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ICE JAMS FORECAST AND TECHNOLOGIES OF THEIR DESTRUCTION ON THE RIVERS OF THE RUSSIAN FEDERATION

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On globe Russia suffers from such dangerous natural phenomena as ice jams on the rivers most of all other countries. The main causes of such situation are the geographical situation of the country in the north of Eurasia, the cold climate, and also mainly northern flow direction of the majority of the Russian rivers. Canada (north), USA (Alaska) and the north of Scandinavian Peninsula have such problem also. But these areas are almost uninhabited and not enough developed territories, and it considerably reduces an acuteness of consequences and the damage from these dangerous natural phenomena.

Among forces of a nature ice jams on the rivers take a special place. And the problem is not only the rate of a material damage, but also complex character and rapidity of these phenomena, in small effectiveness of response measures, difficulty of forecasting and, at last, in almost full absence of effective methods of calculation.
Occurrence and description of ice jams phenomena on the rivers of Russia are shown on map (Fig. 1). Rivers of the coldest areas of Russia - the northern from the European regions, and also all Asian regions of the country have high ice jams repeatability. The high ice jams repeatability (70-100 %), high ice jams levels (10 - 20 meters) and ice jams water rise (4 - 6 meters) are observed on the big rivers of Siberia due to the high ice thickness and ice force, and also due to the high water discharge at a spring high water. As a whole ice jams occurrence at the rivers of the European regions of Russia is lower, than at the Asian rivers.

Researches have shown, the basic characteristics of consequences of ice jams floods are the same, as the consequences of high waters floods and spring high waters. They are the catastrophic flood of a district and formation of a break wave. However scales of these consequences heavier on several parameters:

- ice jams floods occur at low temperatures of air, and that is why the probability of people affection grows;

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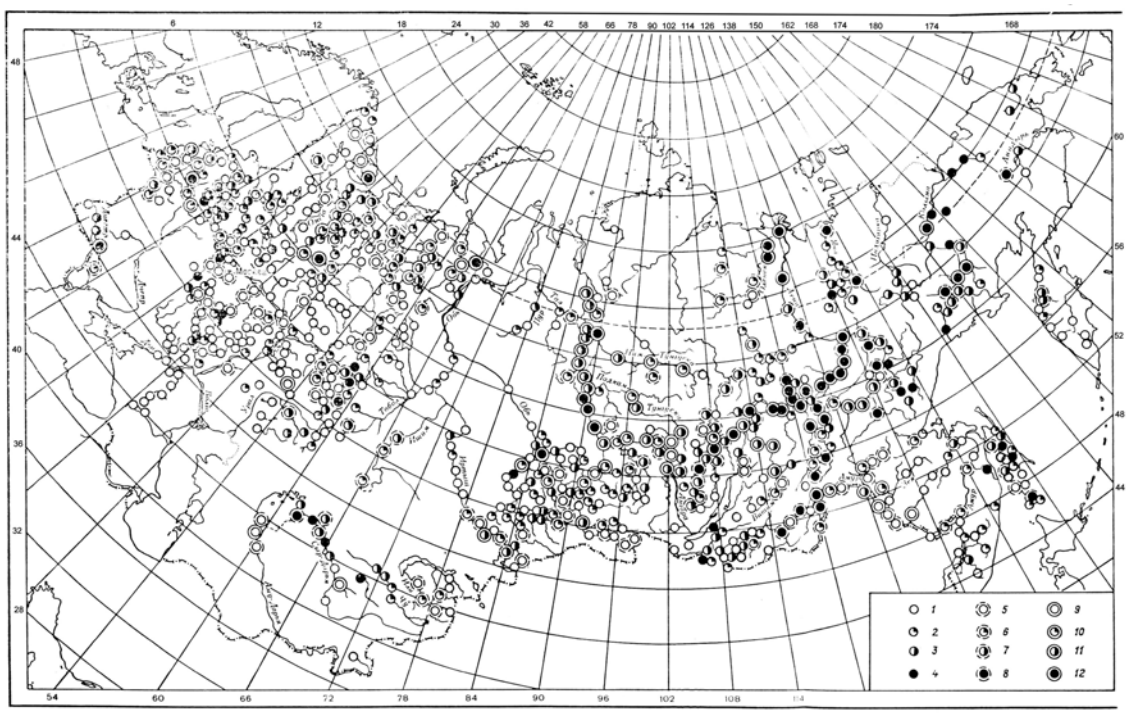

Fig. 1. The map of occurrence and description of ice jams phenomena
on the rivers of Russia, the countries of the CIS and Baltic:
h < 300 cm: 1 – repeatability 20-40%, 2 – 40-60%, 3 – 60-80%, 4 – 80-100%;
300 < h < 500 cm: 5 – repeatability 20-40%, 6 – 40-60%, 7 – 60-80%, 8 – 80-100%;
> 500 cm: 9 – repeatability 20-40%, 10 – 40-60%, 11 – 60-80%, 12 – 80-100%

- at ice jams destruction (especially strong ice jams) the break wave, which contents of the broken ice is very high, flows in downstream direction, that quite often results in sudden flood of below laying district and destruction of settlements, roads, bridges and other engineering constructions;
- additional danger at jams is ice bulks on the river coast and in flood-lands, which are up to 10 - 15 m in height. The big weights of ice press the constructions, break and shift them;
- slow ice melting complicates realization of extreme situation response measures and recovery works, constrains agricultural works.

The damage from ice jams floods is quite often aggravated by spontaneity of the phenomenon, the high dynamism of ice jams formation process and jams sizes and places inconstancy from year to year.

As it is known, one of the most destructive ice jams floods has taken place in May, 2001 on river Lena at city of Lensk. The water level has risen up to a mark of 20,12 m above zero of the diagram of a water-measured post, that is above the average long-term value for all history of supervision (68 years) on 9,5 m. The city of Lensk with the population of 28 thousand people was completely flooded. The damage to economy only at city of Lensk has been up to 4 billion rubles. The damage from ice jams floods on rivers Lena and Aldan for all Republic Saha (Yakutia) has exceeded 6 billion rubles. Flood on river Kuban in January, 2002 has caused the damage for Krasnodar territory and Republic Adygeja which was 3 billion rubles.

Complexity and small predictability of ice jams formation, the big cost and insecurity of the field works connected with studying of this phenomenon, and also difficulty of its scale representation in laboratory conditions, are the reason of a low level of study of this problem.

Now there is a need in creation **of essentially new technologies** of the forecast, monitoring and ice jams response, which will be able to provide the higher efficiency and safety of response and recovery works.

In this connection the Federal Centre of science and high technologies "RSRICDES" (further FC RSRICDES) is actively working on solution of this problem.

In 2003:

- "Recommendations for prevention of ice jams formation on the rivers of the Russian Federation" (further - "Methodical recommendations") was developed, issued and sent out to the bodies of the State system of emergency situations prevention and response (further – RSCHS) together with VNII of hydrotechny named by B.E.Vedeneev; it is carrying out the forecasting and monitoring of hydrological conditions (and ice jams) on the rivers of Russia by Aero Space Information Center;
- the pre-production model of remote helicopter system of ice crushing and ice jams destruction was developed;
- the hardware-software complex of geoinformation system (GIS) "Ice" was developed, which allows predicting floods and ice jams conditions.

Development of methods of ice jams on the rivers and basins forecast, and also the forecast of possible sites and zones of flooding, usually is carried out by bodies of Federal Hydrometeorology and Environmental Monitoring Service. Then the necessary information is transferred to the interested departments, including RSCHS bodies of all levels.

Controls on affairs of Civil Defense and Extreme situations, in turn, develop the forecast of ice jams floods consequences, and also develop measures for reduction of their influence and increase population and territories protection from these dangerous phenomena.

The analysis and monitoring of hydrological situation on the rivers of the Russian Federation is carried out by The Aero Space Information Center of FC RSRICDES. Due to the created geographically distributed system (Fig. 2) which structure includes laboratories in cities of Moscow, Vologda, Krasnoyarsk, Elista and Vladivostok, the Center receives the information on hydrological conditions on all rivers of Russia 4 - 6 times in a day. This information in an operative mode is transferred in Control centre of crisis situations of EMERCOM of Russia and to other interested organizations that allows reacting to the arising extreme situations connected with high waters and flooding operatively.

In connection with the solved problems, reception points are completed with one or several hardware-software complexes, which are consist of: the receiving antenna, antenna and information reception control unit, and also some workplaces of operators of processing of space information.

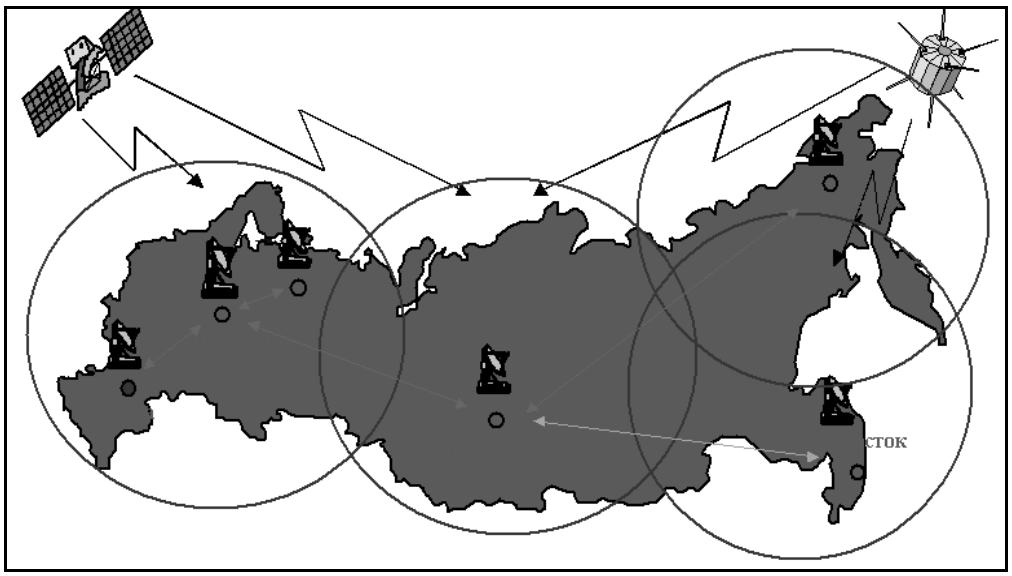

Fig. 2. Structure and an arrangement of points of reception geographically distributed system of receptionand processing of space information of FC RSRICDES. Circles show zones of reception of the nformation from satellites, and arrows show channels of communication

For the effective solution of the problem of ice jams revealing the space information of the low spatial resolution (1000 meters) in infra-red and thermal bands of the electromagnetic spectrum, received from satellites «NOAA» is used. Besides the information of the medium spatial resolution (250 meters) in a visible band of the electromagnetic spectrum, received from satellites «TERRA», and "Meteor-3M" (the resolution is 35 meters) is used.

During a snow cover melting the contrast between various natural objects in thermal and infrared bands is observed that is successfully used at revealing of clean water and an ice edge. As a rule, at the border of clean water and ice cover ice jams are formed. At Fig. 3 the place of ice jam formation on the river Lena is shown.

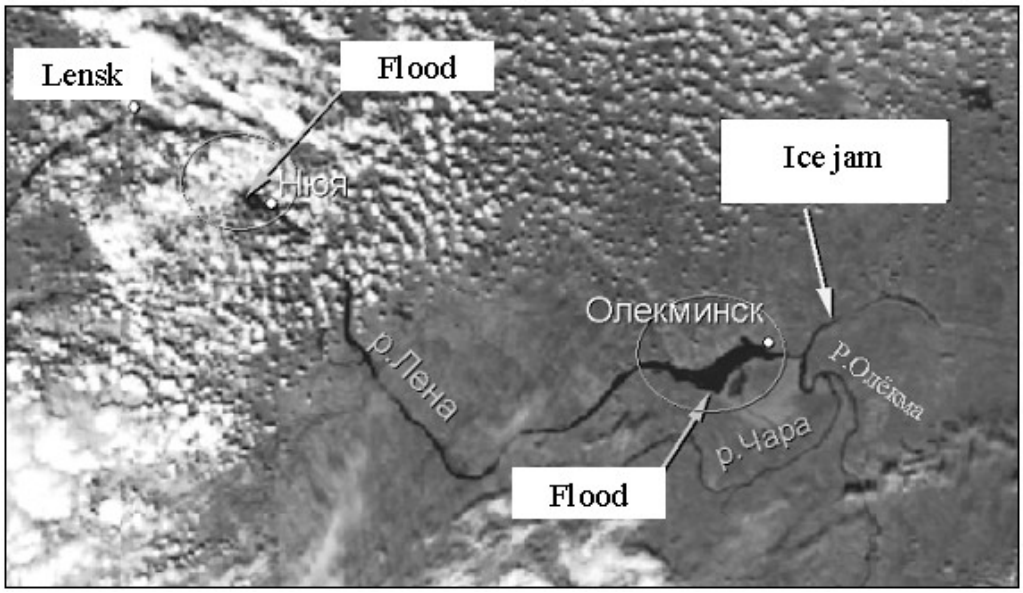

Fig. 3. Flood conditions on river Lena near the cities of Lensk and Olekminsk on data of satellite "NOAA" on 20.05.2001 at 09:21 MOSCOW TIME

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Here the image received from satellite «NOAA» and submitted in pseudo-colors is shown. In this case grey color displays a surface free from snow cover and so, warmer, than other natural objects. Pure white color displays cold overcast. As spectral reflecting ability of water is much lower, than of other objects on the image, so the color of the river is black. Spectral characteristics of clean ice are close to characteristics of overcast, but as at the moment of ice melting its characteristics change greatly there is an opportunity successfully to distinguish ice and overcast. So in Fig. 3 ice coverage of the river Lena is displayed by dark grey color. Here it is visible, that the ice jam downstream of the city Olekminsk has resulted in flood in area around the city.

On Fig. 4, 5 changes of hydrological conditions on the river Lena at the territory near the city of Olekminsk are shown. So on Fig. 4 the places of possible ice jams formation are revealed. On Fig. 5, received next day, ice jams in prospective places of their formation are revealed. Serviceability of a method of revealing of ice jams thus is proved.

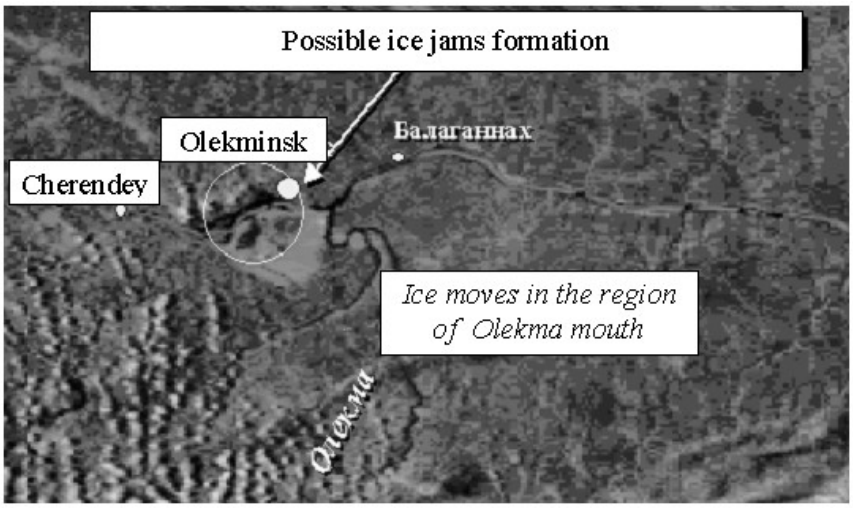


Fig. 4. Hydrological conditions on river Lena near the city of Olekminsk on data of satellite «NOAA» on 14.05.2001

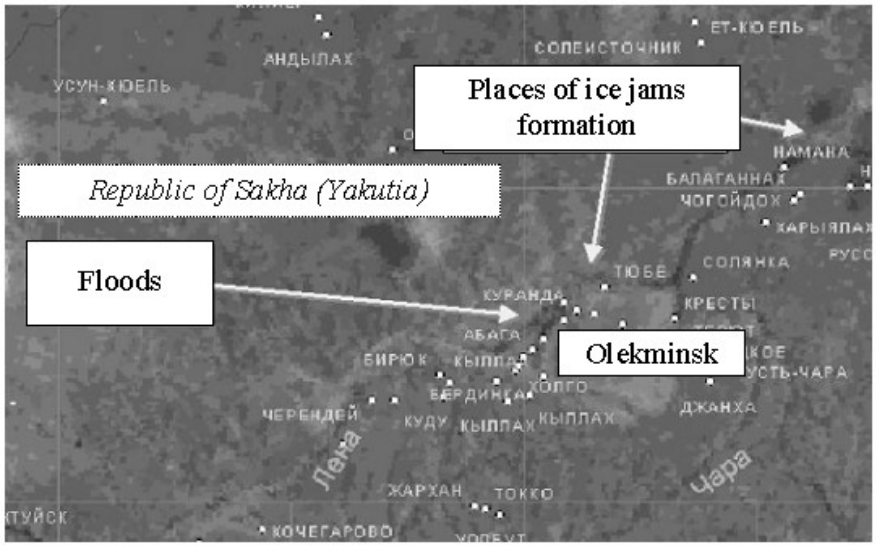


Fig. 5. Hydrological conditions on river Lena near the city of Olekminsk on data of satellite «NOAA» on 16.05.2001

For reception of the operative information in the area of an extreme situation experts of FC RSRICDES developed the compact remotely pilot aircraft, which is capable to transfer the information in a real time mode to the point of management (Fig. 6).

This aircraft is the small-sized helicopter (diameter of the main rotor is 1.5 meters, take-off weight is 5.5 kg), equipped with a system of control and the equipment for supervision and for information transfer. The management and reception point on the basis of the portable computer includes the compact device for reception, processing and distribution of the received information, the device for aircraft flight control and the special onboard equipment control, device for reception and display of the data on aircraft position (on data of GPS receiver). The special software of the complex allows receiving and displaying the received data, thus position of the device and area of shooting are displayed on a map of district. Compact dimensions and weight of a complex allow using it in the area of extreme situation.

The monitoring organized thus will allow to provide at occurrence of an extreme situation operative exploration of ways for drive of equipment, the control and documenting of dynamics of emergency situation development and process of elimination of its consequences.

The combination of the aircraft with GPS system gives the opportunity of realization of monitoring of ice jams by aerial photographs of the high resolution processing with application of geographical information system (further - GIS).

Hardware-software complex GIS "Ice" contains a full complex of means for estimation of conditions at ice jams formation: from modelling of ice jam formation at the site of the river up to an estimation of consequences of its formation.

The basis of forecasting of flooding of territories of the Russian Federation with use of GIS "Ice» is the data received from the Federal network of water-measured posts of supervision over freshet conditions.

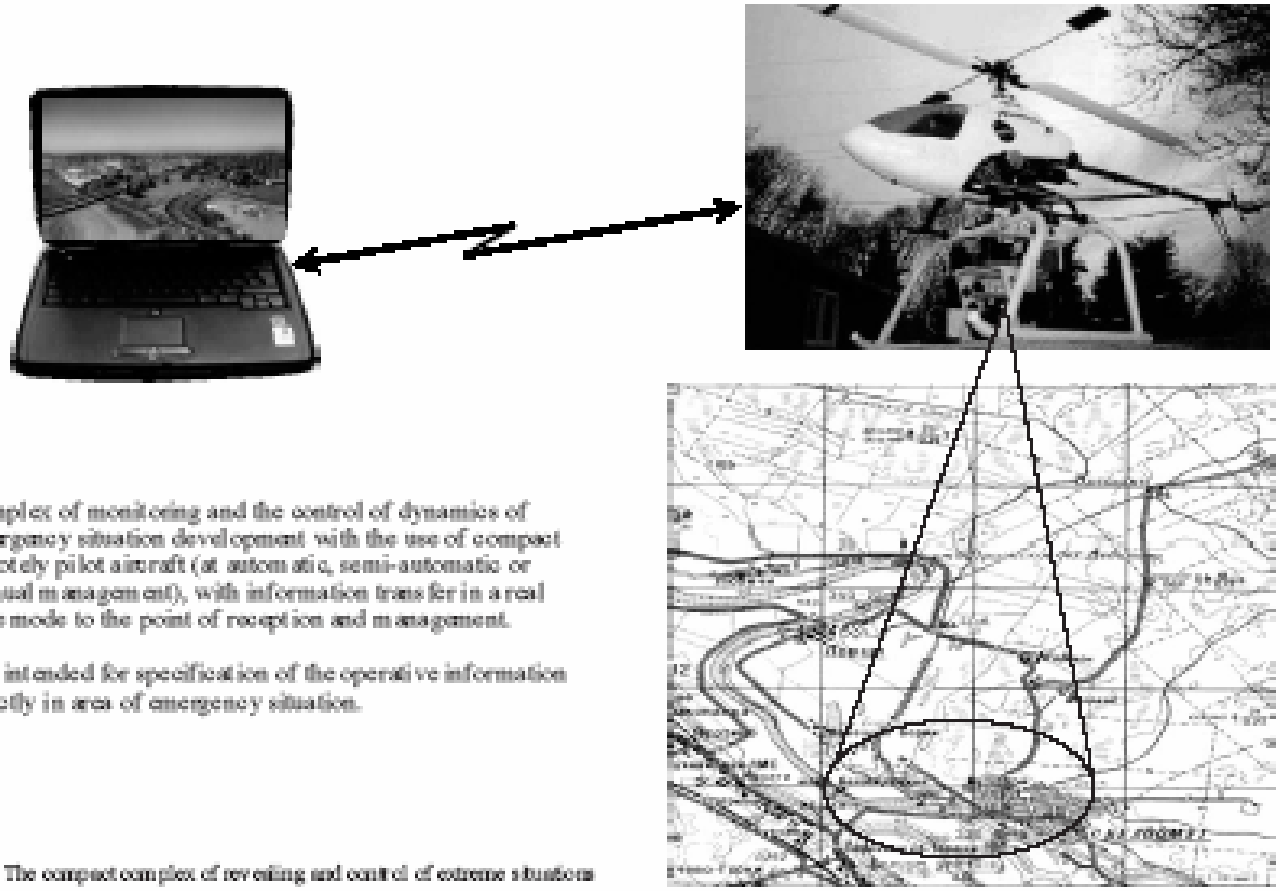
GIS "Ice" was developed in program environment ArcInfo 8.3 which is one of main means in the field of geoinformation technologies and is most distributed in our country and abroad.

Opportunities of GIS "Ice" in the field of spatial analysis allow not only to estimate the sizes of a zone of possible catastrophic flooding, but also to determine precisely its area in view of a landscape, that, in turn, at presence of the full information on settlements allows estimating the engineering conditions and number of victims among the population.

Calculations and display of results are made on the basis of an electronic map of a district which contains the following basic layers: settlements, hydrography, road system, vegetation, and communications.

For an estimation of engineering conditions in a zone of possible catastrophic flooding GIS uses the electronic model of settlements (Fig. 7). It includes a layer with the information on building of the city, and containing the following data on buildings:

- type of a building (housing stock, administrative, industrial, cultural object);
- the material (wooden, brick, ferro-concrete);
- building height;
- mumber of people, who are in the building.



Complex of monitoring and the control of dynamics of emergency situation development with the use of compact remotely pilot aircraft (at automatic, semi-automatic or manual management), with information transfer in a real time mode to the point of reception and management.

It is intended for specification of the operative information directly in area of emergency situation.

Fig. 6. The compact complex of revealing and control of extreme situations

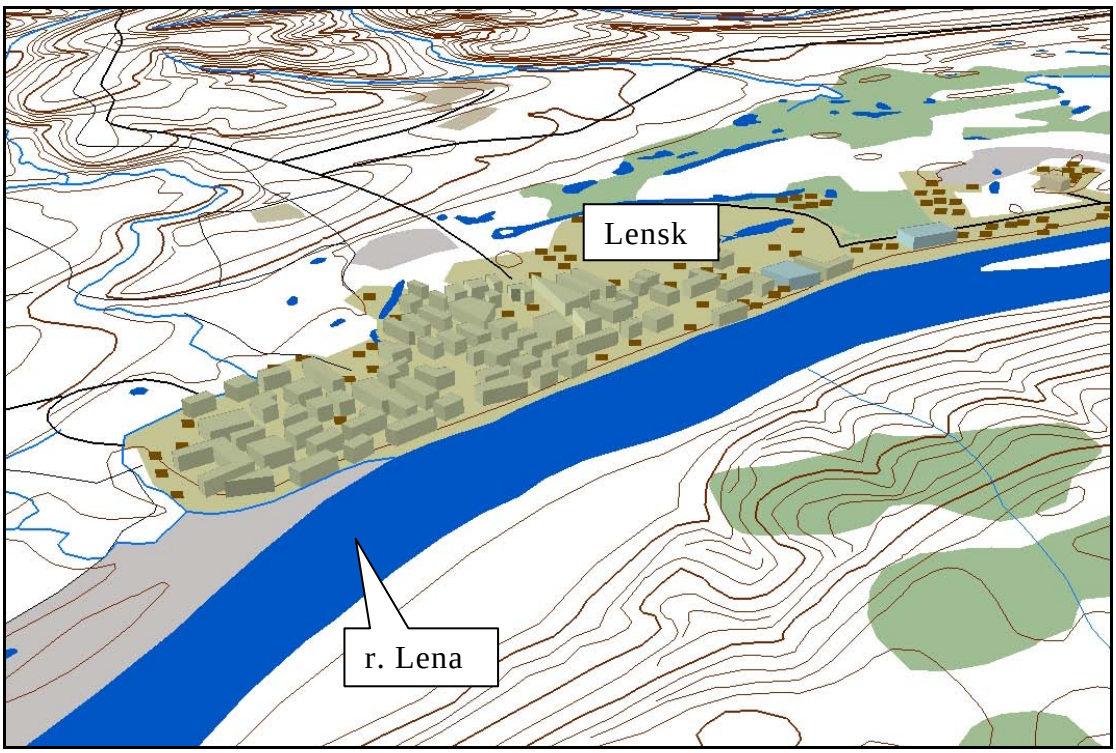


Fig. 7. The part of an electronic map of river Lena near the city of Lensk

The main danger of ice jam is the significant rise of a water level in the river at which water overflows banks and floods adjoining district. The border of zone of possible flooding is determined according to the maximal ice jam water levels**.**

The geoinformation system "Ice" on the basis of three-dimensional models allows to predict development of conditions at formation of an ice jam (maximum levels of water, flow speed, depth of flooding, and a zone of possible catastrophic flooding) and to display results of calculation on an electronic map of a district (Fig. 8, 9).

Probable conditions as a result of ice jam formation are shown at Fig. 8 – rise of a water level, the beginning of flooding of territory (at the example of a jam near the city of Lensk).

On Fig. 9 predicted conditions at the maximal rise of a water level and catastrophic flooding of the area of Lensk and the territories nearby at ice jam formation near Batamaysky Island are shown.
For the settlements which have got in a zone of catastrophic flooding, GIS "Ice" allows to make an estimation of engineering conditions, number of the victims and the population to be evacuated, required forces and means for realization of rescue and other urgent works, means of rescue and life-support.

GIS "Ice" may be used for information support of decision making at various levels at occurrence of the extreme situations caused by ice jams in the way:

– increases of reliability, presentation and completeness of the used cartographical data;

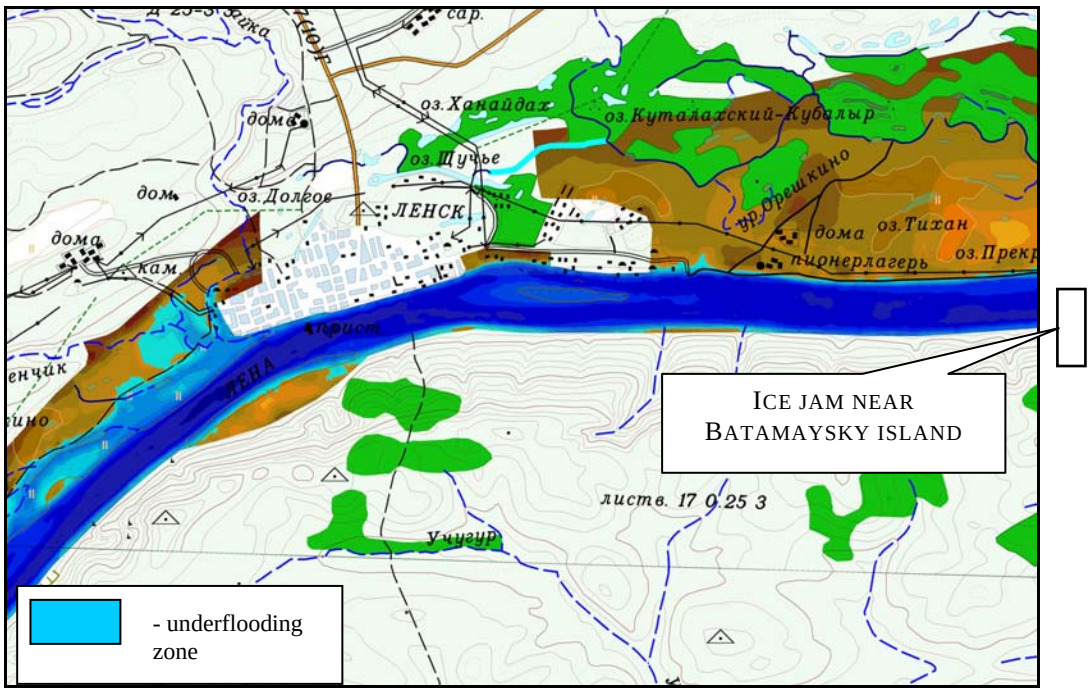


Fig. 8. Result of forecasting of conditions after the ice jam formation near the city of Lensk with the use of GIS "Ice"

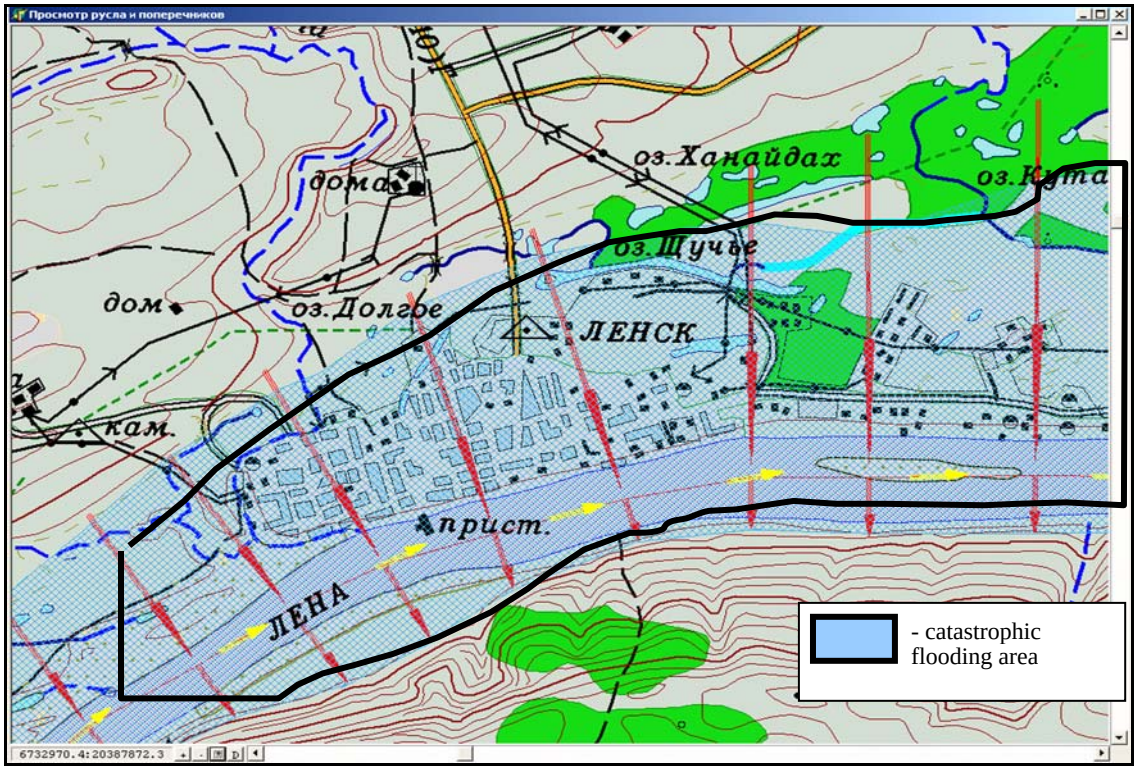


Fig. 9. Zone of catastrophic flooding as a result of ice jam formation (result of modeling with the use of GIS “Ice”)

– increases of efficiency of the decision of administrative tasks, reduction of time for search, processing, transfer and distribution of the information for decision making;

– improvement of quality of accepted decisions and plans on the basis of use of quantitative methods of their estimation, the semantic and spatial analysis.

As it is known, the problem of struggle against ice jams is solved in three ways:

a) by preliminary forecasting of the place of ice jam formation, ice force and duly acceptance of measures;

b) by acceptance of precautionary measures on management of process of ice jam formation and its drain, i.e. on an establishment or easing of the reasons and conditions of occurrence of ice jams;

c) by direct struggle against ice jams and high water levels already formed (destruction of a jam).

The generalized list of the basic preventive actions which are carried out on reduction of risk of emergency situation caused by jams and flooding occurrence by RSCHS controls was developed and given in mentioned above "Methodical recommendations".

Liquidation of the formed ice jams is usually carried out in the case of their unexpected occurrence in a undesirable place, despite of realization of precautionary actions.

In territory of Russia the explosive way, aviation bombing, artillery bombardment and an icebreaking way of struggle against ice jams are traditionally applied. All of them were applied at liquidation of well-known catastrophic phenomena on the rivers Sukhona (1997), Yenisei and Lena (1998-2001) in the areas of Lensk and Yakutsk, and also on river Kuban (2001-2002).

Quite often the combination of various means of struggle with ice jams is applied for their destruction.

Now there is a need in creation of essentially new technologies of struggle against the ice jams providing higher efficiency and safety of works. The pre-production model of remote helicopter system of crushing of ice and destruction of ice jams with the use of fuselage charges pickup on the basis of helicopter Mi-8Mt (RHS-DIJ-FCP) agrees with these requirements. At its application the exit of the personnel conducting explosive works on a surface of ice is completely excluded. It essentially raises safety of explosive works and enables to carry out these works both during initial motions of ice, and during an active ice drift.

The structure of the equipment of helicopter system includes:

- fuselage charges pickup (FCP) (Fig. 10);
- multi-purpose slow-acting detonator (MPSD) of a special design (Fig. 11);
- Interposing detonating device (IDD);
- shelves for placing of the complete set of explosive charges;
- set of explosive charges (10 items) with MPSD and FCP.

In Fig. 12 and 13 the moments of emission of a charge of explosives in weight of 40 kg on ice, and also explosion of this charge are shown.

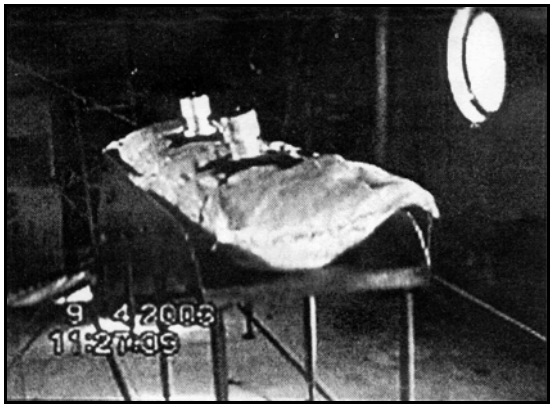


Fig. 10. Fuselage charges pickup

Fig. 11. Multi-purpose slow-acting detonator (MPSD)
with the interposing
detonating device (IDD)

Fig. 12. The moment of emission of explosive
charge in weight of 40 kg on ice

Fig. 13. Explosion of the charge

Flight tests of the system were carried out in 2002 on Yenisei in the area of village Vorogovo of Krasnoyarsk Region, and in March, 2003 - on the river Malaya Severnaya Dvina in the area of Velikiy Ustyug. While testing the system has been working trouble-free.

The developed technology is much more effective in comparison with bombing. So, experience of its application on the river Yenisei has shown, that time of detonation of ten charges of explosives with a total weight of 400 kg with all preparatory and finalizing operations does not exceed 15 minutes, thus the processable area of ice thickness may make of 1,1 m up to 1000 m^2. Cost of crushing of ice does not exceed 15 – 20 rubles/m, which is lower than cost of similar works with application of bombing aircraft.

The generalized information on remote helicopter system is shown in figures 14-15.

From stated it is visible, that experts of FC RSRICDES developed an effective complex of measures, methods, ways and the recommendations, allowing best to predict, warn and struggle against flooding and to reduce a level of their consequences and even to liquidate the extreme situations caused by the specified phenomena on the rivers of the Russian Federation.

The important value in this connection has creation of the state multipurpose geoinformation system of monitoring of environment, closely coordinated with a global interstate observant network, including with satellite technologies.

For this purpose it is necessary to increase density of a network of hydrometeorological supervision in the country and cardinally to update instrument and material base of existing stations and posts of Federal Hydrometereology and Environmental Monitoring Service.

DESCRIPTION

Characteristics	RHS-DIJ (for one flight) Modifications		
	FCP	M1	M2
Thickness of ice crushing (jam), m	0,5-0,7	UP TO 1,5	UP TO 3
Area of ice crushing (jam), m^2	400 - 500	600-900	400-500
Width of ice-hole, m	3-4	UP TO 5	8-10
Allocation time of 1 item, min.	3-5	1-3	1-3

REALIZATION OF EXPLOSIVE WORKS WITH USE OF RHS-DIJ-FCP COSTS 200 THOUSAND ROUBLES (FOR ONE FLIGHT)

IT IS INTENDED: FOR THE PREVENTION OF OCCURRENCE OF FLOODS ON THE RIVERS OF RUSSIA DUE TO APPLICATION OF MOBILE AND EFFECTIVE HELICOPTERS PROVIDING EXPLOSIVE CRUSHING OF ICE AND DESTRUCTION OF ICE JAMS WITHOUT LANDING OF HELICOPTERS ON ICE AND EXIT OF THE PERSONNEL ON AN ICE SURFACE

FC RSRICDES HAS THE LICENSE OF GOSGORTEKHNADZOR OF RUSSIA 00 BP № 012801

STAGES OF CREATION:
2004 - RHS-DIJ-FCP
2007 - RHS-DIJ-M1 AND RHS-DIJ-M2

Fig. 14. Remote helicopter system of explosive crushing of ice and ice jams destruction

Diameter of ice-hole at explosion of a charge in weight of 40 kg
at thickness of ice 0,7 m – 9-10 m;
at thickness of ice 1,2 m – 7-9 m.

Fig. 15. Explosions of charges on ice surface

It is necessary to active the system both purposeful research and experimental works on complex studying of places of formation of dangerous ice jams and their changes, water, ice and flow modes of the rivers of the country on forecast and estimation of risk of occurrence of emergency situations, caused by flooding, and researches on the prevention and regulation of ice jams formation, and also on prevention and mitigation of consequences of emergency situations connected with ice jams formation.

It is necessary to create the All-Russia register of settlements and objects of the economy, constantly exposed for catastrophic flooding.

In places of constantly formed jams of ice protection of territory against flooding is necessary.

Building along coasts of the rivers should be carried out on the high-altitude marks exceeding maximal ice jams rising of water of 1 % supply (that is 1 time in 100 years).

At the organization of struggle against dangerous jams the management of the commissions should include the skilled experts professionally owning the hydrometeorological information and methods of struggle with ice jams formation on the rivers of Russia, capable to make non-standard decisions. Otherwise expenses of means may appear useless and even will promote strengthening of negative consequences.

CONCLUSION

Thus, in the given report the technology of struggle against ice jams on the rivers of the Russian Federation, including space monitoring and investigation of ice conditions, remote helicopter system of destruction of jams, and also hardware-software complex GIS "Ice" is shown. Basic elements of the given technology have lain in a basis of the contents of "Methodical recommendations", which are used in all subjects of the Russian Federation at realization of practical actions for the prevention and liquidation of ice jams.

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