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Dynamics of the River Channel Deformations along the Latitudinal Section of the Middle Reaches of the Ob River

Abstract: The paper describes the dynamics of stream erosion of the right bank of the Ob river in the Nizhnevartovsk area in the Khanty-Mansi Autonomous Okrug – Yugra. Furthermore, it presents an analysis of fifteen-year monitoring of the river channel deformations at the Ust-Vakh observation station using field-established benchmarks through interpretation of diachronous satellite images and registration of the riverbank line using the satellite positioning. The paper presents a comparison of methods and indicates their positive and negative aspects. The obtained survey results are required for the development of integrated engineering efforts to protect river banks at populated localities as part of the targeted program "Transfer of people from residential houses located in the floodplain zone exposed to erosion". These surveys allow to accurately predict the dynamics of stream erosion of the river banks along the latitudinal section of the middle reaches of the Ob river, where various floodplain types are formed, banks are unprotected, islands occur in the river channel, and the floodplain is dissected by a braided river channel.
Keywords: river channel evolution, river channel deformations, riverbank range, lateral erosion.

1. Introduction

Intensive river channel deformations along the latitudinal section of the middle Ob are an unfavourable process. The issue of secure economic management in the lateral erosion zone is pressing in Russia, especially in West Siberia, which is highly exposed to the negative impact of river channel deformations (Vershinin et al., 2013). Various types of erosion develop under the influence of natural factors. In the populated areas of the Nizhnevartovsk district of KhMAO-Yugra located along the latitudinal section of the middle Ob, as a result of spring snow melting, the water level in the river rises significantly and this leads to the destruction of the unprotected river bank and flooding in the flood plain zone. Therefore, this issue is pressing, especially in the river sections where residential areas are located within the floodplain (Korkin and Mironova, 2015). River channel deformations are rated as natural hazards related to stream water processes, of which stream-bank erosion is most strongly manifested (Zavadsky et al., 2013). Riverbank deformations occur due to the processes of erosion-accumulation systems and are characterized by the formation of watercourse channels depending on the water discharge, the shape and other parameters of the channel, sediment run-off, and other characteristics that enable the identification of corresponding types of river channel evolution and morphodynamic channel types (Chalov, 2013). In the long-term development, the irregularities of horizontal river channel deformations depend on the annual rainfall in general and the seasonal flooding in particular (Korableva and Chernov, 2008). The paper of V. V. Surkov (1999) provides data on stream-bank erosion rates for the middle reaches of the Ob, which are on average 3-5 m/year, with the maximum of 24 m/year. The channel of the Ob downstream from the Novosibirsk Hydro Power Plant is more stable: Ks = 4.6-14.5, on the average 12.2 (Ruleva, 1988). The survey presented in the paper is based on the methodological part developed by R. S. Chalov, A.S. Zavadsky and A.V. Panin (Chalov et al., 2004; Chalov, 2008, 2011).

Extensive experience in surveying and forecasting river channel deformations in the Tomsk region has been gained by researches of TSU Geography and Hydrology Departments A. A. Zemtsov, D.A. Burakov; the surveys started at the end of the 1950s and were continued by Yu. I. Kamenskov, V.A. Lgotin, N.S. Evseeva, V.S. Khromykh and others (Zemtsov and Khromykh, 1999). In 1975, O. I. Bazhenova presented a report on the development of bends and existing geomorphological processes in the middle courses of the Ob, comparing pilot charts from 1928 and 1968 (Bazhenova, 1999). Papers prepared based on numerous surveys present data on river types and the extent of stream-bank erosion; they analyse river bed/channel evolution factors and contain forecasts of the bank processes (Evseeva and Zemtsov, 1990; Zemtsov, 1976; Kamenskov, 1987; Lgotin, 1990; Khromykh, 1979). A.A. Zemtsov predicted the development of a 20 m wide bank stream erosion in the area of Nizhnevartovsk over 20 years (Zemtsov, 1976).

2. Methods

This paper describes methods of monitoring the river channel deformation dynamics along the latitudinal section of the middle reaches of the Ob: a field method that uses satellite positioning systems and measurements of bank recession rates by field-established benchmarks; a method of satellite imagery interpretation. The satellite imagery interpretation method consists in digitizing the riverbank line according to satellite images, using the GIS-package MapInfo Professional. Satellite images from 1982, 1994, 2001 and 2014 provided by the Laboratory of Information Space Technology of the Yugra Scientific-Research Institute for Information Technologies (Khanty-Mansiysk) were used. Monitoring surveys of active lateral erosion have been carried out using field--established benchmarks in cross section for 16 years, and since 2014 geodesic surveys of the plot in question have been carried out using 2x Leica GS10 satellite receivers.

3. Results and discussion

The researched "Ust-Vakh" test plot is located on the latitudinal section of the middle reaches of the Ob and is characterized by a large floodplain. River bends are unprotected and braided channels are separated by small islands (Korkin et al. 2015). The Ob channel within the surveyed area is formed under conditions of active development of river channel deformations. In 1974, an observation station was founded by the Tyumen complex geological survey expedition on the right bank of the Vartovskaya river, a tributary of the Ob, within the urban area of Nizhnevartovsk. In 1980, the observation station was transferred to the area of the Vakh river mouth because of the active riverbank development where annual measurements were carried out till 1994. In 2001, monitoring on the test plot was resumed by students and scientists of the Nizhnevartovsk State University. The maximum bank recession rate from 2001 to 2016 was recorded in 2004, i.e. 17.5 m in cross section 5 (Isypov and Korkin, 2016). Given the annual average activity, the obtained values vary from 7.8 m/year in 2002 to 0.7 m/year in 2012 (Table 1).

According to the Tyumen complex hydro-geological and engineering-geological survey, the average annual bank recession rate in particular years was as follows: in 1983 – 9.8 m/year; 1984 – 4.9 m/year; 1985 – 2.76 m/year; 1986 – 3.01 m/year; 1987 – 3.9 m/year; 1988 – 10.42 m/year; 1989 – 3.26 m/year; 1990 – 7.72 m/year; 1991 – 1.54 m/year; 1992 – 5.7 m/year; 1993 – 4.84 . The long-term average annual rate for 11 years amounted to 5.26 m/year.

Taking into account the average annual rate from 2002 to 2016, the Ob bank edge shifting rate was as follows: in 2002 – 7.8 m/year; 2003 – 2.35 m/year; 2004 – 3.46 m/year; 2005 – 2.89 m/year; 2006 – 4.19 m/year; 2007 – 3.25 m/year; 2008 – 1.93 m/year; 2009 – 2.36 m/year; 2010 – 1.57 m/year; 2011 – 1.51 m/year; 2012 – 0.68 m/

Table 1. Results of riverbank deformation measurements for the years 2002–2017 (“Ust-Vakh” observation station)

Cross section No.	I	II	gully	the Ob	1-III	2-IV	V	3-VI	4-VII	5-VIII	6	7-X	8	9	10	Av.	Total
2002					5.6	9.6		5.4	*	10	*	*	*	*	*	7.8	31.3
2003	*	*	*	*	2.2	0.1	*	-	*	2.8	2.6	4.9	3.15	-	0.7	2.35	16.45
2004	0	2.3	1.0	1.5	0.2	2.8	17.5	-	*	6.3	0	1.6	0.6	-	7.8	3.46	41.6
2005	0	0.2	0	1.2	0.7	7.5	0.5	9	8.2	0.3	6.1	7.3	3.4	-	1.0	2.89	28.9
2006	0	0	0.2	1.2	0.5	0	0.7	12.8	8.8	0	4.0	5.5	14.8	-	10.2	4.19	58.7
2007	0	2.3	0	0.9	0	1.7	0	0	8.08	0.5	7.3	4.1	3.45	11.6	5.5	3.25	45.3
2008	0	0.5	0	2.2	0.8	0.5	0.3	-	2.6	2.9	3.0	1.7	0	12.1	0.4	1.93	27.0
2009	0	0	2	1.2	2.1	0.1	1	5.67	3.3	0	3.7	4.3	4.95	*	0	2.36	28.32
2010	0	0	0	0	0	n.d.	0	0	-	0	3.16	2.6	-	-	13.1	1.57	18.86
2011	0	0.3	0	1.35	0.9	2.04	0.5	1.93	8.7	-	1.39	2.63	0	-	0	1.51	19.74
2012	0	0.1	0	1.05	0	2.6	0	1.4	2.7	0	0.0	0	0.2	-	0.8	0.68	8.85
2013	0	0.1	0.8	0.3	0	6.4	0.5	1.4	4.1	9.7	0.0	6.1	1.3	-	0	2.36	30.7
2014	0	0	0	0	0	7.9	0	1.5	0	-	9.2	0.7	1.3	-	13.7	2.45	34.3
2015	0	2.2	3.6	4.5	4.2	2.0	4.7	0	4.6	11.0	0	7.0	9.2	-	17.0	5.0	70.0
2016	0	0	0.22	1.8	1.63	2.2	0.4	0	4.04	2.12	2.34	3.69	1.89	-	2.43	1.69	23.76
2017	0	0	0	1.6	1.28	0	15.4	0.1	6.31	2.78	6.96	0.95	0.64	-	0	2.57	35.97
	0.0	0.6	0.6	1.3	1.3	3.0	3.0	3.0	5.1	3.5	3.3	3.5	3.2	11.9	4.8		

* - year of benchmark installation, n.d. - no data are available due to the measurement technical complexity.

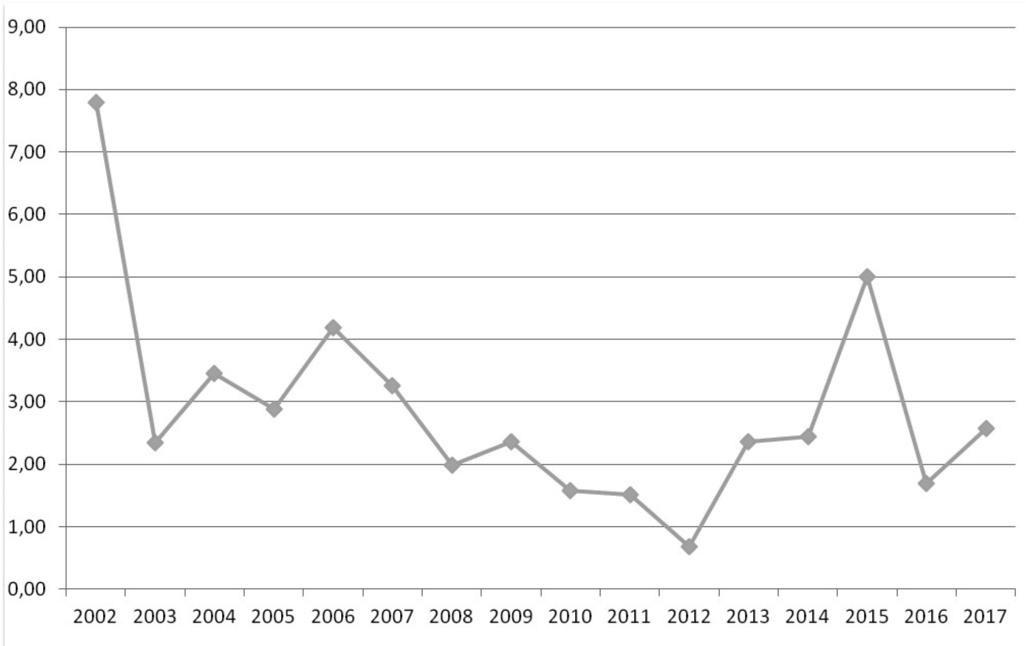

Figure 1. The Ob bank edge shifting rate in cross section from 2002 to 2017 (on the vertical axis: average annual rates in meters; on the horizontal axis: years)

year; 2013 – 2.36 m/year; 2014 – 2.45 m/year; 2015 – 5.0 m/year; 2016 – 1.69 m/year; 2017 – 2.57 m/year (Fig. 1). The long-term average annual bank recession rate by monitored cross section over 16 years is 2.9 m/year. The maximum bank edge recession rate was recorded in 2004 and amounted to 17.5 m/year at the fifth cross section, which corresponds to the data specified on the map "Morphology and dynamics of the Ob and Irtysh channels" of the Khanty-Mansi Autonomous Okrug – Ugra Atlas (Volume II, p. 75, 2004).

When comparing the two monitoring periods, it is evident that the activity of stream bank erosion in 1983 to 1993 was higher than in the subsequent years. To verify the obtained values,

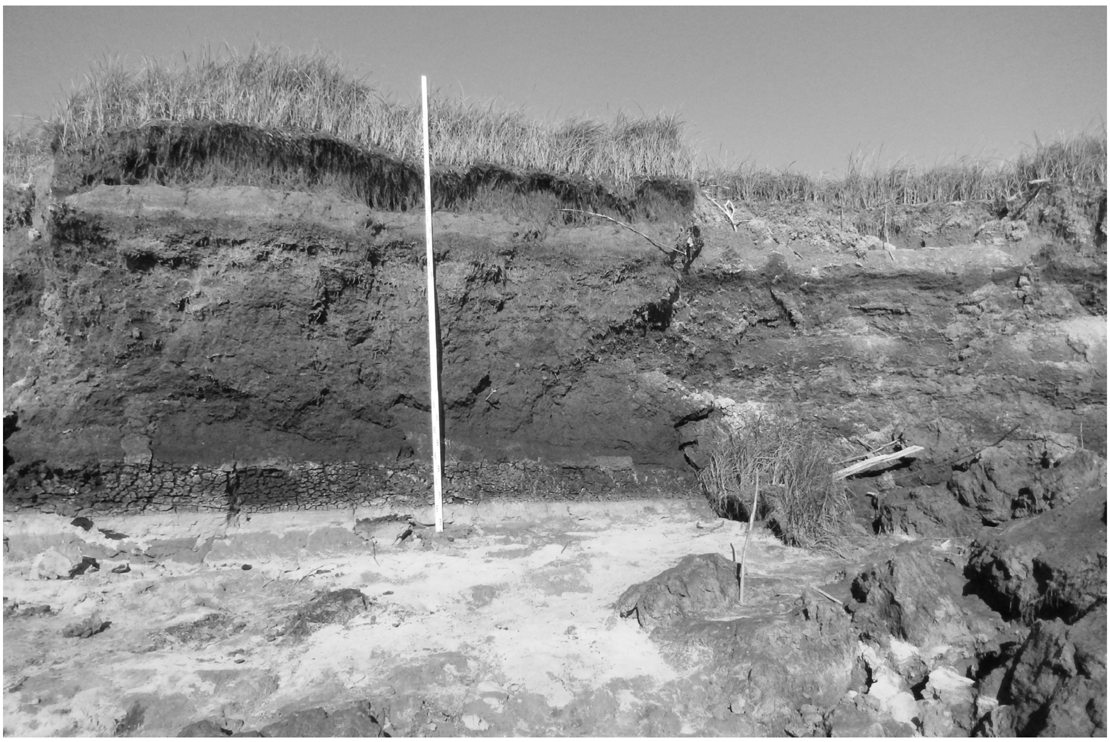

Figure 2. Cross section No. 10 in 2015 with the maximum washout of 17 m/year.

Figure 3. Reference No. V in 2017 with the maximum washout of 17 m/year.

the matching method for satellite images from 1982, 1994, 2001, and 2014 was used. The land lost due to bank erosion was identified for the three periods: from 1982 to 1994 – 416,200 m^2; from 1994 to 2001 – 225,000 m^2; from 2001 to 2014 – 200,800 m^2. Land losses caused by riverbank deformations from 1982 to 2014 amounted to 842,000 m^2. According to the analysis of the three periods, the activity of the Ob river right bank erosion from 1982 to 1994 was higher, which is confirmed by the data obtained from the field measurements (Korkin and Isypov, 2017).

The results of the channel monitoring from 2014 to 2017, using the GNSS satellite equipment, show that the washout area in 2015 was 29,472 m^2, in 2016 – 11,403 m^2, and in 2017 – 15,400 m^2, and the volume of the washed away soil in 2015 with the average bank height of 4.9 m amounted to 144,412,8 m^3; in 2016 with the average bank height of 4.8 m – 54,734 m^3, and in 2017 with the average bank height of 5.3 m – 81,620 m^3.

The obtained data show that the average bank erosion in cross section at the "Ust-Vakh" observation station are as follows: in 2014 – 2.45 m/year with the maximum of 13.7 m in cross section 10; in 2015 – 5.0 m/year with the maximum of 17 m in cross section 10 (Fig. 2); in 2016 – 1.69 m/year with the maximum of 4.04 m; in 2017 – 2.57 m/year with the maximum of 15.4 m in reference area V (Fig. 3). The differences in the erosion rate observed over the years are due to climatic and hydrologic factors.

4. Conclusions

The obtained results show that river bank erosion depends on local conditions in particular river sections as well as on annual hydrological conditions. The increase in the erosion rate could be connected with more humid conditions in particular years. Since this area is used for economic purposes such as grasslands, it can therefore be concluded that fodder production areas are lost. Monitoring of this area will be helpful in making further predictions regarding the Ob river channel deformations.

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