Horizontal Deformations of the Ural River Bed on the West Kazakhstan Territory

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Abstract. A retrospective analysis of river bed deformations over the 30 years' period for the Ural River in the West Kazakhstan in different environmental conditions have been carried out for the first time. A geomorphologic description of the Ural River bed and floodplain within the West Kazakhstan have been made. The dynamics of channel processes on the Ural river have been studied. The planned river bed adjustments of the Ural river have been determined. The article describes the results of sketch maps compilation and consolidation of the collected factual material related to the planned Ural river bed adjustments within the West Kazakhstan. The peculiarities of hydrologic and hydro chemical regimes of the Ural river have been reviewed. Main river bed types, peculiar to flat territories have been pointed: relatively straight lined, unbranched, meandering and divided. West Kazakhstan territory can be referred to the region with the medium ecologic stress in river beds and in floodplains

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Keywords: River bed evolution, river bed, meander, the Ural river bed morphodynamics, river bed deformation appraisal, soil, floodplain, river bed adjustments, forecast, bed-formation factors, river beds, typification, meandering.

1. Introduction

Studies of N.I.Makkaveev, V.V. Ivanov, B.V.Matveev, A.V.Chernov, M.Zh.Zhandaev, K.M.Berkovich, R.S. Chalov [1,2,3,4,5,6] are dedicated to the river bed evolution processes. R.S.Chalov (1996) and others emphasize three main river bed types, specific for even lands: relatively straight unbranched, meandering and branched [7].

In the Al-Farabi Kazakh National University this matter was studied by S.A. Abdrasilov, Doctor of Sciences (Geography), [8], he published a monography entitled "River bed evolution and the formation of intercontinental delta (case study the Ili River delta)". Spatial patterns of erosion development of the Ural river bed were studied by G.A. Kabdulova [9,10] in her thesis "Modern erosion processes in the steppe and semi-desert areas of the West Kazakhstan" in 2003, but this research requires further study and the expansion of methodological approaches.

The dynamics of rivers and lakes' development on the basis of the analysis of cartographic and space-related documents is studied by scientists of the Bashkir State Pedagogical University named of M.Akmulla under the guidance of G.T-G.Turikeshev [11-14].

Historic-geographical and environmental aspects of the Ural river cross-border basin's optimization have been highlighted in the monography named "Basin of the Ural: History, Geography, Ecology" of A. A. Chibilev, Doctor of Sciences (Geography), (Institute of Steppe, Ural Branch of Russian Academy of Sciences) [15], compiled of material collected during a comprehensive field expedition called "Ural-ecology", held in 1976-1985, and augmented during the Russian-Kazakh expeditions in 2002-2007. But main indicators of bed erosion and the role of natural and anthropogenic factors in the spatial differentiation of river network were not evaluated in this monography. The monitoring of river bed evolutions and of the hydraulic structures on water bodies is required. Also a regional program on the protection against the harmful effects of water is needed.

The river bed evolutions are being also actively studied abroad. For example, the scientists of China put more and more emphasis on the research of river bed evolutions of the Yangtze River, as well as to its morphology and dynamics in the last decade. It was determined that the most common morphodynamic type of river bed on the adapted and wide-floodplain areas of middle and lower streams of the Yangtze – branched [16]. It is the most complicated in its morphology and adjustments channel type, which is characterized by certain features of the evolution of forms.

Riverbank erosion has important implications for channel adjustment and long-term channel change, meander development, catchment sediment dynamics, riparian land loss and downstream sedimentation problems [17]. Because of poor understanding of riverbank erosion processes, river dynamics and sediment transport models are weakly integrated into river management strategies [18]. Furthermore, such knowledge gap complicated the relationship between flow energy and bank retreat rates [17] as both the fluvial and non-fluvial erosion processes take place in bank erosion system and because of the duration of process and response along with the lack of information on erosion or accretion. Despite decades of research, the erosion of cohesive riverbanks remains difficult to predict [19, 20, 21]. Models of cohesive river bank erosion must include a wide variety of erosional processes including fluvial erosion induced by hydraulic forces [22] and mass wasting processes related to soil strength and bank geometry [23]. Bank erosion is strongly influenced by the pore water pressures and the moisture content within the bank, which are influenced by hydrologic processes and riparian vegetation [24]. Lateral erosion**:** a river erodes its bank. This results often in serious problems such as loss of agricultural lands [25]. Dense vegetation at the river bank may prevent bank erosion.

There are three process groups active in stream bank erosion: subaerial, fluvial entrainment, and mass failure processes [26, 27]. The subaerial process is active throughout the river system but is particularly dominant in headwater reaches [26], fluvial processes generally dominate in mid-basin reaches [28, 29] and mass failure processes tend to dominate in the downstream reaches [29,30]. The overall rates of bank erosion are controlled by fluvial processes that remove bank material that may be delivered to the bank toe by mass failure [31, 32].

2. Materials and Methods. The object of research – are the Ural River bed evolutions within the West Kazakhstan (WK). The Ural River is the second largest river, flowing into the Caspian Sea. On the north it flows towards East-West direction, and on the south of Uralsk it sharply changes the direction for the meridional. The river flows between the Common Szyrt and Poduralsky plateau along the Predsyrt Escarpment (Ural lowland) and to the south of Chalk hummocks (Derkul ridge) enters the territory of a young Caspian depression. Everywhere, within the region, the river flows in unconsolidated sediments of Pliocene and Quaternary age, washing, in places, the deposits of more ancient epochs.

Retrospective and hydrologic-morphological research methods were applied as base methods for the analysis of the direction and rates of river bed adjustments over the historical period of time. The core of the retrospective method is in the comparison of asynchronical maps and plans, and the updated data of the remote sensing (aerial photographs); the core of hydrologic- morphological method - in linking the channel parameters and hydrological indicators.

The methods of historical river bed studies with the application of remote sensing data were used in the study. This method consists in the comparison and analysis of asynchronical cartographic, air- and space-related materials; determination of the river bed positions at different time slices, their analysis and the comparison of factor changes of the river bed evolutions. As a result of this work, there will be obtained the scheme of the river bed adjustments through the twentieth century. Their comparison with the floodplain relief's features, recognizable by the pictures will allow reconstructing and the conclusions of possible river bed adjustments by means of the pictures, and on the basis of special field studies [33, 34, 35].

The analysis of asynchronical topographic maps, reduced to a single scale, and comparison of the results with the geological, geomorphologic, geodesic materials with the performance of different morpho-metric plottings and measurements, compiles the cartographic studies, [36,37]. During the work, there were used the cartographic materials and the deciphering of large-scale aerial photographs (APG). The data processing of the obtained materials was carried out by the mathematical statistics methods with the use of ECM. The planned shifts of the Ural river bed were determined as per the large-scale (1:25,000) cartographic materials (1950's) and the APS (1980s). The time interval has amounted to about 30 years [10, 37]. According to the available cartographic material, a number of characteristics have been detected. The magnitude and speed of the river bed shifts have been determined. At that, the morpho-dynamic types of river beds (meandering, furcating, straight lined) were first identified. Based on data collection and the studying of text, tabular and cartographic information on the Ural river bed evolution the main types of river beds, typical for lowland areas have been identified: relatively straight lined unbranched, meandering and divided (branched). s in the channels and floodplains. According to the classification of K. M. Berkovich, R. S. Chalov, A.V.Chernov [5], the WK area can be attributed to the area with an average environmental stress in river beds and floodplains.

The analysis of river beds evolution over the historical time which gives us the reliable data on river bed morphology changes and on the main factors of river bed evolutions (river bed maps, the data of hydrological observations, etc.) allows us to assess the nature and intensity of river bed deformations due to natural processes, and also in the current human impact conditions.

Reconnaissance survey was conducted by the hydrographic survey method along the routes specified in the design stage. The routes were conducted according to the navigation maps of 1:25,000 scale, drawn up in pre-field period, with the preliminary plotting of the objects slated for inspection and the observation points along the route, located through the kilometric grid along the river bed.

The scope of work under the reconnaissance routes included: a survey of the Ural river with the description of banks, river bed and floodplain (valley) of the river and the area adjacent to the valley, establishing the indirect characteristics of the height of the spring flood water rise and rain floods, the description of hydraulic structures, riverbed deformation places, soils. The georeference and photographing of the most characteristic objects and observation points with a field book maintaining was carried out during the roots. Localization of observation points was carried out using the GPS system with the 12-channel GPS-receiver of Garmin eTrex model. GIS ArcGis 9.2 package was used as a means of map creation, which allows the processing and displaying of the spatial information.

3. Results and discussions. The average annual flow module of the Ural river, considering the river water tributary to the region in the north is 2.10 l/s. km, and the flow module, forming within the region is 0.98 l/sek.km². Due to the flow de-concentration within the Caspian lowlands, the Ural has the flow module of 1.45 l/sek.km² on the border of the transition to the Atyrau region. The average annual water flow on the Ural River on the territory of the region is 10,955 million m³. On the border with the Russian Federation the catchment area of the Urals is 165790 km², and in the region this value is added only by 26,125 km².

The number of outstanding floods in the Ural River has been registered during the observations – in 1914, 1922, 1923, 1931, 1940-1942, 1946-1948, 1957, 1970, 1993-1995. The main factors determining the high floods - are the large snow reserves (140 - 200% of the norm), a chorus snowmelt, minor water losses due to seepage of water on a large frozen soil moisture, and in some years the formation of ice under the snow cover[38].

The annual sediment yield is characterized by large variability. Its significant fluctuations are stipulated by differences in spring flood vigor, the intensity of snowmelt, the level of the autumn soil moisture and the amount of autumn rainfall in some years. In the north, the Ural takes a number of tributaries with high water turbidity. The river waters turbidity that flow into the Ural from Poduralsky plateau and Common Szyrt range from 100 to 200 g/m³. Further, the Ural flows along the valley, dissected by ravines and gullies, and that itself produces the high erosion activity. Therefore, the average water turbidity of the Ural River is very high - 400-800 g/m³. Towards the south of Kushum village the Ural River does not accept any tributaries, and therefore, its turbidity doe not increase. 94.5% of suspended load flow off on the Ural River accounts for spring, and only 5.5% - for the low-water period (June-February).

The river bed of the Ural is sinuous, presented by secondary (formed as a result of the watercourse itself) free, or meandering bends (meanders). The river bed width ranges from 180 to 260 m within each meander. Concave washed coasts are characterized by steep cliffs, called “the ravines”. They are based on the overdeepened sections of the river – river pool like trough cloughs at depth down to 5-7 m (rarely to 12 m). Ravines have a height of 6.5 m. to over 30 m (indigenous banks).

The Ural River within the WK region flows at the boundary of Burlin and Zelenovsky regions, along the southern border of the Uralsk city, and the western border of Terektinsky district, and along Akzhaykskogo district’s territory.

For example, the Ural River in Zelenovsky district starts from the Old Ural arm near the Kirsanov village, and ends at the Bogatsk village. The river length in Zelenovsky district is 263 km (without 34 km within the boundaries of the Uralsk city). The lower part of the middle stream (before the Kushum village) and the upper part of the lower stream (before the Bogatsk village) are in Zelenovsky district.

In the middle steram the river width varies from 100 m to 200 m. Depth in the shallows is 0.3 m, and on river pools - up to 8 m. The flow rate on river pools reaches 0.3 to 0.5 m / sec, and in the shallows - up to 1 m/sec (on some shallows it reaches 2 m/sec.) The bottom of the river bed in the shallows is sandy and gravel, and on river pools - sandy.

The banks of the river bed are mostly steep, sometimes flat. Their height varies from 3 - 4 and 7 - 8 m. The banks are formed of sand-clay sediments, mixed with gravel stones at places. At the end of the segment there are sandy loam and loams. The river bed is sinuous. Floodplain is composed of alluvial sand - loamy sediments, mixed with gravel stones. Only in some places against the steep slopes they are absent. Along the entire length it is crossed by dead stream branches, floodplain lakes, channels and gullies.

The degree of ruggedness by them in different places is different. The height of the slopes of the valley varies from 5 to 25 meters. On the slopes of the valley there are the above floodplain terraces.

In comparison with the average flow, the valley of the Ural river within the Caspian lowlands (downstream) has a young look. It separates by a low (2-4 m) flattened in some places ledge from the surrounding plain. On the slopes of the valley two terraces are developed. The valley is quite broad. The floodplain has different widths, from 2 - 3 km to 8 - 12 km. It separates by from the terrace by shoulder height of 4 - 5m. It is composed of layered alluvial deposits of variegated texture. The surface of the flood plain is cut by a network of narrow channels and is maculated by dead stream branches and flood plain lakes.

The river bed is sinuous, its width is usually from 100 m to 130 m, but there are places where it is much wider - up to 220 m. The depth on the reaches of 2 - 6 m, and in some river pools - 12 m. On the shallows, the depths, on the average, are equal to 1-2 m., and in places are reduced to 0.4 - 0.8 m. The flow rate on the river pools is within 0,25 - 0,60 m / sec, and on the shallows - 0.6 – 1.1 m / sec. The banks of the channel are represented by alternating cliffs and sandy shoals. In places, where the banks coincide with the staggered terraces or indigenous banks of the valley, the height of the coast reaches 10 - 20 m. Erosion of the banks are defined along the entire length of the river. Spring water can wash off the coast sections, which width are few meters or tens of meters.

The study of the planned displacements on the Ural River was conducted in three distinctive areas. The first section - "Zharsuat - Rubezhinskoe" - located in the steppe zone, the second - "Bolshoy Chagan - Budarino" is located in the semi-arid zone, the third - "Bazartobe-Taipak" is located in the semi-desert and desert areas. The river bed type, the displacement value were determined at these sections. All the major indices are given in Figure 1.

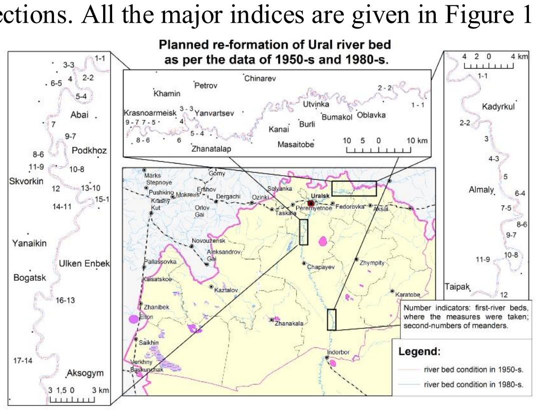

Figure 1- Planned re-formations of the Ural river bed, according to the 1950 - 1980

The "Zharsuat-Rubezhinskoe" section (Figure 1) is located in the steppe zone within Predszyrt ledge. Three tributaries flow into the Ural River from the right side: Embulatovka, Bykovka, Rubezhka. This site, as per the classification of R.S.Chalov (1996) [7], refers to the branched meandering river bed type. The sinuosity coefficient in this area is 1.75. The river is strongly meandering within the site, has many channels, dead stream branches. Between the meanders there are straight line segments. The greatest displacements are observed at the top of meanders and the changes range from 3.87 to 10.34 m / year. Displacements at the top of meanders have, mainly, a transverse direction against the river bed. Only on the branched-sinuous segment both the transversal and longitudinal river bed displacements are observed. Such significant displacements can be explained by the high water discharge and the distribution of easily washed sand - clay rocks. On relatively straight-lined segments there is a slight river bed displacement (0.77 m/year). The smallest displacements are at the top of those meanders, which wash the bedrock coasts, composed of dense clays.

Basically, there is a bank caving of the right flat banks. River valley on the first section teems with lakes-dead stream branches, canals, which prove the existence of the planned displacements of the river bed. The direction and magnitude of scheduled displacements that have occurred over thirty years, are shown in Figure 1 (all meanders are numbered for reference). On the first section, a chest-type meander dominates and over thirty year period their appearance has not changed. Section length is 25.31 km. During this period it has increased up to 3.71 km.

The "Bolshoy Chagan – Budarino" section (Figure 1) is located on the Caspian depression within the semi-arid zone. River slopes, compared with the first section are getting smaller. We also refer this section to a meandering river bed type. The sinuosity coefficient on this section is 2.02. The Kushum river branches off, taking the Ural river water above this section. One tributary falls into the Stary Chagan river. The river in this area is also strongly meandering. There are many dead stream branches in the river floodplain. The sizes of meanders and the amount of their displacement are noticeably increasing in comparison with the first section. The largest planned longitudinal displacement - 16.38 m/year observed in meander # 10, the minimal - 2.59 m/year, at the meander # 2. Straight-line segments are also heavily biased (from 3.0 to 7.76 m / year). Straight-lined segments are also heavily displaced (from 3.0 to 7.76 m/year). It is difficult to clearly distinguish the direction of river bed displacement, as in some areas there is a longitudinal displacement, and in others – crossed one. Due to the smaller slopes in the second section, the river starts meandering more strongly, washing out the sand-clay rocks of the Ural River valley. The most common in the 1950s were the following types of meanders: segmental, chest-like and omega-shaped. The meander types have not almost changed over thirty years, except the meander number 10. Here, the segmental type of meander is replaced by a the choked one, which is confirmed by the riverbed displacement downstream. The length of the river section is 46.14 km. During this period it has increased by 2.64 km.

The "Bazartobe-Taypak” section (Figure 1) is located within the semi-desert and desert zones of Caspian depression. The river bed relates to a meandering type. Sinuous coefficient in this area is 1.5. The river at the site does not accept any tributaries. The largest planned displacements are observed at meander number 5 (23.71 m/year) and at meander number 4 (14.65 m/year). The meander displacement against the river bed is mainly longitudinal. It is significant that some meanders (#5) over thirty years have transformed from segmental into choked, which is confirmed by significant meander displacement downstream. The planned river bed displacements are non-significant on the relatively straight sections, and are 0.86 m / year. The maximum river bed displacement on a straight segment reaches 4.31 m / year. Figure 1 shows the undermining of the Ural river bank in Taypak village (former Kalmykovo). On the third section, in the 1950-s, mostly segmental and choked meander types dominated. And in the 1980-s, segmental meanders transformed into the choked ones and omega-shaped. Length is 41.78 km on the river’s section. During this period it has increased by 1.79 km.

4. Conclusions.

Our analysis shows that by virtue of the extensive development of easily washed unconsolidated sediments and the pretty high water content on the Ural river (especially at high water), the planned river bed adjustments have extensively been developed. Particularly extreme manifestations of this process are expressed at the Vladimirovka village (Zelenovski district of WK).

In general, such a significant average displacements (7.6 m/year) are explained by the distribution of loose sand - clay deposits, significant river discharge and by the peculiarities of the hydrological regime. The obtained data of the planned displacements show their significant values. According to the classification of K.M.Berkovich, R.S.Chalov, A.V.Chernov (2000) the territory of the West Kazakhstan region can be attributed to the area with an average environmental stress in river beds and floodplains [4].

In general, from the steppe to the desert zones, the values of planned displacements increase, reaching a maximum in desert zone. This is explained by the decrease of water flow downstream (within the region) and by the decrease of slopes. The transverse displacements dominate in steppe zone against the river bed, and towards the desert area they are replaced by longitudinal. The greatest changes of types and sizes of meanders also happen in the desert zone. Meanders of the semi-desert and desert zones are larger in size than in the steppe.

The Ural river bed is represented by the secondary (formed as a result of the watercourse itself) free, or migratory bends (meanders). The river bed width changes in the range from 180 to 260 m. Within the each meander there are complexes of erosive and accumulative fluvial landforms among the loose sediments typical for lowland rivers. For lowland river systems of erosive and accumulative fluvial landforms. Concave undermined banks, are characterized by steep cliffs, called “the ravines”. They are based on the overdeepened sections of the river - river pool like trough cloughs at depth down to 5-7 m (rarely to 12 m). The height of ravines is 6.5 m. to over 30 m (indigenous banks).

Detection of regional patterns in the development of river bed adjustments and their forecast estimates give the opportunity to objectively assess the probability of certain adjustments and prevent all kinds of adverse consequences. The research results can be used in long-term forecasts of river bed regime changes in global environmental and climate changes, as well as under the development of river bed management projects for different economic sectors.

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