

International Symposium:

**CROSS-BORDER DRINKING
WATER MANAGEMENT**

**29th January 2016
Rijeka, Croatia**

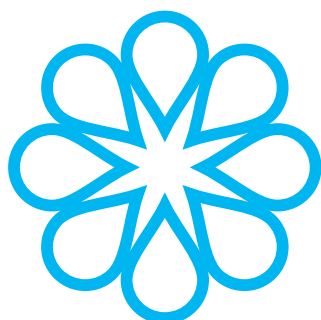
PROCEEDINGS



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DRINK ADRIA

Symposium organizers	University of Rijeka, Faculty of Civil Engineering
Symposium coorganizers	Water Utility of Istria Region of Istria Croatian Geological Survey
Publisher	University of Rijeka, Faculty of Civil Engineering
Editors	Barbara Karleuša, Ivana Sušanj
Graphic preparation	Ivana Sušanj, DRINKADRIA (Networking for drinking water supply in Adriatic region) and Tiskara Viškovo j.d.o.o.
Graphic identity:	DRINKADRIA (Networking for drinking water supply in Adriatic region)
ISBN:	978-953-6953-45-5
CIP:	CIP record is available in a computerized catalog of the University library Rijeka under the number 130816028
Press:	Tiskara Viškovo j.d.o.o.
Copies:	200

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University of Rijeka, Faculty of Civil Engineering (Croatia)

Josip Terzić

Croatian Geological Survey, Zagreb, (Croatia)

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Tamara Crnko

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(Croatia)*

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Croatian Geological Survey, Zagreb, (Croatia)

Ivana Radman

*University of Rijeka, Faculty of Civil Engineering
(Croatia)*

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Authors

Primož Banovec
Marija Brajković
Dejan Dimkić
Barbara Čenčur Curk
Melita Čohilj
Marina Filipović
Tihomir Frangen
Mohor Gartner
Kristjan Gašperin
Nataša Jakominić Marot
Barbara Karleuša
Bruno Kostelić
Nino Krvavica
Jasmina Lukač Reberski
Mircea Margarit Nistor
Tamara Marković
Marko Marjanović
Pravoslav Marjanović
Branislava Matić
Natalija Matić
Marijana Miletić-Radić
Marijuča Nemarnik
Nevenka Ožanić
Dragana Pejović
Ivana Radman
Josip Rubinić
Alen Sprčić
Josip Terzić
Vanja Totman
Goran Volf

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Preface

The key objectives of the International Symposium: *Cross-Border Drinking Water Management* are to improve the scientific and practical knowledge regarding the cross-border water resources and water supply management and to advance networking and cooperation among water management scientists and experts.

The Symposium is organised within the scope of the DRINKADRIA (Networking for Drinking Water Supply in Adriatic Region) Project which is co-financed by the European Union, Instrument for Pre-Accession Assistance, Adriatic Cross Border Cooperation programme 2007-2013 and involves seventeen project partners from eight Adriatic countries.

During the Symposium information and data on new methodologies, approaches, and practices relevant for sustainable cross-border water resources management and cross-border water supply in the Adriatic region are introduced to sustain capitalization and dissemination of the Project results and outputs and their application among scientists, experts and end users.

Ten papers and one extended abstract presented at the Symposium were reviewed by the Scientific Committee members and published in this Symposium Proceedings.

Topics addressed in the papers are quite diverse given the complexity of cross-border water management and water supply. Various interesting and challenging issues are included starting from DRINKADRIA general information; followed by DRINKADRIA project capitalization and sustainability and connection with good practice of dissemination and communication activities; vulnerability of water resources in the Adriatic area; cross-border water resources management in the present conditions and for future scenarios; legal and policies implications of ecosystem services inclusion in drinking water supply systems analyses at the transnational level; approach to developing the “Program of the rehabilitation measures within the sanitary protection zones in the Region of Istria for existing buildings and existing activities”; water resources quality variation in the Water Utility of Istria; impact of land use on groundwater quality in the South Dalmatia test area; contractual framework for cross-border drinking water delivery; implementing the remote control water meters in the Water Utility of Istria for the purpose of the leakage reduction and also preparation and implementation of the EU project: Research Infrastructure for Campus-Based Laboratories at the University of Rijeka Campus.

A round table is included in the Symposium agenda to ensure that the Symposium topic *Cross-Border Drinking Water Management* is

discussed by participants and their expertise and knowledge is capitalized.

This Symposium is organised by the Faculty of Civil Engineering of the University of Rijeka with valuable contribution of co-organisers that are also DRINKADRIA final beneficiaries from Croatia: the Region of Istria, the Water Utility of Istria and the Croatian Geological Survey.

The editors wish to express gratitude to the authors, members of the Scientific Committee and of the Organising Committee for their contribution to Proceedings preparation and organisation of the Symposium.

We hope that this publication will be useful to all participants and encourage the collaboration of scientists, experts, and end users on cross-border drinking water management issues and challenges in the future.

Editors:

Barbara Karleuša

and

Ivana Sušanj

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ABOUT DRINKADRIA PROJECT

Barbara Karleuša (barbara.karleusa@uniri.hr),

University of Rijeka; Faculty of Civil Engineering; Rijeka; Croatia

Abstract

The strategic project Networking for Drinking Water Supply in Adriatic Region DRINKADRIA is co-financed by the European Union within the program IPA Adriatic Cross-Border Cooperation 2007 – 2013. It started on November 1st, 2013, and it will last for 35 months. The total value of the Project is 6,600,000 EUR. The Project aim is to develop a base for strategies and procedures for secure cross-border water supply with specific emphasis on water resources management in trans-boundary context, climate change and specific socio-economic aspects of the Adriatic region. Significant financial resources have been invested in improvement of existing water supply systems in the region, and possibilities of cross-border connection of existing water supply systems analysed. Seventeen partner institutions from the Adriatic region countries are involved in the Project: Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Albania and Greece. This paper provides an overview of DRINKADRIA Project partnership and activities.

Keywords: cross-border, DRINKADRIA, water resources management, water supply management



1. Introduction

While management of water supply systems (WSS) is a broad domain well addressed by professionals and researchers, the issue of cross-border water supply systems (CBWSS) is not so recognized [1]. Cross-border water supply systems by definition provide the water from a water resource in one country through a WSS in this country to another WSS and its users in another country. The management of drinking water supply in a cross-border context is much more complex and had to be investigated.

Most of countries rely on the national territory based water supply defining it in some way as a national priority, even if it would be related to excessive costs. Several WSS turned to be a cross-border water supply system with a development of new borders, defining new countries. In these cases water supply systems which were once conceptualized to operate in one administrative unit, start to operate within two national administrative systems. In the EU such development could be observed especially in the countries of former Yugoslavia.

The protection and management of cross-border water resources used for drinking purpose is also very complex. There are resources that are used for water supply in one country with a part of aquifer/catchment in another country. The EU Water Framework Directive (EU 2000/60) defines the need for a common definition and protection of water resources that are used for supplying population with drinking water. This is implemented by the water management plans [1]. But the drinking water protection areas are still defined for each country separately, with no consensus with the neighbouring country.

In this paper an overview of the Project DRINKADRIA that encompasses the above explained complex problems regarding cross-border water supply systems and water resources management is given.

2. DRINKADRIA Project Partnership

The strategic project Networking for Drinking Water Supply in Adriatic Region DRINKADRIA is co-financed by the European Union within the program instrument for Pre-Accession Assistance Adriatic Cross Border Cooperation 2007 – 2013 [2].

The Project started on November 1st, 2013, and it will last for 35 months with the total budget of 6,600,000 EUR.



The Project aim is to develop a base for strategies and procedures for secure cross-border water supply with specific emphasis on water resources management in trans-boundary context, climate change and specific socio-economic aspects of the Adriatic region.

Significant financial resources will be invested in improvement of existing water supply systems in the region, and possibilities of cross-border connection of existing water supply systems will be analysed.

Seventeen partner institutions from eight countries in the Adriatic region are involved in the Project (Figure 1): Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Albania and Greece [3].

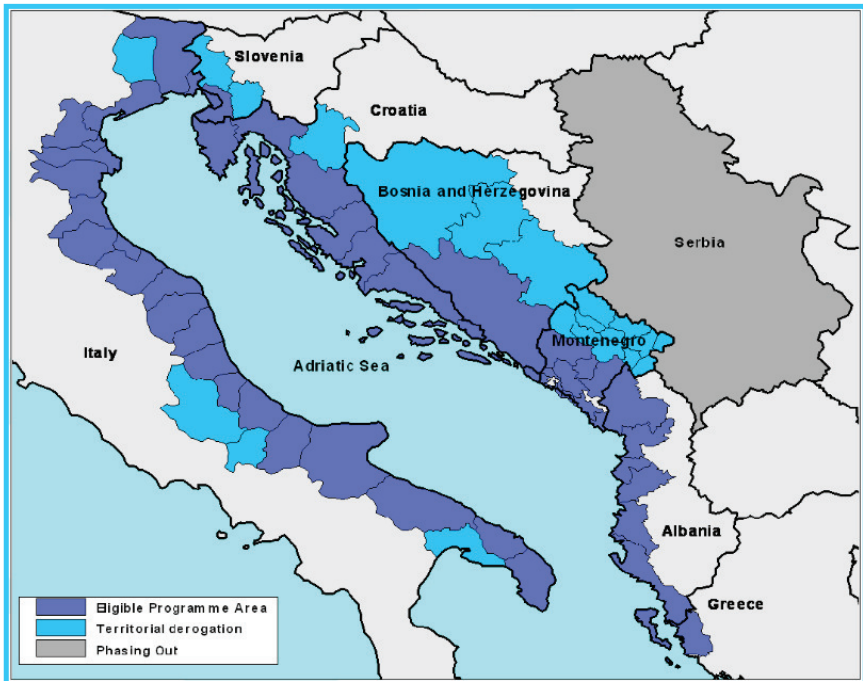


Figure 1. IPA Adriatic CBC 2007-2013 programme cooperation area

The logo of the project represents eight countries involved in the DRINKADRIA project (Figure 2).



Figure 2. DRINKADRIA project logo

The partnership is a well harmonized set of stakeholders from the entire Adriatic area. It is primarily focused on the main actors in the field – water utilities (5 partners), authorities (4 partners), research institutions (7 partners) and one association [2].

From Croatia, the following bodies are involved in the Project: the Faculty of Civil Engineering University of Rijeka, Region of Istria, Water Utility of Istria Ltd. and the Croatian Geological Survey, as project partners, and Croatian Waters, Istrian Water Protection System Ltd. and Primorje-Gorski Kotar County as associate institutions.

The lead partner of the Project is the Area Council for Eastern Integrated Water Service of Trieste (Consulta d'Ambito per il Servizio Idrico Integrato Orientale Triestino - CATO). Other Italian partners are: VERITAS Joint-Stock Company, Optimal Territorial Area Authority n. 3 Central Marche – Macerata and Italian National Council - Water Research Institute. Associate institution from Italy is FEDERUTILITY.

The partners from Slovenia are: Water Utility of Nova Gorica and University of Ljubljana, while associate institutions are the Slovenian Environment Agency and the Ministry of Agriculture and Environment.

The partner from Serbia is the Institute for Development of Water Resources “Jaroslav Černi”, while associate institution is the Ministry of Agriculture, Forestry and Water Management.

From Albania the project partner is the Water Supply and Sewerage Association of Albania (SHUKALB).

From Bosnia and Herzegovina project partners are the Hydro-Engineering Institute of Civil Engineering Faculty, University of Sarajevo and Public Utility NEUM and associate institutions are the Agency for Watershed of the Adriatic Sea and the Municipality of Neum.



The Project partner from Montenegro is Public Utility „Vodovod i kanalizacija“ Nikšić and associate institution is the Water Supply and Treatment of Waste Drainage Association of Montenegro.

From Greece two partners are involved in the Project, the Region of Ionian Islands and the University of Thessaly.

3. DRINKADRIA Project Activities

The DRINKADRIA project is conceptualized on the basis of recognized common and trans-boundary problems related to the water supply in the Adriatic region. In the focus of the project are the cross-border water supply systems and transboundary water resources used for drinking purpose [2].

In the Adriatic region there are examples of WSS that were historically developed in one historical country (i.e. cross-border WSS of Nova Gorica dating in the period before World War II, to a set of WSS constructed between the Republics of former Yugoslavia) but after the changes of boundaries they became CBWSS, delivering drinking water abstracted in one country through a WSS in this country to another WSS and its users in another country.

Management of water supply systems is quite a challenging issue and in the case of cross-border water supply system this complexity is multiplied. Characteristics of WSS in the Adriatic region are also: ageing infrastructure, increased demand, seasonal fluctuations (tourism), high water losses, low economic efficiency and issues related to water governance processes, etc.

Cross-border water supply is in all participating countries subject to negotiations regarding the quantity and quality of water supplied, supply dynamics, short- and long- term planning, maintenance, costs and payments. These negotiations are currently being performed without general framework. In order to avoid conflicts, the already established CBWSS are now sometimes being abandoned.

DRINKADRIA will address these issues by development and implementation of a common code of good practice (measures) for water utilities, depending upon current status of partner pilot case and will range from development of full-pipe asset management, to improvements in WSS measurements, developing district metering areas (DMAs), implementation of active leakage control (ALC) tools, advanced hydraulic modelling and real-time control of WSS.

Drinking water supply in the Adriatic area is historically bound to tight cross-border cooperation due to political changes in last decades, which will be demonstrated by pilot examples. The objective is to



develop strategies for secure cross-border water supply, managing at the same time drinking water demand and supply in cross-border context in present and future situation (future scenarios), which would function as a reference body of applicative procedures ensuring long-term cross-border water supply. With implementation of pilot actions a great number of local or regional users will benefit from innovative technologies for water efficiency use and water quality.

In the Adriatic region water resources are facing different human and natural pressures, causing alterations in water quantity and quality. The DRINKADRIA project will focus on cross-border water resources with common cross-border protocols and measures for drinking water resources management (water quality and quantity) with consideration of climate change. A special focus will be on protection of water resources that are used for drinking in one country but part of catchment that has to be protected is in other country.

Furthermore in the DRINKADRIA project a regional platform (network) of water supply experts (utilities, authorities, regulatory agencies and research institutions) will be developed for sharing knowledge and experiences (know-how) regarding WSS developments aiming at long-term WSS stability and security.

In the DRINKADRIA project the issue of efficient and effective cross-border water supply and water resources management will be addressed in its complexity through six work packages (WP) as presented in Figure 3 [4].

Work package 1 (WP1) covers Project management and coordination. It includes coordination of activities between the partners during various meetings, by on-line communication and referent group meetings, preparation of activity reports and project progress reports etc.

Work package 2 (WP2) covers communication with the general public and dissemination of Project results. Communication and dissemination activities include production of promotional materials and publication of results for all interested stakeholders through the project website (www.drinkadria.eu), scientific and professional journals, conference proceedings and media.

Work packages WP1 and WP2 are led by the lead partner Area Council for Eastern Integrated Water Service of Trieste.

Work package 3 (WP3) covers capitalization and sustainability of the Project, which also includes the period after its completion. This package is led by Institute for Development of Water Resources "Jaroslav Černi". Within this work package national workshops are held in all countries that participate in the Project. It is important to involve



bilateral commissions, local and regional government units, utility companies, educational institutions and others in the Project, in order to inform them about the Project activities so that they can contribute to Project results and use them in future.

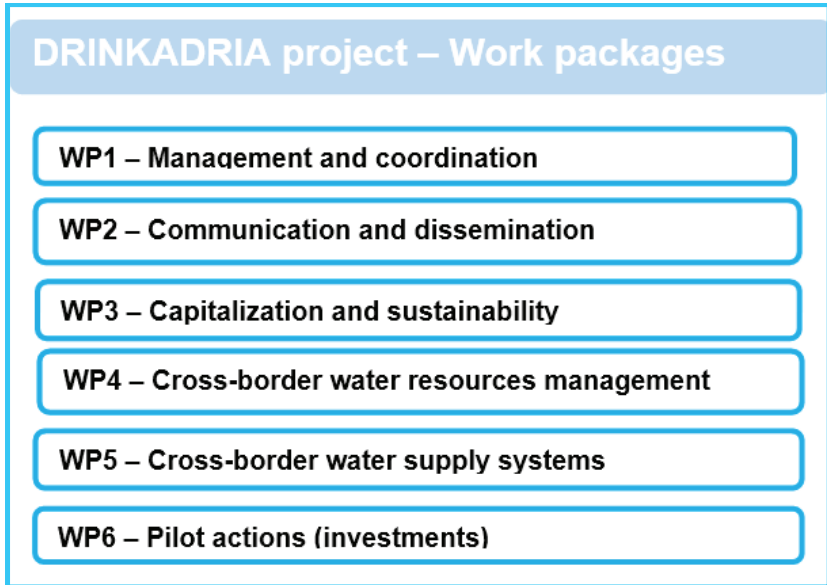


Figure 3. Structure of work packages

Within Work package 4 (WP4) which is led by the Faculty of Civil Engineering, University of Rijeka cross-border water resources management issues are analysed. Regulations of the countries involved in the Project related to water resources management are analysed, in order to develop a common basis for the protection of transboundary water resources which are used in water supply. Drinking water protection areas are defined for each country separately, with no consensus with the neighbouring country. For example, Slovenia defined drinking water protection areas only to the Slovene-Croatian border and vice versa. A unified approach to protection of transboundary aquifers is crucial for ensuring safe water supply [1]. Partners applied common approaches and methodologies for analysing the impact of climate change (CC) on water resources availability. Using different scenarios of changes in water demand in the future, the Water Exploitation index (WEI) is calculated for total use and for drinking use in order to analyse the risk in test areas [5]. Water quality trends in test areas and impact of changes in land-use (due to CC and future development) on water resources quality are analysed too.



Work package 5 (WP5) is dealing with cross-border water supply systems management. Within this work package, which is led by the University of Ljubljana, the following activities are under implementation: historical overview of cross-border water supply, analysis of existing and potential cross-border cooperation, development of protocols and procedures for effective cross-border water supply and the development of economic model. They are necessary for the analysis of current status of CBWSS and long-term planning of cross-border and regional water supply systems.

Within work package 6 (WP6), led by VERITAS Joint-Stock Company, pilot actions are carried out, i.e. investments which should result in more effective water supply and water resources management. This work package consists of three activities: development of common analytical framework, individual pilot actions/investments, and development of rules and documentation of experiences.

4. DRINKADRIA Project – Expected Outcomes and Results

Measurable project outputs and related results of the DRINKADRIA project are [2]:

- ◆ Climate change impact on water resources and drinking water supply with identification of adaptive measures, resulting in stakeholder and target groups' awareness of CC impact on drinking water supply.
- ◆ Common methodologies for water resources vulnerability, risk and hazard and water protection areas determination with elaboration of measures and proposal of legislation harmonization for cross-border water resources protection.
- ◆ Implemented pilot actions as examples of good practice in different fields of water resources and water supply management resulting in improved water services.
- ◆ Established protocols for cross-border water resources and supply management which will serve as reference protocols for stable long-term cross-border drinking water supply, which is essential for secure water supply, resulting in harmonized interdependence of countries.
- ◆ Established Internet-based communication platform for continuous exchange of experiences developed in pilot actions with possible post-project life, resulting in increased number of end-users benefiting from innovative technologies for water efficiency use and water quality improvement. The platform will provide a decision



support system (DSS) for preserving limited water resources with established open regional partners' network for capacity building.

- ◆ Water loss (non-revenue water) reduction decision support system implemented and upgraded from the EU Water loss project, resulting in improved water supply efficiency.
- ◆ Improved operational reliability and safety of water supply systems (WSS) as important concern of EU legislation under development.
- ◆ Water governance analysis and enhancement of participatory framework in all partner countries with identification of gaps and suggestions for possible improvements, which is priority listed in the Blueprint to safeguard Europe's Waters.
- ◆ Regional drinking water supply economics model is specific non-compulsory output. Water resources economics is underlined by the Water Framework Directive (Art. 9, Annex III, CIS No.12). An economic model will serve as an analysis tool for performance assessment of WSS and for scenario evaluation.

Achievement and durability of results are supported by a clearly structured project progress supervision system, solid communication strategy for dissemination and capitalisation of results during and after the project and establishing of communication platform improving knowledge management within the partnership.

Water supply is a service of general interest, which will be essential also in the far future. Water supply companies are necessary and will thus have political support; financial means for water supply are and will be paid by water consumers.

DRINKADRIA results will improve water supply systems and can be applied by water suppliers eagerly, which ensures project sustainability.

5. Conclusion

DRINKADRIA project results will have a very important impact in the entire Adriatic area – providing practical protocols addressing a wide spectrum of issues that should be determined and maintained in the case of cross-border water supply.

Final beneficiaries are really the people in the Adriatic area countries, who will be supplied with drinking water by more secure, resilient, robust cross-border WSS. This is not only the case for the systems between the states, but also for the WSS that extend across the regions in one country, as the cross-border cooperation between the regions could sometimes be recognized as a difficult one.



The impact of the project extends also beyond the Adriatic area itself. There is only a limited number of cross-border water supply agreements in the world, and the project results will be significant for them too [2].

Another project aim is focused on the practical improvement of water supply with focused pilot actions (investments) showing the applicability of the practical approaches and established platform of partners.

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Acknowledgments

The research for this paper and the preparation of this paper was financially supported by the EU IPA Adriatic Cross-Border Cooperation Programme 2007-2013 (DRINKADRIA project) and the University of Rijeka (research project 13.05.1.3.08 - Development of new methodologies in water and soil management in karstic, sensitive and protected areas).



DRINKADRIA PROJECT CAPITALIZATION AND SUSTAINABILITY AND CONNECTION WITH GOOD PRACTICE OF DISSEMINATION AND COMMUNICATION ACTIVITIES

Branislava Matić (branislava.matic@jcerni.co.rs),

Marijana Miletić - Radić (marijana.miletic@jcerni.co.rs),

Institute for Water Resources Development Jaroslav Černi, Belgrade, Serbia

Abstract

Capitalization and sustainability of DRINKADRIA project activities is important for water resources management given the significance of safe drinking water supply around the globe. Within the scope of project area, these activities comprise of involvement of identified stakeholders in eight countries in addition to institutions involved in project implementation. All relevant information and data collected during the project implementation are available at the Web platform and can be used by stakeholders, decision makers and general public. Since the safe and stable drinking water supply is strategic goal in each country well planned dissemination and communication activities are added value to capitalization and sustainability. This paper summarizes finalized and ongoing capitalization activities that would significantly contribute to the transboundary project sustainability. In addition, implementations of communication and dissemination activities are introduced as an example of good practice.

Keywords: water resources, capitalization, cross–border water supply, stakeholders.



1. Background

The capitalization contributes to the knowledge of the influence and effects of stakeholders on cross-border water supply systems. What are the prevailing interests, strategies of action and interactions among the relevant stakeholders? One of the capitalization objectives is to underline existing risks of stakeholders' behavior and to identify possible ways that would increase flexibility and adaptability of water supply systems.

Capitalization of experiences in DRINKADRIA project is focused on steps that would sustain movement from commitment to action, formalize the lessons of experience, validate skills, debate and integrate experience into practice. Despite capitalization is generally mixed with dissemination, the main difference is reciprocity of experience among stakeholders on specific topics and information dissemination to general public that has interest in that topic.

Involvement of relevant stakeholders in addition to project final beneficiaries, namely authorities, water utilities, research institutions and associates significantly contributes to capitalization and sustainability of DRINKADRIA project. Given that, methodology framework that would support project activities and sustainability is developed by all project partners considering specificities of cross-border drinking water sources, different issues and constrains. Information and data presented hereafter are summarized from inputs and activities of Lead Partner (LP) and all DRINKADRIA project partners from eight countries.



Figure 1. Schematic of countries involved in DRINKADRIA project



2. Stakeholders Identification and Management

Based on premises that DRINKADRIA as the strategic project incorporates ambitious goal and objectives regarding cross-border and regional drinking water supply identification of stakeholders is deliberated based on facts that experience capitalization is future oriented and aims at a change in collective institutional practice. The first step was diagnosis of experience and knowledge practices useful for capitalization and sustainability that exists within the projects team members. Table 1 presents project partners (final beneficiaries - FBs) specific expertise and skills that are identified as significant contribution in capitalization activities.

Table 1. DRINKADRIA final beneficiaries expertise of significance for capitalization

Project partner type	Specific expertise and skills
Authority (LB & FBs : 2, 6, 15)	Inputs and skills regarding regional authorities hand on experience
Water Utilities (FBs: 1, 4, 7, 13, 14):	Identification of long term capitalization from their point of view, particularly inputs to processes that will be supported by networking
Research and education (FBs: 3, 5, 8, 9, and 12)	Integration of research institution know-how into capitalization methodology framework
Associate	Verification of the capitalization methodology

In addition, relevant stakeholders to be addressed at the national and cross-border (bilateral commissions) level are identified based on project objectives. Moreover, key processes and issues of importance for cross-border / regional water supply systems and water management have been elaborated prior to stakeholders' identification.

Secondly, given the complexity of cross-border water supply systems management and its cross-cutting constrains selection of stakeholders assumed that well informed and involved stakeholders influence degree of the project implementation success. As exhibited in Figure 2, stakeholders are evaluated based on their interest and influence with respect to DRINKADRIA goal and objectives.

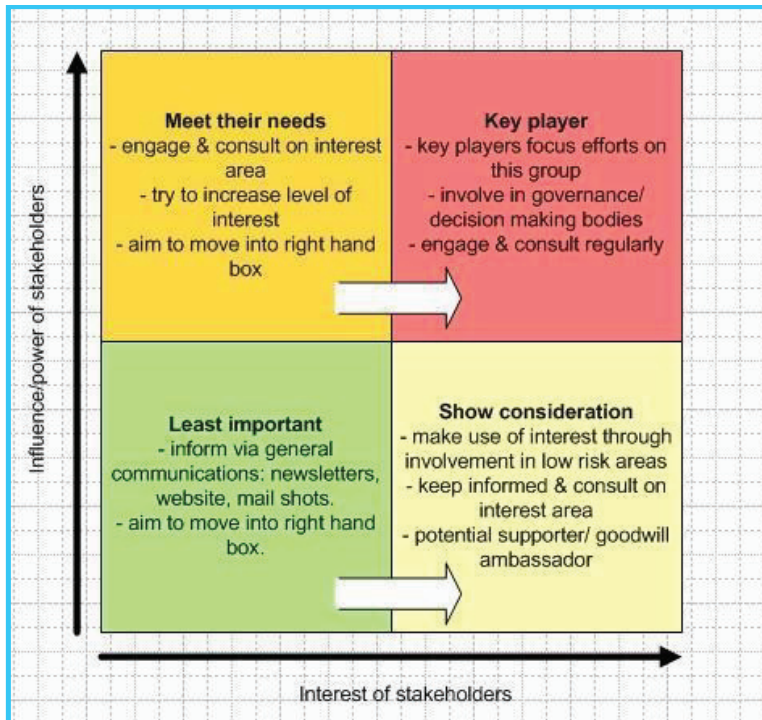


Figure 2. Stakeholders identification approach

Although the majority of countries within the DRINKADRIA project area participate in different bilateral, multilateral, etc. commissions for transboundary water resources management there is still a gap that addresses cross-border water supply systems (CBWSS). In some cases it applies to the regional water supply systems (WSS) in some countries. In addition, the guideline that addresses protection of the cross-border/regional WSS do not exist. Moreover, no common measures exist for the drinking water protection zones that are relevant for more than one country or region.

Despite the existence of interstate and multilateral agreements among some countries, some of them that would address CBWSS are still pending, i.e., B&H/Croatia, B&H/Serbia, B&H/Montenegro, etc. Data and information on cross-border and regional water supply systems are missing, so the monitoring that would fill data gap is needed. The lack of funding is also important, given the costs of WSS infrastructure. In addition to this general issues and processes, specific key issues for cross-border water supply are addressed by water utilities:



- ◆ Losses;
- ◆ Quality;
- ◆ Quantity; and
- ◆ Other.

There are also important cross-cutting issues that should be considered in project implementation and selection of stakeholders:

- ◆ Seasonal changes in water quality and quantity, illegal connections;
- ◆ Water tariffs;
- ◆ Climate change;
- ◆ Policies & legislation framework;
- ◆ Water utilities capacities (technical, human, etc); and
- ◆ Existence/non-existence of bottom-up approach in decision making process.

Stakeholder management (Figure 3) is developed based on above mentioned issues, processes and project goal and objectives, e.g., development of different protocols that would improve cross-border / regional water supply.



Figure 3. Main steps of priority stakeholders selection



3. Methodology Framework and Knowledge Sharing and Exchange Tools for Capitalization and Sustainability

Based on key processes that are recognized as significant for cross-border water management (losses, quality, quantity, etc.) relevant stakeholders groups are identified. In addition to before mentioned stakeholders it is recognized that professional associations, national authorities that have power to advocate adoption of guidance documents that result from other work packages, public institutions (Institutes for Public Health, etc.), professionals involved in planning and design of WSS, students as future stakeholders, etc., are relevant stakeholders.

Capitalization procedures for stakeholders are subsequent:

- ◆ Workshops;
- ◆ Roundtables;
- ◆ Questionnaires;
- ◆ Conferences and regional meetings;
- ◆ WSS associations meetings;
- ◆ Internet based networking platform;
- ◆ Report and guideline; and
- ◆ Project closing conference

Although common methodology is agreed, it is flexible with respect to countries, pilot/test area or cross-border water sources characteristics and constrains. Finally, it is agreed that uniform questionnaire should be used during the stakeholders' national events (24) to allow comparison of outputs in different countries.

In addition, it is recognized that list of relevant projects that are important for DRINKADRIA project should be developed. Accordingly, template for data collection is developed. Over 170 projects are identified within the project area to be significant for DRINKADRIA.

Due to complexity of cross-border WSS and water resources management, objectives of projects considered to be significant for DRINKADRIA capitalization and sustainability differ greatly. Approximately 50 percents of all implemented projects are international as exhibited in Figure 4.

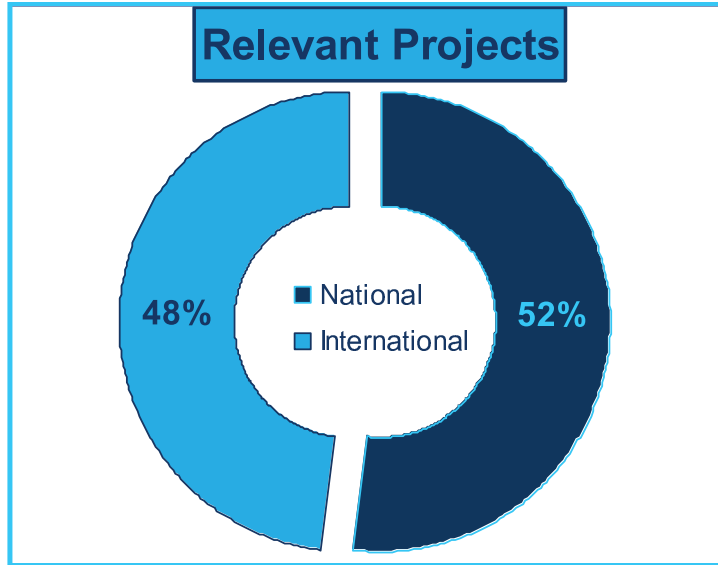


Figure 4. Summary of projects relevant for DRINKADRIA project

3.1. Web Platform Overview

The general objective of the project is improving access to water supply in the framework of the Adriatic basin. One of the main specific goals is to develop a regional platform to connect experts in the field of water supply and water management. Target public for the realization of the project is: professional organizations (public water management companies, water and sanitation, regional water supply systems, various branch associations); scientific institutions (institutes, universities); decision makers - government bodies; nongovernmental organizations; media; citizens. Web Platform (<http://drinkadria.fgg.uni-lj.si/>) incorporates all results, outputs, legal framework, etc. of relevance for the project. Figure 5 depicts snap shot of web platform.

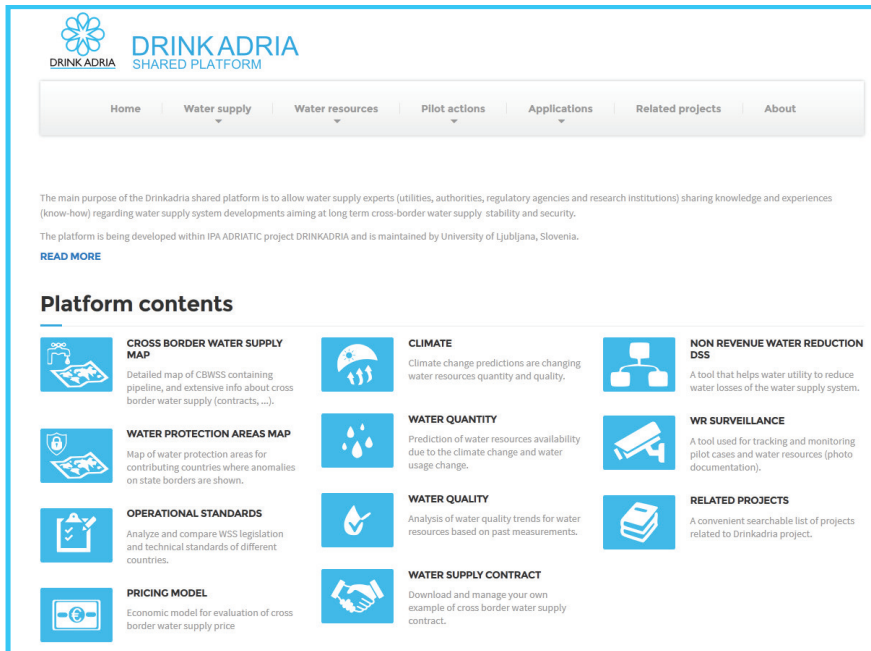


Figure 5. DRINKADRIA Web Platform

4. Outputs from National Events for Stakeholders

National events for stakeholders is main capitalization activity. It is great opportunity to collect numerous valuable information, experience and knowledge. On the other hand, this events are used to familiarize broad group of stakeholders with recent development in project activities.

4.1. The First National Events

Total number of participants in 8 countries is over 250. Questionnaire that is developed includes different questions with main goal to evaluate situation and feedbacks provided by professionals that are involved in drinking water supply on daily basis (majority of them).

In summary, all of them consider DRINKADRIA an important project for cross-border water supply and water resources management. They consider that relevant issues and key processes for cross-border/ regional water supply and water resources management are included in DRINKADRIA Project application form. Majority of the stakeholders recognized water losses as a one of the main problems in water supply management, followed by the water tariffs (water pricing mechanisms) that are still social category in some countries.



Based on answers provided in questionnaires state level institutions are main players but stakeholders recognized the important role of their institutions for sustainable water supply management. Finally, cross-cutting issues should be addressed by better cooperation among the sectors, more political will and strategic frameworks at the national levels.

Figure 6 exhibits answers provided by Italian stakeholders on question: *What are the main water supply management issues/problems at the present?* It is noteworthy that results depicted are similar in all countries.

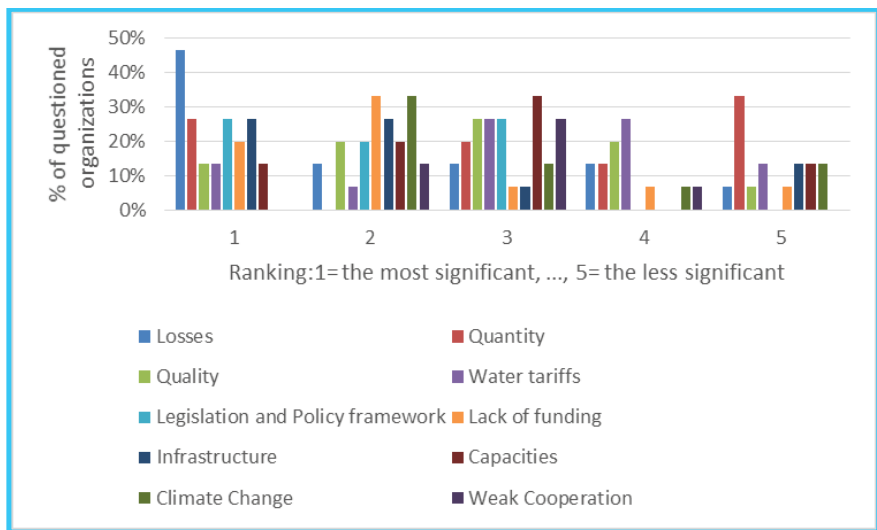


Figure 6. Italian stakeholders answers on main water management issues at the present [4]

With respect to the way to solve cross-cutting issues relevant for water supply stakeholders ranked them as depicted in Figure 7. Over 45 % of them considered financial issues as the most important, followed by separate policy that would address cross-cutting issues and constrains, and better cooperation among the sectors (32 %).

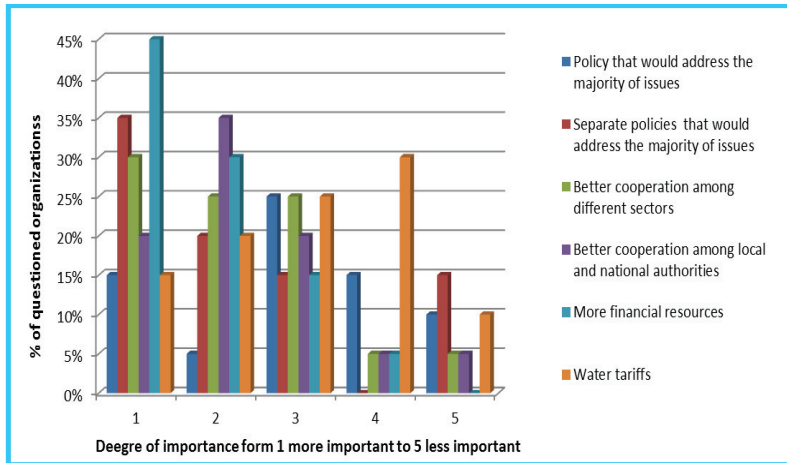


Figure 7. Albanian stakeholders answers on cross-cutting issues solutions [4]

4.2. The Second National Events

Recently organized national events collected data and information with respect to interest of stakeholders to be involved in following methodologies development:

- ◆ Water availability;
- ◆ Estimation of climate change – induced land use changes;
- ◆ Water resources vulnerability;
- ◆ Risks and hazards; and
- ◆ Delineation of water protection areas.

Since technical protocols development is among the DRINKADRIA objectives the stakeholders' opinion on their relevance for cross-border / regional drinking water supply systems is valuable. Importance of following protocols is ranked by second national events participants:

- ◆ Planning;
- ◆ Design;
- ◆ Operation and maintenance;
- ◆ Financing;
- ◆ Water quality;
- ◆ Contingency management; and
- ◆ Governance.



In some countries, additional questions that address country specific issues are included in questionnaire for the Second National Events for stakeholders. Since it is ongoing process, data presented in Figures 8, 9 and 10 reveal stakeholders' answers on particular questions relevant for sustainable water supply management and other DRINKADRIA project objectives for Croatia, Serbia and Slovenia, in a given order.

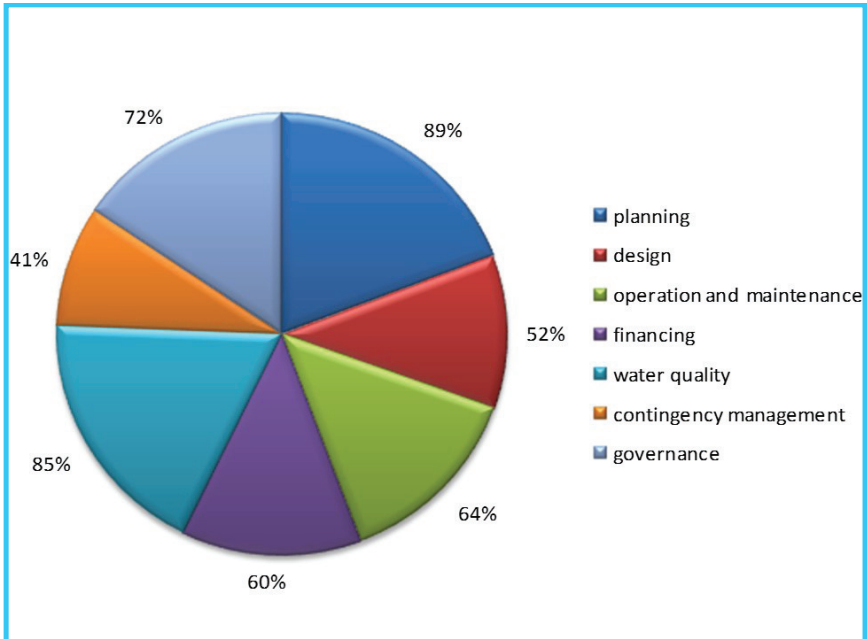


Figure 8. Ranking of technical protocols importance by Croatian stakeholders [5]

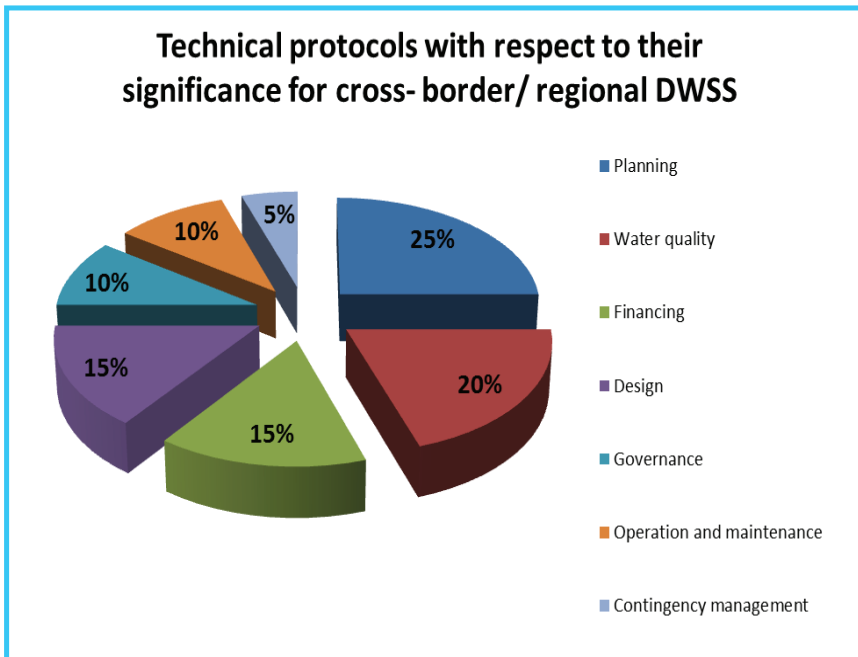


Figure 9. Serbian Stakeholders answers with respect to technical protocols significance [5]

SLOVENIA additional questions			
	Yes	No	Neutral
Would it be appropriate to determine the (technical) standards for drinking water supply central - at the national level?	5	3	5
Are you satisfied with the way of identifying, monitoring, implementing technical standards (ISO, EN, BS et al.) in Slovenia?	2	6	5
Is the existing mechanism of water pricing (and the implementation of network access services) appropriate?	6	3	4
Is the pricing of drinking water supply and supervision adequate?	4	7	1
Is there a need for better alignment of prices with the standards of the public service?	5	3	1
Can you justify the difference in price of drinking water supply schemes between municipalities in Slovenia?	9	3	0
Does your municipality / public utility monitor user perception regarding the price of water supplied (too low / too high) relative to the standard of the service?	4	7	1
Do you find that there is appropriately defined way of determining the price for supplying major users of drinking water (bulk water supply) in Slovenia?	0	6	7

Figure 10. Summary of Slovenian stakeholders answers on additional questions [5]



5. Case Study: Communication Channels and Activities to Disseminate DRINKADRIA Project in the Republic of Serbia

Given the DRINKADRIA project objectives and communication and dissemination scope, planning and implementation of communication activities is defined as important prerequisite for visibility and promotion of the project, and information and results dissemination to the general public with respect to importance of drinking water and water resources for present and future generations.

5.1. Communication Channels and Activities

The following channels of communications are selected: the website of the Institute; printed publications; photography and film; special events and media (Figure 11) for dissemination and communication of the Jaroslav Černi Institute project activities.



Figure 11. DRINKADRIA communication channels used for dissemination and communication in Serbia

On the website of the Institute a special section is created, entitled "International projects", which presents DRINKADRIA project. Page contains the most important information about the project and activities such as workshops, regional meetings, the implemented activities, upcoming actions etc. Through the website one can access to photo and video material as well as presentations from the workshops and meetings. In order to promote the project, two bilingual (Serbian / English) promotional leaflets are created and distributed to Stakeholders National Workshops participants. In addition, posters for the National Workshop with strong visual message are designed.

Activity Plan enables recording of the activities of the Institute Jaroslav Černi through photos and videos, activities at meetings organized by other project partners, as well as professional engineering activities to be implemented during the project implementation on the ground. National events for stakeholders are used as the basis for cooperation with media and to attract greater media attention for



dissemination of information about the project that is important for general public.

The first national workshop on "Increasing the efficiency of Water Supply Systems in Serbia", was held on April 9th, 2014 and attended by journalists of the magazine "Planet". Regional meeting held on November 25-28, 2014 was attended by journalists from the agency "Tanjug" and "Beta" and journalists television from TV station Studio B. The Agency published affirmative news about the Meeting being held. The agency "Beta" published the news on the website of the "Green Serbia", as well as through the social network Facebook. The news was taken over, supplemented with information from previously sent statements from the Institute and published on their websites by the following media: Blic, Danas, Kurir, Akter, and TV stations Studio B, B92, TV Vojvodina. The news was published on the web portals: "E-gate", "On the Water" and "Eco Corner", as well as on the websites of the City of Belgrade, the company "Belgrade Waterworks and Sewerage" and the Jaroslav Černi Institute.

A second national workshop entitled "The Quality of Drinking Water and Protection of Water Resources in Serbia", which was held on April 28th, 2015, following media reported on: Television Studio B, Morning Program, on April 28th, 2015 at 09:15, engaging at the scene, along with a statement from the organizers; Happy TV, news program, April 30, 2015 at 17:55, "TELEMASTER" - information program, annex from the workshop lasting 2:49 minutes; daily paper "Politika", on April 29th, 2014. The news was published on the portal "E-gate". Project progress and intensification of cooperation with the media increased the number of media interested in covering the project. Relations with the media during the course of the project are created as relations of cooperation, through which important information is transmitted to a wider and targeted public and thus contribute to achieving project goals.

6. Conclusions

All capitalization and sustainability activities are implemented by involvement and significant contribution by all final beneficiaries and lead partner of DRINKADRIA project. Stakeholders are identified according to project's goal and objectives. Cross-border / regional sustainable drinking water supply management requires in addition to state level institutions bottom up approach.

Relevant key processes and issues for cross-border / regional drinking water management are well defined within the scope of DRINKADRIA project. However, the great majority of national events



participants recognize water losses as the most significant problem, followed by water tariffs that are still social category in many countries.

There is no big discrepancy among answers regardless country or region. Given the importance of drinking water supply, many cross-cutting issues should be addressed by better cooperation among different sectors. Moreover, stakeholders' feedbacks emphasize lack of political will as the significant constrain for cross-cutting problems.

Communication activities in the implementation of the project DRINKADRIA achieved positive changes regarding development of public awareness on key issues and problems of water supply and cross-border water supply. Also, using the postulates of effective communication, certain effects can be achieved in the direction of acceptance and the introduction of changes in the behavior of the target public, which would facilitate dissemination and communication not only for this project but also for following projects.

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Acknowledgements

This work is elaborated through a project co-funded by the European Union, Instrument for Pre-Accession Assistance, IPA Adriatic CBC Programme 2007-2013 (DRINKADRIA project, 1o str./0004, further info: www.drinkadria.eu).



LEGAL AND POLICIES IMPLICATIONS OF ECOSYSTEM SERVICES INCLUSION IN DWSS ANALYSES AT THE TRANSNATIONAL LEVEL

Branislava Matić (branislava.matic@jcerni.co.rs),

Prvoslav Marjanović (marjanovic.civil@gmail.com),

Marko Marjanović, (marko.marjanovic@jcerni.co.rs),

Dejan Dimkić (dejan.dimkic@jcerni.co.rs),

Dragana Pejović (dragana.spasic@jcerni.co.rs),

Institute for Water Resources Development Jaroslav Černi, Belgrade, Serbia

Abstract

Ecosystem services (ESS) benefits for society are diverse and important. Comprehensive review of legal framework at the national and regional scale identified requirements of water legislation improvement that would advance protection, preservation and enhancement of ecosystem services and drinking water supply (DWS) under the different Climate Change scenarios and land use practices in eight countries within the SEE. Summary outputs of integrated vulnerability index assessment of ES provision services for drinking water supply at the transnational scale within the scope of CC-WARE project are presented in this paper. Based on joint methodology for water resources vulnerability and integrated vulnerability index relative potential of ESS to improve drinking water supply is evaluated at the national and transnational scale. Measures for advancement of ESS provision in supply of pure drinking water in appropriate quantity are grouped in three main categories for selected ecosystems within the scope of CC-WARE project.

Keywords: legal framework, ecosystem services, drinking water supply, transnational level



1. Background

There are number of pressures on drinking water sources worldwide that enlarge vulnerability of drinking water supply. Within the scope of CC-WARE project Lead partner and project partners from eight countries judged existing and future adverse effects on water sources and ecosystem services potential to improve water supply systems under different climate and land use practices changes scenarios at the transnational scale. The methodological framework comprises of diverse parameters and indicators assessment with main goal to identify vulnerability of water resources in South Eastern Europe (SEE) and to propose management options that would mitigate adverse effects drivers by boost of ecosystem services potential in advancement of water supply systems.

Diversity of project area, various drinking water sources, and different ecosystems result in compatible methodological framework that would generate comparable outputs. Despite that all project partners actively contributed in methodology improvement the structure of it is developed by University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Geology (Lead Partner for WP3: Vulnerability of water resources in SEE) and Institute for Water Resources Development Jaroslav Černi, Belgrade (Lead Partner for WP4: Management options for mitigation vulnerability of drinking water sources).

Given the complexity of drinking water supply (DWS) and ecosystem services (ESS) in the content of changes, various legislation and policies are of significance for sustainable DWS management and ESS provision within the SEE. Hence relevant legislation and policy are analysed at national, regional and EU level to identify gaps and provide basis for improvement of land use and water management given the identified transnational issues and constrains. Involvement of relevant decision makers and stakeholders in addition to project partners, contributes in project outputs dissemination. Information and data presented hereafter are summarized from selected CC-WARE outputs that are developed by contribution of Lead Partner and all project partners from eight countries (Figure 1).



Figure 1. Map of countries involved in CC-WARE project

2. Legal and Policy Framework Outline

The main scope and objective of this assessment build on legislation significance for drinking water supply information and data on legal and policy framework of relevance for CC-WARE project are assembled based on outputs provided by project partners (eight national reports). It has been agreed that outputs should underline DWS, ESS, DW source protection, land use, climate change, water management, River Basin Management Plans, and other of relevance for project goal and objectives. In summary, at the EU level 19 documents are emphasized to be significant:

- ◆ **EU Directives:** Water Framework Directive, Drinking Water Directive, Flood Directive, Groundwater Directive, UWWT Directive, Environmental Quality Standards in the Field of Water Policy Directive, Sewage Sludge Directive, Reach Directive, IPPC Directive, and Nitrates Directive; and
- ◆ **GREEN PAPER:** Adapting to climate change in Europe, **WHITE PAPER** - Adapting to climate change: Towards a European framework for action; **BLUEPRINT** to Safeguard European Waters; **CODE(S)** of Good Agricultural Practice, the Common Agricultural Policy (**CAP**); Ministerial Conference on the Protection of Forests in Europe; **EU Forest Strategy**; **ALPINE** Convention, and **CARPATHIAN** Convention.

In addition, in eight national templates legislation of relevance among the others includes: Water Act, Act on Spatial Planning, River Basin Management Plans, Environmental Protection Act, Drinking



Water Protection Zones pieces of legislation, etc. Figure 2 is adopted after [6] and depicts summary of legislation and policies framework analyses that are of great importance for CC-WARE project.

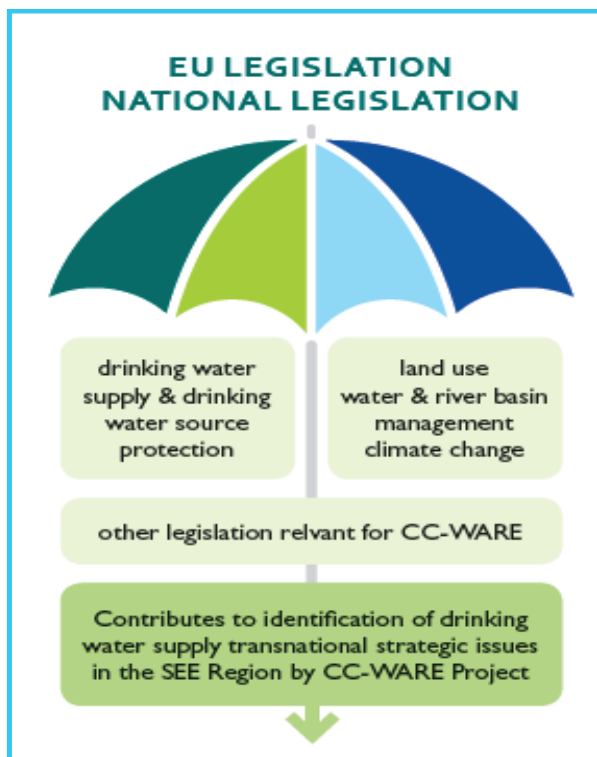


Figure 2. Legislation assessment approach within the scope of CC-WARE project, Source: CC- WARE National/regional Action Plan brochure

2.1. Gaps and Constrains

Comprehensive review and assessment by project partners identified gaps and constrains at all levels (national, regional, and EU) in existing legal framework of relevance for DWS, land use, ESS, and climate change of relevance for integrated approach that reinforce sustainable and adoptive drinking water supply.

It is noteworthy to underline that similar constrains and issues are identified in **EU countries and non EU countries**. Some of the main constrains and issues are:

- ◆ Applicability is sometimes very difficult and they are not well accepted by practitioners due to their contradictions, and complexity as reported by Greece national report;



- ◆ According to national reports, e.g., Serbia, Greece, Hungary, etc., the integrated water resources management is advocated in EU WFD, and number of other policies and strategies, however the implementation of that approach is missing;
- ◆ In some countries, e.g., Romania, within the scope of CC - WARE water supply is not regulated in a comprehensive way and it is just part of some other legislation and policies;
- ◆ In Romania no legislation which defines a common legal framework for drinking water protection areas (DWPA) and in Serbia, Bulgaria, etc., legislation and policy are more or less divided in sectors;
- ◆ In order to have homogeneous DWPA (drinking water protection areas) regulations, a federal law could be evolved in Austria;
- ◆ As stated in Bulgarian report, the full implementation of strict EU requirements is often in discrepancy with national legal framework and available funding sources;
- ◆ In all countries the more integrate approach that would sustain better inter-linkage of DWS, LU. ESS and CC is recognized;
- ◆ All PPs indicated that role of ESS is not recognized in national legislation at the level it should be; and
- ◆ Even existing water protection plans that address climate changes in Italy do not provide clear details on implementation.

2.2. Stakeholders Feedback

During the first Knowledge transfer workshop that gathered stakeholders from project partner countries and beyond the project area. Participant's feedbacks were collected on legal and policy framework given their significance for sustainable DWS. Figure 3 summarizes the answers on the most significant drinking water supply issues recognized by stakeholders.

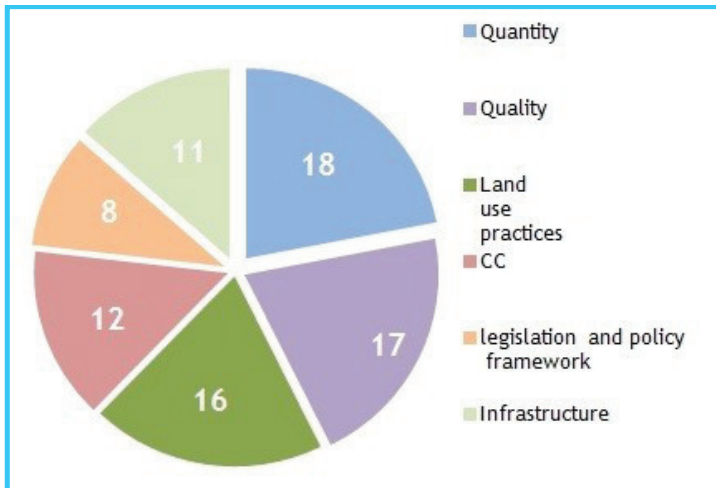


Figure 3. Stakeholders ranking (%) on the most significant drinking water supply issues, Source: [6]

In general, number of cross-cutting issues of relevance for DWS exists. For CC-WARE project this number is even higher as the result of ESS inclusion in drinking water supply system (DWSS) analyses under the different scenarios in the future that consider CC, land use change, etc. Solutions that would contribute in cross-cutting issues better management and implementation of appropriate measures that would decrease drinking water sources vulnerability and increase ES provisioning services for drinking water supply are presented in Figure 4.

It is remarkable that better cooperation among sectors is ranked as the most significant (17 %), followed by sectoral policies that would address majority of cross-cutting issues (15 %). Similar ranking (14 %) is assigned to policy that would address the majority off issues and more financial resources. Finally, approximately 12 % stakeholders ranked better cooperation among authorities at the local and national level as the significant solution for cross-cutting issues. Results are depicted schematically in Figure 4.

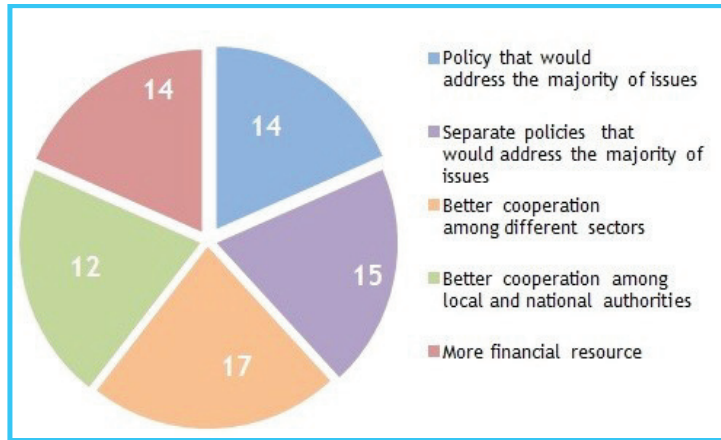


Figure 4: Stakeholders ranking (%) regarding solutions for cross-cutting issues of relevance for DWSS and ESS, Source: [6]

Table 1 summarizes stakeholders' assessment of their knowledge and familiarity on regarding specific topics of relevance for DWS, ESS, land use, climate change, etc.

Table 1. Stakeholders feedbacks on specific topics for cross-cutting issues

TOPIC	ANSWERS (%)		
	Comprehensive	Moderate	Deficient
Familiarity/knowledge with ESS	37	53	11
Ecosystems importance for DWS	72	22	6
More integrated ESS, DWS, LU and CC cross-cutting issues	95	0	5
ESS, DWS, LU and CC cross-cutting issues addressed by EU legal framework & policies	21	63	16
ESS, DWS, LU and CC cross-cutting issues addressed by national legal framework	12	47	41
Familiarity/knowledge with CC impact on WR	55	35	10



As exhibited in Table 1 majority stakeholders (53 %) have moderate knowledge on ESS and ESS role while ES importance for DWS is significant (72 %). According to answers Climate Change impact on Water Resources awareness is evident e.g., over 50 % of participants have comprehensive knowledge and 35 % rated their familiarity as moderate.

Based on outcomes, integrated approach (95 %) rather than divided in sectors (5 %) is crucial for cross-cutting issues with respect to ESS, DWS, LU practices and CC. Only 21 % stakeholders consider that cross-cutting issues are addressed by existing EU legal framework, while over half (63 %) stressed the necessity for its improvement. Diverse actors and actions are indicated to be significant for the improvement and integration of DWS, ESS, LU and CC at national level.

3. Compatible Methodology for ESS Integrated Vulnerability Index Assessment

Based on premises that CC-WARE project incorporates different triggers that affects DWSS the compatibly methodology (Figure 5) for water resources vulnerability assessment and ESS indexes is developed. This approach results in Integrated Vulnerability Index assessment which provides basis for management options evaluation that would mitigate vulnerability of drinking water resources in SEE.

Analyses incorporated number of parameters and indicators assessment under the present conditions and for selected future scenarios given the land use, climate change, DWSS and ESS, based on available data and information within the scope of project area.

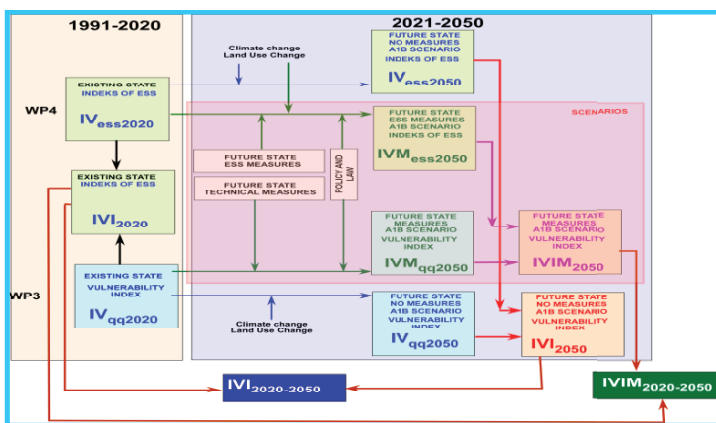


Figure 5. Compatibility methodology schematic developed within the scope of CC-WARE project



For water resources vulnerability subgroups of parameters and variables are divided in those of relevance for water quality and water quantity. The full list of assessed parameters (water demand, water exploitation index, etc.) and variables (P, T, etc.) are available in project reports. Detailed elaboration on vulnerability assessment is beyond scope of this paper. Figure 6 is displayed only as a demonstration of mapping exercise for vulnerability assessment based on modelled outputs from assembled RCMs for CC-WARE project area.

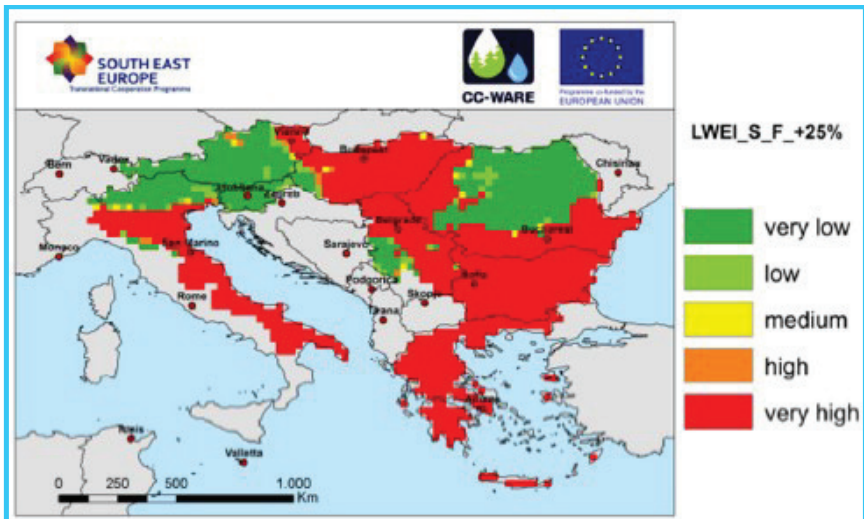


Figure 6. Local Water Exploitation Index (LWEI) future scenarios for increase in water demand in Summer by 25 %, Source: [2]

3.1. Integrated Vulnerability Index Assessment for ESS

Importance of ecosystem service concept is increasingly underlined in recent years. This results in investigation of various corresponding indicators and methodological framework for ESS mapping, quantification and localization [1].

Within the scope of CC-WARE project, development of Integrated Vulnerability Index (IVI) with respect to DWS is accomplished to allow the mapping of ESS vulnerability to CC, land use changes, GDP, and to identify relative potential of ESS to improve DWS in SEE Europe. Great number of parameters and variable has identified to be included in assessment, and integrated vulnerability is calculated for water quantity and water quality.



Finally, the integrated vulnerability index (IVI) is evaluated as the sum of:

- ◆ **WEIn** (Normalized Water Exploitation Index);
- ◆ **WQIn** (Normalized Water Quality Index);
- ◆ **WRI** (Water Retention Index); and
- ◆ **ESSI** (Ecosystem Services Index)

As presented in Figure 7 the integrated vulnerability index is lowest in less populated and areas with low urbanization, i.e., areas presented from blue to gray colours in the map. On contrary, locations with high urbanization and population density rate have higher IVI values, namely localities presented from yellow to red colour. In summary, lower values of IVI indicate higher ESS potential in DWS enhancement given the CC, land use changes, etc., in SEE, while higher values indicate low potential of ESS in DWS improvement.

The next step was estimation of the ESS value for DWS based the 5 scenarios for the future land use that are developed to illustrate land use changes impacts that cannot be represented with state of the art models — and tend to be ignored in policy discussions. Following steps are applied in ESS value for DWS estimation:

- ◆ Ecosystem services potential matrix of Alkemade et al.[1] to select land use categories and ESS types of importance for water supply;
- ◆ Expert judgment (multiple experts) to combine ecosystem services types into 3 main categories, namely:
 - ◆ Water provision;
 - ◆ Water regulation; and
 - ◆ Water quality regulation
- ◆ Expert judgment (multiple experts) to assign relative weights for each land use-ESS category pair. Sum up the weights and normalize them to create ESS value to water Supply index (Index ESS_{ij}) with values between 0 and 1 for each CORINE land use class.

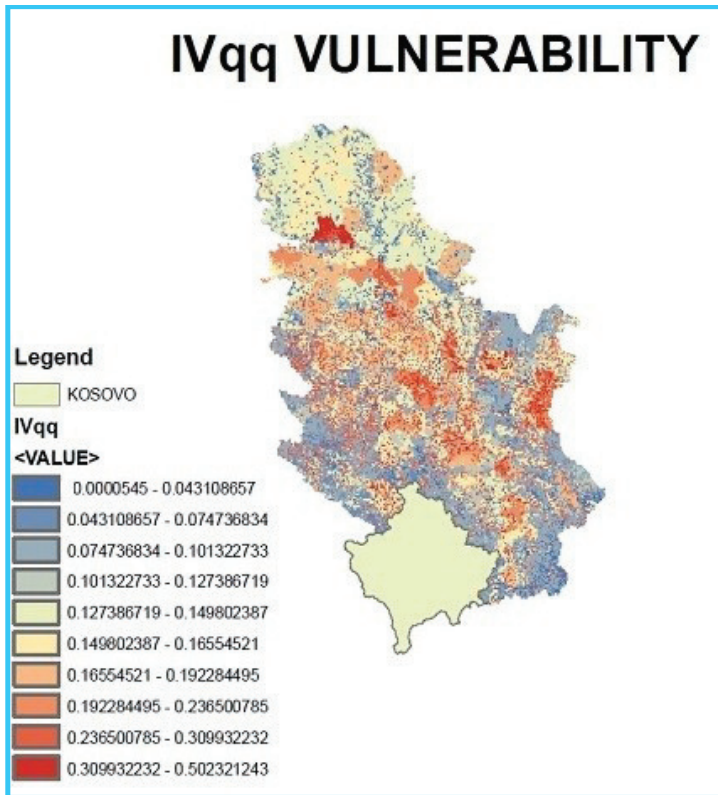


Figure . Integrated Vulnerability Index in Republic of Serbia, based on compatibility methodology application

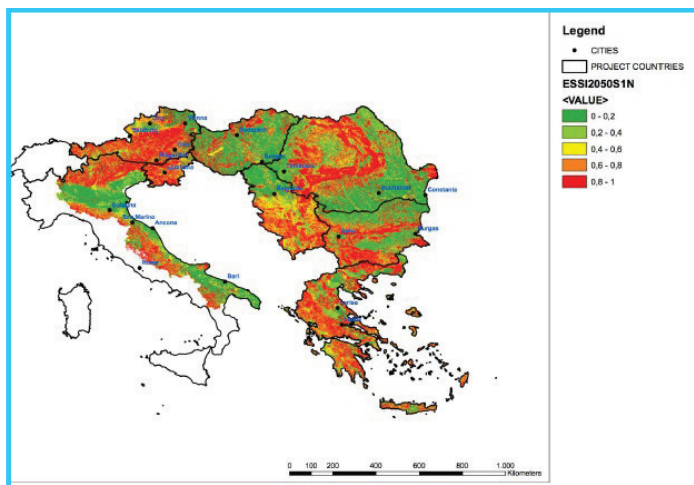


Figure 8. The relative “value” of ESS of importance to water supply in SEE (FUTURE 2050 SCENARIO 1), Source [3]



4. Measures

Ecosystem management that provides benefits for fresh water includes preservation, encasement and conservation within the water source (surface or groundwater) catchment. Given the complexity of the water supply and adverse effects of climate change it is challenging task and requires an adaptive management that provides structured and logical procedures to analyse various options at the catchment and basin level.

In the context of CC-WARE Project Adaptive Management is applicable and desirable. It should be part of every water supply company management system with focus to be amenable to rapid adoption of measures and options to intervene within any given point in the water supply system chain with the main goal to improve the overall system performance and/or its individual components [3].

Strategic Adaptive Management assumes that many different categories of measures and intervention options are available, some of them are following:

- ◆ Measures to improve economic efficiency of a water supply system (e.g. leakage losses);
- ◆ Measures to improve water quality (e.g. ecosystem services, infrastructural measures, etc.);
- ◆ Measures to protect the source of water (e.g. protection zones and land use management);
- ◆ Measures to improve the yield and quality of the source (e.g. ecosystem services measure, etc.);
- ◆ Measures to overcome source limitations, (e.g. water transfers, water use efficiency, etc.);
- ◆ Infrastructure development measures (e.g. regional supply systems, interconnections, etc.); and
- ◆ Ecosystem services measure (management of land use, buffer zones, etc.).

Based on adaption management principles and for definition of vulnerability as a combination of exposure and sensitivity along with adaptive capacity, measures and actions that reduce vulnerability should reduce the exposure to hazards, reduce sensitivity to their effects and increase adaptive capacity.



4.1. Categories of Measures

Management options for drinking water sources vulnerability mitigation, based on improved ESS potential in "supply of pure drinking water in appropriate quantity" provided by selected ES (forests, wetland, grassland, and agricultural land) within the existing legal framework are assembled in the best practice catalogue of measures. The three main groups of measures are important for CC–WARE project objectives:

- ◆ Measures to enhance and preserve water supply ecosystem services that are focused on changing land use and increasing favourable land use and land use practices;
- ◆ Measures to increase adaptive capacity to reduce water supply vulnerability that are focused on demand management, water efficiency and water productivity, infrastructure development, water pricing, etc.;
- ◆ Other measures are focused on creating a favourable environment for the implementation of before mentioned measures (Strategy, Laws and regulations, economic incentives, institutional reform, etc.).

5. Evaluation of the Best Practices Catalogue for Drinking Water Supply

Data and results presented hereafter are based on tremendous work, done by all project partners. The Evaluation of Best Practice Catalogue for Drinking Water Management is based on defined recommendations for adaptive management. Total number of proposed measures is 80, and number of specific measures based on ecosystem type is 28, 25, 24, and 3 for agricultural land, forests, grassland and wetland, respectively.

All the described Best Practices (Management Measures) are evaluated regarding their contribution to Drinking Water Management solutions. An output document [7] provides comprehensive evaluation on adaption measures that are evaluated based on following:

- ◆ Category of the Measure, Ecosystem Service Type (ESS), and Land Use Type;
- ◆ The objectives of the Measures: main objective, specific objective, scale of applicability, and type of the Measure;
- ◆ The expected effect on water supply aspects (on water provision, water quantity, water quality and a short excerpt of the measure description;



- ◆ The evaluation of the Measures regarding measure effectiveness, implementation period, frequency of the measure application, relative measure costs, and potential sources of financing; and
- ◆ Preconditions for their application, i.e. preconditions description, time before the Measure becomes effective, and preconditions for implementation.

For the best practices evaluation radar chart and comments are applied. Generally speaking the most favourable measures are those with high effects on water quality and quantity, water provision, and high vulnerability reduction potential. As presented in excerpts from the catalogue (Figures 9- 13) randomly selected best practices for different ecosystems exhibit different levels of effects and associate costs.

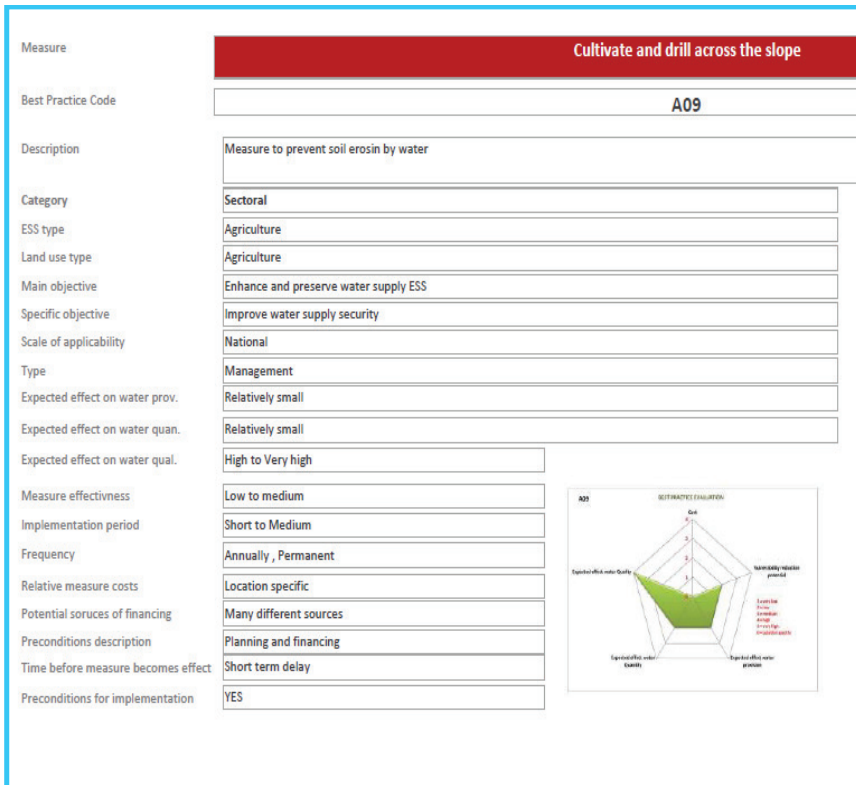


Figure 9. Measure for Agricultural land ecosystem, Source [5]

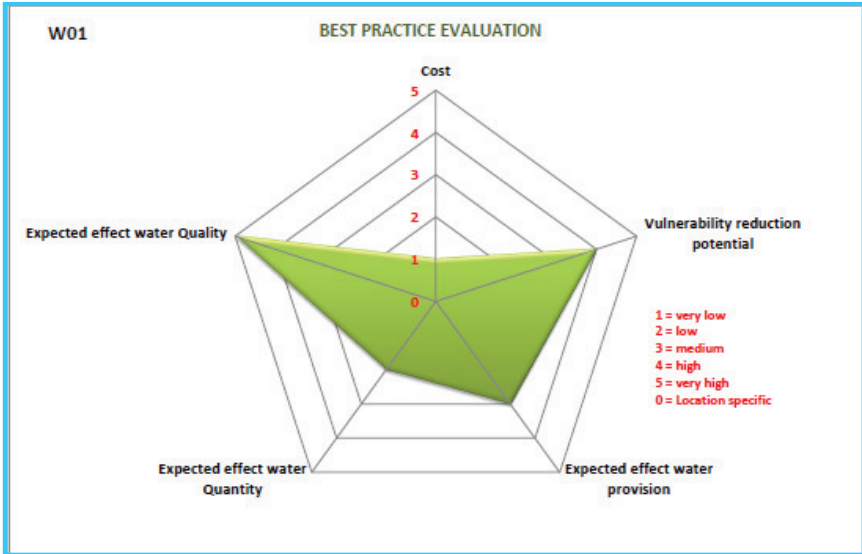


Figure 10. Evaluation of measure for Forests ecosystem - Limitation of Clear Cuts, Source [5]

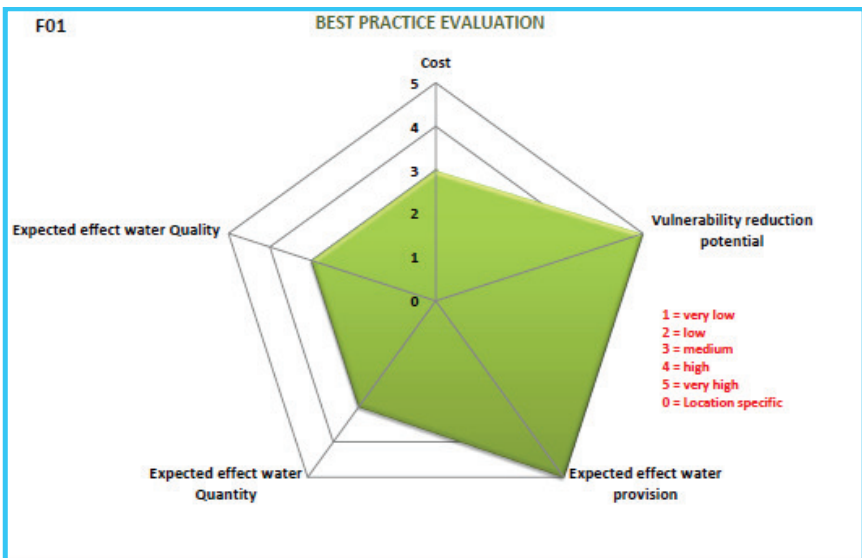


Figure 11. Evaluation of measure for Wetland ecosystem - Preservation and revitalization of wetlands on floodplains, Source [5]

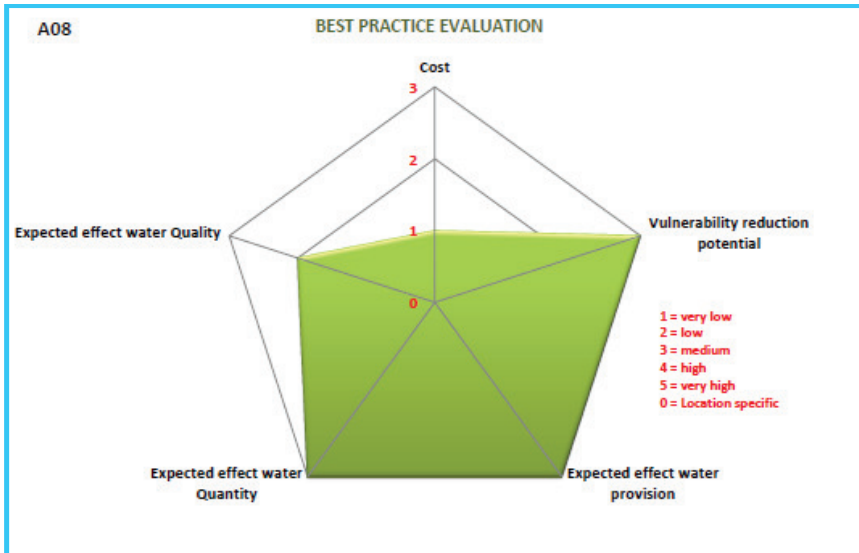


Figure 12. Evaluation of measure for Grassland ecosystem - grassland in DWPA II. (outer zone), Source [5]

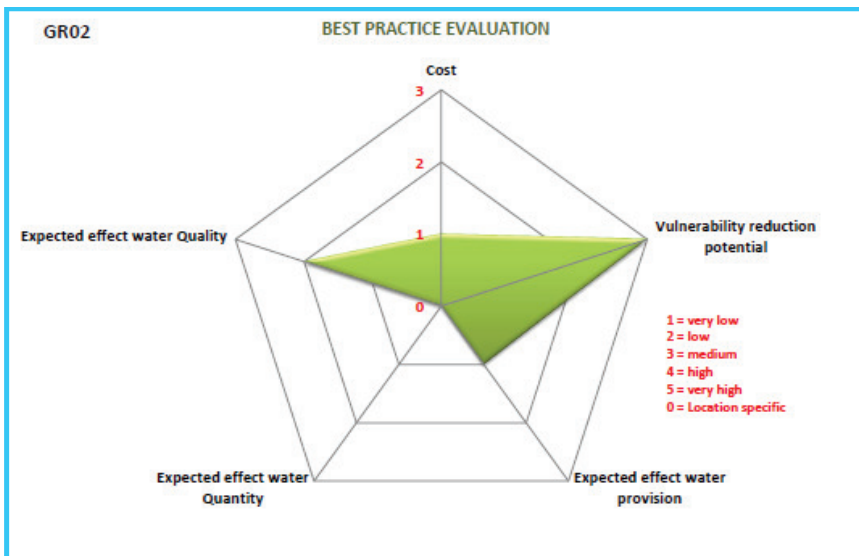


Figure 13. Evaluation of measure for Agricultural land ecosystem - Cultivate compacted tillage soils, Source [5]



6. Conclusions

Results presented in this paper indicate that improvement of the legal framework that address cross-cutting issues of DWS, LU, ESS and CC is required. Despite that questionnaires filled by stakeholders and decision makers from SEE countries indicated that the scope and objectives of CC WARE address cross-cutting issues of DWS, LU, ESS and CC, based on feedbacks provided by participants on significant topics for cross-cutting issues within the scope of CC-WARE project reveals necessity for legal framework improvement.

Applicability of new legal framework should be judged by practitioners to make it more applicable. More integrated approach is needed for DWS and ESS management under the changes in land use and climate patterns. Finally with respect to legal and policy framework the open questions still remain: Do we regulate too much? Do we need just an improvement of the existing legal framework or new legal framework and polices are required?

Complexity of various ES provision services for DWS requires comprehensive evaluation of different variables and parameters that would allow water resources vulnerability assessment within the SEE. Integrated Vulnerability Index includes number of parameters that reflect water quantity and quality, water exploitation index, water retention index, and ecosystem services index.

It is recognized that adaptive approach in water and ES management decrease vulnerability of drinking water sources. Given that, for selected types of ecosystems (forests, grasslands, wetland and agricultural land) best practice Catalogue of Measures is developed.

Total number of measures is 80, and each of them is evaluated against different criteria, e.g., expected effects on water quality and quantity, expected effects on water provision, implementation period, application frequency, main and specific objective, financing, pre requests for implementation ,etc.

It is high time to recognize the fact that many of today's problems are the result of yesterday's solutions and our challenge is to learn to avoid sowing the seeds of tomorrow's problems. Nature has provided us with the answers to all of our questions and it is up to us to use these solutions and set the foundations for a better future. The value of ESS for water supply is highest in forested and wetland ecosystems, followed by grassland ecosystems and lastly by agricultural ecosystems.

Measures taken to preserve ESS in forest and wetland ecosystems shall lead to positive impacts in every situation, as should the



conversion of other categories of land use to forest and/or wetland ecosystems. Justification of each measure would depend on detailed socio economic analysis on a case by case basis. Detailed studies are recommended to come up with appropriate interventions in any given situation.

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Acknowledgements

This work is elaborated through the project co-funded by the European Regional Development Fund (ERDF) and Instrument for Pre-Accession Assistance (IPA). We would like to express our gratitude to the whole CC-WARE project consortium for their tremendous contribution and valuable inputs that result in outputs presented in this paper.



CROSS-BORDER WATER RESOURCES MANAGEMENT IN PRESENT CONDITIONS AND FOR FUTURE SCENARIOS

Barbara Karleuša (barbara.karleusa@uniri.hr),

Josip Rubinić ([jrubic@uniri.hr](mailto:jrubinic@uniri.hr)),

Ivana Radman (ivana.radman@uniri.hr),

Goran Volf (goran.volf@uniri.hr),

Nino Krvavica (nino.krvavica@uniri.hr),

University of Rijeka; Faculty of Civil Engineering; Rijeka; Croatia

Abstract

The aim of the *Networking for Drinking Water Supply in Adriatic Region-DRINKADRIA* Project is to develop a base for strategies and procedures for secure cross-border water supply with specific emphasis on water resources management in transboundary context, climate change (CC) and specific socio-economic aspects of the Adriatic region. This paper provides an overview of project activities and results so far within Work Package 4 (WP4): *Cross-border water resources management*.

In the Adriatic region water resources are facing different human and natural pressures, causing alterations in water quantity and quality. The DRINKADRIA project focuses on cross-border water resources by defining common approaches and methodologies, cross-border protocols and measures for drinking water resources management with consideration of climate change. Partners applied common approach and methodologies for analysing the impact of climate change on water resources availability until the year 2050. Using different scenarios of changes in water demand in the future (until 2050) the Water Exploitation index (WEI) has been calculated in order to analyse the risk in test areas.



Water quality trends in test areas and impact of changes in land-use (due to CC and development) on water resources quality were also analysed.

In last decades increased temperature and frequency of droughts and heavy precipitation events have been observed, so further task of the Project is to provide common guidelines for Water Safety Plans (including drinking water quality and quantity risk) implementation for water suppliers with proposal of response actions and emergency plans in a changing environment.

A special focus will be on protection of water resources that are used for drinking in one country but part of catchment has to be protected in another country. Regulations of DRINKADRIA partner countries related to drinking water resources protection including monitoring activities will be analysed, in order to develop a common basis and unified approach to protection of transboundary aquifers used for water supply.

Keywords: drinking water resources, water supply, cross-border, transboundary, DRINKADRIA, water resources management, climate change, Adriatic

1. Introduction

In the Adriatic region water resources are facing different human and natural pressures, causing alterations in water quantity and quality. In last decades increase in temperature and increased frequency of droughts and heavy precipitation events have been observed. At the same time in this region there are areas with common problems regarding drinking water quantity and quality like increase in drinking water demand especially during summer touristic season, intensification of agricultural production, problems with salinization of groundwater, etc.

In this region there are many transboundary (cross-border) water resources that are used for drinking purpose. The protection and management of cross-border water resources used for drinking purpose is very complex. There are resources that are used for water supply in one country with a part of aquifer/catchment in another country. The EU Water Framework Directive (EU 2000/60) defines the need for a common definition and protection of water resources that are used for supplying population with drinking water. This is implemented by water management plans. But the drinking water protection areas



are still defined for each country separately, with no consensus with the neighbouring country [1].

The DRINKADRIA project will focus on cross-border water resources with common cross-border protocols and measures for drinking water resources management (water quality and quantity) with consideration of climate change.

In this paper an overview of the DRINKADRIA project activities and results so far within Work Package 4 (WP4) that covers the above-listed issues regarding cross-border water resources management is given.

2. Cross-Border Water Resources Management - Project Activities

Within DRINKADRIA Project Work Package 4 (WP4) which is led by the Faculty of Civil Engineering, University of Rijeka, cross-border water resources management issues are analysed through four activities and, depending on the task, on the national, regional and test area levels [1].

The first activity (4.1.) in the Project was to analyse regional characteristics of climate and climate change, and to prepare a Climate and climate change database for the Adriatic area. In this activity a review of existing climate and climate change data was performed based on observed data and afterwards using different climate models for future periods. Analyses were done on the national, regional and test area levels. Modelled data about change in precipitation and temperature were input data for activity 4.2.

The second activity (4.2.) deals with present and future risks on water resources availability with emphasis on drinking water supply. In this activity a common approach and methodologies were setup for determination of water availability and applied in order to estimate the change in water resources availability in test areas for the future period 2021-2050 in comparison to the baseline period 1961-1990. Using different scenarios of changes in water demand in the future (until 2050) the Water Exploitation index (WEI) has been calculated in order to analyse the risk in test areas. Input data for calculation of water availability and results are collected in the hydrological database.

In the third activity (4.3) present and future water safety and risk imposed to the quality of water resources used for drinking water supply is analysed through tasks: analysis of water quality trends in test areas, analysis of present and future land uses impact on water quantity and quality (CC and development impact on water resources),



analysis of seawater intrusion issues and measures to improve the quality of drinking water. The national legislation in the Adriatic Region regarding water sources monitoring is analysed to suggest common protocols.

A more detailed presentation of results so far regarding activities 4.1., 4.2. and 4.3. will be presented in Chapter 3.

Project partners are currently intensively working on 4.4. - Cross-border drinking water resources protection and management. Changing climate is a challenge for water suppliers, above all in the Adriatic region due to high water demand in summer months and decreasing recharge. Some water utilities involved in the Project implemented HACCP (Hazard Analysis Critical Control Point) system for determining drinking water quality risks [2], some of them implemented also water safety plans (WSP) including drinking water quality and quantity risk (water shortage, floods). The aim of the DRINKADRIA project is to provide common guidelines for WSP implementation for water suppliers with proposal of response actions and emergency plans in a changing environment.

Protection of drinking water sources in cross-border catchments suffers from lack of regulatory framework, which results in inadequate technical and institutional tools for the assessment and implementation of the protection measures. In this regard the main tasks are: development of common methodology for drinking water resources vulnerability, risk and hazard determination and harmonization of methodology for delineation of water protection areas. Regulations of countries involved in the Project related to water resources management are analysed, in order to develop a common basis for the protection of transboundary water resources which are used in water supply. Drinking water protection areas are defined for each country separately, with no consensus with the neighbouring country. For example, Slovenia defined drinking water protection areas only to the Slovene-Croatian border and vice versa. Unified approach to protection of transboundary aquifers is crucial for ensuring safe water supply [3].

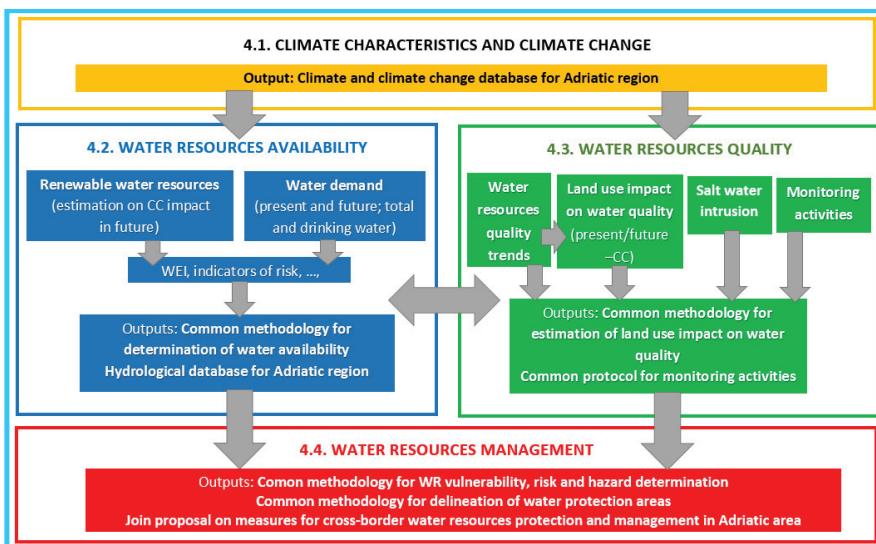


Figure 1. Structure of WP4 Cross-border water resources activities and expected outputs

In the Project, assessment of the availability of water resources and water quality trends is based on case studies in nine (9) test areas that include different water types of resources (surface water, karstic and fractured rock aquifers, porous aquifers...) [1,4]. The location of test areas is presented in Figure 2.

In Italy three test areas are studied. The first is Isonzo Plain, located in the north-eastern side of the Friuli Venezia Giulia Region (Italy) at the border with Slovenia. Although this area has a significant water quantity in the alluvial deposits, there is also a need for careful withdrawal planning because of increasing demand. The water quality is good now. However, the herbicide atrazine degradation products are still present in the aquifers of the plains and in the groundwater, especially in the wells on the north of the Isonzo High Plain. Those wells are more vulnerable to the pollutants. Research in this area is done by the project lead partner (LP) Area Council for Eastern Integrated Water Service of Trieste – CATO. The second is the ATO 3 test area which is located in the central part of Marche Region, stretching from the Apennines to the Adriatic coast. It has two hydro-geological domains - calcareous ridges and alluvial plains. In this test area there is a growing demand for water due to the population increase, and in the last decade, the increase in frequency of the drought seasons was also observed. Regarding the water quality, an increase of pollution by nitrates of agricultural origin has been observed in some pumping wells. Research in this area is done by final beneficiary (FB) 2 Optimal Territorial Area Authority N.3 Marche Centro



– Macerata. The third test area in Italy is Ostuni in Apulia Region, which includes the territories belonging to the Municipality of Ostuni and the surrounding 23 municipalities which span from the Adriatic to the Ionian coast. In this test area the agricultural irrigation has caused a massive exploitation of groundwater resources, and it resulted with a large decrease of the groundwater level and sea water intrusion in most of the coastal areas. An increasing trend in water demand was also observed in the touristic sector on the coast. Research in this area is done by FB3 Italian National Council - Water Research Institute, CNR-IRSA.



Figure 2. Test area locations



In Slovenia FB5 University of Ljubljana analyses the test area that covers the Kobariški stol, Mija and Matajur aquifers, which are cross-border aquifers on Slovenia-Italy border. In this test area settlements are scattered. Some of the inhabitants have public water supply, and some have their own water supply, so there is poor control of the amount of abstracted water and poor water quality monitoring on own water sources. Contamination may occur locally due to agriculture and grazing. Although there are several water sources, only for two of them the water protection areas are determined.

In Croatia two test areas are analysed. First is the test area in Northern Istria, which includes catchments of karst springs Sv. Ivan, Bulaž and Gradole in the Mirna river basin. In this test area there are problems during extremely dry years (e.g. 2012), when spring capacities significantly decrease. Problems with water quality occur during high precipitation events after long-term drought periods, what causes increase of spring abundance, but also turbidity, bacteriological load and chemical quality parameters. There is also a risk of accidental pollution. Water from Gradole in Croatia is transported and sold to Rižanski vodovod to supply with drinking water part of the Slovenian coast. The research in this area is done by FB8 Faculty of Civil Engineering, University of Rijeka in collaboration with FB6 Region of Istria, FB7 Water Utility of Istria and FB9 Croatian Geological Survey. The second test area in Croatia is in Southern Dalmatia. It includes Prud spring and Blatsko polje on the island of Korčula. Possible pollution of Prud is connected with poor determination of catchment boundaries, lack of sanitary protection zones in Bosnia and Herzegovina, settlements within the catchment, roads and small industry. Most of the catchment area of the spring Prud is in Bosnia and Herzegovina, and there are no regulations for the protection of springs in Croatia with catchment in Bosnia and Herzegovina and vice versa. Pollutants in Blatsko polje originate from agricultural production, and there is also a problem with seawater intrusion which usually occurs when there are several dry years in a row. Most of the research in this area is done by FB9 Croatian Geological Survey also in collaboration with FB8 Faculty of Civil Engineering and FB12 Hydro-Engineering Institute of Sarajevo, Faculty of Civil Engineering that analysed the Trebižat river relation to Prud spring.

In Albania the test area Drini river basin, which is located in the Western Balkans is analysed by FB11 Water Supply and Sewerage Association of Albania. The total area of the basin includes the Black Drin, White Drin and Buna Rivers, as well as Shkodra, Ohrid and Prespa lakes. Phosphate has relatively high values in the river Drini. In the river Buna pollution increases during periods of high water levels in its tributaries, and especially in summer during the tourist season.



Regarding groundwater pollution, there is a high nitrite concentration in the Trush zone and surrounding areas.

The test area of the city of Nikšić in Montenegro is analysed by FB14 Public Utility "Vodovod i kanalizacija" Nikšić with the help of FB10 Institute for development of water resources "Jaroslav Černi" from Serbia. Three springs - Gornji Vidrovan, Donji Vidrovan and Poklonci - are included in the water supply system of the city. In the springs Gornji Vidrovan and Donji Vidrovan, during high intensity rainfalls in spring and autumn, there is increased turbidity and mild microbiological contamination.

In Greece the test area is the island of Corfu located in the Region of Ionian Islands. The research is done by FB15 the Region of Ionian Islands and FB16 Civil Engineering Department, University of Thessaly – Greece. In this test area, the natural background (gypsum presence) in the aquifers causes high concentrations of sulphates. Point and diffuse sources of pollution caused increase of the nitrates and ammonium concentrations. High concentrations of chlorides occur locally in the coastal zones due to seawater intrusion caused by excessive pumping and due to natural causes.

3. Cross-border Water Resources Management - Project Results so Far

3.1. Climate and Climate Change in Adriatic Region and in Test Areas

Climate and climate change for the Adriatic area analyses covered the review of existing climate and climate change data (observed data) and afterwards the estimation of future climate and climate change using different climate models for the future. Data on observed and modelled climate change on the national level were collected from literature while for some regions and test areas observed data mostly from the period 1961-1990 were used to model changes in precipitation and temperature for the future period 2021-2050 using different climate modes.

Reports on the national level for most countries are based on the National Communications under the United Nations Framework Convention on Climate Change (UNFCCC), with additional information from other national studies and documents. Climate and climate change characteristics in the Adriatic region on the national level are presented in Table 1 [5].



For future climate simulations SRES (Special Report on Emissions Scenarios) scenarios were used for most of the countries. The IPCC (Intergovernmental Panel on Climate Change) published a new set of SRES scenarios in 2000 for use in the Third Assessment Report [6]. The SRES scenarios were constructed to explore future developments in the global environment with special reference to the production of greenhouse gases and aerosol precursor emissions.

- ◆ A1 storyline and scenario family: a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).
- ◆ A2 storyline and scenario family: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines.
- ◆ B1 storyline and scenario family: a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.
- ◆ B2 storyline and scenario family: a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development [7].

The methodology used for assessment of climate change (in precipitation and temperature) on test areas level is explained in the following text.

The period 1961-1990 is recommended by the World Meteorological Organization as the referent period for the present climate conditions. For most of the test areas, climate change simulations are given for the period 1951-2050.

Present and future climate is assessed based on the results from numerical simulations of the three regional climate models (RCMs): Aladin, Promes and RegCM3. Those models were also analysed in the CC-WaterS project [8], and they participated in the ENSEMBLES project [9]. The mentioned RCMs were not used for test areas in Albania and Greece. The initial and boundary data for each RCM were provided from different global climate models (GCMs). The following



two abbreviations were used: *RCMcorr* (the RCMs' output was bias corrected by EOBS data) and *RCMcorr_adj* (further adjusted model time series due to the differences between EOBS data and local observations). In case of test area Isonzo Plain, a different definition of *RCMcorr* is given (*RCMcorr* is further adjusted model time series due to the differences between the CC models data and local observations).

It must be stressed that models simulations of the future climate should be interpreted as projections of possible state of the climate system which is sensitive to applied initial and boundary conditions, GHGs (greenhouse gases) scenarios and a model internal configuration.

Climate and climate change simulations results for the future on the test area level are presented in Table 2 [5].

In test area ATO 3, test area Ostuni and Croatian test areas, the RCMs were forced by the observed concentrations of the greenhouse gases from 1951 to 2000; from 2001 onwards the IPCC A1B scenario of the GHGs emissions is applied. The reference period for all test areas is 1961-1990, except for test area Drini Basin where changes are related to 1990 [5].



Table 1. Climate and climate change characteristics in the Adriatic region (national level) [5]

Country	Observed			Modelled			
	Period	Temperature	Precipitation	Period	Model and SRES scenario	Temperature	Precipitation
Italy	OP 1865–2003	Trend of 1°C per century all over Italy on yearly basis.	Decreasing tendency; the decreases are very low and rarely significant. On average all over Italy, there is a 5% decrease per century in the annual precipitation amount.			Possible extraordinary heat spells (especially in summer) and increased frequency of extreme weather events (heat waves, droughts).	The anticipated negative impacts are mainly related to increased frequency of extreme weather events (severe rainfalls) and reduced annual precipitation and river flow.
Slovenia	OP 1961-2010 RP 1961-1990	Average increasing across the whole country	The autumn rainfall increases almost across the whole country while the winter precipitation decreases across western Slovenia. In eastern Slovenia no changes are observed	2001-2090	simulation results with 4 MSC methods; A1T, A1FI, A1B, A2, B1, B2	Temperature is expected to rise by 0.5 °C to 2.5 °C (2001 - 2030), from 1 °C to 3.5 °C (2031 - 2060), for 1.5 °C to 6.5 °C (2061 - 2090) (for Ljubljana).	The predictions of changes in annual precipitation are less reliable. The projected changes in annual precipitation in the future range from +10% to -30% (for Ljubljana).
				Aladin and RegCM: 2021-2050, 2071-2100. Promes: 2021-2050	RCMs: Aladin, Promes and RegCM A1B	The future simulations showed the increase on average more than 3°C.	Precipitation data manifests a high degree of ambiguity. General trend pointing to less precipitation in the summer. All models predict an increase of precipitation in autumn (at location Ljubljana).
Croatia	OP 1961-2010 RP 1961-1990	Increasing with the highest trend ranging between 0.3-0.4 °C per decade.	Annual precipitation increasing in the eastern lowland (8% to 11%) and decreasing in the rest of the country (-7% to -2%)	2011-2040 2041-2070	RegCM A2	Period 2011-2040: winter: temperature increase of 0.6°C; summer: 1°C. Period 2041-2070: winter: increase up to 2°C (continental part) and up to 1.6°C (south); summer: up to 2.4°C (continental Croatia), and up to 3°C (coastal zone).	Period 2011-2040: Small changes limited to smaller areas. They vary in the sign depending of the season. The biggest change can be expected in the Adriatic in autumn when RegCM indicates a decrease of precipitation with a maximum of approximately 45-50 mm in the southern Adriatic (not statistically significant). Period 2041-2070: During summer in the mountainous Croatia and in the coastal area a decrease in precipitation is expected. Reductions reach value of 45-50 mm (statistically significant). During winter an increase in precipitation in north-western Croatia and on the Adriatic can be expected (not statistically significant).

Country	Observed			Modelled			
	Period	Temperature	Precipitation	Period	Model and SRES scenario	Temperature	Precipitation
Bosnia and Herzegovina	OP 1981-2010 RP 1961-1990	Increasing ranging between 0.4-0.8 °C	Slightly increasing trend annually. Largest decrease during spring and summer in Herzegovina (up to 20%)	2001-2030	EBU-POM A1B	The mean seasonal temperature change is expected to range from +0,6 to +1,4°C, depending on the region of B&H.	Model showed positive and negative variations. During spring from +5% and during summer even up to +15% (in the north-east part of B&H); up to -20% (in the other parts of B&H, especially south).
Montenegro	OP 41949-present	Significant increase in air temperature, in sea surface and medium sea level	No tendency to increase of decrease, except from the northeast where precipitation increased	2001-2030	EBU-POM A1B	Seasonal changes in mean temperature in the range of +0.6°C to +1.3°C, depending on the season and the area of Montenegro.	Model results show negative and positive changes in precipitation, depending on the part of Montenegro and the season. Positive changes up to 5% (season JJA for the central area of Montenegro, and for the MAM season in parts bordering B&H). Decrease from -10% to 0% (in other areas of Montenegro during the seasons DJF and MAM). Deficient rainfall and the highest values of -20% (MAM season, almost over the whole territory).
Serbia	OP 1949-2006	Highest increase in spring (1.5 °C/100yrs) in winter (0.5 °C/100yrs). In autumn there is a negative trend (0.7 °C/100yrs)	The annual average trend is negative. There is a tendency towards decreasing	2001-2030	A1B	The average temperature change on the annual basis is around +1°C.	Change in precipitation is between -5% to +5%.
Albania	OP 1931-2000	During the end of the first half of the 20 th century there was an increase by 1°C. During the third quarter a cooling of 0.6°C. The rest of the period there is an increase by 1.2°C.	There is a spatial variation in a country level. In the study area there is a slightly decreasing trend	2025-2049 2050-2074	GFDL-ESM2M	Period 2025-2049: during winter increase of 3°C is expected, and 4°C during summer. Period 2050-2074: the expected increase during winter is up to 4°C, and during summer up to 4.5°C.	Significant decrease of precipitation. Although total precipitation is expected to decrease, the number of days with heavy precipitation is likely to increase.
Greece	OP 1949-2006 RP 1961-1990, 1991-2000 2001-2013	Since the '90s annual increase is observed of about 0.4-0.6 °C	Significant decrease especially in the islands of the Ionian and Aegean Sea. In Corfu there is an unstable fluctuation during 1980-2001	2021-2050	RACMO2 A1B	Mean minimum winter temperatures will be ~1.5°C higher in 2021-2050. The increase in mean maximum summer temperatures will exceed 1.5°C and in some cases reach 2.5°C.	Maximum consecutive 3-day precipitation during 2021-2050 will remain essentially unchanged in regions like Western Greece, Eastern Macedonia-Thrace and Crete, but will increase significantly in others.



Table 2. Climate and climate change simulations for future (test area level) [5]

Test area	Station	Model	Time period	Temperature	Precipitation
ITALY: Friuli Venezia Giulia Region - Isonzo Plain	Gorizia CBPI	Regional climate models (RCMs): Aladin, Promes, RegCM3. The ECHAM5 GCM data were used to force	2001-2100	Annual mean temperature (corrected models): 0.34°C/10y (ARPEGE), 0.38°C/10y (ECHAM5), 0.17°C/10y (PROMES).	Annual precipitation amount corrected (RCMs corr): -28 mm/10y (ARPEGE), -12 mm/10y (PROMES), -26 mm/10y (ECHAM5).
	Torviscosa	RegCM3, Aladin was forced by the Arpege GCM and Promes was forced by the HadCM3Q GCM.	2001-2100	RCMs corr: 0.3°C/10y (ARPEGE), 0.5°C/10y (PROMES), 0.4°C/10y (ECHAM5).	RCMs corr: -22 mm/10y (ARPEGE), -30 mm/10y (PROMES), -11 mm/10y (ECHAM5).
	Alberoni		2001-2100	RCMs corr: 0.3°C/10y (ARPEGE), 0.5°C/10y (PROMES), 0.4°C/10y (ECHAM5).	RCMs corr: -19 mm/10y (ARPEGE), -13 mm/10y (PROMES), -6 mm/10y (ECHAM5).
ITALY: Marche Region - ATO 3	Lornano	RCMs: Aladin, Promes, RegCM3. The ECHAM5 GCM data were used to force	1951-2050	RCMcorr: All models simulate statistically significant increasing trends in the mean annual temperature from 0.16 °C/10yr (RegCM3) to 0.30 °C/10yr (Promes).	RCMcorr: RegCM3 and Aladin simulate decreasing trend in the annual precipitation amount, while Promes simulates increasing trend. These trends are not statistically significant.
	Montemonaco	RegCM3, Aladin was forced by the Arpege GCM and Promes was forced by the HadCM3Q GCM.	1951-2050	RCMcorr: All models simulate statistically significant increasing trends in the mean annual temperature from 0.17 °C/10yr (RegCM3) to 0.32 °C/10yr (Promes).	RCMcorr: All models simulate decreasing trend in the annual precipitation amount, but these trends are not statistically significant.
ITALY: Apulia Region - Ostuni	data for station Ostuni is extracted (10 stations are shown in the report)	RCMs: Aladin, Promes, RegCM3. The ECHAM5 GCM data were used to force	1951-2050	Annual mean temperature trend (°C/10yr): RCMcorr: RegCM3 (0.19), Aladin (0.28), Promes (0.29). RCMcorr_adj: RegCM3 (0.16), Aladin (0.24), Promes (0.24).	Annual precipitation amount trend (mm/10yr): RCMcorr: RegCM3 (2.8), Aladin (0.69), Promes (-2.63). RCMcorr_adj: RegCM3 (-0.3), Aladin (-4.84), Promes (-5.57).
	comparison among all 10 stations	RegCM3, Aladin was forced by the Arpege GCM and Promes was forced by the HadCM3Q GCM. (RCM model output downscaled to the observed time series through a q-q plot procedure).	1955-2050	Increasing temperature forecast by all RCMs.	The signs of trends are not equal for all the stations. Promes indicates a uniform in space decrease of precipitation, in the order of 2.5 mm/10yrs (corr), and in the order of 8 mm/10yrs (corr_adj). Aladin also forecasts a tendency to reduction of precipitation, but less significant than Promes and not uniform in space.
SLOVENIA: Kobariški stol, Mia, Matajur and Mima River catchments	Bilje	RCMs: Aladin, Promes, RegCM3. Analyses with RCM corrected and RCM corrected & adjusted data.	1951-2050	Decadal temperature trend: RCM bias corrected models (RCMcorr): Aladin (0.25), RegCM3 (0.17), Promes (0.32). RCM bias corrected and adjusted models (RCMcorr_adj): Aladin (0.25), RegCM3 (0.17), Promes (0.32).	Decadal precipitation amount trend: RCMcorr: Aladin (1.17), RegCM3 (0.04), Promes (1.38). RCMcorr_adj: Aladin (1.17), RegCM3 (0.05), Promes (1.38). Aladin and RegCM3 have statistically non-significant trend at 5% significance



				Trends for all three models have statistically significant regression at 5% significance level.	level, and for Promes the trend is statistically significant.
	Portorož		1951-2050	Decadal temperature trend: RCMcorr: Aladin (0.25), RegCM3 (0.17), Promes (0.30). RCMcorr_adj: Aladin (0.25), RegCM3 (0.17), Promes (0.30). Trends for all three models have statistically significant regression at 5% significance level.	Decadal precipitation amount trend: RCMcorr: Aladin (0.85), RegCM3 (0.56), Promes (1.13). RCMcorr_adj: Aladin (0.85), RegCM3 (0.56), Promes (1.13). All three trends have statistically significant regression at 5% significance level.
CROATIA: Northern Istria – springs Gradole, Sv. Ivan, Bulaž	Pazin	RCMs: Aladin, Promes, RegCM3. The ECHAM5 GCM data were used to force RegCM3. Aladin was forced by the Arpege GCM and Promes by the HadCM3Q3 GCM.	1951-2050	RCMcorr: All models simulate statistically significant increasing trends in the mean annual temperature from 0.17 °C/10yr (RegCM) to 0.31 °C/10yr (Promes).	RCMcorr: All models simulate increasing trend in the annual precipitation amount, but not statistically significant.
CROATIA: Southern Dalmatia – Spring Prud and Blastko polje	Opuzen		1951-2050	RCMcorr: All models simulate statistically significant increasing trends in the mean annual temperature amounting to 0.19 °C/10yrs (RegCM), 0.27 °C/10yrs (Aladin) and 0.31 °C/10yr (Promes).	RCMcorr: Increasing trend for annual precipitation (RegCM3 and Aladin), decreasing trend (Promes). These trends are not statistically significant.
MONTENEGRO: Nikšić	Nikšić	RCMs: Aladin, Promes, RegCM3.	1951-2050	RCM corrected models: Mean annual temperature trend equation - Aladin ($y = 0.0312x - 50.939$), Promes ($y = 0.0323x - 52.976$), RegCM3 ($y = 0.0201x - 28.912$). The reliability of T trends is relatively high.	RCM corrected models: Sum annual precipitation trend equation - Aladin ($y = -0.2899x + 2558.6$), Promes ($y = -1.7665x + 5499.1$), RegCM3 ($y = -0.4440x + 2882.6$).
	Lukovo		1951-2050	/	RCM corrected models: Sum annual precipitation trend equation - Aladin ($y = -0.1897x + 2225.2$), Promes ($y = -1.6554x + 5143.6$), RegCM3 ($y = -0.4914x + 2844$). The reliability of P trends is lower.
ALBANIA: Drini Basin	Theth, Shkoder A, Shishtavec, Peshkopi, Shupenze	A1BAIM scenario (Average values), A2ASF scenario (Min values), A1FIMI scenario (High values).	Years: 2030, 2050, 2080, 2100	The annual temperature is likely to increase (related to 1990) up to 1.8°C (1.3 - 2.4°C) by 2050; 2.8°C (2.1 - 4.1°C) by 2080 and 3.2°C (2.3 - 5.0°C) by 2100.	Annual precipitation changes related to 1990: - 8.1% (-5.5 to -11%) by 2050, -12.9% (-8.4 to -21%) by 2080, -15.5% (-9 to -26.1%) by 2100.
GREECE: Corfu island	Gouvia	Ensemble (scenario A1B), Prudence (scenario A2), Prudence (scenario B2), REGCM (scenario A1B).	2021-2050	Temperature is expected to increase during all the seasons and annually. The average annual mean temperature is expected to increase from 1.23°C to 4.27°C depending on the model.	Total annual precipitation is expected to decrease from 3.93% to 25.4% depending on the model. Total precipitation decrease especially in the summer months. In the winter months two models predict a slight increase.



3.2. Water Resources Availability in Test Areas

Surface runoff and recharge constitute basic hydrological information for determining the characteristic renewable water resources. In order to understand the impact of CC on renewable water resources it is worth analysing the changes together with alterations in the hydrological basis (long-term averages of the total runoff, spring rate or the recharge).

Results about climate change (temperature and precipitation) were input data for calculation of change in water availability in test areas in the future period 2021-2050.

The common methodology to quantify CC impact on water availability was focusing mainly on the harmonised results, so uniform modelling tool was not proposed. The partners could use existing well known models or their own models to quantify CC impact on water availability.

In order to be able to compare CC impact on water resources in test areas it was agreed to calculate long-term average water resources conditions (m^3/s) for the period 1961-1990 and if data were available it was agreed to calculate also characteristic renewable water resources (m^3/s) for the period 1961-1990. Based on results from climate models and change in precipitation and temperature for the period 2021-2050 using available models it was agreed to calculate long-term average conditions (m^3/s) for the future period 2021-2050 and if data were available also characteristic renewable water resources (m^3/s) for the period 2021-2050. Both for long-term average conditions and characteristic renewable water resources the change (in %) between results for the period 2021-2050 and the baseline 1961-1990 had to be calculated [10].

It was important to use adequate models that were also calibrated and validated. Following the classification defined in the previous project CCwaterS, resources are characterized according to estimated changes [8]:

- ◆ low changes $\leq 10\%$ (green),
- ◆ medium changes 11-25% (yellow),
- ◆ high changes 26-50% (orange) and
- ◆ extreme changes $>50\%$ (red).

Table 3 gives core results of activity 4.2. [10]. It shows the representative values for all test areas as the basis for the evaluation, providing basic information for the assessment of possible water shortages considering different scenarios of future water demands.



Figure 4 shows changes in average flow and recharge in test areas for the future period 2021-2050 compared to the 1961-1990 baseline period [10].

Table 3. Basic hydrological information for the evaluation of the climate change on water resources [10]

Country	Test area		WR (m ³ /s)				Changes in WR in future (2021-2050) compared to baseline (1961-1990) in %		
			1961-1990	2021-2050			RegCM3	Aladin	Promes
				RegCM3	Aladin	Promes			
Italy	Isonzo plain	ACWR	41.6	40.97 - 42.53			-20 to +20		
	Ostuni- Adriatic	ACWR	6.23	5.81	4.84	4.61	-6.7	-22.3	-26.0
	Ostuni - Ionic	ACWR	5.24	4.86	4.80	3.46	-7.3	-8.4	-34.0
Croatia	N. Istria – Gradole	ACWR	2.17	2.13	2.08	2.00	-1.9	-4.1	-7.8
	N. Istria – Gradole	CRWR	0.86	0.80	0.81	0.75	-7.2	-5.6	-13.1
	N. Istria –Sv. Ivan	ACWR	0.92	0.92	0.86	0.60	-0.3	-6.5	-34.9
	N. Istria –Sv. Ivan	CRWR	0.42	0.42	0.39	0.17	-0.5	-8.4	-60.3
	N. Istria – Bulaž	ACWR	1.70	1.56	1.55	2.22	-6.3	-8.8	30.8
	N. Istria – Bulaž	CRWR	0.32	0.28	0.28	0.45	-11.4	-11.2	41.2
	S. Dalmatia - Prud	ACWR	6.16	5.60	5.39	5.01	-9.1	-12.5	-18.7
	S. Dalmatia - Prud	CRWR	3.36	3.13	3.05	2.92	-6.8	-9.2	-13.1
	S. Dalmatia - Blatsko polje	ACWR	0.287	0.259	0.235	0.222	-9.8	-18.1	-22.6
	S. Dalmatia - Blatsko polje	CRWR	0.043	0.042	0.040	0.039	-2.3	-7.0	-9.3
Albania	Drini basin – Drini river	ACWR	(1951-1985) 360	340	310	290	-5.6	-13.9	-19.4
	Drini basin – Buna	ACWR	(1951-1985) 320	305	290	275	-4.7	-9.4	-14.1
	Drini basin – Drini+Buna	ACWR	(1951-1985) 680	645	600	565	-5.1	-11.7	-16.8
	Drini basin – Drini of Lezha	ACWR	(1951-1985) 30	27	25	22	-10	-16.7	-26.7
Greece	Corfu - GR0500010	ACWR	2.38	1.78-2.97			-25 to +25		
	Corfu - GR0500020	ACWR	1.27	0.95-1.59			-25 to +25		
	Corfu - GR0500030	ACWR	1.27	0.95-1.59			-25 to +25		

ACWR – average conditions water resource
CRWR - characteristic renewable water resource



For Isonzo plan and Corfu test areas changes in water resources availability are given by expert evaluation, for all other test areas climate data (temperature and precipitation) from the climate models RegCM3, Aladin and Promes were used as input data for water resource models.

The test areas in the North (e.g. Northern Istria) show lower changes than those in the Southern part of the Adriatic Region (Southern Dalmatia, Ostuni, Drini Basin). The highest changes in water availability can be noticed in use of the Promes model, after that Aladin, and the lowest changes by the RegCM3 climate model.

Analyses carried in Croatian test areas covered mean annual discharge and lowest mean monthly discharge, so extreme conditions were also analysed (Table 3).

As an example of part of conducted analyses the possible impacts of foreseen climate changes/variations on water resources within the selected test areas, spring Gradole in Northern Istria (Croatia) is taken [11]. Gradole is the most significant spring and groundwater intake in Istria whose catchment is not in the cross-border impacts domain, but its water balance has a pronounced cross-border impact given that it also supplies water to a part of the Slovenian coast. Considering the already present negative trends of increase in air temperature and discharge in that spring from the middle of the last century until today, and the expected continuation and intensification of negative climate changes/variations, it is clear that the risks of unfulfilled possibilities of assuring the expected water supply needs from that spring also grow. The reduction of 1st degree in water supply which was introduced in the area of the Istrian Region during summer in 2012 has further intensified the beliefs about the risks in the future. Within the DRINKADRIA project, the Croatian Meteorological and Hydrological Service and experts have carried out the climate conditions assessment (precipitation and air temperatures) until the year 2050 with several climate models (RegCM3, Promes, Aladin), which have given different estimates of the intensity of those impacts [12]. It was found that more negative scenarios than those observed until now are also possible in the future.

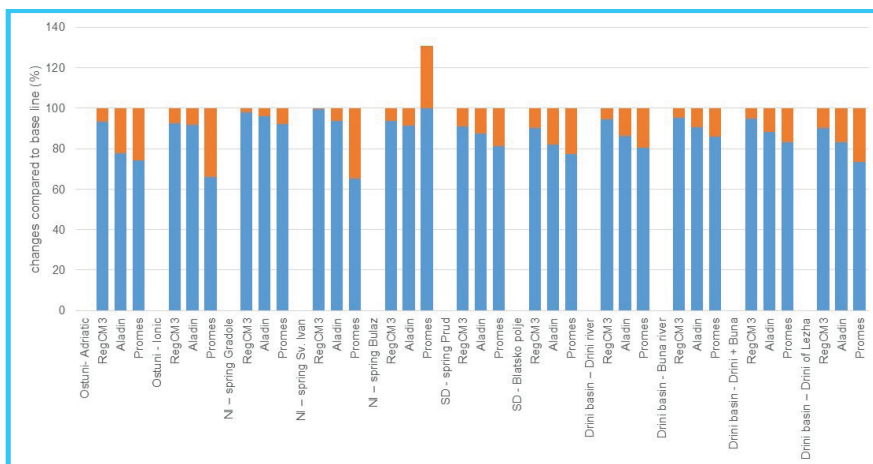


Figure 3. Changes in average flow and recharge for the future period 2021-2050 (orange) compared to the 1961-1990 baseline period (blue+orange) [10]

On the level of 30-year averages, it is expected that there will be no significant differences in precipitation, but their greater variability in terms of occurrence of extremely dry years is foreseen. Average annual air temperatures should increase significantly according to all models, whereby model results are quite different. Average mean 30-year air temperature increase for the model Aladin is 1.6 0C, 1.2 0C for RegCM3 and even 2.2 0C (+19%) for Promes, also with increased maximum and minimum air temperatures. An overview of air temperature and precipitation in the period 1951-2050 is given in Figures 4 and 5, generated by the model RegCM3. After generating the impact of those changes on characteristic parameters of spring Gradole water balance (mean annual discharge and minimum mean monthly discharge), the model RegCM3 has given the lowest intensity of change.

Generating of discharges was conducted on the basis of the mentioned mean annual air temperatures and annual precipitation amounts which were generated with climate models, and runoff estimation conducted based on them - effective infiltration of precipitation from catchments into karst aquifers [12]. Figure 6 shows the results of modelling of the minimum mean monthly discharges based on climatological data generated by the model RegCM3. They are selected as representative because of the highest homogeneity of historical and generated discharge data series.

The results of the assessments show that the average value of minimum mean monthly discharges in the period 2021-2050 in relation to the reference period 1961-1990 could be reduced by 7.2%, the maximum value of mean monthly discharge could increase by 12.2%,



and the minimum value of mean monthly discharge could decrease by as much as 30.7% [11].

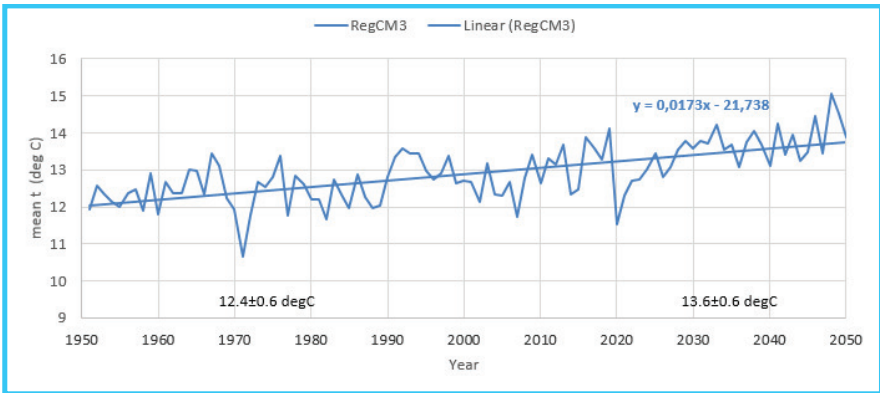


Figure 4. Pazin station: mean annual temperature and associated linear trend in RegCM3 for the period 1951-2050. The numbers at the bottom of the panel are mean values and standard deviations for the periods P0 (1961-1990) and P1 (2021-2050). The model time series are for RCMcorr [12]

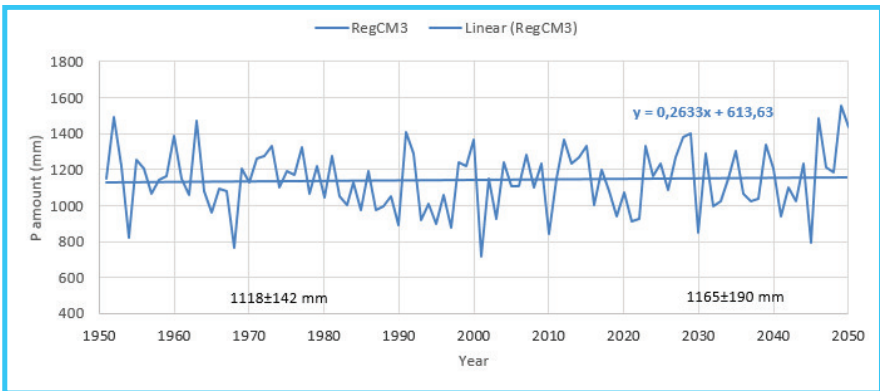


Figure 5. Pazin station: annual precipitation amount and associated linear trend in RegCM3 for the period 1951-2050. The numbers at the bottom of the panel are mean values and standard deviations for the periods P0 (1961-1990) and P1 (2021-2050). The model time series are for RCMcorr [12]

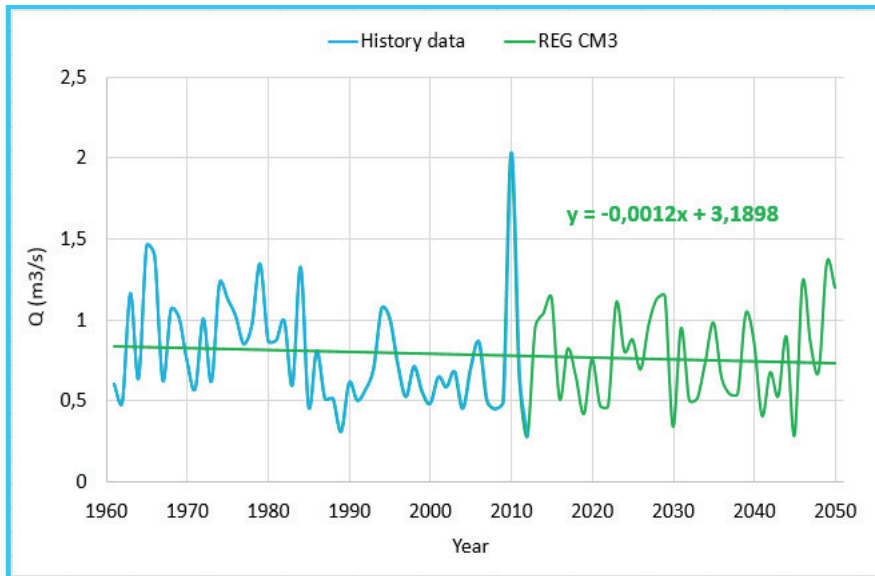


Figure 6. Historical and generated synthetic series of minimum mean monthly discharges of spring Gradole (1961-2050) with associated trend by the model REGCM3 [11]

Sensitivity and vulnerability of water supply depends on the water exploitation level and available water resources. To analyse the risk in test areas WEI was selected [10]. WEI is the ratio of the water demand (WD) and renewable water resources (WR):

$$WEI = WD / WR$$

Total water demand consists of drinking water, water for irrigation, industry and if known ecological water demand. Although, the common practice is to determine water exploitation index using the total water use, in this case, WEI for drinking water was also calculated in some test areas.

FBs had to calculate the total demand and if possible drinking water demand in test areas. It was agreed that water demand should be calculated for three scenarios [10]:

- ◆ Scenario 0 (WD_0): present water demand
- ◆ Scenario 1 (WD_1): future water demand 1 (water demand increased by 25% according to present demand)
- ◆ Scenario 2 (WD_2): future water demand 2 (water demand decreased by 25% according to present demand)



Four different combinations of water demand scenarios and renewable water resources (Average Conditions Water Resource - ACWR and Characteristic Renewable Water Resource – CRWR from Table 3) were considered [10]:

- ◆ $WEI_1 = WD_0 / WR_{1961 - 1990}$
- ◆ $WEI_2 = WD_0 / WR_{2021 - 2050}$
- ◆ $WEI_3 = WD_1 / WR_{2021 - 2050}$
- ◆ $WEI_4 = WD_2 / WR_{2021 - 2050}$

This assessment should have some threshold values to define different stages of vulnerability or risk. Following the classification defined in the previous project CCwaterS [8], 70% exploitation rate has been selected for indicating strong risk (instead of the usual 90% a lower threshold is applied, considering a 20% decrease because of the uncertainty related to water dependent ecosystems) and 50% for indicating possible difficulties, so thresholds for defining risk based on the WEI that are applied are:

- ◆ low risk ≤ 0.50 (green),
- ◆ possible difficulties 0.51-0.70 (yellow),
- ◆ strong risk 0.71-1.00 (orange),
- ◆ not sustainable > 1.00 (red).

Results are shown in Table 4. For Ostuni test area the ecological water demand was included in the total water demand.

Water demand in Northern Istria was assessed using a simplified approach based on the measured data for overflow, abstracted and total discharges at Sv. Ivan, Gradole and Bulaž springs. Intra-annual distribution indicates that the highest water demand occurs in July and August, which coincides with the decrease in water resources. Those are typical summer months, with very high temperatures, low precipitation, tourist arrivals, and increased irrigation demands (Figure 7).

The proportion of drinking water use in total water use was assessed based on the data from the extremely dry summer of 2012, when a 1st degree water restriction was declared in Istria County. During this time an average decrease in water use by 15% was observed [14]. Using this information, drinking water use was calculated as 85% of total water use.

WEI was calculated separately for Water Resource Average Conditions (WRAC) represented by average annual abstracted quantities, and Characteristic Renewable Water Resources (CRWR) represented by long-term mean of August monthly averages of abstracted quantities [11]. For average conditions all combinations of WEI_{1-4} indicate very low risk, but for characteristic renewable water



possible difficulties at present and in the future if the water demand stays the same. If the water demand increases by 25% WEI_3 indicates strong risk for total water use, and possible difficulties for drinking water use. On the other hand, if the future water demand decreases by the same amount, WEI_4 indicates almost no risk (Table 4).

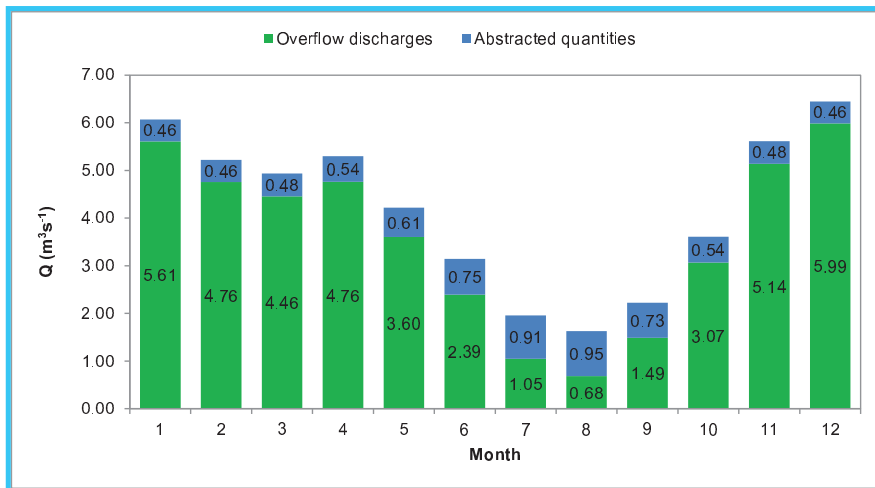


Figure 7. Intra-annual distribution of the long-term mean of average monthly overflow discharges and abstracted quantities from springs Gradole, Sv. Ivan and Bulaž combined (1991 – 2012) [11]



Table 4. Water exploitation index calculated for four different combination of water demand scenarios and renewable water resources [10]

Country	Test area		WEI ₁		Climate models	WEI ₂		WEI ₃		WEI ₄					
			Total use	Drinking water		Total use	Drinking water	Total use	Drinking water	Total use	Drinking water				
Italy	Isonzo/Soča plain	AAAQ / ACWR	0.44	0.43	Expert evaluation	0.45	0.44	0.46	0.45	0.43	0.43				
					RegCM3	0.90		1.13		0.68					
						Aladin	1.08		1.35		0.81				
	Promes	1.13		1.42			0.85								
	Ostuni – Adriatic	AAAQ / ACWR	0.85		RegCM3	1.04		1.30		0.78					
					Aladin	1.05		1.31		0.79					
					Promes	1.45		1.82		1.09					
	Ostuni – Ionic	AAAQ / ACWR	0.98		RegCM3	0.13	0.11	0.17	0.14	0.10	0.08				
					Aladin	0.14	0.12	0.17	0.15	0.10	0.09				
Promes					0.13	0.11	0.16	0.14	0.10	0.08					
Croatia	Northern Istria - springs Sv. Ivan, Bulaž and Gradole	AAAQ / ACWR	0.13	0.11	RegCM3	0.63	0.54	0.79	0.67	0.49	0.41				
					Aladin	0.64	0.54	0.80	0.68	0.49	0.42				
					Promes	0.69	0.59	0.86	0.73	0.53	0.45				
		LTMAM AAQ / CRWR	RegCM3	0.021		0.026		0.016							
			Aladin	0.022		0.027		0.016							
			Promes	0.023		0.029		0.017							
	Southern Dalmatia – Prud spring	LTMAM AAQ / CRWR	0.052		RegCM3	0.056		0.070		0.042					
					Aladin	0.058		0.072		0.043					
					Promes	0.079		0.075		0.045					
	Southern Dalmatia – Blatsko polje	AAAQ / ACWR	0.120		RegCM3	0.131		0.166		0.100					
					Aladin	0.145		0.183		0.111					
					Promes	0.153		0.194		0.117					
LTMAM AAQ / CRWR		RegCM3	1.095		1.381		0.833								
		Aladin	1.150		1.450		0.875								
		Promes	1.179		1.487		0.897								
Greece	Corfu - GR0500010	AAAQ / ACWR	0.092	0.086	Expert evaluation	0.070	0.065	0.153	0.143	0.092	0.086				
					Corfu - GR0500020	AAAQ / ACWR	0.175	0.100	Expert evaluation	0.133	0.075	0.292	0.166	0.175	0.100
					Corfu - GR0500030				AAAQ / ACWR	0.360	0.114	Expert evaluation	0.274	0.087	0.600

ACWR – average conditions water resource

CRWR - characteristic renewable water resource

AAAQ – average annual abstracted quantities

LTMAMAAQ – long-term mean of August monthly averages of abstracted quantities



3.3. Water Resources Quality in Test Areas

Water quality trends and land use changes impact on water resources quality in test areas are analysed in activity 4.3.

Data from the Corine Land Cover (CLC), which represents a digital database on types of land cover/use, were used to define the present land use and assess changes in land use in the past.

Basic water quality indicators, trends and present land use in the DRINKADRIA test areas are presented in Table 5 [15,16].

An increase of nitrates was observed, due to intensive agriculture in ATO3 test area, anthropogenic activities on Corfu Island, or contribution of unused nitrates from the soil zone in the wet season in Southern Dalmatia test area Blatsko polje [15]. Four test areas that have a problem with seawater intrusion and groundwater salinization due to groundwater over-abstraction are ATO3 test area, Ostuni, Blatsko polje and Corfu Island.

In some cases there are problems with microbiological contamination which occur due to the following reasons: hydrological conditions (in Northern Istria, the Trebižat river and test area in Nikšić), untreated urban waste waters from settlements (in Northern Istria and the Trebižat river), wild animals or livestock in the watershed areas of springs (in Northern Istria), small water sources which are in many cases obsolete and not well maintained (ATO3 test area). Some test areas have an increasing trend of total suspended solids (TSS). TSS content depends primarily on the amount of rainfall (Slovenian test area and Northern Istria), so this should not be considered as an indicator of pollution. High values can also occur due to the interventions in the river bed, like in Slovenian test area.

For assessment of land use change in the future the climate change impact and development impact in the area were analysed [16]. Climate change data from activity 4.1. and also data about development in test area in the future (from spatial or other plans) were used. It is expected that changes in land use in the future will have an impact on water resources quality.

For the description of relevant processes which endanger water quality, it was agreed to apply the DPSIR framework in the project as a common methodology.

The European Environmental Agency (EEA) assesses the State (S) of the environment using the DPSIR methodology. Namely, the State (S) is the result of specific Drivers (D) and Pressures (P), positive or negative, which Impact (I) the environment. The Responses (R) represent the solutions (e.g. policies, investments) that should then be



done to improve or maintain that state. The EEA report also looks at Outlooks (O) for the state of the environment—namely, what will happen to that state over time based on various scenarios [17].

The DPSIR framework is in some way a conceptual model (see Figure 8) representing direct interactions through a loop in the way that human beings interact with the environment [17]. The DPSIR approach was used in the DRINKADRIA project to analyse present, past and future land use impact on water resources quality (Figure 9) [16].

As an example of the DPSIR approach, application in test areas in Northern Istria (Croatia) is shown in Table 6.

In the Project, measures to improve water resources quality proposed and applied in test areas are collected to prepare a joint proposal of measures for cross-border resources in the Adriatic region [18].

As an example, some measures that are used in test areas in Northern Istria (springs Sv. Ivan, Bulaž and Gradole) are listed below [18]:

- ◆ *Istrian County Spatial Plan* gives advantage to organic farming which means production without mineral fertilisers, pesticides, hormones and similar products.
- ◆ In the *Istrian County Spatial Plan* it can also be seen that most of drinking water sources areas are under protected areas.
- ◆ With implementation of Istria water protection system plan *Sewerage and wastewater treatment for small settlements in drinking water sanitary protection zones of Istria County* the problem of wastewaters drainage with corresponding waste water treatment plants will be solved. It is also expected that the application of other structural and non-structural measures will achieve reduction of negative pressures on water resources.

Table 5. Basic water quality indicators, trends and present land use in DRINKADRIA test areas [15,16]

Country and test area	Basic water quality characteristics and trends	Land use
ITALY: Friuli Venezia Giulia Region - Isonzo plain	Nitrate content on pumping wells had always quite low concentrations (<15 mg/l) over a legal limit of 50 mg/l. A fossil marine aquifer is present in the depths in the carbonates, therefore the high chloride values in the northern wells can be linked to this resource and not to the salt water intrusion. The general sulphates trend is quite constant, slightly increasing within last years for 2 wells, but below the legal limit. The analyses showed a complete absence of any kind of microorganisms	Agriculture 58.81%, urbanised area 22.48%, natural environment 10.5%, water surface 3.56%, industry 3.14%, sport and leisure 0.94%, quarry and landfill 0.57%.
ITALY: Marche Region – ATO3	Very rich mountainous area in terms of aquifers, potentially providing large volumes of good quality water. Progressive worsening in the valleys (medium-high hilly area and flat-coastal zone) of water quality features: electric conductivity between 600 and 1400 $\mu\text{S}/\text{cm}$, dry residue between 0.3 and 0.8 g/l. significant increase in nitrates concentration.	Calcareous Ridges: agriculture 35%, forestry 63%, artificial surfaces ~ 1%, water bodies ~ 1%. Alluvial Plains: Agriculture: 77%, forestry: 16%, artificial surfaces 6%, water bodies <1%.
ITALY: Apulia Region - Ostuni	Electrical conductivity of the groundwater at Salento coastal area exceeds 15000 $\mu\text{S}/\text{cm}$. Reduction in water withdrawal of 17% might be achieved by using treated water from the sewage plants in the coastal area in the irrigation period. The percentage of water supplied for irrigation purposes might be restored, during the non-irrigation season (surplus of treated effluent may be 27%).	Agriculture 80%, forestry 13%, artificial surfaces 7%.
SLOVENIA: Kobariški stol and Mia – Matajur aquifers	The physical and chemical parameters of surface and groundwater show the characteristics of natural conditions. Possible human impacts practically absent within the test area. All measured parameters (pH, EC, oxygen regime, TOC, nutrients, microbiology, and metals) indicate that surface water and groundwater in test areas are not polluted and have a good chemical status. Groundwater hydro-chemical type is Ca - HCO ₃ . Good surface and groundwater quality status in test areas in NW Slovenia (Kobariški stol and Mia – Matajur aquifers).	Artificial areas 0.28%, agricultural areas 14.56%, forest and semi natural areas 85.27%.
CROATIA: Northern Istria-springs Gradole, Sv.Ivan and Bulaž	There is an increasing trend of total suspended solids on all springs. However, the content of TSS depends primarily on hydrological conditions, so this should not be considered as an indicator of pollution. During 2003-2013 there was a decreasing trend of nitrates (bellow MAC). Microbiological contamination is present and is associated to the hydrological conditions. Higher concentrations of total number of microorganisms and microorganisms of fecal origin were occasionally observed, mostly from untreated urban waste waters. For all springs phosphates and total phosphorus are very low. The values of nearly all indicators are decreasing, and the water quality on springs improves.	Gradole: non-irrigated arable land 0.21%, coniferous forest 0.40%, discontinuous urban fabric 0.98%, vineyards 2.46%, pastures 5.73%, complex cultivation patterns 7.73%, mixed forest 7.92%, transitional woodland 12.69%, broad-leaved forest 26.41%, land principally occupied by agriculture 35.48%.
CROATIA: Southern Dalmatia -spring Prud and Blatsko polje	Different hydro-chemical facies of the two pilot areas in Southern Dalmatia (SD). Sampled waters from island test area (Blatsko polje) range from calcium - hydrogencarbonate to sodium-chloride hydro-chemical facies which indicates strong influence of the sea water intrusions. Waters from continental test area range (Prud) from calcium-hydrogencarbonate to calcium-sulfate hydro-chemical facies, suggesting recharge from deposits rich in sulphate minerals. Trends of indicators of water quality are negative, showing decrease in the concentration of water quality indicators.	Blatsko polje: agriculture: 56.8%, forestry: 38.7%, artificial surfaces 4.5%. Prud: forest and semi natural areas: 68.88%, agricultural areas 29.14%, artificial surfaces 1.77%, water bodies 0.18%, wetlands 0.04 %.

Country and test area	Basic water quality characteristics and trends	Land use
BOSNIA AND HERZEGOVINA: Trebižat river*	In Trebižat River highly saturation with oxygen, mostly due to fitobentos activities and occasionally content of the substances that can be oxidized and decomposed by microorganisms. Increased concentrations of copper and total chromium which were above the Maximum Allowable Concentration (MAC) for surface water (2010-2014). Concentrations of lead in the range of limit values. In Trebižat River absence of fresh pollution indicators in the basin (could be potentially eutrophicated and have impact on biological status).	-
MONTENEGRO: Nikšić	Good quality of water used for water supply in the test area in Nikšić. Deviations of quality parameters (turbidity and mild microbiological contamination) from maximum allowable concentration only during heavy precipitation. Only chlorination is applied in springs.	Agriculture 28.73%, forestry: 65.13%, artificial surfaces 4.94%, water bodies 1.2%.
SERBIA: Veli Rzav and tributaries**	Veli Rzav very vulnerable to the impacts of weather. There are areas exposed to erosion, as well as arable land. The conditions of heavy rainfall or rapid snowmelt bring on drastic deterioration in water quality. Sources of water pollution classified into two categories: scattered and concentrated ones. Concentrated pollution is characterised by the point of discharge of wastewater into the recipient, whereas the scattered sources of pollution are generated spatially. The scattered sources of pollution include all surface and groundwater pollutants which originate from: the population not connected to the sewerage, tillage, leaching from forest and soil surfaces, livestock, unregulated municipal landfills and other human activities.	-
ALBANIA: Drini basin	Discharging of industry polluted water and untreated municipality sewage water in river Drini i Bardhë has a huge consequence for the waters' fauna. A long and uncontrolled discharge of municipal sewage water, agriculture and industrial waste in Drini i Bardhë River, inflicted the change of waters' quality. With the polluted water in the bank of Drini i Bardhë River also the organic and inorganic substances are being discharge. It is possible to reduce or to stop this negative trend. Turbidity exceeds the standards of drinking water. Information provided by CCME-WQI describes drinking water quality, used by water users, suppliers, etc. Tastes and odours in water may be derived from a variety of conditions and sources (e.g., chlorination).	Agriculture 30.26%, forestry 21.76%.
GREECE: Corfu Island	Water quality of the surface water systems of Corfu is good. No heavy pressures identified. The three groundwater systems identified assessed to be in a good chemical quality status. High concentrations of sulphates due to the increased values because of the natural geological background. Increased values of nitrates and ammonium are due to the diffuse and point pollution sources of human activities. In the coastal areas some increased values of chlorides due to the sea intrusion because of the exploitation and of natural causes.	Area under cultivation and fallow land 73.0%, forests 10.2%, areas occupied by settlements 4.9%, pastures 4.7%, areas under water 1.1%, other areas 6.1%

* Related to test area Prud in Croatia.; ** Not test area for all activities.

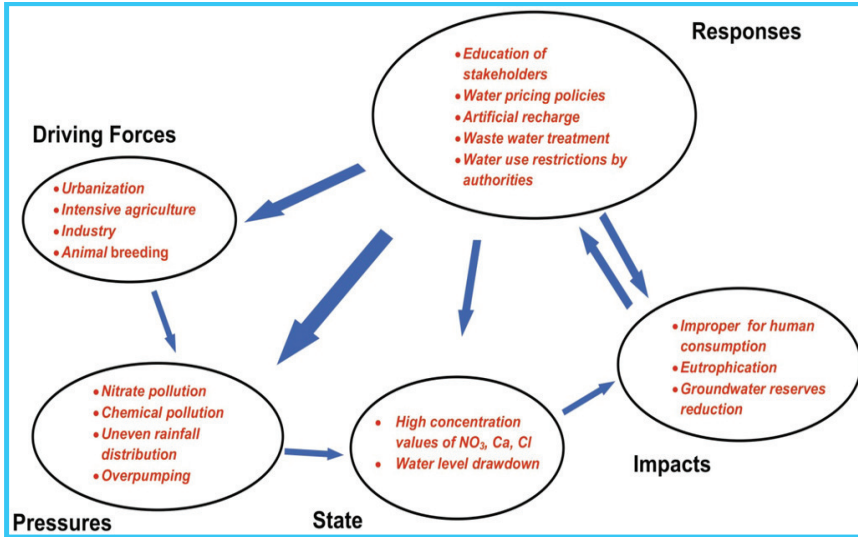


Figure 8. DPSIR methodology [17]

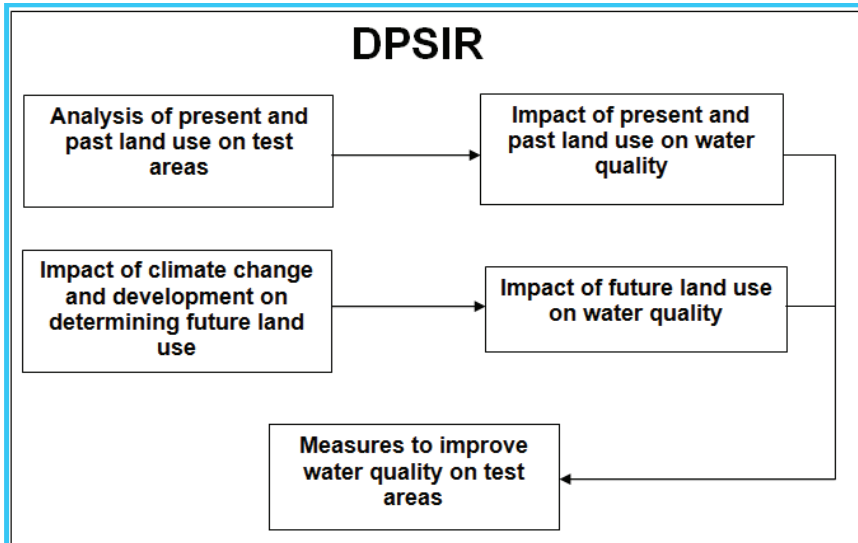


Figure 9. The DPSIR approach used in test areas [16]



Table 6. Most significant Driving forces, Pressures, States, Impacts and Responses in test areas in Northern Istria [18]

URBAN AREAS				
Driving forces	Pressures	State	Impacts	Responses
Areas without sewage system Runoff from paved structures Collection and storage of wastewater Health service Waste disposal	Emission of microbiological pollutants, pathogens, nutrient N&P compounds, chemicals, heavy metals	Groundwater state Health	Deterioration of underground water quality, impact on human health	Implementation of appropriate measures, i.e. construction of sewer systems and WWTP
AGRICULTURE				
Driving forces	Pressures	State	Impacts	Responses
Use of fertilisers (N and P consumption)	Diffuse N contribution (runoff and percolation)	Groundwater state Biodiversity Landscape Health	Deterioration of underground water quality, impact on human health	Implementation of appropriate measures, i.e. organic farming: Nitrates Directive 91/676/EEC
FARMS				
Driving forces	Pressures	State	Impacts	Responses
Farms	High concentration of pathogenic animal waste	Groundwater state Health	Deterioration of underground water quality, impact on human health	Implementation of appropriate measures, i.e. appropriate WWTP and waste disposal

4. Conclusion

The aim of this paper was to present the DRINKADRIA project and provide an overview of the project activities and results so far regarding Project Work Package 4: Cross-border water resources management.

Cross-border water resources management issues are analysed through four activities and, depending on the task, on the national, regional and test area levels. Altogether nine test areas are selected to be case studies.

The first activity in the Project was to analyse regional characteristics of climate and climate change to prepare Climate and climate change database for the Adriatic area. Analyses were done on



the national, regional and test area levels. Modelled data about change in precipitation and temperature were input data for the second activity.

The second activity covered present and future risks on water resources availability with emphasis on drinking water supply. In this activity a common approach and methodologies were set up for determination of water availability and applied in order to estimate the change in water resources availability in test areas for the future period 2021-2050 in comparison to the baseline period 1961-1990. Using different scenarios of changes in water demand in the future (until 2050) the Water Exploitation index (WEI) has been calculated in order to analyse the risk in test areas. Input data for calculation of water availability and results are collected in the hydrological database.

In the third activity present and future water safety and risk imposed to the quality of water resources used for drinking water supply is analysed through tasks: analysis of water quality trends in test areas, analyses of present and future land uses impact on water quantity and quality (CC and development impact on water resources), analysis of seawater intrusion issues and measures to improve the quality of drinking water.

Project partners are currently intensively working on fourth activity - cross-border drinking water resources protection and management. The aim of this activity is to provide common guidelines for WSP implementation for water suppliers with proposal of response actions and emergency plans in a changing environment, develop common methodology for drinking water resources vulnerability, risk and hazard determination and harmonization of methodology for delineation of water protection areas.

Joint results regarding all partner countries and test areas were presented in the paper for each activity while a more detailed presentation of results was given for one test area in Croatia that is Northern Istria – springs Gradole, Sv. Ivan and Bulaž as an example. The analysis of climate change impact on water resources availability was explained in more detail on Gradole spring while the WEI was calculated for all three springs together. For this test area most significant driving forces, pressures, states, impacts and responses related to water quality were presented. Measures to improve water resources quality that are used in the area were also listed.

Results from implementation of the DRINKADRIA project are available on the Project web page <http://www.drinkadria.eu/> and <http://drinkadria.fgg.uni-lj.si/>.



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Acknowledgments

The research for this paper and the preparation of this paper was financially supported by the EU IPA Adriatic Cross-Border Cooperation Programme 2007-2013 (DRINKADRIA project) and the University of Rijeka (research project 13.05.1.3.08 - Development of new methodologies in water and soil management in karstic, sensitive and protected areas).



PREPARATION AND IMPLEMENTATION OF THE EU PROJECT: RESEARCH INFRASTRUCTURE FOR CAMPUS-BASED LABORATORIES AT THE UNIVERSITY OF RIJEKA CAMPUS

Nevenka Ožanić (nevenka.ozanic@gradri.uniri.hr),

University of Rijeka; Faculty of Civil Engineering; Rijeka; Croatia

Nataša Jakominić Marot (natasa@uniri.hr),

University of Rijeka; Centre for EU projects; Rijeka; Croatia

Abstract

This paper shall discuss the preparation and implementation of an infrastructural project following the example of the project *Research Infrastructure for Campus-based Laboratories at the University of Rijeka*. The project was approved for funding within the framework of the Operational Programme Regional Competitiveness 2007-2013. The beneficiary of the project is the University of Rijeka (UoR) and project leader prof. Nevenka Ožanić, PhD.

The project's total value is around 24 million EUR. It is fully funded from external sources, 85% (approximately 20.5 mEUR) from the European Fund for Regional Development (ERDF) and the remaining 15% (approximately 3.5 mEUR) from national contribution.

Section 1 gives the context in which the University of Rijeka works and describe the framework conditions in Croatia. Section 2 shortly describes the University itself and the structure which secured over 24 million euro for the first and most significant infrastructural project funded upon Croatian accession to the European Union.

Section 3 discusses the above-mentioned project which provides high-end research equipment aiming at creating remarkable research results directed towards satisfying the needs of the regional and national economies. This shall allow stronger links between the industry and the University thus positively influencing the development of the University itself.



Section 4 presents the equipment bought for the Faculty of Civil Engineering, present the foreseen results and discuss future options and the challenges faced. This is followed by the Conclusion.

Keywords: EU project, sustainable development, scientific equipment, research laboratories

1. Framework Conditions in Croatia

Croatia's overall investments in Research and Development (R&D) have continued dropping in the last few years. Croatia is currently investing only 0.76 % of its Gross Domestic Product in research and development, while EU average was 2 % in 2010 and 2.06% in 2012 [1] and 2.07 % in 2013 [2].

Croatia's Gross domestic expenditure on research and development (GERD) of 0.88% in 2008, has dropped in the period 2009-2012 when it reached 0.75%. In 2013 it increased to 0.81%. At the same time, EU-28 average was significantly higher. From 1.85% in 2008 it continued rising to reach 2.02% in 2013. The difference between Croatia and other countries is significant and it is the only country for which GERD has decreased in comparison with 2000 [1].

What is most striking is that over 90% of the total budget of the Ministry of Science, Education and Sports (MoSES) is spent on salaries. In the period 2008-2011 the share of salaries in total budget grew by about 5% yearly [3].

Until July 2013 there were two primary national instruments for financing research projects in Croatia, the grant scheme Z-projects granted by the Ministry of Science, Education and Sports' (MoSES) and the grants offered by the Croatian Science Foundation (CSF). MoSES's Z-projects scheme financed scientific projects of research teams at higher education institutions and public research organisations, as well as other research organisations in Croatia. The average size of grants received by the University of Rijeka was 5.000 EUR. The selection was more rigorous for competitive CSF projects. Still, in the last few years, only a few projects were financed in each research area. The situation has changed in late 2013, when MoSES delegated all national research projects to CSF. CSF will primarily fund best scientists and excellent projects, career development grants, collaborative projects with industry, support for participation in EU scientific and innovation projects and networking programmes. The projects shall be significantly larger in size than the former Z-projects.



In addition to CSF research grants, the MoSES finances institutional overheads and a lump-sum for research activities within the multi-annual institutional financing, the amount of which, for the first allocation, depended on the institutional performance indicators evaluated in the first half of 2013. These indicators took into account the full time equivalent (FTE) researchers employed but also scientific productivity, number of patents, international and national competitive projects and mobility as well as collaboration with the industry and other actors in the society. The performance of the University of Rijeka in comparison with the others, secured some 850.000 EUR per year (second highest amount for Croatian universities) as a lump-sum for research costs which the University shall autonomously grant on the basis of its own criteria. This amounts to almost 25% of the funds granted to the University of Zagreb which is by far the largest Croatian university. Even if it only has 79 FTE less than Rijeka, the University of Osijek received only 390.000 EUR per year.

Croatia has been fully associated to the EU Seventh Framework programme (FP7) since 2008 even if it participated in a different capacity in previous framework programmes as well. The absorption rate in FP7 has exceeded the national contribution for over 130% [3]. Even if the University of Rijeka (UoR) is only the third largest university in Croatia, UoR is the second best university in terms of the funds allocated from the programme [4, p. 130] after Zagreb which is by five times larger in terms of the number of FTE. This suggests that capacities of UoR to propose high quality competitive projects are generally high [5].

The Operational programme Competitiveness and Cohesion 2014-2020 for Croatia foresees approximately 2.7 billion euro for its five competitiveness-fostering priorities: research and innovation, information and communication technologies, development of small and medium enterprises, energy efficiency and education [2].

One of the biggest challenges for the higher education system in Croatia remains to increase the responsiveness of the university research to the needs of the society, primarily those to foster economic growth [5]. This is clearly addressed by Croatia's strategic priorities for the period 2014-2020:

- ◆ “Restructuring R&D sector through organisational reform and investments in modernisation of R&D infrastructure;
- ◆ Supporting projects of national Centres of Research Excellence as a way of strengthening research excellence;
- ◆ Creating conditions for business sector to invest into R&D&I by directing research organisations to focus towards applied research projects which correspond to the needs of economy;



- ◆ Supporting R&D spending in enterprises to increase overall level of R&D spending;
- ◆ Creation of joint interest in implementation of R&D projects between R&D institutions (including academic sector), public authorities and enterprises;
- ◆ Creation of favourable environment for enterprises in the area of RDI“[2, p. 3].

Absorption of funds available from the European Regional Development Fund (ERDF) and the European Social Fund (ESF) will depend on the capacity of all the stakeholders. Beneficiaries need to have a support system and resources for implementation of projects, they need to recognize opportunities, prepare good projects in a timely manner and adapt their organisation to the challenges of the new funding system. Given the administrative burden in projects granted under the Structural funds, it is unrealistic to expect a high absorption rate if staff implementing projects is not adequately trained and granted sufficient time for the new tasks. If potential beneficiaries fail to address these issues appropriately and on time, many opportunities for development will be wasted [5].

Management of resources is one of the biggest challenges because of the university's fragmented structure and insufficiently structured financial resources [5]. Until 2013, when the higher education funding system changed, over 90% of university funding came from the Ministry of Science, Education and Sports (MoSES). It was designated by the Ministry directly for clearly specified costs, mostly salaries. The difficulties in resource management are reflected in the challenges in joint Campus management and cost-sharing system among the university constituents on Campus. Such distribution of funding did not leave much room for autonomous development planning.

The universities lacked high-end research equipment and the existing equipment was inadequately managed. All equipment, including expensive one, was being used by a single researcher who "owned" it. The information on which pieces of equipment were present and where were unavailable. The equipment was mostly financed by the Ministry of Science, Education and Sports. Every researcher could request dedicated funds and equipment for his or her project. Researchers at different departments had no way of knowing whether anyone else had the piece of equipment they needed nor was there a system in place for "borrowing" somebody else's equipment. Thus, it was often the case that expensive pieces of equipment were bought at the same institution or within the same university. Commonly, its usage rate was low.



Importantly, all equipment purchased within this project shall belong to the University, thus all researchers have access to it following the set rules and usage and maintenance procedures.

2. The University of Rijeka

The University of Rijeka was founded in 1973 as the logical expansion of higher education institutions in western Croatia whose roots reach to the 17th century when the Jesuit gymnasium was founded in Rijeka. From its foundation, the University has undergone a series of transformations which were, for the most part, subsequent to changes in the national higher education policy and changes at the University of Zagreb. The last such transformation occurred in late 2006, when the constituents in Pula formed a separate institution, the University of Pula. Therefore, the University of Rijeka embarked on 2015 with about 16.000 students and over 1.600 employees in 10 faculties, an Academy of Applied Arts, four departments and four other constituents. In 2004, the first steps towards construction of University Campus on Trsat were undertaken, where the majority of constituents shall eventually move.

The constituents of the University are as follows:

- ◆ Academy of Applied Arts
- ◆ Faculty of Economics
- ◆ Faculty of Tourism and Hospitality Management
- ◆ Faculty of Humanities and Social Sciences
- ◆ Faculty of Civil Engineering
- ◆ Faculty of Medicine
- ◆ Faculty of Maritime Studies
- ◆ Faculty of Law
- ◆ Faculty of Engineering
- ◆ Faculty of Teacher Education
- ◆ Faculty of Health Studies
- ◆ University Department of Biotechnology
- ◆ University Department of Physics
- ◆ University Department of Informatics
- ◆ University Department of Mathematics
- ◆ University Library
- ◆ Student Centre
- ◆ Science and Technology Park
- ◆ University of Rijeka Foundation.



2.1. Centre for EU Projects

The Centre for EU projects represents a central info point for university researchers in search for information on EU programmes, funding possibilities, possible partners and open calls for proposals. It fosters participation in EU projects, development of international and inter-university cooperation, cooperation with the industry and the local community. Since 2008, it started preparing complex infrastructure projects for EU funds on behalf of the University. Currently, two projects funded from the European Regional Development Fund (ERDF) from an allocation foreseen under the Regional Competitiveness Operational Programme 2013 are being implemented. Both projects were selected at first calls for proposals published after Croatia joined the European Union in 2013.

The Centre's staff has extensive experience in working with international partners in research and development projects and has developed an extensive network of partners and stakeholders, including SMEs, local and regional communities, NGOs and various public institutions.

The University has many years of experience in EU projects, with over 80 successfully implemented international projects over funded from various EU programmes, such as TEMPUS, Lifelong Learning Programme, Jean Monnet, PHARE, CIP IEE, EU Framework programmes, NATO Science and Instrument for Pre-Accession Assistance (IPA components: Human Resources Development, Regional Competitiveness and Cross Border Cooperation), South East Europe, IPA Adriatic and others.

The majority of projects fit into funding schemes related to higher education and science but nonetheless, projects aiming at establishing tighter relations with external stakeholders are gaining a significant share in a total number of projects since the University sees SME development programmes as the most important economic development factor for Croatia. Through active collaboration with the economic and business sector along with partnerships for community development the University endeavours to contribute toward the socio-cultural transition into a knowledge-based society.

When opportunities to fund large infrastructural projects from non-budgetary sources arose, the responsibility for management and coordination of preparation and implementation of such projects was assigned to the Centre for EU projects.



3. Research Infrastructure for Campus-based Laboratories at the University of Rijeka

3.1. Background

The University of Rijeka is currently in the final phase of implementing a project funded from the European Regional Development Fund: *Research Infrastructure for Campus-based Laboratories at the University of Rijeka*. One of the major reasons it was granted was that project documentation was developed well before available funding was foreseen and staff preparing the project was already very experienced in securing EU funding.

In 2007, the University identified technical and natural sciences as areas which needed to be strongly developed in the future. The project has provided the required infrastructure at Rijeka Campus, necessary for the establishment of a strong and competitive research competence in technical and natural sciences. In 2009, a project summary was submitted to the national authorities following a public call in the frame of preparation of the project pipeline and technical assistance for Structural Funds.

At the end of 2009, the MoSES and Business Innovation Centre Croatia (BICRO), had collected relevant project concepts in the area of innovation infrastructure that would be financed under future Structural Funds. This marked the period when intensive work on developing project documentation started. It was completed in 2014, when the project was finally granted for funding.

To illustrate the importance of the project, one has to note that the entire budget allocated for Croatia from the EU Lifelong Learning Programme in the period 2009 – 2013 amounted to 0.4 million euros less than that for the *Research infrastructure for Campus-based laboratories at the University of Rijeka* project [5].

3.2. About the Project

The *Research Infrastructure for Campus-based Laboratories at the University of Rijeka* project focuses on supply of equipment and achieving the full functionality of:

- ◆ Centre for High Throughput Technology in Biomedicine,
- ◆ Centre for Micro and Nano Sciences and Technologies,
- ◆ Centre for Advanced Computing and Modelling,
- ◆ Faculty of Civil Engineering Laboratories.



Project implementation will solve two major issues of the University of Rijeka:

- ◆ Supply of equipment needed for the performance of basic research and education responsibilities and will create the basic infrastructure needed for the participation of the University of Rijeka in international collaborative research projects. It will enable a higher level of research performance in mono-disciplinary research in Biotechnology, ICT, Micro and Nano Sciences and Civil Engineering.
- ◆ Supply of equipment needed for a greater international recognition of the established structures as Centres of Excellence in research and technological development (i.e. as European Centres of Excellence) and for instrumental convergence of bio, nano and info sciences through the performance of interdisciplinary research projects, i.e. development of the advanced infrastructure required.

After the project's completion, the University of Rijeka will have the potential to become a regional leader in Nano-Bio-Info-Convergence (with an emphasis on instrument convergence: technologies resulting from the development in one field are useful and tend to become essential for research development undertaken in other fields) and an important factor in applied research in the area of civil engineering and thereby significantly contributing towards national education and R&D policies.

The project *Research Infrastructure for Campus-based Laboratories at the University of Rijeka* will ensure full functionality of three research centres, which are envisaged as future Centres of Excellence in Nano-Bio-Info Sciences and several laboratories for improvement of research infrastructure in Civil Engineering.

Through its Centres, the University will enhance opportunity of researchers for collaboration with other research organizations and industry, on local and regional levels. Also it will increase educational quality at graduate and post graduate levels. One of the most important impacts will be on the applied research and enhancement of the university-industry activities and joint projects. Research infrastructure will contribute to technology transfer and commercialization capacities of University of Rijeka, sustainable development and industry competitiveness, which will be accomplished through research projects, development of new products and patents. It will also allow developing interdisciplinary research and innovation-related challenges, managing the interface to external industry and leading to high-quality research, develop scientists and enhance the competitiveness of the economy.



The project's specific objectives are:

- ◆ to develop the knowledge and skills in an area that has been identified as a priority globally, at the EU level and on the national level
- ◆ to increase the collaboration of the academic and industrial sectors in this field
- ◆ to develop of new products and services to the Croatian economy
- ◆ to increase the collaboration with the government institutions
- ◆ to increase the level of scientific output in this area
- ◆ to increase the number of University students
- ◆ to enhance synergic effects with other research institutions, especially abroad
- ◆ to develop a new graduate and post-graduate educational curricula
- ◆ to introduce of new scientific instrumentation and methods to the Croatian S&T sectors

The University of Rijeka is actively dedicated on further expanding and developing the Campus area. At the moment, there are two infrastructural projects in the realisation phase, which are financed through the European Regional Development Fund and are connected to the University campus. The first one is *Research infrastructure for Campus-based laboratories at the University of Rijeka*. It will allow the full development of the existing potential in the concerned fields, while this accommodation infrastructure will enable hosting the expected increase of international academic and private partners in Rijeka.

3.3. Campus Development Plans

In the year 2000, the University of Rijeka embarked on its Campus project to overcome the major obstacles to development identified, to facilitate functional integration of all constituents and to facilitate the transformation of the University into a modern research university.

In October 2001, The University of Rijeka Senate adopted the University Campus Programme Outline [6], which provided an optimal combination of facilities and contents - faculties, research centres, the university library, student accommodation, student facilities and sports objects – all at one single spot – the University Campus.

In 2003, the Government Commission of Asset Management of Republic of Croatia made the decision to transfer the property owned by Ministry of Defence (i.e. Trsat barracks) to the City of Rijeka. All formal conditions were thus fulfilled to secure further financing of the construction of the Campus in that location. A year later, part of the funding was secured through the Ministry of Science, Education and Sports (MoSES) and a consortium of banks. In 2007, an agreement on



building rights on the Trsat area was signed between the University of Rijeka and City of Rijeka. After that, the construction of the Campus began. In 2009, the Ministry of Environmental Protection, Physical Planning and Construction issued a Decree on Evaluation of Environmental Impact which affirms that the University Campus does not require conduct of environmental impact assessment procedure.

The Rijeka Campus is a comprehensive project aimed at increasing the University capacities and quality in education, science, research and innovation development and increasing the students' quality of life and learning outcomes. The overall Rijeka Campus project consists of three main phases, each representing a functional unit for itself.

The construction of the first phase has been finalized. To this date, the University of Rijeka Campus project has realized (reconstructed or built) 6 buildings which currently house 8 constituents of the University, the Student Centre (with the main student restaurant) and the Science and Technology Park, which means that much of the university life takes place on Campus.

The second phase includes Student accommodation, Social-cultural centre, University library, the faculties of Economics, Engineering and Medicine, sports hall and two open sports courts. These facilities should be funded by 2020. *Research Infrastructure for Campus-Based Laboratories at the University of Rijeka* project is envisaged as the second phase of the Rijeka Campus project.

The third phase, planned after 2020, includes two more faculties, a university department building, a research centre and additional sports facilities.

3.4. Project Preparation

In its Strategy for the period 2007-2013, the University of Rijeka emphasized it was "necessary to intensify international cooperation of the university by involving scientists in international projects; by establishing closer cooperation with foreign universities and by inclusion into European and international programmes of university collaboration" [7, p.19].

Experienced and trained staff at the University ensured good preparation of the project *Research infrastructure for Campus-based laboratories at the University of Rijeka* and is crucial for its good implementation. The project shall ensure the high-end research equipment which shall lead to successful research results and favourable base for future development of the University itself but also of its region and the country.



Figure 1 below shows how EU programmes went hand in hand with the development of the University and helped its transformation into a modern research University striving towards excellence.

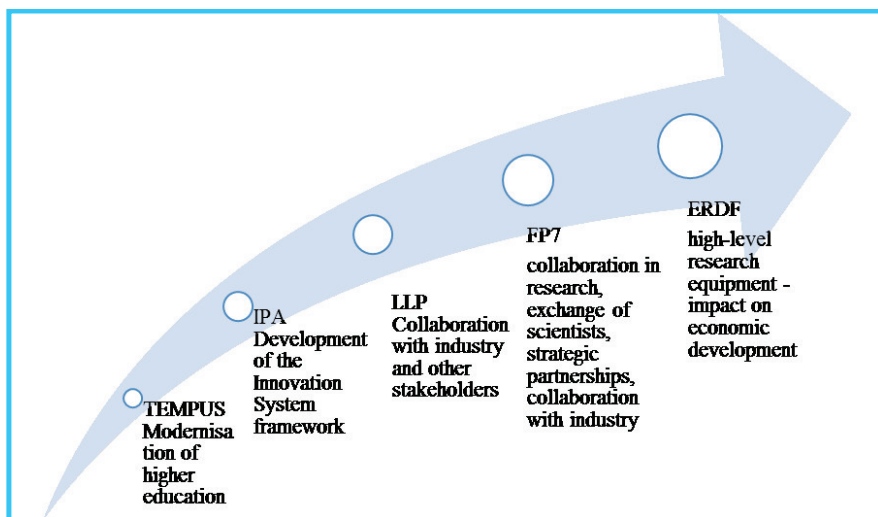


Figure 1. Development Steps of the University and the support system for EU projects (Source: Jakominić Marot, 2015)

As shown in Figure 1, the establishment of the administrative infrastructure or the administrative support system for EU projects was the first step towards reaching the university's strategic goals of raising research competence to foster economic development of Croatia. Work on projects started with Tempus in early 2000, the support system followed the development through IPA and initial participation in EU programmes and reached higher level of development with eligibility to use Structural Funds. This topic will be further discussed in further in the paper.

In its first strategic documents in early 2000s, the University of Rijeka claimed it will create conditions ensuring the quality workspace and leading research equipment for its scientists and students. The most ambitious task for the future was marked by the beginning of construction the University Campus on Trsat endorsed by the Senate in 2001. The former University of Rijeka Strategy 2007-2013 was seen as the period for restructuring and strengthening the University, with the goal of developing it into a strong functionally integrated institution. In that light, the construction of the University Campus in Rijeka was seen as a significant developmental step forward [7, p. 14]

Following its application for the Open call for project ideas published by the Ministry of Science, Education and Sports in 2009, intensive work on preparing the documentation needed had started.



The project was positively assessed and included in the list of potential projects which made the University eligible to receive funding to conduct market research and prepare the feasibility study for the project. Both these activities have been very important in shaping the future project and went on in several phases until late 2013. In December 2013 the Call for proposals for funding from the European Regional Development Fund was finally published whereby the University updated the feasibility study to reflect the then situation and repeated the market research to secure equipment is up-to-date.

Figure 2 shows the timeline of the preparation and implementation of the project, which actually started with the planning of the Campus in early 2000s.

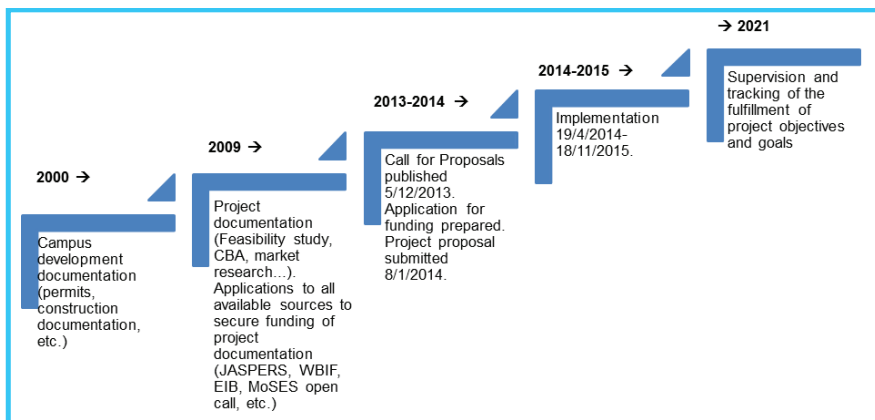


Figure 2. Project preparation and implementation timeline

3.5. Current Status of Implementation

The project's procurement plan foresaw 128 contracts in total for the project. Out of that, 60 procurement contracts are related to the Faculty of Civil Engineering. At the moment, 116 procurement contracts (90.6%) for the overall project and 59 for the Faculty of Civil Engineering (98.3%) have been completed. Figure 3 shows the status of implementation of the project and the status comparison of the overall project and Faculty of Civil Engineering.

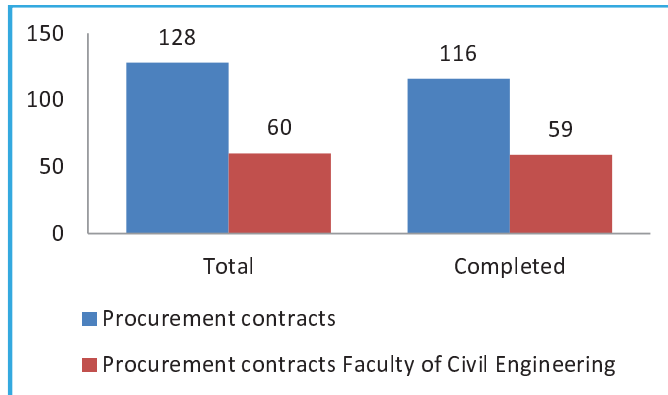


Figure 3. Current status of implementation

Out of the project's total value 63.3%, or over 15m EUR of costs have already been reported to the relevant implementing bodies, successfully audited and refunded to the beneficiary. By completion of this paper procurement contracts for the Faculty of Civil Engineering have been completed (100%).

4. The Equipment for the Faculty of Civil Engineering

The share of funds for equipment purchase and adaptation of premises at the Faculty of Civil Engineering is around 30% of total project budget [6]. Most of the money is dedicated to equipment purchase, while some funds have been used to adapting the premises to accommodate the equipment purchased. Equipping the laboratories shall significantly contribute to increasing the quality of research, as well as doctoral studies in the field of civil engineering and technical sciences in general. In addition, it will improve the conditions for student education at all levels: undergraduate, graduate and post-graduate.

The equipment purchased within the project can be divided into general equipment to be used in the framework of undergraduate and graduate studies and complex, specialised, equipment to be used within doctoral studies and postdoctoral research. The results reached using the equipment in question shall allow the Faculty of Civil Engineering to gain research excellence as well as contribute both the Faculty and the University of Rijeka gain international recognition.

The project will ensure great spin off potential and contribution to the construction sector [6]. Laboratory services will include services specific to the hydraulic engineering in karst areas, research toward



innovative construction materials for karst regions as well as the use of complex 3D models foreseen with supporting facilities from the Centre for Advanced Computing and Modelling [6].

The laboratories of the Faculty of Civil Engineering to be equipped from the project are

- ◆ Hydraulic Laboratory
- ◆ Geotechnical Laboratory
- ◆ Laboratory of Transportation Engineering
- ◆ Materials Laboratory
- ◆ Structures Laboratory

The equipment purchased for the Faculty can be divided in four groups: measurement equipment, laboratory furniture, computers and multimedia, and small tools and other equipment [6].

4.1. Intended Use of the Purchased Equipment in Hydraulic Laboratory

The equipment purchased for the Hydraulic Laboratory within the Faculty of Civil Engineering covers approximately 150 sqm. It will be used for both educational and research purposes.

Purchased equipment will allow the Hydraulic Laboratory to perform and demonstrate different hydraulic and hydrodynamic processes related to:

- ◆ Hydraulics of surface water streams, for example: the flow through the overflow and below the barrier, hydraulic jump, flow in open channels, measurement of flow and velocity in open channels, the energy dissipation, sediment transport etc. Figure 4 shows a multi-purpose hydraulic channel,
- ◆ Filtration flows through the porous granular environment: radial flow, vertical flow around the diaphragm and the foundation of dams, transport of pollution and so on. Figure 5 shows the experimental chamber for filtering,
- ◆ Water infiltration in unsaturated porous media, research interaction of surface and groundwater flows, as well as studies of flow in heterogeneous and anisotropic environments,
- ◆ Research hydrodynamic dispersion and diffusion in the sea, measuring the characteristic parameter wave impact on structures, research of surface flows and dam failure, overflow, outlet, regulation and evacuation facilities and other activities will be carried out using the planned multi-purpose experimental pools (Figure 6).

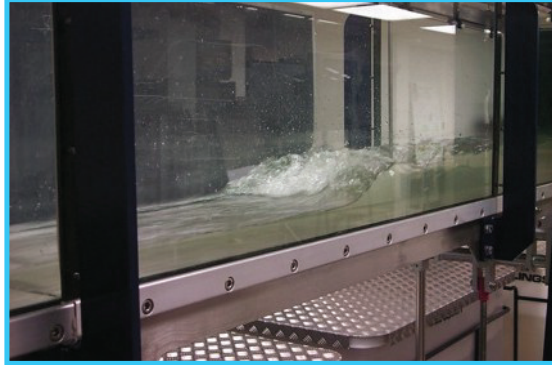


Figure 4: Multi-purpose hydraulic channel

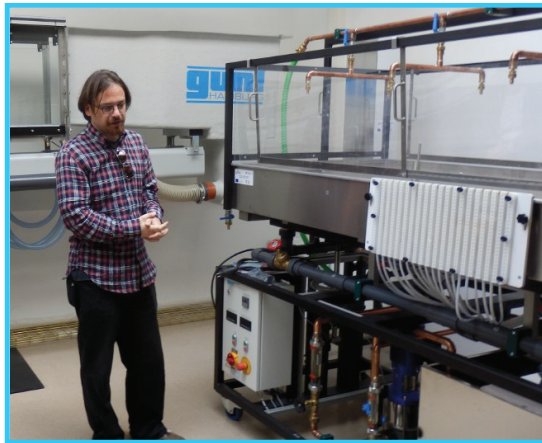


Figure 5. Experimental chamber for filtering



Figure 6. Multi-purpose experimental pool

In addition, 3D printer (Figure 7) will be used to construct the real models of hydro-technical structures to be used for research purposes



within the multi-purpose experimental pool within the Hydraulic Laboratory.

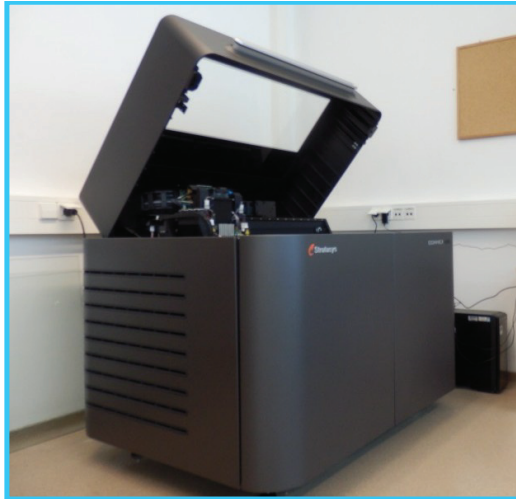


Figure 7. 3D Printer within the Hydraulic Laboratory

Several digital and analog sensors recording different fields of physical values will be used for real time data collection and storage. Some of the most important pieces of sensorial equipment include digital and analog pressure gauges, laser and acoustic Doppler speedometers, gauges, water level tripod gauges and a small waterproof video camera to record and detail visualized local hydrodynamic processes. Development and testing of numerical algorithms will be done jointly with the Centre for Advanced Computing and Modelling. All equipment purchased within the project can be regarded as a huge step forward in the quality of education and research performed by the hydraulic experts at the Faculty.

5. Conclusion

As early as 2000, years before funds became available and the project was actually granted, first steps towards the *Research infrastructure for Campus-based laboratories at the University of Rijeka* project were undertaken. In 2008, the Centre for EU projects already started preparing that and other applications for ERDF funding to be ready once Croatia joins the European Union. Such centralised approach also facilitated bypassing fragmentation and providing state-of-the-art equipment to promote excellent research. This paper showed that timely preparation is crucial to develop an institution and solve its most pressing needs.



The introduction of the technologically advanced equipment secured from the project will enable both researchers and students at the University to develop and implement novel methodologies and techniques in multidisciplinary fields of science and research with a goal to increase the research capacity of the University of Rijeka. The equipment will be used as a platform for networking with other research and higher education institutions in Croatia, the European Union and beyond. It will enhance collaborative research with these institutions.

The implementation of the project will increase the level of research activities at the University, creating the environment for increasing both research and learning outcomes at University's faculties and departments, with an emphasis on collaboration and development of multidisciplinary scientific fields. It should also be noted that, over the last ten years, the University of Rijeka took the lead in brain gain of Croatian researchers from the world's best universities and research institutes. Apart from increasing the quality of research, these scientists indirectly develop partner relations of the UoR with other research and higher education institutions.

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Acknowledgments

This paper has been written within the infrastructural project *Research Infrastructure for Campus-based Laboratories at the University of Rijeka* funded by the European Regional Development Fund. It has been supported from the research project – funded within the University of Rijeka support scheme *Hidrologija vodnih resursa i identifikacija rizika od poplava i blatnih tokova na krškom području (13.05.1.1.03)*. The leader of both projects is prof. dr. sc. Nevenka Ožanić.



APPROACH TO DEVELOPING “PROGRAM OF THE REHABILITATION MEASURES WITHIN THE SANITARY PROTECTION ZONES IN REGION OF ISTRIA FOR EXISTING BUILDINGS AND EXISTING ACTIVITIES”

Natalija Matić (nmatic@voda.hr),

Hrvatske vode – Croatian waters, EU sector, Croatia

Bruno Kostelić (bruno.kostelic@istra-istria.hr),

Region of Istria, Department for sustainable development, Department for nature and environmental protection, Croatia

Abstract

The idea of creating the “Program of the rehabilitation measures within the sanitary protection zones in Region of Istria for existing buildings and existing activities” (hereinafter – Program), is to fulfil all obligations of Region of Istria as regional self-governmental unit, regarding national legislation in a domain of managing of water resources (creation of necessary Case studies, Programs, Plans or Strategies).

Program has to fulfil all obligations stated in the article 43 of the current Decision about sanitary protection zones in region of Istria (Official Gazette of Region of Istria No. 12/2005, 02/2011). According to the article 41 of that Decision, active protection of water sources is conducted on the basis of an “action program for the protection of water resources” which is the main purpose of creating Program. Region of Istria will insure for its future, sustainability of sufficient capacities and quality of drinking water.

The existing Decision about sanitary protection zones in Region of Istria (Official Gazette of Region of Istria No. 12/05, 02/11) is created on the basis of Ordinance about establishing sanitary protection zones Official Gazette of Republic of Croatia No. 55/02. According to the Ordinance about conditions for establishing sanitary protection zones Official Gazette of Republic of Croatia No. 66/11, and Ordinance about



changes of Ordinance about conditions for establishing sanitary protection zones (Official Gazette of Republic of Croatia No. 047/13), the selected creator of this Program has to consider articles 35 and 40 of this Ordinance which obliges regional self governments to determinate active protection measures for increasing water quality, and to determine required procedures and measures for existing buildings and activities in water protection zones areas, as well as for newly planned interventions in the area.

From this Program is expected to determine indicators, as well as to propose measures (active and passive) and adequate monitoring of karst aquifers in order to provide their sustainable use and protection in the future.

For each proposed measure it is necessary to determine stakeholders (a responsible body or Institution) and approximately estimated annual costs and deadline for implementation. It is also needed to predict the extent and ways of informing and educating the public in order to increase public understanding of the importance of water protection. It is expected that better understanding of public will result with less ecological problems in the future which are caused by human factor.

Keywords: karstic springs, sanitary protection zones, Program, Region of Istria

1. Introduction

Groundwater is an important source for water supply and a major natural resource in Croatia providing between 70 and 90 per cent of drinking water supplied in Croatia. In rural areas not served by public or group water schemes, groundwater is usually the only source of supply. The majority of public supplies in Croatia reliant on groundwater have chlorine disinfection treatment only. Groundwater resource is so important that worth to be protected. It is useful to establish the groundwater source protection zone for preventing and repairing water pollution, guaranteeing the safe water supply and realizing the sustainable development of water resources [1, 2]. Groundwater source protection zone is designated to prevent and control water pollution and guarantee groundwater quality and water environment [1, 3, 4, 5].

The area of Istria's water supply system belongs to karst which is featured with a significant underground water circulation, as well as with a high sensitivity to external influences such as water pollution (Figure 1). Groundwater from karst aquifers as well as Butoniga

reservoir are important resource for drinking water supply of community in Istria region and are the basis of water supply that is supplying more than 200.000 residents. About half of the surface water drains underground into karst aquifers and springs and flows into the Adriatic Sea. This is the Dinaric karst aquifer system, which is very important for the ecological biodiversity and the socio-economic development of the region. Karst is characteristic for most of the areas in the Istrian County as it is for Croatia and the neighbouring Slovenia and Italy.

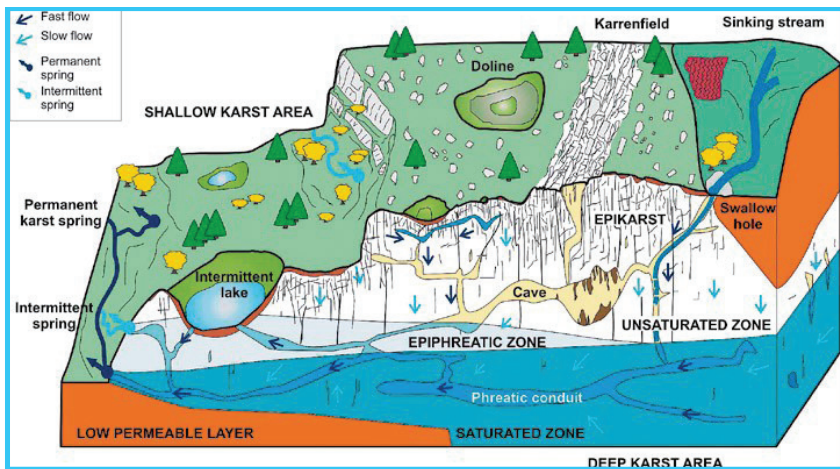


Figure 1. Schematic model of a karst aquifer [6]

Special characters of karst aquifers, such as fast concentrated infiltration and rapid transport into the conduits network over long distances (several kilometres) make them particularly vulnerable to contamination due to various human and land-use activities (Figure 2). Because of the increased human pressure (industry, tourism, land-use activities etc.) in the last decades we witnessed a strong degradation of the underground environment and natural vulnerability of karst landscapes provides challenges for environmental managers. Consequently, karst groundwater requires specific and appropriate karst groundwater protection schemes (i.g. protection zones outlining for capture work and land-use planning) in order to combine land use practices and sustainable water management.

Threat to karst waters depends on ecological burden of the aquifer which is controlled by different forms and degree of industry, active and latent sources of pollution and by better hygienic organization of the environment. Also, threat to karst waters depends on natural sensitivity (vulnerability) of the aquifer. Vulnerability of the karst aquifer (Figure 2) depends on infiltration, hydro-geological conditions of the aquifer that control way and time underground drainage, quantity of water and rate of dilution [7].

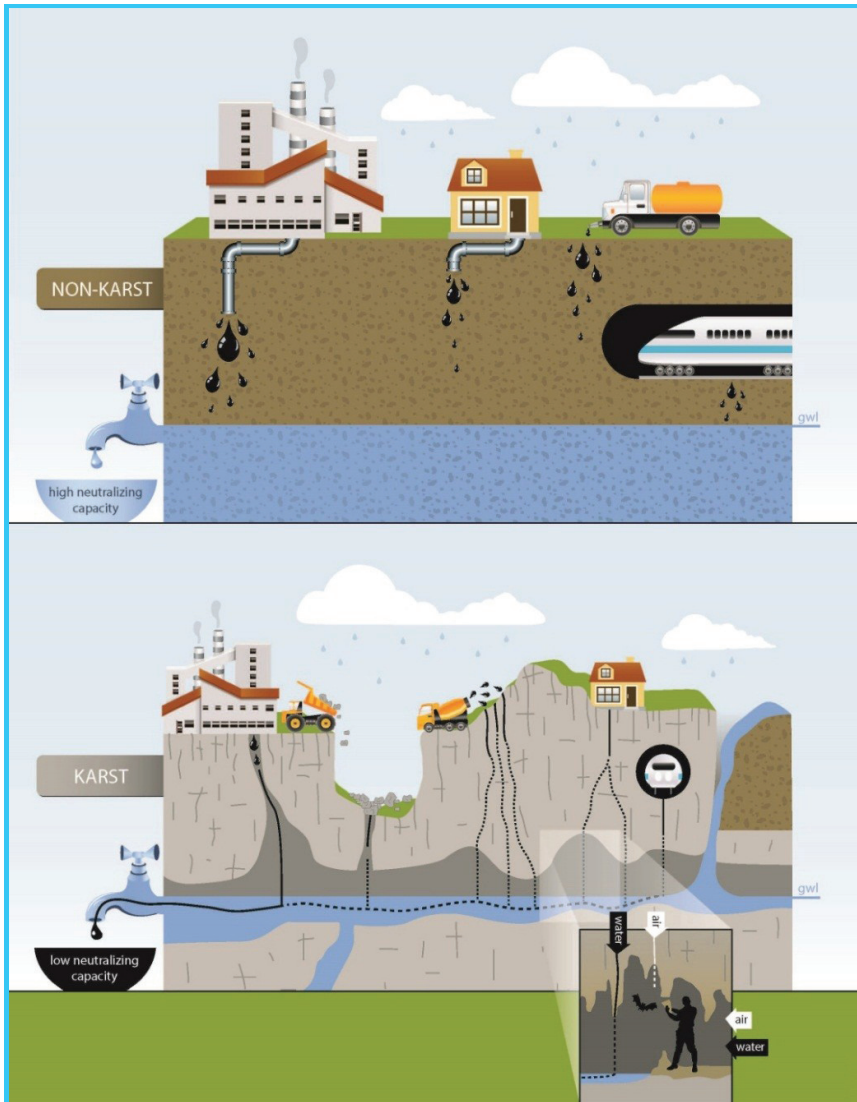


Figure 2. Vulnerability of karst and non karst aquifer - different types of human impact [8]

2. Basic Description of the Area – Region of Istria

The study area is located in the Region of Istria. In this area allocated to three typical hydro-geological units: high carbonate massif of Čićarija and Učka, the central area built by flysch and low carbonate platform of southern and south-western Istria. Characteristics of the source of these three units are diverse, but their common feature is that



the main drainage of groundwater are located along major river valleys, as well as parts of the lowest elevations of the field (Figure 3). On the Istrian peninsula there are separated five basins or regions:

- ◆ Basin of the coastal resources in the Kvarner hinterland;
- ◆ Basin of the rivers Raša and Boljunčica which drains part of the eastern part of the Istrian peninsula. Those waters are part of Čičarija, Učka and most of the hilly flysch pool with surface runoff in the central part of the peninsula. Sources which are located in this basin are sources Rakonek, Mutvica, Fonte Gaja - Kokoti, Kožljak and Plomin. It is planned a grip on sources that includes Bubić pit, St. Anton and Blaž. The catchment area of source is divided according to the degree of danger in four protection zones: zone I - immediate protection zone, zone II - zone of immediate protection, zone III- zone of beyond protection and zone IV – zone of limits;
- ◆ The area of southern Istria. This basin occupies an area on the southern and southwestern part of the Istrian peninsula. This is an area which starts from the mouth of the river Mirna diagonally across the peninsula to the mouth of the river Raša. The fundamental characteristic of this area is open coastal zone with numerous coastal resources at the lower western part of Istria. For the water supply, in this basin affects the groundwater on these wells: Šišan, Škatari, Jadreški, Fojbon, Tivoli, Karp, Peroj Valdragon III, IV, V, Campanož I, II, III and Rici. There have been four protection zones;
- ◆ Mirna river basin occupies the central and western part of Istria. The basin is characterized by significant groundwater circulation and surface runoff. For water supplies are affected higher sources: Sv. Ivan, Bulaž and Gradole that certain four protection zones: zone I - zone of strict regime, zone II – zone of strict restrictions, zone III – zone of limits and controls, and zone IV - zone beyond the protection zone. In the Mirna river basin there was constructed accumulation Butoniga which is now included in the water supply area of Istria. Basin of accumulation is only superficial, within flysch basin of the central part of the peninsula. For the accumulation there are determined three protection zones: zone I - zone of strict regime, zone II – zone of the strict restrictions and zone III – zone of restrictions and controls and
- ◆ Dragonja river basin: on the left edge of the river valley are sources Gabriela and Bužin, affected the public water supply. They are powered from the part of the limestone plateau Savudrija - Buzet. For these sources there are identified four zones of protection.

Region of Istria is established by the Law on Counties, Cities and Municipalities in the Republic of Croatia (Official Gazette of Republic of



Croatia No. 33/01, 60/01 and 106/03). In accordance with the provisions of the Law on Local and Regional Government, the county's district (regional) governments whose area represents natural, historical, commercial, economic, social and self-governing entity, and shall be organized to carry out the tasks of the regional interests. Administratively Region of Istria is divided in 41 territorial local authorities - 10 cities and 31 municipalities (Figure 3).

Region of Istria is regional self-governmental unit which, according to Croatian legislation has an obligation of issuing a document which should regulate procedures and measures for protection of drinking water sources and ways for conducting mentioned measures.

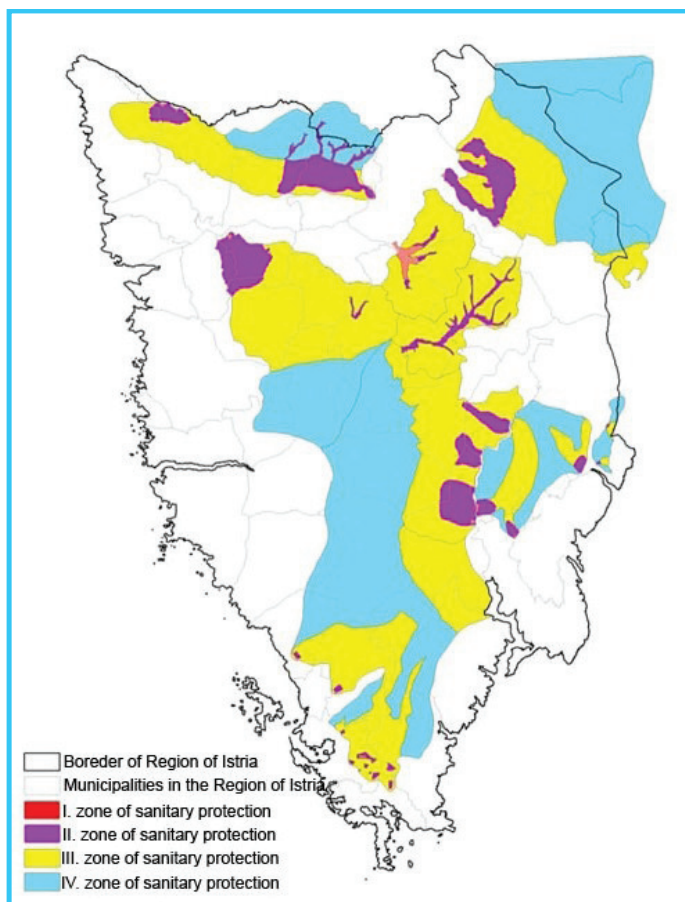


Figure 3. Zones of sanitary protection in Region of Istria (Decision about sanitary protection zones in region of Istria [9])

Cross-border and trans boundary groundwater aquifer (Figure 3) are also very important sources of freshwater for different purposes and



mainly for drinking water supply in many regions i.g. Istria area (spring Rižane). The Rižana is mainly fed from areas within Slovenia, while the Sv. Ivan and Bulaž springs are mainly fed from areas within Croatia, but a smaller proportion of the water in these springs comes from the neighbouring country. Republic of Slovenia and the Republic of Croatia are for years using a common aquifer to supply the population of Istria. Today, the water from the springs Bužini, Gabrijeli and Gradole located on the territory of the Republic of Croatia, are partly used to supply the population with drinking water in the Slovenian part of Istria. Effective strategies for management and protection of water resources in karst terrains thus must be based on reliable information about the properties of the karst conduit system. Underground water flow does not respect political borders and obeys hydro-geological laws. It is also necessary to plan the protection of water sources with a transboundary recharge area. The transboundary karst aquifer needs to be treated as a single system in hydro-geological research. For size and classification of protection zones, it is necessary to define a uniform regime of measures for the protection of water sources within the entire recharge area on both sides of the border [10].

3. The Review of Previous Investigations

Researches on water protection in karst areas in Istria have been intensified at the beginning of the 80s of the last century. The diverse approaches to this problem have proposed different solutions, and the result was unevenness in defining a protective space.

In 2002 the Ordinance on the determination of sanitary protection zones (Official Gazette of Republic of Croatia No. 55/02) [11] came into force. The Ordinance establishes the obligation to harmonize the existing decisions on the protection of drinking water sources with its provisions. Therefore, in order to avoid major conflicts in the area resulting from requests to use the land covered by the existing sanitary protection zones or in their immediate vicinity, the Region of Istria set to analyse the boundaries of water protection zones before conducting any further research predicted by the Ordinance. Analysis was conducted with the aim of adopting a single decision on water protection zones. A study entitled "Research in order to protect sources of water supply in the area of the Istrian peninsula" [12] was developed with the purpose of creating a new proposal of sanitary protection zones.

The proposal was supposed to be only preliminary, while the definite zone boundaries had to be determined only after the research provided by the study and planned to be carried out over a period of five years. After the performed research, a proposal for rehabilitation



had to be drafted based on the results of the executed work. In addition, the City of Pula had not accepted the proposed changes to the boundaries of the area of Pula's wells. Ultimately, it was decided to create a unique Decision on zones of sanitary protection of drinking water for all the springs in the County except for Pula's wells (Official Gazette of the Region of Istria No. 12/05) [9]. For Pula's wells a new decision had been adopted keeping the existing boundaries of water protection zones with the application of measures of behaviour within the boundaries in accordance with the new Decision (Official Gazette of the City of Pula no. 5/83; 8/88; 1/91 and Official Gazette of the Region of Istria No. 7/95). Additional research, as well as the obligation to prepare a proposal of rehabilitation are included in the provisions of the adopted decision. Among all the required additional water research, by 2011 hydro-geological research was carried out in order to determine source protection zones in the County and update the second sanitary protection zones for springs Gradole and St. Ivan [13] Bužini and Gabrijeli [14]. Based on the above research, a revision of the boundaries was conducted (Official Gazette of Region of Istria no. 12/05, 02/11) [9].

Pursuant the adoption of the new Ordinance on the conditions for the establishment of sanitary protection zones (Official Gazette of Republic of Croatia No. 66/11, 47/13) [15] and pursuant to the provisions of the Water Act (Official Gazette of Republic of Croatia No.153 / 09, 63/11, 130/11, 56/13, 14/14) [16], the Region of Istria is obliged to harmonize the existing decision on sanitary protection zones with the provisions of the mentioned legislation, which includes the revision of zones on the basis of new research results.

In the area of sanitary protection zones, specific interventions or activities may be exceptionally allowed, although usually not permitted, if detailed water research (micro zoning) is carried out showing no impact on the aquifer within the narrow area of the sanitary protection zone where the activity is about to take place. To this day, 21 micro zoning studies have been produced and all of them should be taken into account when drafting the revised Decision on sanitary protection zones.

For these reasons, the Region of Istria decided to draft a new decision with the proposal of the new cartographic representation of zone boundaries, as well as a program of the rehabilitation measures within the sanitary protection zones for existing buildings and existing activities within the project activities of the DRINKADRIA project. The Program will represent an integral part of the Decision and the legislation must be made within one year of the adoption of the amended Decision.



4. Objective, Purpose and Expected Results of the Program

Hereinafter the starting points and the current situation within the sanitary protection zones and sources of the Region of Istria are presented. Also the planned approach to the Program for determining the risk of threats to drinking water is set out, as well as the proposed measures for existing and planned buildings within the sanitary protection zones and establishing of indicators for determining the risk of insufficient quantity of drinking water in Istria.

4.1. The State of Water Resources

The purpose of the Program is to analyse the current state of water resources based on measures defined in the Decision and Spatial planning documentation, and to put the results of those analyses in correlation with the legislation of Croatia and the EU.

The fundamental EU directive that deals with water protection is the Water Framework Directive 2000/60/EC whose main objective is to maintain and improve the condition of water bodies. Complying the provisions of the Directive, on 26 June 2013, Croatia passed the Decision on the adoption of River Basin Management Plan (hereinafter: RBMP) for the period from 2010 to 2015, and is currently preparing the new River Basin Management Plan for the period from 2016 to 2021 (a draft version was published in April 2015) [17].

Within RBMP the state of waters is described considering the water bodies as the basis for the analysis of the characteristics and water quality management.

In the area of the Region of Istria 54 surface water bodies have been identified on the mainland, 6 of which are cross-border. Between these surface water bodies, only 19 have at least a good ecological state (Figure 4).

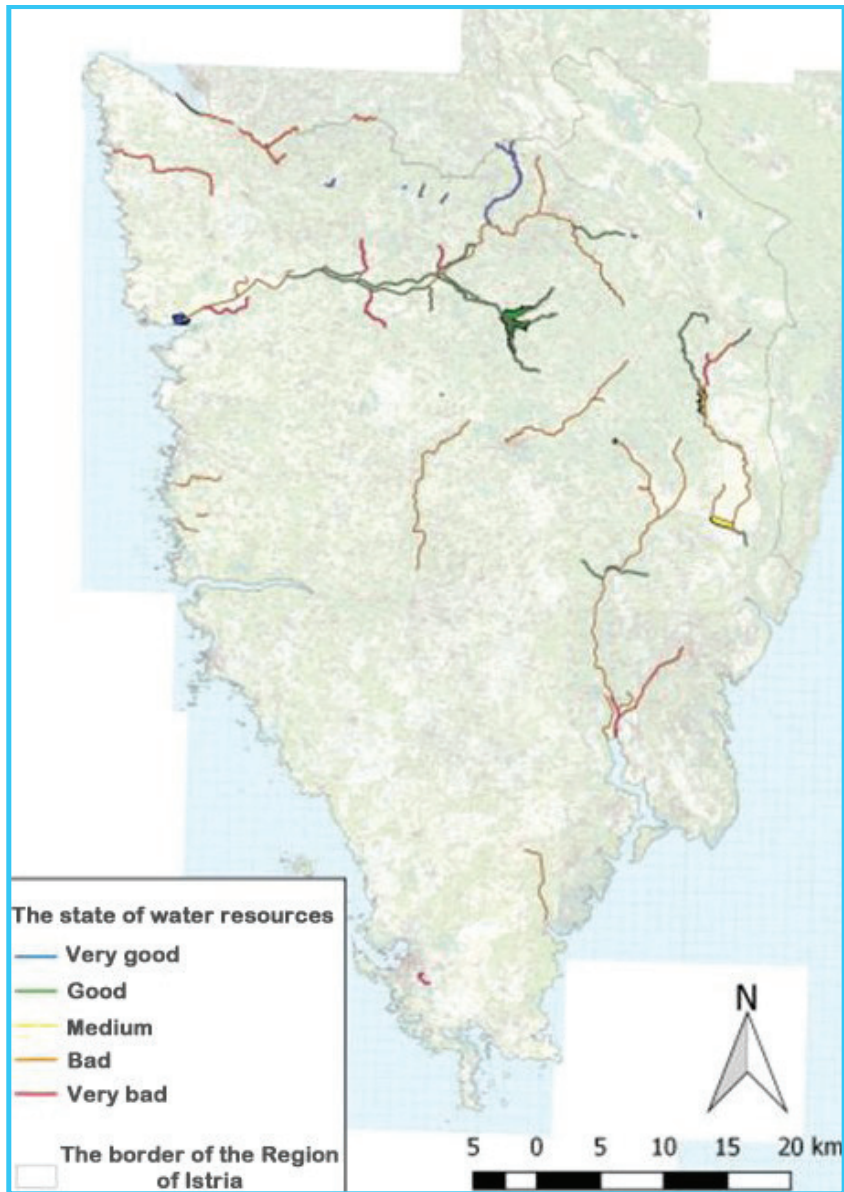


Figure 4. The total ecological state of inland surface water bodies in the Region of Istria [17]



In the Region of Istria there are four clustered underground water bodies, whose characteristics are shown in Table 1.

Table 1. General information on the clustered water bodies of the underground water in Istria [17]

Code	Title of the clustered water body of underground water	Porosity	Area (km ²)	The average annual flow of underground water (*10 ⁶ m ³ /god)	Natural vulnerability	Groundwater depending ecosystems (according to the National Ecological Network)	Type of Ecosystem	State affiliation of the clustered groundwater body
JKGIKCPV_01	Northern Istria	Fractured-cavernous	901,61	306	Very low to low in the flysch, and medium and high to very high in the carbonate rocks	The river Mirna and wider area of Butoniga The Gradole spring The forest of Motovun	water	HR/SLO
JKGNKCPV_02	Northern Istria	Fractured-cavernous	1.470,22	467	Low, medium, high and very high		-	HR
JKGNKCPV_03	South Istria	Fractured-cavernous	391,18	79	Medium to high		-	HR
JKGIKCPV_04	the Bay of Rijeka	Fractured-cavernous	440,33	483	Medium to very high		water and land	HR/SLO

At the Adriatic river basin district about 3% of the average annual flow of waters is utilised and the utilisation ranges from 7.9% in the Northern Istria to the negligible 1% on the Adriatic islands. For groundwater in the Region of Istria (Figure 5) it is estimated that two of four clustered water bodies are in a poor condition due to the volume of salt water intrusion: South and North Istria. The underground water body of North Istria is a cross-border water body that is also used for water supply in Slovenia.



Figure 5 - The total state of clustered groundwater in the Region of Istria [17]



4.2. The Protected Areas and the Ecological Network

The Region of Istria has a total of 35 protected areas, which cover about 7% of the total surface. Nine protected areas are located within one zone of sanitary protection. Regarding the ecological network, there are 27 out of 66 declared protected areas in the sanitary protection zones in Istria (Figure 6; Table 2).

Table 2. Review of the status of the ecological network (27 locations) within the sanitary protection zones [18]

<p>The Program analyses the existing prescribed measures of protection of these areas, their compliance with the Decision on zones of sanitary protection of drinking water for all the springs in the Region of Istria as well as their implementation.</p> <p>SANITARY PROTECTION ZONE</p>	<p>Ecological network area (No.)</p>
Bulaž spring	5, 6, 7, 13, 19, 24, 25, 26
Sv. Ivan spring	8, 9, 14, 20, 22, 27
Rakonek spring	1, 16, 18
Gradole spring	23
Kožljak spring (Plomin)	14
Mutvica, Fonte Gaja, Kokoti springs	3
The wells of Pula	11, 17
Butoniga	4, 12, 21
Spring catchment on Učka	14
<u>Reserved area – planned spring</u>	
Streams of Pazin	10, 15
Bubić cave	2

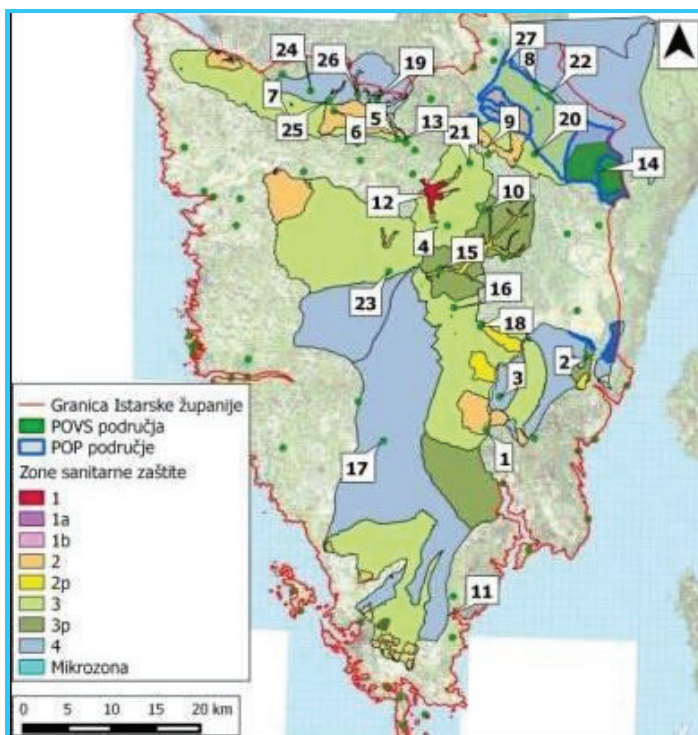


Figure 6. Areas of the ecological network within the sanitary protection zone [18]

4.3. The Risks of Threats to Drinking Water

One of the most important tasks of the Program's implementation is the analysis of existing pressures on water resources with the aim of defining and valorising risk threats to drinking water. The water supply system of the County consists of three water supply systems operated by companies registered for the activity of public water supply: Water utility of Istria Ltd., Water utility of Pula Ltd. and Water utility of Labin Ltd.

The recognized pressures on water resources are traffic, official and illegal landfills, polluters, i.g. economic entities with significant impact on water resources, population and areas of intended use of space such as agriculture, livestock and forestry.

The Program plans to consider the impact of such pressures in relation to the springs as well as within individual sanitary protection zones and group them by the geographical area of water supply systems belonging to one of the three water utility companies in Istria (Figure 7). In addition to these pressures covered by the „existing

procedures“, the Program plans to analyse the same pressures grouped as „planned interventions“ based on the current Draft of the Regional plan which is in the final stage of adoption.

The same methodology of analysing existent and planned pressures will be applied to the area of four springs reserved for water supply: Bubić cave, Bolobani, St. Anton and Blaz.

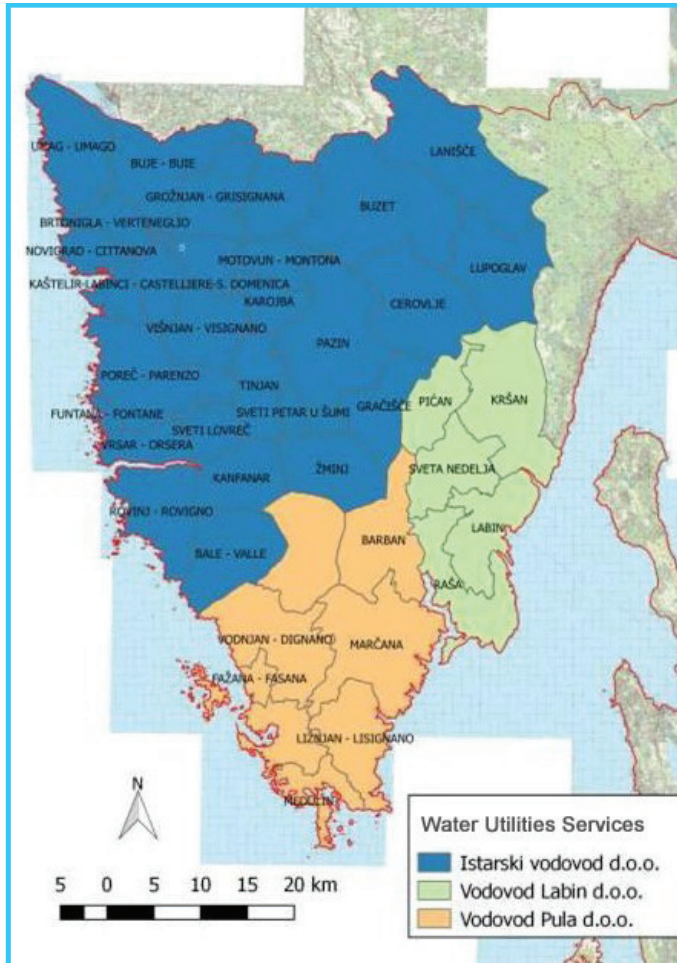


Figure 7. Grouping of water systems according the geographical area of the three water utility companies in Istria [18]

Based on the conducted analysis, the Program is planned to define measures grouped according the analysed pressures, as well as the responsible institutions and estimate the cost of implementation of these measures.



4.4. The Salinization of Springs

In coastal karstic aquifers, due to rapid passage of water through the unsaturated zone, the large apparent velocity of underground streams, and the proximity of large cities there are many potential sources of contamination of groundwater. Besides the mainly anthropogenic causes the input of pollutants into the underground on the mainland, the risk of coastal aquifers comes with the sea salinity. Such problems occur mainly during the summer dry periods due to reduced inflow of groundwater in the hinterland, while the increased use of water is caused by the tourism season. Then, as a result of excessive exploitation of underground water, problems occur with occasional elevated salinity at the water pumping stations. In completely natural conditions (without pumping and re-pumping) the increase of salinity of groundwater may occur if the equilibrium of fresh and salt water is infringed.

One major factor that affects the stability of salt and fresh water is the exploitation of underground water. Pumping out fresh water lowers the water table of piezometric levels in the aquifer thereby disturbing the balance between fresh and sea water, i.g. there is seawater intrusion in the pumped layer. Pumping causes a conical rising of salt water and interferes between the limits of mixing towards the object. Locations, on which the pumping stations are established, can be natural springs, zones of discharge, but also artificially made objects. These are for example different types of capitation galleries, exploitation wells (dug, drilled), tunnels, surface storage etc.

The program plans to analyse the occurrence of salinization of springs in the County, as well as to assess the risk of groundwater pumping in some parts of the county and to propose protective measures.

4.5. Determination of Indicators for Identifying the Risk of Insufficient Quantities of Drinking Water in the Region of Istria

The projected increase in water consumption and at the same time reduction of the available amount, due primarily to the consequences of climate change, threaten the security of drinking water supplies in Istria. The expected sea level rise, which is also a possible consequence of climate change, could result in increased salinization of coastal springs. The increase in the number of consumers is primarily related to an increase in the number of tourists, but also to the potential increase in the industrial need for water. An additional problem is that tourism is a seasonal activity, with the largest water consumption levels at a time



with the lowest natural availability of drinking water. Furthermore, the fraying of water supply system may increase losses if control measures, but also rehabilitation and reconstruction of the water supply aren't regularly undertaken. Water pollution in the environment by human activity limits its use, whereas increases the price of processing that is necessary for human consumption of water.

The Program is planned to analyse the above mentioned potential causes of safety threats to drinking water supplies with the purpose of drafting the management system of Istrian aquifers. Measures which will ensure sustainable water management can be classified into following groups:

- ◆ decreasing water losses in the water supply system,
- ◆ reducing water pollution in the environment,
- ◆ alternative water resources (rainwater, purified wastewater, etc.) for the purposes for which it can be permitted,
- ◆ reducing consumption.

The analytical framework used to assess the connection between human activity and the environment and which ultimately results in determining indicators of the state and changes in the conditions of the system, the so-called "DPSIR analysis" (from the acronym D-Drivers-P-Pressures, S-State, I-Impacts, R-Response, that is drivers-pressures-state-impacts-responses, Figure 8).

By implementing the aforementioned analytical approach, for the specific problem of sustainable management of water for human consumption in Istria, the program plans to determine the drivers, pressures, indicators of the state, impacts and responses.

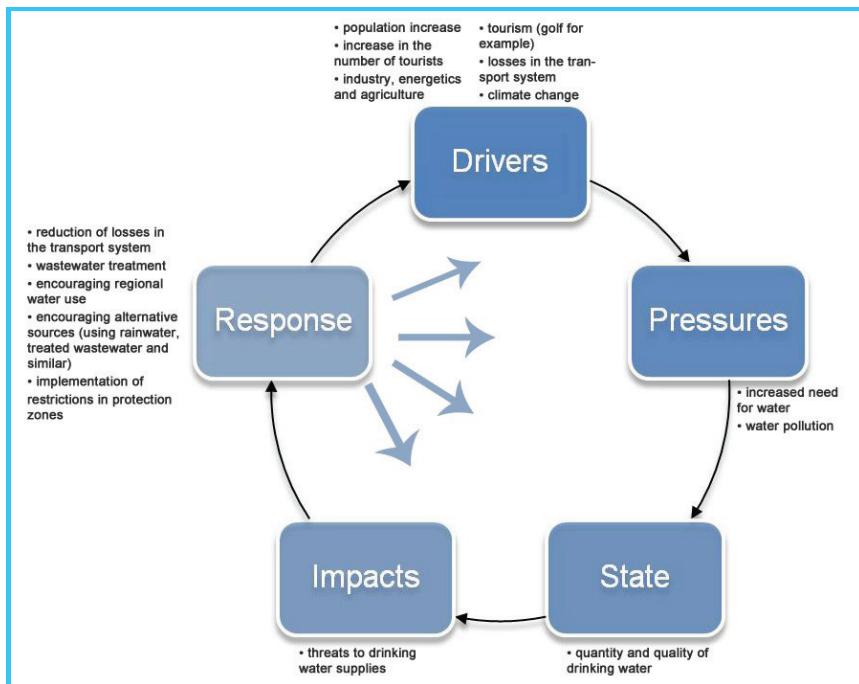


Figure 8. DPSIR analysis [18]

5. Conclusion

The area of Istria's water supply system belongs to karst and karst aquifers as well as Butoniga retention are important resource for drinking water supply of community in Istria region and are the basis of water supply that is supplying more than 200.000 residents. The water supply system of the Region of Istria consists of three water management systems governed by companies which carry out water supply activities: Water utility of Istria Ltd., Water utility of Pula Ltd. and Water utility of Labin Ltd. This is the Dinaric karst aquifer system, which is very important for the ecological biodiversity and the socio-economic development of the region. Karst waters depends on natural sensitivity (vulnerability) of the aquifer. Vulnerability of the karst aquifer depends on infiltration, hydro-geological conditions of the aquifer that control way and time underground drainage, quantity of water and rate of dilution. Water resources are impacted by many known pressures such as: traffic, public and illegal landfills, polluters, i.g. economic entities that have known impacts on water resources, population and areas intended for agriculture or forestry.

The study area is located in the Region of Istria with three typical hydro-geological units: high carbonate massif of Čičarija and Učka, the



central area built by flysch and low carbonate platform of southern and south-western Istria.

Cross-border and trans boundary groundwater aquifer are also very important sources of freshwater for different purposes and mainly for drinking water supply in many regions i.g. Istria area (spring Rižane). Republic of Slovenia and the Republic of Croatia are for years using a common aquifer to supply the population of Istria. Today, the water from the springs Bužini, Gabrijeli and Gradole located on the territory of the Republic of Croatia, are partly used to supply the population with drinking water in the Slovenian part of Istria.

The purposes of the „Program of the rehabilitation measures within the sanitary protection zones in Region of Istria for existing buildings and existing activities“ is to analyse the current state of water resources based on measures defined in Decision and Spatial planning documentation, and to put the results of those analyses in correlation with the legislation of Croatia and the EU.

Approximately 3 percent of the annual water flow is used along the Adriatic water area, with values ranging from 7.9 percent in Northern Istria all the way to 1 percent on the Adriatic islands. Out of four defined groundwater bodies in the Region of Istria, two of them are troubled by salt water intrusion. These bodies are Southern and Northern Istria. Northern Istria's underground water body is a cross-border water resource which is also used for Slovenian water supply.

The Program aims at detecting and analysing the phenomenon of salinization of Istrian springs, estimating the risks of underground water pumping in certain parts of the County and suggesting measures of protection if needed. Also, the influence of known impacts on spring areas in the Istrian sanitary zones will be detected, correlated and clustered according to geographical area under the supervision of the Istrian water management entities. Apart from known impacts, the Program will also analyse possible future impacts based on data provided by the proposed Spatial Plan of the Region of Istria which is currently in its final stage of adoption.

The Program will analyse potential threats to the safe distribution of drinking water with the goal to compose a document intended for managing Istrian aquifers. Planned measures for sustainable water management include: reducing the loss of water inside the water management system, reducing water pollution, using alternative water resources where possible (rainwater, purified waste water...), reducing water consumption. Also, through a comprehensive analytical approach, designed for solving the issues concerning sustainable water management in Istria, the Program will determine polluters, pressures, possible impacts, condition indicators and will provide useful answers.



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SPRING AND RESERVOIR WATER QUALITY VARIATION IN THE WATER SUPPLY SYSTEM OF WATER UTILITY OF ISTRIA, BUZET

Marijuča Nemarnik (marijuca.nemarnik@ivb.hr)

Water Utility of Istria, Buzet, Croatia

Abstract

This paper describes the water quality variation of the Sveti Ivan, Gradole and Bulaž springs, as well as the Butoniga reservoir in the period between the 2011 – 2015. In mentioned period, 2011 and 2012 were extremely dry years from the hydrological aspect, while 2013 and 2014 were recognized as years with a big amount of the participation. The Sveti Ivan and Gradole springs trends analysis based on the annual reports of the turbidity and abundance discharge data is conducted as well as the Butoniga reservoir water quality variation analysis due to the seasonal changes and the depth of water in reservoir. Analysis showed that the water temperature is the most important physical parameter that has impact on the water quality. In spite of the raw water quality variation and the environmental influences, at the Sveti Ivan, Gradole and Butoniga water conditioning systems, the raw water is treated for human consumption according to the Rules on compliance parameters and methods of water analysis for human consumption (Gazette 125/13 and 141/13) [7]. Climate changes has influence on the future water availability but in order to provide the sufficient quantity of the water, binding of the water supply systems in the Istria County is recommended.

Keywords: water quality, springs, turbidity, spring abundance, water supply



1. Distribution System at Water Utility of Istria, Buzet

Springs Sv. Ivan, Gradole, Bulaž, and the Butoniga reservoir are the part of the Water Utility of Istria in the city of Buzet.

The Sv. Ivan spring is placed in the river Mirna valley, about 1 km south-east of the city of Buzet and about 200 m from the river Mirna bed, at 49,0 m above the sea level. In the case of the flood, excess water from the spring is redirected by outlet into the river Mirna. The spring abundance discharge varies from 200 l/s to 2.000 l/s, while the extreme minimum spring discharge is around 90 l/s.

The Gradole spring is placed on the left side of the river Mirna valley, with overflow elevation at 8m above the sea level. The biggest spring abundance discharge is usual in the winter and spring periods when it exceeds 10.000 l/s, while the minimal spring abundance discharge is 1.000 l/s and its extreme minimum discharge is below 400 l/s. However, in 2012 its abundance was below 300 l/s.

The Bulaž spring is placed at the top of the river Mirna valley stretching along the mid-section of the river Mirna and near the Istarske toplice Spa. The Bulaž spring biggest depth is 25 m, and the overflow elevation is placed at 17m above the sea level. Annual medium abundance is little above the 2000 l/s, while the minimum discharge is 42 l/s, and the maximum around 38 000 l/s (ratio 1:900). The lowest abundance is recorded in 2015 with discharge of 15 l/s. During the drought periods, this spring is used in order to fulfil top water requirements in the Sv. Ivan spring. With the implementation of the pipe connection from the Bulaž to the Gradole spring, water requirements of the Gradole spring is also fulfilled. The Bulaž spring is connected by pipeline with the Butoniga reservoir water treatment in 2012 in order to fulfil top water requirements. In the months of January and February of 2013 the reservoir was also topped up with the water of Bulaž.

The Butoniga reservoir is placed on the left bank of the River Mirna, and it is collecting water from the three river Mirna tributaries: Butoniga, Draguć and Račice. The volume of the reservoir is $19.7 \times 10^6 \text{ m}^3$ at the spillway crest elevation (41.00 m above the sea level). The reservoir itself is a multi-purpose hidrotechnical object although its main purpose is water accumulation for the water supply. Others purposes are prevention from the hazards caused by water and irrigation. Water quality varies according to year seasons and level of the water in the reservoir. The reservoir water turbidity increase is follow by heavy rain events. Thermal stratification appears between April and October, and it has effect on the water's physical and chemical characteristics which is why the raw water abstraction is done on 4 different water levels.



The raw water quality analyses at the Sveti Ivan, Gradole, Bulaž springs as well as at the Butoniga reservoir indicated that the water requires purification treatment before it is directed into the water supply system. The springs Sveti Ivan, Gradole and Bulaž are typical karstic springs characterised by coincidence of the increase of turbidity and large discharge induced by precipitation. Increase of the turbidity causes higher organic matter content and nitrogen compounds as well as microbiological pollution. Chemical quality of raw water is significantly better during the low precipitation periods although microbiological pollution is present throughout the entire year.

The Sveti Ivan water treatment plant includes three key phases in water production for human consumption: raw water intake, pre-treatment (flocculation, coagulation and sedimentation), fast filtration, filter and sedimentation basins waste water treatment by the methods of ultra filtration, UV disinfection, primary disinfection by gas chlorine at leaving the plant, water distribution to tanks and consumers as well as additional chlorine treatments along the mains network.

Key phases in water production for human consumption at the Gradole spring are: raw water attaining from the Gradole spring to the plant, pre-treatment, fast filtration, tank water quantity control, primary disinfection, secondary disinfection and water distribution to tanks.

The process of production of the water for human consumption water at the Butoniga reservoir plant had been designed to include all the necessary stages for optimal treatment of surface waters. The treatment process includes primary ozone treatment, coagulation and flotation, fast filtration, main ozone treatment, slow filtration and primary and secondary disinfection by which alike quality of potable water is always maintained at the end of the process, regardless of changes in reservoir raw water quality.

Thanks to the possibility of transferring water from one system into the other and water mixing from various springs, the water distribution is carried out according to the Winter-Summer pumping regime (Figure 1).

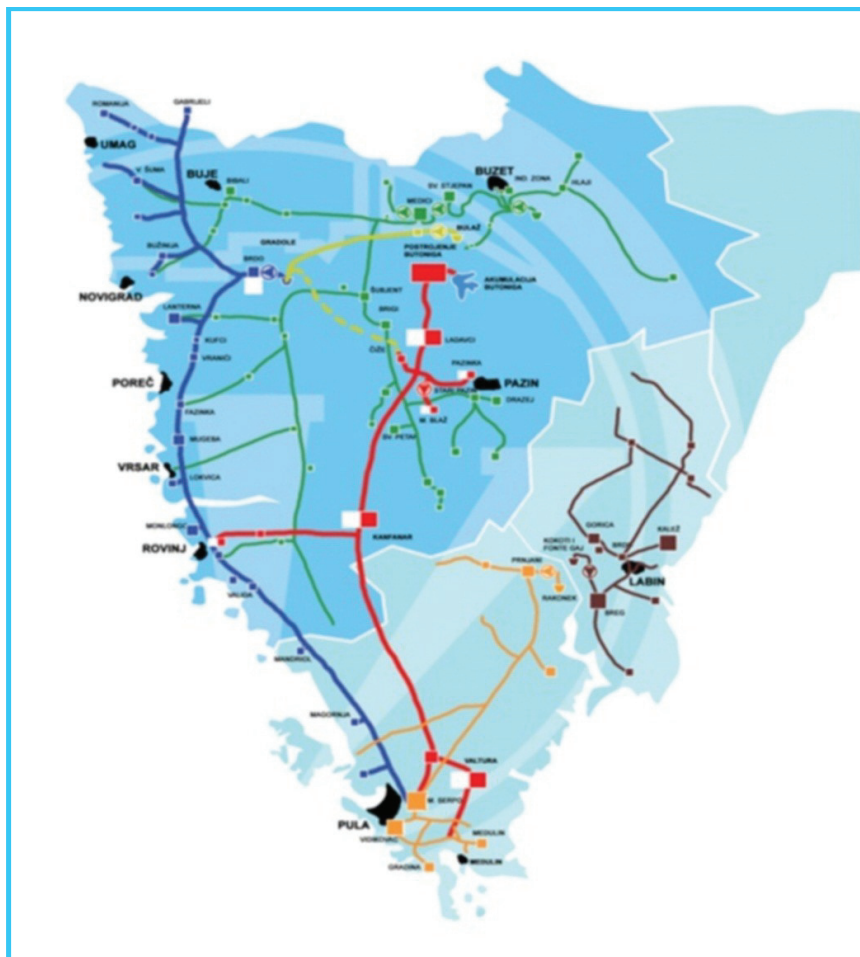


Figure 1. Water Utility of Istria; Distribution Systems (green – Sv. Ivan water supply system; blue – Gradole water supply system; yellow – Bulaž and Čiže water supply system; red – Butoniga water supply system; orange – Rakonek water supply system; Brown – Fonte Gaj water supply system)

2. Water Control for Human Consumption

The Technological and Laboratory Services analyse the raw water quality at the Sveti Ivan, Gradole and Bulaž springs as well as at the Butoniga reservoir the results of which are utilised in the production of water for human consumption as well as the water compliance parameter human consumption in the water supply system.

The spring monitoring is conducted once a year by Croatian Institute of Public Health from Zagreb, while the Istrian County Institute



of Public Health carries out monitoring according to the Sampling Plan for Raw and Human Consumption Water.

2.1. HACCP System – Daily Supervision of Critical Control Points (CCP)

By implementation of the Hazard Analysis Critical Control Point- HACCP system, the Water Utility of Istria (WUI) guarantees the identification and analysis of the possible dangers by Daily Supervision of the Critical Control Points (CCP), defining the critical boundaries and measures of prevention in all the phases of the technological process of production and distribution of human consumption water. Since March 2007 when it was implemented, its principles have been successfully applied. The HACCP team, that has regular multidisciplinary HACCP team meetings, supervises the system, identifies improvement areas and implements upgrading as WUI aims for the best water quality and safety by means of both internal and supervisory audit.



Figure 2. Gradole water treatment plant Laboratory

The process of water treatment is daily supervised and the parameters are defined by HACCP for the Plants and its Distribution System are continuously checked (Figure 2).



2.2. Raw and Treated Water Quality in the Springs and the Reservoir in 2011

2.2.1. Raw and Treated Water Quality at Sveti Ivan Spring

2011 can be described as exceptionally dry year. Although Sv Ivan spring reacts fairly quickly even to low precipitations, the amount of raw water was sufficient throughout the year (Figure 4). Also precipitations at the beginning of the 2011 caused a short increase of the turbidity in raw water (Figure 3) [2].

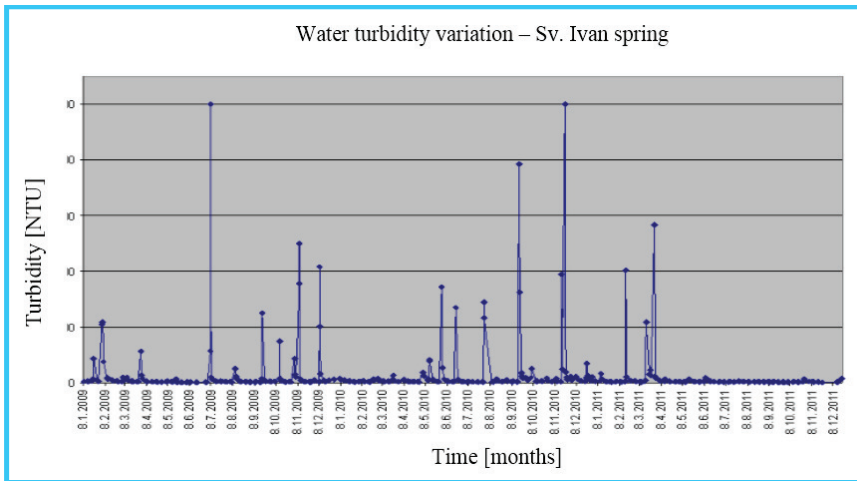


Figure 3. Water turbidity variation during 2009, 2010 and 2011

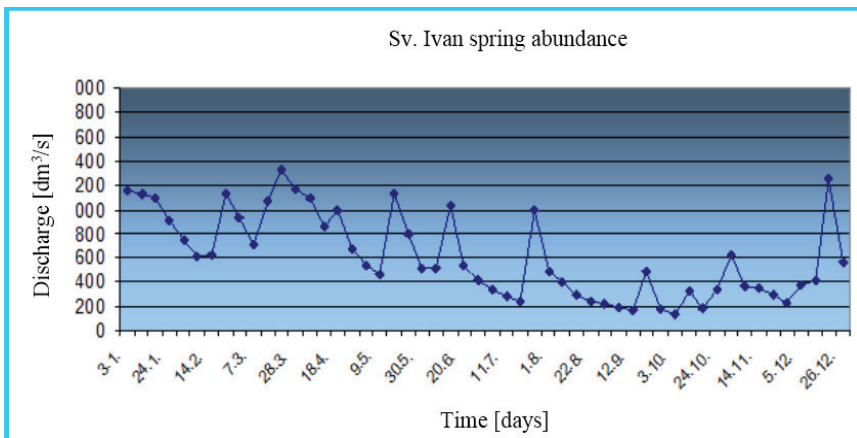


Figure 4. Sv Ivan spring abundance in 2011



2.2.2. Raw and Treated Water Quality at Gradole Spring

The Gradole spring abundance in 2011 was above 7000 l/s at the beginning of the year (Figure 5), which resulted in mild turbidity increase up to 50 NTU as is presented in Figure 6; and a short boost of abundance and turbidity was marked in March again. Small amount of precipitations in July ensured the spring abundance above 1000 l/s, which was enough for the spring not to be recharged for top requirements of water during August. This is all followed by a very dry period during which the abundance decreases, marking the end of the year at 500 l/s. The treatment process of the raw water at the Gradole plant was working properly during 2011 despite of the small amount of the produced water and water quality remained unchanged [1].

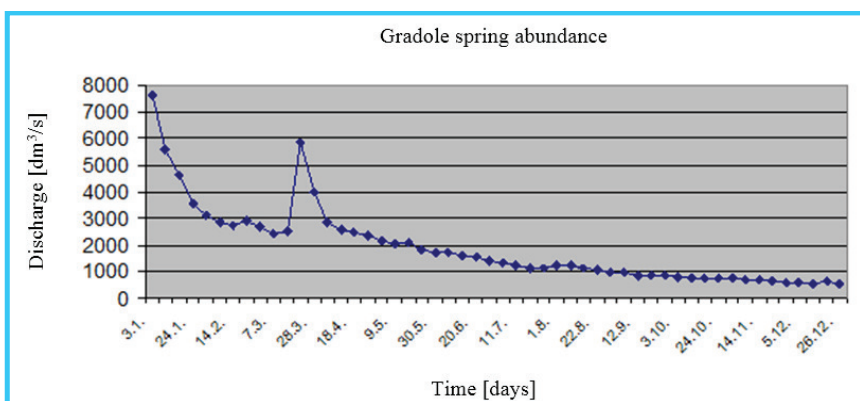


Figure 5. Gradole spring abundance in 2011

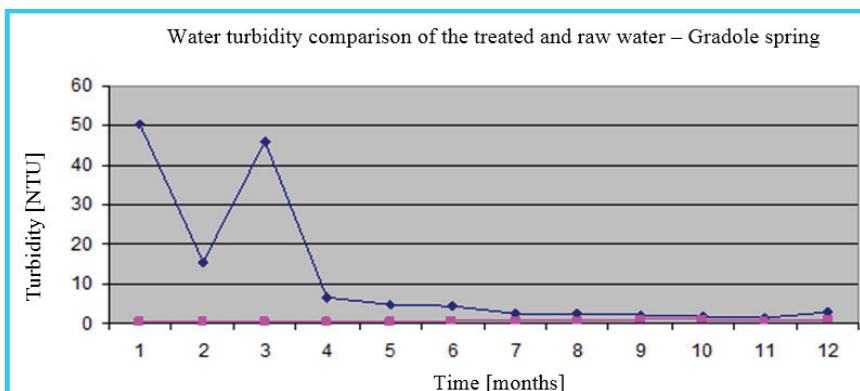


Figure 6. Raw and treated water turbidity variation at the Gradole spring in 2011 (blue – raw water; pink – treated water)



Water level variation in the Butoniga reservoir directly influences the raw water quality. As in 2010 the highest water level in the past five years was recorded, the raw water quality was significantly better. Minimal water temperature and manganese quantity were detected in 2010. At the beginning of 2011 the water level at 38, 21 m above the sea level was recorded, which is by 1, 37 m lower than in the beginning of 2010. Maximum water level in 2011 was 40, 39 m above sea level. The water level was lowered for 0, 86 m and the raw water was let out of the reservoir in March due to high quantities of precipitations. In the end of summer the water level went down to 39, 57 m above the sea level. In September the regular autumn outlet release of the water took place (Figure 7).

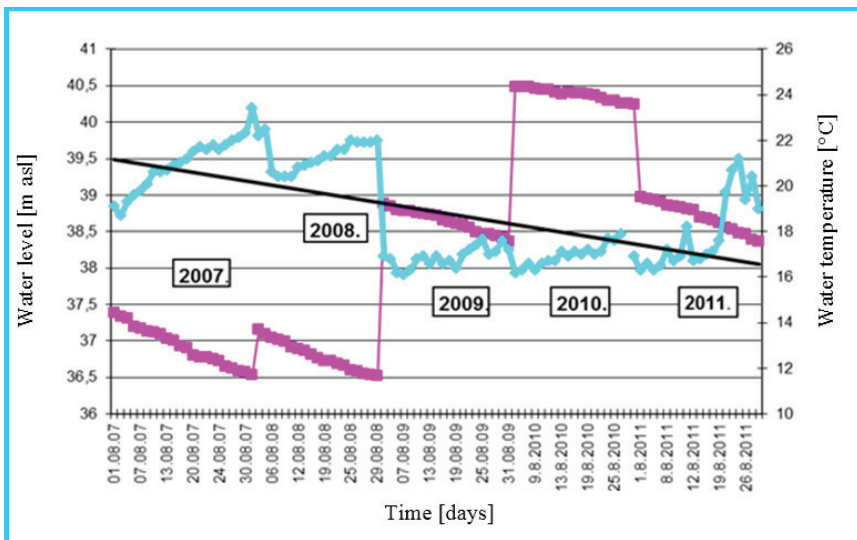


Figure 7. Raw water temperature and Butoniga reservoir level comparison in August during 2007, 2008, 2009, 2010 and 2011 (magenta – level of the water in reservoir; cyan – water temperature; black – trend line of the water temperature)

The analysis results clearly show that all the raw water quality parameters of the Butoniga reservoir vary significantly, which was caused by seasonal differences in water quality of the accumulation. Critical parameters in raw water quality are low oxygen concentration, higher temperature, turbidity, organic matter, Ammonia concentration and metals concentration (iron and manganese) as well as microbiological pollution. In 2011 the Butoniga reservoir plant resulted with good quality in supplied water regardless of the water levels abstraction [3]. Analysed parameter values after the water treatment were within the boundaries prescribed by the Rules on Potable Water Safety, Gazette 47/08 [5].



2.3. Raw and Treated Water Quality for 2012

Thanks to somewhat good abundance of the Sv Ivan spring, which rose due to precipitations in May and June, treated water was used to fulfil the Bulaž spring requirements during the summer months, all in order to augment the Butoniga reservoir treatment capacity and the abundance of the Gradole spring. The lowest spring abundance at Sv Ivan was recorded between the end of July and mid-August with discharge of 100 l/s. Short precipitation events resulted in mild increase of the raw water turbidity up to 20 NTU. Along with the decrease of the abundance, the turbidity also become smaller, and resulted between 2 and 3 NTU. Higher increase of the turbidity was again recorded in November and December, when it reached its maximum value at 434 NTU (Figure 8) [2].

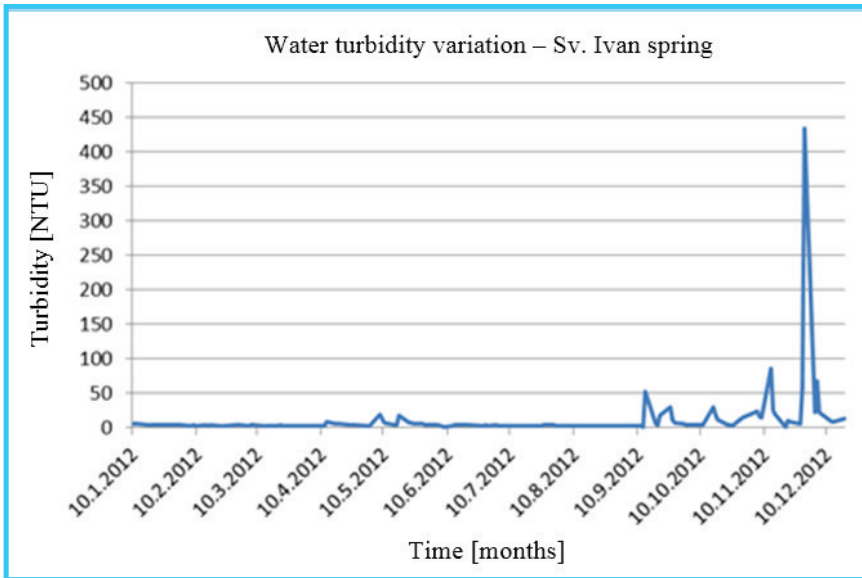


Figure 8. Raw water turbidity variation at Sv Ivan spring in 2012

A dry period without precipitation which began in early 2011 influenced the raw water quality at the Gradole spring. The extremely low abundance in December 2011 with discharge of 500 l/s only continued its decreasing trend even in 2012. The programme of water consumption reduction and saving was put into practice at the start of the year when the time between two quick filter backwashings and the time of quick filter backwashing was maximally prolonged. In order to preserve raw water the Gradole spring was being recharged up from the Bulaž spring from as early as the 3rd March, 2012 with amount of 90 l/s. The process was continued well during spring with, more or less, small interruptions. The completion of the Bulaž – Butoniga pipeline on



the 14th June, 2012 provide the possibility that a part of the raw water from Bulaž can be redirected to the Butoniga reservoir and water treatment plant.

In August the abundance of the Gradole spring dropped below 300 l/s (extreme min 237 l/s) which had not been recorded since 1986. The amount of water was sufficient to supply only the area of the Cities of Umag and Novigrad so on the 1st of August 2012 part of the pipeline, the Poreč branch, section Mukle was shut down. At the end of the holiday season, a drop in water consumption was evidenced but the spring abundance did not increase until November, thanks to heavy rains. Extremely low abundance of the Gradole spring during the whole of the 2012 resulted in many difficulties as demand was high and supply of water low (Figure 9). However, the treatment process continued on without problems. Along with the measures of water consumption reduction it remained stable and resulted in clean and safe water throughout the whole year [1].

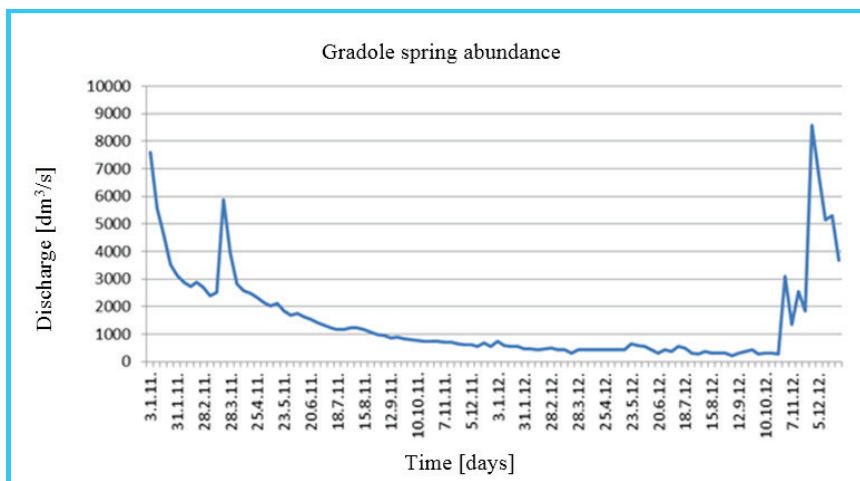


Figure 9. The Gradole spring abundance in 2011 and 2012

An extremely dry 2011 during which the amount of recorded precipitations were 694 mm/m², which is 2,2 times lower than in 2010 resulted in very low water level in the Butoniga reservoir. The lowest ever water level was recorded on 10th October, 2012 at 32,44 m above sea level. The significant increase of water level was not recorded until 1st November, 2012 when water level raised for 17 cm. Since then the level kept on increasing and at the end of the year it was at the level of 37,62 m above sea level. In two and a half months the level increased by 5,18 m. Considering all the problems with water supply we asked for an opinion from the scientists at the University of Zagreb, Department of Science and mathematics. According to their opinion, they allowed

using water up to levels lower than the ones supposed in order to preserve the lake's biocoenosis. The assessments were made on the basis of field work and research as well as long-term experience in the field of fauna's life in the Butoniga reservoir. At the same time, it was important to pay attention to the lake's lower oxygen and H₂S concentration at the lower layer levels, as well as the level of thermocline in order to prevent the mixing of water.

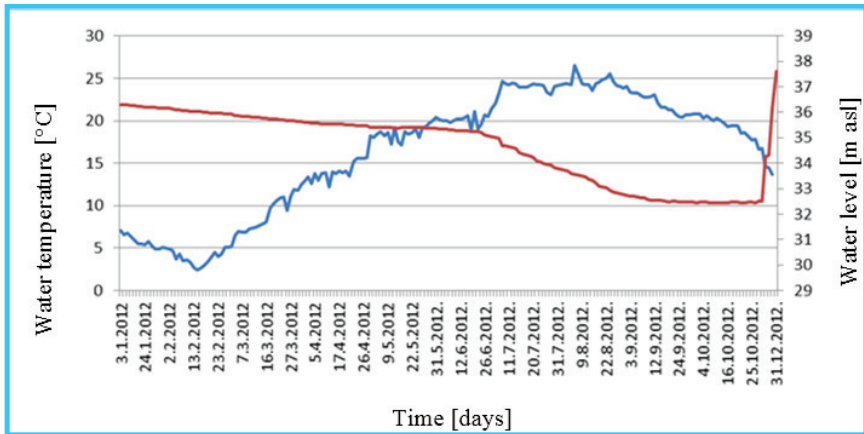


Figure 10. Temperature and water level at Butoniga reservoir in 2012 (red – level of the water in reservoir; blue – water temperature; black)

Water temperature was the most critical parameter and it was the only one which surpassed the MAC - maximum allowed concentration value of 25°C prescribed by the Rules (Gazette 47/08) (Figure 10)[5]. Measurements on the lake itself showed maximum water temperature of 28°C so the treated water temperature would have been even higher had it not been mixed with the raw water of the Bulaž spring. Cooler water of constant temperature of 15°C from the Bulaž spring did not succeed in cooling down the treated water below 25°C. In comparison to 2011, when the maximum temperature of 22,5 °C was recorded in September or to 2010 when maximum temperature was 20,4 °C, in 2012 treated water was warmer by 5°C. The surpassed values of 3 °C were approved by the Ministry of Health. Nearly throughout the summer and a part of autumn a correction in pH values was needed in order to fulfil the water stability index [3].

Due to the low abundance on all Istrian water springs the measure of Level 1 water consumption reduction and saving was introduced throughout Istrian County between the 23rd July, 2012 and 24th September, 2012. An Executive Plan for the implementation of measures in case of water supply shortage was drawn and water sampling was carried out more often. Beside our internal laboratory, sampling was done more often by the County Offices as well as the



State ones and the Sanitary Inspection. Along with all the activities of system connections and water mixing from different springs and of different qualities, based on the results gained from internal and County laboratories along with that of Public Health Office in Pula, it was concluded that the water distributed to the consumers was in accordance with the Rules, apart from the temperature which was higher on some points. Water disinfection was increased to 0,5 mg/l of the residual chlorine. Furthermore, by including the additional springs of Bužini and Gabrijeli into the water supply system, the Gradole spring was used to slightly supply the water supply system of Rižana water supply system [4].

2.4. Raw and Treated Water Quality for 2013

Precipitations in spring and fall (Figure 12) resulted in higher turbidity at the Sv Ivan spring. The maximum value of raw water turbidity was 457 NTU. As the spring abundance decreased, so did the turbidity and it was between 2 and 3 NTU (Figure 13). Such low turbidity made the process of treatment much easier and coagulants were added only every now and then. Microbiological pollution was present throughout the year and due to precipitations the microbiological values were somewhat higher (Figure 11) [2].

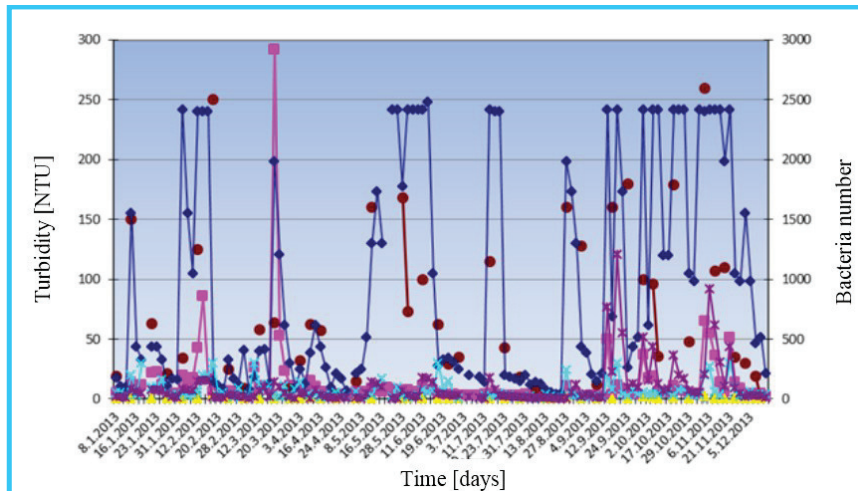


Figure 11. Microbiological raw water quality at Sv. Ivan spring (magenta – Turbidity; brown – Streptococcus bacteria; blue- Coliforms; green – Clostridia; yellow – Pseudomonas; cyan – Aerobic bacteria; purple – Coliforms – fecal bacteria)

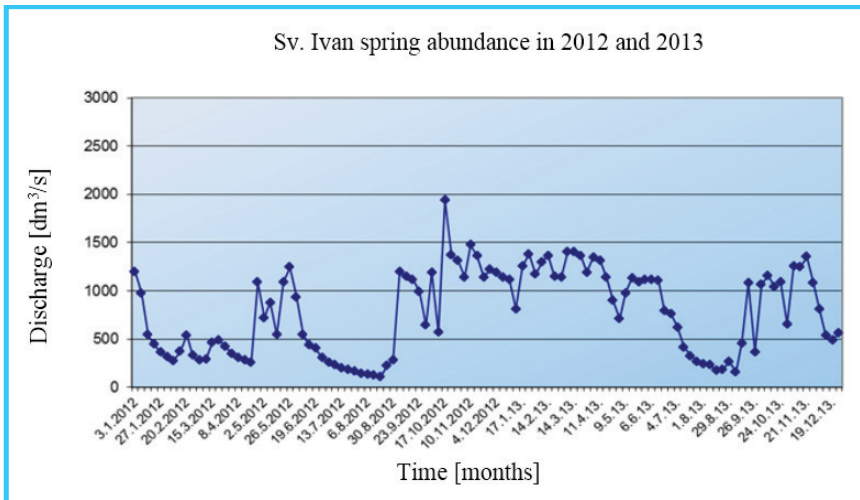


Figure 12. Sv. Ivan spring abundance comparison in 2012 and 2013

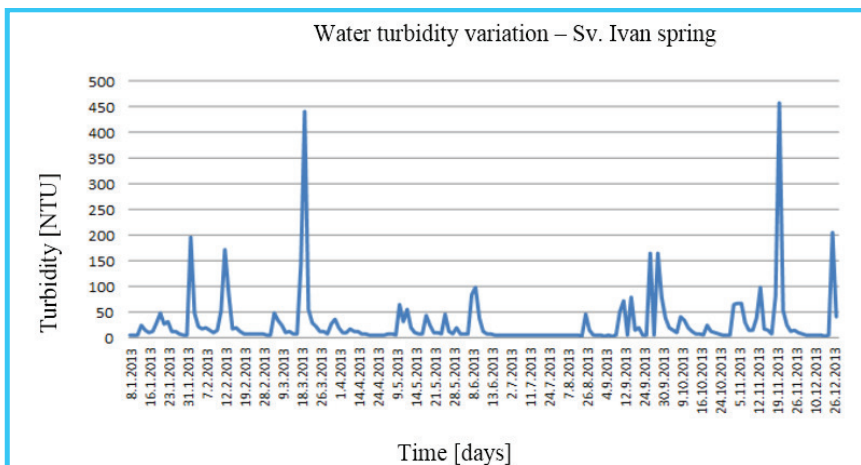


Figure 13. Turbidity of raw water at the Sv Ivan spring in 2013

By comparing the abundance at the Gradole spring in the past three years it is evident that the abundance was at its highest in 2013 (Figure 14). The maximum discharge of the Gradole spring in 2013 was 9014 l/s. The increased abundance of the Gradole spring in 2013, taking into consideration the precipitations in 2011 and 2012, was the result of increased precipitations in spring and late autumn of 2013. Minimal abundance at the Gradole spring in mid-September was 1287 l/s. In 2013 the Gradole spring was not recharged by water of the Bulaž spring [1].

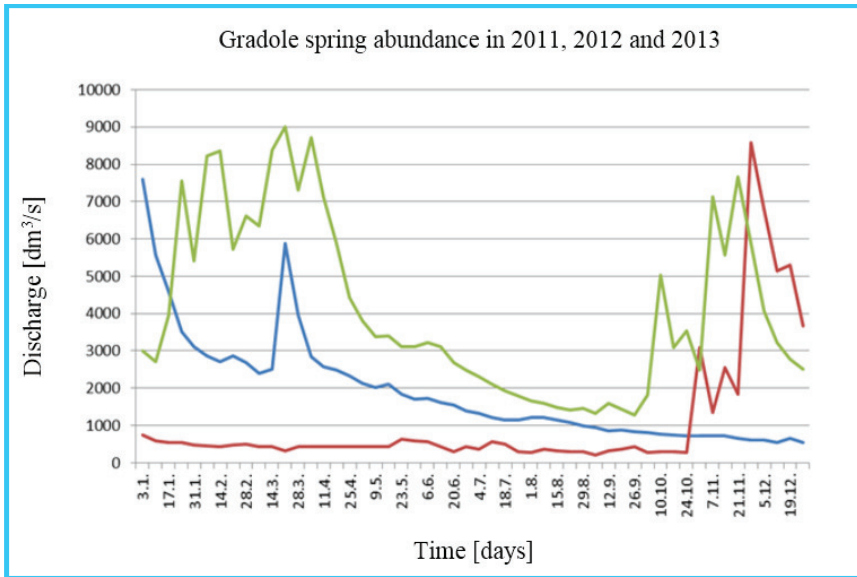


Figure 14. Abundance at the Gradole spring in 2011, 2012 and 2013 (blue – 2011; red – 2012; green – 2013)

2.4.1. Water Quality at the Butoniga Reservoir

Unlike season 2012, in 2013 the weather conditions were much better for water accumulation. Thanks to great amount of precipitations in the winter, in spring and autumn periods, at outlet the water which cumulatively almost reaches the amount of the whole volume in the lake was released. Water release increases a better quality of raw water and directly affects the operation of the technological treatment process. Furthermore, it lowers the concentrations of values which affect the raw water quality (iron, TOC and aluminium), especially that of manganese which is affected the most by the autumn natural water level release. Even though the months of July and August there was enough water in reservoir, and there was no need to lower the water abstraction level, there is no guarantee the temperature will not surpass 25°C (Figure 15).

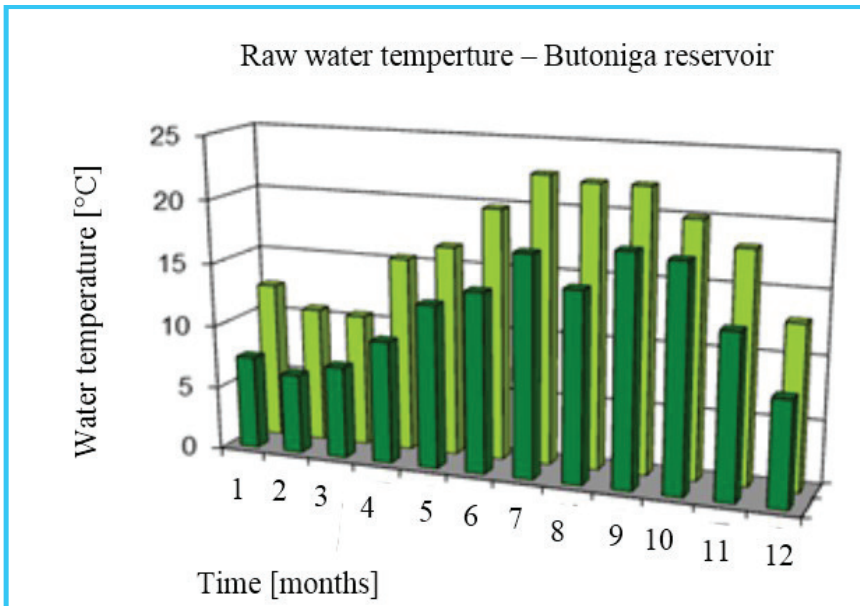


Figure 15. Raw water temperature in the Butoniga reservoir in 2013 (light green – maximum temperature; dark green – minimum temperature)

Raw water turbidity varied between 0,6 and 20,7 NTU. The maximum turbidity of the raw water at 20,7 NTU was recorded in January when the process of treatment used the water from the Bulaž spring. The technological process of the Butoniga water treatment plant is adjusted to the treatment of surface waters, and thus it is difficult to adjust it to the treatment of waters which come from the Bulaž spring [3].

2.5. Raw and Treated Water Quality for 2014

The increase in turbidity of the Sv Ivan spring with the value of over 1000 NTUs, was caused with frequent rain events that began in July and lasted until the end of 2014. The maximum analysed value of raw water turbidity was at 1150 NTUs on the 18th July, 2014 and the minimal value of raw water turbidity was at 2, 35 NTU. The treatment process had to be stopped on several occasions due to high turbidity of over 1000 NTU (Figure 16). Nevertheless, regardless of the high oscillations in raw water turbidity at the Sv Ivan spring, the coagulant which has been in use for numerous years gave good results with exit turbidity at all raw water conditions. During 2014 in the technological process of water production at Sv Ivan, the phase of technological waste water treatment is implemented [2].

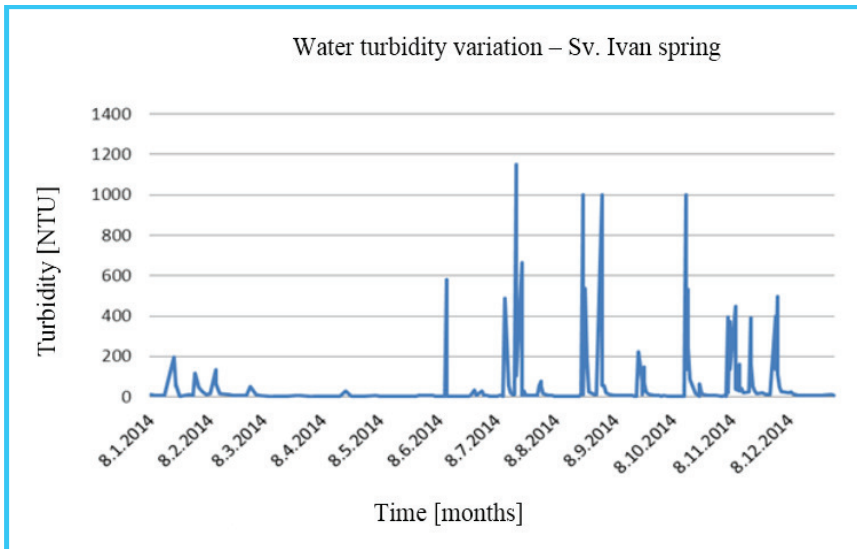


Figure 16. Raw water turbidity at Sv Ivan spring in 2014

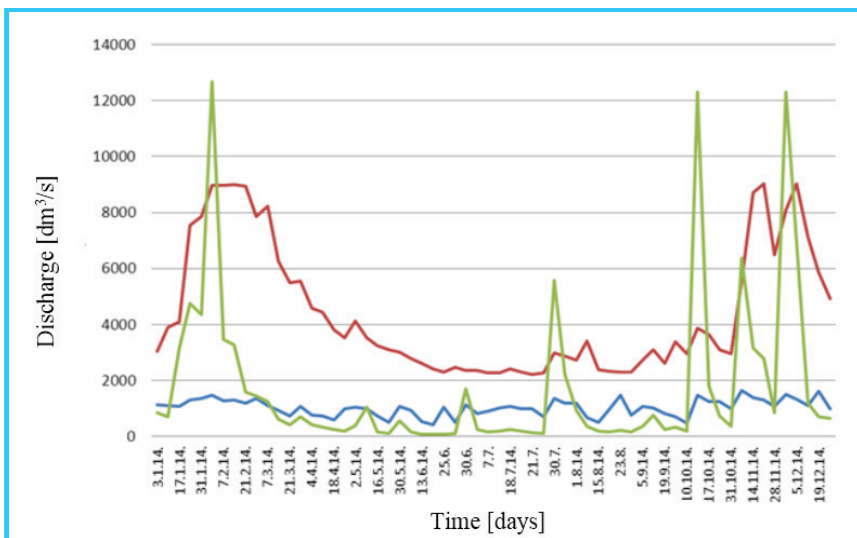


Figure 17. Comparison of abundance at springs Sv Ivan, Gradole and Bulaž in 2014 (blue – Sv. Ivan spring; red – Gradole spring; green – Bulaž spring)

Analysis of the amount of precipitations and its influence on the abundance is done as well as abundance comparisons between springs in the 2014 (Figure 17). From Analysis it is evident that the abundance at the Gradole spring was at its highest discharge in 2014



(Figure 19). The increase in water turbidity reached up to the value of 71 NTU, which did not considerably affect nor disturb the treatment process. The minimal turbidity values in raw water was 1,13 NTU (Figure 18). None of the analysed parameters in the treated water at the Gradole spring surpassed the allowed MAC-maximum allowed concentration values prescribed by the Rules on compliance parameters and methods of water analysis for human consumption. A detailed project for the technological waste water treatment for the Gradole spring is designed, and it is implementing the same treatment technology as that of the Sveti Ivan water treatment plant [1].

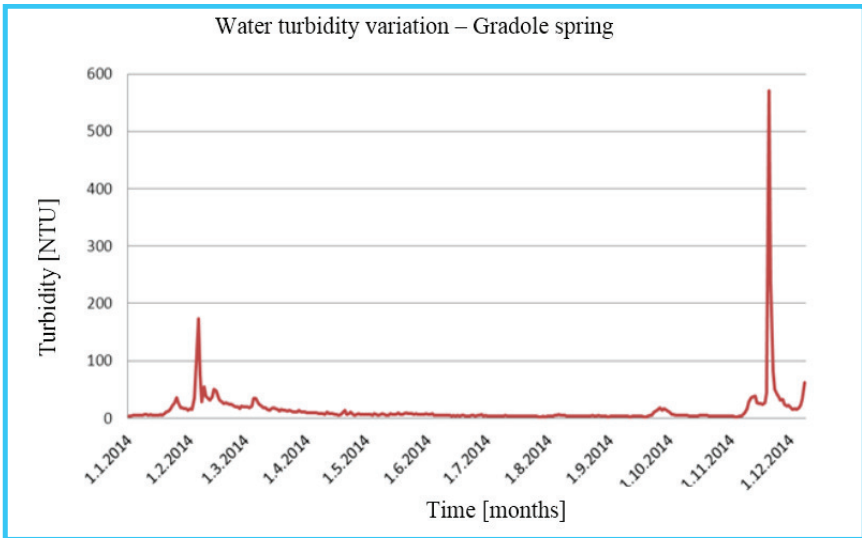


Figure 18. Raw water turbidity at the Gradole spring in 2014



Figure 19. Spilway at the Gradole spring



The big amount of the participation that was recorded during the summer in 2014, had a considerable influence on the raw water quality at the Butoniga reservoir. As is shown in Figure 20 the water level on in the reservoir, during the whole summer period, stood at its maximum level and it was necessary to release water at its outlet for several times during the year as the water reached the level of the spillway crest. The increase of water level resulted in high turbidity, especially in the second half of the year. The big increase of the turbidity also induced increase of iron and manganese concentration in water. The turbidity rise continued in the autumn months, reaching its maximum in November, when the on-line measurements recorded the turbidity value of 100 NTU. The whole treatment process is designed to treat surface waters, and it is not accustomed to high turbidity amount. The summer months brought warming of the water in the reservoir which directly affects the rise in the temperature after the treatment process. When the raw water temperature approaches its critical point, the Plant staff undertakes preventive actions and thus on the 23rd July, 2014 we began abstracting mixed water from the 3rd and 4th water levels. Changes in water quality range from year to year and a constant surveillance is needed in order to be able to undertake preventive measures for the eutrophication process minimisation and decrease of the water quality, in order to make the whole process as safe as possible [3].

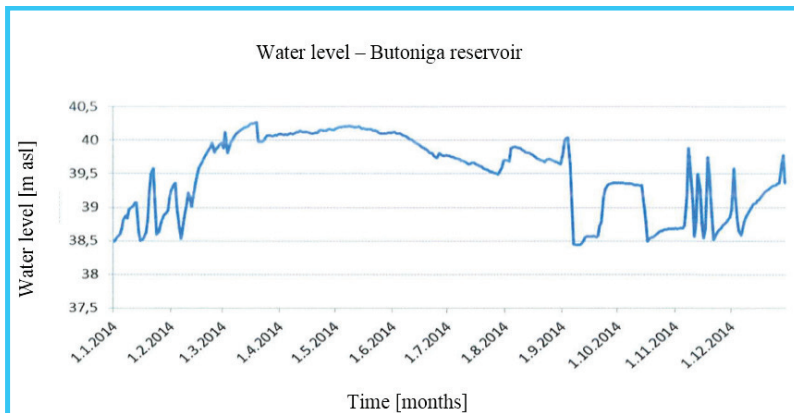


Figure 20: The Butoniga reservoir water level in 2014

2.6. Water Quality in 2015 (January – August)

The summer of 2015 was considerably dry until mid-August but the abundance at the Sv. Ivan spring was considerable and satisfactory for water distribution and supply from the Sveti Ivan water supply system. The Sveti Ivan spring response with the immediate increase of the



turbidity and discharge in the case of the big amount of the participation. The maximum recorded value of raw water turbidity was at 135 NTU-a (June), while the minimal one was 2,45 NTU (Figure 21). The turbidity peak amount lowered quite quickly so there was no need for the treatment process to be stopped. The highest value of the turbidity, in treated water, was 2,42 NTU.

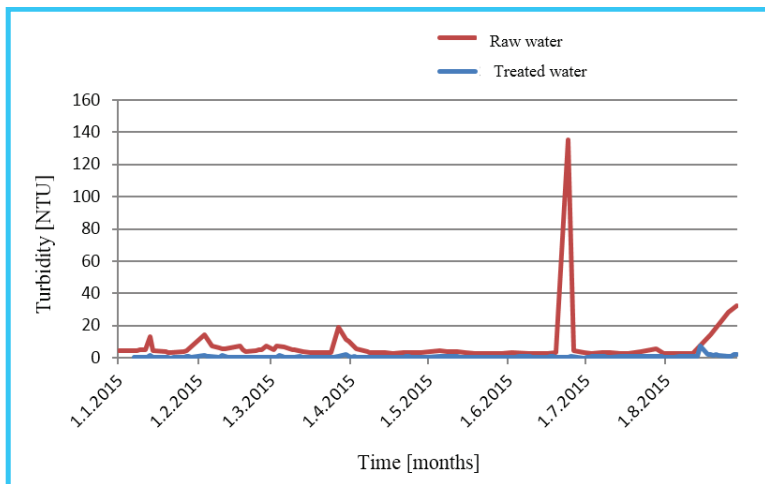


Figure 21. Raw and treated water turbidity (NTU) at the Sveti Ivan spring in 2015

During the first eight months of 2015 the treated water quality from the Sv Ivan Water Treatment Plant was in accordance with all the parameters of Rules on compliance parameters and methods of water analysis for human consumption.

At the Water Treatment Plant Gradole, the raw water quality in all of the phases of the technological process is daily monitored. On the Plant, the concentration of dissolved aluminium, chlorine residual and the water turbidity (Figure 23) is directly analysed while the complete microbiological, physical and chemical analysis is carried out at the laboratory. The summer of 2015 was considerably dry and without precipitations but the abundance at the Gradole spring was satisfactory and abundant in fulfilling the needs for water. The highest abundance for the Gradole spring for a determined period is recorded with discharge of 7286 l/s (in February), while the lowest was at 1250 l/s (in mid-July) (Figure 22). The Gradole spring was not recharged with raw water from the Bulaž spring. The raw water quality was in accordance with the Rules on compliance parameters and methods of water analysis for human consumption.

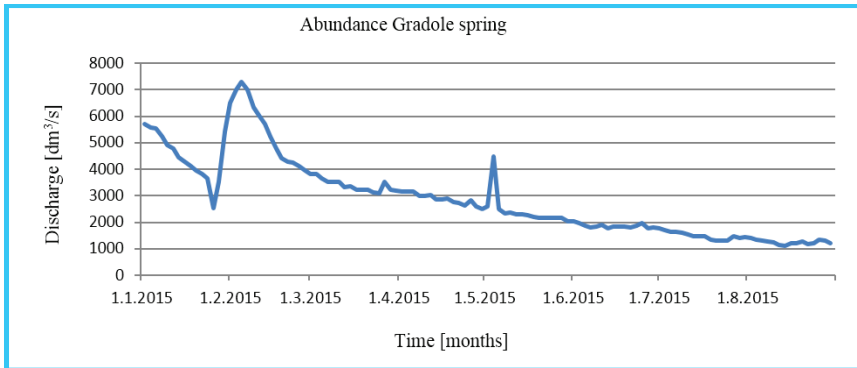


Figure 22. Abundance at the Gradole spring in 2015

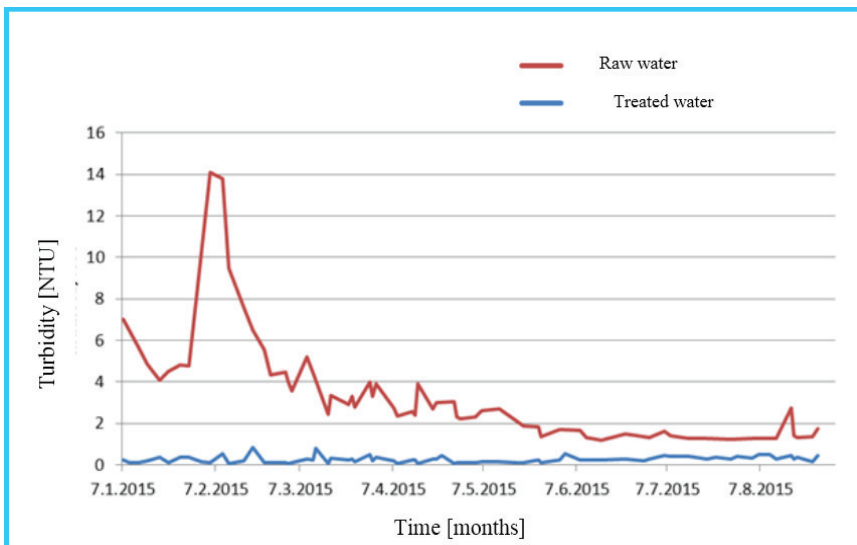


Figure 2. Turbidity variation at the Gradole spring

Raw water quality parameters at the Butoniga reservoir vary due to several factors which affect it, those being: (i) seasons, (ii) amount of the rainfall, (iii) amount of water inside the reservoir, (iv) water level from which the raw water is abstracted. At the beginning of 2015, the Butoniga reservoir had a water level at the 39,02 m above the sea level. Due to rainfall events, the amount of water in the lake increased up to its maximal peak of 40 m above the sea level so in February and March a part of water was released at its outlet. The most critical water quality parameter in the summer months were the high levels of the manganese concentration and the high water temperature which reached MAC- maximum allowed concentration values; because of that



in the beginning of July we started with water mixing from the abstraction levels 3 and 4. During the monitored period (January – August) the raw water temperature at the entrance of the technological process varied from 6,4°C to 23,6°C. By optimization of the treatment process (the corrections in the adding of the chemicals), all the parameters for the first eight months of 2015 were in accordance with the Rules on compliance parameters and methods of water analysis for human consumption. Water quality parameter analysis at the exit of the treatment process is showing that the process is stable regardless of raw water quality [8].

3. Conclusion

Regardless of raw water quality and influences of pollution at the springs of Sv Ivan, Gradole and Butoniga the raw water is treated to the point of becoming appropriate for human consumption in accordance to the Rules on compliance parameters and methods of water analysis for human consumption (Gazette 125/13 and 141/13). Reached quality for human consumption as: (i) outward turbidity below 1 NTU, (ii) low concentrations of residue aluminium at the exit of the process (below 0,05 mg/l) and (iii) THM – by-products of chlorine disinfection are within MAC - maximum allowed concentration limits; all the results are in compliance with the Regulations on Potable Water Safety and Rules on compliance parameters and methods of water analysis for human consumption [6] [7]. Climate changes affect the attaining of sufficient quantity of water for distribution purposes. Nevertheless, by connecting the system appropriately there is enough water attained for distribution purposes and public need.

4. References

- [1] Raw water quality at Gradole Source and treated water quality at Gradole Water Treatment Plant in 2011, 2012, 2013 and 2014 (by Sonja Zorko, Biotech. Eng., Danijela C. Linardon, Sanit. Eng.)
- [2] Raw water quality at Sv Ivan Source and treated water quality at Sv Ivan Water Treatment Plant in 2011, 2012, 2013 and 2014 (Sonja Zorko, Biotech. Eng., Danijela C. Linardon, Sanit. Eng.)
- [3] Water Quality in 2011, 2012, 2013 and 2014 according to the results of the analyses carried out by internal laboratory at the Butoniga Reservoir (Danijela C. Linardon, Sanit. Eng., Sonja Zorko, Biotech. Eng.)



- [4] Annual Report for 2011, 2012, 2013 and 2014 (Marijuča Nemarnik Chem. Eng., Bojana Flego, MSc Biotech.)
- [5] Regulations on Potable Water Safety (Gazette 47/08)
- [6] Water for Human Consumption Act (Gazette 56/13)
- [7] Rules on compliance parameters and methods of water analysis for human consumption (Gazette 125/13 and 141/13)
- [8] Management review (January – August 2015)



IMPACT OF LAND USE ON GROUNDWATER QUALITY IN SOUTH DALMATIA TEST AREA

Jasmina Lukač Reberski (jlukac@hgi-cgs.hr),

Josip Terzić (jterzic@hgi-cgs.hr),

Marina Filipović (mfilipovic@hgi-cgs.hr),

Tihomir Frangen (tfrangen@hgi-cgs.hr),

Tamara Marković (tmarkovic@hgi-cgs.hr),

Croatian Geological Survey; Department of Hydrogeology and Engineering Geology, Zagreb, Croatia

Abstract

DRINKADRIA project in South Dalmatia test area includes two catchments: spring Prud and Blatsko polje. All surrounding inhabited area is supplied by groundwater from these catchment areas. Water supply systems of spring Prud and Blatsko polje are typical seasonal with uneven consumption during the year. Maximum rates are always extracted in the summer seasons when the need for water is increased as a result of tourism and agricultural production, while the recharge in this half of the year is usually minimal or none. Human activities commonly affect the distribution, quantity, and quality of water resources. A broad range of human activities affects water resources. Major negative impacts on groundwater quality in these areas are agricultural activities and sea water intrusions. In this paper, the basic groundwater quality parameters of the investigated area are presented. Land use map, analysis of trends of major quality indicators was estimated to establish a negative influence on groundwater. Evaluated trends of changes in Corine land cover shows that there is no significant change in land use categories over the years. Trend analysis of chloride and nitrate has shown that values are quite dispersed at both sites, but long-term trends are negative or stagnating. In spite of this, due to the fact that water supply system of spring Prud is currently under construction which plans to double the amount of pumping, as well as the negative predictions of climate changes, it is necessary



systematic monitoring and analysis of trends in water quality in order to timely detect possible adverse changes in water quality.

Keywords: land use impact, water quality, ground water, south Dalmatia, Prud, Blatno polje

1. Introduction

In the Croatian part of DRINKADRIA project, within the test area south Dalmatia, are two sub-areas. The first sub-area, Prud spring catchment, is on continental part, and the second one is Blatsko polje which is situated on the island of Korčula (Figure 1). They have completely different catchments, but their water supply and water management systems are interrelating. Spring Prud has much bigger and complex catchment area. It is capped for the purpose of regional water supply system Neretva-Pelješac-Korčula-Lastovo (NPKL). On the other side, western part of the island of Korčula uses its own sources for water supply – these are extraction wells in Blatsko polje test area. But, due to insufficient island groundwater capacities, whole eastern part of the island is supplied by water from shore with regional water supply system that uses water from the spring Prud.

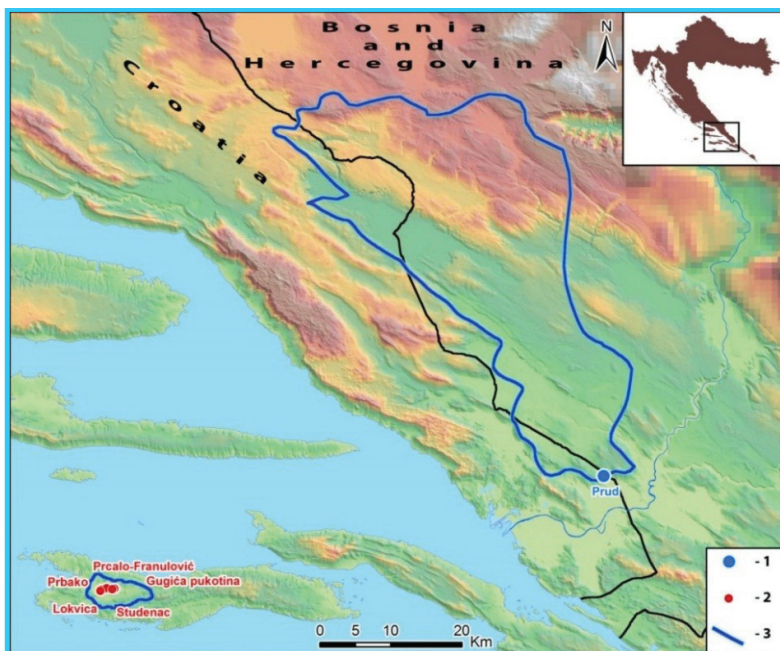


Figure 1. Test areas in southern Dalmatia. 1-spring, 2-pit well, 3-groundwater divide.



Prud is a big spring situated in karst environment of Dalmatia, Croatia (HR), close to the boundary with Bosnia and Herzegovina (B&H). Whole catchment area is composed of karstified carbonate rocks, karst poljes, and within the catchment boundaries there are several settlements, including town Ljubuški in B&H. Karst geomorphology of the right bank of the Neretva river, to which spring Prud catchment area belongs, is marked by the great complexities and intertwinement of hydro-geological relations. Despite numerous investigations and tracing experiments in this system there are still a great number of uncertainties and doubts. The underground connection, surface streams that are sinking and appearing on the surface again, karst springs, estavelles or swallow holes present a big challenge for hydro-geological investigations. According to current knowledge, the size of Prud catchment area is about 1200 km², while much bigger part of catchment area is situated in B&H. Prud spring is the most important spring in the lower course of the Neretva river. It represents the basis of water supply in the regional aspect. This spring could supply nearly half a million inhabitants, but so far only 10% of its capacity is used. Minimum discharge of spring Prud is 2770 l/s [1]. Current possibilities of water supply system due to construction capacity are 382 l/s, 280 l/s which supply about 20 thousand inhabitants is in use, but in summer the population number doubles in size due to tourism. Current system upgrading, which will achieve designed capacity, will almost double the water consumption. Thus, around 45 thousand people and just as many tourists in the top of the tourist season will be supplied by water from this catchment. In comparison to other karst springs, fluctuations of minimum and maximum discharge is relatively small: $Q_{min} : Q_{max} = 2,5 : 20 \text{ m}^3/\text{s}$ [1].

Blatsko polje is a natural depression, a karst field situated in the western part of the island Korčula. Eastern from the Blatsko polje there is small town Blato with close to 3700 inhabitants. The terrain is built of more or less karstified carbonates (mostly Cretaceous) and poljes that are covered with Quaternary deposits with red soil, so called „terra rossa“. The lowest point of Blatsko polje is around 6 m a.s.l. In the polje the hydromelioration network of canals has been built. Through these canals water is led toward the lowest point of the field and to the nearby entrance into a drainage tunnel that was constructed because during wet winter periods polje flooded. The catchment area of Blatsko polje is spreading over 28 km². Groundwater used for public water supply is pumped from four pit wells: Studenac, Franulović, Prbako and Gugić [1]. Water from Prud is transported through pipelines from the mainland to Blato but the community (Water Supply Company) does not use it because of the preference toward their own groundwater supplies. Quantities from Prud are held as reserve for extreme hydrological



conditions when Blato aquifer is exposed to seawater intrusions. Maximal pumping rate from Blatsko polje wells is about 60 l/s [2]. Water supply system Blatsko polje supplies about 8000 people in the winter time which doubles in summer season. Both of water supply systems, Prud and Blatsko polje, are typical seasonal with uneven consumption during the year. Maximum rates are always extracted in the summer seasons when the need for water is increased as a result of tourism and agricultural production, while the recharge in this half of the year is usually minimal or none.

2. Groundwater Hydrochemistry - Water Quality Indicators

At the Prud catchment test area, hydro-chemical data were collected and analysed at monthly intervals from December 2013 until December 2014. Prior to sampling, the following parameters were measured on-site by probes of the WTW Company: electrolytic conductivity (EC), temperature (T), pH and dissolved oxygen concentration. Alkalinity was also measured on field, by the titration method with 1.6 M H₂SO₄. Water samples for laboratory analysis were filtered on-site (0.45 µm, single use Schleicher&Schuell cellulose filters) and collected in cleaned polyethylene bottles. Samples for cation analysis were acidified with suprapur HNO₃. Samples were stored at 4°C until they were analysed. At the Hydro-chemical Laboratory of the Department of Hydrogeology and Engineering Geology at the Croatian Geological Survey major anion concentrations (SO₄²⁻, NO₃⁻ and Cl⁻) were measured by Ion Chromatography (LabAlliance Ltd.). Major cations (Na⁺, K⁺, Ca²⁺ and Mg²⁺) were measured by Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer Analyst 700). Together with these data, data for spring Prud were acquired from the Neretva-Peljesac-Korčula-Lastovo water supply company. For the Blatsko polje test area water quality data of monitored wells were acquired from the Vodovod Blato d.o.o. (Blato Water Utility) for the period from 1997 until 2010. This data were collected for the purpose of CC-WaterS project and will be used for the purposes of this report [3]. For the purpose of this paper only data collected from well Studenac have been considered because Studenac is the most important extraction site in Blatsko polje from which is more than 80% of water from Blatsko polje catchment is extracted.

According to the chemical composition, geochemical facies of the water from spring Prud range from Ca-HCO₃ towards Ca-SO₄ hydro-chemical type (Figure 2). The sulphate in some springs of Tihaljina river is the principal anion, and since these waters contribute to the waters in the Prud spring catchment they also affect its water chemistry. The origin of the sulphate is attributed to the presence of gypsum and



anhydrite deposits in the deeper parts of the karstic aquifer [4]. Sometimes Prud spring water has slightly higher Cl concentration because of mixing with seawater. Groundwater of well Studenac belongs to Ca-HCO_3 and $\text{Ca-HCO}_3\text{Cl}$ (Figure 2) hydro-chemical type, which is principally derived from dissolution of carbonate minerals in the limestone aquifer. The latter depends on the influence of seawater on the aquifer.

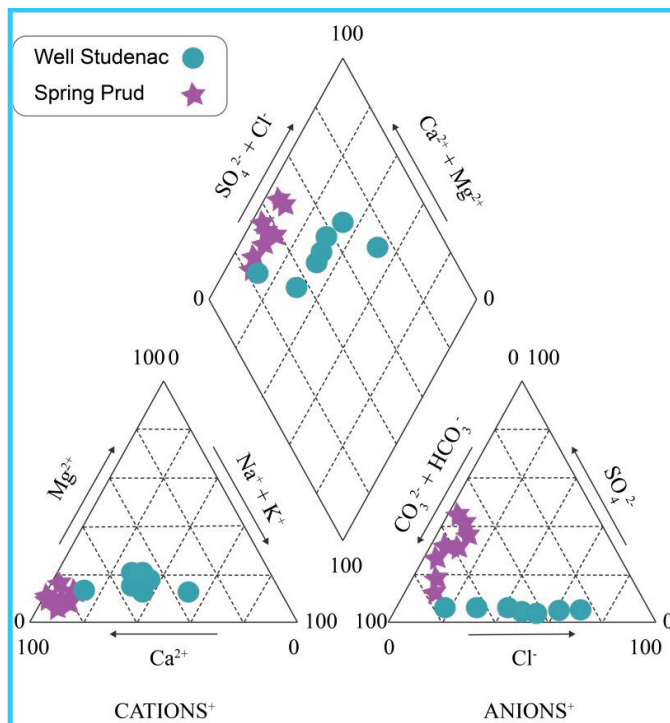


Figure 2. Piper diagrams of sampled waters at Prud (data collected from different hydrologic conditions for the period of 2013-2014) and Studenac (Blatsko polje, data collected for the purpose of CC-WaterS project from different hydrologic conditions for the period from 2003-2010)

Groundwater temperature indicates the mean annual temperature of the recharge area. Temperature values at observed locations are changing during the year according to change of seasons and changes in air temperature (Figure 3). Such changes are common, but the differences between the minimum and maximum values and the speed of their changes indicate hydro-geological characteristics of their aquifer. Temperature on Studenac is expectedly higher than on the spring Prud, because it's geographical position which is characterized by warmer climate.



Electroconductivity (EC) values at wells and springs in coastal area depend largely on sea water intrusions which are connected with hydrologic conditions in the aquifer. Lowering of the groundwater level allows intrusion of sea water into the aquifer. Salinized water causes degradation of water quality. This is one of the most common and biggest problems in coastal aquifers. As the electroconductivity of sea water is much higher than fresh water, it is a very good indicator of salinization of spring and well waters (in the coastal area). Electroconductivity values may also reflect the hydrodynamic properties of aquifer. Studenac has quite higher values of electroconductivity than spring Prud (Figure 3). Reasons are several risk factors that well Studenac is facing: lower hydraulic gradients, small catchment, location closer to the sea, bottom of the well at 0,24 m a.s.l., aquifer composition of karstified rocks.

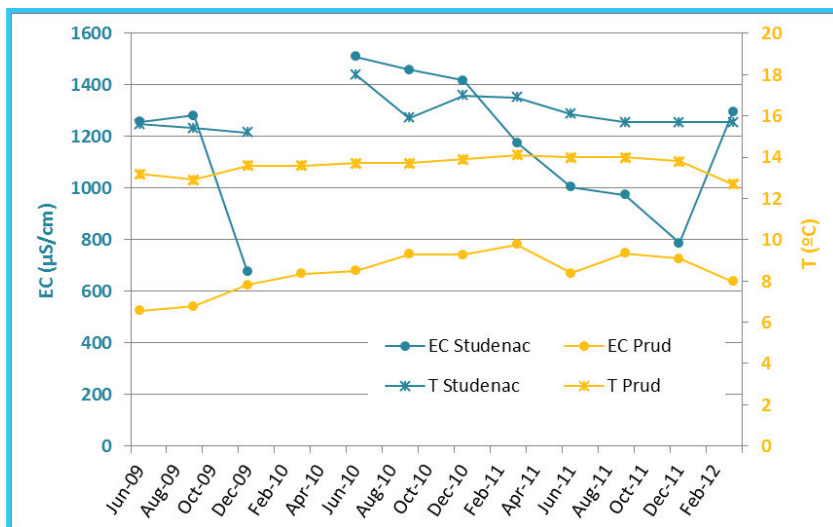


Figure 3. EC and T distributions at Prud and Studenac (Blatsko polje)

Nitrates and chlorides have the biggest impact on the groundwater quality in the study area. Based on available data, long-term trends of these indicators have been done (Figure 4,5). Values of chloride and nitrate are quite dispersed at both sites, but long-term trend is decreasing or shows stagnant trends. Chlorides have negative trends on spring Prud and nitrates on Blatsko polje. Negative trends have positive impact on water quality. High dispersion indicates highly karstified carbonates and well-developed network of connected fractures and channels in the aquifer. This allows quick response of hydro-geological system on precipitation, and thus great variation of hydro-chemical parameters.

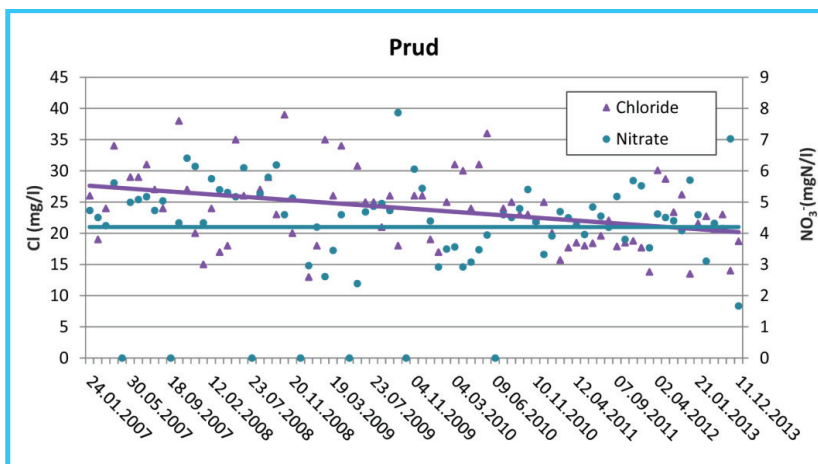


Figure 4. Chloride and nitrate concentrations distribution and trends at Prud spring

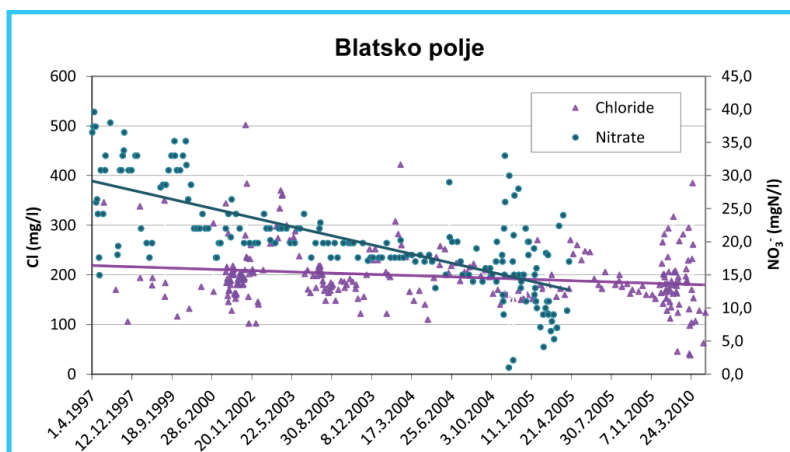


Figure 5. Chloride and nitrate concentrations distribution and trends at Blatsko polje

3. Land Use on Test Areas

Corine land cover (CLC) which presents land use on test areas is a digital database on types of land cover/use [5]. Actual land use was present for the year 2006 for both test areas. Prud spring catchment area is a transboundary aquifer. Although spring Prud is located in Croatia, most of its catchment belongs to Bosnia and Herzegovina. CLC 2012 for Croatia is already done and available on the web site of the Croatian environmental agency, while for B&H CLC 2012 is still not available. Thus, as majority part of the catchment area belongs to B&H, for both test areas are presented CLC maps for 2006 (Figure 6).

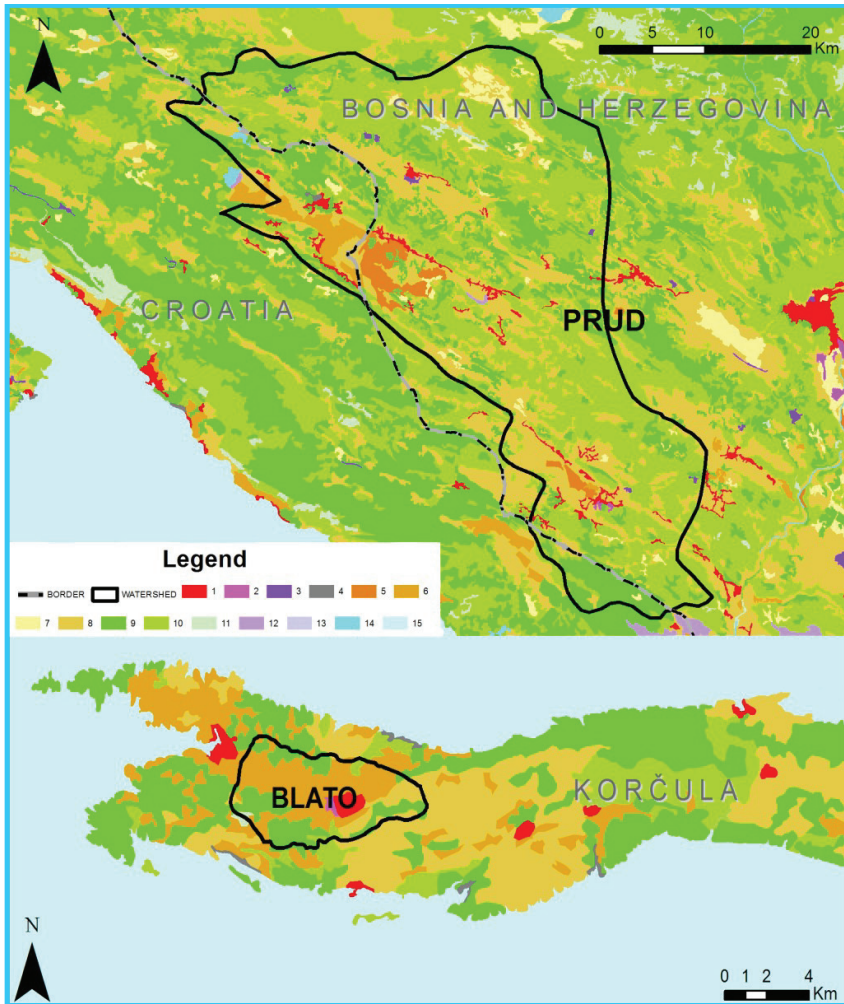


Figure 6. Corine land cover for the spring Prud catchment area and Blatsko polje for year 2006 [5]. 1-Urban fabric; 2-Industrial, commercial and transport units; 3- Mine, dump and construction sites; 4- Artificial, non-agricultural vegetated areas; 5-Arable land; 6-Permanent crop; 7-Pastures; 8- Heterogeneous agricultural areas; 9-Forests; 10- Scrub and/or herbaceous vegetation associations; 11- Open spaces with little or no vegetation; 12-Inland wetlands; 13-Maritime wetlands, 14-Inland Waters; Marine waters.

Land cover categories expressed as a percentage show that the largest percentage of agricultural land are in Blatsko polje area (Figure 7) which occupy more than half of its catchment. Catchment area of spring Prud covers a somewhat higher percentage of agricultural land on the Croatian part of the catchment, but considering that the Bosnian



part of the catchment is far greater, expressed as surface area, part of the agricultural land in Bosnia and Herzegovina belonging to the Prud catchment is several times greater than the surface of whole Prud catchment on Croatian side.

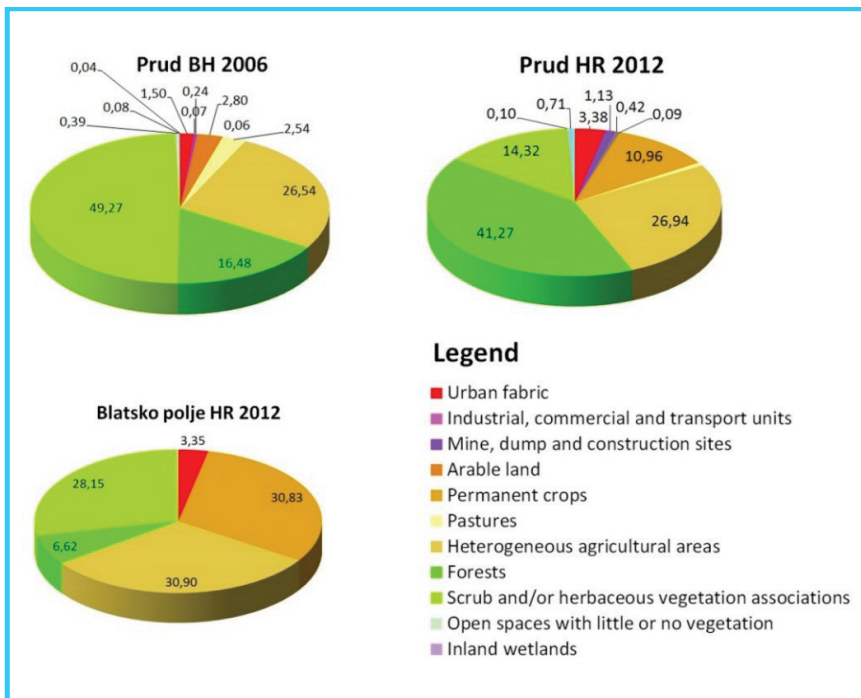


Figure 7. Percentage of land use area in B&H part of catchment Prud (CLC 2006) [5], Croatian part of catchment Prud and Blatsko polje catchment (CLC 2012) [6]

Comparing CLC for different years in order to evaluate trends in land use it was observed following:

- ◆ Part of Prud spring catchment area in Bosnia and Herzegovina
 - there is no change in land use comparing CLC 2000 and 2006 (Table 1)
- ◆ Part of Prud spring catchment area in Croatia
 - there is just minor changes in land use - areas of Pastures and Scrub and/or herbaceous vegetation associations are reduced while, Mine, dump and construction sites and Heterogeneous agricultural areas are slightly increased (Table 2)
- ◆ Blatsko polje catchment
 - there are significant changes, but in a way that there has been a change in use of agricultural areas – areas of Permanent crops are reduced approximately as much as Heterogeneous



agricultural areas are increased, but there is no significant change between agricultural and natural areas (Table 3)

Table 1. Comparison in land use categories for different years of CLC for the Prud catchment test area on Bosnian-Herzegovinian side [5]

Prud B&H CLC	2006	2000
Land use categories	Area (%)	Area (%)
Urban fabric	1,50	1,50
Industrial, commercial and transport units	0,07	0,07
Mine, dump and construction sites	0,24	0,24
Arable land	2,80	2,80
Permanent crops	0,06	0,06
Pastures	2,54	2,54
Heterogeneous agricultural areas	26,54	26,54
Forests	16,48	16,48
Scrub and/or herbaceous vegetation	49,27	49,27
Open spaces with little or no vegetation	0,39	0,39
Inland wetlands	0,08	0,08
Inland waters	0,04	0,04



Table 2. Comparison in land use categories for different years of CLC for the Prud catchment test area on Croatian side [5,8]

Prud Croatia CLC	2012	2006	2000
Landuse categories	Area (%)	Area (%)	Area (%)
Urban fabric	3,38	3,38	3,25
Mine, dump and construction	1,13	1,13	0,00
Artificial, non-agricultural	0,42	0,42	0,42
Arable land	0,09	0,09	0,00
Permanent crops	10,96	10,96	10,87
Pastures	0,69	0,69	1,07
Heterogeneous agricultural areas	26,94	26,94	22,77
Forests	41,27	41,27	40,39
Scrub and/or herbaceous	14,32	14,32	20,52
Open spaces with little or no	0,10	0,10	0,00
Inland waters	0,71	0,71	0,71

Table 3. Comparison in land use categories for different years of CLC for the Blatsko polje test area [5,8]

Blatsko polje CLC	2012	2006	2000
Landuse categories	Area (%)	Area (%)	Area (%)
Urban fabric	3,35	4,06	4,06
Permanent crops	30,83	50,12	50,12
Heterogeneous agricultural areas	30,90	11,59	11,59
Forests	6,62	29,76	29,76
Scrub and/or herbaceous	28,15	2,92	2,92
Open spaces with little or no	0,16	0,50	0,50



4. Impact of Land Use on Groundwater Quality

Land use is an important driver determining water quality. The most widespread land uses on test areas in Southern Dalmatia are agriculture and urban areas. Therefore, the most important driving forces are the use of fertilizers and nonexistent or ineffective sewage systems. The pressures they cause are release of microbiological pollutants, nitrogen and phosphorus compounds of nutrients, diffuse nitrogen contribution (runoff and percolation). Negative effect from agricultural areas and sewage systems is usually monitored through nitrate content.

Evaluated trends of changes in Corine land cover shows that there is no significant change in land use categories, which could have negative impact on water quality, over the years. Moreover, after county spatial plans in land use in the future significant negative changes on groundwater quality on Croatian part of Prud catchment and Blatsko polje are not expected. On the other side, there are number of measures which are in County strategic plan [9] which should have positive impact on groundwater quality. These are:

- ◆ development of energy which would promote clean technologies,
- ◆ renewable energy, entrepreneurial development
- ◆ environmental protection
- ◆ reduced use of fertilizers
- ◆ building of sewer systems in areas where they don't exist and making devices for wastewater treatment
- ◆ restoration of existing and construction of regional waste disposal sites
- ◆ making of sanitary protection zones for the spring Prud" which should enable better protection of groundwater from agricultural areas located in the Prud catchment

Comparing the water from Blatsko polje (Studenac) and Prud, it is obvious that Studenac has much higher values of nitrates and chlorides. It is previously discussed that high chloride values is a consequence of sea water intrusion into the aquifer. This is particularly expressed in the summer season, when the water needs are largest, and the recharge of aquifers is negligible. When hydrological conditions are extremely unfavorable, there is significant salinity increase of the pumped water. The sea water intrusion happen only when the pumping rates are close to maximum and a dry season (much below average) has lasted for at least one hydrological year. In such years surface flow does not occur at all, so there is no surface water to retain before the tunnel entrance. In the seasons when surface flow occurs, the underground will usually be saturated enough to prevent so that sea



water intrusions during the summer season. At this moment there are no problems associated with seawater intrusion at the spring Prud, but recent activity in Bosnia and Herzegovina have shown that this is a very sensitive area. Large construction project of six hydropower plants upstream from this area, caused drop of groundwater level, which was reduced its water pressure and allowed seawater to flow further inland. Consequently, spring downstream from spring Prud has been salinized. Until then, this spring was capped for water supply of nearby city Metković, and as a result of spring salinization, city Metković needs to connect to another water supply system - spring Prud. In addition to this, spring Prud is located on the edge of the Neretva river valley, which was also salinized due to intensive agricultural production. Water used to irrigate agricultural land is also saline. Thus, this situation is a major threat to this valuable agricultural area.

Nitrate concentrations in groundwater of Blatsko polje catchment are low during the dry season, but in the wet season the contribution of unused NO_3^- from the soil zone (unsaturated zone) increases the concentration of NO_3^- in groundwater (from 35 to 43 mg/l near the maximal permitted concentration, which is 50 mg/l in Croatia). That process was emphasized until the spring of 2004, when cabbage production was removed from the close vicinity of pumping sites Studenac and Gugić. Because of movement of cabbage production to peripheral parts of the polje and significant reduction of nitrate concentration at the extraction sites occurred, nitrate concentrations in Studenac and other wells showed decreasing trend [7].

The surface of polje is drained by a network of channels and is used for extensive agricultural production. Blatsko polje had been flooded almost every year till the year of 1912 when the drainage tunnel was dug. Flooding conditions were very unfavorable for agricultural production. Also, while the valley was flooded, there were many diseases (even malaria). Controlled closing and opening of the tunnel entrance was an option for improving the hydrological conditions in the island's karst underground during recent investigations. The purpose of that drainage control was to diminish or avoid sea water intrusion into the karst aquifer by increasing the infiltration, but it was concluded that this is pointless, because the increase of salinity occurs only after long-lasting dry periods, and in such years surface flow does not occur at all, so there is no surface water to retain before the tunnel entrance. In the seasons when surface flow occurs, the underground will usually be saturated enough not to allow any sea water intrusions during the summer season.



5. Conclusions

Groundwater quality, as well as the management of water for water supply purposes, significantly affects the quality of life in a given area. Groundwater at island and coastal parts is often faced with the problem of seawater intrusion, especially in summer when the need for water is largest, and recharges of aquifers are minor. In addition, there are numerous ways of land use that could have negative effect on groundwater quality, of which, on these catchment areas, the most important influence has agricultural activity. Considering also very weak protection measures and insufficient awareness of the local population on the need to preserve water quality, it can be concluded that these natural resources are at risk of further deterioration. Preserving groundwater and preventing deterioration of its quality and quantity requires careful management of the water resources.

As the two test areas have intensive agricultural production, and by the fact that they are characterized by karst nature which is very sensitive to pollution, it would be highly preferable to increase organic agriculture in the future that will ensure the best preservation of underground water. This is important not only for the people, but for the entire ecosystem. It is also of great importance to organize public education at the local level to raise people awareness for the need of preserving the water quality and quantity and the ways in which this can be achieved, which creates a basis for good health and quality of life.

The sea water intrusion problems on Blatsko polje test area can be solved by decreasing pumping rate, because this leads to groundwater levels recover and its pressure improves the underground dynamic relation of fresh and seawater, partially according to the Ghyben-Herzberg law. Since such events are quite rare the problem is not too extent, but according to predicted climate changes [3,10] and their influence on water balance, pumping at present rates at Blatsko polje wells will lead to more expressed and more usual saline intrusions of this karst aquifer. The situation will, in the periods after that, only get worst. That will probably cause the necessity of decreasing the pumping rates, especially during the summer dry periods, when water demand is on its yearly peak because of tourism and agriculture. This water, on the other hand, does not influence any protected water dependent ecosystem [6].

Due to the negative predictions of climate change [3,10] it is necessary to establish continuous monitoring of the karst system behavior – by the monitoring of groundwater levels, their quantity (especially chloride ion concentrations and – to make the monitoring

efficient, fast and cheap – electrical conductivity). Also, there is a need for further exploration of the karst aquifer by pumping tests with further assessments of the present state and future risk.

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CONTRACTUAL FRAMEWORK FOR CROSS-BORDER DRINKING WATER DELIVERY

Primož Banovec (primoz.banovec@fgg.uni-lj.si),

Mohor Gartner (mohor.gartner@fgg.uni-lj.si),

University of Ljubljana, Faculty of Civil and Geodetic Engineering, Ljubljana, Slovenia

Abstract

In the framework of EU IPA ADRIATIC CBC 2007-2013 project DRINKADRIA among other deliverables also detailed analysis of cross-border water delivery contracts was performed. Within the project, cross-border water delivery and contracts primarily addresses water delivery between different countries, but it is similar for cross-regional water delivery and in some cases also for the water delivery between municipalities.

One of the project hypothesis was that the limiting factor for successful development of cross-border (CB) water supply are also weakly defined contractual relationships. Weak contractual definitions often lead towards the different understanding of contractual relationship. As a consequence tensions between the partners might occur, resulting finally in the termination of the contract, which has adverse effects on water supply – that should be based upon the mutual benefits defined in long term.

Analysing CB water delivery contracts in eight countries involved in the project it was recognized, that the existing cross-border contracts are under-defined, as they only address very basic contractual elements (contractual parties, price, and annual amount of water delivered), while other potential contractual processes are usually omitted.

In the technical paper the results of the analysis of the existing CB water delivery contracts in addressed region is presented, while in the second part processes that should be defined by the contract with the reference to comparable cross-border water delivery from other countries. The results are quite disappointing, recognizing that only a very limited set of scenarios defining contractual parties is actually



addressed by the existing contracts. The article is therefore recognizing the critical points of current relationships and providing a way forward – how to address them.

Addressed issues and constraints are mainly focused on the cross-border (cross-regional) drinking water supply, but could be useful as a guidance for the negotiation and contracting process in other cases, e.g., water delivery between local communities.

Keywords: cross-border, water supply, contractual framework, contract comparison

1. Introduction

Several components define quality and reliability of the cross-border (CB) water supply. To begin with the national legislation of each country involved in the CB water supply. Different levels of national legislation are addressing the drinking water supply. At the most precise level is applicable technical standards in the field of water supply. They are usually mirroring standards defined by international standardization body (i.e. EN), but transposed to national legislation (SIST-Slovenia, DIN-Germany). Starting from this level it is quite clear that the case of CB water delivery it is important that both contractual partners identify common standards, but also differences aiming at effective harmonization of the legislation that will be governing the CB water supply. A transparent mirroring process is therefore necessary to compare and align the applicable standards.

In this process both countries entering the partnership can also learn one from another and as a consequence improve their national legislation. In order to support this process an interactive web spreadsheet was developed in the framework of the DRINKADRIA project, which could be used for the comparison of the legislation and technical standards in the eight countries involved in this EU project (Figure 1). Harmonization or at least comparability of technical standards governing the CB water delivery process is one of the preconditions for the long-term successful cooperation in the CB water delivery.



ABOUT LEGISLATION (OVERVIEW) **LEGISLATION (COMPARISON)** TECHNICAL STANDARDS (COMPARISON) TECHNICAL STANDARDS (COMMON)

Legislation comparison: SVN vs HRV

Select to compare:

HRV, SVN ▾ by Level Area of Legislation

For details: click into any cell of the table.

Level	Country	HRV	SVN
EU		<ul style="list-style-type: none"> •The Drinking Water Directive •Water Framework Directive •Measuring instruments Directive 	<ul style="list-style-type: none"> •The Drinking Water Directive •Water Framework Directive •Measuring instruments Directive
National		<ul style="list-style-type: none"> •Regulations of metrology requirements for water meters for cold water •Waters Act •Act of financing water management •The Water Management Strategy •Water for human consumption Act •Chemicals Act •Regulations on parameters of conformity and methods of analysis of water for human consumption •Regulations of sanitary - technical, hygiene and other condition which have to obey water supply facilities 	<ul style="list-style-type: none"> •Rules on measuring instruments •Waters Act •Decree on drinking water supply •Action plan •Decree of tariff system for public service on the environmental field •Rules on drinking water
Municipal			•Order on drinking water supply
Utility		<ul style="list-style-type: none"> •General and technical conditions of delivery of water services •Decision about the price of water services 	•Rules on technical performance, operation and management of facilities and instruments on public water supply system

Level	Country	Area of Legislation	Document Name	NO	Authorities	PDF(s)	URL	Comment
Municipal	SVN	Supply Service Management	Order on drinking water supply	42/14	Municipality of Nova Gorica		link	Defines area of public water supply, conditions, approach of water supply service, requirements, standard of equipment and activities of public utility.

Figure 1. Interactive spreadsheet enabling comparison of national legislations in the field of water (example showing the comparison between Slovenia and Croatia). Available on: <http://drinkadria.fgg.uni-lj.si/water-supply/operational-standards/> [1].

Harmonized legislation and technical standards by themselves are not enough for the maintenance of the contractual relationship; these documents have to be observed in the dynamic partner cooperation perspective. The entire arch defined by status analysis, contractual framework and the contract itself should be considered (Figure 2).



Figure 2. Process for the development of the cross-border water delivery contract.

At this stage, it can be recognized that the renewal of current CB water delivery contracts is much the same as development of new CB



water delivery contracts as they are in large scale under-defined as demonstrated later.

Within the Process of development of CB water delivery contract partners first mutually exchange a set of information on water supply systems providing high level of transparency in the relationship. Information on (1) legislation, (2) technical standards, (3) water resources availability and vulnerability, (4) current water demand, (5) status of the water supply system (maintenance level, water losses, etc.), (6) action plans and trends, (7) forecasted water resources availability and forecasted water demand should be exchanged. In a case that a new water supply connection is anticipated draft designs, prefeasibility and feasibility studies are necessary. Special attention should be given to analysis of related costs (construction, O&M), and comparison of different optional measures that are all aiming at the objective status – safe and efficient water supply in both involved countries.

Evaluation of present circumstances has to be efficiently interlaced with the negotiation framework, where partners meet, discuss and harmonize their positions and terms under which they are willing to connect two water supply systems. The second step is closely interlaced with the third stage, i.e., draft contract that both parties intended to adopt, since adequately defined contractual relationships are essential prerequisite for the long term effective and efficient CB water supply.

1.1. Analysis of Comparable Contractual Relationships in the Field of Cross-border Water Supply

Analysis of existing contractual relations is providing a basis for their comparison and later improvement. In the comparison, also bulk (wholesale) water supply contracts are included, as well, they are in many aspects comparable to cross-border drinking water delivery contracts.

In the DRINKADRIA project, all the existing CB water supply contracts from the area were collected. As their extent (and contents) is quite limited (some of them only a couple of pages), it was clear that analysis of more elaborated contract is necessary. Contracts from USA [2]–[4], Great Britain [5], South Africa [6], and Australia [7] (Table 1) were analysed.



Table 1. Examples of analysed negotiation frameworks and bulk water supply contracts

Country	Document (year)	Document type	Area	link
USA	<i>Issues to consider in wholesale water supply agreement negotiations (2011)</i>	Contractual framework	Kentucky	http://smallutilities.ky.gov/Portals/0/Wholesale_Contract_Negotiations.pdf
	<i>Water supply agreement (2008)</i>	Bulk water supply contract	From Pennsylvania to Borough of Sharpville	http://tlally.com/Borough/Water/Bulk%20Water%20Agreement.pdf
	<i>Sample Bulk Water Purchase Agreement (2005)</i>	Draft bulk water supply contract	Iowa	http://www.cvcia.org/content/projects/7_water.and.wastewater.collaboration/alternatives.legal.arrangements/sample.bulk.water.purchase.agreement.pdf
Great Britain	<i>Negotiation bulk supplies - a framework (2013)</i>	Negotiation framework	-	http://web.archive.nationalarchives.gov.uk/20150624091829/http://www.ofwat.gov.uk/competition/review/pap_pos201308bulksupply.pdf
South Africa	<i>Model Bulk Water Supply Contract (2006)</i>	Draft bulk water supply contract	-	http://ppp.worldbank.org/public-private-partnership/library/model-bulk-water-supply-contract
Australia	<i>Bulk Water Supply Agreement (2012)</i>	Bulk water supply contract	City of Melbourne v Barwon	http://www.melbournwater.com.au/about/customersandprices/Documents/Bulk_Water_Agreement_-_Barwon_Water.pdf

The listed contracts and negotiation frameworks were decomposed on common paragraphs and contractual definitions and later compared with existing CB contracts in the Adriatic macro region.



2. Comparison and Analysis of Existing Cross-border Contracts in the Adriatic Macro Region

In the frame of DRINKADRIA project, 26 CB water supply systems (WSS) are identified, while project partners provided contracts for only 14 CB WSS. For remaining 12 WSS contracts could not be obtained [8]. For some CB WSS delivery contracts do not even exist, usually when the supplied water quantity is extremely low and the supply obligations are defined in other bilateral agreements. In some cases, water utilities consider that CB water delivery contracts are internal documents and not considered public. The issue of open access to public information was raised several times during the communication process. The partners have realized that the information related to public-to-public water transfer contracts should be considered public. Regardless to that, it could be realized that in some countries open access to public information is not fully implemented yet.

Table 2 shows the comparison of analysed CB water delivery contracts by the key chapters and sub-chapters. With the interpretation of the table reader should consider, that specific simplifications were necessary for the comparison. That is why specific chapters and sub-chapters should only be evaluated on the basis of original contract wording. Beside that one should also pay attention to the versioning of the contracts, as some of them changed during the project.

Table 2 is including only the components/chapters that are included in the analysed contracts from Adriatic macro-region. One can easily identify that the addressed paragraphs are not comprehensive. Nevertheless, the cross-comparison of analysed contracts demonstrates deficiencies, as there are more white fields in the table than green ones.

From the analysis performed and presented in the Table 2, we can identify some important areas that are under-regulated:

- ◆ Contractual history;
- ◆ Rules regarding contract extension;
- ◆ Clear definition of water supply types;
- ◆ Declared availability of the water resources;
- ◆ Rules applicable in the case of limited service;
- ◆ Regulations addressing pressure management on the delivery location;
- ◆ Water supply system operating standards – maintenance and repair procedures, unexpected failures, leakage, water scarcity, ownership, delivery location management;
- ◆ Maintenance, testing and calibration of water meters;
- ◆ Rules in case of water meter failure;



- ◆ Price change (revalorization) management;
- ◆ Interest on late payments;
- ◆ Allocation of future maintenance and investment costs;
- ◆ Other protocols (i.e. peak discharge rates, daily volume of water);
- ◆ Bank guarantees;
- ◆ Contract breach rules;
- ◆ Vis major scenarios;
- ◆ Communication and coordination rules, nominated representatives and contact information;
- ◆ Attachments to the contract.

Only few contracts are addressing financing, planning, and construction of infrastructure (new CB connections), necessary for the cross-border water supply. This content is by itself not essential, as it can be determined as separate contract, usually based upon the standard construction contractual framework (i.e. FIDIC [9]).

At this point, it is also necessary to identify the role of different appendices to the water supply contracts. The appendices are important as they declare in more detailed way several protocols and definitions. In reality appendices to the analysed contracts are quite limited, existing for example for the water quality standards (usually corresponding to the standards of EU Drinking Water directive). This is an easy way out as the water quality standards are well defined within EU.

The analysed contracts do not have many appendices. Nevertheless we would recommend forms for water meter reading, forms for invoicing, forms for water meter testing and calibration, designs of delivery location and other. Specific attention should be given to water safety plans defined by a set of standards [10]–[16].



Table 2. Examples of analysed negotiation frameworks and bulk water supply contracts

LEGEND:

Chapter / subchapter included in the contract

Chapter / subchapter **not** included in the contract

			CB water supply contract														
			Cross-border						Cross-regional								
			BIH-HRV	HRV-SLO	SLO-HRV	ITA-SLO	SLO-ITA	ITA-SLO	ITA	ITA	ITA	ITA	ITA	ITA	SRB	SRB	SRB
Chapters	Sub-chapter	No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Introduction	Partners		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Objectives													x			
	Contractual history			x													
Obligations	Supplier														x		
	Common								x								
Term of the contract	Commencement		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Duration			x	x	x	x	x	x		x	x	x	x			
	Extensions							x	x		x		x				
Delivery type	Temporary							x									
Water source	Nominal availability			x				x									
Water supply standards	Water quantity and upgrade of delivery point			x	x		x	x	x		x	x	x	x	x	x	x
	Limited supply (drought / high demand)			x			x						x				x
	Water quality		x	x	x		x	x			x	x		x			
	Flow rate		x	x	x	x	x	x		x	x	x	x	x	x	x	x
	Water pressure					x		x		x							
System operating standards	Normal maintenance and repairs - interruptions in supply			x		x	x	x							x		
	Unexpected failures and leaks				x	x	x										
	Drought			x													
	Ownership and responsibilities of delivery point					x					x	x		x			
Water meter(s)	General			x	x	x	x	x		x		x	x	x			
	Maintenance														x		



LEGEND:

x	Chapter / subchapter included in the contract
	Chapter / subchapter not included in the contract

			CB water supply contract													
			Cross-border						Cross-regional							
			BIH-HRV	HRV-SLO	SLO-HRV	ITA-SLO	SLO-ITA	ITA-SLO	ITA	ITA	ITA	ITA	ITA	SRB	SRB	SRB
Chapters	Sub-chapter	N o	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Testing / calibration						x	x						x		
	Malfunction					x	x	x						x		
	Meter reading / measurement			x	x	x	x	x		x				x		
	Invoicing (date)							x								
	Water price per m ³		x	x	x	x	x	x		x	x	x	x	x	x	x
	Revalorization of price						x								x	
	Deadline to pay the invoice		x	x	x	x	x			x	x	x		x	x	
	Interest on late payments				x			x			x			x		
	Currency exchange rate				x											
	Costs of customs declaration				x											
	Recipient query for incorrect invoice							x								
	Infrastructure investments / maintenance cost						x	x								
	Costs	Other costs										x	x	x		
	Protocols	Common defined protocols													x	
	Risk management	Bank guarantee						x							x	
	Breach of contract	Minor breach									x	x				
		Material breach									x	x		x		
	Vis major	Supplier free of duties and obligations		x				x			x			x		
		Obligatory written notice to other party			x			x							x	
		Remedy ASAP						x							x	
	Damage caused between parties systems	Parties acknowledge that it could be possible						x								
	Termination	Reasons		x	x	x	x	x	x		x		x			
		Termination process						x	x							
	Disputes resolution	Negotiation		x	x											x
		Arbitration						x	x		x	x				x



LEGEND:

x	Chapter / subchapter included in the contract
	Chapter / subchapter not included in the contract

			CB water supply contract														
			Cross-border						Cross-regional								
			BIH-HRV	HRV-SLO	SLO-HRV	ITA-SLO	SLO-ITA	ITA-SLO	ITA	ITA	ITA	ITA	ITA	ITA	SRB	SRB	SRB
Chapters	Sub-chapter	No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
	Court of Jurisdiction		x	x	x					x				x			
Communication and coordination							x		x								
Principal and Operating Representatives	Contact information and appointment of representatives							x									
Possible amendment/annex												x		x			
In accordance with customs and countries regulations				x		x											
Design and construction agreement	Economic and financial management		x						x	x					x	x	
	(Joint) design and construction								x	x					x	x	

3. Identified Key Deficiencies in Relation to international Reference Negotiation Framework and Bulk Water Supply Network

Deficiencies identified in the previous chapter can lead to misunderstanding and conflicts in the implementation of the contract between contractual partners. Limited set of contractually defined scenarios, which can occur in the lifetime of specific project, is the main reason for the different interpretations of the scenarios. There is obviously consequence to that – the aim is to define during the contractual negotiation process enough scenarios and roles of both parties that this process would actually cover for all, or at least all likely scenarios that can occur in the contract lifetime.

Comparing the existing cross-border contracts in the Adriatic region (Table 2) with the examples of analysed negotiation frameworks and bulk water supply contracts (Table 1) we can identify additional items, which are omitted from all listed CB WSS contract applied in the Adriatic macro region.

Listed are key identified concepts missing in the existing contracts:

- ◆ Definitions of terms for common definition of addressed phenomena;



- ◆ Definitions of vis major. This is especially addressing firewater demand on supply, as well as demand side when it is usually difficult to (pressure, discharge) in WSS;
- ◆ Possible temporary request for the exceptional increase of supplied water;
- ◆ Paragraphs with the defined access to information on the water supply system of opposite collaborate (technical, but also economic data);
- ◆ Analysis of future scenarios – forecasting the water resource availability, future water demand, forecasted water cost and prices etc.;
- ◆ Infrastructure insurance and liabilities. Which part of the WSS is insured by which partner and to which level;
- ◆ Defined scenarios for the contract termination (vis major, long term suspension of water delivery – or water demand);
- ◆ Requested fulfilment of contractual obligations (especially water delivery and consumption) during active disputes between partners;
- ◆ Coverage of costs related to dispute solution;
- ◆ Rules regarding the information provided to the contractual partner;
- ◆ Penalties defined for different scenarios of contractual obligations breach (i.e. unjustified water delivery suspension);
- ◆ Common commitment of partners that they will engage in finding solutions for quality and successful cooperation;
- ◆ Rules on water delivery/demand above the defined thresholds. Option is to provide extra charge on the authorized water consumption above the contractually defined range;
- ◆ Payment for water losses;
- ◆ Allowed change of pressure (range and dynamics);
- ◆ Improved dispute resolution mechanisms (engagement of negotiation procedure, mediations, and arbiters before the judicial process);
- ◆ Improved mechanisms for the water price definition and changes.

This is not a closed list of items that should be defined by the CB water delivery contract, but only necessary technical definitions that should be incorporated in the contract. Several important juridical items are missing like preamble to the contract and of course well defined partners with necessary authorizations. Existing contracts are signed directly by water utilities. It is recommended to include also as co-signers all relevant institutions that are involved in the implementation of contractual agreement like local communicates, state water agencies (permitting procedure) and perhaps representatives of bilateral commissions for water management. It is quite clear that a final



redaction of the contract should be done by qualified lawyer with experience in the addressed domain.

4. Conclusion

Comparison and analysis of the existing water delivery contracts in the Adriatic region is providing a result, which could be matter of concern. The contracts analysed are short and open to different interpretation of, possible scenarios that could occur during the years of operation of the CB WSS. This could eventually lead to conflicts and in worst-case scenario also to the termination of the cross-border water delivery. Chain of events would afterwards lead to increased risks and affected quality, costs and reliability of water supply for the end-users.

It is therefore necessary to develop a suitable negotiation framework which would incorporate the experiences of existing contractual negotiation processes, leading towards well elaborated contracts. This standard CB drinking water delivery negotiation framework could be used as an outline for the development of cross-border water supply contract. Such outline, under development within the DRINKADRIA project, could be considered as harmonized technical backbone which still requires adequate final editing from the legal experts, but the core set of scenarios is nevertheless defined and significantly contributes to the reliable CB water supply matching the agreed standards.

An essential part of the negotiation process and contract is a well-defined pricing mechanism, which should be developed on the basis of actual costs of cross-border water supply. This mechanism is being developed within the EU IPA DRINKADRIA project as well, but is not in the focus of this article.

Another component which is not in the centre of attention of this article are technical standards defined (mandatory, recommended) and actually implemented for each water supply system. Water utilities achieving high performance standards are usually adequate partners for cross-border water supply, which could be demonstrated with their performance indicators.

Described analysis and comparison of the contract for cross-border water delivery is focused towards the delivery across the country borders, hoping that key stakeholders will use the negotiation framework and draft contracts available on the web shared platform drinkadria.fgg.uni-lj.si. This could turn currently negative trend in the field of water supply systems, where the existing connections are terminated to development of new connections providing more reliable and cost-efficient water supply.



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Acknowledgements

This work is elaborated through a project co-funded by the European Union, Instrument for Pre-Accession Assistance, IPA Adriatic CBC Programme 2007-2013 (DRINKADRIA project, 1o str./0004, further info: www.drinkadria.eu)



IMPLEMENTING THE REMOTE CONTROL WATER METERS AT ISTARSKI VODOVOD BUZET, WATER UTILITY OF ISTRIA, FOR THE PURPOSE OF LEAKAGE REDUCTION

Marija Brajković (marija.brajkovic@ivb.hr),

Melita Čohilj (melita.cohilj@ivb.hr),

Alen Sprčić (alen.sprcic@ivb.hr),

Vanja Totman (vanja.totman@ivb.hr),

Water utility of Istria, Buzet, Croatia

Kristjan Gašperin (sisteh@kolektor.com),

Kolektor Sisteh Ltd., Ljubljana, Slovenia

Abstract

The paper presents the implementation of the DRINKADRIA Project within the Istarski vodovod Buzet, Istrian Water Utility, which officially commenced on the 1st November, 2013. The Project's duration time is 35 months. DRINK ADRIA is a strategic project the goal of which is to develop strategies and procedures for safe cross-border water supply within the Adriatic Region. It has consequently been co-financed by EU funds within the IPA Adriatic Cross Border Cooperation (CBC) 2007 – 2013 frame. As a Partner in the project, Istarski vodovod Buzet, Istrian Water Utility has implemented the water meters system for remote reading, in order to decrease water losses. The implementation of remote monitoring required development of the additional water losses monitoring procedure. According to the new procedure, Operational Instruction for Early Breakages/Leakages Detection within the Water Supply System has been introduced. Furthermore, staff has been given additional responsibilities.



Keywords: strategic project, remote reading system, Operations Decision, procedure, responsible staff

1. Introduction

Water Utility of Istria, Buzet (WUI) provides drinking water supply service in the areas of 21 municipalities (Bale, Brtonigla, Funtana, Gračišće, Grožnjan, Kanfanar, Karojba, Kaštelir - Labinci, Lanišće, Lupoglav, Motovun, Oprtalj, Sv.Lovreč, Sv.Petar u Šumi, Tar-Vabriga, Tinjan, Višnjan, Vižinada, Vrsar, Žminj and Pićan) and 7 Cities (Buje, Buzet, Pazin, Poreč, Rovinj, Novigrad and Umag), which makes over 60% of the area within the County of Istria. WUI distributes water to 98.000 inhabitants and more than 2 million tourists every year. The biggest water requirement is usual in August when WUI have to supply water to the local inhabitants and around 200.000 visitors on a daily basis [1, 2]

The inhabitants, industries and institutions (eg. hospitals, schools, retirement homes, kindergartens, cultural and sports centres, units of local government and so forth) the tourists, Water Utility of Rižana, Koper (cross border water distribution) and the Water Utility Pula are the target groups to which water is being distributed.

Thanks to the DRINKADRIA Project, the WUI has implemented the Pilot Project - "Control Water Meters for More Water". Project consist of the control water meters installation, remote sensing devices as well as the application for consumption control. The new control system Automatic Meter Reading (AMR control 2.0) is connected to the existing Supervisory Control And Data Acquisition (SCADA).

The realization of the Project ensures the WUI to lower water losses, energy consumption and the existing operational expenses. Furthermore, water supply will become safer and the biological minimum in water sources that are in the Water Supply System (WSS) are expected to increase due to lower demand for water abstraction.

Three WUI employees have been working on the Project along with the support of the Team for the Implementation of Remote Reading System. The experience gained by the WUI during this Project is absolutely invaluable as it will bring benefits for work in other projects.

The aim of the project "Control Water Meters for More Water", is to identify leakage and pipe breaks within the WUI water supply system, which will ultimately result in decrease of the water losses. The activities which have been identified in this project include the analysis of the present WSS on the consumption control locations placed in



District Metered Areas (DMA) - the control water meters, the activities connected to the tendering procedures, equipment commissioning, operation of the AMR control 2.0., employees' training and finally, all the activities connected to the project results.

Table 1. District Metered Areas (DMA)

Operational Units (OU)	DMA
Buje	20
Buzet	38
Pazin	23
Poreč	23
Rovinj	25
Overall:	129

2. Pilot Project Description and Information on Water Supply

The supply point into each DMA is monitored by one or more control water meters, out of which 118 are mechanic ones and others electromagnetic, connected to the SCADA. Within the DMA there are additional control water meters, mainly mechanic ones (Figure 1). In total, there are 543 water meters situated on 408 locations.

All the mechanic control water meters are being read at least once a month. Consumer water meters are being read on the monthly basis. According to the collected data, analyses on water consumption and water losses within the DMA, Operational Units (OU) and whole distribution system area are conducted.

WUI has been implementing and using the SCADA for many years. The SCADA consists of the Dispatching Centre placed in the Buzet WUI centre and three sub-centres: Sveti Ivan, Gradole and Butoniga.

SCADA main task is (Figure 2):

- ◆ Efficient monitoring and management of the processes of water treatment production and distribution, from its source to the final consumer;
- ◆ Secure availability of water - prevention of large disturbances and breaks in water supply;
- ◆ Secure effectiveness of the supply system – coordination between the plant and production process;



- ◆ Saving's plan – minimising of the cost while keeping a high level of water supply.

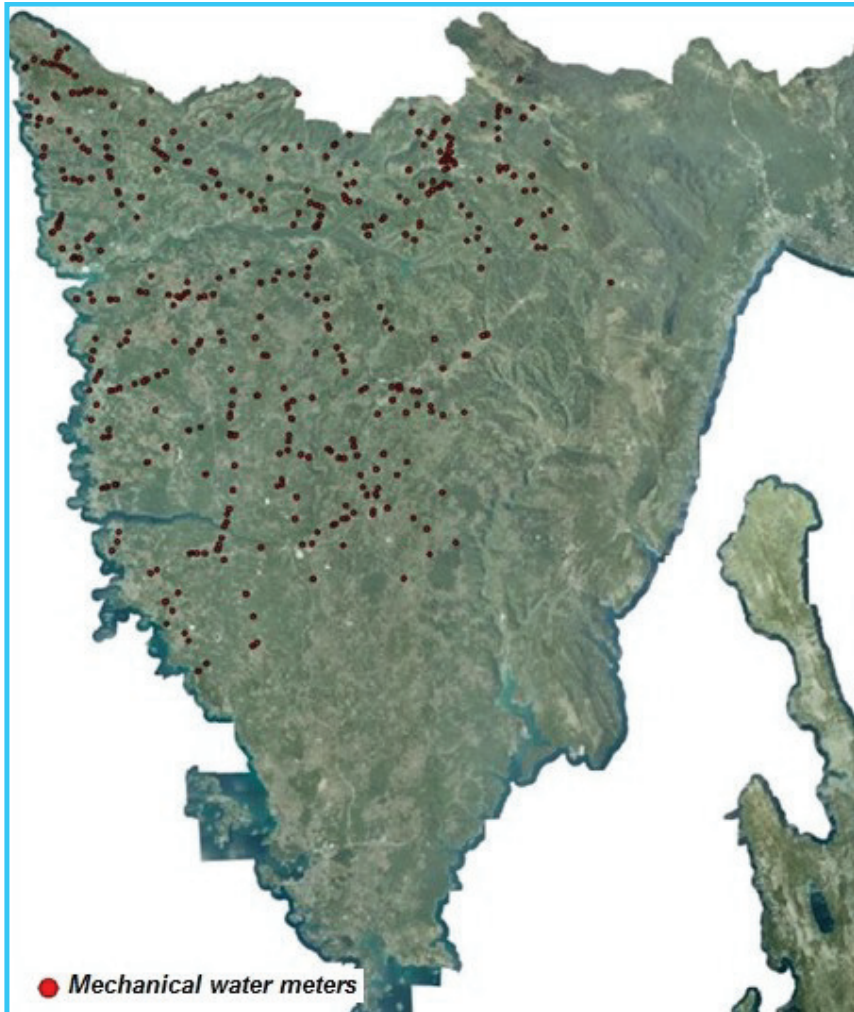


Figure 1. Operational area of WUI and the position of mechanical water meters existing before the Project realisation

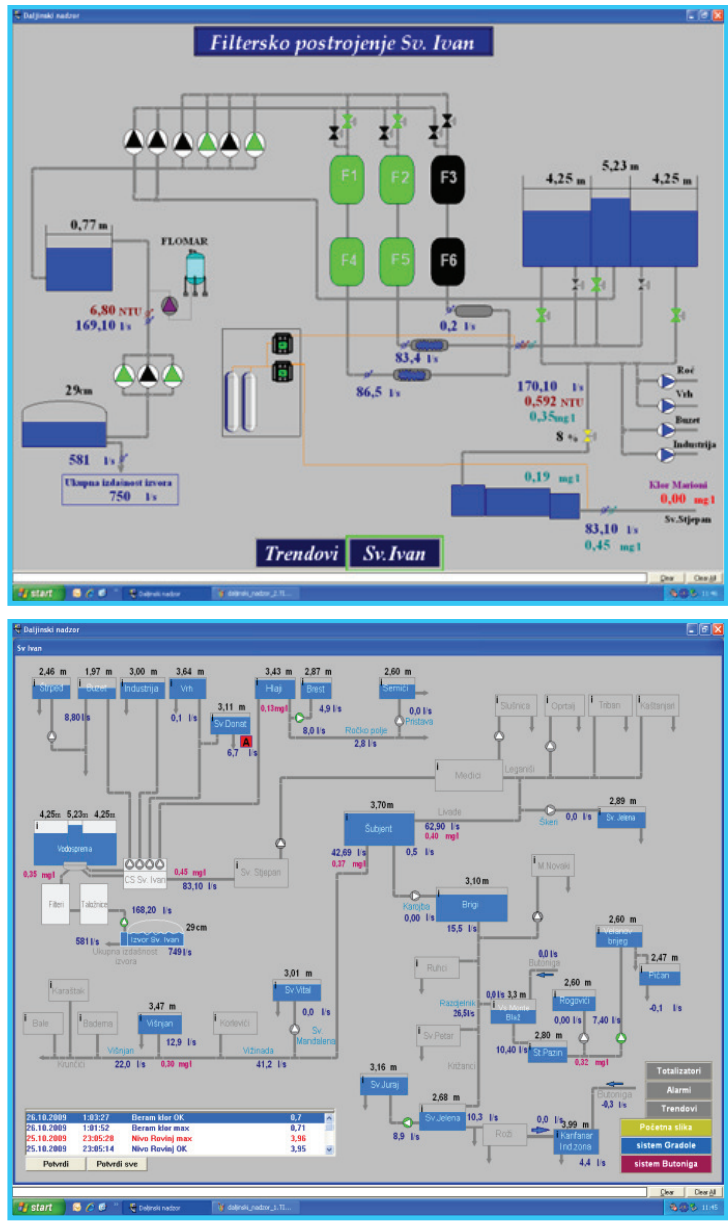


Figure 2. Supervisory Control And Data Acquisition (SCADA)

The general aim of the DRINKADRIA Project is to secure distribution of the good quality water. The Team for the Installation of Remote Reading System established tasks and brought conclusions, as well as set responsibilities. The Team's task was to find appropriate technology in order to fulfil the Project in the best possible way - lay out



the specifications for the procurement and organise the tendering process according to Procedures and Practical Guide (PRAG). Furthermore, the Team followed the commissioning of the water meters, telemetry devices and pressure gauges. Following the equipment installation, the Team has been following all the changes within the system in order to provide the necessary data for the Report. The planned activities of the DRINKADRIA project are presented in Table 2.

Table 2. Planned activities

DRINKADRIA PROJECT												
TIME PLANS AND DEADLINES												
PHASES OF REALISATION	2014				2015		2016					
	IX	X	XI	XII	I	I-VI	VII-XII					
PHASE I												
Team activities												
Drafting of technical documentation for the Tendering according to PRAG, choice/decision												
Contract												
PHASE II												
Procurement of water meters												
Procurement of loggers												
Procurement of pressure gauges												
PHASE III												
Commissioning of water meters												
Commissioning of loggers												
Commissioning of pressure gauges												
PHASE IV												
ADJUSTING THE SYSTEM TO REMOTE READING												
PHASE V												
SYSTEM SURVEILLANCE: AMR control 2.0 - consumption control system on water meters.												



3. The Parameters for the Reduction of Water Losses

Since 2000 a new method by the International Water Association for the losses analysis has been used (IWA methodology). The key novelty brought by the IWA Water Loss Specialist Group (WLSG) is the methodology for Water balance and the calculation of all of the non-revenue water components as well as the standardization (unification) of the components and the terminology. By calculation of the accurate amounts of the real and apparent losses as a part of the water balance, it is possible to plan the activities and measures for decreasing losses overall.

With the implementation of the AMR control 2.0 in the WUI and the continuous water meter reading and water balancing in real time, the IWA methodology within the Utility will be immensely improved and the quality of its data accuracy increased.

WUI shall follow the measurements of the AMR control 2.0:

- ◆ Daily consumption (24 hours);
- ◆ Consumption the day before (48 hours);
- ◆ Comparison (over, under - realized in %) for the last two days;
- ◆ Minimal night consumption;
- ◆ Consumption within the DMA (without the consumers);
- ◆ Alarms.

The data gathered via this system will be utilized for the hydraulic (numerical modelling) as well as for the improvements and the construction of the water supply network in the future (e.g. reconstruction works and building of new branches).

The implemented AMR control 2.0 of the water meters and its monitoring indicated the activities that are necessary in the future:

- Development and updating the Geographic Information System (GIS) data base with the exact pipeline locations, types, materials and diameters.
- Using the Global Positioning System (GPS) devices to gather the leakage locations and entering the locations into the GIS data base
- Leakage location analysis according to the frequency and amount of loss
- Use of the collected data to plan annual reconstructions and renovations



4. Procedures and Methods

WUI has applied an operational instruction: Operational Instruction for Early Breakages/Leakages Detection within the Water Supply System by following the AMR control 2.0 application and the Procedure for Breakage/Leakage Repairs list evidence assistance (Figure 3) in the Leakage Log document, created especially for this purpose [3].

The most important details from the Operational Instruction for Early Breakages/Leakages Detection within the Water Supply System include:

- ◆ AMR control and the Leakage Log are used for the remote water meter readings and early breakage detection as well as following the daily consumption
- ◆ AMR control 2.0 Application and the Leakage Log are being updated by the Informatics Department of the WUI
- ◆ The AMR control 2.0 Application is available to the Management, the Managers, distribution officials, system analysts in the Technical Department, foremen, dispatchers and the officials in charge of losses detection in the Operational Units

The new Procedure for Breakage/Leakage Repairs list evidence assistance includes (Figure 3):

- ◆ The Application is reviewed daily by the officials assigned the task and, if necessary, the system analyst and the production and distribution official from the Technical Department.
- ◆ If the assigned officials from the operational unit who control the Breakage Log (the breakage/leakage alert application) notice discrepancies from the Parameters, they note them and take the necessary activities in order to locate the leakage within the next 48 hours. The located leakage or pipe break must be repaired within the following 72 hours.
- ◆ If the breakage/Leakage is impossible to detect, then the Distribution Unit in Buzet is alerted via the Application. The Unit takes further measures and steps to locate the breakage. If needed, the operational unit has to provide the plumber who is familiarized with the mains in that area. After the breakage had been detected, the Unit notifies the OU's Distribution official who further organizes the repair works with his/her foreman. The time span between the detection and the repair must not exceed 72 hours.
- ◆ After the repair works, the operational unit official notes down the breakage/Leakage position together with the GIS officials. In the Breakage/Leakage Log we insert data like: pipe material, its profile and the cause of breakage/leakage.



- The overall time of taken action, from breakage/leakage detection in the Application to the repair, must not exceed 144 hours, i.e. six days.
- In case that the repair works fall on the days of the weekend or holidays, the decision on the repairs is made by the OU Manager.

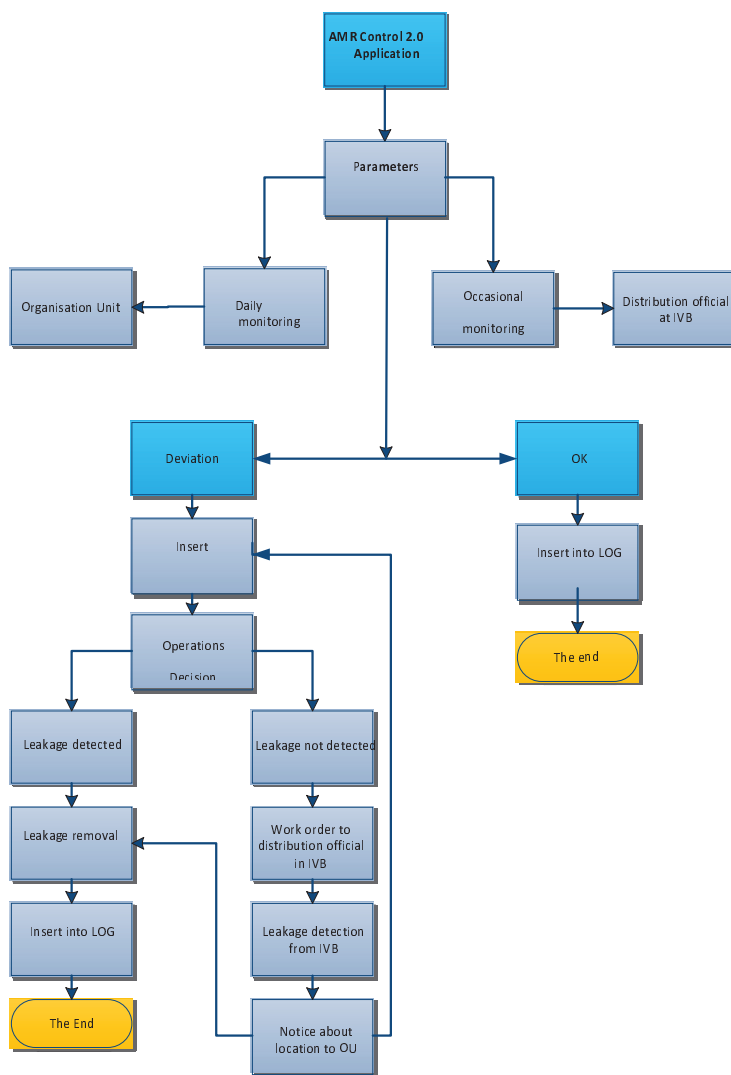


Figure 3. Procedure for Breakage/Leakage Repairs list evidence assistance



5. The Equipment Implemented into the Water Supply System of Istarski vodovod Buzet, Water Utility of Istria With support of the DRINKADRIA Project

In its area of operation, the WUI has, within the DRINKADRIA Project, introduced the AMR control 2.0 application. The purpose of implementation was real-time monitoring of water consumption and early detection of breakages and leakages. In order to get better accuracy ultrasonic and/or electromagnetic water meters and telemetry devices have been installed.

The new equipment enables:

- ◆ Accurate water distribution measurements, which present the primary module of a supply network management and thus create a basis for a safe water supply system, water balance and efficient picture of losses.
- ◆ Reliable data acquisition from each of the control locations for the possibility of remote diagnostics and further data analysis in the control center.
- ◆ Reliable, simple and up-to-date data analysis from the control locations for an efficient comparison of controlled measurements within water distribution, efficient management of losses and efficient adjustments of production and distribution of water to the real water consumption.

5.1. Accurate Water Distribution Measurements

In order to achieve exact and accurate measurements, the ultrasonic water meters ARAD OCTAVE (Figure 4) and pressure gauges APLISENS PCE-28 (Figure 6) were installed.

5.1.1. 344 Arad Octave ultrasonic water meters, Version 4.00.

The water meters ARAD Octave [4] are the most reliable solution, taking into consideration the Utility's needs and the nature of measurements:

- ◆ Compact product, IP68 protected
- ◆ Accuracy class according to MID, R=500 (Table 3)
- ◆ No movable parts (ultrasonic measurement technology):
 - No wear and tear of parts – longer reliability and accuracy life span, cheap maintenance;



- Resistant to hydraulic anomalies which are constantly present on the control level of water consumption measurements – changes in pressure, air in the pipeline, hydraulic stroke;
- Resistant to debris in the pipeline (stones, sand etc.).
- ◆ Autonomous battery charge, 15 yearlong battery life span – 90% of the control measuring posts are located in places with no possibility of electric charge; battery are therefore necessary.
- ◆ Local diagnostics on the LCD screen – digital measurement technology enables the implementation of multiple diagnostic functions. Thus, the new devices are not just flow meters but have also become a great diagnostics tool. It permits a complete insight into the measuring post, allowing a better surveillance of the water supply system: an overview of the cumulative consumption, current flow, flow direction, alarm system in case of consumption increase, leakage, air in pipes etc.
- ◆ Flexible ways of communication for a simple and overall data transmission from the water meter to the control center: double exit for the cumulative consumption, electric exit 4-20 mA for flow and encoded exit mode.
- ◆ The extensible span of flow measurements (dynamic span) – ensures accuracy in measurements with minimal and maximal flows. Therefore, no more problems with frequent breakdowns in water meters, which were the result of large flows in over dimensioned water meters. At the same time it registers the smallest of flows that were previously undetectable due to the over dimensioned water meters.
- ◆ Economic mounting – control measuring spots are often found on hard-to-reach locations and in small chutes. It is hence important to have the possibility of “economic mounting” – no need to install flat pieces on pipes in front of and behind the metres. Furthermore, there are the options of horizontal/vertical/diagonal mounting and there is no need for the debris grip.
- ◆ Minimal pressure loss at Q3 (nominal flow) – at control measuring and distribution posts special attention is given to the loss of pressure in installed equipment. With non-mechanic water meters the loss of pressure is 0, 16 Bars. Nevertheless, mechanic water meters have the loss of 0, 80 Bars.
- ◆ Ultrasonic water meters have a positive influence on water quality.



Table 3. Metrological accuracy of ARAD Octave acc. to MID-u (ISO 4064, 2005)

Meter Performance Acc. ISO 4064-rev.2005 Performance Requirements								
flowrate m ³ /h	meter size							
	DN 40 - 1½"	DN 50 - 2"	DN 80 - 3"	DN 100 - 4"	DN 150 - 6"	DN 200 - 8"	DN 250 - 10"	DN 300 - 12"
Q4	50	50	80	125	313	500	1250	1250
Q3	40	40	63	100	250	400	1000	1000
Q2	0.125	0.125	0.200	0.320	0.800	1.280	3.2	3.2
Q1	0.080	0.080	0.125	0.200	0.500	0.800	2	2
R10-Q3/Q1	500	500	500	500	500	500	500	500



Figure 4. Arad Octave Ultrasonic Water Meters with DRINKADRIA labels

DNEVNIK MONTAJE VODOMJERA																	
3P UNIVALEN NAJLAKŠE BUBREŽ																	
3P NAVISUŠI KLASIČAN I MONTIR: 0 PJ																	
VODOMJER						MONTAŽA			KONTROLA		POTROŠIČE		FOTO				
Red. br.	Statistički broj vodomer	Datum primanja na čistoću i dila	Datum primanja na čistoću i dila	Datum isprema i kontrola	Broj serijski	Šifra tipa	Broj pripreme u PI	ID Vodomer u OŠ - OŠ	Broj isprema u PI	Broj isprema u logu is montažu	Datum Montaje	Ime i prezime montera	Ime i prezime kontrolera	Potrošač ekod preciznija	Potrošač kod montaže	Datum fotografiranja	
1	142035039	1.12.2014	1.29.1.2015	01.12.2014	1711	000/2014	507	206 od 1.12.2014	PI100VČ-300MESH	539 od 1.12.2014	53030	2.12.2014	PI100VČ-300MESH	18273	MORSKO GRIGORIĆ		10.12.2014
2	142035039	1.12.2014	1.29.1.2015	01.12.2014	1711	000/2014	507	206 od 1.12.2014	PI100VČ-300MESH	535 od 1.12.2014	53028	2.12.2014	PI100VČ-300MESH	18274	MORSKO GRIGORIĆ		10.12.2014
3	142035035	1.12.2014	1.29.1.2015	01.12.2014	1711	000/2014	507	206 od 1.12.2014	ZUM170 - 470MESH	533 od 1.12.2014	53023	1.12.2014	DRAGAN MATIŠEVIĆ ROBERTO PRAČIĆ	18275	MORSKO GRIGORIĆ		10.12.2014
4	142035041	1.12.2014	1.29.1.2015	01.12.2014	1711	000/2014	507	206 od 1.12.2014	300VČ-470MESH	532 od 1.12.2014	53054	1.12.2014	DRAGAN MOJANON DANIJEL PRAČIĆ	18276	MORSKO GRIGORIĆ		11.12.2014
5	142035032	1.12.2014	1.29.1.2015	01.12.2014	1711	000/2014	507	206 od 1.12.2014	200VČ-470MESH	509 od 1.12.2014	53033	5.12.2014	PI100VČ-300MESH	18277	MORSKO GRIGORIĆ		10.12.2014
6	142035033	1.12.2014	1.29.1.2015	01.12.2014	1711	000/2014	507	206 od 1.12.2014	300VČ-470MESH	509 od 1.12.2014	53007	5.12.2014	DRAGAN MOJANON	18282	MORSKO GRIGORIĆ		5.12.2014

Figure 5. A page from the Diary of water meter installation

5.1.2. Aplisens pressure gauge PCE – 28

Water utility of Istria installed 10 Aplisens pressure gauges with characteristic:

- ◆ measurement span 0-16 Bars
- ◆ Accuracy 0,2%
- ◆ Analogue voltage socket 0-2,5 Vdc
- ◆ IP67



Figure 6. Aplisens - pressure meter PCE – 28

5.2. Reliable Data Acquisition and Transfer to AMR Control 2.0 Application

Because of the terrain configuration and location of the measurement point on the places where no possibility of electric connection exists, the problem of the data collection and sending to the AMR control 2.0 application is solved with the long life batteries. Equipment that is used for that purpose is 329 Inventia MT – 713 HC , GPRS telemetric module.

329 Inventia MT – 713 HC, GPRS telemetric module with characteristic:

- ◆ Autonomous battery charge (alkaline or lithium-ion batteries) – easily replaceable ;
- ◆ Intelligent data logger (4 MB Flash RAM with 1 sec minimal noting interval);
- ◆ 5 entries (binary/ counter) all compatible with potentially free contacts;



- ◆ 3 analogue 0-5 Vdc entries with adjustable alarm thresholds and hysteresis; exits
- ◆ Sensor for open lid (protected access);
- ◆ Adjustable schedules and actions initiated by measuring and date transmission – the user makes the adjustments according to needs;
- ◆ Outside antenna 5dBi, SMA antenna socket;
- ◆ IP67;
- ◆ GUI application for local and remote parameter setting, diagnostics and device upgrading.



Figure 1. Inventia MT – 713 HC – logger



Figure 2. Measurement location

DNEVNIK MONTAŽE LOGERA														
ISPUNJAVA ISTARSKI VODOVOD BUŽET										ISPUNJAVA TVRTKA MONTER				
Red.br.	TIP	inventarni broj logera	ID Vodomjera u IWB	Serijski broj logera	Datum dolaska u tvrtku montera	GSM broj	MONTAŽA			KONTROLA		POTEŠKOĆE		FOTO
							Tvrtka zadužena za montažu	Datum montaže	Ime montera	Potpis montera	Kontrola ugradnje i najepnica	Potpis kontrole ugradnje	Poteškoće kod preuzimanja/ nepoznanice	
1	LOGER	18783	117MEH 118MEH	173.14.44.144	14.11.2014.	0996012737	Control Engineering d.o.o.	02.12.2014.	Saša Sokač, Matija Torić		Boris Jakovac			117MEH 118MEH
2	LOGER	18782	28MEH	173.14.44.62	14.11.2014.	0996012742	Control Engineering d.o.o.	02.12.2014.	Saša Sokač, Matija Torić		Boris Jakovac			28MEH
3	LOGER	18781	67MEH	173.14.44.3	14.11.2014.	0996012744	Control Engineering d.o.o.	02.12.2014.	Saša Sokač, Matija Torić		Boris Jakovac			67MEH
4	LOGER	18780	64MEH	173.14.44.22	14.11.2014.	0996012743	Control Engineering d.o.o.	02.12.2014.	Saša Sokač, Matija Torić		Boris Jakovac			64MEH 65MEH
5	LOGER	18779	154MEH	173.14.44.61	14.11.2014.	0996012738	Control Engineering d.o.o.	02.12.2014.	Saša Sokač, Matija Torić		Boris Jakovac			154MEH
6	LOGER	18787	205MEH	173.14.44.26	14.11.2014.	0996012763	Control Engineering d.o.o.	03.12.2014.	Saša Sokač, Matija Torić		Boris Jakovac			205MEH
7	LOGER	18789	217MEH	173.14.43.82	14.11.2014.	0993746574	Control Engineering d.o.o.	03.12.2014.	Josip Devčić, Davor Pečko		Boris Jakovac			217MEH

Figure 3. A page from the Diary of logger installation

5.3. Reliable, Simple and Up-to-date Data Analysis From the Control Posts

In order to ensure accurate water distribution measurements, dependable logging and measured data transmission, it is important to obtain the required software equipment for surveillance, data analysis and management. Applications that are used for that purpose are Meter Data Management (MDM) applications and software AMR control 2.0. is one of those. (Figure 10 – 12). AMR control 2.0. Application enable the WUI constant access to data from the network, anywhere and anytime.

AMR control 2.0 consist of:

- Surveillance/management of the water supply:
 - Automatic generating of periodic water consumption reports or generating reports on demand (Figure 10);
 - Interactive map of measuring posts locations – GIS module (Figure 11);
 - Table or graphic overview of the measured data;
 - Grouping of the devices according to zones for water loss detection, information of unauthorized consumption and help with the information of unauthorized water consumption (Figure 12);
 - Management, alarm analysis and direct informing of the customers (e-mail, SMS);
 - Export of the gathered and measured data for further use and management in other system of surveillance (SCADA etc.).

- Real and true water consumption analysis:
 - A simple comparison between the produced and consumed water within the distribution network – allows adjustments of distributed water to the real and true consumption (water and energy are saved).

The screenshot shows the AMRcontrol2.0 interface with a table of water meter data. The table has columns for 'Mjetro', 'Mjetro ID', 'Mjetro opis', 'ID', 'Vrijeme posljednje', 'Lokacija', 'Stanje (m3)', 'Vrijeme 2. stanja (m3)', 'Vrijeme 3. stanja (m3)', 'Mj. brzina (l/s)', 'Preostalo %', 'P2', 'Preostalo', 'Bilješka', and 'Status'. The data rows list various meters with their IDs, descriptions, and current status.

Figure 10. AMR CONTROL 2.0 - tracking system changes every hour

The screenshot shows the AMRcontrol2.0 interface displaying the 'ID card' of a water meter. It includes a left sidebar with configuration options, a central panel with meter details, and a right panel with an aerial map of the meter location.

Mjetro opis: 175.14.44.39 (ID: ROV-49)

Stanje (m3): 0.00

Vrijeme 2. stanja (m3): 0.00

Vrijeme 3. stanja (m3): 0.00

Mj. brzina (l/s): 0.00

Preostalo %: 0.00

Preostalo: 0.00

Preostalo 2. stanja: 0.00

Preostalo 3. stanja: 0.00

Preostalo 4. stanja: 0.00

Preostalo 5. stanja: 0.00

Preostalo 6. stanja: 0.00

Preostalo 7. stanja: 0.00

Preostalo 8. stanja: 0.00

Preostalo 9. stanja: 0.00

Preostalo 10. stanja: 0.00

Preostalo 11. stanja: 0.00

Preostalo 12. stanja: 0.00

Preostalo 13. stanja: 0.00

Preostalo 14. stanja: 0.00

Preostalo 15. stanja: 0.00

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Preostalo 17. stanja: 0.00

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Preostalo 98. stanja: 0.00

Preostalo 99. stanja: 0.00

Preostalo 100. stanja: 0.00

Figure 4. ID card of the water meter

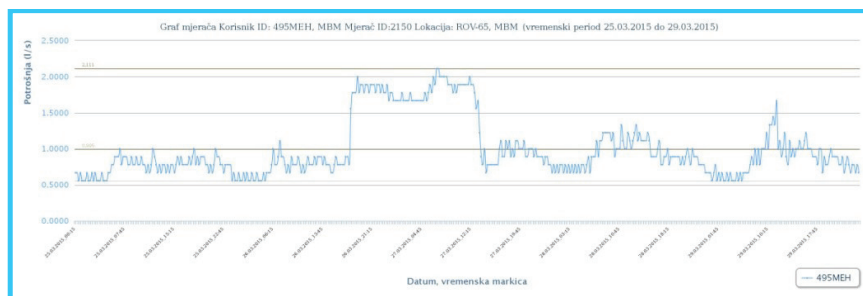


Figure 5. Water meter (495Meh) on which two leakages are detected

6. Benefits Gained from the DRINKADRIA Project

- ◆ Improved water distribution surveillance within zones – earlier supplied water within certain zones was monitored whereas the amount of supplied water within the 24 hours can be observed;
- ◆ Following possible losses in the network according to the quantity of lost water – earlier the losses were detected after a week i.e. a month, depending on the location (taking into consideration that some meter were read on a weekly basis i.e. monthly basis, depending on their location). Confirmation of losses within a certain zone was given monthly, when comparisons with the supplied water was made. Now losses are detected after mere 24 hours, the confirmation coming immediately after the same data has been repeated, i.e. the consumption is higher.
- ◆ Following possible losses according to night consumption – every consumption during night time is a possible loss. The water meters take note of supply every 15 minutes and, based on the difference in volume at a time interval, average consumption is calculated. If consumption is noted during the night on any of the meters, one can assume that there are losses in the network following that water meter.
- ◆ Improved measurement accuracy – the new water meters have better accuracy than the ones which had been replaced (even though we only talk about control water meters so that level of accuracy does not carry that much weight);
- ◆ Documenting – all the taken measurement data enters the measurement data base and is stored. In this way it documents the consumption which may be useful in the future as a reference, for example or it can be used in further distribution analysis.
- ◆ Data comparison – taking into consideration all the measurement data is archived, it is possible to carry out comparisons of the current measurements with, for example measurements from recent periods. In this way, we can detect anomalies in the system.



- ◆ Graphic layout of all data – the application for data gathering and management can show all the measurements data in graph form and in this way facilitate the overview of data on a particular place in particular time;
- ◆ Data comparison – the measured values can be simultaneously monitored (for example measuring inputs in one zone, on one measuring post and measuring outputs from the zone on multiple measuring locations);
- ◆ Water supply system pressure monitoring – the results show us the taken values on defined points in the system. Following the oscillations in pressure, data on distribution system operations is gained within a certain area, as are all the anomalies therein;
- ◆ Displayed battery status and signal strength – data on particular measuring location on the basis of which an intervention or the needed maintenance are planned.

7. Encountered Difficulties during Implementation

During the implementation of the DRINKADRIA Project different problems were met as this was the first time for the WUI to enter a project involving EU co-financing:

- ◆ Document preparation;
- ◆ Calls for tendering;
- ◆ Appeal to the Decision and Documentation;
- ◆ Water meter delivery;
- ◆ Short deadline (105 days) of System of Remote Reading implementation;
- ◆ There are continuous problems with the mobile connection and the signal for water meter readings being sent to AMR CONTROL 2.0;
- ◆ Introduction of : Operational Instruction for Early Breakages/Leakages Detection within the Water Supply System

7.1. Reached Goals

The DRINKADRIA project brought to attention certain flaws within the monitoring system. As a result, improvements were made;

- ◆ Monitoring the daily and night flow (consumption) of water in the distribution system;
- ◆ Faster responses to failures;
- ◆ 129 DMA on AMR CONTROL 2.0. application;
- ◆ Modernization of the existing water supply system;
- ◆ Key parameters for future surveillance were defined;
- ◆ The process of system surveillance and leakage repairs was redefined;



- ◆ Application for informing and evidence of leakage repairs agreed and launched;
- ◆ Three-month report period on activities of noted and repaired breakages/leakages was defined.

8. Conclusion

Work on the DRINKADRIA project still is a great challenge. Nevertheless, the hardest part of work has been completed.

Future steps:

- ◆ Updating of the existing the GIS base (pipes position, types of pipes and the diameters);
- ◆ Zoning: (129 zones) division to smaller zones according to implemented water meters;
- ◆ Introducing the management of losses according to IWA methodology or the ILI indicator;
- ◆ Analysis of leakage;
- ◆ Pressure adjustments in the critical zones (according to ILI indicators);
- ◆ With the possibility of daily and night consumption surveillance 94 leakages and pipe breaks have been found and repaired 94 (56 in February and 38 in March).

9. References

- [1] URL1;http://www.istra.hr/.app/upl_files/TZ_2014_01-12.pdf)
- [2] URL2;http://www.istra.hr/.app/upl_files/TZ_2014_08.pdf)
- [3] URL3;http://www.juricakovac.com/images/Uvod_u_IWA_WLTF_metodolo_giju_analize_gubitaka_vode_v231210v1.pdf
- [4] URL4;<http://arad.co.il/product/octave/>



VULNERABILITY OF WATER RESOURCES IN THE ADRIATIC AREA

Barbara Čenčur Curk (Barbara.cencur@ntf.uni-lj.si),

*University of Ljubljana, Faculty of Natural Sciences and Engineering,
Department of Geology, Slovenia*

Mircea Margarit Nistor (renddel@yahoo.com),

*University of Modena and Reggio Emilia, Department of Chemical and
Geological Sciences, Modena, Italy*

Extended abstract

Water resources are under increasing pressure from land use change, changes in the quantity and manner of water use by man and climate change. Climate changes indicate an increase of mean annual temperature combined with decreasing and/or increasing precipitation. Furthermore, associated with the economic situation and possible future changes in the southeast EU region, the land use pattern is also expected to change. An increase in water use by man is often very important in water balance analysis, especially in a region where a decrease in precipitation is expected. Thus, all these processes will most likely have severe impacts on water resources in general and drinking water resources in particular. The main objective of the EU transnational project CC-WARE (Southeastern Europe programme) is the attempt to develop an integrated transnational strategy for water protection and mitigating water resources vulnerability. Integrated vulnerability is considered as an integrated indicator which includes:

- ◆ water resources vulnerability considering water quantity and quality and
- ◆ adaptive capacity considering natural system (ecosystem services) and socio-economic conditions (GDP).

Vulnerability maps were produced with GIS software and designed for two periods: recent from 1991 to 2020 and future from 2021 to 2050. Climate change scenarios were obtained from an ensemble of three RCM models ALADIN, Promes and RegCM3.

Climate changes are considered as a major driver, which affects water resources. Thus, climate indices (precipitation and



evapotranspiration) were defined for the calculation of water availability. Furthermore, a Water Exploitation Index (WEI) or water quantity vulnerability (Figure 1) was calculated by dividing water demand with water availability [1]. High and very high water stress on annual level is in the Po plain and southern Italy, coastal area of Slovenia, around Belgrade and in central Serbia and in Corfu, Greece. In the future the pattern will be the same, only areas with medium, high and very high stress will be larger.

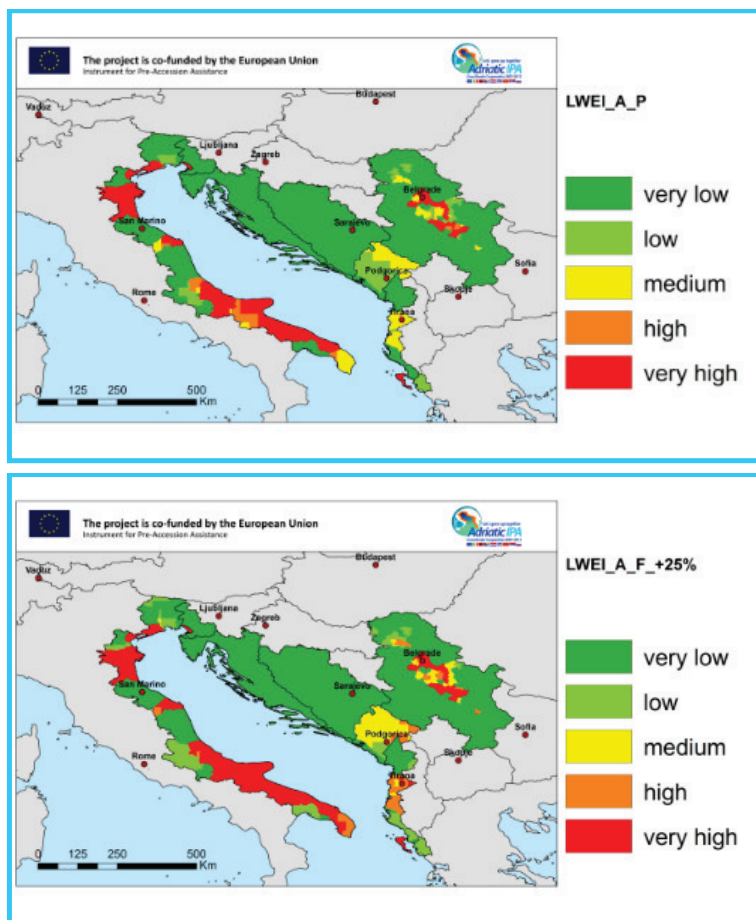


Figure 1. Annual Local Water Exploitation Index (LWEI_a) for present (1991-2020) and one future (2021-2050) scenario of water demand (WD+25%) based on mean annual ensemble values of RegCM3, ALADIN and PROMES models for DRINKADRIA countries within IPA-ADRIATIC area.

For water quality vulnerability – surface water quality index (Figure 2), land use is a major driver, therefore land use load coefficients were applied to Corine land cover maps [1]. With this surface water quality



vulnerability was obtained. The highest water quality vulnerability is in the industrial and agricultural areas. Groundwater vulnerability (Figure 2, right) is much lower than surface water vulnerability, because it is not directly exposed and depends on infiltration capacity of particular aquifer type. The latter was considered in 'HG' factor, with which surface water quality index was multiplied [1].

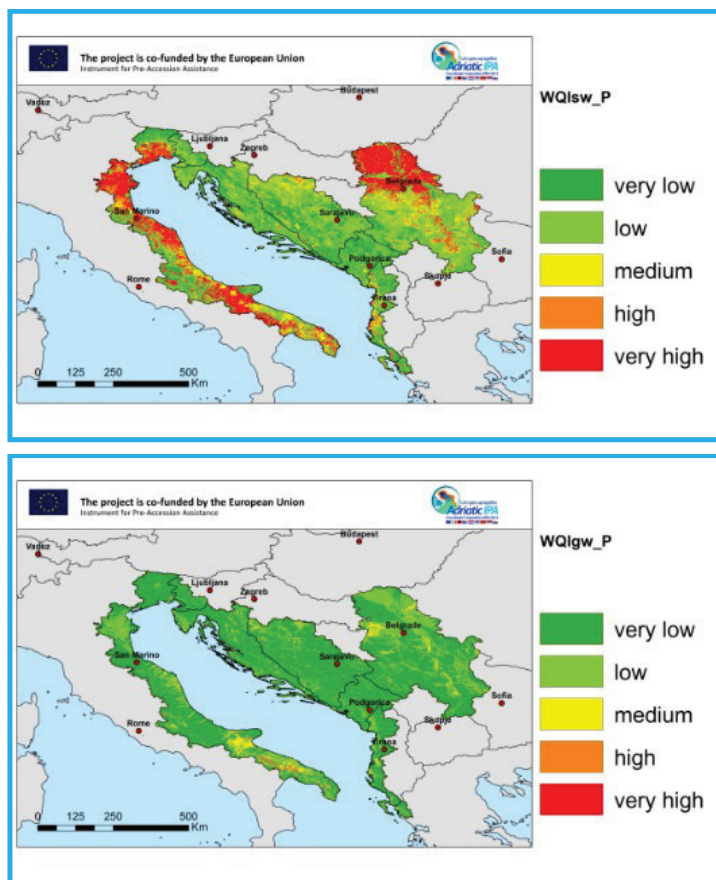


Figure 2. Potential pollution load – surface water quality index (WQISW) and groundwater quality index (WQIGW) for present situation (1991-2020) for DRINKADRIA countries within IPA-ADRIATIC area

Adaptive capacity (Figure 3) of the Adriatic area was assessed considering natural system (ecosystem services, considering three functions: Provisioning Ecosystem Service, Water Regulation and Water Quality Regulation) and socio-economic conditions (GDP) [1]. GDP is dominating adaptive capacity, because GDP was normalized in order to bring proportion with other data sets for calculations, with this the distribution is very homogeneous because of extreme GDP values



in the most developed region in Europe (Po plain area), where adaptive capacity is very high and with this very low vulnerability.

Integrated vulnerability was assessed by combining water resources vulnerability and adaptive capacity with consideration of weighting and balancing factors [1]. High integrated vulnerability (Figure 4) is in the most of the project area except in the Alps in northern Italy and Slovenia, Istria and northern Dalmatia, south-western Serbia, central Bosnia and Herzegovina, where integrated vulnerability is low. Very high integrated vulnerability is in scattered areas in Italy and Albania, in northern Serbia and in Corfu, Greece.

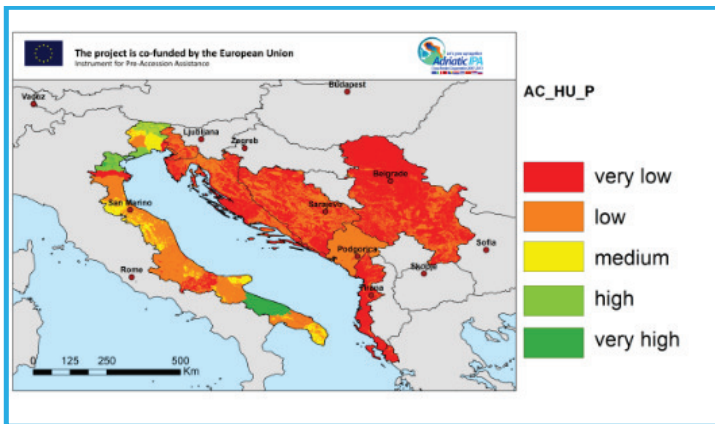


Figure 3. Adaptive capacity for present (P) period (1991-2020) situation for DRINKADRIA countries within IPA-ADRIATIC area

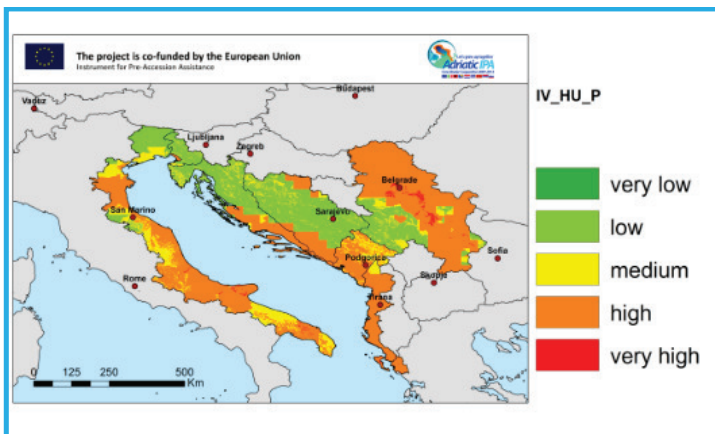


Figure 4. Integrated vulnerability index based on mean annual ensemble values of RegCM3, ALADIN and PROMES models for present (P) period (1991-2020).



It should be stressed that all maps were elaborated based on grids and interpolation. Spatial resolution is 0.25° , which is approximately 25 km when projected. The resulting maps are presenting a regional scale and can be used as indicators for measures to be applied in a region with high vulnerability.

References

- [1] Čenčur Curk, B. (ed.): WP3 - Vulnerability of Water Resources in SEE. CC-WARE – Mitigating Vulnerability of Water Resources under Climate Change. 2014. URL: <http://www.ccware.eu/output-documentation/2-uncategorised/23-output-wp3.html>. (2.11.2015)



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