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Imotsko polje and South Dalmatia springs

EXCURSION BROCHURE

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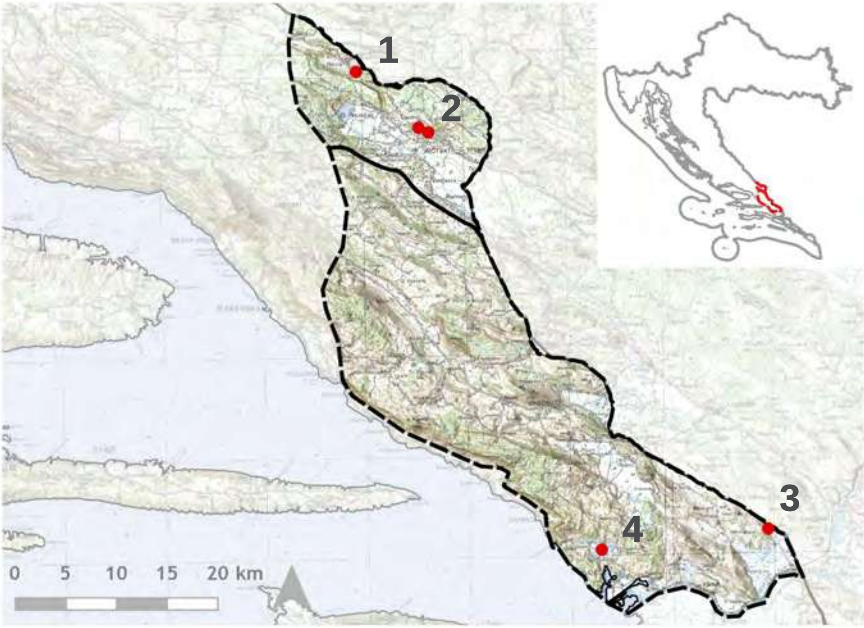

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1 IMOTSKO POLJE and RESERVOIR RIČICE

Imotsko-Bekijsko polje, typical karstic field characterized by very complex hydrogeological features, stretches parallel to Dinaric direction (NW-SE) on area of 92 km². Imotsko polje is partly located within the territory of Republic of Croatia, while the remainder is in the neighbouring Federation of Bosnia and Herzegovina. The largest settlement in this area is Imotski with 10 000 inhabitants. Several springs (Opačac being the largest one) form "the eight name river", locally called Vrljika, the largest watercourse and recipient in Imotsko polje which drains the water through ponor (swallow-hole) on the southeastern part of polje and through Pećnik tunnel towards Federation of Bosnia and Herzegovina (reoccurring in the spring area of Tihaljina and through groundwater connections in Vrgoračko polje).

Imotsko-Bekijsko polje is largely built of limestones and dolomites of Cretaceous age (145-66 Ma), characterized by fracture-cavernous porosity. The oldest deposits that form the catchment are of Lower Cretaceous age (Rajić et al., 1977). The surrounding mountains and other elevations as well as karstic plateaus are all built from well permeable limestone, while the valleys are made in the less resilient limestone-dolomitic and dolomitic rocks or in the younger, Tertiary semi-permeable and impermeable deposits. Tertiary deposits (65-2.58 Ma*), mostly consisting of flysch, lie transgressively on the Cretaceous base, while the Quaternary ones (2.58-0 Ma) are deposited in Imotsko polje. These consist mostly of alluvial deposits of sand, gravel, loam, mixed with terra rossa and humus, and in the central part of the polje Pleistocene deposits (2.58-0.01 Ma) are located - clay, gravel and sand.

As a typical karst field, Imotsko polje has numerous springs (NE part) which form complex hydrological network in asymmetrical catchment. Besides Vrljika, other notable streams are Ričina and Suvaja (which forms Prološko Blato - protected wetland area, periodically exposed to floods).

*Ma = million years ago

As a typical karst field, Imotsko polje has numerous springs (NE part) which form complex hydrological network in an asymmetrical catchment. Besides Vrljika, other notable streams are Ričina and Suvaja (which forms Prološko Blato - protected wetland area, periodically exposed to floods). The deposits in one part of the Imotsko polje represent a topographical barrier, while the major part of the polje has the function of an overhanging barrier. Quaternary deposits of the field, up to 150 m thick, of a clay-sandy composition in the part of the field around Opačac spring, have the function of a complete barrier and cause the drainage of the groundwaters that gravitate towards the field from the carbonate hinterland in the north and northeast. The most complicated hydraulic relationships are observed in the NW part of the Imotsko polje, where there are several hydrogeological phenomena of different hydraulic mechanisms at relatively low distances (Slišković, 2014).

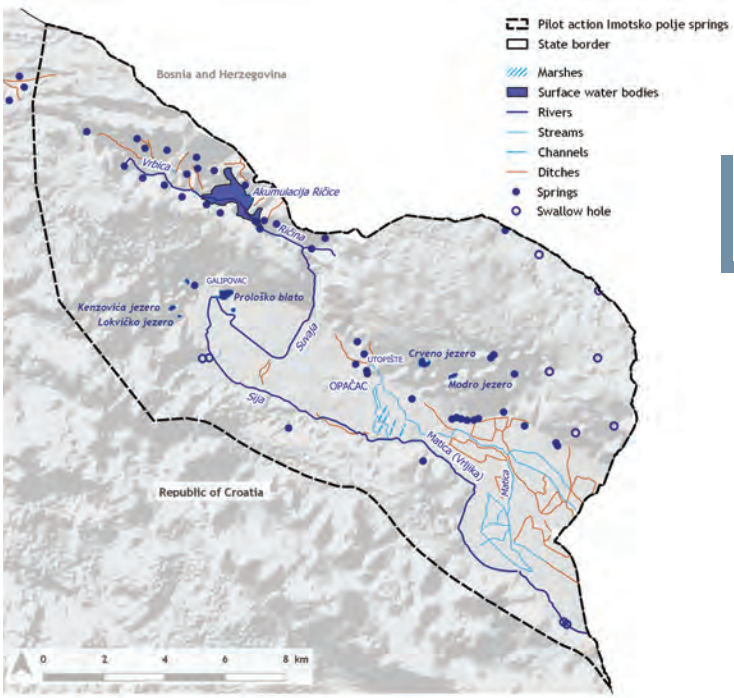

Fig. 1. Hydrographic network of the Pilot action Imotsko polje springs

Investigations have found that the springs of the Vrljika River (Opačac and others) are completely independent of nearby lakes.

Imotsko polje is faced with two basic problems: seasonal flooding and intensive agricultural activity (pollution and increased water demand). A major part of Imotsko polje was being flooded by Suvaja (Ričina) until Ričice reservoir (known as "Zeleno lake") and channel system have been built.

The construction of the multifunctional Ričice reservoir was possible due to natural conditions of wider Ričice village area, located in the valley of intermittent Ričina River and its tributary Vrbice (Bojanić and Ivičić, 1978). The accumulation area is mainly built out of Promina deposits: marl complex, marly limestones and sandstones. These deposits are entirely impermeable. Bauxite can be found in the right side of the dam and in places where older Eocene limestones (56-33.9 Ma) meet these deposits.

Fig. 2. Ričice reservoir

Limestones and limestone breccia that form the higher parts of right side of the reservoir, part of the terrain near Parlov, carbonate area Kotao and bridge across Ričina River towards Ričice, represent permeable deposits.

Tectonic cracks, fractures, channels, caverns etc. contribute to the permeability of mentioned deposits. According to the structural-tectonic observation of carbonate deposits within the accumulation area, certain parts have the predisposition for potential groundwater pathways through which water flows towards Imotsko polje. These pathways can be defined as rather permeable zones than privileged pathways (Buljan et al., 1997).

Water losses from the reservoir can be related to these permeable zones, which prevent exceeding of the foreseen maximum water level. Unfortunately, proposed observations and measurements that encompass controlled water discharge through the main outlet were not executed according to the programme. Technical solutions are required to tackle the water losses, after their location and quantity is determined.

At the time of small and medium water levels, the water losses from the reservoir lake can be linked to the most upstream carbonate part of the accumulation. The percolation also occurs in case of water level reaching the carbonates in right embankment. Without further investigation, the quantification of losses between these two areas is not possible.

Fig. 3. Ričice reservoir

2 IMOTSKI LAKES: Crveno and Modro lakes

Lakes of Imotski are a specific hydrogeological phenomena. Crveno Lake was described a number of times, but the data regarding its morphology is not consistent. Northwestern part of the Crveno Lake is almost vertical, while the southeast part has an inclination of 45 degrees. Garašić (2000) believes that the bottom of the lake is situated on -6 m below sea level, and according to Roglić (1938) the maximum registered water level was 320 m a.s.l.

Fig. 4. Crveno Lake

Modro Lake is located 550 m southeast of Crveno Lake. The lake's width is 230 m in NE-SW direction, and 90 m in NW-SE. According to Petrik (1960) the bottom of the lake is on 239 m a.s.l., and the maximum water level according to Roglić (1938) was 345 m a.s.l.

Slišković and Ivičić (1999) explain the fluctuation of water levels in these lakes and other ones located within polje with separate hydrological systems - inflow and outflow of Modro Lake through bottom and inflow and outflow through lateral channels of Crveno Lake. Two processes are happening simultaneously. The first one being dissolution and erosional destruction of the karstic underground via groundwater flow, resulting in branching out and accumulation of karstic forms.

The second process is the general relief reduction due to exogenous factors (dissolution, water, wind and ice erosion, abrasion) which causes resurfacing of the accumulated karst underground shapes.

In the Late Miocene, a rather large lake existed in the area around Imotski, with swallow holes at its SW border. Through these swallow holes the water flowed down to the existing erosional base. Subsequent neotectonic activity dissected the area and differential movements of blocks caused the desiccation of the lake and the swallow holes ceased to function. Later on, the collapse processes of the margins plugged the swallow holes which were thus transformed into very deep pit (Crveno Lake) and/or huge sinkholes (Modro Lake). It is important to note that the Crveno and Modro Lakes are unique shapes, even for karst morphology. However, from geological and hydrogeological point of view, they do not represent extraordinary karst landscape forms, because they fit into the described origin scenario of the wider geological and hydrogeological area. Their morphological grandeur is a result of huge quantity of water in time of their formation, big gradient between the water sink altitude and closest local erosional base, and the tendency of the wider area for the development of karstic hydrogeology.

Fig. 5. Modro Lake

3 KARST SPRING PRUD
4 BAĆINA LAKES

The Dinaric karst is a locus typicus for karst morphology, and it is quite famous in the hydrogeological community. It is determined by very deep and irregular karstification caused by compressive tectonics and an accumulation of soluble carbonates which can reach up to several km in thickness. The geology, tectonics, and structural framework of the Croatian Dinaric karst region have been reported in numerous publications; however, the evolution of the region is still a matter of debate and fundamental research (Vlahović et al., 2005; Velić, 2007; Korbar, 2009).

Delineation of catchments in such karstic terrains is very difficult and numerical modelling is practically impossible. Numerous methods should be applied and systems have to be divided into mutually dependent catchments and sub-catchments (Terzić et al., 2012, 2014). The Baćina Lakes have been studied recently within one scientific hydrogeological project funded by Croatian Waters (Tezić et al., 2015) - together with limnological research, and partially within the Drinkadria project (funded by EU within IPA Adriatic Programme) and still ongoing PROLINE-CE project (funded by EU within Interreg CE Programme). Preliminary results have been reported in a few publications (Lukač Reberski et al., 2016, 2016a; Terzić et al., 2015a).

The Prud karst spring and Baćina Lakes belong to the discharge zone common to both the South-Dalmatian and West-Herzegovinian Dinaric karst catchments. Although the Prud spring is situated in Croatia, most of its catchment is in Bosnia and Herzegovina, which raises transboundary issues considering groundwater protection zones and water use. The spring is used for extraction for the water supply of Metković town, and also the more widespread water utility NPKL (Neretva River - Pelješac Peninsula - Korčula Island - Lastovo Island). The water is generally of decent quality, and only concentrations of sulfate ions are increased, as a consequence of the dissolution of gypsum and anhydrites in the Herzegovinian underground.

Fig. 6. Prud spring

Fig. 7. Prud spring

The Baćina Lakes are situated to the south of the Prud spring, close to the Adriatic Sea coast near the town of Ploče. They are composed of seven lakes (Crniševo, Očuša, Podgora, Vrbnik, Sladinac, Vitanj and Plitko). Within their zone there are several springs, and also a tunnel which drives water from the upper zones (karst polje Jezero near Vrgorac; constructed in 1938) and the tunnel which drains water from the lakes into the sea (constructed in 1913). The deepest lake of Crniševo is subject to the underground influence of seawater penetration, and is also polluted by local waste disposal.

Fig. 8. Tunnel from Baćina Lakes to Vrgoračko polje

Close to the lakes there is the Klokun karst spring, which is used as a water supply source for Ploče town and its surroundings.

The discharge zone spreads from the right boundary of the Neretva river valley. The first spring in Croatia is the Prud, then there are several karst springs, especially in the Desne area with Modro oko (local water supply) as the most important one. Close to the Baćina Lakes and the zone finishes with the coastal spring Mandina mlinica, after which the flysch rock barrier influences the groundwater flow, also preventing extensive penetration of seawater into the aquifer. Therefore, after Mandina mlinica there is no important karst spring or vrulja (submarine spring) for over 50 km along the coast of the Adriatic Sea.

Fig. 9. Baćina Lakes

Hydrogeological relationships in this karst terrain are very complex and interrelated. Although there has been lots of exploration to date (including tracing experiments), many uncertainties and problems with interpretation still exist. Groundwater, surface flows which sink and reappear, karst springs, poljes, estavelles, vruljas and swallow holes, speleological features, and their mutual relationships represent big challenges for hydrogeological researchers even today (Bonacci et al., 2013; Ivičić, 2000; Slišković, 2014; Terzić et al., 2015).

Fig. 10. Baćina Lakes

Within the most recent study, this big catchment area (total surface 1757 km^2) was taken as a hydrogeological system and divided into several sub-catchments which interrelate depending on any given moment in a hydrological cycle. To make this terrain even more complex, there are quite a lot of man-made interventions: a network of canals in karst poljes, tunnels draining water from karst poljes, and artificial barriers such as small dams. This recent delineation has to consider big parts of terrain in Bosnia and Herzegovina, although most of the hydrogeological and hydrochemical exploration has been performed in Croatia.

All these issues raise questions of transboundary protection of spring water which is being extracted for public water supply use (Prud, Klokun, Modro oko, Butina, Banja). **Generally, the water is of good quality, and the hydrochemical facies vary from the Ca-HCO3 type (usual for karst waters), to somewhere close to Na-Cl (mixing with the sea in coastal zones) or Ca-SO (proof of sulfate rocks).** This research is being continued and particular importance will be given to stable isotope measurements, especially establishment of the local meteoric water line (LMWL) because there has been no such research in this area before.

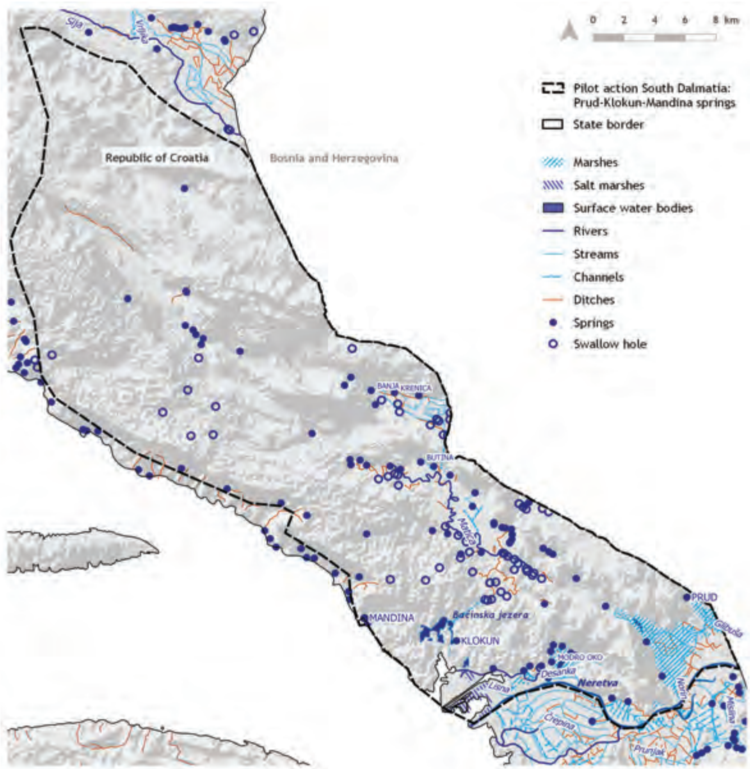

Fig. 11. Hydrographic network of the Pilot area South Dalmatia: Prud, Klokun and Mandina springs

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Fig. 12. Flooded Vrgorac polje

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Fig. 13. Vrgorac polje

PROLINE-CE project

Efficient Practices of Land Use Management Integrating Water Resources Protection and Non-structural Flood Mitigation Experiences

The main objective of PROLINE-CE is to improve the protection of drinking water resources as well as protecting regions against floods and droughts in an integrated land use management approach.

Project duration
01.07.2016 - 30.06.2019

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13 financing partners and 5 associated partners, originating from 8 central European countries

Project budget
€2.750.209 in total, €2.267.296 ERFD funding

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