

Basic spatial data of water ecological GIS

Irina N. ROTANOVA, Anna A. WAGNER, Russian Federation

The current state of information technologies, the development of concepts of the creation of analytical systems, the improvement of methods and tools for digital processing of cartographic information give new possibilities for the analysis of the large body of different spatial data and their use in the expert management support systems. The attention is given to the basic spatial data as a subset of information considered in the specific unified form of presentation determined by the goals and objectives of information gathering and processing.

The reference spatial data as a part of information-cartographical provision should be in line with the organizational-management and industrial-technological field. Their infrastructure is aimed at the support of management and technological processes through the development of geoinformation (GIS) and geoinformation-analytical systems.

In terms of the large body of source space-related data the necessity of the distributed access to geoinformation, the demand for analytical search tools the formation of infrastructure spatial interdisciplinary data for management decision making is timely, called-for and efficient solution of goals of information environment development. These are as follows:

- *Inventory goals* – the study of environment and its components, the use of natural resources and natural potentiality of the territory;
- *Evaluation goals* – the assessment of anthropogenic impact on the environment, the extent of unfavorable processes, the aftereffects of natural or anthropogenic eco-catastrophes, the ecological-geographical evaluation of the territory;
- *Dynamical goals* – the study of changes of environmental and natural conditions due to economic and natural factors, nature management and anthropogenic impact on the environment;
- *Predictive goals* – the forecast of the change of environmental and natural conditions caused by the anthropogenic impact or the development of natural complexes, the revealing of trends and dynamics of nature evolution as a result of human economical activity.

Of importance in the development of information and management systems is the water-oriented (water-resource and water-ecological) line that is dictated by the urgency of similar problems in many regions.

Practical application of GIS projects covers different lines and kinds of activity in the field of development of the systems for ecological monitoring on the local, regional and basin levels; territorial cadastres of natural resources; assessment of natural

resources state and use including water, land, forest, biological and atmosphere ones; ecological assessment of problems caused by anthropogenic factors (eco-diagnosis); ecological expertise of territories, objects and projects; the development of GIS-technologies for sustainable development of territories as well as for the solution of hydrological, water-resource, water-management and water-related ecological problems.

In line with normative-legal documentation, the Schemes of complex use and conservation of water objects (SCUCWO) currently developed for some basins of large rivers of Russia contain information support activities, i.e. mapping and development of basin geoinformation systems, in other words, creation of infrastructure of spatial data of a basin level [1, 2].

The goal of SCUCWO development is tools' formation for expert system support. Item 12 of "Methodical guidance...» states that Schemes are based on GIS-technologies in compliance with technical and software requirements to support the digital map layers [3]. Item 22 refers mapping and GIS to fundamental (basic) activities under development of program options for conservation and restoration of water objects, steady functioning of water-economic systems as well as achievement of target indices on prevention of negative water effects [3].

This approach is of great importance for provision of uniformity and continuity of information, normative-methodical systems of the Russian Federation in the field of water objects use and conservation, systematization of materials on water objects' state, structure of water-economic and water protective activities.

The Schemes must include a set of situation, evaluation, operative and predictive maps (in electronic and paper form) constructed in scale 1:1 000 000 - 1: 100 000 and supported by inset map of larger scale, if necessary.

A set of situation maps representing factual information for a moment of their construction consists of:

- a topographic map;
- a landscape map with the mapped protected areas;
- a drainage map with boundaries of hydrographic units and water-resource regions, hydrologic and hydrochemical monitoring stations including tables with studied hydrological situation in the river basin;
- a map of water-resources regions including their major characteristics;
- a map of water objects by categories including tables that characterize water objects and their regimes;
- a map of basin infrastructure with water-management systems and waterworks facilities including the tables with their parameters and features;
- a map of ground water aquifers;

- a map of aquifers characterized by intensive ground water intake (monitoring wells, deposits of ground water, boundaries of depression whirlpools, aquifers' protection from pollution).

A set of evaluation maps representing the outcomes of the data analysis from situation maps and documentary data on water object management consists of:

- a map of watershed zoning by level of anthropogenic load on water objects;
- a map of water risks stipulated by various water impact;
- a map of the basin's territories exposed to occasional floods (at different water providing - 1%, 3%, 5%, 10%, 25% and 50%);
- a map of river basin by level of flood threat;
- a map of key types of water use;
- a map of natural and industrial pollution of surface water;
- a map of natural and industrial pollution of ground water;
- a map of water management balance (by water-resources regions);
- a map of water objects assessment due to the data obtained in the course of state hydrochemical monitoring of water objects;
- a map of environmental assessment of water objects;
- a map of protection of exploited aquifers from pollution.

A set of operative and predictive maps that forecast situations consists of:

- a map of predictive change in water content of the river basin for the period of Scheme validity (taking into account natural-climatic and anthropogenic factors);
- a map of predictive change of anthropogenic load on water objects of the river basin for the period of Scheme validity;
- maps of limits and quotas for water intake from water objects according to stages of Scheme implementation (by water-resources regions);
- maps of limits and quotas for waste water discharge into water objects according to stages of Scheme implementation (by water-resources regions);
- maps of target indices of water quality in water objects;
- maps of target indices of negative effects of water;
- maps of development of water objects and systems monitoring;
- maps of planned structural activities to be implemented on the basin's territory;
- a map for forecasting depression whirlpools development within ground water basins and aquifers characterized by intensive ground water exploitation.

Unfortunately, a large list of maps that differ in quantity and quality is not methodically supported. Moreover, the indices to be mapped are not approved. SCUCWO should be developed for one of the largest water objects in Russia- the Ob basin. Ob river takes 5th place in the world and first- in Russia by a watershed area (3 mln km²), and the third one (after Yenisei and Lena) - by 400 km³/year runoff. A complex of research activities (RA) on " State-of-the-art study, scientific grounding of methods and support for steady operation of a hydroeconomic system in the Ob' basin" precedes SCUCWO development. The goals of RA are as follows:

- integrated assessment of water objects in the Ob'-Irtys' basin, qualitative and quantitative assessment of surface and ground water;

- elaboration of information-modeling complexes and expert support systems (ESS) for solving tasks of integrated water resources management in the Ob' basin;
- scientific grounding of methods and tools for steady water use and hydroecological safety;
- information validation for development of Ob' basin SCUCWO.

Main tasks in geoinformation-cartographic block are the following:

Cartographic assessment of water resources state-of-the-art and use in the Ob' basin:

- collection, processing and analysis of available cartographic source information containing the data on description and assessment of conditions for water resources formation as well as the ones on qualitative and quantitative analytical and evaluation indices of water object state in the Ob' basin;
- application of cartographic research method to integrated assessment of water object state in the Ob' basin;
- formulation of basic principles and standings of water-resource and water-ecological cartographic methods to be used for information support under Ob' basin SCUCWO development;
- preparation of basic digital maps and materials with the infrastructure of spatial data are to be used under development of a series of situation, evaluation and predictive maps.

Cartographic investigations of formation processes of surface and ground water's quality and quantity including their influential factors:

- landscape-cartographic field works to obtain data on the environmental assessment of water objects and their catchments;
- method preparation on water-resource and water-ecological small-, mid-, and large-scale mapping for geoinformation-cartographic support under SCUCWO development;
- cartographic evaluation of qualitative and quantitative indices of surface and ground water and their influential factors using the existing cartographic methods;
- structure development of specific databases on the basin's water objects in line with the State water register and water objects monitoring;
- elaboration of the concept, structure and information filling of a geoinformation-cartographic block of the expert support system aimed at water resources management in the Ob' basin (using model water objects);
- creation of a cartographic block with target GIS database, development of cartographic support for a pilot GIS-project.

The creation of scientifically grounded infrastructure of spatial data and information-cartographic support for steady functioning of water-economic complex in the Ob' basin due to development of:

- cartographic evaluation method of influence of diffusive sources of water pollution;
- a block of geoinformation-cartographic support for ESS information-modeling complexes aimed at specific water ecosystems management in the Ob' basin;

- integrated assessment maps of water objects subject to the peculiarities of watersheds and resource potential;
- GIS cartographic block for ESS aimed at water resources management in the Ob' basin;
- cartographic methods and construction of water-resource and water-ecological maps for model basin rivers.

To carry out research on natural conditions, revealing their peculiarities effecting on water resources formation in the Ob' basin, the territory was split into hydrographic units, i.e. river basins (a basin level), subbasins (a subbasin level), water-resource regions and sites [4]. According to water-economic zoning, the territory of the Ob'-Irtys' basin is divided into 72 water-economic sites: 36 are in the Ob' basin and 36 - in the Irtys' river basin.

The cartographic study of the basin, in particular, the landscape-cartographic provision of research was analyzed that allowed conclusion about the availability of a great quantity of landscape-typological maps for specific administrative territories. However, the coverage of the basin area is uneven. The difference in approaches to the definition of natural-territorial complexes of different rank takes place that hampers the complex assessment of the region under study. The scale to be used to construct the original and resulting maps is justified. The infrastructure of spatial data for GIS creation is discussed, and the software tools are chosen. Much consideration is given to the development of geodata bases, the unification of the original information (the creation and use of classifiers), the development of custom interface for data retrieval, analysis and visualization.

The research outcomes serve as the basis for the development of geoinformation-analytical system (GIAS) "Water and ecology of Siberia" intended for matching and integration of different cartographical materials, data base resources and metadata. GIAS is considered as the element of information filling of the system of decision making support (SDMS) for water management in the Ob basin (using the model water objects) and the development of territorial systems of Siberia.

The specific feature of GIAS is its water-ecological orientation, the creation of catalog of the distributed geoinformation resources metadata and the accessibility and the development of the system for introducing the outcomes of mathematical modeling, the addition of the data of field observations as well as the reference information. Besides, GIAS uses the technologies of remote data processing, the results of cartographical modeling, methods of interdisciplinary data integration as well as the outcomes of research based on the spatial characteristics and features. In the framework of GIAS the problems typical for GIS and specific issues including the formation of ground waters, physical and chemical characteristics of groundwater flow, the analysis of ground and surface water quality, their availability for drinking water supply, the characteristics of sources and level of water pollution, the development of rapid and efficient access and storage of information in data bases

including the ones of space images, mathematical-cartographical modeling are solved.

The structurally developed GIAS is a logical model incorporating the data bases (metadata), a specialized software support and the analytical block. The analytical part of GIAS is based on the multidimensional data base including the subject-oriented information. The information is retrieved from the network data warehouse. The GIAS analytical block involves the methods, algorithms and programs oriented to the subject domains. Two subject domains conventionally called as “Water” and “Geo” are considered within the system framework.

The concept of the data warehouse (a subject-integrated, invariant data set formed for decision making support) serves as the basis for the creation of thematic data bases. In terms of multidisciplinary information the formation of the data warehouse assumes the approach that

- is oriented to the ecologically significant objects (water basins, territorial entities) and situations (assessment of state, impact and aftereffects);
- includes the object-oriented data sets containing the consistent and aggregated cartographical and factual information for the solution of theoretical and practical problems.

The objective level of GIAS involves primarily the river basins that represent the hydrographical units in a specified order hierarchy. The major model basins are of Ob and Irtysh rivers. The basins of principal rivers are differentiated into the ones of the large, medium-size and small rivers. The hydrographical units are used in the analysis of factors for the formation of water resources and the ecological state of water objects for the development of the information-modeling system.

The GIAS objects also include the RF subjects (the units of political division) and the units of hydrological zoning representing the system of hydrological sites specified with hydrographical-geographical and economic-geographical approaches to the territory zoning.

For the creation of standardized descriptions the principles of information system, formalization and unification were used under the development of the distributed information-expert systems on the GIS bases for interdisciplinary research. The description of attributive and cartographical information and the formation of metadata comply with the State standard on spatial data content SSS P 52573–2006 “Geographical information. Metadata”. Using the standard, its “projection” on the subject domain GIAS “Water and ecology of Siberia” was made and the subject profile oriented to the system being developed was obtained.

The pilot program system for the metadata base formation and support was developed. The metadata base for the distributed cartographical base was created with ESRI ArcCatalog Metadata Master.

The possibility to define large blocks in such ecology-oriented maps as water-ecological, bioecological, anthro-ecological, socio-ecological, economic-ecological, and integrated ones is assumed.

The formation of the structure of cartographical information in data base (metadata base) provides for the component-by-component approach to the use of environmental data. However, in spatial analysis the natural complexes (landscapes of different topological level) are used as territorial entities. The aspects of content-richness and information value under the different scale map modeling (scale 1:500 000, 1:1 000 000, 1:2 500 000) were worked through. The typification and generalization of landscape maps for Novosibirsk, Omsk, Kemerovo oblasts, Altai Krai and Republic of Altai were carried out, and the electronic versions of landscape maps were made.

The mathematical-cartographical modeling within GIAS is considered to mean the development and analysis of mathematical models with the data obtained from the maps as well as the construction of the new (optional) ones on their basis. In this case such chains and cycles as map-mathematical model-new mathematical model are formed. The mathematical-cartographical modeling uses the methods of the correlation, regression, and factor and cluster analysis.

The approach to the solution of the subject-oriented objectives under the lack of source information is defined within the framework of GIAS. The approach involves a number of methods among which are the use of the unified attributive and cartographical data base; the development of techniques for complex assessment using the supplementary information; cartographical modeling of the subject domain. The GIAS "Water and ecology of Siberia" is aimed at the solution of a wide range of water-resource and water-ecological issues.

The representative dataware for the development of SCUCWO, the creation of cartographical and thematic data bases, the development of pilot GIS will contribute to the formation of the infrastructure of the basic spatial data and the justified expert system for the sustainable hydrologic functioning of the Ob basin system.

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CONTACTS

Dr. Irina N. Rotanova
Deputy Director on Science
Head of the Laboratory of Ecological-Geographical Mapping
Institute for Water and Environmental Problems
Siberian Branch of the Russian Academy of Sciences (IWEP SB RAS)
1, Molodyozhnaya Ul.
Barbaul, 656038
Russian Federation
E-mail: rotanova07@inbox.ru

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