International Scientific Conference *People, Buildings and Environment 2014* (PBE2014)
15-17 October, 2014, Kroměříž, Czech Republic, www.fce.vutbr.cz/ekr/PBE

AN APPROACH TO WATER QUALITY MANAGEMENT IN RURAL AREAS

Gorana Ćosić-Flajsig [1]*, Barbara Karleuša[2]

[1] Polytechnic of Zagreb, Department of Civil Engineering, Zagreb, Av. V. Holjevca 15, Zagreb
[2] Faculty of Civil Engineering – University of Rijeka, Radmile Matejčić 3, 51 000 Rijeka

Abstract

Implementation of the Water Framework Directive is a key starting point for integrated river basin management. Lack of sanitation in communities less than 2000 People Equivalent (PE), combined with agricultural activities, represent a special challenge for national water quality management. Sanitation for agglomerations smaller than 2000 PE in the rural areas represent a big source of organic pollution not tackled by EU legislation, and a threat for achieving good status for all water bodies and environmental objectives of the river basin. Croatia and Slovenia comprise a large area of agglomerations smaller than 2000 PE. Proper management of those areas is crucial for preserving water resources, as well as biodiversity. This paper will analyze the management of rural areas using the DPSIR (Driving Forces - Pressures - State – Impact - Response) approach taking into account the principles of sustainability. Successful management of rural areas includes a variety of measures ranging from expensive sanitation of point and diffuse sources of pollution to low-cost solutions for pollution prevention of water bodies. The use of appropriate mathematical models can assist in responding to environmental impact assessment and the optimization of the measures. The paper will present preliminary analysis of the mathematical models, as their applied and limiting possibilities for water quality management of the river basin. The preliminary selection of the appropriate models for small, rural, agricultural Sutla river basin as assessed by SWAT watershed model showed that it is most applicable and can be adapted or upgraded according to specific needs.

Key words

DPSIR approach; rural areas; organic pollution; environmental impact assessment; mathematical models

To cite this paper: *Ćosić-Flajsig, G., Karleuša, B. (2014). An approach to water quality management in Rural areas, In conference proceedings of People, Buildings and Environment 2014, an international scientific conference, Kroměříž, Czech Republic, pp. 545-557, ISSN: 1805-6784.*

*Corresponding author: Tel.: +385-98-406-725
E-mail address: gcflajsig@tvz.hr

1 INTRODUCTION

Implementation of the European water policy and Water Framework Directive (hereinafter referred to as WFD) is a key starting point for integrated river basin management and introduces the necessity for applying new methodological approaches for the sustainable management of water resources.

Rural river basins, with the lack of sanitation in smaller communities (e.g. less than 2000 People Equivalent ("PE")) combined with intensive agricultural activities in those communities, represent a special challenge for national water quality management. Their solution contributes to management of point and diffuse sources. Additionally, sanitation for agglomerations smaller than 2000 PE is not included as priority measure in the European water policy. This problem is solved by national implementation programmes and measures.

Thus, rural areas represent a big source of organic pollution not tackled by EU legislation and a threat for achieving good status for all water bodies and environmental objectives of the river basin. Moreover, in countries like Croatia and Slovenia there are agglomerations smaller than 2000 PE (more than half of the territory). Proper management of those areas is crucial for preserving water resources as well as biodiversity. Stricter water protection, by implementation of “combined approach” is a prerequisite for achieving good water status and fulfilling several environmental protection objectives in the river basin.

Some methodological approaches to implementing parts of such a complex Directive have been developed in Europe [1]; Borja et.al., 2004 a, b, c [2], [3], [4]. Taking into account the considerable amount of work to be carried out, some complementary research should be undertaken in order to accomplish WFD, DPSIR (D-Driving Forces: P-Pressure: I-Impact: S-State: R-Responsible) framework approach and the above mentioned environmental objectives.

According to [1], pressures and impacts assessment is ideally a four-step process:

- describing the *driving forces* especially land use, urban development, industry, agriculture and other activities which lead to pressures, without regard to their actual impacts,
- identifying *pressures* with possible impacts on the water body and on water uses, by considering the magnitude of the pressures and susceptibility of the water bodies;
- assessing the *impacts* resulting from the pressures; and
- evaluating the *risk* of failing the WFD objectives.

The analysis of pressures and impacts mostly considers how pressures would be developed, prior to 2015, in ways that water body would be at risk of failing to achieve ecological good status if appropriate programmes of measures were not designed and implemented [5]. Therefore, it is not clear how to assess, in practice, the risks of failing to achieve this objective. Clarification may be provided in the daughter Directive, to be established under Article 17, related to criteria for the identification of significant upward trends.

The analysis of the watershed models for impact assessment on water bodies, respectively the preliminary analysis and the selection of watershed models that would be suitable for solving the problems of the Sutla river basin, will be presented in this paper.

2 SUTLA RIVER BASIN

Related to problem of rural river basins, the research has been done on the Sutla river basin case study (Figure 1). In the past, the organic pollution from point and diffuse sources, as hydrology and hydraulic features of the river, caused the eutrophication in the river Sutla basin. Despite of the implemented water quality measures, especially the construction of waste water treatment plants, related to monitoring data - river Sutla is loaded with organic substances and nutrients (Figure 2). The possibility of river's eutrophication still exists.

River Sutla (Sotla) forms the border between the Republic of Slovenia and Republic of Croatia. The size of the Sutla river basin is almost 600 km^2. The Sutla Lake/Vonarje reservoir of 12.4 million m^3 was built and filled in 1980. The main purpose was drinking water supply for both, Slovenian and Croatian settlements and flood protection of downstream areas. Shortly after filling, water in the reservoir became eutrophicated.

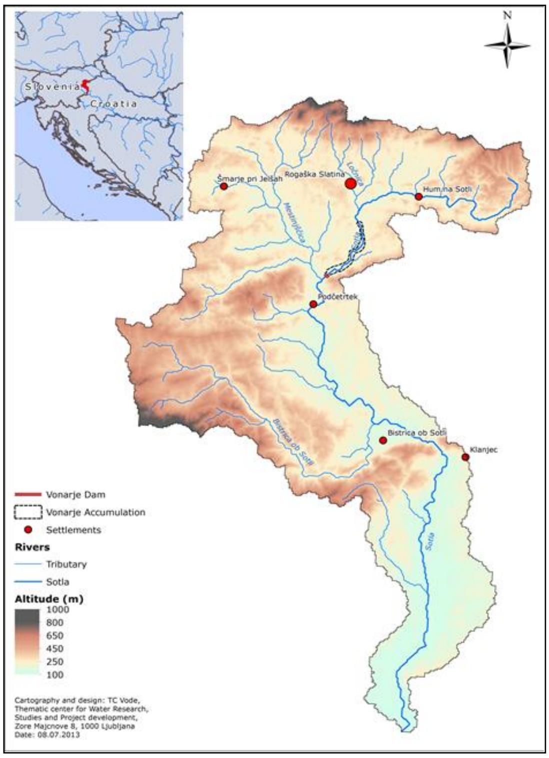


Fig. 1: *Location of Sutla river and Vonarje Reservoir/Sutla Lake*

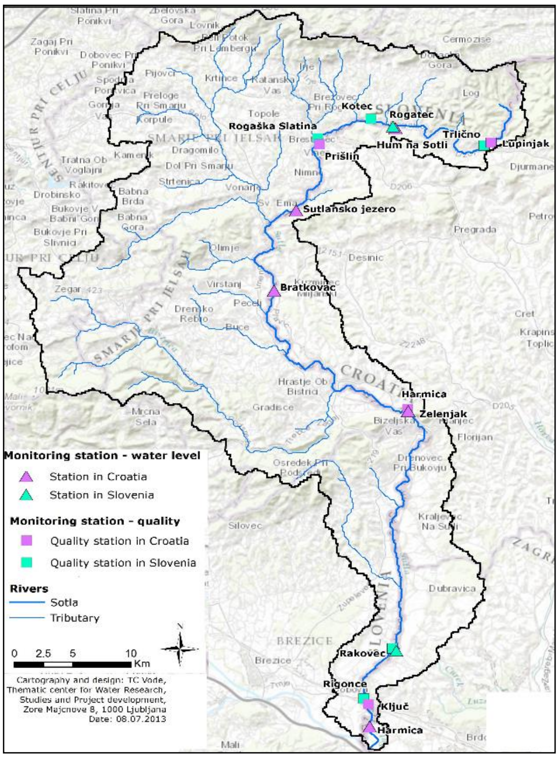


Fig. 2: Monitoring stations of water level and monitoring station of water quality

Besides, other extreme water quality problems have been detected not only in the lake water but also in the river water downstream. Due to high risk for the humans and the environment that has been hardly managed successfully, in the absence of better remediation measures, the reservoir was completely drained in 1988. It now operates only as a dry retention basin for flood protection (Figure 3). Wetland ecosystems have been developed in the bottom of nature retention/reservoir. This has been the reason that the area of the reservoir, as well as the entire river Sutla, has also been declared as NATURA 2000 site.

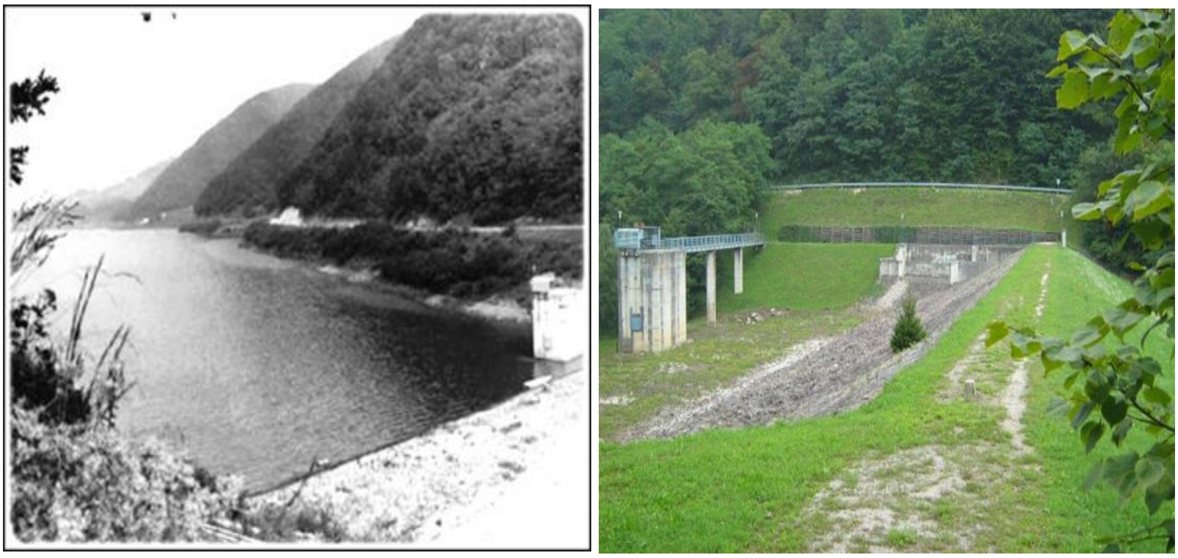
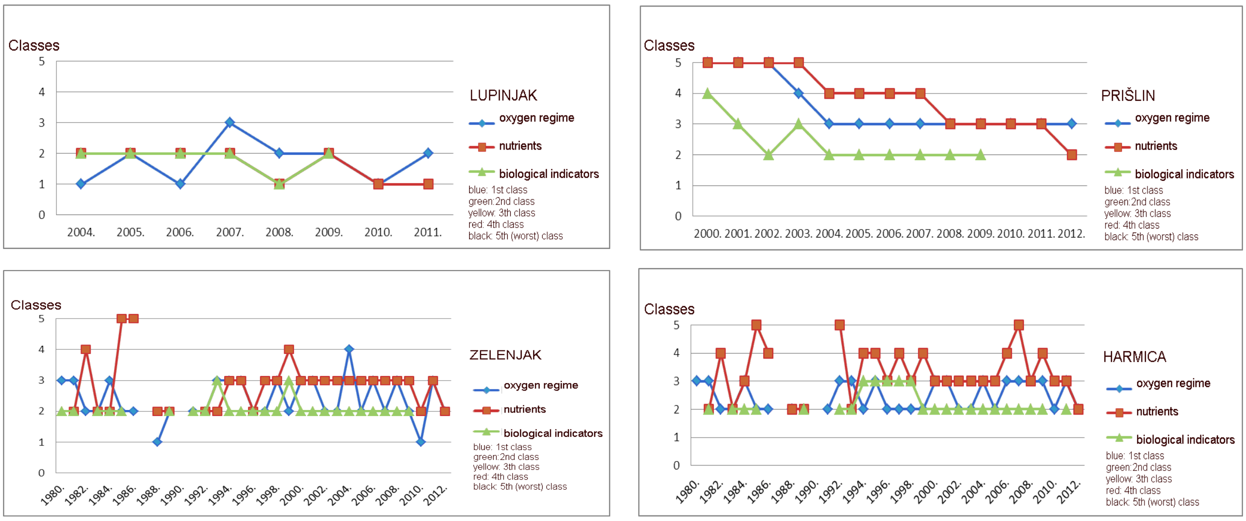


Fig. 3: Sutla Lake in the past and now

Massive blooms of planktonic algae occur in severe cases of eutrophication. Some blooms are toxic. As dead algae decompose, the oxygen in the water is used up; bottom-dwelling animals die and fish either die or leave the affected area. Increased nutrient concentrations can also lead to changes in the aquatic vegetation. The unbalanced ecosystem and changed chemical composition make the water unsuitable for recreational and other uses such as fish farming. The water becomes unusable for human consumption. The main source of nitrogen pollution is run-off from agricultural land, whereas most phosphorus pollution comes from households and industry.

Related to monitoring data some problems frequently occur in the water quality monitoring station Prišlin, the location where concrete bulkhead is built to form Sutla Lake (Figure 4.).



Monitoring station	chem. and phys. elements 2010	chem. and phys. elements 2011	biol. elements. makrozoobentos 2011	chem. and phys. elements 2012	biol. elements makrozoobentos 2012
Harmica	good	good	good	good	good
Zelenjak	good	good		good	good
Prišlin	poor	bad		bad	moderate
Lupinjak	good	good			

Fig. 4: Trends of water quality classes for four monitoring stations in Croatia

3 DPSIR FRAMEWORK APPROACH

DPSIR framework approach - Driving forces, Pressures, State, Impacts and Responses elements for a chosen (analysed) environmental issue operates through a set of indicators and indexes. European and international experiences in management of rural areas, using a life-cycle concept with the problem-oriented DPSIR approach taking into account the principles of sustainability including the environment, sociology and economy, have been applied on Sutla river basin. The issues that authors considered in the area of Sutla river basin are the reasons for eutrophication and organic pollution, as the necessity of their prediction will be explained in the following chapter.

Based on the example of Sutla river basin, the application of DPSIR approach will be presented.

Driving forces lead to human activities that exert pressures on the environment, as a result of production or consumption processes, which can be divided into three main types a) excessive use of environmental resources, b) changes in land use, and c) direct or indirect emissions (of chemicals, waste, radiation, noise) to air, water and soil. They may exert hazard to human health and change natural state of environment compartments (air, water, soil, biodiversity). The state of environment is described with physical, chemical and biological conditions. The changes in the physical, chemical or biological state of the environment determine the quality of ecosystems and the welfare of human beings. In other words, changes in the state may impact the functioning of ecosystems, their life supporting abilities, and ultimately human health and the economic and social performance of society.

Describing the causal chain from driving forces to impacts and responses is a complex task, and tends to be broken down into sub-tasks, e.g. by considering the pressure-state relationship. The DPSIR framework can be used as an analytical tool for assessing and modelling water issues. A DPSIR framework for water is shown in Figure 5.

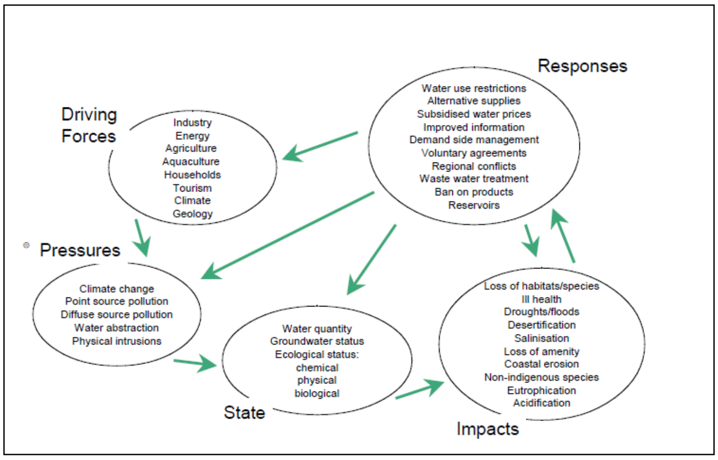


Fig. 5: A DPSIR framework for water environment

Many of the pressures, relevant for Sutla river basin, and the underlying driving forces are common to all or a number of the issues. For example, *agriculture* is a significant driving force in terms of ecological quality of water, water pollution by nutrients and hazardous substances. *Dams and accumulation of water*, as it is the case of dams on the Sutla river, even being „stopped“ for a short period of time, cause high physical and hydrological (water flow dynamics) pressures on river ecosystems and eventually a deterioration of river ecological quality. *Expanding urbanisation and intensifying industrial and socio-economic-financial service activities* increase demands for water supply. Urbanisation is identified as „driving force“, water pumping is identified as „pressure to water resources“. As a consequence, ecological quality of river deteriorates due to less water in river (water quantity problem).

Identification and description of the driving forces

In order to predict how socio-economic forces might affect the water quality, it is necessary to describe the present drivers influencing the pressures in the study area.

Identification of significant pressures related to Sutla river basin

The significant anthropogenic pressures are: (a) point source pollution, (b) diffuse source pollution, water abstraction for urban, industrial, agricultural and other uses, (c) water flow regulation, on overall flow characteristics and water balances, (d) morphological alterations to water bodies, (e) other anthropogenic impacts on the status of surface waters, and (f) land use patterns, including identification of the urban, industrial and agricultural areas, fisheries and forests.

All the information had to be integrated in the GIS for later spatial analysis, following the requirements of the WFD guidance on GIS (Vogt, 2002). [6]

Although the WFD establishes that significant pressures should be considered in the risk assessment, neither the WFD nor IMPRESS (2002) [5] determine the meaning of „significant“. This might mean any pressures, and may lead to failing to achieve the specified objectives. Such an interpretation introduces a scale – dependence.

Identification of the most relevant pressures

After studying all the information compiled in the GIS, nine relevant pressures were identified in rural river basin and some of them identified in Sutla river basin:

(i) *pressure from nutrients*;

The nutrients modify the ecosystems and cause eutrophication, as the most important impact. By comparing the total nutrient loads, with sensitivity, a pressure level has been derived.

(ii) *water pollution* as the percentage of water samples not complying with the quality objectives for some priority substances;
(iii) *the surface of water body containing polluted sediment* was used also to determine sediment pollution pressure;
(iii) *abstraction of water* can modify natural flows, representing hydrological reference conditions;
(iv) *morphological changes;*
(v) *shoreline reinforcement* causes morphological changes;
(vi) *intertidal losses* in response to land reclamation;
(vii) *the number of berths* as another index of morphological changes,
(viii) *taking into account that most of the fish are caught out of water bodies*, benthic alien species are the only relevant biological pressure.

Assessing the impact of water bodies

Assessment of the environmental impact and the impact of water bodies can be made by some indicators or by watershed mathematical models to provide holistic interpretations of how natural systems driven by hydrologic processes are impacted by anthropogenic disturbances.

Assessing the risk of failing the WFD objectives

By comparing overall pressures and detected environmental impacts, on each water body, following the methodology, it is possible to assess the risk of failing to achieve the WFD objectives and good ecological status, by 2015.

4 WATERSHED MODELS FOR THE ASSSESSING OF THE WATER BODIES IMPACT

As the part of the water quality management for rural river basins, successful management of rural areas (small agglomerations) includes a variety of measures ranging from expensive sanitation of point and diffuse sources of pollution to low-cost solutions for pollution prevention of water bodies. The proposed methodology includes: assessment of the water body impact, the risk assessment of failing to achieve WFD objectives, and optimization of available measures (construction and non-structural measures). For all the crucial issues, the methodology proposes the use of appropriate mathematical models that can help with responding to these requests.

The popularity of watershed models is no surprise due to their ability to provide holistic interpretations of how natural systems, driven by hydrologic processes, are impacted by anthropological disturbances. The model structure is generally designed for representing the components of the hydrologic cycle: precipitation, infiltration-surface runoff, evapotranspiration, interflow, groundwater, and stream flow [6]. From the large group of watershed models, small number of watershed models that are public to approach and suitable to use in rural river have been analysed and briefly described.

Some watershed models simulate the components of the hydrological cycle using algorithms that differ among the models. Watershed models simulate natural processes of the flow of water, sediment, chemicals, nutrients, and microbian organisms within watershed, as well as quantify the impact of human activities on these processes. Simulation of these processes plays a fundamental role in addressing a range of water resources, environmental, and social problems. The current generation of watershed models is quite diverse and varies significantly in sophistication of data and computational requirements.

Today it is difficult to think of an environmental or water resources problem where solution does not involve application of some kind of watershed model. Watershed models have become a main tool in addressing a wide spectrum of environmental and water resources problems, including water resources planning, development, design, operation and management.

Assessing the impact of climate change on national water resources and agricultural productivity is made possible by watershed models. Water allocation requires integration of watershed models with models of physical habitat, biological population, and ecosystem response.

Comparison of watershed models

There are numerous watershed models, and their diversity is so wide that one can easily find more than one watershed model for addressing any practical problem. Many models are quite comprehensive in that they can be applied to a range of problems. Several models attempt to integrate ecosystems and ecology, environmental components, biological systems, geochemistry, atmospheric science, and coastal processes with hydrology – well distributed in space and time.

Although watershed models have become increasingly sophisticated there is a long way to go before they become “household“ tools[7]. Most of them aren’t user - friendly, they have large data requirements, lack of quantitative measures of their reliability, clear statements of their limitations, and clear guidance as to the conditions for their applicability. Also, some of the models cannot be embedded in social, political, and environmental systems.

Data systems

Each data set is examined with respect to homogeneity completeness, errors, and accuracy. Storage, handling, retrieval, processing, management, analysis and manipulation of data are other important issues in data processing.

GIS and DBMS

Geographical information systems (GIS), data base management systems (DBMS), and graphic and visual design tools are employed for processing of large quantities of data (Singh and Fiorentino, 1996). They are integrated with watershed hydrology models for designing, calibrating, modifying, evaluating, and comparing watershed hydrological models. The use of GIS permits subdividing a watershed into hydrologically homogenous subareas in both horizontal and vertical domains. With GIS, it is possible to delineate soil loss rates, identify potential areas of nonpoint source agricultural pollution, and map groundwater contamination susceptibility. GIS enhances the ability to incorporate spatial details and with much better resolution of terrain, streams, and drainage areas, and the ability to delineate more appropriate grid layers for a finite-element or finite-difference watershed model. Analyses of the watershed models have been done related to some criteria: scenario analysis, applicability of the quantification tools in different conditions, calibration and validation approaches and performance evaluation methods and watershed modelling systems: GIS interface, hydrology, hydraulics, surface flow, subsurface flow, sub-models.

Based on analysis of available works, this paper presents the most important and suitable results related to the comparison procedures, the most important parts of the work that deals with the analysis of models and their applicability to different aspects, and some approaches related to different scenarios.

With respect to scenarios dealing with the nutrient management strategies, it is clear that models that include agricultural practices will potentially have the ability to predict the impact of land management strategies on nutrient losses on surface waters due to changes in the amounts and timings of applications of nutrient input related to fertiliser and manure [8]. In order to ensure adequate tools for the end user, the European Commission has financially supported EUROHARP [8]. Current European needs for harmonization and transparency project have met the quantitative assessment of diffused sources of nutrient losses. EUROHARP project encompasses 22 research institutes from 17 European countries (2002-2005). This project compared nine different catchment models for simulation of the non-point sources of pollution from agriculture on numerous catchments in Europe (Table 1). Overview of the strengths and weaknesses has been done for all nine common used models. The results of the project ranked Soil and Water Assessment Tool (SWAT), along with Nutrient Losses on CATchment scale (NL-CAT) and Transport - Retention - Source Apportionment: Pollution Loads to the Sea (TRK-N) models in the top three, suitable for all types of scenario analysis. Thus, only SWAT and TRK out of the nine EUROHARP models were very suitable for the purpose to model eutrophication issues. The model NL-CAT has not been tested outside The Netherlands. For TRK model high skill level for application is required. For small rural river basin, with great impact of agriculture, SWAT is the most suitable model. SWAT model is expected to give the best results. SWAT is open to researchers' and modellers' community and provides great possibilities for education.

EUROHARP study also showed that the modellers are not yet able to propose only one on the best and the most appropriate model for all river basins in Europe, because the quality of the models is based on the input data quality along with quality of modellers.

Tab. 1: Potential suitability of models for three types of scenario analysis [8]

QT	Nutrient Management	Land use Changes	Water Measures
EVENFLOW-N	0	+	+
MONERIS-N	+	+	-
MONERIS-P	+	0	-
NLCAT-N	++	++	++
NLCAT-P	++	+	++
N-LES CAT-N	+	0	-
NOPOLU-N	0	0	-
NOPOLU-P	-	-	-
REALTA-P	-	-	-
SA-N	-	-	-
SA-P	-	-	-
SWAT-N	++	++	++
SWAT-P	+	+	++
TRK-N	++	++	++
TRK-P	-	-	-

++ very suitable (e.g. dynamic effects on turnover are modelled)
+ suitable (key processes are considered, at least in a lumped manner)
0 more or less suitable (e.g. only long-term effects assessed without major recalibration)
- not suitable (model does not take account of management practices)

The applicability of the quantification tools is the most complicated question to consider because different criteria can be used to qualify applicability. In the EUROHARP study the models have been ranked related to the following criteria of suitability: climatic conditions, landscape, flow path, agricultural activities and soil conditions (Table 2). Related to defined criteria, the most applicable models for Croatian rural river basins are SWAT and NL-CAT.

Tab. 2: Overview of the tentative suitability/applicability of the quantification tools to apply the tool on different conditions that occur within Europe [8]

	Climatic conditions						Landscape					Flow paths				Agricultural activity			Soil conditions		
	N	W	M	S	SE	NE	M	H	P	D	R	R	SS	AD	DG	I	M	E	UD	US	S
NLCAT-N	+/-	++	++	+/-	+	+/-	+/-	+	++	++	+	+/-	++	++	++	++	++	+	++	+	++
NLCAT-P	+/-	++	++	+/-	+	+/-	+/-	+	++	++	+	+/-	++	++	++	++	++	+	++	+	++
SWAT-N	+/-	++	++	+	+	+/-	+/-	++	+	+/-	+	++	++	++	++	++	++	++	++	+	++
SWAT-P	+/-	++	++	+	+	+/-	+/-	++	+	+/-	+	++	++	++	++	++	++	++	++	+	++
TRK-N	++	++	++	+/-	+/-	++	+/-	++	++	+/-	+/-	+/-	++	++	+	++	++	++	++	++	++
TRK-P	+	+/-	+/-	+/-	+/-	+/-	+/-	+	+	+/-	+/-	+	++	++	+	-	+/-	-	++	++	++
MONERIS-N	+/-	++	++	+	+	+	+	++	++	+	-	++	++	++	+/-	++	+	+	+	+	+
MONERIS-P	+/-	++	+	+	+	+	+	+	+	+	-	+	+	+	+/-	++	+	+	+	+	+
EVENFLOW-N	+/-	+	+	+/-	+	+	+	+	+	-	-	+	+	+	+/-	++	++	+/-	+	+	+
N-LESS-CAT-N	+/-	++	+	+/-	+/-	+	+/-	+	+	+/-	+/-	-	-	-	-	++	++	+	+	+	+/-
NOPOLU-N	+/-	+	+	+	+	+	+/-	+	+	+	+	+	+	+	+	+	+	+/-	+	+	+
NOPOLU-P	+/-	+	+	+	+	+	+/-	+	+	+	+	+	+	+	+	+	+	+/-	+	+	+
REALTA-P	-	++	+/-	+/-	+/-	-	+/-	++	-	+/-	-	++	-	-	-	++	++	++	+	+	+
SA-N	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SA-P	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+

++ = very suitable; + = suitable; +/- = uncertain; - = not suitable/applicable
Climatic condition: Northern Europe (no, Swe,F); Mid Europe (Ger, Au, Sw, Czs.Rep); West Europe 8UK, Ire, Dk, NL, Be, Fr); Southern Europe (Sp, It, Gr)**; Easter and South Easter Europe (HU, SK,SL, HR, YU, BG, MO);** North eastern Europe (Pl, ES, LT,LI); **Riparian zone**: Mountainous; Hilly; Plains; deltas; Riparian zones**; Flow paths**: Runoff; Subsurface drainage; Artificial drainage; deep Groundwater flow; **Agricultural activity**: Intensive, Moderate; Extensive; **Soil conditions**: Unstructured Deep soils; Unstructured Shallow soils; Structured soils (e.g. clay and peat)

To provide a common background and platform for consensual development of calibration and validation guidelines, model developers [9] have ranked watershed models (Table 3). The models range from field to watershed scales for simulating hydrology, sediment, nutrients, bacteria, and pesticides at temporal scales varying from hourly to annually. SWAT model and its calibration and validation approach are satisfactory.

Tab. 3: Summary of calibration and validation approaches and performance evaluation methods and criteria as suggested by the developers and/or expert users of the H/WQ models in this collection [10]

Model	**Calibration Approach**	**Validation Approach**	**Suggested Performance Evaluation Methods and Criteria**	**References**
SWAT	Systematic processes: hydrology, sediment nutrients, pesticides, (including budgets). Manual and automated.	Split sample, adjacent watershed	Statistical: coefficient of determination, Nash Sutcliffe efficiency, root mean square error, percent bias, objective functions, autocorrelation, cross-correlation, non-parametric- tests, t-test, Graphical: time series	Arnold et.al.,2012
SWIM	Manual, water balance	Split sample, adjacent watershed	Statistical: Nash Sutcliffe efficiency, root mean square error to standard deviation ratio mean error, mean absolute error, 95 % confidence interval Graphical: time series	Huth et al., 2012
TOUGH2	Weighted least squares objective function with several minimization algorithms	Use uncertainty analysis based on linear or first-order second – moment error	Statistical: minimum value of objective function	Finsterle et.al., 2012
VS2DI	Manual, parameter-estimation programs (e.g.PEST)	Split sample	Statistical: weighted correlation coefficient Graphical: time series	Healy and Essaid, 2012
WAM	Process-based: source cell nutrient load and flow generation, cell to stream routing, and in-stream routing	Split sample	Statistical: weighted correlation coefficient, root mean square error, Graphics: time series	Bootcher et.al.2012
WARMF	Systematically adjust model input parameters within normal ranges to beginning with flow. Manual and automated.	Split sample, adjacent watershed	Statistical: relative error, absolute error Graphical: time series	Herr and Chen, 2012
WEPP	Stepwise procedure: hydrology, erosion	Split sample, adjacent watershed	Statistical: means, standard deviation , root mean square error, percent bias, Sutcliffe coefficient, relative root mean square errors	Fanagan et.al., 2012

Authors of the article [10] have also prepared analyses of the characteristics and features of watershed models (Table 4). SWAT model, as sub-model of Automated Geospatial Watershed Assessment Tool (AGWA) system and Better Assessment Science Integrating point & non-point Sources (BASINS) system, is the most applicable model for rural areas. It is the most suitable model for agriculture watersheds, excellent for calculating Total Maximum Daily Load (TMDL) and simulating a wide variety of conservation practices and other BMPs. SWAT has been successfully applied across watersheds in several countries and it is publicly available. Main components of the model are: hydrology, weather, sedimentation, soil temperature and properties, crop growth, nutrients, pesticides, agricultural management and channel and reservoir routing.

Tab. 4: Watershed Modelling Systems Summary [10]

System	GIS Interface	Hydrology	Hydraulics	Surface	Subsurface	Sub-Models
AGWA	ArcView 3x	yes	yes	yes	yes	KINEROS, SWAT
BASINS	Map Window	yes	yes	yes	no	PLOAD, AUATOX, WinHSPF, AGWA
MODFLOW-What		no	yes	yes	yes	DAFLOW, RT3D, BLTM
SAC		no	no	no	no	
WEPP	ArcView	no	yes	yes	yes	MASS2
WISE	yes, unknown	yes	yes	yes	no	HEC-1,HEC-2, HEC-RAS, FLO-2D, CHAMPS, WHAFIS, SWMM,NSPM
WMS	ArcView	yes	yes	yes	yes	HEC-1,TR-20, TR-55, NFF, MODRAT, OC Rational, HSPF, HEC-RAS, SMPDBK, CE-QUAL-W2,GSSHA

Related to previous analysis of the watershed models is concluded that SWAT model is most appropriate model for Sutla river basin. The SWAT model is physically based, deterministic, watershed-scale simulation model developed by United States Department of Agriculture **(**USDA**)** Agricultural Research Service [11]. SWAT has evolved from numerous individual models over a 30-year period and has been tested for a wide range of regions, conditions, practices, and time scales. Gassman et.al. are summarized more than 250 referred journal articles reporting researches using SWAT around the world [12]. Evaluation of daily, monthly, and streamflow and pollutant outputs indicate that SWAT functioned well in a wide range of watersheds.

Overview of the potential strengthens and weaknesses of the quantification tools of the SWAT is given in Table 5.

Tab. 5: Overview of the potential strengths and weaknesses of the quantification tools of the SWAT [8]

Watershed model	Strengths	Weaknesses
SWAT	- The model describes in detail the complete N and P cycles and fate in streams - Continuous in time and capable of simulating long periods for scenario analysis e.g. management or climate changes - Allows point sources impact to be modelled - Quite widely used all across the world and in Europe - Computationally efficient to operate on large basins in a reasonable time - Available for ESRI ArcView (Windows NT/2K) and GRASS (Unix) GIS - Allows a flexible watershed configuration (unlimited number of sub-watersheds) - Very co-operative users' network	- Forest growth simulation is poor - P simulation somewhat simple - Hydrological Response Units are not georeferenced within a sub-basin - Extensive input data requirements

SWAT is being increasingly used to assist watershed planning with increased sophistication for targeting critical pollutant source area and practices. Modellers have demonstrated the importance of temporally and spatially accurate model input data, such as precipitation and land use. No studies were presented, related to authors information, that connected SWAT hydrologic and water quality results to their impact on ecosystem services. This observation points out the need for increased integration of SWAT and other watershed models with climatic, ecologic, and socio-economic models to better represent the impact of landscape management and society [12].

The use of SWAT model has to be included in the integrated modelling framework (Figure 6) with different models for: scenarios, technology for data access and environmental characteristics, other watershed models (water quality, mercury, aquatic community, habitat), simulating poss-processing (ecosystem services) and technology for simulation, calibration, optimisation and visualisation.

Related to research results and experience on Reka and Dragonja catchment areas [13], small rural transboundary catchment areas between Croatia and Slovenia, like Sutla catchment area, the SWAT watershed model proved to be suitable for small rural catchment areas. Authors of [13] have explained that SWAT is able to represent hydrologic behaviour of heterogeneous catchments and rivers. Related to available data, model is able to represent sediment and nutrients load concentrations and cumulative distributions. Model's results can demonstrate diffuse pollution control with agri-environmental measures. Measured nutrients, N from agricultural activities and P from point sources, and their critical ratio, can cause eutrophication of the freshwater ecosystem, as it presented in Table 5.

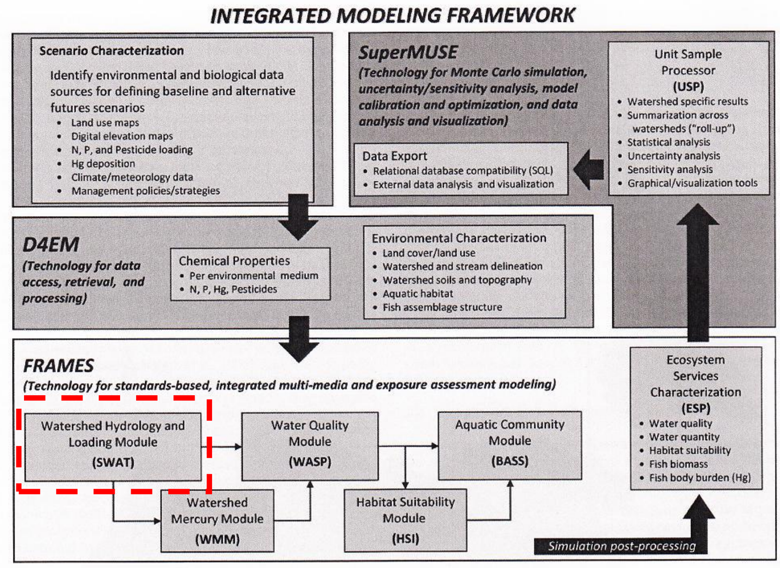


Fig. 6: Conceptual diagram of the Integrated Modelling Framework [14]

6 CONCLUSIONS

DPSIR, problem oriented approach for Water Framework Directive EU and methodological approach to assess the risk of failing to achieve good ecological status, is the starting point for solving eutrophication problems. Assessment of the environmental impact and the impact on water bodies can be done by using watershed mathematical models.

Related to problems of small rural river basins, the case of Sutla river basin and need for water body impact assessment and risk assessment of not achieving good status have been analyzed. Based on a preliminary analysis of the available commercial models, presented in this paper, it can be concluded that they cannot give all the answers for successful river basin management. Based on the analysis of published works, each watershed model has its limitations.

For the small, rural, agricultural Sutla river basin is assessed that SWAT watershed model is applicable for the part of the problems related to hydrology, land use, nutrient pollution for point sources and diffuse sources, etc. The advantages of SWAT watershed model are GIS presentation availability and very co-operative users' network. For other problems related to river basin Sutla, as is it usage of the nature retention, preserving the sites of NATURA 2000 and usage of ecosystem service, watershed model has to be adapted or upgraded according to specific needs, or some other models can be used.

ACKNOWLEDGMENT

The publication of this paper is supported by University of Rijeka (research project support: 13.05.1.3.08 – Development of new methodologies in water and soil management in karstic, sensitive and protected areas).

REFERENCES

[1] Borja A., Galparsoro I., Solaun O., Muxika I., Tello E.M., Uriarte A., Valencia V.,(2006), The European Water Framework Directive and DPSIR, a methodological approach to assess the risk of failing to achieve good ecological status, Estuarine, *Coastal and Shelf Science*, **66**, pp. 84-96.

[2] Borja A. et.al., (2004), Implementation of European Water Framework Directive from the Basque Country (methodological approach), *Marine Pollution Bulletin*, **48**(3-4), pp. 209-218.

[3] Borja A. et.al, (2004), The Biotic Indices are the Water Framework Directive: the required consensus in the benthic monitoring tools, *Marine Pollution Bulletin*, **48**(3-4), pp. 405-408.

[4] Borja A. et.al. (2004), The Water Framework Directive: water alone or in association with sediment and biota, in determining quality standards? *Marine Pollution Bulletin*, **49**(1-2), pp. 8-11.

[5] IMPRESS (2002) Guidance for the analysis of pressures and impacts in accordance with the Water Framework Directive. Common Implementation Strategy Working Group 2.1., 156 pp. Office for Official Publications of the European Communities. Retrieved on July 12, 2005 from http:// forum. Europa.eu.int/Public/irc/env/wfd/library, ISBN:92-894-5123.

[6] Migliaccio K.W., Srivastava P., (2007) Hydrologic Components of Watershed-Scale Models, *American society of agricultural and Biological Engineers*. ISSN 0001-2351, **50**(5), pp. 1695-1703.

[7] Singht Vija P., Frevert Donald K., (2006), Watershed Models, ISBN 0.8493-3509-0

[8] Schoumans O.F., Silgram M., (2003), Review and Literature Evaluation of Quantification Tools for the Assessment of Nutrient Losses at Catchment Scale, EUROHARP 1-2003.

[9] Moriasi D.N., Wilson B.., Douglas-Mankin K.R., Arnold J.g., Gowda P.H., (2012). Hydrologic and Water Quality Models: Use, Calibration, and Validation, *American Society of Agricultural and Biological Engineers*. ISSN 2151-0032, **55**(4), pp. 1241-1247.

[10] Edsel B.D., Camp J.V., LeBoeuf E. J., Penrod J.R., Dobbins J.P. and Abkowitz M.D., (2011), Watershed Modeling and its application; A State-of-the-Art Rewiew, *The Open Hydrology Journal*, 2011, **5**, pp. 26-50.

[11] Douglas-Mankin K.R. (2010), Soil and Water Assessment Tool (SWAT) Model; Current Development and application, *American Society of Agricultural and Biological Engineers*, ISSN 2151-0032, **53**(5), pp.1423-1431.

[12] Gassman et.al., (2007), The Soil and Water Assessment. *Tool: Historical development, applications, and future research directions*, trans. ASABE, **53**(3), pp. 711-740.

[13] Glavan M. and Pintar M., (2012), Modelling of Surface Water Quality by Catchment Model SWAT, *Studies on Water Management Issues*, ISBN 978-953-307-961-5. Available at: www.intechopen.com

[14] Johnston J.M. et.al., (2011), An integrated modelling framework for performing environmental assessments: Application to ecosystem services in the Albemarle-Pamlico basins (NC and VA, USA), *Ecological Modelling* **222**, pp. 2471-2484.