WATER RESCUE

Water resources efficiency and conservative use in drinking water supply systems

WP	**4 Common Methodologies and Tools**
Deliverable *Tool*	**4.3.1 Cross border water resources vulnerability assessment methodology report** *Joint Deliverable*
Sub-Deliverables integrated	**D.4.1.1, D.4.2.1, D.4.4.1, D.4.5.1, D.4.6.1**
Project Beneficiary No	**PB3**
Beneficiary Institution	**University of Thessaly-Special Account Funds for Research-Department of Civil Engineering**

The Project is co-funded by the European Regional Development Fund (ERDF) and by national funds of the countries participating in the Cooperation Programme Interreg V-A "Greece-Bulgaria 2014-2020".

Table of Contents

Chapter 1. Introduction: The WATER RESCUE project in brief

1.1 The Project in brief

WATER RESCUE project's concept is based on the common cross-border (CB) water management problems in the two international river basin districts (RBDs) shared between Greece & Bulgaria (Struma-Strymonas; Maritsa-Evros). The common CB problems include water resources quality & quantity being at risk due to natural and human activities and climate change conditions. The consequence is that water bodies fail to meet the good ecological status (GES) (recorded in the river basin management plans-RBMP). In particular, drinking water faces significant risks due to the deteriorated water resources quality while at the same time significant water volume is lost in the water distribution networks (WDNs). The project aims at the sustainable and efficient management of drinking water supply by increasing drinking water use efficiency in WDNs and improving water quality in the whole water supply cycle (from the source and back to the environment). Good Ecological Status can be achieved by improving water quality and reducing water abstraction and can be maintained by taking climate change adaptation measures. The project focuses in drinking water supply management suffering from high Non-Revenue Water (NRW) levels and deteriorated water quality jeopardizing the drinking water consumers' safety and health and their quality of life. Urban water volumes end up to the sewerage networks while wastewater treatment plants are a pressure to water resources quality. Surface water bodies are both used for drinking water abstraction and are the final recipient of treated effluents. Thus, their ecological status is affected by both water quantities abstracted and water quality in the whole water supply cycle (from the resource to the water supply and the wastewater treatment plant and back to the environment).

1.2 Theme of the Project

WATER RESCUE project is expected to achieve Non-Revenue Water/water losses reduction by upgrading and adapting already developed methodologies, technologies and tools including Water Balance assessment and Performance Indicators, hydraulic simulation models, decision support systems and GIS tools. Additionally, WATER RESCUE is expected to achieve water quality improvement across the entire water supply chain (from the water intake point and the raw water treatment plant, back to the environment after the waste water treatment plant) through constant monitoring of water quality parameters in real time, water quality simulation models (including water age) and automatic chlorination systems on line and in line. Climate change impacts will be assessed to finally propose and adopt measures for climate change adaptation. WATER RESCUE has a clear innovative character since the methodologies and tools are integrated and do not tackle individual problems. It is the first time that integrated methodologies will be adapted to include the entire drinking water supply cycle. These methodologies/tools will serve as Early - Warning Systems both for water quantity and quality. WATER RESCUE results will improve drinking water management. At the same time as drinking water is involved, the consumers' safety and health are safeguarded and their quality of life is improved. Non-Revenue Water reduction will increase water resources efficiency, since less water will be abstracted from surface and groundwater bodies and reduce energy consumption as water and energy are interconnected in water supply systems (water-energy nexus). Drinking water quality will be improved through real time monitoring of water quality parameters across the entire water supply chain, from the water intake points, to the water treatment plant and the water distribution network, back to the environment through the wastewater treatment plant. Thus, drinking water quality will be safeguarded from its source up to the consumer's tap. As wastewater effluents return to water resources, their quality monitoring prevents water resources degradation due to this pressure. Water and energy resources efficiency will be promoted and the ability of the cross-border area to adapt to climate change conditions will be improved as all possible natural and man-made pressures will be evaluated, including climate change conditions. Water saving will be accomplished through water losses reduction and increase of the environmental awareness of the public. The quality of life is expected to be upgraded with special emphasis to the protection of the natural environment. Joint policy recommendation guidelines and papers will be developed. Good governance, transparency and participation of all stakeholders in the design, implementation and monitoring of these policies is expected. Know-how and technology transfer will take place not only among the beneficiaries but also in the stakeholders' network that will be developed.

1.3 Project Objectives

The project's main objective is the sustainable cross –border drinking water supply management aiming at water resources efficiency and conservative use through:

1. Adaptation of a joint methodological framework for water resources management (qualitatively and quantitatively) in relation to the climate change and the natural and human activities and reduction of the water resources vulnerability;

2. Increase water use efficiency through the reduction of Non-Revenue Water and water losses in the water supply networks by implementing measures tackling NRW causes;

3. Improve water quality and safety in the whole drinking water supply cycle, from the water resources to the water distribution network and back to the environment through the continuous monitoring of water quality parameters in real time and the in-line disinfection to reduce the risk of low chlorine residuals and excessive concentrations of THMs (toxic substances causing cancer);

4. Increase innovative technologies use through the integrated management of water resources including GIS-based applications; hydraulic simulation models & decision support systems;

5. Development of "green behavior", increase water saving & reduce water consumption through public awareness campaigns.

WP	Task	Leader	Duration	Nov 2017	Dec 2017	Jan 2018	Feb 2018	Mar 2018	Apr 2018	May 2018	June 2018	July 2018	Aug 2018	Sept 2018	Oct 2018	Nov 2018	Dec 2018	Jan 2019	Feb 2019	Mar 2019	Apr 2019	May 2019	June 2019	July 2019	Aug 2019	Sept 2019	Oct2 019	Nov2 019
WP1: Project Management & Coordination	1.1 Preparation activities	LB	10/11/2017-9/11/2019																									
	1.2 Project Management																											
	1.3 Self evaluation																											
	1.4 Steering committee meetings																											
	1.5 Audit Costs																											
WP2: Project Communication & Dissemination	2.1 Project Communication Plan	LB	10/11/2017-9/11/2019																									
	2.2 Project Website																											
	2.3 Publication & Dissemination Material																											
	2.4 Awareness events																											
	2.5 Final events Awareness Events																											
WP3: Current Status Analysis & Assessment	3.1 Climate change impacts asssessment	PB5	10/11/2017-9/11/2018																									
	3.2 Water Audit																											
	3.3 Water quality																											
WP4: Common Methodology & Tools	4.1 Cross border water resources vulnerability assessment	PB3	10/11/2017-9/5/2019																									
	4.2 Water use efficiency																											
	4.3 Water quality																											
WP5: Pilot Actions	5.1 Ex Ante evaluation	PB2	10/11/2017-9/11/2019																									
	5.2 Pilot actions implementation																											
	5.3 Workshops & transfer visits																											
	5.4 Ex Post evaluation																											
WP6: Policy Recommendation	6.1 Joint water efficiency policy recommendation	PB4	2/5/2019-9/11/2019																									
	6.2 Joint water quality policy recommendation																											

Figure 1. WATER RESCUE timetable

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1.4 The Project structure and timetable

The project consists of six work packages:

- WP1: Project Management and Coordination (duration: 24 months)
- WP2: Project Communication and Dissemination (duration: 24 months)
- WP3: Current Status Analysis & Assessment (duration: 12 months)
- WP4: Common Methodology and Tools (duration: 18 months)
- WP5: Pilot Actions (duration: 24 months)
- WP6: Policy Recommendation (duration: 6 months)

The total project duration is 24 months, from 10/11/2017 to 9/11/2019 (Figure 1).

1.5 Project Beneficiaries

Lead Beneficiary is the Municipal Water Supply and Sewerage Company of Komotini (Greece); Beneficiary 2 is the Municipal Water Supply and Sewerage Company of Thermi (Greece); Beneficiary 3 is the University of Thessaly-Special Account Funds for Research-Department of Civil Engineering (Greece); Beneficiary 4 is the Municipality of Kardzhali (Bulgaria); Beneficiary 5 is the Municipality of Gotse Delchev (Bulgaria); and Beneficiary 6 is the Municipal Water Supply and Sewerage Company of Thermaikos (Greece).

Table 1. WATER RESCUE beneficiaries

PB #	PB name	City	Country
PB1	Municipal Water Supply and Sewerage Company of Komotini	Komotini	Greece
PB2	Municipal Water Supply and Sewerage Company of Thermi	Thermi	Greece
PB3	University of Thessaly-Special Account Funds for Research-Department of Civil Engineering	Volos	Greece
PB4	Municipality of Kardzhali	Karddzhali	Bulgaria
PB5	Municipality of Gotse Delchev	Gotse Delchev	Bulgaria
PB6	Municipal Water Supply and Sewerage Company of Thermaikos	Neoi Epivates	Greece

1.4 The present deliverable

1.4.1 The subject of the present deliverable

The present deliverable refers to WP4.1. This deliverable includes a joint methodology regarding the water resources vulnerability assessment and mapping (water resources vulnerability index) including the development of “what-if” scenarios regarding the climate change impacts on water quality and quantity. Specifically, the deliverable presents the methodology of how to estimate the water resources vulnerability taking into consideration climate, water availability and water quality. The project beneficiaries have also responded to a questionnaire providing information about their countries and areas. In this way a joint methodology will be developed.

1.4.2 The approach applied developing the present deliverable

WATER RESCUE beneficiaries, beyond their common agreement to work closely together, should be guided by the scientific beneficiary, University of Thessaly, to ensure the prompt delivery of what was expected by the WATER RESCUE project. Thus, the University of Thessaly (WP leader), prepared the methodology and the questionnaires for this task and will prepare the joint deliverable for WP4.1.

Regarding the implementation of Phase 4.1., the beneficiaries reported on the vulnerability of their water resources. University of Thessaly (PB3) provided a questionnaire consisting of the following chapters: (a)

Cross Border water resources vulnerability; and (b) Strategy and Measures taken. All beneficiaries provided their deliverables to the WP leader, who properly elaborated the data in order to prepare the joint deliverable. The WP leader prepared the respective deliverable D4.1.

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Chapter 2. Cross Border Water Resources Vulnerability Assessment – The methodology

This deliverable aims at presenting a joint methodology for cross-border water resources vulnerability assessment. It is well-known that water resources do not meet borders, and this is why they should be managed in cooperation.

The common methodology has been adopted and capitalized from the CC-WARE project, funded within Southeast Europe Programme. The methodology is presented in final CC-WARE WP3 report (CC-WARE, 2014a). This methodology has been used within the DRINKADRIA project to assess the vulnerability of water resources in the IPA Adriatic territory (DRINKADRIA, 2016).

Climate change impacts are expected to effect water supply and water demand, especially in countries facing water scarcity conditions. Thus, water resources vulnerability is a critical issue. Vulnerability of freshwater resources as potential drinking water resources is characterized by increasing water demand and decreasing water availability due to climate change and deterioration of water resources quality. Land uses paly an important role on water resources quantity and quality. The vulnerability assessment of water resources can provide useful information about areas being at risk, so that the competent authorities can design corrective strategies.

Vulnerability is defined as "*the degree, to which a system is susceptible to, or unable to cope with, adverse effects of environmental change*" (IPCC, 2001). A natural and socio-economic system's vulnerability depends both on the character, magnitude, and rate of the hazard on the one side and the system's sensitivity and adaptive capacity on the other (IPCC, 2014; NERI, 2002; Hamouda et al., 2009; Jun et al., 2011; Kanakoudis et al., 2017). Water resources vulnerability is complicated, related to many different factors, both natural and human. CB water resources used for water supply are extremely important as they are used for drinking water needs. Many researchers dealt with water resources vulnerability using many methodologies and different indices. During CC-WARE project the vulnerability is given by examining the exposure (predicted change in climate), sensitivity (the responsiveness of a system to climatic changes) and adaptive capacity (the ability of the system to adjust to climate change) of a range of indicators (DRINKDARIA, 2016).

It is generally accepted that water resources vulnerability is affected by climatic, hydrological, geological and socio-economic factors. The methodology proposed for CB water resources management is based on four pillars: (a) climate characteristics and climate change; (b) water resources availability assessment; (c) water resources quality assessment; and (d) water resources safety and security assessment (Figure 2).

Climate changes are expected in terms of temperature and precipitation and can be addressed as exposure. Sensitivity factor refers to the degree to which the systems respond to changes, such as reduced precipitation is expected to reduce water availability. Adaptive capacity shows how well a system can adapt of modify to cope with climate changes (DRINKADRIA, 2016). Adaptive capacity refers to natural, economic and social systems. Limited adaptive capacity can result in higher vulnerability of a system. Adaptive capacity indicators can include the ecosystem services and GDP, as high ecosystem services (the ecosystem is in good status and provides services are low cost) result in saving financial resources. This whole concept refers to the environmental damage, where large investments are needed to restore the environment to its initial good status.

The index of integrated resources vulnerability is based on indicators referring to water quantity and availability, to water quality and to the adaptive capacity (Figure 2).

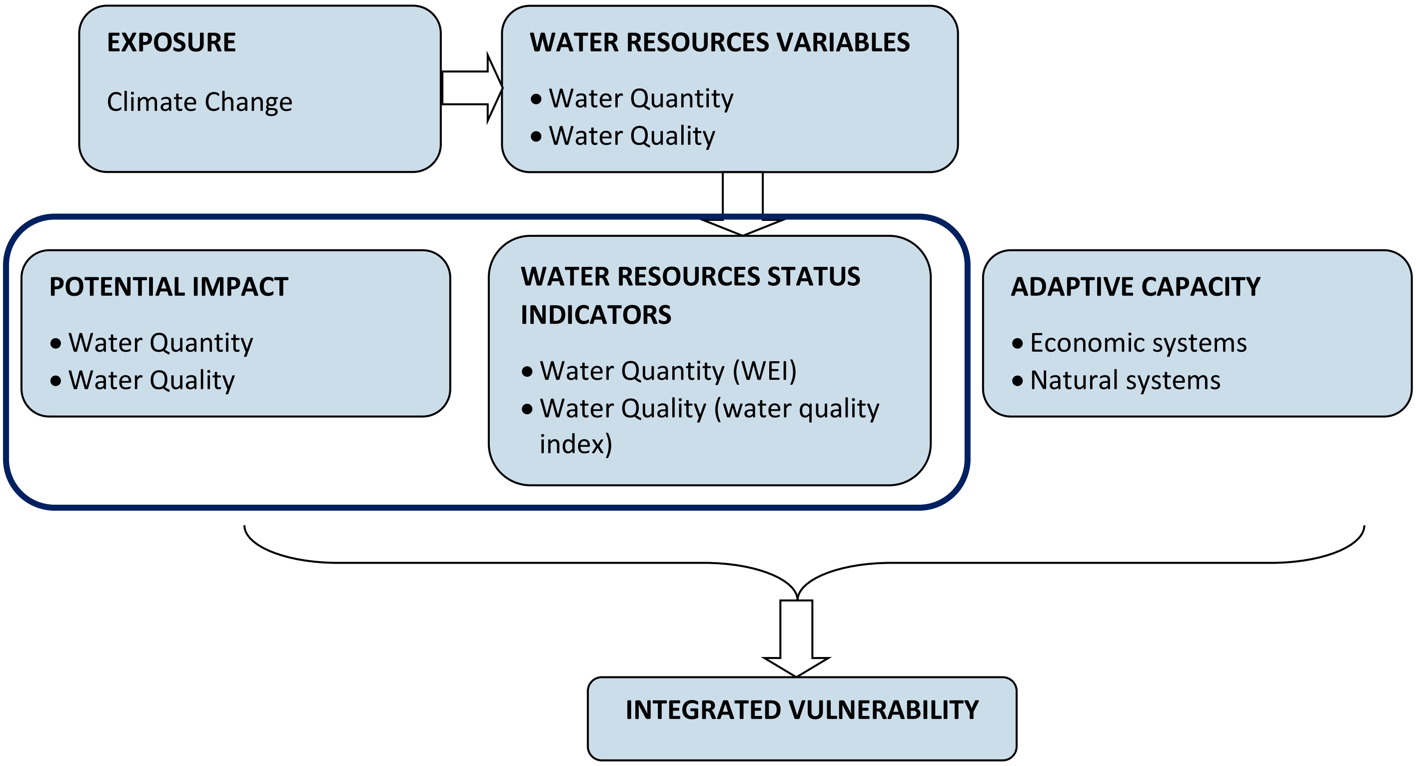

Figure 2. Integrated Vulnerability index

2.1 Climate characteristics and climate change

Climate characteristics are crucial parameters for water resources variability, as decreased precipitation along with high temperatures and increased evapotranspiration can result in possible droughts. The objective is to provide climate indicators relevant for analyzing the water resources vulnerability. Climate indicators are temperature, precipitation and evapotranspiration.

Initially temperature and precipitation values should be gathered based on historical data (e.g. 1961-1990: recommended reference period by the World Meteorological Organization). Such data can be found at national databases and from National Communications under the UNFCCC. Actual evapotranspiration (AET) can be calculated using Budyko's original equation (Budyko, 1974). Using this equation actual evapotranspiration can be calculated on a catchment scale.

To assess temperature and precipitation trends in the future, some climate models can be used. Regional climate models (RCMs) are Aladin, Promes, RegCM3 and others. The IPCC (Intergovernmental Panel on Climate Change) published a set of SRES (Special Report on Emission Scenarios) scenarios in 2000 for use in the Third Assessment Report (IPCC, 2000). These scenarios were prepared in order to explore future developments in the global environment with special reference to the production of greenhouse gases and aerosol precursor emissions. They cover a wide range of key "future" characteristics such as demographic change, economic development and technological change. Four qualitative storylines yield four sets of scenarios called "families". The set of scenarios consists of six scenario groups drawn from the four following families:

(a) A1 storyline and scenario family: a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies;

(b) A2 storyline and scenario family: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines;

(c) B1 storyline and scenario family: a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies;

(d) B2 storyline and scenario family: a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development).

A variety of SRES scenarios with a several assumptions regarding driving forces is being used. The six scenario groups – the three scenario families A2, B1, and B2, plus three groups within the A1 scenario family, A1B, A1FI, and A1T – and four cumulative emissions categories were developed as the smallest subsets of SRES scenarios.

Other climate indices can be used such as De Martonne Index of aridity (equation 1) which is used for the evaluation of water availability in an area.

$$MA = \frac{RR}{T+10} \quad (1)$$

Where MA is the De Martonne aridity index, RR is the annual precipitation in mm and T is the annual mean temperature (^oC). Baltas (2007) classified areas in aridity classes (dry; semi-dry; mediterranean; semi-humid; humid; very humid; extremely humid) based on the MA and the precipitation level (Table 2).

Table 2. Aridity classification based on De Martonne index (Baltas, 2007)

Aridity classification	MA	Precipitation (mm)
Dry	<10.0	<200.0
Semi-dry	10.0-19.9	200.0-399.9
Mediterranean	20.0-23.9	400.0-499.9
Semi-humid	24.0-27.9	500.0-599.9
Humid	28.0-34.9	600.0-699.9
Very humid	35.0-55.0	700.0-800.0
Extremely humid	>55.0	>800.0

With all the above-mentioned available data, climate variables maps can be elaborated (DRINKADRIA, 2016; Kanakoudis et al., 2017) taking into consideration present and future values of the climate variables (Figure 3).

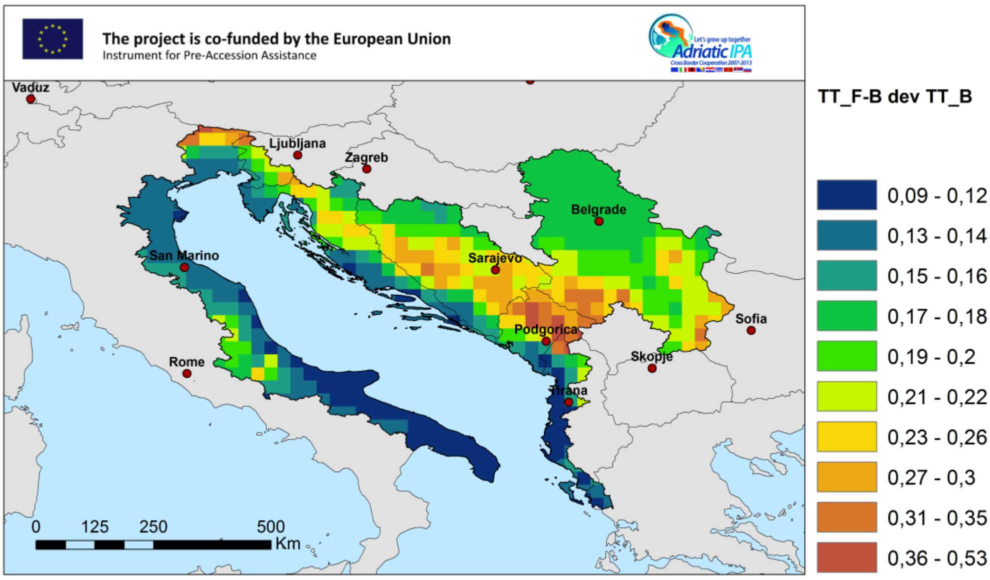

Figure 3. Relative differences in average temperature values between future (2021-2050) and baseline (1961-1990) period (Kanakoudis et al., 2017)

2.2 Water Resources Availability

Water resources availability assessment involves the estimation of water demand and water supply and the estimation of indices such as the Water Exploitation Index (WEI) or water stress. WEI is the ration of total water demand (domestic, industrial and agricultural) to the available amount of renewable water resources (DRINKADRIA, 2016).

Water availability can be estimated by using the equation (2):

$$Q = RR - AET + \Delta S \quad (2)$$

Where Q is total runoff (surface and groundwater, RR is precipitation, AET is actual evapotranspiration and ΔS is storage change term (neglected when long term annual values are used).

The long-term average water resources conditions and the characteristic renewable water resources can be estimated for 1961-1990 period, based on the precipitation and temperature values. Based on the precipitation and temperature estimation for the future, the long-term average conditions and the characteristic renewable water resources for the future (2021-2050) can be also estimated, provided that the initial data are available.

Water demand can be estimated by estimating the water demand of various sectors such as agricultural, domestic, industrial, etc. Water demand can be estimated at country level or at river basin level.

For future water demand, several scenarios can be developed, including increasing and decreasing of water demand up to 25%.

The Water Exploitation Index (WEI) is used to assess the risk of water resources availability for present and future state. WEI is defined as the ratio of water demand (WD) and renewable water resources (WR) (equation 3).

$$WEI = \frac{WD}{WR} \quad (3)$$

Then, several scenarios can be developed taking into consideration present and future values and making several combinations. For example, four WEI indices that can be calculated are: WEI1, WEI2, WEI3, WEI4:

$$WEI_1 = \frac{WD_0}{WR_0} \quad (4)$$

Where, WD_0 is the present water demand and WR_0 is the renewable water resources at the present period (1961-1990).

$$WEI_2 = \frac{WD_0}{WR_1} \quad (5)$$

Where, WD_0 is the present water demand and WR_1 is the future renewable water resources at the period 2021-2050.

$$WEI_3 = \frac{WD_1}{WR_1} \quad (6)$$

Where, WD_1 is the future water demand (e.g. increase of 25% compared to the present water demand) and WR_1 is the future renewable water resources at the period 2021-2050.

$$WEI_4 = \frac{WD_2}{WR_0} \quad (7)$$

Where, WD_2 is the future water demand (e.g. decrease of 25% compared to the present water demand) and WR_1 is the future renewable water resources at the period 2021-2050.

With such WEI values, the water resources availability can be assessed. WEI values show the water resources availability status. Specifically, WEI Index values can be assessed based on the thresholds adopted in CCWaters project (Table 3). Up to 0.49 the system faces a low risk regarding its water availability. For values ranging from 0.5 to 0.69 there are possible difficulties, while for values ranging from 0.7 to 0.99 there is a strong risk. Systems with WEI values greater than 1, are not sustainable.

WEI index can be estimated annually or taking into consideration seasonal variations.

Table 3. WEI thresholds

WEI from - to		Comment
0	0.49	low risk
0.5	0.69	possible difficulties
0.7	0.99	strong risk
1		not sustainable

2.3 Water Resources Quality

2.3.1 Water Quality Index

Water resources quality can face problems due to human activities or natural conditions, such as geological conditions. “Water pollution index” shows the tendency of pollutants to reach water resources (DRINAKDRIA, 2016).

There are water resources quality indices for surface water and for groundwater. Based on Drinkadria (2016) the “pollution load index for surface water” is a sum of particular land use load coefficient multiplied by the particular land use area. Normalized Pollution load index is an indicator for surface water quality – Water quality index SW. Ground water quality indicators are a function of pollution load and effective infiltration coefficient. The latter depends on hydrogeological characteristics of sediments and rocks, which define the aquifer type. Thus, the HG factor is introduced. The HG factor is expressed as the effective infiltration coefficient, which was determined according to the International Hydrogeological Map of Europe (BGR & UNESCO, 2014). Multiplying Surface water quality index with HG factor and normalizing, we obtain the indicator for groundwater quality - Water quality index GW. The methodology for the assessment of the surface and groundwater quality index was developed within the CC-WARE project (CC-WARE, 2014a).

To estimate the Water Quality Index, land use data can be obtained by CORINE land use.

2.3.2 DPSIR framework

The impact of land use changes to water quality can be assessed, using the DPSIR (Drivers, Pressures, State, Impact, Responses) framework. The DPSIR framework (Figure 4) is used to:

- characterize groundwater bodies;

- for decisional context for river basin management planning.

Driver: An anthropogenic activity that may have an environmental effect. Drivers produce a series of pressures and are quantified by aggregated data, e.g., population density, hectares of irrigated land, industrial units etc.

Pressure: The direct effect of the driver. Pressures degrade the State of water bodies and have an Impact on them as well as on humans. Increased irrigation-industrial-domestic demands, precipitation decrease, point or non-point source pollution could be considered as pressures.

State: The condition of the water body resulting from both natural and anthropogenic factors (e.g. chemical or ecological characteristics, water quantity, etc.).

Impact: The effect upon environment and/or human wellbeing.

Response: The measures taken to improve the state of the water body.

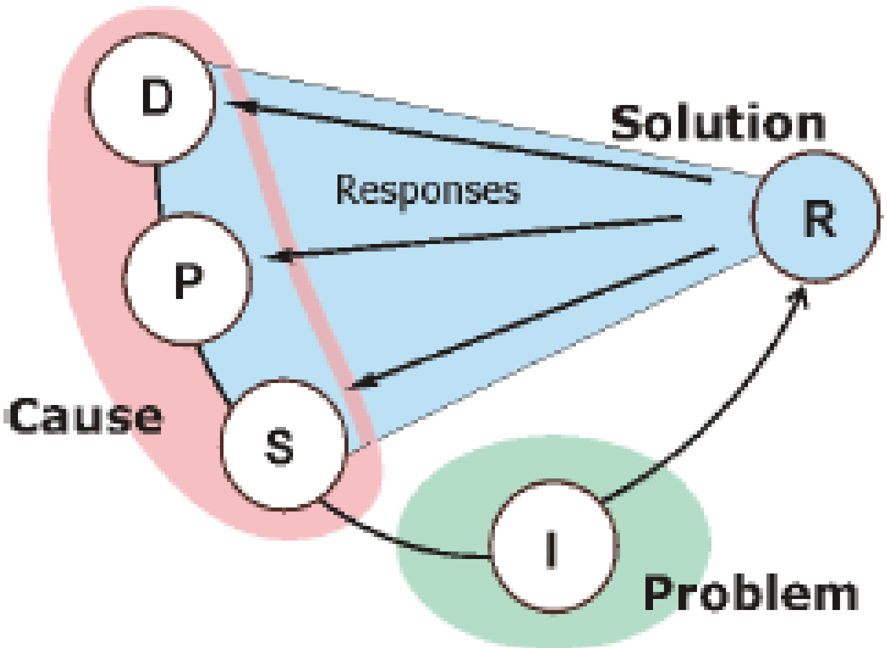

Figure 4. The DPSIR framework

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2.3.3 Protection Zones

Under the framework for water resources quality, protection zones can be assessed. Delineation of protection zones differs from country to country. Zones for the protection of drinking water abstraction points from groundwater systems are mainly three:

- Zone of absolute protection I
- Zone of controlled protection II, and
- Zone of protection III.

The legislation defines the activities that are prohibited in these zones. To delineate water protection zones, specific hydro-geological studies need to be elaborated.

There is also delineation of zones of drinking water from surface systems.

2.4 Adaptative Capacity

Adaptive capacity describes how well a system (water resources quantity and quality) can adapt or modify to cope with the climate changes (DRINKADRIA, 2016). Adaptive capacity might reflect socio-economic and natural conditions, including physical, environmental and socio-economic features. Indices used are the ecosystem services index for natural adaptive capacity and GDP as socio economic index (CC-WARE, 2014a,b).

2.4.1 Socio-economic adaptive capacity

The Gross Domestic Product (GDP) is an indicator for socio-economic adaptive capacity as the economic status plays an important role in how climate change can be adapted in drinking water supply systems. The lower the GDP, the lower is the adaptive capacity and therefore, the system is more vulnerable to climate change impacts.

2.4.2 Natural adaptive capacity

Ecosystem Services (ESS) can be the indicator for natural adaptive capacity. Ecosystem services expresses the role of the ecosystem to provide water in sufficient quantity and quality (DRINKADRIA, 2016). The methodology used in CC-WARE project to estimate Ecosystem Services index is that relative weights of importance for drinking water supply are assigned to each land use category and ESS type. ESS types include Provisioning Ecosystem Service, Water Regulation and Water Quality Regulation. The sum of the weights for each CLC land use class for all three ESS and then normalization of them, creates the values of Water Supply Index (values from 0 to 1).

2.5 Water Resources Vulnerability

Water Resources Vulnerability Index can be determined using various methods (DRINKADRIA, 2016). This index derives from other quantitative indices such as Water Resources Indicators group (consisting of WEI and Groundwater Quality Index) and Adaptive Capacity Indicators Group (consisting of GDP and Ecosystems Services Index) (Figure 5). The combination of these indicators can result in the Integrated Water Resources Vulnerability Index. When WEI values are high (due to low total runoff or increased water demand), the pollution potential is high and adaptive capacity is low, then the vulnerability is high.

The different methodologies used to estimate the Water Resources Integrated Vulnerability Index can be summarized as (DRINKADRIA, 2016):

* Integrated vulnerability according to composite programming formula (HU method)

* Integrated vulnerability according to expert classifying matrix (AT-method)
* Integrated vulnerability taking into account maximum values – worst case scenario (MAX-method).

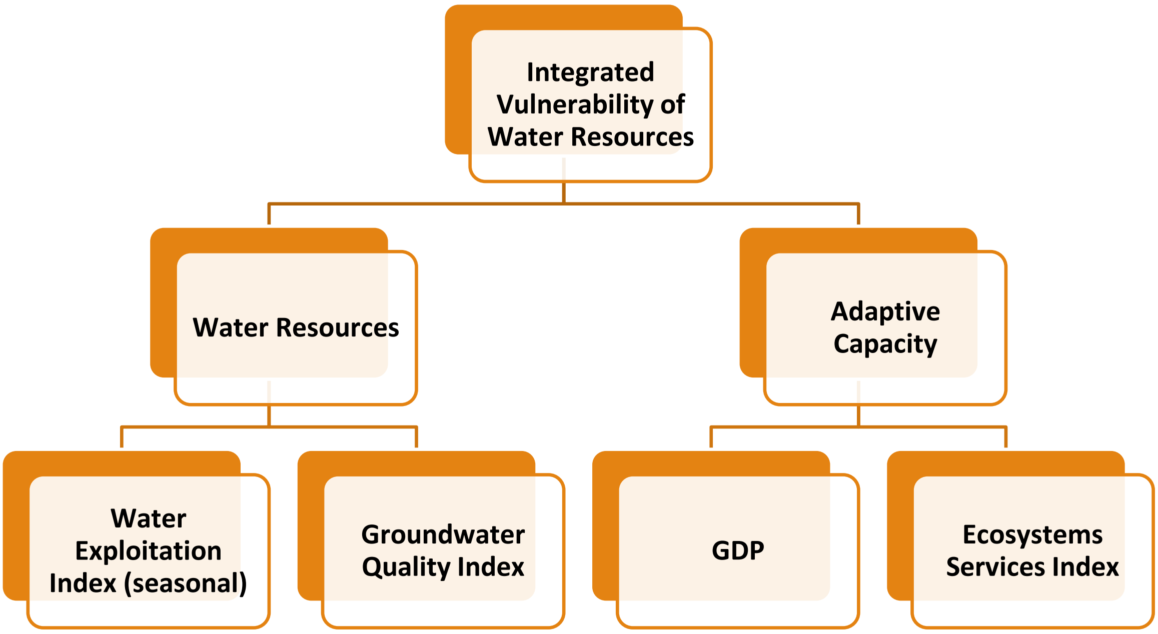

Figure 5. Integrated Vulnerability of Water Resources determination methodology

2.5.1 Integrated Vulnerability according to composite programming formula (HU method)

The methodology as it has been used previously is based on multi criteria method (composite programming), which provides a transparent method of assessment and organizes indicators into a hierarchical structure. The indicators have various weighting factors. Weights represent the relative importance of each indicator. Then, balancing factors are assigned for each group of indicators. The role of balancing factors is to show the relative importance that is assigned to the maximal deviations of the indicators and limit the ability of one indicator to substitute for another. Both weighting factors and balancing factors are based on experts' opinions.

The Integrated Vulnerability Index is estimated by using equation 8 (DRINKADRIA, 2016):

$$IV_j = \left[\sum_{i=1}^{n_j} a_{ij} \cdot S_{ij}^{P_j}\right]^{1/P_j} \quad (8)$$

Where, IV_j is the integrated vulnerability index for group j;

S_{ij} is the normalized values of the basic indicator I in the group j of indicators;

n_j is the number of indicators in group j;

a_{ij} is the weight of expressing the relative importance of indicators in group j in a way that they sum up to one;

P_j is the balancing factors among indicators for group j.

2.5.2 Integrated Vulnerability according to expert classifying matrix (AT method)

Combining Water Resources Index with Adaptive Capacity Index forming a matrix can determine the integrated vulnerability index. The classification is based on experts' opinions. Five classes are used to classify Water Resources Index and Adaptive Capacity Index, very low, low, medium, high and very high. For each index, classification to one of the five classes is done for Water Quantity and Water Quality forming the matrix of Water Resources Index and GDP and ESS Index forming the matrix of Adaptive Capacity Index. Then, the combination of these matrices (by merging them) arrives to the formation of the Integrated Vulnerability Index matrix (Figure 6) (DRINKADRIA, 2016).

Integrated Vulnerability			**Adaptive Capacity**				
			Very low	low	medium	high	Very high
			1	2	3	4	5
Water Resources Index	Very low	A	A1	A2	A3	A4	A5
	Low	B	B1	B2	B3	B4	B5
	Medium	C	C1	C2	C3	C4	C5
	High	D	D1	D2	D3	D4	D5
	Very high	E	E1	E2	E3	E4	E5

Integrated Vulnerability				
Very low	low	medium	high	Very high

Figure 6. Integrated Vulnerability matrix

2.5.3 Integrated Vulnerability taking into account maximum values – worst case scenario (MAX-method)

To estimate the Integrated Vulnerability, the indicators are combined using maximum values. The indicators' values are normalized from 0 to 1. The worst scenario is examined. The maximum value of Water Resources Index is the maximum value of the WEI and the Water Quality index. Then, the maximum value of Adaptive Capacity is the maximum value of GDP and ESS index. Finally, Integrated vulnerability is determined as the maximum value of Water resources index or Adaptive Capacity.

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Chapter 3. Cross Border Water Resources Vulnerability Assessment – Results & Discussion

In the context of this deliverable where the methodology to determine Water Resources Vulnerability, the WATER RESCUE beneficiaries were asked to provide some data on the vulnerability of their cross-border water resources. Water availability and water quality of the water resources are assessed at local level and land uses are given. Then, the strategy and the measures taken are provided at national and regional level (where applicable).

3.1. PB1 – Municipal Water Supply and Sewerage Company of Komotini, Greece

3.1.1. General presentation

DEYA Komotinis takes water from the River Basin (RB) of Komotini Streams – Loutro Evrou (EL1209), one of the RBs of the Water District of Thrace. The population of the Water District of Thrace is 408,186 people (2011 census) showing a small increase compared to the 2001 census.

The River Basin (RB) of Komotini Streams – Loutro Evrou covers an area of 1,958.3 Km^2, its average altitude is 289m and its maximum altitude is 1,459m. There are 31 surface water bodies identified in the RB of Komotini streams – Loutro Evrou: 28 rivers, 2 heavily modified river systems and 1 lake (Table 4). There are 4 groundwater systems identified in the RB of Kmotini streams – Loutro Evrou (Table 5).

Table 4. Surface Water Bodies in the WD of Thrace (EL12)

Type of surface water bodies	River Basins					Total
	EL1207	EL1208	EL1209	EL1210	EL1242	
Rivers	50	28	**28**	63	7	**176**
Heavily modified rivers	2		**2**	1		**5**
Lakes			**1**			**1**
Transitional	3	1		1		**5**
Coastal	3	2		4	3	**12**
TOTAL	**58**	**31**	**31**	**69**	**10**	**199**

Table 5. Groundwater systems in the RB of Komotini stream – Loutro Evrou

Groundwater system name	Groundwater system code	Area (Km^2)
Filiouris system	EL1200040	332.07
Drosiniou system	EL120B100	1,807.04
Maronias system	EL1200110	190.00
Rodopis system	EL1200120	755.58

DEYA of Komotini supplies with water the whole municipality of Komotini, having 66,379 inhabitants. The water resources used are Vosvozis river (EL1209R0000010085N) and the groundwater system of Rodopi (EL1200120). Their characteristics are:

- Vosvozis river: (EL1209R0000010085N – length: 7.70Km; river basin area: 74.91Km^2; average annual runoff: 42.52hm^3)
- Rodopi system: (EL1200120 - area 755.58Km^2)

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From Vosvozis river 2,750,000 m^3 of water were used by DEYA Komotinis in 2016 while from Rodopi system 3,550,000 m^3 of water were also abstracted in the same year.

The competent authority for water resources management in East Macedonia and Thrace is the Water Directorate of Eastern Macedonia and Thrace.

3.1.2. Water Availability

Based on the RBMP of Thrace annual water demand is 1,602hm^3 allocated in all water uses as shown in Table 6. The dominant water user is agriculture consuming 85.6% of the total water use. Domestic water use is 7.8%.

Table 6. Annual water demand per water use in the WD of Thrace and the RB of Komotini - Loutro Evrou treams (source: RBMP, 2017)

Water Demand	**WD of Thrace**		**RB of Lomotini-Loutro Evrou streams**	
	hm³	**%**	**hm³**	**%**
Agriculture	941.4	58.8	160.44	85.6
Domestic	60.5	3.8	14.66	7.8
Livestock	3.9	0.2	0.7	0.4
Industry	14.1	0.9	11.55	6.2
Hydroelectrical production	582.0	36.3		
Total	**1,602.0**		**187.35**	

The water volume used for hydroelectrical production can be considered as water use.

DEYA Komotinis is supplying Komotini municipality with water from the river of Vosvozis and the groundwater system of Rodopi. Based on data from the RBMP (2017) water availability, average annual abstraction (total and per water use) is shown in Table 7. The system of Rodopi is used at a rate of 29.1%.

Table 7. Water availability and average annual abstraction of the groundwater system of Rodopi (source: RBMP, 2017)

Groundwater system	**Water availability (10^6 m^3)**	**Average annual abstraction (10^6 m^3)**	**Agriculture (10^6 m^3)**	**Domestic (10^6 m^3)**	**Livestock (10^6 m^3)**	**Quantitative status**
Rodopi	50.4	14.7	12.0	2.5	0.2	Good

Based on the results from the deliverable 3.1.1, it is shown that the groundwater system of Rodopi is at low risk at its current state. Even when water demand increases and water availability decrease, the system is still at low risk (WEI values below 0.49). The same stands when drinking water use is examined.

3.1.3. Water Quality

Total pollution loads in Komotini – Loutro Evrou streams RB account for 2,398.4 ton/year of BOD, 991.7 tons/year of N and 65.6 tons/year of P. Point sources contribute more to the total pollution loads. The groundwater system supplying DEYAK with water is assessed for its chemical and quantitative status (RBMP, 2017) which is found to be good. There are no problems identified in this groundwater system (Table 8).

The river basin of Komotini-Loutra Evrou streams consists of 28 river surface water systems and 4 groundwater systems. 18 surface water systems are found to be at good ecological status; 4 at moderate ecological status; 2 at poor ecological status; and 4 in unknown ecological status. Only one surface water system is found to be in bad chemical status. One out of 4 groundwater systems are found to be in bad chemical status. All groundwater systems are found to be in good quantitative status. The river Vosvozis supplying DEYAK with water is found to be in poor ecological status and good chemical status (generally poor qualitative status).

Table 8. Water resources quality assessment of the groundwater system of Rodopi (source: RBMP, 2017)

Water system	Chemical status	Quantitative status	Increased values due to physical background	Increased values due to human pressures	Main pressures	Salt water intrusion	Quality problems
Rodopi	Good	Good	-	-	-	No	No
Vosvozis river	Poor	-	-	-	-	-	-

3.1.4. Land Uses

Based on the RBMP (2017) the land uses identified in the WD of Thrace are the following: forests take the major part of land (47.91%) followed by agriculture (32.54%) and pasture (13.81%). At the RB of Komotini – Loutro Evrou streams the dominant land use is agriculture (39.49%), followed by forests (35.79%) and pasture (19.83%) (Table 9).

Table 9. Land uses in the RB of Komotini streams – Loutro Evrou (source: 1st updated RBMP of the WD of Thrace)

Land use	Area (acres)	% coverage
Urban	17,847	0.92
Pasture	385,557	19.83
Agriculture	767,828	39.49
Forests	696,009	35.79
Roads - Water	37,521	1.93
Other	39,734	2.04
TOTAL	**1,944,497**	**100.00**

3.1.5. Strategy and measures taken

The study by the Bank of Greece (Bank of Greece, 2011) has shown that changes in the frequency and intensity of extreme phenomena will be one of the climate change main impacts on Greece with consequent negative effects on the vulnerability of societies and ecosystems due to their exposure to new intensive environmental risks.

More specifically, summer drought is expected to increase even further, leading to a prolongation of drought periods and pressures on water reserves of areas with already increased vulnerability. At the same time, heavy rainfall is expected to become more frequent in the next 70 years, with the consequence that in urban areas sudden floods are becoming more and more frequent due to intense local rainfall.

In 2016, the Ministry of the Environment and Energy drafted the National Climate Change Adaptation Strategy which sets out the general objectives, guiding principles and means of implementing a modern effective and developmental adaptation strategy within the framework set by the Convention on Climate Change United Nations Climate Change, European Guidelines and international experience. The National Climate Change Adaptation Strategy sets out actions and measures per sector affected by climate change. For water resources, these actions include the following:

Action 1. Creating a geo-portal of integrating information on the impacts of climate change on water resources. The purpose of the action is to gather all the information (data, studies, descriptive information)

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on the impact of climate change on water resources and on the dissemination of information on the internet.

Action 2. Projects addressing the impacts of climate change on water resources related to the following:

- Rising sea levels / Coastal zones. Impact assessment on coastal areas from sea level rise and / or coastal erosion and support for actors to design and implement appropriate projects.
- Reduction (quantitative and qualitative) of the performance of hydropower projects. The quantitative reduction in the yield of coastal water works (the main measure to prevent or reduce sewage). Confrontation: Avoiding or limiting the phenomenon is to reduce or totally disrupt the abstraction of coastal aquifers, as well as the abstraction of surface water discharged into the sea.
- Change in runoff basin level. The change in runoff basin level, which is a change in the erosion and deposition regime, is related to the corrosive or depositing status of the upstream branches of the hydrographic network. Confrontation: Implications can be identified and quantified using specific models for different scenarios of the phenomenon.
- Changing the apparent weight of structures. The entry of the sea into the inland results in an increase in the level of underground water, with a change in the apparent weight of the structures (buoyancy). Fluctuations in elevation and buoyancy by offshore projects will cause stress on foundations. Confrontation: To study the phenomenon as before.
- Precautionary measures for groundwater body vulnerability study. It requires the creation of vulnerability maps, natural or intinsic vulnerability, and specific or integrated vulnerability maps.
- Study of hydrographs of source discharges. Construction, analysis and study of hydrograph of basic source discharges. Main concern is the estimation of the available benefit in the dry season of the year.
- Anticorrosion protection of soils. The phenomenon is quite frequent and disturbing from the waves and small creeps of the creep, up to the large-scale sliding, collapse, subsidence and other forms of territorial instability.
- Desertification. The causes of desertification are: climate, physiography, geology, soil, hydrology and hydrogeology, as well as anthropogenic activities such as over-exploitation, over-grazing. Greece, like the rest of the Mediterranean basin, faces a high risk of desertification (estimated at least 35% of the land area). Areas of high risk are the Aegean islands, Crete, a part of Thessaly, East Sterea Hellas and the Eastern Peloponnese.
- Maintaining ecological flow. Each water body plays a specific role in maintaining the ecosystem and is affected by the lack of eco-flow: a specific supply that continues its flow when there is a natural disruption for specific reasons and does not go, at least as a whole, “lost” at the sea. Confrontation: The need for (correct) assessment of eco-supplies, with climate change data, is now imperative. The lack, in Greece, is temporarily covered by the Joint Ministerial Decision for RES.
- Irrigation water. The impacts of climate change in Greece are on reducing supply and irrigation water. If this is combined with rising temperatures, irrigation intensification and longer irrigation are threatened.
- Irrigation networks. Irrigation networks, where they exist, show significant water losses due to age, poor, not adequate or no maintenance at all, construction type, etc. (replacement of damaged parts or change of irrigation method, even crop change). Confrontation: In cooperation with the Agricultural Cooperatives, a large program of irrigation network repair, extension of use of irrigation networks, exploration of the choice of less water varieties, selection of varieties thawing out of the summer, removal of free irrigation water, irrigation with reusable water , placing a water meter on the head of forced private irrigation drilling and capture control based on a previous study of the area.

- Returned irrigation flow. Refers to problems met in irrigation areas with water pumped from the same irrigated area, especially when irrigation is frequent. After each pumping-irrigation, a rest of irrigation water returns to the aquifer, having undergone four pollution processes. Given that the velocity of groundwater in the porous media is of the order of a few meters or tens of meters per year, it is understood that, after some irrigation, the irrigation water is severely contaminated. Confrontation: Switching irrigation water use, where possible, partially or wholly.
- Water supply networks. Water losses from the water supply networks of cities are significant. This is due to the aging of large sections of networks. Another problem in this regard is the replacement of parts of the networks made up of asbestos cement pipes for reasons of public health protection. Confrontation: Co-operation of Regions and Local Authorities, it is recommended to repair damaged parts and replace sections of asbestos pipes in water supply networks.
- Bottled water. Bottled water is drinking water which must comply with quality standards. Areas of perimeter protection of water abstractions and water bottling facilities are everyday practice, for decades, in developed countries and, above all, in Europe. The reason for their existence is to avoid pollution of groundwater, which feeds population groups, from human activities. These zones, following a specific hydrogeological study, are designated Zone I (direct protection zone), Zone II (biological protection zone) and Zone III (chemical protection zone). The Day X Line is also set for the major pathogenic microorganisms, depending on the speed of movement of each microorganism.
- Cross-border waters. The issue concerns surface (mainly) and underground waters with Greece in a downstream position (Evros, Strymonas, Nestos, Axios), with the exception of Aoos where Greece is upstream. Problems are identified in the quantitative field (water shortage or floods) and in the quality sector (chemistry and water pollution). In the underground waters, areas of interest have been identified in Epirus (the hydrogeological basin of Heimaras springs, mainly located in Greece), Prespes (escape of groundwater, along with surface waters) and elsewhere.
- Desalination. Today, the problem of water supply in the islands is treated, alternatively, by the use of small desalination units, but these have considerable problems, such as high purchase and maintenance costs, energy-intensive operation, disposal of the brine and the organoleptic characteristics of desalinated water require it to be mixed with the underground water before it enters the water supply network.

Action 3. Saving water - Effective water use - Reducing pumping of aquifers. It concerns mainly areas where there is a shortage of water both in winter and in summer and includes the following measures:

- Measure 1. Promote water saving in all sectors and uses, especially in areas with shortages and support for rainwater recycling.
- Measure 2. Encourage the treatment of waste and the use of recycled water in plant production or in green areas, especially in areas with shortages.
- Measure 3. Improve efficiency in the energy sector in terms of water absorption and consumption and future hydroelectric power stations.
- Measure 4. Optimization of the existing water stock in the agricultural sector and creation of artificial reservoirs in accordance with environmental constraints, in addition to the improvement measures for water use.
- Measure 5. Encourage change in consumer patterns and intellectual attitudes.

Action 4. Development of land-use activities and uses that are compatible with local available water resources. This includes identifying potential adaptation scenarios for activities involving heavy water consumption in areas experiencing shortages, optimizing aquatic resources, developing efficient farming activities and reducing soil impermeability, thereby promoting water scarcity. It includes the following measures:

- Measure 1. Determine potential adaptation scenarios for activities that use large quantities of water in areas already in deficiencies.
- Measure 2. Optimize existing water storage methods and create new ones, if necessary, especially by replacing pumping during low flow periods.
- Measure 3. Rational use of water in activities such as the agricultural sector, tourism, etc.
- Measure 4. Improvement of the potential for land reclamation, so that rain water can also be used.

Action 5. Inclusion of the impacts of climate change on water planning and water management, particularly in the subsequent water services intervention programs (2013-2018) and water management development programs (2016-2021). This action aims to integrate the expected impacts of climate change and the adaptation measures required in water management planning tools on a hydrographic basin scale.

Action 6. Assessment of the impact of climate change on hydropower generation. Since the "fuel" of hydroelectric projects is water, the purpose of this action is to study and assess the impact of the imminent reduction of surface drainage on the country's hydroelectric projects, both economically (reduction of energy production) and socio-economic (reduction of available water for agricultural use) and environmental aspects (maintenance of ecological supply).

Action 7. Educational programs on the impact of climate change on water resources.

The formulation of the program of measures takes into account and incorporates actions included in the National Climate Change Adaptation Strategy.

Specific Measure included in the RBMP of the WD of Thrace included the pilot measures for the implementation of precision farming (**M12S1601**) (1st update of the RBMP of Thrace WD, 2017). Specifically, this measure seeks to exploit new technologies, which can include the implementation of new, innovative processes, including the search for new cultivation practices and production practices that contribute to environmental protection and adaptation to climate change. Measure 16 of the RDP 2014-2020 provides for aids in the context of producer group partnerships with other stakeholders (consultants, researchers, other food chain actors and innovation brokers) to achieve the objectives:

1. Reduce water consumption through the adoption of advanced irrigation systems, and the adoption of precision agriculture.

2. Produce safer and healthier foods for either the whole population or special categories.

3. Reduction of input costs that entails both economic and environmental benefits (reduction of fertilizer use, pesticide use, adoption of new varieties better suited to local soil, hydrological and climatic conditions, utilization of RES for substitution of minerals fuel).

4. The exploitation of by-products of agricultural production either for the production of feed or for the production of energy.

5. To highlight the specific nutritional characteristics of agricultural products and their contribution to nutrition (such as foods rich in Ω3, naturally unsaturated, low-calorie).

6. Better integration into the food chain of Greek livestock products such as goat's milk.

7. The adoption of more friendly agricultural practices and the adoption of crops for the exploitation of poor organics and soil nutrients.

3.1.6. Conclusions

DEYA Komotinis uses both surface and groundwater systems to supply the municipality of Komotini with drinking water. Domestic water use in the RB of Komotini – Loutro Evrou is 7.8% of its total water demand. Water availability assessment of the groundwater system used, showed that water stress is low in this system (Rodopi groundwater system). Rodopi groundwater system is assessed to be in good chemical and quantitative status, while Vosvozis river (surface water system) is found to be in poor ecological status but good chemical status. The dominant land use in the RB is agriculture, followed by forests.

A national climate change adaptation strategy is set by the Ministry of Environment and Energy in Greece. This strategy consists of seven (7) actions. In the Water District of Thrace the RBMP has set a measure for precision farming implementation.

3.2. PB2 – Municipal Water Supply and Sewerage Company of Thermi, Greece

3.2.1. General presentation

DEYA Thermis takes water from the River Basin (RB) of Chalkidiki (EL1005), one of the RBs of the Water District of Central Macedonia. The population of the Water District of Central Macedonia is 1,420,321 people (2011 census) showing a small increase compared to the 2001 census. It covers an area of 10,163.38 Km^2. The River Basin (RB) of Chalkidiki covers an area of 5,545.86 Km^2. Its population is 1,154,315 people (2011 census). 27% of the total area of the RB has an altitude of less than 100m, 20% of the total area has an altitude of 100-200m, 14% of the total area has an altitude of 200-300m and the remaining 39% has higher altitude. The RB's average altitude is about 275m. The total water supply at the RB is 653 hm^3.

DEYA Thermis supplies with water the municipality of Thermi with 53,201 people (2011 census).

The Water District of Central Macedonia includes 124 surface water systems (RBMP, 2017): 104 rivers, 6 lakes, 3 transitional systems and 11 coastal systems. Table 1 shows the surface water systems of each river basin. Chalkidiki RB has 53 rivers, 3 lakes, 2 transitional water bodies and 9 coastal bodies, totally 67 surface water bodies (Table 10).

Table 10. Surface water systems in each river basin (RBMP, 2017).

Type of system	Axios RB	Gallikos RB	Chalkidiki RB	Athos RB	TOTAL
Rivers	35	16	53	-	**104**
Lakes	2	1	3	-	**6**
Transitional	1	-	2	-	**3**
Coastal	-	-	9	2	**11**
TOTAL	**38**	**17**	**67**	**2**	**124**

Thirty-seven (37) groundwater systems have been identified in the RBMP (2017), 21 of them in the RB of Chalkidiki. Three of them supply the city of Thermi with water. They are:

- Anthemountas system, SystemSubsystem of down flow of Anthemountas: (EL1000081 – area:92.03Km^2)
- Anthemounts system, Subsystem of Thermi – N. Risio: (EL1000083 - area 177.00Km^2)
- Cholomontas – Oreokastro system, Subsystem of Cholomontas - Oreokastro: (EL1000193 - area 1597.41 Km^2)

The competent authority for water resources management in Central Macedonia is the Water Directorate of Central Macedonia.

3.2.2. Water Availability

Agriculture is the dominant water user (81%) while domestic water use account for 15% in the WD of Central Macedonia (Table 11). The average annual water supply in the WD is 5.3 $*10^9$ m^3, of which 32% are from own sources and 68% come from the water inflow from Axios river coming from FYROM.

Table 11. Annual water demand per water use in the WD of Central Macedonia and for each River Basin (RB) (source: RBMP, 2017)

	Whole WD		**Axios RB**		**Gallikos RB**		**Chalkidiki RB**	
Water Demand	**hm^3**	**%**	**hm^3**	**%**	**hm^3**	**%**	**hm^3**	**%**
Agriculture	953.080	80.9	697.701	95.0	49.765	74.4	205.614	54.5
Domestic	177.856	15.1	20.749	2.8	3.647	5.5	153.460	40.7
Livestock	7.228	0.6	2.585	0.4	1.152	1.7	3.491	0.9
Industry	40.421	3.4	13.254	1.8	12.321	18.4	14.846	3.9
Total	**1,178.586**		**734.289**		**66.885**		**377.411**	

Chalkidiki river basin consists of 67 surface water systems and 21 groundwater systems. 5 of the surface water systems are found to be at a bad quantitative status and the remaining ones are found to be in good quantitative status. Four out of 21 groundwater systems are found to be in bad chemical status.

Overexploitation of groundwater systems is a fact in 5 groundwater systems in Chalkidiki RB resulting in gradual reduction of their permanent groundwater inventories. These systems face salinization phenomena as well. The groundwater subsystem of down flow of Anthemountas faces overexploitation and it is assessed to be in bad quantitative status (RBMP, 2017).

DEYA Thermis is supplying the municipal district of Thermi with water from groundwater boreholes from three groundwater subsystems: down flow of Antemountas; Thermi – N. Risio; and Cholomontas - Oreokastro. Based on data from the RBMP (2017) water availability, average annual abstraction (total and per water use) is shown in Table 12. It is evident that the subsystem of down flow of Anthemountas and Thermi – N. Risio is overexploited since 37.02 hm^3 are abstracted while only 33.6 hm^3 is the annual water availability.

Table 12. Water availability and average annual abstraction of three groundwater systems in Chalkidiki River Basin (source: RBMP, 2017)

Groundwater subsystem	**Water availability (10^6 m^3)**	**Average annual abstraction (10^6 m^3)**	**Agriculture (10^6 m^3)**	**Domestic (10^6 m^3)**	**Industry (10^6 m^3)**	**Quantitative status**
Down flow of Anthemountas	33.6*	37.02*	25.32*	9.71*	1.77*	Bad
Thermi – N. Risio						Good
Cholomontas - Oreokastro	99.0**	81.64	64.60	9.51	0.35	Good

* It includes also the water supply and use of the subsystem of Galarino-Galatista (EL1000082)

** Includes also the water supply and use of the subsystems of Skouries (EL1000191) and Olympiada (EL1000192).

DEYA Thermis water abstraction is allocated in the groundwater systems as shown in Table 13. DEYA Thermis supplies water to the following towns: Thermi, Mikra, N. Redestos, Tagarades, N. Risio, Vasilika, Souroti, Agia

Paraskevi, Agios Antonios, Lakkia, Peristera and Livadi (Table 13). The major water volume (97.8%) comes from the subsystems of Anthemountas down flow and Thermi – N. Risio. The first subsystem is assessed in bad quantitative and chemical status, while the second is assessed in good quantitative and chemical status. Only 2.1% of water volume comes from the Cholomontas - Oreokastro subsystem which is found to be in good chemical and quantitative status.

Table 13. Water availability, average annual abstraction and DEYA Thermis abstraction of three groundwater systems (source: RBMP, 2017)

Groundwater subsystem	**Towns supplied with water**	**Water availability (10^6 m^3)**	**Average annual abstraction (10^6 m^3)**	**DEYA Thermis (m^3)**	**Chemical status**	**Quantitative status**
Down flow of Anthemountas	Thermi, Mikra, N. Redestos, Tagarades, N. Risio, Vasilika, Souroti, Ag. Paraskevi	33.6	37.02	7,187,700	Bad	Bad
Thermi – N. Risio	Thermi, Mikra, N. Redestos, Ag. Antonios, Lakkia				Good	Good
Cholomontas - Oreokastro	Peristera, Livadi	99	81.64	158,500	Good	Good

Based on the water availability analysis on the deliverable 3.2.1 (estimating the WEI index), it is found that the subsystems of Anthemountas down flow and Thermi – N. Risio (EL1000081 & EL1000083) are not sustainable at their present state. The results show that for these subsystems there are cases that show possible difficulties with water availability only if water demand decreases and renewable water resources increase. Strong risk exists only in the cases where water demand decreases or increases up to 10% and renewable water resources increase. In most cases the subsystem is unsustainable. Regarding drinking water demand the risk is low, regardless of the increase or decrease of water demand and renewable water resources.

Based on the analysis of deliverable 3.2.1, the subsystem Cholomontas - Oreokastro (EL1000193) is facing a strong risk at its present state. The system becomes not sustainable when water demand remains the same or increases and at the same time renewable water resources decrease. There are possible difficulties only when water demand decreases more than 5% and renewable water resources increase by more than 5%. Regarding drinking water demand, there is a low risk regardless of the increase or decrease of water demand and renewable water resources.

3.2.3. Water Quality

Based on the RBMP (2017) there are point pollution sources and diffuse pollution sources met in the River Basin of Chalkidiki. Point pollution sources examined are wastewater treatment plants, industrial units, thermal power plant, livestock farming, mines – quarry, aquaculture and fishfarming. The most polluting activity is industries and wastewater treatment plants. The thermal power plant pollution refers mainly to Cr, Zn, As, Cu, HC, PCBs, Cd, Pb, Hg, Ni. The mines and quarries pollution refers to SO_4^{-2}, Fe, Mn, Zn, Pb, Sb, As (RBMP, 2017).

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Diffuse pollution sources include urban, agricultural, livestocks and other sources. The most polluting, followed by urban wastewater not discharged to WWTT activity is livestock for BOD loads, while agriculture is the most polluting activity followed by livestocks regarding nitrogen and phosphorous loads.

Totally the annual BOD load is 5,155.68 tons/year, the annual N load is 3,136.11 tons/year and the annual P load is 868.41 tons/year in Chalkidiki RB.

The subsystem Anthemountas down flow faces pollution problems due to agriculture, livestock farming, urban wastewater and over-abstraction (Table 14). Salt water intrusion problems also exist. Increased values of Mn, Fe, B, Cr, As, Cl, are due to the physical background. Especially As values are due to geothermic fluids. The system’s chemical and quantitative status is bad. The subsystem Thermi – N. Risio does not face pollution problems (Table 14). Increased values of Fe, Mn, B, As, Cl, Na, H_2S are due to the physical background and especially the geothermic fluids and the Anthemountas crack. Cholomontas - Oreokastro subsystem does not face pollution problems or over-abstraction (Table 14).

Table 14. Water resources quality assessment of the three groundwater systems (source: RBMP, 2017)

Groundwater system	Chemical status	Quantitative status	Increased values due to physical background	Increased values due to human pressures	Main pressures	Salt water intrusion
Down flow of Anthemountas	Bad	Bad	Fe, Mn, B, Cr, As, Cl, E.C.	NO_3, Cl	Agriculture, livestock farming, urban wastewater, salt water intrusion, over-abstraction	Yes
Thermi – N. Risio	Good	Good	Fe, Mn, B, As, Cl, Na, H_2S	-	-	No
Cholomontas - Oreokastro	Good	Good	-	-	-	No

3.2.4. Land Uses

Based on the RBMP (2017) the land uses identified in the WD of Central Macedonia are shown in Table 15. The dominant land use is agriculture (56.74%) followed by forests (37.89%).

Table 15. Land uses in the WD of Central Macedonia (source: RBMP, 2017)

Land Uses	%
Agriculture	56.74
Forest	37.89
Artificial surface	3.31
Transport networks	0.12
Water & wetlands	2.12
TOTAL	**100.00**

3.2.5. Strategy and Measures taken

The National strategy on climate change adaptation is applied in this area as well.

Specific Measure included in the RBMP of the WD of Central Macedonia included the pilot measures for the implementation of precision farming for the reduction of water consumption (**M10S1601**) (1st update of the RBMP of Thrace WD, 2017). Specifically, this measure seeks to exploit new technologies, which can include the implementation of new, innovative processes, including the search for new cultivation practices and production practices that contribute to environmental protection and adaptation to climate change.

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Measure 16 of the RDP 2014-2020 provides for aids in the context of producer group partnerships with other stakeholders (consultants, researchers, other food chain actors and innovation brokers) to achieve the objectives:

1. Reduce water consumption through the adoption of advanced irrigation systems, and the adoption of precision farming.

2. Reduction of input costs that entails both economic and environmental benefits (reduction of fertilizer use, pesticide use, adoption of new varieties better suited to local soil, hydrological and climatic conditions, utilization of RES for substitution of minerals fuel).

3.2.6. Conclusions

DEYA Thermis takes water from three groundwater systems in the RB of Chalkidiki, to supply with water the people of the Municipality of Thermi. The basic groundwater system providing water to DEYA Thermis is over-exploited and it is found in bad quantitative status. The assessment using WEI index showed that the subsystems of Anthemountas down flow and Thermi – N. Risio are not sustainable at their present state. The third subsystem Cholomontas - Oreokastro (EL1000193) is facing a strong risk at its present state. The water quality assessment showed that the groundwater system of down flow of Anthemountas is in bad chemical and quantitative status, receiving many pressures (e.g. agriculture, livestock farming, urban wastewater etc.) and at the same time faces salt water intrusion problems. The other two groundwater systems (Thermi – N. Risio and Cholomontas – Oreokastro) are in good chemical and quantitative status without salt water intrusion problems. Increased values of some chemical elements are due to the geological background in the groundwater system of Thermi – N. Risio. The dominant land use is agriculture. The national strategy on climate change adaptation is applied in this area as well. A specific measure included in the RBMP is the implementation of precision farming to reduce water consumption.

3.3. PB4 – Municipality of Kardzhali, Bulgaria

3.3.1. General presentation

The water resources in the area of Kardzhali are formed by underground and surface water sources, which are mainly fed by precipitation. Specifically, in the area of "VIK" Ltd.-Kardzhali there are the following water resources:

- **Surface water bodies**

Arda River code BG3AR100R020 falls 100% in the territory of the Municipality of Kardzhali. Varbitsa River (BG3AR400R074) is the longest and fuller tributary of the Arda River, running entirely on the territory of Smolyan and Kardjali. Krumovitsa River (BG3AR200R009) falls 10% on the territory of the Municipality of Kirkovo, 10% to the Municipality of Momchilgrad and 80% to the territory of the Municipality of Krumovgrad. Borovitsa River (BG3AR600R024) is the part from Borovitsa Reservoir to the Kardjali dam. 15% of it is on the territory of the Municipality of Kardjali. River Perperek (BG3AR300R011) 60% falls on the territory of Kardjali Municipality. Kioshed River (BG3AR500R019) which is a tributary of the Arda river in its part between the Kardzhali dam and the Studen Kladenets dam, falls at about 80% on the territory of the Municipality of Kardzhali. Kardzhali dam (BG3AR570L021) falls by 50% on the territory of Kardjali Municipality. Studen Kladenets dam (BG3AR350L010) falls by 70% on the territory of the Municipality of Kardzhali.

- **Groundwater bodies**

The settlements on the territory of the Kardzhali district use part of the groundwater water resources in the underground water bodies "Karst Water - Ardino-Nedelinski Basin" (BG3G00000Pt042), "Cracked Water in the Central Rhodope Complex" (BG3G00000Pt046), "Cracked Waters in Eastern Rhodope Complex" (BG3G00000Pg028) and" Porous waters in Quaternary - Arda River" (BG3G000000Q010).

Water Supply and Sewerage "Ltd. - Kardzhali manages 70 abstraction facilities from groundwater. Until now, "Water supply and sewerage" Ltd.-Kardzhali and the municipalities were issued permits for water abstraction for 18 water abstraction facilities. For the other 52 water abstraction facilities the permits for water abstraction have expired

3.3.2. Water Availability

To measure the quantity and quality of surface water in the Kardzhali territory, the constructed and operating backwater hydrometric network of Maritsa, Arda, Tundzha and their tributaries is used. It consists of 8 hydrometer stations (HMS), of which two HMS are on the Maritsa River, one on the Arda River and the other five HMS on their main tributaries in the area of the Kardzhali district (Table 16).

Table 16. Surface water inflow

Location of a hydrometric station	Area of catchment area [km^2]	Outflow Module [l/s/km^2]	Average amount of flow [m^3/s]	Minimum flow [m^3/s]	Maximum flow rate [m^3/s]
Arda River, the village of Velhino (HMS 61700)	858,4	17,723	15,213	6,534	26,000
Arda River at dam "Ivailovgrad"	5060	13,98	70,75	26,31	144,7
Varbitsa, Dzhebel (HMS 61500)	1149	14,431	16,581	4,912	37,400
Krumovitsa River, Krumovgrad (HMS 61550)	497,6	14,712	7,320	2,827	15,100
Harmanliyska at Harmanli (HMS 73550)	952	4,459	4,245	1,409	10,100
Byala river, Dolno Lukovo (HMS 62800)	448	11,705	5,244	1,805	16,019

The surface waters of the Borovitsa dam are used for drinking and domestic water supply in the town of Kardzhali, town of Momchilgrad and 47 settlements in the municipalities of Kardzhali, Momchilgrad and Chernoochene. The surface waters of Kosma dere are used for water supply in the village of Raven only two months of the year (according to the data of «VIK» Ltd. - Kardzhali). Surface waters from other rivers and dams in the territory are only used for irrigation, aquaculture and energy production. The quantities of water supplied by "ViK" Ltd - Kardzhali for drinking water supply in the period 2009-2011 are given in Table 17.

Table 17. Extraction of surface water for 2009 – 2011

No.	River / dam - Location of water abstraction	How to use the water	Year	Average quantity extracted [l / sec.]	Average quantity extracted [m3 / day.]	Average quantity extracted [m^3 / yr]
1.	River water catchment - the	WB of Lale and N.Bozveli, General. Momchilgrad	2009	4,00	158,33	9 500
			2010	4,00	134,17	8 050
			2011	4,00	159,83	9 590

2.	Borovitsa Dam	PBN of Kardjali, town of Momchilgrad and 47 settlements in the municipalities of Kardzhali, Momchilgrad and Blackheath	2009	178,08	15 385,90	5 615 851
			2010	172,65	14 917,25	5 444 797
			2011	176,50	15 249,19	5 565 954
	TOTAL:		2009	182,08	15 544,23	5 625 351
			2010	176,65	15 051,42	5 452 847
			2011	180,50	15 409,02	5 575 544

The East Aegean Basin Basin Directorate defined the maximum water quantities allowed for extraction. The total maximum flow from all surface water sources is Qmax = 802.45 l / s; Q = 10,237.96 .103 m^3

The drinking water supply of the settlements in the Kardzhali District during the period 2009 ÷ 2011 was carried out by the ground water through abstraction facilities. The amount of groundwater extracted during the period 2009-2011 is shown in Table 18.

Table 18. Quantity of underground water extracted - 2009-2011.

№	Water Supply System	Obtained water quantity / m3 / year /			Comment
		2009	2010	2011	
1	Ardino	140 006	137 922	140 171	
2	Benkovski	129 402	131 275	140 009	
3	Jebel	75 275	72 114	78 295	
4	Krumovgrad	232 475	230 134	240 561	
5	Kardzhali	2 027 148	2 011 981	1 991 789	
6	Momchilgrad	361 870	347 582	360 443	
	Total	2 966 176	2 931 008	2 951 268	

3.3.3. Water Quality

Surface Water Quality

The surface water in the area served by the territory is used for drinking water supply to the population, water used for technical needs, irrigation, recreation and water bodies are the successor of the waste water from the industry and the population in the area. It is necessary that the quality of the surface water used for certain purposes meets the regulatory requirements.

The assessment of the status of surface drinking water bodies is carried out depending on the category of water sources in them. The category of water sources is determined on the basis of the results of the monitoring performed and the norms in Annex 1 of Ordinance No. 12 of 2002 on the assessment of surface water quality for drinking and household purposes. According to this regulation water sources are classified into three categories depending on the quality of the water - A1, A2, A3, and A1 is for the best quality. On the territory of the Kardzhali region there are 2 water catchments for drinking water supply from surface waters in the basin of Arda river - Borovitsa dam and Kosma dere. In addition, the drinking water body of the Kazatsite River is defined. The procedure for issuing a permit for the drinking water supply of the water intake has been started.

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The two water catchments are in category A2 and A3 according to Annex 1 of Regulation 12, which determines the good condition of the water bodies, and they are suitable for drinking purposes.

Surface water bodies status - water bodies, waste water receivers (issued by BDIBR Discharge Discharge) must meet the requirements of the legislation in force. Surface waters that are contaminated above the specified requirements create health conditions for the population in the area. Continuous and periodic monitoring is carried out to determine the quality of water at certain points of water bodies. On the basis of the monitoring data, the water body pollutants are assessed as a result of the discharge of waste water as point pollutants. At present, water bodies are polluted mainly by untreated untreated water by the population and industrial enterprises.

The most typical are the NASEM sites of RIEW-Haskovo, which also reflect the impact on the waters in the Arda River and its tributaries.

Characteristic "Sensitive Areas" along the Arda River:

- the Arda River, from the spring to the village of Arda;
- the Arda River, after the village of Arda to the town of Kardzhali;
- "Borovitsa" Reservoir - "Sensitive Zone";
- Kardzhali dam - "Sensitive zone";
- the Arda River after the town of Kardzhali to the border;
- Studen Kladenets Reservoir after the inflow of the Cherna river to the influx of the Krumovitsa River;
- Varbitsa River, after the village of Bankovski until its influx into the Studen Kladenets Reservoir.

For agglomerations that are in a "sensitive area", the requirements of Directive 91/271 / EEC on waste water treatment from agglomerations of more than 10,000 PE are applied. and agglomerations of 2000 to 10,000 PE. According to the said Directive, the waste water from the agglomerations of Kardzhali, Momchilgrad, Krumovgrad, Ardino, Djebel and Benkovski needs to be purified to remove the nutrients nitrogen and phosphorus to the higher requirements, and in the design works for WWTP facilities are provided to achieve an increased level of reduction of nutrients Nt and Pt.

Groundwater quality

The quality of groundwater used for drinking water supply from all water abstraction facilities corresponds to Ordinance № 9 / 16.03.2001. for the quality of water intended for drinking and household purposes, of the Quality Standard in Ordinance №1 / 10.10.2007. for the exploration, use and protection of groundwater and Directive 98/86 / EC.

Protection of water quality is ensured through the establishment of sanitary protection zones in three zones, the boundaries of which are regulated by Ordinance №3 / 16.10.2000r. on the conditions and procedure for investigation, design, validation and exploitation of the sanitary-security zones around the water sources and the facilities for drinking water supply and around the water sources of mineral waters used for healing, prophylactic, drinking and hygienic needs. The quality of groundwater used for drinking and domestic water supply from all water abstraction facilities corresponds to Regulation 9 / 16.03.2001 for the quality of water intended for drinking and household purposes, of the Quality Standard in Ordinance №1 / 10.10.2007. for the exploration, use and protection of groundwater and Directive 98/86 / EC.

The issue of permits for water use, the setting up of water treatment plants around the water sources in three zones and observance of the regime for use of the territory of the respective belts is of paramount importance for the protection of water quality.

Table 19 provides a summary of water resources quality.

Table 19. Summary of water resources quality

Water Supply Zone	Compliance with Standards	Problematic parameter	Comments
"Karst Water - Ardino-Nedelinski Basin" with code BG3G00000Pt042	The quality of groundwater corresponds to Ordinance No. 9 / 16.03.2001, the Quality Standard in Ordinance No. 1 / 10.10.2007. and of Directive 98/86 / EC	No problem parameters	The water is suitable for drinking purposes
„ Cracked Water in the Central Rhodope Complex "with code BG3G0000Pt046	The quality of groundwater corresponds to Ordinance No. 9 / 16.03.2001, the Quality Standard in Ordinance No. 1 / 10.10.2007. and of Directive 98/86 / EC.	No problem parameters	The water is suitable for drinking purposes
„ Cracks in Eastern Rhodope Complex "with code BG3G0000Pg028	The quality of groundwater corresponds to Ordinance No. 9 / 16.03.2001, the Quality Standard in Ordinance No. 1 / 10.10.2007. and of Directive 98/86 / EC.	No problem parameters	The water is suitable for drinking purposes
„ Cracked water - Krumovgrad - Kirkovska zone "with code BG3G00PtPg023	The quality of groundwater corresponds to Ordinance No. 9 / 16.03.2001, the Quality Standard in Ordinance No. 1 / 10.10.2007. and of Directive 98/86 / EC.	Problem parameter Fe	Water is not used for drinking purposes
"Porovi River leads to Quaternare - Arda "code BG3G000000Q010	The quality of groundwater corresponds to Ordinance No. 9 / 16.03.2001, the Quality Standard in Ordinance No. 1 / 10.10.2007. and of Directive 98/86 / EC.	No problem parameters	The water is suitable for drinking purposes

A basic principle regarding the ownership of natural resources on the territory of the Republic of Bulgaria is that they are the property of the state. This principle is also applicable to the right of ownership of waters and water bodies. Public state property is the waters of the rivers, the waters in the water reservoirs and those in the dams and the micro dams, the natural lakes and the underground waters. State-owned public property is also the complex and significant dams under Annex No. 1 under Article 13, paragraph 1 of the Water Act.

Those waters and non-state water bodies are public municipal property. Such are the waters and water bodies, incl. and natural springs, lakes and marshes located on land - municipal property, incl. and mineral waters, dams and micro dams.

It is also possible to have private ownership of waters and water bodies, but only on those that originate in private property and lakes that are not fed by water - public state or public municipal property.

Groundwater under Article 11 (3) of the Water Act is public state property. The ground water abstraction should be based on permits for water abstraction by the Basin Directorate for Water Management in the East Aegean Region with the center of Plovdiv.

Problematic areas with scarcity of water or conflicts between different consumers (domestic, industrial, agricultural and electric)

The water resources in the Kardzhali area and mainly the surface runoff of the rivers in the area are used by the hydro-economic sub-sectors of hydropower and water supply. There are very few built irrigation systems and facilities on the territory.

Drinking and domestic water supply

Major water consumers are:

1. For domestic water supply

In the separate area of "VIK" Ltd-Kardjali is built one river catchment for drinking water supply from surface water. In addition, the waters of Borovitsa dam are used for water supply in Kardzhali and Momchilgrad and 47 settlements in the municipalities of Kardzhali, Momchilgrad and Chernoochene.

2. For irrigation

A detailed description of the operating irrigation fields in the separate area of "VIK" Ltd. - Kardjali, which are in the Arda River and the Byala Reka River and their tributaries, is given in Appendix 3-1. On the territory of Kardzhali District there are 6 municipal marshalling irrigation dams, managed by "Irrigation Systems" EAD.

3. For power generation

In the valley of the Arda River and its tributaries, included in the territory of the «VKK» Ltd. - Kardjali, built and in operation hydro power plants are: "Dolna Arda" cascade, consisting of three dams - Kardjali dam, Studen kladenets dam and Ivailovgrad dam and three hydropower plants under them. Only Ivailovgrad Dam does not belong to the separate area of the Water Supply and Sewerage - Kardzhali.

There are no problematic areas with water scarcity or conflicts between the different consumers (domestic, industrial, agricultural and electric) in the territory of VIK OOD-Kardzhali.

Water bodies designated as recreational waters, including those designated as drinking water for groundwater in the basin of the Arda River basin, which are under water quality protection, are provided by the establishment of sanitary protection zones.

Areas for the protection of water for the conservation of habitats where maintenance or improvement of water status is an important factor in their conservation, including the relevant Natura 2000 sites designated under Habitats Directive 92/43 / EEC and Directive 79/409 EEC for poultry.

The Habitats Directive and the EU Birds Directive and Council of Ministers Decisions define the respective areas where the water use of surface and / or groundwater is restricted.

These areas are defined as "sensitive" to protect habitats where maintenance or improvement of water status is an important factor in their conservation, including relevant sites under Natura 2000 'defined in accordance with Directive 92/43 / EEC and Directive 79/409 / EEC. In order to ensure the conservation of natural habitats and habitats of species, plans, programs, projects and investment intentions are assessed for compatibility with the subject and conservation objectives of the respective protected area. The terms and procedure for carrying out the assessment are regulated in an Ordinance under Art. 31 of the Biodiversity Act.

Areas sensitive to biogenic elements defined as "Sensitive" according to Directive 91/271 / EEC and areas declared as "Vulnerable" according to Directive 91/676 / EEC.

- All surface water bodies on the territory of "VIK" Ltd. - Kardzhali, which have been categorized as receiving in a "sensitive zone" and some of them fall under the requirements for nitrate vulnerable zones.

- Waste water from all agglomerations that are in a 'sensitive area' is necessary to purify to remove the nutrients nitrogen and phosphorus to the higher requirements. In the designed WWTP for agglomerations Kardzhali, Momchilgrad, Ardino, Krumovgrad, Dzhebel and Benkovski has provided facilities for an increased level of nutrient reduction Nt and Pt.

POTENTIAL POLUTION THREATS

A potential threat to groundwater is point and diffuse sources of pollution. Among the point sources of pollution are landfills, tailings ponds, industrial sites, mines, oil bases, etc. Diffuse pollution is mainly from agricultural sources - agriculture and livestock breeding.

Potential threats of water pollution in the area of the territory are some of the significant problems that have a negative impact on the quality of surface and groundwater. Potential threats to surface water are also point and diffuse sources of pollution (Table 20).

Table 20. Types of pressures resulting in water bodies at risk of different activities

Types of pressure	Significant sector / activity
Diffuse pollution	- - Urbanized areas without sewerage system and WWTP and lack of sewerage in many of the settlements in the area. Household water is collected in septic tanks and creates real risk for groundwater and human health - - Production plants and sites of industrial enterprises without an efficient site sewerage system, potential soil and water pollutants (oil products stores, unprocessed old oil holdings, chemical stores used as raw materials in industrial plants, etc.). - There is a risk of over-pollution of soil and water. - - Farming - unregulated fertilization, which does not correspond to good agricultural practice. Warehouses for pesticides and others. plant protection products. - - Livestock breeding - farms that do not use good farming practice, uncontrolled accumulation of fertilizer masses, leaks of contaminated waste water, etc. There is a risk of over-pollution of water with biogenic elements, nitrogen compounds, phosphorus compounds and others. - - Landfills, unregulated landfills, uncontrolled accumulation of waste (construction and household) on the outskirts of the settlements. - - Auto-transport and transport activities - washing of vehicles in car washes in places without sewerage, spillage of oil and petroleum products, etc. - - heavy metals pollution in areas with developed mining, tailing ponds and others. - inefficient control and management of the sites create conditions of potential risk of pollution in case of non-compliance with requirements for environmental protection.
Point contamination	- Urbanized areas with sewerage of the settlements without WWTP: Kardzhali, Momchilgrad, Krumovgrad, Ardino, Dzhebel, Benkovski and others. (the implementation of waste water treatment plants is in the pipeline) and partially

	constructed sewerage sections of other settlements in the separate territory - the content of organic pollutants in the receiver is increased, the dissolved oxygen content is reduced, the content of biogenic elements is increased, which leads to eutrophication, conditions for negative impact on the biodiversity and sustainable development of the aquatic ecosystem are created, the self-purifying capacity of the water body is reduced. Prerequisites for health risk are created - Industrial plants forming waste water discharged directly into water bodies in the case of insufficiently effective LPGs or lack thereof. Potential contaminants are many enterprises of the food industry, transport companies and others. in the separate territory. In some parts of the Arda river basin, heavy metals contaminants Cd, Pb, Ni and others have been found. from advanced mining and enrichment of metal ores (limiting the damage from old pollution). The Arda River - from Kardzhali to the border with Greece - pollution is registered in the following sections: - Student Kladenets Reservoir - discharge of waste water from "Kardzhali" OOD and accumulation of sediments in the tail of the dam. Single cases of pollution are recorded in the middle and on the wall of Studen Kladenets Reservoir; - Arda River after Studen Kladenets Reservoir, periodic pollution is found on the bridge between the village of Potoknitsa (Krumovgrad Municipality) and outside the separate territory - the village of Rabovo (Municipality of Stambolovo, Haskovo District); - livestock farms, etc., to create conditions for uncontrolled emergency water discharge; - Industrial plants forming waste water discharged into sewerage systems in the settlements without efficient LPGs - create a precondition for burst pollution of the total waste water stream and may compromise the optimal purification of water in future WWTPs.
Morphological changes	Industry (extraction of sand and aggregates, etc.), dykes and river corrections.
Other specific	Erosion processes, intrusion.

3.3.4. Conclusions

Both surface and groundwater bodies are used for the water supply of Kardjhali municipality. Water Supply and Sewerage "Ltd. - Kardzhali manages 70 abstraction facilities from groundwater. Surface water from the Borovitsa dam are used for drinking and domestic water supply in the town of Kardzhali, the town of Momchilgrad and 47 settlements in the municipalities of Kardzhali, Momchilgrad and Chernoochene. The surface waters of Kosma dere are used for water supply in the village of Raven only two months of the year.

Both surface and groundwater quality abide to the legislation in force. Sanitary zones are delineated, and sensitive areas are determined. Some possible pollution threats include morphological changes, diffuse and point pollution sources.

3.4. PB5 – Municipality of Gotse Delchev, Bulgaria

3.4.1. General presentation

Water resources which are used for water supply of region of Gotse Delchev are following (Table 21):

Table 21. Water resources used for water supply of Gotse Delchev region

Water source	Capacity	Type	Altitude

Tufcha	420 l/s	Ground water source (catchment)	1 146 m
Barakata	91 l/s	Spring	1 555 m
Sofiata	16 l/s	Spring	1 430 m
Papaz Chair	11 l/s	Spring	1 382 m

The main water source for the region is water catchment Tufcha, water is taken near village Breznika at sanitary protected area of river Breznitsa (also known as Tufcha). Water pas through a Potable Water Treatment Plant (PWTP). After it is treated, main quantity is supplied to water supply network of Gotse Delchev and rest is provided for Gospodinovci and Garmen.

The area of the catchment of River Breznitsa (also known as Tufcha) is 123 km^2. Average annual flow of the river near village Breznitsa is 1,42 m^3/s with annual maximum in May and minimum in September. The village of Breznitsa in Gotse Delchev municipality is the only settlement along the river. River Breznitsa is a right inflow of river Mesta.

Responsible body for water resource management is Basin Directorate West Aegean Region. Its operation is controlled and coordinated by Ministry of Environment and Water.

Protected areas are defined in River Mesta basin (Figure 6).

3.4.2. Water Availability

As a part of Regional Master Plant for the territory served by WSC Blagoevgrad, for water supply system of Gotse Delchev an assessment of water stress was performed. Results from it show that even in case water losses are reduced with 35% water stress index in 2038 still will be 104% (an optimum value is 40%). As a part of the report it was concluded that in order an optimum value of 40% for water stress to be reached in addition to water loss reduction, an extension of capacity of water sources should be provided as an additional measurement to guarantee efficient water supply for the region. Results from assessment of capacity of volume of water reservoirs for the regional of Gotse Delchev show that capacity of existing reservoirs is enough and in 2038 volume index of available water reservoirs will be 160%.

3.4.3. Water Quality

Three of water source for the region of Gotse Delchev are mountain springs and as a result their main problem is related with constantly changing chemical and microbiological composition. Water from them is rich of organic matter with undissolved and colloidal clay particles. Because of this water has high level of turbidity and color that cause problems with its taste and smell. Very often in case of intense snow melting and heavy rainfall physico-chemical or microbiological parameters exceed limit values set in Ordinance №12 which regulates quality requirements of surface water intended for potable water supply.

Water for main water source for the region of Gotse Delchev which is also used for the water supply of city of Gotse Delchev is extracted from a ground water source which is protected from human impact by sanitary protection area. In addition, water passes through a potable water treatment plant and no quality problems are reported.

3.4.4. Strategy and Measures taken

In May 2018, World Bank has prepared a draft of a National Climate Change Adaptation Strategy and Action Plan for the Government of Bulgaria. Water is one of the main subjects covered in the document. This draft National Climate Change Adaptation Strategy and Action Plan for the Republic of Bulgaria is intended to serve as a reference document, setting a framework for climate change adaptation action and priority directions up to 2030, identifying and confirming the need for climate adaptation action both at economy-wide and sectoral levels (including water), while highlighting the consequences of no action. Main objectives of the documents are:

- Assessment of options to address climate risks across the economy;
- Formulation of a National Climate Change Adaptation Strategy and Action Plan, which shall cover the period to 2030
- Strengthen capacity for implementation and cross-sector coordination on climate change adaptation

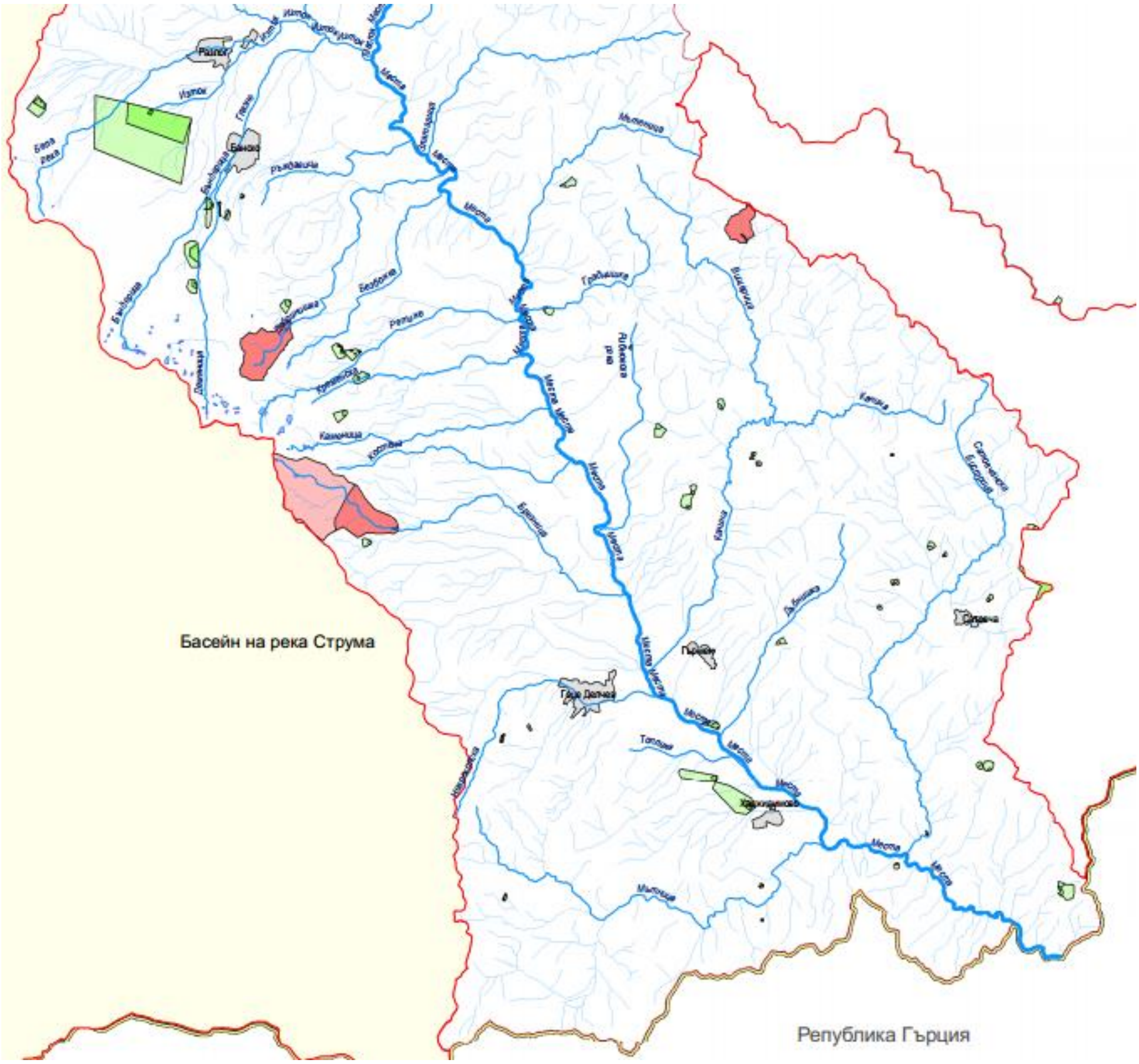

Figure 6. River Basin Management Plan in West Aegean Region – Protected areas for River Mesta Basin

	Sanitary protected area for ground water category 1
	Sanitary protected area for ground water category 2
	Sanitary protected area for underground water category 1
	Sanitary protected area for underground water category 1
	Main river
	Inflow of main river

As a part of National Climate Change Adaptation Strategy and Action Plan following strategic objectives for water sectors are considered:

Strategic Objective	Type of options considered	Examples
Enhance Adaptive Governance	Adaptation of legal framework to make it instrumental for addressing climate change impacts	Clarify roles and responsibilities for CCA
Strengthen knowledge base and awareness for adaptation	Use of research and education institutions	Provide research support to River Basin Directorates through framework agreements
	Awareness, education and training	CCA training of public administration and water operators
	Monitoring and flexibility	Extend and upgrade CCA related monitoring networks of precipitation, water resources and water use
Enhance adaptive management of water system infrastructure	Adapting design and construction	Revise and update design and construction norms
	Adapting operations	Develop methodology and assess adaptive capacity of significant water infrastructure

In addition, following top five adaptation options for the water sector were selected for quick integration:

- Adapt of legal framework to make it instrumental for addressing climate change impacts
- Establish of a dynamic publicly available GIS database supporting climate change decision making;
- Maximize the use of research and education institutions;
- Operate water infrastructure to increase resilience to climate change for all users and sectors;
- Strengthen adaptation capacity: CCA awareness raising campaigns, education, and training

Following results from implementation of National Climate Change Adaptation Strategy and Action Plan:

- For adaptation options supporting the strategic objective to enhance adaptive governance, expected results are identified as: Improved coordination amongst institutions, effective and efficient implementation of RBMPs, and the adoption of more water efficient and less water polluting technologies and practices.
- Under the strategic objective to strengthen the knowledge base and awareness for adaptation the key expected results are: the availability of the latest research achievements and reliable water monitoring data, enhanced quality of plans and programs developed by RBDs, raised public awareness, and increased preparedness of stakeholders. Overall the adaptation actions will contribute to improved decision making under uncertainty.
- For the strategic objective to enhance adaptive management of water system infrastructure expected results are: the adaptive design and construction of managed water systems, identification of significant water infrastructure which needs reinforcement, and adequately and safely operated water systems.

3.4.6. Conclusions

Springs and groundwater bodies are used for drinking water supply in the municipality of Gotse Delchev. The use of freshwater resources puts on a risk water supply of the region in case of snowless winter occurrences which are expected with climate changes. Effects from this could be limited in case of presence of dams which can keep certain water volume to guarantee efficient water supply for the area even for certain period even in case of a non-snowy winter. Currently dams for water supply are not available on the territory of Gotse Delchev.

There are some high values in specific water quality parameters mainly due to the fact that springs are used. Therefore, there is a water treatment plant to avoid such water quality problems. Also, sanitary zones are defined in groundwater abstraction points. There is a National Climate Change Adaptation Strategy and Action Plan for the Republic of Bulgaria which sets a framework for climate change adaptation action and priority directions up to 2030, identifying and confirming the need for climate adaptation action both at economy-wide and sectoral levels (including water), while highlighting the consequences of no action. Main objectives of the documents are:

- Assessment of options to address climate risks across the economy;
- Formulation of a National Climate Change Adaptation Strategy and Action Plan, which shall cover the period to 2030;
- Strengthen capacity for implementation and cross-sector coordination on climate change adaptation.

3.5. PB6 – Municipal Water Supply and Sewerage Company of Thermaikos, Greece

3.5.1. General presentation

Municipality of Thermaikos is located in the River Basin District of Central Macedonia (GR10) and in particular in the River Basin of Chalkidiki (EL05) with an area of 5,546 km^2. The boundaries of the municipality crosses three Groundwater Subsystems, and in particular:

1. Groundwater Subsystem Epanomis – Moudanion. It has a total area of 681.77 km^2, its renewable reserves are estimated at 81.2x10^6 m^3/year[1], while the mean annual water abstraction is estimated at 121.32x10^6 m^3/year[2]. According to Central Macedonia River Basin Management Plan, the Chemical status of the Groundwater Subsystem Epanomis – Moudanion is characterised as Bad, while the Quantitative status is characterised as Poor.
2. Groundwater Subsystem Kato Rou Anthemounta. According to Central Macedonia River Basin Management Plan, the Chemical status of the Groundwater Subsystem Kato Rou Anthemounta is characterised as Bad, while the Quantitative status is characterised as Poor.
3. Groundwater Sybsystem of Thermis – Neo Risio. According to Central Macedonia River Basin Management Plan, the Chemical status of the Groundwater Subsystem Kato Rou Anthemounta is characterised as Good, while the Quantitative status is characterised as Good.
   The Groundwater Subsystems of Kato Rou Anthemounta and Thermis – Neo Risio are part of the Groundwater System of Anthemounta with a total area of 309.45 km^2, renewable reserves of 33.6x10^6 m^3/year[3] and mean annual water abstraction of 37.02x10^6 m^3/year[4]

A map of the region is presented in the following Figure 1. The competent authority for water resources management is the Water Directorate of the Decentralised Authority of Macedonia and Thrace.

[1] According to IGME (2010)
[2] According to Central Macedonia River Basin Management Plan (2014)
[3] According to IGME (2010)
[4] According to Central Macedonia River Basin Management Plan (2014)

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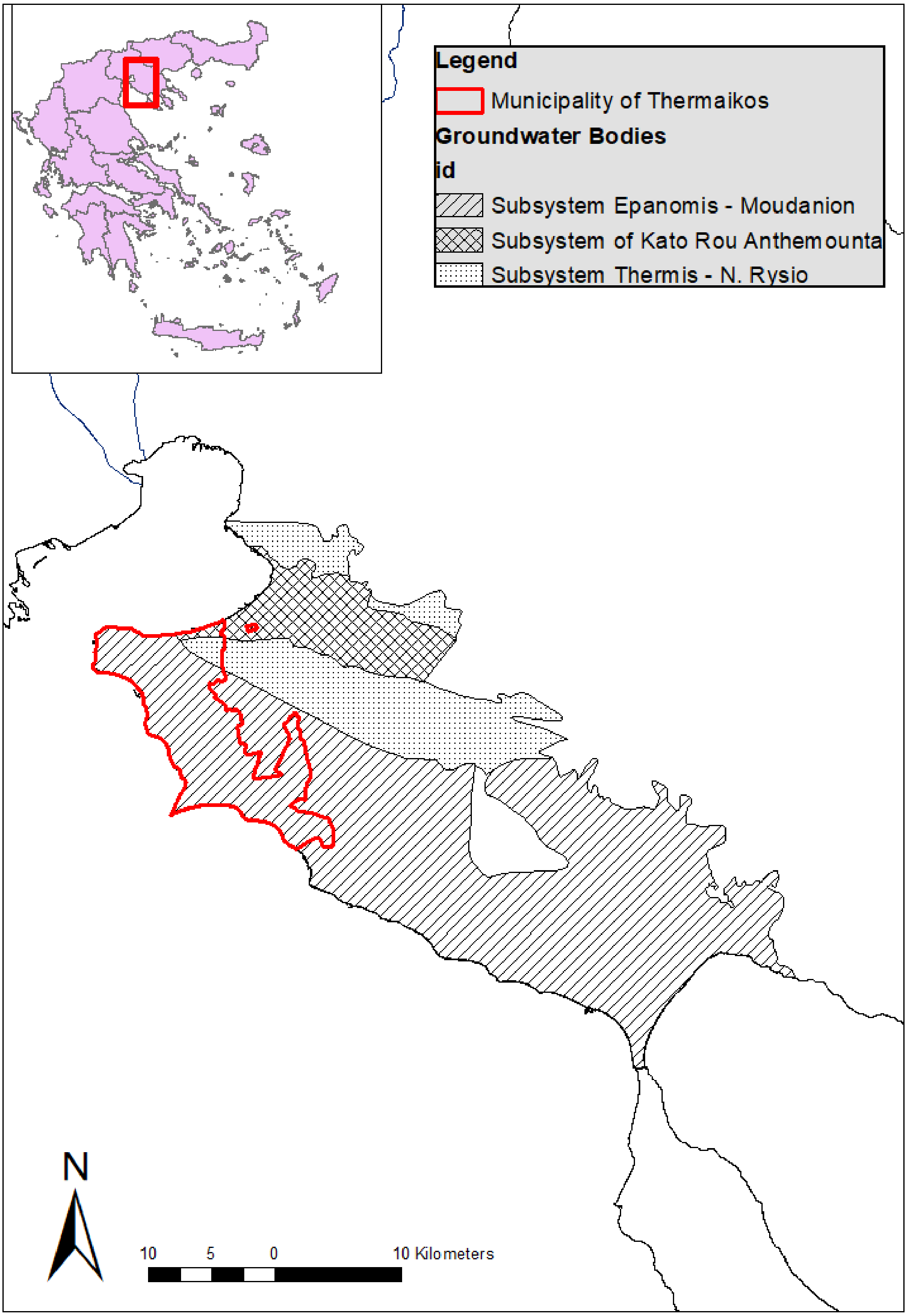
Legend
Municipality of Thermaikos
Groundwater Bodies
id
Subsystem Epanomis - Moudanion
Subsystem of Kato Rou Anthemounta
Subsystem Thermis - N. Rysio
N
10 5 0 10 Kilometers

3.5.2. Water Availability & Quality

Two out of three of the groundwater subsystems in the area have a Bad chemical status and also a Bad Quantitative status, revealing the vulnerability of the water resources in the area. Moreover, according to the River Basin Management Plan, the annual water abstraction is larger than the annual recharge, resulting with a continuous increase of the pumping depth. That fact, combined with the vicinity of many boreholes to the sea, results in salinity problems in the area, as presented in the following Figure 2[5].

Figure 1. Salination Areas in Central Macedonia River Basin

3.5.3. Strategy and Measures taken

According to the Central Macedonia River Management Plan, the measures to confront the climate change impact can be grouped as i) long-term measures for an equilibrium between supply and demand, ii) measures for increasing the availability of water and iii) measures minimizing the effects of droughts.

i. The measures for an equilibrium between supply and demand could be technological, economical or social. For the management of water demand these measures could include new technologies for saving water, reducing leakages in water networks, reuse of water, new agricultural policies, new water pricing, better public education and increasing the public awareness. On the other hand measures for increasing the supply of water could include better natural reserve in river basin, use of alternative water sources or transfer of water from other districts.

[5] From Central Macedonia River Basin Management Plan (2014)

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ii. The measures for increasing the availability of water could include the design and implementation of drought mitigation plans, the development of early warning systems and the education of the public in water saving.

iii. The measures minimizing the effects of droughts could include a) Strategic measures, such as Development of River Basin Management Plans, Adopt long-term water resource management measures, Establishing appropriate indicators and limits for the different stages of drought, Establishing drought-fighting actions, Inventory and maintenance of drought infrastructures b) Operational like Determination of water use priorities in drought periods, c) Organizational, like Definition of organizational structure for the preparation and implementation of management plans, Definition of available resources, Coordination of stakeholders

3.5.4. Conclusions

Municipality of Thermaikos is located in the River Basin District of Central Macedonia (GR10) and in particular in the River Basin of Chalkidiki (EL05) with an area of 5,546 km^2. Groundwater sources are used for the supply of water to the municipality. Two out of three of the groundwater subsystems in the area have a bad chemical status and also a bad quantitative status, revealing the vulnerability of the water resources in the area. Moreover, the annual water abstraction is larger than the annual recharge, resulting with a continuous increase of the pumping depth. That fact, combined with the vicinity of many boreholes to the sea, results in salinity problems in the area. Measures are taken to confront climate change impacts.

Chapter 4. Discussion & Conclusions

This deliverable aims at presenting a methodology for the water resources vulnerability assessment. The methodology described is part of a methodology also applied in other EU-funded projects CC-WARE and DRINKADRIA, where the vulnerability index of water resources is estimated. Trying to capitalize the knowledge from other projects, the same methodology is described here.

Water Resources Vulnerability Index is an index deriving from the combination of water availability indices (such as WEI), water quality indices, climate characteristics, and adaptive capacity (consisting of socio-economic and natural indicators). Water resources vulnerability index is very important as it shows how vulnerable water resources are and this information can be an input for policy makers in order to design strategies and take measures on time.

In the context of this deliverable the beneficiaries of WATER RESCUE project provided information on the water resources they are using. The provided some general information, they assessed the availability of their water resources, they assessed the quality of water resources and they provided strategies and measures taken at national and local level.

All water utilities use both surface water and groundwater bodies for drinking water supply. Some of the water resources are found in good status regarding their availability, while there are some water resources found in over-exploitation status. Generally, water quality is good. The European and national legislation safeguards water quality especially when it is intended for human use. There are national strategies for the adaptation of climate change in both countries, Greece and Bulgaria. There are also local measures taken.

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Appendix: Beneficiaries' reports

The Project is co-funded by the European Regional Development Fund (ERDF) and by national funds of the countries participating in the Cooperation Programme Interreg V-A "Greece-Bulgaria 2014-2020".

WATER RESCUE

Water resources efficiency and conservative use in drinking water supply systems

WP	**4 Common Methodology & Tools**
Deliverable *Tool*	**4.1.1 Cross border water resources vulnerability assessment methodology report** *Questionnaire*
Project Beneficiary No	**PB1**
Beneficiary Institution	**Municipal Water Supply and Sewerage Company of Komotini**

The Project is co-funded by the European Regional Development Fund (ERDF) and by national funds of the countries participating in the Cooperation Programme Interreg V-A "Greece-Bulgaria 2014-2020".

Table of Contents

Name of the organization/institution: Municipal Water Supply and Sewerage Company of Komotini

Beneficiary number: PB1

1 Introduction

DEYA Komotinis takes water from the River Basin (RB) of Komotini Streams – Loutro Evrou (EL1209), one of the RBs of the Water District of Thrace (Figure 1). The population of the Water District of Thrace is 408,186 people (2011 census) showing a small increase compared to the 2001 census.

Figure 1. The Water District of Thrace and its River Basins (source: 1st updated RBMP of the WD of Thrace)

The River Basin (RB) of Komotini Streams – Loutro Evrou covers an area of 1,958.3 Km2, its average altitude is 289m and its maximum altitude is 1,459m.

The land uses in this RB are: agriculture 39.49%, forests 35.79% and pastures 19.83% (Table 1).

Table 1. Land uses in the RB of Komotini streams – Loutro Evrou (source: 1st updated RBMP of the WD of Thrace)

Land use	Area (acres)	% coverage
Urban	17,847	0.92
Pasture	385,557	19.83
Agriculture	767,828	39.49
Forests	696,009	35.79
Roads - Water	37,521	1.93
Other	39,734	2.04
TOTAL	**1,944,497**	**100.00**

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There are 31 surface water bodies identified in the RB of Komotini streams – Loutro Evrou: 28 rivers, 2 heavily modified river systems and 1 lake (Table 2).

Table 2. Surface Water Bodies in the WD of Thrace (EL12)

Type of surface water bodies	River Basins					Total
	EL1207	EL1208	EL1209	EL1210	EL1242	
Rivers	50	28	**28**	63	7	**176**
Heavily modified rivers	2		**2**	1		**5**
Lakes			**1**			**1**
Transitional	3	1		1		**5**
Coastal	3	2		4	3	**12**
TOTAL	**58**	**31**	**31**	**69**	**10**	**199**

There are 4 groundwater systems identified in the RB of Kmotini streams – Loutro Evrou (Table 3).

Table 3. Groundwater systems in the RB of Komotini stream – Loutro Evrou

Groundwater system name	Groundwater system code	Area (Km^2)
Filiouris system	EL1200040	332.07
Drosiniou system	EL120B100	1,807.04
Maronias system	EL1200110	190.00
Rodopis system	EL1200120	755.58

DEYA of Komotini supplies with water the whole municipality of Komotini, having 66,379 inhabitants. The water resources used are Vosvozis river (EL1209R0000010085N) and the groundwater system of Rodopi (EL1200120). Their characteristics are:

- Vosvozis river: (EL1209R0000010085N – length: 7.70Km; river basin area: 74.91Km^2; average annual runoff: 42.52hm^3)
- Rodopi system: (EL1200120 - area 755.58Km^2)

From Vosvozis river 2,750,000 m^3 of water were used by DEYA Komotinis in 2016 while from Rodopi system 3,550,000 m^3 of water were also abstracted in the same year.

The competent authority for water resources management in East Macedonia and Thrace is the Water Directorate of Eastern Macedonia and Thrace.

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2 Water Resources Vulnerability Assessment

2.1. Water Availability

Based on the RBMP of Thrace annual water demand is (Table 4).

Table 4. Annual water demand per water use in the WD of Thrace and the RB of Komotini - Loutro Evrou treams (source: RBMP, 2017)

Water Demand	WD of Thrace		RB of Komotini-Loutro Evrou streams	
	hm^3	%	hm^3	%
Agriculture	941.4	58.8	160.44	85.6
Domestic	60.5	3.8	14.66	7.8
Livestock	3.9	0.2	0.7	0.4
Industry	14.1	0.9	11.55	6.2
Hydroelectrical production	582.0	36.3		
Total	**1,602.0**		**187.35**	

The water volume used for hydroelectrical production can be considered as water use.

The dominant water user is agriculture consuming 85.6% of the total water use. Domestic water use is 7.8%.

DEYA Komotinis is supplying Komotini municipality with water from the river of Vosvozis and the groundwater system of Rodopi. Based on data from the RBMP (2017) water availability, average annual abstraction (total and per water use) is shown in Table 5. The system of Rodopi is used at a rate of 29.1%.

Table 5. Water availability and average annual abstraction of the groundwater system of Rodopi (source: RBMP, 2017)

Groundwater system	Water availability (10^6 m^3)	Average annual abstraction (10^6 m^3)	Agriculture (10^6 m^3)	Domestic (10^6 m^3)	Livestock (10^6 m^3)	Quantitative status
Rodopi	50.4	14.7	12.0	2.5	0.2	Good

Based on the results from the deliverable 3.1.1, it is shown that the groundwater system of Rodopi is at low risk at its current state. Even when water demand increases and water availability decrease, the system is still at low risk (WEI values below 0.49). The same stands when drinking water use is examined.

2.2. Water Quality

Total pollution loads in Komotini – Loutro Evrou streams RB account for 2,398.4 ton/year of BOD, 991.7 tons/year of N and 65.6 tons/year of P. Point sources contribute more to the total pollution loads.

Table 6. Water resources quality assessment of the groundwater system of Rodopi (source: RBMP, 2017)

Water system	Chemical status	Quantitative status	Increased values due to physical background	Increased values due to human pressures	Main pressures	Salt water intrusion	Quality problems
Rodopi	Good	Good	-	-	-	No	No
Vosvozis river	Poor	-	-	-	-	-	-

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The groundwater system supplying DEYAK with water is assessed for its chemical and quantitative status (RBMP, 2017) which is found to be good. There are no problems identified in this groundwater system.

The river basin of Komotini-Loutra Evrou streams consists of 28 river surface water systems and 4 groundwater systems. 18 surface water systems are found to be at good ecological status; 4 at moderate ecological status; 2 at poor ecological status; and 4 in unknown ecological status. Only one surface water system is found to be in bad chemical status. One out of 4 groundwater systems are found to be in bad chemical status. All groundwater systems are found to be in good quantitative status. The river Vosvozis supplying DEYAK with water is found to be in poor ecological status and good chemical status (generally poor qualitative status).

2.3. Land Uses

Based on the RBMP (2017) the land uses identified in the WD of Thrace are the following: forests takes the major part of land (47.91%) followed by agriculture (32.54%) and pasture (13.81%). At the RB of Komotini – Loutro Evrou streams the dominant land use is agriculture (39.49%), followed by forests (35.79%) and pasture (19.83%).

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3 Strategy and Measures taken

The study by the Bank of Greece (Bank of Greece, 2011) has shown that changes in the frequency and intensity of extreme phenomena will be one of the climate change main impacts on Greece with consequent negative effects on the vulnerability of societies and ecosystems due to their exposure to new intensive environmental risks.

More specifically, summer drought is expected to increase even further, leading to a prolongation of drought periods and pressures on water reserves of areas with already increased vulnerability. At the same time, heavy rainfall is expected to become more frequent in the next 70 years, with the consequence that in urban areas sudden floods are becoming more and more frequent due to intense local rainfall.

In 2016, the Ministry of the Environment and Energy drafted the National Climate Change Adaptation Strategy which sets out the general objectives, guiding principles and means of implementing a modern effective and developmental adaptation strategy within the framework set by the Convention on Climate Change United Nations Climate Change, European Guidelines and international experience. The National Climate Change Adaptation Strategy sets out actions and measures per sector affected by climate change. For water resources, these actions include the following:

Action 1. Creating a geo-portal of integrating information on the impacts of climate change on water resources. The purpose of the action is to gather all the information (data, studies, descriptive information) on the impact of climate change on water resources and on the dissemination of information on the internet.

Action 2. Projects addressing the impacts of climate change on water resources related to the following:

- Rising sea levels / Coastal zones. Impact assessment on coastal areas from sea level rise and / or coastal erosion and support for actors to design and implement appropriate projects.
- Reduction (quantitative and qualitative) of the performance of hydropower projects. The quantitative reduction in the yield of coastal water works (the main measure to prevent or reduce sewage). Confrontation: Avoiding or limiting the phenomenon is to reduce or totally disrupt the abstraction of coastal aquifers, as well as the abstraction of surface water discharged into the sea.
- Change in runoff basin level. The change in runoff basin level, which is a change in the erosion and deposition regime, is related to the corrosive or depositing status of the upstream branches of the hydrographic network. Confrontation: Implications can be identified and quantified using specific models for different scenarios of the phenomenon.
- Changing the apparent weight of structures. The entry of the sea into the inland results in an increase in the level of underground water, with a change in the apparent weight of the structures (buoyancy). Fluctuations in elevation and buoyancy by offshore projects will cause stress on foundations. Confrontation: To study the phenomenon as before.
- Precautionary measures for groundwater body vulnerability study. It requires the creation of vulnerability maps, natural or intinsic vulnerability, and specific or integrated vulnerability maps.
- Study of hydrographs of source discharges. Construction, analysis and study of hydrograph of basic source discharges. Main concern is the estimation of the available benefit in the dry season of the year.
- Anticorrosion protection of soils. The phenomenon is quite frequent and disturbing from the waves and small creeps of the creep, up to the large-scale sliding, collapse, subsidence and other forms of territorial instability.
- Desertification. The causes of desertification are: climate, physiography, geology, soil, hydrology and hydrogeology, as well as anthropogenic activities such as over-exploitation, over-grazing. Greece,

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like the rest of the Mediterranean basin, faces a high risk of desertification (estimated at least 35% of the land area). Areas of high risk are the Aegean islands, Crete, a part of Thessaly, East Sterea Hellas and the Eastern Peloponnese.

- Maintaining ecological flow. Each water body plays a specific role in maintaining the ecosystem and is affected by the lack of eco-flow: a specific supply that continues its flow when there is a natural disruption for specific reasons and does not go, at least as a whole, “lost” at the sea. Confrontation: The need for (correct) assessment of eco-supplies, with climate change data, is now imperative. The lack, in Greece, is temporarily covered by the Joint Ministerial Decision for RES.
- Irrigation water. The impacts of climate change in Greece are on reducing supply and irrigation water. If this is combined with rising temperatures, irrigation intensification and longer irrigation are threatened.
- Irrigation networks. Irrigation networks, where they exist, show significant water losses due to age, poor, not adequate or no maintenance at all, construction type, etc. (replacement of damaged parts or change of irrigation method, even crop change). Confrontation: In cooperation with the Agricultural Cooperatives, a large program of irrigation network repair, extension of use of irrigation networks, exploration of the choice of less water varieties, selection of varieties thawing out of the summer, removal of free irrigation water, irrigation with reusable water , placing a water meter on the head of forced private irrigation drilling and capture control based on a previous study of the area.
- Returned irrigation flow. Refers to problems met in irrigation areas with water pumped from the same irrigated area, especially when irrigation is frequent. After each pumping-irrigation, a rest of irrigation water returns to the aquifer, having undergone four pollution processes. Given that the velocity of groundwater in the porous media is of the order of a few meters or tens of meters per year, it is understood that, after some irrigation, the irrigation water is severely contaminated. Confrontation: Switching irrigation water use, where possible, partially or wholly.
- Water supply networks. Water losses from the water supply networks of cities are significant. This is due to the aging of large sections of networks. Another problem in this regard is the replacement of parts of the networks made up of asbestos cement pipes for reasons of public health protection. Confrontation: Co-operation of Regions and Local Authorities, it is recommended to repair damaged parts and replace sections of asbestos pipes in water supply networks.
- Bottled water. Bottled water is drinking water which must comply with quality standards. Areas of perimeter protection of water abstractions and water bottling facilities are everyday practice, for decades, in developed countries and, above all, in Europe. The reason for their existence is to avoid pollution of groundwater, which feeds population groups, from human activities. These zones, following a specific hydrogeological study, are designated Zone I (direct protection zone), Zone II (biological protection zone) and Zone III (chemical protection zone). The Day X Line is also set for the major pathogenic microorganisms, depending on the speed of movement of each microorganism.
- Cross-border waters. The issue concerns surface (mainly) and underground waters with Greece in a downstream position (Evros, Strymonas, Nestos, Axios), with the exception of Aoos where Greece is upstream. Problems are identified in the quantitative field (water shortage or floods) and in the quality sector (chemistry and water pollution). In the underground waters, areas of interest have been identified in Epirus (the hydrogeological basin of Heimaras springs, mainly located in Greece), Prespes (escape of groundwater, along with surface waters) and elsewhere.
- Desalination. Today, the problem of water supply in the islands is treated, alternatively, by the use of small desalination units, but these have considerable problems, such as high purchase and maintenance costs, energy-intensive operation, disposal of the brine and the organoleptic

characteristics of desalinated water require it to be mixed with the underground water before it enters the water supply network.

Action 3. Saving water - Effective water use - Reducing pumping of aquifers. It concerns mainly areas where there is a shortage of water both in winter and in summer and includes the following measures:

- Measure 1. Promote water saving in all sectors and uses, especially in areas with shortages and support for rainwater recycling.
- Measure 2. Encourage the treatment of waste and the use of recycled water in plant production or in green areas, especially in areas with shortages.
- Measure 3. Improve efficiency in the energy sector in terms of water absorption and consumption and future hydroelectric power stations.
- Measure 4. Optimization of the existing water stock in the agricultural sector and creation of artificial reservoirs in accordance with environmental constraints, in addition to the improvement measures for water use.
- Measure 5. Encourage change in consumer patterns and intellectual attitudes.

Action 4. Development of land-use activities and uses that are compatible with local available water resources. This includes identifying potential adaptation scenarios for activities involving heavy water consumption in areas experiencing shortages, optimizing aquatic resources, developing efficient farming activities and reducing soil impermeability, thereby promoting water scarcity. It includes the following measures:

- Measure 1. Determine potential adaptation scenarios for activities that use large quantities of water in areas already in deficiencies.
- Measure 2. Optimize existing water storage methods and create new ones, if necessary, especially by replacing pumping during low flow periods.
- Measure 3. Rational use of water in activities such as the agricultural sector, tourism, etc.
- Measure 4. Improvement of the potential for land reclamation, so that rain water can also be used.

Action 5. Inclusion of the impacts of climate change on water planning and water management, particularly in the subsequent water services intervention programs (2013-2018) and water management development programs (2016-2021). This action aims to integrate the expected impacts of climate change and the adaptation measures required in water management planning tools on a hydrographic basin scale.

Action 6. Assessment of the impact of climate change on hydropower generation. Since the "fuel" of hydroelectric projects is water, the purpose of this action is to study and assess the impact of the imminent reduction of surface drainage on the country's hydroelectric projects, both economically (reduction of energy production) and socio-economic (reduction of available water for agricultural use) and environmental aspects (maintenance of ecological supply).

Action 7. Educational programs on the impact of climate change on water resources.

The formulation of the program of measures takes into account and incorporates actions included in the National Climate Change Adaptation Strategy.

Specific Measure included in the RBMP of the WD of Thrace included the pilot measures for the implementation of precision farming (**M12S1601**) (1st update of the RBMP of Thrace WD, 2017). Specifically, this measure seeks to exploit new technologies, which can include the implementation of new, innovative processes, including the search for new cultivation practices and production practices that contribute to environmental protection and adaptation to climate change. Measure 16 of the RDP 2014-2020 provides for aids in the context of producer group partnerships with other stakeholders (consultants, researchers, other food chain actors and innovation brokers) to achieve the objectives:

1. Reduce water consumption through the adoption of advanced irrigation systems, and the adoption of precision agriculture.

2. Produce safer and healthier foods for either the whole population or special categories.

3. Reduction of input costs that entails both economic and environmental benefits (reduction of fertilizer use, pesticide use, adoption of new varieties better suited to local soil, hydrological and climatic conditions, utilization of RES for substitution of minerals fuel).

4. The exploitation of by-products of agricultural production either for the production of feed or for the production of energy.

5. To highlight the specific nutritional characteristics of agricultural products and their contribution to nutrition (such as foods rich in Ω3, naturally unsaturated, low-calorie).

6. Better integration into the food chain of Greek livestock products such as goat's milk.

7. The adoption of more friendly agricultural practices and the adoption of crops for the exploitation of poor organics and soil nutrients.

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River Basin Management Plan (RBMP) of Thrace 1st Revision, 2017. Available at: http://wfdver.ypeka.gr/wp-content/uploads/2017/12/EL12_SDLAP_APPROVED.pdf (in Greek)

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WATER RESCUE

Water resources efficiency and conservative use in drinking water supply systems

WP	**4 Common Methodology & Tools**
Deliverable *Tool*	**4.2.1 Cross border water resources vulnerability assessment methodology report** *Questionnaire*
Project Beneficiary No	**PB2**
Beneficiary Institution	**Municipal Water Supply and Sewerage Company of Thermi**

The Project is co-funded by the European Regional Development Fund (ERDF) and by national funds of the countries participating in the Cooperation Programme Interreg V-A "Greece-Bulgaria 2014-2020".

Table of Contents

The Project is co-funded by the European Regional Development Fund (ERDF) and by national funds of the countries participating in the Cooperation Programme Interreg V-A "Greece-Bulgaria 2014-2020".

Name of the organization/institution: Municipal Water Supply and Sewerage Company of Thermi
Beneficiary number: PB2

1 Introduction

DEYA Thermis takes water from the River Basin (RB) of Chalkidiki (EL1005), one of the RBs of the Water District of Central Macedonia (Figure 1). The population of the Water District of Central Macedonia is 1,420,321 people (2011 census) showing a small increase compared to the 2001 census. It covers an area of 10,163.38 Km^2. The River Basin (RB) of Chalkidiki covers an area of 5,545.86 Km^2. Its population is 1,154,315 people (2011 census). 27% of the total area of the RB has an altitude of less than 100m, 20% of the total area has an altitude of 100-200m, 14% of the total area has an altitude of 200-300m and the remaining 39% has higher altitude. The RB's average altitude is about 275m. The total water supply at the RB is 653 hm^3.

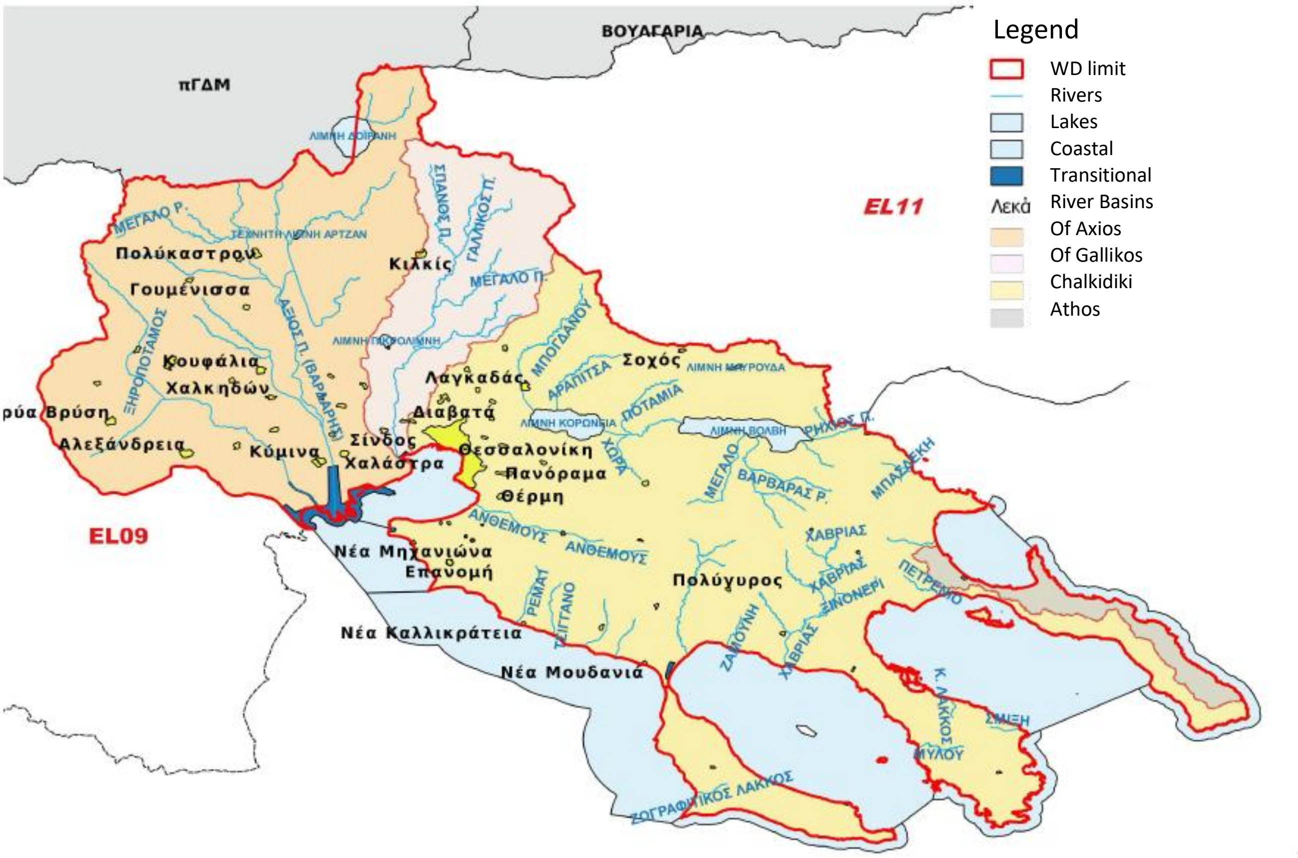

Figure 1. The Water District of Central Macedonia and its River Basins (source: 1st updated RBMP of the WD of Central Macedonia)

DEYA Thermis supplies with water the municipality of Thermi with 53,201 people (2011 census).

The Water District of Central Macedonia includes 124 surface water systems (RBMP, 2017): 104 rivers, 6 lakes, 3 transitional systems and 11 coastal systems. Table 1 shows the surface water systems of each river basin. Chalkidiki RB has 53 rivers, 3 lakes, 2 transitional water bodies and 9 coastal bodies, totally 67 surface water bodies (Table 1).

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Table 1. Surface water systems in each river basin (RBMP, 2017).

Type of system	Axios RB	Gallikos RB	Chalkidiki RB	Athos RB	TOTAL
Rivers	35	16	53	-	**104**
Lakes	2	1	3	-	**6**
Transitional	1	-	2	-	**3**
Coastal	-	-	9	2	**11**
TOTAL	**38**	**17**	**67**	**2**	**124**

Thirty-seven (37) groundwater systems have been identified in the RBMP (2017), 21 of them in the RB of Chalkidiki. Three of them supply the city of Thermi with water. They are:

- Anthemountas system, SystemSubsystem of down flow of Anthemountas: (EL1000081 – area:92.03Km^2)
- Anthemounts system, Subsystem of Thermi – N. Risio: (EL1000083 - area 177.00Km^2)
- Cholomontas – Oreokastro system, Subsystem of Cholomontas - Oreokastro: (EL1000193 - area 1597.41 Km^2)

The competent authority for water resources management in Central Macedonia is the Water Directorate of Central Macedonia.

The Project is co-funded by the European Regional Development Fund (ERDF) and by national funds of the countries participating in the Cooperation Programme Interreg V-A "Greece-Bulgaria 2014-2020".

2 Water Resources Vulnerability Assessment

2.1. Water Availability

Based on the RBMP of Central Macedonia, annual water demand is given in table 2. Agriculture is the dominant use (81%) while domestic water use account for 15%. The average annual water supply in the WD is 5.3 $*10^9$ m^3, of which 32% are from own sources and 68% come from the water inflow from Axios river coming from FYROM.

Table 2. Annual water demand per water use in the WD of Central Macedonia and for each River Basin (RB) (source: RBMP, 2017)

	Whole WD		**Axios RB**		**Gallikos RB**		**Chalkidiki RB**	
Water Demand	**hm³**	**%**	**hm³**	**%**	**hm³**	**%**	**hm³**	**%**
Agriculture	953.080	80.9	697.701	95.0	49.765	74.4	205.614	54.5
Domestic	177.856	15.1	20.749	2.8	3.647	5.5	153.460	40.7
Livestock	7.228	0.6	2.585	0.4	1.152	1.7	3.491	0.9
Industry	40.421	3.4	13.254	1.8	12.321	18.4	14.846	3.9
Total	**1,178.586**		**734.289**		**66.885**		**377.411**	

Chalkidiki river basin consists of 67 surface water systems (Table 1) and 21 groundwater systems. 5 of the surface water systems are found to be at a bad quantitative status and the remaining ones are found to be in good quantitative status. Four out of 21 groundwater systems are found to be in bad chemical status.

Overexploitation of groundwater systems is a fact in 5 groundwater systems in Chalkidiki RB resulting in gradual reduction of their permanent groundwater inventories. These systems face salinization phenomena as well. The groundwater subsystem of down flow of Anthemountas faces overexploitation and it is assessed to be in bad quantitative status (RBMP, 2017).

Table 3. Water availability and average annual abstraction of three groundwater systems in Chalkidiki River Basin (source: RBMP, 2017)

Groundwater subsystem	**Water availability (10^6 m^3)**	**Average annual abstraction (10^6 m^3)**	**Agriculture (10^6 m^3)**	**Domestic (10^6 m^3)**	**Industry (10^6 m^3)**	**Quantitative status**
Down flow of Anthemountas	33.6*	37.02*	25.32*	9.71*	1.77*	Bad
Thermi – N. Risio						Good
Cholomontas - Oreokastro	99.0**	81.64	64.60	9.51	0.35	Good

* It includes also the water supply and use of the subsystem of Galarino-Galatista (EL1000082)

** Includes also the water supply and use of the subsystems of Skouries (EL1000191) and Olympiada (EL1000192).

DEYA Thermis is supplying the municipal district of Thermi with water from groundwater boreholes from three groundwater subsystems: down flow of Antemountas; Thermi – N. Risio; and Cholomontas - Oreokastro. Based on data from the RBMP (2017) water availability, average annual abstraction (total and per water use) is shown in Table 3. It is evident that the subsystem of down flow of Anthemountas and Thermi – N. Risio is overexploited since 37.02 hm^3 are abstracted while only 33.6 hm^3 is the annual water availability.

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DEYA Thermis water abstraction is allocated in the groundwater systems as shown in Table 4. DEYA Thermis supplies water to the following towns: Thermi, Mikra, N. Redestos, Tagarades, N. Risio, Vasilika, Souroti, Agia Paraskevi, Agios Antonios, Lakkia, Peristera and Livadi (Table 4). The major water volume (97.8%) comes from the subsystems of Anthemountas down flow and Thermi – N. Risio. The first subsystem is assessed in bad quantitative and chemical status, while the second is assessed in good quantitative and chemical status. Only 2.1% of water volume comes from the Cholomontas - Oreokastro subsystem which is found to be in good chemical and quantitative status.

Table 4. Water availability, average annual abstraction and DEYA Thermis abstraction of three groundwater systems (source: RBMP, 2017)

<table>
<tr><th>Groundwater subsystem</th><th>Towns supplied with water</th><th>Water availability (10^6 m^3)</th><th>Average annual abstraction (10^6 m^3)</th><th>DEYA Thermis (m^3)</th><th>Chemical status</th><th>Quantitative status</th></tr>
<tr><td>Down flow of Anthemountas</td><td>Thermi, Mikra, N. Redestos, Tagarades, N. Risio, Vasilika, Souroti, Ag. Paraskevi</td><td rowspan="2">33.6</td><td rowspan="2">37.02</td><td rowspan="2">7,187,700</td><td>Bad</td><td>Bad</td></tr>
<tr><td>Thermi – N. Risio</td><td>Thermi, Mikra, N. Redestos, Ag. Antonios, Lakkia</td><td>Good</td><td>Good</td></tr>
<tr><td>Cholomontas - Oreokastro</td><td>Peristera, Livadi</td><td>99</td><td>81.64</td><td>158,500</td><td>Good</td><td>Good</td></tr>
</table>

Based on the water availability analysis on the deliverable 3.2.1 (estimating the WEI index), it is found that the subsystems of Anthemountas down flow and Thermi – N. Risio (EL1000081 & EL1000083) are not sustainable at their present state. The results show that for these subsystems there are cases that show possible difficulties with water availability only if water demand decreases and renewable water resources increase. Strong risk exists only in the cases where water demand decreases or increases up to 10% and renewable water resources increase. In most cases the subsystem is unsustainable. Regarding drinking water demand the risk is low, regardless of the increase or decrease of water demand and renewable water resources.

Based on the analysis of deliverable 3.2.1, the subsystem Cholomontas - Oreokastro (EL1000193) is facing a strong risk at its present state. The system becomes not sustainable when water demand remains the same or increases and at the same time renewable water resources decrease. There are possible difficulties only when water demand decreases more than 5% and renewable water resources increase by more than 5%. Regarding drinking water demand, there is a low risk regardless of the increase or decrease of water demand and renewable water resources.

2.2. Water Quality

Based on the RBMP (2017) there are point pollution sources and diffuse pollution sources met in the River Basin of Chalkidiki. Point pollution sources examined are wastewater treatment plants, industrial units, thermal power plant, livestock farming, mines – quarry, aquaculture and fishfarming (Table 5). The most polluting activity is industries and wastewater treatment plants. The thermal power plant pollution refers mainly to Cr, Zn, As, Cu, HC, PCBs, Cd, Pb, Hg, Ni. The mines and quarries pollution refers to SO_4^{-2}, Fe, Mn, Zn, Pb, Sb, As (RBMP, 2017).

Diffuse pollution sources include urban, agricultural, livestocks and other sources (Table 5). The most polluting, followed by urban wastewater not discharged to WWTT activity is livestock for BOD loads, while agriculture is the most polluting activity followed by livestocks regarding nitrogen and phosphorous loads.

Table 5. Annual BOD, N and P loads due to point and diffuse pollution sources in Chalkidiki RB (source: RBMP, 2017)

Point sources	**Point Pollution sources**	**Diffuse Pollution sources**	**Total**
Annual BOD (tons/year)	3,260.9	1,894.78	**5,155.68**
Annual N (tons/year)	1,541.44	1,594.67	**3,136.11**
Annual P (tons/year)	197.57	670.84	**868.41**

The subsystem Anthemountas down flow faces pollution problems due to agriculture, livestock farming, urban wastewater and over-abstraction (Table 6). Salt water intrusion problems also exist. Increased values of Mn, Fe, B, Cr, As, Cl, are due to the physical background. Especially As values are due to geothermic fluids. The system's chemical and quantitative status is bad. The subsystem Thermi – N. Risio does not face pollution problems (Table 6). Increased values of Fe, Mn, B, As, Cl, Na, H_2S are due to the physical background and especially the geothermic fluids and the Anthemountas crack. Cholomontas - Oreokastro subsystem does not face pollution problems or over-abstraction (Table 6).

Table 6. Water resources quality assessment of the three groundwater systems (source: RBMP, 2017)

Groundwater system	**Chemical status**	**Quantitative status**	**Increased values due to physical background**	**Increased values due to human pressures**	**Main pressures**	**Salt water intrusion**
Down flow of Anthemountas	Bad	Bad	Fe, Mn, B, Cr, As, Cl, E.C.	NO_3, Cl	Agriculture, livestock farming, urban wastewater, salt water intrusion, over-abstraction	Yes
Thermi – N. Risio	Good	Good	Fe, Mn, B, As, Cl, Na, H_2S	-	-	No
Cholomontas - Oreokastro	Good	Good	-	-	-	No

2.3. Land Uses

Based on the RBMP (2017) the land uses identified in the WD of Central Macedonia are the following (Table 7):

Table 7. Land uses in the WD of Central Macedonia (source: RBMP, 2017)

Land Uses	**%**
Agriculture	56.74
Forest	37.89
Artificial surface	3.31
Transport networks	0.12
Water & wetlands	2.12

TOTAL	**100.00**

Agriculture is the dominant land use (56.74%) followed by forests (37.89%).

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3 Strategy and Measures taken

The study by the Bank of Greece (Bank of Greece, 2011) has shown that changes in the frequency and intensity of extreme phenomena will be one of the climate change main impacts on Greece with consequent negative effects on the vulnerability of societies and ecosystems due to their exposure to new intensive environmental risks.

More specifically, summer drought is expected to increase even further, leading to a prolongation of drought periods and pressures on water reserves of areas with already increased vulnerability. At the same time, heavy rainfall is expected to become more frequent in the next 70 years, with the consequence that in urban areas sudden floods are becoming more and more frequent due to intense local rainfall.

In 2016, the Ministry of the Environment and Energy drafted the National Climate Change Adaptation Strategy which sets out the general objectives, guiding principles and means of implementing a modern effective and developmental adaptation strategy within the framework set by the Convention on Climate Change United Nations Climate Change, European Guidelines and international experience. The National Climate Change Adaptation Strategy sets out actions and measures per sector affected by climate change. For water resources, these actions include the following:

Action 1. Creating a geo-portal of integrating information on the impacts of climate change on water resources. The purpose of the action is to gather all the information (data, studies, descriptive information) on the impact of climate change on water resources and on the dissemination of information on the internet.

Action 2. Projects addressing the impacts of climate change on water resources related to the following:

- Rising sea levels / Coastal zones. Impact assessment on coastal areas from sea level rise and / or coastal erosion and support for actors to design and implement appropriate projects.
- Reduction (quantitative and qualitative) of the performance of hydropower projects. The quantitative reduction in the yield of coastal water works (the main measure to prevent or reduce sewage). Confrontation: Avoiding or limiting the phenomenon is to reduce or totally disrupt the abstraction of coastal aquifers, as well as the abstraction of surface water discharged into the sea.
- Change in runoff basin level. The change in runoff basin level, which is a change in the erosion and deposition regime, is related to the corrosive or depositing status of the upstream branches of the hydrographic network. Confrontation: Implications can be identified and quantified using specific models for different scenarios of the phenomenon.
- Changing the apparent weight of structures. The entry of the sea into the inland results in an increase in the level of underground water, with a change in the apparent weight of the structures (buoyancy). Fluctuations in elevation and buoyancy by offshore projects will cause stress on foundations. Confrontation: To study the phenomenon as before.
- Precautionary measures for groundwater body vulnerability study. It requires the creation of vulnerability maps, natural or intinsic vulnerability, and specific or integrated vulnerability maps.
- Study of hydrographs of source discharges. Construction, analysis and study of hydrograph of basic source discharges. Main concern is the estimation of the available benefit in the dry season of the year.
- Anticorrosion protection of soils. The phenomenon is quite frequent and disturbing from the waves and small creeps of the creep, up to the large-scale sliding, collapse, subsidence and other forms of territorial instability.
- Desertification. The causes of desertification are: climate, physiography, geology, soil, hydrology and hydrogeology, as well as anthropogenic activities such as over-exploitation, over-grazing. Greece,

like the rest of the Mediterranean basin, faces a high risk of desertification (estimated at least 35% of the land area). Areas of high risk are the Aegean islands, Crete, a part of Thessaly, East Sterea Hellas and the Eastern Peloponnese.

- Maintaining ecological flow. Each water body plays a specific role in maintaining the ecosystem and is affected by the lack of eco-flow: a specific supply that continues its flow when there is a natural disruption for specific reasons and does not go, at least as a whole, “lost” at the sea. Confrontation: The need for (correct) assessment of eco-supplies, with climate change data, is now imperative. The lack, in Greece, is temporarily covered by the Joint Ministerial Decision for RES.
- Irrigation water. The impacts of climate change in Greece are on reducing supply and irrigation water. If this is combined with rising temperatures, irrigation intensification and longer irrigation are threatened.
- Irrigation networks. Irrigation networks, where they exist, show significant water losses due to age, poor, not adequate or no maintenance at all, construction type, etc. (replacement of damaged parts or change of irrigation method, even crop change). Confrontation: In cooperation with the Agricultural Cooperatives, a large program of irrigation network repair, extension of use of irrigation networks, exploration of the choice of less water varieties, selection of varieties thawing out of the summer, removal of free irrigation water, irrigation with reusable water , placing a water meter on the head of forced private irrigation drilling and capture control based on a previous study of the area.
- Returned irrigation flow. Refers to problems met in irrigation areas with water pumped from the same irrigated area, especially when irrigation is frequent. After each pumping-irrigation, a rest of irrigation water returns to the aquifer, having undergone four pollution processes. Given that the velocity of groundwater in the porous media is of the order of a few meters or tens of meters per year, it is understood that, after some irrigation, the irrigation water is severely contaminated. Confrontation: Switching irrigation water use, where possible, partially or wholly.
- Water supply networks. Water losses from the water supply networks of cities are significant. This is due to the aging of large sections of networks. Another problem in this regard is the replacement of parts of the networks made up of asbestos cement pipes for reasons of public health protection. Confrontation: Co-operation of Regions and Local Authorities, it is recommended to repair damaged parts and replace sections of asbestos pipes in water supply networks.
- Bottled water. Bottled water is drinking water which must comply with quality standards. Areas of perimeter protection of water abstractions and water bottling facilities are everyday practice, for decades, in developed countries and, above all, in Europe. The reason for their existence is to avoid pollution of groundwater, which feeds population groups, from human activities. These zones, following a specific hydrogeological study, are designated Zone I (direct protection zone), Zone II (biological protection zone) and Zone III (chemical protection zone). The Day X Line is also set for the major pathogenic microorganisms, depending on the speed of movement of each microorganism.
- Cross-border waters. The issue concerns surface (mainly) and underground waters with Greece in a downstream position (Evros, Strymonas, Nestos, Axios), with the exception of Aoos where Greece is upstream. Problems are identified in the quantitative field (water shortage or floods) and in the quality sector (chemistry and water pollution). In the underground waters, areas of interest have been identified in Epirus (the hydrogeological basin of Heimaras springs, mainly located in Greece), Prespes (escape of groundwater, along with surface waters) and elsewhere.
- Desalination. Today, the problem of water supply in the islands is treated, alternatively, by the use of small desalination units, but these have considerable problems, such as high purchase and maintenance costs, energy-intensive operation, disposal of the brine and the organoleptic

characteristics of desalinated water require it to be mixed with the underground water before it enters the water supply network.

Action 3. Saving water - Effective water use - Reducing pumping of aquifers. It concerns mainly areas where there is a shortage of water both in winter and in summer and includes the following measures:

- Measure 1. Promote water saving in all sectors and uses, especially in areas with shortages and support for rainwater recycling.
- Measure 2. Encourage the treatment of waste and the use of recycled water in plant production or in green areas, especially in areas with shortages.
- Measure 3. Improve efficiency in the energy sector in terms of water absorption and consumption and future hydroelectric power stations.
- Measure 4. Optimization of the existing water stock in the agricultural sector and creation of artificial reservoirs in accordance with environmental constraints, in addition to the improvement measures for water use.
- Measure 5. Encourage change in consumer patterns and intellectual attitudes.

Action 4. Development of land-use activities and uses that are compatible with local available water resources. This includes identifying potential adaptation scenarios for activities involving heavy water consumption in areas experiencing shortages, optimizing aquatic resources, developing efficient farming activities and reducing soil impermeability, thereby promoting water scarcity. It includes the following measures:

- Measure 1. Determine potential adaptation scenarios for activities that use large quantities of water in areas already in deficiencies.
- Measure 2. Optimize existing water storage methods and create new ones, if necessary, especially by replacing pumping during low flow periods.
- Measure 3. Rational use of water in activities such as the agricultural sector, tourism, etc.
- Measure 4. Improvement of the potential for land reclamation, so that rain water can also be used.

Action 5. Inclusion of the impacts of climate change on water planning and water management, particularly in the subsequent water services intervention programs (2013-2018) and water management development programs (2016-2021). This action aims to integrate the expected impacts of climate change and the adaptation measures required in water management planning tools on a hydrographic basin scale.

Action 6. Assessment of the impact of climate change on hydropower generation. Since the "fuel" of hydroelectric projects is water, the purpose of this action is to study and assess the impact of the imminent reduction of surface drainage on the country's hydroelectric projects, both economically (reduction of energy production) and socio-economic (reduction of available water for agricultural use) and environmental aspects (maintenance of ecological supply).

Action 7. Educational programs on the impact of climate change on water resources.

The formulation of the program of measures takes into account and incorporates actions included in the National Climate Change Adaptation Strategy.

Specific Measure included in the RBMP of the WD of Central Macedonia included the pilot measures for the implementation of precision farming for the reduction of water consumption (**M10S1601**) (1st update of the RBMP of Thrace WD, 2017). Specifically, this measure seeks to exploit new technologies, which can include the implementation of new, innovative processes, including the search for new cultivation practices and production practices that contribute to environmental protection and adaptation to climate change.

Measure 16 of the RDP 2014-2020 provides for aids in the context of producer group partnerships with other stakeholders (consultants, researchers, other food chain actors and innovation brokers) to achieve the objectives:

1. Reduce water consumption through the adoption of advanced irrigation systems, and the adoption of precision farming.

2. Reduction of input costs that entails both economic and environmental benefits (reduction of fertilizer use, pesticide use, adoption of new varieties better suited to local soil, hydrological and climatic conditions, utilization of RES for substitution of minerals fuel).

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WATER RESCUE

Water resources efficiency and conservative use in drinking water supply systems

WP	**4 Common Methodology & Tools**
Deliverable *Tool*	**4.4.1 Cross border water resources vulnerability assessment methodology report** *Questionnaire*
Project Beneficiary No	**PB4**
Beneficiary Institution	**Municipality of Kardzhali**

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Table of Contents

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Name of the organization/institution: Municipality of Kardzhali
Beneficiary number: PB4

1 Introduction

Please name the CB water resources of your region. Provide general data for these water resources, e.g. area (km^2), specific characteristics, etc. Please provide a map.

Please identify the responsible body for the water resources management.

WATER RESOURCES

GENERAL CHARACTERISTICS

The water resources in the area are formed by underground and surface water sources, which are mainly fed by precipitation.

A separate territory of "VIK" Ltd.-Kardzhali has the following water resources:

Surface water

The Arda River is a river with codes of the water bodies BG3AR100R006, BG3AR100R008, BG3AR100R020 and BG3AR100R028. The first and second water body fall respectively at 20% and 50% in the territory of Krumovgrad Municipality, the third one - 100% in the territory of the Municipality of Kardzhali and the fourth - 60% in the territory of the Municipality of Ardino.

The Varbitsa River is the longest and fuller tributary of the Arda River, running entirely on the territory of Smolyan and Kardjali. It is a water body with code BG3AR400R074 - Varbitsa River and the tributaries from the town of Zlatograd to the estuary. It falls to 50% on the territory of the Municipality of Kirkovo, 20% to the Municipality of Momchilgrad, 25% to the Municipality of Djebel and 5% to the territory of the Municipality of Krumovgrad.

The Krumovitsa River is a water body with code BG3AR200R009 - the Krumovitsa River and tributaries. It falls to 10% on the territory of the Municipality of Kirkovo, 10% to the Municipality of Momchilgrad and 80% to the territory of the Municipality of Krumovgrad.

Borovitsa River is a water body with codes BG3AR600R024 - the Borovitsa River and tributaries from the Borovitsa Reservoir to the Kardjali dam and BG3AR600R026 - a spring of the Borovitsa River near the Borovitsa Reservoir. The first body is 60% on the territory of the Municipality of Chernoochene, 5% in the Municipality of Ardino and 15% on the territory of the Municipality of Kardjali. The second body falls 30% on the territory of Chernoochene Municipality.

The River Perperek is a water body with the code BG3AR300R011 - the River Peperek to the inflow into the Studen Kladenets Reservoir. It falls to 40% on the territory of Chernoochene Municipality and 60% on the territory of Kardjali Municipality.

The Kioshed River is a water body with code BG3AR500R019- Kioshedere - a tributary of the Arda river in its part between the Kardzhali dam and the Studen Kladenets dam. It falls to 20% on the territory of the Municipality of Ardino and 80% on the territory of the Municipality of Kardzhali.

The Kosma dere River is a water body with code BG3AR300R013. It falls 100% on the territory of the Municipality of Momchilgrad. There is a river water catchment for drinking and household needs of the village of Lale and Neofit Bozveli.

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Buukdere River (Golemitsa) is a water body with code BG3AR300R012. It falls 100% on the territory of the Municipality of Momchilgrad.

The River Davidkovska is a water body with code BG3AR700R027. It falls to 5% on the territory of Chernoochene Municipality and 10% to the Municipality of Ardino.

Nedelinsky water body with code BG3AR400R016 - Nendelska River (Uzundere) - left tributary of the Varbitsa River. It falls to 10% on the territory of Djebel Municipality.

The Harmanlianska River is a right tributary of the Maritsa River with the water body code BG3MA100R013. It falls to 50% on the territory of Chernoochene Municipality

The White River is a water body with code BG3AR100R210. It falls to 20% on the territory of the Municipality of Krumovgrad.

Kardzhali dam is a water body with code BG3AR570L021. It falls to 50% on the territory of Kardjali Municipality and 50% to the Municipality of Ardino.

Studen Kladenets dam is a water body with code BG3AR350L010. It falls to 70% on the territory of the Municipality of Kardzhali, 10% to the Municipality of Momchilgrad and 5% to the Municipality of Krumovgrad.

Borovitsa dam is a water body with code BG3AR600L025. It falls 100% on the territory of Chernoochene Municipality.

Thracian Dam is a water body with code BG3MA100L012. It falls to 50% on the territory of Chernoochene Municipality.

"Benkovski" dam is a water body with code BG3AR400L015. It falls to 50% on the territory of the Municipality of Kirkovo and 50% to the Municipality of Djebel.

The quantity and quality of surface waters in the Kardzhali territory make them suitable for their use in drinking and domestic water supply, therefore, there is a surface water catchment of the Kosma dere and one dam

Borovitsa for drinking and domestic water supply.

Groundwater

The settlements on the territory of the Kardzhali district use part of the groundwater water resources in the underground water bodies "Karst Water - Ardino-Nedelinski Basin" with code BG3G00000Pt042, "Cracked Water in the Central Rhodope Complex" with code BG3G00000Pt046, "Cracked Waters in Eastern Rhodope Complex "With code BG3G00000Pg028 and" Porous waters in Quaternary - Arda River "with code BG3G000000Q010.

The area, resources and permissible annual volume of water abstraction from the listed underground water bodies in a regional aspect are reflected in the following table according to data from the River Basin Management Plan in the East Aegean Region

- Plovdiv:

Table Regional resources and permitted water abstraction from groundwater

Groundwater body code (PVT)	Area of PTT km2	Regional resources, l / s		Permissible annual harvest, l / s	Free volumes, l / s
		Natural	Available		
BG3G00000Pt042	68	68	68	66,1	1,9
BG3G00000Pt046	2 241	2 241	1 116	79,9	1 036,1
BG3G00000Pg028	3 228	968	968	73,9	894,1
BG3G000000Q010	101	202	202	49,7	152,3

SURFACE WATER SOURCES

General

The Kardzhali territory includes parts of the catchments in the middle course of the Maritsa River and its tributaries in this part of the river. Their orohydrographic characteristics are given in Table 3-2.

Table Orohydragraphic characteristics of the rivers in the Kardzhali territory

River	River length river	River length in a separate area of water	Area of the catchment area	Medium river slope	Medium inclination of the	Afforest ation
	км	км	км^2			**%**
Arda	241,3	178	5201	5,8	0,320	**34,4**
Varbitza	98,1	55	1203	11	0,242	**43,3**
Krumovitsa	58,5	58,5	670,8	19	0,206	**35,3**
Borovitsa	42	42	300,6	-	-	**--**
Harmanlian	91,93	91,93	952	5,3	0,097	**45**
White River	72,3	72,3	448	-	-	**-**
Davidkovska	35,7	35,7	232	-	-	**-**
Perperec	44	44	219,9	-	-	**--**
Kiosdere	**20,9**	**20,9**	**41,9**	**-**	**-**	**-**

More detailed data on surface water on the territory of WSS Kardjali are presented in Appendix to p.3.1.

Make sure that you are in the hot water

To measure the quantity and quality of surface water in the Kardzhali territory, the constructed and operating backwater hydrometric network of Maritsa, Arda, Tundzha and their tributaries is used. It consists of 8 hydrometer stations (HMS), of which two HMS are on the Maritsa River, one on the Arda River and the other five HMS on their main tributaries in the area of the Kardzhali district.

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Table Surface water inflow

Location of a hydrometric station	Area of catchment area [km^2]	Outflow Module [l/s/km^2]	Average amount of flow [m^3/s]	Minimum flow [m^3/s]	Maximum flow rate [m^3/s]
Arda River, the village of Velhino (HMS	858,4	17,723	15,213	6,534	26,000
Arda River at dam "Ivailovgrad"	5060	13,98	70,75	26,31	144,7
Varbitsa, Dzhebel (HMS 61500)	1149	14,431	16,581	4,912	37,400
Krumovitsa River, Krumovgrad (HMS 61550)	497,6	14,712	7,320	2,827	15,100
Harmanliyska at Harmanli (HMS 73550)	952	4,459	4,245	1,409	10,100
Byala river, Dolno Lukovo (HMS 62800)	448	11,705	5,244	1,805	16,019

In the separate area of "VIK" Ltd-Kardjali there is a surface water extraction for drinking and domestic water supply. The surface waters of the Borovitsa dam are used for drinking and domestic water supply in the town of Kardzhali, town of Momchilgrad and 47 settlements in the municipalities of Kardzhali, Momchilgrad and Chernoochene. The surface waters of Kosma dere are used for water supply in the village of Raven only two months of the year (according to the data of

«VIK» Ltd. - Kardzhali). Surface waters from other rivers and dams in the territory are only used for irrigation, aquaculture and energy production. The quantities of water supplied by "ViK" Ltd - Kardzhali for drinking water supply in the period 2009-2011 are given in Table 3-4.

Table 3-4 Extraction of surface water for 2009 – 2011

No.	*River / dam - Location of water abstraction*	How to use the water	Year	Average quantity extracted [l / sec.]	Average quantity extracted [m3 / day.]	Average quantity extracted [m³ / yr]
1.	River water catchment - the	WB of Lale and N.Bozveli, General. Momchilgrad	2009	4,00	158,33	9 500
			2010	4,00	134,17	8 050
			2011	4,00	159,83	9 590
2.	Borovitsa Dam	PBN of Kardjali, town of Momchilgrad and 47 settlements in the municipalities of Kardzhali, Momchilgrad and	2009	178,08	15 385,90	5 615 851
			2010	172,65	14 917,25	5 444 797
			2011	176,50	15 249,19	5 565 954
	TOTAL:		2009	182,08	15 544,23	5 625 351
			2010	176,65	15 051,42	5 452 847
			2011	180,50	15 409,02	5 575 544

The water quantities allowed for extraction from the East Aegean Basin Basin Directorate are given in Table 3-5.

Table 3-5 Permitted for extraction of water from the BDWWRD for 2009-2011

No.	River / dam - Location of water abstraction	How to use the water	Average quantity extracted [l / sec]	Average quantity extracted [m³ / yr]
1.	River catchment - the Kosma Dere River	WB of Lale and N.Bozveli, General. Momchilgrad	2,45	37 960
2.	Borovitsa Dam	PAB of Kardzhali, town of Momchilgrad and 47 settlements in the municipalities of Kardzhali, Momchilgrad and	800	10 200 000

The total maximum flow from all surface water sources is Qmal = 802.45 l / s; Q = 10,237.96 .103 m 3

Fluctuations in surface water volumes - monthly and annual for 2011.

The characteristics of the natural annual runoff in water quantities and water volumes of HMS falling within the Kardzhali division are given in Appendix 3-1.

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From Table 3-3 it can be seen that the average annual flow of rivers in the Arda River valley in the separate area under consideration changes from 7.32 m3 / s for the Krumovitsa River to 70.75 m3 / s for the Arda River at the " Ivaylovgrad ". The fluctuations of the runoff during the period under review (2009-2011) are within the range of 0.366 to 19.348 m3 / s for the Krumovitsa River and from 6.411 to 150.942 m3 / s for the Arda River for the same points.

The drainage module, which gives an idea of the intensity of the decommissioning on average on the catchment areas along the rivers in the separate area of the Water Supply - Kardzhali, varies between 13,98 - 17,723 l / s / km2 in the respective HMS, ie. relatively large territorial differences due to the similarity of the relief and small differences in the altitudes of the individual catchments for rivers from the Arda river basin and significantly lower values for the river valley

Harmanliyska.

The minimum annual runoff shows values of 2,827 m3 / s for the Krumovitsa River to 26,31 m3 / s for the Arda River. Depending on the area of the pool, the annual minimum runoff has been greatly changed.

Table 3-6 gives the annual breakdowns by month in percent for typical points along the main rivers in Kardzhali.

Table 3-6 Percentage breakdown by month for typical posts

River, point	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	год
Arda River, the village of Vetino, HMS	11,4	15,3	14,0	13,4	9,8	6,6	3,4	1,8	1,6	2,6	7,0	13,4	100
Arda-Ivailovgrad Dam	13,1	17,75	14,43	11,5	8,24	5,43	2,58	1,32	1,2	2,6	6,9	14,95	100
Varbitsa, Dzhebel, HMS No. 61500	15,2	21,2	14,3	9,4	6,3	3,5	1,3	0,5	0,8	2,8	7,6	17,7	100
. Krumovitsa, Krumovgrad, HMS 61550,	15,2	22,0	15,3	9,9	6,4	3,3	1,1	0,4	0,7	2,4	6,9	17,1	100
. Harmanlianska near Harmanli, HMS No 73550	12,5	19,5	16,4	9,3	7,7	5,1	3,8	3,5	3,3	4,5	4,7	9,7	100
Byala, Dolno Lukovo, HMS 62800	14,7	23,9	17,0	10,9	7,4	3,3	0,7	0,3	0,4	1,9	5,9	14,6	100

Annex 3-1 (Tables 2 and 3) provides a synthesized estimate of the territorial and temporary variability of river runoff by months and years for the entire bay, separately for the annual runoff and its yearly distribution.

A common characteristic of the drainage regime, which relates to all the streams of the Arda River, is their great deterioration. Most of the rivers with small catchments are characterized by both extremes: complete droughts and sudden large floods with intense rainfall. The unevenness of the aggregate annual drains, which in the dry years fall to 30% of the average annual, and is over 300% over the year. This rude character is attributed to the main river Arda. From the calculations given in Table 3- 6 for the percentage distribution of the runoff by months for typical points on the main rivers in a separate territory Kardzhali show that in the Arda River basin, the combination of continental and Mediterranean climatic influences, forming the annual rainfall distribution, the potential of evaporation and the accumulation of water in the snow cover, form the differences of the individual catchments. For southern tributaries it is evident that the high waters, which account for 17-22%, are in December and February, while the low waters, whose share is below 0,4 - 0,8%, are in July - September. The Northern tributaries have a smooth maximum in February - April, which is 10 to 15%, which is dictated exclusively by the rainfall, whose regime is almost the same as that of the runoff, and the minimum is in August - September, whose share is 1.7 - 3.2%, which is the result of rainfall reduction. On the main river, of course, there is a mixture of these two states, with the predominant involvement of the southern tributaries to the lower part of the valley. From a water supply point of view, the northern tributaries have a more advantageous flow distribution.

The hydrological regime of the Varbitsa River near Dzhebel and Krumovitsa in the town of Krumovgrad is characterized by two peaks. The primary peak is in January-February and secondary - in October-November. The minimum is usually one and starts from May to the end of September, due to a decrease in precipitation, mostly occurring in August. The spring peak occurs almost in winter, proving that the highlands are precipitated by rainfall and almost no snacking. At the beginning of October, as a result of precipitation, there was an increase in the runoff and the autumn peak.

The hydrological regime, characteristic of the southeastern tributaries of the Maritsa River (in the case of Harmanliyska), is that the waters of the left tributaries are smaller because of the lower rainfall and the lower altitudes. For them, the maximum of the captain is in February, and the minimum is in August-September.

The flow of the Byala River is formed under the influence of the Mediterranean climate, fluctuating within a very wide range. The coefficient of variation of the runoff at Dolno Lukovo is very high - 0.616, as well as the asymmetry coefficient - 1.785. The runoff modulus is 11.7 l / sec per square km due to the insignificant altitude. At maximum outflow (February) the Byala River turns into a large river, takes bridges, forms wide meanders. Typical for the monthly minimum runoff is that for the Byala River near Dolno Lukovo it becomes almost zero. This feature is characteristic of the catchments subject to the Mediterranean climate impact, which is characterized by the unfavorable annual rainfall distribution.

Surface water quality

The surface water in the area served by the territory is used for drinking water supply to the population, water used for technical needs, irrigation, recreation and water bodies are the successor of the waste water from the industry and the population in the area.

It is necessary that the quality of the surface water used for certain purposes meets the regulatory requirements.

Condition of surface water sources for drinking and domestic water supply.

The assessment of the status of surface drinking water bodies is carried out depending on the category of water sources in them. The category of water sources is determined on the basis of the results of the monitoring performed and the norms in Annex 1 of Ordinance No. 12 of 2002 on the assessment of surface water quality for drinking and household purposes. According to this regulation water sources are classified into three categories depending on the quality of the water - A1, A2, A3, and A1 is for the best quality. On the territory of the Kardzhali region there are 2 water catchments for drinking water supply from surface waters in the basin of Arda river - Borovitsa dam and Kosma dere. In addition, the drinking water body of the Kazatsite River is defined. The procedure for issuing a permit for the drinking water supply of the water intake has been started. Table 3-7 gives the results of determination of the category of water sources and determination of the status of surface drinking water bodies according to monitoring data for 2012.

Table 3-7 Surface drinking water bodies on the territory of Kardjali District.

Protected code territory	Water body code	*Water body name*	Water source		Water Source Category	Water body condition
G3DSWAR04	BG3AR600L025	Borovitsa Reservoir - PVB	1	Borovets dam	A2	A2
G3DSWAR06	BG3AR300R013	R. Kosma dere (tributary of the Bucuée dere) to catch water for PVB	2	Kosma dere	A3	A3

The two water catchments are in category A2 and A3 according to Annex 1 of Regulation 12, which determines the good condition of the water bodies, ie fit for drinking purposes.

Surface water bodies status - water bodies, waste water receivers (issued by BDIBR Discharge Discharge) must meet the requirements of the legislation in force. Surface waters that are contaminated above the specified requirements create health conditions for the population in the area. Continuous and periodic monitoring is carried out to determine the quality of water at certain points of water bodies. On the basis of the monitoring data, the water body pollutants are assessed as a result of the discharge of waste water as point pollutants. At present, water bodies are polluted mainly by untreated untreated water by the population and industrial enterprises.

The most typical are the NASEM sites of RIEW-Haskovo, which also reflect the impact on the waters in the Arda River and its tributaries. More detailed information on the status of surface water bodies is given in Annex 3-4.

Characteristic "Sensitive Areas" along the Arda River:

- the Arda River, from the spring to the village of Arda;

- the Arda River, after the village of Arda to the town of Kardzhali;

- "Borovitsa" Reservoir - "Sensitive Zone";

- Kardzhali dam - "Sensitive zone";

- the Arda River after the town of Kardzhali to the border;

- Studen Kladenets Reservoir after the inflow of the Cherna river to the influx of the Krumovitsa River;

- Varbitsa River, after the village of Bankovski until its influx into the Studen Kladenets Reservoir.

For agglomerations that are in a "sensitive area", the requirements of Directive 91/271 / EEC on waste water treatment from agglomerations of more than 10,000 PE are applied. and agglomerations of 2000 to 10,000 PE. According to the said Directive, the waste water from the agglomerations of Kardzhali, Momchilgrad, Krumovgrad, Ardino, Djebel and Benkovski needs to be purified to remove the nutrients nitrogen and phosphorus to the higher requirements, and in the design works for WWTP facilities are provided to achieve an increased level of reduction of nutrients Nt and Pt.

UNDERGROUND WATER RESOURCES

General

Water Supply and Sewerage "Ltd. - Kardzhali manages 70 abstraction facilities from groundwater (shaft wells, capped springs and drains). By type and water supply systems, the water abstraction facilities from which 128 villages are supplied are differentiated in Table 3-8:

Table 3-8 Distribution of used water abstraction facilities

Water Supply System	Type of water abstraction equipment, num.				Total number
	Shaft wells	Pipe wells	Captains	Drains	
Ardino	2	2	3	-	7
S. Benkovski	1	-	-	1	2
Jebel	3	-	8	-	11
Krumovgrad	4	1	10	-	15
Kardzhali	8	2	11	1	22
Momchilgrad	8	-	3	2	13
EVERYTHING	26	5	35	4	70

Until the moment of "Water supply and sewerage" Ltd.-Kardzhali and the municipalities were issued permits for water abstraction for 18 water abstraction facilities. For the other 52 water abstraction facilities the permits for water abstraction have expired (51 water abstraction facilities under permit № 0349 / 06.06.2001 and one water abstraction facility under License №300066 / 01.09.2003). The water quantities of permits for water abstraction, including expired ones, are summarized in Annex 3-3, from which it follows that the total value of the authorized water quantities from underground waters is 4.0724 mil.m3 / year (129 , 1 l / s). Their distribution over underground water bodies and water supply systems is shown in Table 3-9.

Table 3-9 Distribution of Groundwater Resources

Water Supply System	Permissible water quantities per groundwater bodies, m3 / year.				Total m3 / year
	BG3G00000Pt042	BG3G00000Pt046	BG3G00000Pg028	BG3G000000Q010	
Ardino	398 372	-	-	331 128	729 500
Benkovski	-	-	-	355 000	355 000
Jebel	-	6 307	113 303	282 930	402 540
Krumovgrad	-	21 557	244 500	1 203 200	1 469 257
Kardzhali	-	2 488	183 453	557 767	743 708
Momchilgrad	-	-	-	372 415	372 415
Total	398 372	30 352	541 256	3 102 440	4 072 420

Amount of groundwater

The drinking water supply of the settlements in the Kardzhali District during the period 2009 ÷ 2011 was carried out by the ground water through the abstraction facilities described in Appendix 3-3.

The amount of groundwater extracted during the period 2009-2011 is shown in Table 3-10.

Table 3-10 Quantity of underground water extracted - 2009-2011.

№	Water Supply System	Obtained water quantity / m3 / year /			Comment
		2009	2010	2011	
1	Ardino	140 006	137 922	140 171	
2	Benkovski	129 402	131 275	140 009	
3	Jebel	75 275	72 114	78 295	
4	Krumovgrad	232 475	230 134	240 561	
5	Kardzhali	2 027 148	2 011 981	1 991 789	
6	Momchilgrad	361 870	347 582	360 443	
	Total	2 966 176	2 931 008	2 951 268	

Groundwater quality

The quality of groundwater used for drinking water supply from all water abstraction facilities corresponds to Ordinance № 9 / 16.03.2001. for the quality of water intended for drinking and household purposes, of the Quality Standard in Ordinance №1 / 10.10.2007. for the exploration, use and protection of groundwater and Directive 98/86 / EC.

Protection of water quality is ensured through the establishment of sanitary protection zones in three zones, the boundaries of which are regulated by Ordinance

№3 / 16.10.2000r. on the conditions and procedure for investigation, design, validation and exploitation of the sanitary-security zones around the water sources and the facilities for drinking water supply and around the water sources of mineral waters used for healing, prophylactic, drinking and hygienic needs. The quality of groundwater used for drinking and domestic water supply from all water abstraction facilities corresponds to Regulation

9 / 16.03.2001 for the quality of water intended for drinking and household purposes, of the Quality Standard in Ordinance №1 / 10.10.2007. for the exploration, use and protection of groundwater and Directive 98/86 / EC.

The issue of permits for water use, the setting up of water treatment plants around the water sources in three zones and observance of the regime for use of the territory of the respective belts is of paramount importance for the protection of water quality.

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Table 3-11 Summary of water quality table

Water Supply Zone	Compliance with Standards	Problematic parameter	Comments
"Karst Water - Ardino-Nedelinski Basin" with code BG3G00000Pt042	The quality of groundwater corresponds to Ordinance No. 9 / 16.03.2001, the Quality Standard in Ordinance No. 1 / 10.10.2007. and of Directive 98/86 / EC	No problem parameters	The water is suitable for drinking purposes
„„ Cracked Water in the Central Rhodope Complex "with code BG3G0000Pt046	The quality of groundwater corresponds to Ordinance No. 9 / 16.03.2001, the Quality Standard in Ordinance No. 1 / 10.10.2007. and of Directive 98/86 / EC.	No problem parameters	The water is suitable for drinking purposes
„ Cracks in Eastern Rhodope Complex "with code BG3G0000Pg028	The quality of groundwater corresponds to Ordinance No. 9 / 16.03.2001, the Quality Standard in Ordinance No. 1 / 10.10.2007. and of Directive 98/86 / EC.	No problem parameters	The water is suitable for drinking purposes
„ Cracked water - Krumovgrad - Kirkovska zone "with code BG3G00PtPg023	The quality of groundwater corresponds to Ordinance No. 9 / 16.03.2001, the Quality Standard in Ordinance No. 1 / 10.10.2007. and of Directive 98/86 / EC.	Problem parameter Fe	Water is not used for drinking purposes
"Porovi River leads to Quaternare - Arda "code BG3G000000Q010	The quality of groundwater corresponds to Ordinance No. 9 / 16.03.2001, the Quality Standard in Ordinance No. 1 / 10.10.2007. and of Directive 98/86 / EC.	No problem parameters	The water is suitable for drinking purposes

A basic principle regarding the ownership of natural resources on the territory of the Republic of Bulgaria is that they are the property of the state. This principle is also applicable to the right of ownership of waters and water bodies. Public state property is the waters of the rivers, the waters in the water reservoirs and those in the dams and the micro dams, the natural lakes and the underground waters. State-owned public property is also the complex and significant dams under Annex No. 1 under Article 13, paragraph 1 of the Water Act.

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Those waters and non-state water bodies are public municipal property. Such are the waters and water bodies, incl. and natural springs, lakes and marshes located on land - municipal property, incl. and mineral waters, dams and micro dams.

It is also possible to have private ownership of waters and water bodies, but only on those that originate in private property and lakes that are not fed by water - public state or public municipal property.

Table 3-12 Resource use permits for WFD

№	Populated place	Waterborne facilities	Number and date of the water abstraction	Code of the water body
1.	Village of Raven, municipality Momchilgrad	River catchment of the Kosma dere	№ 31110010/02.06.2009г.	BG3AR300R013
2.	Bezvodno village - Chernoochene municipality	Borovitsa Dam	№ 003538/18.03.2005г.	BG3AR600L025

Groundwater under Article 11 (3) of the Water Act is public state property. The ground water abstraction should be based on permits for water abstraction by the Basin Directorate for Water Management in the East Aegean Region with the center of Plovdiv. For more detailed information on water abstraction permits, see 3.1.3.1.

3.1.4.2. Problematic areas with scarcity of water or conflicts between different consumers (domestic, industrial, agricultural and electric)

The water resources in the Kardzhali area and mainly the surface runoff of the rivers in the area are used by the hydro-economic sub-sectors of hydropower and water supply. There are very few built irrigation systems and facilities on the territory.

Drinking and domestic water supply

Major water consumers are:

1. For domestic water supply

In the separate area of "VIK" Ltd-Kardjali is built one river catchment for drinking water supply from surface water. In addition, the waters of Borovitsa dam are used for water supply in Kardzhali and Momchilgrad and 47 settlements in the municipalities of Kardzhali, Momchilgrad and Chernoochene.

2. For irrigation

A detailed description of the operating irrigation fields in the separate area of "VIK" Ltd. - Kardjali, which are in the Arda River and the Byala Reka River and their tributaries, is given in Appendix 3-1. On the territory of Kardzhali District there are 6 municipal marshalling irrigation dams, managed by "Irrigation Systems" EAD.

3. For power generation

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In the valley of the Arda River and its tributaries, included in the territory of the

«VKK» Ltd. - Kardjali, built and in operation hydro power plants are: "Dolna Arda" cascade, consisting of three dams - Kardjali dam, Studen kladenets dam and Ivailovgrad dam and three hydropower plants under them. Only Ivailovgrad Dam does not belong to the separate area of the Water Supply and Sewerage - Kardzhali.

There are no problematic areas with water scarcity or conflicts between the different consumers (domestic, industrial, agricultural and electric) in the territory of VIK OOD-Kardzhali.

3.1.4.3. It is important that we use our nose pins

and / or under ground water and for all agglomerates

Areas designated for water abstraction for human consumption are given in Table 3-13.

Table 3-13 Surface water bodies used for PBA in the Arda River Basin

«VIK» Ltd - Kardzhali.

№	Protected Site Code	Water body code	Water body name	Water source	Location
1	BG3DSWAR04	BG3AR600L025	Borovitsa Dam - PWB	Borovitsa dam	Chernooc hene
2	BG3DSWAR06	BG3AR300R013	Kossma Dere (Baulk dere influx) to water catchment area PVB	Kosma dere	Village of Raven, Municipality of Momchilgrad

Water bodies designated as recreational waters, including those designated as drinking water for groundwater in the basin of the Arda River basin, which are under water quality protection, are provided by the establishment of sanitary protection zones.

Bathing zones according to Directive 76/160 / EEC.

Table 3-14 Bathing areas declared in the basin of the Arda River

Zone code	Zone name	Settlement place	Code of the water body	Name of the water body
BG3BATHAR01	Kardzhali Dam, Beach 1	Village of Brosh	BG3AR570L021	Kardzhali Dam”
BG3BATHAR02	Kardzhali Dam, Beach 2	village of Glavatartsi	BG3AR570L021	Kardzhali Dam
BG3BATHAR03	"Studen kladenets" dam	village of Gnyazdovo	BG3AR350L010	"Studen kladenets" dam

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Areas for the protection of water for the conservation of habitats where maintenance or improvement of water status is an important factor in their conservation, including the relevant Natura 2000 sites designated under Habitats Directive 92/43 / EEC and Directive 79/409 EEC for poultry.

The Habitats Directive and the EU Birds Directive and Council of Ministers Decisions define the respective areas where the water use of surface and / or groundwater is restricted

Table 3-15 Areas with limited water use of surface and / or groundwater

	Agglomeration	Water bodies	Natura 2000
1. Protected areas under the Habitats Directive.			
.	Chernoochene Municipality and Ardino Municipality	Dyadovska River BG3AR700R027	ZZ "Rodopi Sredni" BG 00001031
.	ChernoocheneMunicipality and the Municipality of Kardzhali	Peperek BG3AR300R011	
.	Chernoochene Municipality,	Borovitsa dam BG3AR600L025	
.	Chernoochene Municipality,	Borovitsa River BG3AR600R026	
.	Municipality of Ardino, Municipality Chernoochene and the Municipality of Kardzhali	Borovitsa River BG3AR600R024	
.	Ardino Municipality and the Municipality of Kardzhali	Kardzhali Dam BG3AR570L021	
.	Chernoochene Municipality	Harmanliyska, the river valley Maritsa BG3MA100R013	
	Chernoochene Municipality and Municipality of Kardzhali	Peperek BG3AR300R011	ZZ "Rhodopes Eastern" BG0001032
	Municipalities Kirkovo, Momchilgrad, Kardzhali and Krumovgrad	Varbitsa BG3AR400R074	
0	The municipalities of Momchilgrad,Kardzhali and Krumovgrad	Studen Kladenets Reservoir BG3AR350L010	
1	The municipalities Krumovgrad Momchilgrad, and Kirkovo	Krumovitsa BG3AR200R009	
2	Municipality of Momchilgrad	Büyükdere (Golemitsa) BG3AR300R012	
3	Municipality of Momchilgrad	Kosma Dere BG3AR300R013	
4	The municipalities of Krumovgrad	Krumovitsa BG3AR200R009	

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	Agglomeration	Water bodies	Natura 2000
	Momchilgrad, and Kirkovo		
5	Municipality of Krumovgrad	Arda river from the influx of Krumovitsa River to Kardzhali Dam BG3AR100R006 and Arda River BG3AR100R008	
2. Protected areas under Directive 79/409 / EEC for birds			
·	The municipalities of Krumovgrad Momchilgrad, and Kirkovo	*Krumovitsa BG3AR200R009*	ZZ "Studen Kladenets" Reservoir BG0002013
	Municipality of Krumovgrad	Arda BG3AR100R008	
	Municipality of Krumovgrad	Arda BG3AR100R006 and Arda River BG3AR100R008	ZZ Arda River Bridge BG0002071
	Municipalities Krumovgrad, Momchilgrad and Kirkovo	Krumovitsa BG3AR200R009	
	Municipalities Krumovgrad, Momchilgrad and Kirkovo	Krumovitsa BG3AR200R009	ZZ River Krumovitsa BG0002012
	Municipality of Krumovgrad	Biala BG3AR100R210	
	Municipality of Krumovgrad	Arda BG3AR100R006	
	Municipality of Momchilgrad	Buchukdere (Golemitsa) BG3AR300R012	
	Municipalities Krumovgrad, Momchilgrad and Kirkovo	Krumovitsa BG3AR200R009	ZZ White River BG0002012
)	Municipality of Krumovgrad	Biala BG3AR100R210	

These areas are defined as "sensitive" to protect habitats where maintenance or improvement of water status is an important factor in their conservation, including relevant sites under

Natura 2000 'defined in accordance with Directive 92/43 / EEC and Directive 79/409 / EEC. In order to ensure the conservation of natural habitats and habitats of species, plans, programs, projects and investment intentions are assessed for compatibility with the subject and conservation objectives of the respective protected area. The terms and procedure for carrying out the assessment are regulated in an Ordinance under Art. 31 of the Biodiversity Act.

Areas sensitive to biogenic elements defined as

"Sensitive" according to Directive 91/271 / EEC and areas declared as

"Vulnerable" according to Directive 91/676 / EEC

- All surface water bodies on the territory of "VIK" Ltd. - Kardzhali, which have been categorized as receiving in a "sensitive zone" and some of them fall under the requirements for nitrate vulnerable zones (given in 3.1.2.3.).

- Waste water from all agglomerations that are in a 'sensitive area' is necessary to purify to remove the nutrients nitrogen and phosphorus to the higher requirements. In the designed WWTP for agglomerations Kardzhali, Momchilgrad, Ardino, Krumovgrad, Dzhebel and

Benkovski has provided facilities for an increased level of nutrient reduction Nt and Pt.

3.1.5. POTENTIAL THREADS OF POLLUTION

A potential threat to groundwater is point and diffuse sources of pollution. Among the point sources of pollution are landfills, tailings ponds, industrial sites, mines, oil bases, etc. Diffuse pollution is mainly from agricultural sources - agriculture and livestock breeding.

Potential threats of water pollution in the area of the territory are some of the significant problems that have a negative impact on the quality of surface and groundwater.

Potential threats to surface water are also point and diffuse sources of pollution.

Table 3-16 Types of pressure resulting in water bodies at risk of different activities

Types of pressure	Significant sector / activity
Diffuse pollution	- - Urbanized areas without sewerage system and WWTP and lack of sewerage in many of the settlements in the area. Household water is collected in septic tanks and creates real risk for groundwater and human health - - Production plants and sites of industrial enterprises without an efficient site sewerage system, potential soil and water pollutants (oil products stores, unprocessed old oil holdings, chemical stores used as raw materials in industrial plants, etc.). - There is a risk of over-pollution of soil and water. - - Farming - unregulated fertilization, which does not correspond to good agricultural practice. Warehouses for pesticides and others. plant protection products. - - Livestock breeding - farms that do not use good farming practice, uncontrolled accumulation of fertilizer masses, leaks of contaminated waste water, etc. There is a risk of over-pollution of water with biogenic elements, nitrogen compounds, phosphorus compounds and others. - - Landfills, unregulated landfills, uncontrolled accumulation of waste (construction and household) on the outskirts of the settlements. - - Auto-transport and transport activities - washing of vehicles in car washes in places without sewerage, spillage of oil and petroleum products, etc. - - heavy metals pollution in areas with developed mining, tailing ponds and others. - inefficient control and management of the sites create conditions of potential risk of pollution in case of non-compliance with

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	Types of pressure	Significant sector / activity
		requirements for environmental protection.
	Point contamination	- Urbanized areas with sewerage of the settlements without WWTP: Kardzhali, Momchilgrad, Krumovgrad, Ardino, Dzhebel, Benkovski and others. (the implementation of waste water treatment plants is in the pipeline) and partially constructed sewerage sections of other settlements in the separate territory - the content of organic pollutants in the receiver is increased, the dissolved oxygen content is reduced, the content of biogenic elements is increased, which leads to eutrophication, conditions for negative impact on the biodiversity and sustainable development of the aquatic ecosystem are created, the self-purifying capacity of the water body is reduced. Prerequisites for health risk are created - Industrial plants forming waste water discharged directly into water bodies in the case of insufficiently effective LPGs or lack thereof. Potential contaminants are many enterprises of the food industry, transport companies and others. in the separate territory. In some parts of the Arda river basin, heavy metals contaminants Cd, Pb, Ni and others have been found. from advanced mining and enrichment of metal ores (limiting the damage from old pollution). The Arda River - from Kardzhali to the border with Greece - pollution is registered in the following sections: - Student Kladenets Reservoir - discharge of waste water from "Kardzhali" OOD and accumulation of sediments in the tail of the dam. Single cases of pollution are recorded in the middle and on the wall of Studen Kladenets Reservoir; - Arda River after Studen Kladenets Reservoir, periodic pollution is found on the bridge between the village of Potoknitsa (Krumovgrad Municipality) and outside the separate territory - the village of Rabovo (Municipality of Stambolovo, Haskovo District); - livestock farms, etc., to create conditions for uncontrolled emergency water discharge; - Industrial plants forming waste water discharged into sewerage systems in the settlements without efficient LPGs - create a precondition for burst pollution of the total waste water stream and may compromise the optimal purification of water in future WWTPs.
	Morphological changes	Industry (extraction of sand and aggregates, etc.), dykes and river corrections.
	Other specific	Erosion processes, intrusion.

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WATER RESCUE

Water resources efficiency and conservative use in drinking water supply systems

Interreg
Greece-Bulgaria
WATER RESCUE
European Regional Development Fund

EUROPEAN UNION

WP	**4 Common Methodology & Tools**
Deliverable *Tool*	**4.5.1 Cross border water resources vulnerability assessment methodology report** *Questionnaire*
Project Beneficiary No	**PB5**
Beneficiary Institution	**Municipality of Gotse Delchev**

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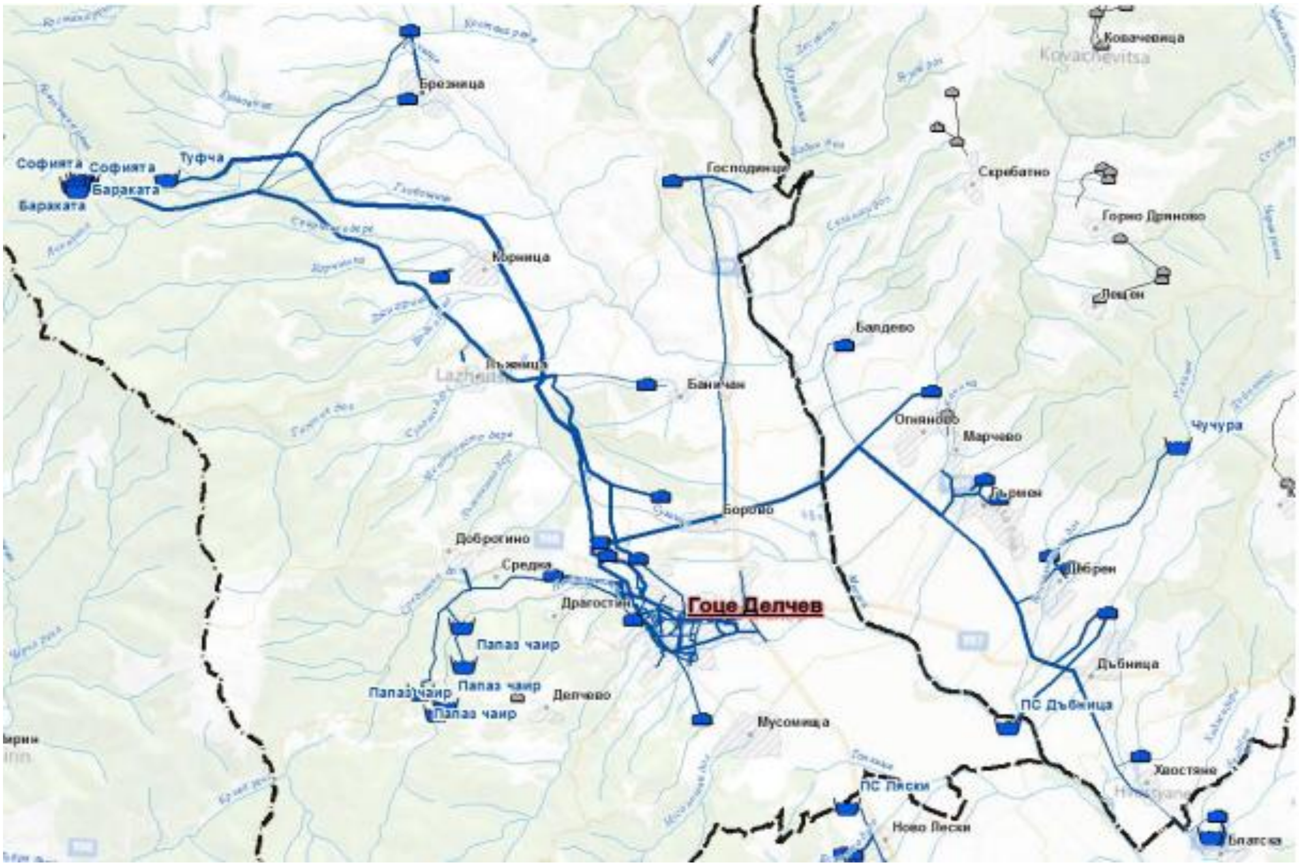
Table of Contents

Name of the organization/institution: Municipality of Gotse Delchev
Beneficiary number: PB5

1 Introduction

Water resources which are used for water supply of region of Gotse Delchev are following:

Water source	Capacity	Type	Altitude
Tufcha	420 l/s	Ground water source (catchment)	1 146 m
Barakata	91 l/s	Spring	1 555 m
Sofiata	16 l/s	Spring	1 430 m
Papaz Chair	11 l/s	Spring	1 382 m

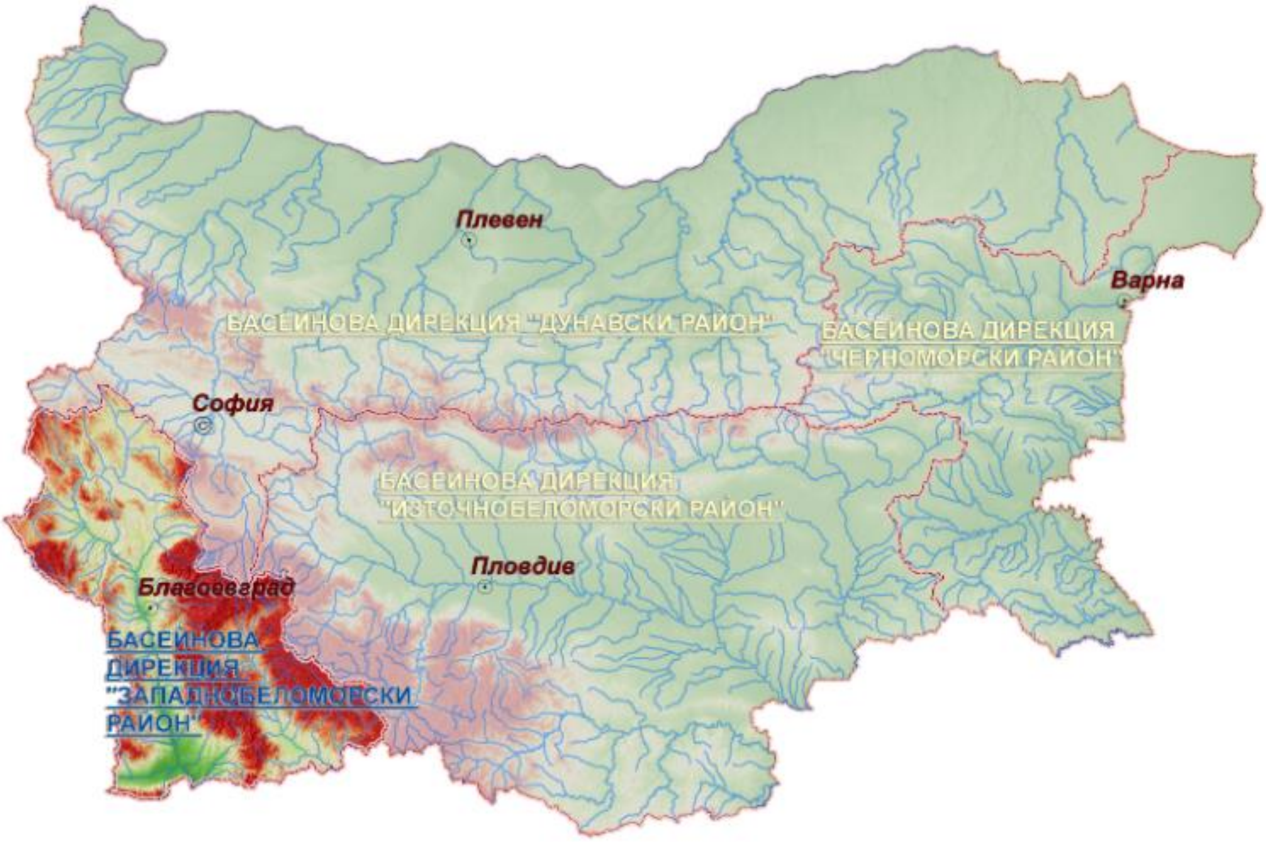


Scheme 1 – water source which are used for water supply of region of Gotse Delchev

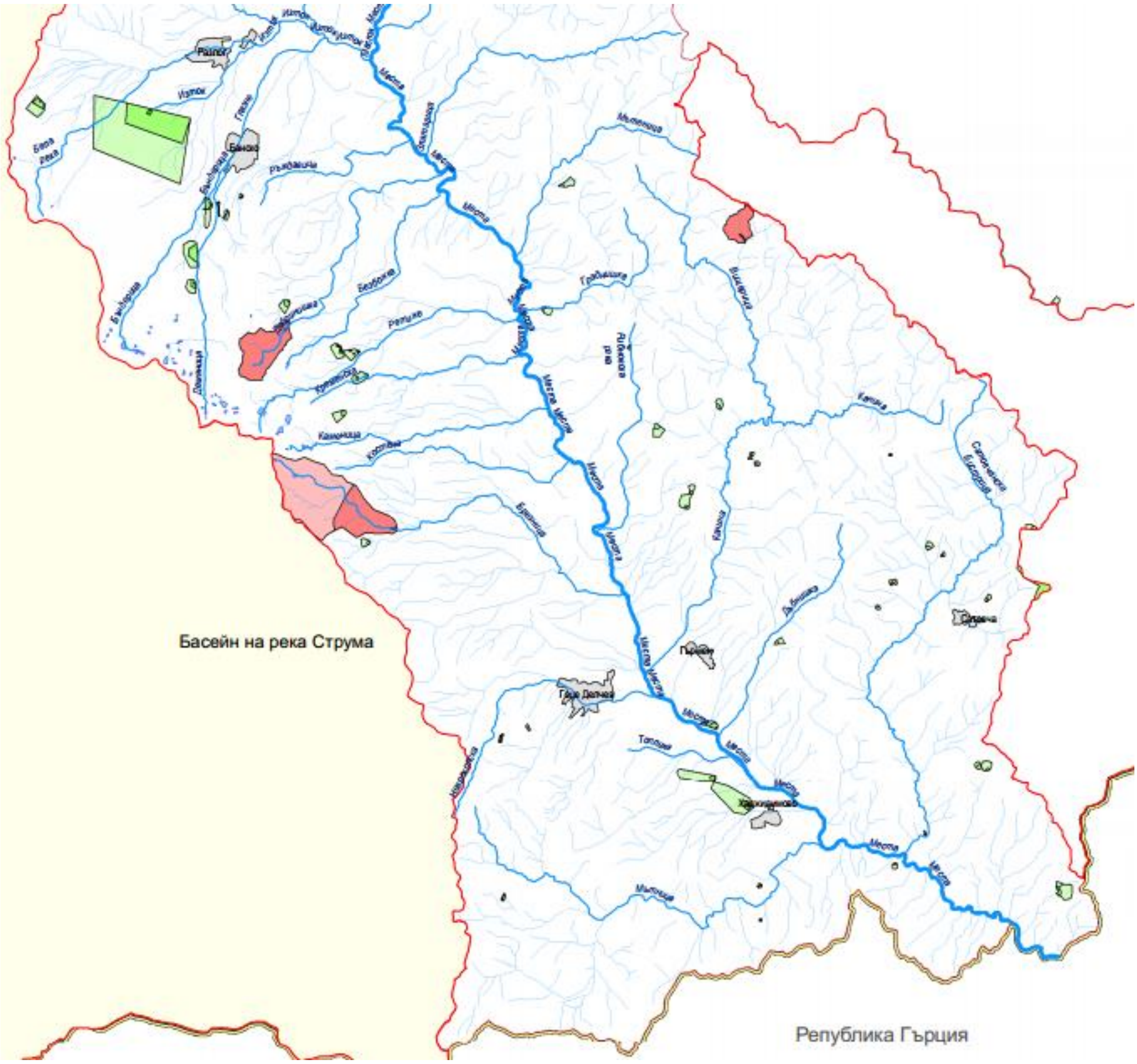
Main water source for the region is water catchment Tufcha, water is taken near village Breznika at sanitary protected area of river Breznitsa (also known as Tufcha). Water pas through a Potable Water Treatment Plant (PWTP). After it is treated, main quantity is supplied to water supply network of Gotse Delchev and rest is provided for Gospodinovci and Garmen.

The area of the catchment of River Breznitsa (also known as Tufcha) is 123 km2. Average annual flow of the river near village Breznitsa is 1,42 m3/s with annual maximum in May and minimum in September. The village of Breznitsa in Gotse Delchev municipality is the only settlement along the river. River Breznitsa is a right inflow of river Mesta.

Responsible body for water resource management is Basin Directorate West Aegean Region. Its operation is controlled and coordinated by Ministry of Environment and Water.



Scheme 2 – Territory of West Aegean Region



Scheme 3 – River Basin Management Plan in West Aegean Region – Protected areas for River Mesta Basin

	Sanitary protected area for ground water category 1
	Sanitary protected area for ground water category 2
	Sanitary protected area for underground water category 1
	Sanitary protected area for underground water category 1
	Main river
	Inflow of main river

2 Water Resources Vulnerability Assessment

As a part of Regional Master Plant for the territory served by WSC Blagoevgrad, for water supply system of Gotse Delchev an assessment of water stress was performed. Results from it show that even in case water losses are reduced with 35% water stress index in 2038 still will be 104% (an optimum value is 40%). As a part of the report it was concluded that in order an optimum value of 40% for water stress to be reached in addition to water loss reduction, an extension of capacity of water sources should be provided as an additional measurement to guarantee efficient water supply for the region. Results from assessment of capacity of volume of water reservoirs for the regional of Gotse Delchev show that capacity of existing reservoirs is enough and in 2038 volume index of available water reservoirs will be 160%.

Three of water source for the region of Gotse Delchev are mountain springs and as a results their main problem is related with constantly changing chemical and microbiological composition. Water from them is rich of organic matter with undissolved and colloidal clay particles. Because of this water has high level of turbidity and color that cause problems with its taste and smell. Very often in case of intense snow melting and heavy rainfall physico-chemical or microbiological parameters exceed limit values set in Ordinance №12 which regulates quality requirements of surface water intended for potable water supply.

Water for main water source for the region of Gotse Delchev which is also used for the water supply of city of Gotse Delchev is extracted from a ground water source which is protected from human impact by sanitary protection area. In addition water passes through a potable water treatment plant and no quality problems are reported.

3 Strategy and Measures taken

In May 2018, World Bank has prepared a draft of a National Climate Change Adaptation Strategy and Action Plan for the Government of Bulgaria. Water is one of the main subjects covered in the document. This draft National Climate Change Adaptation Strategy and Action Plan for the Republic of Bulgaria is intended to serve as a reference document, setting a framework for climate change adaptation action and priority directions up to 2030, identifying and confirming the need for climate adaptation action both at economy-wide and sectoral levels (including water), while highlighting the consequences of no action. Main objectives of the documents are:

- Assessment of options to address climate risks across the economy;
- Formulation of a National Climate Change Adaptation Strategy and Action Plan, which shall cover the period to 2030
- Strengthen capacity for implementation and cross-sector coordination on climate change adaptation

As a part of National Climate Change Adaptation Strategy and Action Plan following strategic objectives for water sectors are considered:

Strategic Objective	Type of options considered	Examples
Enhance Adaptive Governance	Adaptation of legal framework to make it instrumental for addressing climate change impacts	Clarify roles and responsibilities for CCA
Strengthen knowledge base and awareness for adaptation	Use of research and education institutions	Provide research support to River Basin Directorates through framework agreements

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Strategic Objective	Type of options considered	Examples
	Awareness, education and training	CCA training of public administration and water operators
	Monitoring and flexibility	Extend and upgrade CCA related monitoring networks of precipitation, water resources and water use
Enhance adaptive management of water system infrastructure	Adapting design and construction	Revise and update design and construction norms
	Adapting operations	Develop methodology and assess adaptive capacity of significant water infrastructure

In addition following top five adaptation options for the water sector were selected for quick integration:

- Adapt of legal framework to make it instrumental for addressing climate change impacts
- Establish of a dynamic publicly available GIS database supporting climate change decision making;
- Maximize the use of research and education institutions;
- Operate water infrastructure to increase resilience to climate change for all users and sectors;
- Strengthen adaptation capacity: CCA awareness raising campaigns, education, and training

Following results from implementation of National Climate Change Adaptation Strategy and Action Plan:

- For adaptation options supporting the strategic objective to enhance adaptive governance, expected results are identified as: Improved coordination amongst institutions, effective and efficient implementation of RBMPs, and the adoption of more water efficient and less water polluting technologies and practices.
- Under the strategic objective to strengthen the knowledge base and awareness for adaptation the key expected results are: the availability of the latest research achievements and reliable water monitoring data, enhanced quality of plans and programs developed by RBDs, raised public awareness, and increased preparedness of stakeholders. Overall the adaptation actions will contribute to improved decision making under uncertainty.
- For the strategic objective to enhance adaptive management of water system infrastructure expected results are: the adaptive design and construction of managed water systems, identification of significant water infrastructure which needs reinforcement, and adequately and safely operated water systems

4 Comments

In general region of Gotse Delchev has significant freshwater resources. Main water sources for the region are mountain springs and surface catchments which capacity depends on snow following during the winter time. This put on a risk water supply of the region in case of snowless winter occurrences which are expected with climate changes. Effects from this could be limited in case of presence of dams which can keep certain water volume to guarantee efficient water supply for the area even for certain period even in case of a non-snowy winter. Currently dams for water supply are not available on the territory of Gotse Delchev.

Appendix A:

WATER RESCUE

Water resources efficiency and conservative use in drinking water supply systems

WP	**4 Common Methodology & Tools**
Deliverable *Tool*	**4.6.1 Cross border water resources vulnerability assessment methodology report** *Questionnaire*
Project Beneficiary No	**PB6**
Beneficiary Institution	**Municipal Water Supply and Sewerage Company of Thermaikos**

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Table of Contents

Name of the organization/institution: Municipal Water Supply and Sewerage Company of Thermaikos
Beneficiary number: PB6

1 Introduction

Municipality of Thermaikos is located in the River Basin District of Central Macedonia (GR10) and in particular in the River Basin of Chalkidiki (EL05) with an area of 5,546 km^2. The boundaries of the municipality crosses three Groundwater Subsystems, and in particular:

1. Groundwater Subsystem Epanomis – Moudanion. It has a total area of 681.77 km^2, its renewable reserves are estimated at $81.2x10^6$ m^3/year[1], while the mean annual water abstraction is estimated at $121.32x10^6$ m^3/year[2]. According to Central Macedonia River Basin Management Plan, the Chemical status of the Groundwater Subsystem Epanomis – Moudanion is characterised as Bad, while the Quantitative status is characterised as Poor.
2. Groundwater Subsystem Kato Rou Anthemounta. According to Central Macedonia River Basin Management Plan, the Chemical status of the Groundwater Subsystem Kato Rou Anthemounta is characterised as Bad, while the Quantitative status is characterised as Poor.
3. Groundwater Sybsystem of Thermis – Neo Risio. According to Central Macedonia River Basin Management Plan, the Chemical status of the Groundwater Subsystem Kato Rou Anthemounta is characterised as Good, while the Quantitative status is characterised as Good.
   The Groundwater Subsystems of Kato Rou Anthemounta and Thermis – Neo Risio are part of the Groundwater System of Anthemounta with a total area of 309.45 km^2, renewable reserves of $33.6x10^6$ m^3/year[3] and mean annual water abstraction of $37.02x10^6$ m^3/year[4]

A map of the region is presented in the following Figure 1. The competent authority for water resources management is the Water Directorate of the Decentralised Authority of Macedonia and Thrace.

[1] According to IGME (2010)
[2] According to Central Macedonia River Basin Management Plan (2014)
[3] According to IGME (2010)
[4] According to Central Macedonia River Basin Management Plan (2014)

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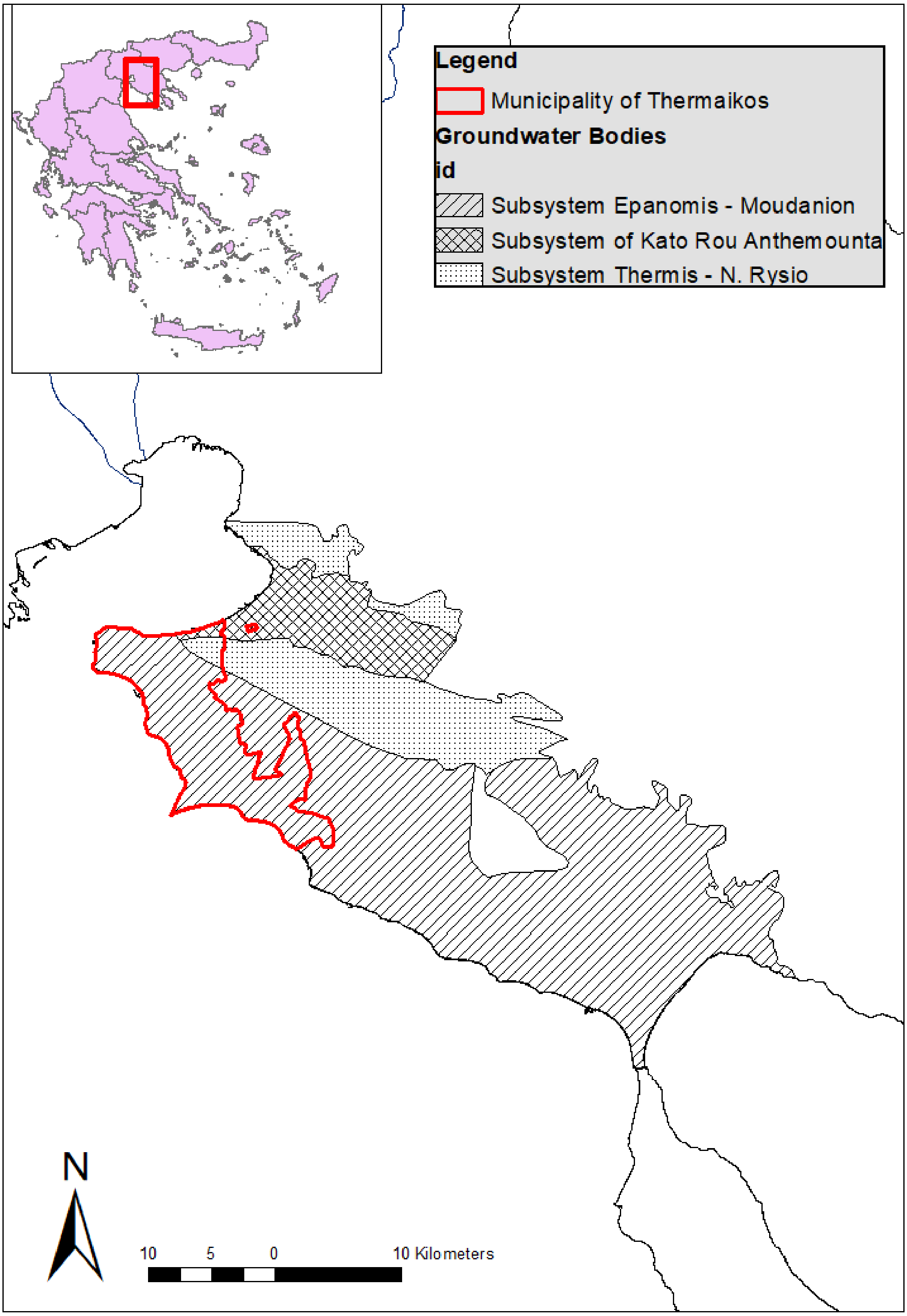

Figure 1. Groundwater bodies in Municipality of Thermaikos region

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2 Water Resources Vulnerability Assessment

- Two out of three of the groundwater subsystems in the area have a Bad chemical status and also a Bad Quantitative status, revealing the vulnerability of the water resources in the area. Moreover, according to the River Basin Management Plan, the annual water abstraction is larger than the annual recharge, resulting with a continuous increase of the pumping depth. That fact, combined with the vicinity of many boreholes to the sea, results in salinity problems in the area, as presented in the following Figure 2[5].

Figure 2. Salination Areas in Central Macedonia River Basin

3 Strategy and Measures taken

According to the Central Macedonia River Management Plan, the measures to confront the climate change impact can be grouped as i) long-term measures for an equilibrium between supply and demand, ii) measures for increasing the availability of water and iii) measures minimizing the effects of droughts.

i. The measures for an equilibrium between supply and demand could be technological, economical or social. For the management of water demand these measures could include new technologies for saving water, reducing leakages in water networks, reuse of water, new agricultural policies, new water pricing, better public education and increasing the public awareness. On the other hand

[5] From Central Macedonia River Basin Management Plan (2014)

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measures for increasing the supply of water could include better natural reserve in river basin, use of alternative water sources or transfer of water from other districts.

ii. The measures for increasing the availability of water could include the design and implementation of drought mitigation plans, the development of early warning systems and the education of the public in water saving.

iii. The measures minimizing the effects of droughts could include a) Strategic measures, such as Development of River Basin Management Plans, Adopt long-term water resource management measures, Establishing appropriate indicators and limits for the different stages of drought, Establishing drought-fighting actions, Inventory and maintenance of drought infrastructures b) Operational like Determination of water use priorities in drought periods, c) Organizational, like Definition of organizational structure for the preparation and implementation of management plans, Definition of available resources, Coordination of stakeholders

4 Comments

Please provide any comments.

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Appendix A:

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