System methodology application to make water resources management plan for unstudied rivers

S A Dvinskikh and O V Larchenko

Perm State University, Perm, Bukireva street, 15, 614990, Russia
e-mail hydrology@psu.ru

Abstract. Current public monitoring network is not able to involve in and to control water chemical composition of a rivers basin, and there is no coasts monitoring of water objects. As a result, the complete comprehension of rivers use and pollution is impossible. Due to this fact, a new conception of water resources management has been worked out. The conception is based on new approaches to define parameters that characterise usage potentialities and range.

1. Introduction

Currently, to keep balance between economic progress and geosystems possibilities is extremely important. This fact has been mentioned in the sustainable development program. However, not all parts of the geosystem play an equal role to keep their sustainability. Water is one of the significant parts [1, 2]. Its sustainable use and protection must be implemented within river basins. It may be explained by the fact that, any activity, even if water is not included directly in industrial processes, influences water resources quantity and quality. The lack or not sufficient river basins management is the reason for that. Due to this, an integrated water resources management (IWRM) has been worked out in the European Union (EU) [3, 4]. In the Russian Federation, the water code determines the management tasks for water objects use, rehabilitation and protection. These tasks are explained in the complex water objects use and protection scheme (CWOUPS) [5, 6]. The purpose of the scheme is to register water consumers within basins of large rivers. Currently complex water objects use and protection schemes have been worked out for main river basins. In addition, the next step is to apply the results for water resources management. However, there are huge challenges there. Also, we have to pay attention to the following facts:

1. Average and small basins as key points of sustainable development are not considered in these schemes.
2. CWOUPS includes water quality analysis based on monitoring data but the monitoring network is slightly developed or is absent. In this case, water quality characteristic (and water forecast in particular) may not be objective, and the management plan for its protection may be incorrect.
3. Co-ordination order and realization of target documents have not been worked out.
4. The scheme does not have “a direct action”, it is not a plan but rather a foundation for working out and acceptance of plans at federal and regional levels; target indices are not standards but rather are aims to improve river basin condition. The scheme does not determine the permissible load but rather is the fundamental for its determination. Water resources management is conducted from local authorities to water users, so called from “the top to the bottom” authority level.
2. Material and methods

Efficient water consumption suggests such impoundments use when negative consequences of anthropogenic impact do not have a place. In this case, management issues become significantly important. These issues are connected to the regulation of an object (environment) and a subject (a human) interactions and subject-object relations that occur as the result of these interactions [7]. They are presented in a form of blocks in figure 1. The first block includes objects that are key environment components: leading (geological composition and relief; climate, surface and underground waters) and supporting (soils, fauna and flora). The second block includes subjects and their possible effects on objects included in the first block. The third block includes a geosystem that has changed as the result of its functioning (the change of meteorological indices, hydrodynamic regime features, etc.). This block, being the result of subject-object relations, is not passive: its components influence the object (feedback) and make it function within the conditions that have already changed (figure 1).

![Figure 1. Geosystem functioning scheme [1]](image)

These blocks may be considered as an aggregate of basis (I block is an object) and factors (II and III blocks are a subject and subdominant components correspondingly. These components are connected with the subject by relations, interactions and regulation. The role of the second and third blocks will depend on the effect type on the subject. If a subject includes both natural and anthropogenic components and the influence of the latter increases the impact of the natural one, then the geosystem becomes opened and slackens subject-object ties (figure 2). An object changes in the result of transformation quantitative changes into qualitative ones.

![Figure 2. Geosystem functioning scheme with strong anthropogenic influence [1]](image)

As the result of these changes, the geosystem changes the initial development trend and loses ecological balance. The more an object changes, the closer the geosystem to an ecological crisis is (challenges of the Aral and the Sevan lakes, etc). To liquidate crisis another type of ties- between I and II blocks- is created. This type of ties is called adaptation ties (figure 3).

![Figure 3. Geosystem functioning scheme with adaptation ties [1]](image)

Most current activities (diversion of runoff, building of waste disposal plans, etc) allow only to adapt the changed conditions (III block) to the geosystem (I block). However, adaption ties do not
always guarantee the liquidation of ecological hazards. That is why it is necessary to create management ties that close the geosystem. These ties should regulate the relations between a human (II block) and environment (I block) to prevent ecological balance destruction caused by the functioning of the created system (figure 4).

![Geosystem functioning scheme with management ties](image)

**Figure 4.** Geosystem functioning scheme with management ties [1].

3. **Results and discussion**

Are management ties mentioned in CWOUPS? To reveal this, two projects statements (table 1) were compared.

| **Table 1.** The comparison of the CWOUPS and IWRM statements. |
|---------------------------------------------------------------|
| **CWOUPS** [10,11] | **IWRM** [8,9] |
| **Purpose** | To determine the permissible anthropogenic water objects load; to determine water resources demand in future; to provide water objects protection; to determine main activity trends to prevent negative impact of waters. | To provide coordinated development of water, land and resources associated with them to optimize ecological and social well-being without ecosystem sustainability risk. |
| **Main task** | To make management-decision tools to achieve target indices of water quality of water objects of the case study river basin; the target indices are determined by the CWOUPS; to reduce negative consequences caused by flooding or by other types of water negative impact. | To preserve water for people and food production; to create working places; to protect vitally important ecosystems; risks management; to make public awareness; to strengthen political will to act; to provide international and inter-industry cooperation. |
| **The data are provided** | For planning and implementation of water protection and water-management activities in the frameworks of the federal investment program and other target programs; for the development of water protection and water-management activities; for making offers concerning payment for water objects usage; water use management. | For national organizations; to develop management strategies from local authorities to water users and vice versa from water users to local public authorities; for management at a state/province/ region levels; for river basin management structure. |
| **When being developed the following aspects should be considered** | The social-economic forecasts, based on industry branches and on regions; territorial planning schemes; current regional and local documents concerning the territory development planning, protected natural territories; plans and programs concerning water-management and water protection activities; international agreement provisions in the field of the joint use and protection of transboundary water objects (for transboundary water objects mentioned in the Scheme). | Consciousness of workers involved in payment collection and data assessment about basin water resources, involved in making plans and offers about investment and payment for water use; budget for organization maintenance and investment in water infrastructure; international role of basin organizations; local authorities importance; participation of public authorities and communities. |
Thus, from table 1 despite the differences among these programs, still there are some similarities; they are both devoted to multi-purpose decrease of negative influence on water resources with the help of object-oriented programs. The main approach is basin, but IWRM is a philosophy, policy and guide in the field of water resources management, whereas CWOUPS is only a part of IWRM connected to complex water resources use and gives recommendations only.

Nowadays, a new system to control water-management activity has been created in the multipurpose water-resources scheme of Russia [10, 11]. However, current legislation system and legal acts do not always correspond to ecological, social and political situation. The key challenge is the lack of a scientifically valid methodology. Moreover, a system-methodological approach (SMA) may become such a methodology [12]. The application of this approach needs a clearly defined social-eco-political development strategy of a region. The SMA has been used to study ecological situation in large towns and cities of Perm Krai (Berizniki, Solikamsk, Perm), as well as to study the role of water objects in the creation of ecological surroundings in Perm Krai [13].

The present research presents a water resources management conception that suggests the selection of fundamentally new approaches to determine indices that characterise possibilities and ranges of usage. To obtain impartial data about a main river, solving management tasks from the lower (local) levels of authorities to upper (regional) ones, i.e. from particular objects and issues to larger ones is strongly suggested. The system methodology that is being used suggests studying “reason-result” relations between different components of the geosystem, such as driving force (ecological changes), loads (on the environment), condition (of the environment), impact (on the society, economy, ecosystem) and response (of the society). The initial point is the pilot analysis of the geosystem. This analysis determines the geosystem borders, demonstrates obvious disadvantages of the obtained data (e.g. not enough data about water chemical composition), identifies main loads (settlements, intensive agricultural activity, industrial agglomerations, etc.) and specifies subsystems that have been potentially affected (ploughed up land, lawn-and-gardens, recreational zones, etc.). The geosystem is spatially divided into river systems of different range (subsystems). Their size is determined by an actual river basin length. The minimum basin range that is used a river study unit is determined by a hydrological regime, potential impacts distribution, their “impact range” and available information (i.e. initial data volume and quantity). The key purpose of researches is determined during the discussion with privies. The privies are water users who are directly or indirectly involved in river system usage. They are invited, for example, to participate in a consulting council.

The data that have been obtained are used to make management decisions. The Nytva river basin has been chosen as a pattern as it is a typical case study basin of medium and small rivers. There are some average industrial and agricultural enterprises and settlements on the basin territory. Nowadays, drinking water shortage is an acute problem for the Nytva population. This challenge is closely connected to the basin siltation and eutrophication.

The procedure to work out management decisions (in the case study of the Nytva river basin) is divided into three parts: project domains, schedule of works and the expected results [14]. In this article, only the main project domains and expected results (tables 2-3) are considered.
Table 2. Procedure for management decision making in the field of river basins water resources (in the case study of the Nytva river basin): project domains.

| Challenges                                      | Project domains                                                                 |
|------------------------------------------------|--------------------------------------------------------------------------------|
| **Practical:**                                 |                                                                                |
| Ecological situation in the river basin and the reservoir eutrophication | 1. To characterize water objects pollution                                       |
|                                                | 2. To study technogeneous loads                                                 |
|                                                | 3. To distinguish reasons of eutrophication                                    |
| **Scientific:**                                |                                                                                |
| To work out schemes for water resources management of the basins of unstudied rivers that suffer from anthropogenic impact | 1. To develop methodology for “the Nytva river basin” geosystem study             |
|                                                | 2. To study the current management system                                       |
|                                                | 3. To access the main factors that influence the runoff, chemical composition, technogeneous loads and their roles in the basin ecological situation |
|                                                | 4. To make a simulation model of chemical composition and eutrophication formation |
|                                                | 5. To make schemes for water resources management of the basins of unstudied rivers that suffer from anthropogenic impact |
| **Methodical:**                                |                                                                                |
| The selection and development of calculation and research methods | 1. To develop a calculation method for runoff and hydrological regime features when there are no observational data |
|                                                | 2. To use a balance method to access chemical composition and hydrodynamic features of the reservoir |
|                                                | 3. To prove the array pitch of technogeneous load intensity distribution in the basin |
| Field and laboratory researches                | 1. Reconnaissance method (selection of sites and sample sites, water, soil, sediments and snow samples for chemical analysis) |
|                                                | 2. To measure flow speed with a subsequent water flow determination            |
|                                                | 3. Morphological description of soils                                          |
|                                                | 4. Laboratory tests of chemical and physical-chemical indices in the selected samples |
|                                                | 5. To access the amount of phosphates and nitrates in soils, their mobility, water migration and amount in the basin water objects |
| Statistical treatment of data and results mapping | 1. Data collection, analysis and statistical treatment                         |
|                                                | 2. Mapping of technogeneous loads sources and the basin zoning (subsystems separation) according to their type and impact intensity |
|                                                | 3. The basin territory zoning according to phosphates and nitrates amount (for 95% and 5% flow probabilities and lag time) |
| Modern computer technology use                 | Development of the Nytva river basin GIS that contains different layers         |
Table 3. Procedure for decision making in the field of river basin water resources management (in the case study of the Nytva river): the expected results.

| Research theme                                                                 | Expected results                                                                 |
|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Development of the research methodology                                       | Methodology of the integrated assessment, management and forecast of the basin water resources condition |
| Study of the current management system of the basin water resources            | Development of the current management system: its advantages and disadvantages    |
| Assessment of the main factors that determine the runoff, chemical composition and their impact on the basin ecological situation | Formation of the surface runoff, chemical composition and suspended matters flows. Equations of water and chemical balance |
| Technogeneous loads and their influence on the basin ecological situation      | Types and intensity of technogeneous loads on the basin                            |
| Study the reasons of the Nytva reservoir eutrophication                       | To characterise watershed factors that contribute to eutrophication, their spatial distribution, nitrogen and phosphorus content |
| Assessment of the basin ecological situation                                  | The basin zoning according to anthropogenic loads type and amount and according to ecological situation destruction |
| Field and laboratory researches                                               | Data about runoff, chemical composition, hydro-biological indices                 |
| Development of the Nytva river basin GIS that contains different thematic layers | Databases and digital maps collections                                             |
| Development of the simulation model of chemical composition and eutrophication formation | A simulation model                                                               |
| Development of a management scheme of water resources of the basins of previously unstudied rivers that suffer from anthropogenic impact | A management scheme of water resources of the basins of previously unstudied rivers that suffer from anthropogenic impact |

The result of the present research is the development of a multi-functional procedure to create a plan for water resources management in previously unstudied average basins for the administrative support of the decision making of their sustainable development. The study believes that, this plan implementation to manage a basin together with CWOUPS will reduce efforts to achieve the specified water quality characteristics and will minimize ecological risks.

References
[1] Newson M 1998 *Land, Water and Development: Sustainable Management of River Basin Systems* (London, New York: Routledge) p 423
[2] Danilov-Danilyan V I 2007 *Voda – strategicheskiy faktor razvitiya ekonomiki Rossii* [Water is a strategic factor in the development of the Russian economy] *J. Bulletin of the RAS* **77** 108 – 44
2000 Directive 2000/60/EC of The European Parliament and of The Council *J. Of The European Communities* (Luxembourg) p 72

2017 *Competition for Water Resources: Experiences and Management Approaches in the US and Europe* ed Jadwiga Ziolkowska and Jeffrey Peterson (Amsterdam: Elsevier) p 478

Bogacheva N Yu, Khranovich I L and Chen Zi 2000 Obosnovanie strategiy ratsionalnogo ispolzovaniya vodnyih resursov v usloviyah riska [Rationale for strategies for the rational use of water resources under risk] *J. Engineering ecology* 6 2 – 21

Danilov-Danilyan V I and Bolgov M V 2009 O vodnoy strategii Rossiyskoy Federatsii na period do 2020 goda [On the water strategy of the Russian Federation for the period until 2020] *Proc. Int. Conf. on Water problems of large river basins and ways to solve them* (Barnaul: Russia) 59 – 81

Dvinskikh S A 2007 Metodologicheskie aspekty formirovaniya riska na vodnykh ob"ektakh [Methodological aspects of risk formation at water objects] *Proc. Int. Conf. on Current problems of water resources and their catchment areas* 1 (Perm: Russia/Perm State University) 8 – 17

2012 *Handbook for integrated water resources management in transboundary basins of rivers, lakes and aquifers* (Stockholm: Sweden /International Network of Basin Organizations) p 124

2009 *Handbook for integrated water resources management in basins* 2009 (Stockholm: Sweden / International Network of Basin Organizations) p 104

2003 Nekotoryie regionalnyie osobennosti ispolzovaniya vodnyih resursov v sovremennoy Rossii [Some regional features of water resources use in modern Russia] *J. Regional Research of Russia* 4 77 – 85

2003 Novyie podhodyi v probleme kompleksnogo upravleniya vodnymi resursami [New approaches to the problem of integrated water resources management] *J. Computing Center of the RAS* 54

2009 Sistemno-metodologicheskii podkhod k planirovaniyu prirodookhrannoi deyatelnosti [System methodological approach to plan nature protection activity] *Proc. Conf. on hydrology and hydroecology of the Ural* (Perm: Russia/Perm State University) 101–121

2015 Opyt ispol'zovaniya sistemnogo podkhoda v gidrologicheskikh issledovaniyah [Experience of using a system approach in hydrological research] *J. Geographical Bulletin* 1 44 – 51

2015 Novaya osnova dlya upravlencheskih reshenii. Primenenie mnogofunktsional'nogo metoda pri sozdaniy plana upravleniya vodnymi resursami neizuchennym rek [A new basis for management decisions. Multi-functional method application to make a management plan for water resources of unstudied rivers] *J. Water MAGAZIN* 2 46 – 50