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Current trends in the development of channel deformations in small and medium-sized rivers (rivers of the Southern Urals and the Cis-Urals – the case study)

Abstract: The paper considers the main regularities indicating the activation of channel deformations in small and medium-sized rivers as a result of changes in slope and river runoff depending on the impact of degradation of landscape-nature complexes on catchment areas in the Southern Urals and the Cis-Urals as a result of human economic activity. The paper shows that changes in slope and river runoff contribute to the formation of the maximum water flow rate and the destructive force of water flows at the level of overlapping anthropogenic factors and natural historical processes. In accordance with the above, long-term changes in small and medium-sized river channels may occur in a multidirectional way. For example, it has been established that significant changes occurred in the conditions of increasing climate aridity and the growing human impact on landscape-nature complexes in the basins of small rivers in the period from the 1940s–1950s to the 1980s–1990s. They consist i.a. in the transformation of some small rivers of the 1st order into intermittent streams, or changes in the pattern of the hydrographic network.
Keywords: landscape-nature complex, catchment area, anthropogenic factors, degradation, channel evolution.

1. Introduction

A number of integral conceptual approaches have been developed, presenting the genesis and morphodynamics of river channels. Among the renowned papers related to the issues mentioned above, the works of M.A. Velikanov (1958), N.I. Makkaveyev (1955), R.S. Chalov (2008, 2016) and others are among the most important. The aforementioned authors have developed a theory of riverbed studies, comprehensively describing its theoretical foundations and practical importance. Thus, the law of the limited number of morphological complexes, formulated by M.A. Velikanov (1958), allows for typology of river channel processes. Whereas, the shape of river channels and their deformations forming by the flow structure are dynamic as well as the morphological classification of river channels. Thus, such a classification is based on morphodynamic characteristics and the defined components are morphodynamic types of riverbeds (Chalov, 2016).

Morphometric characteristics of the channels for any cross-section are directly related to the corresponding water discharges over a long period of time and within a year, and the transport capacity of streams, which together cause erosion (destructive effect) and/or sedimentation in the channel. As a result of the consistent increase in the destructive erosive effect of water streams along their movement in the slope-channel system in the temperate climate zone, both vertical and horizontal changes are determined by the influence of a large number of factors, including mainly: the intensity of a linear increase in water discharges; destructive and transporting capacity of water; resistance of the river channel to erosion; the rate of vertical movements of the Earth's crust; the rate of anthropogenic transformation of landscape-nature complexes in the catchment area, and their natural capacity for water flow regulation (Gareyev and Khabibullin, 2010; Erosion and riverbed systems, 2017).

2. Methods and study area

In the presented study, the geosystem approach and the basin principle have been used as a methodological basis, which fully and comprehensively allow conducting research based on the identification of cause-and-effect relations in the formation of regularities in river basins of various size categories under the influence of a large set of natural and anthropogenic factors.

As shown by the results of studies carried out at the Department of Hydrometeorology and Geoecology of BashSU, directed by Professor A.M. Gareyev for a long time, the most important factors in the activation of erosion and channel processes in the mountain forest zone of the Southern Urals and forest-steppe of the Cis-Urals, in the conditions of a multiple increase in the impact of anthropogenic factors on landscape-nature catchment complexes, are those resulting both from the changes in the slope and river runoff and long-term changes in factors affecting the hydrological processes. These factors affect the catchment's water balance and affect the occurrence of cyclical fluctuations in the river runoff and the occurrence of dry and humid periods (Gareyev, 1997; Gareyev and Khabibullin, 2010).

Within the mountain forest zone of the Southern Urals (in the Republic of Bashkortostan), the features of the formation and transformation of the slope runoff as well as the runoff of the first-, the second- and the third-order rivers (according to the hierarchical classification) were studied at test sites with different slopes, at intermittent streams, the Septinsky stream (the first-order tributary of the Belaya river), the Belaya river up to the Avnyar river mouth and the Avnyar river (at the mouth). The collected data showed that the highest values of the specific runoff (compared to intermittent streams and test sites on the slopes) are recorded along the first-order rivers, which is determined by the stable drainage of the catchment area and the surface and groundwater flow in conditions when watercourses are deeply cut into the ground. During all years of observations on slopes with different exposures, slope runoff and intermittent streams were not observed in areas covered with forest.

3. Results

In order to justify the methodological assumptions concerning the calculation of the increase in the maximum water discharge, which has a destructive effect on soils and bedrocks, the runoff coefficients and specific runoff were estimated. It has been established that the most convenient and reasonably applicable indices are the specific runoff that are indicative of not only the water absorption conditions in the catchment area, but also the influence of the entire set of runoff factors. This predetermines the convenience of hydrological calculations and evaluations. Thus, the indicators of specific runoff are based on actual measurements of discharges using current flow meters, so there is no need to carry out a snow survey in the catchment area. Moreover, these indicators do not depend on the catchment area and are easy to use in the calculations of discharges in intermittent streams and rivers of various size categories (Gareyev, 2017).

Based on the data obtained during our observations, it has been established that values of the maximum specific runoff (q_1) for intermittent streams ranged from 277.2 to 445.8 $l \cdot s^{-1} \cdot km^{-2}$. In the case of the first-order river (the Septinskiy brook), the values (q_2) reached 609.8-634.1 $l \cdot s^{-1} \cdot km^{-2}$, and this leads to the following relation:

$$K = \frac{q_2}{q_1} = 1.4\text{-}2.2$$

which in the first approximation can be treated as a transition coefficient when calculating the maximum water discharges of unmonitored first-order rivers and when assessing the degree of their destructive erosive capacity in the basins with degraded landscape-nature complexes.

Depending on the features of the formation, spatial and temporal variability of the runoff, four groups can be identified based on the impact of the set of factors: 1) slope runoff, 2) runoff of small first-order rivers, 3) runoff of the nth-order rivers (small and medium-sized rivers), 4) runoff of large rivers.

The results obtained in the mountain forest zone of the Southern Urals were completed with results of more detailed research carried out on the basins of small and medium-sized rivers in the Southern Cis-Urals in 1999-2008, taking into account the availability of genetic links both between the main runoff factors and the combined effect of factors and water discharges on the cross sections under study during a long period of time.

The dynamics of changes in the main (natural) runoff factors over time were studied by meteorological observation stations and sites located in particular river basins, selected so as to minimize the impact of artificial water reservoirs on the obtained results.

Based on the analysis of the results of calculations and estimates, including the analysis of charts, it has been established that the trends in river runoff changes typical of the rivers of mountainous Bashkortostan are specific to the Cis-Urals. At the same time, the relative increase in the maximum runoff for 1970-2000 varies in significant proportions (5-16%), which, in addition to spatial differentiation of anthropogenic loads, ploughing in catchment areas, etc., depends on karst factors occurring in individual drainage basins.

Thus, based on the generalisation of extensive materials obtained during the long-term research on the river basins of Bashkortostan and the Cis-Urals, it can be concluded that the degradation of landscape-nature complexes in river catchment areas is accompanied by a significant increase in the slope runoff and the maximum water discharges in small rivers. This subsequently leads to changes in environmental and economic characteristics of the territories, which should be taken into account not only in the adjustments to the river runoff indicators, but also in the management of hydroeconomic and water protection activities in river basins of different size categories. With significant decreases in minimum water discharges during the summer-autumn and winter period of low water levels, this characterises significant changes in the annual distribution of river runoff, which is of considerable importance in activating the channel deformation of small and medium-sized rivers.

The Ki coefficient, calculated in order to determine the maximum water discharges (including those capable of triggering the activation of riverbed evolution and catastrophic floods), taking into account anthropogenic loads within the mountain forest zone of the Southern Urals, are shown in Table 1.

In this case, the anthropogenic component of the maximum water discharges of spring floodwater, involved in the destruction of river banks and the development of floods on the Belaya (in the upper river reaches) is up to 9.0-11.0%, which can be considered as a correction (multiplying) coefficient in hydroeconomic calculations.

As it was shown before, the flood that occurred in Bashkortostan in 1990 (within 2.6-2.9% flood risk) was devastating. It was determined that about 11% of the flood runoff was caused by anthropogenic transformation of the catchment (Gareyev and Khabibullin, 2010).

As for the forest-steppe Cis-Urals, it has been established that in the conditions of a large-scale and long-term negative impact of human economic activity, there was a multi-

Table 1. Values of the transition coefficient (Ki), taking into account the maximum discharges of small rivers of Bashkortostan and the degree of anthropogenic transformations of landscape-nature complexes in the studied catchments (Gareyev, 1997)

Groups of areas	Area number – the degree of anthropogenic load	Ki
I	1, 5, 9 – reference	1,00
II	3, 4, 8 – insignificant excess	1.25
III	2 – average excess	1.50
IV	7 – significant excess	2.00
V	6 – high exceedance	2.50

Table 2. Values of the coefficient (K) for the calculation of the maximum discharges of meltwater in the basins of the Bashkir Cis-Urals rivers (Gareyev, 2010)

No.	River - cross section	K	Note
1	Chermasan – village of Novoyumranovo	1.12	
2	B. Ik – Taishevo village	1.08	
3	Bui – village of Tatarskaya Urada	1.27	to be determined
4	Bir – village of Malosukhoyazovo	1.14	
5	Urshak – Lyakhovo village	1.17	
6	Lemeza – village of Low Lemeza	1.14	
7	Miyaki – Miyaki-Tamak village	1.14	

ple reduction in the area of forests and other natural lands. This also led to the transformation of the slope runoff and the corresponding increase in the maximum water discharges during the spring flood, as well as the redistribution of small rivers' runoff during the year, contributing to the change and characteristics of the channel-forming water discharge.

As shown in Table 2, for most of the rivers of the Cis-Urals, the multiplying coefficient of the maximum water discharges (K) ranges from 1.12 to 1.17. The deviation is observed in the basins of the rivers Large Ik (Taishevo village) and Bui (Tatarskaya Urada village). In the first case, this is due to the good preservation of forest complexes in the drainage basin, whereas in the second case – should be determined during further calculations and assessments.

The series of observations was used during the calculations, including indicators from the beginning of the observations until 2000, which not only determine their completeness, but also provide a sufficiently high reliability of calculations due to the full representation of high and low water-level phases. This becomes quite obvious during the comparative analysis of cartographic materials shown in Figures 1 and 2, based on two stages of observations: 1) prior to large-scale development of landscape-nature complexes in the catchment area, i.e. 1950 – 55; 2) in 1990-2000 – in the period of the greatest impact of anthropogenic factors on landscape-nature complexes and in the period of the impact exerted on channel processes by excessive inflows of sand and gravel deposits from the White and the Ufa rivers, which act as local erosion bases for many small watercourse.

As mentioned before, the activation of the channel deformation processes involves, in addition to anthropogenic deformations, natural and historical processes caused by cyclical long-term and multi-century humidity (rainfall) fluctuations and, consequently, the discharges of rivers of different size categories.

As a result of anthropogenic factors overlapping with natural factors, specific conditions are created that determine the temporal variability in accumulation processes and river erosion, which cause not only the horizontal and vertical variations in river channels, but also significant transformations of the drainage system. As shown in Figures 1 and 2, in the period from the 1950s to the beginning of the 21st century, individual first- and second-order rivers were transformed into intermittent watercourses, and some of them ceased to exist. The channel processes were activated in the lower reaches of the left-bank tributaries of the Belaya river: the Urshak, the Dyoma, the Chermasan and the Karmasan. This activation is manifested as an increase in the intensity of vertical erosion and horizontal movements of river channels, which poses a threat to residential areas and commercial facilities due to erosion of river banks and landslides.

It should be noted that many small and medium-sized rivers, flowing within the mountain forest zone of the Southern Urals, have not change significantly for the indicated periods of time due to their high natural capacity to regulate water in 75-95% of the forested catchment areas.

This is evidenced by the research of E.V. Vodogretskiy (1990), which emphasizes the importance of forests and forest zones in the reduction of slope runoff, and thus preventing erosion.

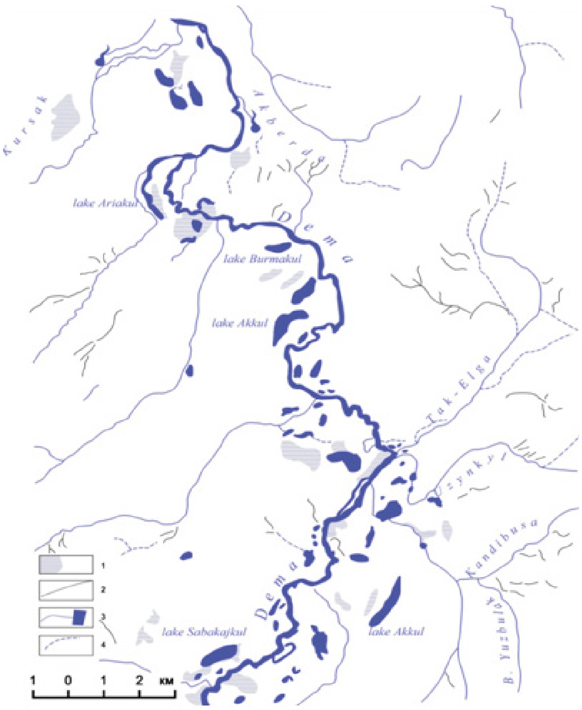

Figure 1. Hydrological network within the middle reaches of the Dema river in 1840–1842. 1 – marshes; 2 – ravines; 3 – rivers and lakes; 4 – intermittent watercourses.

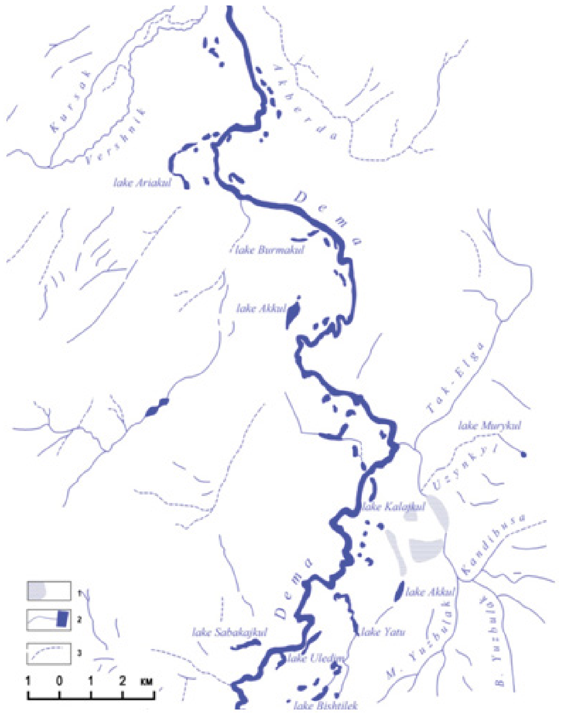

Figure 2. Hydrological network within the middle reaches of the Dema river in 1984–1997. 1 – marshes; 2 – rivers and lakes; 3 – intermittent watercourses.

4. Conclusions

The following conclusions can be drawn based on the materials collected during long-term observations, experiments and tests carried out in the basins of small and medium-sized rivers in the South Urals and the Cis-Urals, as well as the analysis of cartographic materials for different periods:

1. Modern trends in the activation of channel processes are related to the influence of a large set of natural and anthropogenic factors associated with river basins of different size categories. They are quite clearly evident in small and very small rivers, which directly receive the slope runoff, and which are to some extent transformed as a result of human impact.
2. The natural cyclical nature of the processes is manifested in significant variability in river discharges both during a year and in the long term, and the associated variability in processes of erosion and sediment accumulation. Therefore, both the drainage system (river system) and morphometric characteristics of river channels are not constant (stable) and depend on periodical rainfall changes and natural conditions determining the natural water-regulating capacity of catchment areas during certain historical periods.
3. The intensity of channel evolution activation in small rivers depends on the scale of transformation and the degree of degradation of landscape-nature complexes in the catchment, and consequently the transformation of slope and river runoff, which is reflected in an increase in the maximum river discharge (meltwater and stormwater), and a noticeable reduction in the minimum runoff. This should be taken into account when carrying out design and survey work and construction operations on water bodies.
4. The siltation index of small river channels (especially in the middle and lower reaches) is not an indicator of their "aging", but it is a result of the impact exerted by a complex of anthropogenic and natural factors together with the unquestionable influence of climate factors over a given period of time.

References

Velikanov M.A., 1958. Ruslovoy protsess. M. Nauka [In Russian].

Vodogretskiy V.E., 1990. Antropogennoye izmenenie stoka malykh rek. L. Gydrometeoizdat [In Russian].

Gareyev A.M., 1997. Nekotorye kharakteristiki izmenchivosti prirodnykh kompleksov and sklonovogo stoka (na primere verkhovyev basseyna r. Belaya). Upravlenie ustoychivym vodopolzovaniem. M. Minprirody RF [In Russian].

Gareyev A.M., Khabibullin I.L., 2010. Yestestvennye i antropogennye factory aktivatsii razvitia erozionnykh protsessov. Ufa. RIC BashSU [In Russian].

Makkaveyev N.I., 1955. Rusla reki i erozia v eye basseyne. M. Nauka [In Russian].

Chalov R.S., 2008. Ruslovedenie: teoria, geografia, praktika. M. Izd-vo LKI [In Russian].

Chalov R.S., 2016. Ruslovye protsessy (ruslovedenie). Uchebnik. M. INFRA-M [In Russian].

Chalov R.S., ed., 2017. Erozionno-ruslovye sistemy. M. INFRA-M [In Russian].

Gareyev A.M., 2017. Characteristics of the slope and river runoff transformation and its influence on the activation of erosion and fluvial processes – a case study of small river basins in the Southern Urals and the Cis-Urals. Geography and Tourism 5(2), 51-56.