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The 2013 Extreme Flood Within the Amur Basin: Analysis of Flood Formation, Assessments and Recommendations

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Abstract—For solving the problems of analyzing the 2013 flood within the Amur river basin we undertook an array of investigations including field work, a statistical processing of hydrological monitoring results, a hydrodynamical modeling, calculations of the flood flow regulation in the simulation mode, a study of flow formation, etc. We discuss the formation conditions of the highest discharges and levels for the flooding process, and examine the state of knowledge concerning the drainage basin, and the methods of assessing the calculated hydrological characteristics. An analysis is made of the processes of directional accumulation in the lower reach of the Amur, and their effects on the degree of flood hazard. It is shown that the height of flood in the lower reach is influenced, in addition to economic development, by specific factors caused by alluvium accumulation in the river valley. The study revealed a substantial decrease in discharge capacity of the river channel in the area of the Khabarovsk water node and downstream, including as a result of the measures for purposeful streamflow redistribution between the branches, which contributed to an increase in water surface elevations in 2013 to extreme values. An analysis of the water levels in the middle and lower reaches of the Amur was made using a package of models to demonstrate that the existing nonstationarity of changes in water surface elevations is largely due to the streamflow regulation as well as to the various types of anthropogenic impact on the state of the channel and floodplain, and on the hydraulic state of the water flow.

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INTRODUCTION

The flood problem in the Russian Federation is becoming increasingly challenging. The floods that have occurred recently in Krymsk, on Altai, on Kamchatka, in Magadan oblast, within the Amur and Kolyma basins, and many other, less disastrous, events posed a great variety of tasks and problems which are particularly difficult to deal with [1–5].

Economic development of territories, characterized by an increased degree of risk of occurrence of hazardous natural processes, including hydrological ones, is proceeding without implementing the package of prevention and protection measures; the existing normative base is not enforced in full measure, and the forecasting techniques for hazardous natural processes are inadequately advanced. Ambiguous progress is also observed in the development of technology as well as of the methods of engineering protection of territories against the negative influences of the waters; the present-day possibilities of monitoring the hydrological regime of extensive undeveloped territories are highly limited; water discharges in the transboundary stretches of the rivers have not been measured over a extended period of time.

A critical hydrological goal under these circumstances is to interpret results of hydrological calculations and predictions, and to assess the various effects of anthropogenic impacts on the channel and floodplain and the consequences of flood mitigation discharge regulation. The existing sparse hydrometeorological monitoring network does not permit reliable forecasts of the inflow to the HEP reservoirs with the required earliness of forecast and gives no way of taking the most optimal solution as to their management.

The modern application techniques of hydrological computations are mainly built upon an approximate schematization of the discharge formation processes; the procedures of obtaining computed values are dominated by purely scholastic models and statistical methods. To date the practices of hydrological forecasting incur a substantial deficit of real time information and information technologies as well as advanced sophisticated modeling tools. Most of hydrology disciplines lack specific, well-grounded recommendations as regards the issue of taking into account climatic changes. It should of course be noted that in 2014 Rosgidromet accomplished a great deal of efforts as to automation of hydrological observation stations within the Amur basin, more specifically within the basins of large reservoirs, the development of new (and improvement of existing) methods of hydrological forecasts, and the introduction of novel technologies of acquisition, processing and visualization of factual and forecasting information.

With a view to coping with some of the above goals and challenges within the Amur basin, an array of hydrological investigations was carried out. In this paper, a brief analysis is made of the findings and relevant conclusions.

ANALYSIS OF THE FORMATION MECHANISMS OF FLOOD DICHARGES AND OF THE EVOLUTION OF THE FLOOD WITHIN THE AMUR RIVER BASIN DURING THE SUMMER-AUTUMN PERIOD OF 2013

According to the pattern of water regime, the rivers of the Amur basin refer to the Far-eastern type, with a clearly pronounced feed by rain water. The contribution from the feed by rain water, snowmelt water and underground water in the volume of annual discharge is 47–85, 2–26 and 9–31%, respectively. The relationship of the sources of alimentation in each individual case is determined by the geographical location of the drainage area; of significant importance is its height and permafrost occurrence [6–8].

A high intensity of summertime precipitation, with a significant preceding humidification of earth materials and soils, encourages formation of powerful rain-caused floods on many rivers within the basin, and is accompanied by floods in the middle and lower reaches of the Amur. The large area of the basin, combined with a diversity of the conditions within its boundaries, is responsible for the existence of several flood-producing centers. The main centers are the Upper-Amur, Zeya-Bureya, Sungari and Ussuri [9, 10]. Long-term fluctuations in hydraulicity of the aforementioned portions of the Amur basin are generally not in agreement; their contributions in the overall discharge are different and extremely dynamical as viewed in terms of long-term humidity variations. The contribution from the Argun' and Shilka in the Amur discharge makes up 9.1%, while the Zeya and Bureya contribute 27.2, the Sungari 27.6 and the Ussuri 11.3%, respectively [11]. Together, the other tributaries account for about one fourth of the discharge.

Each of the aforementioned flood centers can serve as the formation zone of the conditions for occurrence of a significant flood on the Amur. Outstanding floods in this case arise out of a coincidence of the flooding activity in two centers or more. For instance, the 1957 flood (the highest discharge of water was as large as 35 500 m^3/s) occurred in the Sungari center (48%) and the Zeya-Bureya center (42%). In 1958, the chief cause for the flood was the flood discharge that formed in the Zeya-Bureya center (62%), and then within the Upper-Amur basin (19%). In 1984 (the highest discharge of water at Khabarovsk was 32 900 m^3/s), the largest value corresponded to the Upper-Amur center (about 32–35% of the highest discharge at Khabarovsk), and the Zeya-Bureya center (about 35–38% of the highest discharge at Khabarovsk). At the passage of the maximum, the discharge of the Sungari and Ussuri at Khabarovsk made up about 18 and 8–10%, respectively.

The main reason behind the historical flood of 2013 for the Lower Amur (with the highest discharge of 46 400 m^3/s [12]) was a high degree of time coincidence between formation and travel of flood waves from almost the entire territory of the Amur basin [4] (Fig. 1).

Calculations showed that an important cause of the historical flood of 2013 for the entire period of instrumental observations along the section of the Middle Amur from the village of Nagibovo and for the entire Lower Amur was a sequential occurrence of floods on the tributaries, and the travel of flood waves at the maximum of displacement of the main Amur flood (see Fig. 1). Also, the main tributaries and small rivers of the basin were all abundant of water. The contribution from the Upper Amur to the formation of the discharge peak at Khabarovsk made up about 20–22%, from the Zeya approximately 25–27, the Bureya 5–6, the Sungari 28–30, and from the Ussuri 15–17%.

The range of the highest moduli of flow for the small and medium-sized rivers was 28.6–384 L/(s/km^2), i.e. the difference between the minimum and maximum values is 15-fold, which characterizes the diversity of the formation conditions for peak discharges. The rivers with higher values (10–100 thou km^2) exhibit an almost identical range of values (57.1–333 L/(s/km^2)), indicating a fundamental similarity and time-coincidence of the discharge formation processes at the occurrence of an outstanding flood within the Amur basin. The Zeya basin and the adjacent portion of the Middle-Amur basin clearly shows a group of rivers with extremely large values of the highest moduli of flow (200–400 L/(s/km^2)). This implies the attainment

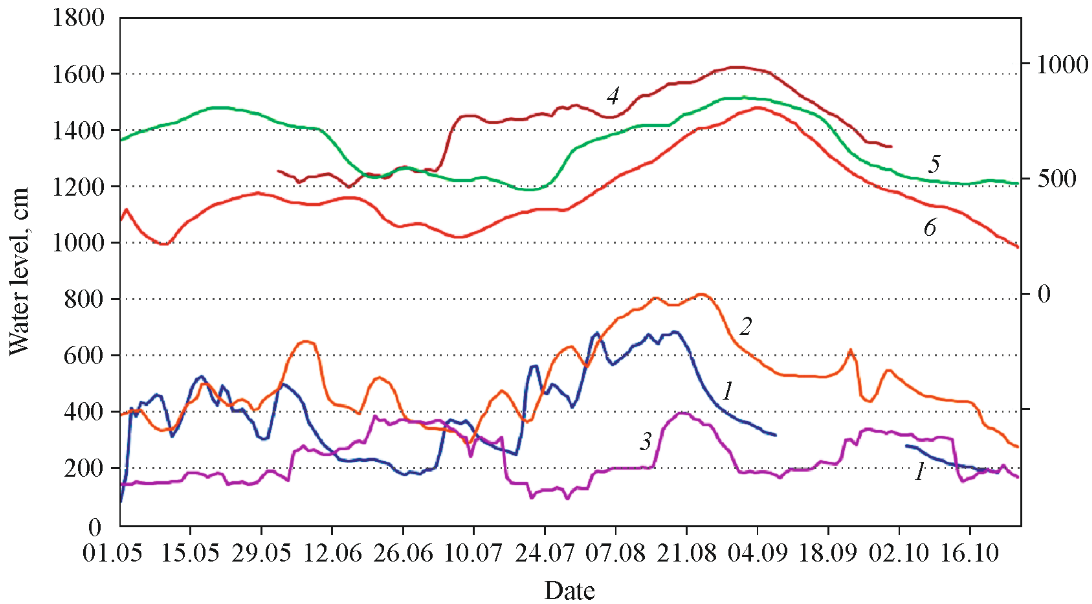

Fig. 1. Combined plots of variation of water levels within the Amur river basin for the water-abundant period of 2013. Line gauge: 1 – Amur r. – vil. Chernyaevo, 2 – Zeya r. – vil. Belogorye, 3 – Bureya r. – vil. Malinovka, 4 – Sungari r. – Jiamusi, 5 – Ussuri r. – vil. Sheremetyevo, 6 – Amur r. – Khabarovsk.

of the maximum values of about 1% probability as observed in a single year across a huge territory [13].

Sequence of flood development. The Amur stream rise of 2013, which led to a large-scale flood, began in July in the western part of the basin where the main zones of precipitation lay over the eastern portion of the drainage area of the Zeya reservoir, over the flat portion of the Upper and Middle Amur in Amurskaya oblast, and in China over the upper reaches of the Nenjiang river (the Sungari basin) [4]. As a result, the first spill streams were the small rivers of the Zeya basin; the Pravyi Urkan river showed an exceedance of the historical maxima by 108 cm, while the floodplain was drowned for a period of more than one month (07.19–08.19).

The discharge of the Upper Amur in 2013 was not an extreme one, although the Shilka and Argun' showed an increased hydraulicity in July and in the first half of August. On the Argun' (village of Olochi), the hazardous phenomenon (HP) marks were found to be increased by 133 cm in early August. The Argun' floodplains in the Priargunskii, Nerchinsko-Zavodskoi and Gazimuro-Zavodskoi districts were drowned to a depth of 215, 394 and 137 cm, respectively.

The sources of the Argun' are situated nearby the sources of the Nenjiang river, the main tributary of the Sungari, where precipitation was most intense. Since most of the river basin is occupied by forest-steppe and steppe and considerable closed drainage areas, the discharge in the confluence node with the Shilka was not as large then. The Shilka basin developed floods at regular intervals, with the water overflowing the edges of the floodplain banks in some stretches; however, the water levels did not reach the HP marks.

As a result, the highest levels of the Upper Amur in Amur oblast on August 16–18, 2013 were much lower than the flood occurrence hazards with a floodplain drowning depth of about 0.5–1.0 m. Only in the section of the Amur downstream of the confluence of the Humarhe river (China) did the floodplain drowning depth exceed 3 m. During August 16–20, the highest levels of the Middle Amur in Amurskaya oblast, in the Zeya channel, exceeded the HP marks by 0.22–1.74 m. The floodplain drowning depth was as large as 4.5 m, and the flooding width was 20–30 km.

The 2013 Amur flood built up due to the discharges of the main southern tributaries: the Sungari (China), and the Ussuri (China and Russia) as well as to the numerous smaller tributaries. As a result, there arose differences between the disastrous flood of 1984 and 2013 (Fig. 2). In the stretch of the Middle Amur between the city of Blagoveshchensk and the village of Ekaterino-Nikol'skoe, the flood, in its evolution, was virtually pattering after the characteristics of the 1984 flood. Further downstream, the Amur levels in 2013 were substantially higher. The small Russian and Chinese tributaries of the Amur in 2013 were more abundant of water, because the zones of precipitation and the increased preceding humidity of the basin surface remained in the presence of a displacement of the wave of the main flood.

Downstream of the confluence of the Sungari (at the village of Leninskoe), the level of the Amur was already more than one meter higher than that in 1984. Both the Sungari and the Ussuri were more abundant of water in 2013. The highest discharge of the Sungari at the city of Jiasumi was 13 300 m^3/s (August 31). A higher discharge of water in the Sungari was observed only

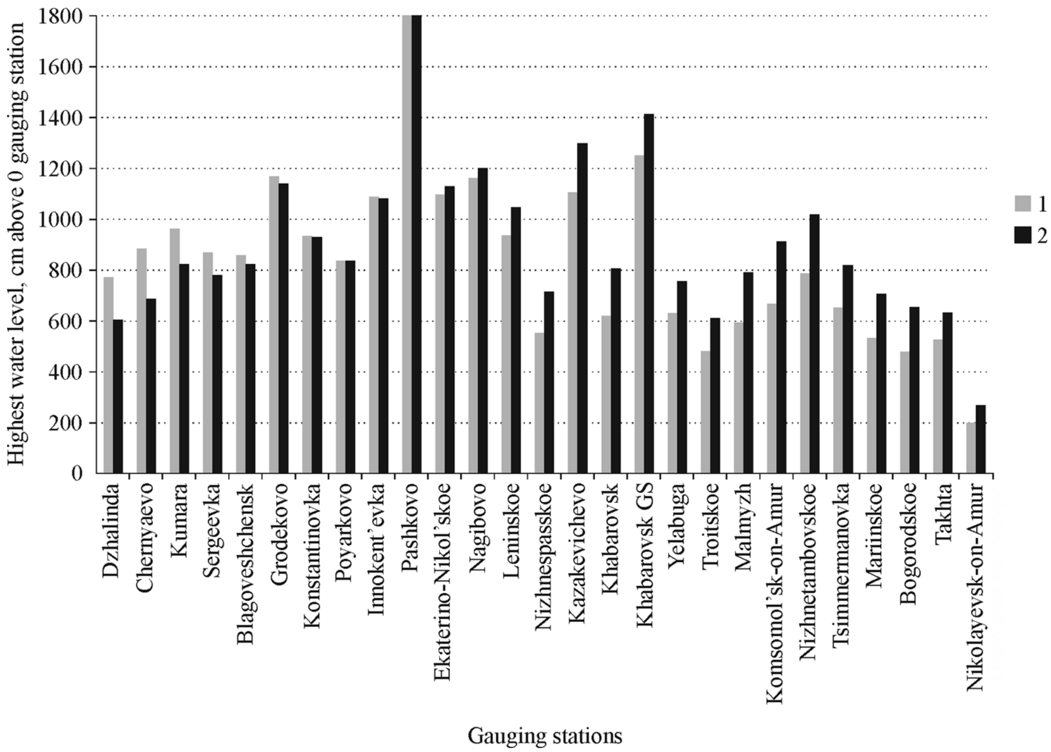

Fig. 2. Comparison of the highest levels for 1984 and 2013.
1 – 1984, 2 – 2013.

in 1960 (18 400 m^3/s), and in 1988 (16 200 m^3/s). The contribution from the Sungari discharge in 2013 made up about 30% of the Amur discharge at Khabarovsk at the maximum, and the Ussuri and Bureya discharges contributed about 16 and about 6%, respectively; in 1984, the Sungari, Ussuri and Bureya contributed about 18, 9 and 5%, respectively.

In the stretch more than 1000 km from the village of Nagibovo in Jewish Autonomous Oblast to Khabarovsk krai (123 km from the mouth), the highest marks exceeded the historical maxima by 0.40–2.11 m. The duration of the stand of such high levels (exceeding the historical maxima and hazardous marks) was about one month or more at large cities, while the duration of drowning of the floodplain with depths of 2–4 m was as long as two months or longer in places [12].

Further downstream, the flood on the Amur gradually flattens out, and at Nikolaevsk-on-Amur 48 km of the mouth, at the head of the Amur liman, although its levels exceeded a critical mark during September 10 to October 15, they were much lower than the 2014 May flood caused by ice phenomena (Fig. 3).

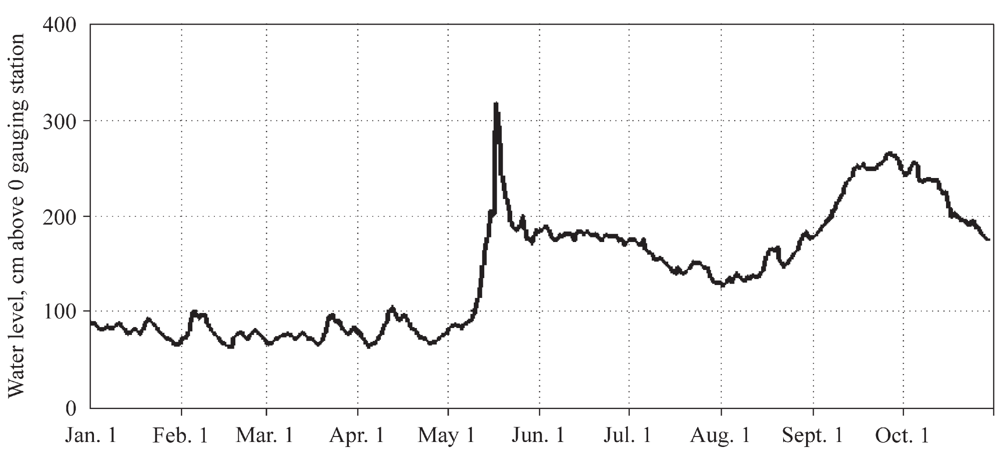

Fig. 3. Variation of the Amur water levels near Nikolaevsk-on-Amur in 2013.

ASSESSING THE INTENSITY OF DIRECTIONAL ACCUMULATION IN THE LOWER REACHES OF THE AMUR AND OF ITS INFLUENCE ON FLOOD OCCURRENCE HAZARD

The height of floods in the lower reaches of the Amur is influenced by some specific factors caused by sediment accumulation in the river valley. The Amur refers to the rivers which, in their evolutionary development, do not cut into the valley bottom; instead, they rise on the accumulating sediments [14]. Accordingly, as time elapses, the floodplain surface and the river encroachment lines are rising at different water levels relative to zero of the gauging stations.

The bulk of fluvial sediments of the Amur river is generated in its middle reaches. Here, along the length of less than 1000 km, the Amur receives its largest tributaries: the Zeya, Bureya, Sungari, and Ussuri which, together, contribute about 65% of the entire water discharge and more than 90% of the suspended sediment yield. The widespread occurrence of soft (primarily, clay) deposits within the basins of these rivers, coupled with a high activity of the channel processes, is responsible for a substantial increase in water turbidity in the middle and lower reaches of the Amur (approaching 400–500 g/m^3), and for an increase in sediment yield.

On the other hand, there occurs a consistent, regular decrease in water turbidity along the length of the river. It averages 30–35% [15]. The Amur downstream, there is also taking place a decrease in the mean size of particles transported by the flow [16, 17]. This is due to the predominant settling of the largest particles; as they approached the mouth of the river, they were decreasing in their number in the water flow. While in the area of Khabarovsk the number of suspended particles less than 0.005 mm in size constitutes about 20% of the total volume of terrigenous material, in the area of th village of Bogorodskoe it increases to 60% or more (Table 1).

Sedimentation on low ground of the valley is proceeding nonuniformly. On mid-channel bars and in low islands, a clay sheet 30–40 cm in thickness can accumulate during one flood. As regards the 2013 flood, the maximum thickness of the clay sheet on the floodplain approached 1 m. At the same period, the floodplain deposits were undergoing in places by water flow-induced scouring. These erosion-accumulation processes, having a local and alternating character, combine with the presence of a general directional rise of the valley bottom [19].

The stretch of the river downstream of the mouth of the Sungari (more than 1200 km in length) is characterized by the resultant of the river load balance which corresponds to their directional accumulation [20]. According to data of paleogeographical reconstructions, the duration of the accumulation stage is 5–6 thou years. It is preceded by a relatively short-lasting but active incision of the Amur into the surface of an extensive plain that formed at the end of the Late Quaternary. Evidence of this incision has persisted in many places of the valley in the form of steep benches 4–8 m high dominating the present-day floodplain. Nowadays, the incision is almost entirely filled with channel and floodplain deposits.

The ongoing accumulation in the lower reaches of the Amur arises out of the regional lowering of a vast territory east of the Lesser Khingan. The movements have a differential character. Some areas are sinking at the rates varying from 1–2 to 7–8 mm/year. A similar situation is also typical of the other large rivers of Russia [21].

Along the valleys of the Ussuri, Khor, Anyui, Tunguska and Amgun' rivers, retrogressive accumulation penetrates upstream of their mouths to a distance of 60–120 km, which is to be taken into consideration when assessing the flood height in their lower reaches. Its influence is more pronounced directly in the estuarine region of the tributaries and is attenuated nearer the transient region of retrogressive accumulation.

In the mouths of the smaller tributaries of the Amur, lakes are formed under afflux conditions. Accumulation of river sediments in their hollows triggers a retrogressive displacement of the lakes upward along the valleys of the tributaries. During floods, extensive areas surrounding the lakes become submerged but, unlike the floodplains, such areas show no presence of the flow of water. In 2013, an increase in the size of Lake Gassi interrupted motor traffic between Khabarovsk and Komsomol'sk-on-Amur.

During disastrous flood, the water in many places goes beyond the floodplain and reaches the lower-lying areas of the Middle-Amur and Udyl'-Kizinskaya Lowlands, flooding hundreds of square kilometers of the bogs in the Amur region. In the area of Lake

Table 1. Changes in size of suspended sediments along the length of the Amur river for moderate water level [18]

Location	Particle size, mm					
	1–0.5	0.5–0.2	0.2–0.1	0.1–0.005	0.005–0.001	< 0.001
Khabarovsk	24.2	38.4	11.7	6.9	18.8	–
Komsomol'sk-on-Amur	4.6	21.8	8.9	5.3	20.6	38.8
Bogorodskoe	0.2	5.3	9.6	18.6	44.6	21.7

Bolon’, a shallow (but broad) flow of water from the Amur is heading to the lowlands of the Kharpi river. Such floods are also known in the lowlands of some other tributaries of the Amur as well as the Ussuri and Amgun’. They cause a particularly serious damage in the interfluve area of the Khor and Kiya (the tributaries of the Amur), as they cause flooding of the fields and destruction of the roads.

Analysis of available data shows that the annual suspended sediment yield of the Amur river in the Komsomol’sk-on-Amur hydrometric section amounts to 19 mil. t; near Khabarovsk, it is 24 mil. t. The segment of the Amur between Khabarovsk and Komsomol’sk-on-Amur accumulates an average of about five mil. t of mineral particles every year. To date it is still not possible to determine the degree of nonuniformity of the sedimentation rate along the length of the Lower Amur. Basically, these data hold true for the river channel within the boundaries of the Middle-Amur Lowland. Sand-and-clay particles accumulate on the river bed, the floodplain and in the lakes, increasing the surface level by 1.2–1.5 mm/year [14].

Taking into consideration the sediment yield from the Amur tributaries (the Anyui, Gur, and others) and the transported deposits of the river, the value of increase in the valley bottom surface within the boundaries of the lowland is about 1.7–1.8 mm/year, or 17–18 cm for a hundred years. The floodplain surface and the river bottom increases by such a height, on average, relative to the surrounding terrain. This is a considerable “addition” to the characteristic (mean, highest, and lowest) water levels in the Amur. Compared to the water levels during the historic 1897 flood, the water surface marks in 2013 (with equal water discharges) were 20 cm above those observed in 1897. An additional rise in the water levels had maximal negative implications for the safety of many human settlements along the valley of the Lower Amur, including two major cities: Khabarovsk, and Komsomol’sk-on-Amur [19].

On the whole, the tendencies in pressure changes for a year are different in different regions of the ATR. Thus, a positive estimate of the pressure trend is obtained for Western Siberia (0.39 hPa/10 years), whereas for Primorie the value of the trend is negative (–0.24 hPa/10 years). An increase in pressure in January and December is characteristic for all regions, except for Primorie, throughout the entire year, and maximum values of the trends were obtained for the territory of Western Siberia. Here, a drop of pressure occurs mostly during the spring–summer months when March holds the lead.

ASSESSING THE CHARACTERISTICS OF LEVEL REGIME OF THE AMUR

Under these circumstances, the importance of assessments of the flooding levels along the valley of the Middle and Lower Amur will continue to escalate. In spite of the availability of long-term series of observations (in some cases, covering a time interval as long as a hundred years), the problem is not a trivial issue for lack of unambiguous normative recommendations as regards selection of the highest water levels during snow-melt floods and high-water periods. The series of the levels are not uniform for most of the currently exploited rivers are nonuniform. The construction of protection embankments, the deepening of the river bed, the construction of bridges and berths, extraction of nonmetallic building materials (sand, and gravel) from channel deposits, floodplain development, changes in the shape of the transverse profile of the river valley, an increase in the volume of deposits as a result of an accumulation of sediments or their scouring, streamflow control, etc. are able to have a dramatic influence on the marks of the water surface level along the river channels [22].

The main method of analyzing the possible changes in the water level as a result of anthropogenic and other impacts involves summarizing data of hydrometric efforts and hydrological observations for different periods. By comparing the dependencies of the discharges on the levels, it is possible to look into the dynamics of directional changes in hydraulicity as well as hydraulic characteristics. For the Middle and Upper Amur this problem is quite challenging, because it is since the end of the 1960s that no measurements were made of the water flow rates along the entire transborder reach of the Argun’, Amur, and Ussuri rivers up to Khabarovsk.

In the lower reaches of the Amur, three discharge gauging stations (city of Khabarovsk, village of Bogorodskoe, and city of Komsomol’sk-on-Amur) are in operation, and long-term series of observations are available for them.

A statistical processing of the time series of the highest annual water levels showed that they are not uniform relative to their mean value. This conclusion is rendered most convincing by the analysis of data obtained by dividing the initial series into two samples, in accordance with the “breaking” point (here, 1975 is the year of commissioning of Zeya HEP), identified by means of difference-integral curves. A change in the mean values of the water levels, dH, (an increment in the highest level determined from the interval of the series prior to and after the “breaking” point) shows that the most significant changes of the value of dH are characteristic for the observation stations located within the 500-kilometer section of the Amur river downstream of the Zeya mouth near Blagoveshchensk. The decrease in the highest level here is about 1 m or more. The influence of Zeya HEP on the mean values of the highest water levels is clearly seen along almost the entire length of the Middle and Lower Amur.

The variation coefficient of the distribution of the highest levels over a year also underwent a drastic change for the period of river regulation. The increase of the variation coefficient at the gauging stations on the Middle and Lower Amur (as far as Khabarovsk) is accounted for by the substantial role played by the protection dikes, mainly on the territory of China, and of the other hydraulic structures (bankheads) that were constructed in the Amur channel. Damming of the channel limits the zone of channel-floodplain water exchange thus causing an increase in the highest levels in the portions of the floodplain with no anthropogenic influence.

It was found that during the period after 1975, as a result of various effects on the Amur level regime, the design 1% water levels underwent a change with respect to the period prior to 1975.

In the area of the gauging station near Blagoveshchensk, a decrease of the levels by 50 cm or more is generally observed, because of the regulation role of the Zeya reservoir. Downstream of the Zeya, this role is attenuated. In this case, there is an enhancement in the role of the factors encouraging an increase in the fluctuation range of the water level (construction of protection dikes, accumulation of sediments, afflux of the flow by means of various technogenic structures, etc.).

At the hydrometric section near Khabarovsk, the design water levels with respect to the period prior to 1975 increased by 0.5–2 m. The distance dependence of the level increment (P = 1%) along the length of the river is irregular in character, which is determined by a differing integral effect (scale) of anthropogenic impacts.

For recovering the natural conditions of formation of the level regime, it is possible to carry out a retransformation of the discharge corresponding to the absence of anthropogenic impacts on the marks of water surface. This problem is difficult to resolve in full measure due to a shortage of initial data. By way of example let us consider the role played by the regulation effect of the Zeya and Bureya hydroelectric power scheme on the design discharges of the Amur near Khabarovsk. For this purpose, we shall use the Kalinin–Milyukov transformation model for the flood wave [23].

The task of reconstructing the hydrograph of the water discharge in the hydrometric section near Khabarovsk during the 2013 flood was dealt with by transforming the set of input hydrographs (main inflows) and discharges through the power dams. It is supplemented by the solution of an additional problem where the hydrographs of the inflow of waters to these reservoirs correspond to the discharge hydrographs downstream of the Zeya and Bureya hydroelectric power schemes.

Analysis of the results obtained (Table 2, Fig. 4) showed that, in the absence of the reservoirs, the highest water discharge would increase by 3400 m^3/s, or additional 50 cm to the highest water level observed. Similar estimates of the influence of this factor on variation in water levels at the beginning of the section of the Lower Amur were obtained in [3].

CONCLUSIONS

The water levels as measured at the gauging stations integrally reflect the effect of all factors and processing occurring within the basin, on the bench marks of the water surface. A statistical processing of data on the water levels yields reliable results for subsequent efforts involving territorial zoning, and design of various facilities with due regard for the genetic contribution from these factors. Analysis of the water levels in the middle and lower reaches of the Amur showed that the nonstationarity as observed in the variation of the marks of the water surface is largely caused by streamflow regulation as well as by the various kinds of anthropogenic impact on the state of the channel and floodplain, and on the hydraulic state of the water flow.

In hydrological design, it is recommended that the data series be separated into statistically homogeneous samples to be subjected to statistical analysis. For the conditions of the Middle and Lower Amur, data samples covering the time period prior to and after 1975 can be considered homogeneous. In this case, calculations will ensure determination of the background (without an appreciable anthropogenic effect) values of the

Table 2. Actual and calculated (reconstructed) characteristics of the 2013 flood near Khabarovsk

Varinats of runoff hydrograph	Actual data	Results of calculations			
		according to actual data from input line gauges	with replacement of Bureya escapage by inflow	with replacement of Zeya escapage by inflow	with replacement of Zeya and Bureya escapage by inflow
Q_{max}	46 400	46 700	48 200	48 300	49 800
Formation date of Q_{max}	3–4.09	31.08–1.09	31.08–1.09	30.08	30.08
Period of MHP*, days	32	32	40	36	42

*The period of MHP is calculated as the formation of discharges in excess of 33 000 m^3/s, which corresponds to the level of 600 cm for the Amur – Khabarovsk line gauge.

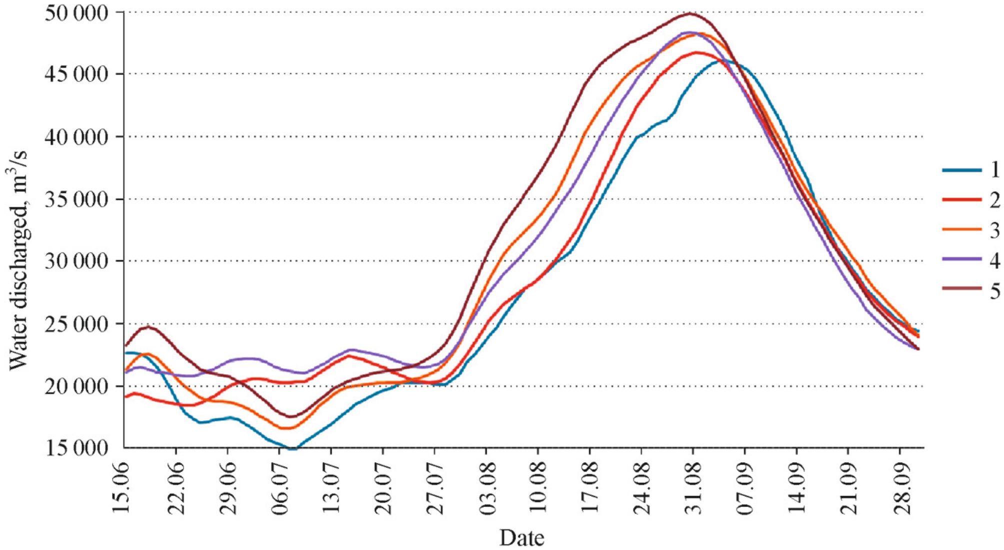

Fig. 4. Actual and design runoff hydrographs in summer 2013 for the Amur r – Khabarovsk gauging station. 1 – measured water discharges Q; 2 – value of Q as deduced by the Kalinin–Milyukov method and from actual boundary values of Q; 3 – calculated value of Q where the actual water discharge at the Bureyagauging station (vil. Malinovka) is replaced by the value of the diurnal water inflow to the Bureya reservoir; 4 – calculated value of Q where the actual water discharge at the Zeya gauging station (Zarechnaya Sloboda) is replaced by the value of the diurnal water inflow to the Zeya reservoir; 5 – calculated value of Q where the actual water discharge of the Zeya and the Bureya is replaced by the value of the diurnal water inflow to the reservoirs.

water levels which had occurred within the river basin before 1975, and the value which will be characteristic during the operation of existing and projected facilities. The solution of such a problem becomes a considerably more complicated issue in the absence of data on the regime of runoff, the morphological properties of the channel and floodplain, and on the characteristics of the economic exploitation of the water and other resources of the river basin.

Different sections of the river show ambiguous influences on the marks of the water surface from the particular factors and processes. Downstream of the Zeya outlet, the highest water levels could be substantially higher in the absence of the Zeya reservoir. The Zeya downstream, in the area of the Khabarovsk water node, an increase of the water surface marks is influenced by accumulations of sediments in conditions where the water flow separates into branches of braiding. A substantial decrease in the discharge capacity of the channel in these sections, including as a result of the purposeful actions aimed at redistribution of the flow between branches, made an added contribution to a relative increase of the water marks to extreme values in 2013.

The increased values of the water levels during the floods after 1984 led to the suggestion that the climatic changes across the region could play a role. Analysis of the time history of synoptic processes during the 2013 flood intimated that no reliable data were revealed for the influence of climate changes on the formation mechanisms of this flood and its magnitude. The outstanding flood of 2013 was caused by an array of natural and anthropogenic factors which manifested themselves simultaneously within the Amur basin.

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