ISSN 0097-8078, Water Resources, 2012, Vol. 39, No. 4, pp. 488–495. © Pleiades Publishing, Ltd., 2012.

WATER RESOURCES DEVELOPMENT: ECONOMIC AND LEGAL ASPECTS

Management Information System of Lakes and Reservoirs[1]

Dušan Stefanović[a], Ivana Radojević[b], Ljiljana Čomić[b], Aleksandar Ostojić[b], Marina Topuzoviić[b], and Ana Kaplarević-Mališić[a]

[a] *Institute of Mathematics and Informatics, Faculty of Science, University of Kragujevac, 34000 Kragujevac, Radoja Domanovića 12, Serbia*

[b] *Institute of Biology and Ecology, Faculty of Science, University of Kragujevac, 34000 Kragujevac, Radoja Domanovića 12, Serbia*

e-mail: dusans@kg.ac.rs

Received March 17, 2011

Abstract—Information technologies provide a significant support in the management of lakes and reservoirs. Existing information systems mostly did not comprise all the necessary data and enabled collecting only a limited set of reports. More complex data analyses such as statistical analyses and data research were conducted in separate environments and recquired additional preparation of the data. Information system of lakes and reservoirs in Serbia (SeLaR) was produced in order to provide all the neccessary information for lake and reservoir management. The information system integrates a large data set and provide users with necessary information in the form of reports and charts. The users of the system are scientists and experts who study these issues, as well as students with the objective of continuous education. Furthermore, an interface was produced to enable linking with data research software. In this way a unique working environment was created to provide users with an efficient model of acquiring all the information necessary for the management and to find out new facts in data interaction, and also to make a forecast. This study presents an overview of the information system, its production model, the information available and the possibilities of data research.

Keywords: information system, data mining, management, water quality, lakes, reservoirs

DOI: 10.1134/S0097807812040124

Contemporary world is facing the fact that there is a discrepancy between different needs for drinking water and available resources of relatively clean water. There is a tendency for the proportion between the needs for and the availability of clean water to be violated under the influence of a rising number of populations as well as a greater contamination of water systems. Therefore, it is necessary to maintain the state of reservoirs, both natural and artificial ones, at a satisfactory level. As lakes are evolutionary, natural and contemporary hydrographic objects, the research, especially if related to the living world and ecological relations, has to be constant, systematic, versatile and purposeful. Lake ecosystems are very susceptible to various influences, which is caused by a small degree of self-regulation, wherefore the preventive lake protection is better than remediation of the harmful effects [13].

The application of information technologies is very significant in managing lakes and reservoirs. Information technologies enable merging all the relevant facts needed for managing as well as for showing them in the form best suitable for the user. For example, the unique information system of European lakes where the data are organised within a relational database in five basic tables: station information, chemistry sample information, biology sample information, chemistry values (including variables such as pH or phosphorus) and biological values (such as biomass or abundance per taxon) [22]. A special attention is given to the systems dealing with water quality. For example, information system for determining IBI (The Index of Biotic Integrity) for fish communities based on a greater number of input parameters [31], information system for managing water resources by integrating hydro-chemical, hydrological, data about microbiology, phytoplankton, zooplankton, macrophytes etc. [15], information system based on relational database containing a fuzzy models for water quality determining [19, 20, 21], real time information and control system for decision support [11], etc.

The objective of the information system (IS) SeLaR is creating an integral and purposeful information system about lakes and reservoirs in Serbia. It should enable gathering in one place all the available data concerning lakes and reservoirs in Serbia, a relatively easy access to scientific data and manipulation, a new, modern and contemporary insight into the state of lakes and hydroreservoirs in Serbia, as well as an

[1] The article is published in the original.

integrated and coordinated management of the data and obtaining the information necessary for monitoring, management and education. Besides various previews of combined data, IS SeLaR should also give answers to other challenges such as information analysis and application, parameter comparison, statistical supplementation, etc. The objective of the data analysis is to determine dependence between entities, unknown relations, regularities of dynamics of specific characteristics, and predictions. Database designed in this way can also be the basis for simulation.

Information system (IS) SeLaR was created in order to improve the management of lakes and reservoirs. It is the first system containing ordered data related to the state of lakes and reservoirs in Serbia. The system is designed for a great number of users, especially in the fields of biology and ecology (researchers, students, etc.), as well as for other participants in reservoir managing. Hence, it is implemented as the Intranet and the Internet application. It supports all kinds of management, as well as a sustainable exploitation of water resources in general.

CREATING INFORMATION SYSTEM

Object-oriented approach with the use of UML (Unified Modelling Language) was used for creating the information system [3, 23]. UML enables modelling of information systems of various applications using several diagrams, comprising basic Use Case and Class diagram. Use Case diagram gives an overview of the system from the viewpoint of the user, i.e. the overview of what should be included in an information system. Class diagram gives an overview of the classes in the system where those related to real system entities can be directly transformed into a data model, and then into a relational database. Basic components of SeLaR information system are database maintaining, report and the analysis of data. Database as the model of the real system contains all the entities relevant to the realisation of the set objectives. These entities are lakes and reservoirs, physical dimensions, location, events, etc. (Table 1). The entities have their characteristics which are contained in the database. In the scope of data analysis tools, these characteristics are marked as variable. Individual values of the characteristics are marked as objects (in the database they correspond to classes in the table). The aim is to enable different aspects of researching lakes and reservoirs by covering these data.

The selection of significant components for creating IS (in this case entities) is based upon scientific facts which are obtained on the basis of previous research which study lakes and reservoirs, and which refer to their functioning and the parameters which influnce them [4, 5, 17, 30]. All the necessary data are concentrated in the relational database, all in one place. One group of these parameters refers to physical, climatic and topographic characteristics of lake surroundings, the other to physical-chemical and biological characteristics of lakes and reservoirs [7, 8, 16]. The important parameters are the depth and the location within the lake [26]. Regarding the importance of lakes and reservoirs in quality drinking water supplying, different methods of analysing and assessing water quality have been developed [18, 14]. According to this, three groups of entities have been integrated into the database: the entities referring to characteristics of lakes and reservoirs and their surroundings, the entities containing the values of different parameters (physical-chemical and biological) and calculated values representing the characteristics of the system such as water quality and the entities referring to systematic categories. A brief description of all basic entities which correspond to the classes in the class diagram is as follows in Table 1.

Data model, i.e. database, provides a high degree of semantics of a real system. This means that it contains essential data about lakes and reservoirs, which provide objective realisation of the information system. These data are structural and linked in order to enable a quality and effective maintaining (new data input, changing or deleting) and a simple acquisition of various information in the form of inquiries, tables and graphical overviews. This enables monitoring relevant parameters in managing lakes and reservoirs, such as the state of flora and fauna, water quality state in space and time and such like. Besides these features, SeLar information system enables far more advanced methods of data analysing such as statistical analysis and Data Mining [6, 12, 27, 29]. There is a unique interface which provides an automatic transfer of data from the database to data structures recquired by the software for statistical processing and Data Mining. This provides a unique working environment where data are input into the system only once, when they are created, afterwards being available in the realisation of inquiry and analysis.

A data model formed in this way has a universal character and it is useful in producing the information system of lakes and reservoirs independently of their location.

INFORMATION SYSTEM OVERVIEW

The basic functions of the information system are maintaining of the datebase and generating reports. Database maintaining is a set of activities including new data inputs, alteration and deletion of data. Database maintaining is realised through a set of screen forms for new data inputs, alteration and deletion of existing data. These screen forms should provide the quality of existing data as well as efficiency and order in the working process. The first three columns of the main page (Lake and reservoir, Register and Register of systematic) refer to maintaining the database and they consist of a set of screen forms which correspond to certain entities. Generating report presents the set

Table 1. Overview of the entity system

Name of entities	Description of entities
Ecosystem	Types of ecosystem (Lake or Reservoir/LR)
LR Types	Types of Lake or Reservoir (LR) regarding the way of their creation (tectonic, aeolian, reservoir, etc.)
Types of water mixing	The type of water mixing
Retention Time	The average time a water molecule will spend in that reservoir
Events	Data about relevant events which have impact on LR, such as floods, algal bloom, rapid water level falling, etc.
Activities	Activities such as tourism, sport activities, fishing, traffic, etc.
Climatic characteristics	Data such as air temperature, water temperature, precipitation, etc.
Land use	Data such as fields, woods, pastures, orchards, sport, roads, etc.
Surrounding population	Data such as the number of settlements, population density, etc.
Interventions	Data such as addition of $CuSO_4$, hypolymnetic aeration, etc.
Physical dimensions	Data about surface area, volume, maximal depth, average depth, average annual amplitude, surface area, length and width of the basin, the batimetric map of the lake, etc.
Purification	Data such as activities on sanitary protection and waste water purification
Lake-Reservoir	Basic, time invariable characteristics of lakes and reservoirs such as LR description, location (geographical length and width, altitude, map), data related to dam (height, length, top, length of the dome)
Rivers and channels	Data about rivers and channels flowing into or out of LR
Physical-chemical parameters	Physical-chemical parameters with appropriate units
Biological parameters	Data about biological parameters including the appropriate units
Group Characteristics	Characteristics referring to a specific biological community
Method_characteristics	Methods applied for individual characteristics. For example, standard methods for assessing water quality [1, 2]
LR_GC_Values	The values of characteristics measured on a specific date for micro-location in the lake (location on LR, depth). According to this it is possible to record more values of one characteristic—for example, the values of water characteristics referring to different reservoirs, locations in the lakes and dates together with different methods of water quality measuring
Units	Codes of units referring to values of all types of parameters
Phylum, Class, Ordo, Family, Genus, Species	Systematic categories

of screen forms and the reports which provide all the necessary information to the users. An example of a standard report is presented in Fig. 1. The report includes basic data on the reservoir Gruža with a photo.

Besides the contents of the entities and their relations, there are also reports which contain connected data from more entities or which present certain calculations (indexes, water quality characteristics). The objective is to present discrepancies in the reports without a detailed analysis. Users access the database, both for its maintaining and for reporting, through an appropriate user interface. SQL Server is used for the realisation of this system as the system for database managing, SQL Project as the user interface and EXCEL for graph data.

The following Fig. 2 and Fig. 3 show some of many graphical interpretations of the reports. Data refer to Gruža Reservoir. Figure 2 shows a threedimensional graphical report of average annual proteolytic bacteria on three selected locations. It can be observed that the highest values are registered in 1999, in the year of great diluvial waves. Lake code, years, locations and characteristics are specified as input parameters in order to obtain reports.

Figure 3 shows the report of water quality according to WQI method. In order to obtain the information, the following data are input: lake code (from the pull-down list of all lakes), time period for calculating

Fig. 1. Basic data on Lake Gruza.

quality and the method according to which water quality is determined from the appropriate pull-down list.

DATA ANALYSIS

The aim of data analysis is to determine still unknown relations (dependences) between entity attributes, their mutual characteristics and the prediction of future behaviour. Data analysis enables making conclusions and conducting appropriate measures within managing lakes and reservoirs according to proposed objectives. As seen from the database description, all relevant changes upon entities are registered per date and location. It enables data analysis in temporal and spatial dimension. Before starting data analysis it is necessary to conduct denormalisation [9]. Denormalisation is conducted through specialised user interface which transforms relations from relational database into the structures suitable for processing by the software suitable for analysis. Specialised software is used for data analysis: SQL Server, Analysis Services, Excel and SPSS.

Data analysis in Excel is conducted by using analytical components of SQL Server 2008 [28]. Data from relational database are transformed into appropriate multidimensional structures through a specialized user interface. It means that the user can use appropriate data structures transformed from the database with no engagement of his own. Excel offers different possibilities for data analysis and serves as powerful, flexible and easy to use client application [10]. Each analysis contains the following steps: modelling, model realisation and report presenting. Modelling encompasses, first of all, determining features, e.g. physical-chemical (oxygen, BOD, total phosphates, orthophosphates, nitrites, nitrates, ammonia,

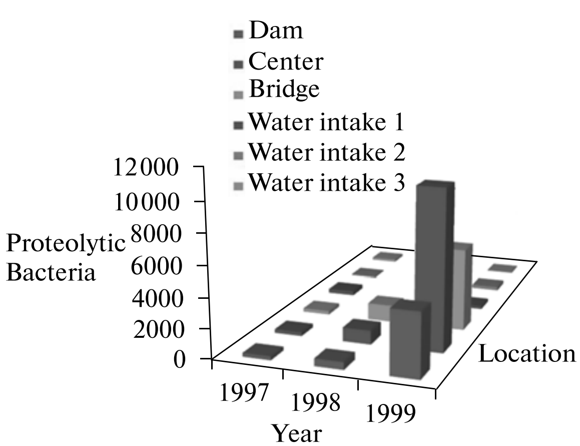

Fig. 2. Average annual values of proteolytic bacteria for three selected years per one location.

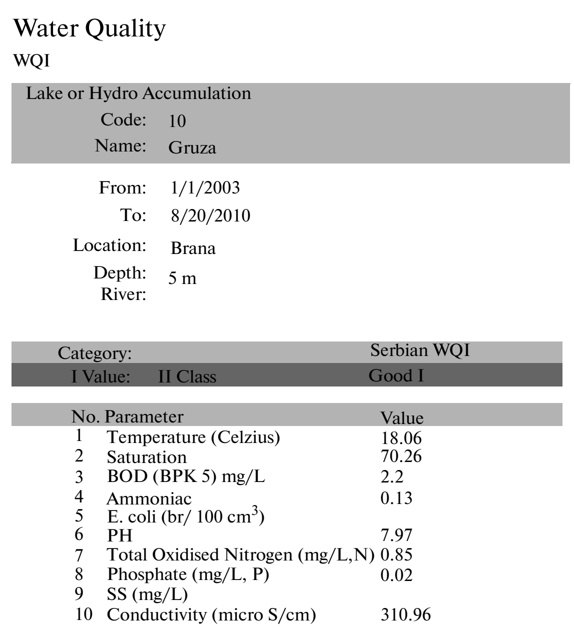

Fig. 3. Water quality data according to WQI method.

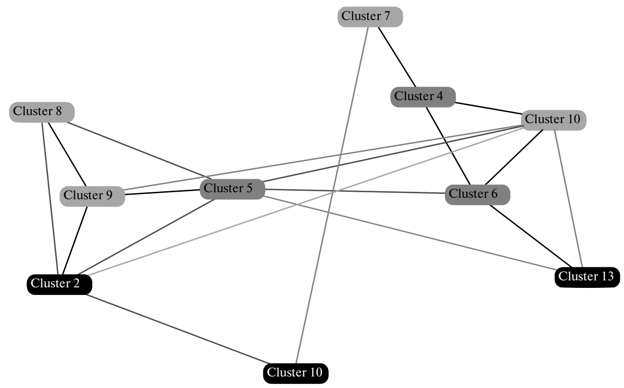

Fig. 4. Cluster diagram for the projected model.

etc.), microbiological (heterotrophic psychrophiles and mesophiles, fecal coliform, total coliform, E. coli etc.), features such as location, depth, which are included in the model. Determining entity features which are included in the model depends on the objective of the analysis. Before carrying out the algorithm it is necessary to check and clear the data and to determine parameters. For example, in Cluster analysis some parameters which are used are: Minimum_Support controls when a cluster is considered "empty" and it is discarded and reinitialised, Stopping Tolerance is used by the algorithm to determine when a model has converged. Model realisation represents carrying out a particular algorithm on the model. The reports consist of a table and graphical overviews. Overviews of the analysis for cluster and classification are given on the example of oxygen level in Gruza accumulation.

Cluster

Cluster has a similar function as Detect Categories only it provides more information. The objective of clustering is to find groups that are very different from each other, and whose members are very similar to each other. Unlike classification (see Predictive Data Mining below), you do not know what the clusters will be when you start, or by which attributes the data will be clustered. If each object is assigned one and exactly one cluster then this is *hard clustering*. There are several algorithms used for Cluster [9, 28]. The Microsoft Clustering algorithm allows two distinct methods of cluster assignment: *K-means* and *expectation maximization* (EM).

The example below shows a model which consists of locations, depths, water temperatures and oxygen. The objective is to identify, if present, patterns according to which features contained in the model behave. 10 clusters were initialised. Figure 4 presents a Cluster diagram which shows a graphical representation of the data associations found. The significant clusters or nodes of data are shown as shaded rectangles. The most important are the first three clusters, and then the fourth one. The majority of the objects is concentrated in these clusters. Dark lines represent a strong connection between the clusters.

A more detailed analysis of the cluster is possible based on other cluster overviews, whereas the most important one is the description of their characteristics. Out of 10 clusters, clusters 2 and 6 are presented below as an illustration (Table 2).

Variable (feature) spectrums and probabilities with which they participate in a specific cluster are given for each cluster. Based on the analysis of cluster features dominant variables and probabilities in specific clusters can be detected. For example, if the focus of analysis is oxygen (which is determined by modelling), we can see that it is predominant in cluster 2 with values of 10.5–19 mg/L and the probability of 81%. Also, the most influential feature in this cluster is the location with the values of 21–32 (these locations refer to deltas and tributaries of accumulations). Relatively important influence is that of water temperature 50% with values of 0.2–9.8°C, then depth values of 14–15 and

Table 2. Overview of the characteristics of cluster 2 and cluster 6

Cluster 2			Cluster 6		
Variables	Values	Probability, %	Variables	Values	Probability, %
Location	21–32	89	Oxygen	0.1–5.0	92
Oxygen	10.5–19.0	81	Depth	2–7	80
Temperature	0.2–9.8	50	Location	10–15	72
Depth	14–15	34	Temperature	14.4–19.1	52
Temperature	9.8–14.4	26	Temperature	9.8–14.4	31
Oxygen	7.8–10.5	18	Location	1–9	28
Depth	11–13	16	Depth	8–10	20
Temperature	14.4–19.1	11	Temperature	19.1–30.5	14
Location	16–20	8	Temperature	0.2–9.8	3
Temperature	19.1–30.5	3			
Oxygen	5.0–7.8	1			

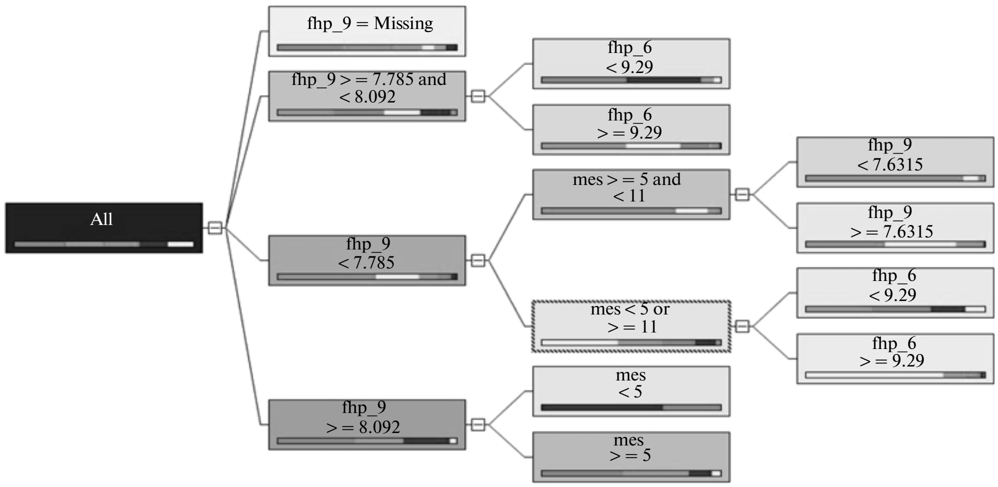

Fig. 5. Decision tree for oxygen.

the probability at 34%. As opposite to cluster 2, the lowest levels of oxygen are in cluster 6 (0.1–5 mg/L) with the probability of 92%. Importantly, depth values reach 2–7 meters (80%) and water temperature from 10 to 15°C with the influence of 72%. The analysis of differences can be observed in the best way in Cluster discrimination.

Model realisation can be repeated with a changed parameter which refers to a maximum number of clusters. As the maximum number of clusters increase, so does the convergency of the model.

Classify

A classification model extracts patterns that predict individual values of one column based on the values in other columns. Algorithms used are Decision Trees, Naive Bayes and Neural Nets. Microsoft Decision Tree is a hybrid and supports classification, regression and association. The classification for oxygen was made regarding other physical-chemical parameters. The first obtained diagram reveals the dependency net. Oxygen values for Gruza accumulation depend on pH, temperature and month. The next diagram which is obtained is a decision tree.

Figure 5 presents a decision tree showing the identified pattern upon which the dependency net with pH, temperature and month was determined. The pattern identified five classes which are formed based on grouping oxygen values. The first category consists of oxygen values <3.1 mg/L, the second ≥11.88 mg/L, the third 3.1–6.88 mg/L, the fourth 6.88–9.38 mg/L and the fifth ≥9.38–11.88 mg/L. Probabilities for oxygen values were calculated according to categories for each node. Each category is marked by one colour on the decision tree diagram which is proportional to its probability. On the root node (All) which refers to the whole sample irrespective of pH values, temperature and month, probabilities of oxygen values according to caterogies (Table 3) are calculated. It can be observed that ogygen values in the range 6.88–9.38 will appear with the probability of 22.29.

Level 2 shows that pH values exert a primary influence on oxygen values. Generally, higher pH values produce a higher level of oxygen and vice versa, lower pH values produce a lower level of oxygen. For pH ≥ 8.1 the probability that oxygen values will be >6.88 mg/L is even up to 95.16%. In the months during summer the probability will be significantly increased. So, for pH ≥ 8.1 and the month <5 the probability that oxygen values will be >9.38 mg/L is increased up to 99.63%, whereas the probability that it would be >11.88 mg/L is 67.03%. For pH < 8.1 the probability that oxygen value is <6.88 mg/L is 78.00%, and that it is <3.1 mg/L is 53.47%. During summer months it decreases significantly, so during the period from the fifth to the tenth month the probability that oxygen value is <6.88 mg/L is 91.56%, whereas the probability that it will be <3.1 mg/L is 73.71%.

Analysis of the impacts of different parameters on oxygen content in the reservoir Gruza was tested based on data from the database and other tools and models, which are all shown similar conclusions [24, 25]. Some specifics and differences can be explained by the

Table 3. Probabilities of oxygen values on a root level

Value	Cases	Probability	Color
<3.1	228	20.43	Green
≥11.88	176	15.83	Purple
3.1–6.88	170	15.29	Yellow
6.88–9.38	249	22.29	Red
9.38–11.88	290	25.92	Blue

smaller data set and their coherence during a shorter time period.

The examples show that IS SeLar can provide necessary information to the users in the way that is the most suitable for them. The information may be about entities such as general characteristics about lakes and reservoirs, the state of water quality, the state of various biological communities, etc. Additionally, obtaining information on the dynamics of variables in space and time and comparing variables of different lakes and reservoirs is also possible in a quite simple way. A complete statistical data processing and Data Mining are enabled. A particular convenience is the possibility to use software tools for statistical analysis and Data Mining excluding additional preparation of data which is a usual procedure. The users of the system can use it without engaging computer specialists.

The IS enables various ways for management of Serbian lakes and reservoirs at the local level, as well as at higher regional or even national level, requiring the cooperation of all relevant institutions. It is currently used in cooperation with the Public Utility Company for Water Supply and Sewerage for the various reporting and analysis that were applied in practice for the management of the reservoirs Gruza and Grosnica.

CONCLUSION

Informational system SeLaR presented in this paper was developed with the purpose of integrating all the relevant factors for monitoring and management of reservoirs and lakes in Serbia. It is a necessary step toward improving the current situation in management of lakes and reservoirs. SeLaR IS enables:

—Collecting and maintaining of all relevant data;

—Spatial and temporal monitoring of the state trough physical, climatic, topographic characteristics of the lake surroundings, as well as hydrological, physical, chemical and biological characteristics and human influence;

—Finding and analyzing relationships between variables;

—Dynamics analysis;

—Detection patterns of dynamic variables or groups of variables;

—Creation of different Data Mining models for predictions and decision support.

All this was accomplished by a specific original application logic which links the database of the information system with data structures and models which are necessary for statistical processing of the data and Data Mining. SeLaR information system is a scientifically

based system for water resources management and enables assessment of the efficiency of the existing monitoring system and provides ways of their improvement. The system supports a great number of users, especially in a field of science, but also for the other participants in management of reservoirs and it enables their cooperation. It provides all forms of management and sustainable exploitation of water resources in whole, and enables transfer of information and knowledge as well as creation of network of researchers. The SeLaR IS represents virtual laboratory available to a grate number of users which can coordinate, synchronise and exchange their research data.

ACKNOWLEDGMENTS

This research was supported by the Ministry of Science of Serbia. The authors are thankful to the Public Utility Company for Water Supply and Sewerage which gave access to data needed for the purpose of this paper.

REFERENCES

1. APHA, Standard Methods for the Examination of Water and Wastewater, 19th ed. Washington, D.C.: American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1995.
2. APHA, AWWA, WEF, Standard Methods for the Examination of Water and Wastewater, 21st ed. Washington, DC: American Public Health Association, American Water Works Association, and Water Environment Federation, 2005.
3. Booch, G., Rumbaugh, J., and Jacobson, I., *The Unified Modeling Language User Guide*, Addison Wesley, 1998.
4. Bremigan, M.T., Soranno, P.A., Gonzalez, M.J., et al., Hydrogeomorphic Features Mediate the Effects of Land Use/Cover on Reservoir Productivity and Food Webs, *Limnol. Oceanogr.*, 2008, vol. 53, no. 4, pp. 1420–1433.
5. Cheruvelil, K.S. and Soranno, P.A., Relationships between Lake Macrophyte Cover and Lake and Landscape Features, *Aquat. Bot.*, 2008, vol. 88, pp. 219–227.
6. Conrads, P. and Roehl, E., Estimating Water Depths Using Artificial Neural Networks, *HIC, 7th International Conference on Hydroinformatics*, Nice, 2006.
7. Elçi, S., Effects of Thermal Stratification and Mixing on Reservoir Water Quality, *Limnol.,* 2008, vol. 9, no. 2, pp. 135–142.
8. Gergel, S., Turner M., and Kratz, T., Dissolved Organic Carbon as an Indicator of the Scale of Watershed Influence on Lakes and Rivers, *Ecol. Appl.*, 1999, vol. 9, no. 4, pp. 1377–1390.
9. Han, J. and Kamber, M., *Data Mining: Concepts und Techniques*, Morgan Kaufmann Publischers, 2000.
10. Harts, D., *Microsoft Ofice 2007 Bussines Intelligence*, McGraw-Hill, 2008.
11. Imberger, J., A Lake Diagnostic System for Managing Lakes and Reservoirs, *Water Resources Impact.,* 2004, vol. 6, no. 1, pp. 7–10.
12. Jørgensen, S.E., The Application of Models to Find the Relevance of Residence Time in Lake and Reservoir Management, *J. Limnol.,* 2003, vol. 62 (Suppl. 1),

Papers from Bolsena Conference (2002), Residence Time in Lakes: Science, Management, Education.

13. Jørgensen, S.E., Löffler, H., Rast, W. and Straskraba, M., Lake and Reservoir Management, *Developments in Water Sciences*, 2005a, vol. 54, pp. 1–502, Elsevier, B.V., Amsterdam, ISBN: 978-0-444-51678-7.
14. Jørgensen, S.E., Xu F.-L. and Costanza, R., *Handbook of Ecological Indicators for the Assessment of Ecosystem Health*, 2005b, Elsevier, New York.
15. Kondrat'ev, S.A., Ul'yanova, T.Yu., Moiseenkov, A.I., Izmailova, A.V., and Shkrebets A.E., Information Support for Studying Water Resources of Lake Ladoga and Its Basin, *Water Resources*, 2006, vol. 33, no. 5, pp. 494–498.
16. Magnuson, J.J., Webster, K.E., Assel, R.A., Bowser, C.J., Dillon, P.J., Eaton, J.G., Evans, H.E., Fee, E.J., Hall, R.I., Mortsch, L.R., Schindler, D.W., and Quinn, F.H., Potential Effects of Climate Changes on Aquatic Systems: Laurentian Great Lakes and Precambrian Shield Region, *Hydrol. Process.,* 1997, vol. 11, pp. 825–871.
17. Martin, S.L. and Soranno, P.A., Lake Landscape Position: Relationships to Hydrologic Connectivity and Landscape Features, *Limnol. Oceanogr.*, 2006, vol. 51, pp. 801–814.
18. May, R., Dandy, G., Maier, H., and Nixon, J., Application of Partial Mutual Information Variable Selection to ANN Forecasting of Water Quality in Water Distribution Systems. *Environ. Model. Soft.*, 2008, vol. 23, nos. 10–11, pp. 1289–1299.
19. Menshutkin, V.V., Filatov, N.N., and Potakhin, M.S., "Karelian Lakes" Expert System: 1. Ordinal and Nominal Characteristics of Lakes, *Water Resources*, 2009a, vol. 36, no. 2, pp. 148–159.
20. Menshutkin, V.V., Filatov, N.N., and Potakhin, M.S., "Karelian Lakes" Expert System: 2. Classification of Lakes. Water Resources, 2009b, vol. 36, no. 3, pp. 284–295.
21. Mitreski, K., Koneski, Z., Naumov, N., and Davcev, D., Web-Based Information System for Pollution Monitoring of Lake Ohrid, *Water, Air and Soil Pollut.: Focus*, 2004, vol. 4, nos. 4–5, pp. 189–199.
22. Moe, J., Dudley, B., and Ptacnik R., REBECCA Databases: Experiences from Compilation and Analyses of Monitoring Data from 5,000 Lakes in 20 European Countries, *Aquat. Ecol.*, 2008, vol. 42, no. 2, pp. 183–201.
23. Naiburg, E. and Maksimchuk, R., *UML for Database Design*, Addison Wesley, 2001.
24. Ranković, V., Radulović, J., Radojević, I., Ostojić, A., and Čomić, Lj., Neural Network Modeling of Dissolved Oxygen in the Gruža Reservoir, Srbija, *Ecol. Model.*, 2010, vol. 221, pp. 1239–1244.
25. Ranković, V., Radulović, J., Radojević, I., Ostojić, A., and Čomić, Lj., Prediction of Dissolved Oxygen in Reservoirs Using Adaptive Network-Based Fuzzy Inference System, *J. Hydroinformatics*, 2011, (in press), Available online 25 April 2011. DOI:10.2166/hydro.2011.084
26. Roehl, E. and Cook., J., Effects of Nonpoint Source Marsh Loading on Complex Estuaries, *NEIWPCC, Conference on Nonpoint Source Loading*, Plymouth, MA, 2010.
27. Soranno, P.A., Cheruvelil, K.S., Stevenson, R.J., Rollins, S.L., Holden, S.W., Heaton, S., and Torng, E., A Framework for Developing Ecosystem-Specific Nutrient Criteria: Integrating Biological Thresholds with Predictive Modeling, *Limnol. Oceanogr.*, 2008, vol. 53, no. 2, pp. 773–787.
28. Tang, Z. and MacLennan, J., *Data Mining with SQL Server 2005*, Wiley Publishing, Inc., 2005.
29. Tong, S. and Chen, W., Modeling the Relationship between Land Use and Surface Water Quality, *J. Environ. Manage.*, 2002, vol. 66, no. 4, pp. 377–393.
30. Webster, K.E., Soranno, P.A., Baines, S.B., Kratz, T.K., Bowser, C.J., Dillon, P.J., Campbell, P., Fee, E.J., and Hecky, R.E., Structuring Features of Lake Districts: Geomorphic and Landscape Controls on Lake Chemical Responses to Drought, *Freshw. Biol.*, 2000, vol. 43, pp. 499–515.
31. Williams, J.B. and Poff, N.L., Informatics Software for the Ecologist's Toolbox: A Basic Example, *Ecol. Inform.*, 2006, vol. 1, no. 3, pp. 325–329.