PROLINE-CE

WORKPACKAGE T2, ACTIVITY T2.2

IMPLEMENTATION OF BEST PRACTICES FOR WATER PROTECTION IN PILOT ACTIONS

D.T2.2.2 PARTNER-SPECIFIC PILOT ACTION DOCUMENTATIONS

PILOT ACTION: PA2.4 Groundwater protection in karst area

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1. Introduction

Best management practices (hereinafter BMPs) for drinking water protection and management derived from T1 were reviewed and relevant BMPs were selected for particular pilot action. Implementation status of BMPs was verified in Pilot Actions (T2); in case of lacks identified, possibilities of improvement and implementation were also assessed. Drinking water protection and management and best practices are strategically implemented in the pilot actions, in order to achieve a function-oriented land-use based spatial management for water protection at the operational level. Measures and actions were analysed and proposed concerning mitigation of extremes and achieving a sustainable drinking water level. PROLINE-CE pilot actions reflect the broad range of possible conflicts regarding drinking water protection, such as: forest ecosystem service function; land-use planning conflicts; flooding issues; impact of climate change and land-use changes; demonstration of effectiveness of measures including ecosystem services and economic efficiency.

Review of main land use conflicts and BMPs on Pilot Action level has already been done in Pilot Action BMPs reports, which were a basis for *D.T2.1.2 Transnational case review of best management practices in pilot actions*. Description of natural characteristics of Pilot Site is presented in *D.T.1.4 Descriptive documentation of pilot actions and related issues*.

Activities within Pilot Action were done according to set-up which was described in *D.T2.1.5 Set-up report about adaptation of the transnational concept to pilot action level*.

The Deliverable *D.T2.2.2 Partner-specific pilot action documentations* presents final Pilot Action report regarding the management actions examined in the Pilot Action, description of conducted activities and identified solutions for case-specific adaptations of management concepts. This report presents final work report regarding the implementation of best management practices for drinking water protection in pilot action PA2.4 Groundwater protection in karst area. Pilot action activities in PA2.4 were performed in two adjacent test areas: 2.4.1 – South Dalmatia: Prud, Klokun and Mandina spring and 2.4.2 – Imotsko polje springs.

2. Testing of BMPs in Pilot Action

2.1. Objective(s) of Pilot Action

The karstic fields, due to their natural characteristics, represent rare areas in the karst where there is a surface water flow yet at the same time they are very suitable for agricultural activity. Given the fact that agricultural activity has a negative impact on both quality and quantity of water, karst fields represent a major challenge for water management and protection.

The pilot actions have several major issues, the most important being: field flooding, intensive agricultural activity, deficiencies in the sewage and waste water drainage systems, illegal waste dumps, water supply system losses, lack of sanitary protection zones, climate predictions for these areas point to a great possibility of substantial loss of water resources, public negligence to water protection. Due to all of this, concentrated monitoring of water quality and quantity is mandatory, as well as regular sampling and general public awareness raising activities.

2.2. BMPs of Pilot Action

▪ Identified GAP provoking action	
GAP short name	**Increased water demand**
GAP short description	Agricultural production that is purely conventional in this area presents the greatest negative impact both on the quality and quantity of the water resources. The main polluting agents (nitrates, phosphates, chemical residues and insoluble mineral particles) are generated by excessive application of fertilisers to crop fields, by use of fertilisers inadequate for crop cycles and by inappropriate tillage or irrigation practices. Water for the purpose of irrigation is used from watercourses (Neretva) or from mixed melioration systems for drainage and irrigation of closed karstic fields (Vrgoračko polje). Smaller part of the water used for irrigation comes from groundwater sources hence the need to monitor its quality. Agricultural production currently covers around 1,500 ha in Imotsko polje and is expected to increase to 3,330 ha after the construction on irrigation and melioration system (IM-BE Field project). Irrigation system will drastically change agricultural production, accompanied by intensification of production of fruits, vegetables and arable crops, hence increasing water demand.
▪ Best management Practice / Management Action	
Name of BMP	**Establishment of groundwater level monitoring network in Imotsko polje and South Dalmatia**

Type of land use regarded	Agriculture	
Location	Croatia, Pilot action Imotsko polje springs and South Dalmatia: Prud, Klokun, Mandina springs	
BMP description	Profitable agricultural production (of fruit and vegetables) causes increased pressure on water quantity, so it is necessary to establish groundwater level monitoring network. Proposed monitoring networks includes several stations (piezometers) located in: • Prološko blato – protected wetland area, floodplain karst field, which could be endangered due to drainage related to expansion of agricultural land. • Opačac – largest spring of Vrljika River, the largest watercourse and also the main recipient of Imotsko Polje. Opačac spring is captured by the water supply of Imotski and surrounding towns and villages. • Bosnia and Herzegovina – Imotsko polje stretches into neighbouring country (west Herzegovina, Bekijsko polje), therefore it is necessary to establish cross-border monitoring since transboundary catchment area size is not negligible and plays important role in water balance of Imotsko polje. • Upper part of the Vrgoračko polje (Butina spring) • Estavellas around Staševica • Sinkhole zone in the southeast part of the Vrgoračko polje	
Advantages of this BMP in PA	Since there is no monitoring of groundwater levels in pilot areas, this BMP will drastically reduce uncertainties, predict long term stresses on water balance in pilot area, support climate change data and evaluate impacts of new infrastructure on groundwater levels.	
Challenges of this BMP in PA	The main challenge is relatively high costs connected with establishment of monitoring systems, especially if it involves drilling of new boreholes. Decision makers and financiers (e.g. county, community) must be addressed adequately in order to realise the long term importance of establishing a monitoring network.	
Relevance	Water protection functionality	Medium to high
	Cost of the measure	Medium to high (site specific)
	Duration of implementation	Short term
	Time interval of sustainability	Long term
Limitations	There are no technical limitations connected to this BMP, but financing could pose a problem.	
Implementation of	This BMP has not yet been implemented in pilot area but will be suggested to	

the BMP in PA	stakeholders through meetings and consultation.
Comments	Related BMPs for further consideration: increase of irrigation efficiency (reduction of losses, efficient systems – sprinkles or drips), prevention of illegal connections to water systems, subsidies for efficient and good agricultural practices or cultures that require low amount of water or vineyards which require no irrigation.
References / sources	

▪ Identified GAP provoking action	
GAP short name	**Periodic field flooding**
GAP short description	Large part of Imotsko polje is regarded as an area of potentially significant flood risk. Around 70% of area is exposed to periodic floods of variable intensity and duration. South-eastern part of Imotsko polje is exposed to flooding primarily due to the operation of HPP Peć-Mlini in neighbouring Bosnia and Herzegovina. Several facilities were built for flood mitigation (Prološko blato retention, Ričica accumulation, channels). Considering large catchment area (and Vrljika river as main recipient of all internal waters in Imotsko polje), non-structural flood defence measures (e.g. protective forests) could only have limited effect, especially during severe meteorological events (FAO and CIFOR, 2005). Despite structural flood defence measures, Vrgoračko polje is still exposed to significant flood risk. Tunnel which connects Rastok (upper polje) to Jezero (lower polje) is not in function, so floods occur frequently during rainy season. Lower polje (Jezero) drains excess waters towards Baćina lakes via Krotuša tunnel, and then the excess water from the lakes is drained towards the sea via another tunnel.
▪ Best management Practice / Management Action	
Name of BMP	**Infrastructure maintenance and reconstruction / Non-structural flood mitigation measures**
Type of land use regarded	All
Location	Croatia, Pilot action Imotsko polje springs and South Dalmatia: Prud, Klokun, Mandina springs
BMP description	In order to reduce property and agricultural damage caused by floods, it is necessary to reconstruct and regulate existing infrastructure. This is partly intended with project IM-BE Field (new irrigation system in Imotsko-Bekijsko polje). Focus should be put on reconstruction of Pećnik tunnel and downstream regulation (Trebižat/Tihaljina river). In order to achieve this, cross-border cooperation and joint action is necessary. Furthermore, all existing infrastructure needs cleaning, which hasn't been done since the infrastructure was constructed. A new tunnel is planned which would drain

	excess waters from Vrgoračko polje towards Birina lake. Such a tunnel would also improve ecological state of Birina lake. Furthermore, all existing infrastructure needs cleaning, which hasn't been done since the infrastructure was constructed. Concerning non-structural aspects of flood defense, focus should be laid on awareness raising and adaptive strategies. One way to achieve this is to encourage cultivation of annual plants or vineyards (and prevent land use changes). Flooding of well-drained soil types, where water disappears in one or two days, usually has no significant impact on vine growth. Vines are resilient and can return to production in the following season even if soil waterlogged and roots die due to lack of oxygen. Furthermore, establishment of protective forests could be beneficial on small scale application (e.g. some parts of Imotsko polje). According to FAO and CIPHER (2005), forest cover may influence small to moderate floods in small catchments (<10 km^2), but usually has little influence in large catchments (>10 km^2) or during severe meteorological events. From the point of land use, south-eastern part of Imotsko polje is characterized by vineyards, urban fabric and complex cultivation patterns. Increasing the portion of e.g. broad-leaved forests, could help mitigation floods by means of water use by trees and the "sponge effect". Forest soils tend to have a more open structure resulting from greater amounts of organic matter, the action of tree roots and soil fauna. The presence of a network of macropores helps to transmit water quickly to depth, reducing the likelihood of surface saturation and rapid run-off (Nisbeth and Thomas).	
Advantages of this BMP in PA	Reduced damage to population, property and agriculture, increased cross-border cooperation and harmonized action in flood mitigation, long term effects on flood mitigation, financial savings (loss avoidance).	
Challenges of this BMP in PA	Main problem is downstream regulation and maintenance of infrastructure (Trebižat/Tihaljina river). Poor trans-border cooperation is a scenario that must not be disregarded. Non-structural measures are usually harder to implement because of indirect effects, and usually they require more time to be effective. Besides that, financial incentives are lacking so it is unclear at the moment who whould provide stimulus for afforestation or land use change in pilot area.	
Relevance	Water protection functionality	High
	Cost of the measure	High
	Duration of implementation	Short/medium term
	Time interval of sustainability	Long term
Limitations	Lack of trans-border cooperation, lack of funds	

Implementation of the BMP in PA	A first step towards the implementation of this BMP, will be the stakeholder involvement actions (authorities, local community, economic subjects etc.) through which an educative brochure encompassing all relevant gaps and proposed solutions/measures will be disseminated.
Comments	
Referencs / sources	https://www.sttas.com.au/sites/default/files/media/documents/forestsprotectionfromfloodingroberts.pdf https://www.wineaustralia.com/getmedia/4ddeda8b-d142-4b01-8ead-5ef41ca55ed4/2012-flooded-vineyard-case-studies.pdf https://www.forestry.gov.uk/pdf/woodland_flood_control_iale_paper_2006.pdf/$FILE/woodland_flood_control_iale_paper_2006.pdf https://www.dalmacija.hr/Portals/0/docs/UOZastitaOkolisa/dokumenti/Rje%C5%A1enje/rje%C5%A1enje%20-%20hrvatske%20vode%20-%20vrgorsko%20polje0001.pdf https://www.wineaustralia.com/getmedia/4ddeda8b-d142-4b01-8ead-5ef41ca55ed4/2012-flooded-vineyard-case-studies.pdf https://www.forestry.gov.uk/pdf/woodland_flood_control_iale_paper_2006.pdf/$FILE/woodland_flood_control_iale_paper_2006.pdf

▪ Identified GAP provoking action	
GAP short name	**Insufficient number of proclaimed drinking water protection zones on valuable springs in South Dalmatia**
GAP short description	The sanitary protection zones in the area of research have been proclaimed only for the Prud spring and for smaller springs of Grebica, Vrutak, Orašje and Izbitac located in the northwestern edge of the investigated area. For other springs used for water supply, sanitary protection zones have not yet been established. Although every spring/well in Croatia used for water supply should have defined sanitary protection zones, the existing Ordinance on determination of sanitary protection zones still does not have legal authority and it is impossible to initiate court proceedings in cases where no sanitary protection zones are established.
▪ Best management Practice / Management Action	
Name of BMP	**Defining and establishing sanitary protection zones in South Dalmatia**
Type of land use regarded	All
Location	Croatia, Pilot action South Dalmatia: Prud, Klokun, Mandina springs
BMP description	Determination of drinking water protection zones (DWPZ), obligatory measures and limitations that are conducted in them as well as the deadlines for

	decisions on protection and the process of making these decisions are governed by The Ordinance on the conditions for the establishment of sanitary protection zones (Official Gazette No. 66/11 and 47/13). Established sanitary protection zones are implemented into spatial planning documents (spatial plans of counties, cities or municipalities). Within recent studies, it has been established that the Vrgoračko polje, which is intensively farmed, belongs to the second zone of sanitary protection (according to the valid Ordinance). This fact should encourage the local population to turn to ecological farming because such production prohibits the use of most mineral fertilizers and almost all pesticides whose use is prohibited.	
Advantages of this BMP in PA	For the purpose of protection of surface and groundwater resource and unique and valuable ecosystems dependent on water, protected areas are established by the Water Act and other legislatives for the common good of the community. By protecting the drinking water sources, strategic natural resources are secured.	
Challenges of this BMP in PA	Since the Ordinance on determination of sanitary protection zones does not have any legal authority, the greatest challenge would be to implement penalties.	
Relevance	Water protection functionality	High
	Cost of the measure	Medium
	Duration of implementation	Long term
	Time interval of sustainability	Long term
Limitations	Unwillingness of people to cooperate and no legally binding obligations to abide by pose a serious threat to the administration of the measures.	
Implementation of the BMP in PA	It has not been implemented yet and for its success needs educational activities for the local community.	
Comments		
References / sources		

▪ Identified GAP provoking action	
GAP short name	**Insufficiently effective waste water treatment system that needs to be reconstructed and expanded**
GAP short description	Currently, sewage system exists only in the area of Imotski and settlment Donja Glavina. The system is outdated, and only 25-30% of population is connected to it. Urban waste water treatment facility, located in Donja Glavina, was built during 1980's (II. level of purification, capacity 10.000 PE). Surrounding settlements and villages do not have adequate sewage network

	nor the connection to waste water treatment facility. Such waste waters are disposed into surface waters, septic tanks and groundwaters, causing pollution (e.g. pathogens).
▪ **Best management Practice / Management Action**	
Name of BMP	**Natural waste water treatment system**
Type of land use regarded	Urban
Location	Croatia, Pilot action Imotsko polje springs
BMP description	Plant purification systems have been in use for the past 50 years and have proven their efficiency in comparison to other treatment methods. They represent artificial swamps that simulate natural purification processes. The waste water is completely purified via biological, chemical and physical processes (aerobic and anaerobic decomposition, evaporation, sedimentation and plant incorporation). Almost all organic and mineral components are removed, as well as toxic compounds and bacteria of various origin. Swamp plants such as common reed (*Phragmites australis*), broadleaf cattail (*Typhia latifolia*), yellow flag iris (*Iris pseudacorus*) etc. are grown on the substrate whose roots penetrate the soil and further stabilize the substrate. The roots offer an expanded surface for the development of microorganisms, the plants partly embed the toxic components (phosphorous and nitrogen) and the dead vegetation offers heat isolation during the winter that disables the freezing of water in the substrate.
Advantages of this BMP in PA	Natural waste water treatment systems cost three times lower price than common purification methods, and they are also easy to maintain. High degree of purification (in summer 90-99%, winter 70-80%) is accomplished with no energy or machinery required. These systems adapt well to the environment and they produce no foul smells. Sludge produced from these systems can be used in compost production.
Challenges of this BMP in PA	Extensive land surface needed for the method (up to 5 m^2 per PE), favourable terrain incline, system sensitivity to oxygen levels, weed control in the early stages.
Relevance	Water protection functionality: High
	Cost of the measure: Medium to high (depending on the size)
	Duration of implementation: Medium
	Time interval of sustainability: Short term
Limitations	Relatively high price (which is also case with other purification methods)
Implementation of the BMP in PA	A first step towards the implementation of this BMP, will be the stakeholder involvement actions (authorities, local community, economic subjects etc.) through which an educative brochure encompassing all relevant gaps and proposed solutions/measures will be disseminated.

Comments	The first system in Croatia was built on the island of Cres for 330 PE in 2001 and has high purification success rate. Another successful implementation example is city of Vrlika, Croatia.  **Figure 1: Example of natural waste water treatment system.**
References / sources	Figure 1. https://greentumble.com/natural-wastewater-treatment-systems/

▪ Identified GAP provoking action	
GAP short name	**Unsanitary and illegal waste disposal**
GAP short description	Split-Dalmatia County is on a second place concerning the total produced quantity of municipal waste (246,396 t) in The Republic of Croatia, right after the City of Zagreb. It is also one of the worst counties in Croatia concerning municipal waste recovery, with a rate of only 11.3%. Due to inappropriate waste management such as unsanitary waste disposal and numerous illegal disposal sites in the wider Pilot Action area, not only that are soil, surface water and groundwater endangered, but the potential pollution poses a grave threat to human health. Even though waste management plans on country and county level envisaged various measures of waste reducing, recycling and separate collecting, their implementation in practice is still lacking, especially due to inefficient allocation of tasks and insufficient coordination between different administrative levels. According to the initiative "Čisto podzemlje (Clean underground)" of Croatian speleologists there is at least one location within pilot action Imotsko polje and eight confirmed locations within pilot action South Dalmatia where municipal waste was illegally dumped into speleological objects such as

	karstic pits and caves, but also in swallow holes and springs. In Krčevac spring, which is a documented habitat of an endemic species *Proteus anguinus*, around 3 m^3 of waste (car tyres, oil canisters etc.) was illegally disposed. Furthermore, Kozjačić the main landfill of wider Imotsko polje area is actually an unsanitary dump without proper barrier liner system, gas venting and leachate collection systems. The landfill remediation process is in preparation stage. Ajdanovac and Lovornik landfills in South Dalmatia are actually unsanitary dumps without proper barrier liner and cover systems, gas venting and leachate collection systems. The remediation process of both mentioned landfills is in preparation stage. The case of Lovornik landfill is an example of insufficient coordination and cooperation among different administrative levels (ministry-city-municipality level). The remediation process of this landfill was prolonged due to issues with property rights which dated back to 2008 according to the official City of Ploče news (2017).
▪ **Best management Practice / Management Action**	
Name of BMP	**Educative brochure and awareness raising activities**
Type of land use regarded	Urban
Location	Croatia, Pilot action Imotsko polje springs and South Dalmatia: Prud, Klokun, Mandina springs
BMP description	An increase of environmental awareness through educative brochure and local community and economic subjects' involvement actions are a prerequisite for the sustainable waste management. It should be emphasized how illegal waste disposal in karstic pits, swallow holes and springs directly affects the groundwater, its vulnerable ecosystems and consequently human health. A clear and easy to understand illustrations of these negative impacts should be primarily given to economic subjects who deal with waste materials but also to local communities which should be promptly informed on all relevant waste management activities. To ensure long-term benefits from an environmental, economic and social perspective, the engagement in recycling, reusing and reducing waste activities ought to be encouraged on a consumer level.
Advantages of this BMP in PA	Raising awareness among local communities, opens up the possibility of positive change in their behaviour and current habits and by doing so increases the likelihood of environmentally friendly activities which could indirectly reduce negative impacts on water resources.
Challenges of this BMP in PA	Selecting a suitable and effective approach to initiate stakeholder's involvement and motivate them to apply environmentally safe practices.
Relevance	Water protection functionality — Medium

	Cost of the measure	Low-medium (depending on the scope of activities)
	Duration of implementation	Short term
	Time interval of sustainability	Long term
Limitations	Unwillingness of the local community to adopt new environmentally friendly habits as a consequence of insufficient education on environmental issues and lack of government stimulations.	
Implementation of the BMP in PA	A first step towards the implementation of this BMP, will be the stakeholder involvement actions (authorities, local community, economic subjects etc.) through which an educative brochure encompassing all relevant gaps and proposed solutions/measures will be disseminated.	
Comments	Programme of educative-informative activities on sustainable waste management prescribe educative flyers and brochures, educative workshops, TV and radio broadcast on sustainable waste management (recycling, separate collecting, reuse etc.) as the activities which local self-government units are bound to conduct.	
References / sources		

▪ Identified GAP provoking action	
GAP short name	**Unsanitary and illegal waste disposal**
GAP short description	Split-Dalmatia County is on a second place concerning the total produced quantity of municipal waste (246,396 t) in The Republic of Croatia, right after the City of Zagreb. It is also one of the worst counties in Croatia concerning municipal waste recovery, with a rate of only 11.3%. Dubrovnik-Neretva County stands with 17.4%. Due to inappropriate waste management such as unsanitary waste disposal and numerous illegal disposal sites in the wider Pilot Action area, not only that are soil, surface water and groundwater endangered, but the potential pollution poses a grave threat to human health. Even though waste management plans on country and county level envisaged various measures of waste reducing, recycling and separate collecting, their implementation in practice is still lacking, especially due to inefficient allocation of tasks and insufficient coordination between different administrative levels. According to the initiative "Čisto podzemlje (Clean underground)" of Croatian speleologists there is at least one location within pilot action Imotsko polje and eight confirmed locations within pilot action South Dalmatia where municipal waste was illegally dumped into speleological objects such as karstic pits and caves, but also in swallow holes and springs.

▪ Best management Practice / Management Action		
Name of BMP	**Encourage and promote innovative solutions of sustainable waste management**	
Type of land use regarded	Urban	
Location	Croatia, Pilot action Imotsko polje springs and South Dalmatia: Prud, Klokun, Mandina springs	
BMP description	Encouragement and promotion of innovative solutions for sustainable waste management such as: applications for smartphones which educate and help citizens with separate waste disposal and recycling or allow them to report illegally disposed waste, damaged waste infrastructure etc.; online databases with all relevant info on waste management activities (active or closed landfills, landfills in remediation process, dump sites etc.).	
Advantages of this BMP in PA	Innovative solutions are vital for the future of waste management and its synergy with the environment. Innovative app-based technology could help to increase community involvement in a sustainable waste management process.	
Challenges of this BMP in PA	Selecting a suitable and effective approach to initiate stakeholder's involvement and motivate them to apply environmentally safe practices.	
Relevance	Water protection functionality	Medium
	Cost of the measure	Low
	Duration of implementation	Short term
	Time interval of sustainability	Long term
Limitations	Unwillingness of the local community to adopt new environmentally friendly habits as a consequence of insufficient education on environmental issues and lack of government stimulations.	
Implementation of the BMP in PA	A first step towards the implementation of this BMP, will be the stakeholder involvement actions (authorities, local community, economic subjects etc.) through which an educative brochure encompassing all relevant gaps and proposed solutions/measures will be disseminated.	
Comments	Programme of educative-informative activities on sustainable waste management prescribes the making of a smartphone application for sustainable waste management as one of the activities which local self-government units are bound to conduct.	
References / sources	An online web page on the activities for waste reduction by Croatian Agency for the Environment and Nature: http://sprjecavanjeotpada.azo.hr/ Free online application for waste sorting and proper disposal: https://www.razvrstaj.me/hr/ e-ONTO or Register on waste generation and its cycle (from the producer to disposal site) by Croatian Agency for the Environment and Nature:	

	http://eonto.azo.hr/#/Ulaz Online map viewer of speleological object with illegally disposed waste: http://www.cistopodzemlje.info/?q=map Some examples of smartphone applications for separate waste collecting and reporting on illegally disposed waste locations, developed on city level: "ZelenKO" and "E-otpadnici".

▪ Identified GAP provoking action	
GAP short name	**Pressure on water resources quantity**
GAP short description	Climate change in form of droughts, floods, shorter winter season with reduced snow cover, in general change of the timing of seasonal events etc., will drastically affect freshwater resources. This problem is enhanced by high losses in water supply in Croatia – 42% national average, while pilot area is one of the worst supply areas in the country – with losses up to 80%.
▪ Best management Practice / Management Action	
Name of BMP	**Climate change adaptation and resilience / Reconstruction of public water supply network**
Type of land use regarded	All
Location	Croatia, Pilot action Imotsko polje springs and South Dalmatia: Prud, Klokun, Mandina springs
BMP description	Croatia has recently developed drafts for CC Adaptation Strategy 2040-2070 and Action Plan 2019-2023 which serve as a basis for future mitigation action against CC. Roughly speaking, measures be divided into 2 categories (Rubinić, 2017): • Initial measure – to minimize the presence of negative anthropogenic pressures • Administrative measures: rationalization of water consumption and water re-use wherever possible; promoting alternative sources of water; spatial planning measures for mitigation of flood effects in flood prone areas; monitoring and modelling projections; improvements in legal regulations • Structural measures: reduction of losses from water supply network; construction and revitalization of accumulation structures; construction of thresholds in the basin to stabilize the water level in river/lake bed and the surrounding aquifer; construction of retention objects in flood prone areas; control of surface runoff in urban environment (construction of separate systems for meteoric water and sewage); construction of green retention and infiltration zones, green roofs, urban retention and accumulation

Advantages of this BMP in PA	A timely reaction and development of CC adaptation plans benefits all ESS and population, therefore, it is a prerequisite for freshwater availability of future generations. Furthermore, adaptation plans, and strategies could save money in the long run due to prevention, instead of intervention.	
Challenges of this BMP in PA	Raising awareness on the climate change and adaptive management practices among relevant stakeholders Financial support in form of subsidies for adaptation	
Relevance	Water protection functionality	High
	Cost of the measure	High
	Duration of implementation	Long term
	Time interval of sustainability	Long term
Limitations	Lack of funds, long implementation periods, low awareness of key stakeholders	
Implementation of the BMP in PA	A first step towards the implementation of this BMP, will be the stakeholder involvement actions (authorities, local community, economic subjects etc.) through which an educative brochure encompassing all relevant gaps and proposed solutions/measures will be disseminated.	
Comments		
References / sources	Ministry of Environment and Energy project - http://prilagodba-klimi.hr/ Drinkadria - http://www.drinkadria.eu/ CC Waters - http://www.ccwaters.eu/	

3. Activities in the Pilot Action

3.1. Hydrogeological field investigations

Since July 2017, experts from Department of Hydrogeology and Engineering geology are conducting hydrogeological field investigation on numerous springs and water courses in pilot areas. Locations of regular monthly sampling are: Opačac, Banja, Krenica, Butina, Klokun, Modro oko, Mandina mlinica, Čeveljuša, Prud and Neretva (Metković). Several sampled springs are used for public water supply. Furthermore, for stable isotope analysis, rain collectors are installed at: mount Biokovo, Makarska, Dubrovnik, Opačac and Butina.

Investigations include field measurements: physio-chemical conditions (temperature, water level, pH, resistivity, electrical conductivity, oxygen levels, bicarbonates concentration) and laboratory measurements (atomic absorption spectrometry, ion chromatography, stable isotope

analysis). The purpose of these investigations is to improve protection of drinking water resources by defining complex hydrogeological properties of karst catchments.

3.2. Modelling

Hydrological modelling of potential climate change impacts on water resources (their quantity in particular) was conducted in the pilot actions (see: PROLINE-CE D.T2.3.3. "PA reports about climate change issues in pilots"). The presumed size of the catchment area and an analysis of previous hydrological observations (discharge, precipitation and air temperature) were used as an input data. The hydrological model consists of climate changes projections based on the regional climate models (RCM), namely Aladin (Bubnova et al., 1995), RegCM3 (Pal et al., 2007) and Promes (Castro et al., 1993), while Turc (1954) and Langbein (1962) methods were used to acquire average annual discharges.

All 3 models estimate that the air temperatures in the analysed catchment area are steadily increasing: RegCM3 (0.28°C/100 years), Promes (1.4°C/100 years). In reference to the 30-year historical period (1961-1990), it is expected that the average annual temperature could increase between 0.2 and 0.4°C until 2020, while an increase between 0.1 and 0.9°C is expected until 2050, where the greatest rise is developed according to the Promes model.

Regarding the precipitation, small trends of precipitation reduction have been observed, the smallest is in the Aladin model (57.8 mm/100 years) and the highest in the Promes model (131.8 mm/100 years). When the 30-year period is compared throughout the models, a decrease of order of magnitude 100 mm is observed. And concerning precipitation extremes, a significant decline is expected up to 2050 for about 200 – 250 mm, as well as the reduction of precipitation during intense droughts for about 100 mm.

Average annual discharge from the karst Dalmatia area, calculated based on the average discharge values according to Turc and Langbein methods, have a reduction trend. The evaluation results of the characteristical 30-year averages for the planned future 30-year periods are similar in relation to the historical period 1961-1990. The decrease of the water balance input of the analysed area is expected for about 10% in average annual discharge data sets. The most emphasized reduction of the average annual inflows is according to the Promes model. Extreme annual discharges are expected more frequently in the future with an increase of the highest and lowest annual values, especially in the last 30-year period (2021-2050). According to the projections and the analysis of historical discharge data, the most significant values appeared during the period from the 1980s up until the extreme droughts in 2011 and 2012.

3.3. Solutions for case specific adaptation of best management practices

Table 1: GAPs and proposed BMPs with recommendations for implementation in Pilot Action.

Actual management practice (GAP)		Increased water demand	Pressure on water resources quantity
Proposed BMP		Establishment of groundwater level monitoring network in Imotsko polje and South Dalmatia	Climate change adaptation and resilience / Reconstruction of public water supply network
Proposed solutions and recommendations	adaptation of existing land use management practices	If BMP is implemented, more efficient use of water in agriculture could be achieved. On the basis of new findings, agricultural stress on groundwater could be quantified and if necessary, land use change could be prevented.	Aim of measures is to mitigate negative effects of CC, therefore to prevent negative land use change and spreading of concrete surfaces. Instead, green retention and infiltration zones must be designated
	Adaptation of existing flood/drought management practices	Groundwater monitoring network will reduce uncertainty and could enable better responses and management action in case of floods and droughts	Flood management practices should include further construction of retention objects in flood prone areas. Agricultural production must adapt to upcoming CC scenarios and prolonged droughts by rationalizing water consumption and making it more effective
	Adaptation of policy guidelines	Relevant for water market: if necessary, revisions of payments, schemes and quotas	CC Adaptation Strategy 2040-2070 and Action Plan 2019-2023 provide good guidelines for adaptation and resilience for CC. Local authorities should incorporate it in local plans and strategies
Remaining issues to be solved		The measure is simple, but requires funding sources, which is unclear at the moment	First step is raising awareness on the climate change and adaptive management practices among relevant stakeholders. A timely reaction and development of CC adaptation plans benefits all ESS and population, therefore, it is a prerequisite for freshwater availability of

		future generations. Furthermore, adaptation plans, and strategies could save money in the long run due to prevention, instead of intervention.

Actual management practice (GAP)		Unsanitary and illegal waste disposal	Unsanitary and illegal waste disposal
Proposed BMP		Educative brochure and awareness raising activities	Encourage and promote innovative solutions of sustainable waste management
Proposed solutions and recommendations	adaptation of existing land use management practices	Not relevant	Not relevant
	Adaptation of existing flood/drought management practices	Not relevant	Not relevant
	Adaptation of policy guidelines	Policy guidelines are good, penalties are prescribed for illegal waste dumping, but inspections are poor, and misdemeanour is not punished	Innovative solutions for waste management are not mandatory, but rather an option. However, positive management examples can serve as a catalyst to improve waste management guidelines.
Remaining issues to be solved		As above	Stakeholders are a bit doubtful about the success of this measure. Although positive trends can be observed, the process is slow and requires persistence.

Actual management practice (GAP)	Insufficiently effective waste water treatment system that needs to be reconstructed and expanded	Periodic field flooding
Proposed BMP	Natural waste water treatment system	Infrastructure maintenance and reconstruction / Non-

			structural flood mitigation measures
Proposed solutions and recommendations	adaptation of existing land use management practices	If measure is to be applied, land use and spatial planning documents and practices must be modified in a way that the municipality designates an area to be utilised as natural WWTS. This usually requires 3-5 m^2 per population equivalent, making it ideal for small settlements, industrial sites, farms or landfills	Non-structural flood mitigation measures include prevention of land use change, establishment of protective forests and promotion of cultures resistant to floods (e.g. grapevines).
	Adaptation of existing flood/drought management practices	Natural WWTS must be flood-proof to avoid spreading of pollutants and degradation of water quality	Proposed measures could enhance flood mitigation and management action
	Adaptation of policy guidelines	Plans for the extension of sewage and purification network must shift towards green and innovative methods	Prevention of land use change should be included in designated sensitive areas (e.g. prevention of agricultural land spread on the account of Prološko Blato wetland areas).
Remaining issues to be solved		Challenges include high costs (which is also case with other purification methods) and extensive land surface is needed for the method (up to 5 m^2 per PE, which is problematic for high scale systems)	Measure is complex, as it faces resistance of local population, lots of financial compensation for losses, and generally, structural measures are still favoured

Actual management practice (GAP)		Insufficient number of proclaimed drinking water protection zones on valuable springs in South Dalmatia
Proposed BMP		Defining and establishing sanitary protection zones in South Dalmatia
Proposed solutions and recommendations	adaptation of existing land use management practices	If sanitary protection zones are proclaimed, land use management practices must definitely change. This is mostly related to agricultural practices, construction, spatial planning and waste management.
	Adaptation of existing flood/drought management practices	Not relevant

	Adaptation of policy guidelines	Policy guidelines are well developed concerning DWPZ, but implementation is lacking, inspections are inadequate, and penalties are rarely given.
Remaining issues to be solved		Stakeholders and experts strongly support implementation of this measure, however, unwillingness of people to cooperate and since there are no legally binding obligations to abide pose a serious threat to the administration of the measure. Further education activities and awareness raising are needed to fully implement DWPZs.

4. Conclusions

This report showcases the main gaps in the pilot areas and proposes specific actions in response to those gaps. The main issues are increased water demand (due to rise in agricultural production), periodical field flooding, poor condition of water supply network, illegal waste dumps, inadequate waste water treatment and non-compliance with regulations and restrictions set out by DWPZ ordinance. BMPs are expected to promote topics such as water protection, pollution and climate changes, resulting in an increased awareness among the whole community and water users. Intensive stakeholder involvement is the first step towards the implementation of any BMP. Perhaps the hardest thing to change is the human consciousness and this is where further efforts must be directed – this refers both to decision makers and population. Decision makers must directly stimulate good practices, and vice-versa, the population should adapt and generally change their attitude towards changes in actual management practices (which often include negative financial repercussions). Although PROLINE-CE duration is too short to test the BMPs in pilot areas, indications towards positive changes in practices could be observable within project timeline. Croatian geological survey is a research institution, and therefore is not competent to directly implement measures and BMPs, but could only push such incentives via brochures, consultation with decision makers, education and further research.

5. References

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