Integrated Water Resources Management in the Lower Jordan Rift Valley

Sustainable Management of Available Water Resources with Innovative Technologies

SMART

Work package 3-3, Deliverable D 328

IWRM concept of regional deployment of desalination units

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http://www.iwrm-smart2.org/

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1 Role of Brackish water Treatment in the IWRM-concept

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In arid and semiarid areas growing population and industrialization on the one hand and increasing water pollution on the other hand have led to a severe shortage of fresh water serving drinking water supply and irrigation for food production. The effect of climate change contributes additionally to this dramatic development. The technical and educational implementation of concepts like Integrated Water Resources Management (IWRM) may help to improve the situation. However, the state of practical art is still insufficient and further research and development are needed to lay a profound basis for daily life operation. The limited availability of fresh water resources asks for technical solutions to treat salty water and/or polluted water and thus keeping it involved in the utilization of the water cycle. The use and re-use of brackish water belongs to the most attractive approaches to meet this aim.

The occurrence of brackish water in arid and semi-arid areas is relatively high. For the Lower Jordan Rift Valley about 49 – 55 Mm^3 (Jordan, Lower part of Jordan Valley and Deir Alla Region), 30 Mm^3 (Israel, Feshcha), 10 Mm^3 (Palestine, Jericho) and 5 Mm^3 from Jordan River has been estimated (SMARTII Final Report, 2013). In addition waste water and waste water treatment plant effluents from industries and population has become a valuable source of reuse of water. Among the different possibilities to treat the salty raw waters properly for application, membrane technologies have emerged as promising methods for fresh water production. One of the major pitfalls of desalination by membranes was the high amount of energy necessary for operation. In the last decades, however, the development of high performance low pressure Reverse Osmosis (RO) membranes have opened the doors to high operational salt rejection at relatively low energy input. This approach has gained additional attractivity in combination with energy recovery systems and the use of renewable energy sources. E.g. decentralized photovoltaic power generation has become available recently and is especially attractive for sunlight intensive areas.

Desalination technology can play and active role in the IWRM concept. Knowledge of the specific influence of brackish water chemistry and reliable local infrastructure are crucial to understand the membrane process and guarantee a proper plant operation. Of course all has to be seen in the frame of a general concept for a safe and efficient water supply system and its essential components like treatment and water transport. Inclusion of resource protection and management of already existing infrastructure has to be considered and powerful strategies for environmental protection have to be introduced to support the sustainability of public water supply. This includes ecologically acceptable solutions for the brine issue and other resulting waste streams, which have become one of the major challenges for the installation of membrane plants by this for a successful IWRM in general.

An additional aspect which needs to be considered for an optimal membrane plant operation is the availability of well-trained operators. They need to understand the entire process and they need to develop rules for a continuously safe operation of the plant. Investigation of cleaning frequencies, selection of suitable antiscalants to minimize specific fouling processes and a meaningful control and monitoring system have to be developed in cooperation with the membrane producers and scientific/technical advisers.

A convincing IWRM concept has also to include an active capacity development. The relatively complicated technical facilities of today and the complexity of the daily life ask for science and technology based education with social and economic competence. Thus, the built up capacity is most promising for coping with the increasing water crisis also in the lower region of the Jordan Valley and to answer urgent questions connected to the over-exploitation of water sources, to the influence of climate change on aquatic systems and to the more pronounced alterations of draught and foods.

In addition to wise political decision towards IWRM concepts, the needs of integration of water saving and water quality protection in industrial production, in daily life products and finally in consumer habits are obvious. In all cases education towards environmental awareness and towards the development of suitable technical tools for keeping the hydrological cycle functioning are indispensable for human life. Brackish water in its bridging function between fresh water and sea water offers an ideal and rewarding interdisciplinary playground with high potential for natural scientist, engineers and ever, sociologist and economist.

2 Desalination of Brackish Water in Jordan Valley for Agricultural Purposes in Jordan

Dr. Khair Al-Hadidi

Water Authority of Jordan

2.1 Introduction

Jordan is among the world's countries least well endowed with water resources. Its nearly 5.039 million inhabitants have far less water at their disposal than an arid country needs. This includes the water required for self-sufficient food production in irrigated agriculture, along with municipal and industrial requirements. Although the amount of water Jordan receives may not be easily increased, the efficient use of existing water resources can be. So, the safe utilization of saline water resources, without deteriorating the already limited and to some degree deteriorated land resources, is of utmost importance and is considered as a national need.

As the volume of saline water is increasing by time as a result of over-exploiting groundwater or due to pollution, there is a growing need to come out with an environmentally safe package to allow the use of such water qualities to both increase the planted area, and increase the production of strategic crops that are badly needed on the national level. There are no social, economic, or technical constraints to use saline water resources for agriculture in Jordan, as this would relief other fresh water resources for domestic uses, but all technical and environmental considerations should be regarded.

About 41% of the total irrigated area is located in the arid and semi-arid regions, 39% is in the very arid region, and the remaining 20% of the total irrigated area is located in the semi-desert region. The irrigated area of the Jordan Valley and southern Ghors is about 30.4 thousand Hectare. The main source of irrigation water is from surface water and expansion in the use of groundwater. There is evidence that ground water resources are being stressed (increasing salinity).

2.2 Jordan River Side Wadis and Jordan River Valley.

The water quality of the Upper (Shallow) aquifer Complex is considered to be suitable for the use of all purposes in the Jordan River side Wadis Basin. In contrary to this the water quality of the ground water resources in the Jordan River Valley where salinity increases rapidly due to the dissolution process of the evaporate in the Lisan Marl Unit as well as due to irrigation return flow. In most cases the water of the Upper aquifer in the Jordan River Valley is not suitable for domestic rises and even for industrial or agricultural uses.

2.3 Dead Sea Basin

The water quality of the Upper Aquifer Complex in most parts of the Basin is considered to be of good quality and can be used for different purposes. Local salinization in the last five years was noticed in some areas where salinity reached more than 3000 mg/1. This was attributed to irrigation return flows in some places while in others, it was attributed to the over exploitation of the aquifer and upward leakage of the deeper Aquifer (saline and thermal). The salinity of the ground water at the eastern shores of the Dead Sea increases very rapidly towards the Dead Sea. This is attributed to the dissolution of evaporates in the Lisan Marl Unit as well as the over exploitation of the alluvial Aquifer in the utilization for agricultural purposes.

Table 1 Irrigation Water Sources in the Southern Jordan Valley

Source	**ECiw range (dS/m)**	**Totals**	**Fresh water ECiw < 3 dS/m**	**Brackish water ECiw>= 3dS/m**	**Remarks**
KAC	0.9-1.5	1	1		10 measuring points
KTR	1.7	1	1		1 measuring point
JR	3.7-6.4	1		1	5 measuring points
Other reservoirs	0.7-0.8	2	2		Kafrein, Shueib
Wadis	0.6-8.4	5	3	2	FRESH WATER: Kufranhah, Rajeb, Hisban, BRACKISH WATER: Al Khor, Zaraq
Wells	0.8-9.2	163	82	81	25 wells are located outside DAs, but used for irrigation; 10 wells supply RO plants for desalination; additional 24 wells are temporarily closed
Springs	1.9-15.0	27	10	17	
Drains	2.3-16.4	20	2	18	
Totals		220	101	119	

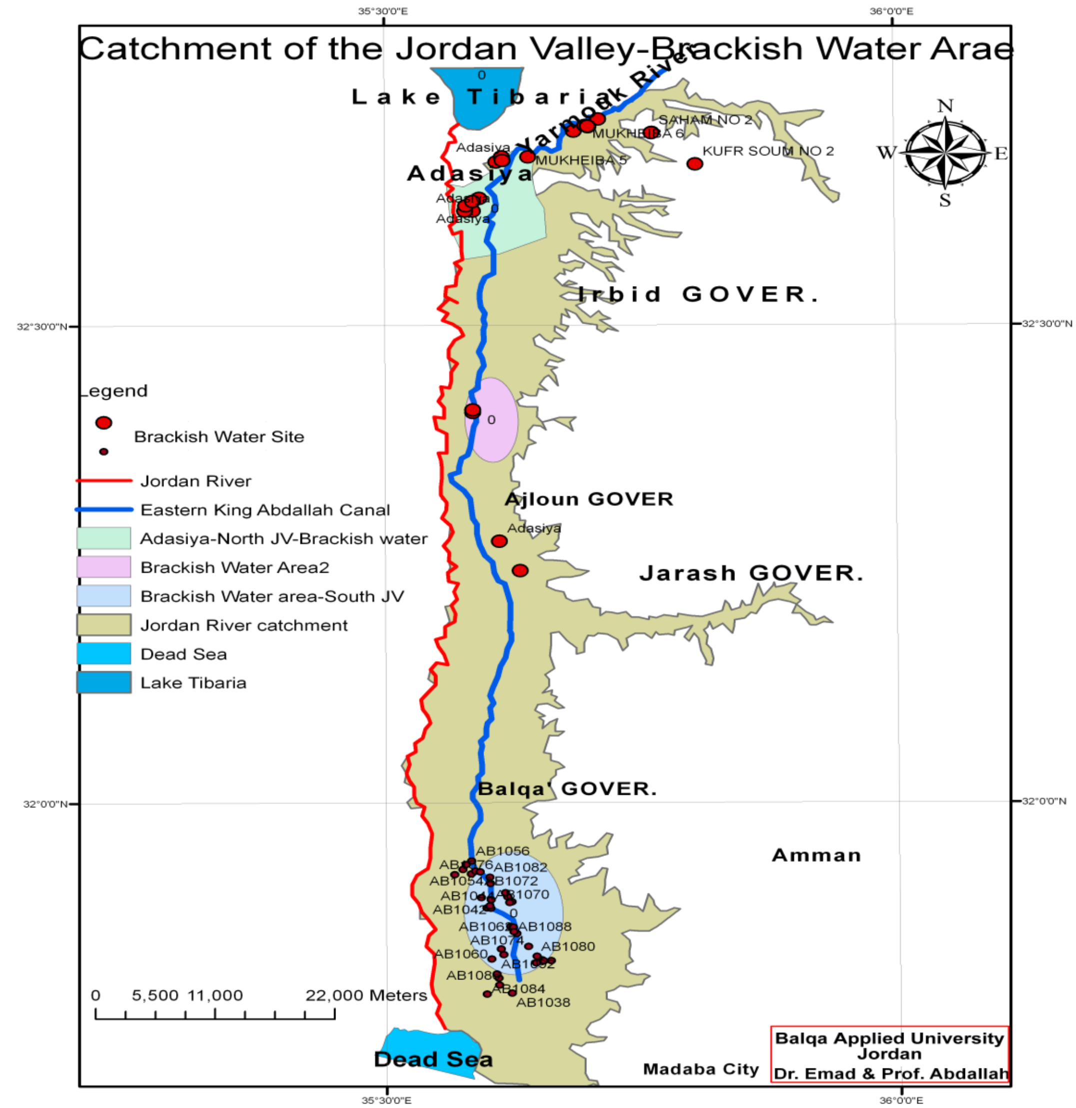
Water with a salinity of ECiw = 0.7-3.0 dS/m (450-2000 ppm) is classified as slightly to moderately restricting the use for irrigation, above 3 dS/m as severely restricting. Takinginto account the relatively light soils and relatively high CaCO3 contents in many soils of the project area the brackish water project regards water of ECiw >= 3dS/m as brackish water and below as freshwater . Water sources above 10 dS/m have no practical relevance for agricultural irrigation unless their water is desalinized. According to the threshold of 3 dS/m, 19 water sources (54%) in the Ghor area are brackish. This means an increase of 10 brackish water sources as compared to 2001, which is mainly due to the fact that new wells were discovered in the southern area. Many of these sources have local importance; however none of the brackish water sources is included in the supply network of JVA.

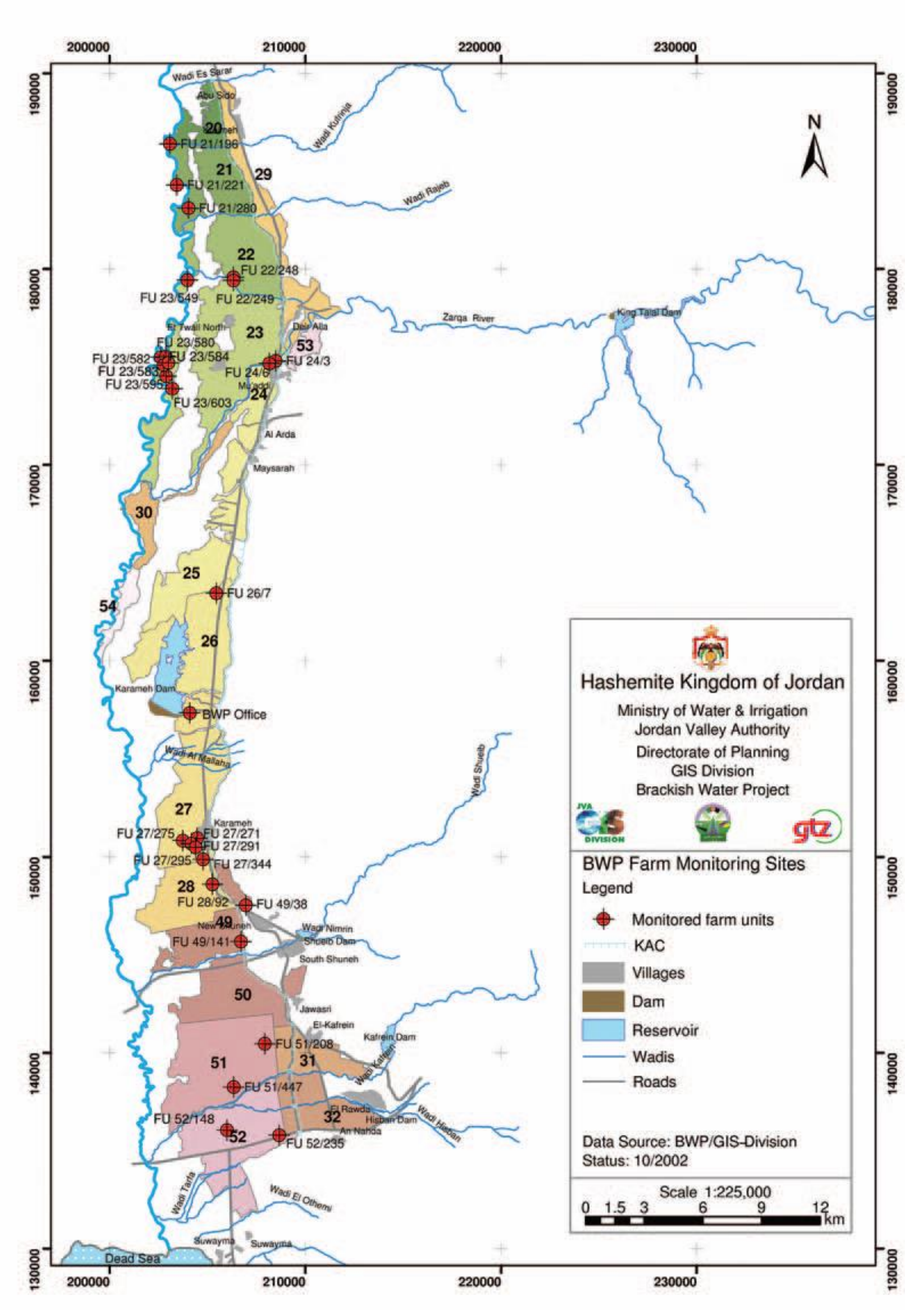
There are about 5700 farm units between Wadi Kufranjah and Sweimeh. In 2002, 1251 farm units (22%) were not irrigated and 4424 units (78%) were irrigated using various fresh water and brackish water sources in the area. Focusing on the importance of the use of brackish water and private fresh water sources, the following observations and assessments are interesting:

- In 2002 there are about 561 farm units using at least one brackish water source (11% less than in 2001). Out of these, only 171 units use only brackish water (5% more than in 2001), five units use brackish water and private fresh water, and 380 unit use brackish water and JVA- fresh water sources (16% less than in 2001).

- Assuming an average farm unit size of 3.0 Hectare and yearly irrigation depth of 1000 – 1300 mm with a 70 – 100% fraction of brackish water or private fresh water, the yearly volume of irrigation water from other than JVA sources in the Southern Jordan Valley amounts to roughly 23.5 MCM compared to about 58.8 MCM supplied by JVA from Wadi Kufranjah to the Dead Sea. (JVA Control Directorate in Deir Allah).

Figure 2: Mapping of potential sites for brackish water desalination





Hashemite Kingdom of Jordan
Ministry of Water & Irrigation
Jordan Valley Authority
Directorate of Planning
GIS Division
Brackish Water Project
BWP Farm Monitoring Sites
Legend
Monitored farm units
KAC
Villages
Dam
Reservoir
Wadis
Roads
Data Source: BWP/GIS-Division
Status: 10/2002
Scale 1:225,000
0 1.5 3 6 9 12 km
Zarqa River
King Talal Dam
Karameh Dam
BWP Office
Dead Sea
Wadi Shueib
Wadi Nimrin
Shueib Dam
South Shuneh
Kafrein Dam
Hisban Dam
Wadi Hisban
Wadi El Othemi
FU 21/186
FU 21/221
FU 21/280
FU 22/248
FU 22/249
FU 23/549
FU 23/580
FU 23/584
FU 24/3
FU 24/6
FU 23/603
FU 26/7
FU 27/275
FU 27/271
FU 27/291
FU 27/295
FU 27/344
FU 28/92
FU 49/38
FU 49/141
FU 51/208
FU 51/447
FU 52/148
FU 52/235

2.4 Existing Situation

In 2010 a survey was done by private sector[1] that showed the number of desalination units that use RO technology were 50 belongs to farmers (private). The total irrigated areas were 4750 dunums; with a total capital cost about 3 million JD.

The resource of desalination water was 85 wells, operates through electricity for about 24 hours in summer and 8 hours in winter. Table 1 shows the water quality of desalination plants.

Table 2: water quantity and related salinity in ppm of desalination plants in Jordan

Average quantity of desalinated water	**1300 m^3/hr**
Quantity of Brine water	450 m^3/hr
Rate of salinity intake water	3000 ppm
Desalinated water salinity rate	250 ppm
Average TDS for water use in irrigation	650 ppm
Average Brine salinity	8000 ppm

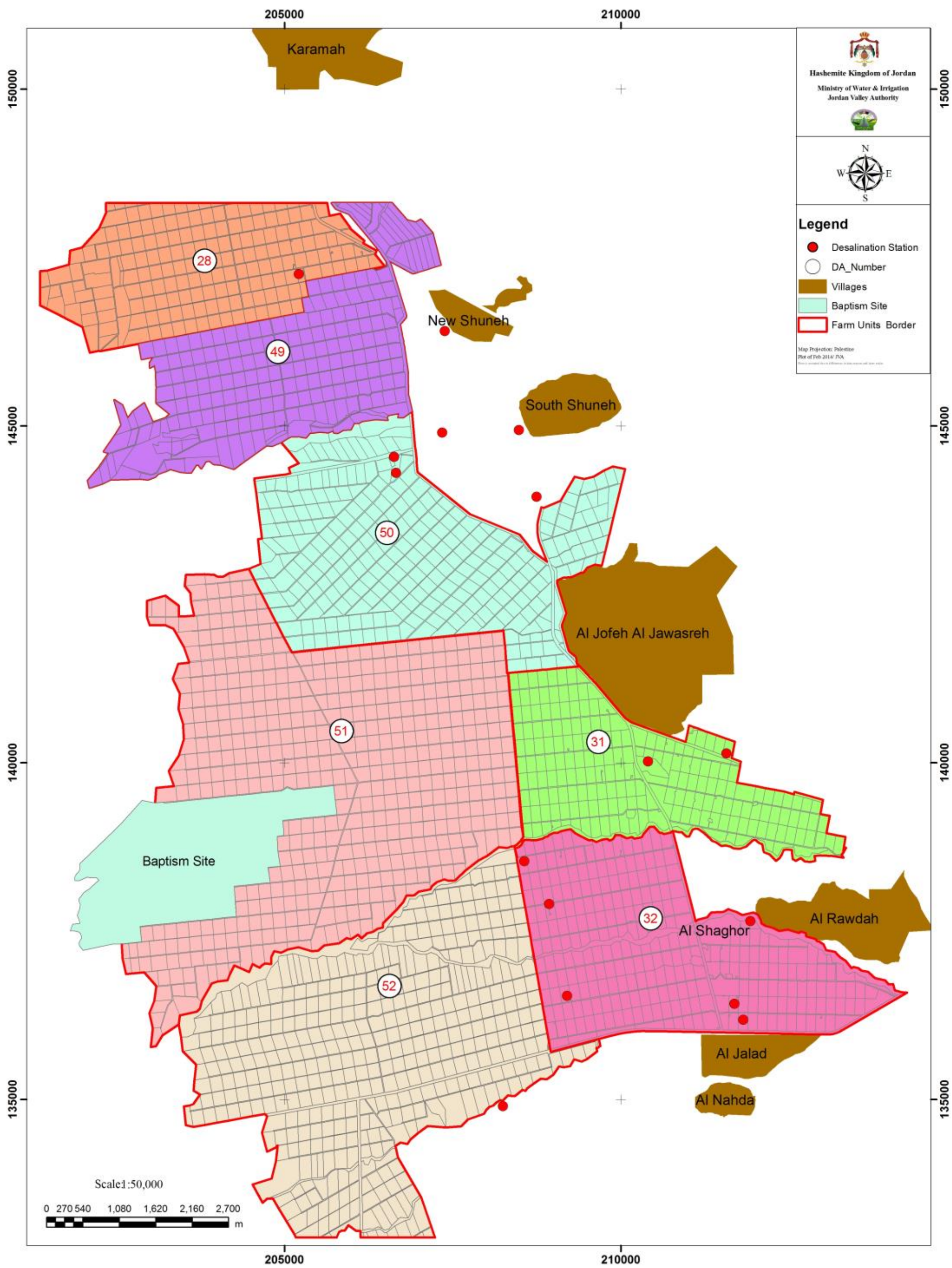
General View of desalination plants

Figure 2: location of desalination plants in the south Jordan Valley (legend? What are the red dots standing for and the numbers) Are there any information which hydrogeological formation are tabbed? Is it possible adjust the the size of the dots accorting to the water quantity which is taken out?

[1] Eng. Nayef Seder, Jordan Desalination and Reuse Association, Water Users association.

What are the areas standing for and the respective colours?

Personal recommendation: it better to use a scale bar instead of writing 1:45,398; because if you zoom the map the scale bar provides always the right proportions.



2.5 Justification for water desalination brackish water:

Table 3: Water availability and demand in the adjacent countries in the LJV (see Klinger et al. 2014)

	Israel		**Jordan**		**Palestinian Territories (West Bank)**	
Year	2010	2020	2010	2025	2010	2022
Freshwater resources (MCM/year)	1,170 [(3)]	1,170 [(3)]	780 [(7)]	483 [(8)]	127 [(4)]	> 127 [(6)]
Inland brackish water desalination (MCM/year)	25	75 [(1)]	57	82	0.5	22
Seawater desalination (MCM/year)	270	650 [(2)]	--	370	--	--
TWW reuse in agriculture (MCM/year)	400	570 [(1)]	100	247	--	30.6
Population (million)	7.7	9.1	6.1	8.5	2.65 [(5)]	5.7
Total water demand (MCM/year)	1,994	2,596	1,315	1,652	125 [(5)]	712 [(9)]
Deficit of water (demand – resources) (MCM/year)	129	131	361	470	2	>>2

Abbreviations: TWW=Treated Waste Water; MCM=Million Cubic Meters; Superscript numbers: [(1)] *2015 value,* [(2)] *2017 value,* [(3)] *Pumped water,* [(4)] *Domestic and agricultural water supply, including purchases from Mekorot utility,* [(5)] *2012 value,* [(6)] *Depends on the access to water resources,* [(7)] *Estimated natural groundwater and surface water resources,* [(8)] *Renewable and non-renewable groundwater only,* [(9)] *Long-term water strategy as of 2022.*

Sources: Guttman, J. (2011), Rosenthal, G and Katz, D. (2010), Palestinian Water Authority (2012), RCW & MWI (2009)

The table reflects that all riparian of the Jordan Valley take future water demand into account within their water strategies. In particular in Jordan and Palestine it is the aim to increase the desalination of brackish water desalination to mitigate the situation. The deficit of water demand and water availability is already significant and will increase in the next ten to fifteen years.

- Scarcity of fresh water and availability of saline groundwater.

Availability of irrigable lands without water resources e.g. (14.5 km extension irrigation project) This project aim to turn flood waters in Winter of Yarmouk River via the King Abdullah Canal to irrigate an area of 60 thousands dunums (the method of irrigation is sprinkler or drip) south of the Karameh town. the extension of the King Abdullah Canal distance 14.5 km to the south and the establishment of a network of compressed pipes.

-
- Cultivation of crops with high economic returns
- Improve plant growth, quality and increase production
- Prevent calcification in the network of irrigation networks and drippers.

Improve the qualities of soil physical, chemical that irrigate with little brackish water and wash salts in the soil.

Table 4: Total irrigated area of desalinated water (dunm)

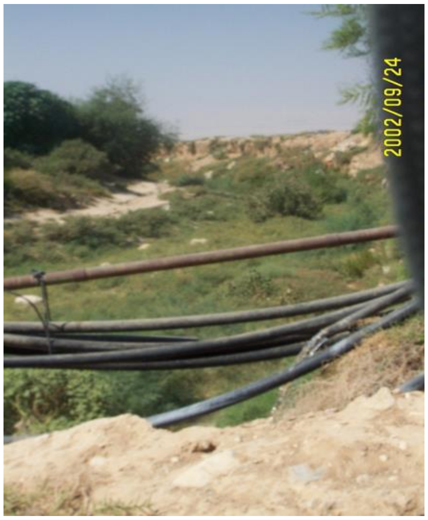
Crop type	Irrigated area (dunm)
Banana	2570
Grapes	280
Vegetables	1600
Citrus & Date Palm	300

2.6 Disadvantages of desalination plants

- High salinity drainage (brine), that increase the rate of salinity (8000 ppm) which affects the environment. A proper disposal of brine is needed to not cause an environmental impact (human beings, animals, soil, surface and groundwater). Its negative impact is limited to the area between its outlet in wadi and its outlet in the Jordan River, it does not affect the quality of water of the Jordan River, where the salinity of the river water up to 6000 ppm almost South King Hussein Bridge.
- Lack of qualified operation and maintenance staff. Desalination plants need good management, operation and maintenance technicians in addition to good irrigation management.

- The high costs of desalination plants.Negative impact on soil and vegetation in the valleys and groundwater when brine reaches it.

These photos show the brine quantity that drainage to wadi.



3 Recommendations:

- Conduct the necessary studies of the environmental impact of water coming out from the desalination plants.
- Development of standards and metrology for desalination of brackish water, brine disposal, limits for effluents.
- Study for use of brine for fish feeding.
- Make feasibility study for brackish water desalination and assess the cost per cubic meter of desalinated water.
- Study the transfer of water to the Jordan River through pipes.
- Development of licensing for desalination plants.

4 References

Klinger, J., Riepl, D., Wolff, H.-P., Heinz, I., Rödiger, R., Guttman, J., Samhan, S., Tamimi, A., Subah, A., Sauter, M., Müller, R., Geyer, S., Ali, W., Hötzl, H., Goldscheider, N. (2014): SMART - concepts for integrated water resource management in the Lower Jordan Valley; in: Integrated Water Resources Management: Concept, Research and Implementation, Springer Verlag, submitted