Spring riverfloods in Nizhnevartovsk: Specific features

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Abstract. Compared to other emergencies, flooding is considered the most common and devastating natural disaster. Therefore, the Russian state program on the "Reproduction and use of natural resources" currently states the protection of population and economic facilities from the negative effects of water as a topical priority. Nizhnevartovsk is located on the right bank of the Ob River and was built on marshy terrain. The average long-term water consumption here is 5634 m³/sec. River floods usually last for 60-130 days, with the maximum water levels registered in 1966, 1970, 1979, 2007, and 2015. In June 2015, the city authorities introduced a municipal emergency regime in some areas of Nizhnevartovsk due to the high level of floodwaters and flooding of a significant part of gardeners' partnerships. The water level reached the maximum value of 1061 cm on June 19, 2015. After abatement in water, the city authorities together with the chairmen of gardeners’ partnerships examined summer cottages, where citizens registered and resided permanently, and assessed the effects of the flood as well as the state of roads and bridges in the flood zone. After flooding, many summer cottages could not be restored. Based on the water level indicators in the Ob River, the study develops the trends in the actual and calculated maximum water levels with components of the Fourier series. The results of the study can be used to elaborate city development plans and reduce flood damage.

1. Introduction

Hydrologists consider river floods as short-term water rises in rivers under the influence of rain or increased melting of snow and ice. River floods occur at different times of the year but most often in the spring during river opening.

High water is the annually repeated long-term increase in the river water, causing a rise in its level. Under certain conditions during river floods and high water, the rivers in certain Russian regions leave their banks, flood floodplains and cause flooding.

Compared to other emergencies, flooding is considered the most common and devastating natural disaster. Even though floods cause significant damage and many human deaths, there is still insufficient attention paid to the analysis of socioeconomic consequences, consideration and classification of floods [1]. Special attention is paid to ecological consequences since floods affect both the life of society and the environment [2].

The Russian state program on the "Reproduction and use of natural resources" currently states the protection of population and economic facilities from the negative effects of water as a topical priority [3]. According to the Russian Ministry of Civil Defense, Emergencies and Disaster Relief, flood hazardous areas include 3296 towns, 34 sections of railways, and 885 roads [4].
Depending on the sources of water and the ways of its movement, there are underground and surface types of river nourishment. The total amount of incoming water and the role of individual types of river nourishment depend on the physical and geographical conditions of the basin (climate, terrain, the geological structure of the basin, and vegetation). Most water for the river comes from underground, which can reach up to 70% of the annual amount of water that enters the river, depending on the above factors.

Snowmelt causes a significant increase in water flow in rivers located in the northern and middle latitudes. At the same time, spring river floods are much greater than flash floods on large and small rivers in terms of water onflow. The total water onflow, resulting from snowmelt, is affected by the amount of snow (height and density of snow cover) at the beginning of melting as well as the rate of melting. The Siberian rivers, flowing from south to north, have severe spring river floods due to snowmelt that start in the upper and middle reaches [5].

2. Models and methods

Nizhnevartovsk is located on the right bank of the Ob River and was built in a marshy area. A significant area of Nizhnevartovsk, its southwestern and southeastern parts, in particular, is located within the river floodplain. The terrain is flat and slightly billowy, with surface slopes not exceeding 5%, except for slopes in the Ob River valley. In geological and morphological aspects, the city is located on the I-II floodplain terrace of the Ob River with elevations of 40-50 m cut by a network of small streams and rivers with swampy areas. The surface of the urban territory is flat and partially marshy [6]. During the spring high water period, the water level in the Ob River rises to critical levels with possible soil washouts. During the flood period, the maximum runoff is formed, which leads to flooding of low-lying territories, towns, and agricultural lands. Within the studied area, the water level usually increases from mid-April to July, with highest levels in May and June [7].

The studied area is located in the temperate climatic zone. According to A.A. Grigorieva and M.I. Budyko, the area is classified to have a humid climate, moderately warm summers, and moderately severe snowy winters.

The average monthly temperature of the coldest month (January) is -22°C, with an absolute minimum of -57°C in winter. The average monthly temperature of the warmest month (July) is +22.7°C, with an absolute maximum of +35°C in summer. The average annual air temperature is -1.2°C. The average annual amount of precipitation is 664 mm. Most precipitation is in the warm season [8].

The snow cover is developed in October and early November and usually melts in late April or early May. The cold snowy period here lasts for six-seven months. The average of the maximum ten-day snow cover heights for winter is 76 cm in enclosed areas and approximately 47 cm in open areas. The snow cover period in Nizhnevartovsk is 200–210 days [9].

In Nizhnevartovsk area, the Ob River is 700 m wide on average, with the greatest depth of 8 m and the flow velocity of 1.5 m/sec during high water period. The average long-term water flow of this part of the river is 5634 m³/sec [10]. The high water season is 60-130 days on average. The river is characterized by snow nourishment and spring high waters.

Choosing a site for the city, the developers considered long-term levels of significant floods, with the maximum value determined by the condition of flood once in every 50 or 100 years. The value was 42.0 meters in the Baltic system of vertical reference to the surface. Based on the above conditions, Mosgiprogor-2 design institute of the USSR Gosstroy chose the area to build the city in the early 1960s, with no water-dam construction projects planned for the territory.

From the riverside, the city is protected only by the embankment. The engineering constructions include shore reinforcement (city embankment) on the right bank of the Ob, with 11 m of the walking platform and 12 m 20 cm of the upper parapet. The city’s embankment is 3 078.51 m long. Figure 1 shows the dynamics of the maximum water levels on the Ob River, which reached the highest values in 1966, 1970, 1979, 2007, and 2015.
Generally, forecast models of objects are constructed within statistical models, models for interpolation and extrapolation of regular components, and estimates of the impact of random components [11]. Flood forecasting techniques have evolved over the past 100 years. At first, regression methods appeared, which are still successfully used [12].

For forecasting, we construct smoothing of indicators using the components of the Fourier series:
\[
\bar{y}_t = a_0 + \sum_{k=1}^{m} (a_k \cos kt + b_k \sin kt)
\]

(1)

In our case, we consider periodic fluctuations in the water level over 24 years via three components superimposed on each other. Using the least squares method, the equation of the Fourier series is as follows:
\[
y_t = 875.5 + 41.0 \cos t - 0.7 \sin t + 109.5 \cos 2t - 16.9 \sin 2t + 132.4 \cos 3t + 30.9 \sin 3t
\]

(2)

where \( t \) is determined from 0 (for the year of 1991) with an increase equal to \( 2\pi/n \); \( n \) is the number of levels of the empirical series (\( n=24 \)).

We can develop trends in the actual and estimated maximum water levels in the Ob River in Nizhnevartovsk area (figure 2).
3. Results and discussion
The city master plan involves protecting the area from high river floods by strengthening the embankment and the project is already being implemented. However, these riverbank reinforcement structures may not save the city from flooding since the forecasts fail to be accurate and are built by extrapolating the previous river behavior. For instance, in spring and summer 2015, Nizhnevartovsk area was exposed to an adverse hydrometeorological situation. In June 2015, the city authorities introduced a municipal emergency regime in some areas of Nizhnevartovsk due to the high level of floodwaters and flooding of a significant part of gardeners’ partnerships. The water level reached the maximum value of 1061 cm on June 19, 2015 [13]. This situation could have been caused by an abnormally large snow cover in winter 2014–2015, as well as intense rainfall in summer 2015, with the amount of precipitation of 24–32 mm per day in some days [6]. After abatement in water, the city authorities together with the chairmen of gardeners’ partnerships examined summer cottages, where citizens were registered and resided permanently, and assessed the effects of the flood as well as the state of roads and bridges in the flood zone. After flooding, many summer cottages could not be restored.

4. Conclusion
Many cities in the world located on the banks of rivers are prone to flooding. Over the past 20 years, the water level in the Ob River in Nizhnevartovsk has risen twice above 10 meters (2007 and 2015), which was due to high snow reserves at the beginning of melting, high rate of melting caused by high air temperatures and heavy rainfall. Today, the issue of human adaptation to floods is becoming more complex due to an attempt to resolve the conflict between the need to develop coastal lands and the inevitable flood losses [14].

Using the methods of mathematical statistics, we have considered the trends in the actual and estimated maximum water levels in Nizhnevartovsk. The forecasts show that water levels have risen during the spring-summer river flood over the past decades. The results can be used for city development plans, reducing flood damage as well as forecasting the nature and extent of flooding.

The studies of urban flooding are of particular social, economic and environmental significance. Socially, such studies give recommendations for placing residential buildings and industrial facilities in the flood zone as well as developing evacuation and resettlement measures for the population affected by flooding and implementing preventive work to ensure people’s safety. Economically, the studies aim to avoid severe financial losses caused by flooding. Environmentally, the studies are to reduce the damage to the environment due to pollution of the flooded territory.

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