Protection of Jeita Spring

funded by BMZ
Federal Ministry
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COUNCIL FOR DEVELOPMENT AND RECONSTRUCTION

BGR Bundesanstalt für Geowissenschaften und Rohstoffe

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2013

German-Lebanese Cooperation Project *Protection of Jeita Spring*

Jeita Spring

Sound of roaring water – the literal translation from the Arabic *Jeita* (جعيتـــا) into English demonstrates the tremendous importance of the karst spring Jeita for Lebanon. With an annual discharge of around 170 million cubic meters it provides approximately 75% of the drinking water supply for the Greater Beirut area, home to almost 2 million people.

A *spring* is defined by the location where groundwater naturally exits the lithosphere to enter the free atmosphere or the sea. Such a *location*, however, may be difficult to define because of the areal extend of a spring. In fact, the *spring complex* Jeita consists of a 10 km long underground cave, which forms a grotto for the final 400 meters. Above of the grotto, a fossil gallery, partly directly connected to the grotto below, expands for 3 km. In total, this cave system is locally up to 100 meters high with an endless number of stalactites and stalagmites, as well as flow stones, sinter terraces, draperies and up to 10 meter high columns – altogether constituting a karst cave of incomparable genesis and state.

The cave's very good condition is related to its relatively recent discovery in 1836, by Reverend William Thomson. From this year on, the cave has been subject to intensive exploration by speleologists (*Speleo Club du Liban*). Since 1958, the upper galley has been open for the public, allowing visitors to directly feel the roaring water within Lebanon's most spectacular touristic sight - and most important source of water.

Groundwater Catchment of Jeita Spring

A hydrological catchment defines a certain land surface, in which surface water flows towards a specified point, the catchment's outlet. However, catchments can not only be related to surface water flows but also to groundwater flows, e.g. a spring.

A groundwater catchment defines the groundwater contribution zone, here that of Jeita spring. A surface catchment is delineated according to the relief of the surface, i.e. its topographic boundaries. Similar to a funnel, surface water flows along land surface following gravity towards a specified outlet point. However, part of that surface water will infiltrate into the underground, then forming groundwater. Groundwater catchments and surface water catchments can be very different in shape, especially in karstic areas, such as Lebanon. To define the boundaries of a groundwater catchment is much more challenging because it refers to water flows which take place in the rocks and are hidden from our direct observation. In karst systems groundwater flow takes place in fractures in the limestone rocks and large cavities which have developed over time by dissolution. Tracer tests (colorations) are the only means to determine the groundwater contribution zone of a spring or well. Springs are points where groundwater is discharged and reaches the land surface (or sea). Springs are the most important water source in Lebanon. Therefore it is important to understand the origin of this groundwater. Often surface water and groundwater are interconnected. Depending on the geological conditions, surface water could infiltrate in certain areas, while in other areas groundwater may discharge into surface water, often without notice.

The extent of a surface catchment and a groundwater catchment can be very different for the same outlet, as is the case for Jeita spring. Its surface catchment has a size of 249 km^2, including a large share south of *Nahr el Kalb* in the *Metn* district. This area in the *Metn* district, however, does not contribute to Jeita spring, i.e. is not part of the Jeita groundwater catchment. In turn, the groundwater catchment extends quite far beyond the northern and eastern limits of the surface catchment, covering an area of approximately 406 km^2, including large parts of the neighboring *Nahr Ibrahim* surface catchment.

Topography

The groundwater catchment of Jeita is located in the center of Lebanon, extending from approximately 15 km northeast of Beirut to the eastern limit of the Mount Lebanon mountain range, between *Mount Sannine* in the south and almost *Dahr el Kadib* in the north. In terms of elevation the Jeita groundwater catchment ranges between 60 m above mean sea level (asl) at Jeita spring and 2,626 m asl at *Mount Sannine*. The relief of the study area is shaped by prominent geological and tectonic features. The eastern part is dominated by a high plateau. Here there is almost no surface water runoff. There are close to 2,000 dolines on this plateau; there, during snow melt, water will rapidly infiltrate into groundwater. Also at medium elevation there are vast areas that are relatively flat due to the geological dip but are dissected in west-east direction by steep valleys. Towards west, near the coast, reliefs become steeper, coinciding with the appearance of the coastal flexure. The massive *Keserwan limestone* of the Jurassic often forms steep cliffs and narrow gorges, e.g. in the *Upper Nahr Ibrahim Valley*, near *Janne* or in the *Lower Nahr el Kalb Valley*, upstream of Jeita spring.

Hydrogeology

Hydrogeology is the discipline that deals with the occurrence of groundwater in the geological underground. Rocks that are permitting only very limited groundwater flow are called *aquitards*, while porous or karstified rock media, permitting groundwater flow are called *aquifers*. In Jeita's groundwater contribution zone we find alternating layers of aquitards and aquifers. The *Sannine Formation* (*Upper Cretaceous*) forms the *Upper Aquifer* and occurs mainly at higher altitudes. Four major springs discharge from this aquifer: Afqa, Rouaiss, Assal and Labbane. Below this aquifer we find, at intermediate elevations, a series of geological rock that are considered together as the *Aquitard*. Finally, in the lowest position in the groundwater system we have the *Lower Aquifer* in the *Keserwan Formation* (Jurassic). Both aquifers are highly fractured and karstified. Groundwater flows are controlled by the dip of the base of the aquifers and major tectonic elements such as faults, flexures and basalt intrusions (dykes). These are caused by tectonic activities, mainly related to the collision of the African and Arabian plates with the Eurasian plate, which have shaped the *European Alps*, the *Zagros Mountains* and the *Dead Sea Transform Fault System*, part of which is the *Beka'a Graben*. The tectonic movements, which occurred in the Mount Lebanon area

since the Tertiary, have shaped the Jeita groundwater catchment.
In an infiltration zone in the *Upper Nahr Ibrahim Valley* large amounts of surface water discharged from the Rouaiss and Afqa springs infiltrate into the *Lower Aquifer*. From there this infiltrated groundwater finds its way along conduits to Jeita. Thus flow from the Afqa catchment contributes to 24% and from the Rouaiss catchment to 16% of Jeita's annual discharge. Luckily, Jeita spring receives its major contribution from the *Sannine Formation* at higher altitudes, otherwise the Jeita groundwater would be much more polluted because of the numerous pollution sources in the lower part of the catchment. Due to the high karstification in the *Upper Aquifer*, groundwater recharge, i.e. the amount that infiltrates into the underground as percentage of the rainfall and snow, is around 75%. In the *Lower Aquifer* it is around 50%.

Climate

The regional climate is described as *Mediterranean*, with oceanic, i.e. wet, conditions during winter and sub-tropical, i.e. dry, climatic conditions during summer. In April conditions are classified as *semi-humid*, *arid* from May to the end of October, *humid* in March and November and *wet* from December until end of February.
Lebanon's narrow and flat coastal strip, extending north-south, is openly exposed to the Mediterranean Sea. Humid air that is carried from the sea towards the shore enters the land and moves upwards with the topography of the catchment (orographic lifting). By doing so, moist air is cooled down - resulting in fog during spring and autumn. Precipitation increases with altitude. On *Mount Sannine*, average annual precipitation is around 2,100 mm, while near the coast precipitation is only around 900 mm (Jeita: 919 mm). During the year, precipitation varies strongly: between October and April, the groundwater catchment of Jeita receives 97% of its annual precipitation. Between November and April precipitation at higher elevations falls as snow. Snowmelt occurring between March and May results in a rapid increase in groundwater flow from higher altitudes towards Jeita. These facts leads to the pronounced seasonal variation of spring discharge of Jeita.

Project Description

The German-Lebanese Technical Cooperation (TC) Project *Protection of Jeita Spring* is funded by a grant from the German Government (Ministry of Economic Cooperation and Development) to the Lebanese Government. Its aim is to "reduce important risks for the drinking water supply of Beirut through measures implemented in the Jeita catchment". On the German side, the project is implemented by the Federal Institute for Geosciences and Natural Resources (BGR). The project partners on the Lebanese side are the Council for Development and Reconstruction (CDR), the Ministry of Energy and Water (MoEW) and the Water Establishment Beirut Mount Lebanon (WEBML). Important components of the TC project are:

- Integration of water resources protection aspects into the investment planning and implementation process in the wastewater sector;
- Integration of water resources protection aspects into landuse planning and improved spring capture and water conveyance;
- Establishment of a monitoring system;
- Proposal for an improved Jeita spring capture and conveyance system to Dbayeh.

Raw water from the Jeita and Kashkoush springs is treated at the Dbayeh treatment plant where it arrives via a canal and tunnel system. This conveyance system is already more than 100 years old, leaky and also highly vulnerable to pollution. Because of the dependency on Jeita water, a major pollution event in the groundwater catchment of Jeita spring can heavily affect the health of the population in the Greater Beirut area that is served by Jeita water. Thus, prevention of GW-pollution is crucial - and raising awareness for the different hazards - is an important part of the project activities.

Achievements

- Identification of a suitable location for a wastewater treatment plant for villages in the lower groundwater catchment of Jeita spring;
- Establishment of a wastewater master plan;
- Delineation of the hydrological boundaries of the groundwater catchment through field studies, incl. tracer tests and stable isotope analyses;
- Collection of continuous discharge records for Jeita spring (every 20 minutes);
- Collection of water quality parameters (electrical conductivity, pH, temperature, turbidity, oxygen content);
- Establishment of a groundwater vulnerability map;
- Delineation of groundwater protection zones;
- Establishment of a hydrological model for the monthly water balance through Water Evaluation & Planning (WEAP);
- Systematic assessment of potential groundwater hazards;
- Providing advice to WEBML concerning urgent groundwater pollution problems;
- Establishment of a new geological map, incl. karst features;
- Awareness campaign in schools within the groundwater catchment.

TC of BGR in the MENA Region

Since 1959, BGR has conducted technical cooperation in the MENA region. The first bilateral cooperation has been agreed with Jordan. Until then, cooperation with Yemen, Syria and finally Lebanon has followed. At the regional scale BGR is conducting cooperation projects together with UN ESCWA (Economic and Social Commission of Western Asia) and ACSAD (Arab Center for the Studies of Arid Zones and Dry Lands). In the early years, the main focus of cooperation was on the establishment of national geological surveys and the exploration of mineral resources, such as the oilshales and phosphates in Jordan. Since the 1970s the main objective has shifted towards the assessment, development and protection of water resources in order to promote a sustainable use of this scarce and valuable resource in the region. Currently the water sector in the Middle East is in the focus of technical cooperation for BGR.

Snow is the lifeline of Lebanon. The high plateau in the east of the catchment is Jeita's main groundwater recharge area. Around 50% of the annual spring discharge comes from groundwater recharge taking place on this plateau, mainly during snowmelt in spring. Collecting hydroisotope samples was important to determine the average elevation of all groundwater catchments. This elevation is reflected by the ^{18}O and ^{2}H composition of the springs. Analyzing Jeita's isotopic composition made it possible to identify the mean catchment elevation and the shares of the different contributions of water to Jeita spring.

January 2013

Sun	Mon	Tue	Wed	Thu	Fri	Sat
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2.2 / 2.1

Drinking water supply is mostly based on springs. However, many springs are contaminated due to a high number of pollution sources resulting from a lack of landuse planning. Groundwater protection zones must be declared and water resources protection aspects have to be integrated into landuse planning so that springs could again safely be used for drinking water supply.

February 2013

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The rocks in Mount Lebanon consist predominantly of limestone. Limestone can be dissolved by water containing carbon dioxide (then forming carbonic acid). Dissolution, following preferred pathways, creates special karst features, such as conduits, often extending over several kilometers. Rain and contaminants can easily infiltrate in karst areas and reach groundwater. Transfer of water and contaminants in dissolution channels (conduits) can be very fast. In Mount Lebanon groundwater flow velocities reach up to 2 km per hour, as tracer tests have shown.

March 2013

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31						

4.2/4.1

At the beginning of the rainy season in October/November, rivers usually carry a very high pollution load. Within this period rivers turn black for several days and smell like wastewater. Treatment of such water for drinking purposes is not feasible. During these times springs and surface water should not be used for domestic supply.

Huge amounts of surface runoff are currently not used but flow into the sea. There are possibilities to artificially increase infiltration into groundwater (Managed Aquifer Recharge) or store surface water in dams. In both cases, sites have to be thoroughly investigated.

April 2013

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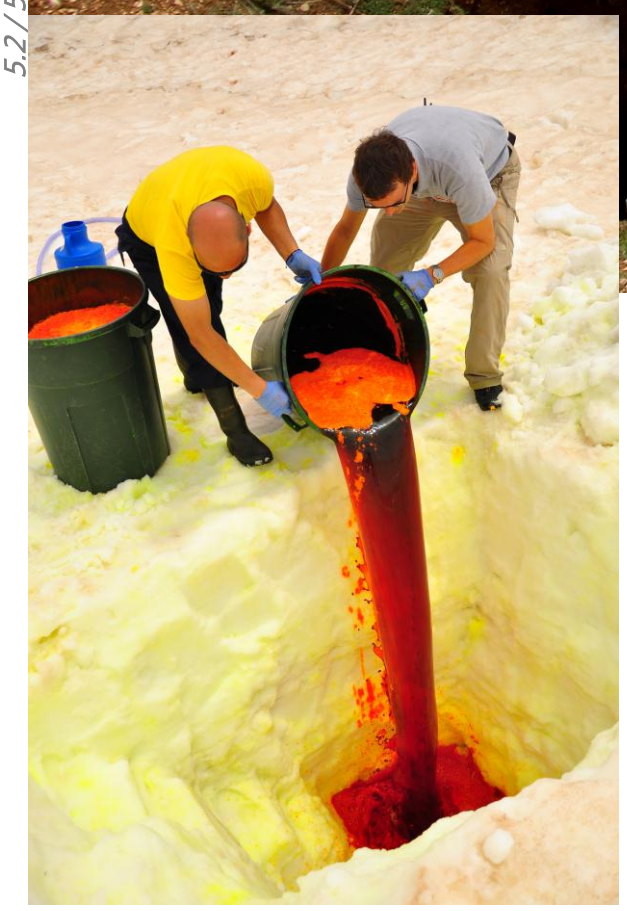
5.2/5.1



Tracer tests are commonly used in hydrogeology to determine the groundwater flow path in karst aquifers. The BGR project used more than a dozen tracer tests to assess the boundaries of the Jeita groundwater catchment and the flow velocities in the groundwater system. Different to previous assumptions it was proven that the Jeita groundwater catchment is very different from the Jeita surface water catchment. The groundwater catchment extends far towards north, where it covers around 50% of the neighboring Nahr Ibrahim surface water catchment.

May 2013

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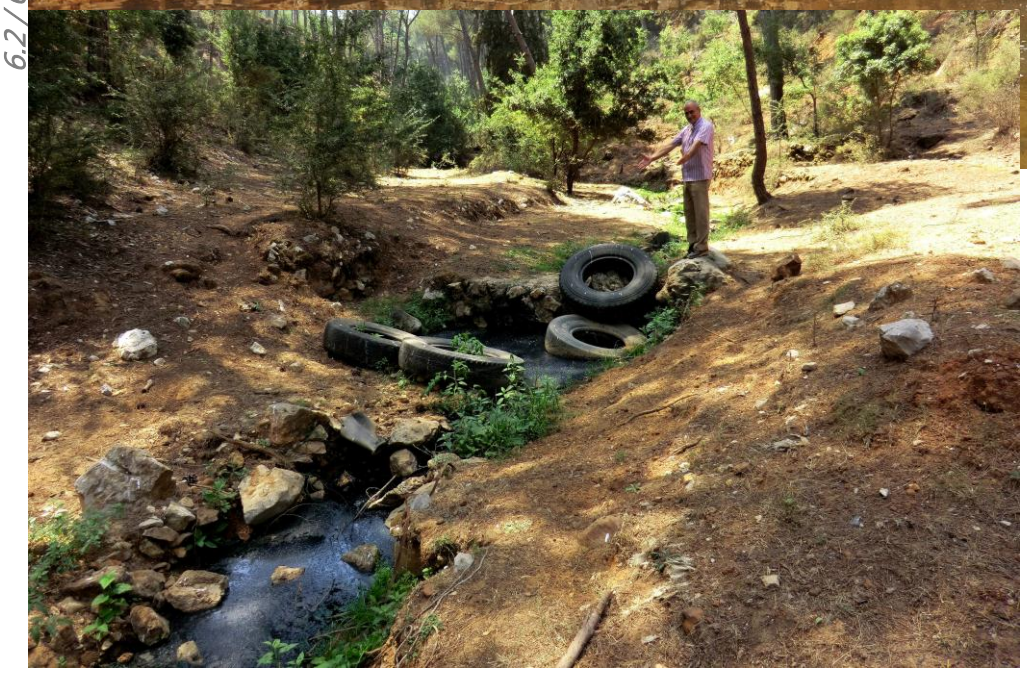
6.2/6.1



Until now, there is no wastewater collection and treatment system in the Jeita catchment. Untreated wastewater is often directly discharged into rivers or groundwater. This is the reason why bacteriological contamination of Jeita and other springs is continuously high. Two German projects are currently planning wastewater collection and treatment systems for large parts of the Jeita catchment in a coordinated effort to overcome this dangerous situation.

June 2013

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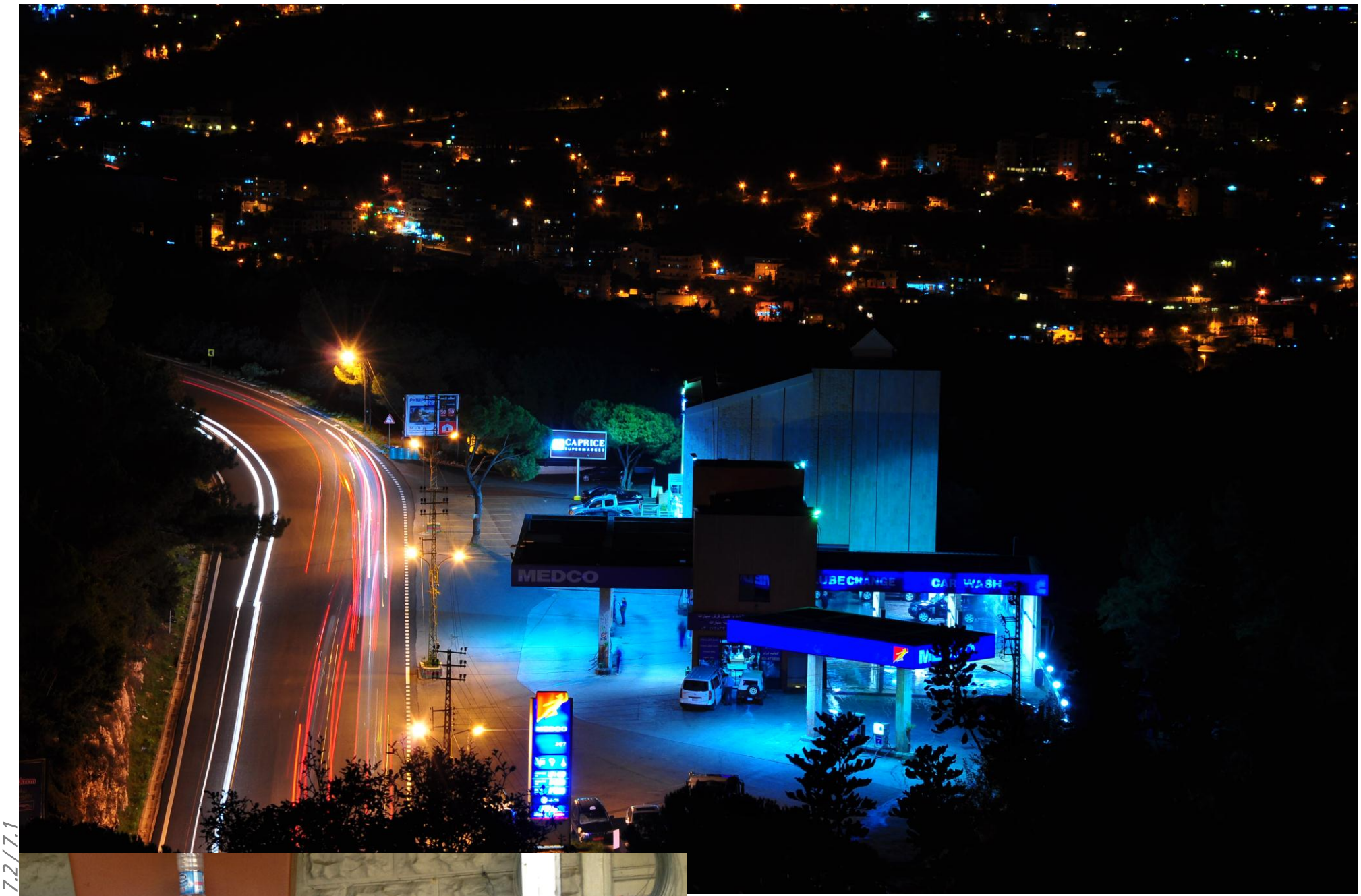

There are more than 80 gas stations in the Jeita groundwater catchment. None of them has double-layer tanks and leakage of oil and fuel is assumed to contribute to the contamination of Jeita spring. Permits for gas stations in the karst areas of Mount Lebanon should only be given if technical measures are installed that prevent contaminants from infiltrating into groundwater. No new gas stations should be allowed in groundwater protection zone 2.

July 2013

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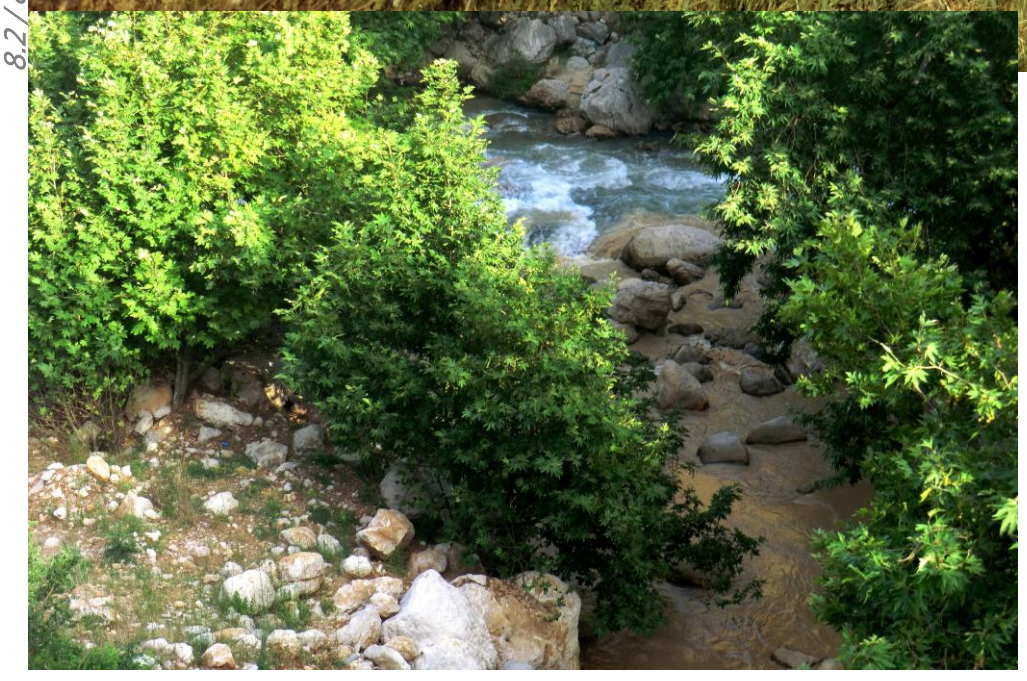
8.2/8.1



There are numerous sandstone- and limestone quarries in the Jeita groundwater catchment, although none of them has an official license. Two main problems are associated with these quarries. Fuel and oil used for the machines is not stored and handled in an environmental-friendly manner so that they can infiltrate into groundwater. Fine sludge from rock cutting factories and quarries infiltrate into groundwater causing high turbidity. This high turbidity creates huge problems for conventional treatment methods for drinking water.

August 2013

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9.2 / 9.1

Excessive use of fertilizers and pesticides can cause contamination of groundwater. Many farms use unfermented manure as fertilizer. Organic fertilizer must be treated before application in agriculture.

September 2013

Sun	Mon	Tue	Wed	Thu	Fri	Sat
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10.2 / 10.1

Living in the Jeita catchment has become popular. Over the past two decades residential areas have spread in an uncontrolled manner. All houses in the Jeita catchment have so-called cesspits which are open at the bottom or even injection wells to discharge untreated wastewater directly into groundwater. The severe deficits in landuse planning are the main reason for groundwater contamination.

October 2013

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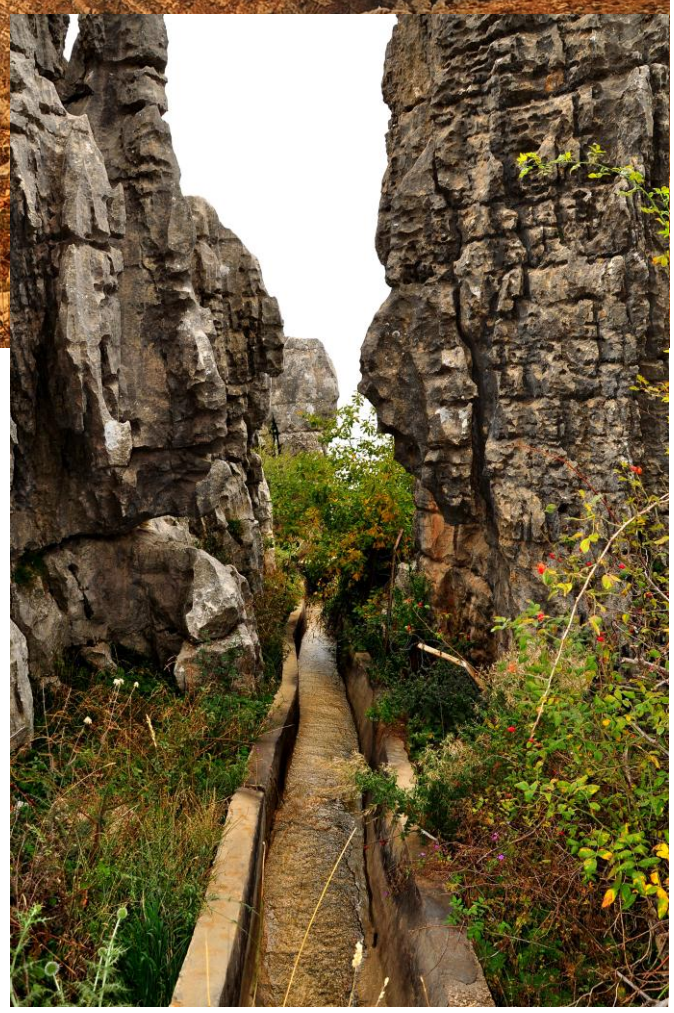

11.2 / 11.1

An effective water infrastructure needs proper planning and maintenance. The planning of dams in karst areas is a challenge. The geological and hydrogeological conditions need to be thoroughly investigated. Such investigations are often lacking professionalism as there is a considerable lack in such expertise in Lebanon. Projects, once conducted, are rarely professionally maintained. The Jeita - Dbayeh collector is one such example. It has been built some 140 years ago and has only been rudimentary maintained. If the conveyor or tunnel was damaged, the Greater Beirut Area would be practically without water for a long time.

November 2013

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12.2 / 12.1

Waste collection for household waste is managed through a private company (Sukleen). However, many commercial and industrial businesses do not properly dispose their wastes. There are several large illegal waste dumps in the Jeita groundwater catchment contributing to the contamination of the spring. Waste separation at household level (glass, paper, plastics and metals) would reduce waste volumes significantly and recycling would create major benefits for the society. Proper waste management is urgently needed for industrial-, commercial- and hospital waste.

December 2013

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
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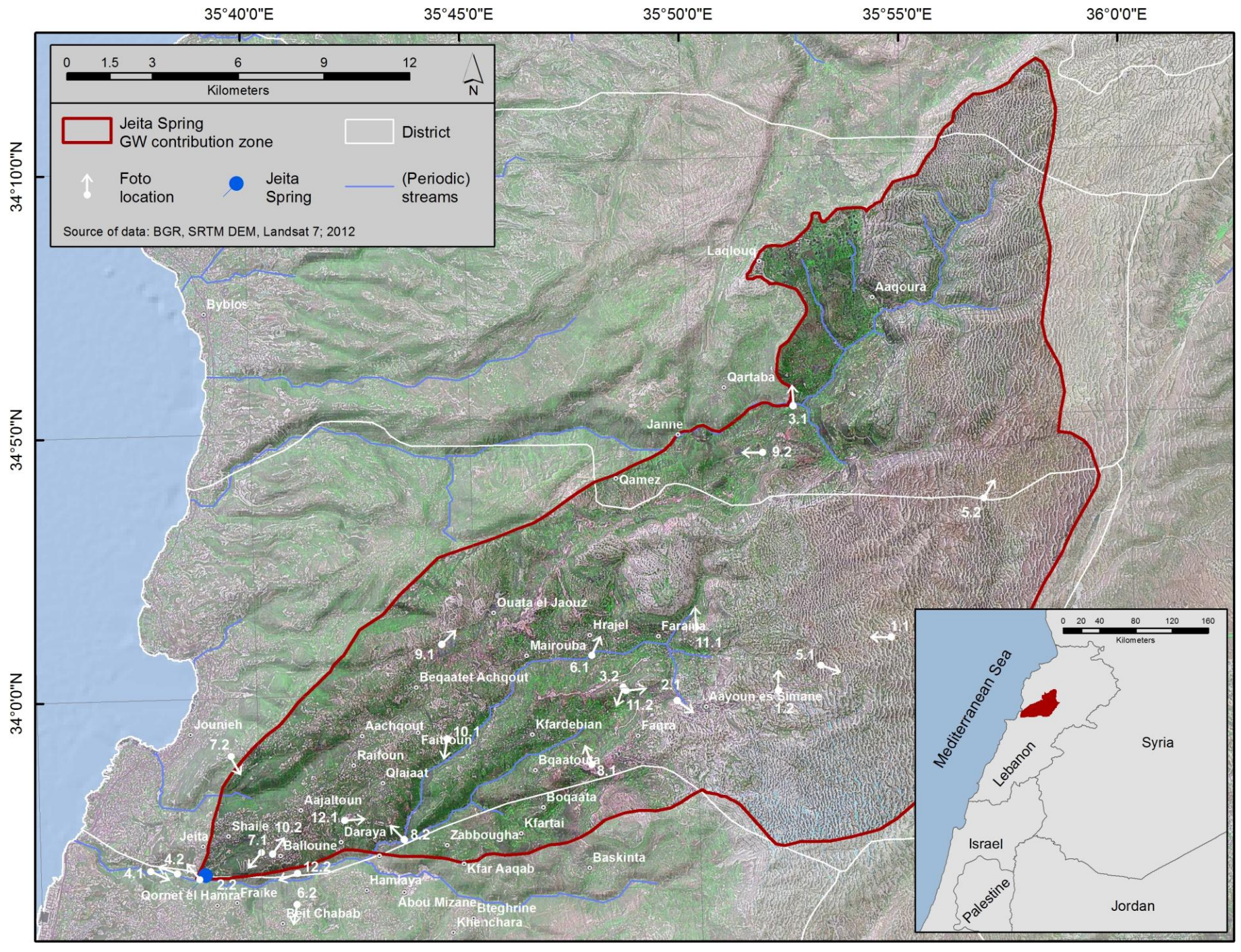
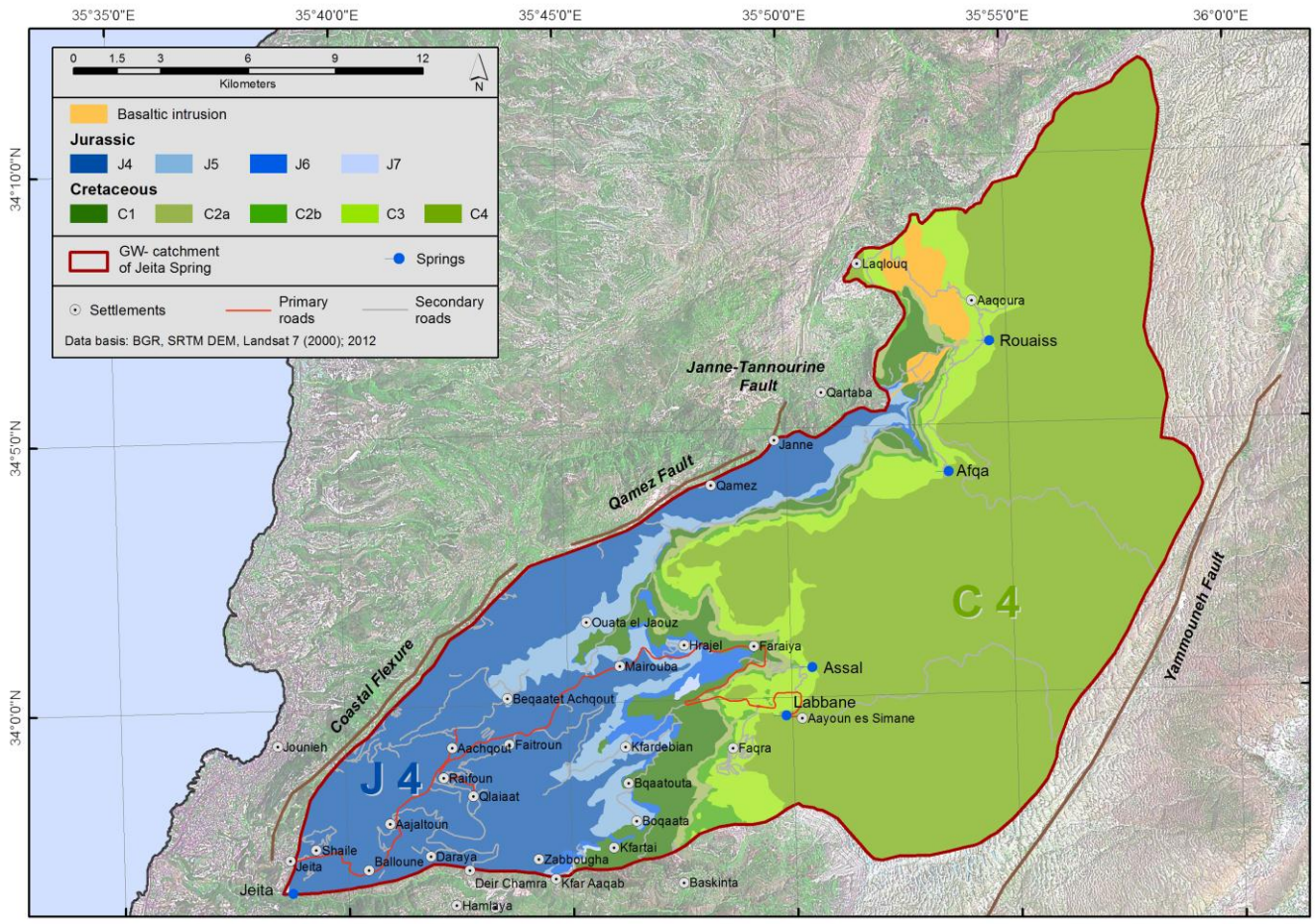
Annex

I. Foto Credits

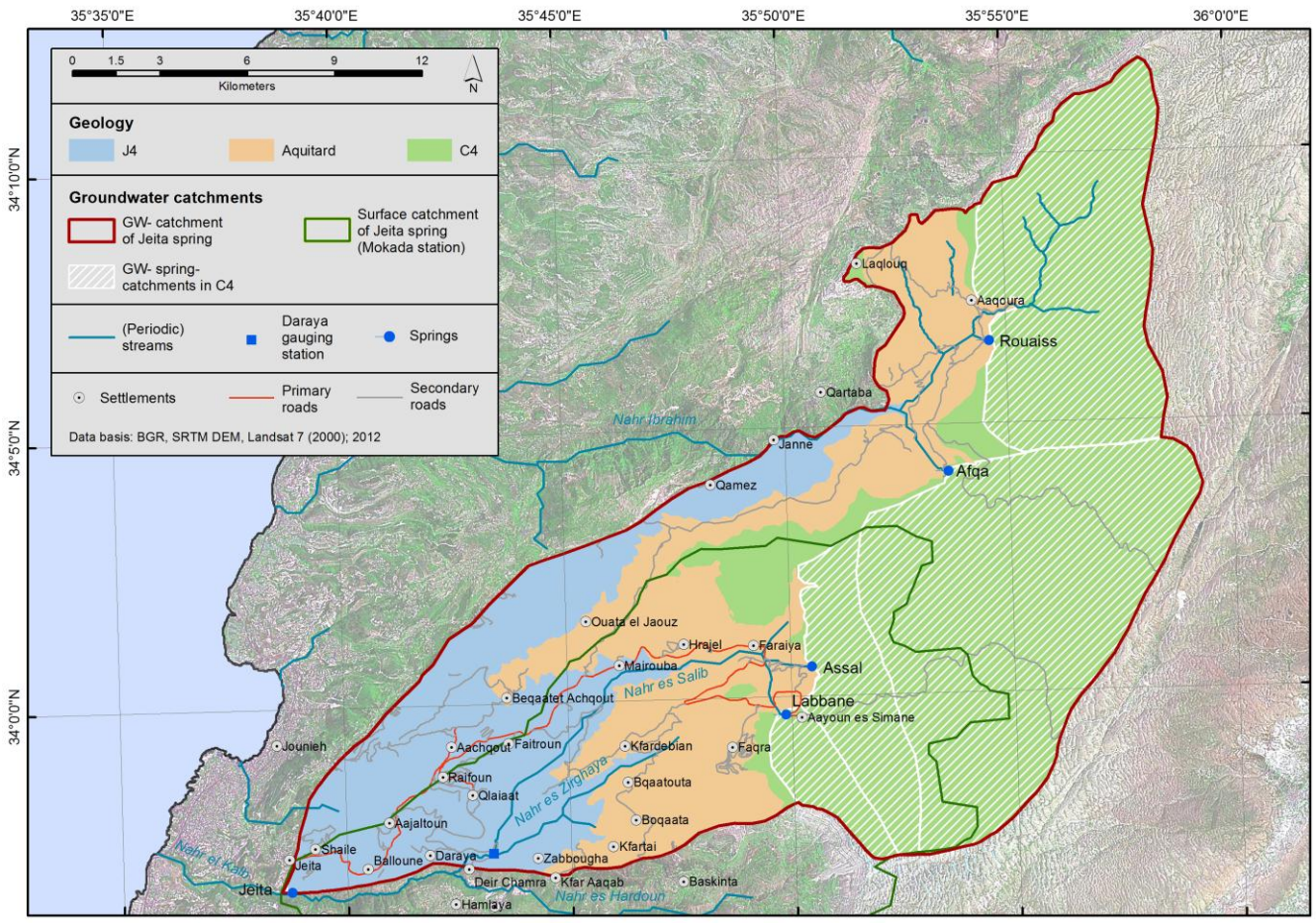
Foto ID	Description
Title	Snow cover on top of the C4 from a plane.
1.1	Snow cover on top of Mt. Sannine C4 geological unit.
1.2	Hydroisotope sampling campaign.
2.1	Labbane spring immediately downstream of the skiing resort Aayoun es Simane.
2.2	Jeita spring capture.
3.1	Prominent karst features and caves near the Nahr Ibrahim surface water infiltration zone at Yanouh (J4 geological unit).
3.2	Highly karstified C2b limestone near the Faqra archaeological site.
4.1	Nahr el Kalb River at Animal City (near Mokhada). Waste that is dumped near the river is carried away during periods of high water levels in the river.
4.2	The Jeita-Dbayeh water conveyor follows Nahr el Kalb River. The conveyor is around 140 years old and leaky. During periods of high water level in the river, polluted water from the river can enter the conveyor.
5.1	Tracer test 4B-2 was conducted in a sinkhole near Wardeh. All tracer was recovered in Afqa spring (mean travel time 42 hours, distance 7.3 km).
5.2	Uranine, an organic color commonly used for tracer tests, injected in a sinkhole during snowmelt in April 2012. Tracer arrived in Afqa (5.1 km distance) after 36 hours.
6.1	Discharge of wastewater into the surface water of Nahr es Salib in Hrajel.
6.2	The villages of Beit Chebab and Mar Boutros discharge untreated wastewater directly into Nahr el Kalb some 2-3 km upstream of Jeita spring. These wastewater discharges are believed to be the main pollution source for Kashkoush spring.
7.1	One of the many gas stations along the highway from Jeita for Aayoun as Simane.
7.2	Low awareness about the potential health threats of organic hydrocarbons.
8.1	Sandstone quarry near Faqra Club.
8.2	Sludge flushed from a sandstone quarry enters Nahr es Salib and causes high turbidity in Jeita spring.
9.1	Greenhouses near Ouida el Janus.
9.2	Irrigation pond near Lassa.
10.1	Housing project in the highly certified Flatiron area.
10.2	A cesspit for a new house in Ballooned is being prepared.
11.1	Chabrouh dam.
11.2	Irrigation canal crossing the Faqra archaeological site.
12.1	Dumping of construction waste near Mar Roukoz College.
12.2	Dumping of commercial waste near Balloune.



II. Geology



III. Hydrogeology



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Jean Abi Rizk, Geographer
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Philip Schuler, Geographer and Water Resources Manager

IV. List of Publications

MARGANE, A. & MAKKI, I. (2010): Reducing Pollution Risks for the Water Supply of Beirut in a Karst Aquifer. – World Water Week, 5-11 September 2010, Workshop 5: Management of Groundwater Abstraction and Pollution, Abstract Volume: p. 245-246; Stockholm.

MARGANE, A. & MAKKI, I. (2010): Reducing Pollution Risks for the Water Supply of Beirut in a Karst Aquifer. – Fifth Environmental Symposium of German-Arab Scientific Forum for Environmental Studies – Impact of Global Warming on Water Resources in the Middle East and North Africa, 20-21 September 2010, paper, poster and presentation, abstract volume; Byblos.

MARGANE, A. & TOLL, M. (2011): Integration of Water Resources Protection Aspects into the Planning of Wastewater Facilities in Lebanon and Syria. – Conference on Water and Climate Change in the MENA-Region Adaptation, Mitigation and Best Practices, 28-29 April 2011; Berlin. [abstract: http://www.menawater-2011-berlin.de/abstracts/Armin_Margane.html]

MARGANE, A., MAKKI, I., TOLL, M., SHALAK, K., GRIEB, A., DICKMANN, T. & JACOBI, S. (2011): Safeguarding the Drinking Water Supply of the Cities of Beirut and Damascus by Water Resources Protection in Karstic Environments. – World Water Week, 21-27 August 2011, Workshop 1: Cities in a 3-D Landscape Perspective - Hidden Risks, Abstract Volume: p. 28-29; Stockholm.

MARGANE, A. & MAKKI, I. (2012): Water Resources Protection for the Water Supply of Beirut. – Conference Hydrogeology of Arid Environments, 14-17 March 2012, paper, poster and presentation, conference proceedings: p. 89-91; Hannover. [Borntraeger]

MARGANE, A. & DOUMMAR, J. (2012): Delineation of the Groundwater Contribution Zone of Jeita Spring, Lebanon, using Tracer Tests in a Karst Aquifer System. – 39th IAH Congress, 16-21 September 2012, proceedings volume; Niagara Falls.

MARGANE, A. & MAKKI, I. (2012): Hydrogeological Investigations for Investments in the Wastewater Sector to Protect the Drinking Water Resources of Beirut in a Karst Aquifer. – 39th IAH Congress, 16-21 September 2012, proceedings volume; Niagara Falls.

KOENIGER, P. & MARGANE, A. (2012): Stable isotope studies on altitude effect and karst groundwater catchment delineation of the Jeita spring in Lebanon. – 39th IAH Congress, 16-21 September 2012, proceedings volume; Niagara Falls.

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