Hydromorphological dependences of the meandering riverbed forms in the lower course of the Amudarya river

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Abstract. At coming up with of civil engineering constructions within the watercourse hydraulic calculation of the riverbeds is made. Hydraulic calculation establishes bottom main parameters: width, depth of a stream and radius of curvature of the river beds, and so on. In article results of studying of changes of morphological parameters of the riverbed are yielded: width of a bed, average depths of a stream and radius of a dynamic axis of a stream on river beds in conditions of regulated a water flow on water basins. On the footing of the statement of results from examination of hydraulic parameters of a stream with use of a method of dimension connections of width, average depths of a stream and radius of a dynamic axis of a stream from the factor forming a river bed are received.

1. Introduction
In the conditions of regulated water flow by the reservoir below the dam, changes in the hydrological situation are most pronounced. The sketch exist the lining up of the flow, disinherit in will the high water grasped fashionable the accumulation discharges from it bring about an increase of cheap water, efficiently reduced the flow of solid residue from liquid solution. Due to this, the lower stream receives less sediment than it did before the creation of the reservoir. The stream coming out of the reservoir, which is under saturated to the transporting capacity by sediments, begins to wash away the bottom of the riverbed. As a result, the riverbed goes from multi-arm to single-arm, meandering of the riverbed develops.

2. Materials and methods
The works of V. M. Makkaveyev [4], S. T. Altunin [1, 2], N. I. Makkaveyev [5], N. A. Rzhanitsyn [6], H. A. Ismagilov [3] and so forth exist committed to the study of the hydromorphological limit of the riverbed. The studies of these authors have connection with the unaffected unregulated condition of the flow of water fashionable penal institution.

The semantic limit distinguish the connection middle from two points the wideness of some amount and insight of the riverbed from the determinant of the riverbed leadership of organization in the environment of controlled water flow, in addition to the normal leadership of organization [7], arise the suppose of M. V. Lohtin [8]. Every waterway, if we turn over in one's mind it not only at individual points, but all at once, exist make by a combination of three main essential feature that act not believe each one, that is to say:
High water content, contingent upon of or in the atmosphere and soil environment of moisture in air or falling from sky ahead of penal institution area and their flow into penal institution from tributary;

2. Slope or tilt bring about apiece landscape of penal institution pathway to traverse larger path region;

3. Greater or secondary deterioration or stability of penal institution bed, matching to the characteristic of the coating of the soil poke hole in by allure flow.

Considering the active side of the riverbed establishment, M. A. Velikanov [9] particularized these three classification, utilizing the following three parameters: flow rate (Q), slope (i), and the extent or bulk of some dimension of below atom (d). These three principles, in accordance with M. A. Velikanov, bear decide the average morphometric trait of the riverbed flow: wideness of some amount (B), distance down or across (H), sweep of curvature (R), etc.

Object of researches. At the beginning of the lower course of the Amu Darya River, the Tuyamuyun repository exist innate 1982. The water pressure in contact the repository exist 20 m. At 240 km beneath the repository, the Tahiatash hydroelectric complex bear get along in life because 1974. Below the accumulation, the riverbed exist regulated by two-habit dams [10].

To study the change of riverbed width, average depth of flow was carried out for a regulated flow conditions of water according hydrological stations below the Tuyamuyun reservoir on the river Amu Darya.

Below the Tuyamuyun reservoir on the Amu Darya River there are 5 hydrological posts: Tuyamuyun, Kipchak, Nietbaytas, Samanbay, Kyzyljar.

Tuyamuyun the gauging station is located below the reservoir in the common area of erosion. The analysis of the data showed that the riverbed is currently being re-formed in the area of the water metering stations and the riverbed process has not yet stabilized.

The Kipchak water metering stations is located 185 km below the Tuyamuyun reservoir and the post is located in the alignment of the pontoon bridge. The bridge narrows the riverbed by 2 times, and the current here passes in the retaining mode and does not reflect the mode of the free flow of the stream.

The Nietbaytas water metering stations is located 8 km above the Tahiatash hydroelectric complex and the flow regime here is affected by the backwater created by the hydroelectric complex.

Samanbay hydro station is located 17 km below the Tahiatash hydroelectric complex. As the analysis of the hydrological data showed, the riverbed process in the area of the water metering stations has already more or less stabilized.

The Kyzyljar water metering stations is located 100 km below the Tahiatash hydroelectric complex. The sediment transport process is stable.

Thus, out of 5 water metering stations located below the Tuyamuyun reservoir, at two water metering stations Samanbay and Kyzyljar, the riverbed process has now stabilized and data from these two posts were provided for the analysis of the hydraulic parameters of the flow and the riverbed.

3. Results and discussion

Following the first position of M. V. Lakhtin, the connection graphs $B=f(Q)$, $H=f(Q)$ are presented in Figure-1. As can be seen from these graphs, the points near the curve have a good connections. The correlation coefficients of these connections exceed 0.9.
The following connections are obtained on the basis of these graphs for the regulated water flow conditions of the lower course of the Amudarya.

For width of riverbed

\[ B = 25 \cdot Q^{0.37} \]  \hspace{1cm} (1)

For flow depth

\[ H = 1,1 \cdot Q^{0.15} \]  \hspace{1cm} (2)

Although these connections have good correlation coefficients, they do not satisfy the scale. To satisfy the scale, the second and third propositions of M. V. Laxtin were used, and formulas (1) and (2) are given in the following forms:

\[ B = 25 \cdot Q^{0.37} = K_1 \cdot \left( \frac{Q}{\sqrt{gi}} \right)^{0.37} \cdot d^{0.075} \]  \hspace{1cm} (3)

Where

\[ K_1 = \frac{25 \left( \sqrt{gi} \right)^{0.37}}{d^{0.075}} \]  \hspace{1cm} (4)

\[ H = K_2 \cdot \left( \frac{Q}{\sqrt{gi}} \right)^{0.15} \cdot d^{0.625} = 1,1 \cdot Q^{0.15} \]  \hspace{1cm} (5)

Where

\[ K_2 = \frac{1,1 \left( \sqrt{gi} \right)^{0.15}}{d^{0.625}} \]  \hspace{1cm} (6)

**Table 1.** The value of the size of bottom sediments and the slope of the Amu Darya River according to the water metering stations [11].

| Name of the water metering stations | Tuyamuyun | Kipchak | Nietboytas | Samanboy | Kiziljar |
|------------------------------------|-----------|---------|------------|----------|---------|
| Distance from the                  | 450       | 250     | 207        | 185      | 100     |
former mouth, km

| Size of sediments, $d$, mm | 0.15 | 0.12 | 0.11 | 0.10 | 0.08 |
|---------------------------|------|------|------|------|------|
| Slope, $i$                | 0.00015 | 0.00012 | 0.00011 | 0.0001 | 0.00008 |

Table 1 shows the sediment size ($d$) and slope ($i$) values for the lower course of the Amudarya along the target. As shown in Table 1, the size of the sedimentary rocks and the slope along the length of the riverbed change from the top to the bottom. Although the longitudinal slope of the sediment and river bed is different, but in separate sections they have constant values. The values of $K_1$ and $K_2$ were set in formulas (4) and (6) using sediment size and slope data. After replacing the values of $K_1$ and $K_2$, formulas (3) and (5) take the following form:

$$B = 25 \frac{Q^{0.37} \cdot d^{0.075}}{\left(\sqrt{gi}\right)^{0.37}}$$  \hspace{1cm} (7)

$$H = 200 \left(\frac{Q}{\sqrt{gi}}\right)^{0.15} \cdot d^{0.625}$$  \hspace{1cm} (8)

Formulas (7) and (8) describe the connections between the main factors that make up a river bed: latitude ($B$) and depth ($H$); flow velocity ($Q$), slope ($gi$), and size ($d$) regulated water flow conditions.

4. Results of analysis on the plan-forms

The study of changes in the morphological parameter on a curved section of the river in the conditions of regulated water flow was carried out using space cartographic materials [12, 13, 14] of the lower course of the Amu Darya River. The following morphological parameters: the width of the riverbed ($B$), the radius dynamic-axis flow on a curved section of the river ($R$), the distance between the bends ($L_{step}$), the sinuosity of the riverbed: $K_{tor} = L_t / L_s$; where $L_t$—length of twisting line; $L_s$—for straight line. (Figure 2).

**Figure 2.** According to plan - high-rise space photographing of Gurlen area in regulated a site of the riverbed of Amu Darya.

The obtained data on cartographic materials morphological parameters on a curvilinear site of the river of Amu Darya in conditions of the regulated a water flow are presented in table 2. As can be seen
from table 2, the first curved section for filming on 25 September 2010, is on 48 km below a dam of the Tuуamuyun water reservoir in territories of the right coast of Turtkul area and on the left coast of Hanka area. On this bend the radius of curvature of a dynamic axis of a stream makes 2200 m, width of a riverbed of 360 m, and tortuosities 1.2.

The following plots are curved from the first curved portion at a distance of 48 km, where on the right Bank is Beruni district, on the left Bank Kurlansky district. The shooting dates back to August 31, 2011. There are 4 curved sections here. The radius of curvature of the dynamic axis of the flow ranges from 740 to 4100 m, the width of the riverbed from 310 to 400 m. The distance between the curved sections of the 2400 – 12200 m Tortuosity coefficient 1.2-1.4, R/B ratio = 2.76-10.25; \( \frac{L_{step}}{B} = 7.74-30.50 \).

Next, the shooting of June 21 and September 11, 2010 is considered. These surveys relate to the section of the river from the Kipchak water metering stations, located 185 km below the Tuyamuyun reservoir to the Tahiatash hydroelectric complex. The length of the section is 85 km. In this section, 3 bends were recorded in June and 2 bends in September. The radius of curvature ranges from 1170 to 2950 m. Width 310-490 m. The distance between the bends is 7000-25400 m, the tortuosity coefficient is 1.2-1.3, R/B=2.66-7.0; \( \frac{L_{step}}{B} = 14.24-65.81 \) [15].

The remaining data shown in the table refer to May and September 2009 and to August 2012. All these data characterize the curved sections below the Tahiatash hydroelectric complex. Changes in the parameters are as follows: radius of curvature 400-3450 m, riverbed width 50-140 m, distance between bends 2000-19500 m. riverbed curvature 1.2-1.5, R/B=3.17-10.0; \( \frac{L_{step}}{B} = 23.64-87.14 \).

| №  | Shooting date | B (m) | R (m) | \( L_{step} \) (m) | R/B | \( \frac{L_{step}}{B} \) | \( L_t \) (m) | \( L_s \) (m) | \( K_{tor} \) |
|----|--------------|-------|-------|-------------------|-----|----------------|-------------|-------------|----------|
| 1  | 25.09.2010   | 360   | 2200  | -                 | 6,11| -              | 6280        | 5410        | 1,2      |
| 2  | 31.08.2011   | 380   | 1050  | -                 | 2,76| -              | 2200        | 1690        | 1,3      |
| 3  | 31.08.2011   | 310   | 740   | 2400              | 2,39| 7,74           | 2000        | 1420        | 1,4      |
| 4  | 31.08.2011   | 400   | 1400  | 7100              | 10,25| 17,75         | 7570        | 6170        | 1,2      |
| 5  | 23.08.2011   | 400   | 3700  | 12200             | 9,25| 30,50          | 9280        | 6750        | 1,4      |
| 6  | 11.09.2010   | 420   | 2620  | 11300             | 6,24| 26,90          | 5750        | 4500        | 1,3      |
| 7  | 11.09.2010   | 490   | 2950  | 7000              | 6,02| 14,29          | 4580        | 3930        | 1,2      |
| 8  | 21.06.2010   | 440   | 1170  | 25400             | 2,66| 57,73          | 2350        | 1870        | 1,3      |
| 9  | 21.06.2010   | 310   | 2200  | 20400             | 7,10| 65,81          | 4370        | 3510        | 1,2      |
| 10 | 21.06.2010   | 400   | 2800  | 7100              | 7,00| 17,75          | 6210        | 4940        | 1,3      |
| 11 | 28.08.2012   | 300   | 3450  | 19500             | 11,50| 65,00         | 5740        | 4960        | 1,2      |
| 12 | 28.08.2012   | 120   | 380   | 4500              | 3,17| 37,50          | 990         | 700         | 1,4      |
| 13 | 28.08.2012   | 120   | 950   | 6300              | 7,92| 52,50          | 2040        | 1620        | 1,3      |
| 14 | 28.09.2009   | 140   | 1300  | 12200             | 9,29| 87,14          | 2890        | 2510        | 1,2      |
| 15 | 28.09.2009   | 110   | 450   | 4000              | 4,09| 36,36          | 1300        | 880         | 1,5      |
| 16 | 28.09.2009   | 110   | 690   | 3900              | 6,27| 35,45          | 2030        | 1350        | 1,5      |
| 17 | 28.09.2009   | 110   | 500   | 2600              | 4,55| 23,64          | 1370        | 980         | 1,4      |
| 18 | 28.09.2009   | 110   | 1100  | 3000              | 10,00| 27,27         | 2980        | 2420        | 1,2      |
| 19 | 28.09.2009   | 105   | 780   | 2500              | 7,43| 23,81          | 1500        | 1250        | 1,2      |
| 20 | 22.05.2009   | 70    | 600   | 2000              | 8,57| 28,57          | 1270        | 1010        | 1,3      |
| 21 | 22.05.2009   | 50    | 400   | 2300              | 8,00| 46,00          | 1000        | 760         | 1,3      |
Using the data in Table 2, a graph of the $\lg R = f(\lg B)$ relationship was constructed. (Figure 3). As can be seen from figure 2, the relationship between radius of curvature and width of the riverbed is good, is linear and the correlation coefficient is 0.7. When the graph shows that with increasing the width of the riverbed occurs and the growth of the radius of curvature of the stream. Based on this graph, the relationship between the radius of the dynamic flow axis and the width of the riverbed was obtained in the following form:

$$R = 11.38 \cdot B^{0.88}$$

(9)

Substituting the value of $B$ from (7) to (9) we get:

$$R = 150 \frac{Q^{0.35} \cdot d^{0.125}}{\sqrt{gi}^{0.35}}$$

(10)

Comparison of indicators of the degree of water consumption in the formula (7), (8) - (10) Under regulated water flow conditions, these figures have been shown to be much lower than in the inland state of the river [16, 17]. This is due to a decrease in flow average annual turbidity under domestic conditions, the average annual turbidity of the flow is reduced to 2-3 kg/m$^3$ [18, 19], and 0.2-0.3 kg/m$^3$ [20, 21] under regulated flow conditions.

![Figure 3. Graphic of connection $\lg R = f(\lg B)$.](image)

5. Conclusions

In conclusion, it can be noted that based on the results of the analysis of the hydrological and topographic data of the lower Amu Darya River, the hydromorphological connections (7), (8) and (10) for the conditions of regulated water flow are obtained. It is recommended to use these connections for the hydraulic calculation of the riverbeds during protective and regulatory measures and to assess the capacity of the regulated sections of the Amu Darya River.
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