UDC 502.7:551.215(282.251.1)

APPLICATION OF FLOOD INDEX IN MONITORING FLOOD-PLAIN ECOSYSTEMS (BY THE EXAMPLE OF THE MIDDLE OB FLOOD-PLAIN)

V.P. Bolotnov

Institute of climatic and ecological systems monitoring of the Siberian Branch of the Russian Academy of Science, Tomsk
E-mail: bolotnov07@mail.ru

The concept of regional hydroecological monitoring has been developed for the flood-plain of the Middle Ob. Its object is to control the state of flood-plain ecosystem productivity for organization of scientific, regional-adopted and ecologically regulated nature management. For this purpose hydroecological zoning of flood-plain territory performed, the most representative stations of water-gauge observations for each flood-plain zone organized, the scheme of flood-plain flooding was prepared. On the basis of observations within more than 50-years flood hydrographs were composed, the part which forms the flood influence was calculated. It was presented through the complex factor – index of flood influence. The graphs of the flood influence index changes at reference water stations from 1935 to 2000 were presented.

The river Ob occupies the central part of Western Siberia. Its pool integrates all spatial and dynamic changes of the Western Siberia ecosystem. Sites – the Top Ob, the Average Ob, the Bottom Ob are allocated along the pool. Each site is characterized by its specific water mode.

The site of the Average Ob has well generated flood-plain, which is actively being developed by people. Efficiency of biological components of flood-plain ecosystem is few times higher than of surrounding territory due to variety of conditions. The presence of the tail water site of the Novosibirsk water basin dam with changed water mode is characteristic for the given flood-plain site. Water mode surveys at the Middle Ob site are carried out at water station posts. However these surveys on water level, water flow, water quality obtained by the Hydrometservice can not be used directly in surveys on ecological condition of flod-plain ecosystems. Often, the maximum level or water flow is simply used to describe flood influence. It is not enough to characterize interaction of floods and live organisms inhabiting flood-plain and to obtain specific correlation communications.

Therefore the concept of regional hydroecological monitoring was developed for the Average Ob flood-plain. By definition monitoring is the survey, estimation and forecast of environment condition in connection with human economic activities [1]. Problems of monitoring in a general view are reduced to comparison of surveys with critical points of system condition, including survey, forecast and defined by the purpose of applied or scientific researches. The attention to abiotic, biotic or anthropogenous component of the ecosystem is more or less paid depending on the purpose of researches. Surveys, or data interpretation of the «influence – response» model, or even more complex model with the analysis of direct and reverse coupling are used as methodical approach [2]. The approach when variables are analyzed under the scheme «influence – response» is suggested to use as methodical basis of monitoring for the Middle Ob flood-plain ecosystem. The part of the river flow which fills the flood-plain is considered as abiotic external variable, and component efficiency of flood-plain ecosystems as response.

The purpose of monitoring is the control over efficiency condition of flood-plain ecosystem to organize scientifically-proved, regional-adapted and ecologically regulated wildlife management. It leans on the pool approach which reflects connections of the allocated area of researches with other sites of the river and the territory forming the flow. Hydroecological zoning of flood-plain territory has been done for such purpose, the most representative posts of water-measuring surveys for each site of the flood-plain have been allocated, and the scheme of flood-plain flooding has been made. On the basis of observations within more than 50-years flood hydrographs were composed, the part which forms the flood influence was calculated. Communications of the hydrological parameters describing influence of a water mode and a condition of efficiency of the basic parameters of a ecosystem condition are calculated. As the basic producers the condition of meadow efficiency has been as main producers, water-field mouse and muskrat as consumers of the I level, the condition of fish community and bird population have been studied separately. Bird population is considered as the most sensitive element of the ecosystem.

The resource approach when parameters of economic efficiency are used has been applied at estimation of biological components condition. Similar data are used at designing hydraulic engineering actions, at planning nature protection activity. It does not make the given approach distinct from biological monitoring when detailed surveys over separate kinds of animals and plants are carried out. As a rule, because of high amount of effort input, such surveys are carried out on insufficient quantity of platforms, not completely covering flood-plain territory, and they do not last long periods of time (no more than 5 years). Therefore similar surveys can serve as a good addition to a big number of surveys to explain discrepancies at dynamics analysis of connections «flood – biotic component». Complexity of the analysis can be also explained that spring flood is though significant, but is only a part of one year or long-term cycle of biotic component. It mainly defines their development but after some time during a year or few years at long-term cycle of development the action of other factors is imposed which shades influence of high waters. Therefore it is unreal to set the goal to obtain 100 % of connections among these factors. Apparently, they can be used with certain assumptions in the first or in the second approach.

At analyses of annual transformation system caused by flood changes it is necessary to allocate the whole component of the water mode which forms the dynamic system. This component includes a part of the river flow which flows directly onto the flood-plain renders favorable or adverse influence, up to catastrophic. Such influence at high flood shows itself for live organisms and vegetation, located in flood-plains of rivers in reduction of dwelling area, fodder places, and, on the contrary, in creating the best conditions for spawning and bringing up offspring for fishes. Besides, various sites of flood land, are differently adapted for influence of high waters.

We offer the technique to calculate complex index of flood influence, which considers area of flood-plain flooding in this or that year, height of flood-plain flooding, duration of flooding, date of water inflow onto flood-plain and date of water outflow from flood-plain (which is connected with heating of inflown onto flood-plain water), data on water quality. The binding has been done to the general statistical characteristics – security of level flooding which has cleared subjectivity at estimation of flood, present at estimation of flood influence by biologists when simply low meadows are allocated which are being frequently flooded, high crests which are rarely being flooded and very high areas of flood-plains which are being filled with water in catastrophic floods. What important is that at calculation of flood separate characteristics they are referred to average annual values. It allows to obtain their value in relative units, to unite into a complex parameter and the main thing – to come to estimation in the system «influence – response» in relation to average annual characteristics.

The general equation of the flood influence index (FII) has the view:

$$I = \frac{1}{6} \cdot (I_d + I_h + I_p + I_{PL} + I_T + I_Z).$$

Particular equations have the view:

$$I_d = \frac{d_{95\%} + a_d\ d_{75\%} + b_d\ d_{50\%} + c_d\ d_{25\%}}{\overline{d}},$$

$$I_p = \frac{p_{95\%} + a_p\ p_{75\%} + b_p\ p_{50\%} + c_p\ p_{25\%}}{\overline{p}},$$

$$I_h = \frac{h_{95\%} + a_h\ h_{75\%} + b_h\ h_{50\%} + c_h\ h_{25\%}}{\overline{h}},$$

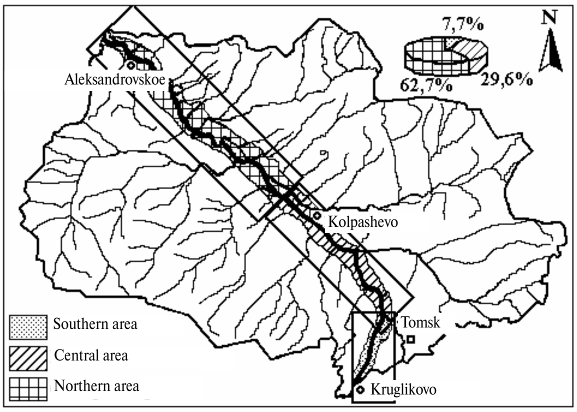
$$I_{PL} = \frac{PL_{95\%} + a_{PL}\ PL_{75\%} + b_{PL}\ PL_{50\%} + c_{PL}\ PL_{25\%}}{\overline{PL}},$$

$$I_T = \frac{T}{\overline{T}}, \quad I_Z = \frac{Z}{\overline{Z}}.$$

Here I_d, I_p, I_h, I_{PL}, I_T, I_Z are accordingly the date indexes of the beginning of flood-plain flooding, durations of flooding, heights of flooding, area of the studied area flooding, temperature and water pollution; d, P, h, PL, T, Z are accordingly the annual absolute values of the date of beginning flood-plain flooding, durations of flooding, heights of flooding, area of the studied area flooding, temperature and water pollution; $\overline{d}$, $\overline{p}$, $\overline{PL}$, $\overline{T}$, $\overline{Z}$ are accordingly the average annual values of these parameters. *a, b, c* are the weight coefficients reflecting adaptedness of biotic components at various levels of flooding. Figures 95, 75, 50, 25 % characterize supply of flood-plain high-altitude horizons, that is they show in percentage number of years during which the set horizons can be exceeded by flood.

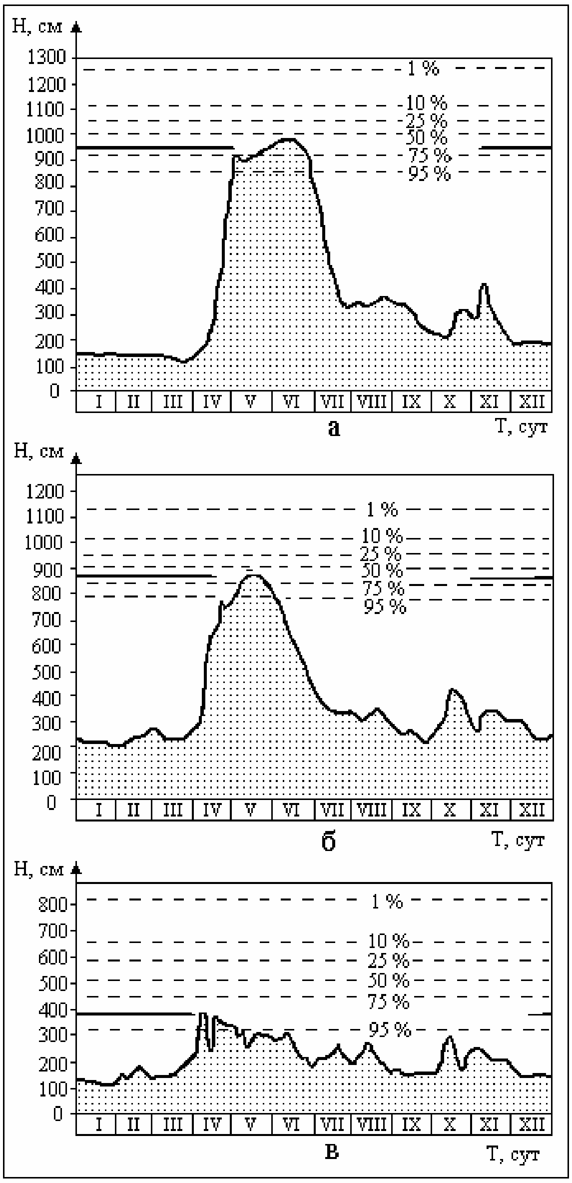
The method of index calculation is stated in detail in works of the author [3, 4]. Water levels were offered to be used as basic hydrological characteristics instead of water flow as they can be counted in view of «0» of water station schedules at high-altitude marks of the Baltic system and correlated with high-altitude marks of flood-plain territory.

As a result of the flooding analysis of the Average Ob flood-plain the settlement characteristics necessary for organization of hydroecological monitoring in flood-plains were defined: the zoning scheme of the investigated flood-plain site; the schedule of maximum water level supply for long-term period; typical (modeling) schedules of the water level course corresponding to design supply; cross-section structure of the investigated site with deposited flooding levels of various supply; a part of the schedule of water flow level for each year corresponding to flood-plain flooding; schedules of flood-plain flooding duration of design supply; schedules of flood-plain flooding area of design supply; maps of flood-plain flooding; dates of water outflow and inflow on and off floodplain; water pollution parameters; data on water temperature in the watercourse; data on air temperature (for the analysis of shoaliness heating and beginning of the vegetative period); data on annual efficiency of biological components in flood-plain ecosystem.



Pic. 1. *The scheme of the river Ob flood-plain along the borders of Tomsk area with allocated, by flooding conditions, areas*

The scheme of hydroecological monitoring is developed for the Average Ob flood-plain in administrative borders of Tomsk oblast. The length of the site is 1169 km which makes almost 1/3 from the total length of Ob (3676 km). Running through territory of Tomsk oblast from southeast to northwest the river Ob crosses in the middle current the subzone of southern and partially middle taiga. As it runs from the south to the north of the territory water content of the river Ob strongly increases due to inflows of the rivers: Tom, Chulym, Chaya, Ket, Parabel, Vasugan, Tym, Vakh, etc. Except the river Tom and upper river of the river Chulym, all of them are typically taiga rivers with boggy flood-plains, highly twisted, with small inclinations and low flow velocity (in low water 0,3 m/s).



Pic. 2. *Combined schedules of level flow in the year of average water content (1999) foe water stations: а) Kruglikovo village; б) Kolpashevo city; в) Aleksandrovskoe village. H is height of water level in sm from «0» of water station graph. см – sm, сут – day*

The river Ob in the average current, based on B.D. Zaykov's classification of the water mode [5] refers to rivers of the Western-Siberian type (Figure 1). The main phase of the water mode is the spring-and-summer flood observed from April to July. Up to 70 % of an annual flow occurs during flood. The presence of big flood-plain, rugged by numerous channels, inundated small rivers and lakes is characteristic for of the river Ob valley. Its width changes from 6 km in the south (Kozhevnikovo village) up to 20 km in the north (Molchanovo village, Aleksandrovskoe village). The channel of the river Ob is highly twisted. On many sites it is dismembered by islands. It promotes strong coast floods. The greatest depths and flow velocity are dated to such floods. The inclination of water surface is insignificant – 0,044 ‰. Average flow velocity during low water is 0,5...0,7 km/s and during flood is 2,0...2,5 km/s. The average annual flow changes from 60 km^3 (Pobeda village) up to 195 km^3 (Aleksandrovskoe village).

Floods run through a river valley as a wave. As a result maxima of levels in consecutive river valves do not come simultaneously, but shift in time concerning one another. By combining in one drawing schedules of flood wave passage in several valves (Figure 2), it is possible to obtain evident enough representation about river mode during particular period in various river valves – about flood height, its duration.

At the analysis of long-term level flow at water posts, the author allocates the highest FII in 1937, 1941, 1966 (Figure 3). The low flood-plain of the river Ob all the way from Kolpashevo to the north border of the area annually turned up under water. Average duration of the low flood-plain flooding makes at: Kruglikovo village – 8 days, Kolpashevo – 63 days, Aleksandrovskoe village – 68 days. The greatest duration of the Average Ob flood-plain flooding is 2...3,5 months. And at the north of the Aleksandrovskoe village water station water horizons of set supply can be observed 2...2,5 months later, than at the Kruglikovo village water post.

Spring level rise usually begins in the second half of April (early and late terms – the beginning and the end of April), at freeze-up. In the general water level flow of the river Ob one wave with intensive enough rise and very slow recession is observed. On the site before the confluence of the river Tom an edge water level flow or two-three low-grade flood waves, formed as a result of subsidence along the river of well expressed multitopmost flood in the upper river of the river Ob, are observed. Flood duration can be from 120 days during «amicable» springs up to 150 days and more during long springs. The end of flood is observed, accordingly, in July or August. The average height of water level rise above preflash, on the site up to the confluence of the river Tom, is about 5 m, below 7...8 m, the greatest at the Aleksandrovskoe village water station is 9...11 m. The duration of level rise is 30...35 day, the average intensity of rise is 30...35 sm/day.

Flood-plain zoning with large area allocation connected with features of flooding (Figure 1) was conducted for the site of the Average Ob. The role of natural zoning consists in unification of data about object and can serve as its model. The offered zoning of the Average Ob flood-plain is subordinated to the purpose – to reveal interaction features of floods and biotic components of the flood-plain ecosystem for ecologic-economic planning at a level of one or several administrative areas, districts, regions. That is, on the one hand, the basis is biogeographical zoning as it is based, as a rule, on the analysis of flood-plain distinctions by height, and on the other hand for administration management of territory, ecologic-economic characteristics of ecosystem condition at a level of large administrative areas are used.

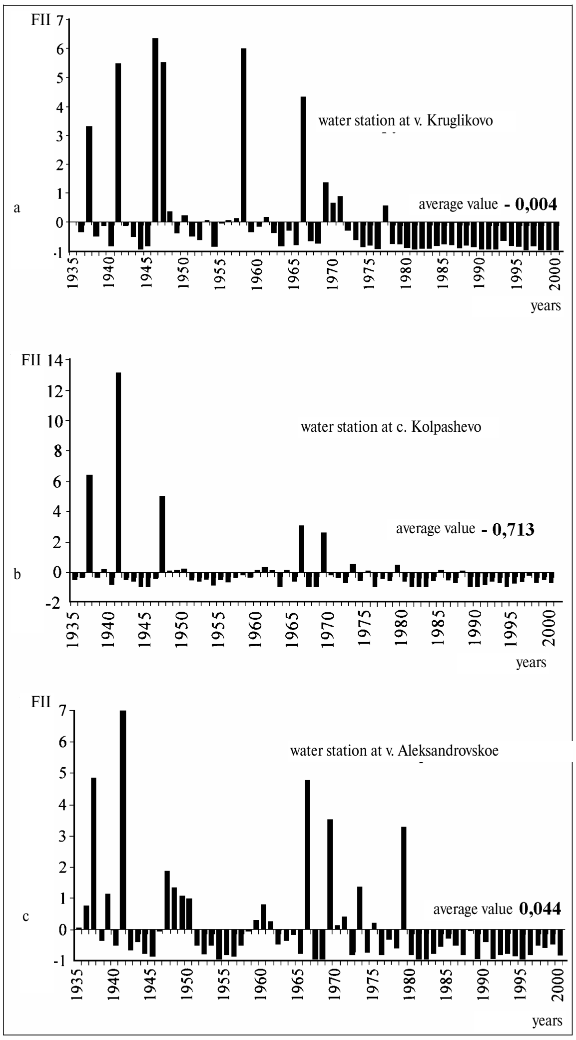


Fig. 3. *Graphs of long-term changes of flood influence index (FII) at water stations*

Flood-plain zoning by conditions of flooding differs from the accepted before, in a way that flood action is connected with larger geomorphological forms and extends on more significant distances than those which is accepted to allocate at detailed geobotanical mapping or leaning on it landscape mapping, and was based on number of works [6–8].

As a result in the Ob flood-plain, within the limits of Tomsk oblast, 3 areas were allocated, differing in climate influence, soil surface and spring floods. As a basis the fact was set that from the south border of Tomsk oblast up to the mouth of the river Ket the zone active action of Novosibirsk water basin with reduction of flood average maximum levels up to 2,3 m, from the mouth of the river Tom up to the mouth of the river Ket – on 0,3...0,5 m, and lower – up to northern border of oblast – unchanged. As a result of the analysis the following flood-plain areas are allocated at borders of Tomsk oblast: southern flood-plain area (1076 km^2) which includes flood-plain sites of Kozhevnikovskiy, Shegarskiy and Tomsk areas; central flood-plain area (4143 km^2) including flood-plain sites of Krivosheinskiy, Molchanovskiy, Chainskiy and Kolpashevskiy areas; northern flood-plain area (8762 km^2) which includes flood-plain sites of Parabelskiy, Kargasokskiy and Aleksandrovskiy areas.

Southern area of the flood-plain has the length of 136 km, the width – 6...8 km. The flood-plain of southern area differs in genesis as it belongs to the flowage-island type, has smaller width, smaller flooding duration, it is characterized by prevalence of high crests. Central area of the flood-plain is located between the mouth of the river Tom and the mouth of the river Ket and makes 444 km, its width is 18...22 km. The flood-plain is mainly unilateral, asymmetric and rugged by small rivers and channels which promote flooding of greater areas of the flood-plain even at low horizons of water. The relief of the flood-plain is strongly rugged. Northern area of the flood-plain is stretched out on 308 km from the mouth of the river Ket up to northern border of Tomsk oblast. Here the flood-plain increases the width up to 24...28 km. It is more gently sloping. Meadows and lakes occupy the most territory. More detailed characteristic of the flood-plain areas is presented in the work [10]. On Figure 2, the comparison of schedules of level flow in 1999 is carried out. That year is close in characteristics to an average year in water capacity, for main water stations. It is noticeable on the schedule that for water station at Kruglikovo village (Figure 3, *a*) a part of spring flow is taken by Novosibirsk water basin as maximum levels are cut and are on marks between 75...95 % of supply. Here summer-autumn discharges from the water basin lead to duration increase of low levels 75...95 % of supply and to bogging of low meadows. For water stations at Kolpashevo city and Aleksandrovskoe village (Figure 3, *b*, *c*) influence of the Novosibirsk water basin is getting better and maximum levels here are close to 50 % of supply. For water station at Aleksandrovskoe village a greater duration of flood-plain flooding is characteristic.

Schedules of changes of flood influence index (FII) at main water stations from 1935 up to 2000 are presented on Figure 3. They are expressed in relative units – in relation to average long-term values and show deviation from average value at abounding in water or shallow year. Besides, as FII includes flooding areas of various supply, modified by means of adaptable coefficients, they consider relief features of the allocated site of flood-plain. As FII are expressed in relative units it is possible to carry comparison of various areas of the Average Ob flood-plains on flood influence. It is necessary to note, that on Figure 2 the vertical scale for water station at Kolpashevo city is two times larger than for water stations at Kruglikovo and Aleksandrovskoe villages. That means the intensity of high waters influence here is stronger. It can be explained that the given area of the flood-plain occupies transitional position from rather narrow flood-plain (up to 6 km) on southern site of the flood-plain being fully under the influence of Novosibirsk water basin and northern site of the flood-plain where the width of the flood-plain reaches 22 km. Here the flood-plain is more leveled and is subject to long flooding. The majority of FII parameters are synchronous among themselves though can differ in value. In the period after 1980s for all water stations it is possible to note prevalence of influences or shallow floods, or floods close to an average long-term value.

Thus, fundamental long-term number of surveys on flood influence which can be compared to «responses» – reaction of biotic components of the Average Ob flood-plain ecosystem and to conduct monitoring to see their changes.

REFERNCES

1. Israel Ju.A. Ecology and environment condition control. – Moscow: Gidrometizdat, 1984. – 560 p.
2. Israel Ju.A., Mann R.E. Monitoring of environment and renewable resources // System researches. Methodological problems. A yearbook, 1987. – Moscow: Nauka, 1988. – P. 326–351.
3. Bolotnov V.P. Composition of a complex parameter of spring flood influence on biological resources of river flood-plains (by the example of the Average Ob flood-plain) // Wildlife management / Coll. Edited by A.E. Berezin. – Tomsk, 2000. – P. 51–62.
4. Bolotnov V.P. Complex parameter of spring flood influence on biological resources of river flood-plains (by the example of the Average Ob flood-plain) // Bulletin of the Tomsk State University – 2001. – № 274. – P. 118–121.
5. Zaykov B.D. Sketches of hydrological researches in Russia. – Leningrad: Gidrometizdat, 1973. – 325 p.
6. Maximov A.A. Experience of zonal characteristic of the river Ob flood-plain at spring-and-summer floods // Nature of the river Ob flood-plain and its economic development: Works of Tomsk University. – 1963. – V. 152. – P. 32–47.
7. Petrov I.B. The Ob-Irtysh flood-plain (typification and quality estimation of earths). – Novosibirsk: Nauka, Siberian branch, 1979. – 136 p.
8. Hromykh V.S. Natural zoning of the Average Ob flood-plain // Questions of Siberia geography. – Tomsk: Publishing house TSU, 1979. – Issue 12. – P. 69–86.
9. Bolotnov V.P. Features of geomorphological structure and dynamics of the Average Ob flood-plain // Self-organization and dynamics of geomorphosystems: Materials of the XXVII Plenum of the Geomorphological commission of the Russian Academy of Science. – Tomsk: Publishing house of Institute of atmosphere optics of the Siberian Branch of the Russian Academy of Science, 2003. – P. 93–102.

Received on 27.09.2006