Dynamic phosphorus expert system with QoS support algorithms

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Abstract— **In this paper we present conceptual model for ecological management system with data acquisition module, combine with telecommunication-routing algorithms for data processing which help to deliver the data to processing station; fast and accurate. Then as a part of this system, the data will be used to build mathematical model for the total phosphorus concentration for short-term period. The total phosphorus (TP) component plays an important role in the functioning of aquatic ecosystem, affecting the whole food web chain that this element is participating. This is why; the protection of the lake must be direction in controlling this kind of ecological hazards. In our case study of the Lake Prespa we used data collected for 16 months period using old style-techniques, we build mathematical model of the total phosphorus component. Presented conceptual system starts with data acquisition with wireless sensors networks using advanced routing algorithms with high-level of QoS provisioning. Later the data is inputted into the model to give reliable information about the ecological status of the lake ecosystem for short period. After the processing the results are available to the decision-maker and environmental management engineers. In future we plan to develop more precision ecological models and telecommunication modules and combine with GIS techniques for better spatial view of the ecosystem.**

***Index Terms*— Lake Prespa, QoS routing algorithm, Phosphorus concentration**

I. Introduction

THE ecological state of the aquatic ecosystems is very unstable value because the system has own dynamic equilibrium and always changes. With this effect the lake ecological status is hard to determinate and it needs constant monitoring and analysis of the data. In best cases, the collected measurements are used to forecast the future state of the lake. Building an ecological model for the given lake ecosystem in non-trivial task, due to the complex interaction that living organisms and the environment have. The model depends from many factors, both the most important is the quality and quantity of the measured data. Keeping this on mind, the presented paper introduces a conceptual diagram of such model, taking into account one of the three largest lakes in Macedonia, Lake Prespa. This lake has own geographical specification that we have embedded into the presented model and we will show, later in the paper that state of the lake is corresponding with our results gain from the model [3, 5].

Acquiring data have been proven to be more robust and fast if we use more advance QoS algorithms in the data delivering process.

The formal definition for the dynamic phosphorus model of the lake ecosystems is presented in section 2. The inside look of the TP model – mathematical equations for Lake Prespa, together with the experimental results gain from the model are given in section 3. In section 4 is presented a possible implementation of sensor networks for collecting the needed parameters with QoS algorithm which can be used, while section 5 concludes the paper and gives direction of further research.

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II. PHOSPHORUS COMPONENT IN LAKE ECOSYSTEMS

The main source in our model, are the inflow rivers from the Prespa catchment. These sources of phosphorus are mainly from the agricultural activity in that area, human activity, and industrial waste [4]. In this model the flow rate and the TP concentration of the three main rivers are taken. Then the phosphorus cycle continues into the main lake basin, where takes part into the sedimentation process. This process is very hard to modeled, cause complex interaction between the abiotic and the living organisms are taking into place. This process depends from many factors, but the model takes into account only the temperature and the rate of sedimentation. A value of the sedimentation coefficient is calibrated using the measured data for the lake measuring stations. The calibrated value does not extend out of the normal values for lakes. Into the sedimentation the fluxes of material play an important role. They influence transport, bio-uptake and ecological effects of most toxins and nutrients. Complex nutrient and biological variables must be taken in order to describe the real picture of this process inside of the lake Due to missing of data such TP model, takes the basics influent factors, which remain in focus of our future research [8]. The outputted phosphorus which in this lake in out from the springs as Sv. Naum, takes an amount of the phosphorus, thus jeopardizing the Lake Ohrid ecological status. A conceptual/functional diagram which shows the participation of the phosphorus element into the web-food chain is presented in Fig.1. The TP model is composed from the differential equation that describes the process of phosphorus cycle. The TP is not the only component that has enormous impact on the life inside of the Lake.

TP ordinary differential equation, which is the equation taken in consideration here (1), is described mathematically as the sum of the inputted phosphorus from the rivers, minus the sum of the outflow from the lake and the sedimentation process. Note that the Soluble Reactive Phosphorus - SRP that comes is a part of the Total Phosphorus (TP) inside of the lake. This simple molecule pays a key role into the living organism's life.

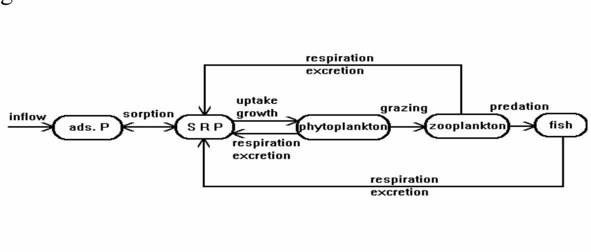

Fig. 1 - Conceptual diagram showing the components of the model as a part of the phosphorous cycle

But, because of the specific procedure that is need to extract from the water sample and from the TP, in this research is not taken into account, because of the lack of data.

$$\frac{dTP}{dt} = \left(\frac{TP_{r1} * Q_{r1} + TP_{r2} * Q_{r2} + TP_{r3} * Q_{r3}}{V}\right) - K_s * f(T) * TP - \frac{Q_{out}}{V} * TP \qquad (1)$$

So, the task that we have put in front of us is to calculate TP for the next years, so we could be able to predict the further impact of this element on the lake.

III. DYNAMIC TOTAL PHOSPHORUS MODEL OF LAKE PRESPA

In the previous paragraph we have look flow of the phosphorus component and the basis of the process that we have to model them now. The model that we have built has three main parts, which represents the dynamical process of the phosphorus component inside of the lake. Differential equation (1) contains from three main parts. The *TP* equation (1) contains sub-equations that mathematically are describe by the equations (2, 3, 4 and 5), but generally they present the three processes of the lake; inflow, sedimentation and the outflow.

$$f(T) = V^x \exp\left(x\left(1 - V\right)\right) \qquad (2)$$

$$V = \frac{T_m - T}{T_m - T_o} \qquad (3)$$

$$x = \left[\frac{W\left(1 + \left(1 + 40 / W\right)^{0.5}\right)}{20}\right]^2 \qquad (4)$$

$$W = \ln(\Theta^{10})(T_m - T_o) \qquad (5)$$

. The T_m represents the maximum temperature of the lake. T_o the optimal temperature and the T is the input temperate of the model. The rate of inflow into the rivers are presented with Q_{rx} (x=1...3) for the three main rivers and TP_{rx} for the Total Phosphorus concentration for each river, respectively. Then this sum is divided with the volume of the lake. The constants of the model, is presented with a blue block into the model (Fig. 2).

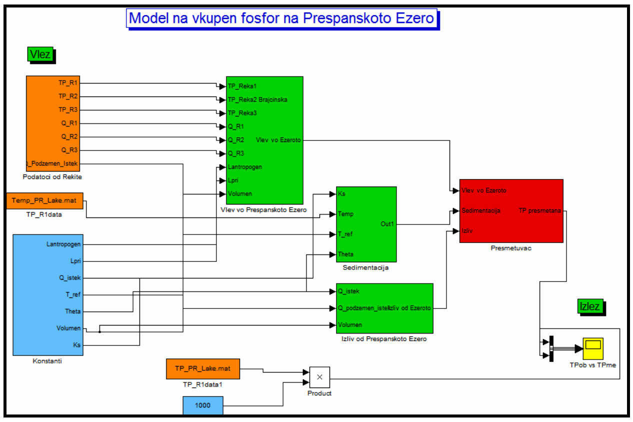

Fig. 2 - The TP model of the Lake Prespa in Matlab Simulink

The sedimentation process which includes the temperature factor is representing with the exponential function. The value of Θ is calibrated using measured data together with the *Ks* from the equation (1). The outflow part of the model is mathematically described with outflow rate (Q_{out}) divided with the volume of the lake. Then all this processes are calculated and the output result is delivered. This output result is then compared with the actual measured data. The model allows us for given input of two variables that are taken into account, the temperature and the phosphorus component to see how they contributed in the future development of the ecological state of the Lake Prespa. Measured data is taken from different measurement stations around the Lake, for one year period, 03/2005-04/2006 [10].

The TP represents the left component of the differential equation (1), so the will be represented as output of the dynamic model and then using numeric mathematics we will calculate *TP* which is present inside of the lake. To develop fast response of the dynamic model between the measured and the results gain from the model for long-term period we have modified the model to consider different changes between the two input parameters. As we pointed earlier, now we can examine the long-term period of the eutrophication of the lake by taking input measured temperature values and values of the phosphorus component.

A. *Experimental Results*

Now, let's simulate. First what we do with the model is calibration. This is done by changing the ODE constants to gain relevant output from the measured data. Of course, there will be an error between the values that we have gain from the model, but this error must not extend more than 10% error. This is normal, because the model has not included all the processes of the lake and the error of the measured data is also present. The measured data is far from been perfect, in order to model almost all the relationships that exist between the components of the model.

The simulation results for the period of 12 months are presented on output graphic which is given on Fig. 3. The blue line represents the TPc from the measured data, while the red line represents the dynamic evolution of the lake gain from the model results. From the Fig. 3 we can see that, the dynamic behavior of the lake ecosystem is fallow in almost 80% of the all measured data. If some information is old, or delayed, the output can be proceeded to show error results and alarms to the decision-makers.

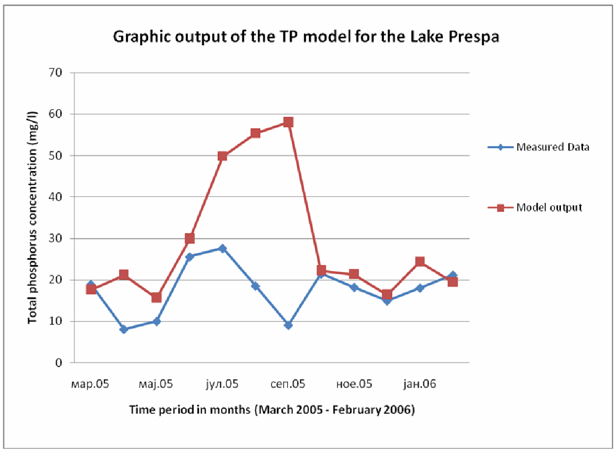

Fig. 3 - Graphic output of the TP model of the Lake Prespa for 12 months period

This is very important because the given model needs only a calibration of the constants to be accurate. This calibration must be done on larger dataset. Lack of data is the main problem. From ecological point of view it will be interesting to see, how this model predicts the impact of the outside environmental condition with their change. For this reasons implementing and achieving effective QoS provision is from essential importance.

IV. Sensor networks with QoS provisioning in Lake Prespa

In this section, a novel sensor network with high-level QoS support, in the Lake Prespa, is introduced. From essential importance is implementing sensor networks in the Lake Prespa due to the on-demand necessity of measured parameters, which must be collected in real-time and distributed to the main data centre for further processing. Here we propose seven sensor networks in the key locations of the Lake Prespa, but in future this number will be higher. Because of the attractive nature and performances of sensor networks, they take a mayor place, not only in the researchers sphere of modern telecommunications, but also in industrial world. Furthermore, some of the main advantages of sensor networks are: relatively small power consumptions, infrastructure-less, self-configuration, mobility, anytime-anywhere deployment and etc. On the other hand, wireless medium in Mobile Ad-hoc Networks and Sensor Networks has a lot of disadvantages, (like: limited bandwidth, increased errors from physical obstacles, interference from other devices, channel fading, low degree of scalability, and etc.) creating and achieving a desired QoS provisioning and technical complexity is an ultimate masterpiece, since it requires great thoughtfulness and analysis. However, today there are many routing algorithms which provide QoS support especially for real-time traffic, which is necessary in our case, because of the measured result, which must be instant delivered to the dynamic model of total phosphorus concentration.

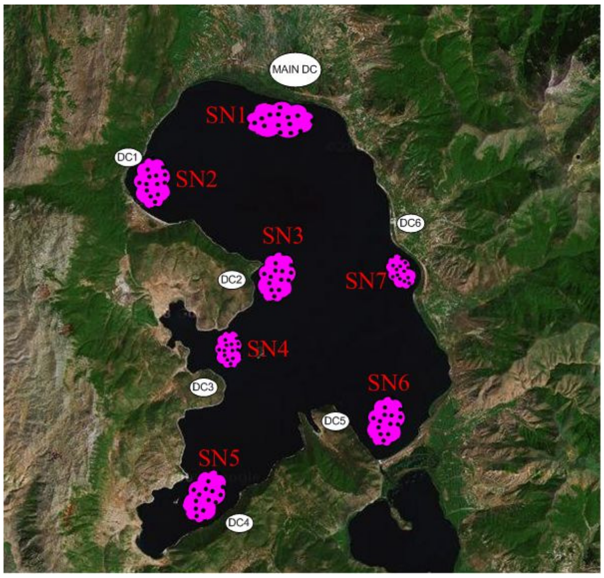

Fig. 4 - Locations of proposed sensor networks in the Lake Prespa

If some information is old, or delayed, the output can be proceeded to show error results and alarms to the decision-makers. For this reasons implementing and achieving effective QoS provision is from the essential importance. Some of those algorithms, which can be implemented in our sensor network are: Emergent Ad hoc Routing Algorithm with QoS provisioning (EARA-QoS) [1] (bio-inspired algorithm, upgrade of ARA [2], includes QoS provision (high priority for real-time traffic) scheme with incorporated different cross-layer information, reduces amount of control traffic and etc.), Ad-hoc QoS on-demand routing in mobile ad hoc networks

(AQOR [7], with provisioning end-to-end QoS support, in terms of bandwidth and end-to-end delay), QoS version of AODV [6], Combined-KKT-GA [9] approach (demonstrated efficient and effective packet-level resource allocation for wireless sensor networks with effective QoS provisioning, and fulfillment of desirable balance between performance and computational complexity) and etc. Which algorithms will be implemented, depends from the measured performances in terms of QoS provisioning (especially for real-time traffic) and from our goal. In a first place, must be implemented sensor networks. Here, seven sensor networks are proposed for implementation. In Fig.4, the locations of those sensor networks are shown. In every sensor network (SN), each sensor temporally will collect measurement about temperature and the level of the phosphor in specific locations in the lake. Those sensors can move from time to time, and will send measured parameters to the nearest Data Centre (DC in Fig.4, which can include Base Station in it or be near Base Stations and collect information from it). As can be seen, there have only one Main Data Centre (-MAIN DC in Fig.4), where the dynamic model of total phosphorus concentration is implemented and which is connected (wireless with GSM/GPRS – Global System for Mobile Communications/ Generic Packet Radio Service) with other six Data Centers. When the measured parameters are collected in the MAIN DC further calculation can be done, which are described above. Furthermore, the calculated results together with additional information (about the locations of measurement, alarm zone, temperature and etc.) can be send via MMS, from MAIN DC, through the current GSM/GPRS network to the receiver/client. In future, with novel 3G (Universal Mobile Telecommunications System) and 4 G mobile networks in combination with those sensor networks, will appear new applications and new potentiality (like better resolution of the MMS picture, more detail information, remote deactivation of some alarms, better QoS support an etc) for delivering the measured results and outputs from the model.

V. Conclusion

The conceptual diagram of the ecological management system, with data acquisition module using advance routing algorithms to process the data to the base station database is presented in this paper. The data from the sensors is then used to build a mathematical model of the TP concentration to predict the short-term dynamic of the ecosystem.

The entire ecological management system helps to improve the decision-making process in many important ways. The gathered data gain from this system, can be processed in real time using first of all services from the internet to gain data, process this data through ecological model which in fact improves in time, as the data comes as input parameter.

Our results have clearly pointed of the alarming condition of the Lake Prespa surface water and it’s pollution with phosphorous component. Building a water waste management can prevent this further growth of available phosphorous inside of the lake. With these results at hand, we propose preventing system for this rare aquatic system from extinction of many spices and living organisms. For fast and accurate collecting data we propose implementation of seven sensor networks is of significant value, due to the easier and flexible performing of measurements, and the on-demand necessity of measured parameters for calculation of the model outputs in future work, from telecommunication point of view. Implementation of more complex processes, with new differential equations may give us more reliable picture on what is happening within the lake ecosystem. Also, visualizing with GIS application can give more reliable picture of the influence of the toxic element on the lake ecosystem, such as phosphorus component. By taking more complex processes and interaction between the organisms it’s possible to build bigger and more complex model that inspect different aspects of environmental engineering. In future, more experiments must be done, with implemented sensor networks, with one aim - the more satisfied routing algorithm to be chosen with effective QoS provision. For future building more advance expert systems, similar like this one, analyzing the data with more precision or advance algorithm, such as data mining (decision trees, rule induction, fuzzy logic and etc.) which have been proved for extracting valuable knowledge about the ecological information of the ecosystem must be investigated and implemented.

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