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# ORIGIN AND FINAL CUT-OFF OF THE WANASGALLA WATTA MEANDER OF THE DIKOYA, CENTRAL SRI LANKA

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## ABSTRACT

Although meander cutoffs are normal in large natural rivers, they are not commonly reported from small streams of the size of the Dik Oya, which has a catchment area of about 40 $km^2$. The largest meander in this stream was breached due to a series of flood events during extreme rainfalls in October and November, 2010. This study attempts to explain the origin of this meander (Wanasgalla Watta meander) and the associated sedimentary formations in the Dik Oya valley.

The research methods used in this study are a combination of field measurements, analysis of detailed topographic maps, and perusal of historical records on past human activity in the region. The channel pattern was obtained from topographic maps and Sinuosity Index (SI) was calculated for 29 channel segments. The meteorological events that led to the meander cutoff was obtained from the daily rainfall records from a nearby farm.

The unique geometry of this meander appears to be linked to human activity in the ancient times. A man-made lake or tank mentioned in an inscription found at a nearby ancient site, a ruined bund depicted on a topographic map, the narrow ridge across the broad valley and channel pattern indicate that the Wanasgalla Watta meander formed due to the blocking of the river by a earth bund and its subsequent breach. Sedimentological studies done in the vicinity by several authors discovered evidence compatible with a lacustrine environment above the meander. Origin of the meander and upstream sedimentation are more likely to be linked to a man-made reservoirs/tank, than to glacio-fluvial sedimentation claimed by previous authors.

***Keywords**: Meander, Sinuosity, Permo-triassic, Weuda, Sedimentation*

## INTRODUCTION

"The most characteristic feature of all stream channels, regardless of size, is the absence of long straight reaches and the presence of frequent sinuous reversal of curvature" (Leopold and Wolman, 1960). Rivers normally do not flow in a straight course longer than ten times their widths (Leopold and Wolman, 1957). Meandering however is a phenomenon that is not confined to natural river channels, but it is common to many linear fluid flows in nature, such as ocean currents, supraglacial channels, jet stream, etc., all of which display smooth meandering patterns.

A quantitative measure that is used for the determination of whether a river course is meandering or not is called Sinuosity Index (SI), which is defined as the ratio between the meandering channel length (arc length) and the straight line length of a channel reach.

$$SI = \frac{L}{l}$$

Where L is the length of the river channel between two consecutive inflections and $l$ is the direct distance . Based on this index, river channel forms can be divided into four types (Knighton, 1984) as stright (SI<1.0), sinuous (SI=1.0 – 1.5), meandering (SI=1.5 – 3.0) and tortuous (SI >3.0).

Causes of river meandering are many and complex. It is generally observed that many processes, such as "erosion and deposition, secondary circulation in the cross-sectional plane, sieche effect as in lake sieches" and many other individual processes deterministically affect meandering of river channels. "Although each of these individual effects is in itself completely deterministic, such effects can be treated as if they were stochastic." (Langbein and Leopold, 1966). This process is modeled as the Random Walk Model.

Boggs, (2010) sums up what is known about the reasons for sinuosity in rivers in the following statement: "The factors that influence channel sinuosity and braiding have been suggested to include the magnitude and variability of stream discharge, channel slope, grain size of sediment, bed roughness, the amount and kind of sediment load (bed load vs. suspended load), and the stability of the channel banks. These factors are complex, interrelated, and not fully understood. The exact causes of meandering and braiding remain somewhat obscure."

River meanders may be cut into the alluvium in a river floodplain or into the bedrock in the upper reaches of a river. Once formed a meander develops to such an extent that the ever narrowing neck of the meander is eventually breached to shorten the river channel path usually during a flood stage. A meandering channel also has a lower channel gradient than that is produced by a meander cutoff. Meandering therefore decreases channel slope and increases bank friction leading to a reduction in the flow velocity. The opposite happens when a meander cutoff takes place. Meanders move across floodplains by accretion inside the meander and erosion of the outside bank. But no record is found to show that meanders are caused by human activity.

Meandering is also seen as a river channel's effort towards achieving a stable channel form. A river channel would progressively change from straight to meandering and back to straight over long periods of time. Meander cutoffs during extreme flood events change a meandering channel form to a straight or less meandering form. Most rivers in the world have left behind evidence of meander formations and meander cutoffs in their flood plains. River meanders are also found in the upper reaches of bedrock controlled channels (Whol, 1998). In the recent history, humans have also intervened in this process by straightening meandering rivers to enhance navigation, and for flood prevention by increasing the velocity of flow of water in a channel. In most such interventions, humans were involved in shortening the river courses by artificial meander cutoffs, but there is evidence that remeandering takes place in some of them. However, no past studies available on river meanders caused by human activity.

An opportunity arose to study the behaviour of a meander in a small tributary stream, known as the Dikoya near Weuda off the main Kandy-Kurunegala Road near 21 km post (Figure 1). The extreme rainfall events at the end of 2010 in the upper catchment areas of Dik Oya increased the river flow to such an extent that a fairly well developed meandering channel was straightened by breaching at the neck of the meander. This study analyses the meandering pattern of the Dik Oya and investigates the origin and the events that lead to the meander cutoff.

## STUDY AREA

The Dik Oya originates on the western slopes of the northwestern Hill Country and joins the

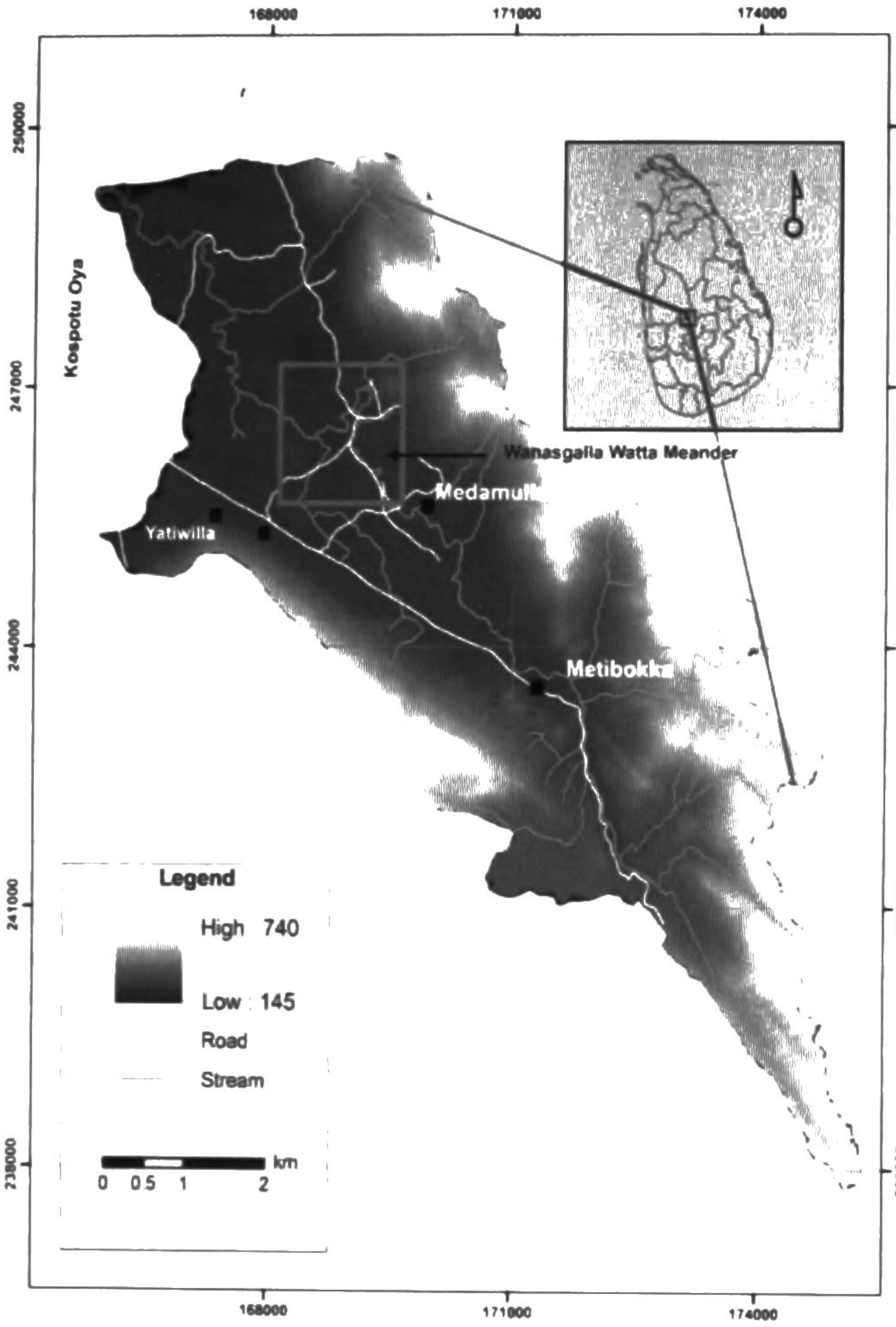


*Fig. 1 Location and topography of the Dik Oya micro-catchment.*

Deduru Oya after reaching Weuda plain (Figure 1). The elevation of the Dikoya basin ranges from about 140 m to 740 m. The main tributary that originates from Girihagamakanda, at an elevation of about 600m, flows through the Galagedara Pass to join the Kospothu Oya at Arampola. The Dikoya micro-catchment is located in the southeast corner of the Deduru Oya river basin. Its basin area is about 40 $km^2$. The river forms a series of meanders in its lowermost reaches where the relief is very low. The Wanasgalla Watta meander is located just below the break in the slope of the long profile of the channel marking the boundary between the almost flat and more steeply sloping bed.

The catchment is located mostly in the Wet Zone and recieves the highest rainfall from the convective rains during the First Intermonsoon (FIM) and Second Intermonsoon (SIM) periods. The former is in the months of March and April and the latter in October and November. During these two seasons, the Dik Oya has a high discharge. The two monsoons are noted for the lowest discharge because of the low rainfall received by the catchment. The upper basin has a forest cover and the river does not go dry at any time of the year. Jayasena (1998) suspects this situation is to be due to trans-basin seapage from the Mahaweli Reservoirs through the fractures in the bedrock of the upper catchment.

The Weuda area has been the subject of several previous studies (Dahanayake and Dasanayake, 1981, Dahanayake, et al., 1989, Premaratne and Jayasena, 2009) which came to the conclusion after the study of stratigraphic sections and the textural characteristics of sediment that these sediments were of glacial or glacio-fluvial origin. Two stratigraphic sequences described by Dahanayake and Dasanayake (1981) are from Metibokke and Medamulla which are located in the broad valley above the Wanasgalla Watta meander. The third site is located outside this catchment. They identified interlayered sediment sequences at these sites including, sand, clayey sand, peaty clay and gravel. Cross-bedding was observed in sandy beds.

## DATA AND METHODOLOGY

This study is based on both primary and secondary data in the form of field measurements, maps, historical sources, etc. The primary data collection involved in the mapping of the valley around the place where the meander cutoff has taken place. Field measurements of channel cross-sections were done in order to understand the gradual evolution of the newly formed channel after the meander cutoff. Among the secondary data used, most important are the detailed (large-scale) maps and plans depicting the channel and its environment in the past. The current position of the meandering channel and elevation data of the catchment were obtained from the 1:10,000 ABMP and recent cadastral maps. These data were supplemented by the use of high-resolution satellite imageries from Google Earth. The topography and the river network of the Dik Oya were obtained from the 1:10,000 topographic maps of the Survey Department. The different sets of maps used in this study were brought into one coordinate system using ArcGIS software.

## RESULTS

### THE MEANDER PATTERN

Dik Oya from its origin to the confluence with the Kospotu Oya flows in a Northwesterly direction in a steeply sloping course up to an elevation of about 165m and on a gentle slope thereafter (Figure 2). The channel form of the reach from Galagedera to the confluence with Kospotu Oya is largely sinuous as shown by the Sinuosity Index calculated for 29 channel segments (Figure 2 and Table 1). The only exceptions were the four meandering, and one tortuous channel reaches. The tortuous reach (Wanasgalla Watta Meander) that has a very high Sinuosity Index of 11.4 was subjected to meander cutoff in 2010. This meander stands out among all channel segments not only for its high sinuosity, but also for many other characteristics in the channel geometry as well as the general geomorphology of the site requiring further analysis (Figure 3 and 4 and Table 1).

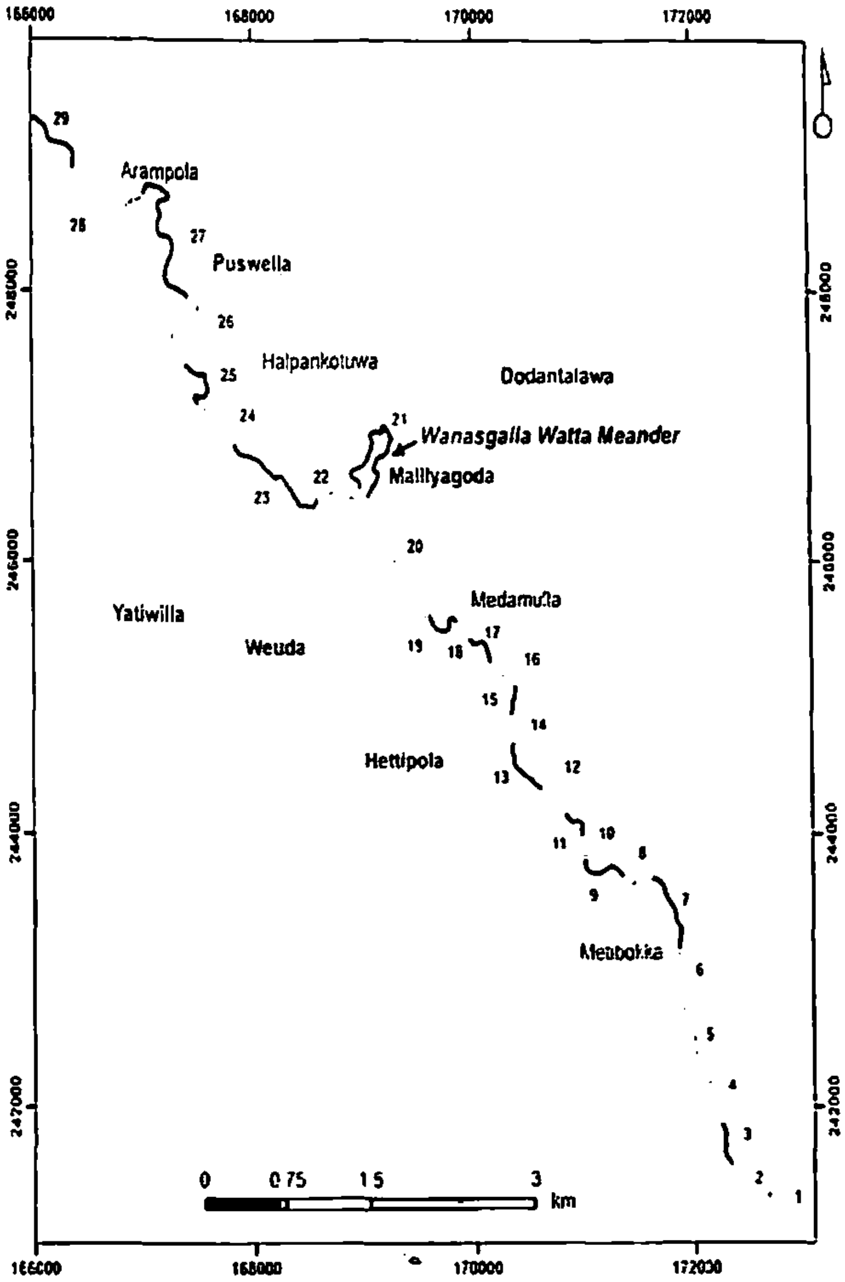


*Fig. 2 Dik Oya channel segments.*

Normally meanders are formed by joining two arcs in the shape of the letter 'S.' One meander has two concave bends and two convex bends. Development of meanders takes place by deposition in the concave inner bend and erosion in the outer bend. The Wanasgalla Watta meander has one long arc and a short arc at a macro level. The meandering channel at Wanasgalla Watta has a secondary meandering pattern making it a complex meander. The secondary meanders in the upper lobe and lower lobe of the large meander are different. The lower and upper lobes of the Wanasgalla Watta meanders have meandering and sinuous channel patterns respectively. These two patterns can be demarcated by

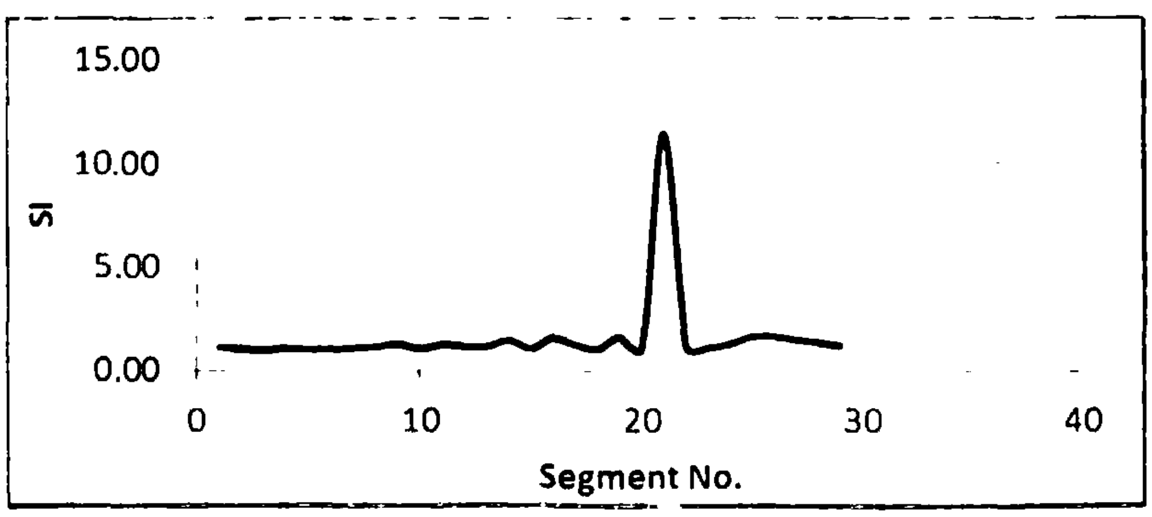


*Fig. 3 Sinuosity of the channel in the Weuda Plain.*

***Table 1 Characteristics of the Dik Oya channel***

| Type | Sinuosity Range | Number of Segments |
|---|---|---|
| Straight | <1.0 | 1 |
| Sinuous | 1.0-1.5 | 23 |
| Meandering | 1.5-3.0 | 4 |
| Tortuous | >3.0 | 1 |

the tributary that joins the meain river at the bend of the meander loop. The SI for upper and lower lobes are 1.2 (sinuous) and 1.6 (meandering) respectively. Thus the upper lobe is straighter than the lower lobe. The meander loop of the Wanasgalla Watta Meander has a length of about 590 m along its longest axis and a width of about 50-80 m (Figure 4). The meander has two well defined 'goose necks' at points B and C, the latter is narrower than the former. They are potential sites of meander cutoff. The river turns abruptly to NE at A and flows about 590 m and then reverses the direction making a smooth curve at the valley wall of the right bank (RB). At this point, a tributary also joins the main river. The river contiues to flow up to a point just opposite the upper point of inflection of the channel at A

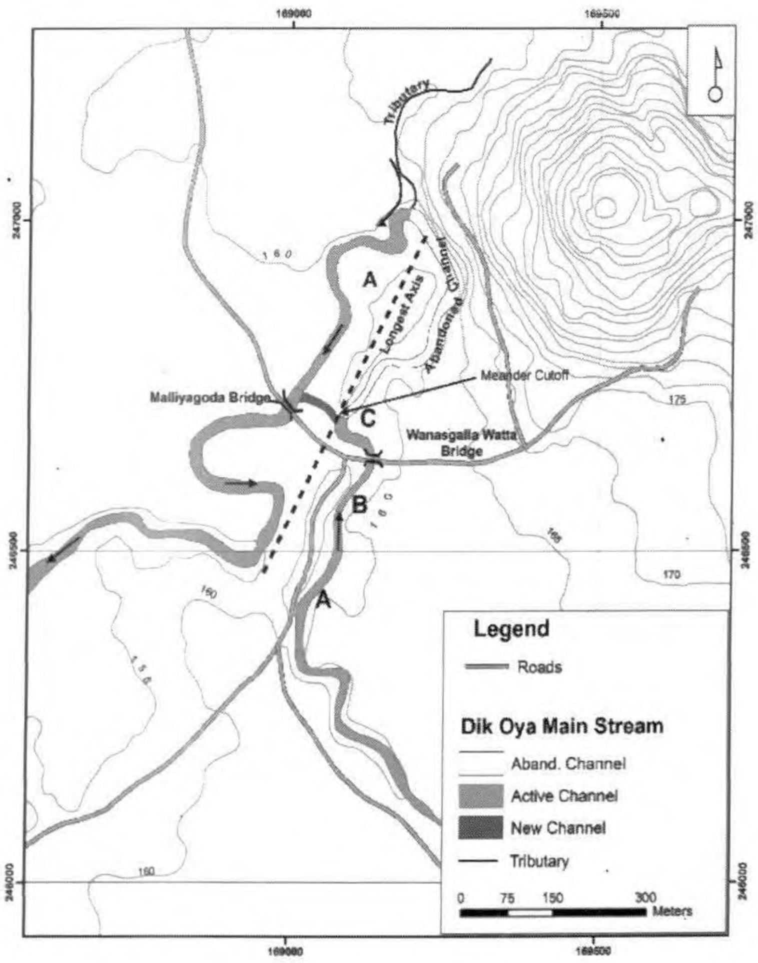


*Fig. 4 Geometry of the Wanasgalle Watta.*

and turns NW again and continues in the same direction until it joins the Kospotu Oya.

Examination of the contour pattern of the valley reveals many unusual characteristics. This is well illustrated by the two contours, 160 m and 165 m, which provide some hints about the past events in this location (Figure 5).

The anomalies in the contour patterns and stream channel characteristics can be listed as follows:

- The 160 m contour defines a narrow ridge-like feature inside the Wanasgalla Watta meander loop (Figures 4 and 5). This ridge is broken into two parts as depicted by the two closed contours. The meander loop encircles this ridge which has been breached near the valley wall on the right. The upper lobe of the meander flows in a valley defined by two 160m contours. The 160 m on the upstream side runs across the broad valley almost to the other end. The contour shows another valley aligned in SW-NE direction on the RB side through which a small tributory flows (Figure 5). This secondary valley has no relation to the general alignment of the Dik Oya valley. The shape of this 160m contour is very different from that of the 155 m contour which follows the general alignment of the valley. The 160 m contour therefore shows the modification of the original surface by the construction and subsequent breaching of a tank bund.

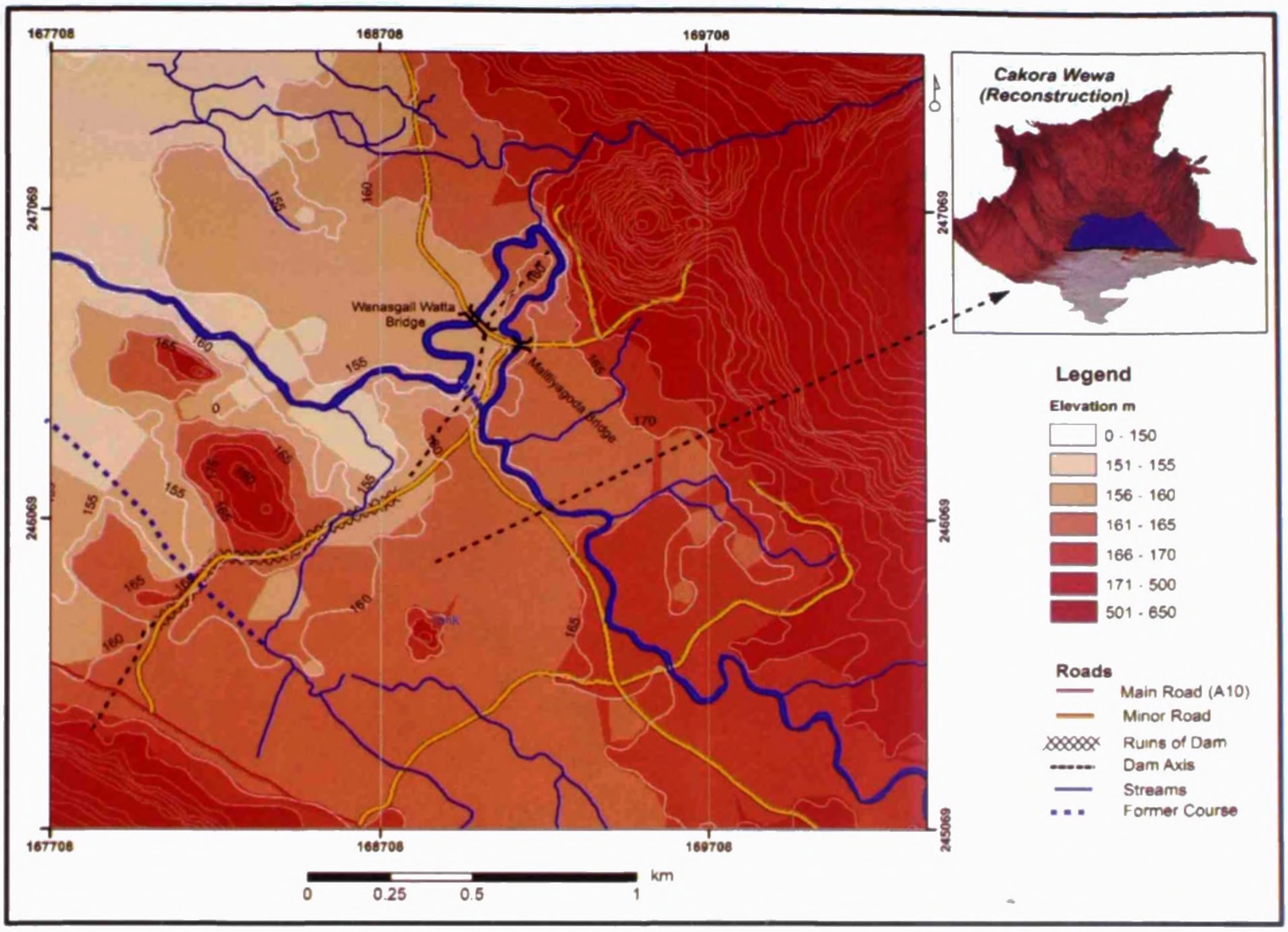


*Fig. 5 Map showing Wanasgalla Watta Meander and Cakora Wewa.*

- The 165 m contour shows a wedge shaped body of sediment and does not show the presence of a valley where the main channel of Dik Oya is located. The contour bends in a down-valley direction (Figure 5 and 6). The position of the the Dik Oya main channel in the broad flat valley is not at the lowest position. The valley surface tends to slope

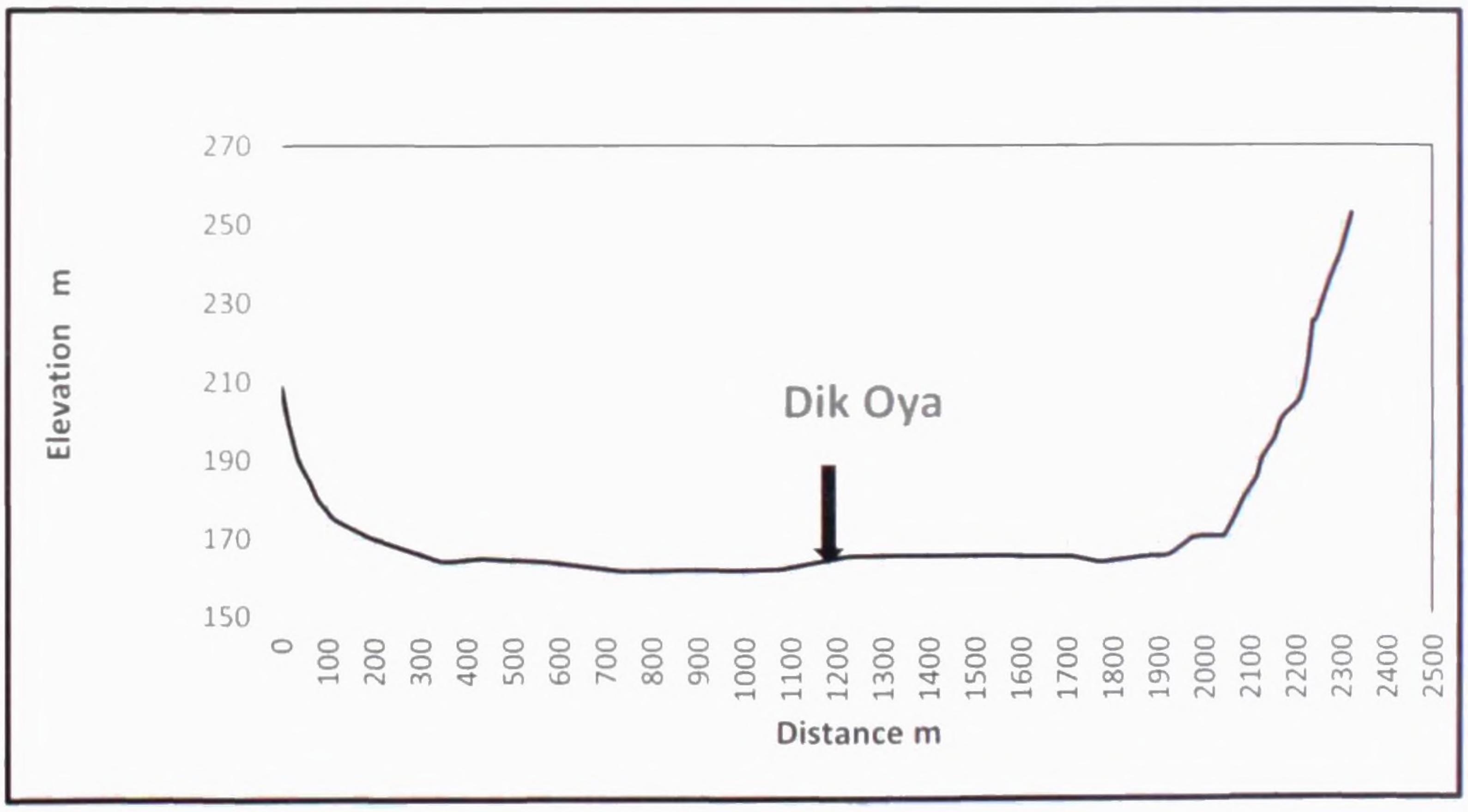


*Fig. 6 Aggradation of the Dik Oya Valley.*

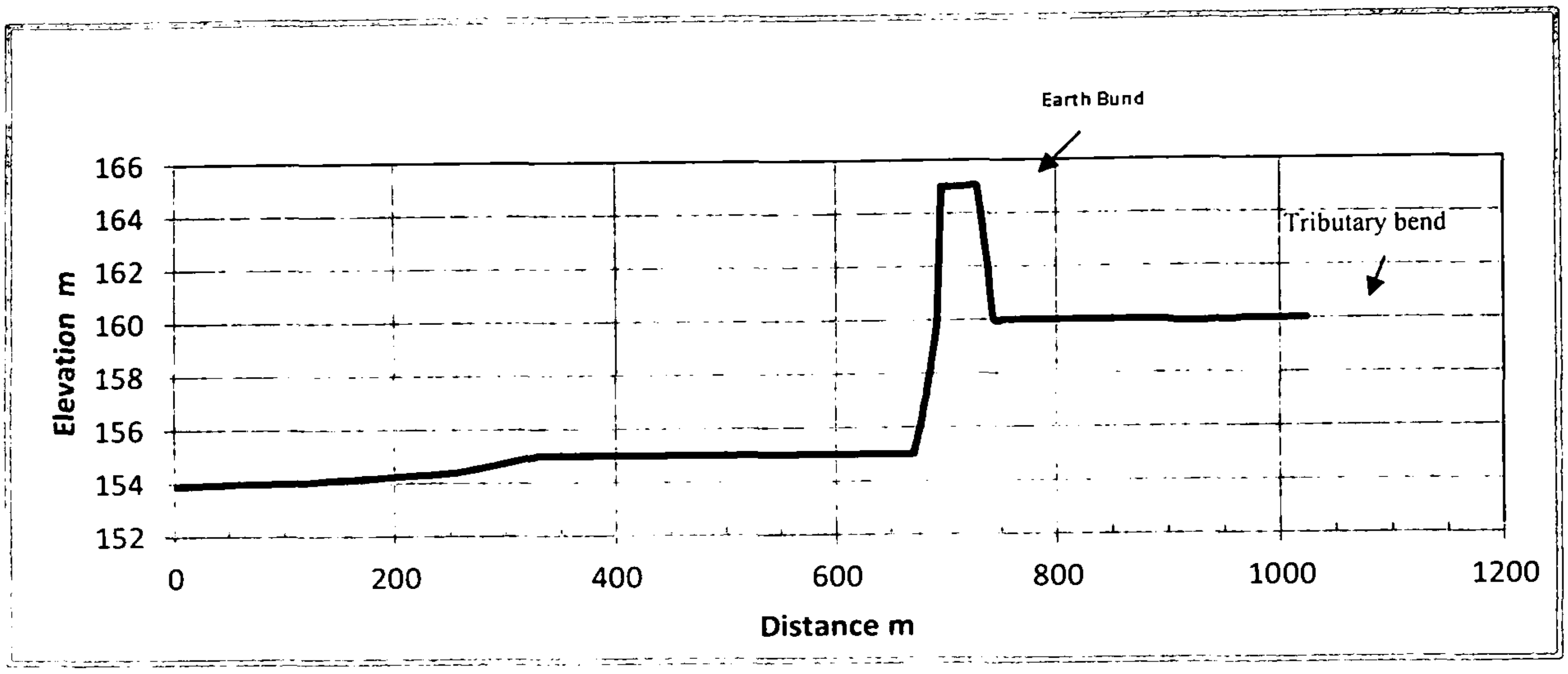


*Fig. 7 Elevation across the Earth Bund.*

away from the channel.

Both the main river and a tributary on the left side abruptly change direction close to the 160 m contour (Figure 5). The deflected tributary stream flows through a breach in the dam and joins Dik Oya. Right opposite the bend of the tributary, there is a valley (155 m contour) interrupted by a narrow high ground (Figure 5). This valley is now occupied by a short tributary of the Dik Oya.

Arhaeological and historical evidence suggests that there was a reservoir nearby. A Brahmi inscription dating back to 2$^{nd}$ century BC at an ancient site called Viharagoda in Yatiwilla mentions a tank (reservoir) named *Cakora* (Pranavitana,1928). Nicholas (1979) also mentions a reservoir called *Cakora* at Weuda. This site has all the conditions that are considered necessary for the construction of a tank. At this location both ends of the valley have steeply rising hills. On the LB there is a hill inside the valley providing further support for an earth dam. This hill divides the broad valley of the Dik Oya into two parts. The broad valley above this point has sufficient storage area for a tank. Another piece of evidence comes from Kurunegala one-inch topographic map which depicts a remaining section of a bund (about 50 m long) on the LB area further confirming that *Cakora Wewa* was located here (Figure 5).

Figure 7 shows the elevation profile across the dam at the tributary bend on the RB. It shows an abrupt rise of elevation from about 155 m to 165 m at the crest of the dam. The present width of the flat crest is about 15 m. The elevation drops again abruptly to about 160 m. Bund shows a sharp rise from both upstream and downstream sides and the two sides have an elevation difference of about 5 m signifying agradation above the dam. This feature is most likely to be an artificial feature.

## ORIGIN OF THE WANASGALLA WATTA MEANDER

The Wanasgalla Watta meander is unlikely to be a product of natural fluvial processes, but a result of human intervention. This intervention is in the form of construction of a tank bund at the location of this meander. Before the tank bund was constructed the river appears to have flowed in a natural course in northwesterly direction as marked on Figure 5. The main river and a tributary make a sharp turn to the right just above the bund and flow some distance parallel to it and then flow across the bund through two breaches. The main river flows across the bund at its RB end and joins the channel of a RB tributary that drains

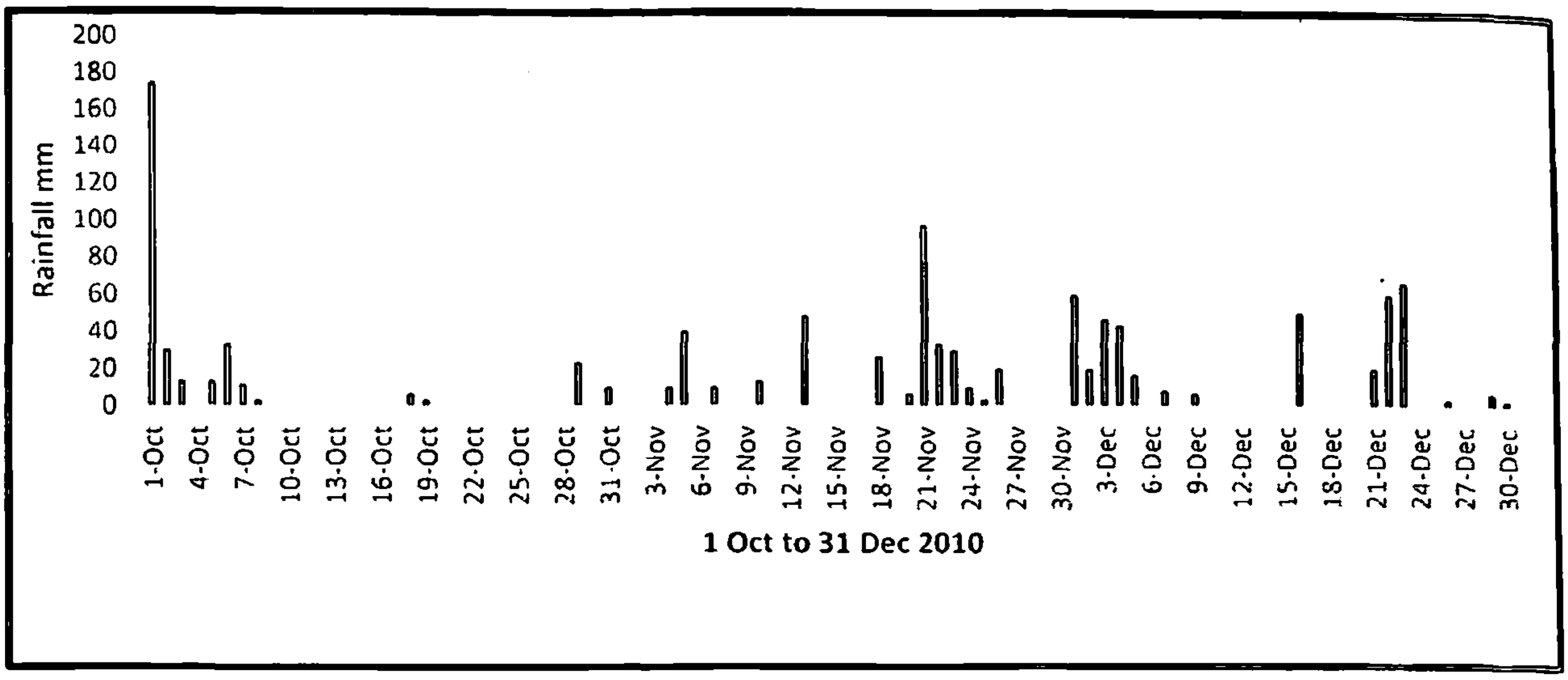


*Fig. 8 Rainfall before the Meander Cutoff on.*

the hills to the north. This completes the formation of a rather exaggerated meander.

## MEANDER CUTOFF

The man-made Wanasgalla Watta meander lasted for about 2000 years or more until the meander breach following the freak rainfall events in October and November, 2010, which caused bank erosion and shutting off of the meandering channel below the Wanasgalla Watta bridge by uprooted trees brought down from the upstream area. The heavy rains in 1997 also raised the water level of the river to the bankful stage causing erosion to the LB above the Malliyagoda Bridge endangering the road (personal communication with villagers). Erosion at this location was stabilized by the government authorities to protect the road, that prevented further narrowing of the meander neck at point B (Figure 4). Another spell of heavy rains in October and November, 2010 caused erosion of the LB just below the Malliyagoda Bridge. On October 1st, 2010, 174 mm of rain fell in 24 hours. This was the most destructive event which brought fallen trees from the upper catchment and partially blocked the channel at C (Figure 4). The rains continued till October 9th with a reduced intensity (Figure 8). Another spell of heavy rains started on 28th October peaking on 21st November. Blocking of the channel by trees forced the flood water to create a new channel connecting the upper and lower channel segments of the meander on this day (Appendix Plate 1 and 2). Thereafter, the new

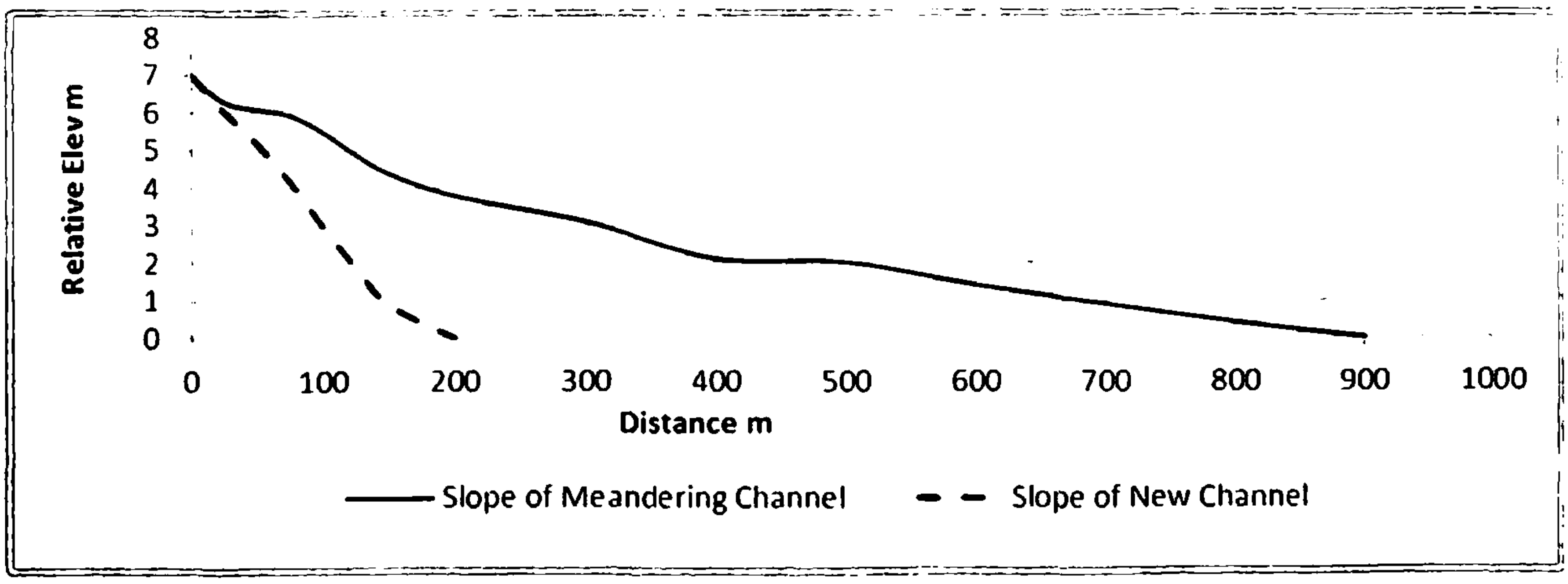


*Fig. 9 Dik Oya channel slope before and after meander truncation.*

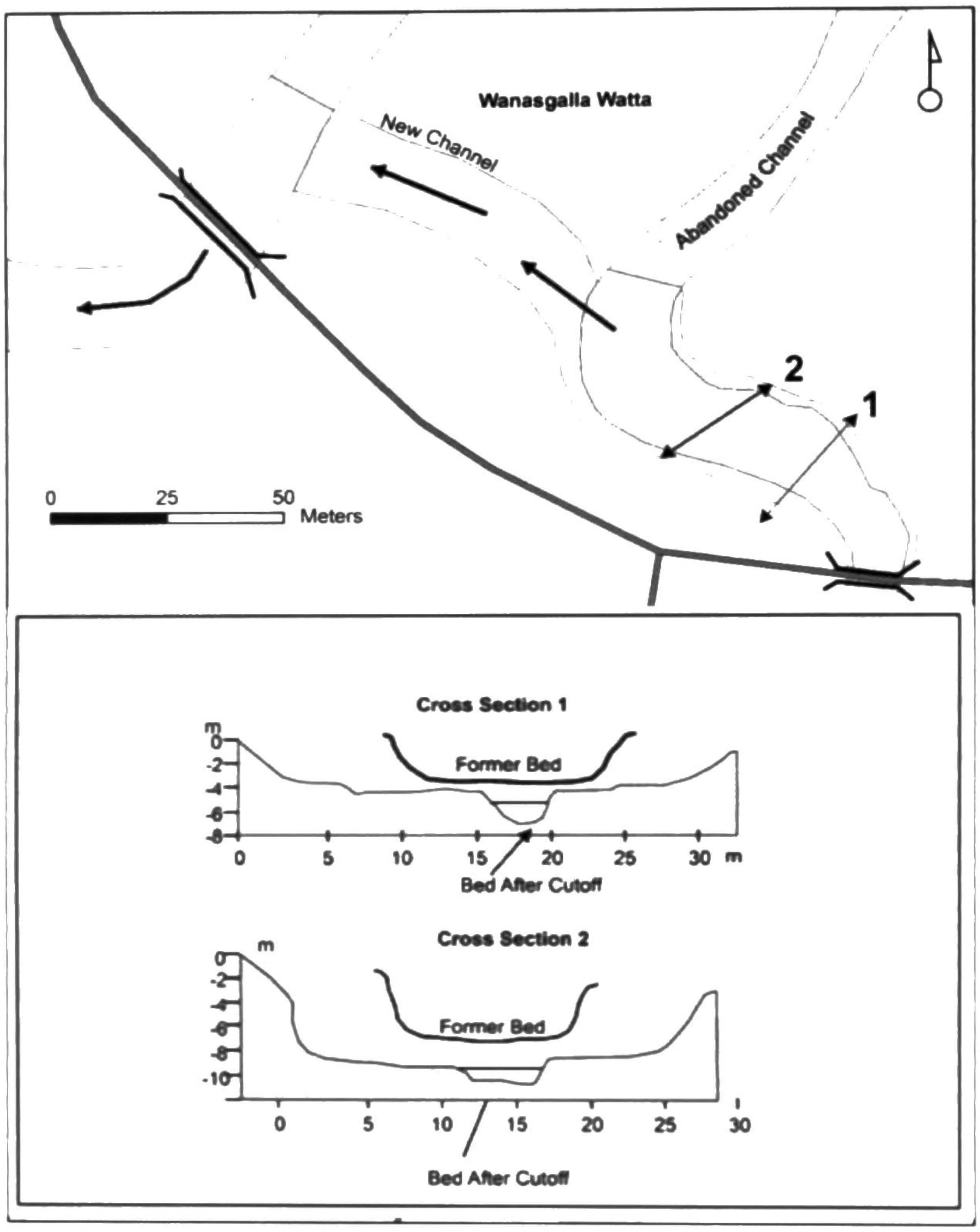


*Fig. 10 Channel bed erosion after meander cutoff.*

channel was widened and deepened by erosion while the old channel left abandoned, except the channel segment which now forms the lower end of a RB tributary. The upper part of the abandoned channel does not carry water now and the channel bed is dry.

## THE ADJUSTMENT OF THE CHANNEL SLOPE OF NEW CHANNEL

The new channel has a steeper gradient compared to the former one (Figure 9). The elevation difference between the top and bottom of the new channel is about 7 m. Earlier the river flowed along a long meandering course with a gentler slope. Meander cutoff increased the gradient of the channel leading to channel bed erosion as is clearly vissible at the Malliyagoda Bridge (Figure 9). Bed erosion has extended up to the Wanasgalla Watta bridge at which concrete lined section of the river channel under the bridge prevents the erosional adjustment of the long profile further upstream. As a result, there is a bed level difference of about 1m at the downstream marging of the bridge and continues to erode.

After meander cutoff the channel length has shortend significantly causing an increase in the channel bed slope (Figure 9). The new channel expends its excess energy resulting from reduced resistance in the old long meandering course for eroding the channel bed and banks as can be seen from Figure 10 and Appendix Plate 3. The upstream migration of channel bed erosion has been stopped by the concrete foundation of the Malliyagoda bridge.

## DISCUSSSION AND CONCLUSION

Formation of a meander with extremely high sinuosity at Wanasgalla Watta and filling of the upstream valley with sediment may well be due to the creation of an irrigation tank at Weuda. When the bund was breached at its northeastern end the Dik Oya main river was forced to flow towards NE parallel to the bund axis and joined the channel of the tributary just below the dam forming a meander. This meander appears to have lasted over 2000 years, but finally experienced meander cutoff as a result of long-term bank erosion and the high flows due to freak rainfall events of 2010.

The upper limb of the meander was controlled by the presence of a dam and therefore it flowed in a straigter course. The lower limb was probably the lower reach of the tributary and shows more sinuous channel form. Another tributary on LB also has been deflected to the right away from its natural course by the tank bund and it now flows across the bund through a breach. Only a narrow raised ground separates the upstream and downstream segments of the former valley of this tributary. Only reference available to this tank, known as *Cakora Wewa*, is a 2nd century inscription found at a nearby temple premises. That indicates this tank was not repaired after the breaching perhaps in the early part of the Christian era. The later developments in the area have obscured the ancient topography of the site. The descriptions of sediments in this area by several authors (Dahanayake and Dasanayake, 1981, Dahanayke, et al., 1989 and Premaratne and Jayasena, 2009) indicate that they were laid down in a lacustrine environment. The present study also demonstrated, based on the valley bottom topography, the the probable existence of an extensive layer of sediment along the main channel and also along the tributaries. The flatness of the valley also can be attributed to the filling up of the original v-shaped valley. The most important features of these sediments described by Premaratne and Jayasena (2009) at Medemulla, Metibokke and Puswella are interlayered angular gravel, sand and peaty clay deposits. These sites are located in the bed area of *Cakora Wewa* referred to in this study. All three papers however concluded that these sediments were glacio-fluvial deposits dating back to the Permo-Triassic. Premaratne and Jayasena (2009) however expressed some doubts about the presumed age of these sediments on the grounds that "it is questionable whether the sediments could be preserved with the original structure after more than 200 million years". None of the previous authors was aware of a tank at this location. The evidence reported in this study pointing to an ancient tank explains the varve-like sediment reported. The alternating sequences of sand and peaty clay layers and angular gravel deposits are compatible with a lacustrine sedimentary environment, natural or man-made. The coarse sediment is more likely to have been transported during floods. The distance of transport of quartz gravel is not enough to undergo rounding and polishing. The peaty clay layers would have been settled under calm conditions. Sand deposits, Premaratne and Jayasena (2009) mapped below the bund may well be floodplain deposits of the Dik Oya. The *Cakora Wewa* is located at a point where the river begins to enter a flat terrain. After the construction of the tank, the river sediment would have deposited in the tank bed area. This is a fine example for a life cycle of a man-made meander which was finally changed by prolong erosion despite some interventions by man.

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## APPENDIX

*Plate 1 Newly built channel after meander cutoff.*

*Plate 2 Abandoned channel with logs.*

*Plate 3 Bed erosion.*