DIKTAS

Protection and Sustainable Use of the Dinaric Karst Transboundary Aquifer System

Transboundary Diagnostic Analysis (TDA)

- Summary -

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gef UNDP UNESCO United Nations Educational, Scientific and Cultural Organization International Hydrological Programme of UNESCO

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SELECTED ACRONYMS

Agency of Environment and Forestry (of Albania)	AEF
Bosnia and Herzegovina	B&H
Groundwater Dependent Ecosystems	GDE
Groundwater bodies	GWBs
Hydro-electrical power plants	HPP
Hydrogeology Working Group	HGWG
International Sava River Basin Commission	ISRBC
Ministry of Environment, Forestry and Water Adm. (Albania)	MoEFWA
National Consultation Meetings	NCMs
National Water Council	NWC
Root cause analysis	RCA
State Ministry of Foreign Trade and Economic Relations	MOFTER
Strategic Action Programme	SAP
Strengths/Weaknesses/Opportunities/Threats	SWOT
Transboundary aquifer	TBA
Transboundary Diagnostic Analysis	TDA
United Nations Development Programme	UNDP
United Nations Educational, Scientific and Cultural Organization	UNESCO
Water Framework Directive	WFD

1 Introduction

Protection and Sustainable Use of the Dinaric Karst Transboundary Aquifer System (DIKTAS) is a regional project aimed at improving the management of karst groundwaters in the Dinaric Karst shared by several countries in South-Eastern Europe. As such, the project is the first ever attempt to globally introduce integrated management principles in a transboundary karst freshwater aquifer system of such magnitude.

Karst is a special type of geologic environment that is formed when soluble rocks, such as limestone and dolomite, are corroded and dissolved by percolating water. Karst hydrogeology is characterised by high permeability of preferential flow zones developed along fractures, faults and conduits, high aquifer recharge rates, high velocities of groundwater, and almost total absence of permanent surface water.

Groundwaters of the Dinaric Karst System in South-Eastern Europe form some of the World's largest and most prolific karst aquifers which host numerous first magnitude springs. The system extends from north-eastern Italy through Slovenia, Croatia, Bosnia and Herzegovina, and Montenegro to Albania. Karst formations have also developed in carbonate rocks of the Dinaric Mountains in the neighbouring Serbia, FYR Macedonia, and possibly in north-western Greece. For the most part, this region is characterised by still pristine environments and a variety of unique geomorphological landforms. It also hosts numerous karst underground species, many of which are endemic such that some of the Dinaric karst localities are recognized as the most bio-diverse worldwide.

The DIKTAS Project started in 2010 and will continue until the end of 2014. The project was initiated by the aquifer-sharing states and is a full-size Global Environment Facility (GEF) regional project, implemented by United Nations Development Programme (UNDP) and executed by UNESCO. The activities of the project focus on Albania, Bosnia and Herzegovina, Croatia and Montenegro. Several other countries and international organizations have also joined this challenging project and are providing valuable contributions to the realisation of its objectives.

At the global level, the project aims to focus the attention of the international community on the abundant but vulnerable water resources contained in karst aquifers. The project's main outputs include the Transboundary Diagnostic Analysis (TDA), the establishment of cooperation mechanisms at national and regional level, and the adoption of a regional Strategic Action Program (SAP) and corresponding National Action Programs (NAP) for each of the countries involved.

The TDA was conducted in the period 2011-2013 by the DIKTAS Project Team in accordance with the GEF guidelines provided in the TDA/SAP Training Manual. The TDA is based on a substantial regional analysis that is required in order to fully understand the context of transboundary issues. The regional analysis was particularly important given the complexity of the karst environment and regime and the interconnectivity of karst aquifers. The regional analysis also enabled a delineation of transboundary aquifers (TBAs) shared by the project countries. The Project Team was organised in four working groups, reflecting the main issues of the regional analysis: (1) environmental and socio-economic analysis; (2) hydrogeology of the Dinaric karst; (3) legal and institutional framework and policy; and (4) stakeholder analysis.

The regional analysis was followed by an in-depth analysis of the transboundary aquifer areas that focused on observed and potential issues of transboundary concern. The analysis was carried out in a systematic way that included climate, hydrology, hydrogeology, groundwater reserves and their

utilization, groundwater quality and water resources protection. For each aquifer, the major issues of concern were determined and priority actions proposed.

This document presents a summary of TDA findings, written with a purpose to reach a broad public. The complete TDA document and the annexes are available as well; an extensive collection of DIKTAS project documents can be accessed via the DIKTAS portal at http://diktas.iwlearn.org.

2 Environmental and Socio-Economic Analysis

The analysis of the environmental and socio-economic situation in the DIKTAS project countries showed a degree of similarity and regional inter-connectivity. The countries share the same or similar geographic characteristics, the common or related history, and similar development trends. All these countries have their orientation to the Adriatic Sea, including Bosnia and Herzegovina through the delta of the River Neretva. Croatia and Bosnia and Herzegovina (and Montenegro to a limited extent) are also oriented to the River Sava which they share for several hundred kilometres.

Regarding the economic development, Albania, and Bosnia and Herzegovina, are the poorest countries in the region (based on GDP), with income levels between 21 and 28% of the EU27 average. Montenegro is a middle-income country, with shares between 35 and 42%, whereas Croatia, the most developed state in the region, has a relative income level comparable with Poland, with an income share of 62% of the EU27 average. With the exception of Croatia, south-east Europe has been recovering from the crisis and shows more dynamic growth than the EU27, and constant development have been foreseen for the future. The countries are at various stages of the EU integration process except Croatia who become member recently.

Out of the four DIKTAS countries, Croatia has the largest population with 4.29 M inhabitants followed by Bosnia and Herzegovina (3.8 M), Albania (2.8 M) and Montenegro (0,62 M). The population density is the highest in Albania (98.5/km^2) and lowest in Montenegro (50/km^2).The population growth rate is low or negative for all four countries. Across the region, there is a trend of migration from remote, rural areas towards urban areas and industrialized zones. Small settlements are extremely dispersed, and a number of settlements in rural areas are already abandoned. This trend becomes visible in the TBA areas, most of which are rural. Due to tourism, population numbers may vary considerably across the year, with peaks in the summer season (especially along the Adriatic coast).

Hydropower plays a central role for energy production in all DIKTAS countries. Amounting to more than 90% of its energy production, Albania relies almost entirely on hydropower. With more than 2,000 MW, Croatia has the highest hydro-power installed capacity among the countries, while its share of hydropower to total energy production is the lowest among the DIKTAS countries (31%). About 2/3 of total existing hydro power facilities are located in the DIKTAS karst area, therefore hydro power generation from Diktas karst system plays significant role in countries economies.

The GDP percentage of the agriculture sector in the participating countries varies from 8% to 18%. The percentage of countries' agricultural area ranges from 24 to 47%. In Albania, the percentage of agricultural area is lower than in other countries, yet the agricultural sector in Albania has the highest contribution to GDP (more than 18%) compared with the other DIKTAS countries. Agricultural activities and the economic importance of agriculture is decreasing at the regional level. Agricultural sector is directed mainly to production of corn, maize and wheat in the continental parts, and grape, vegetables and fruits in southern parts of the DIKTAS region.

Major industries are iron works, aluminium, mining, and pharmaceutical industries, shipyards and the food-processing industry. During the transitional period (post 1990 year period), the majority of the industries have rapidly decreased with limited success of recovering afterwards and with noticeable decrease in the role of heavy industry in the economies of all four countries. Heavy pollution in the form of PCBs, PAH, heavy metals, acids, fluoride, chlorine, lead, zinc, iron, copper and other metals have been registered from historical pollution hot-spots. Nowadays, economy of

the countries has shifted from industrial and agricultural towards services oriented economies. Economic Indicators are showing constant improvement in the countries' economies that exert increasing pressures on the karst environment.

Across the region, the tourism sector is expanding and provides an important source of income (revenues range between 250 and 7000M Euro per year and share 2-15% of countries' GDP). In all four countries trends show significant and continual development of touristic sector. This is linked to the use of numerous natural resources and additional pressures on the environment. In Croatia, Albania and Montenegro tourism is seasonal (along the Adriatic coast) and the countries work towards diversification of touristic offer and activation of tourist destinations in mountains and rural countryside. Increased tourism development increases pressures on water utilization and protection.

The total estimated amount of generated solid communal waste is in: Albania is 400 000 t/year, B&H 1 400 000 t/year, Montenegro 280 000 t/year and in Croatia is 1.30,0000 t/year with different stage of development of waste management systems (for example, there is no system for the safe management of hazardous waste in Albania and Montenegro). Historic industrial sites are one of the main sources of pollution in the region. The main method of waste disposal is in unlined landfills which are present in an insufficient number, although it should be noted that new landfills are being constructed by EU standards.

Sewage systems are not at the desirable level and service coverage rate is much lower in rural than in urban areas. Wastewater (in rural and some urban areas) is discharged in improvised permeable septic pits, smaller adjacent surface streams or depressions polluting these streams with organic content, leading to pollution of the whole hydrological system and endangering drinking water sources. Therefore, waste and wastewater pollution has been identified as major threats to the protection of the Dinaric Karst Aquifer System.

None of the countries in the DIKTAS project have complete and operational network for systematic monitoring of groundwater quality. Consequently, a detailed assessment of the overall quality of the groundwater in the project region is not feasible. However, based on the available information, the quality of karst groundwater in the region can be rated as generally very good, and most of the time in line with the standards for drinking water quality without any pre-treatment needed. Problems concerning chemical parameters of karst groundwater are very rare, and the main problems are turbidity (typically caused by the rapid infiltration of precipitation) and microbial contamination. Contamination with pathogens is mostly related to human activities, including inappropriate disposal of wastes and wastewater. Another issue of concern is proper establishment and enforcement of the source protection zones around springs and wells utilized for public water supply. All countries have necessary legislation in place but proper implementation is frequently missing which jeopardizes a generally good quality of groundwater at the source.

Monitoring network of surface water quality is developed on different scales in the DIKTAS region. Croatia has a systematic network of monitoring stations that measure surface water quality at more than 400 locations, while Montenegro has a network with more than 60 monitoring stations in place. Although different national classification of water quality exists, the surface water quality in the Project region can generally be described as good to average (according to the EU WFD) in most cases. Quality of surface waters deteriorates immediately downstream of larger settlements and industrial pollution sites where it does not meet European Union standards. Major treats for the quality of surface (and ground) water are identified as very high percentage of untreated waste disposal and wastewater discharge (frequently directly to the recipient) as well as a large number of untreated/unsecured industrial pollution hotspots, mainly from the heavy industries (closed or partly in function) left from/after transition period to open economy principles in the 1990's.

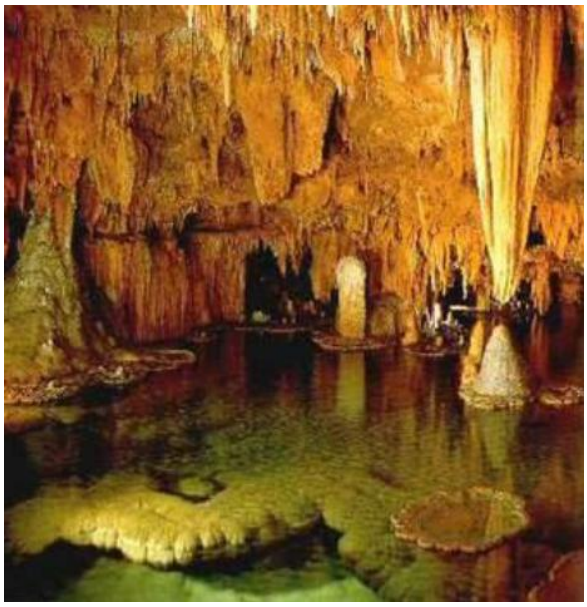

Figure 1 Vjetrenica Cave in Popovo Polje (Bosnia and Herzegovina) is considered by many as the most diverse karst underground habitat in the world.

All DIKTAS countries are considered to have abundant groundwater resources at their disposal. However, during the summer period water shortages may occur, particularly in tourist areas along the Adriatic coast. Quantities of water use for different sectors correspond well with the level of economic development; still, most water in the region is used for drinking water supply. Main source for drinking water supply is groundwater basins, contributing as much as 90% to the water supply (in Montenegro and Bosnia and Herzegovina 90%, in Albania 70%). Large quantities of water are also used for production of electrical power. Most water supply systems in urban areas are regularly monitored for quality, while rural water supply systems may not be subject to any system of quality control. Percentage of total population connected to the public supply system varies from 48% (Entity of Republic of Srpska in Bosnia and Herzegovina) to 80% (in Croatia), with significant discrepancies between rural and urban areas. Water quantities used for industry and irrigation are significant, but those numbers rapidly decreased since 1990s. Floods are frequent in the project region due to the natural conditions, regime of the dams, and shortage of funds for flood protection.

Figure 2 Proteus anguinus (proteus) is an endemic amphibian species found in the DIKTAS project region (IUCN conservation status: threatened). It is the only cave-dwelling chordate found in Europe.

The region is abundant with pristine nature areas, which are often vulnerable and under threat. Yet, none of the countries recognized the vulnerability, complexity, and importance of integrated protection of karst environment through national policies. The percentage of protected surface to the total area of the Country varies from 0,5-12,4% but none of the protected areas (or categories) in any country is solely related to the Groundwater Dependent Ecosystems (GDEs). Croatia has reported 29 sites that may be potential GDE (based on N2000), while info for rest of the Countries is missing and GDEs in those countries need to be investigated and properly acknowledged. Natural wetlands are dispersed over the region and are considered to be areas of high ecological value. Thirteen of them are Ramsar sites and are severely threatened by water use (such as for hydropower) and land-based sources of pollution and drainage. There are a number of caves in DIKTAS region, but most of them are not commercially utilized or known to the wider public. Higher institutional attention (identification and management) of sensitive karst morphological features is strongly needed as they represent unique (eco) systems of geological and biological importance and valuable parts of groundwater depended ecosystems (Figures 1 and 2).

In conclusion, the Dinaric karst is providing essential and extremely valuable ecosystem services and supports development of the countries' economies (drinking-water supply, tourism, hydro power

production). At the same time, it is threatened by the ongoing activities including industrial pollution hot-spots, waste and wastewater disposal, and unsustainable water use and management.

3 Hydrogeology of Dinaric Karst

3.1 General Characteristics

The Dinaric system (Dinarides) represents a geologically heterogeneous, south European orogenic belt of the Alpine mountain chain (Alpides) and is considered a classic karst region worldwide. This is a mountainous region with a prevalence of highly karstified rocks and large karst poljes and valleys created by perennial and sinking streams. Dinaric karst system extends from Italy in the northwest (from *Carso* area around Trieste-Monfalcone in Italy) over the countries of former Yugoslavia (Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, FYR of Macedonia) and ends in the southeast in the territories of Albania and Greece (Figure 3). The total surface area of the Dinaric system, including non-karst rocks, is estimated at 136,700 km^2, out of which 110,410 km^2 belong to four project countries (Croatia, Bosnia and Herzegovina, Montenegro and Albania). Approximately 60% (65,545 km^2) of the study area belongs to the Adriatic basin, while the Black Sea basin covers about 40% (44,865 km^2).

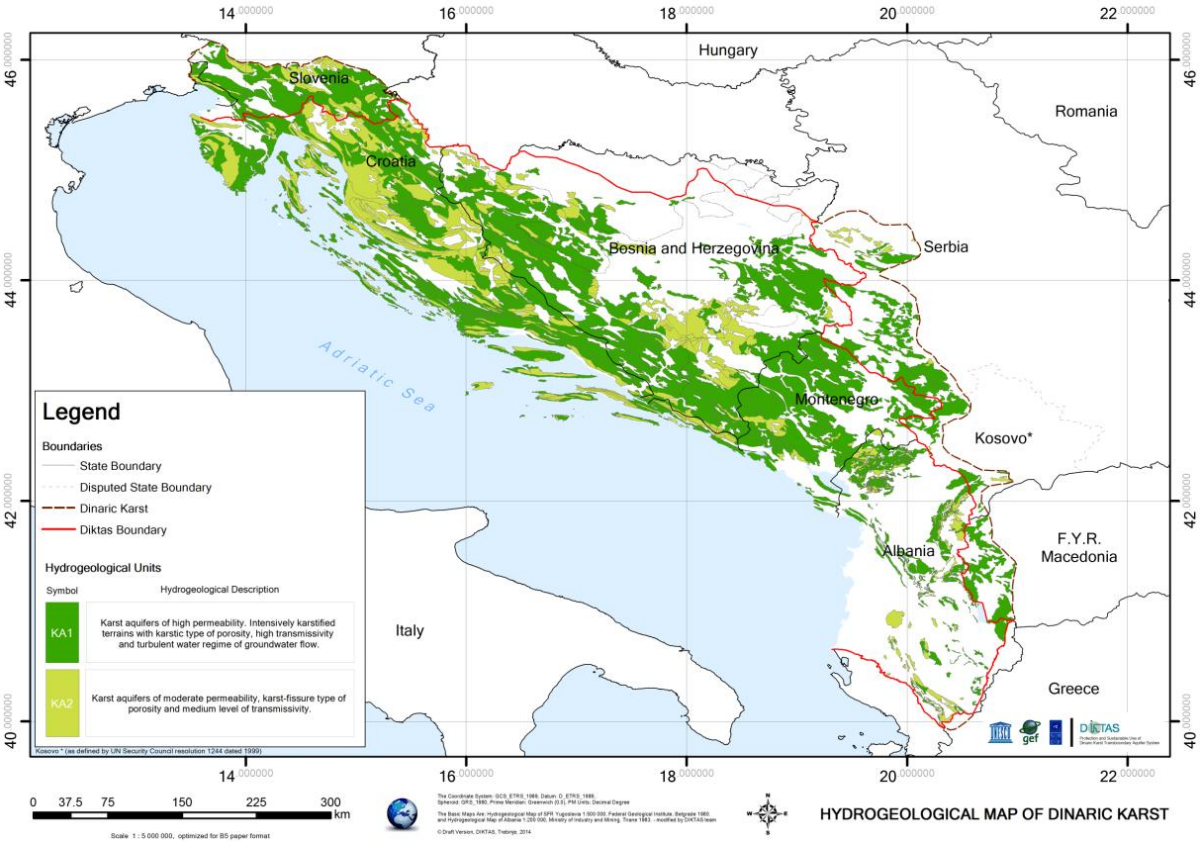

Figure 3 Hydrogeological map of the Dinaric karst with the DIKTAS project area and administrative boundaries

Not only was the term karst born in the area, but thanks to Jovan Cvijić, who performed most of his work in the Dinaric karst, a new scientific discipline - karstology -as well. Germanicised as “karst”, the

Dinaric *Carso* (*Kras* in Slovene) thus became the type area for dissolutional landforms and aquifers; the term karst is now applied to modern and paleo dissolutional phenomena worldwide. (Ford, 2005). Some local terms were introduced in international karst terminology and are still widely used (e.g. ponor, doline, uvala, and polje). Following the groundbreaking work by Cvijić (1893), a large number of scientists further improved the knowledge of the Dinarides in terms of hydrology, geomorphology, geology, and hydrogeology.

The Dinarides consist of three major tectonic units: External (closest to the Adriatic Sea), Central and Inner Dinarides. The main sedimentation cycle in the Mediterranean geosyncline (Tethys) started in the Permian and lasted through Upper Cretaceous. At the end of the Upper Cretaceous and during the Paleocene, intensive uplifting and folding took place, during which most of the carbonate and flysch rocks were tectonically disturbed. After the Laramian tectonic phase, the next intensive movements occurred in the Helvetian phase (Eocene/Oligocene). All the main nappes along the Adriatic/Ionian Sea coastline can be related to this stage (Meçe & Aliaj, 2000).

The Cretaceous sediments in the Dinaric region are almost entirely carbonate (limestones and dolomites) with the exception of the Durmitor Mountain in Montenegro, where Upper Cretaceous flysch also developed.

Cvijić stated that “there is no deeper or more complete karst development than in the karst of Herzegovina and Montenegro that is located between the lower Neretva River, Lake Skadar and the Adriatic Sea”. In Albania, the best developed karst phenomena are in the Albanian Alps, and in the Mirdita and Ionian zones. Several national parks and protected areas such as those under Ramsar's Convention, and endemic species which inhabit underground world of caves are also present in the region. Due to its historical importance for the development of karst science (including exemplary karst development with numerous geo-heritage sites, and abundant groundwater resources), an initiative has recently been taken to include the Dinaric region and its selected areas in the UNESCO list of World Heritage Sites.

The Dinaric region contains all types of **karst landforms and features** including karren (lapies), dolines, pits (jamas), ponors (swallow holes, sinks), dry and blind valleys, caves and caverns as single forms; and uvalas (Figure 4), poljes and karst plains as larger complex forms (Katzer, 1909; Božičević, 1966; Roglić, 1972). For example, in certain areas a number of dolines is up to 150/km^2. Dry and blind valleys are numerous in the Dinaric karst: Once hosting running surface streams, they gradually lost their hydrologic function as surface water was diverted into the subsurface through ponors (sinks) and fractures in the underlying carbonates.

According to Milanović (2000), in the Dinaric karst region there are approximately 130 poljes. The total area of all these poljes is about 1,350 km^2. The Livanjsko Polje (B&H), considered the world’s largest karst polje, covers an area of 380 km^2, and together with Buško Blato, which morphologically may be considered its integral part, totals 433 km^2. Drainage of the karst polje surface water is through ponors located both along the polje perimeter and at the polje floor within unconsolidated sediments or exposed carbonates. The ponors are frequently located in the polje areas nearest to the prevailing erosion base. The Adriatic and the Ionian Seas are regional erosional bases to which a

cascade system of poljes is oriented. In the Nikšićko Polje (Montenegro), about 880 ponors and estavelles were identified, 851 of which are located along its southern perimeter.

Figure 4 Small depression (uvala) used for crop cultivation (Orjen Mountain, Montenegro and Bosnia and Herzegovina, photo Z.S.)

Krešić (1988) listed some 15 potholes (jamas, pits, shafts) in the former Yugoslavia deeper than 400 m. Several much deeper potholes have recently been discovered in Croatia including Lukina Jama-Trojama (-1421 m) and the Slovačka Jama (-1320) in the Velebit Mountain National Park. These jamas are among the deepest speleological phenomena in the World. Some areas, such as Kameno More (the Stone Sea) and Mount Orjen above Risan (Kotor Bay, Montenegro), contain numerous deep vertical potholes. For example, within an area of only 8 km^2 more than 300 vertical shafts were registered (Milanović, 2005). Some of them have been speleologically investigated to depths of 200-350 m. In Croatia, approximately 7,000 speleological objects have been surveyed, many of which host spectacular cave formations and speleothems. Water is permanently or periodically present in approximately 25% of the Croatian caves.

Along with its richness in various karst features, the Dinaric region is by far the richest in Europe in water resources which, however, are unequally distributed throughout the year mostly due to climate conditions and high karstification rate. The inner Dinaric part has a continental climate, while the Mediterranean climate prevails along the Adriatic and Ionian coasts. The main characteristics of the continental climate are long and cold winters and short and hot summers (annual air temperature varies between -20^{0}C and 40^{0}C). Annual precipitation varies between 700 mm in the northern and over 2000 mm in the southern part. In Boka Kotorska Bay, Montenegro average annual precipitation, from the sea level up to an elevation of 1,800 m varies from 2,000 mm to more than 5,000 mm which is the highest recorded annual rainfall in Europe.

In the **Adriatic Sea basin**, the density and length of surface streams are small, whereas groundwater flows through well developed karst underground systems are significant. The Neretva River with drainage area of approximately 7,950 km^2 is the largest surface stream. It is shared between Bosnia and Herzegovina and Croatia. A significant sea influence and intense mixing of saltwater and freshwater is evident in the Lower Neretva delta. Other large Croatian rivers flowing into the Adriatic Sea are Lika, Zrmanja, Krka and Cetina. The Trebišnjica River in Bosnia and Herzegovina is the largest European sinking stream. Until construction of a large hydro-energy system Trebišnjica had regularly flooded the Popovo Polje. More than 500 ponors, estavellas and intermittent springs have been registered in the Popovo Polje (Milanović, 2006), while the total sinking capacity has been estimated at 300 m^3/s. The length of the Trebišnjica is 90 km, from the springs near Bileća (now submerged) to

the Ponikva ponor in the Popovo Polje. The total area of the Adriatic Sea watershed in Montenegro is 6,267 km^2. Morača River with its tributaries Zeta, Cijevna, Rijeka Crnojevića and Orahovštica discharges into Lake Skadar, and from there the Bojana-Buna River flows towards the Adriatic Sea first crossing the Albanian territory and then making the border between the two countries further downstream (Hrvačević, 2004). Lake Skadar (Shkodër, Skutari) is the largest lake on the Balkan Peninsula. Lake Skadar has had the status of a National Park since 1983, and it was included on the Ramsar list of internationally protected wetlands in 1995. It represents a winter safe haven for European birds. Around 60% of the lake is in Montenegro, while 40% is in Albania. The largest rivers in Albania are the above mentioned Cemi, Buna, Drini and Black, as well as the White Drini, Semani and Vjosa. The average perennial flow of Albanian rivers is approximately 1,245 m^3/s. The annual discharge of all the streams in Albania reaching the sea is estimated at about 40 x 10^6 m^3/year.

The Una River basin, which belongs to **the Black Sea basin**, is the western-most river basin in the Dinaric karst of Bosnia and Herzegovina. About 97.5% of the Una basin belongs to Bosnia and Herzegovina and just about 2.5% (238 km^2) of the catchment is in Croatian territory. Sana, Vrbas, Bosna and Drina are the four major river basins of the inner part of the Dinarides in the territory of Bosnia and Herzegovina. All of them are tributaries of the Sava River (Sana via Una) and belong to the Black Sea basin. Lim, Ćehotina, Piva and Tara are four major rivers in the northern part of Montenegro. They are tributaries of the Drina and also belong to the Black Sea basin. The Tara canyon is protected by UNESCO. With only 140.5 km of water course (of which 83 km is through the canyon), a catchment area of 1,853 km^2 and an average flow of 64 m^3/s, clear and wild River Tara flows through pristine nature. The Piva river flow is regulated by a large dam Mratinje.

Large seasonal differences in water regime are typical for this region. Although classical floods are not very common due to the large infiltration capacity of the karst, the ponors cannot always absorb runoff water from intensive rainfall, which causes regular flooding of many karst poljes. This is also the main reason why large projects to regulate river flows were initiated in all the countries in the region after WWII and many of these were implemented during the 1960s and 1970s. The idea to regulate flows is much older; the Klinje dam (Mušnica stream, Bosnia and Herzegovina) was built in the period 1888-1896, while the **hydro-electrical power plant** (HPP) at Kraljevac (Cetina, Croatia) was erected in 1912. Today many streams are dammed and their waters are utilized by HPPs. The major dams and reservoirs were built on the Cetina, Trebišnjica, Piva, Zeta, and Drini rivers.

The Cetina water system is managed by the Croatian water authority although a considerable amount of water originates in the territory of Bosnia and Herzegovina including catchments of the Kupres, Glamoč, Duvno, and Livno Poljes, and Buško Blato. Currently there are five HPPs on the Cetina River. The largest storage reservoir, Buško Blato, has capacity of 831 x 10^6 m^3. Bonacci (1987) stated that Cetina surface area is from 3,700 to 4,300 km^2 of which the topographic watershed encompasses about 1,300 km^2 and the subsurface watershed about 2,700 km^2. The average river flow is 118 m^3/s.

The main structures of the Trebišnjica water system are the Bilećko Lake (i.e Bileća Reservoir) behind the Grančarevo dam, and the Gorica dam and reservoir downstream. Active operating HPPs are Trebinje I (180 MW), Trebinje II (8MW), Čapljina (420 MW) and Plat (Dubrovnik, 210 MW). Losses at

the Grančarevo and Gorica dam sites of 74.3 m^3/s and 85.6 m^3/s respectively, are approximately only 5-7% of the average river flows.

Some areas, such as southern Montenegro, are characterized by a very dynamic water balance where the average specific yield is over 40 $l/s/km^2$. However, the number of artificial reservoirs in Montenegro is small in comparison with the hydropower potential. The total capacity of these reservoirs amounts to slightly more than 1 x 10^9 m^3 of water. With respect to the total amount of surface water (about 14 x 10^9 m^3/year) formed in the territory of Montenegro, this amounts to about 7% (Hrvačević, 2004). There are two reservoirs in the Black Sea basin: Piva on the River Piva and Otilovići on the River Ćehotina. The installed power is 360 GWh, with an average annual production of about 750 GWh. In the Adriatic basin, the reservoirs in the Nikšićko Polje including Krupac, Slano and Vrtac have been formed on the River Zeta, while the Liverovići dam controls the flow of the Gračanica River. Waters from the reservoirs are utilized by the HPP Perućica (307 MW). All the reservoirs in the Nikšićko Polje have been built in highly karstified rocks. Slano and Vrtac required intensive and expensive water loss prevention works from the very beginning. The grout curtain along the southern rim of Slano is one of the longest in the world. It is 701 m long, 57m deep and its surface area is 396,122 m^2.

The current hydropower exploitation capacity of the main Albanian HPPs is 1,750 MW, and most of the dams were built on the Drini catchment.

Karst aquifer system of the Dinarides is formed within a very thick (over 1000m) complex of Mesozoic limestones and dolomites. The aquifer recharge is from precipitation and waters percolated from sinking rivers. The average infiltration rate varies between 50% and 80% of precipitation depending on locality, morphology and degree of karstification.

As a result of intensive karstification, a network of highly permeable underground channels act as preferential pathways of intensive groundwater circulation. It is very difficult to estimate the overall **effective porosity** (considered also as a storage coefficient) of the karst aquifer because of the anisotropic and heterogeneous character of limestones and dolomites. Most references provide values in the range of 0.008-0.02, while locally it can be significantly higher.

Komatina (1983) states that more than 650 localities were investigated in the Dinaric karst of the former Yugoslavia. In eastern Herzegovina alone 281 localities were subject to **tracer tests**, and in the catchment area of the Cetina River there were 99 such localities. Tracer tests were conducted in 77 localities in the Lake Skadar catchment area. Milanović (2000) states that more than several hundred investigations have been performed in the Dinaric karst for the purposes of finding major flow paths of groundwater flow. By analysing data from these experiments, he concludes that the average flow velocity varies within a wide range from 0.002 to 55.2 cm/s.

The main **erosional base** of the External Dinarides is the level of the Adriatic and Ionian Seas, while the local erosional base for numerous springs are the edges of karst poljes or the contact of carbonate and non-carbonate rocks. Some authors estimate that in the Dinaric region of former Yugoslavia there are 230 **springs** with a minimal discharge over 100 l/s, while about 100 springs have a minimal discharge of over 500 l/s. Out of four capitals of the DIKTAS project countries, three are

getting water for their citizens from karst springs (Croatia is an exception). Almost all cities along Adriatic and Ionian coast depend on karst groundwater for their water supply (Stevanovic & Eftimi, 2010). Milanović (2005) stated that three large springs along the Neretva Valley and Adriatic coast (Buna, Bunica and Ombla - see Figure 5) and a few spring zones in the Boka Kotorska Bay (Orahovačka Ljuta, Spila, Sopot, Morinje Springs, Škurda and Gurdić) annually discharge more than 150 m^3/s, on average. Some of these springs completely dry out during summer (e.g. Sopot, Spila), while after intensive rainfall or at the end of winter some of them can discharge over 100 m^3/s (e.g. Sopot - see Figure 6). Some large springs are used for water supply such as Jadro (3–50 m^3/s) for the city of Split (Bonacci, 1987). Regional water supply system for the Montenegrian coast was recently completed by intake constructed on the Bolje sestre Spring in the Skadar Lake basin (the minimum spring flow is 2.3 m^3/s, Radulovic, 2000; Stevanovic, 2010).

Figure 5 Ombla Spring (source of Rijeka Dubrovačka, Croatia, photo Z.S.)

Figure 6 Sopot Spring near Risan (Montenegro) during peak flow discharge (photo Z.S.)

In the Albanian karst there are roughly 110 springs with an average individual discharge exceeding 100 l/s. Of these, 17 have discharges exceeding 1,000 l/s (Eftimi, 2010). The majority of them are in the Dinaric part of the country (north from Vjosa). It is estimated that two thirds of groundwater resources in the entire country are in karst aquifers which provide more than 60% of the water consumed in Albania (Eftimi, 2010).

Extremely high rainfalls and glaciations during the Quaternary era stimulated the karstification process (MIjatovic, 1984) and greatly influenced the current **regime of karst waters** in the area. The much lower sea water level at that time (as much as 100 m during certain glaciation episodes) and steep groundwater gradients have additionally contributed to deep groundwater circulation in the karstified Mesozoic rocks. Current evidence of this deep circulation is numerous submarine springs in the wide open Mediterranean littoral. Therefore, a general erosion base of karst groundwater discharge is situated between 100 and 150 m below the current sea level in the Mediterranean.

The main characteristic of karst springs is a very variable flow regime (Pekas et al. 2012). The ratio between the maximum and minimum discharge of large karst springs in the External Dinarides karst can greater than 1000 as in the case of some Kotor Bay springs. Other large springs such as Trebišnjica and Oko (tapped for Trebinje's water supply) also have highly variable discharge regimes with a ratio of 800 and 80 respectively. On the other hand, several very large springs such as Buna, Bunica, and Ombla do not regularly exceed 1:25 in an average hydrological year. According to Šarin et al. (1983), variation in the karst springs' discharge expressed by the ratio Qmax/Qmin is often larger than 100. For instance, this ratio is 197 for the River Una spring; and 100 for the River Cetina spring. In contrast, there are springs with a relatively more stable regime of discharge. As a rule, ascending contact springs have a more stable discharge throughout the hydrologic year compared to gravity springs.

Similarly, a large fluctuation of the water table is common in the region. For instance, the water level can change by 312 m during a period of 183 days (example of the observation borehole Z-3 in the Nevesinjsko Polje). In the Cetina River basin the maximum recorded water table increase was 3.17 m/h (UNEP, 2000).

3.2 Transboundary Aquifers

The DIKTAS project is focusing on transboundary karst aquifers (TBAs), examining current and potential issues of concern. The analysis of TBAs also provides an opportunity to test the applicability of outcomes of the regional analysis on a local scale, dealing with concrete issues of transboundary concern (Kukuric, 2011). Based on five criteria (importance, representativeness, data availability, issues of concern, relevance) eight TBAs have been selected for detailed analysis: Una, Krka, Cetina, Neretva, Trebišnjica (all shared by Croatia and Bosnia and Herzegovina); Bilećko Lake and Piva shared by Bosnia and Herzegovina and Montenegro) and Cijevna/Cemi (Montenegro and Albania). Six of these TBAs belong to the Adriatic Sea catchment area and two (Una and Piva) are part of the Black Sea basin. The TBAs comprise a total surface area of 12,000 km^2, which is approximately 10% of the entire study area. The surface area of the individual TBAs varies from 291 km^2 (Piva) to 3,455 km^2 (Cetina).

Some of the selected TBAs, such as Una, Krka, Neretva or Cijevna/Cemi, are of particular importance because they represent parts of designated protected zones, or wetlands, or the habitat for endangered species. In the Una catchment there is the Plitvice Lake, Croatian national park also protected by UNESCO as the world heritage site. Krka is another Croatian national park, while Neretva deltaic marsh is an important biodiversity area. Finally, the Cijevna/Cemi aquifer drains into the Skadar Lake, an important bird settlement included in the Ramsar list. Therefore, knowledge of groundwater distribution, flow pattern and extraction rate is essential for sustainable development of the studied karst aquifers and dependent eco systems of high importance.

A delineation of the aquifer surface area was the first step in the hydrogeological analysis of each TBA. These areas usually comprise allogenic and autogenic zones of karst aquifer recharge, and it is quite common that size of surface areas is variable depending on seasons (wet or dry). Further analysis included the characterization and development of conceptual models for each TBA.

Groundwater budgeting of TBAs represents a base for the assessment of groundwater reserves and availability, as well as for plans and measures aiming to ensure sustainable development of TBAs.

The analysis indicated that water extraction is still far below aquifer's recharge potential, and there is no evidence of significant over-exploitation in the studied TBAs. For instance, in case of the Cetina and Neretva TBAs the average extraction of groundwater is ten times lower than the total minimum discharge of the springs (dynamic reserves). However, shortage of water is locally evident during summer and early autumn months coinciding with increased demands during tourist season. Importantly, even under such circumstances the principles of EU Water Framework Directive (WFD) regarding ecological flow for downstream consumers have to be fully met.

The karst water quality is generally relatively satisfactory even though Dinaric karst aquifers are very vulnerable to pollution. This is mostly due to sparsely populated catchments in the mountainous areas and the absence of intensive agricultural or industrial activities. However, when sources of pollution are present (e.g., mines, industrial and domestic wastewaters, solid waste dumps, agriculture), a deterioration of water quality in unconfined karst aquifers is almost certain. Therefore, proven connections between ponors and certain important springs in the territory of the neighbouring countries (e.g. Plitvice-Klokot, Trebišnjica-Ombla) require strict enforcement of already established sanitary protection zones and preventive measures. The Dinaric karst aquifer system areas require specific solutions and compromises in land use planning on one hand, and the protection of nature and water resources, on the other. Some of the important springs with catchments shared by the Dinaric countries should be included in the SAP as demonstration sites for application of methodology and design of sanitary protection zones.

The most problematic from an environmental standpoint is the identified pollution of parts of the Una transboundary (TBA) aquifer by PCBs released by destruction of a military airport, radio-relay and other facilities in the Željava - Plješevica Mountain area near Bihać during the civil war in 1990s. A project for evaluation, sanitation and remedial measures at these sites is therefore recommended as part of the SAP.

In case of the Cetina TBA, untreated wastewater and solid waste disposal along with diffuse sources of pollution and minimal springflows during (recession) periods have been identified as the major issues of concern. As part of the SAP, the engineering regulation measures and managing aquifer recharge aiming to improve water situation are proposed for consideration at some of the TBA localities.

Regarding the actual monitoring of groundwater, the situation in the region and in the studied TBAs is far from satisfactory. Only in Croatia the characterization of groundwater bodies and their monitoring has been completed in accordance with the EU WFD. One of the tasks of the DIKTAS project is to prepare a proposal for the creation of a new groundwater monitoring network which will fully consider karst-specific behaviour and include local water users (waterworks, dams, irrigation, industry, etc.). The Cijevna/Cemi TBA is identified as the most problematic concerning available data on water resources and is proposed for the installation of a modern monitoring network for observation of climate elements, surface and groundwaters.

A list of environmental impact indicators, which includes 23 different parameters for assessing pressures on groundwater quantity and quality, has been prepared as part of the diagnostic analysis. Their knowledge and observation may support sustainable water use and protecting the status of dependent eco-systems. A few of them are proposed to be continually observed: renewable groundwater resources; groundwater exploitation index; groundwater depletion; specific pollutants index; drinking water quality (by observing selected critical parameters).

The Dinaric region has the most dynamic water budget in all of Europe, and there are numerous challenges for sustainable utilization of groundwater. This includes high annual variation of natural flows and the vulnerability of aquifers to pollution. It is therefore important to (1) improve the quality of water by eliminating or mitigating sources of pollution, (2) regulate the minimum spring discharges, (3) ensure ecological flows, and (4) establish proper water monitoring systems. These actions are recommended as priority during implementation of the DIKTAS SAP (Strategic Action Program).

4 Legal and Institutional Framework and Policy

To address effectively all the barriers that hinder sustainable groundwater management in the region, the Transboundary Diagnostic Analysis (TDA) was performed with the aim to identify the proximal, intermediate and fundamental causes of environmental problems and threats in the Dinaric Karst Aquifer System. The TDA includes the regional Dinaric Karst Aquifer System SWOT analysis and a comprehensive overview of the legal and institutional framework and policy in the region, which is supported by relevant national laws regulatory documents and international instruments and guidelines on transboundary aquifers.

The regional SWOT analysis, provided during the TDA preparation phase, clearly showed shortcomings in the formal transposition of the EU Water Framework Directive, WFD (2000/60/EC) and the Groundwater Directive, GWD (2006/118/EC) in national legislations. Regarding institutional aspects, the following was identified: gap/overlapping in coordination among institutions, in particular between local and central government; weak institutional setup for water (particularly groundwater) monitoring, poor performance of law enforcement with regard to application of water management principles, and lack of integrated water resources management approach in groundwater investigation.

In all four countries (Croatia, Bosnia and Herzegovina, Montenegro, and Albania) water issues are covered by different ministries and institutions at the different administrative levels. However, coordination and clear division of responsibilities among the institutions at different levels (e.g. in Albania) have not been properly defined and the level of law enforcement is not sufficient in all countries. Although all four countries have designated responsible institutions for implementation of EU water acquis (communautaire) there is a need for capacity building and education of personnel in those institutions, on issues like characterization of water bodies, establishment of reference conditions, analysis of human impacts, application of the 'combined approach' principle and development of river basin management plans and programme of measures.

Regarding the legal aspects, it is determined that current regulations have many gaps and ambiguities linked to groundwater monitoring, due to unclear criteria related to the use of appropriate indicators/parameters of groundwater status, choice of measurement points and the frequency of monitoring. There is a lack of consideration of groundwater dependent ecosystems and the areas (water bodies) intended for the abstraction of drinking water (drinking water protected areas, DWPA) are not properly defined in national legislation. The regional SWOT analysis revealed that no clearly defined relationship exists between groundwater bodies, which are intended for the abstraction of drinking water, and sanitary protection zones which are defined to ensure protection measures within drinking water protected areas.

The concept of management and water protection in respective countries is determined by the national strategic documents. Croatia, Albania and B&H's entity Federation of B&H have adopted Water Management Strategies. Albanian Water Strategy dates from 2004, and a new Strategy is under preparation. B&H's entity Republic of Srpska has the Framework Plan for Water Management Development (2006) as well as Draft RS Strategy of integrated water management (2012). Montenegro has the Water Basis Document that dates from 2001, and a new Water Basis should be prepared and adopted. Although all these documents set out the vision, mission, goals and tasks of state policies in water management, including groundwater management, they differ in the level of harmonization with the requirements set in the WFD and the GWD. Besides, these water policy documents are only partly harmonized with other sectoral strategies, which are adopted years ago

and are obsolete. It is evident that sectoral policy documents, such as e.g. energy development strategies, the strategies of industrial development, territorial development strategies, etc. imply the existence and consumption of water as a resource. On the one hand these sectoral strategies are not harmonized with each other, and on the other hand they rarely estimate real demand for water and water pollution potential of sectoral activities, which may threaten the implementation of the water protection measures both on the national and on regional (transboundary) levels.

In all four countries there are on-going efforts for transposition of the fundamental principles, objectives and measures from the EU Water Framework Directive, WFD (2000/60/EC) and the Groundwater Directive, GWD (2006/118/EC) in national legislations. Although the "polluter pays" principle and the principle of "recovery of the costs" are promoted in national legislative documents, the principle of cost recovery is not fully transposed either in national regulations or in water management practices, with regards to implementation of the environmental and resource costs in water pricing policies. There is no legal or policy document in any of these countries which adequately defines and prescribes the integration of environmental and resource costs into development of pricing policies. It should be noted that the main shortcoming of the legislative framework in all countries is an underdeveloped system of by-laws and insufficient implementation of present legislation due to lack of human resources and financial means for fulfilling legal and policy requirements. Due to the lack of clear development strategies, programs and plans on water management issues, the Dinaric Karst region cannot be considered as an example of successful implementation of the "user pays", "polluter pays" and "cost recovery" principles. National financial resources are not sufficiently developed to cope with the accumulated problems and due to its small budget, local communities, in principle, have to rely upon the assistance of the state and international donors.

All four countries have a wide experience in international cooperation for the protection and sustainable use of transboundary waters. The countries are part of multilateral framework conventions, and have bilateral and multilateral agreements at the ministerial level among themselves, covering transboundary water issues. Albania, Bosnia & Herzegovina and Croatia are parties to the *Convention on the Protection and Use of Transboundary Watercourses and International Lakes (UN Economic Commission for Europe, 1992) and to the Protocol on Water and Health* (1999), adopted under this Convention. Countries are signatories to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention) adopted in 1976. As regards multilateral agreements, Bosnia and Herzegovina, Croatia and Montenegro are parties to the *Convention on Co-operation for the Protection and Sustainable Use of the River Danube (Danube River Protection Convention)* (1994). Also, Montenegro ratified the *Convention on the Protection and Use of Transboundary Watercourses and International Lakes (UN Economic Commission for Europe, 1992).* Furthermore, Bosnia and Herzegovina and Croatia are also parties to the *Framework agreement on the Sava River Basin* (signed in 2002, in force in 2004), which was the basis for establishment of the International Sava River Basin Commission (ISRBC) in 2005, aiming to transboundary cooperation for sustainable development of the region. The International Sava River Basin Commission and Montenegro signed a Memorandum of Understanding in Belgrade in December 2013.All countries have bilateral agreements on water management issues, related to transboundary water bodies, such as the agreement between Albania and Montenegro (signed on 14 December 2010), which covers the Basin of Shkodra Lake, Drini and Buna rivers, and related to the water streams at the border, such as agreement between Croatia and Bosnia and Herzegovina (signed in 1996).

The main challenges to effective groundwater management at the regional level are mainly related to: harmonization of the water sector with other sectors, implementation of the Integrated Water

Resources Management (IWRM) principles in groundwater governance, capacity building for public administration and strengthening the role of public participation in taking decisions.

Program of measures at the regional level should be defined on the basis of application of economic criteria (cost effectiveness) and principles of "combined approach" and "best environmental practice“. This is particularly important when applying measures to prevent the introduction of hazardous substances or measures to restrict the introduction of priority substances and other pollutants. The principle of cost recovery should be redefined in existing national water legislations as a goal to be achieved in the future. Specifically, it means that water pricing policies need to be based on the assessment of costs and benefits of water use and have to consider both the financial costs of providing services as well as environmental and resource costs. Implementation of water pricing policies means a combination of pricing and metering, in order to provide adequate incentives for using water efficiently and to change user’s behaviour.

It is essential that measures at transboundary level are implemented within the time frame which is realistic and acceptable for countries. This requires transboundary agreements on the measures to be taken, political commitment to their enforcement, and sustained cooperation to monitor their effectiveness. A joint program of measures should stimulate the rational use of water resources and should make distinction between users with regard to pollution, not with regard to economic sector (thus applying polluter pays principle). Of particular importance for DIKTAS might be recommendations for integrating environmental principles in hydropower sectoral development activities. The key challenge is how to get the main players from the energy and water sector on board in order to achieve joint understanding of challenges. For this purpose, the outcome of the International Commission for the Protection of Danube River (ICPDR) activity might be used, i.e. Status report on hydropower in Danube region and guiding principles on hydropower development in the Danube region. Policy and legal mechanisms at the regional level should be implemented to ensure application of measures to prevent or limit input of pollutants into groundwater from point or diffuse sources, such as industrial agglomeration, deposition of air pollutants or permeable sewage network. On the one hand it means promoting investment in the field of wastewater collection and treatment for large and small agglomerations and on the other hand it requires introduction of provisions for remediation of contaminated soil and water in national and regional legal documents.

Another key challenge of the water governance in the region is adaptation to climate change impacts and mitigation of changes in land use on transboundary groundwater resources. Adaptation and mitigation mechanisms and establishment of adequate supervision system(s) under these processes should be reflected in national legislations and transboundary agreements. The goal is to reduce the uncertainty in predictions of groundwater quality and quantity status determination and to enhance the conceptual understanding of the (karst) aquifer system and its interactions with receptors, terrestrial and aquatic ecosystems.

Harmonization of monitoring programmes, in accordance with the WFD, is needed in order to ensure comparability and continuity with historical data from national monitoring programmes, which has great value in relation to the assessment of climate change impacts, the effects of land use change, water quality trends, and the beneficial impacts of programmes of measures.

To effectively manage problems related to the protection and sustainable use of vulnerable transboundary water resources in the Dinaric karst region, the attention of the water governance bodies has to be turned to the management of water demand by measures such as water pricing mechanisms, reduction of water losses, water reuse and recycling, increasing the efficiency of domestic, agricultural and industrial water uses, and water saving campaigns supported by public

education. Capacity building for public administration and strengthening the role of public participation in taking decisions are an absolute "must" in order to improve existing state and practice of transboundary water management in the countries. There is a general consensus that lack of human resources can significantly slow the implementation of IWRM principles in the region. Hence, it is needed to develop an efficient education system for the public administration working on (ground) water management issues, in cooperation with stakeholders.

Activities that might be launched in this regard are manifold and include the establishment of the Dinaric Karst Aquifer System Water Partnership, which may be foreseen as a platform of stakeholders for better policy/science interfacing, providing ad-hoc and permanent mechanisms for the involvement of the interested stakeholders and ensuring improved communication between decision-makers, legislators and scientists working on national or international scientific or professional (ground)water projects. This joint platform can enable a better transfer of the results of scientific investigations to target groups, namely the legislators, the decision-makers and those working in the implementation of IWRM principles in the region. It should also be possible for the decision-makers and legislators at all levels of decision-making to formulate the needs for future scientific investigations of the Dinaric Karst Aquifer System.

5 Stakeholder Analysis

The analysis of stakeholders identified different actors that could influence/affect or be influenced/affected by the Project, as well as the management of the karst aquifers in the Dinaric karst region. Representatives of a wide spectrum of stakeholder groups participated in the activities which led to the stakeholder analysis, including water management-related ministries, regional authorities and research institutions, groups associated with tourism, NGOs working with nature and ecosystems, and the private sector, industries and hydropower. In general, there has been a good representation of stakeholder groups except the ones in the tourist sector and in agriculture and animal husbandry, the latter being under-represented and consequently not identified in the analysis. The water management-related institutions - perceived by the stakeholders as the most influential actors in the field of karst aquifers management - were those best represented.

Overall, all the stakeholder groups are in favour of the DIKTAS Project and its envisaged outcomes contributing to the sustainable management of karst aquifers in the region. The industrial sector has been identified as one of the main sectors in terms of pressures exerted on the resource and along with the private sector these are the two areas to have a neutral or negative attitude towards DIKTAS' aims and objectives.

Hydropower in particular is regarded as one of the most important economic activities in the region and the second most important user in terms of exerting pressure on groundwater. It is perceived to cause significant impacts on the quantity and quality of the resource. Sustainable tourism is regarded as the foremost proposed development option for the area with the agriculture development coming second; the identified groups in the above sectors have been less engaged in karst aquifer-related actions so far.

Some of the perceived transboundary issues, such as pollution, are common in all four project countries. Unsustainable and insufficient wastewater and solid waste management –especially inadequate landfills – are recognized as the most important pressure in this regard. Pollution from industry and agriculture is also indicated as significant. It was clearly shown that there is a need for more information and education in water resources management as well as more research and scientific knowledge exchange among stakeholders. Lack of cooperation among stakeholders, institutions and initiatives at all levels is noted. The development of joint bodies and agreements is proposed. Inadequate implementation and enforcement of legislation is believed to be an issue. The harmonization of national legislations among neighbouring countries and the completion of the transposition of the EU Directives are thought to be of importance. Stakeholders from all the countries stipulate the need for improvement in the overall management of water resources, combining in this all of the above mentioned issues.

Major issues of concerns and priority actions are provided here for the most significant TBAs shared by the DIKTAS project countries, named after the related rivers/surface water bodies: Una, Cetina, Neretva, Trebišnjica, Bilećko Lake and Cemi/Cijevna.

The analysis has shown that transboundary aquifers have some unique major issues of concern and some that are shared. Specifically, TBAs Una, Trebišnjica, and Bilećko Lake share the issues of absence of a comprehensive groundwater monitoring program, including a necessary bilateral agreement and lack of a database on point and non-point sources of surface water and groundwater contamination (landfills, septic tanks, quarries, wastewater discharges and others). The lack of defined sanitary zones and uncontrolled collection and treatment of sewage water that is usually

discharged into the ground are mainly issues for the TBAs Cemi/Cijevna and Cetina. The absence of harmonized criteria for delineation of the sanitary protection zones and of legal framework for establishment and law enforcement in sanitary protection zones affects the Una, Trebišnjica, Neretva and Cetina TBAs. The lack of harmonization of regulatory framework on groundwater protection including a legal mechanism for establishment and law enforcement in sanitary protection zones of karst springs used for public water supply is an important issue for the Una, Trebišnjica, Neretva and Cetina aquifers. Tourism initiated by the existence of national parks can trigger significant economic development and additional water abstraction that needs to be planned for; this is a major issue for both the Una and Trebišnjica TBAs. Specific major issues of concern for each TBA are provided in Table 1.

Table 1. Major issues of concern for each TBA

Major issue of concern	TBA
Possible microbiological contamination of karst springs in the Bihać region (B&H) due to lack of wastewater treatment (mostly from Croatia); Possible contamination of karst springs in the Bihać region (B&H) by spills of PCBs from destroyed military installations including Željava Airport in the very state border area and Udbina which is located in Croatia; Absence of reliable data on groundwater consumption in rural areas without a centralized water supply; Existence of big cities close to TBA can project pressures on the TBAs environmentally due to extensive economic demands.	Una
Lack of water users analysis; Sanitary outflow from rural settlements is mostly unregulated (usually septic tanks that allow discharge in the ground) ; Construction of a hydro-power plant in the upper part of the Trebišnjica catchment is considered as an issue of concern by some stakeholders because of the possible change of water regime downstream.	Trebišnjica
Possible contamination of the Prud spring by nitrates, pesticides and phosphates as a result of agriculture activities in the Ljubuško Polje; Possible of contamination of the Prud spring due to the inadequate wastewater collection and treatment system of the town of Ljubuški; Possible contamination of the Neretva delta area due to the extensive use (or use of illegal types) of pesticides and fertilizers.	Neretva
Poor implementation of protection measures of drinking water in B&H; good implementation in Croatia; Possible water pollution at the springs in Croatia due to inadequate wastewater collection and treatment systems of settlements in B&H; Probable negative consequences on water quality due to the plans for developing large open pit coal mines in Duvanjsko and Livanjsko Poljes; Unregulated and/or unplanned economic activities based on the absence or abundance of water in the area.	Cetina
A concern from Montenegro is that although a part of Bilećko Lake's catchment area is in Montenegrin territory, Montenegro doesn't share benefits from the hydropower generated by using water from Bilećko Lake. Water from Bilećko Lake is used for water supply of the Herceg Novi municipality. The concern of Montenegro is that Montenegro pays a high price to the communal company of Konavle in Croatia for transfer of water to Herceg Novi.	Bilećko Lake
Lack of a sewage system in almost all the settlements in the TDA zone; A high degree of vulnerability of the karst aquifers because of the lack of vegetative cover and forests; Water exploitation and discharge without permits or control by the authorities; Lack of an appropriate drinking water system (water pipelines are local and amortized).	Cemi/Cijevna

Similarly to the major issues of concerns, some actions are proposed to one or two TBAs and some to all of them. That some actions are not proposed for a specific TBA is question of priority rather

than irrelevancy of the action (therefore 'not exclusive' in the table below). Actions that affect most TBAs are the establishment of a common groundwater monitoring program and the harmonisation of hydrological criteria for delineation of source protection zones as the basis for policy harmonisation and protection of karst springs in B&H and Croatia used for public water supply. All actions and the TBAs that these affect are provided in Table 2.

Table 2. Proposed actions and suggested TBAs where they can be performed

Proposed Action	Proposed for TBA(s), not exclusive
1. Establishment of a common groundwater monitoring program;	All TBAs
2. Improvement of wastewater treatment especially in the Bihać region	Una, Neretva (Ljubuški town)
3. Harmonisation of hydrogeological criteria for delineation of source protection zones as the basis for policy harmonisation and protection of karst springs in B&H, Croatia, Montenegro and Albania, used for public water supply;	Una, Neretva, Cetina, Bilećko Lake, Cemi/Cijevna
4. Creation of future projections of water demands depending on socio-economic analysis	Una, Neretva, Trebišnjica, Cetina, Bilećko Lake
5. Definition of common criteria for: a) delineation of the sanitary protection zones and b) for setting cost-efficient measures for groundwater protection in karst areas;	All TBAs
6. Definition of legal framework for establishment and law enforcement in sanitary protection zones	Una, Neretva, Cetina
7. Inventory of non-point and point sources of pollution (landfills, septic tanks, quarries, wastewater discharges, and others);	All TBAs
8. Establishment of regulations between the countries to set up regulatory frameworks concerning the discharge of wastewaters into the land stressing the importance of a unified policy	All TBAs
9. Fostering better control of the current agricultural and similar practices;	Neretva
10. Promotion of eco-tourism;	Neretva
11. Precise mapping of land and water usage; drafting of future utilization plans, minimizing the negative effects on water resources;	Cetina
12. Identification of the permanent and local sources of pollution in Albania and Montenegro and their influence in these countries;	Cemi/Cijevna
13. Systematic investigation of Groundwater Dependent Ecosystems (GDEs) characteristics; proposing special protection measures in a (possible) joint management plan of the Cijevna River as a joint Natura 2000 site.	Cemi/Cijevna

The major issues of concern and the proposed actions are the main input for the DIKTAS Strategic Action Program.

6 Concluding Remarks

The TDA showed that, based on the information made available to the Project Team, the state of groundwater in the DIKTAS project region is generally good in terms of both quantity and quality with a few exceptions and with a number of serious potential threats. The main threat to the overall groundwater quality in the DIKTAS region is solid waste and wastewater disposal. There are hundreds of unregulated landfills and illegal dumping sites in the four project countries. The number of wastewater treatment plants is insufficient, with about half of the population not connected to this service. For the vulnerable karst environment of the Dinaric region, which has a very limited auto-purification capacity, this is the most serious current as well as (potential) future problem. To a lesser degree, karst groundwater resources in the region are also being contaminated by agricultural and industrial activities.

Currently no common legal framework and no common criteria exist for a) the delineation of water source sanitary protection zones, and b) setting cost-efficient measures for groundwater protection in the Dinaric Karst region. This was identified as the main issue of concern in the TBAs with centralized public water supply systems: Trebišnjica, Neretva, Cetina and Una.

Stakeholder analysis revealed a pressing need for transparent, public sharing of knowledge, information and scientific data on the many unique characteristics of karst aquifers in the DIKTAS region. Stakeholders view DIKTAS as an opportunity for cooperation, networking and communication between government authorities, agencies, non-governmental organizations (NGOs) and other actors at transboundary level and, most importantly, for the harmonization of legal and karst aquifers management frameworks among the countries. Opportunities for participation in the decision-making process are also among the most widely anticipated outcomes of DIKTAS.

A major added value of the TDA is the collection and harmonisation of a large amount of data and information relevant for the assessment and management of karst groundwater resources in the region. This gathered information was not always complete and in some cases there were still significant information gaps. Nevertheless, the DIKTAS TDA was the first thorough regional groundwater analysis that covers Albania, Montenegro, Bosnia and Herzegovina and Croatia. Outputs of the TDA, including GIS materials such as thematic maps and databases, and quantitative hydrogeological analyses, form the basis for developing groundwater resources management models at both regional and local scales.

While the TDA has produced a fair assessment of groundwater resources in the region it also revealed limitations of knowledge on their actual state and trends in terms of quality and quantity. The main obstacle for this was a lack of monitoring data at both regional and local scales, such as in the vicinity of solid waste and wastewater disposal (treatment) sites, mines, intensive agriculture areas, and industrial facilities handling and generating hazardous materials. Therefore, a strong message resulting from the TDA is a request for improvement of the groundwater monitoring network throughout the region and the need to intensify capacity building in the public sector.

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