The Evaluation of Natural Risks of Floods in the Delta of the River Selenga and Engineering Protection Against Flooding

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Abstract. The article contains the results of studies of integrated analysis and integrated risk assessment due to flooding for the mouth of the river. Selenga and the development of recommendations for the implementation of measures for engineering protection of the population and economic facilities. In the dynamics since 1931 the hydrological situation of the maximum monthly and multi-year levels and water discharge has been considered, the analysis of genesis, features of formation and mechanism of flooding is given. Scales of possible flooding, underflooding and a list of economic objects within the territory under consideration are presented based on the simulation of flooding zones at estimated water levels of a given probability of exceeding. Estimates of damages from flood floods of 1% of supply are shown. Proposed measures to protect the territories with an assessment of their feasibility and cost-effectiveness.

1. Introduction

The emergence of extreme hydrological events in the delta of the river Selenga are elevated by high risks of economic loss for different branches of the economy and for basic human function, but also by heighten tensions and increased water-ecological problems, negative anthropogenic effects for the lake Baikal, which also lead to economic and environmental damage.

Risks of occurrence of emergencies of a hydrological nature in the mouth of the river Selenga is mainly associated with both high and low water content, the development of channel processes, expressed in erosion and collapse of the banks, accumulation of sediments, and rearranging of channels. Of these, floods are manifested with a rather high frequency and proceed much more catastrophically.

In general, Selenga is the largest river in the lake Baikal. It flows through the territory of two countries, the catchment area is 447000 sq. km. Russia accounts for almost 148000 sq. km., that is, 33% of the basin area. However, with a total annual flow of the river cubic km 30, more than half (cubic km 15.4) is formed in the Russian part of the basin. Selenga refers to rivers with a high probability of flooding. The mouth of the river is the most vulnerable area due to the lowland flat relief and the backwater of the lake Baikal.

Over the past 100 years, the largest flood for the lower course of the river and it's delta was recorded in 1936. It was "caused by short-term rainfall falling in the first decade of June. The sharp warming caused an intensive melting of snow in the mountains. It began on the Uda, then (in 1-2 days)

on the rivers Khilok and Chikoy. "It was a catastrophic character for the lower part of the river Selenga. Not only Ulan-Ude, but also the settlements of the estuary part of the river, caused huge damages. In the archives is noted that intensive flooding of the plain began with the simultaneous release of groundwater, houses, farm buildings, gardens suffered. By the forces of the local population, the banks were built and strengthened. Three settlements were resettled. It should also be noted the high floods in 1971 and 1973 and in the 90s [1].

In socio-economical, the territory is one of the rather developed areas of the Baikal region, which is associated with a special historical process of movement towards. In the XIX century, navigation developed actively, Selenga served as an important initial transit site for the transport of chinese goods, later called the "Great Tea Road". In the delta, goods were transferred to sea vessels. In addition, fishery was developed, timber harvesting, agriculture, etc. At present, in connection with the inclusion of the lake Baikal in the list of World Natural Heritage sites around the lake are regulated certain types of economic activities with strict environmental restrictions. Where more than 15000 people live on the territory there are 23 rural settlements with the center of the Kabansk district. In the summer, the number increases due to vacationers.

The settlements are located on the coastal territories are only partially protected from the negative impact of water. Therefore, the goal of the work is a comprehensive analysis of the causes and peculiarities of flood development in the mouth of the river Selenga, an assessment of their negative consequences and justification of the recommendations of engineering protection.

2. Background information and research methods

The basis for the study served as archival, literary, reference materials and various information about the guidance on the river Selenga and it's estuary part, as well as on the objects of the economy located in the coastal zones. For estimating operations, the level regime data were used in dynamics since 1931, the maximum expenditure, the intensity of the rise and fall, and the duration of standing of high marks.

The cartographic base was the topographic basis, high resolution space images of the Lansad line, orthophotomaps, thematic cartographic materials. Statistical methods of processing hydrological information, mapping and GIS technologies were applied in the process of work.

The damage assessment was carried out according to the methodology for assessing the probabilistic damage from the harmful effects of water and assessing the effective of implementing preventive water management measures [2].

Recommendations for the implementation of measures for engineering protection against the negative impact of water are developed in accordance with the provisions of the Water, the Urban and the Land Codes of Russia, state standards of norms and rules for engineering protection of areas from flooding and flooding. [3, 4, 5, 6, 7].

3. Factors and general spatial and temporal patterns of occurrence of floods

In the mouth of the Selenga has a flat character with small inclines and low flow velocity. By Zhilino is divided into two largest hoses, which communicate with each other through small ducts and break down into separate channels, forming an extensive delta. The main are Levoberezhnaya, Kharauz, Lobanovskaya.

The genesis of flood formation is characterized by runoff associated with a very high flow and water level in the river and its delta channels, as well as shut-off, caused by great resistance to water flow. Shut-off phenomena is very local, recorded in certain areas of bends or narrowing of the channel and the branches of the river and don't cause significant damage, for example, in the area of Murzino. Floods are the most dangerous: floods, which are formed due to rain and melting snow and glaciers in the mountains, but mostly flooded due to heavy precipitation [1, 8]. Distribution of the inter-annual average monthly flow for the period 1990-2015 is shown in Figure 1. (hydrological post Selenga-Kabansk).

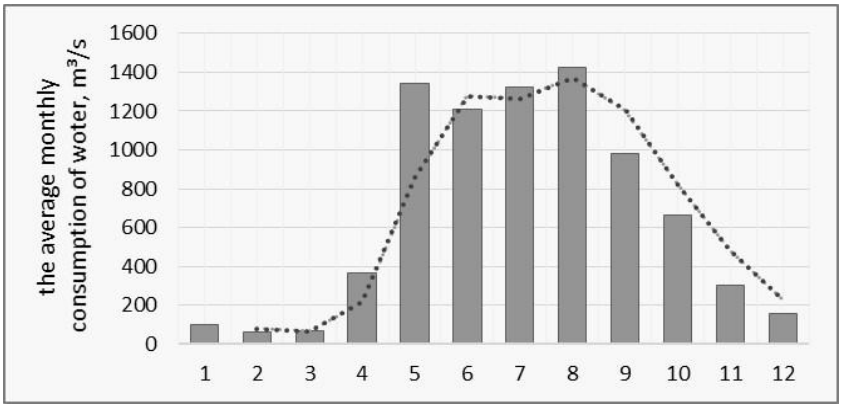

Figure 1. Distribution of intra-annual flow in the estuary of the Selenga.

In dynamics since 1931 there are three high-water periods, in which a series of floods recorded 1931-1941, 1968-1976, 1990-1998 (Figure 2).

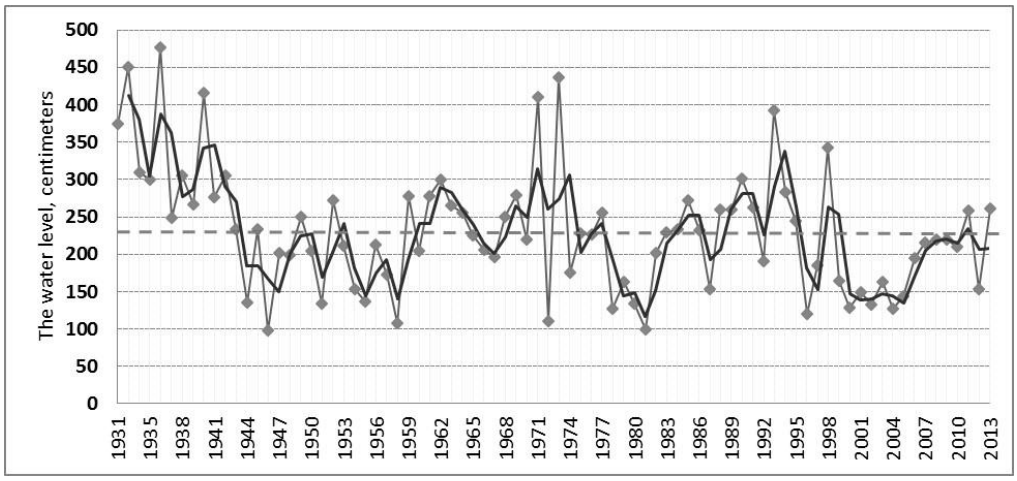

Figure 2. The dynamics of maximum water level Selenga.

The complexity of the passage of floods in the mouth of the river Selenga is determined by significant areas of flooding and the duration of standing high marks due to low absolute marks and small deviations of the earth's surface. High marks of the lake Baikal creates a backwater and hampers the natural flow of the river. In this case, due to the close groundwater up to 1 m, exit to the surface.

Calculations of hazard indicators, performed on the basis of long-term hydrological data of the level regime, water flow and other hydrological and morphometric characteristics, have shown that the frequency of catastrophic floods for the estuary is 8-12 %, while in the middle course this indicator is 14 %. The flooding depth of the floodplain is small (significantly lower than in the basin) from 0.4 to more than 1.2 m, which is explained by the "spreading" of water along the floodplain. However, the duration of standing of high marks can last 40-48 or more day. [1, 8, 9].

In the mouth of the river Selenga several possible options for the formation of extreme events. Territories can be prone to flooding only by the waters of the river. Selenga, or joint exposure at extreme elevations of the lake Baikal.

The definition of flooding and flooding zones was carried out using ArcGIS at calculated water levels of a given probability of exceeding. The boundaries of the flooding areas obtained in the GIS

package from the raster format are converted into a vector format (Figure 3) [10, 11, 12, 13, 14, 15, 16, 17]. It's established that as a result of floods, the area prone to flooding can reach 82.5 thousand ha and when the lake level rises Baikal to the mark of 457.49 - 457.23 m (1971, 1973, 1994), the area of flooding (groundwater yield) - 32.1 thousand ha. Comparison of the areas of flood zones along the river basin shows that if in general 3.4 % of coastal territories can be exposed, of which 9.5 % of agricultural land, then in the estates of the developed part of Selenga this figure reaches 22.6 %.

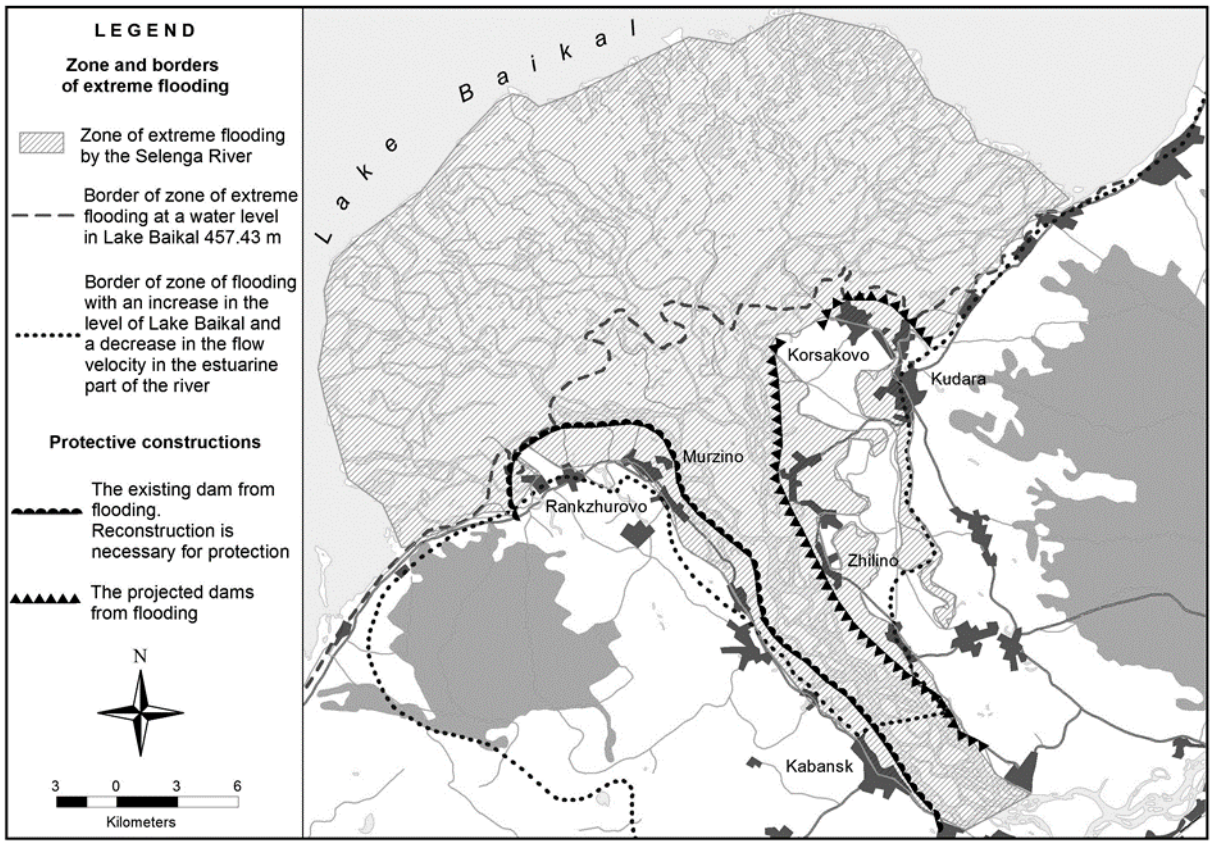

Figure 3. Zones of flooding of the mouth of the river Selenga and engineering protection of settlements against negative impacts of water.

4. Risk assessment of negative consequences

Cartographic mapping and overlapping layers of land using made possible to assess the extent of the negative impact of water and determine the list of objects. Land of agricultural purpose, lands of settlements and industry fall into the zone of flooding. Periodically flooded 17 settlements, the area of damage is 1048.75 ha, which are home to 6496 people; 34.4 thousand ha of agricultural land, of which 6.8 thousand ha of arable land occupied by cereals and vegetable crops, 7.5 thousand ha - hayfields, 20.1 thousand ha - pastures [10, 18].

In assessing damages, normative, integrated specific indices of the cost of damage caused by floods to apartment houses, infrastructure facilities, industrial enterprises, communications, various production and agricultural facilities and structures, as well as plowed fields, orchards, kitchen gardens and other agricultural lands were used. In accordance with the methodology, a territorial coefficient, taking into account natural and climatic conditions, was used in calculations and the deflator appreciation factor was used [2].

The results show that direct socio-economic damage from flooding in the mouth of the river. Selenga reaches more than 3.6 billion rubles. The possible economic damage to economic facilities is estimated at 2.9 billion rubles. For the population (social) damage - 607 million rubles. For the

agricultural sector in the non-receipt of products - more than 120.4 million rubles. The largest losses can be caused with Kabansk, damage 1.6 billion rubles.

5. Justification of engineering protection against floods

As a result of the catastrophic flood of 1936 on the left part in 1941, a dam was built. The beginning of the dam is located in Kabansk from the source of the Istok channel, the end of the defensive structure at the mouth of the river. Selenga (the district of the village of Rankzhurovo). The total length of the hydraulic structure is 28.7 km. The width of the crest, depending on the area, is 1.5-3.5 m; the maximum height of the dam is 2.0-4.0 m. The dam is federal property and is on the balance of the Buryatmeliovodkhoz FGBU. During it's operation periods of high water flow in the river, certain sections of the dam were washed away, in places "eroded" were formed and water flooded the developed floodplain lands. Over the years, major repairs were carried out on individual sections of the dam, almost every year there are small ongoing repairs, such as piling up rock embankments and damming off the shoreline, which in some areas approached the base of the dam.

As a result of the reconnaissance survey of this hydraulic structure, there is widespread deformation and structural weakening of the dam's body with breach of slopes and inconsistency with the design excess over the maximum calculated level. Currently, the dam is in a pre-emergency condition and in case of a breakthrough in the passage of floods of rare occurrence is a threat to 9 adjacent settlements. The safety level of the hydraulic structure is assessed as dangerous. Reconstruction is necessary for protection.

There are no defensive structures along the right bank. In the flooded area there are 8 settlements. In the period of the catastrophic floods of 1971 and 1973, along the river, a protective mound built by the 'method' was laid on separate sites. Now it is completely destroyed.

Objectively, the early implementation of preventive protective hydraulic measures can be significantly reduce the amount of damage caused to the territories and specific objects by the water element. Therefore, on the basis of an analysis of the studies carried out and the results obtained for effective protection of settlements in the estuary of the river Selenga is necessary reconstruction of the left dam (28.7 km), as well as the construction of a new site in the village of Kabansk with a length of 2.5 km and shore protection of 3.7 km. In addition, for the protection of settlements along the right bank, the construction of embankment dams with a total length of 18.9 km and shore protection of more than 0.76 km is required (Figure 3), [4, 5, 6, 7, 19, 20, 21].

Calculations of the cost of the complex of measures of engineering protection are carried out according to the procedure [2]. In general, the cost of the recommended measures will be about 1.5 billion rubles. The inadvertent damage will amount to more than 2.1 billion rubles.

The main criterion of profitability in the design of measures to prevent and reduce the consequences of negative impacts of water is the indicator of economic efficiency. For the site of the mouth of the river Selenga it is 2.3, that is, measures for engineering protection are estimated as cost-effective.

6. Conclusions

Thus, the conducted studies, based on statistical long-term hydrological data and analysis of the peculiarities of formation conditions, types and mechanism of flooding in the mouth of the river Selenga allowed to simulate flooding zones at calculated water levels of a given probability of exceeding, as well as to identify the extent of the negative impact of water and determine the list of economic objects. Based on the obtained intermediate results, an estimate of probabilistic damage is given. Direct socio-economic damage during the passage of floods of rare occurrence in the mouth of the river. Selena is estimated at more than 3.6 billion rubles. and poses a threat to 6500 people. To minimize risks, the necessary measures for engineering protection of territories and, first of all, the right-bank part of the valley are justified for protection.

In general, the reduction of the risk of runoff floods will be facilitated not only by the implementation of appropriate flood control measures: reconstruction of existing and construction of new dams, but also development of economic mechanisms of tax benefits and insurance system.

The obtained quantitative estimates, maps of flooding zones, risks are an objective basis for effective management of the functional organization of the territory and ensuring the constitutional right to the necessary degree of safety and protection of the population from flooding.

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