Transformation of hydrographic network in the National park “Belavezhskaya Pushcha” and its influence on the river flow

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Belavezhskaya Pushcha (BP) is a unique nature place in Europe included in the list of UNESCO heritage. The growing scale of man’s economic activity requires new research of particular ecosystems. A small hydrographic network is an essential part of any natural region, as well as BP. The network’s state is an indicator of changes in such regions.

A few large melioration complexes have been created as a result of melioration in Pushcha’s watershed. The main melioration method applied was lowering the groundwater level by digging canals. The riverbeds (the rivers Lesnaya, Narevka, Gvozna, Belaya and others) were straightened and deepened to improve the water intake.

At present the main parameters used to study the state of a hydrographic network are its sinuosity and thickness. To calculate the watercourse sinuosity with its watershed asymmetry one should use the following equation

$$\rho' = \frac{L}{l \cdot \xi}, \tag{1}$$

where $\xi = f(\left|\sum_i A_{R,i} - \sum_i A_{L,i}\right|, L, l)$; l and L are river lengths, straight-line and along the riverbed, respectively.

Coefficient ξ is directly proportional to the difference of the sum of right $\sum_i A_{R,i}$ and left $\sum_i A_{L,i}$ squares. At the same time it is inversely proportional to riverbed length L and straight line from the river source to its mouth l. Taking this into account one can derive a generalized formula for estimation ξ

$$\xi = \frac{\left|\sum_i A_{R,i} - \sum_i A_{L,i}\right|}{L \cdot l} \cdot \alpha + 1, \tag{2}$$

where α is proportionality coefficient, $\alpha = 2,26$ [0].

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A quantitative index of the river shift is a value of mean shift S_{genl} of the riverbed per unit of its length

$$S_{genl} = \frac{\sum_i A_{R,i} + \sum_i A_{L,i}}{L}, \quad (3)$$

where $\sum_i A_{R,i}$ and $\sum_i A_{L,i}$ are sum of the squares of the figures received by crossing riverbed lines at a starting time (t_0) and at a current time (t) (Fig. 1). Indexes R (right) and L (left) show the squares of the received figures to the left and to the right of the riverbed at a time $t_a - t_b$.

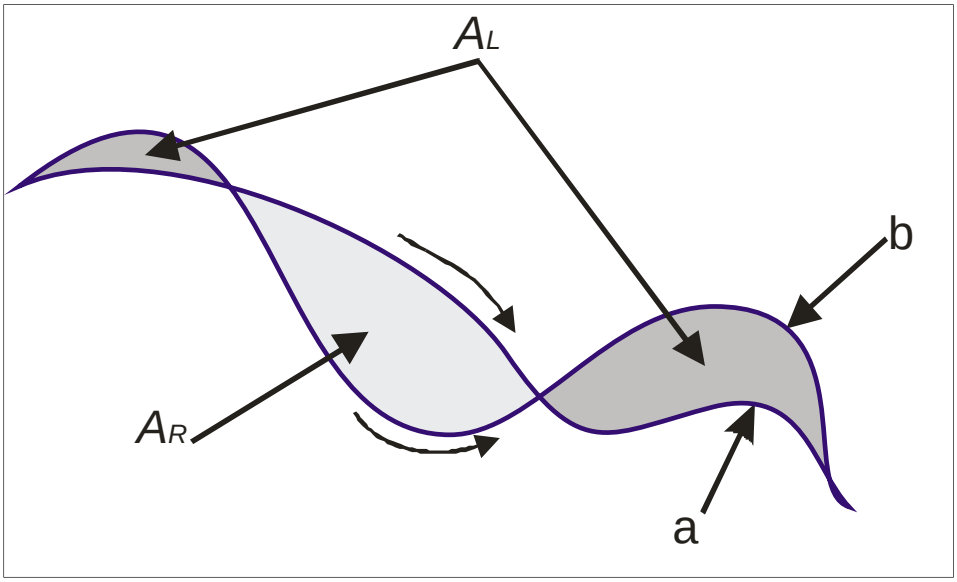

Fig. 1: Analytical model of riverbed shifting
a – state of river line at a time t_a; b – state of river line at a time t_b;

If we present equation (3) as following

$$S_{vect} = \frac{\sum_i A_{R,i} - \sum_i A_{L,i}}{L}, \quad (4)$$

then we receive the value of predominant mean shifting of the riverbed per unit of its length. The fulfillment of the condition $\sum_i A_{R,i} - \sum_i A_{L,i} \approx 0$ corresponds to partial straightening of the riverbed.

The analysis of human influence on hydrographic network within the main Pushcha's watershed (Tab. 1) was carried out with the use of GIS of hydrographic network in BP as well as the methods mentioned above. The watersheds of the Narev and the Ross rivers stand out as their hydrographic networks were the thickest in 1930 and they are the least transformed in the result of man's activity (the thickness of hydrographic network has increased less than twice). As a result of building melioration canals, the hydrographic network of the river Zelvyanka (with its originally insignificant thickness of 0.116 km/km^2) has increased by 40%, which indicates slight transformation in the runoffs structure.

The hydrographic networks in watersheds of such rivers as Lesnaya Levaya, Lesnaya Pravaya, Narevka, Yaselda have thickened four times as much, due to the above

mentioned factors. Although in the early 20th century the hydrographic networks of their watersheds were the least thick.

Applying the methods described there was conducted an analysis of riverbed shift (equations (3), (4)) and sinuosity transformation (equation (1)). The results of the analysis of numerical data are presented in Table 2.

River name	Square of watershed, km²	Square of lakes and reservoirs within watershed, ha	Thickness of hydrographic network, km/km²		Increase in hydrographic network thickness	Extent of trans-formation
			in 1930	in 2005		
Zelvyanka	888	117	0.116	0.165	1.43	*III*
Lesnaya Levaya	808	16.1	0.162	0.685	4.22	*II*
Lesnaya Pravaya	893	251	0.159	0.828	5.20	*I*
Narev	1,119	10	0.212	0.419	1.98	*III*
Narevka	593	102	0.164	0.913	5.58	*I*
Ross	119	4.0	0.172	0.230	1.34	*III*
Yaselda	820	540	0.148	0.662	4.48	*II*

Tab. 1: Main rivers in BP and their characteristics

River name	Sinuosity of riverbed (ρ)		Sinuosity of riverbed with watershed asymmetry (ρ')		Riverbed shift m	
	in 1930	in 2005	in 1930	in 2005	Medium S_{genl}	Predominant S_{vect}
Zelvyanka	2.22	2.22	2.03	1.98	86	10
Lesnaya Levaya	2.53	2.36	1.69	1.52	111	103
Lesnaya Pravaya	1.29	1.34	1.21	1.26	50	3
Narev	1.37	1.35	137	1.33	52	3
Narevka	1.52	1.47	1.17	1.13	65	51
Ross	1.36	1.33	1.29	1.33	13	11
Yaselda	1.39	1.21	1.37	1.17	385	92

Tab. 2: Sinuosity transformation of riverbeds in BP

The watersheds were classified on the basis of the data analysis. The groups established according to the extent of transformation are as follows: *I* – greatly transformed watershed; *II* – moderately transformed watershed; *III* – slightly transformed watershed. Figure 2 represents the results of the classification in terms of spatial analysis.

The hydrographic networks in watersheds of such rivers as Lesnaya Levaya, Lesnaya Pravaya, Narevka, Yaselda have thickened four times as much, due to the above mentioned factors. Although in the early 20th century the hydrographic networks of their watersheds were the least thick.

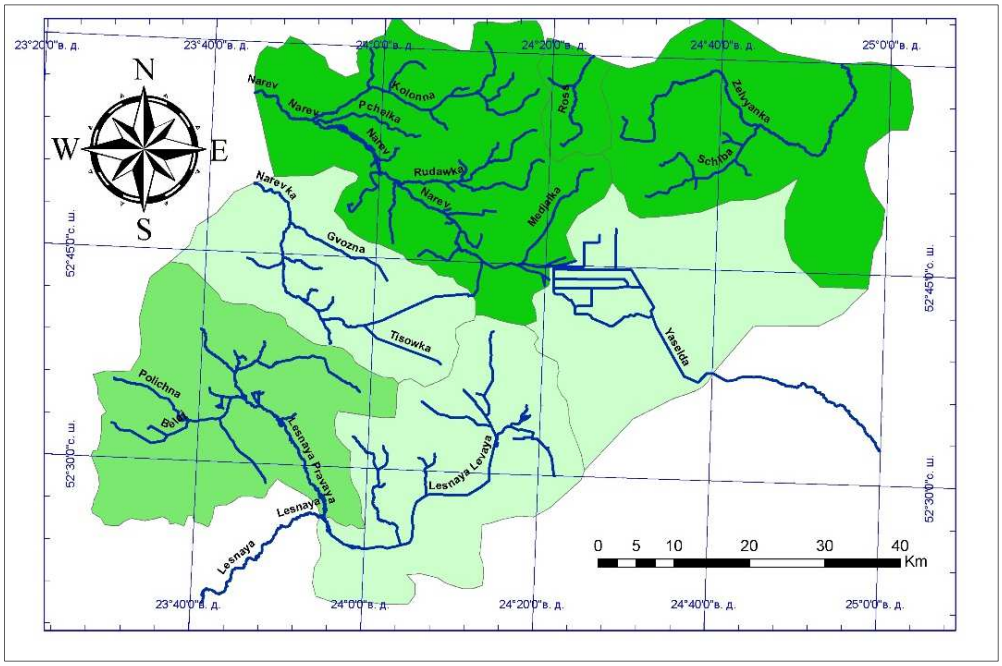

Fig. 2: Transformation of hydrographic network
(I – greatly transformed watershed; II – moderately transformed watershed; III – slightly transformed watershed)

The article discusses up-to-date scientific approach to the analysis of transformation of a small hydrographic network as one of the most important constituent elements of ecosystems. On the basis of transformation parameters the three zones within BP were determined. They characterize the scale of hydrographic network transformation. The first zone (greatly transformed watershed) covers the watersheds of the rivers Narevka, Lesnaya Levaya, Yaselda. The second one (moderately transformed watershed) includes the river Lesnaya Pravaya, and the third one (III – slightly transformed watershed) covers the rivers Narev, Ross, Zelvyanka.

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