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TECHNICAL COOPERATION

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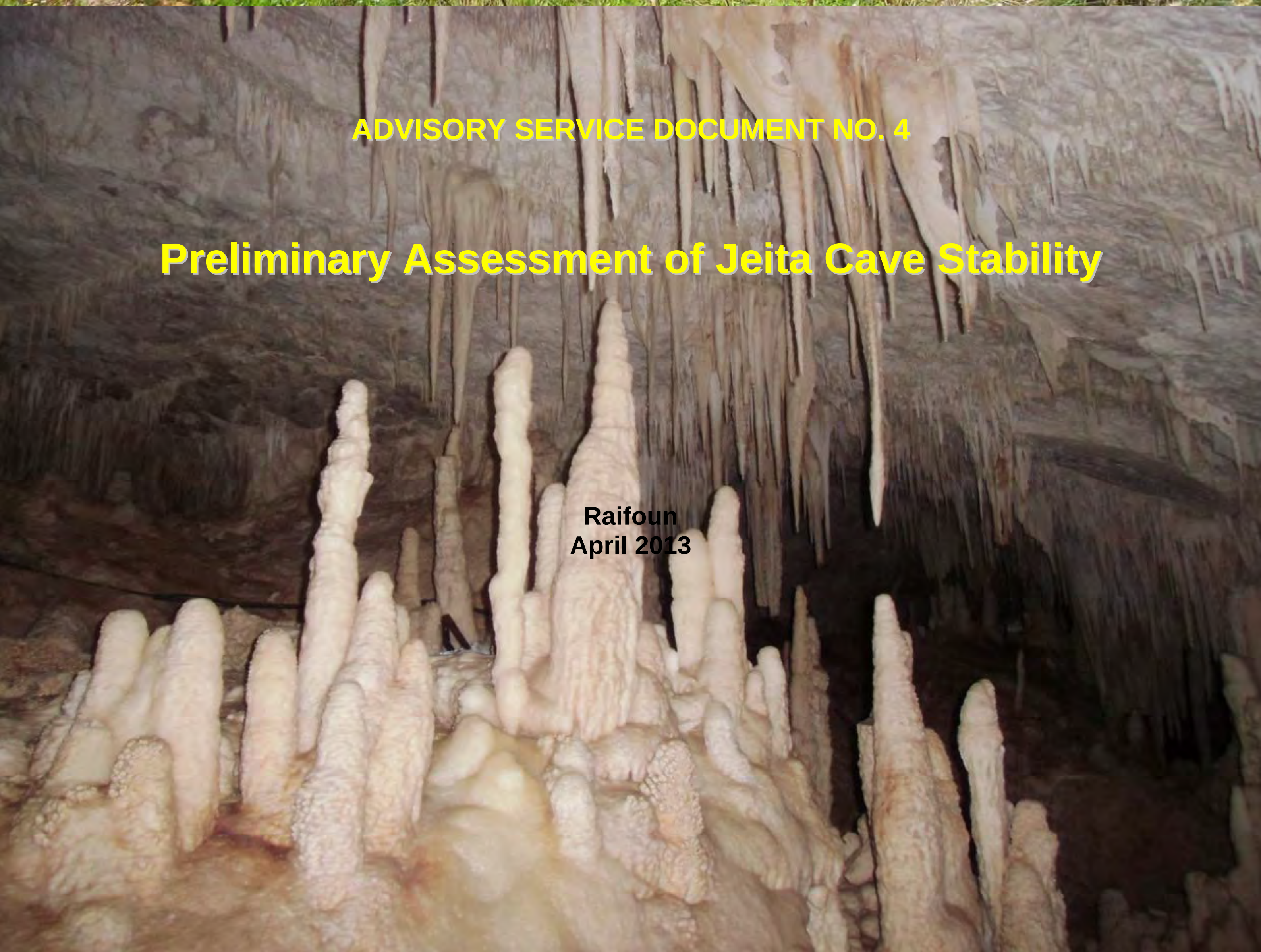
Protection of Jeita Spring



ADVISORY SERVICE DOCUMENT NO. 4

Preliminary Assessment of Jeita Cave Stability

Raifoun
April 2013

Preliminary Assessment of Jeita Cave Stability

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List of Abbreviations

asl	Above mean sea level
BGR	German Federal Institute for Geosciences and Natural Resources
BMZ	German Ministry of Economic Cooperation and Development
CDR	Council for Development and Reconstruction
GW	groundwater
KfW	German Bank for Reconstruction and Development (KfW Development Bank)
MAPAS	Company operating Jeita Grotto
MoEW	Ministry of Energy and Water
SW	Surface water
TC	Technical cooperation
WEBML	Water Establishment Beirut and Mount Lebanon
WW	Wastewater
WWTP	Wastewater treatment plant

List of Reports prepared by the Technical Cooperation Project Protection of Jeita Spring

Report No.	Title	Date Completed
Technical Reports		
1	Site Selection for Wastewater Facilities in the Nahr el Kalb Catchment – General Recommendations from the Perspective of Groundwater Resources Protection	January 2011
2	Best Management Practice Guideline for Wastewater Facilities in Karstic Areas of Lebanon – with special respect to the protection of ground- and surface waters	March 2011
3	Guideline for Environmental Impact Assessments for Wastewater Facilities in Lebanon – Recommendations from the Perspective of Groundwater Resources Protection	November 2011
4	Geological Map, Tectonics and Karstification in the Groundwater Contribution Zone of Jeita Spring	September 2011
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6	Water Balance for the Groundwater Contribution Zone of Jeita Spring using WEAP including Water Resources Management Options and Scenarios	March 2013
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4	Proposed National Standard for Treated Domestic Wastewater Reuse for Irrigation	July 2011
5	Artificial Tracer Tests 4B - May 2011*	September 2011

Report No.	Title	Date Completed
6	Artificial Tracer Tests 5A - June 2011*	September 2011
7	Mapping of Surface Karst Features in the Jeita Spring Catchment	October 2011
8	Monitoring of Spring Discharge and Surface Water Runoff in the Groundwater Contribution Zone of Jeita Spring	March 2013
9	Soil Survey in the Groundwater Contribution Zone of Jeita Spring	First Draft November 2011
10	Mapping of the Irrigation System in the Jeita Catchment	First Draft November 2011
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1 - 1	Addendum No. 1 to Main Report [Quantification of Infiltration into the Lower Aquifer (J4) in the Upper Nahr Ibrahim Valley]	June 2012
2	Locating the Source of the Turbidity Peaks Occurring in April - June 2012 in the Dbayeh Drinking Water Treatment Plant	June 2012

Report No.	Title	Date Completed
3	Locating the Pollution Source of Kashkoush Spring	September 2012
4	Preliminary Assessment of Jeita Cave Stability	April 2013
Reports with KfW Development Bank (jointly prepared and submitted to CDR)		
1	Jeita Spring Protection Project Phase I - Regional Sewage Plan	October 2011
2	Jeita Spring Protection Project - Feasibility Study - Rehabilitation of Transmission Channel Jeita Spring Intake – Dbaye WTP	May 2012
3	Jeita Spring Protection Project - Environmental Impact Assessment for the Proposed CDR/KfW Wastewater Scheme in the Lower Nahr el Kalb Catchment	In Progress

* prepared in cooperation with University of Goettingen

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0 Executive Summary

The Technical Cooperation (TC) Project Protection of Jeita Spring is implemented by BGR and CDR with the aim to reduce pollution in the groundwater catchment of Jeita spring. This report presents investigations carried out within the framework of the environmental impact assessment for the Mokhada wastewater treatment plant currently under planning by the Council for Development and Reconstruction (CDR) and the KfW Development Bank in the framework of the Jeita Spring Protection Project (GITEC, 2011). The BGR project provides geoscientific advice to this project (MARGANE, 2011; MARGANE et al., 2011; GITEC & BGR, 2011; MARGANE & ABI RIZK, 2011).

The Greater Beirut Area receives its major share of water from Jeita spring. Through field observations **the thickness of limestones overlying Jeita Grotto was found to be reduced to between 60 and 75 m**, in a valley directly overlying the upper level of Jeita Grotto and the underground river of Jeita**.** This geological overburden is believed to be highly karstified, fractured and cavernous and Jeita cave may collapse in this area in case of exertion of natural forces (earthquake, tectonic movements) or human activities such as construction excavations.

Constructions in the high-risk zone of cave collapse, located entirely in the municipality of Jeita, carry a high risk of cave collapse. Cave collapse might occur in the touristic part of Jeita Grotto and endanger lives of visitors and staff. **A critical zone for cave collapse was delineated. It is strongly recommended to ban further development and construction activities in this high-risk zone with immediate effect.**

Permanent water flows from the valley to the upper level and finally to the lower level of the Jeita Grotto (underground river) have been observed. Untreated wastewater is currently being discharged from houses built on the escarpment overlooking this valley. Because this may lead to direct pollution of the drinking water source of Jeita spring, currently constituting around 70 % of drinking water supply in the Greater Beirut Area, **the valley has been classified as groundwater protection zone 1**. Protection zone 1 constitutes the area with highest requirements to water resources protection and under normal conditions access to persons without authorization (water utility staff) is blocked. **The project kindly requests the Ministry of Energy and Water to find a practicable solution for the optimal protection of groundwater in this built-up area.**

Both, cave collapse and groundwater pollution would have a disastrous effect on water supply and the use of Jeita Grotto (MAPAS) as the most important touristic site in Lebanon, if current landuse practices are

continued without action and a construction ban was not immediately implemented.

1 Introduction

The work presented in this report was conducted in the framework of the German-Lebanese Technical Cooperation project *Protection of Jeita Spring*.

The German-Lebanese Technical Cooperation (TC) Project *Protection of Jeita Spring* is funded by a grant of the German Government (Ministry of Economic Cooperation and development, BMZ). 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:

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

Jeita spring constitutes around 70 % of the water supply for the Greater Beirut Area has thus an immense importance. Because of the dependency on Jeita water, a major pollution event in the groundwater (GW) catchment of Jeita spring can impact heavily on the health of the population being served by Jeita water.

In the framework of environmental impact assessment (EIA), done for the planned Mokhada wastewater treatment plant (WWTP), the alignment of the collector lines were investigated. During this investigation it became obvious that there is an area, directly overlying the upper level of Jeita Grotto, which is covered by only a very thin geological overburden. Measurements of the absolute elevation of the land surface and the ceiling of the cave were done. At some places this overburden reaches only 60-75 m. Even within this overburden there might be caves. The underground river follows this valley and the upper level and lower level of the cave are connected under this valley.

A high risk of cave collapse and at the same time a high risk of contamination of Jeita spring water was assumed. The investigation focused on the thickness and constitution of the geological overburden.

2 Description of Measurements

The upper level of Jeita Grotto was surveyed by SCL (KARKABI, 1990). This map was later elaborated by VERHEYDEN et al. (2008) but without having a coordinate system. The BGR project georeferenced the map starting from the end of the entrance tunnel to the upper level in the UTM36N grid. The E/N (xy) accuracy is estimated at ± 10 m. Absolute elevation (z) reference was established using a calibrated Greisinger GTD 1100 piezo precision barometer (accuracy ±1.5 mbar) calibrated at the sea near Dbayeh. Elevation determined by the barometer was controlled using the Garmin Oregon 450ht GPS with barometric compensation. Total z accuracy is estimated at ± 2 m.

The top of the cave ceiling was measured using the calibrated barometer and a Bosh laser DLE 50 Professional (for distances of up to 50 m; accuracy 1.5 mm). Topography in the valley was established following a track along the deepest point wherever possible.

3 Determination of the High-Risk Zone for Cave Collapse

The map of the upper level of Jeita cave, adopted from VERHEYDEN et al. (2008), is shown in Figure 1. Four points were measured by the BGR project (the elevation of the ceiling is given in brackets):

- endpoint of entrance tunnel to upper level (100 m asl)
- the water pools at the "grand gours" (125 m asl)
- the touristic endpoint at the "salle du concert" at the last platform (platform-3) (155 m asl)
- the highest point of the ceiling of the cave in the upper level (beyond the accessible part for tourists) (161 m asl)

Between the pools and the highest point, the cave has a SW-NE direction and follows the course of the underground river. Here, the cave is directly under the valley (Figures 2, 3). The underground river is at approximately 60 m asl.

The valley is deeply incised. The difference in elevation between escarpment and valley bottom partly exceeds 50 m. The topography in the valley was surveyed, following the bottom of the valley between the residential area and the Hamilat Ttyb monastery of the Sauveurs sisters (track shown in Figure 4).

The superposition of both data shows that :

- at the pools, which is continuously fed by water, the **thickness of the overburden is around 75 m** (200 m -125 m). This water must come from infiltration near the land surface. A layer of round 6-10 m thick deposits of construction waste has been dumped here above the upper level pools so that the overburden must partly be less than 75 m !
- at the highest point in the cave the **thickness of the overburden may only be 60 m** (225 m - 161 m).

This zone of overburden is part of the uppermost J4 geological unit, commonly highly karstified and cavernous (ABI RIZK & MARGANE, 2011; MARGANE, 2012a, b). Between the land surface and Jeita cave there may be other yet undetected caves or dissolution channels in the limestone. The ceiling of the upper level shows that the limestones are highly fractured and water flows permanently along those fractures (Figure 5). Due to the fractures, assumed dissolution channels and caves, the ceiling of the cave is believed to be at high risk of collapse. In historic times the cave had already experienced an extensive collapse at this point. The large amounts of soil deposited at the 'salle du concert' are witness for a transport of soil from the land surface (valley) to this point probably during and after cave collapse.

The critical zone in which there is a high risk for cave collapse is shown in Figure 6. It covers the area near the valley where geological overburden is minimal and that part overlying Jeita Grotto upper level to the SE, i.e. on the property of the Hamilat Ttyb monastery.

The municipality of Jeita has allowed construction of multi-storey residential buildings to the north of the valley (Figure 7). Extensive amounts of construction waste (around 6-10 m thick above the upper level pools) have been dumped here into the valley (Figure 8). Wastewater is discharged into the valley through pipes (Figure 9) or open cesspits.

Any excavation activity may cause cave collapse and thus lead

- **to the destruction of the touristic attraction with highest value for Lebanon - the Jeita Cave; and**
- **to the blockage of Jeita spring water and thus the disruption of the water supply for the Greater Beirut Area.**

<u>Consequences</u>

It is proposed that with immediate effect the following action should be taken:

- **construction ban (also for existing permits) in the entire critical zone for cave collapse;**
- **rerouting of proposed main wastewater collector for Mokhada WWTP** (already agreed; Figure 11).

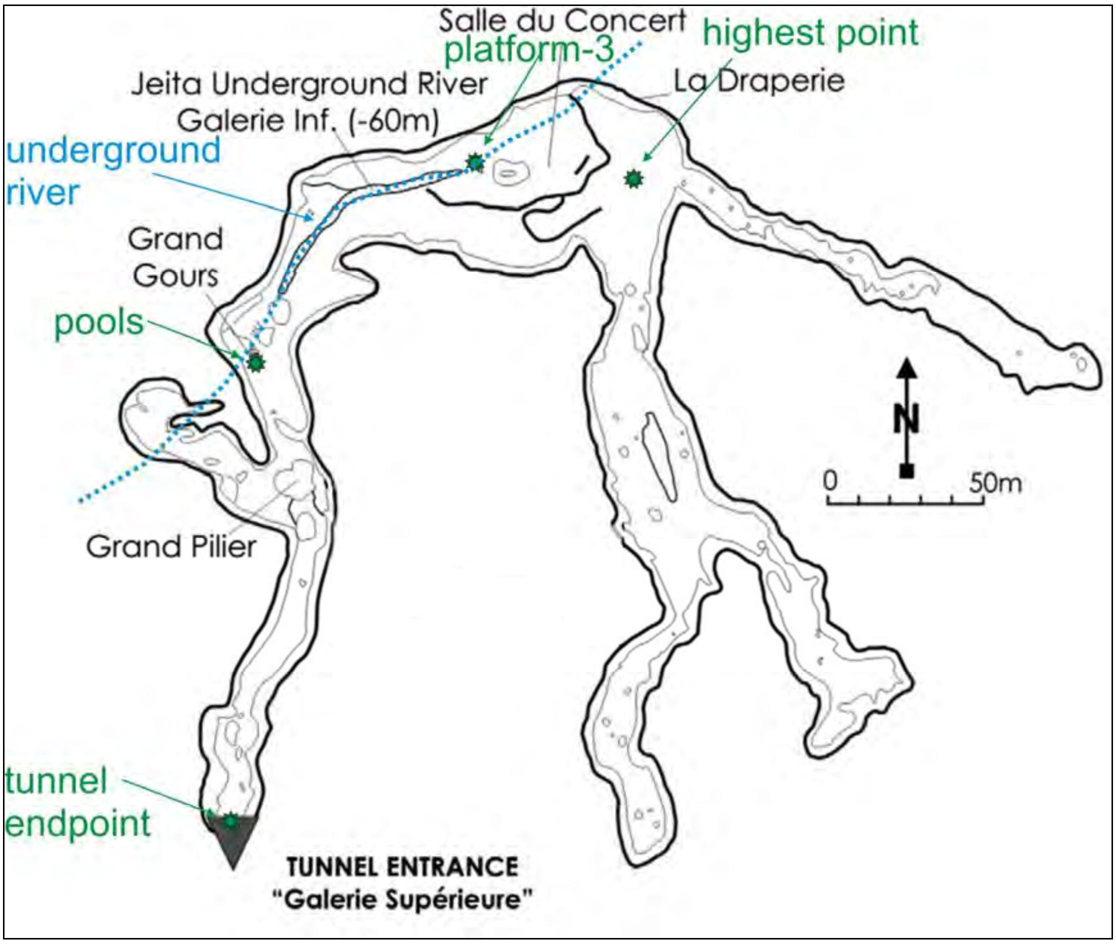

Figure 1: Topographic map of Jeita cave upper level with measured points (green)
(modified after VERHEYDEN et al. (2008))

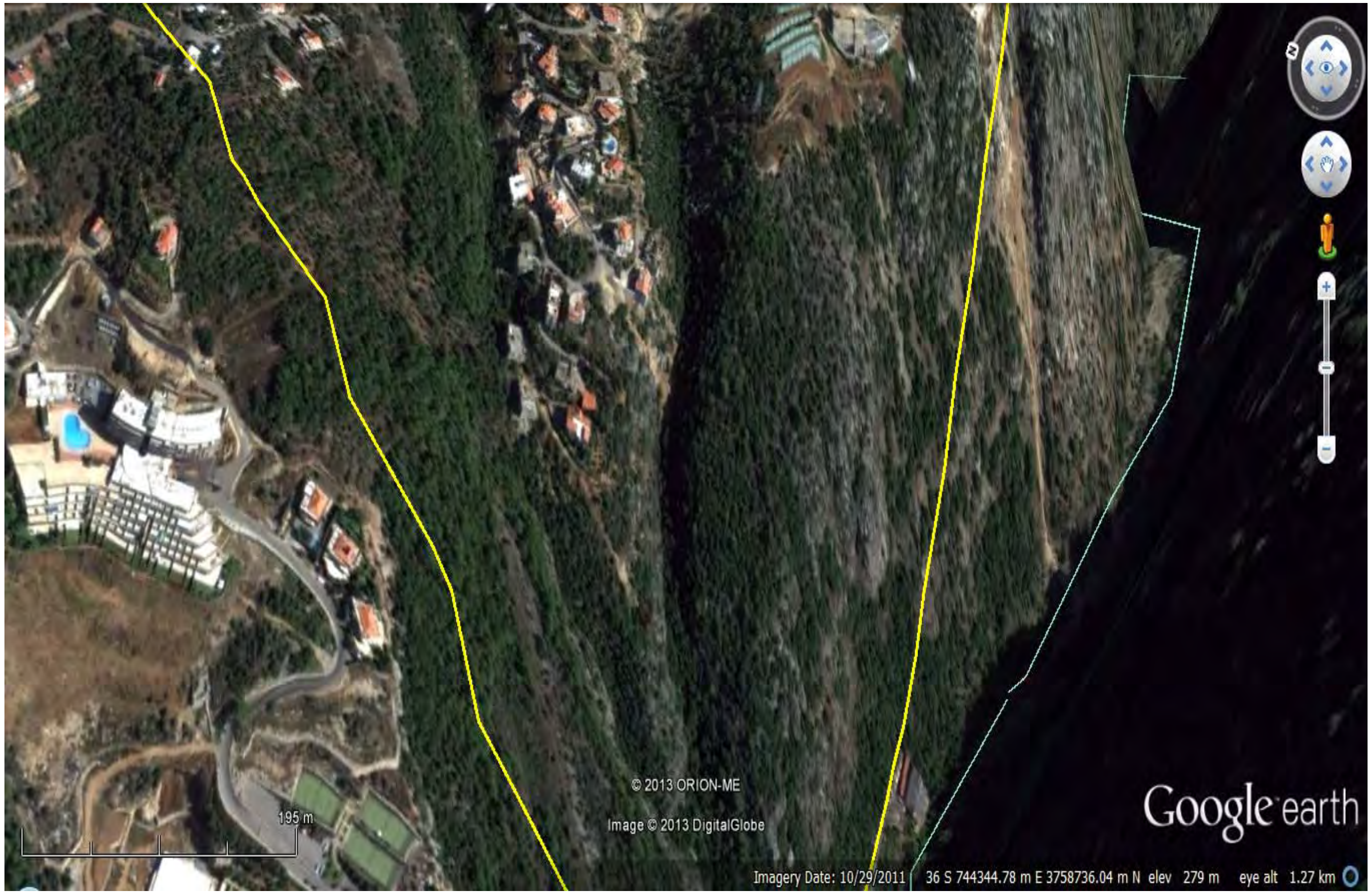

Figure 2: 3D view towards high-risk zone from W with topography in Jeita cave upper level

Figure 3: Superposition of Jeita cave upper level, underground river and satellite map in Google Earth

Figure 4: Topographic survey of Valley (following deepest topographic point) with measured elevations

Figure 5: Development of interconnected columns (calcium carbonate precipitation) along a fracture in the Jurassic (J4) limestones in the Jeita Grotto upper level at the critical zone of cave collapse

Figure 6: Critical zone for cave collapse

Figure 7: Construction of multi-storey buildings at the escarpment of the valley with dumping of construction waste into the valley

Figure 8: Extensive dumping of construction waste in the valley overlying Jeita cave upper level

Figure 9: Wastewater discharge into valley from residential buildings

4 Risk of Groundwater Contamination

In the entire area following the valley there is a high risk of groundwater contamination due to the fact that the geological overburden is of very low thickness and most likely consists of highly karstified, fractured and cavernous limestone, permitting rapid infiltration. The upper level of the cave is hydrogeologically connected with the underground river as is witnessed by the flow of water from the pools to the underground river. During the past three years we have been more than 100 times passing this water fall in the lower cave. Although during summer the amount of water is less than during winter, the flow of water never ceased.

Infiltration of contaminated water must be strictly avoided for protection of the Jeita spring which is used as drinking water in the Greater Beirut Area and for protection of the touristic environment in the upper level cave. Infiltration of contaminants may lead to unpleasant odors and unwanted colorations of the cave walls.

Due to the fact that a direct infiltration from the land surface can rapidly reach the drinking water source of Jeita, GW protection zone 1 was extended to this part of the valley (Figure 10).

Figure 10: Groundwater Protection Zone 1

Within GW protection zone 1 there is normally no access to persons other than authorized staff (i.e. access should principally be granted only for authorized water utility staff). There are, however, some building already established. Unless the government decides to remove those buildings and compensate the owners, usage with certain limitations has to be allowed.

Access for cars (visitors, others) must be physically blocked (check point or gate). **Cars repairs, dumping or burning of waste, discharge of wastewater, use of fertilizers and pesticides within the properties of the owners of houses inside zone 1 cannot be allowed. A wastewater collection system should be established for the buildings inside zone 1 immediately and with high priority.**

It is recommended

- to erect a wall at the road to avoid dumping of waste or wastewater by tankers;
- to ban discharging wastewater into the valley and to inform all households which are currently doing so;
- to not allow the building of new houses or the extension of existing houses along the entire valley (up to Saint Sauveur school).

The Hamilat Ttyb monastery of the Sauveurs sisters is located in GW protection zone 2A. It has an approx. 4,000 m² large agricultural production area, where mainly produce tomato, cucumber, cabbage, parsley and coriander is grown. The monastery uses pesticides and chemical fertilizers. In GW protection zone, however, only sterilized organic fertilizers are allowed to be used, while pesticides are not allowed.

5 Rerouting of Wastewater Collector

Initially it was planned to lay down the main wastewater collector of the Mokhada wastewater treatment plant (WWTP) inside the newly proposed groundwater protection zone 1 (Figure 10; MARGANE & SCHULER, 2013) and inside the high-risk zone for cave collapse (Figure 6).

Due the high risk of wastewater infiltration and cave collapse the BGR project proposed the main wastewater collector ('escarpment collector') to be rerouted to the location shown in Figure 11. This proposal was accepted by the CDR/KfW Jeita Spring Protection Project (JSPP).

Figure 11: Proposed Rerouting of Main Wastewater Collector of the Mokhada WWTP

6 Conclusions and Recommendations

The field work conducted by the BGR project showed that a large part of the upper level of Jeita Grotto is overlain by only a very thin layer of highly karstified, fractures and cavernous limestone. The overburden is estimated to be only 60-75 m under the deeply incised valley between Jeita and Jeita Grotto. Cave collapse is an immanent risk in this zone due to the possibility of earthquakes, tectonic movements or human activities, such as excavations, exerting forces of pressure on the rocks. **A critical zone of cave collapse was delineated. In this zone no construction of any kind should be allowed.** Also existing construction permits should be withdrawn. The wastewater collector, currently planned by the CDR/KfW Jeita Spring Protection Project, must be rerouted. This was already agreed by CDR.

The valley was classified as groundwater protection zone 1, due to the high risk of infiltration of contaminants reaching groundwater rapidly. Part of protection zone 1 is already inhabited and untreated wastewater from the existing houses is directly discharged to the valley. Therefore there is an urgent need to collect wastewater from these buildings. **The construction of a wastewater collector in this groundwater protection zone must have highest priority.**

If no action is taken, this may lead to

- **the destruction of the touristic attraction with highest value for Lebanon - the Jeita Cave; and**
- **the blockage of Jeita spring water and thus the disruption of the water supply for the Greater Beirut Area.**

Inspections are required to follow up on implementation. The municipality of Jeita should document and report regularly to the Ministry of Energy and Water that it is implementing the proposed recommendations.

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