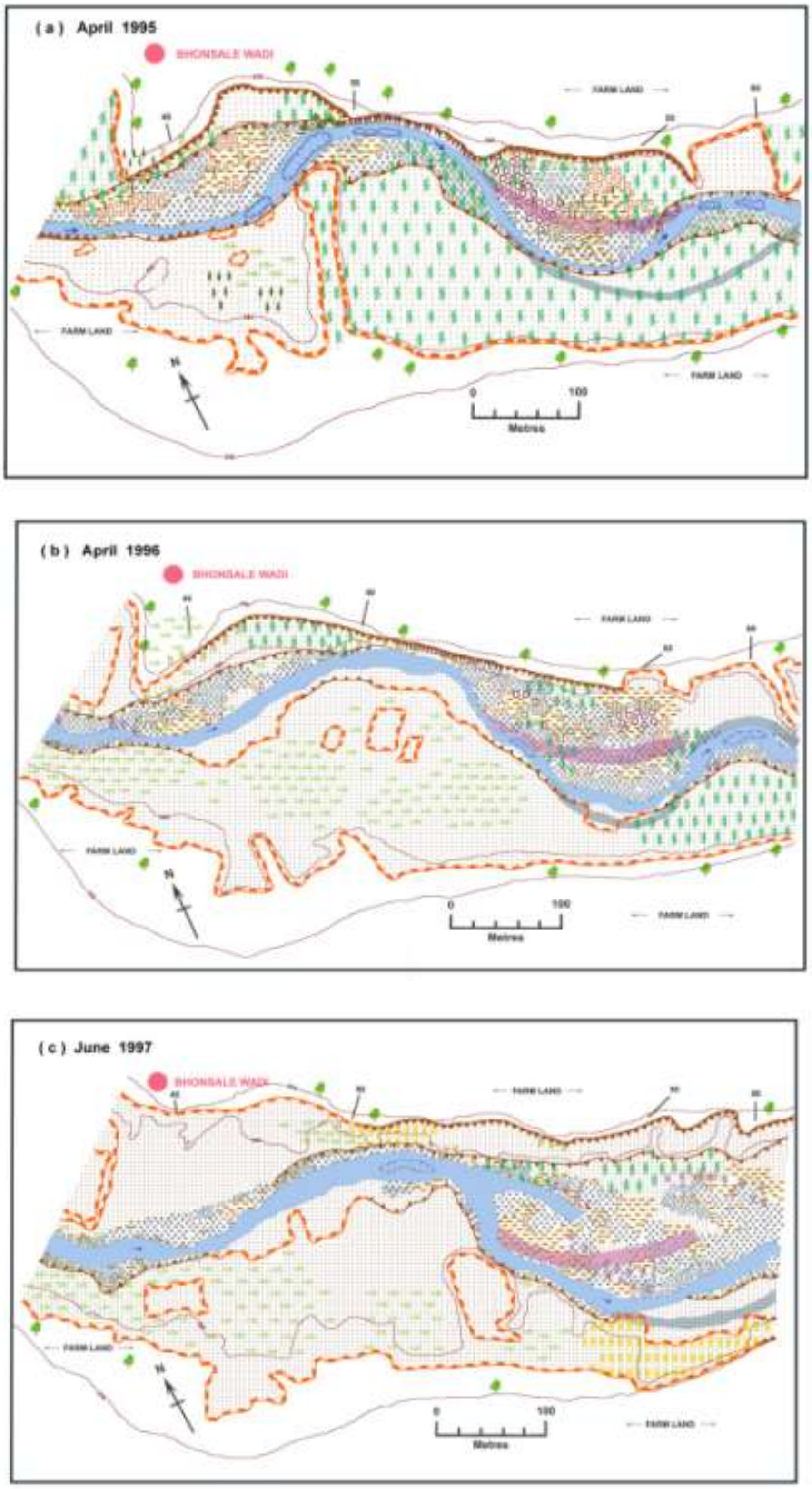

Fig. 4 Stretch No. 4: Flow lines and material along Tarali channel (Distance - 2485 to 3250 metres) surveyed in (a) April 1995, (b) April 1996 & (c) June 1997

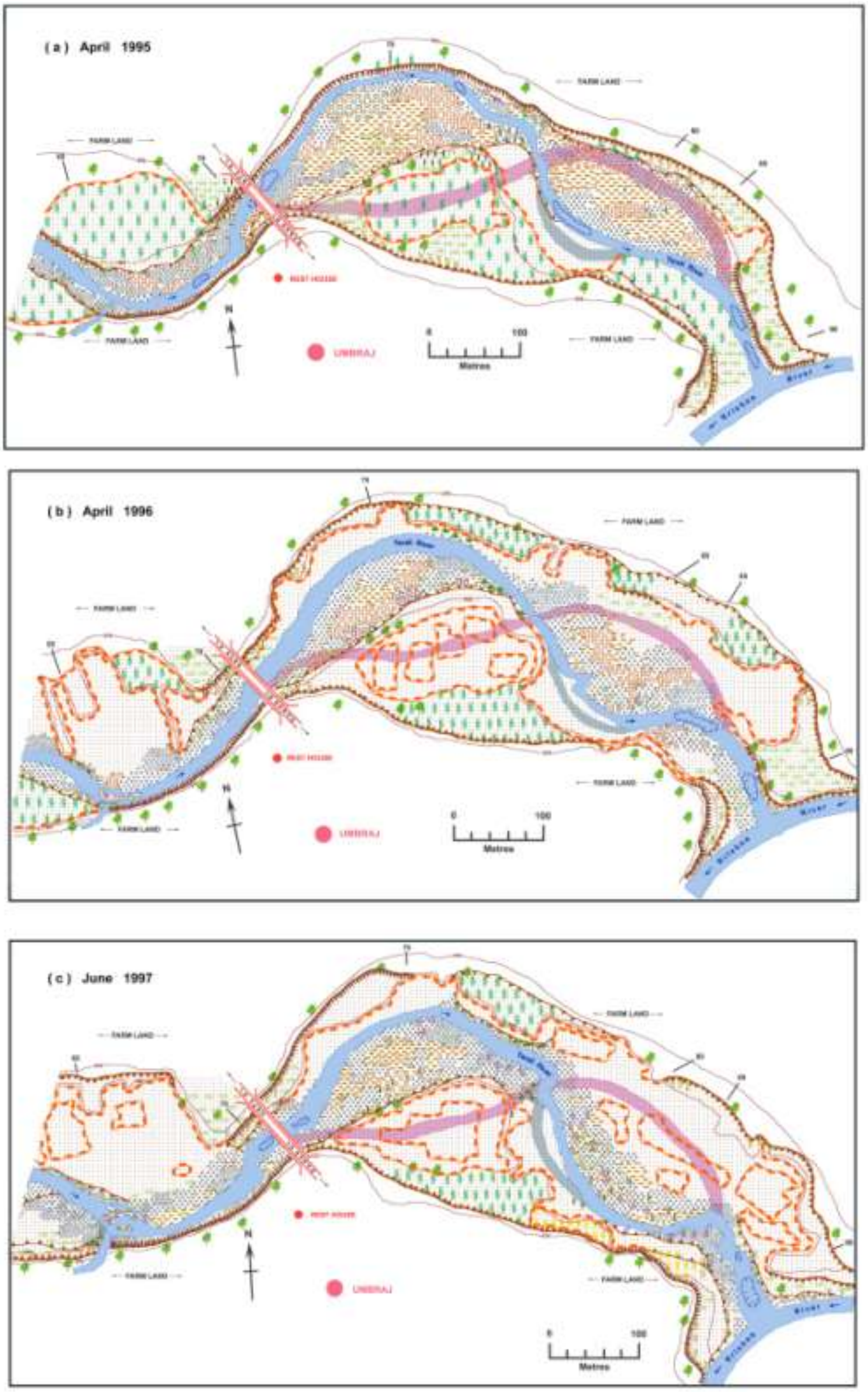

Fig. 5 Stretch No. 5: Flow lines and material along Tarali channel (Distance - 3250 to 4325 metres) surveyed in (a) April 1995, (b) April 1996 & (c) June 1997

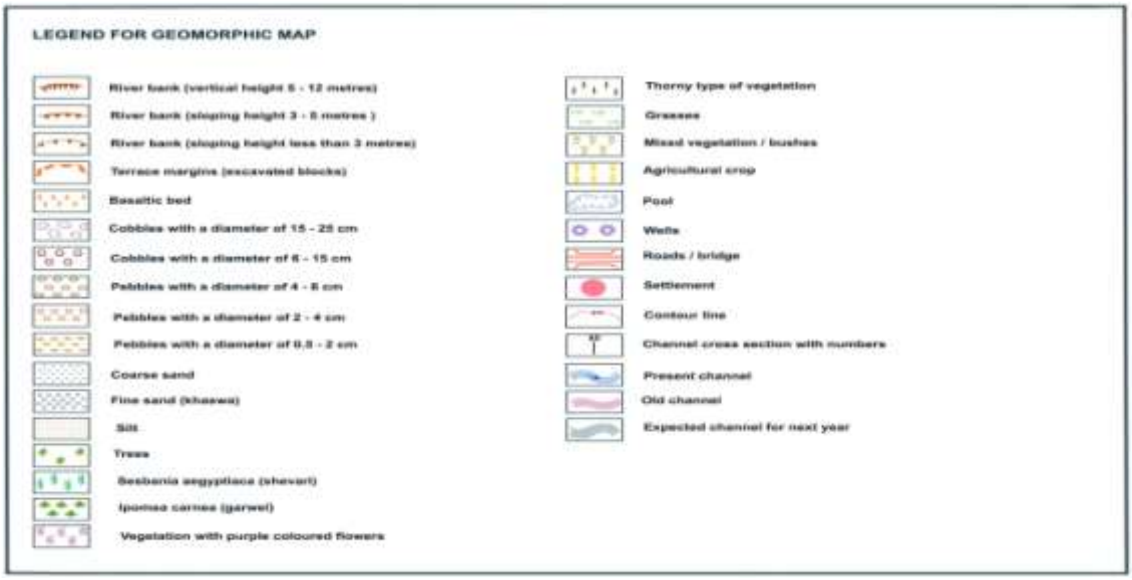

Plate 1: Trench was dug on the left bar to shift the channel

Plate 2: Deposition on the bar and lowering of bed in the right due to trench

Plate 3: Row of sand bags across the main flow to control the shift of channel, a practice adopted by local people

Plate 4: Right bank upper terrace excavated up to water level near confluence, river shifted to right

Some parts fine material is spread over the coarser material in the bed. Generally next to half portion of this stretch for 1st two years ,the flow of river water was along the right bank for a distance of 270 m, then it shifted to left, during the year 1997, more shifting of river occurs in right side for maximum distance of 24 m. The same location also indicates the formation of large bar along the left side as a result of vegetation.

During 1996, on the middle portion of the same Bar a continuous trench was dug (plate 1) up to a depth of 6-8 metres for a length of 200 metres in the left side of the channel by local people. As per their perception they tried to shift the channel forcefully towards its left in next year. But their efforts failed, channel shifted to its right instead of the left side. This resulted in increase of the height of the bar by 1 metre due to the deposition of small sized material for a diameter of 0.5 to 2 cm with coarser and fine sand on the bar. During the survey period of 2002 such type of practices were highly responsible for the lowering (plate 2) of bed to another side of the bar. Opposite to this bar it appears to be the continuous alluvium extraction along right bank, extending for a distance of 150 m from the river. Sign of silt deposition for 0.8 m in Jan 96 has also been observed. Between CS 55-60 a large meander shift was expected to its right during Apr 96 and was marked in the map of Apr 95. But channel was shifted with a small meander for 7-8 m to its right. The encroachment of channel to its expected location may be encountered due to the shevari plantation and dumping of sand bags (plate 3) near CS 51. But during Jun 97 the channel entered in the right excavated block and shifted for 60 metres towards its right as per the expected channel, marked in Apr 95.

3.2.5 Stretch V (Fig. 5 a b c Distance 3250 to 4325m C S NO. 62 - 90)

In this section channel is wide but near CS 70, located near the Umbraj highway bridge, the channel is very narrow. This location has escaped from excavation activity due to the Pune-Bangalore Highway Bridge. From the bridge downward, the line of trees clearly indicates the shift of the channel as shown in map, also marked by old channel. Near CS 75, left bank cutting in April 96 has been observed. Opposite to this location up to CS 80, the extraction activity have been noticed in the right side of the bank, more alluvium has been extracted in April 96 from this site. The average width of the channel is 200 m, but the channel gets reduced at the area of the confluence, where it was about 50-60 m. The scratching of alluvium from the bank/field up to the water level of river also identified between CS 80 and 85 during 1996 and 1997(plate 4). Same location also indicated the development of large lateral bar with coarser material along the left side of the river. During Jan96 and Apr 96, recent extraction activity of alluvium has seen along left bank near the confluence, which has extended to 150 m to the left side of the bank and with this regard CS 90 of Oct 2002 clearly shows the poorly excavated block up to the thalweg of river Krishna, that means totally scratched up to the water level.

IV. CONCLUSION

The channel of river Tarali under consideration represents a case of effect of human interventions on the morphology of the channel. The normal process of adjustment of width, depth and velocity with variations in discharge has got mostly obliterated in this part of the channel. It is more than obvious from the available data of load that the brick kilns in the area are exploiting the river bank material at scale that are far beyond the annual yield of sediments. The excavation activities largely influenced on channel morphology, as it alters channel geometry, causes lowering of the beds, affects the water surface in the river, subsequently decreases or increases the flow velocity and the sediment transport capacity. Hence, it is recommended that some kinds of restrictions on excavation of agricultural land along the banks are introduced.

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