THE HASHEMITE KINGDOM OF JORDAN

Adaptation to Climate Change In the Zarqa River Basin

Executive Summary for Decision Makers On

(Prioritization of Adaptation Interventions and Adaptation Programme for the Zarqa River Basin)

MDG ACHIEVEMENT FUND

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يتحمل المؤلف كامل المسؤولية القانونية عن محتوى مصنفه ولا يعبّر هذا المصنف عن رأي دائرة المكتبة الوطنية

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Foreword

Jordan is classified as one of the four most water scarce countries in the world. The National Agenda that sets Jordan's development vision till 2015, as well as the United Nations Development Assistance Framework (UNDAF) document (2008-2012), stress that Jordan's remarkable development achievements are under threat due to the crippling water scarcity, which is expected to be aggravated by Climate Change. The UNDAF (2008-2012) addresses four key related challenges to sustain progress towards the MDGs, which include: (i) water scarcity; (ii) drinking water supply security and quality; (iii) health, agriculture and food production vulnerability to Climate Change; and (iv) vulnerability of local biodiversity to Climate Change.

Jordan's Initial National Communication (INC) to the United Nations Framework Convention on Climate Change (UNFCCC) foresees that over the next three decades, Jordan will witness a rise in temperature, drop in rainfall, reduced ground cover, reduced water availability, heat-waves, and more frequent dust storms. The Second National Communication (SNC) to the UNFCCC identifies water as a priority area.

There are several barriers to water sector adaptation to Climate Change that threaten the sustainability of Jordan's achievement of the MDG targets, these include: (i) Climate Change risks not sufficiently taken into account within sectoral policies and investment frameworks; (ii) existing climate information, knowledge and tools are not directly relevant for supporting adaptation decisions and actions; and (iii) weak national capacity to develop sectoral adaptation responses. Jordan's success in adapting to increased water scarcity and related threats to health, food security, productivity, and human security induced by Climate Change is the key to sustaining its human development achievements and growth.

The government of Jordan represented by the Ministry of Planning and International Cooperation (MOPIC), the Ministry of Water and Irrigation (MWI), the Ministry of Health (MOH), the Ministry of Agriculture (MOA), and the Ministry of Environment (MoEnv) have been the implementing partner in carrying out the activities of the United Nations Country Team (UNCT) Joint programme (JP) on "Adaptation to Climate Change to Sustain Jordan's MDG Achievements" which is supported by a team of UN agencies in Jordan consisting of UNDP, UNESCO, WHO-CEHA, and FAO. The JP has worked on the identification of adaptation barriers and gaps have to be addressed, assessment of the direct and indirect impacts of climate change on the health, nutrition, and livelihood security of people, screening and assessing potential adaptation strategies prior to wide scale application, and assessing and strengthening existing national adaptation capacities.

In addition to the key role of the JP to strengthen and develop the capacity of different institutions and communities in adaptation to Climate Change the JP is to disseminate the wealth of results, information, and studies accumulated during the period of its implementation to stakeholders, scientific and research community, and the public at large.

The component of the JP implemented by the MoEnv in cooperation with UNDP has been focusing on the Zarqa River Basin (ZRB) for its activities. The major activities of this component are:
Identifying the direct and indirect impacts of Climate Change on the water sources of the ZRB, identifying barriers and opportunities for Climate Change adaptation in the basin, Developing a Climate Change adaptation programme for the basin, and pilot Climate Change intervention for groundwater protection on one local community in the basin.

This document is the result of a collaborative and joint efforts of many professionals from the government, private sectors, NGO's, and local community representatives to identify the appropriate adaptation measures, come up with tools for prioritization of adaptation to Climate Change interventions, and develop programmes to better adapt to Climate Change impacts for the ZRB towards strengthening the capacity of the basin to adapt with Climate Change impacts. It is hoped that this study will be a motivator for other studies in other basins of the country.

We at the MoEnv hope that this and other studies of the JP will provide a practical guide for the harmonization of the implementation of climate change adaptation and issues within the conceptual system of the strategic planning of all concerned parties.

Eng. Ahmad Al-Qatarneh

Secretary General
Ministry of Environment

Acknowledgements

This study was part of a multi task project implemented by the MoEnv with support from UNDP. The project represents one component out of four with together form the UNCT joint programme titled "Adaptation to Climate Change to Sustain Jordan's MDG Achievements" implemented by the MWI, MoEnv, MOA, MOH, and MOPIC, in cooperation with UNDP, WHO-CEHA, UNESCO, and FAO.

This component (MoEnv-UNDP project) was coordinated by a national participatory process that lasted for three and a half years and involved tens of national experts and organizations resulted in the preparation of this and many other studies. The project was funded by the Spanish MDG-F, administered by UNDP, and implemented by the Ministry of Environment.

The project was coordinated by:

- Dr. Munjed Al-Sharif – Joint Programme Co-ordinator and Chief Technical Advisor
- Ms. Rana Saleh - JP assistant

The project management team was supported by the influential efforts of the various counterparts in the Ministry of Environment with special thanks going to Eng. Ahmad Qatarneh, the SG of the MoEnv and head of the MoEnv task force, Eng. Hussein Shahin, Director of Nature Directorate and Eng. Hussein Badareen, Director of Monitoring and Assessment Directorate, the project counterparts at the MoEnv and members of the task force. Appreciation is also extended to the other members of the task force Eng. Abdel Majeed Khaboor, Director of Zarqa Environment Directorate, and Mr. Batir Wardam, Head of the Zarqa river rehabilitation project and unit at the MoEnv.

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- Dr. Ali El Naqa, Team Leader (Hashemite University, HU).
- Dr. Mohammad Al Qinneh (HU)
- Dr. Nizar Hammori (HU)
- Dr. Salahuddin Jaber (HU)

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The Ministry of Environment would like to express thanks for all the experts participating in the project reports and action plan development, partners in the Ministry of Water and Irrigation, Ministry of Planning and International Cooperation, UNDP and all organizations that were influential and positive in their support of the project.

ملخص

يورد هذا الملخص التنفيذي مراجعة لخيارات التكيف والتخفيف والأستجابات مع تغير المناخ ووضع اولويات لهذه الخيارات على مصادر المياه المتاحة ونوعيتها في حوض نهر الزرقاء ضمن المشروع المعنون «تطوير تدابير التكيف وصياغة استراتيجية خطة التنفيذ مع التغير المناخي من خلال الإدارة المتكاملة لمصادر المياه في حوض نهر الزرقاء»، فقد تم هنا عمل مراجعة وتقييم خيارات التكيف مع تغير المناخ المطبقة عالمياً من خلال مراجعة التقارير الصادرة عن الهيئة الحكومية الدولية بتغير المناخ (IPCC) والتي اشتملت على الأبعاد المحتملة لتغير المناخ على مصادر المياه من حيث وفرتها ونوعيتها وكيفية التكيف مع هذه الأبعاد وتناول هذا التقرير الأجراءات وأولويات وخيارات التكيف بتغير المناخ على ادارة مصادر المياه في حوض نهر الزرقاء وامكانية تطبيقها في مجالات ادارة المياه من حيث التزويد وادارة الطلب واستخدام السياسات والأجراءات والأدوات التي تساعد في ادارة المصادر المائية في الحوض خاصة وفي الأردن عامة تحت ظروف التغير المناخي علماً بأن ان ندرة وشح المصادر هي سمة من سمات المنطقة الجافة أو شبه الجافة ويضيف تغير المناخ بعداً اخر لمشكلة انخفاض توافر المصادر المائية في الحوض المذكور. كما يستعرض هذا الملخص خيارات التكيف مع تغير المناخ باستخدام معايير معينة لوضع اولويات لخيارات التكيف والتي يمكن تطبيقها اخذين بعين الأعتبار فاعلية وفوائد التكيف وسرعة الأستجابة وعامل الزمن وغيرها من المعايير لترتيب خيارات التكيف مع تغير المناخ حيث اعطي كل خيار وزناً معيناً حسب اهميته ودرجة تقييم أو قيمة استدلالية تراوحت من ١ – ٥.

واعتماداً على هذه المعايير فقد اعطي كل خيار من خيارات التكيف قيمة عددية وتم عمل ترتيب تنازلي لهذه الخيارات والتي يمكن تطبيقها على حوض نهر الزرقاء.

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1. Preface

According to Model Contract for Professional Consulting Services between UNDP and Science Triangle for Research, Training and Management No. (8/2010), This report summaries the results of the first objective of the project "Development of Adaptation Measures to Climate Change and Formulation of Needed Strategy Implementation Plan Relevant to Climate Change and IWRM for the Zarqa River Basin" that includes (1) revision and evaluation of all possible adaptation measures for water availability and water quality in term of suitability and applicability to the study area and the existing conditions of the ZRB, and (2) Suggesting and prioritizing the best possible adaptation measures for water availability and water quality at the ZRB.

2. Scope of the Report

This report's main objective is to compile adaptation measures that are relevant to water availability and quality of water resources in ZRB that can be considered best-practice for adaptation to climate change. By doing this it aims to support the efforts of the Government of Jordan through the Ministry of Environment to incorporate climate change into the water management of ZRB.

This report presents an extensive list of possible adaptation measures that can be considered best-practice). Adaptation measures can be classified according to different dimensions. This report uses the main climate change impact addressed by the measure (e.g. water scarcity and drought, flooding), as the basis for classifying adaptation measures. (It should be kept in mind that adaptation measures frequently have significant secondary effects, both positive and negative, related to other climate change impacts on water; secondary effects are particularly interesting for their synergy potential.) Each of the sections begins with a brief discussion on current knowledge of the impact's consequences, as well as relevant aspects such as associated effects.

Measures that do not address an impact but rather deliver adaptation for the purposes of a particular economic sector or activity, or measures whose effects are evenly split between different climate change impacts, have been taken up in a section on adaptation measures grouped according to sector (e.g. agriculture, energy, urban development).

In the course of this study it became evident that not all impacts of climate change have received the same attention. For instance, the flooding of coastal zones, flash floods, and water scarcity & drought as a result of climate change have been frequently addressed in research and pilot implementation projects, whereas deteriorating water quality as a result of climate change does not seem to have enjoyed the same level of attention. On another plane, the level of activity regarding adaptation will differ, which focus on their own particular problems.

Due to the fact that many measures are being developed in the context of the national adaptation approaches regarding climate change, background information on these is necessary to provide the context and the rationale behind the measures.

3. Introduction

Many of the world's countries already struggle under existing water stress from various pressures such as irrigation demands, industrial pollution and water borne sewerage. These pressures will be significantly exacerbated by climate change, which for many regions will result in reduced rainfall and increasing temperatures, further reducing the availability of water for drinking, household use, agriculture and industry. As these competing demands intensify under climate change, effective governance for balancing water demands will become essential, particularly in the face of strong pressures to prioritize industrial uses over other uses such as drinking supplies.

Climate change will result in significant impacts on our water resources and some of the effects are already visible now. Nearly all the countries in the world are expected to be negatively affected by impacts ranging from increased frequency and intensity of floods and droughts, worse water scarcity, intensified erosion and sedimentation, reductions in glaciers and snow cover, sea level rise, and damage to water quality and ecosystems. Moreover, climate change impacts on water resources will have cascading effects on human health and many parts of the economy and society, as various sectors directly depend on water such as agriculture, energy and hydropower, navigation, health, tourism – as does the environment (UN, 2009).

Observational evidence from all continents and most oceans shows that many natural systems are being affected by anthropogenic climate changes. One of those affected systems is the hydrological cycle which encompasses water availability and water quality as well as water services (IPCC, 2007). Adaptation to climate change is, consequently, of urgent importance. The impacts will certainly vary considerably from region to region and even from basin to basin. This poses serious challenges for water resources management.

Adaptation to climate change is therefore a moral, economic and social imperative: action is needed now and water management should be a central element in the adaptation strategy of any country. Inaction could put sustainable development at risk: during the first years of the 2000s alone, thousands of lives and billions of dollars were lost through water related disasters worldwide. On the other hand, the potential rewards of early action are high, as improved prevention, disaster preparedness and other adaptation measures, as well as adaptation of lifestyles, can vastly reduce these figures (UN, 2009).

4. Climate Change Impacts on Water Resources

Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater. Higher water temperatures, increased precipitation intensity, and longer periods of low flows exacerbate many forms of water pollution, with impacts on ecosystems, human health, water system reliability and operating costs. Climate change affects the function and operation of existing water infrastructure as well as water management practices. The negative impacts of climate change on freshwater systems outweigh its benefits.

The IPCC AR4, (2007) summarized the observed changes in climate change impacts that have been reported in the Third Assessment Report. Table 1 shows some of these impacts that can be categorized in physical and biological systems.

Table 1: Observed climate change impacts

Changes in physical systems	Changes in biological systems
Sea ice: Arctic sea-ice extent had declined by about 10 to 15% since the 1950s. No significant trends in Antarctic seaice extent were apparent.	Range: plant and animal ranges had shifted poleward and higher in elevation.
Glaciers and permafrost: mountain glaciers were receding on all continents, and Northern Hemisphere permafrost was thawing.	Abundance: within the ranges of some plants and animals, population sizes had changed, increasing in some areas and declining in others.
Snow cover: extent of snow cover in the Northern Hemisphere had decreased by about 10% since the late 1960s and 1970s.	Phenology: timing of many life-cycle events, such as blooming, migration and insect emergence, had shifted earlier in the spring and often later in the autumn.
Snow melt and runoff: snowmelt and runoff had occurred increasingly earlier in Europe and western North America since the late 1940s.	Differential change: species changed at different speeds and in different directions, causing a decoupling of species interactions (e.g., predator-prey relationships).
Lake and river ice: annual duration of lake- and river-ice cover in Northern Hemisphere mid- and high latitudes had been reduced by about 2 weeks and become more variable.	Preliminary evidence for changes in human systems:Damages due to droughts and floods: changes in some socioeconomic systems had been related to persistent low rainfall in the Sahelian region of Africa and to increased precipitation extremes in North America.
	Most of the increase in damages is due to increased wealth and exposure. However, part of the increase in losses was attributed to climate change, in particular to more frequent and intense extreme weather events in some regions.

In the last decade, climate change has emerged as an equally challenging threat to water availability in the region, whereby increased global temperatures are leading to changes in the hydrologic cycle and increased water demand.

Table 2: Some impacts on water resources expected with changing climate (Based on El-Fadel and Bou-Zeid, 2003).

Biophysical resources	Major impacted components	Potential effects
Hydrologic resources	– Precipitation – Evaporation – Transpiration – Runoff – Recharge	– Soil moisture changes – Reduced ground water recharge – Water shortages or surpluses – Dam failure due to floods – Dam storage loss due to sedimentation
Water quality	– Water temperature – Water salinity – Pollutant concentrations – Fauna and flora	– Changes in chemical quality – Changes in biological quality – Changes in thermal quality
Biophysical resources	– Major impacted components	– Potential effects
Aquatic systems	– Streamflows – Erosion and sedimentation – Water levels in surface water – Water levels in aquifers – Water fluxes in the subsurface	– Droughts or floods – Dam failure due to floods – Dam storage loss due to sedimentation
Socio-economic resources	– Major impacted components	– Potential effects
Water supply	– Water demand per capita – Agricultural water demand	– Water demand increase beyond projected levels
Water management systems	– Streamflows – Water level in surface water bodies – Water levels in aquifers	– Reduced water supply – Changing loads on water treatment systems – Changing hydropower production potential

Higher temperatures and changes in extreme events, including more and more intense floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution – from sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt – and also cause thermal pollution, with possible damage to ecosystems, human health, and water system reliability and operating costs. In addition, sea-level rise is projected to extend areas of salinization of groundwater and estuaries resulting in a decrease of water availability for ecosystems and humans. Table 3 summarizes observed changes for some environmental factors.

Table 3. Observed changes in runoff/streamflow, lake levels and floods/droughts.

Environmental factor	Observed changes	Time period	Location
Runoff/ streamflow	Annual increase of 5%, winter increase of 25 to 90%, increase in winter base flow due to increased melt and thawing permafrost	1935-1999	Arctic Drainage Basin: Ob, Lena, Yenisey, Mackenzie
	1 to 2 week earlier peak streamflow due to earlier warming-driven snow melt	1936-2000	Western North America, New England, Canada, northern Eurasia
Runoff increase in glacial basins in Cordillera Blanca, Peru	23% increase in glacial melt	2001-4 *vs.* 1998-9	Yanamarey Glacier Catchment
	143% increase	1953-1997	Llanganuco catchment
	169% increase	2000-2004	Artesonraju catchment
Floods	Increasing catastrophic floods of frequency (0.5 to 1%) due to earlier break-up of river-ice and heavy rain	Last years	Russian Arctic rivers
Droughts	29% decrease in annual maximum daily streamflow due to temperature rise and increased evaporation with no change in precipitation	1847-1996	Southern Canada
	Due to dry and unusually warm summers related to warming of western tropical Pacific and Indian Oceans in recent years	1998-2004	Western USA
Water temperature	0.1 to 1.5°C increase in lakes	40 years	Europe, North America, Asia (100 stations)
	0.2 to 0.7°C increase (deep water) in lakes	100 years	East Africa (6 stations)
Water chemistry	Decreased nutrients from increased stratification or longer growing period in lakes and rivers	100 years	North America, Europe, Eastern Europe, East Africa (8 stations)
	Increased catchment weathering or internal processing in lakes and rivers.	10-20 years	North America, Europe (88 stations)

Water is central to many different sectors hence the impacts of climate change are expected to have far-reaching effects on society. Economic sectors which are projected to be most affected are agriculture (increased demand for irrigation and forestry), energy (reduced hydropower potential and cooling water availability), recreation (water-linked tourism), fisheries and navigation. Because of the importance of these sectors for national and individual welfare, climate change impacts on water have important direct and indirect effects. Serious impacts on biodiversity also loom (Table 4).

Table 4: Risks for water and other sectors through climate change (Bates et al. 2008, IPCC 2007)

EXAMPLES OF MAJOR PROJECTED IMPACTS BY SECTOR, MAINLY THROUGH WATER				
PHENOMENON	**Water resources**	**Agriculture, ecosystems**	**Health**	**Industry and society**
Heavy precipitation events	• Flooding • Adverse effects on quality of surface and groundwater due to sewer overflows • Contamination of water supply • Water scarcity may be relieved	• Damage to crops • Soil erosion • Inability to cultivate land due to waterlogging of soils	• Increased risk of deaths, physical injuries and infectious, respiratory and skin diseases • Risk of psychological disorders	• Disruption of settlements, commerce, transport and societies due to flooding, migration • Pressures on urban and rural infrastructures • Loss of property
Higher variability of precipitation, including increased droughts	• Changes in run-off • More widespread water stress • Increased water pollution due to lower dissolution of sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt, as well as thermal pollution • Salinization of coastal aquifers	• Land degradation • Lower yields/ crop damage and failure • Increased livestock deaths • Increased risk of wildfire	• Increased risk of food and water shortage; Increased risk of malnutrition; • Increased risk of waterand food-borne diseases	• Water shortages for settlements, industry and societies • Reduced hydropower generation potentials • Potential for population migration
Increased temperatures	• Increased water temperatures • Increase in evaporation • Earlier snow melting • Permafrost melting • Prolonged lake stratification with decreases in surface layer nutrient concentration and prolonged depletion of oxygen in deeper layers • Increased algae growth reducing dissolved oxygen levels in the water body which may lead to eutrophication and loss of fish • Changes in mixing patterns and self purification capacity	• Less water available for agriculture, more irrigation needed • Changes in crop productivity • Changes in growing season • Changes in species composition, organism abundance, productivity and phonological shifts, for example earlier fish migration	• Changes in vector-borne diseases • Increase of fatalities due to heatwaves, and decreased personal productivity • Increased risk of respiratory and skin diseases due to ozone and pollen	• Risk for infrastructure fixed in permafrost • Degradation of freshwater quality

5. Adaptation Measures

5.1 Definition and keys

It has long been recognized that adaptation is critical to enable societies to deal with the impacts of both natural and anthropogenic environmental change, especially in low-income countries. This need was recognized in the process leading up to the Rio Conference in 1992. Perhaps foremost among current challenges to development is the threat of anthropogenic climate change due to greenhouse gases (GHGs). Adaptation to climate change is, consequently, of urgent importance. The impacts will certainly vary considerably from region to region and even from basin to basin, imposing serious challenges for water resources management.

Adaptation to climate change is therefore a moral, economic and social imperative: action is needed now and water management should be a central element in the adaptation strategy of any country. On the other hand, the relationship between climate change mitigation measures and water is a reciprocal one. Mitigation measures can influence water resources and their management, and it is important to realize this when developing and evaluating mitigation options.

5.2 Setting and Assessing Mitigation Measures

Various methods are presented in literature detailing different approaches to propose and assess mitigation measures in water sector. FAO (2007) and the Jordanian 2nd assessment report (2009), have set two major adaptations; adaptation is likely to occur through autonomous actors as individuals, households, businesses and communities respond to the opportunities and constraints they face ("autonomous adaptation"). While "planned" approaches based on vulnerability assessments are important, it is equally important to understand and enable the adaptive responses that are occurring in an unplanned manner within society. Education and capacity-building are very important not only to promote adaptive responses but also to prevent adverse effects of autonomous adaptation measures. For example, in drought-prone regions, individuals might "adapt" by using more water for irrigation or by drilling their own wells, which can however only aggravate the situation by reducing overall water availability.

To enable climate proofing of water management, the guidance on water and adaptation to climate change (UN, 2009) distinguishes 5 different types of measures that together form the so-called "safety chain": prevention measures, measures to improve resilience, preparation measures, response measures, and recovery measures. All such measures are generally based on risk, hazard and vulnerability maps under different scenarios. Prevention measures are measures taken to prevent the negative effects of the climate change and climate variability on water resources management. This includes mitigation measures, designed to reduce the change in climate. Measures to improve resilience are those designed to reduce the negative effects of climate change and climate variability on water resources management by improving the coping capacity. Preparation measures are measures designed to reduce the negative effects of extreme events on water resources management. Response measures are those designed to alleviate the direct negative effects in the aftermath of extreme events. Recovery measures aim at restoring the societal system after an extreme event has taken place. Recovery measures include, for instance, reconstruction of infrastructure (UNECE/WHO, 2008).

According to IPCC, AR4 (2007), assessments of climate change impacts, adaptation and vulnerability (CCIAV) are undertaken to inform decision making in an environment of uncertainty. The demand for such assessments has grown significantly since the release of the IPCC Third Assessment Report (TAR), motivating researchers to expand the ranges of approaches and methods in use, and of the characterizations of future conditions (scenarios and allied products) required by those methods. In previous years, IPCC Working Group II1 has devoted a Special Report and two chapters to assessment methods (IPCC, 1994; Carter et al., 1996; Ahmad et al., 2001). Moreover, the TAR also presented two chapters on the topic of scenarios (Carter et al., 2001; Mearns et al., 2001), which built on earlier descriptions of climate scenario development (IPCC-TGCIA, 1999). Some approaches are given in table 5.

However, an overview of the possible adaptation measures in water sector are presented in table 6, by which the options are subdivided according to the five measures types of the Safety chain.

Table 5: Various approaches methods used to assess climate change impacts, adaptation and vulnerability (IPCC-AR4, 2007).

	Approach			
	Impact	Vulnerability	Adaptation	Integrated
Scientific objectives	Impacts and risks under future climate	Processes affecting vulnerability to climate change	Processes affecting adaptation and adaptive capacity	Interactions and feedbacks between multiple drivers and impacts
Practical aims	Actions to reduce risks	Actions to reduce vulnerability	Actions to improve adaptation	Global policy options and costs
Research methods	Standard approach to CCIAV Drivers-pressure-stateimpact- response (DPSIR) methods Hazard-driven risk assessment	Vulnerability indicators and profiles Past and present climate risks Livelihood analysis Agent-based methods Narrative methods Risk perception including critical thresholds Development/sustainability policy performance Relationship of adaptive capacity to sustainable development		Integrated assessment modelling Cross-sectoral interactions Integration of climate with other drivers Stakeholder discussions Linking models across types and scales Combining assessment approaches/methods
Spatial domains	Top-down Global -› Local	Bottom-up Local -› Regional (macro-economic approaches are top-down)		Linking scales Commonly global/regional Often grid-based
Scenario types	Exploratory scenarios of climate and other factors (e.g., SRES) Normative scenarios (e.g., stabilisation)	Socio-economic conditions Scenarios or inverse methods	Baseline adaptation Adaptation analogues from history, other locations, other activities	Exploratory scenarios: exogenous and often endogenous (including feedbacks) Normative pathways
Motivation	Research-driven	Research-/stakeholder-driven	Stakeholder-/research-driven	Research-/stakeholder-driven

Table 6: Overview of possible measures (UN, 2009)

	Flood prone situation	Drought prone situation	Impaired water quality	Health effects
revention Measures	• Restriction of urban development in flood risk zones • Measures aiming at maintaining dam safety, afforestation and other structural measures to avoid mudflows • Construction of dykes • Changes in operation of reservoirs and lakes • Land-use management • Implementation of retention areas • Improved drainage possibilities • Structural measures (temporary dams, building resilient housing, modifying transport infrastructure) • Migration of people away from high-risk areas	• Reducing need for water • Water conservation measures/ effective water use (industrial and other sectors' practices and technologies) • Water saving (permit systems for water users) • Improved irrigation efficiency • Land-use management • Fostering water efficient technologies and practices (e.g. irrigation) • Enlarging the availability of water (e.g. increase of reservoir capacity) • Improving the landscape water balance • Introduction or strengthening of a sustainable groundwater management strategy • Joint operation of water management networks or building of new networks • Identification and evaluation of alternative strategic water resources (surface and ground) • Identification and evaluation of alternative technological solutions (desalinization; reuse of wastewater) • Increase of storage capacity (for surface and ground waters) both natural and artificial • Considering additional water supply infrastructure • Economic instruments like metering, pricing • Water reallocation mechanisms to highly valued uses • Reducing leakages in distribution network • Rainwater harvesting and storage • Reducing water demand for irrigation by changing crop mix and calendar, irrigation method • Promoting indigenous practices for sustainable water use • Importing water intensive agricultural products (virtual water)	• Prevention of and cleaning up of dump sites in flood risk zones • Improved waste water treatment • Regulation of wastewater discharge • Improved drinking water intake • Safety and effectiveness of waste water systems • Isolation of dump sites in flood risk zones • Temporary wastewater storage facilities • Catchment protection (e.g. increasing protected areas)	• Strengthen and use a capacity for long-term preparation and planning, especially to identify, address and remedy the underlying social and environmental determinants that increase vulnerability • Use existing systems and links to general and emergency response systems • Ensure effective communication services for use by health officials • Regular vector control and vaccination programs • Public education and awareness raising • Measures against the heat island effect through physical modification of built environment and improved housing and building standards

Preparation Measures	• Flood warning (incl. early warning) • Emergency planning (incl. evacuation) • Flash-flood risks, (measures taken as prevention, as the warning time is too short to react) • Flood hazard and risk mapping	• Development of drought management plan • Changing reservoir operation rules • Prioritization of water use • Restrictions for water abstraction for appointed uses • Emergency planning • Awareness-raising • Risk communication to the public • Training and exercise	• Restrictions to wastewater discharge and implementation of emergency water storage • Regular monitoring of drinking water	• Strengthen the mechanism for early warning and action • Improved disease/ vector surveillance/ monitoring • Ensuring well-equipped health stations and availability of communication and transport facilities • Developing water safety plans
Response Measures	• Emergency medical care • Safe drinking water distribution • Safe sanitation provision • Prioritization and type of distribution (bottled water, plastic bags, etc.)			
Recovery Measures	• Clean-up activities • Rehabilitation options such as reconstruction of infrastructure • Governance aspects such as legislation on, inter alia, insurance, a clear policy for rehabilitation, proper institutional settings, rehabilitation plans and capacities, and information collection and dissemination. • Specially targeted projects: new infrastructures, better school, hospitals … • All kinds of financial and economical support • Special tax regimes for investments, companies, people • Insurance • Evaluation			

In summary, climate change or not, adaptation measures involve both supply and demand management options. Adaptations may be independent in nature and not part of a conscious response to climate stimuli, but resulting from changes to meet altered demands and expectations which, whilst not deliberately designed to cope with climate change, may lessen the consequences of that change. On the other hand, adaptations may be planned in nature, resulting from deliberate policy decisions and specifically taking climate change and variability into account [1] . Autonomous adaptations are the most frequently applied adaptations and they are the most suitable for ESCWA countries, to be implemented as part of a national IWRM framework. Table 6 presents examples of climate change adaptation encountered worldwide.

5.3 Evaluating and Prioritizing Mitigation Measures

Because of the uncertainties over the impacts of climate change on the water environment, where possible measures that can cope with a range of future climate conditions should be chosen. The following types of measures should be prioritized (in decreasing order of priority) taking into account the transboundary context as well:

- Win-win options
- No-regrets options
- Low-regrets (or limited-regrets) options
- Flexible adaptation options

According to literature, similar criteria were adopted for evaluating climate change mitigation responses (Table 7). Mitigation measures could be assessed and prioritized according to weighing judgments or scores. Canada, Island and other countries have adopted scoring technique using ratio function composed from either 3 to 5 levels. Some have rated the adaptation options and classified them in four categories according to urgency alone; (i) urgent adaptation options that can be done by communities themselves, (ii) urgent adaptation options for which communities needed assistance from the government, (iii) adaptation options that were less important/urgent, and (ix) adaptation options for which there was no need or willingness to implement.

[1] Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., 2008. Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

Table 7: Suggested criteria for evaluating climate change responses (based on Bizikova et al., 2008)

Category	Mitigation co-benefits Criteria	Description of the criteria
Sustainability	Mitigation benefits	Changes in the level of greenhouse gas emissions created by the adaptation measure
	Environmental impacts	Identify environmental impacts on biodiversity
	Equity	Number of people benefiting from the adaptation— if possible disaggregated by gender, age, class
	Implementation cost	Identify the approximate cost of implementation; you could compare these costs with cost of inaction over time
	Operating and maintenance cost	Identify the cost of operation and maintenance over time, compared to other budget expenditures
Effectiveness	Robustness	Elaborate how effective this measure could be for a diverse range of plausible future scenarios
	Reliability	Identify if this measure is untested or the effectiveness of this measure is proven
Risk and Urgency	Urgency	Identify the time frame of impact occurrence from recent past, present until short- and long-term futures
	Degree of risk or impact	Identify potential extent of future risks from minor and reversible until irreversible
	Precautionary	Estimate how well the risks are understood
Opportunity	Ancillary benefits	Identify how this measure will contribute to other community goals
	No-regret option	Indentify if this measure has benefits regardless of actual climate change impacts
	Window of opportunity	Identify if there is currently a window of opportunity to implement this measure
Implementation	Public acceptability	Elaborate on public support or opposition to this measure
	Funding sources	Identify availability and sources of potential funding
	Capacity (information, technical, staff, resources)	Estimate if current capacity is sufficient and, if not, what are lacking capacity gaps
	Institutional	Identify if implementation is within local control or it requires coordination with, or action by, other jurisdictions

6 Water Sector at ZRB

6.1 Current water status

The Zarqa River is the second largest in Jordan in the area of its drainage basin and its mean annual discharge. The river consists of two main branches; Wadi Dhuleil, which drains the eastern part of the catchment area, and Seel-Zarqa, which drains the western part. Both meet at Sukhna to form the Zarqa River. Naturally, the eastern branch drains only flood flows as a result of precipitation, whereas the western branch drains flood and base flows. The most densely populated area in Jordan, which is the catchment area of Zarqa River, comprises around 65% of the country's population and more than 80% of its industries.

The groundwater safe yield of the basin is about 90 MCM while the abstraction rate amounts to about 158 MCM. Part of the deficit in Baqa and Amman-Zarqa aquifers may be compensated from seepage due to leaks in pipe network or excess irrigation. Amman area receives about 40 MCM from the basin groundwater for municipal uses. Industries in the basins pump about 8 MCM. Extractions for irrigation are estimated at 110 MCM. The annual effluent of the wastewater treatment plants totals about 60 MCM where most of it flows into KTD while only about 5 MCM are used in the basin and along the river banks for restricted irrigation. Municipal use, including Amman, totals about 180 MCM/yr. Industries use about 8 MCM coming mostly from groundwater.

The urban wastewaters are generally sewage and treated in different wastewater treatment plants to varying degrees. Also, most industries located in the catchment area treat their waste waters before discharge into the surface water system. In addition, solid waste disposal sites are located within the catchment area. Their leachate reach surface and groundwater resources causing local pollution and threatening to contaminate the aquifers.

Precipitation over the highlands may be in the form of snow; in the eastern part of the catchment it is generally rainfall. The highest amount of precipitation falls over the highlands of Salt and Amman. In an average year it reaches 550mm; it increases in a wet year to 750mm and decreases in a dry year to 350mm. In the most eastern part of the catchment the average precipitation in a normal year is 80mm, increasing to 150mm in a wet year and decreasing to 50mm in a dry year.

The potential evaporation ranges from 1600mm/year along the western highlands, to 2000mm/year in the eastern part of the catchment. Meanwhile, there is not enough water to satisfy the needs of the evaporation force of the climate, which is far less during the winter months than during the summer months, a fact which allows precipitation water to infiltrate and recharge the ground water during the rainy season.

The average annual discharge of Zarqa River at Deir Alla for the years 1950 to 1976 was 64.88 MCM/year. After 1976, the natural system of the river was changed by different factors such as construction of the King Talal Dam on the Zerka River (1977), importing water into the catchment area for domestic and industrial uses and discharging their effluents to the Zarqa River system. Such activities controlled the river flow and increased its discharge on the one hand, and negatively affected its water quality on the other.

The primary issues are water shortage, competition between sectors, groundwater depletion, water quality deterioration and reuse in the Jordan Valley, highland industries, landscaping and agriculture. At present, the domestic and industrial wastewater contributions to the inflows of the river are estimated at 50% of its discharge. The water quality of the river changes dramatically between summer and winter. In winter, flood water constitutes most of the river discharge.

6.2 Possible Climate Change Impacts

Amman Zerqa basin was initially studied in the first national communication report to the United Nations Framework Convention on Climate Change (UNFCCC) under the theme of “Vulnerability and Adaptation to Climate Change” at 1999. The system represents the surface water resources in the study. The monthly water balance components simulation was assessed through the application of the Surface-Infiltration- Base Flow (SFB) model. Areal precipitation and potential evapotranspiration are the main input of the model while the outputs are the monthly surface runoff, the monthly soil moisture, and the monthly actual evaporation. In general, the model preformed well for the Zarqa River for which the correlation coefficient is about 0.88, the error of the observed and simulated runoff was within the acceptance limit and found to be around 11 percent. The model performance in the validation stage is reasonable and comparable to those of the calibration stage.

The generated GCMs and incremental climate change scenarios were applied on the Zarqa River basin to investigate the possible impact of climate change on the water budget of this system. The results reveal that the surface runoff decreases as temperature increases. The timing of the peak flow is not changed but the magnitudes of these peaks are reduced.

In this study, As-Samra wastewater treatment plant was considered as non-conventional water resource. This plant is recognized as one of the largest stabilization pond systems in the world (Abdulla, 2000). Two representative meteorological stations for As-Samra plant were selected: Amman Airport station and Dhulail station.

With elevated temperatures, evaporation water losses from As-Samra WWTP tend to increase while evaporation loss decreases as precipitation increases. This means that in dry hot summer season, evaporation rates do increase causing a considerable loss of water to evaporation. In the same time, this evaporation loss cause, a concentration effects on all water quality parameters in the plant effluent. Moreover, under hot and dry scenarios, dissolved oxygen levels in the ponds will be less causing the treatment processes to go more into the anaerobic conditions which results in more release of hydrogen sulfide and consequent obnoxious odors.

According to the vulnerability assessment and adaptation in water sector by Jordan's Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC), 2009, the potential impacts of climate change on hydrological system and water resources of Amman Zarqa Basin were analyzed using WEAP hydrological model. The assessment was performed using 20 incremental and three different GCM models (HADGEM1, CSIROMK3 and ECHAM5OM).

Incremental scenarios had shown that generally surface runoff amounts will highly affected by different scenarios proposed . Twenty incremental scenarios were tested. These scenarios had assumed the temperature will be increase; and a decrease in the amount of precipitation was increased in some scenarios and decrease in others. For both basins, it was noticed that the surface runoff amounts will be increased only when the precipitation increased 110% and 120%. There was no change in the surface runoff amounts when the precipitation was assumed to be not changed, even if the mean temperature was raised four degrees. On the scenarios where temperature and precipitations were increased, the amounts of surface runoff for both basins were declined. Among these scenarios, 13 scenarios were predicted that the amounts of surface runoff are going to be decreased. The major decrease is expected to take place in January, February and March.

The results from analyzing GCM scenarios hold different results for Amman Zarqa Basin. According to CSIROMK3, there will be a decrease in the amounts of surface runoff. This decrease will take place in Jan, Feb, Nov and Dec., while an increase is expected in Mar, Apr and Oct. On the other hand, ECHAM5OM expected little decrease in Mar, Apr and Nov, while the other months will not be affected. HADGEM was with the least results regarding the impacts of climate change (Table 8). The effect of climate change on water resources is expected to be significant as a result of decrease in precipitation and projected changes in its spatial and temporal distribution. Temperatures in both in its maximum and minimum extent were expected to increase by 2oC, and clear decreasing trends were observed in the annual precipitation of around 20%.

Table 8: Results of GCM Scenarios Analyses (based on Second National Communication Report to UNFCC, 2009).

Month	Base Scenario	CSIROMK3		ECHAM5OM		HADGEM1	
		Value	Change	Value	Change	Value	Change
Jan	2.82	2.03	-0.79▼	2.82	0.00	2.82	0.00
Feb	2.54	2.43	-0.11▼	2.54	0.00	2.55	0.00
Mar	1.87	1.90	0.03▲	1.85	-0.02▼	1.90	0.03▲
Apr	0.58	0.74	0.16▲	0.57	-0.01▼	0.59	0.01▲
Oct	0.34	0.36	0.03▲	0.34	0.00	0.34	0.00
Nov	1.58	1.43	-0.16▼	1.57	-0.02▼	1.57	-0.01▼
Dec	2.11	1.92	-0.19▼	2.12	0.00	2.13	0.01▲

According to Water Pavilion at the IUCN World Conservation Congress, Barcelona 2008, ZRB was described having three main problems; (i) decrease of natural flow by which withdrawals for water supply from aquifers in the upper Amman-Zarqa groundwater basin have reduced the natural base-flow of the Zarqa River, (ii) pollution by industrial wastewater, and (iii) pollution by partially-treated domestic wastewater. The flow characteristics have been further modified by the discharge to the river of treated domestic and industrial wastewater that compose nearly all of summer flow and substantially degrade the water quality. At the same time, the current state of environment in ZRB is at high risk due to (i) high air pollution due to the surrounding industrial areas (thermal power plants, oil refinery, industrial stack emissions), (ii) over pumping of groundwater for agriculture, drinking and industrial uses, and (iii) surface and groundwater resources pollution caused by waste-water from partially operated treatment plants.

7 Possible Adaptation Measures

Climate change and adaptation measures studies conducted in Jordan are very limited. However, the Jordan's Second National Communications Report to the United Nations Framework Convention on Climate Change (UNFCCC), 2009, had proposed some adaptation measures categorized under residential water supply, irrigation, water quality, socio-economic themes (Table 9).

Table 9: Proposed some adaptation measures in the Jordan's Second National Communications Report to the United Nations Framework Convention on Climate Change (UNFCCC)

	Residential water supply	Irrigation	Water quality	Socio-economic issues
Adaptation measures	(i) Reduce water losses in distribution pipes. (ii) Introduce water metering. (iii) Introduce water saving technologies such as low-flow toilets and showers, and efficient appliances. (iv) Collection of rainwater for garden, toilets, and other applications. (v) Promote water saving by awareness campaigns.	(i) Introduce water saving technologies in irrigation schemes such as drip, micro-spray, night irrigation, etc. (ii) Introduce new varieties of crops that use less water and are salt-tolerant. (iii) Increase the efficiency of irrigation systems. (vi) Reform water pricing. (vii) Use groundwater more efficiently.	(i) Improve wastewater treatment plants (WWTP). (ii) Recycle wastewater. (iii) Develop river protection and sanitation zones. (iv) Improve chemical and biological monitoring.	(i) Train people of different ages and social statuses on water saving and sanitation methods. (ii) Increase public awareness to water related issues. (iii) Introduce water cleaning and softening technology. (iv) Introduce policy measures to ensure the equity in access to water. (v) Carry out studies to estimate the impacts of hydrological disasters such as flash floods and thunderstorms. (vi) Improve the drought prediction and mitigation system.

Proposed adaptation measures of the demand and supply management, surface water development, groundwater management, non-conventional water resources development (wastewater, industrial water, brackish water, grey water, and virtual water), irrigation management, in addition to social development were categorized according to the five safety chain; prevention measures, measures to improve resilience, preparation measures, response measures, and recovery measures are presented in table 10. The adaptation measures were more of anticipatory rather than reactionary.

Table 10: Proposed adaptation measures classified into safety chain

	Prevention measures	Measures to improve resilience	Preparation measures	Response measures	Recovery measures
Demand and supply management	Reduction of losses from the supply networks	Transfer of water among different basins in Jordan	Water harvesting		
	Introduction of water saving technologies	Adaptation of different cropping patterns	Reuse of treated wastewater and industrial wastewater resources		
		implementing soil and water programs	Desalination		
			Weather modification (cloud seeding)		
			Public awareness campaigns on water consumption		
Surface water Development	Modernizing and upgrading the storage capacity of existed water reservoirs	Protecting surface water supplies from point and non-point pollution sources	Constructing new surface dams and ponds		
	Minimizing losses by surface evaporation from existed water bodies	Conversion of open canal systems to a pressurized pipe system	Construction of desert dams		
	Minimizing losses by subsurface seepage from existed water bodies	Management of flash floods	Constructing subsurface storage and dams		
	Reduction of deposition of sediments beyond the construction and mining areas	Protecting dams and stream flow	Increase the monitoring systems		
Groundwater Pro	Introducing metering	Providing sources for recharge the aquifer	Protection of groundwater from contamination		
	Use of piping for transfer of treated water from WWTP	Importing water from other basins	Remediation of all polluted groundwater sources		
		Public and stakeholder participation in groundwater management			
		Substitute by treated wastewater for industrial uses			
		Developing and utilizing deep groundwater aquifers			
		Desalination of brackish groundwater			
		Increase of monitoring systems			

		Prevention measures	Measures to improve resilience	Preparation measures	Response measures	Recovery measures
Unconventional Water Management	Wastewater	Recharge to groundwater	Efficient utilization of treated wastewater	Improvement of existed wastewater treatment plants	Transfer of water among different basins in Jordan	Transfer of water among different basins in Jordan
				Better management of septic tank water		
				Temporary wastewater storage facilities		
				Raising awareness and Training programs		
				Constructing small power station		
				Expansion of the use of decentralized WWTPs		
				Effective water quality monitoring and compliance		
				Emergency programs		
	Industrial Wastewater	Reuse of treated wastewater in industry	Use of brackish industrial water for specific on-site plant programs	Implementation of on-site industrial WWTP		
		Recycle of treated industrial water		Developing of a new Industrial Waste Water Treatment Plants (IWWTP)		
		Reuse of industrial wastewater locally		Developing and enforcing laws and regulations regarding industrial wastewater		
				Implementation of an industrial wastewater discharge fee system		
				Implementation of an industrial waste minimization program		
				Implementation of a central toxic and hazardous waste handling and treatment facility		
				Emergency handling and containment facilities for industrial waste dischargers		
	Brackish water			Implementing new desalinization projects		
	Grey Water	Introduce the use of greywater for gardening		Construction of on-site water treatments in large enterprises		
	Virtual Water			Importing water intensive agricultural products		

	Prevention measures	Measures to improve resilience	Preparation measures	Response measures	Recovery measures
Irrigation management	Use of drought-tolerant and salt-resistant crops	Conservation and restoration of eco-systems	Upgrading irrigation infrastructure		
	Use of water-efficient technology		Engaging in water trade, in either the temporary or permanent market		
	Alter the mix and level of production		Construction of small on-farm reservoirs		
	Reduce production		Implement water harvesting techniques at farm level		
	Improve farm management practices		Raising awareness		
	Use of greywater		Development of drought management plan		
	Desalination of brackish water at farm level				
Social Development		Use existing systems and links to general and emergency response systems	Building resilient housing	Restriction of urban development in flood risk zones	
		Public education, awareness raising, and public participation	modifying transport infrastructure		
		Strengthen the mechanism for early warning and action	Migration of people away from high-risk areas		
			Strengthen and use a capacity for long-term preparation and planning, especially to identify, address and remedy the underlying social and environmental determinants that increase vulnerability		
			Developing water safety plans		
			Establish Climate Information System (CIS)		

8. Evaluation and Prioritizing the Proposed Adaptation Measures

In order to have a feasible, legitimist, correct evaluation of all suggested measures, a combined criteria were suggested and adopted in this study, taking into account the sustainability, effectiveness, risk and urgency, opportunity, and implementation feasibility as described in Table 11.

At the same time, a score method was used to derive into the correct evaluation point. The score represent the sum of the weights of each sub-criteria used in the evaluation multiplied by the ratio. Weights were assigned by the stakeholders according to their importance in the evaluation, and sums up to 100%. The ratio is the stakeholder judgment for each proposed adaptation under each sub-criteria (criterion) having a range from 1 to 5, where 1 represent the lowest level and 5 represent the high ratio level.

Criteria among the five criteria's used for evaluating the suggested adaptation measures of climate change in ZRB namely Sustainability Effectiveness Risk and Urgency Opportunity and Implementation opportunity are shown in table 12 The weight ranged from 10 % effect for opportunity to 25% was given to implementation. Each criterion was subdivided into subgroups with weight relative to its impact on the adaptation change on water sector.

In order to have a clear judgment of the evaluation process, most of the related parties and stakeholders with this project have been participated through individual meetings with the team to define the weights and the scores of the suggested criteria (Table 13). The results of the evaluation indicates that the highest score (85.6%) was associated with the "Development of drought management plan" measure in the irrigation management sector followed by the "Public awareness campaigns on water consumption" and "Adaptation of different cropping patterns" at the demand and supply management with scores of 85.3% and 85%, respectively. Also, in general, the unconventional water management sector had the lowest scores especially at the implementation criterion.

The least preferred measure according the evaluation results is the "Transfer of water among different basins" and Use of piping for transfer of treated water from WWTP and Weather modification (cloud seeding) due to their poor sustainability, effectiveness, the high risk and low opportunity and high implementations required.

Finally, table 14 shows the prioritized adaption measures according to score results obtained by the evaluation.

Table 11: Criteria used for evaluating the suggested adaptation measures.

Criteria	Sub-criteria	Description	Weight	Sub-weight
Sustainability	Mitigation (adaptation) benefits	Changes in the level of greenhouse gas emissions created by the adaptation measure	25	10
	Ecosystem Impact	The degree of environmental impacts on biodiversity		7
	Equity	Number of people benefiting from the adaptation - if possible disaggregated by gender, age, class		8
Effectiveness	Robustness (ability to adopt under different scenarios)	Elaborate how effective this measure could be for a diverse range of plausible future scenarios	20	5
	Reliability	Identify if this measure is untested or the effectiveness of this measure is proven		5
	Cost Effectiveness (Low-regret)	Identify if this measure will bring high relative benefits to the costs		10
Risk and Urgency	Urgency	Identify the time frame of impact occurrence from recent past, present until short- and long-term futures	15	5
	Degree of risk (potential extent of future risks)	Identify potential extent of future risks from minor and reversible until irreversible		5
	Uncertentity or Precautionary	Estimate how well the risks are understood		5

Opportunity	Ancillary benefits	Identify how this measure will contribute to other community goals	10	3
	No-regret option	Indentify if this measure has benefits regardless of actual climate change impacts		3
	Window of opportunity	Identify if there is currently a window of opportunity to implement this measure		4
Implementation	Initial cost	Identify the approximate cost of implementation; you could compare these costs with cost of inaction over time	30	5
	Operating and maintenance cost	Identify the cost of operation and maintenance over time, compared to other budget expenditures		5
	Public acceptability	Elaborate on public support or opposition to this measure		5
	Funding sources	Identify availability and sources of potential funding		5
	Capacity (information, technical, staff, resources)	Estimate if current capacity is sufficient and, if not, what are lacking capacity gaps		5
	Institutional	Identify if implementation is within local control or it requires coordination with, or action by, other jurisdictions		5

Table 12: Multi Criteria Analysis (MCA) sheet for suggested adaptation measures.

Criteria	Sustainability			Effectiveness			Risk and Urgency			Opportunity			Implementation						Score	
Sub-criteria	Mitigation (adaptation) benefits	Ecosystem Impact	Equity	Robustness (ability to adopt under different scenarios)	Reliability	Cost Effectiveness (Low-regret)	Urgency	Low degree of risk (potential extent of future risks)	Uncertentity	Ancillary benefits	No-regret option	Window of opportunity	Initial cost	Operating and maintenance cost	Public acceptability	Funding sources	Capacity (information, technical, staff, resources)	Institutional		
Weight	25			20			15			10			30						Total	Percentage
Sub-weight	10	7	8	5	5	10	5	5	5	3	3	4	5	5	5	5	5	5	500	(%)
1. Demand and Supply Management																				
Implementation of artificial groundwater recharge to sustain water demands																				
Water harvesting																				
Reuse of treated wastewater and industrial wastewater resources																				
Desalination																				
Weather modification (cloud seeding)																				
Transfer of water among different basins																				
Reduction of losses from the supply networks																				
Introduction of water saving technologies																				
Public awareness campaigns on water consumption																				

Adaptation of different cropping patterns																				
Implementing soil and water programs																				
2. Surface Water Development																				
Modernizing and up-grading the storage capacity of existed water reservoirs,	4	0	5	5	5	3	4	5	5	3	5	5	1	4	4	3	5	5	384	76.8
Constructing new surface dams																				
Construction of desert dams																				
Constructing sub-surface storage and dams																				
Minimizing losses by surface evaporation from existed water bodies																				
Minimizing losses by subsurface seepage from existed water bodies																				
Protecting surface water supplies from point and non-point pollution sources																				
Conversion of open canal systems to a pressurized pipe system																				
Reduction of deposi-tion of sediments beyond the construc-tion and mining areas																				
Increase the moni-toring systems																				
Management of flash floods																				
Protecting dams and stream flow																				

3. Groundwater Protection																				
Introducing metering																				
Providing sources for recharge the aquifer																				
Importing water from other basins																				
Protection of groundwater from contamination																				
Public and stake-holder participation in groundwater management																				
Substitute by treated wastewater for industrial uses																				
Developing and uti-lizing deep ground-water aquifers																				
Desalination of brackish ground-water																				
Remediation of all polluted groundwa-ter sources																				
Use of piping for transfer of treated water from WWTP																				
Increase of monitor-ing systems																				
4. Unconventional Water Management 4.1 Domestic Wastewater																				
Improvement of existed wastewater treatment plants																				
Better management of septic tank water																				
Temporary wastewa-ter storage facilities																				
Efficient utilization of treated wastewater																				
Raising aware-ness and Training programs																				

Constructing small power station																				
Recharge to groundwater																				
Expansion of the use of decentralized WWTPs																				
Effective water quality monitoring and compliance																				
Emergency programs																				
4.2 Industrial Wastewater																				
Implementation of on-site industrial WWTP																				
Reuse of treated wastewater in industry as a substitute for groundwater																				
Recycle of treated industrial water																				
Reuse of industrial wastewater locally																				
Use of brackish industrial water for specific on-site plant programs																				
Developing and enforcing laws and regulations regarding industrial wastewater																				
Developing of a new Industrial Waste Water Treatment Plants (IWWTP)																				
Implementation of an industrial wastewater discharge fee system																				
Implementation of an industrial waste minimization program																				

Implementation of a central toxic and hazardous waste handling and treatment facility																				
Emergency handling and containment facilities for industrial waste dischargers																				
4.3. Brackish water																				
Implementing new desalinization projects,																				
4.4. Greywater																				
Introduce the use of greywater for gardening,																				
Construction of on-site water treatments in large enterprises,																				
4.5. Virtual Water																				
Importing water intensive agricultural products																				
5. Irrigation Management																				
Use of drought-tolerant and salt-resistant crops																				
Upgrading irrigation infrastructure																				
Use of water-efficient technology																				
Conservation and restoration of ecosystems																				
Engaging in water trade, in either the temporary or permanent market.																				

Alter the mix and level of production																				
Reduce production																				
Construction of small on-farm reserviors																				
Implement water harvesting techniques at farm level																				
Improve farm management practices																				
Use of greywater																				
Desalination of brackish water at farm level																				
Raising awareness																				
Development of drought management plan																				
6. Socio																				
Use existing systems and links to general and emergency response systems																				
Building resilient housing																				
Restriction of urban development in flood risk zones																				
Public education, awareness raising, and public participation																				
Modifying transport infrastructure																				

Strengthen the mechanism for early warning and action																				
Migration of people away from high-risk areas																				
Strengthen and use a capacity for long-term preparation and planning, especially to identify, address and remedy the underlying social and environmental determinants that increase vulnerability																				
Developing water safety plans																				
Establish Climate Information System (CIS)																				

Table 13: Evaluation results of suggested adaptation measures according to stakeholder participation.

Implementer	TEAM		MoENV		MWI		Farmers		MoAgr		Muncipality		Overall	
Criteria Sub-criteria	Score		Score		Score		Score		Score		Score		Score	
Weight	Total	Percentage	Total	Percentage	Total	Percentage	Total	Percentage	Total	Percentage	Total	Percentage	Total	Percentage
Sub-weight	500	(%)	500	(%)	500	(%)	500	(%)	500	(%)	500	(%)	500	(%)
1. Demand and Supply Management														
Implementation of artificial ground-water recharge to sustain water demands	451	90.2	326	65.2	334	66.8	370	74	420	84	383	77	381	76
Water harvesting	454	90.8	379	75.8	343	68.6	392	78	432	86	400	80	400	80
Reuse of treated wastewater and in-dustrial wastewater resources	409	81.8	354	70.8	336	67.2	366	73	393	79	372	74	372	74
Desalination	414	82.8	305	61	385	77	368	74	408	82	370	74	375	75
Weather modifica-tion (cloud seeding)	256	51.2	211	42.2	382	76.4	283	57	346	69	281	56	293	59
Transfer of water among different basins	380	76	164	32.8	100	20	215	43	318	64	239	48	236	47
Reduction of losses from the supply networks	390	78	412	82.4	439	87.8	414	83	431	86	420	84	418	84
Introduction of water saving technologies	447	89.4	415	83	304	60.8	389	78	442	88	390	78	398	80
Public awareness campaigns on water consumption	458	91.6	418	83.6	390	78	422	84	446	89	426	85	427	85
Adaptation of different cropping patterns	467	93.4	390	78	400	80	419	84	449	90	426	85	425	85
Implementing soil and water programs	467	93.4	399	79.8	384	76.8	417	83	448	90	424	85	423	85

2. Surface Water Development														
Modernizing and up-grading the storage capacity of existed water reservoirs,	384	76.8	377	75.4	399	79.8	387	77	395	79	386	77	388	78
Constructing new surface dams	412	82.4	367	73.4	400	80	393	79	409	82	394	79	396	79
Construction of desert dams	447	89.4	350	70	400	80	399	80	433	87	404	81	405	81
Constructing subsurface storage and dams	333	66.6	309	61.8	300	60	314	63	326	65	317	63	316	63
Minimizing losses by surface evaporation from existed water bodies	381	76.2	352	70.4	310	62	348	70	373	75	350	70	352	70
Minimizing losses by subsurface seepage from existed water bodies	377	75.4	334	66.8	300	60	337	67	364	73	341	68	342	68
Protecting surface water supplies from point and non-point pollution sources	472	94.4	389	77.8	372	74.4	411	82	449	90	420	84	419	84
Conversion of open canal systems to a pressurized pipe system	373	74.6	308	61.6	382	76.4	354	71	383	77	352	70	359	72
Reduction of deposition of sediments beyond the construction and mining areas	346	69.2	284	56.8	200	40	277	55	328	66	282	56	286	57
Increase the monitoring systems	388	77.6	369	73.8	490	98	416	83	462	92	416	83	423	85
Management of flash floods	381	76.2	346	69.2	400	80	376	75	395	79	374	75	379	76
Protecting dams and stream flow	388	77.6	359	71.8	395	79	381	76	394	79	380	76	383	77
3. Groundwater Protection														
Introducing metering	399	79.8	405	81	400	80	401	80	404	81	402	80	402	80
Providing sources for recharge the aquifer	385	77	372	74.4	400	80	386	77	396	79	385	77	387	77

Importing water from other basins	363	72.6	193	38.6	466	93.2	341	68	438	88	331	66	355	71
Protection of groundwater from contamination	462	92.4	374	74.8	400	80	412	82	444	89	419	84	418	84
Public and stake-holder participation in groundwater management	430	86	435	87	285	57	383	77	444	89	380	76	393	79
Substitute by treated wastewater for industrial uses	359	71.8	364	72.8	300	60	341	68	366	73	340	68	345	69
Developing and uti-lizing deep ground-water aquifers	309	61.8	258	51.6	385	77	317	63	363	73	314	63	324	65
Desalination of brackish ground-water	421	84.2	312	62.4	300	60	344	69	391	78	356	71	354	71
Remediation of all polluted groundwa-ter sources	385	77	357	71.4	300	60	347	69	378	76	349	70	353	71
Use of piping for transfer of treated water from WWTP	338	67.6	302	60.4	200	40	280	56	331	66	282	56	289	58
Increase of monitor-ing systems	405	81	384	76.8	400	80	396	79	404	81	397	79	398	80
4. Unconventional Water Management 4.1 Domestic Wastewater														
Improvement of existed wastewater treatment plants	419	83.8	394	78.8	390	78	401	80	412	82	404	81	403	81
Better management of septic tank water	413	82.6	324	64.8	300	60	346	69	388	78	355	71	354	71
Temporary wastewa-ter storage facilities	331	66.2	348	69.6			340	68	346	69	343	69	342	68
Efficient utilization of treated wastewater	445	89	387	77.4	385	77	406	81	430	86	412	82	411	82
Raising aware-ness and Training programs	476	95.2	425	85	300	60	400	80	464	93	404	81	412	82
Constructing small power station	354	70.8	295	59	300	60	316	63	339	68	322	64	321	64
Recharge to ground-water	334	66.8	337	67.4	345	69	339	68	343	69	340	68	339	68

Expansion of the use of decentralized WWTPs	322	64.4	343	68.6	400	80	355	71	384	77	361	72	361	72
Effective water quality monitoring and compliance	402	80.4	397	79.4	450	90	416	83	437	87	417	83	420	84
Emergency programs	394	78.8	359	71.8	300	60	351	70	385	77	354	71	357	71
4.2 Industrial Wastewater														
Implementation of on-site industrial WWTP	401	80.2	347	69.4	360	72	369	74	389	78	374	75	373	75
Reuse of treated wastewater in industry as a substitute for groundwater	351	70.2	332	66.4	275	55	319	64	347	69	320	64	324	65
Recycle of treated industrial water	333	66.6	348	69.6	200	40	294	59	351	70	290	58	303	61
Reuse of industrial wastewater locally	382	76.4	335	67	200	40	306	61	372	74	308	62	317	63
Use of brackish industrial water for specific on-site plant programs	392	78.4	346	69.2	300	60	346	69	379	76	351	70	352	70
Developing and enforcing laws and regulations regarding industrial wastewater	399	79.8	393	78.6	300	60	364	73	403	81	363	73	370	74
Developing of a new Industrial Waste Water Treatment Plants (IWWTP)	401	80.2	332	66.4	300	60	344	69	381	76	352	70	352	70
Implementation of an industrial wastewater discharge fee system	363	72.6	325	65	210	42	299	60	356	71	301	60	309	62
Implementation of an industrial waste minimization program	303	60.6	323	64.6	309	61.8	312	62	319	64	313	63	313	63

Emergency handling and containment facilities for industrial waste dischargers	369	73.8	332	66.4	205	41	302	60	363	73	304	61	312	62
4.3. Brackish water														
Implementing new desalinization projects,	426	85.2	326	65.2	205	41	319	64	397	79	328	66	334	67
4.4. Greywater														
Introduce the use of greywater for gardening,	386	77.2	358	71.6	205	41	316	63	385	77	317	63	328	66
Construction of on-site water treatments in large enterprises,	400	80	328	65.6	205	41	311	62	381	76	317	63	324	65
4.5. Virtual Water														
Importing water intensive agricultural products	305	61	385	77	205	41	298	60	362	72	292	58	308	62
5. Irrigation Management														
Use of drought-tolerant and salt-resistant crops	433	86.6	422	84.4	300	60	385	77	437	87	384	77	394	79
Upgrading irrigation infrastructure	428	85.6	433	86.6	300	60	387	77	440	88	384	77	395	79
Use of water-efficient technology	459	91.8	420	84	300	60	393	79	452	90	395	79	403	81
Conservation and restoration of ecosystems	415	83	431	86.2	300	60	382	76	433	87	379	76	390	78
Engaging in water trade, in either the temporary or permanent market.	317	63.4	337	67.4	385	77	346	69	371	74	352	70	351	70
Alter the mix and level of production	418	83.6	315	63	400	80	378	76	417	83	378	76	384	77
Reduce production	338	67.6	254	50.8	300	60	297	59	327	65	301	60	303	61

Construction of small on-farm reserviors	400	80	348	69.6	316	63.2	355	71	385	77	360	72	361	72
Implement water harvesting techniques at farm level	458	91.6	346	69.2	365	73	390	78	432	86	400	80	398	80
Improve farm management practices	443	88.6	376	75.2	250	50	356	71	426	85	362	72	369	74
Use of greywater	385	77	348	69.6			367	73	382	76	368	74	370	74
Desalination of brackish water at farm level	414	82.8	327	65.4			371	74	406	81	374	75	378	76
Raising awareness	408	81.6	417	83.4			413	83	416	83	414	83	414	83
Development of drought management plan	450	90	397	79.4			424	85	445	89	425	85	428	86
6. Socio														
Use existing systems and links to general and emergency response systems	404	80.8	360	72			382	76	400	80	384	77	386	77
Building resilient housing	370	74	353	70.6			362	72	368	74	362	72	363	73
Restriction of urban development in flood risk zones	395	79	313	62.6			354	71	387	77	357	71	361	72
Public education, awareness raising, and public participation	409	81.8	424	84.8			417	83	423	85	419	84	418	84
Modifying transport infrastructure	376	75.2	308	61.6			342	68	370	74	345	69	348	70

Strengthen the mechanism for early warning and action	394	78.8	330	66			362	72	388	78	364	73	368	74
Migration of people away from high-risk areas	371	74.2	277	55.4			324	65	362	72	327	65	332	66
Strengthen and use a capacity for long-term preparation and planning, especially to identify, address and remedy the underlying social and environmental determinants that increase vulnerability	394	78.8	380	76			387	77	393	79	388	78	388	78
Developing water safety plans	384	76.8	362	72.4			373	75	382	76	374	75	375	75
Establish Climate Information System (CIS)	370	74	335	67			353	71	367	73	354	71	356	71

Table 14: Prioritized adaptation measures based on MCA Analysis.

1. Demand and Supply Management
2. Surface Water Development
3. Groundwater Protection
4. Unconventional Water Management
5. Irrigation Management
6. Socio

Suggested Mitigation Measure	Score
Development of drought management plan	85.6
Public awareness campaigns on water consumption	85.3
Adaptation of different cropping patterns	85.0
Increase the monitoring systems	84.7
Implementing soil and water programs	84.6
Effective water quality monitoring and compliance	84.0
Protecting surface water supplies from point and non-point pollution sources	83.8
Protection of groundwater from contamination	83.7
Public education, awareness raising, and public participation	83.7
Reduction of losses from the supply networks	83.5
Raising awareness	82.7
Raising awareness and Training programs	82.3
Efficient utilization of treated wastewater	82.1
Construction of desert dams	81.1
Improvement of existed wastewater treatment plants	80.7
Use of water-efficient technology	80.6
Introducing metering	80.4
Water harvesting	80.0
Implement water harvesting techniques at farm level	79.7
Introduction of water saving technologies	79.5
Increase of monitoring systems	79.5
Constructing new surface dams	79.2
Upgrading irrigation infrastructure	79.1
Use of drought-tolerant and salt-resistant crops	78.7
Public and stakeholder participation in groundwater management	78.6
Conservation and restoration of ecosystems	78.0
Strengthen and use a capacity for long-term preparation and planning	77.6
Modernizing and upgrading the storage capacity of existed water reservoirs	77.6
Providing sources for recharge the aquifer	77.4
Use existing systems and links to general and emergency response systems	77.2
Alter the mix and level of production	76.8
Protecting dams and stream flow	76.5
Implementation of artificial groundwater recharge to sustain water demands	76.1
Management of flash floods	75.7
Desalination of brackish water at farm level	75.6
Developing water safety plans	75.0
Desalination	75.0

Implementation of on-site industrial WWTP	74.7
Reuse of treated wastewater and industrial wastewater resources	74.4
Developing and enforcing laws and regulations regarding industrial wastewater	74.1
Use of greywater	74.0
Improve farm management practices	73.8
Strengthen the mechanism for early warning and action	73.5
Building resilient housing	72.6
Restriction of urban development in flood risk zones	72.3
Expansion of the use of decentralized WWTPs	72.2
Construction of small on-farm reserviors	72.1
Conversion of open canal systems to a pressurized pipe system	71.8
Emergency programs	71.4
Establish Climate Information System (CIS)	71.1
Importing water from other basins	71.1
Better management of septic tank water	70.9
Desalination of brackish groundwater	70.8
Remediation of all polluted groundwater sources	70.6
Minimizing losses by surface evaporation from existed water bodies	70.5
Use of brackish industrial water for specific on-site plant programs	70.4
Developing of a new Industrial Waste Water Treatment Plants (IWWTP)	70.3
Engaging in water trade, in either the temporary or permanent market	70.3
Modifying transport infrastructure	69.6
Substitute by treated wastewater for industrial uses	69.0
Minimizing losses by subsurface seepage from existed water bodies	68.5
Temporary wastewater storage facilities	68.3
Recharge to groundwater	67.9
Implementing new desalinization projects,	66.7
Migration of people away from high-risk areas	66.5
Introduce the use of greywater for gardening,	65.6
Developing and utilizing deep groundwater aquifers	64.9
Reuse of treated wastewater in industry as a substitute for groundwater	64.8
Construction of on-site water treatments in large enterprises,	64.7
Constructing small power station	64.2
Reuse of industrial wastewater locally	63.4
Constructing subsurface storage and dams	63.3
Implementation of an industrial waste minimization program	62.6
Emergency handling and containment facilities for industrial waste dischargers	62.5
Implementation of an industrial wastewater discharge fee system	61.8
Importing water intensive agricultural products	61.6
Reduce production	60.6
Recycle of treated industrial water	60.5
Implementation of a central toxic and hazardous waste handling and treatment facility	59.7
Weather modification (cloud seeding)	58.6
Use of piping for transfer of treated water from WWTP	57.8
Reduction of deposition of sediments beyond the construction and mining areas	57.2
Transfer of water among different basins	47.2

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