THE PECULIARITIES OF EROSION AND SOIL PROCESSES IN LOWER KURA RIVER AND THE RISK OF FLOODS

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Abstract

The section of the Kura River from the downstream of the Mingechevir dam to the Caspian Sea is called the Lower Kura. The Kura River flows on an alluvial layer, created by him over the millennia. The water course has turbulent character, with transverse circulation. The dynamic axis of water flow wanders. Water has character of a disperse liquid. In turbulent flow the disperse liquid behaves as an emery paper. It considerably accelerates process of erosion of coastal dams. According to our field investigations and theoretical estimations, in some years of a high water annual displacement of meanders reaches 9 ÷10m. Case studies have shown that the displacement of the meander on the Kura River passing through the villages of Ashagy Surra, Yukhary Garaimanly and Kurgarabujag in the Neftchala region was 450 m over 50 years (1967-2017). The region is densely populated and has a dense infrastructure. The horizontal displacement of the meander leads to the destruction of coastal structures and creates the risk of flooding. The economic damage caused by the flooding in 2010 was over US $ 500 million.

Keywords: Kura River, meander, erosion, channel migration, turbulent flow, flooding

I. Introduction

The Kura is the largest river in Caucasus and undergoes to seasonal flooding. The growing risk for inhabitant, ecosystems, and the economy of flooding in the lower Kura region were partly due to reclamation of floodplains for agriculture and increasing siltation from erosion in the watershed. Some rivers of the Kura basin have extremely irregular discharge throughout a year. Ratio of extreme average discharge is 1.6-6.6, which makes sometimes difficult to overcome its negative impact. The Kura River was named because of heavy flooding as "Mad River" [1, 2] among the people, to similarly that as the Chinese name Huang He River "Grief of Chine" [3]. The researches have shown that these rivers have many similar features. 80 million persons living in a Huang He valley, and 4 million living in the Kura-Araz lowland, who constantly feels fear of the catastrophic flooding.

The headwaters of the Kura River is in Turkey at the Kizil-Giadik mountain range in Ardahan province, winding its way through Georgia and Azerbaijan into the Caspian Sea. Its main tributary Araz River originates in Erzurum province in eastern Turkey. It flows along the Turkey-Armenia border, along the Iran-Armenia border, along the Iran-Azerbaijan border, before flowing into Azerbaijan, where it joins the Kura in the centre of Kura-Araz lowland. The total length of the Kura river is 1515km (915 km of which are on the territory of Azerbaijan) and the total area of the Kura-Araz basin 188.000km^2, occupying the greater part of the South Caucasus. The river is formed by snow (36%), groundwater (30%), rains (20%) and glaciers (14%). In spite of distributing of this area amongst the Turkey, Georgia, Azerbaijan, Armenia and Iran, but neither, except for Azerbaijan, the Kura River is the main source of life for Azerbaijan and its troubles can be nation-wide.

The Lower Kura is the plains river. The longitudinal slope of riverbed from village Yukhari Qarkhun of Yevlakh district (N 40° 37' 24″; E 47° 11' 23″; H =+17m) to a mouth (H = –27m, Caspian Sea) makes only 7‰, i.e. 7cm in 1km. (For comparison, the riverbed longitudinal slope is 600cm and 250cm in 1 km, in Turkey and Georgia, accordingly.

As the Kura River, Araz River runs on plain in the centre of Azerbaijan. Therefore, Azerbaijan, located on low territories of the Kura and Araz rivers receives the great quantity of mud from both river systems. As a result of the mud accumulation in the Kura River, there is vertical dynamics of a riverbed [4].

Flooding is a yearly occurring phenomenon, especially in the Lower Kura. Shore protection works also continually take place during year. In the recent 15 years (in 2003, 2006, and 2010) three catastrophic floods occurred in Lower Kura. The damage to the country's economy caused by the flood in 2010, costs for 500 million US dollar [5, 6].

The increased frequency of dangerous flooding was attributed to a number of causes, including climate changes and non-climatic origins [7], vertical and horizontal dynamics of a riverbed [1], isolation of the riverbed from floodplain [4], continuous rains, anthropogenic factors and etc. Unfortunately, any of the above mentioned approaches does not explain the true reasons of flooding in Lower Kura. Naturally, as result of the erroneous approach, flooding remains the main problem of a sustainable development of the Azerbaijan.

The basic mistake of all existing approaches of the analysis of the reasons of flooding consists that authors of researches do not consider peculiarities of erosion - accumulation processes in Lower Kura.

II. EXPERIMENTAL RESULTS

Figure 1 shows the horizontal change of the riverbed in the part of the Kura River passing through Neftchala region for 50 years (1967-2017). This place is the part of the Kura River passing through Ashagi Surra, Yukhari Garaymanli and Kurgarabujag villages of Neftchala region.

The average meandering coefficient on the route from the lower part of the Mingachevir dam to the delta of the Kura into the Caspian Sea is K ≥ 2.5. However, there are such huge meanders in different locations of the channel that the local meandering coefficient is very high. In the above location, the straight line distance between the entrance and exit of the huge meander on the old track (1967) is 1100 m. But the distance along the channel between that entrance and the exit is 6200m. Thus, the meandering coefficient of the huge meander here is 6200m: 1100m = 5.6.

The change of the meander peak is 450 m in 50 years. In other words, the huge meander in the indicated location changes its location by 9 meters in the horizontal direction every year. However, the projected change over the next 50 years could be even greater.

In order to study the flow processes occurring in this meander, we have been conducting bathymetric and flow velocity experiments since 2017. In this meander the flow is directed from Ashagi Surra village to Kurgarabujag village. Because of the studying area is in the northern hemisphere, according to Behr's law, the Coriolis force in the northern hemisphere is directed to the right in relation to the movement of water, and these shores become sharper as the current erodes the right side. The soil mass formed as a result of erosion accumulates on the left bank according to the granulometric parameters depending on the distribution of water velocity in the stream.

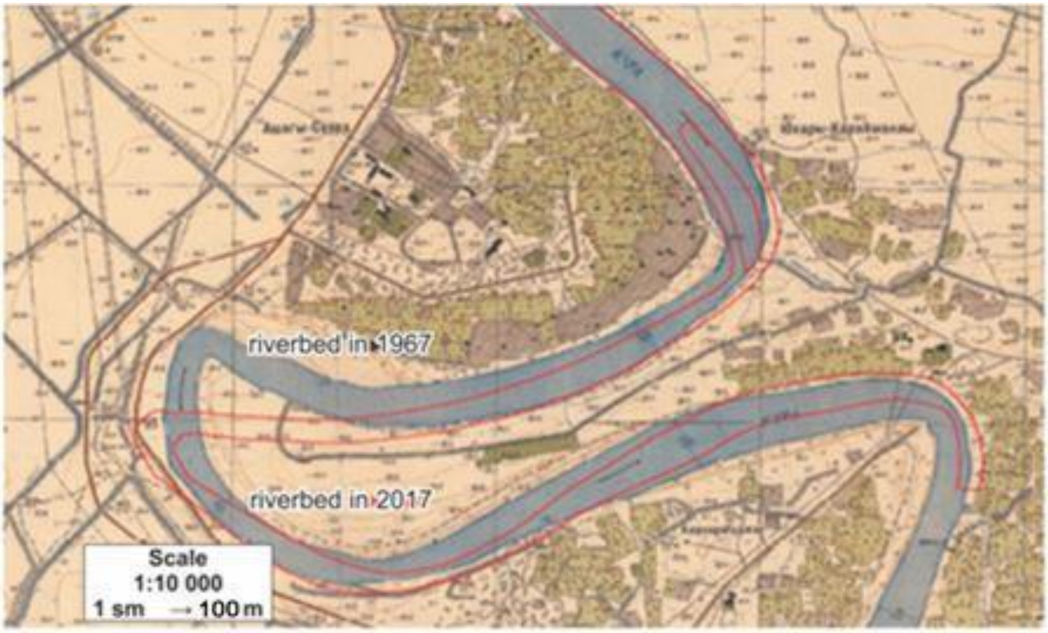
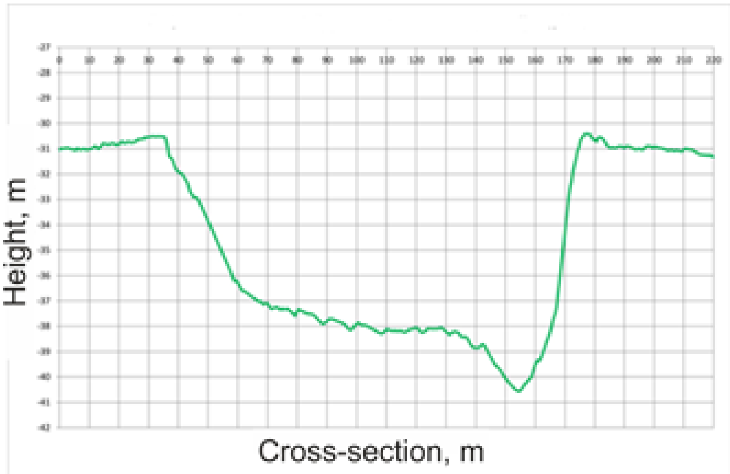


Figure 1: *Map of horizontal change of the riverbed in the Lower Kura for 50 years (1967-2017).*

Figure 2 shows the results of bathymetric measurements at that location. The cross-section distribution of the velocity of the water in the same location also proves that water velocity increases sharply as it approaches the right bank. Figure 3. shows the curves of the velocity distribution of water velocity in the absence of turbulence in the curve of the meander we studied.



Figures 2: *The result of bathymetric measurements at the peak of huge meander*

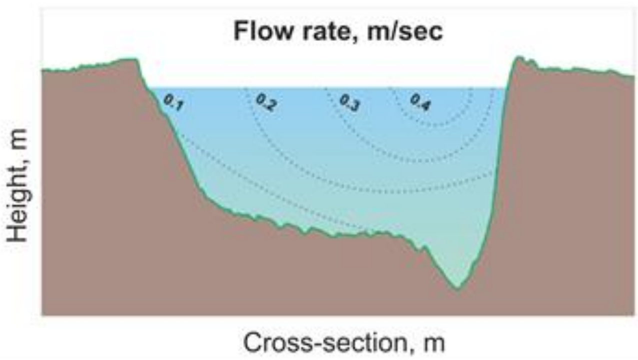


Figure 3: *Water velocity distribution curves in the non-existing of turbulence at the peak of a huge meander*

As the water moves in a curved motion at the peak of the meander, turbulence occurs in the flow. Turbulent flow erodes the soil on the right bank. This process is especially widespread in times of drought. Figure 4. shows a schematic of this process.

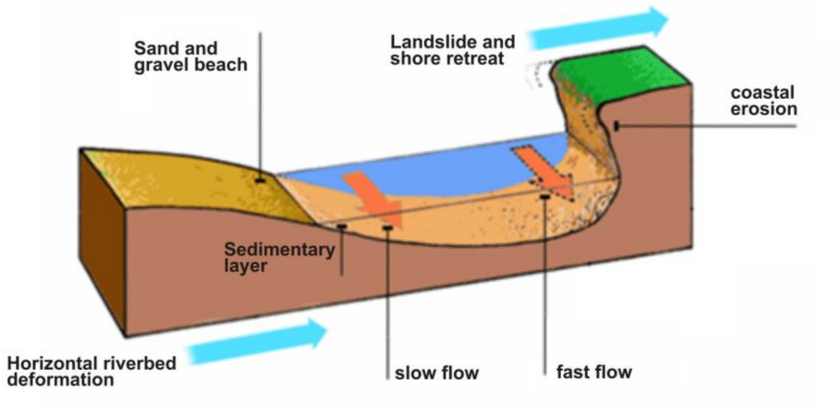


Figure 4: *Turbulent flow of water and erosion-accumulation processes at the peak of the meander.*

In order to compare the results of our experimental studies in the huge meander with the calculations of the mathematical model, the granulometric parameters of the impurities in the water were determined at the indicated location. Supplies with granulometric parameters of 0.2-1.0 mm are 5-8%, impurities with 0.05-0.20 mm are 20-25%, and impurities with <0.1 mm are 70-80%. These values are about 20% higher than the parameters given by R.K. Abbasov and R.N. Mahmudov [7] for close locations. It is natural that in the area up to the mouth there is an intensive process of subsidence of large grains. As a result of the formation of "traffic jams", the speed of water flow is reduced to such an extent that "ice jams" observed in the Siberian rivers. The water cannot flow forward in the channel, and gradually there is a backward pressure. Even so, owning one is still beyond the reach of the average person. As we approach the source, the flow is 90-100% with a diameter of <0.1 mm.

Analysis of scientific and technical literature shows that there have been attempts to model the migration of the river bed. Our results are well described by the model proposed by Timothy J. Randle [8]. It has been shown that the coastal erosion rate is a multi-parameter function. To describe the erosion process, the author used many empirical coefficients.

$$B_e = \left\{ \left[a_1 C_s \left(\frac{W_b}{R_c} \right) \right]_{at\,L} - \left[a_2 \left(r_\gamma \frac{r_d}{h_b} \right) + a_3 \left(LWD \frac{d_W}{D} \right) + a_4 (PI) + a_5 \left(d_c \frac{h_b}{D} \right) \right]_{at\,L + \text{Phase Lag}} \right\} a_6 V$$

where B_e – rate of bank erosion [L/T]; W_b –bankfull channel width [L]; Cs – bed-material sediment concentration [ppm]; R_c – channel radius of curvature [L]; L – distance along the channel; Phase Lag –planform phase lag along the channel (see Figure1); r_γ – fraction of bank area covered by vegetation roots [%]; r_d – vegetation root depth [L]; h_b – bank height [L]; LWD – fraction of bank area covered by trees or large woody debris [%]; d_W – average height of large woody debris jams [L]; D – hydraulic depth of the channel [L]; PI – plastic index; d_c – portion of bank sediment too coarse for incipient motion [%]; V – mean channel velocity [L/T]; a_1 and a_6 are empirical coefficients and a_2, a_3, a_4, and a_5, are weighting factors.

As follows from the formula all the parameters on the right-hand side of equation produce dimensionless terms except for the average channel velocity, which provides dimensions for the bank erosion rate [L/T]. As we noted earlier, the Kura river flows on an alluvial layer, created by him over the millennia [1, 3]. To calculate the coastal erosion rate, we used the soil parameters given by R.V. Lodina [9]. The rest of the parameters were obtained from field measurements in the region of the large meander of the Kura River shown in Figure 1. As a result of calculations according to the above formula, the value of the coastal erosion rate was obtained at 8.5 meters per year. This value is in good agreement with the data of cartographic analysis of the Kura river bed in 1967 and 2017.

III. Conclusions

Erosion and soil processes in Lower Kura, occur under following conditions:

Lower Kura is one of the most turbid rivers of the world and flows on an alluvial layer, created by him over the millennia. Therefore, the river is freely meandering. The water course has turbulent character, with transverse circulation. The dynamic axis of water flow wanders. According to our estimations, the length of meanders accounts for 75 % from total length.

Water has character of a disperse liquid. In turbulent flow the disperse liquid behaves as an emery paper (sandpaper). It considerably accelerates process of erosion of coastal dams. According to our estimations, in some years of a high water annual displacement of meanders reaches 9 ÷10m. Therefore, annual breaks in the coastal dams occur in the same riverbed sites (!). The economic damage caused by the flooding in 2010 was over US $ 500 million.

Because of a large quantity of deposits intake from tributaries, in the conditions of negligibly longitudinal slope of riverbed, there is a strong sedimentation and accumulation of deposits, strong vertical deformation of riverbed. As a result of deforestation in the river basin, deposits intake growth trend is observed.

As a result of vertical deformation of riverbed and permanent shore protection works, forming the anti-valleys, similar to the Huang He, Kuban, Panj, Amu Darya and Syrdarya rivers. All of these rivers tens of years are flowing through countries with socialist agriculture setup (traditions).

Why, coastal dams break occurs in the same riverbed sites of Lower Kura?

The soil material of levee banks consists of alluvial soil, which is easily erosion by a turbulent flow. At shore protection and dike raising works, the state structures responsible for emergency situations use the same accessible (improvised) cheap alluvial material, by the method of excavator dyking (damming-in). Just as it was made in Soviet period. The basic criterion of technical realization of such projects those years was the principle of their minimal cost. Thus question of strategic risk, ecological safety and other, as a rule, at all did not take seriously. Therefore, once dyked in the past banks is repeatedly washed away in a high water.

According to the laws of soil mechanics the levee banks inclined to destructions and washout should become stronger a material with low factor of washout. In due time, Ibad-zadeh Yu.A. has suggested to use loam with 20 % of clay [10].

It is necessary to note, one important fact. The region is of global ecological interest. For example, Conservation International has identified the South Caucasus – an area corresponding closely to the Kura river basin – as being one of the world's top 25 biodiversity hotspots. Over 115 species of waterfowl live along the shores of the Kura and its associated wetlands including many RDB species [11].

These peculiarities of erosion and soil processes sets the Lower Kura River in a unique position of serving as a model for trial-use standard the most up-to-date approaches to flooding risk mitigation and management. Therefore, the solution catastrophic flooding problems in Lower Kura demands new, innovative approaches. Our researches proceed, and results will be presented in the near future.

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