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Council for Development and Reconstruction
CDR
Beirut

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Federal Institute for Geosciences and Natural Resources
BGR
Hannover

TECHNICAL COOPERATION

PROJECT NO.: 2008.2162.9

Protection of Jeita Spring

ADVISORY SERVICE DOCUMENT NO. 1
– ADDENDUM NO. 1 –

Quantification of Infiltration into the Lower Aquifer (J4) in the Upper Nahr Ibrahim Valley

Raifoun
June 2012

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Quantification of Infiltration into the Lower Aquifer (J4) in the Upper Nahr Ibrahim Valley

Author: Dr. Armin Margane (BGR)

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List of Abbreviations

asl	Above mean sea level
bgl	Below ground level
BGR	Federal Institute for Geosciences and Natural Resources www.bgr.bund.de
BMZ	German Ministry of Economic Cooperation and Development www.bmz.de
C4	Sannine Formation (limestone; Cretaceous)
CAS	Chemical Abstracts Service (www.cas.org)
CDR	Council for Development and Reconstruction www.cdr.gov.lb
D	deuterium
DEM	Digital elevation model
GW	Groundwater
J4	Keserwan Fromation (limestone and dolomite; Jurassic)
J5	Bhannes Formation (basalt; Jurassic)
LRA	Litani River Authority
K+A	Khatib and Alami
MAR	Managed aquifer recharge (artificial groundwater recharge)
MCM	Million cubic meters
MoEW	Ministry of Energy and Water
NTU	Nephelometric turbidity units
O-18	Oxygen-18 isotope
ppb	Parts per billion
TC	Technical Cooperation
UTM	Universal Transverse Mercator
WEBML	Water Establishment Beirut and Mount Lebanon

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	First Draft September 2011
5	Hydrogeology of the Groundwater Contribution Zone of Jeita Spring	In progress
6	Water Balance for the Groundwater Contribution Zone of Jeita Spring using WEAP including Water Resources Management Options and Scenarios	In progress
7	Groundwater Vulnerability Mapping in the Jeita Spring Catchment	April 2012
Special Reports		
1	Artificial Tracer Tests 1 - April 2010 (prepared with University of Goettingen)	July 2010
2	Artificial Tracer Tests 2 - August 2010 (prepared with University of Goettingen)	November 2010
3	Practice Guide for Tracer Tests	Version 1 January 2011
4	Proposed National Standard for Treated Domestic Wastewater Reuse for Irrigation	July 2011
5	Artificial Tracer Tests 4B - May 2011 (prepared with University of Goettingen)	September 2011
6	Artificial Tracer Tests 5A - June 2011 (prepared with University of Goettingen)	September 2011
7	Mapping of Surface Karst Features in the Jeita Spring Catchment	October 2011
8	Monitoring of Spring Discharge Investigations in the Groundwater Contribution Zone of Jeita Spring	In Progress

Report No.	Title	Date Completed
9	Soil Survey in the Investigations 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
11	Artificial Tracer Tests 5C - September 2011 (prepared with University of Goettingen)	February 2012
12	Stable Isotope Investigations in the Groundwater Contribution Zone of Jeita Spring	In Progress
13	Micropollutant Investigations in the Groundwater Contribution Zone of Jeita Spring	May 2012
14	Guideline for Gas Stations - Recommendations from the Perspective of Groundwater Resources Protection	May 2012
15	Tritium - Helium Investigations Investigations in the Groundwater Contribution Zone of Jeita Spring	In Progress
16	Hazards to Groundwater and Assessment of Pollution Risk in the Jeita Spring Catchment	In Progress
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1	Quantification of Infiltration into the Lower Aquifer (J4) in the Upper Nahr Ibrahim Valley	May 2012
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

0 Executive Summary

Four discharge measurement campaigns have been conducted between 30 April and 25 May 2012. The results of the first two campaigns were documented in the Advisory Service Document No. 1, submitted on 21 May 2012. In order to give timely advice to the Lebanese Government all results obtained between 20 May and 02 June 2012 are documented in Addendum No. 1. More Addenda will follow when more results of importance for the proposed Janneh dam become available.

The aim of the discharge measurement campaigns 3 and 4 were to

a) confirm the results of the first two tests;

b) try to access the infiltration zone and narrow down its exact location and extent.

Tests 3 and 4 confirmed the results of the first two tests.

The results of all four discharge measurement campaigns are:

Date	Rouaiss [m³/s]	Afqa [m³/s]	Afqa+Rouaiss [m³/s]	Yanouh [m³/s]	infiltration [m³/s]	infiltration [%]
4/30/2012	47.0	26.7	73.7	40.3	33.4	45.3
5/16/2012	21.6	22.7	44.3	28.8	15.5	35.0
5/22/2012	12.1	17.4	29.5	14.3	15.2	51.5
5/25/2012	10.7	15.0	25.7	14.0	11.7	45.5

All four tests prove that a massive infiltration into the J4 aquifer exists in the Upper Nahr Ibrahim Valley. Infiltration varied between 35 % and 52 %. The main infiltration zone was identified but infiltration may also exist elsewhere. Further tests are needed and will be conducted by BGR.

The extent of the infiltration zone could be narrowed down slightly to the zone shown in Figure 23.

The lowest elevation of the assumed infiltration zone could be at approx. 800 m asl. There is a prominent cave at this location which is assumed to reach the valley bottom. **In any case the minimum storage level of the proposed Janneh dam of 834 m asl could most certainly never be reached. Janneh dam would act as an artificial recharge dam for Jeita spring.** It will be tried to access the infiltration zone during low flow.

In view of the current findings, it is strongly recommended not to go ahead with the construction of the planned Janneh dam.

In view of the current findings, it would not make sense to go ahead with the construction of the planned Janneh dam.

The infiltrating water is believed to flow towards Jeita spring, constituting a large share of discharge at Jeita spring. Any interference at the infiltration zone would directly affect Jeita spring. Should it be

attempted to seal the infiltration zone, though practically impossible, discharge at Jeita spring would be significantly reduced.

It is of utmost **importance to conduct the tracer test proposed to WEBML and Khatib and Alami in a borehole at Saraita, to be drilled by WEBML. A related request was submitted to WEBML and Khatib and Alami on 22 May 2012.**

1 Investigation Area

The assumed groundwater contribution zone of Jeita spring is shown in Figure 1 (MARGANE et al., in progr.).

During the first two measurements the infiltration could be narrowed down to an area between around 3,800 m upstream of the proposed Janneh dam going up for around 1 km (Figures 2 and 3).

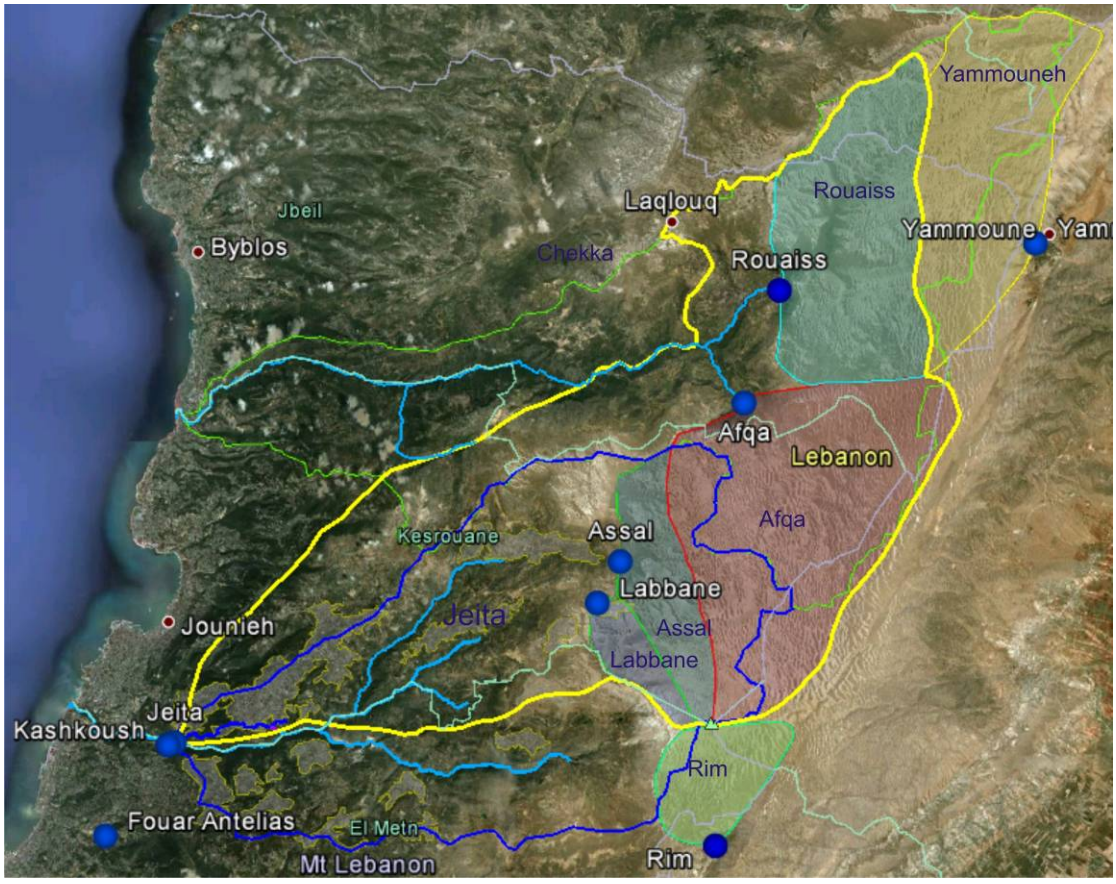


Figure 1: Groundwater Contribution Zone of Jeita Spring (MARGANE et al., in progr.)

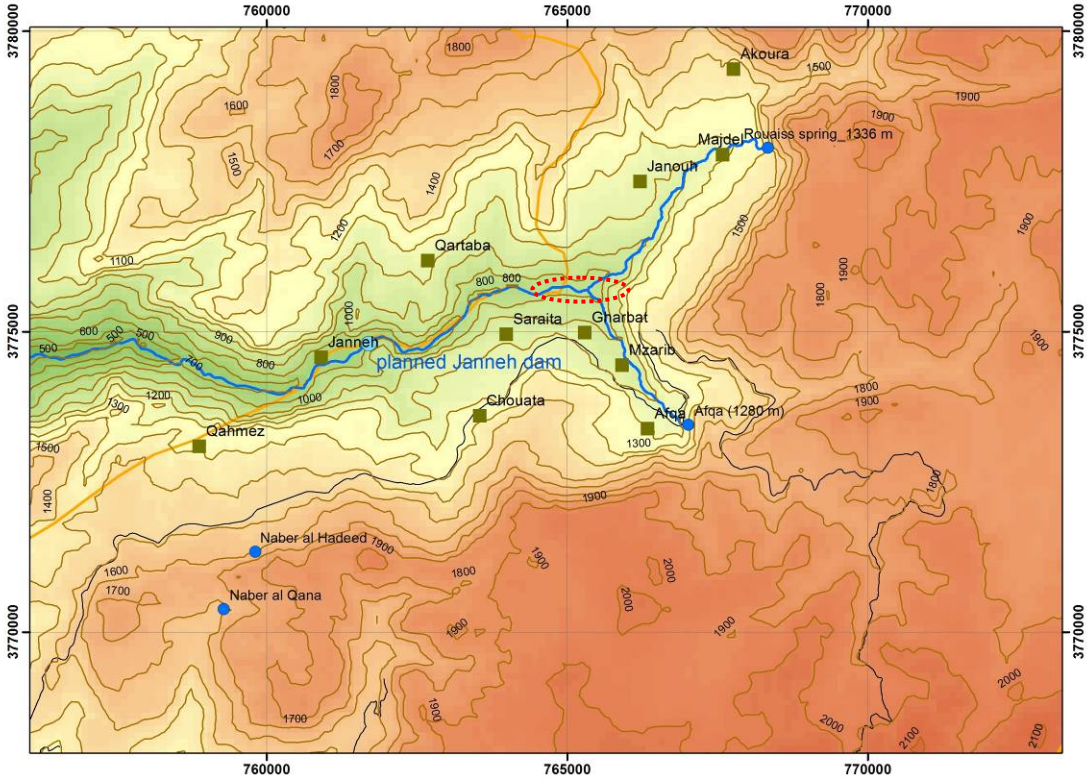


Figure 2: Location of Investigation Area
(remark: red dotted line - assumed infiltration zone)

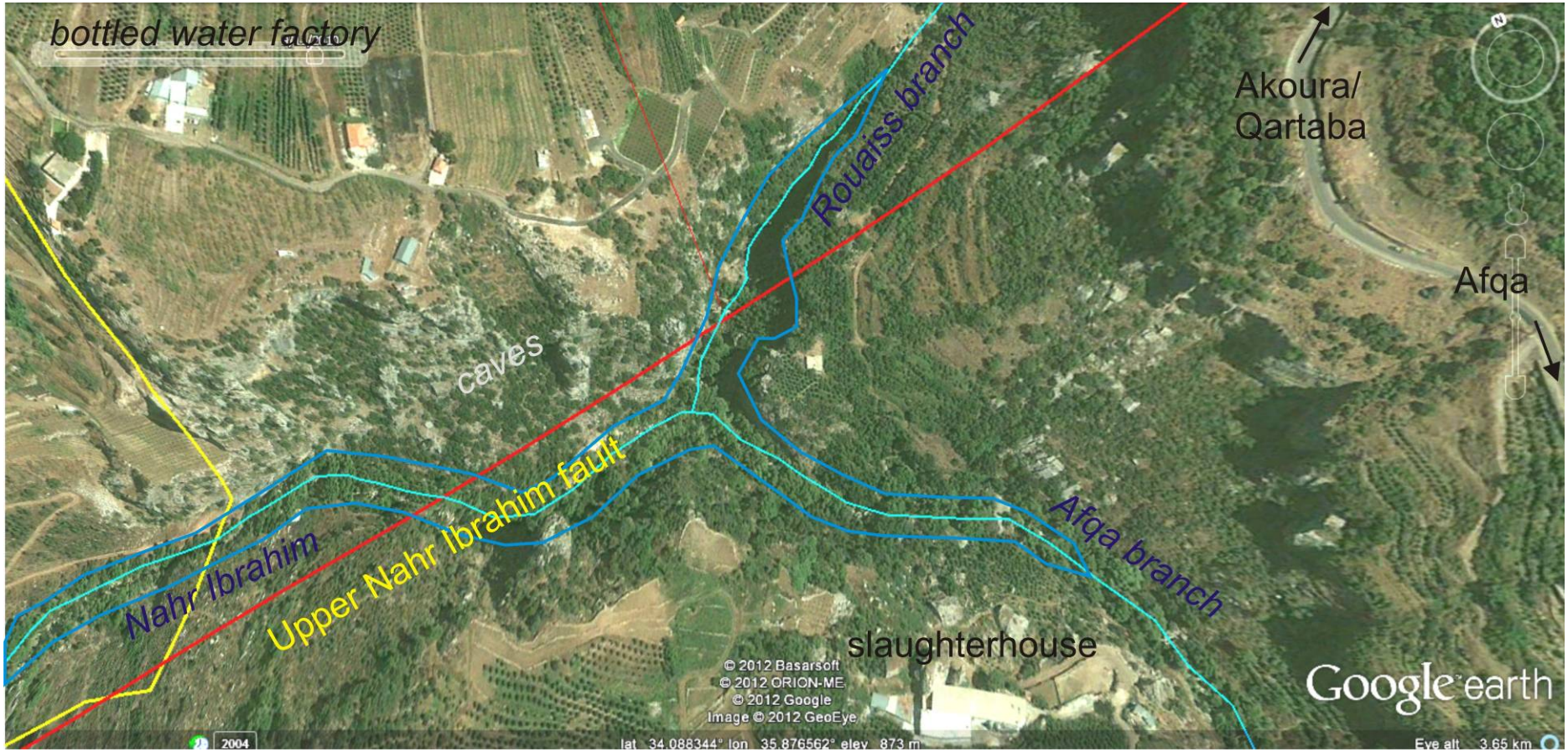


Figure 3: Assumed Main Infiltration Area in the Upper Nahr Ibrahim Valley (near Confluence) [status 20 May 2012]

2 Hydrological Setup

The data collection during the previous reporting had not been compete because until recently this area of Nahr Ibrahim had widely not believed to be part of the Jeita catchment. The LRA monitoring station Rouaiss spring could previously not be located. Now related data were acquired and the station visited. The previously documented discharge measurements for Afqa are corrected in this report.

Average monthly discharge of Afqa spring (LRA station 21) during the water years 2000/01 - 2009-10 (Figures 6, 8, 9) indicate that peak flow is commonly during March to May. Average annual discharge during that period is 123 MCM (Table 1). At the Rouaiss spring station (Figures 7, 8, 10) average annual discharge is 154 MCM. The comparison of Afqa and Rouaiss discharge show some very odd differences (Figure 8). In some years discharge at Afqa was higher than at Rouaiss, in others years is was inverse. Discharge at Rouaiss varies between 76 and 239 % of the Afqa discharge. The monthly discharge pattern is nearly the same at both stations (Figure 11).

Rouaiss spring is also monitored by LRA, however, at an inappropriate location (Figure 5), which is why the station was previously not found. The LRA station is located approx. 1.4 km downstream of Rouaiss spring at the Majdel bridge. However, about 740 m downstream of Rouaiss spring a considerable inflow of surface water takes place from the high plateau NW of Akoura (1800-2000 m asl). The LRA station is therefore not representative of the groundwater discharge at Rouaiss spring but is a combined measurement of groundwater (Rouaiss spring sensu strictu) and surface water (one part of the Rouaiss surface water catchment; Figure 5). A second major inflow to the Rouaiss branch of Nahr Ibrahim from the Laqlouq area (second part of the Rouaiss surface water catchment) is located approx. 1.8 km downstream of Rouaiss spring (or 400 m downstream of the LRA monitoring station. Those two surface water inflows bring a large amount of surface water to the Rouaiss branch as was observed during the snow melt in April/May 2012, however, cease quickly at the end of the snowmelt period.

It is recommended to establish a new station for Rouaiss spring discharge at the spring itself.

The measurements at the current LRA stations Rouaiss and Afqa do, for the above reasons, and furthermore due to the infiltration at the confluence of the Rouaiss and Afqa branches, not provide correct values for the amount of runoff at the proposed Janneh dam. Using a virtual station at Janneh dam, as was done in the hydrological report for Janneh dam, is not correct because groundwater - surface water interactions are not taken into account and because groundwater and surface water catchments do not match.

Moreover the only other downstream surface water monitoring station at the sea mouth of Nahr Ibrahim cannot be used for comparison because surface

water and groundwater catchments are completely different (Figure 4). The Jeita groundwater catchment covers around 60 % of the Nahr Ibrahim surface water catchment (329 km²). Around 49 % of the Jeita groundwater catchment lies within the Nahr Ibrahim surface water catchment. However, not all of the surface water runoff in the Nahr Ibrahim catchment contributes to Jeita spring but only that portion which can infiltrate at specific locations where such infiltration can take place. This is the case at the confluence of the Rouaiss and Afqa branches of Nahr Ibrahim where a significant karst network has developed in the uppermost part at the J4 due to very intensive karstification (MARGANE et al., in progr.).

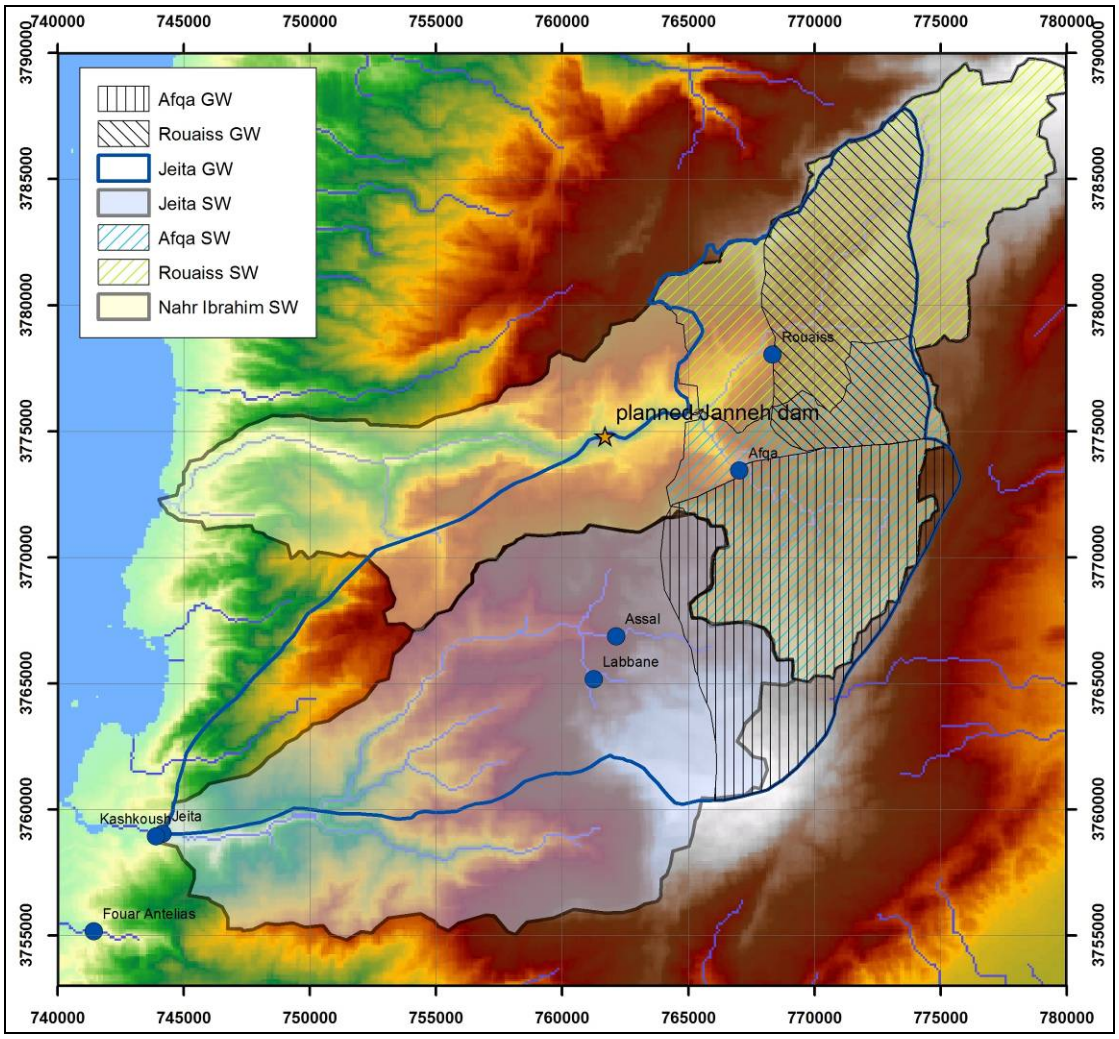


Figure 4: Boundaries of Surface and Groundwater Catchments (MARGANE et al., in progr.)

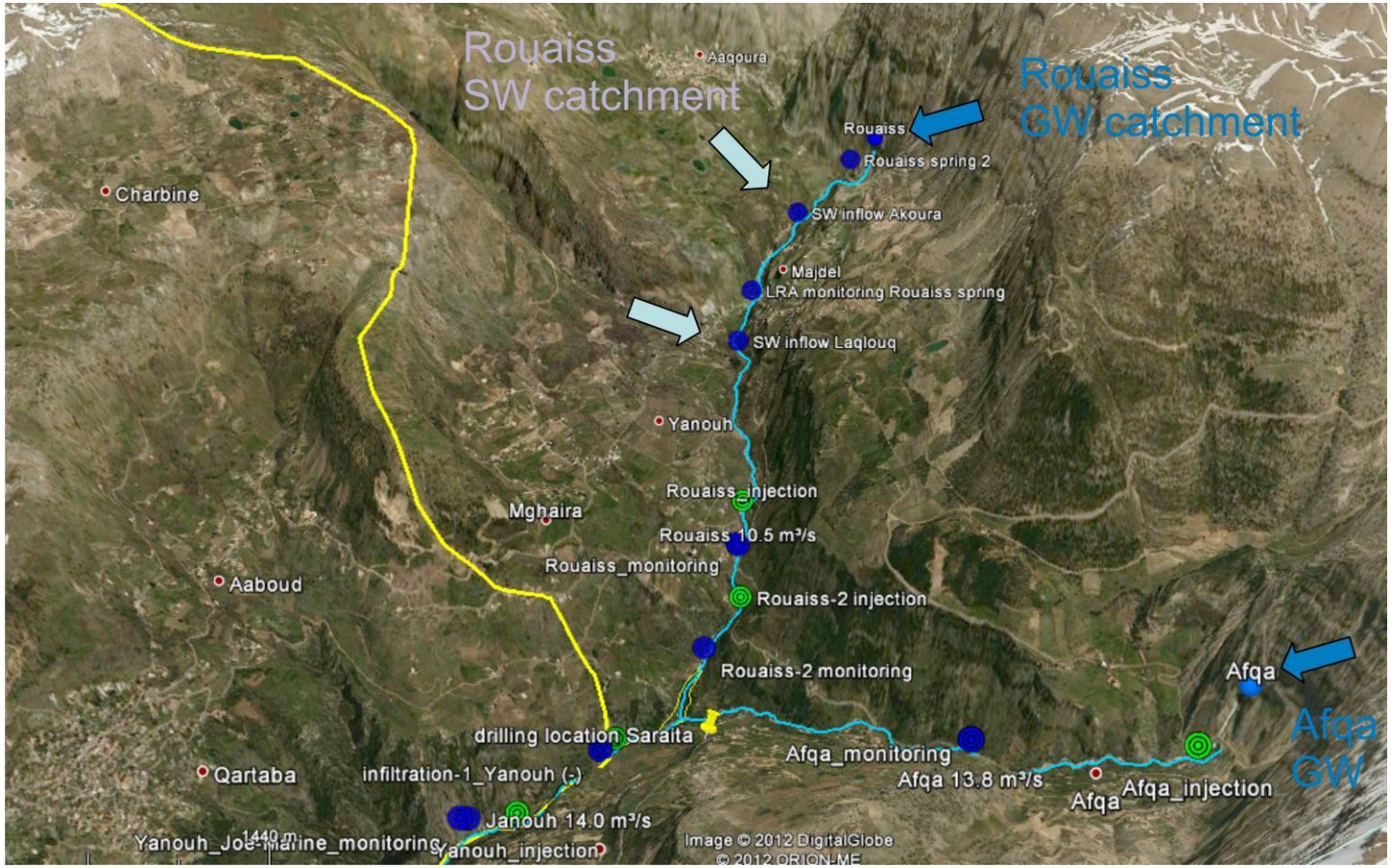


Figure 5: Location of Rouaiss Monitoring Station and Rouaiss Groundwater and Surface Water Catchments

Table 1: Discharge of Afqa Spring Monitored by LRA during Water Years 2000/01 - 2009/10

	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	average
September	0.27	0.33	0.23	0.73	0.32	1.03	1.16	0.82	0.57	0.89	0.64
October	0.31	0.26	0.25	0.42	0.20	0.39	1.21	0.58	0.62	0.52	0.48
November	0.26	0.64	0.26	0.39	9.26	6.63	5.14	0.42	0.94	7.39	3.13
December	0.35	7.59	7.36	0.69	5.80	7.92	2.01	6.94	4.43	15.37	5.84
January	0.88	2.07	9.76	3.49	6.35	13.93	2.27	2.26	7.40	13.61	6.20
February	1.46	13.24	5.18	3.43	15.17	10.43	6.70	1.76	11.84	17.45	8.67
March	24.83	22.93	20.95	31.18	53.78	29.96	23.66	35.19	32.94	24.19	29.96
April	11.22	44.94	66.96	36.45	43.15	38.73	28.46	20.23	77.09	8.71	37.59
May	3.52	7.89	65.14	21.99	25.38	10.73	14.03	4.71	33.38	4.06	19.08
June	0.84	1.63	34.88	6.09	7.84	3.80	3.00	1.66	8.59	2.07	7.04
July	0.30	0.56	13.77	1.61	2.89	3.14	2.14	1.50	3.15	1.38	3.05
August	0.32	0.32	6.89	0.54	1.13	1.59	1.62	1.13	1.13	0.78	1.55
	44.55	102.40	231.63	107.03	171.26	128.27	91.39	77.21	182.08	96.43	123.22

Table 2: Discharge of Rouaiss Spring Monitored by LRA during Water Years 2000/01 - 2009/10

	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	average
September	0.61	0.55	0.36	0.76	0.51	0.40	0.49	1.07	1.24	0.25	1.31	0.62
October	0.64	1.52	0.52	0.45	0.33	0.70	0.79	1.44	1.69	0.45	0.76	0.85
November	0.57	1.58	0.51	0.64	9.39	3.94	7.49	1.41	2.03	3.51	1.29	3.11
December	1.01	6.22	2.80	0.69	10.59	5.23	1.21	12.05	4.78	7.88	3.58	5.24
January	3.40	3.14	11.27	4.78	14.37	18.01	2.00	2.11	11.18	11.36	9.89	8.16
February	4.86	14.22	15.31	10.53	21.73	19.38	15.74	3.06	17.92	36.54	33.68	15.93
March	25.74	17.60	21.93	41.89	63.90	79.93	61.17	30.74	46.09	21.94	61.82	41.09
April	12.52	24.72	50.45	44.02	96.80	131.32	54.71	13.57	72.42	6.42	58.04	50.69
May	2.30	5.59	52.23	24.52	28.70	42.86	20.00	6.56	31.72	3.78	17.94	21.82
June	0.81	1.58	19.07	3.43	3.95	2.93	2.84	1.90	7.46	1.67	2.24	4.56
July	0.49	0.73	4.93	1.49	1.04	1.28	0.97	1.25	2.93	1.66	0.51	1.68
August	0.34	0.54	2.63	0.96	0.69	1.14	0.66	1.32	2.21	1.61	0.50	1.21
	53.27	77.97	181.99	134.14	252.00	307.11	168.05	76.47	201.65	97.07		154.97

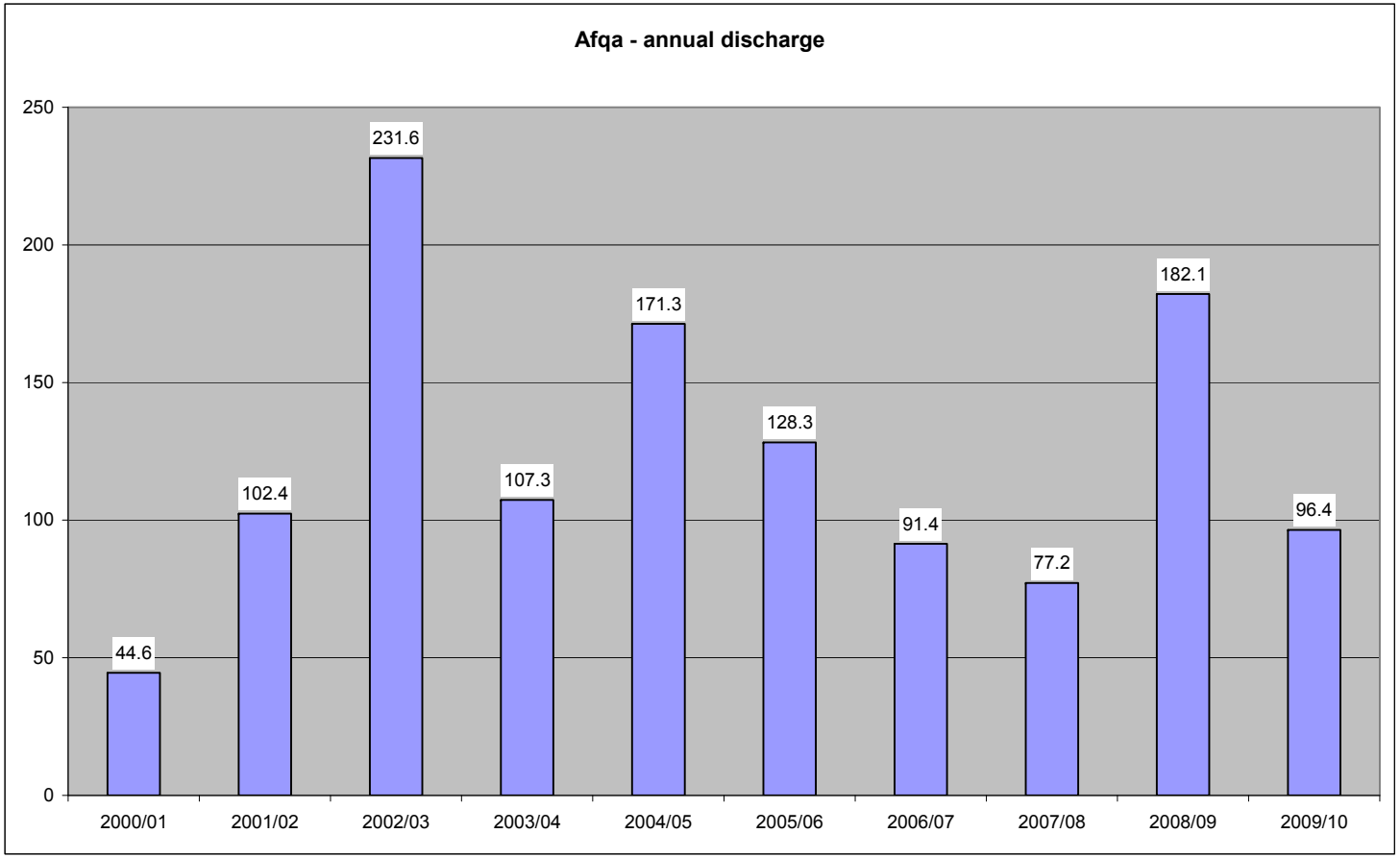


Figure 6: Annual Discharge of Afqa Spring during Water Years 2000/01 - 2009-10 [MCM]

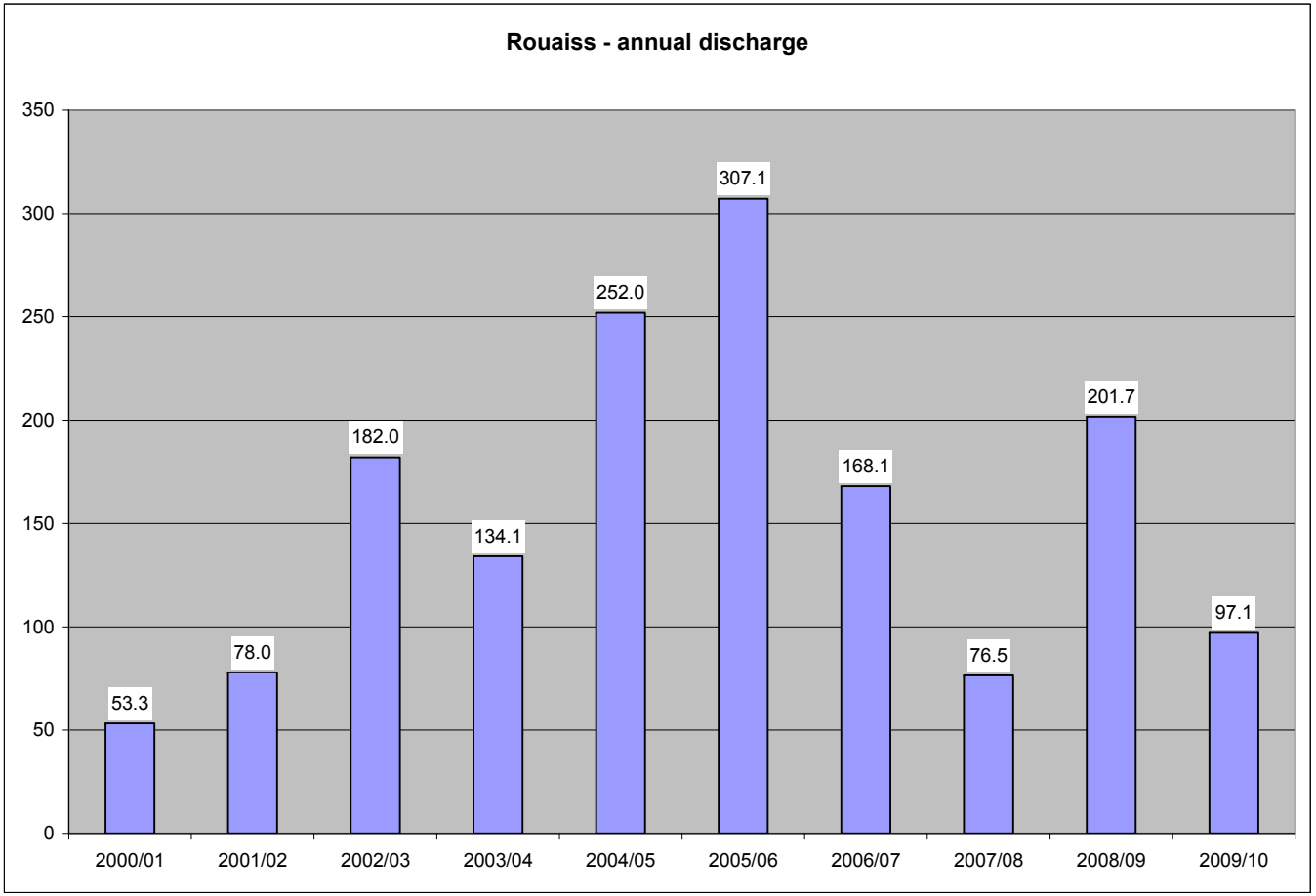


Figure 7: Annual Discharge of Rouaiss Spring during Water Years 2000/01 - 2009-10 [MCM]

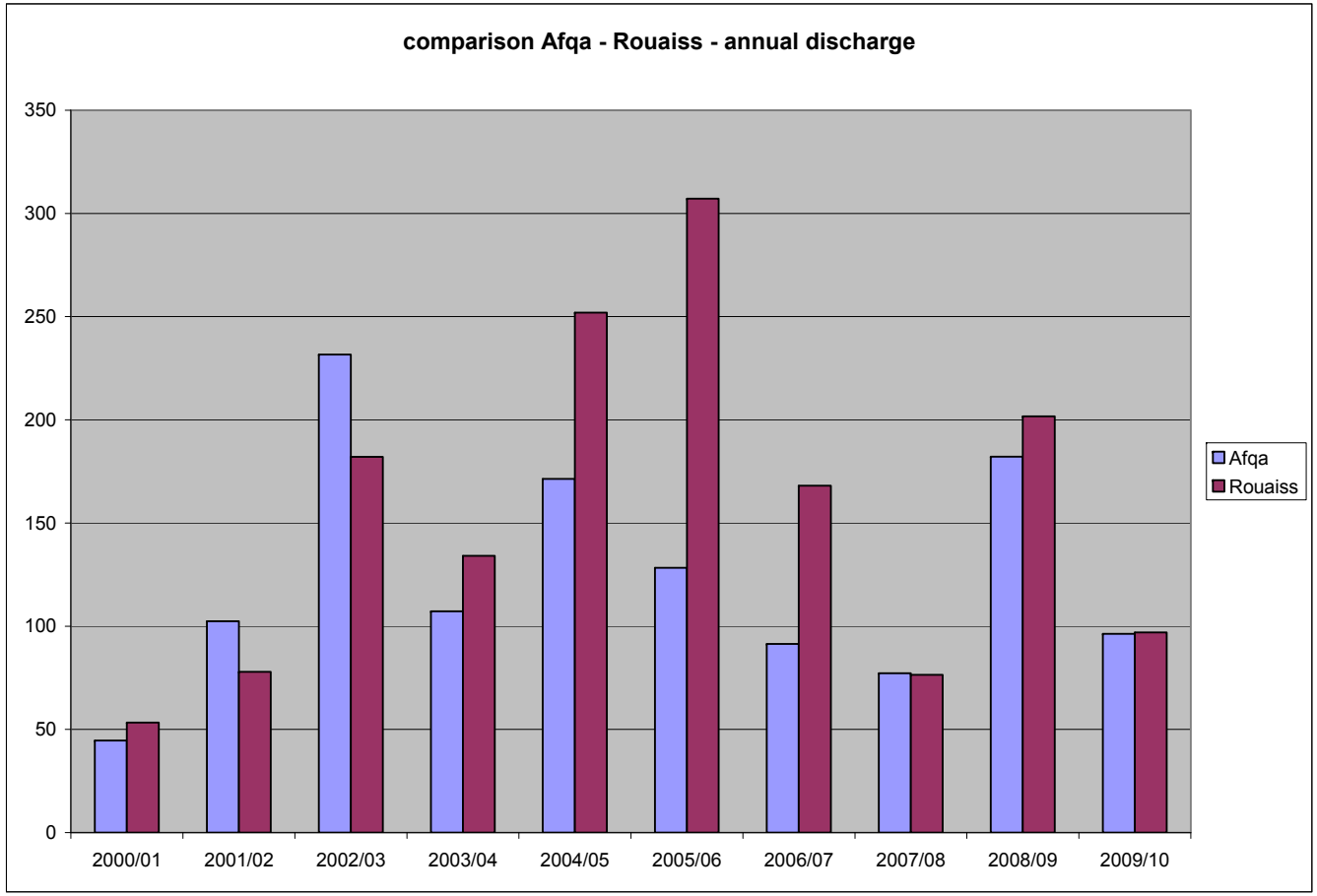


Figure 8: Comparison of Annual Discharge at Afqa and Rouaiss Springs [MCM]

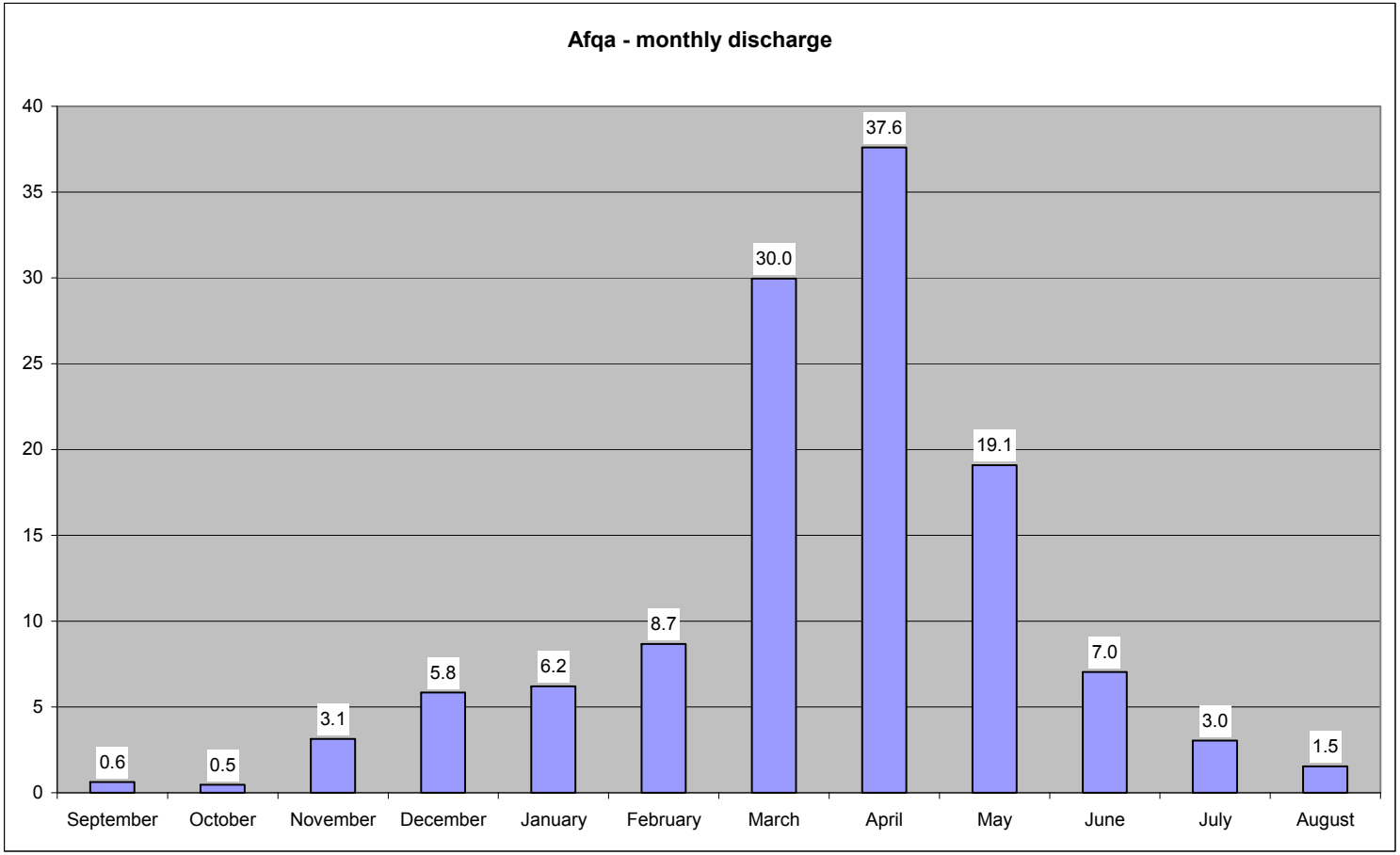


Figure 9: Average Monthly Discharge of Afqa Spring during Water Years 2000/01 - 2009-10 [MCM]

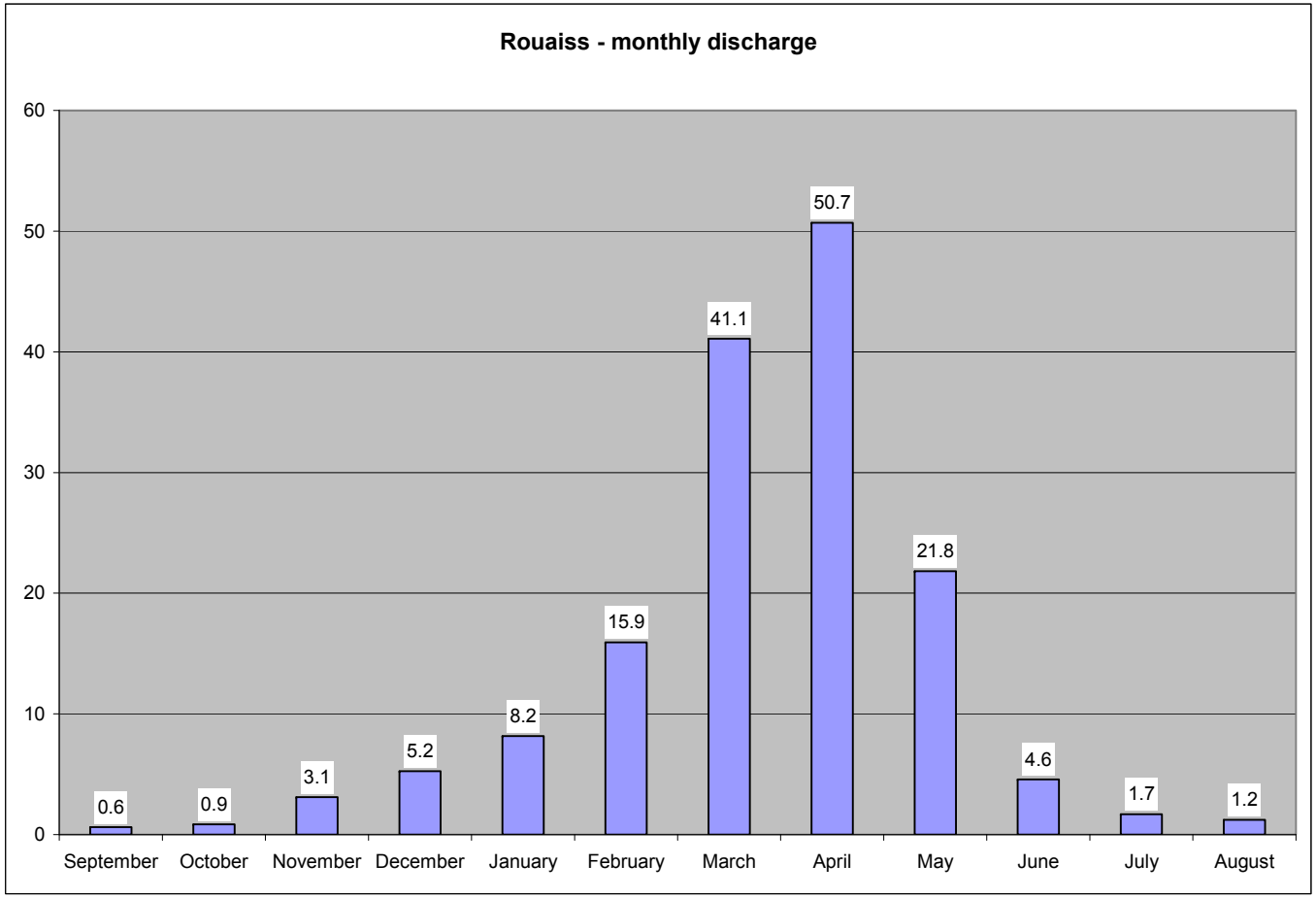


Figure 10: Average Monthly Discharge of Rouaiss Spring during Water Years 2000/01 - 2009-10 [MCM]

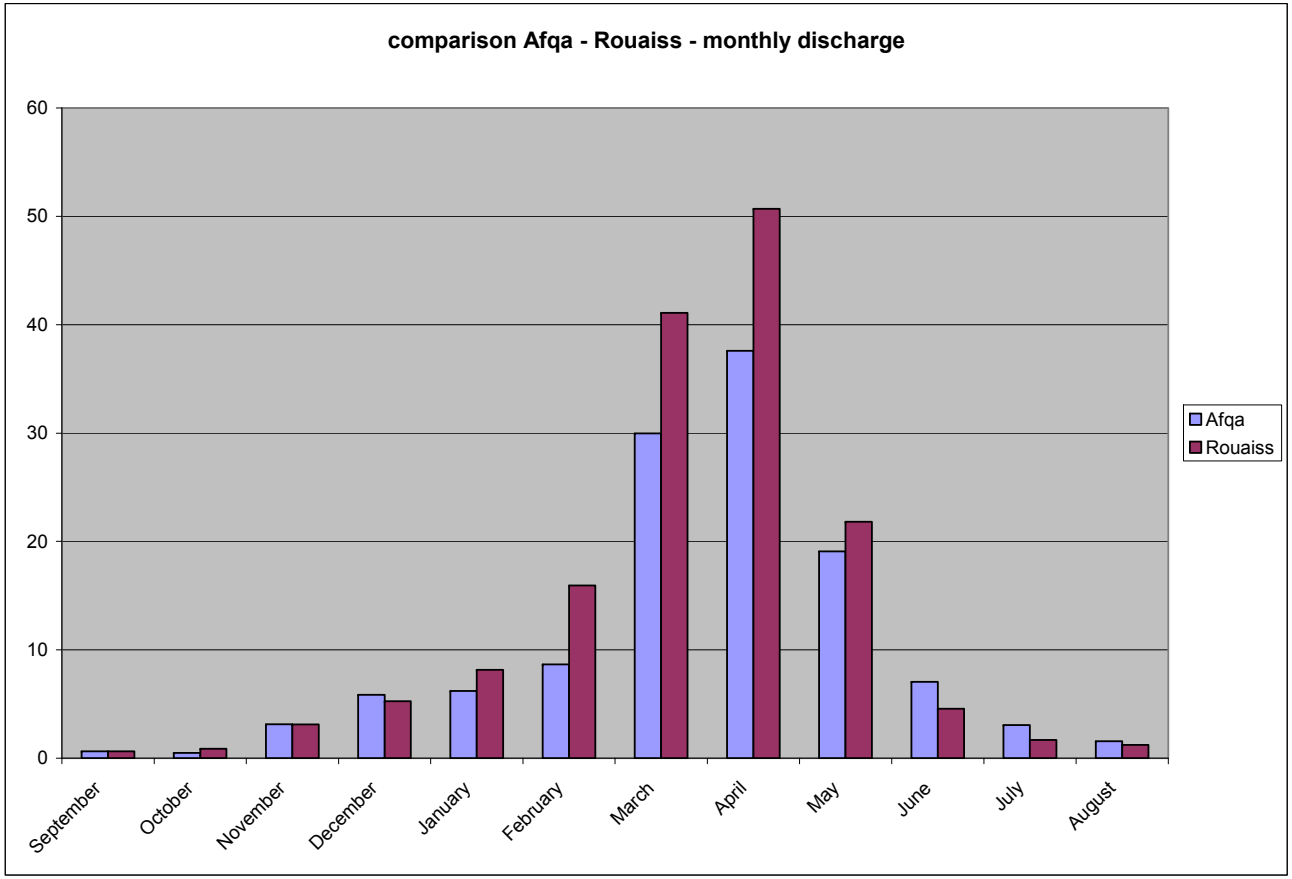


Figure 11: Comparison of Monthly Average Discharge at Afqa and Rouaiss Springs (Water Years 2000/01 - 2009-10) [MCM]

3 Description of Discharge Measurements

In order to confirm the assumed infiltration of surface water in the Upper Nahr Ibrahim Valley, four campaigns of discharge measurements were done:

- first discharge measurements: 30 April 2012
- second discharge measurements: 15 May 2012
- third discharge measurements: 22 May 2012
- fourth discharge measurements: 25 May 2012

While discharge in the Rouaiss branch of Nahr Ibrahim quickly decreased, recession at the Afqa branch was less (Figure 22).

3.1 Locations of Measurements

The first two measurement campaigns were intended to identify the assumed infiltration zone between the beginning of the J4 outcrop and the Janneh bridge. It became clear that infiltration in the Janneh area itself is small and the infiltration zone could be confined to the area near the confluence of the Rouaiss and Afqa branches. For the next two measurement campaigns measurements at the stations Afqa, Rouaiss and Yanouh/Joe Marine were repeated so that now four measurement campaigns with three identical reference stations are available. During the fourth measurement it was tried to carry out a measurement some 900 m upstream of Yanouh/Joe Marine, however, the distance between injection and monitoring was insufficient (95 m) so that this measurement is not correct. This is confirmed by the monitoring of tracer arrival from later injections at Rouaiss and Afqa. All stations used for monitoring and injection are shown in Tables 3 and 4.

Table 3: Location of Monitoring Stations

Location	LONG (E)	LAT (N)
Janneh-2	35.825932°	34.078007°
Janneh-1	35.835430°	34.081150°
Yanouh (Joe Marine)	35.862059°	34.089495°
Upstream Yanouh	35.870615°	34.088936°
Rouaiss (restaurant)	35.884111°	34.093452°
Rouaiss-2	35.878990°	34.090281°
Afqa (Mzarib) 30-04-12 All later meas.	 35.881746° 35.884586°	 34.080736° 34.075785°

Table 4: Location of Injection Stations

Location	LONG (E)	LAT (N)
Janneh-2	35.830210°	34.078910°
Janneh-1 30-04-12 16-05-12	 35.838913° 35.841302°	 34.082293° 34.081215°
Yanouh (Joe Marine)	35.864898°	34.088337°
Upstream Yanouh	35.871643°	34.088950°
Rouaiss (restaurant) 30-04-12 16-05-12 22-05-12 / 25-05-12	 35.885677° 35.890337°	 34.094758° 34.101255°
Rouaiss-2	35.882168°	34.090882°
Afqa (Mzarib) 30-04-12 All later meas.	 35.882116° 35.891567°	 34.078603° 34.068454°

Total distance between Afqa injection and Yanouh monitoring was approx. 3150 m, between Rouaiss injection and Yanouh monitoring approx. 2700 m.

The proposed dam location is at:

LONG (E)	LAT (N)	Elevation
35.836165°	34.081298°	755 m asl

The center of the assumed infiltration zone is at:

LONG (E)	LAT (N)	Elevation
35.876575°	34.089035°	~ 810 m asl

4 Tracer Tests

Accuracy of measurements is assumed to be 10-15 % during the first and 5-10 % during the second, third and fourth campaign.

4.1 Third Campaign

The third discharge measurements were conducted on 22 May 2012. At this time flow at Rouaiss and Afqa springs was much less than during the first two measurements due to receding snowmelt arriving via surface water in the Rouaiss branch. This recession in the Rouaiss branch can clearly be traced (Figure 22).

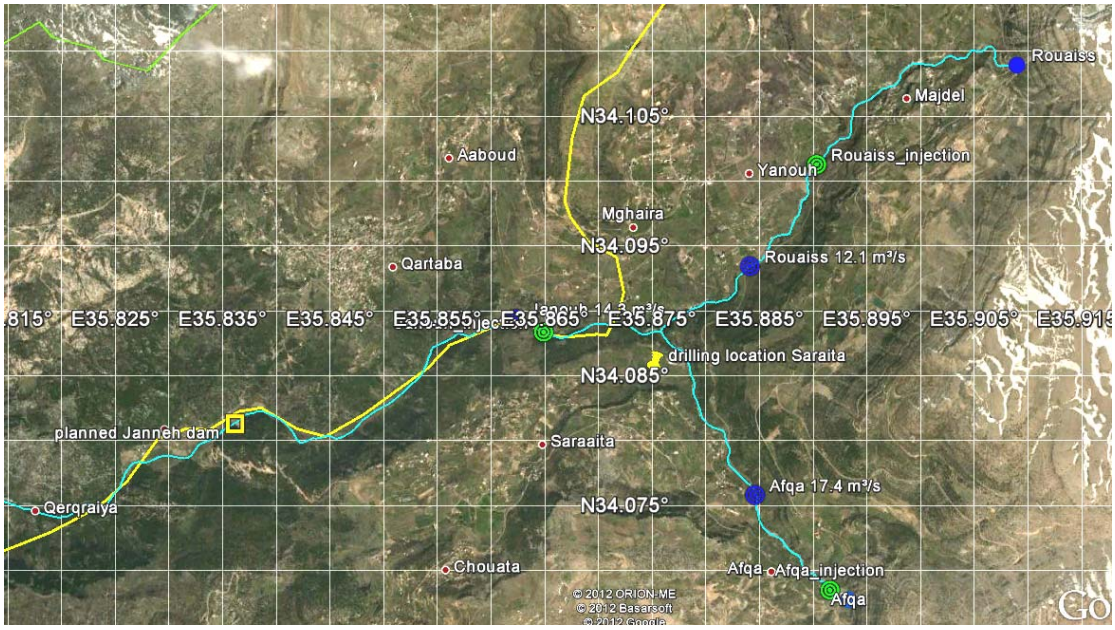


Figure 12: Locations of Injection and Monitoring during Third Measurement Campaign

The following injections were conducted (three at each station):

Table 5: Tracer Injections during Third Campaign

Site	Time	Amount of Tracer (g)	Discharge (m³/s)
Yanouh	10:14	50	14.7
Yanouh	10:30	50	14.0
	10:45	50	14.2
average			*14.3*
inflow	*0.0*		

Site	Time	Amount of Tracer (g)	Discharge (m^3/s)
correction			
Afqa	13:19	50	17.8
Afqa	13:35	50	17.3
Afqa	13:50	50	17.0
average			*17.4*
Rouaiss	14:53	50	12.0
Rouaiss	15:09	50	12.1
Rouaiss	15:24	50	12.2
average			*12.1*
Rouaiss + Afqa			*29.5*

Table 6: Infiltration Measured during Third Campaign

Segment	Infiltration (m^3/s)	Infiltration (%)
Confluence - Yanouh	15.2	**52**

All measurements were conducted using fluorometer 533. At each station a back-up measurement with a second fluorometer was carried out to avoid loss of data.

The tracer arrival from the Rouaiss and Afqa injections was also observed downstream at Yanouh.

Injections were done starting downstream and going up in the catchment. Time interval between injections at one station was usually 15 minutes. In order to be able to separate upstream injections at downstream monitoring sites, commonly between one and two hours had to elapse before starting injections at the next station.

There are no surface water inflows between the three stations.

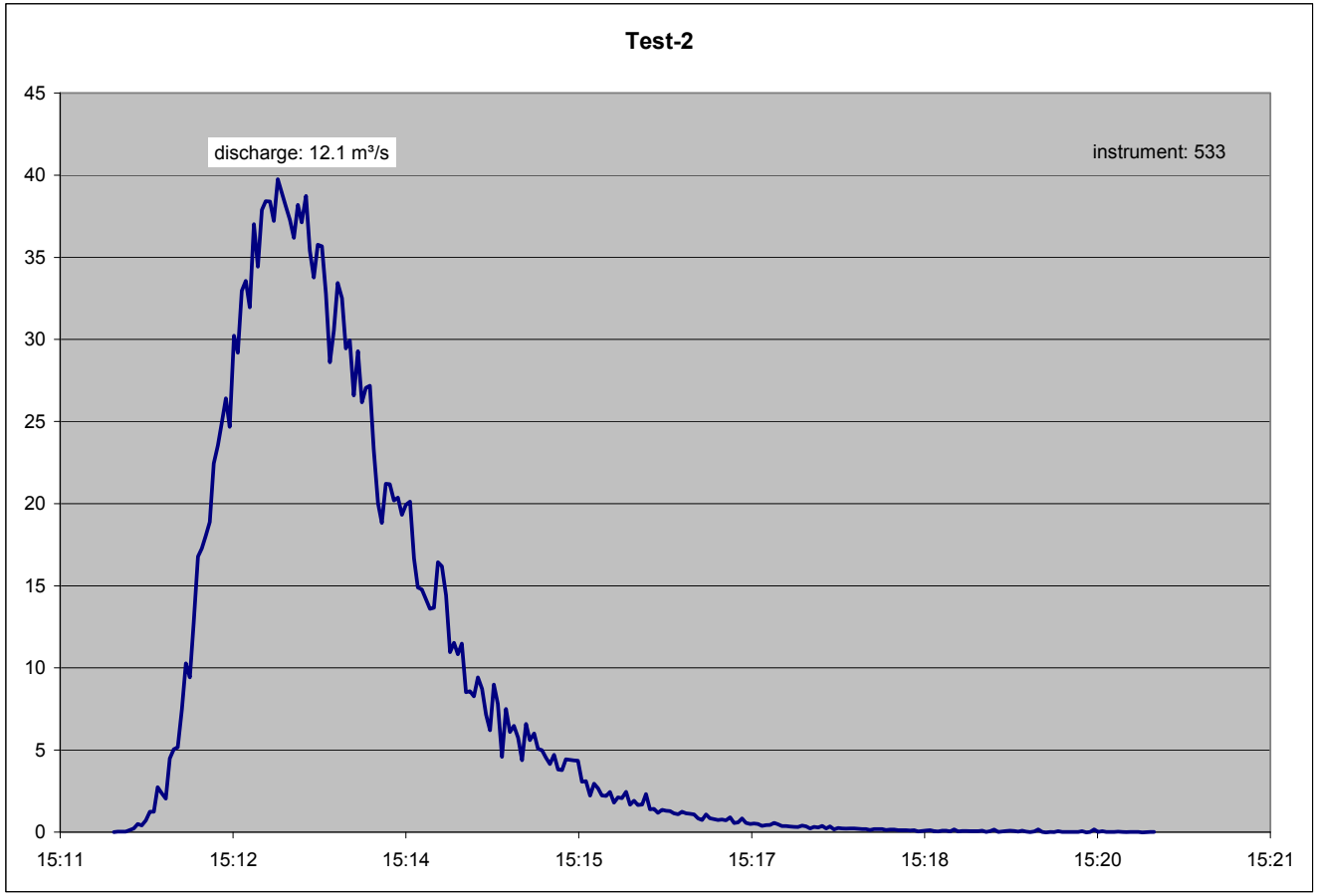


Figure 13: Determination of Discharge at the Rouaiss branch of Nahr Ibrahim during Third Campaign

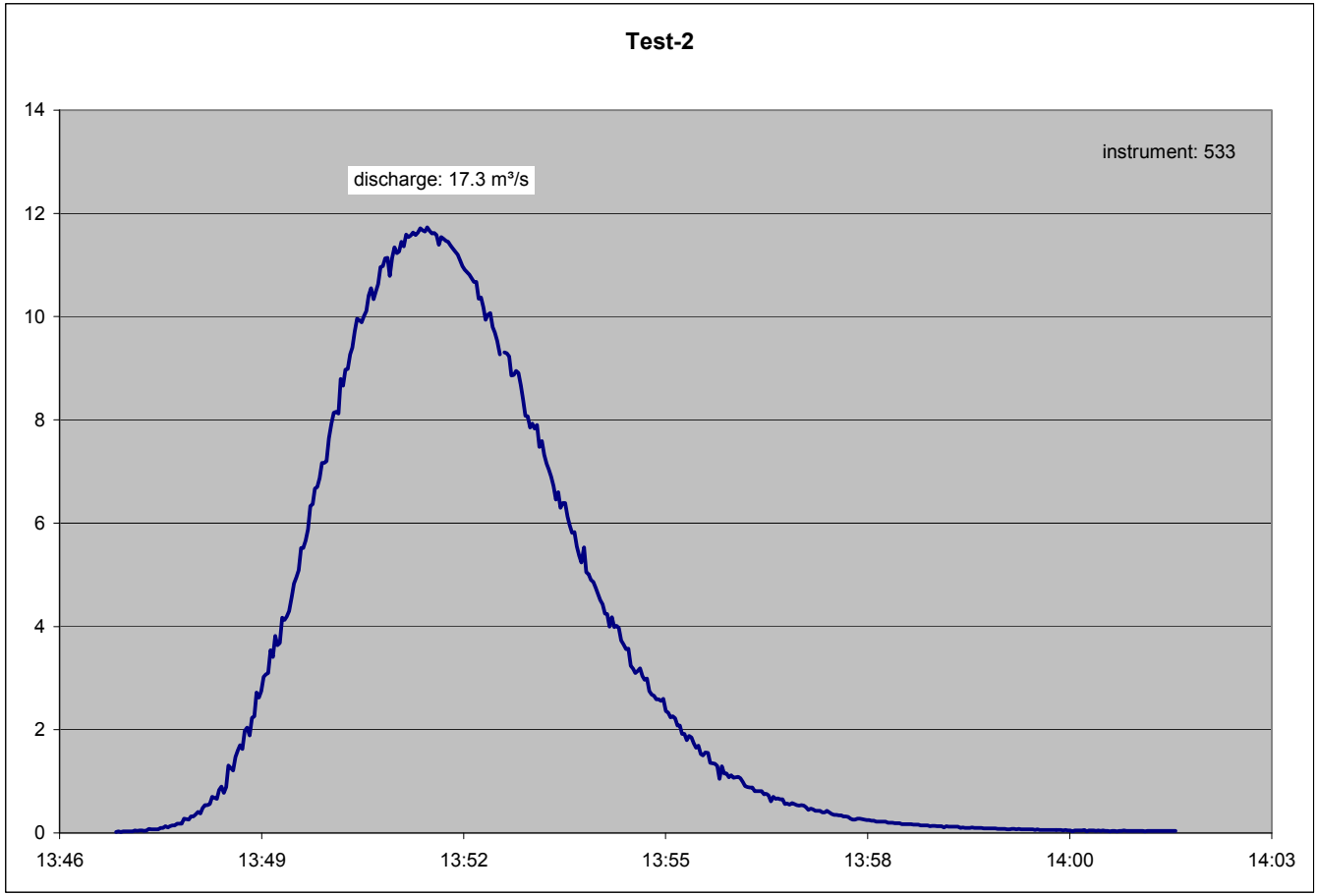


Figure 14: Determination of Discharge at the Afqa branch of Nahr Ibrahim during Third Campaign

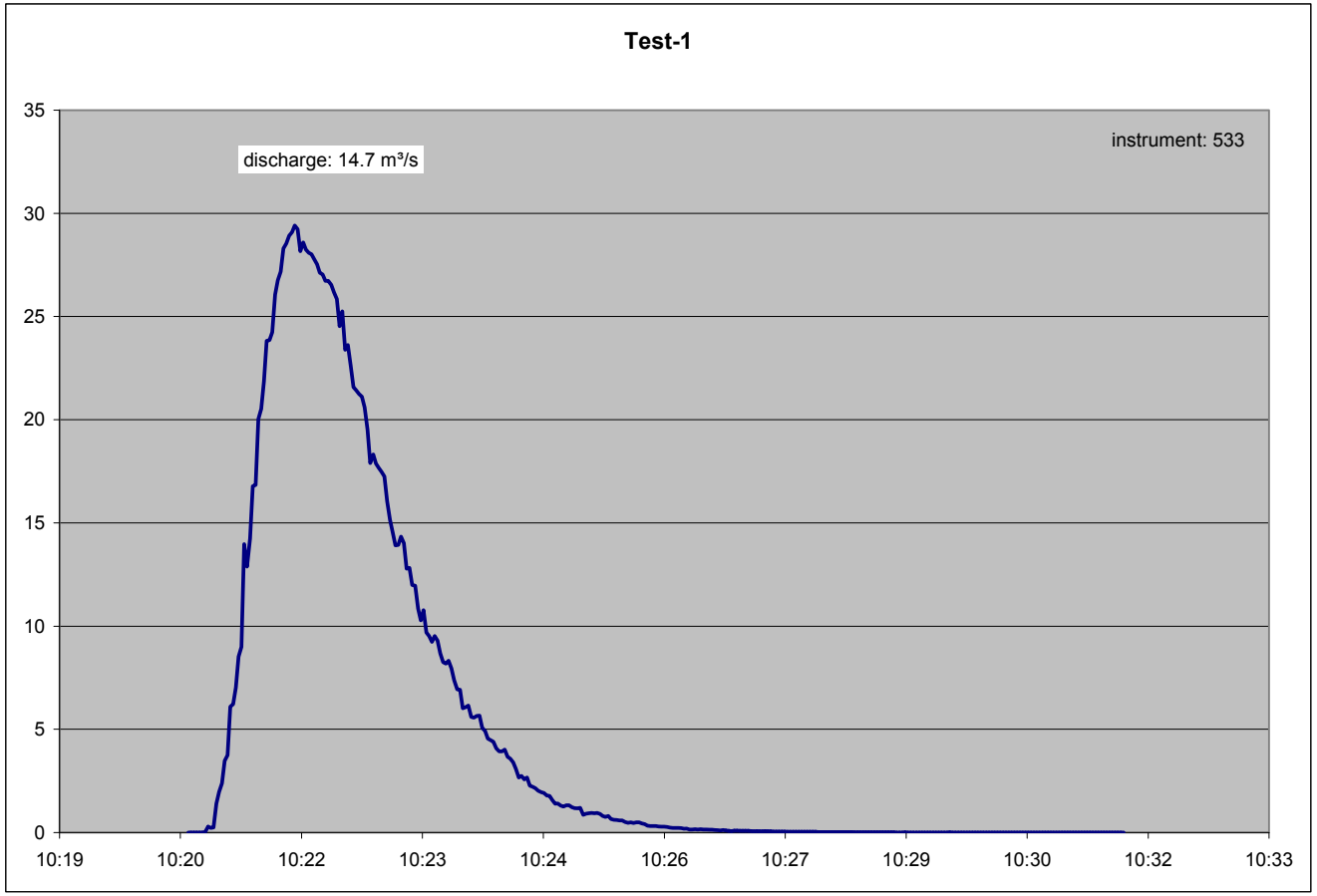


Figure 15: Determination of Discharge at Yanouh (approx. 1350 m downstream of confluence) during Third Campaign

4.2 Fourth Campaign

The fourth discharge measurements were conducted on 25 May 2012 in the presence of Kathib and Alami staff (consultant for Janneh dam).

During the field visit the consultant was shown:

- the presence of strong karstification in the upper J4 (it is not mentioned in the K+A reports)
- the presence of caves and thus a well developed karst network (it is not mentioned in the K+A reports)
- that there is only limestone and no dolomite (geological map of K+A is thus wrong)

Figure 16: Locations of Injection and Monitoring during Fourth Measurement Campaign

remark: thick yellow line - GW catchment Jeita; thin yellow line - modified assumed infiltration zone

The following injections were conducted (two at each station):

Table 7: Tracer Injections during Fourth Campaign

Site	Time	Amount of Tracer (g)	Discharge (m³/s)
Rouaiss-2	10:27:30	50	9.7
Yanouh	11:18	50	14.0
Yanouh	11:39	50	-
average			*14.0*
Yanouh-2	13:08	50	-
Yanouh-2	13:18	50	-
Rouaiss	14:39	50	10.7
Rouaiss	14:49	50	10.8
average			*10.7*
Afqa	15:55	50	15.1
Afqa	16:10	50	14.8
average			*15.0*
Rouaiss + Afqa			*25.7*

Table 8: Infiltration Measured during Fourth Campaign

Segment	Infiltration (m³/s)	Infiltration (%)
Confluence - Yanouh	11.7	**46**

All measurements at the three reference stations were conducted with the same instrument (532). The arriving tracer was observed in all downstream stations by other instruments in order to observe tracer recovery and travel times between stations. In all stations the same amount of tracer (50 g) was used in order to make results easily comparable.

The arrival of tracer at Rouaiss-2 from the Rouaiss injections yields a discharge of 9.9 m³/s, i.e. 0.8 m³/s less than at Rouaiss. This indicates that already in this upper part of the J4 there could be some infiltration (7%). The monitoring of tracer arrival from the Rouaiss and Afqa injections at Yanouh-2 shows a clear difference. While only 38% of the tracer from the Rouaiss injection is lost, 47% of the tracer is lost on the way from Afqa to Yanouh-2. There may thus be a higher infiltration on the Afqa branch compared to the Rouaiss branch. The calculated discharge at Yanouh-2 is 13.5 m³/s, i.e. almost the same as the discharge determined directly at Yanouh.

Injections were done starting downstream and going up in the catchment. Time interval between injections at one station was commonly 10 to 15 minutes. In order to be able to separate upstream injections at downstream monitoring sites, commonly between one and two hours had to elapse before starting injections at the next station.

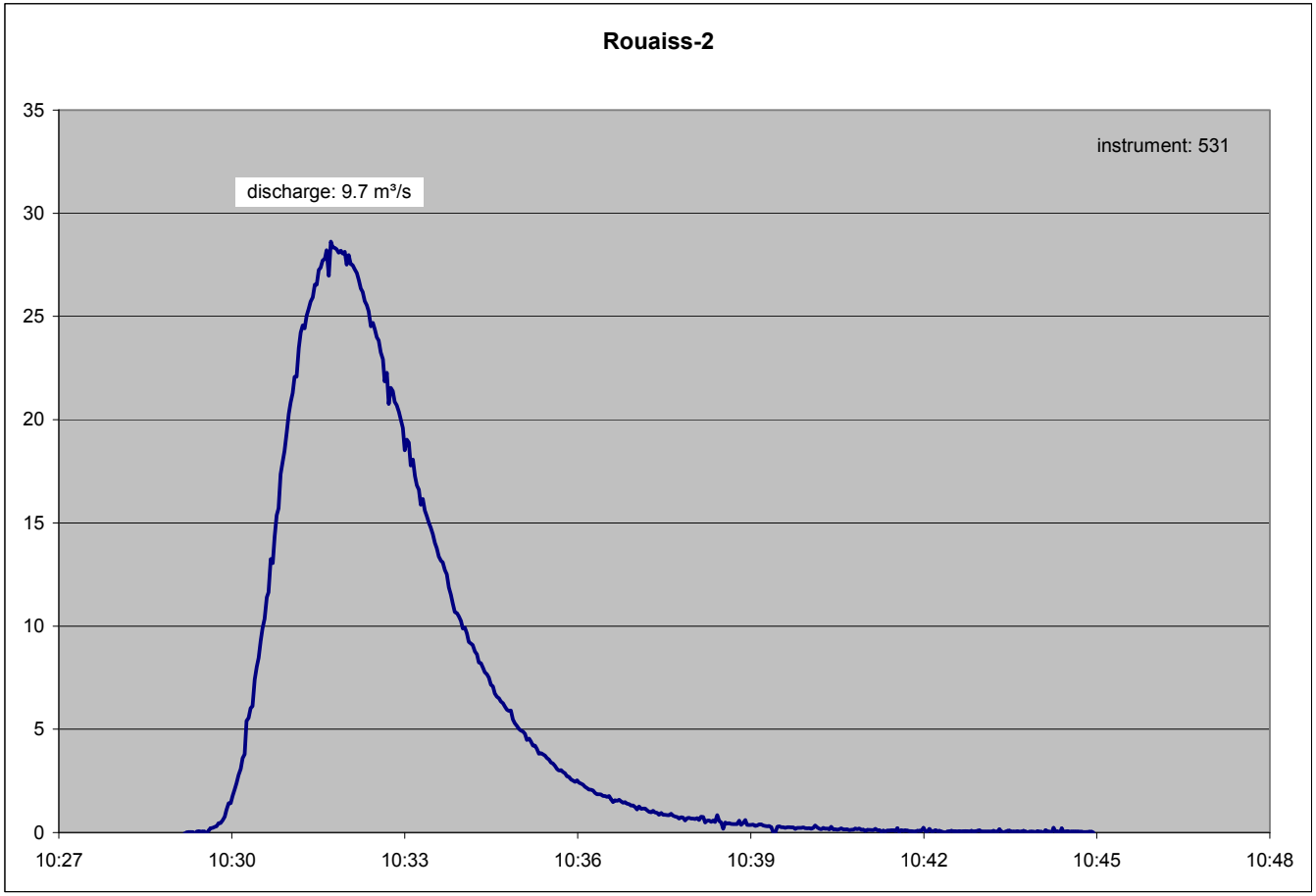


Figure 17: Determination of Discharge at the Rouaiss branch of Nahr Ibrahim during Fourth Campaign (Rouaiss-2)

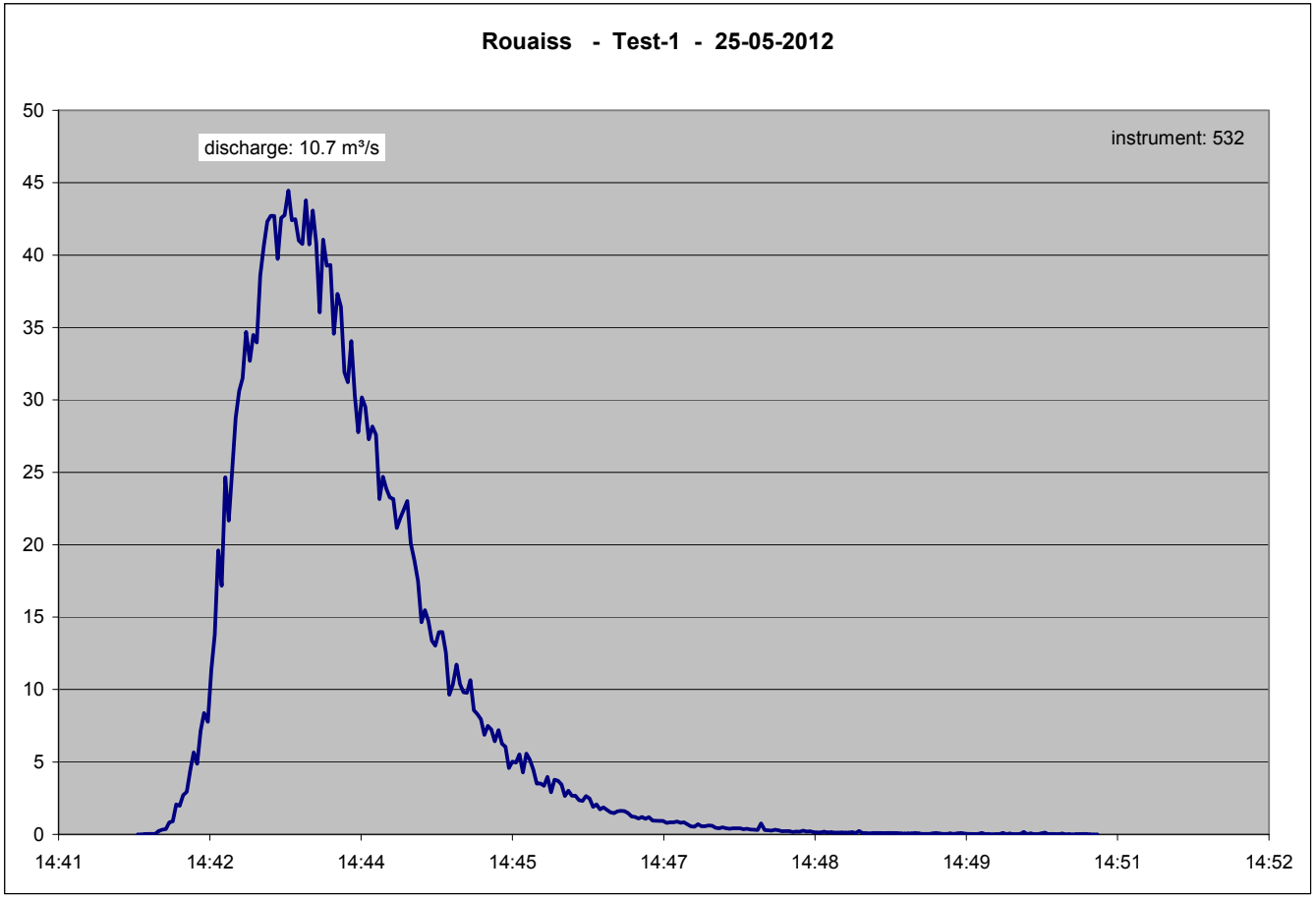


Figure 18: Determination of Discharge at the Rouaiss branch of Nahr Ibrahim during Fourth Campaign

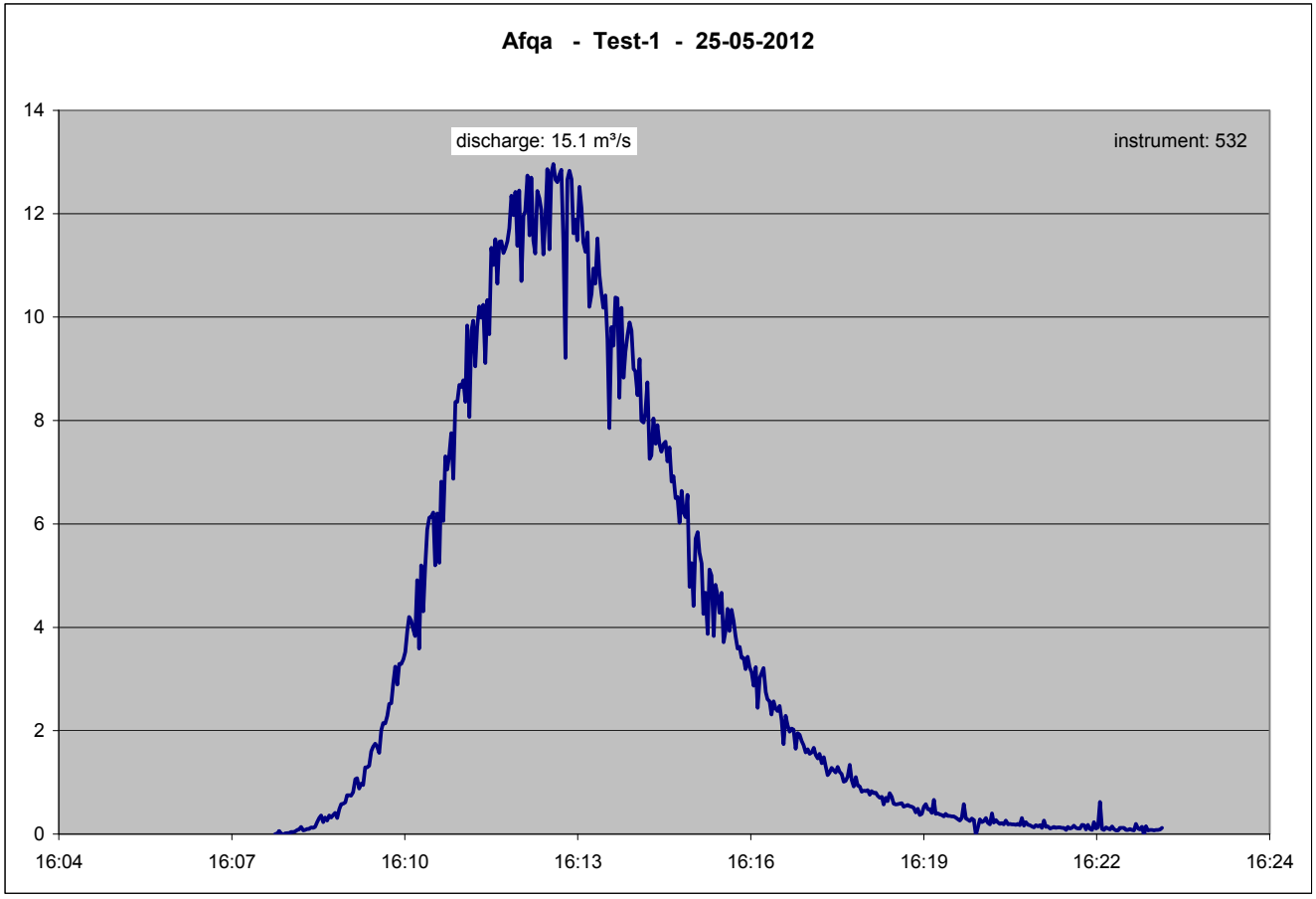


Figure 19: Determination of Discharge at the Afqa branch of Nahr Ibrahim during Fourth Campaign

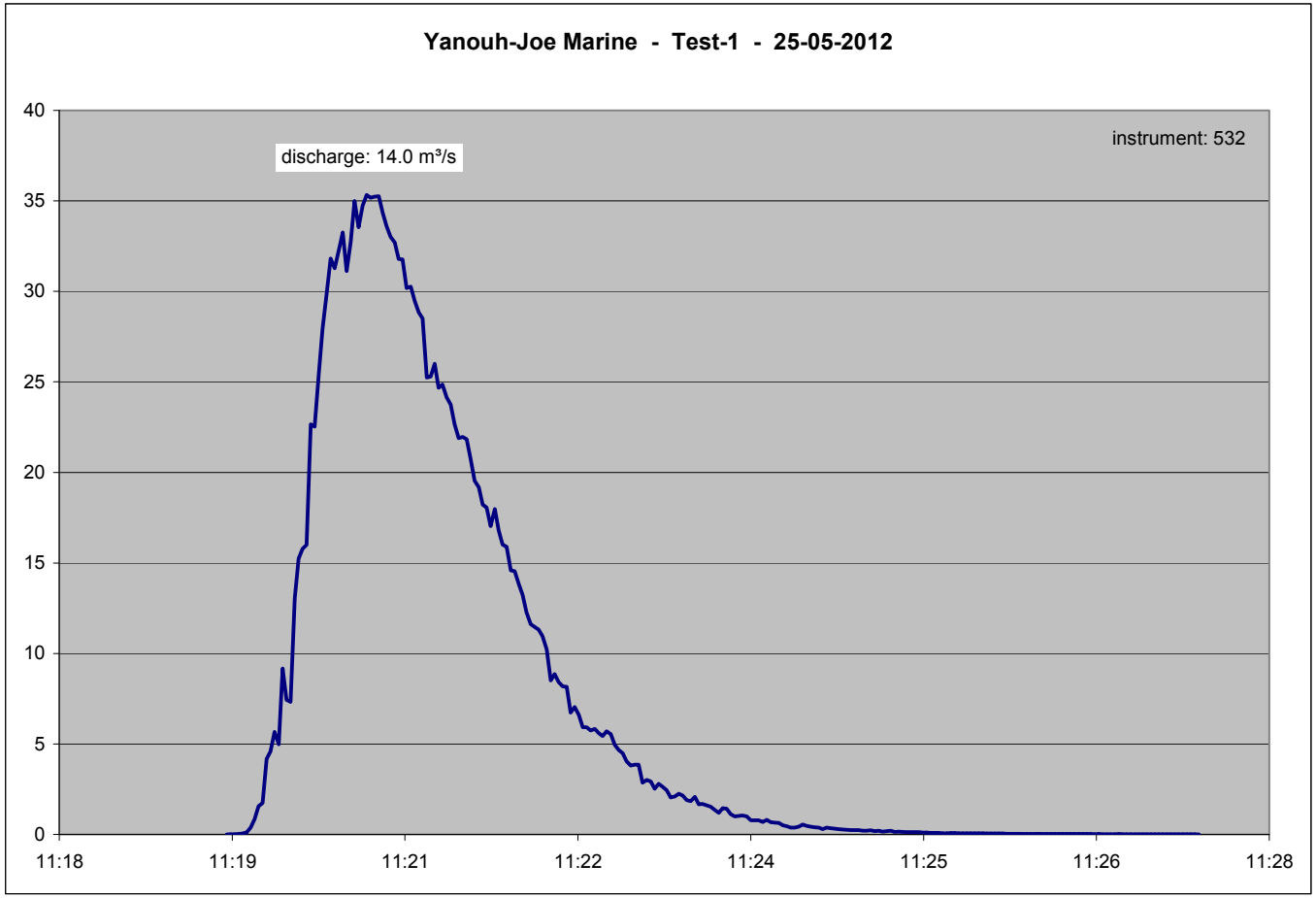


Figure 20: Determination of Discharge at Yanouh (approx. 1350 m downstream of confluence) during Fourth Campaign

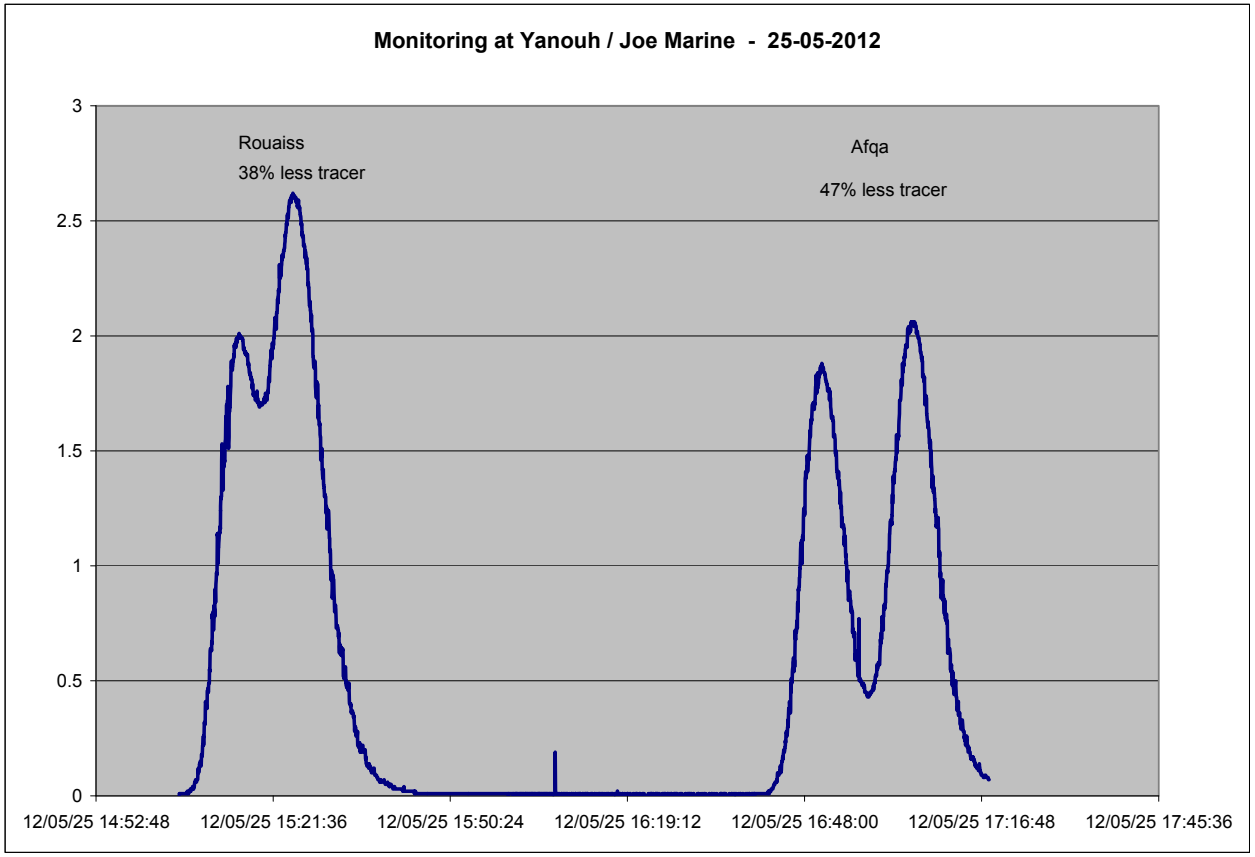


Figure 21: Monitoring of Rouaiss / Afqa Injections @ Yanouh-2 (approx. 500 m downstream of confluence) during Fourth Campaign

4.3 Results

The discharge measurements conducted by the BGR project show that **a very significant infiltration into the Lower Aquifer (J4, Keserwan Formation) occurred during all four campaigns in the Upper Nahr Ibrahim Valley**. **Infiltration varied between around 35 % and 52 %** (Table 9).

The infiltration zone could be narrowed down slightly to the area between Rouaiss-2, Afqa and Yanouh-2 (Figure 23). Monitoring at Yanouh-2, approx. 900 m upstream of the station Yanouh/Joe Marine, after the injections at the stations Afqa and Rouaiss, shows that infiltration must occur mainly upstream of this new station. Monitoring at the new station Rouaiss-2 after the injection at the station Rouaiss shows that there is a small infiltration between those two stations (7%) but the main infiltration must occur between Rouaiss-2, Afqa and Yanouh-2. The infiltration zone thus stretches over approx. 500 m along Nahr Ibrahim and its two tributaries.

Further measurements are required during periods of lower flow. The BGR project intends to conduct at least two more discharge monitoring campaigns for this purpose. It will also be tried to access the infiltration zone during the dry season.

The measurements show clearly that infiltration is varying with time. The reason may be that with higher water levels other parts of the karst network become connected where no infiltration takes place during low flow because their elevation is too high.

It is of utmost importance to conduct the tracer test proposed to WEBML and Khatib and Alami as discussed during the meeting on 21 May 2012 at WEBML and requested by BGR on 22 May 2012 (Annex-1). It was agreed that this borehole would be drilled by WEBML.

The infiltration zone could start at an elevation of approx. 800 m asl going up to around 860 m asl. The major infiltration is assumed to be at an elevation of 810-820 m asl. If a dam is built in this area it would continuously leak large quantities of water into the underlying karst network. Therefore the intended purpose of the Janneh dam, storage, could not be met.

This infiltrating water is believed to flow towards Jeita spring, constituting a large share of discharge at Jeita spring. Any interference at the infiltration zone would directly affect Jeita spring.

Accuracy of effected discharge measurements was around 10-15 % during the first campaign and 5-10 % during the second, third and fourth campaign.

There was no surface water inflow between the monitored stations during the third and fourth campaign.

Table 9: Infiltration Rates determined during the four Measurement Campaigns

Date	Rouaiss [m³/s]	Afqa [m³/s]	Afqa+Rouaiss [m³/s]	Yanouh [m³/s]	infiltration [m³/s]	infiltration [%]
4/30/2012	47.0	26.7	73.7	40.3	33.4	45.3
5/16/2012	21.6	22.7	44.3	28.8	15.5	35.0
5/22/2012	12.1	17.4	29.5	14.3	15.2	51.5
5/25/2012	10.7	15.0	25.7	14.0	11.7	45.5

Infiltration means: amount of surface water runoff being lost between the stations Rouaiss / Afqa and Yanouh-2/Joe Marine. In order to make all measurements comparable, these will be used as reference stations in all consecutive reports.

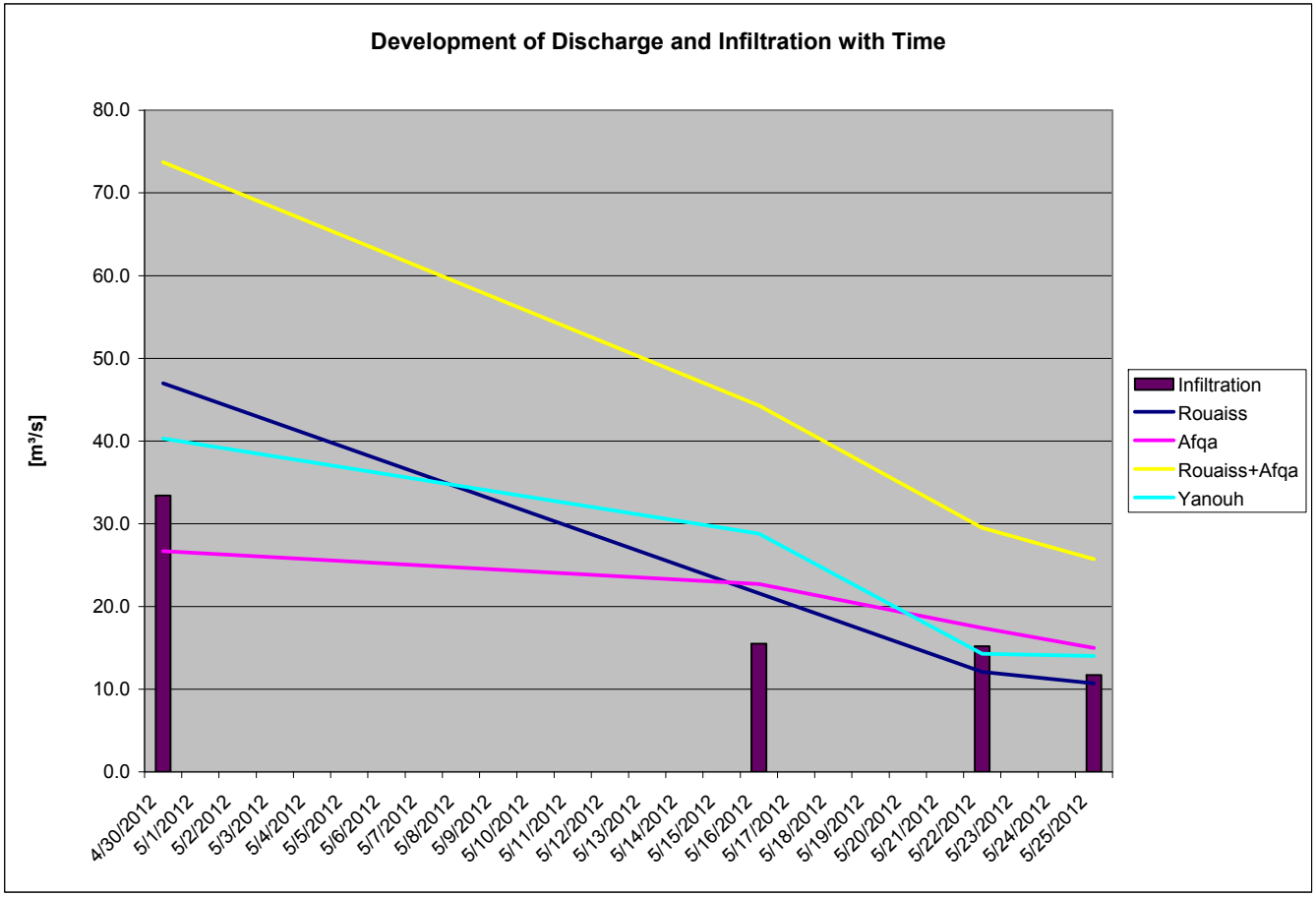


Figure 22: Development of Discharge and Infiltration during the four Measurements Campaigns

5 Conclusions and Recommendations

The results of all four measurement campaigns prove the existence of a massive infiltration into the J4 aquifer in the Upper Nahr Ibrahim Valley and have mayor implications for the currently ongoing planning of the Janneh dam which extends well into the assumed zone of high infiltration.

The exact location of the infiltration zone could be narrowed down to the area shown in Figure 23. **The infiltration zone could start at an elevation of approx. 800 m asl going up to around 860 m asl. The major infiltration is assumed to be at an elevation of 810-820 m asl.** The planned minimum level of the Janneh dam would be at 834 m asl, the maximum level at 839 m asl. Due to the infiltration between 14 and 29 m of storage would be lost completely.

In view of the current findings, it is strongly recommended not to go ahead with the construction of the planned Janneh dam.

The infiltrating water is believed to flow towards Jeita spring, constituting a large share of discharge at Jeita spring. Any interference at the infiltration zone would directly affect Jeita spring. Should it be attempted to seal the infiltration zone, though practically impossible, discharge at Jeita spring would be significantly reduced.

It is of utmost importance to conduct the tracer test proposed to WEBML and Khatib and Alami in a borehole at Saraita, to be drilled by WEBML. A related request was submitted to WEBML and Khatib and Alami on 22 May 2012.

It is recommended to establish a completely new monitoring of spring flow at Afqa and Rouaiss springs because both stations are in a state of disrepair and do not produce useful results. Construction costs for both are in the range of 1 Mio USD.

6 References

(only additional references to the main report)

MARGANE, A., SCHULER, P., ABI RIZK, J., RAAD, R., KOENIGER, P., STOECKL, L. in progr.): Hydrogeology of the Groundwater Contribution Zone of Jeita Spring. – German-Lebanese Technical Cooperation Project Protection of Jeita Spring, Technical Report No. 5, xxx p.; Raifoun/Lebanon.

MARGANE, A. & SCHULER, P. (in progr.): Water Balance for the Groundwater Contribution Zone of Jeita Spring using WEAP including Water Resources Management Options and Scenarios. – German-Lebanese Technical Cooperation Project Protection of Jeita Spring, Technical Report No. 6, xxx p.; Raifoun/Lebanon.

MARGANE, A. (in progr.): Monitoring of Spring Discharge in the Groundwater Contribution Zone of Jeita Spring. – German-Lebanese Technical Cooperation Project Protection of Jeita Spring, Special Report No. 8, xxx p.; Raifoun/Lebanon.

KOENIGER, P. & MARGANE, A. (in progr.): Stable Isotope Investigations in the Groundwater Contribution Zone of Jeita Spring. – German-Lebanese Technical Cooperation Project Protection of Jeita Spring, Special Report No. 12, xx p.; Raifoun/Lebanon.

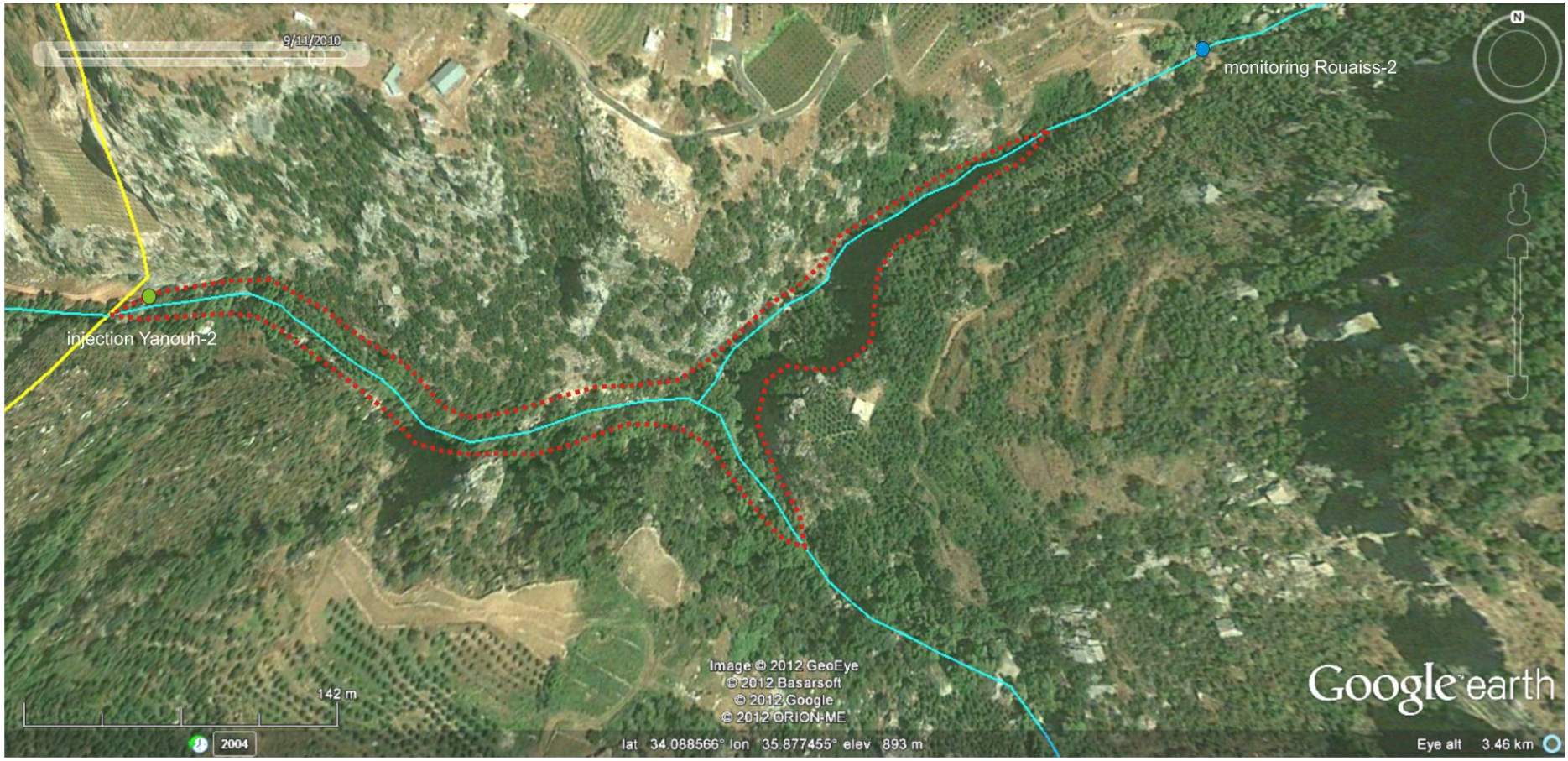


Figure 23: Modified Assumed Main Infiltration Area (red line) in the Upper Nahr Ibrahim Valley (near confluence)

Annex-1: Proposed Drilling Site Saraita

(sent to WEBML and Khatib and Alami on 22 May 2012)

Coordinates
E 35.874819°
N 34.084953°
Alt ~ 950 m asl

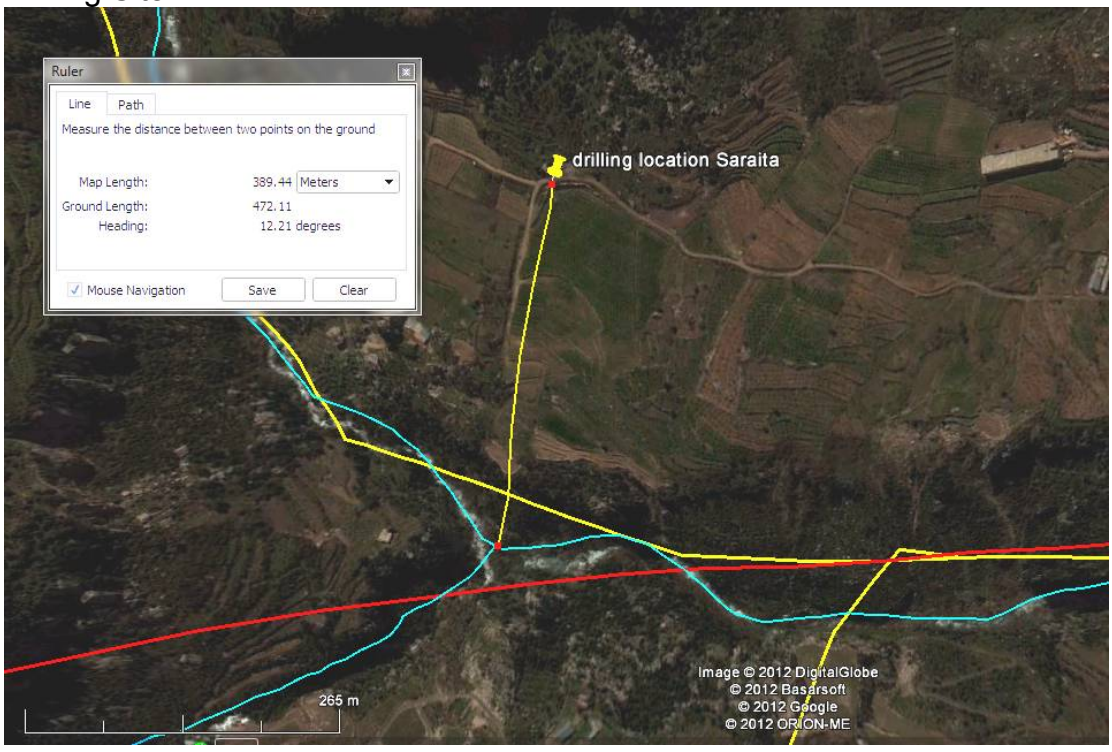
Target: J4 aquifer; tracer injection (~ 20 kg uranine)

Assumed geology: Top J4 ~ 880 m asl (70 m bgl)
Assumed J4 water level: 820 m asl (130 m bgl)
Distance to assumed center of infiltration zone ~ 400 m

Total depth: 250 m (~120 m into J4 aquifer)
Drilling diameter: 8"
Stand pipe 6 m (12")
Below 6 m open hole

Time line: ASAP

Drilling Site:



Annex-2: Photos

Photo 1: Caves near the Rouaiss / Afqa confluence (view from E 35.876214°, N 34.089362°)

Photo 2: Intensive Karstification near the Rouaiss / Afqa Confluence (location near photo 1)

Photo 3: Intensive Karstification near the Rouaiss / Afqa Confluence (location near photo 1)

Photo 4: Intensive Karstification near the Rouaiss / Afqa Confluence (location near photo 1)

Photo 5: Narrow passage at Yanouh-2 Station (E 35.871643°, N 34.088950°) (it was not possible to venture further upstream of this location)