Work Package 2
Peer To Peer for Experience Sharing

"P2P – 9: Drought Risk Management (DRM) (Drought monitoring based on drought characterisation and mitigating drought)"

DRM Report

SWIM and H2020 Support Mechanism

February 2019

Version	Document Title	Authors	Review and Clearance
1	Concept Note "P2P – 9 Drought Risk Management (DRM) (focus on drought characterization with suitable indices) in the partner countries"	Demetris Zarris	Suzan Taha

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1. INTRODUCTION

Under the framework of the SWIM-SM project, a regional assessment[1] of past drought and flood events in the SWIM Partner Countries (PCs) was undertaken in 2013, in order to identify their prevailing characteristics (frequency of occurrence, severity/magnitude, and geographic extent) and potential environmental and socio-economic impacts. The assessment also included an overview of prevailing drought management practices and response actions implemented in three focus countries (Jordan, Palestine and Tunisia). The main finding of the regional assessment, in terms of drought risk, indicated an increasing trend in the occurrence of drought episodes in the partner countries, highlighted the existing gaps in drought management, and concluded that effective response to drought risk is paramount. In this regard, the introduction and/or promotion of concepts and methodologies for proactive management in the region is necessary for shifting from the customary "crisis management" paradigm to "risk management". A well-established risk management system which entails the identification of vulnerability and risk, and incorporates prevention, mitigation and preparedness measures needs to be developed and maintained by governments and other competent actors of the countries of the region. This in turn requires, inter alia, the adoption of enabling policies, robust legal frameworks and proper institutional arrangements at the national and local levels, implementing awareness campaigns, promoting resilience through knowledge, advocacy, research and training, making information available and to up-to date, etc.

The concept of Drought Risk Management Mainstreaming (DRMM) was introduced by the UNDP (UNDP, 2011[2]). Mainstreaming is defined as "a process of change, whereby certain issues are integrated into planning and decision-making processes and these issues continue to be part of the agenda in subsequent planning, implementation and revision" (UNDP, 2008[3]). DRMM clearly relates to proactive risk management, as it helps addressing drought issues not simply as a natural phenomenon but as a more complex development issue. It supports the internalization of drought risk throughout the planning, funding and implementation stages of any development framework, and further ensures that sectors' policies do not counter their intended purposes of drought mitigation and preparedness-related efforts (UNDP, 2011[2]). It further sets the cornerstones towards the identification and development of the proper enabling environment and institutional setting that can strengthen the adaptive capacity of the affected communities in a sustainable way. To achieve DRM mainstreaming a set of steps need to be coherently implemented:

- Step 1: Definition and development of a Drought Risk Profile.

[1] Taha, S., Rabi, A., Touzi, S. 2014. Regional assessment of past drought & flood episodes and their management in selected SWIM-SM PCS (Tunisia, Jordan and Palestine). SWIM-SM Report, WP1, Water Governance and Mainstreaming, Activity 1.3.3.1, February 2014 (accessed 28.03.2016)

[2] United Nations Development Programme (UNDP), 2011. Mainstreaming Drought Risk Management: A primer. UNDP Publication, March 2011 (accessed 28.03.2016)

[3] United Nations Development Programme (UNDP), 2008. Mainstreaming Drylands Issues into National Development Frameworks: Generic Guidelines and Lessons Leant. Nairobi: UNDP.

- Step 2: Identification of DRM options: Design and simulation of mitigation measures.
- Step 3: Prioritization of DRM options: Optimization and Decision-making.
- Step 4: Internalization of DRM: Definition of policy targets and Implementation.

It is important to make here the distinction between *drought* and *water scarcity*. Drought is an extreme meteo-climatic phenomenon, which may come unannounced and be of indefinite duration, being the result of the combined action of several parameters. The drought is not limited to specific areas and is not only a problem for dry and desert areas. Instead, drought in areas characterized by significant amounts of rainfall causes many more problems than those in arid regions, as ecosystems in areas with dry climate are accustomed to survive with little moisture, whereas, in areas with wet climate, it is even possible for ecosystems to be destroyed if the amount of rainfall is significantly reduced.

According to the EU Communication on Water Scarcity and Drought (EC, 2007[4]) "Drought" means a temporary decrease in water availability due to causes such as precipitation deficiency, whereas "Water Scarcity" means a situation in which the demand for water exceeds - in sustainability conditions - the exploitable water resources. Drought, dryness, water scarcity and desertification are common and overlapping processes in Mediterranean countries and are often misinterpreted when used. To clarify these concepts the following definitions are given (MEDROPLAN, 2007[5]):

Drought: Natural casual (random) temporary condition of consistent reduction in precipitation and water availability with respect to normal values, spanning along a significant period of time and covering a wide region. It is caused by natural causes.

Aridity: Natural permanent climatic condition with very low average annual or seasonal precipitation compared to potential evapotranspiration. It is caused by natural causes.

Water Scarcity: Water scarcity occurs when the available water resources are not enough to meet the long-term water needs. It refers to a long-term imbalance between available water resources and demand in a region (or a water supply system) exceeding the service capacity of the natural system. Water scarcity results from the rapid increase in water demand and/or low available water resources, due to population growth, expansion of water consuming crops, etc. It is also caused by the lack of infrastructure in water management (dams, water transmission and distribution systems, etc.). In addition to the quantitative aspect, water scarcity may also arise from poor quality status of the available water resources, which, although being enough in terms of quantity, may however be polluted by point or diffuse sources of pollution and are therefore not available for human consumption.

In arid (or semi-arid) regions, drought is a very common and frequent situation since it is very difficult to distinguish low from very low rainfall. One might say that drought is the normal meteorological condition.

[4] EC, 2007. Communication from the Commission to the Council and the European Parliament, Addressing the challenge of water scarcity and droughts in the European Union. Brussels, 18.07.07, COM(2007)414 final.

[5] MEDROPLAN, 2007. Iglesias A. (ed.), Moneo M. (ed.), López-Francos A. (ed.). Drought management guidelines technical annex. Zaragoza: CIHEAM / EC MEDA Water, 2007. 496 p. (Options Méditerranéennes : Série B. Etudes et Recherches; n. 58)., No. 58, Options Méditerranéennes) ISSN: 1016-1228 – ISBN: 2-85352-359-4

2. Context

During the Fact-Finding missions of SWIM-H2020 SM in 2016, and the communicated priorities by the Project countries (PCs), drought risk management emerged as one of the priority themes for the region. More specifically, Egypt, Jordan, Palestine and Tunisia requests for support related directly to drought risk managements aspects, while requests from Lebanon, Algeria and Morocco are also linked with drought and water scarcity risk mitigation.

Along these lines, and as part of its workplan, SWIM-H2020 SM has launched a regional activity on "Drought Risk Management (DRM) in the partner countries" based on the discussions and findings of the "1st Regional Training on Drought Risk Management Mainstreaming (DRMM)-REG-6" held in Athens, Greece on 14-15 December 2016. The regional activity included" a peer-to-peer (P2P) exchange on **DRM, referred to as P2P NO. 9 (P2P-9)**.

The exchange within the P2P activity is normally focused around pressing/emerging issues of the beneficiary countries, which drove the identification of a focus group following a match-making process between those countries requesting expertise and those offering it. In this regard, a focus group on **"Drought monitoring based on drought characterisation and mitigating drought**" has been identified.

The Countries that have registered for the P2P-9 are:

- Egypt
- Jordan
- Palestine
- Tunisia

The names of the designated peers (receiving expertise) per country are:

Focus Group: Drought monitoring based on drought characterisation and mitigating drought	**Egypt**	**Jordan**	**Palestine**	**Tunisia**
Nominated Peer	**Eng. Taha Ragab Gaber Ahmed**	**Mr. Ali Ghanim**	**Mrs. Salam Abu Hantash**	**Mr. Wasly Abderrahman**

The designated SWIM/H2020 SM expert was Mr. Bernardo MAZZANTI, Director of Hydrologic Sector, Tuscany Regional Administration, Ital. He was appointed as the peer/expert offering Expertise (Email: b.mazzanti@gmail.com, Skype: bernardo.mazzanti), while Mr. Demetris ZARRIS was appointed on behalf of the LDK SA, as the P2P Coach (Email: dez@ldk.gr, Skype: demetris.zarris)

Unfortunately, Mr. Mazzanti resigned, due to personal reasons, in 07/09/2019. It was then decided that, the P2P Coach, will take cover as the Expert for the remaining period until the end of the project.

The peer-to-peer mechanism has been launched during the REG-6 training, since 2017 (circulation of topics, pairing, signing up etc. but full P2P operation commenced by May 2018. The total duration of the P2P process was nine months.

3. Prevailing Issues within the focus group

Initially, peers from the beneficiary countries were invited by the Coach to send specific questions to the Expert. However, peers were reluctant to do so before and after the Webinar (19/07/2018) until the Regional Event (REG-7). Just around the Regional Event (Regional Training on Drought Hazard (DH) Analysis and Mapping" (REG 7), on 24-27 September 2018, Murcia, Spain, the P2P Expert resigned from his position for personal reasons. It was also decided that the P2P Coach will undertake as the P2P Expert.

The Palestinian Water Authority (PWA) has stated the following issues for the P2P-Session (e-mail from PWA peer Mrs. Salam Abu Hantash dated 21/05/2018). PWA needs to be provided the methodology to be applied for the characterization of meteorological and hydrological droughts and monitoring. Drought characterization is complex and there are a wide range of meteorological or hydrological or agricultural indices or indicators that can be used. It requires an accurate selection of drought identification methods and/or indices, able to describe, in a synthetic and clear manner, the evolution of drought conditions in space and time. These indices must comply with the following: they can be calculated from available data and they can be used for predictions and early monitoring systems. Long- and short-term activities and actions that can be implemented to prevent and mitigate drought impacts should be identified that include:

1. Preparedness, early warning, monitoring system
2. Establishing priorities of water use
3. Defining the conditions and the thresholds to declare drought levels
4. Establishing the management objectives in each drought level
5. Defining the Implementation actions

The Ministry of Water and Irrigation (MWI) of the Hashemite Kingdom and its peer (Mr. Ali Ghanim) of Jordan informed the Coach (by email on 14/06/2018) that the ministry of Water an Irrigation, still new in the field of Drought Risk Management, and the Unit of Drought Management do not have a lot of experiences because they are in the beginning. MWI has currently a project funded from The United Nations Development Program (UNDP) work with us to produce: (a) Drought Policy, (b) Drought Vulnerability Maps, and (c) Drought Impact Assessment.

The Ministry of Water Resources (MWR) of the Republic of Tunisia (Peer Mr. OUASLI Abderrahman, Chief Engineer, Rural Engineering, Waters and Forests & Director of Monitoring the Management of the Hydraulic Sector at Bureau de la Planification et des Equilibres Hydrauliques (BPEH) / le Ministère de l'Agriculture, des Ressources Hydrauliques et de la Pèche Tunisien (MARHP) (email on 11/09/2018), stated that Tunis is still in the beginning on drought management issues and are

interested in any topics that can help build up our experiences. Tunisia is interested in the practical side of things, this is the procedural approach and the legal and legislative framework for reporting drought. In a spirit of sharing, they should seize this opportunity to be introduced to and discuss some cases (in the Mediterranean region): who declares the drought (public institution, independent body, scientist, ...)? The stages, the procedural aspects, regulatory, institutional, financial impacts (financial charges, subsidies,), position and synergy with the insurance systems put in place, regional and international cooperation, etc.

The Ministry of Water Resources & Irrigation of the Arab Republic of Egypt peer raised no questions.

All the above issues were discussed during a dedicated session that was held during the regional training on DRM (REG-7) and it was agreed that in addition to the exchange covered by the webinar (See section 6.1), the following will be the subject of the P2P second exchange reflecting the experience of Cyprus:

1. Who declares the drought?
2. Drought stages.
3. Procedural, regulatory and institutional aspects.
4. Mitigating socioeconomic and cultural impacts of drought.

However, due to limited resources, the theme for the P2P exchange was confined to the first two subjects completely with partial reference to the third subject.

4. Scope and Objective

The objectives and expected outcomes are presented here below:

Objective: Peer-to-peer training on selected issues related to DRMM (namely with regards to (1) drought characterization with suitable indices and (2) mainstreaming DRM.

Outcome: Improved knowledge on selected issues related to the DRMM (drought characterization with suitable indices and mainstreaming DRM), capacity building among the PCs, establishment of cooperation and alliances among the PCs.

5. Methodology

The methodology used under the P2P exchange on DRM (P2P-9) included the following:

1. A Webinar aiming to complement the peer to peer exchange involving a moderated discussion and comprising live presentations, ppts and Q&A.
2. E-mailing or skype conferences between the peers and the Expert facilitated by the Coach.
3. Face to Face discussions between the peers and the Expert facilitated by the Coach during the regional training on DRM (REG-7) in Murcia Spain.

4. An evaluation of the impact of the Peer to Peer process on the participants involved and the main beneficiaries was carried out after completion of this activity.

The Webinar was a success with a lively discussion between the peers and the Expert. However, the peers were reluctant to ask questions directly to the Expert by email or skype conference, although they were urged to do so by the Coach.

Finally, the resignation of our Expert (due to strictly personal reasons) just before the REG-7 event in Murcia was an unfortunate circumstance because there was eventually no possibility for a face to face exchange between the peers and the expert, especially that all the designated peers from the PCs were present in REG-7 and the associated study tour (ST-6). However, there was a discussion during the said events between all participants and the experts that participated in REG-7 and ST-6. The P2P Coach took over as the Expert and it was agreed to prepare a report on the administrative and technical procedures that the Republic of Cyprus utilizes for drought management. This report is annexed in ANNEX II.

6. Achieved Outputs

The outputs of the P2P sessions are the following:

1. Presentation of the webinar (Annex 1) distributed to the participants before the webinar.
2. An mp3 audio file from the recordings of the Webinar for both the lecture of the Expert and the following discussion and eventually disseminated among the participants.
3. A report describing the administrative and technical procedures that the Republic of Cyprus utilizes for the drought management (Annex 2).

6.1 Webinar

Webinar was held by means of relative software (e.g. Skype) in one session. The webinar took place on 19th of July with the participation of all the peers, except Jordan's peer (Mr. Ali Ganim) who was on a mission. Before the actual webinar, the coach contacted all participants and check their connectivity with Skype in order to ensure if the available bandwidth of the peer's networks will suffice for the continuous function of the session.

In the beginning of the webinar the coach welcomed the participants and introduce the Expert to the peers. The coach also addressed the webinar with a short talk about the SWIM-H2020 project and the objectives of the webinar. Then the Coach explained the purpose of the webinar, presented the main stages of the peer to peer exchanges in relation to the Regional On Site training and then gave a talk addressing the topics to be addressed during the P2P activity regarding mainly to (a) drought hazard monitoring with appropriate indices, (b) climate change impacts on droughts, and (c) governance and economic analysis.

The Expert has prepared a PowerPoint presentation in pdf format prior to the webinar, that was disseminated to all participants. The presentation was also presented in the Skype screens while the Expert addressed his theme. The presentation consisted of 76 slides (annexed in Annex I).

The Agenda of the webinar is presented below:

Item	Time	Description	Speaker
Half an hour before the web		All participants connect to Skype and a test call is conducted	
#1	08:30 – 09:00	Welcome remarks Short presentation of the "Sustainable Water Integrated Management and Horizon 2020 Support Mechanism" project	Mr Demetris Zarris (SWIM-H2020 SM P2P9 Coach)
		Familiarization among the peers	
#2	09:00 – 10:00	Lecture by the Webinar Expert	Mr. Bernardo Mazzanti, Regione Toscana, Director of Hydrologic Sector
#3	10:00 – 10:30	Questions from the Peers	Peers
#4	10:30 – 11:00	Reply from the Expert	Mr. Bernardo Mazzanti, Regione Toscana, Director of Hydrologic Sector
#5	11:00 – 11:30	Discussion – Conclusions - Recommendations	All
#6	11:30 – 11:45	Closure – Wrap Up	Mr Demetris Zarris (SWIM-H2020 SM P2P9 Coach)

The Expert's lecture lasted at least 1 hour with minor discrepancies due to poor connection to some instances and the delayed participation of Tunisia's peer. The aim of the webinar was to establish a common vision on the way forward in the peer-to-peer activities to follow and expected outcomes from this activity.

After the Expert's lecture the peers asked questions and clarifications to the Expert, followed by a discussion facilitated by the Coach. The discussion among the peers, the Expert and the Coach illustrated how complex is the monitoring of drought in countries with dry climates whatsoever. The peers were also concerned about early warning systems from global circulation models, and the strategy for establishing a drought monitoring procedure in their countries. The whole webinar lasted 2 hours and 15 minutes.

Finally, the Coach summarized the findings of the Webinar and asked again from the peers to take advantage of the opportunity to gain some of the experience of the Expert by asking questions either through Skype conference and / or by email.

Although Skype cannot facilitate recording of the session, the Coach recorded the session (by means of another software) and converted it to an audio file to be available for all peers and the participants of the REG-7 event at the end of September.

6.2 Face-to-face Meeting (dedicated session as part of REG-7)

During the REG-7 event (that took place at Murcia Spain on 25026 of September 2018), there was a dedicated session on the P2P-9 process. There was an overview of the peering results so far and a close meeting between the Coach and the Peers where questions could be addressed. Facing the resignation of the Expert Mr. B. Mazzanti and the poor participation of the peers following the webinar, it was decided that the P2P-Coach has to take over as the Expert also. A thorough discussion in plenary was also made in order to co-decide the P2P theme till the end of the project.

It was decided that the Expert will prepare a report describing the administrative procedure that the Republic of Cyprus utilizes in order to manage and mitigate the adverse effects of drought. The report is presented in Annex II.

7. ANNEX I

Powerpoint presentation attached as a separate pdf file.

8. ANNEX II

DROUGHT MANAGEMENT PROCEDURES ADOPTED IN THE REPUBLIC OF CYPRUS

1. THE WATER DEVELOPMENT DEPARTMENT (WDD)

The Water Development Department (WDD) is responsible for implementing the water policy of the Ministry of Agriculture, Rural Development, Natural Resources and Environment with the aim of providing effective protection, rational development and sustainable management of the water resources in Cyprus. In this context, drought monitoring is included in the WDD responsibilities. A Drought Monitoring Unit (DMU) is organized within the Hydrology & Hydrogeology Section of the WDD. During drought onset DMU is continuously monitoring drought indices to update the alert level according to the Drought Risk Management Plan, that is prepared in the context of the Water Framework Directive (WFD) (2000/60/EC) of the European Union.

Current policies in Cyprus identify as the first priority the maintenance of domestic and municipal water supplies. The second priority is the maintenance of supplies for perennial crops and greenhouses at 80% of the recommended application levels, while irrigation of seasonal vegetables is defined as the third water allocation priority.

The vision of the WDD is the sustainable development, protection and management of the water resources with the aim to secure adequate quantities of good quality water for all uses, in the framework of a modern, flexible and effective organization. In this context, the competencies of the Department cover a wide and varied range, including the following:

a) Collection, quality control, processing, analysis, classification and recording of hydrological, hydro-geological, geotechnical and other data, which are necessary for:

i) The protection and improvement of the qualitative and quantitative status of the surface and ground water bodies and

ii) The study, maintenance and safety of development projects.

b) Feasibility studies, design, implementation, operation and maintenance of infrastructure projects, such as, dams, ponds, irrigation, water supply and sewerage networks, water treatment plants, wastewater treatment and re-use plants, as well as desalination plants.

c) Cultivation of water saving awareness among consumers.

1.1. Main Purpose of the Drought Management Plan

Cyprus has long recognized the need for management and control of the drought phenomenon. It's complex dynamics, are affected both by natural phenomena and by human activity while it has short- and long-term impacts both on the natural environment and society. The management of the consequences of drought is of key importance for combating, also, desertification. A main objective of the Drought Plan must be the quantification of drought with regard to:

(a) the «imprint» of drought on the time series of rainfall and runoff and

(b) the intensity and persistence of drought.

The tool for drought quantification is a drought indices system, which should be defined in such a way that the systematic recalculation of the index values will provide the capability for the timely identification of the presence of a drought and will contribute to its effective management with a view to limiting the adverse consequences of the phenomenon. The indices must inform about the presence and the intensity of drought for all sectors which depend on water resources; and these in Cyprus are both water supply and irrigation as well as the environment.

Following the above, a relationship must be set between the critical indices values and actions to be taken for dealing with the consequences of a drought episode.

Water Banking has been studied in 1999 and was suggested as a water management strategy option facilitating voluntary temporary reallocation of water from farmers to domestic water users and tourism. This would constitute an emergency drought water bank encouraging farmers to exchange for compensation their irrigation water to be allocated to cities and tourism that are in need. This will allow critical and high-value water demands to be met by sectors that add significant value to the economy in contrast to irrigated farming, which demands large quantity of water, but makes a smaller contribution to the economy, without the need for construction of additional capital-intensive infrastructure (desalination plants).

Farmers have invested heavily in farming, and so even if Government legally retains all water rights, it is not politically feasible to unilaterally reallocate water away from agriculture. A Water Bank will seek the cooperation of farmers willing to take cash in lieu of irrigation water. The price to be paid to farmers will be set based on the quantity of water required for reallocation and the profit that the farmer would normally have expected from his produce. In years when reservoir storage is ample and irrigation water available, farmers may put their fields back into production.

2. DROUGHT INDICES

2.1. Indices System

The system of drought indices for Cyprus should include information for the following:

i. Early warning for impeding drought threat, as well as for the commencement and the termination of the drought period.

ii. The intensity, the duration and the geographical area of the drought.

iii. The pressure which is received by the natural environment.

iv. The pressure which is received by river, lake and groundwater bodies.

v. The pressures on the water resources management systems for water supply and irrigation.

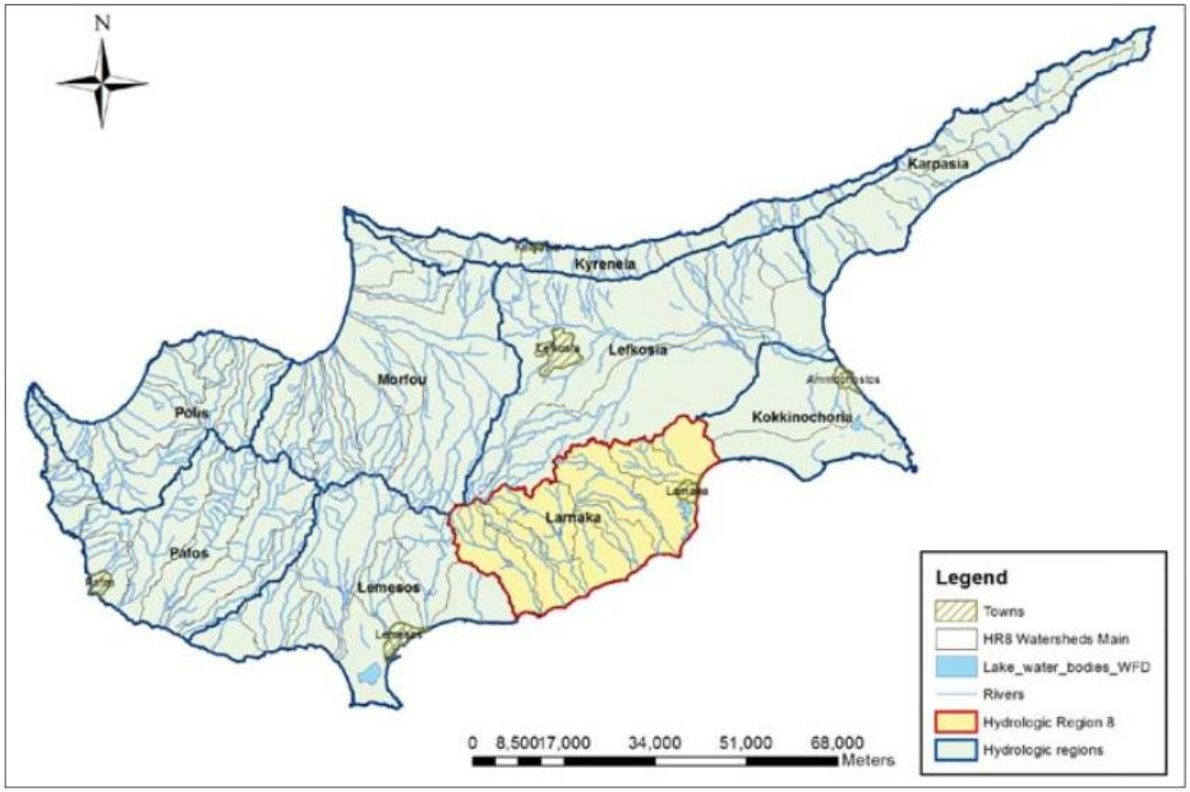
vi. The pressures on the rainfed agriculture.

Additionally, it is necessary that drought conditions in all regions of Cyprus can be comparable between them. It should also be possible, to a degree, to compare conditions with other countries of the Mediterranean and the EU.

Finally, it is desirable that the indices systems shall rely on the processing of measurements which are already being made, within the framework of the existing monitoring network.

The following figure (Figure 1) shows the hydrologic regions of Cyprus to which the indices are geographically referred.

Figure 1: The Hydrologic regions of Cyprus



Based on the above, an indices system was modeled, as follows:

• The geographic partitioning for the monitoring of the geographical extents of the drought phenomenon followed the established Hydrologic Regions of Cyprus (refer to Figure 1).

• The basic index for the monitoring of the phenomenon is meteorological and is dependent on the surface rainfall of the Hydrologic Regions. The selected approach is that of SPI (Standard Precipitation Index) which allows direct comparison between the different hydrologic regions and is a widely applied method worldwide. Given that the hydrologic catchments of Cyprus are small, the contribution of snow fall is very small and rainfall events are concentrated in time, the meteorological index is appropriate as the «leading index» for drought. The selection of the spatial integration of rainfall overall hydrologic catchment ensures that all the measurements from stations are used. The SPI is a moving index, recalculated on a monthly basis. However, because of the characteristics of the climate, in Cyprus with the extremely rare rainfalls during the dry months and their dispersion in certain days of the wet months, the reference time period of the index is always either 12 months or a multiple integer of the 12 months up to 60 months (e.g. the 12 month August index incorporates the total rainfall since last year's August. See also table...). In case of a sudden change of the drought conditions after a year of high rainfall, it is possible that the 12-month SPI will delay detecting such an event. In order to ensure the timely detection of sudden changes, a hydrologic index is defined and monitored as follows:

• For the timely detection of a sudden change towards drought conditions a hydrologic index of runoff **during the wet period** is defined and monitored. This is a moving index calculated for a representative dam (inflows to the reservoir) from each Hydrologic Region for the period from

December to May of each hydrologic year and is linked to the total runoff from October up to the month of calculation and, more particularly, to its deviation from the median runoff for this period.

• For checking the conclusions of the meteorological SPI, a hydrologic index is defined and monitored linked to the total runoff of one (1), two (2) etc. up to five (5) hydrologic years. The index is calculated for the same representative dams as for the wet period runoff index of the previous paragraph. This index is complementary to the SPI and is useful for diagnosing significant effects on runoff from changes in the rainfall regime that is not detected with the SPI.

• In order to detect pressures on the riverine ecosystems due to extremely low flows, a monthly index is defined and monitored, which is dependent on the relationship of the median of the average daily flow of the month in question to the distribution of historic average daily flows for the same month. The index is calculated for a representative hydrologic station for each Hydrologic Region and is monitored only when the commencement of drought conditions is already established.

• In order to monitor the pressure on the reservoirs of the main water schemes (Southern Conveyor and Paphos Dams), an index is adopted which characterizes the storage conditions and which is directly related with the total stored volume at the reservoir of each project. This index is also a main tool for the proposed Water Policy for the Republic of Cyprus and thus ensures the compatibility of the Drought Management Plan with the Water Policy proposals.

• For monitoring the pressures to the groundwater bodies, the monitoring and classification which are applied within the framework of the implementation of the 2000/60 Directive are adopted. The introduction of new measurements is not considered desirable.

The proposed indices and their corresponding monitoring objectives are summarized in the following Table 1). Index *1 in the said table means that water supply is an absolute priority and all dams are committed to contribute to water supply.

Table 1: Proposed indices and their corresponding monitoring objectives

MONITORING OBJECTIVE	INDICES					
	SPI	Wet Period Runoff Index	Hydrologic Years Runoff Index	Monthly Regime Index	Dams Storage Index	Groundwater Bodies Classification
Commencement and ending of drought	✓	✓	✓			
Drought Intensity	✓		✓			
Early detection of presence of drought		✓			✓	
Pressures on the wider natural environment	✓					
Pressures on river water bodies				✓		
Pressures on lake water bodies			✓		✓	
Pressures on groundwater bodies	✓					✓
Pressures on water supply					*1	✓
Pressures on irrigation	✓		✓		✓	✓
Pressures on non-irrigated agriculture	✓					

2.2. Meteorological Drought Index SPI

As already mentioned, the Standardized Precipitation Index (SPI) is adopted as the main drought. The method was developed by McKee et al., 1993 [Mckee,T.B., Doesken, N.J., Kleist, J., 1993. The Relationship of Drought Frequency and Duration to Time Scales, 8th Conference on Applied Climatology, 17-22 January, Anaheim, CA, pp.179-184]. The SPI allows the determination of the scarcity of a drought period for a certain time scale for any location based on a rainfall series of sufficient length. The SPI is calculated after converting the probability distribution function (cumulative form of the probability density function) to a standard normalised distribution, i.e. with an average equal to 0 and a standard deviation equal to 1.

Based on the SPI value, the drought intensity is characterised based on the following Table.

Table 2: Correspondence between Intensity and the SPI value

SPI	Characterization
0 – (-0,99)	Mild drought
(-1) – (-1.49)	Moderate Drought
(-1.5) – (-1,99)	Severe Drought
< -2	Extreme Drought

The commencement of a drought period according to the SPI definition is set as the time during which the index having become negative, reached a minimum value of -1 thereafter, without taking any positive values in between. The end of the drought period is defined as the time during which the index takes again for the first time a positive value. Consequently, mild drought periods (index values ranging between 0 and -1) are considered to be a part of the drought incident only if during the incident the index takes values smaller than -1.

The total cumulative «magnitude» of the drought (drought magnitude (DM)) is defined as the absolute value of the sum of the distributed monthly indices SPIi, where i is the corresponding month, during the drought period:

$$DM = - \Sigma(SPIi)$$

2.3. Hydrologic Year Runoff Index

As already discussed in chapter 2.2, this index is complementary to the meteorological SPI. Since this index depends directly on the surface runoff volume values, it will bring out any weaknesses of the SPI in predicting consequences on runoff, which may arise from the regime and not the actual rainfall. This index is defined by the following equation:

$$Ii = (Xi – Xav) / Sd$$

where Ii corresponds to the runoff index value for the year i, Xi the current year runoff, av the average annual runoff and Sd the standard deviation of the average annual runoff of all years in the available timeseries.

The index is calculated using dam inflows, since this information is directly available under the existing monitoring program of dams run by WDD. Obviously, it would have been possible to select hydrometric stations, instead of dams, however the work load for the indices monitoring would have increased considerably. Representative dams were selected using as a criterion, where possible, not to have large upstream reservoirs and/or large abstractions in comparison to the runoff at the dam's location.

2.4. Wet Period Runoff Index

This **index is used in the early detection of an oncoming drought**. It makes use of the good correlation that is observed in historic samples between very low runoff during the period between October – December and very low runoff in total during the wet period. Inflows to the representative dams for each Hydrologic Region of the previous index are used.

This index depends directly on the scarcity ranking of the current runoff value, as this is derived from the ranking of the historic values. The classification which is proposed is in Table 3

Table 3: Classification of the Alert level according to the Wet Period Runoff Index

Percentile into which falls the runoff value	Alert Level
25%-15%	Medium
15%-5%	High
Below 5%	Very High

2.5. Monthly Regime Index for rivers

One of the main goals of the Drought Management Plan is the monitoring of the pressures on the environment. The pressures on the wider natural environment can be related to the precipitation index (SPI), however the riverine ecosystems are dependent on river flow and particularly on the longer duration runoff, the base flows. The wet period runoff index (see previous section) provides a relatively good indicator for possible pressure on riverine ecosystems; however, it does not provide data for the duration of extremely low flows.

The system is simple and, for reducing work load, it is set in action only when one hydrologic region is already under drought conditions or when the alert level based on the wet period runoff index is at least high. Monitoring involves the calculation of the median value of the average daily flows of the current month for a pre-selected station, representative of the hydrologic region. This is then compared with the flow-duration curve for the Station. The basic criterion for the selection of the station was the existence of a satisfactory historic sample length with an even distribution among all months. The level of pressure to the river ecosystem is characterized as in Table 4:

Table 4: Characterization of the pressure level to the ecosystems.

Important	For a median value of the current month within the 25%-ile of all historic values for that month (less that 75% of the values).
High	For a median value of the current month within the 5%-ile of all historic values for that month (less that 95% of the values).

2.6. Dams Storage Capacity Index

The two large multi-purpose schemes, the *Southern Conveyor* and *Paphos* have a multiyear capacity for surface water storage. It is therefore useful that the drought management system shall include the evaluation of the surface stored reserves. In the case of Cyprus, which relies on significant multiyear storage capacity, the management of storage under a uniform system followed both during drought and during normal periods is absolutely necessary. Failure to have in place sufficient stored quantities before the commencement of drought will lead to very high cuts in water availability. It must be emphasized that the abstractions policy should protect the environment of the reservoirs defined as lake water bodies. These, as heavily modified water bodies shall, based on the Directive 2000/60, maintain the condition of «good ecological potential». The approach followed is to select a reference «drought», relative to the inflows to the reservoirs. For this drought, as well as for the milder ones, it should be avoided to downgrade the ecological status of the lake water bodies. For more infrequent droughts of larger intensity it may be required to resort to the procedure of Article 4.2 of the Water

Framework Directive (WFD) of the European Union[6] regarding the exemptions for temporary downgrading of the ecological status.

The inflows of the reference droughts (the severest droughts for which it is aimed to keep reservoir storage for the benefit of the lake environment) are presented in Table 5. The inflows refer to the sum of inflows to all the dams of each project:

• Kourris (including inflows from Dhiarizos diversion tunnel), Germasogeia, Kalavassos, Lefkara and Dipotamos for the Southern Conveyor Project.

• Aspokremmos, Kannaviou and Mavrokolympos for Paphos Project.

Table 5: Reference drought expressed in inflows (in hm^3) in the dams of the two water schemes.

Drought Duration:	1 Year	2 Years	3 Years	4 Years	5 Years
Southern Conveyor Project	10	30	60	100	140
Paphos Project	1,7	5	12	28	40

Based on the above inflows during the reference drought, the stored reserves of dams were categorized and related to values for total allowable annual abstractions. These are presented in the following tables for the Southern Conveyor and Paphos projects respectively.

Table 6: Categorization of the Dam Storage Capacity Index for the Southern Conveyor Project (in m^3)

DAMS STORAGE ON THE 1st of APRIL	CATEGORY CHARACTERIZATION	ANNUAL ABSTRACTION	MEASURE CHARACTERIZATION
Above 120 million	Adequacy	55 million	
Between 100 and 120 million	Mild Shortage	44 million	Small Cutbacks
Between 80 and 100 million	Moderate Shortage	35 million	Moderate Cutbacks
Between 50 and 80 million	Significant Shortage	25 million	Significant Cutbacks
Below 50 million	Extreme Shortage	15 million	Very Significant Cutbacks

[6] https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF . See also http://ec.europa.eu/environment/water/water-framework/index_en.html

Table 7: Categorization of the Dam Storage Capacity Index for the Paphos Project (in m^3)

DAMS STORAGE ON THE 1st of APRIL	CATEGORY CHARACTERIZATION	ANNUAL ABSTRACTION	MEASURE CHARACTERIZATION
Above 55 million	Adequacy	16 million	
Between 40 and 55 million	Mild Shortage	12 million	Small Cutbacks
Between 25 and 40 million	Moderate Shortage	9 million	Moderate Cutbacks
Between 10 and 25 million	Significant Shortage	6,7 million	Significant Cutbacks
Below 10 million	Extreme Shortage	5 million	Very Significant Cutbacks

2.7. Indices for the Groundwater Bodies

Establishing a uniform system of indices and limits for groundwater bodies as was described for surface bodies is not readily achievable. Each groundwater body has particular characteristics, supply regime, abstractions etc. Emphasis should be placed on the difficulties that may arise from the uncertainties in estimating the pumped abstractions. Clearly, the advent of a drought phenomenon, as detected from an index such as the SPI, would also affect the groundwater bodies. However, it is considered useful to present an organized approach in assessing whether each groundwater body is under particular pressure due to drought by making use of the hydrogeological data independently from the other indices.

2.7.1 Implementation of a Groundwater Drought Indices scheme)

For the near future, the simplest approach proposed is the comparison of the absolute groundwater level (in December or in January or even in February, if there is some margin for the decision taking/intervention process) with that of the previous year. For a year with indications of lower groundwater level, there should be a review of the abstractions policy from the start of the year, provided that the SPI supports the fact that it will be a period of low groundwater recharge.

The discharges from springs directly reflect the meteorological conditions and the pumping conditions and their monitoring provides data for the status of groundwater bodies. These may be used on a case by case basis, depending on the flow regime for the purpose of making management decisions. Most promising are the cases when the peaks are present between the months of December to January.

Prerequisites

The method and the difficulties of the implementation of a groundwater drought monitoring are summarized below:

• Selection of specific corresponding points per groundwater body is required. It is also important to schedule the achievement of independence of the monitoring network from the private boreholes and to establish a permanent and more reliable network based on the government monitoring infrastructure with suitable planning and control.

• Continuous data monitoring and analysis is required. This will demand further human resources and infrastructure for continuous monitoring. While there is sufficient flow of information for the groundwater bodies from the field teams, effort should be made for this information to be more directly applied, after it is checked and any errors dealt with.

• The monitoring frequency requires revision from its current status. For certain groundwater bodies there are data available for December (Kokkinochoria is a much degraded aquifer due to over-pumping) and for others (e.g. Kiti – less degraded) for January, depending on the plans of the responsible authorities. For the implementation of the index, which is based on the recovery rate, the months which are critical for the decision making per groundwater body should be picked and the monitoring revised with the aim of obtaining the relevant information.

• The monitoring of abstracted volumes is required in an indirect or direct way.

• The groundwater body management policy should be reformed based on the indices.

• Based on current data and given that the designated groundwater bodies are in some cases complex and result from the unification of many aquifers, it may not be feasible to implement in all cases a common methodology for supporting the decision-making process.

However, even a partial implementation of this approach, will offer possibilities for ensuring the recovery of the groundwater level and groundwater quality conditions, which do not occur at present. In the future, the monitoring system will have been improved and there will exist a better understanding of the pumping conditions and the natural system. Also, the groundwater body status will have been improved to some degree. It will be possible to design a more precise approach per groundwater body.

• It should be emphasized that the monitoring network established under the implementation of Article 8 of the WFD, provides only an indication of status and cannot be the base of the management of the groundwater bodies. The monitoring network both for the water level and for the water quality should be extensive and dense.

3. SCHEDULE FOR ESTIMATION OF INDICES

It is provided a presentation of the indices system for determining and monitoring the progress of a drought as well as the pressures to the environment, agriculture and other uses. In the following Table 8 the schedule of estimating the indices for a typical hydrological year is presented.

Table 8: Schedule of estimating the indices for a typical hydrological year

	SPI	Runoff Indices	River Regime Indices	Large Projects Reserves	Groundwater Bodies
Oct.	Calculation of moving indices of 12-60 months. During a drought period calculation of the drought magnitude up to now.	Calculation of indices of 1-5 hydrologic years.	If there is an indication of drought, estimation of the median of the month for stations where applicable. *	Forecast of cutbacks for farmers' notification.	
Nov.	As above		As above		
Dec.	As above		As above		
Jan.	As above	Index calculation Oct. – Dec.	As above	Update of cut-backs forecast for farmers' notification.	Assessment of annual variation of the groundwater level and spring runoff taking also into consideration the 12 month SPI.
Feb.	As above	Index calculation Oct. – Jan.	As above		
Mar.	As above	Index calculation Oct. – Feb.	As above		
Apr.	As above	Index calculation Oct. – Mar.	As above	Cut-backs announcement if the "adequacy" conditions are not fulfilled.	
May.	As above	Index calculation Oct. – Mar.	As above		
Jun.	As above		As above		
Jul.	As above		As above		
Aug.	As above		As above		
Sep.	As above		As above		

* Median of the average daily flows of the current month

3.1. Drought Diagnosis – Alert Levels

In correspondence with the «Drought Management Plan Report» (Environmental Directorate EU, Technical Report 2008-23), the dominant drought conditions are characterized as falling either on the alert status or the no alert status. Also, four levels of alert are defined which are the "mild", "moderate", "high" and "severe".

The correspondence between indices and drought levels are presented in Table 9. The main index for each hydrologic region is selected to be the corresponding 12-month SPI based on which the alert status is decided. The 12-month runoff index is used as a check on the SPI, since there is no past implementation of this system in Cyprus. In a case when the runoff index is more adverse than the SPI, a decision shall be taken by the responsible authorities. The alert level status for the River Basin Area (whole of Cyprus), as requested in the aforementioned EU report, will be given by the worst alert level status of the different Hydrologic Regions, since the River Basin is the administrative entity for Directive 2000/60.

However, the measures will apply only in the hydrologic regions it is required. As far as the other indices, presented in Table 9 are concerned, the wet period runoff index provides an early warning tool for the operators, since its calculation can provide an indication of drought earlier than the 12-

month SPI. Finally, the storage capacity index concerns the alert level in relation to the Southern Conveyor and Paphos projects and is directly related to the allowed abstractions.

Table 10 presents the main measures for the mitigation of the adverse effects of drought according to drought alert level.

Table 9: correspondence between indices and drought levels

Alert level	MAIN INDEX	ASSISTING INDICES		
	SPI 12 month	Runoff index 12 month	Wet season runoff index	Storage Capacity
Not alert	>-0,5	>-0,5	>median	Adequacy
Mild	<-0,5	<-0,5	<medina	Mild shortage
Moderate	<-1,0	<-0,7	<25%	Moderate shortage
High	<-1,5	<-0,9	<15%	Serious shortage
Extremely High	<-2,0	<-1,1	<5%	Extreme shortage

Table 10: Actions of the Program of Measures according to Alert Level.

Alert Level	Actions
Mild	Notification of responsible operators. Notification of users for increased consumption awareness. Increase of water supply served from desalination plants. Abstractions from large projects according to the storage capacity index.
Moderate	Notification of responsible operators. Notification of users for increased consumption awareness. Increase of water supply served from desalination plants. Status announcement and intensive public notification program. Intensive controls for restrictions to uncontrollable abstractions and pumping, as well as for wastage limitations. Abstractions from large projects according to the storage capacity index.
High	Notification of responsible operators. Notification of users for consumption reduction. Increase of water supply served from desalination plants. Status announcement and intensive public notification program. Intensive controls for restrictions to uncontrollable abstractions and pumping, as well as for wastage limitations. Abstractions from large projects, according to the storage capacity index, but not more than those that correspond to the action “significant shortage” (refer to Table 2-14). Monthly regime index calculation (refer to chapter 2.5) and measures received relevant to the upstream abstractions, if this is necessary (index smaller than 5%).
Extremely High	Notification of responsible operators. Notification of users for consumption reduction. Maximization of desalination plants production, when excess quantities storage is possible. Status announcement and intensive public notification program. Intensive controls for restrictions to uncontrollable abstractions and pumping, as well as for wasting limitations. Abstractions from large projects, according to the storage capacity index, but not more than those that correspond to the action “extreme shortage” (refer to Table 2-14). Monthly regime index calculation (refer to chapter 2.5) and measures received relevant to the upstream abstractions, if this is necessary (index smaller than 5%). The environmental releases from dams will be limited to the absolutely necessary for the river ecosystem protection and not for groundwater body recharge.