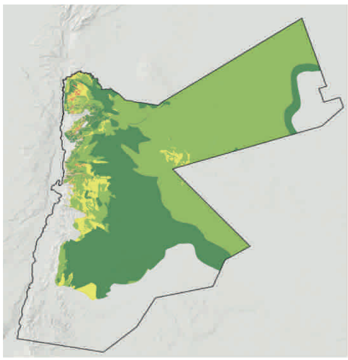
# Vulnerable Water Resources in Jordan | Hot Spots

January, 2020





Hashemite Kingdom of Jordan
Ministry of Water and Irrigation

BGR

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NICE
National Implementation Committee for Effective Integrated Wastewater Management

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# Abbreviations

| Abbreviation | Specification |
|---|---|
| **ALLOWS** | Assessment of Local Lowest-Cost Wastewater Solutions' |
| **APC** | Arab Potash Company |
| **BGR** | German Federal Institute for Geosciences and Natural Resources |
| **BMBF** | Federal Ministry of Education and Research |
| ***E. coli*** | *Escherichia coli* |
| **EIA** | Environmental Impact Assessment |
| **GIS** | Geographical Information System |
| **JS** | Jordanian Standard |
| **JVA** | Jordan Valley Authority |
| **MCM** | Million Cubic Meter |
| **MoH** | Ministry of Health |
| **MPN** | Most Probable Number |
| **MWI** | Ministry of Water and Irrigation |
| **NICE** | National Implementation Committee for Effective Integrated Wastewater Management |
| **RSS** | Royal Scientific Society |
| **UFZ** | Helmholtz Centre for Environmental Research – UFZ |
| **UV** | Ultraviolet Radiation |
| **WAJ** | Water Authority of Jordan |
| **WHO** | World Health Organisation |
| **WWTP** | Waste Water Treatment Plant |

# Summary

Groundwater is an invaluable resource in Jordan. It contributes to about 70% of the domestic water supply and is the major source of drinking water in the country. Thus, its protection is of the highest priority for the Ministry of Water and Irrigation (MWI). Over the last two decades, the MWI has taken a series of proactive measures to protect groundwater resources. In 2011, the MWI, in collaboration with the German Federal Institute for Geosciences and Natural Resources (BGR), implemented Groundwater Protection Zones in Jordan, in which the watershed of each groundwater well was divided into three zones, delineated using GIS maps. In Groundwater Protection Zone 1, no industrial or human activities are permitted, whereas in Zone 2 domestic and agricultural activities are allowed, but with strict limitations and frequent monitoring. Zone 3 covers the rest of the groundwater catchment area and it is assumed that human activities herein are less likely to contaminate the groundwater within the watershed. The concept of Groundwater Protection Zones was followed by the development of Groundwater Vulnerability Maps. Mapping the vulnerability of groundwater aquifers through spatial hydrogeological assessments can pave the way for an enhanced understanding of the sensitivity of natural systems to anthropogenic activities. These maps are an important decision support tool that should be considered for land management planning. Groundwater Protection Zones along with Groundwater Vulnerability Maps are becoming essential in Jordan particularly in areas that are not served with a sewage network.

The main aim of this study originated from a request by the National Implementation Committee for Effective Integrated Wastewater Management – NICE to review and update the previously developed list of Hot Spots. Hot Spots are defined as areas where groundwater resources, through leakage of domestic wastewater from cesspools, septic tanks, or sewage networks or through inappropriate handling of wastewater, have been contaminated or are expected to be contaminated. Based on multi-dimensional criteria i.e. people served, level of pollution, frequency of pollution and the presence of on-site treatment, 16 Hot Spots were identified. The identified Hot Spots, in combination with the Groundwater Protection Zones and Groundwater Vulnerability Maps, can be seen as an important decision support tool for stakeholders and decision makers when deciding where wastewater treatment plants will have the biggest impact for groundwater protection.

# الملخص

تعتبر المياه الجوفية مصدرا ثمينا للمياه في الأردن حيث تشكل حوالي 70% من كمية المياه المنزلية المخصصة لأغراض الشرب في المملكة، وبالتالي فإن الحفاظ على نوعيتها يعتبر من أهم أولويات وزارة المياه والري، حيث قامت الوزارة خلال العقدين الماضيين باتخاذ إجراءات استباقية متتالية للحفاظ على نوعية المياه الجوفية.

وفي عام 2011 قامت وزارة المياه والري، وبالتعاون مع المعهد الفدرالي لعلوم الأرض والمصادر الطبيعية (BGR)، بتحديد مناطق حماية المياه الجوفية في الأردن، وقد تم تقسيم الأحواض المغذية لآبار المياه الجوفية إلى ثلاث فئات، وتم تحديدها باستخدام خرائط نظم المعلومات الجغرافية، حيث لا يسمح في مناطق حماية المياه الجوفية الأولى بالقيام بأي أنشطة صناعية أو بشرية داخل حدودها، بينما يسمح ضمن المناطق الحماية الثانية بالقيام بأنشطة بشرية وزراعية بقيود مشددة ومراقبة متكررة، فيما تغطي مناطق الحماية الثالثة المساحات المتبقية من الأحواض الجوفية بحيث يسمح فيها بالقيام بجميع الأنشطة البشرية بافتراض انها لن تؤثر على المياه الجوفية الواقعة في المسقط المائي.

وبعد تحديد مناطق حماية المياه الجوفية تم إعداد وتطوير خرائط حساسية المياه الجوفية، حيث يمكن أن يساعد تقييم المعلومات الجغرافية المكانية الهيدرولوجية في تحديد مدى حساسية طبقات المياه الجوفية للتلوث و توضيح تأثر النظم الطبيعية بالأنشطة البشرية، وتعتبر أداة دعم مهمة لصناع القرار يجب مراعاتها عند تخطيط وإدارة الأراضي. حيث أن الاستناد إلى تعليمات حماية المياه الجوفية إلى جانب خرائط حساسية المياه الجوفية أصبح أمرا ضروريا في الأردن، وخصوصا في المناطق التي لا تخدمها شبكات الصرف الصحي.

واستنادا إلى طلب اللجنة التنفيذية الوطنية للإدارة المتكاملة للمياه العادمة في الأردن (NICE)، فإن الهدف الرئيسي من هذه الدراسة هو مراجعة وتحديث (قائمة البؤر الساخنة) التي تم تطويرها سابقا، حيث تعرف البؤر الساخنة بأنها مواقع مصادر المياه الجوفية التي تلوثت او من المتوقع ان تتلوث قريبا من خلال تسريب المياه العادمة المنزلية من الحفر الامتصاصية أو الخزانات التحليلية أو شبكات الصرف الصحي أو من خلال المعالجة/ النقل غير المناسبة للمياه العادمة وذلك بناء على معايير متعددة أهمها: الأشخاص المخدومين ومستوى التلوث وتكراره وتوفر آلية المعالجة في موقع الضخ، فإنه قد تم تحديد 16 بؤرة ساخنة، والتي يمكن اعتبارها بالإضافة إلى مناطق حماية المياه الجوفية و خرائط حساسية المياه الجوفية، أدوات مهمة لدعم صناع القرار وأصحاب العلاقة من أجل تحديد المواقع الأفضل لمحطات معالجة مياه الصرف الصحي التي يكون لها الأثر الأكبر في حماية مصادر المياه الجوفية.

# 1. Introduction

The protection of water resources of an appropriate quality is of utmost national importance, and the optimal management and use of the scarce water resources is essential. Groundwater and surface water resources need to be protected in order to restrict pollutants affecting these resources. The majority of water resources in Jordan are contaminated with coliform bacteria originating from leakage of domestic wastewater from cesspools, septic tanks, sewage networks or through inappropriate handling of wastewater.

In the National Framework for Decentralized Wastewater Management (MWI, 2015) and in the Decentralized Wastewater Management Policy (MWI, 2016) various Hot Spots of groundwater contamination from domestic wastewater were identified. Both documents, included a chapter on "*Groundwater Protection*", defining groundwater risk sites as well as a selection of wastewater treatment and reuse sites within groundwater protection zones. The identification of such Hot Spots was based on the Jordanian "*Microbiological Guideline for the Quality of Drinking Water*" issued by the Higher Committee for Water Quality (WAJ et al., 2017). For the impact of domestic wastewater on groundwater, biological agents such as *Escherichia coli (E. coli)*, were the main indicator of contamination.

The main aim of this study, based on a request from the National Implementation Committee for Effective Integrated Wastewater Management – NICE, was to update the chapter from the above-mentioned documents including the list of Hot Spots (MWI, 2015; MWI, 2016). In addition to improving public health and reducing environmental pollution, wastewater management is most beneficial where it supports the protection of groundwater and, in particular, where it facilitates the implementation of groundwater protection zones (MWI, 2016).

To realize these benefits, priority should be given to locations where decentralized wastewater management supports the remediation of groundwater pollution from wastewater or the prevention of groundwater risks associated with wastewater (MWI, 2016).

Through technical cooperation between the Ministry of Water and Irrigation and the German Federal Institute for Geosciences and Natural Resources (BGR), a guideline has issued in 2006, which was updated in 2019, for the protection of water resources, in which a total of twenty-one Groundwater Protection Zones were delineated.

# 2. Principles of Groundwater Protection Zone

Groundwater Protection Zones indicate areas where groundwater is at risk from potentially polluting activities and accidental releases of pollutants. According to the Water Resources Protection Guideline, the Groundwater ***Protection Zone 1*** of a spring has to extend at least 50 m upstream of the well, 10 m downstream and 15 m to each side. The perimeter should be completely fenced and locked, allowing only authorized personnel to access the area. Furthermore, there must be signs indicating restrictions and the significance of Zone 1 (**Figure 1**).


**Figure 1** Signpost marking the boundary of a Groundwater Protection Zone 1 in Jordan (© BGR).

***Protection Zone 2*** starts at the outer boundary of Zone 1 and ends at the line from which groundwater will, theoretically, take 50-days to reach the well. The 50-day line assumes that most pathogenic bacteria die within a period of 40 – 60 days while moving towards the groundwater. By preventing bacteriological contamination entering the groundwater within this 50-day line, it can be assumed that the water arriving at the wells is free of any bacterial contamination. Signs should also be installed to clearly show the most important restrictions (**Figure 2**).


**Figure 2** Signpost marking the boundary of a Groundwater Protection Zone 2 in Jordan (© BGR).

Activities that are allowed within Zone 2 are:

(i) **Residential areas** with a connection to a local sewerage system or installation of a properly managed cesspit;

(ii) **Agricultural activity:** Organic agriculture;

(iii) **Existing industries:** Those that produce wastewater have an obligation to implement all necessary environmentally sound practices and

(iv) **Other activities:** New establishments, extensions or changes are not licensed unless the responsible organization gives permission, referencing Jordanian legislation and related studies.

***Protection Zone 3*** comprises all the remaining groundwater recharge area for the well or spring.

# 3. Concept of Groundwater Vulnerability Maps

In comparison to the aforementioned Groundwater Protection Zones – Groundwater Vulnerability Maps provide an easy to understand tool for decision makers and stakeholders, showing how quickly pollution can reach the groundwater in a given area. While *Groundwater Protection Zones* focus on water sources (wells/ springs/ dams), vulnerability maps consider groundwater resources as a whole.

They are an important decision support tool that should be considered for land management planning. Activities that cause or might cause contamination should not be allowed in highly vulnerable areas. The overall aim is to provide an indication of whether a proposed development or activity is likely to be acceptable or of potential concern.

Various methods have been developed for different geological settings and available data. For the current study in Jordan, Groundwater Vulnerability Maps were produced using the COP-Method (Vías et al., 2006). In contrast to other methods frequently used in Jordan, this approach is able to describe the rapid infiltration of water through karst features (Brückner et al., 2018). Parameters considered in this method are:

- Surface features (e.g. karst, slope, vegetation - **C**oncentration of Flow). The C-Factor represents the infiltration conditions of surface water into the aquifers. In karst environments, water infiltrates rapidly, bypassing the protective cover.

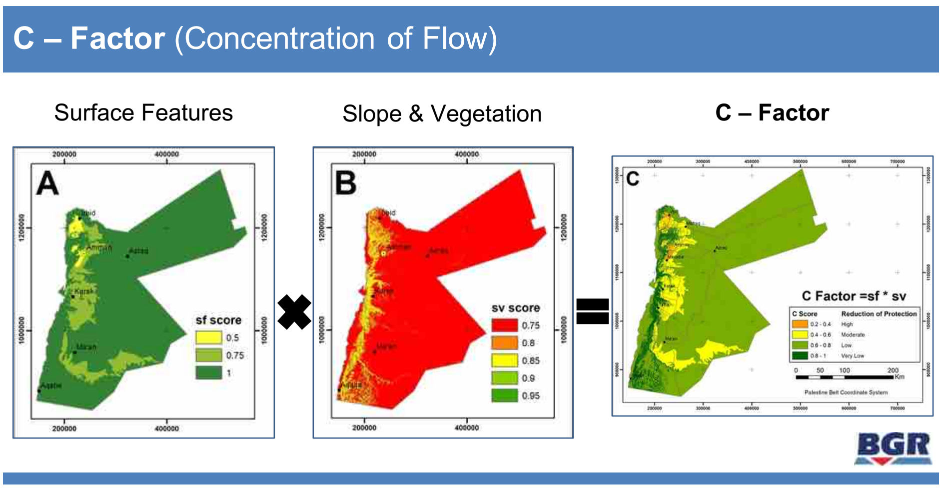



**Figure 3** C-Factor of the COP-Method (© BGR).

- Texture and thickness of the soil cover; thickness and lithology of the geological layers above the groundwater table (**O**verlying Layer). The overlying layers are the basis for the assessment of groundwater vulnerability. The O-Factor is a combination of the vertical distance that contaminated water has to traverse to reach the groundwater table and the retention potential of the soil and rocks.

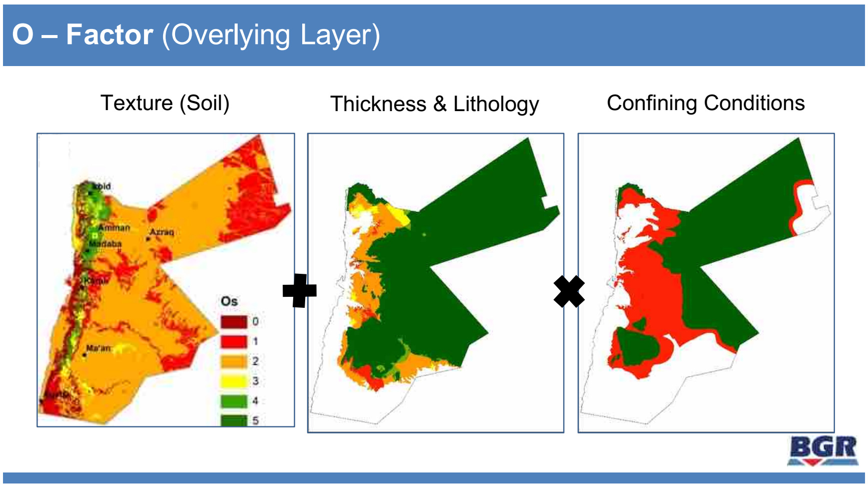



**Figure 4** O-Factor of the COP-Method (© BGR).

- Quantity of rainfall as well as rainfall intensity (**P**recipitation). The average value of wet years during a 30-year period (1984/1985 – 2013/2014) was considered. Recharge is considered indirectly with the precipitation factor. Variability is considered to some degree by using a "*worst case scenario*" (rainfall for wet years only, defined as yearly precipitation that is at least 15% above average).

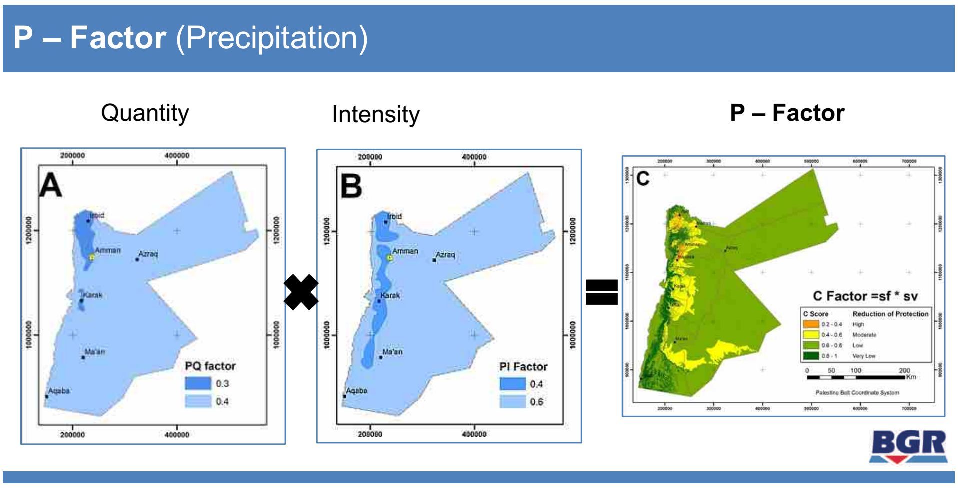



**Figure 5** P-Factor of the COP-Method (© BGR).

A detailed description of the data and procedure for producing the maps can be found in Brückner et al. (2018). The groundwater vulnerability maps presented in this study (see **Figures 7 – 12**) show the vulnerability of the aquifer that is closest to the surface – B4/5, A7/B2, A4 or A1/2 – independent of whether it is exploited or not. Also due to geological conditions, the maps can show the vulnerability of different aquifers. The aquifer which the groundwater vulnerability map refers to at any point, is shown on the inlay map.

This can help to identify pollution pathways, especially by including potential hazards and groundwater flow direction. They also show where establishing a sewage network should be prioritized from a water quality perspective.

The overall data were not sufficient to calculate the vulnerability of the deeper Kurnub and Ram sandstone aquifers which outcrop along the Dead Sea rift in the southern parts of Jordan. The maps show five categories of groundwater vulnerability (*Very High, High, Moderate, Low and Very Low*), which are defined as follows:

- **very high:** groundwater resources that have very limited natural protection
  → very high sensitivity to groundwater pollution from surface activities.
- **high:** groundwater resources that have limited natural protection
  → high overall pollution risk to groundwater from surface activities.
- **moderate:** groundwater resources that have some natural protection resulting in a moderate overall groundwater risk.

- **low:** groundwater resources that have some natural protection resulting in low overall groundwater pollution risk.
- **very low:** groundwater resources that have a high degree of natural protection. This reduces their overall risk of pollution from surface activities. However, activities in these areas may be a risk to surface water due to increased run-off from lower permeability soils and near-surface deposits.

# 4. Prioritization of Hot Spots

## *4.1 Hot Spot definition criteria*

In order to decide where wastewater treatment plants have the biggest impact, hot spots were defined. These Hot Spots are defined as areas where groundwater has been contaminated or is expected to be contaminated from untreated wastewater through (i) e.g. leakage of domestic wastewater from cesspools, septic tanks, or sewage networks or (ii) inappropriate handling of wastewater. As a decisive parameter, the coliform bacterium concentration of *E. coli*, measured as the most probable number (MPN/100 mL), is used for the classification of the level of pollution. The identification is based on the Jordanian Microbiological Guideline for the Quality of Raw Water for Drinking Water issued by the Higher Committee for Water (**Table 3**). In order to identify the source of contamination, the provenances of contamination, as mentioned in the Decentralized Wastewater Management Policy (MWI, 2016), need to be considered: (i) source of pollution such as feces and other pollutants that may directly impact the water resource, (ii) entry point of pollutants to the water supply path and (iii) entry of pollutants due to lack of control measures. Water resources (springs, dams and wells/wellfields) in Jordan were classified into three contamination categories: High, Moderate and Low (see **Table 1**), where principles such as the population served, level of pollution, frequency of pollution and availability of treatment of the water resource were considered. Each criterion was evaluated separately for each water resource. Water resources that were placed in the *High* category were considered to represent a Hot Spot.

**Table 1** Criteria that were considered for the classification of the Hot Spots.

| Criteria | High | Moderat | Low |
|---|---|---|---|
| People served* | > 50.000 | 10.000 - 50.000 | < 10.000 |
| Level of pollution[$] | *E. coli* conc. 2.000 - 20.000 | *E. coli* conc. 200 - 2.000 | *E. coli* conc. 20 - 200 |
| Frequency of pollution per year[&] | Daily to weekly | Monthly to quaterly | Yearly or above |
| Treatment at water resource | Not available | - | Available |

* Population that can theoretically be served; calculated on a daily water consumption basis of 70 l / inhabitant.

[&] According to the classifcation of WAJ.

[$] Only wastewater induced pollution is considered. As a decisive parameter the *E. coli* concentration (Most probable number (MPN)/100 ml) is used for the classification of the level of pollution. The identification is based on the Jordanian Microbiological Guideline for the Quality of Raw Water for Drinking Water.

# 5. Vulnerable Water Resources in Jordan: Hot Spots

Based on the description in: *1. Prioritization of Hot Spots*, various water resources in Jordan were considered and classified according to the criteria presented in **Table 1**. In total sixteen water resources can be considered as *Hot Spots* (**Table 2**; **Figure 6**).

Of these, the following were ranked highest by MWI/WAJ for the implementation of wastewater management solutions:

1. **El-Qantara spring**
2. **Tannur & Rasun spring**

**Table 2** Identified Hot Spots in Jordan for the year 2019.

| Governorate | Water Resource | | Abstraction Volume $m^3/y^{\&}$ | Population served* | GW-Protect. Zone |
|---|---|---|---|---|---|
| | Spring | Well/ Wellfield | | | |
| Irbid | | Hareema | 1.113.375 | 15.905 | n.a. |
| | | Pella | 3.082.526 | 44.036 | √ |
| | | Kufr Asad | 2.359.280 | 33.704 | n.a. |
| Ajloun | El-Qantara | | 473.879 | 6.770 | n.a. |
| | El-Beida<br>Tannur; Rasun | | 944.137 | 13.488 | n.a. |
| Balqa | Shore'a &<br>Hazzir | | 1.295.350 | 18.505 | √<br>√ |
| | Azraq | | 1.389.844 | 19.855 | √ |
| | Baqouriyyeh | | 2.673.537 | 38.193 | √ |
| | | Baq'a | 1.632.283 | 23.318 | n.a. |
| | | Yazidyya | 392.040 | 5.600 | n.a. |
| Zarqa | | Awajan | 3.153.600 | 45.051 | n.a. |
| | | Ruseifa | 2.124.016 | 30.343 | n.a. |
| Madaba | | Heedan | 11.149.269 | 159.275 | √ |
| Karak | | Mujib Dam | 15.027.780 | 214.683 | √ |

n.a.: not available; *calculated on a daily water consumption basis of 70 L/inhabitant; & for the year 2018.

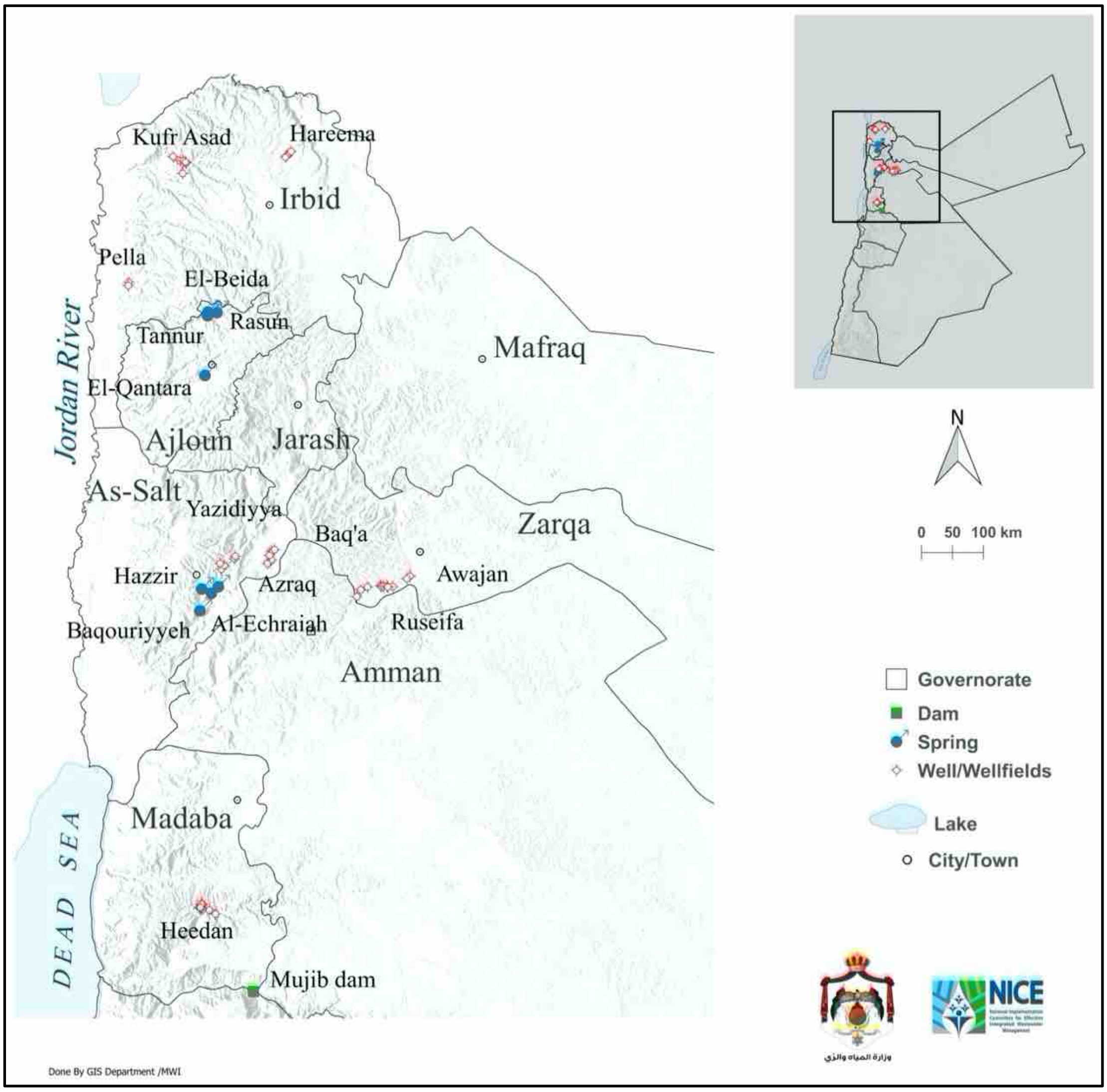



**Figure 6** Locations of the sixteen Hot Spots identified in Jordan.

## *5.1 Irbid Governorate*

The Irbid Governorate is located in the north of Jordan. It has an area of 1571.7 km$^2$ and is characterized by a moderate climate in the summer and a cool and rainy winter. It is the second largest governorate in terms of population, after Amman. Its population was 1,867,000 in 2017 and it has the highest population density in the Kingdom. A significant population increase has been caused by the Syrian crisis: about 133,000 Syrian refuges have moved to the governorate, increasing pressure on the scarce water resources.

Six centralized wastewater treatment plants are located in Irbid Governorate: (i) North Shouna; (ii) Wadi Al-Arab, (iii) Central Irbid, (iv) Wadi Shallala, (v) Ar-Ramtha and (vi) Wadi Hassan.

### *Groundwater vulnerability*

The vulnerability in the Irbid Governorate is mostly classified as moderate (**Figure 7**). In the south and west of Irbid, the A7/B2 aquifer outcrops and exhibits very high vulnerability in the incised wadis, where distance to the groundwater is lower. Vulnerability is very low in areas where the B3 aquifer outcrops and moderate to very high in the north and east of the governorate where the B4/5 aquifer outcrops, again strongly influenced by the occurrence of wadis.

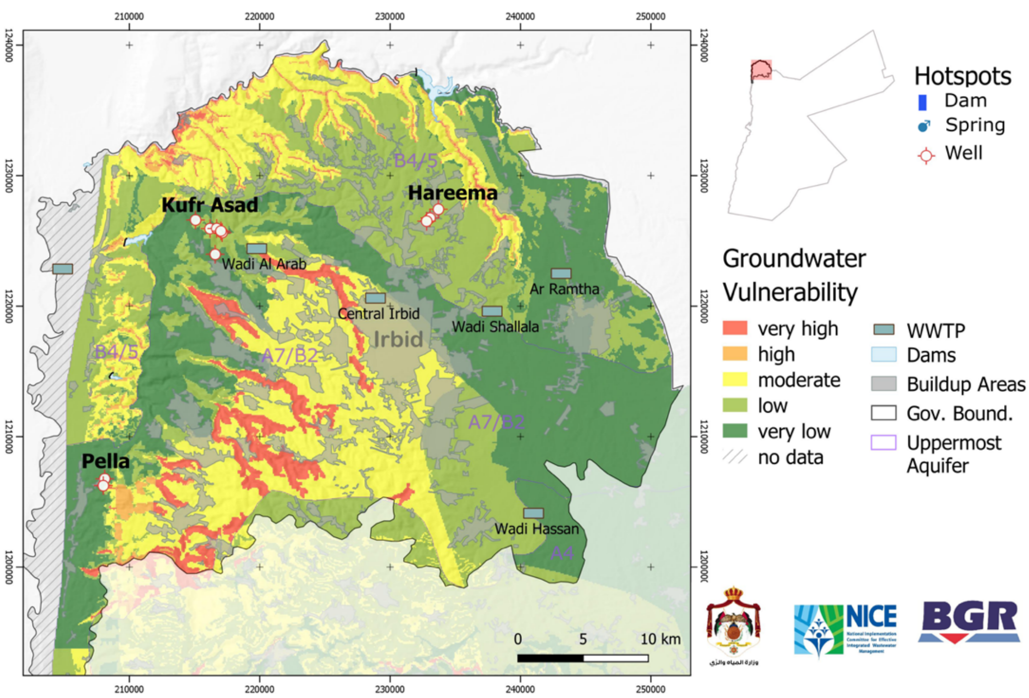



**Figure 7** Groundwater vulnerability map of the Irbid Governorate.

## — Hareema wellfield

Located in the northern part of the Irbid Governorate. Approximately 171 $m^3/h$ of water is extracted providing water for the network including Kharja, Bawakis, Hareema, Khair, Qaseef, Sila, Kharib, Yarmouk Hospital, Sama Al-Rousan – all located in the district of Bani Kinanah – and Kafr Jays.

- Treatment at the wellfield: Chlorination.
- A7/B2 aquifer, covered by B3.
- May be contaminated with Molybdenum, Nickel and Arsenic.

## — Kufr Asad wellfield

Located in the west of the Irbid Governorate. Approximately 281 $m^3/h$ of water is extracted providing water for the network including Kufr Asad, Sidour, Al-Kharaj, Malakah, Mansoura, Hatem, Abder, Umm Qais – all located in the district of Bani Kinanah – and Qumim.

- Treatment at the wellfield: Chlorination.
- A7/B2 aquifer.
- Contamination from the Wadi Arab WWTP as a result of by-pass or overflow due to overloading.

## — Pella wellfield

Pella wellfield (also known as Tabaqat Fahl) is located in the central Jordan Valley. The water has been used since Roman times, and is pumped from five shallow wells in the alluvium of Wadi Jurum. Although the water originates from the A7/B2 limestone aquifer, the deeper wells are causing problems and are contaminating the shallow wells.

Groundwater Protection Zones for the spring were delineated by (Hobler et al., 1999).

Approximately 650 $m^3/h$ are pumped and directed to the network including Fahl, Wadi al-Rayyan, Tall al-Arbaeen, Qal'at al-Sheikh Muhammad and al-Zamiliya.

- Treatment at the wellfield: The raw water is passed through sand filters to reduce turbidity and to achieve low levels of suspended solids. Next, it is pumped through reverse osmosis units to reduce the relatively high concentration of soluble salts. The water is then pumped through a ventilation tower to reduce the high concentrations of sulfur.

Treatment is only required because of the deeper wells, about 3 km north of the spring, which have high salt concentrations and flow into the shallow wells.

## 5.2 Ajloun Governorate

The Ajloun Governorate is located in the north western part of Jordan, with an area of 419,636 km$^2$. It is the second smallest governorate in Jordan after Jarash.

This is one of the governorates in which karst features are frequent due to the steep topography and relatively high amounts of rainfall.

Various springs, streams and artesian wells are present in Ajloun, and these are an important source for drinking water and irrigation.

One central wastewater treatment plant – Kufranjah WWTP – is located in the governorate.

### Groundwater vulnerability

Groundwater vulnerability in Ajloun Governorate is mostly moderate to low. In the depressions around and south of Kufranjah, vulnerabilities are very high because the aquifer outcrops directly. The A7/B2 aquifer outcrops in the northwest of the governorate (**Figure 8**).

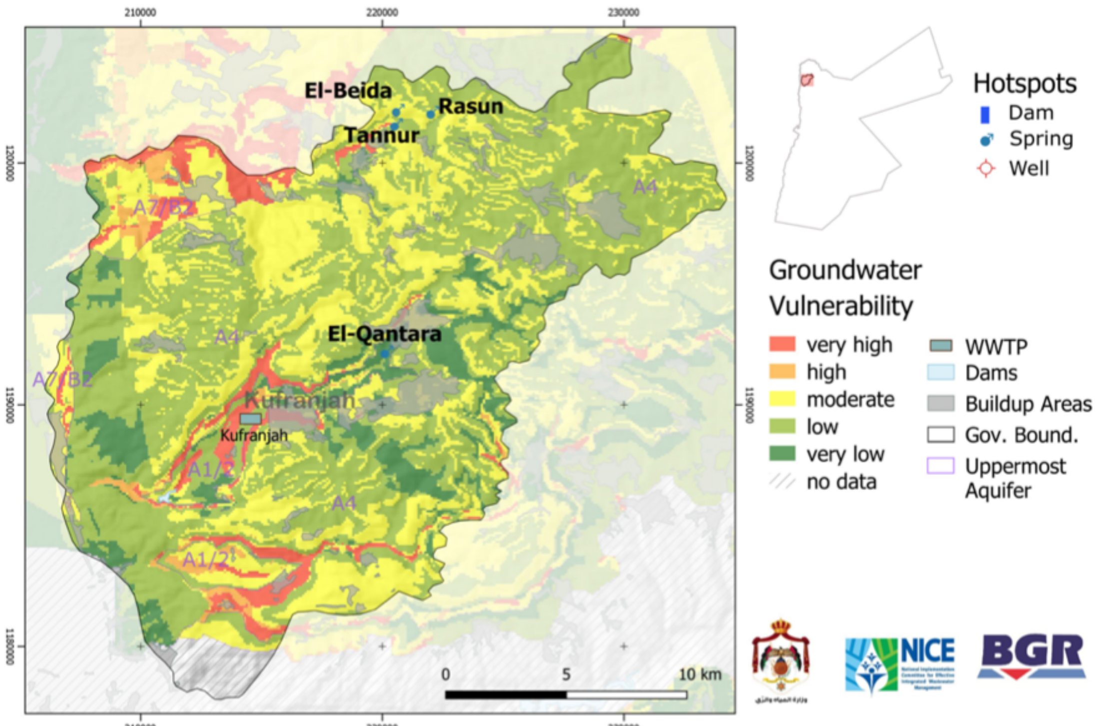



**Figure 8** Groundwater vulnerability map of the Ajloun Governorate.

## — El-Beida spring

Initially pumping at a rate of 35 – 120 $m^3/h$ as this rate is needed to feed the Kufranjah tank and network.

- Treatment at the spring: UV-; filtration and chlorination unit.

Currently the spring is not connected to the main drinking water network and no treatment is applied. Water is taken directly from the spring by tankers.

## — El-Qantara spring

Pumping at a rate 80 – 200 $m^3/h$ to feed the Rasun and Abu Al Hawa network, as well as the Baun reservoir.

- Treatment at the *spring: Chlorination.*

## — Tannur/ Rasun and El-Beida springs

Rasun and El-Beida springs are both located within the catchment of the Tannur spring and are of particular importance since about 20% of the population is supplied with water from them. The adjacent villages are the main recipients, however excess water is distributed to Ajloun, Anjara and Ain Janna via the Ba'oon and Ishtafeina reservoirs.

Investigations for the delineation of groundwater protection zones, as described by (Brückner et al., 2015) and Hamdan (2016) showed abundant karst features and a short spring flow response time to rainfall events.

Contamination events have obliged the WAJ directorate in Ajloun to stop pumping water from the springs for periods between several days to a few weeks. The majority of the contamination events occurred during the rainy season, which usually extends from October to April (Brückner et al., 2015).

Olive oil extraction represents one of the major agricultural industries in Ajloun. This produces large amounts of wastewater as a by-product of the milling process, so called "*zeebar*", with a high pollution load (high concentration of toxic organic compounds like polyphenols). It cannot be treated in conventional wastewater treatment plants and requires collection in isolated pools and transportation to special disposal sites by tanker trucks. The Tannur spring, in particular, is affected.

Rasun spring is contaminated with *E. coli*. The contamination is highly correlated with precipitation and thus usually occurs during the rainy season. The most probable sources of this kind of contamination are the cesspools of the houses in the surrounding villages, which are apparently not sealed properly and leak into the groundwater (Brückner et al., 2015). In summary, the main source of contamination occurs from coliform bacteria after rainfall and illegal dumping of olive oil wastewater.

The Tannur and Rasun springs are protected by a fence, both have a guard on duty at all times and the water is chlorinated before distribution to the water supply system, whereas at the smaller El-Beida spring there is no spring capture or treatment and water is only collected by tanker trucks.

## *5.3 Balqa Governorate*

Balqa is located in the western part of the Kingdom, with an area of 1120.4 $km^2$ and a population of about 518,600 inhabitants. The governorate is characterized by varied climate and terrain reaching from 224 m below sea level in the area of the Jordan Valley to 1130 m in the highlands.

Five centralized wastewater treatment plants are located in Balqa Governorate: (i) As-Salt, (ii) Baqa'a, (iii) Fuheis-Mahes, (iv) Tal Mantah and (v) Al-Echraiah.

### *Groundwater vulnerability*

South and east of Salt, the A7/B2 aquifer outcrops and is highly vulnerable because of the absence of a protective cover. Vulnerabilities are also high along Wadi Shuayb, where several springs that are used for water supply emerge. Vulnerabilities in the rest of the area are mostly low. In the Baqa'a wellfield, water is extracted from the Kurnub Sandstone – data for this aquifer are quite limited so it was not possible to calculate vulnerability in that area (**Figure 9**).

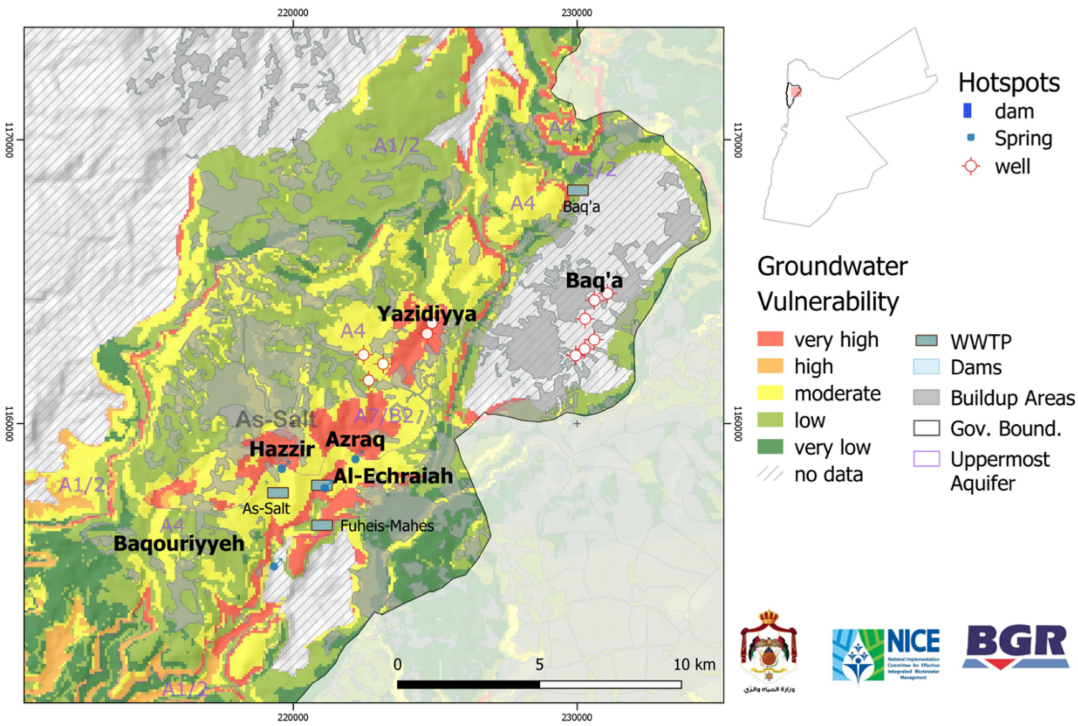



**Figure 9** Groundwater vulnerability map of the Balqa Governorate.

## — Al-Echraiah, Hazzir, Azraq and Baqouriyyeh springs

All springs are located in Wadi Shuayb and are used for the water supply of As-Salt and Fuheis-Mahes; they have been affected by bacteriological contamination for many years.

Margane et al. (2010) delineated groundwater protection zones for the springs and found that leaking cesspools are most likely the source of frequent bacteriological contamination. Grimmeisen et al. (2016) showed that the discharge at the Hazzir spring is influenced by a leaking water supply line, showing a rapid connection between the shallow subsurface and the spring.

The water from all wells is treated at Al-Echraiah and then pumped to Naqab Al-Dabour, Batneh and the reservoir of the Azraq spring.

- Treatment at Al-Echraiah spring: UV, membrane micro-filtration and chlorination with a total capacity of 22,000 $m^3$/d.

The following approximate amount of water is extracted:

- Al-Echraiah spring*:* 75 – 150 $m^3$/h.
- Hazzir spring: 120 $m^3$/h.
- Azraq spring: 160 $m^3$/h.
- Baqouriyyeh spring: 200 – 400 $m^3$/h.

Due to an increase in bacterial concentrations in the Azraq spring, the water can no longer be pumped directly into the Fuheis reservoir.

## — Baq'a wellfield

Located in the north eastern part of the Balqa Governorate. Approximately 383 $m^3$/h of water is extracted providing water for the Baqa’a Camp network.

- Contamination with *E. coli*.
- Treatment at Baq’a wellfield: Chlorination

## — Yazidyya wellfield

Located in the eastern part of the Balqa Governarote. Approximately 540 $m^3$/h of water is extracted, providing water for the Yazidyya, El-Masri, Al- Hadeeb, Sahlooliyyeh, Al- wasiya, Al-Rmamen, Um Sobhiya network.

- Contamination with *E. coli*.
- Treatment at Yazidyya wellfield: Chlorination

## 5.4 Zarqa Governorate

The Zarqa Governorate is located east of Amman. Its desert climate is dry in the summer with little rain in winter and it has a total population of about 1,439,500. Two centralized wastewater treatment plants are located in the Zarqa Governorate:

(i) Azraq Camp and

(ii) Khribit As Samra.

### Groundwater vulnerability

Groundwater vulnerability is mostly low to very low, with the exception of areas around Zarqa city that predominantly have moderate vulnerability (**Figure 10**).

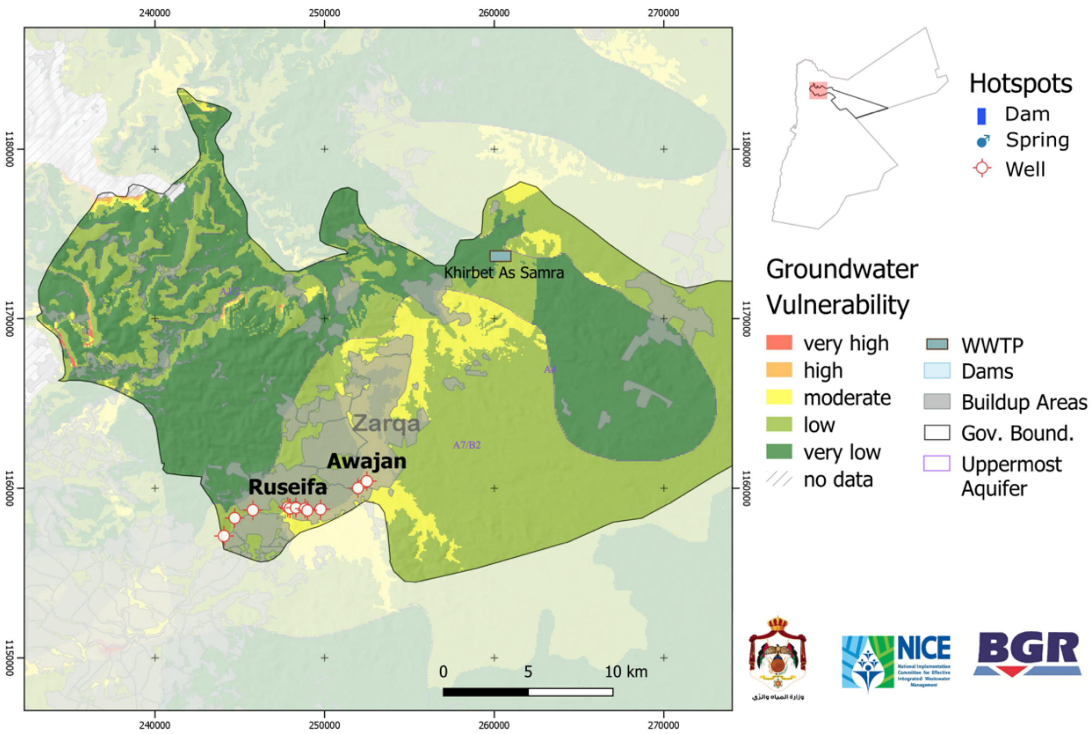



**Figure 10** Groundwater vulnerability map of the Zarqa Governorate.

## — Awajan wellfield

A total of about 410 $m^3$/h is pumped to feed the network of Awajan (Western Region) and Upper Awajan Reservoir.

Treatment at Awajan wellfield: Chlorination.

## — Ruseifa wellfield

Located in the south west of the Zarqa Governarate. Approximately 465 $m^3$/h of water is extracted providing water for the network including Jreba, Jabal Faisal and the Ruseifa tanks.

The hydrogeological conditions are disturbed by leakage from the water supply networks as well as leakage from the wastewater network.

The groundwater vulnerability map above does not give the right impression. Contamination can pass from the A7/B2 to the A4 aquifer due to cross-formation screening.

The wells are contaminated because of the leaking wastewater collection pipes in Seil Zarqa.

- Contamination with *E. coli*.
- Treatment at Ruseifa wellfield: Chlorination.

## *5.5 Madaba Governorate*

Madaba a is one of the central governorates and is characterized by a semi-wet, drought-prone climate. It has a population of about 199,500 inhabitants.

One centralized wastewater treatment plant is located in the Madaba Governorate: (i) Madaba WWTP.

### *Groundwater Vulnerability Map*

Groundwater vulnerability along Wadi Wala is moderate to very high because most of the protective cover has been eroded. In the highlands, vulnerability is mostly low to very low (**Figure 11**).

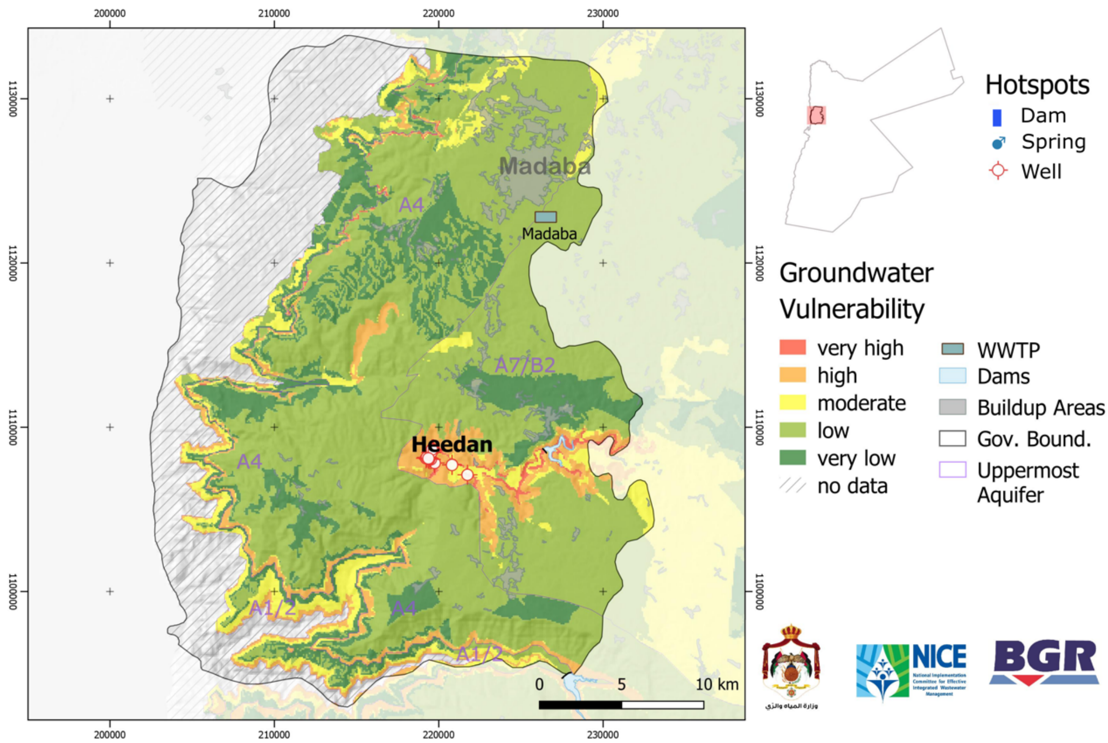



**Figure 11** Groundwater vulnerability map of the Madaba Governorate.

### — Heedan wellfield

The well field is located in Wadi Heedan and its tributary Wadi Wala, downstream of Wala Dam; it is the only source of drinking water for the city of Madaba. Heedan wellfield receives water from managed aquifer recharge at Wala dam, which has been in operation since approximately 2004. Water is mainly extracted from the A7 aquifer (but also from the deeper A4 as well from the A1/2 aquifer), a karstic limestone aquifer with high permeability (Gassen et al., 2016), which has to be shut down regularly due to turbidity and bacteriological contamination. Contamination can be correlated to rainfall events, which flush liquid and solid waste from human septic tanks and animal manure into the wadi. This contaminated floodwater easily infiltrates the aquifer and arrives shortly after at the wellfield (Gassen et al., 2016).

Groundwater protection zones have been delineated by (Gassen et al., 2016).

Approximately 10 MCM/year is extracted from the A7 limestone aquifer and directed to:

- Cement reservoir.
- The Hamaydah network.
- Theban reservoir.

## 5.6 Karak Governorate

The Karak Governorate is located in the south of Jordan, dominated by a desert climate and with an overall population of about 348,180.

Three centralized wastewater treatment plants are located in the Karak Governorate: (i) Lajjoun, (ii) Karak and (iii) Mu'tah (Adnanieh) WWTP.

### Groundwater vulnerability

Groundwater vulnerability is mostly low to moderate with some areas of high vulnerability in the wadis, and at aquifer outcrops, for example in the immediate vicinity of Mujib Dam (**Figure 12**).

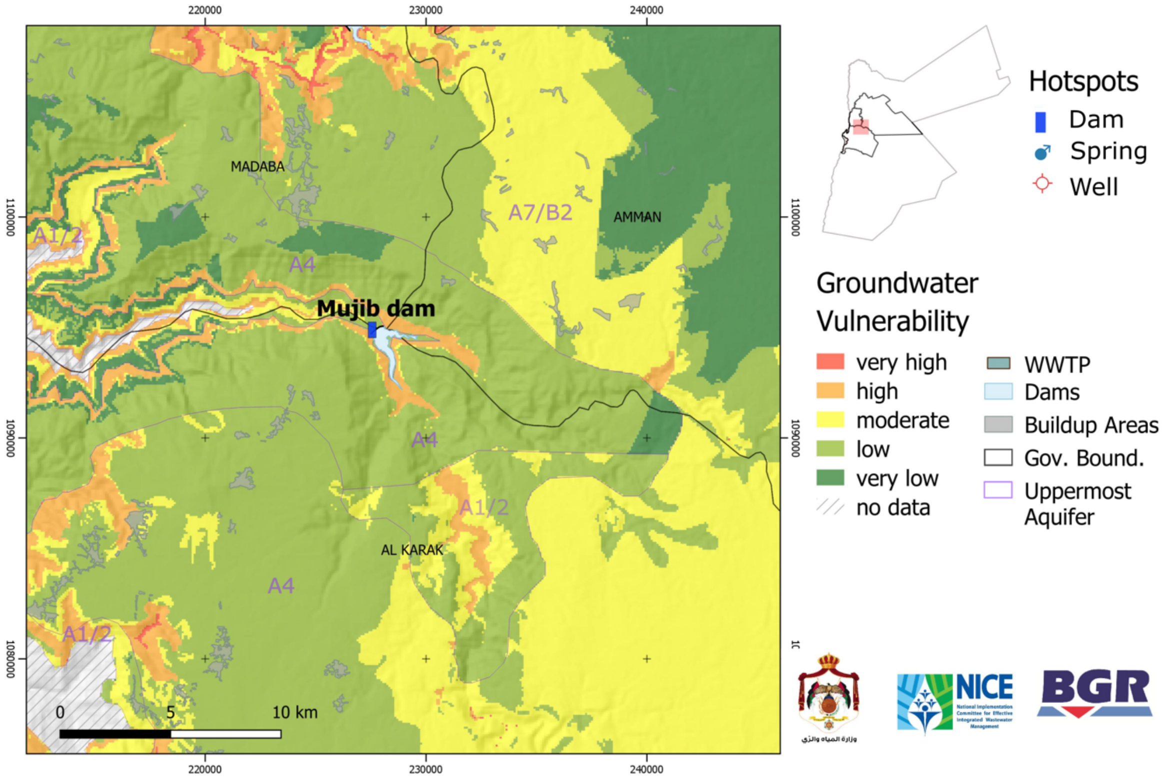



**Figure 12** Groundwater vulnerability map of the Karak Governorate.

## — Mujib Dam

The following information is based on (Margane et al., 2008).

The dam is located in the Karak Governorate, close to the border with the Madaba and Amman Governorates. It was constructed between 1999 and 2003 and started to fill up in the winter of 2003/2004.

Mujib Dam has a maximum storage capacity of 31.2 MCM. In the south it is used to supply the mining and processing industries, such as the Arab Potash Company (APC), the Salt Factory, the Magnesium Factory and the Bromine Factory (altogether demanding approx.10 MCM/year), and provide additional water for irrigation to the Ghor Mazra’a area (approx. 2 MCM/year). It is also intended to be used for water supply to the villages south of the Mujib Dam (Jebel Shihan area, Al Qasr), however water quality problems hinder such use.

The surface water from the Mujib Dam is released whenever needed and flows in the lower Wadi Mujib towards the Dead Sea. Before entering the Dead Sea it is collected and transferred north and south. Since a large proportion of the water will ultimately be used for drinking purposes, the entire lower Wadi Mujib from the dam to the Dead Sea needs to be protected from pollution.

Water quality in the Mujib reservoir is monitored regularly by the WAJ laboratory, Ministry of Health and Environment and parallel to that by the Royal Scientific Society (RSS). The measurements of RSS are carried out on behalf of JVA. Since changes in the main hydro-chemical components are minor, monthly measurements are sufficient to assess the general quality of the surface water.

The most significant aquifers in the vicinity of the Mujib Dam are the A7/B2 aquifer, the A1/2 aquifer and the Kurnub/Disi aquifer. Over most of the western part of the Mujib dam surface water catchment, the A7/B2 aquifer outcrops and thus receives groundwater recharge. The westernmost part the A7/B2 aquifer is overlain by basalt, which acts as an aquifer as well, so that basalt and A7/B2 essentially form a combined aquifer.

Generally, groundwater flow in the Kurnub/Disi aquifer is directed towards Wadi Mujib, which acts as the main collector of its outflow to the Dead Sea.

## Hazards inside Groundwater Protection Zones

*Protection Zones 1 and 2*

- *Agriculture*: oil contamination from the operation of generators, washout of pesticides and fertilizers (mainly from olive groves); chicken farms, with the potential risk of bacteriological contamination in manure.
- *Residential buildings/stables*: contamination by sewage water or animal dung/manure. Disposal of wastewater in cesspits (absent municipal sewage *collection and treatment system in all villages and scattered residential areas in Protection Zones 1, 2 & 3*). Potential risk: leaking and/or overflowing cesspits and/or absence of cesspits - infiltration into groundwater, flushing with surface water runoff to reservoir.
- *Gypsum mines:* contamination by hydrocarbons; landslides; increased amount of sulphates in the reservoir - transfer of sulphates by wind and soil leaching.

*Potential Hazards inside Protection Zone 3*

- The main hazard to the water resources arises from uncollected and untreated wastewater. There is a high risk that wastewater is flushed out from cesspits during heavy rainfall events. Analyses of the reservoir show contamination with *E. coli*.

# 6. Recommendations

The development of recommendations for the protection of the identified *Hot Spots* needs to include a careful assessment of risks and benefits of wastewater treatment in *Groundwater Protection Zones*, including: site selection criteria accounting specifically for hydrological and geological characteristics of the protection zone, and safety considerations for the selection of sites for wastewater collection, treatment and discharge facilities, treatment technologies, reuse of treated wastewater, and sludge management (MWI, 2015).

Due the prevalent karstic geology and ensuing high vulnerability to pollution, the establishment of wastewater treatment systems is confined to *Protection Zone 3*, assuming that additional requirements are fulfilled, i.e. selecting the least vulnerable location within Protection Zone 3. Furthermore, treated effluents should not be discharged into wadis leading to *Protection Zone 2* (JS 893, 2006) or areas of high groundwater vulnerability.

Individual groundwater vulnerability and hazards maps for areas with rapid urban growth and contamination risks reflect the natural protection of the aquifers and the risks prevailing at the time, which can be integrated into land use planning and for land use licensing decisions. In addition, land stability, flooding risk and potential negative impacts of georisks need to be considered. Wastewater collection systems traversing *Protection Zone 2* must be designed in such a way that they cannot cause pollution, e.g. through damage by georisks (rockfalls, landslides, earthquakes, tectonic movements). Specific guidelines for EIAs of wastewater systems in karst areas have been developed by BGR and should be applied here.

When reusing treated wastewater, e.g. in agriculture, the Jordanian Standard for Reuse (JS 893, 2006), is to be complied with.

The open discharge of treated wastewater to the valleys adjacent to *Protection Zones 1* and *2* is prohibited by Article 30 A/3 of the Water Authority Law No. 18 of 1988 and amendments thereof.

It is permissible to use treated wastewater for the purposes of artificial recharge, provided that the water in the aquifer is used for irrigation purposes only. Technical studies must be performed before using reclaimed water to verify that there is no effect on aquifers used for drinking purposes (JS 893, 2006).

For aquifers used for drinking water supply, managed recharge of treated wastewater is prohibited in *Protection Zones 2* and *3,* due to its negative impact on water resources. However, in view of the extreme and increasing water scarcity in Jordan, it is worthwhile examining each case separately and establishing exceptional cases, e.g. in Protection *Zone 3*, where feasible. For this, a feasibility study with a detailed analysis of the hydrogeological situation must include an investigation of groundwater travel times.

## General Measures

In order to put into effect groundwater protection from domestic wastewater the following measures shall be taken:

**Measure 1:** To establish, with urgency, treatment systems for the identified Hot Spots as well as wastewater treatment systems in the surrounding region in order to protect vital groundwater resources from pollution by domestic wastewater.

**Measure 2:** To connect all houses with impermeable cesspools to a sewer wherever new wastewater collection systems are established.

**Measure 3**: To establish a strategy for cooperation between the municipalities and the Water Authority for the enforcement of wastewater regulations.

**Measure 4: To** make groundwater protection from domestic wastewater possible, a wastewater regulation that solves the issue of ”*permeable cesspools*” in Jordan, and in particular the revision of Article 8 (A) of the National Wastewater Regulation 66/1994 shall be implemented.
Article 8 (A) states that "*If a private wastewater sewer cannot be connected to the public wastewater sewer for any reason whatsoever, the owner shall construct at his own expense within the boundaries of his property an absorption pit and/or septic pit in accordance with such instructions and standards as shall be determined by the local council in certain areas in coordination with the Authority*." In the National Wastewater Regulation 66/1994, Article 2 the item "*Absorption Pit*" is defined as "*A pit set aside for all the water extracted from liquid waste and for the drainage thereof through soil cracks and pores*".

## Irbid Governorate

### *Hareema, Kufr Asad and Pella-wellfields*

*Hareema and Kufr Asad wellfields* both serve as drinking water reservoirs for the municipality of Banin Kinana. The installation of impermeable cesspools at all houses, as well as the implementation of decentralized wastewater treatment systems will significantly positively impact both wellfields. Furthermore, the Wadi Al

Arab WWTP currently does not meet the effluent limits according to the Jordan Standard (JS 893, 2006) and therefore potentially threatens the Kufr Asad wellfield through leakage of the treated wastewater from the transfer pipeline.

The WWTP is currently being upgraded.

*Pella wellfields:* Preliminary recommendations have already been presented by (Hobler et al., 1999), including that solids, as well as the wastewater, from all tourist facilities be directed outside the groundwater protection area. The wastewater should be treated using decentralized wastewater management solutions.

The vulnerability of groundwater to pollution in the catchment of the Pella wellfield is high to very high in some parts, because the A7/B2 aquifer outcrops in parts of the wadi. It is therefore urgently recommended that the enforcement of existing regulations is strengthened in order to reduce pollution.

## Ajloun Governorate

*El-Beida, Tannur and Rasun:* Preliminary recommendations have already been presented by (Brückner et al., 2015). Untreated wastewater is the most likely cause of pollution. Because of the remote location and relatively low population, the connection to a centralized wastewater treatment system is not a high priority. Approaches to the disposal of wastewater based on decentralized wastewater management options in the region are necessary.

In order to stop the pollution of the springs with olive oil wastewater, environmental laws have to implemented. This should include systematic control, but also allow the olive mill owners to dispose of wastewater at an acceptable cost. In reality, it is often not economically feasible to bring all of the wastewater to Al-Ekeeder landfill.

*Qantara spring:* Giving citizens incentives (e.g. financial) to have their houses connected to the sewer network.

## Balqa Governorate

*Al-Echraiah, Hazzir, Azraq and Baqouriyyeh springs:* Preliminary recommendations have been presented by Margane et al. (2010) to avoid contamination of the drinking water source and reduce the health risk to the local population.

Rehabilitation of the sewer network at As-Salt city to protect the Hazzir spring from pollution.

*Baq'a a and Yazidyya wellfields:* Connection of the eastern areas of Balqa: Baqa'a, Yazidyya and Um Al-Dananer to the new, currently planned, WWTP.

## Zarqa Governorate

*Awajan- and Ruseifa wellfields:* Expanding the transfer pipeline and installation of new pipelines to avoid overflow of manholes.

## Madaba Governorate

*Heedan wellfield:* Preliminary recommendations were presented by Gassen et al. (2016). The production of the Heedan wellfield is severely reduced by temporary contamination of the groundwater. Such events occur during heavy rainfall events and are characterized by high faecal bacteriological pollution, which leads to the shutdown of the wellfield. A shutdown results in a tremendous shortfall in the water supply to Madaba.

It is recommended that a new wellfield east of Madaba shall be opened and connected to Madaba via the Disi pipeline.

## Karak Governorate

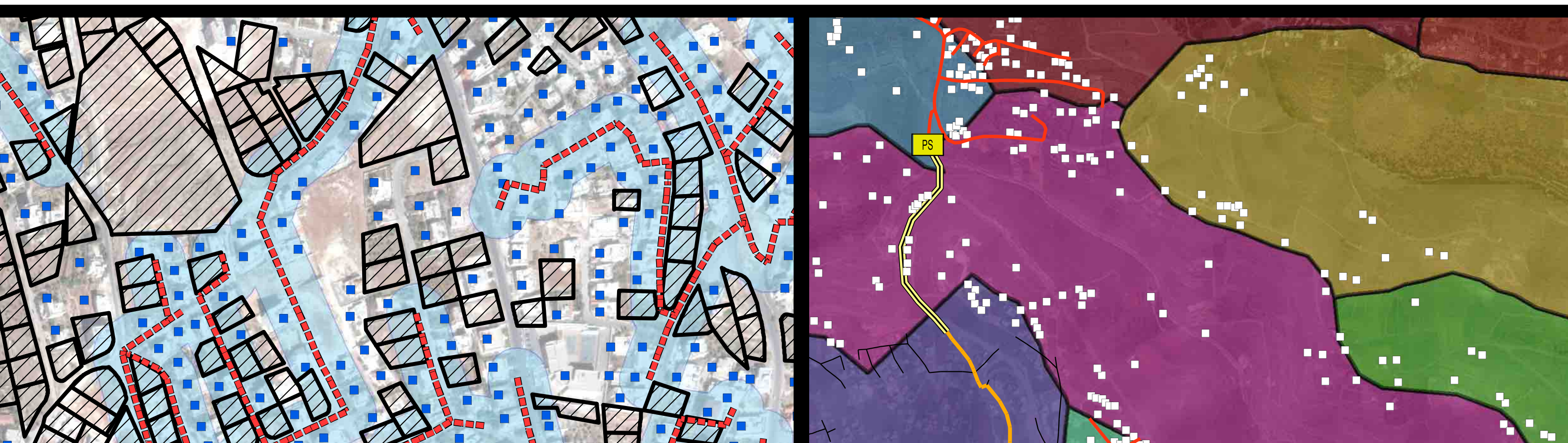
*Mujib Dam:* Preliminary recommendations were put forward by Margane et al. (2008). It is recommended that only one central outtake at the dam itself be established and the irrigation water be distributed from there via pipelines. Agricultural fields inside *Zone 1* have to be abandoned and pesticides should not be applied in protection *Zone 2*, with organic farming methods employed instead of using chemical fertilizer. Fishing in the lake using rowboats should only be allowed by a limited number of persons. Existing residential sites should be connected to an appropriate sewerage network or impermeable cesspools.

It is recommended that a wastewater collection system be established as well as a wastewater treatment system for all villages (either a decentralized or cluster solution, see (MWI, 2015; MWI, 2016).

## Decision-Support Tool ”ALLOWS”

As suggested in the National Framework for Decentralized Wastewater Management and the Policy for Decentralized Wastewater Management in Jordan (MWI, 2015; MWI, 2016), it is recommended that the ALLOWS decision-support tool (*‘Assessment of Local Lowest-Cost Wastewater Solutions’*) shall be used for the development of all wastewater management solutions in Jordan in order to assess whether a centralized or decentralized approach is more feasible at a specific location. ALLOWS is a GIS-based tool that enables the stakeholder and decision-makers to develop different wastewater management scenarios and carry out the cost assessment of each scenario based on the dynamic cost comparison method. This makes the

ALLOWS tool a valuable decision support instrument for decision-makers and stakeholders to choose the most suitable wastewater management solution (van Afferden et al., 2015). Depending on the desired result of the assessment, the ALLOWS tool can be fed with data of any type and any range. While the analysis can be carried out as detailed planning for the scenarios, the data required for the assessment must be accordingly of high resolution and exact. With global data (terrain, infrastructure, and international and national benchmarking cost data) the tool can be used preliminary planning and decision support instrument. Generally, the following data are required for the ALLOWS tool:
(i) *Primary geo-database* provides information on the land surface (relief, terrain), physical infrastructure (streets, buildings, etc.), water bodies, and land use (agricultural, residential, industrial, municipal, etc.); (ii) *Socio-economic database*, which provides information on total population and population growth rates, average household size, land ownership (parcel index), and international and national benchmark prices for all costs associated with wastewater infrastructure (treatment unit, network construction, pump and lifting stations, operation and maintenance of the treatment unit and conveyance, labor, electricity, water, sludge disposal, etc.); (iii) *Water database* provides information on water supply and conveyance, water consumption, connection degree to piped water supply and wastewater disposal, individual wastewater production, wastewater composition (e.g. organic load) and is derived from data from the local Water Authority and verified by field visits or through authorities at the Governorate level and (iv) *Secondary geo-database*, which provides detailed information about the physical infrastructure (built environment including individual buildings and streets) and wastewater infrastructure already in place (network, septic tanks, etc.). The scenario development relies on spatial analysis and designing wastewater infrastructures visualized in GIS; it then generates site-specific financial indicators for different wastewater management scenarios and thus enables planners and decision-makers to identify and select the best solutions for any given local wastewater management problem.



# التوصيات

إن وضع توصيات لحماية البؤر الساخنة المحددة في هذا التقرير يجب أن يشمل تقييما دقيقا لمخاطر وفوائد معالجة المياه العادمة في مناطق حماية المياه الجوفية مثل: معايير اختيار الموقع التي تراعى على وجه الخصوص الخصائص الهيدرولوجية والجيولوجية لمنطقة الحماية، واعتبارات السلامة من أجل اختيار مواقع لتجميع ومعالجة وتصريف مياه الصرف الصحي وتقنيات المعالجة وإعادة استخدام المياه العادمة المعالجة وإدارة الحمأة في مناطق حماية المياه الجوفية.(MWI, 2015)

نظرا للجيولوجيا الكارستية السائدة والتعرض الشديد للتلوث، يقتصر إنشاء أنظمة معالجة مياه الصرف الصحي على منطقة الحماية الثالثة ولاستيفاء المتطلبات الإضافية، أي اختيار أقل المواقع تعرضا للخطر داخل منطقة الحماية الثالثة. علاوة على ذلك، لا ينبغي أن يتم تصريف المياه المعالجة في الوديان المؤدية إلى منطقة الحماية الثانية (انظرJS 893/2006) أو المناطق ذات الحساسية المرتفعة للتلوث.

تعكس خرائط حساسية المياه الجوفية في مناطق النمو السكاني السريع مخاطر التلوث لطبقات المياه الجوفية، والتي يمكن دمجها في اتخاذ القرارات المتعلقة بتخطيط استخدام الأراضي وترخيصها، مع الأخذ بعين الاعتبار مخاطر الفيضانات والآثار السلبية المحتملة لجيولوجية المنطقة.

يجب تصميم مجمعات المياه العادمة التي تمر عبر منطقة الحماية الثانية بطريقة لا تسبب التلوث، من خلال الأضرار التي تسببها المخاطر الجيولوجية (سقوط الصخور والانهيارات الأرضية والزلازل والحركات التكتونية). ولقد قدم المعهد االفدرالي لعلوم الأرض والمصادر الطبيعية تعليمات محددة لتقييم التأثيرات البيئية لشبكات المياه العادمة في المناطق الكارستية والتي لابد من تطبيقها.

يجب الالتزام بالمواصفة الأردنية لإعادة الاستخدام JS 893/2006 عند إعادة استخدام المياه العادمة المعالجة في الزراعة على سبيل المثال.

يمنع التصريف المفتوح للمياه العادمة المعالجة إلى الأودية المجاورة لمناطق الحماية الأولى والثانية بموجب المادة (30أ/3) من قانون سلطة المياه رقم 18 لعام 1988 وتعديلاته.

يسمح باستخدام المياه المعالجة لأغراض إعادة التغذية الاصطناعية شريطة أن يتم استخدام المياه في طبقة المياه الجوفية لأغراض الري فقط. و يجب إجراء الدراسات الفنية قبل استخدام المياه المستصلحة للتحقق من عدم وجود تأثير على طبقات المياه الجوفية المستخدمة لأغراض الشرب (JS 893/2006).

بالنسبة لطبقات المياه الجوفية المستخدمة لتزويد مياه الشرب، يمنع إعادة تغذية المياه المعالجة في منطقة الحماية الثانية والثالثة، بسبب تأثيرها السلبي على مصادر المياه. ومع ذلك، نظرا للندرة المياه الشديدة والمتنامية في الأردن، من الجيد دراسة كل حالة على حدة وإثبات حالات استثنائية، على سبيل المثال في منطقة الحماية الثالثة، حيثما كان ذلك ممكنا مع تحليل مفصل للوضع الهيدروجيولوجي الذي يجب أن يشمل التحقيق في أوقات انتقال المياه الجوفية. علاوة على ذلك، يجب الرجوع إلى دراسة منظمة الصحة العالمية التالية، "أحدث تقرير عن المخاطر الصحية في تغذية طبقة المياه الجوفية باستخدام المياه المستصلحة".

### تدابير عامة

من أجل تفعيل حماية المياه الجوفية من المياه العادمة المنزلية، يجب اتخاذ الإجراءات التالية:

**التدبير 1**: إنشاء أنظمة معالجة للبؤر الساخنة المحددة بأسرع وقت ممكن وكذلك أنظمة معالجة مياه الصرف الصحي في المنطقة المحيطة من أجل حماية مصادر المياه الجوفية من التلوث بالمياه العادمة المنزلية.

**التدبير 2**: ربط جميع المنازل بالخزانات غير المنفذة للمياه العادمة أينما تم إنشاء أنظمة جديدة لجمع مياه الصرف الصحي.

**التدبير 3**: وضع استراتيجية للتعاون بين البلديات وسلطة المياه لتنفيذ التعليمات الخاصة بمياه الصرف الصحي.

**التدبير 4**: كتدبير أساسي لجعل حماية المياه الجوفية من مياه الصرف الصحي المنزلية ممكنة، تنظيم للمياه العادمة يحل مسألة "الحفر الامتصاصية" في الأردن، وخاصة مراجعة المادة 8 (أ) من التعليمات الوطنية للمياه العادمة 1994/66 وتنفيذها. تنص المادة 8 (أ) على أنه "إذا تعذر توصيل مجاري مياه الصرف الصحي الخاصة بشبكة المجاري العامة لأي سبب من الأسباب، فعلى المالك أن ينشئ على نفقته الخاصة داخل حدود ممتلكاته حفرة امتصاصية و/أو خزان الصرف الصحي وفقا مع التعليمات والمعايير التي يحددها المجلس المحلي في مناطق معينة بالتنسيق مع السلطة ". في المادة 1994/66 من التعليمات الوطنية لمياه الصرف الصحي، يعرف البند "حفرة الامتصاص" بأنها حفرة مخصصة لجمع المياه المستخرجة من النفايات السائلة وتصريفها من خلال شقوق التربة والمسام".

### محافظة إربد:

حماية حقل ابار حريما وكفر أسد وطبقة فحل

يمثل كل من بئر حريما وكفر أسد خزانين لمياه الشرب لبلدية بني كنانة. إن ربط جميع المنازل على حفر امتصاصية غير منفذة، وكذلك تنفيذ أنظمة معالجة المياه العادمة اللامركزية سيكون لها تأثير إيجابي على كلا الحقلين.علاوة على ذلك، فإن محطة معالجة مياه وادي العرب حاليا لا تنطبق مع المواصفة الاردنية JS 893/2006، وبالتالي تشكل تهديد لحقل ابار كفر أسد من خلال تسريب المياه المعالجة عن طريق انابيب النقل.

حقل ابار طبقة فحل: التوصيات الأولى قدمت بالفعل من قبل (Hobler et al. 1999) يجب تصريف المياه العادمة والحمأة الخارجة عن جميع المنشآت السياحية خارج منطقة حماية المياه الجوفية. وهنا يجب معالجة المياه العادمة بواسطة حلول ادارة المياه العادمة اللامركزية.

إن حساسية التلوث في حقل ابار بيلا يكون ما بين مرتفع إلى مرتفع جدا في بعض الأجزاء، وذلك بسبب تكشفات الطبقة B2/A7.

على طول حدود الوادي، ولذلك نوصي بشكل عاجل على تحسين تنفيذ التعليمات الحالية من أجل الحد من التلوث.

### محافظة عجلون:

نبع عين البيضاء و تنور و راسون: التوصيات الأولى قدمها (Brückner et al. 2015). السبب المحتمل للتلوث هو المياه العادمة غير المعالجة و يعتبر ربط المنطقة بنظام معالجة مياه الصرف الصحي المركزي ليس له أولوية مرتفعة بسبب الموقع البعيد وعدد السكان المنخفض نسبيا،وبالتالي تظهر ضرورة تبني مفاهيم التخلص من المياه العادمة من خلال حلول إدارة المياه العادمة اللامركزية.

يجب تنفيذ القوانين البيئية من أجل وقف تلوث الينابيع بمياه الصرف الصحي الناتجة عن معاصر زيت الزيتون. يجب أن يشمل ذلك التحكم المنهجي، ولكن أيضا السماح لأصحاب معاصر الزيتون بالتخلص من المياه العادمة مقابل سعر منخفض نسبيا، وفي ظل الظروف االحالية، ليس من المجدي اقتصاديا نقل كل المياه العادمة إلى مكب الأكيدر.

نبع القنطرة: نوصي بمنح المواطنين بعض الحوافز (مثل القروض والأقساط المالية) لربط المنازل على شبكة الصرف الصحي.

محافظة البلقاء:

نبع الشريعة والحزير والأزرق والباقورية: تم اقتراح التوصيات الأولى من قبل

(Margane et al. 2010) من أجل تجنب تلوث مصدر مياه الشرب والحد من المخاطر الصحية على السكان المحليين، وأعادة التأهيل شبكة الصرف الصحي في مدينة السلط لحماية نبع حزير من التلوث المحتمل.

حقول ابار البقعة واليزيدية: ربط الجهة الشرقية من البلقاء (البقعة وأم الدنانير) مع مشروع محطة المعالجة الجديدة.

محافظة الزرقاء: حماية حقول ابارعوجان والرصيفة

توسعة خطوط النقل الحالية وتزويد خطوط النقل الجديدة وذلك تجنبا لفيضان المناهل.

محافظة مادبا: حقل ابار هيدان

حقل ابار هيدان: التوصيات الأولى قدمها

(Gassen et al. 2016) انخفض إنتاج حقل ابار هيدان بشدة بسبب التلوث المؤقت للمياه الجوفية. تحدث مثل هذه الأحداث خلال مواسم الأمطار الغزيرة وتتميز بالتلوث البكتيري الجرثومي العالي للبراز مما يؤدي إلى إغلاق حقل الابار مما يشكل انقطاع هائلا في إمدادات المياه في مادبا.

نوصي بالبدء في حفر حقل ابار جديد في شرق مادبأ، و ربط مادبأ على خطوط مشروع الديسي.

محافظة الكرك:

سد الموجب: أول توصيات قدمها
(Margane et al. 2008).

يوصى بإنشاء حصيلة مركزية واحدة فقط في السد نفسه وتوزيع مياه الري من هناك عبر خطوط الأنابيب،و يجب التخلي عن الحقول الزراعية داخل منطقة الحماية الأولى، ويجب عدم استخدام المبيدات في منطقة الحماية الثانية وكذلك استخدام طرق الزراعة العضوية بدلا من استخدام الأسمدة الكيماوية. ينبغي السماح للصيد في البحيرة باستخدام قوارب التجديف لعدد محدود من الأشخاص فقط. ويجب أن تحتوي الأنشطة السكانية الحالية على شبكة صرف صحي مناسبة أو خزانات/ حفر امتصاصية غير منفذة.

يوصى بإنشاء نظام لجمع مياه الصرف الصحي بالإضافة إلى نظام لمعالجة مياه الصرف الصحي لجميع القرى (سواء كان حلا لامركزيا أو حلا عنقوديا، انظر (MWI, 2015، MWI, 2016).

أداة دعم اتخاذ القرار "***ALLOWS***"

وفقا للإطار والسياسة الوطنية لإدارة المياه العادمة اللامركزية في الأردن

(MWI, 2015، MWI, 2016)، يجب تطبيق أداة دعم القرارات ALLOWS على تطوير جميع حلول إدارة مياه الصرف الصحي في الأردن من أجل التقييم، سواء كان نهج مركزي أم لا مركزي هو أكثر جدوى في موقع معين. ALLOWS هي

أداة قائمة على نظام المعلومات الجغرافية وتمكن المستخدم من تطوير سيناريوهات مختلفة لإدارة مياه الصرف الصحي ومقارنة تكاليف السيناريوهات على أساس منهجية مقارنة التكلفة الديناميكية. يمكن التقييم صناع القرار من إجراء تقييم اقتصادي وتقني لمختلف السيناريوهات بناء على القيمة الحالية الصافية للخيارات المختلفة، مما يجعله أداة دعم قرار تنافسية لحلول إدارة مياه الصرف الصحي

(van Afferden et al. 2015)

يتطلب ALLOWS أربعة قواعد بيانات مختلفة:

(1) قاعدة البيانات الجغرافية الأولية. يوفر معلومات حول سطح الأرض (الإغاثة، التضاريس)، البنية التحتية المادية (الشوارع، المباني، إلخ)، المسطحات المائية، واستخدام الأراضي (الزراعية، السكنية، الصناعية، البلدية، إلخ)؛

(2) قاعدة البيانات الاجتماعية والاقتصادية، التي توفر معلومات عن إجمالي معدلات نمو السكان والسكان، ومتوسط حجم الأسرة، وملكية الأراضي (مؤشر الطرد)، والأسعار المرجعية الدولية والوطنية لجميع التكاليف المرتبطة بالبنية التحتية لمياه الصرف الصحي (وحدة المعالجة، وبناء الشبكات، محطات الضخ والرفع، التشغيل والصيانة لوحدة المعالجة والنقل، العمل، الكهرباء، المياه، التخلص من الحمأة، إلخ)؛

(3) قاعدة بيانات المياه. يوفر معلومات حول إمدادات المياه ونقلها، واستهلاك المياه، ودرجة التوصيل إلى إمدادات المياه عبر الأنابيب والتخلص من المياه العادمة، ومنتجات مياه الصرف، تركيبة مياه الصرف الصحي (مثل الحمل العضوي) وهي مستمدة من بيانات من هيئة المياه المحلية ويتم التحقق منها بالزيارات الميدانية أو من خلال السلطات على مستوى المحافظة

(4) قاعدة بيانات جغرافية ثانوية توفر معلومات مفصلة عن البنية التحتية المادية (البيئة المبنية بواسطة المباني الفردية والشوارع والبنية التحتية لمياه الصرف الصحي موجودة بالفعل (شبكة، خزانات الصرف الصحي، وما إلى ذلك).

يعتمد تطوير السيناريو على التحليل المكاني وتصميم البنى التحتية لمياه الصرف الصحي المتصورة في نظم المعلومات الجغرافية ونتيجة لذلك يولد مؤشرات مالية خاصة بالموقع لسيناريوهات مختلفة لإدارة مياه الصرف الصحي، وبالتالي يمكن المخططين وصانعي القرار من تحديد واختيار أفضل الحلول لأدارة مياه الصرف الصحي المحلية المحددة.

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# 8. Participating Organizations

- Ministry of Water and Irrigation
- Water Authority of Jordan
- Jordan Valley Authority
- Ministry of Health
- Ministry of Environment
- Royal Scientific Society
- Federal Institute for Geosciences and Natural Resources (BGR)
- German Corporation for International Cooperation GmbH (GIZ)
- Helmholtz Centre for Environmental Research – UFZ

# 9. Photo Credits

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# 10. Appendices

## *10.1 Microbiological Guideline for the Quality of Drinking Water*

The document was prepared by the Higher Committee for Water Quality at the Ministry of Water and Irrigation and the Water Authority of Jordan. The Guideline has been mandatory since 2017 and has to be followed by all water companies in Jordan, as well as by owners of drinking water resources. The Guideline identifies the minimum requirements for the raw water treatment of groundwater and surface water resources used for drinking water purposes.

Required treatment stages are defined according to the concept of the World Health Organization's drinking water safety plans and risk management (WHO, 2017). Under these criteria, raw water is classified into one of two categories, (i) protected- and (ii) non-protected groundwater resources. Non-protected groundwater resources are grouped into three categories (Categories I – III, see **Table 3**).

The annual rate of the coliform bacterium concentration of *E. coli* in the raw water is used as the specific factor to categorize the source, which determines the required treatment stages.

## المعايير الميكروبيولوجية لنوعية المياه الخام
## <u>لمصادر مياه الشرب ومتطلبات الحدِّ الأدنى من المعالجة لاستغلال تلك المصادر</u>

هي وثيقة أعدّتها اللجنة العليا لنوعية المياه المشكّلة في وزارة المياه والري/ سلطة المياه ، واتفقت وزارتا المياه والري والصحة على الالتزام بها ، وإلزام شركات تزويد وإدارة مياه الشرب في المملكة بها ، وكذلك إلزام أصحاب مصادر مياه الشرب الخاصة بها، وكان آخر تحديث طرأ عليها عام 2017.
تختص هذه الوثيقة بتحديد متطلبات الحد الأدنى من عمليات المعالجة اللازمة للمياه الخام من المصادر المائية الجوفية والسطحية لتصبح صالحة لغاية الشرب؛ حيث قسِّمت المياه الخام إلى فئات ، وتحديد مراحل المعالجة المطلوبة (الحواجز المطلوبة) لكل فئة عملاً بمفهوم خطط سلامة مياه الشرب وإدارة المخاطر الذي تبنَّتـه منظمة الصحة العالمية.
بموجب هذه المعايير صـنِّـفت مصادر المياه التي ستستخدم لغاية الشرب كمايلي:

1- المصادر الجوفية المحمية.
2- المصادر الجوفية غير المحمية (المصادر الجوفية المعرضة للتلوث) ؛ وهذه قسِّمت إلى ثلاث فئات: الفئة الأولى ، الفئة الثانية والفئة الثالثة.

اعتُمِـد المعدل السنوي لعدد عصيات الايسشيريشيا كولاي (*E. coli*) في عينات المياه الخام كعامل محدد لتصنيف فئة المصدر ، ولتحديد مراحل المعالجة اللازمة تبعًا لذلك.
اشتملت الوثيقة على الإجراءات التشغيلية للمصادر القائمة وللمصادر الجديدة، واشتملت أيضًا على تحديد وتعريف أنواع ايقافات هذه المصادر وآليات التبليغ عنها وآليات إعادة التشغيل؛ والجدول أدناه يلخص أهم ما جاء في الوثيقة:

| الرقم | تصنيف المصدر | عدد عصيات *E. coli* (عصية/100مللتر) | تكرارية جمع العينات | معايير نوعية أخرى | المعالجة المطلوبة | الإيقاف وجوبًا |
|---|---|---|---|---|---|---|
| 1 | جوفي محمي | لم يتأكد وجود *E. coli* في العينات | عينة شهريًا، ولا يقل عن ثماني عينات سنويًا | العكارة لا تزيد عن 5 وحدات نفلومترية 6,5≤ pH≤ 8,5 | التطهير | *E. coli* ≤ 50عصية / 100مللتر و/أو 6,5> pH >8,5 و/أو عكارة>5 وحدات نفلومترية |
| 2 | جوفي غير محمي: 2-1 الفئة الأولى (مياه جوفية) | 20 ≥ *E coli* عصية/ 100 مللتر في أكثر من 20% من العينات المفحوصة خلال عام | عينة شهريًا، ولا يقل عن ثماني عينات سنويًا | العكارة لا تزيد عن 5 وحدات نفلومترية 6,5≤ pH≤ 8,5 | التطهير | *E. coli* ≤ 50عصية/ 100مللتر و/أو 6,5> pH >8,5 و/أو عكارة >5 وحدات نفلومترية |
| | 2-2 الفئة الثانية (مياه جوفية) | 2000 ≥ *E. coli* >20 عصية /100مللتر في أكثر من 20% من العينات المفحوصة خلال عام | 3 عينات في الأسبوع | العكارة لا تزيد عن 5 وحدات نفلومترية 6,5≤ pH≤ 8,5 | • أي من العمليات التالية: الترشيح السريع، الترشيح بالأغشية، التناضح العكسي، الترشيح الرملي البطئ المسبوق بعمليات الخلط والتخثير والترسيب.<br>• يتبع ذلك عملية التطهير | 5000 ≤ *E. coli* عصية/100مللتر و/أو 6,5> pH >8,5 و/أو عكارة>5 وحدات نفلومترية |
| | 2-3 الفئة الثالثة (مياه جوفية و/أو سطحية) | *E. coli* > 2000 عصية/100مللتر في أكثر من 20% من العينات المفحوصة خلال عام | 3 عينات في الأسبوع | العكارة لا تزيد عن 5 وحدات نفلومترية 6,5≤ pH≤ 8,5 | عمليات معالجة إضافية عما ورد للفئة الثانية | 20,000 < *E. coli* عصية/ 100ملليتر |

**Table 3** Classification of water resources according to the Jordanian Microbial Guideline.

| Classification | *E. coli* | Frequency of sampling | Further quality parameter | Req. treatment | Forced shout down |
|---|---|---|---|---|---|
| *1. Protected*<br>Groundwater Resource | -- No *E. coli* | -- one sample / month<br>-- at least eight samples per year | -- Turbidity not more > 5 NTU<br>-- 8.5 ≥ pH ≥ 6.5 | -- Disinfection | -- *E. coli* > 50 MPN/100ml<br>-- 8.5< pH < 6.5;<br>-- Turbidity > 5 NTU |
| *2. Non-Protected*<br>Groundwater Resource | | | | | |
| Catogary I<br>(Groundwater) | -- 20 MPN/100 ml in > 20% of the samples per year | -- one sample / month<br>-- at least eight samples per year | -- Turbidity not more > 5 NTU<br>-- 8.5 ≥ pH ≥ 6.5 | -- Disinfection | -- *E. coli* > 50 MPN/100ml<br>-- 8.5< pH < 6.5;<br>-- Turbidity > 5 NTU |
| Catogary II<br>(Groundwater) | -- 20 < *E. coli* > 2000 MPN / 100 ml in > 20% of the samples per year | -- three samples / week | -- Turbidity not more > 5 NTU<br>-- 8.5 ≥ pH ≥ 6.5 | Any of the following:<br>-- Disinfection<br>-- Rapid filtration<br>-- Nano-, Ultra-, Micro- filtration<br>-- Reverse osmosis<br>-- Slow sand filtration | -- *E. coli* > 5000 MPN/100ml<br>-- 8.5< pH < 6.5;<br>-- Turbidity > 5 NTU |
| Catogary III<br>(Ground- & Surfacewater) | -- 2000 MPN / 100 ml in > 20% of the samples per year | -- three samples / week | -- Turbidity not more > 5 NTU<br>-- 8.5 ≥ pH ≥ 6.5 | -- Same as for Category II | -- *E. coli* > 20000 MPN/100ml |