Council for Development and Reconstruction (CDR)
Ministry of Energy and Water (MoEW)
Water Establishment Beirut and Mount Lebanon (WEBML)

Federal Institute for Geosciences
and Natural Resources (BGR),
Hannover, Germany

German-Lebanese Technical Cooperation Project

Protection of Jeita Spring

Overview of Project Results

Final Project Workshop
11 July 2014

Dr. Armin Margane, BGR

Outline

- Tasks
- Description of Project Area
- Project Results related to
  - Component 1 (Wastewater Sector)
  - Component 2 (GW Protection Zones, Awareness)
  - Component 3 (Monitoring Quantity/Quality, Balance)
  - Component 4 (Improved Jeita Spring Capture) and Conveyor)

BGR

Project Activities

Goal: *Major Risks for the Drinking Water Supply in the Greater Beirut Area are reduced by implementing measures to protect the groundwater contribution zone of the Jeita Spring from pollution*.

1. **Integration of water resources protection aspects into the investment planning and implementation process in the wastewater sector (geoscientific advice in wastewater sector)**
2. **Integration of water resources protection aspects into landuse planning (delineation of GW protection zones)**
3. **Collection and use of monitoring data concerning quality and quantity of water resources**
4. **Support of the partner institutions concerning the implementation of urgent protective measures**

Jeita Spring is the main Source for Water Supply of Beirut

~ 75 % of Beirut‘s water comes from Jeita

Protection of Jeita Spring must be a national priority

→ Awareness Movie „Beirut Waters“

Data Availability

- Insufficient and inadequate meteorological stations/data (not heated > no snow data) (previously >100 stations, now 35 stations in LB)
- No groundwater monitoring > no water levels > no GW model
- Spring discharge monitoring stations not adequately designed, maintained and monitored
- Surface water gauging stations not adequately designed and maintained

► lack of institutional capacity, funds and staff

Water resources assessment needs monitoring system for all water balance components

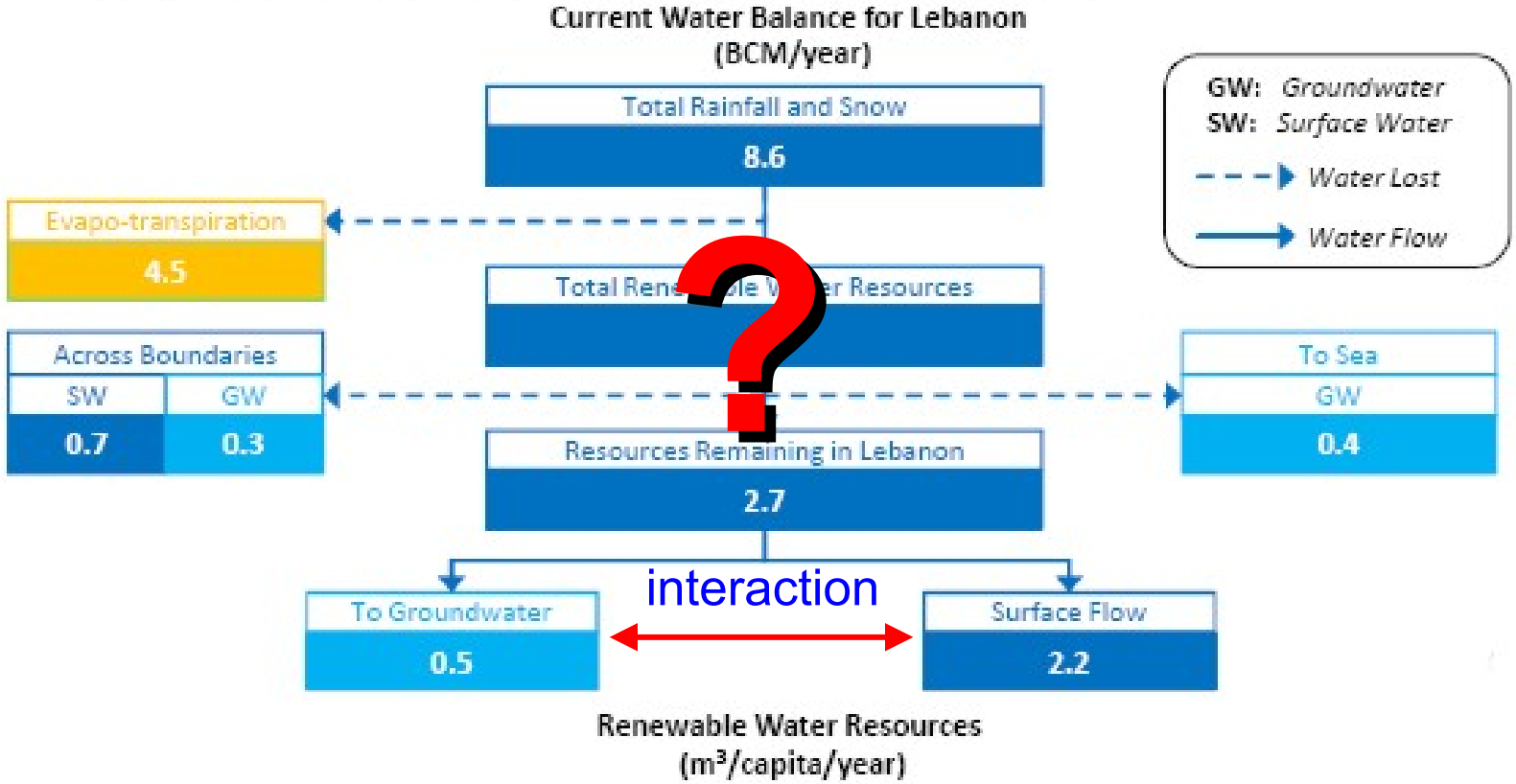
- rainfall / snow
- spring discharge
- runoff (surface water)
- groundwater abstraction
- irrigation water use (return flow)
- domestic water use / losses (return flow)

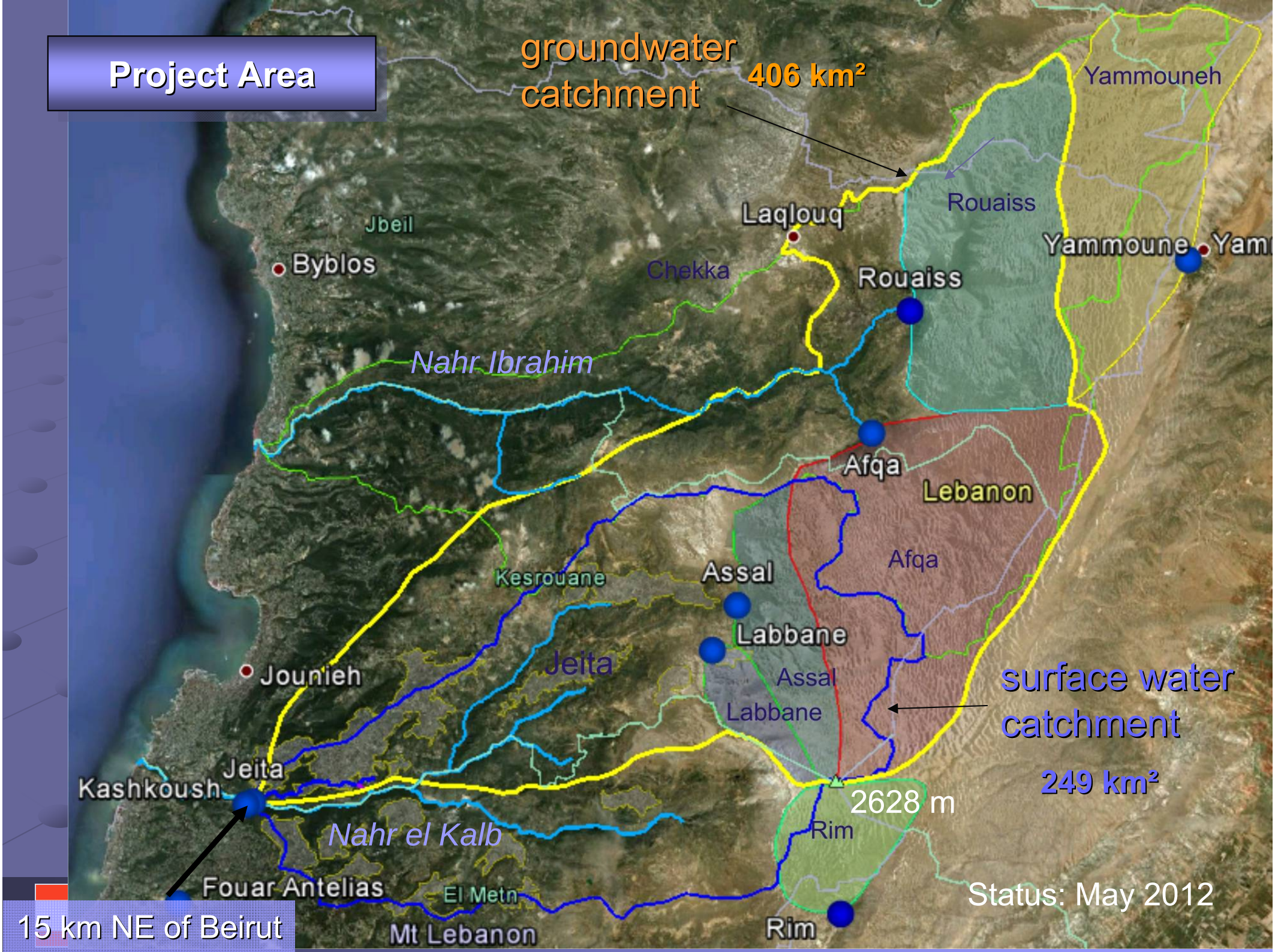
► no data > no correct water resources assessment
► wrong water resources assessment leads to wrong planning !
► failed investments in the water sector

Current Planning in the Water Sector

None of the Components of the Water Balance is monitored
Water Resources Availability was never assessed correctly
wrong Information leads to wrong Planning

Renewable water resources per capita are already slightly below scarcity threshold, with expected decrease in the coming years




Project Area
groundwater catchment
406 km²
Yammouneh
Rouaiss
Laqlouq
Jbeil
Byblos
Chekka
Rouaiss
Yammoune
Yam
Nahr Ibrahim
Afqa
Lebanon
Afqa
Kesrouane
Assal
Labbane
Jeita
Assal
Labbane
Jounieh
surface water catchment
249 km²
Jeita
Kashkoush
2628 m
Rim
Nahr el Kalb
Fouar Antelias
El Metn
Mt Lebanon
Rim
Status: May 2012
15 km NE of Beirut

Where does Beirut's drinking water come from

Importance of Snow

it is time to act !

Cretaceous plateau (1,800 – 3,000 m asl):
~4 m snow (2011/12: up to 10 m and more)
December – April

Very important for GW recharge (~ 81%)
Snow is the lifeline of Lebanon

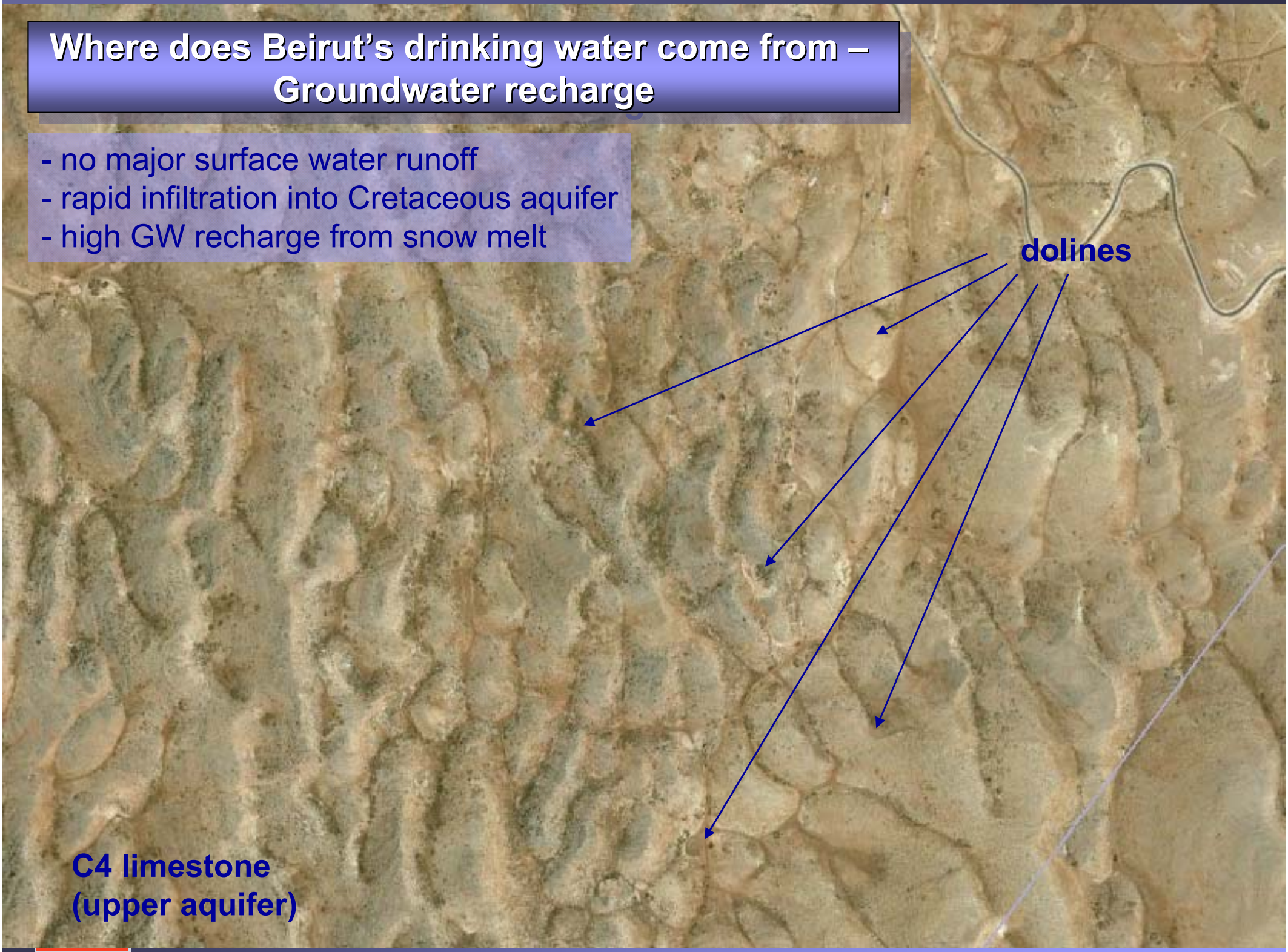
Climate change may lead to a significantly lower groundwater resources availability

Regional climatic scenarios predict less rainfall (15-30%), higher summer and winter temperatures (up to 5°C) and thus less snow and runoff, more evaporation

- **shift of orographic snow line**
- **water shortage in dry season**

Where does Beirut's drinking water come from – Groundwater recharge

- no major surface water runoff
- rapid infiltration into Cretaceous aquifer
- high GW recharge from snow melt

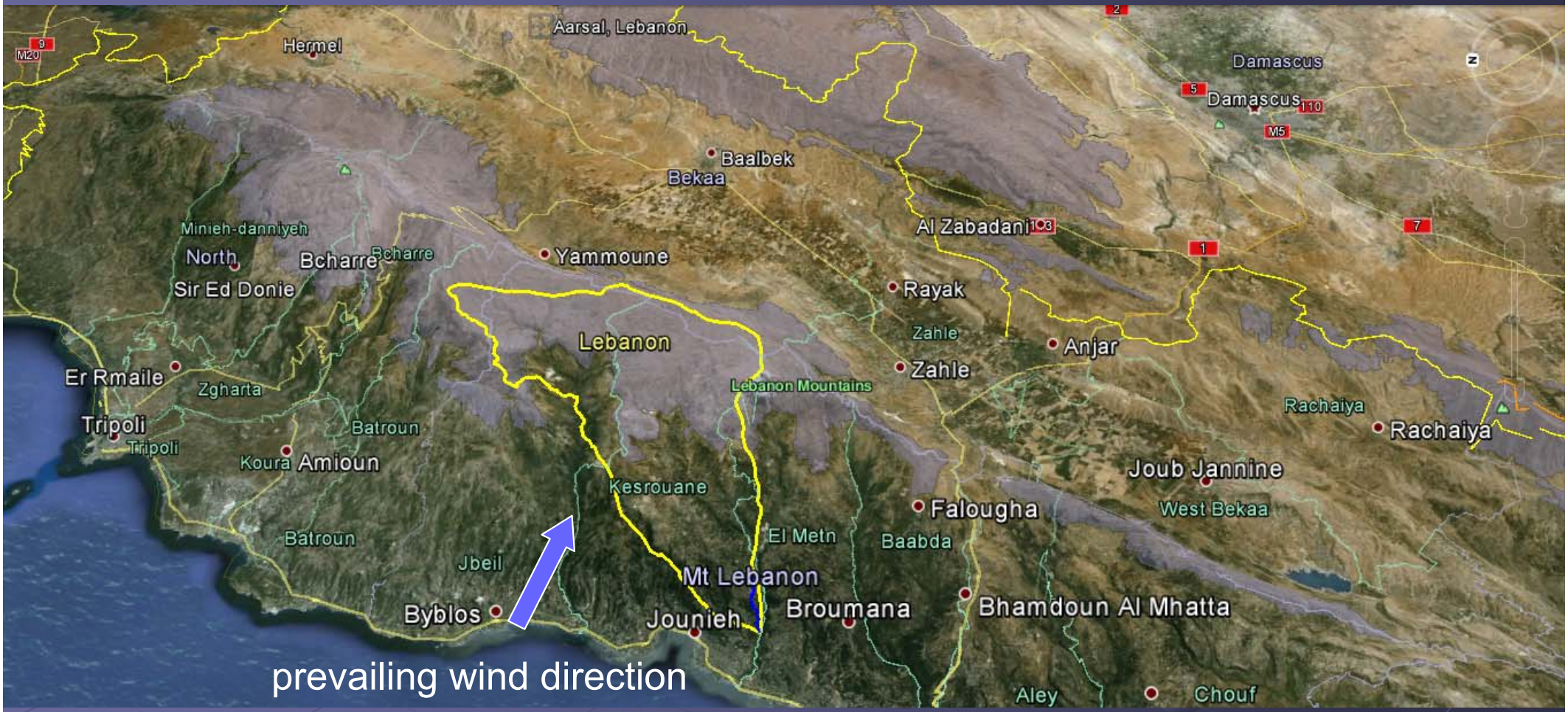


Where does Beirut's drinking water come from – Groundwater recharge

GW recharge via dolines

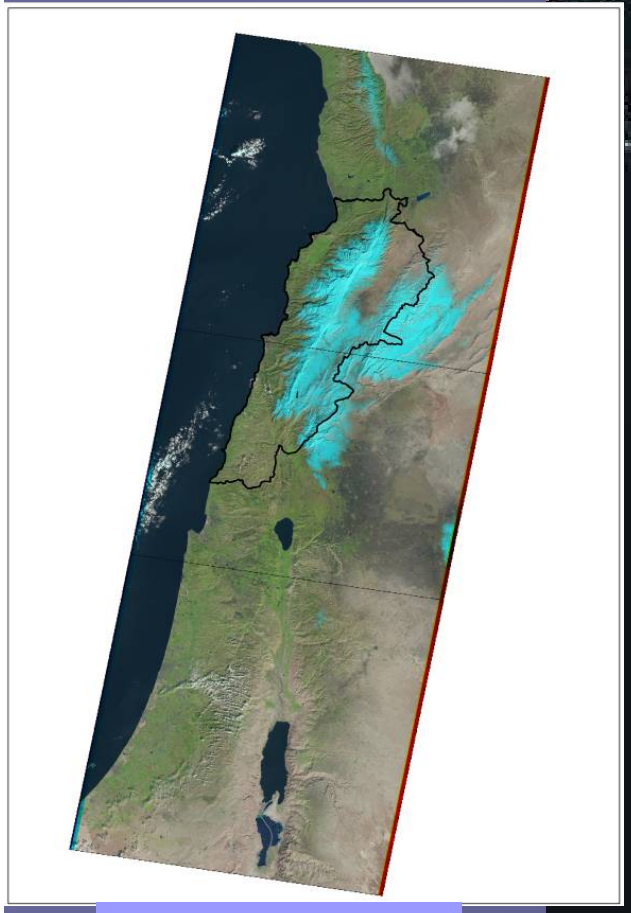
average GW recharge in C4: 81%


High karstification in
Cretaceous limestone
(Faqra)


Aarsal, Lebanon
Hermel
Damascus
Damascus
Baalbek
Bekaa
Al Zabadani
Minieh-danniyeh
North
Bcharre
Bcharre
Yammoune
Sir Ed Donie
Rayak
Lebanon
Zahle
Anjar
Zahle
Er Rmaile
Zgharta
Lebanon Mountains
Rachaiya
Rachaiya
Tripoli
Tripoli
Batroun
Koura
Amioun
Joub Jannine
Kesrouane
Faloughа
West Bekaa
El Metn
Baabda
Batroun
Jbeil
Mt Lebanon
Byblos
Jounieh
Broumana
Bhamdoun Al Mhatta
prevailing wind direction
Aley
Chouf

Area > 1600 m

Snow Cover



Landsat TM7
19.01.2002

deposition of snow predominantly on W-facing slopes

Lebanese restraining bend

DST

Beqa'a Valley

Syria: 80% GWR (Russian studies 1980s)

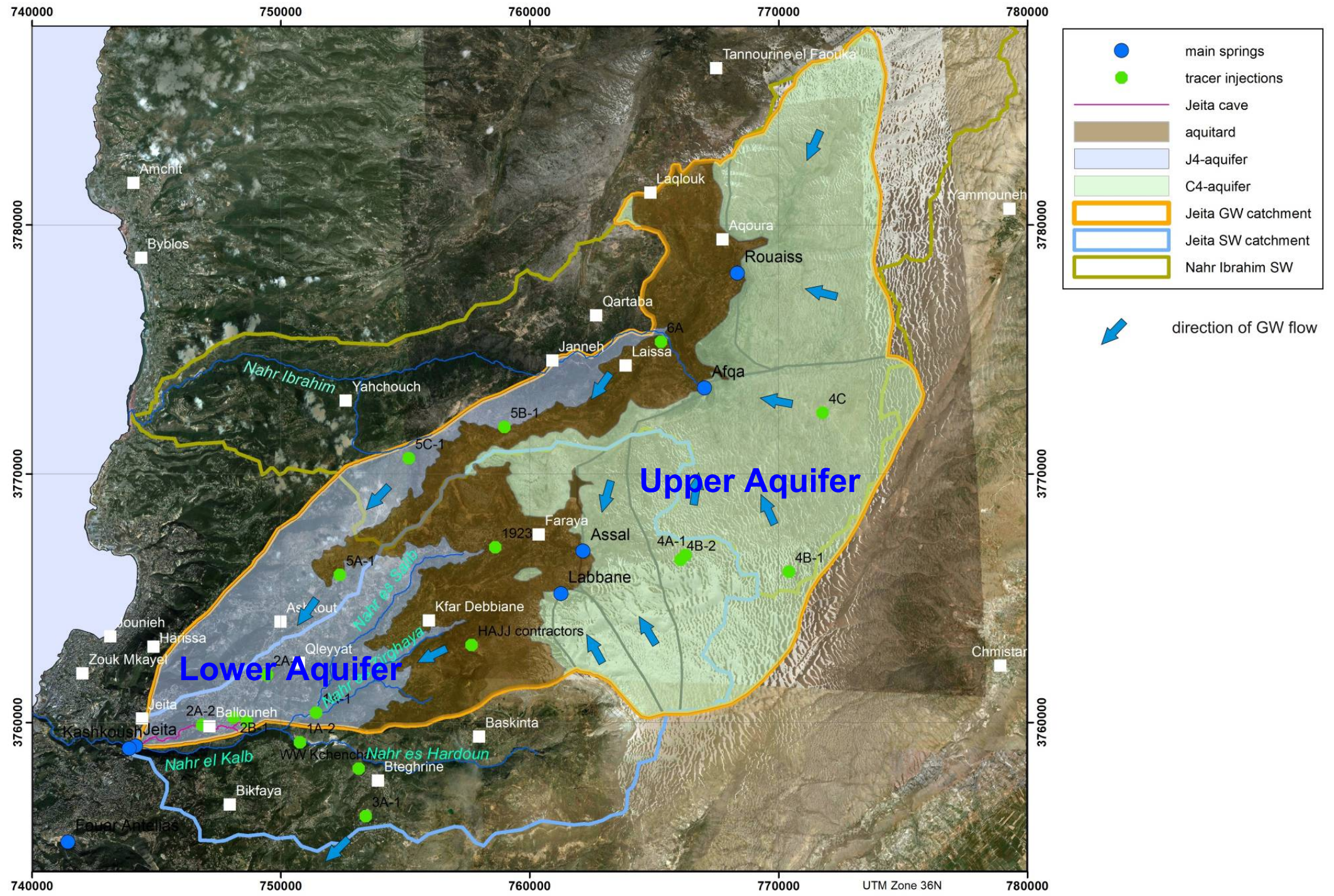
Antilebanon

Jeita spring

Landsat TM7
01.02.2001

Groundwater System

Based on new geological map prepared by BGR



Specific Problems

- High rainfall (on average 1450 mm/a)
- high level of karstification
  ► high infiltration / low retention capacity
  ► high spring discharge peaks during January to April (up to 60 m³/s), low flow during dry season (min. 1 m³/s) > water shortage in Oct/Dec
- high GW flow velocity (up to 2,000 m/h)
- rapid and uncontrolled urban expansion (approx. 200.000 inhabitants)
  ► severe deterioration of water quality over the past decades

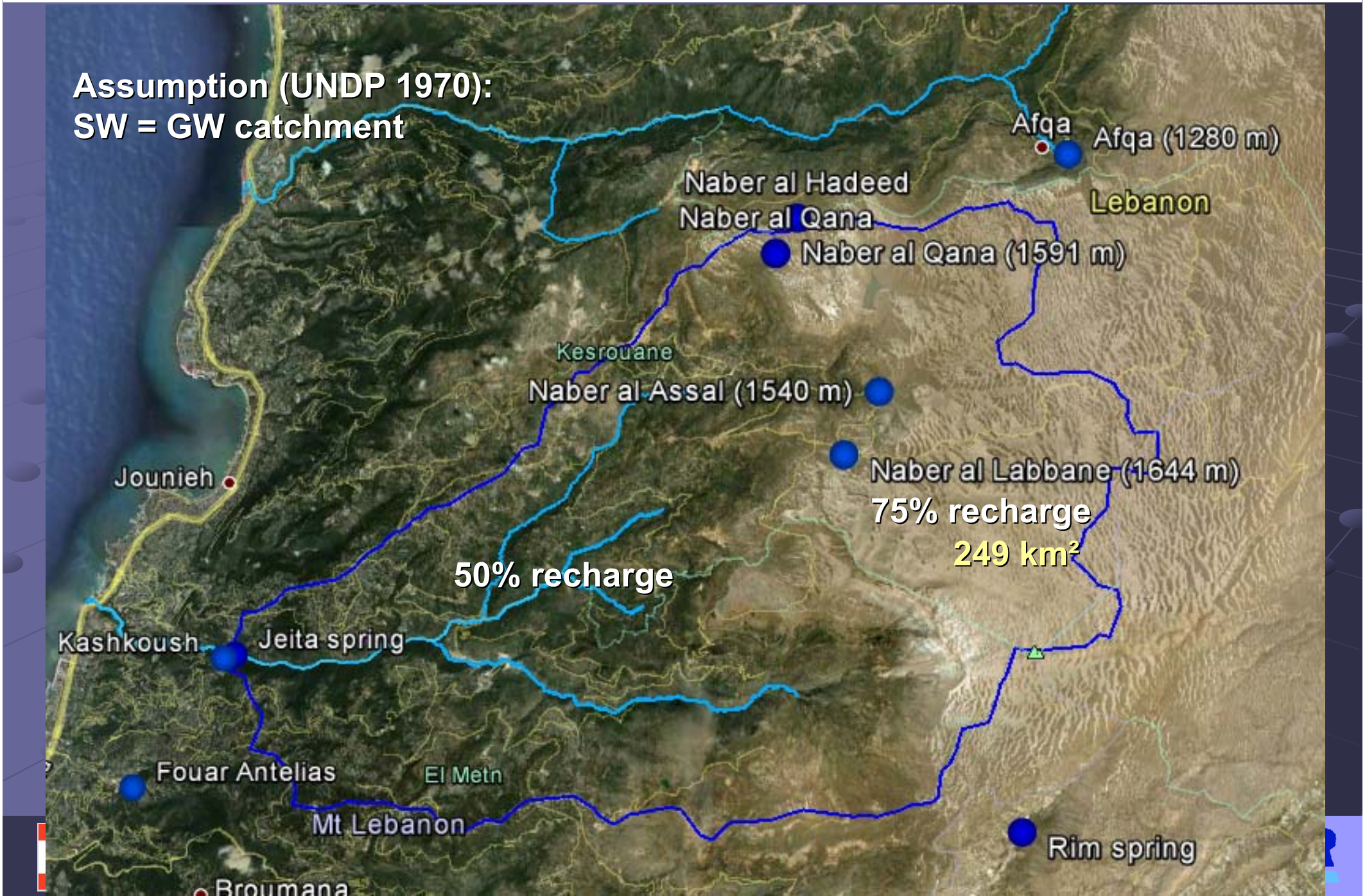
Main pollution sources:

- wastewater (no WWTPs yet)
- waste (often illegal disposal)
- gas stations (54 inside GW catchment; 30 near catchment)
- quarries (sandstone, cement, decoration stone)
- Jeita – Dbaye water conveyor (up to 140 yrs old)

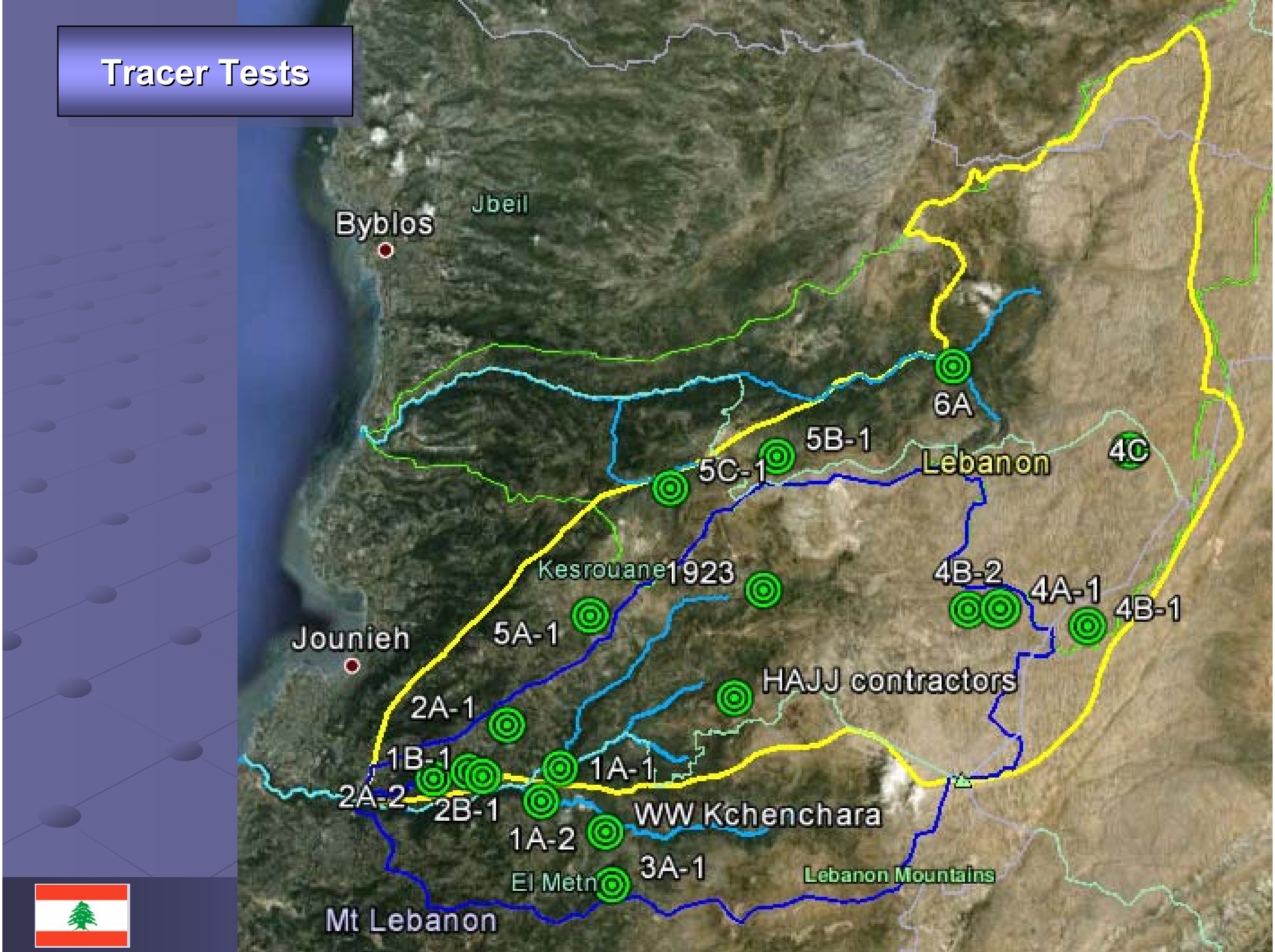
BGR

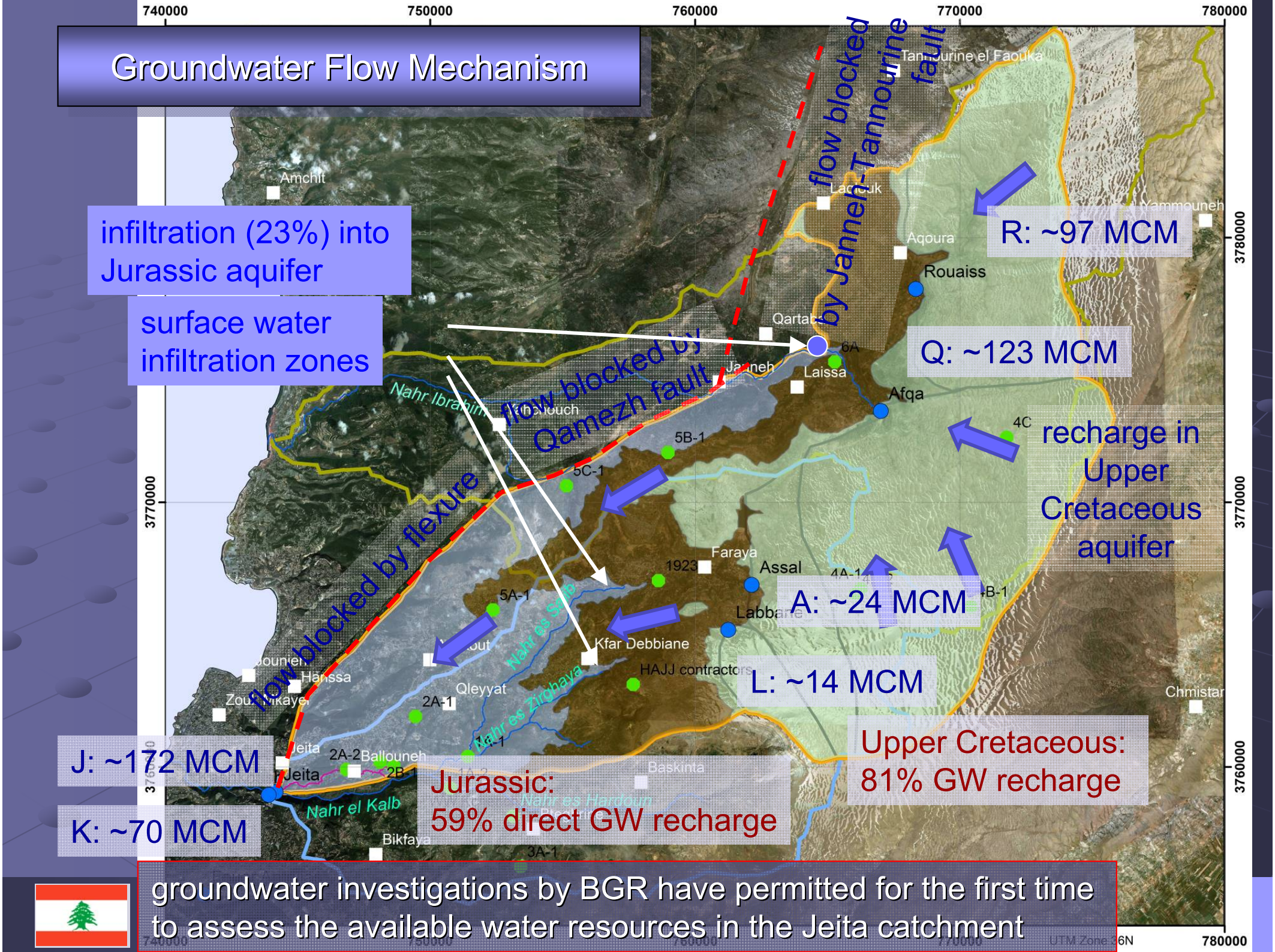
Project Area = Groundwater Catchment

July 2010

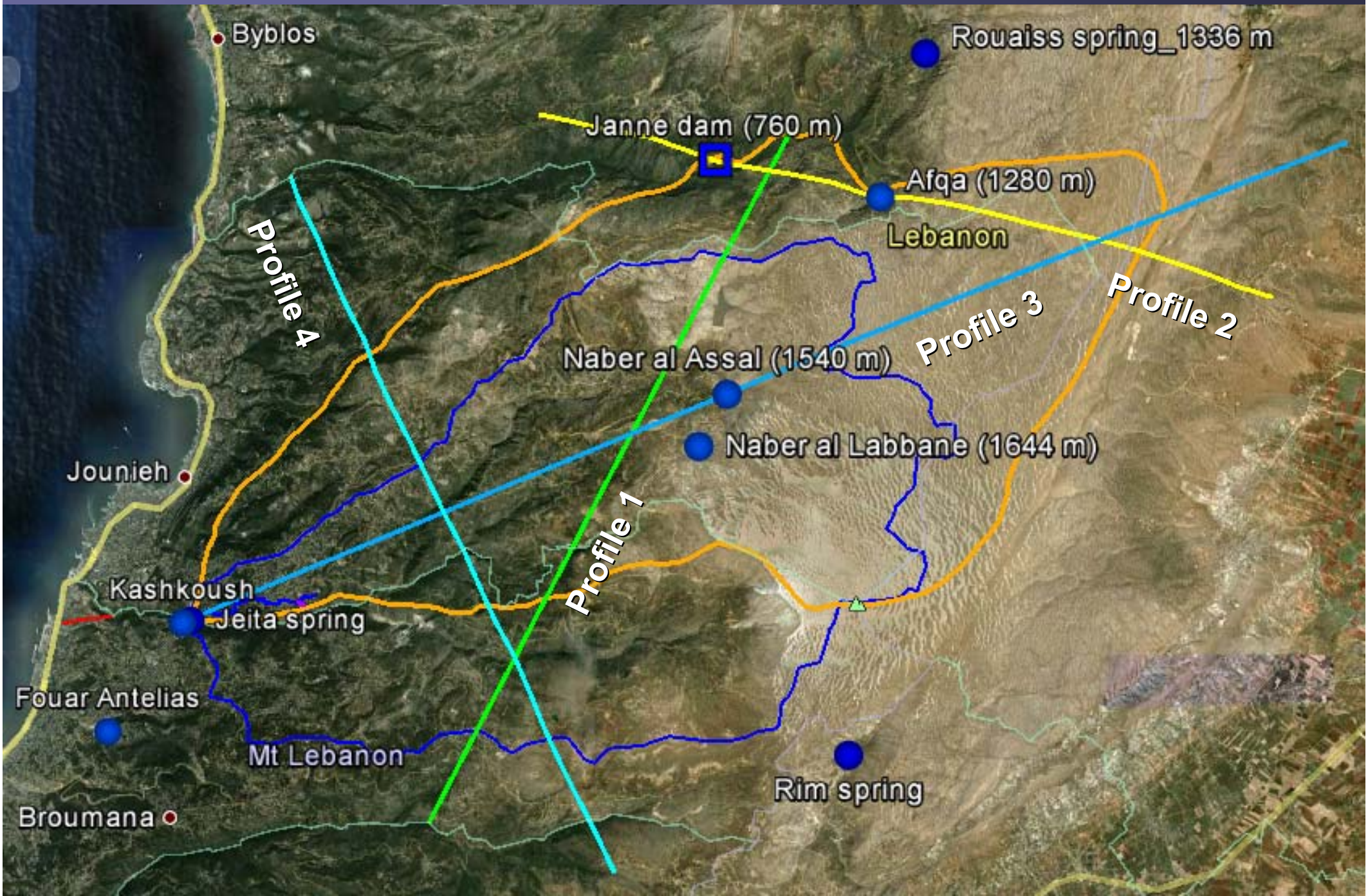


Tracer Tests




Groundwater Flow Mechanism
infiltration (23%) into Jurassic aquifer
surface water infiltration zones
flow blocked by Janneh-Tannourine fault
flow blocked by Qamezh fault
flow blocked by flexure
R: ~97 MCM
Q: ~123 MCM
recharge in Upper Cretaceous aquifer
A: ~24 MCM
L: ~14 MCM
J: ~172 MCM
K: ~70 MCM
Jurassic:
59% direct GW recharge
Upper Cretaceous:
81% GW recharge
groundwater investigations by BGR have permitted for the first time to assess the available water resources in the Jeita catchment
740000
750000
760000
770000
780000
3780000
3770000
3760000
Amchit
Aqoura
Rouaiss
Laissa
Afqa
Faraya
Assal
Kfar Debbiane
Qleyyat
Hanssa
Jeita
Ballouneh
Bikfaya
Chmistar
Nahr el Kalb
Nahr es Salib
Nahr es Zirghaya
Nahr es Hamboun
5A-1
5B-1
5C-1
2A-1
2A-2
2B-1
3A-1
4A-1
4B-1
4C
6A
1923

Geological Cross Sections

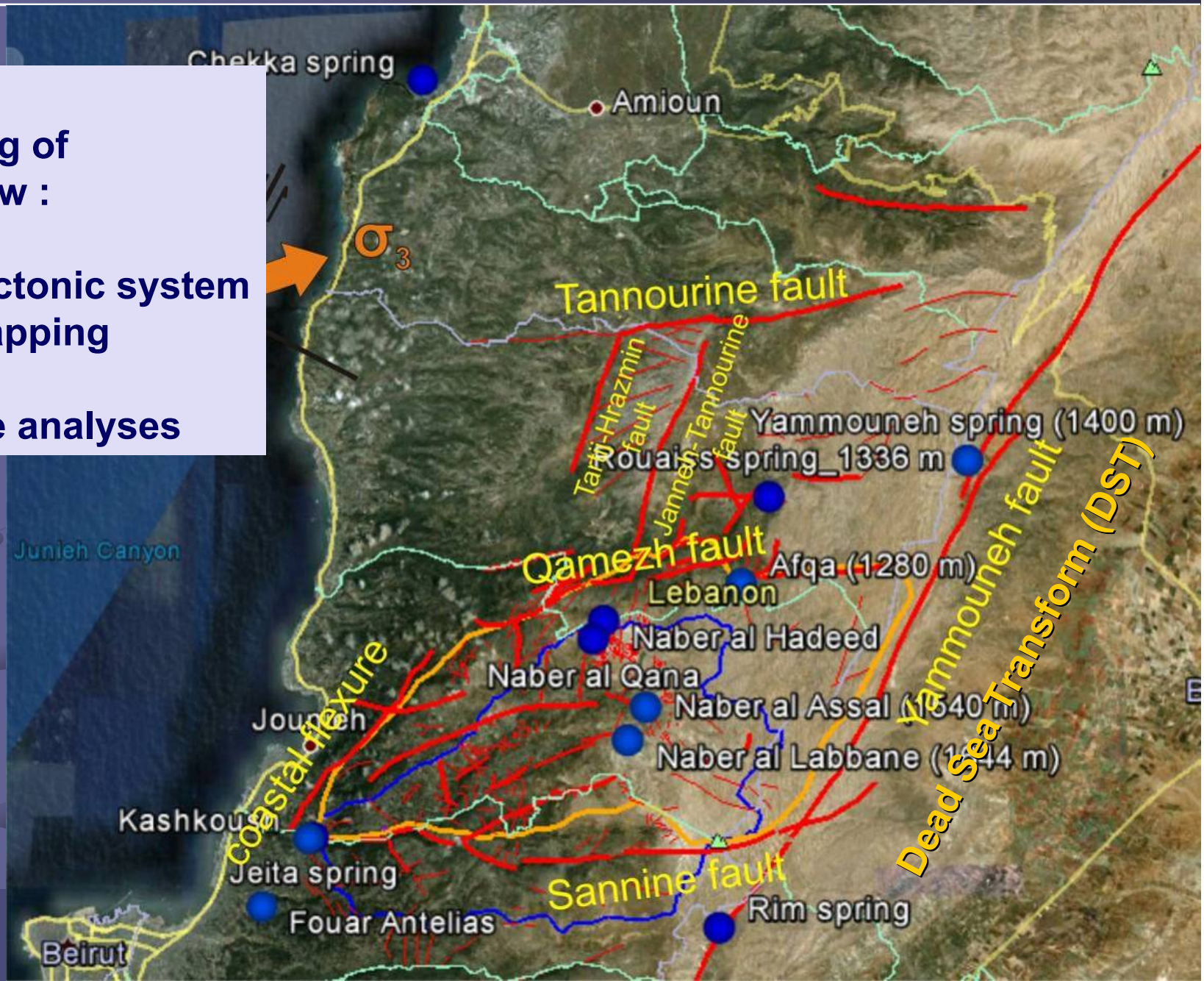


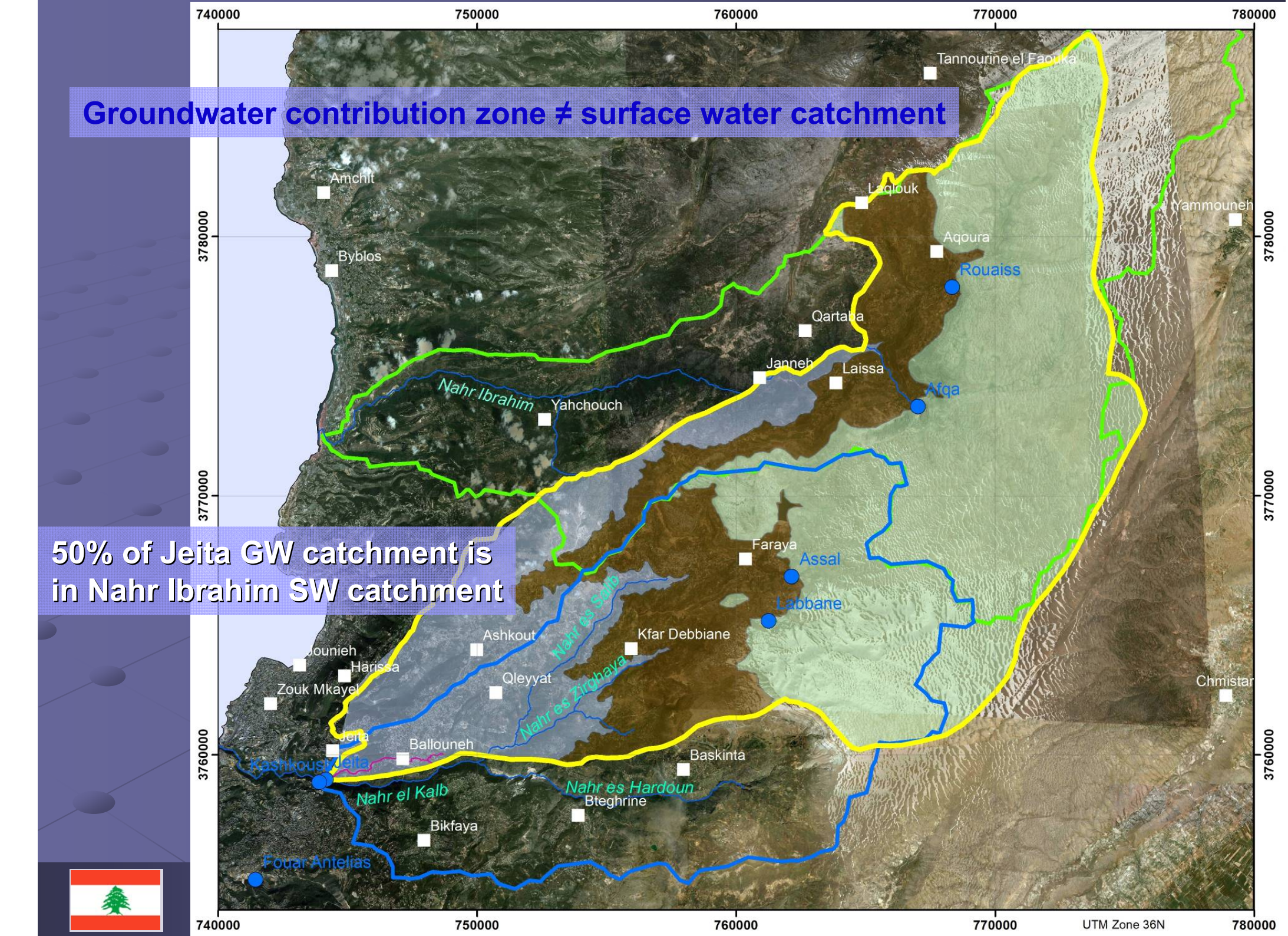
Groundwater Flow

controlled by
- structure (base) and
- tectonics

key elements to understanding of groundwater flow :

- **analysis of tectonic system**
- **geological mapping**
- **tracer tests**
- **stable isotope analyses**




Groundwater contribution zone ≠ surface water catchment
50% of Jeita GW catchment is in Nahr Ibrahim SW catchment
740000
750000
760000
770000
780000
3780000
3770000
3760000
Tannourine el Faouka
Amchit
Laqlouk
Yammouneh
Aqoura
Byblos
Rouaiss
Qartaba
Janneh
Laissa
Afqa
Nahr Ibrahim
Yahchouch
Faraya
Assal
Labbane
Nahr es Saffe
Ashkout
Kfar Debbiane
Harissa
Zouk Mkayel
Qleyyat
Nahr es Zirghaya
Chmistar
Ballouneh
Baskinta
Kashkoush
Jeita
Nahr el Kalb
Nahr es Hardoun
Bteghrine
Bikfaya
Fouar Antelias
UTM Zone 36N

Spring Monitoring

- multiparameter probes
- gauging stations (weir, ADCPs)
- direct discharge measurement
  (> 300 dilution tests)


Labbane spring


Daraya tunnel


old system,
not functioning

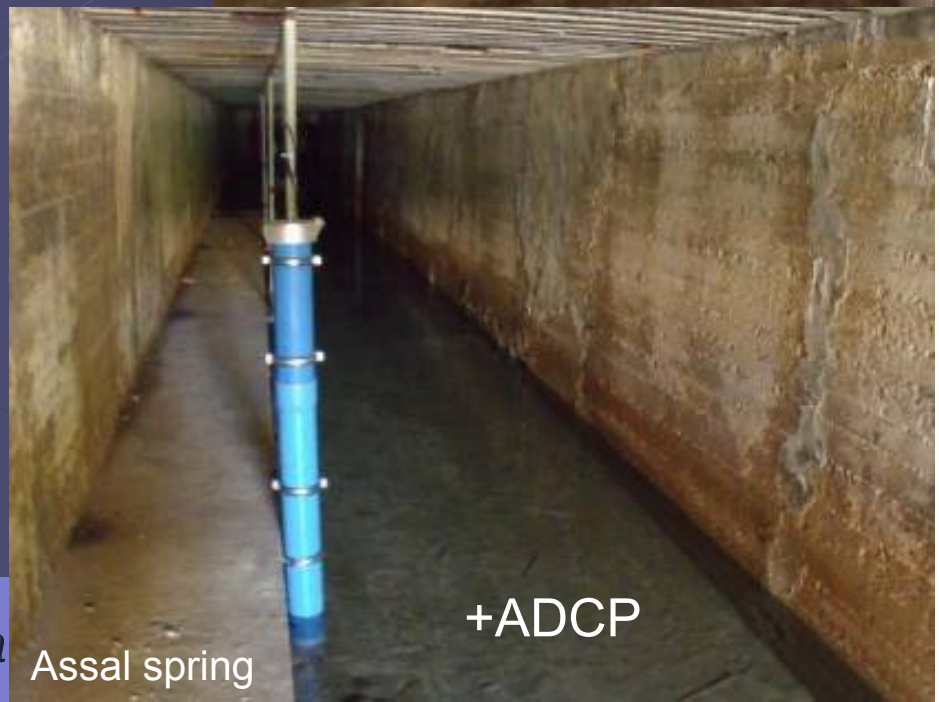
Kashkoush spring


Jeita spring

+ADCP

Multiparameter probes
parameters:
Water level
Temperature
EC
pH
ORP
DO
(ammonium)
(ISE)

Telemetric data transfer


+ADCP

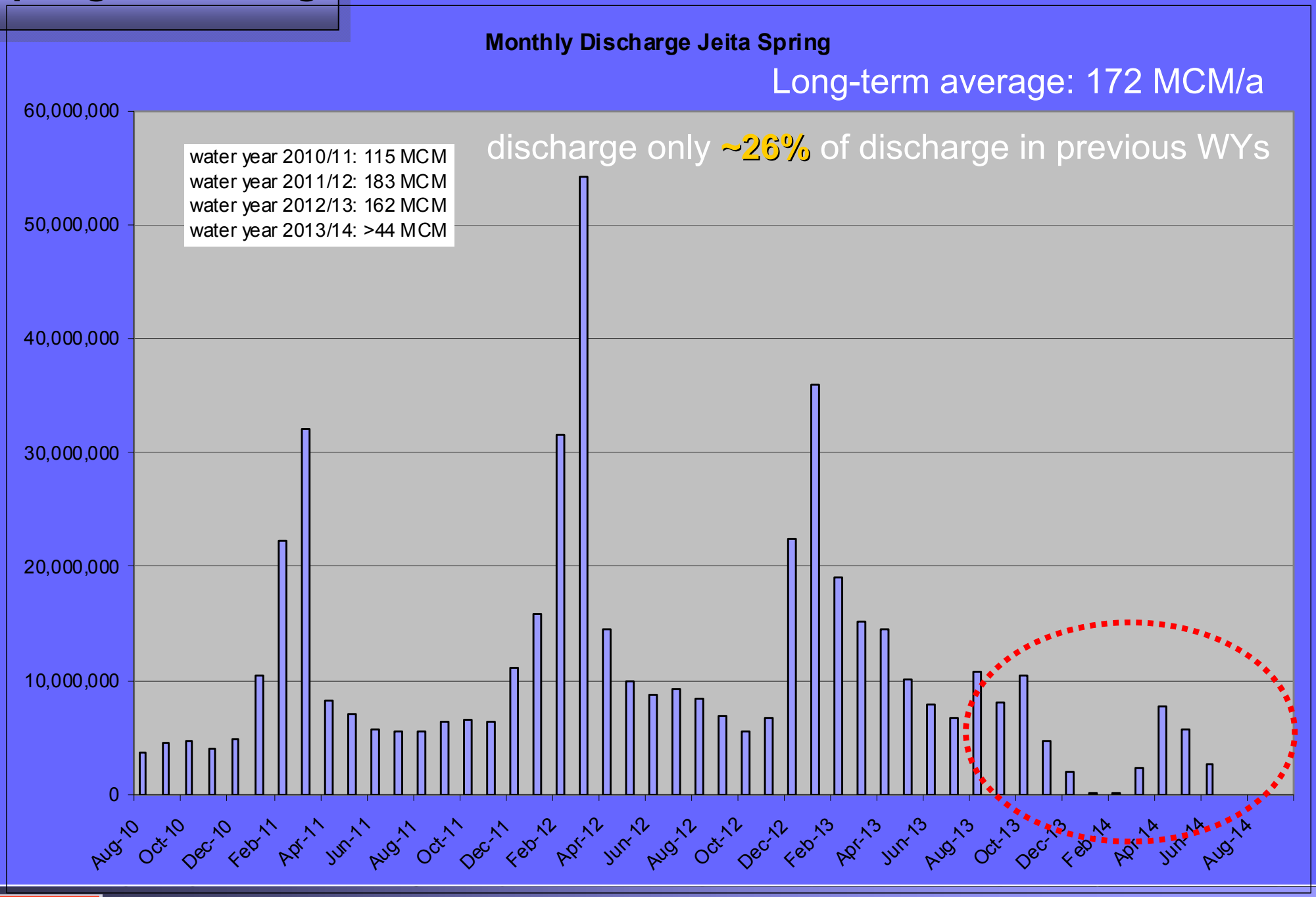
Assal spring

Spring Monitoring

Assal – Monitoring by ADCP & multiparameter probe

ADCP : every **15 min** multiparameter probe: every **20 min**

Jeita – Monitoring by ADCP & multiparameter probe



Climate data

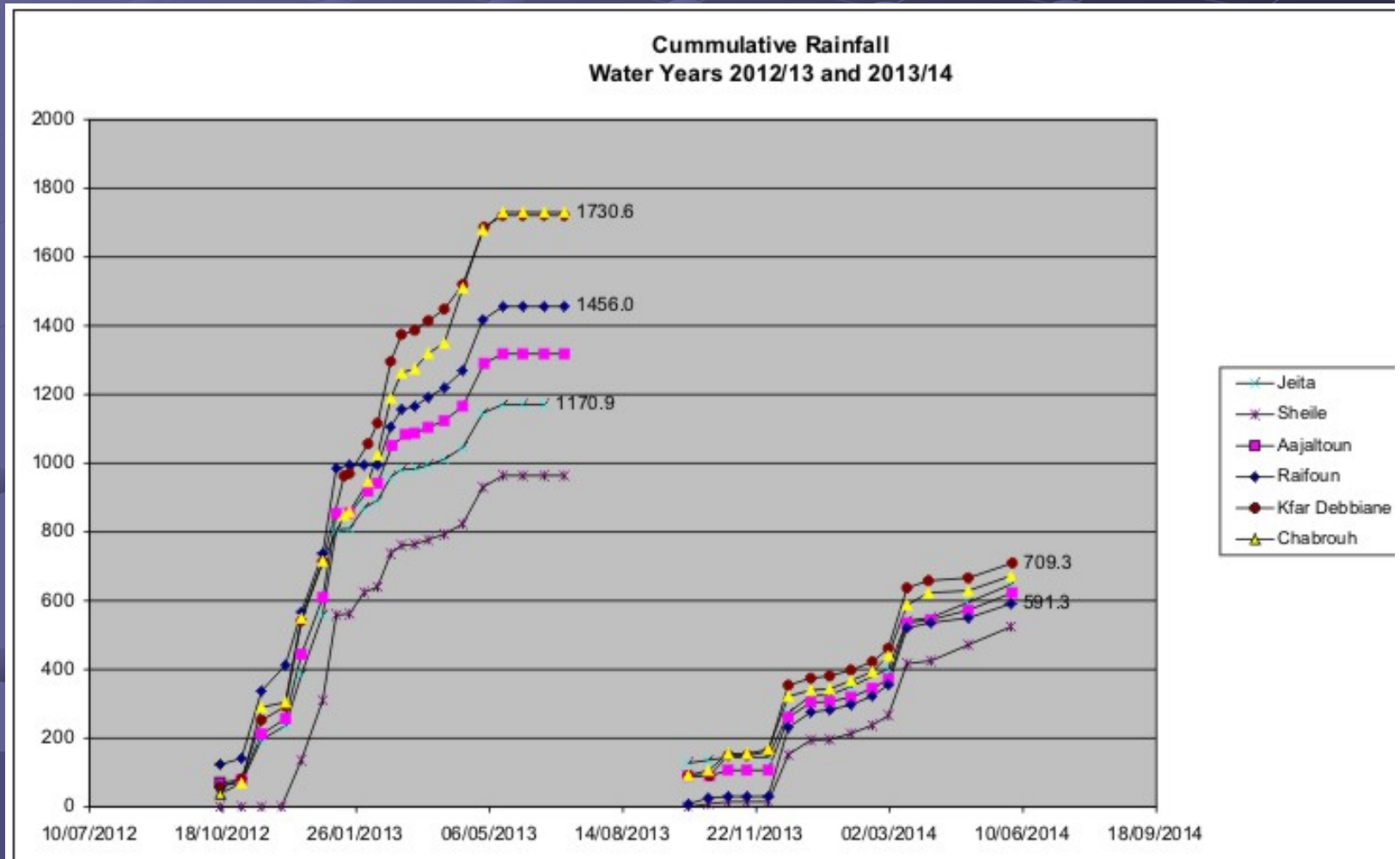
Installation of meteorological stations at

- Sheile (463 m)
- Aajaltoun (821 m)
- Kfar Debbiane (1307 m)
- Bakeesh (1416 m)
- Chabrouh dam (1591 m)

Water Scarcity 2014

Reporting to all parties (CDR, MoEW, WEBML) every 2 weeks:
- rainfall water year 2013/14 compared to WY 2012/13
- spring discharge (Assal, Kashkoush) same period

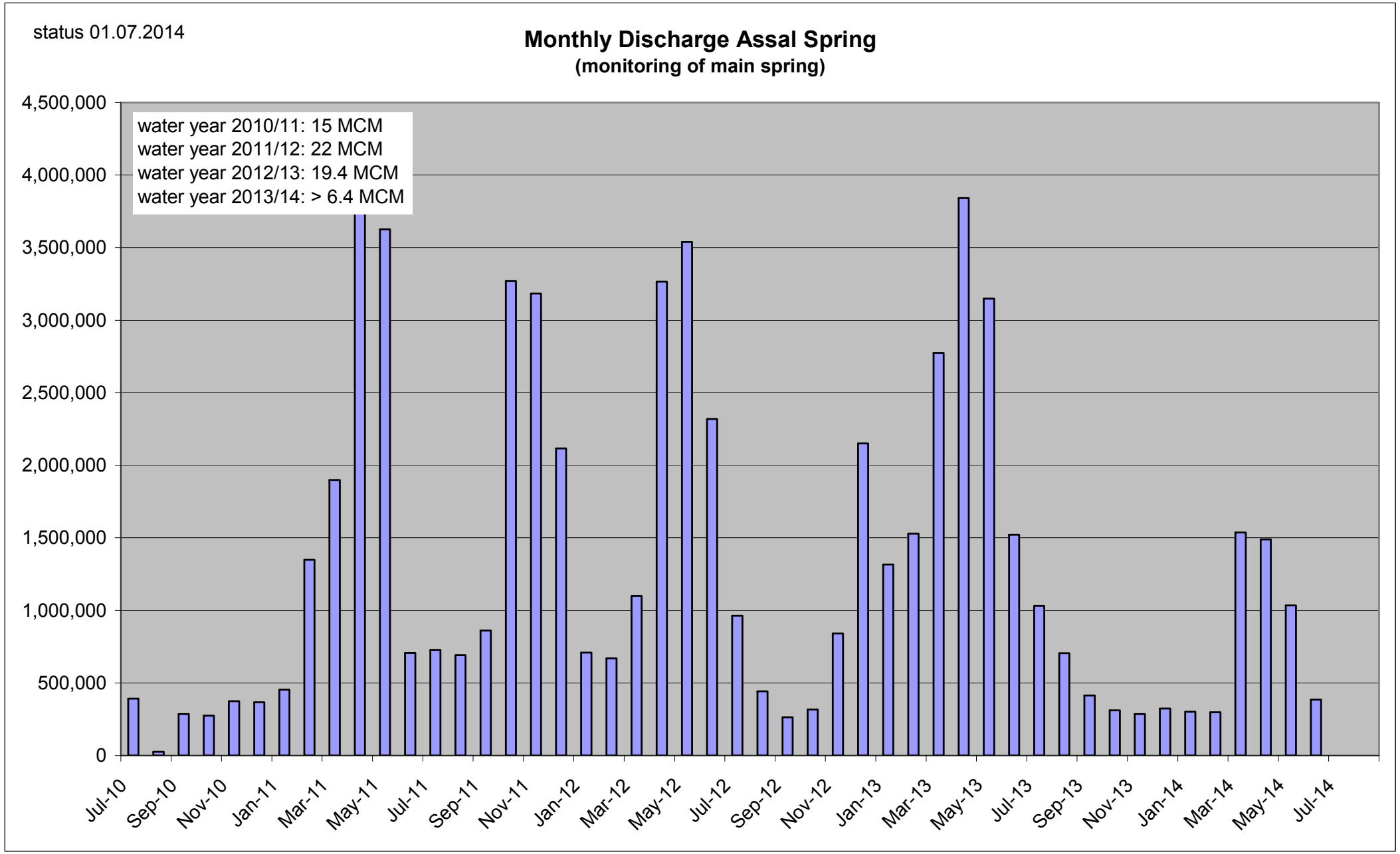
Rainfall in WY 2013/14 only **~40%** of rainfall in previous WY



Water Scarcity 2014

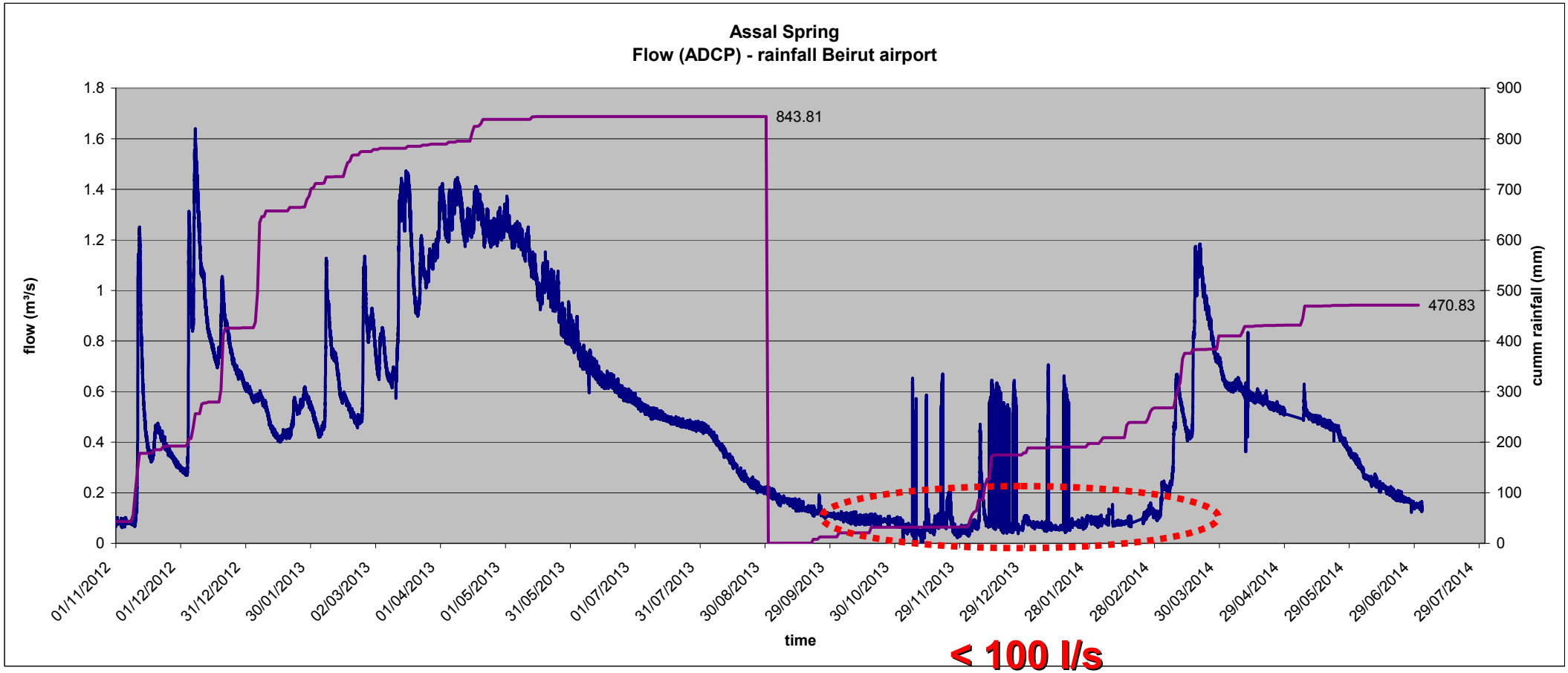
spring discharge Assal since 07/2010

discharge only **~35%** of discharge in previous WYs



Water Scarcity 2014

spring discharge Assal since 10/2012
ADCP data

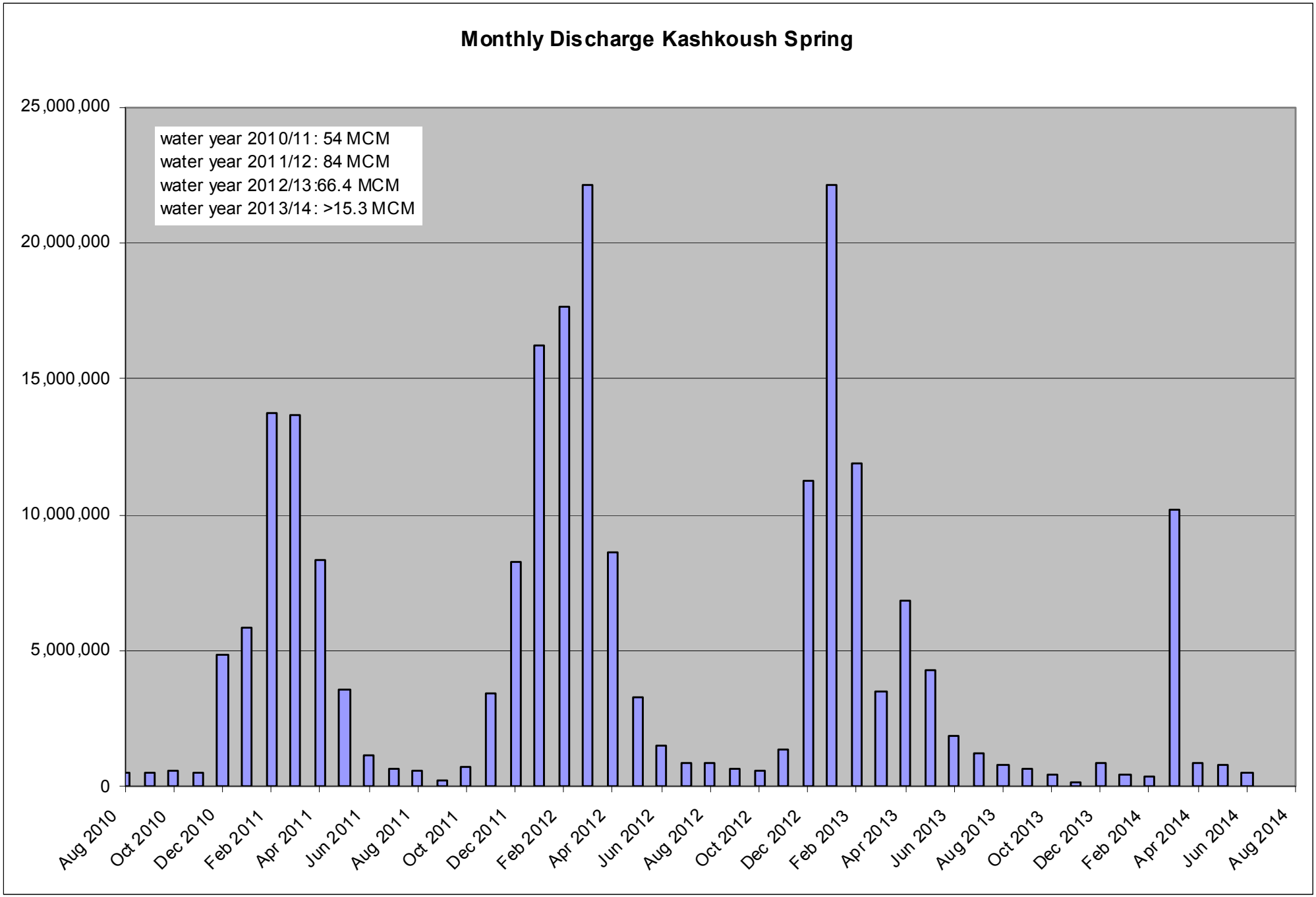


< 100 l/s

Water Scarcity 2014

spring discharge Kashkoush since 07/2010

discharge only **~25%** of discharge in previous WYs

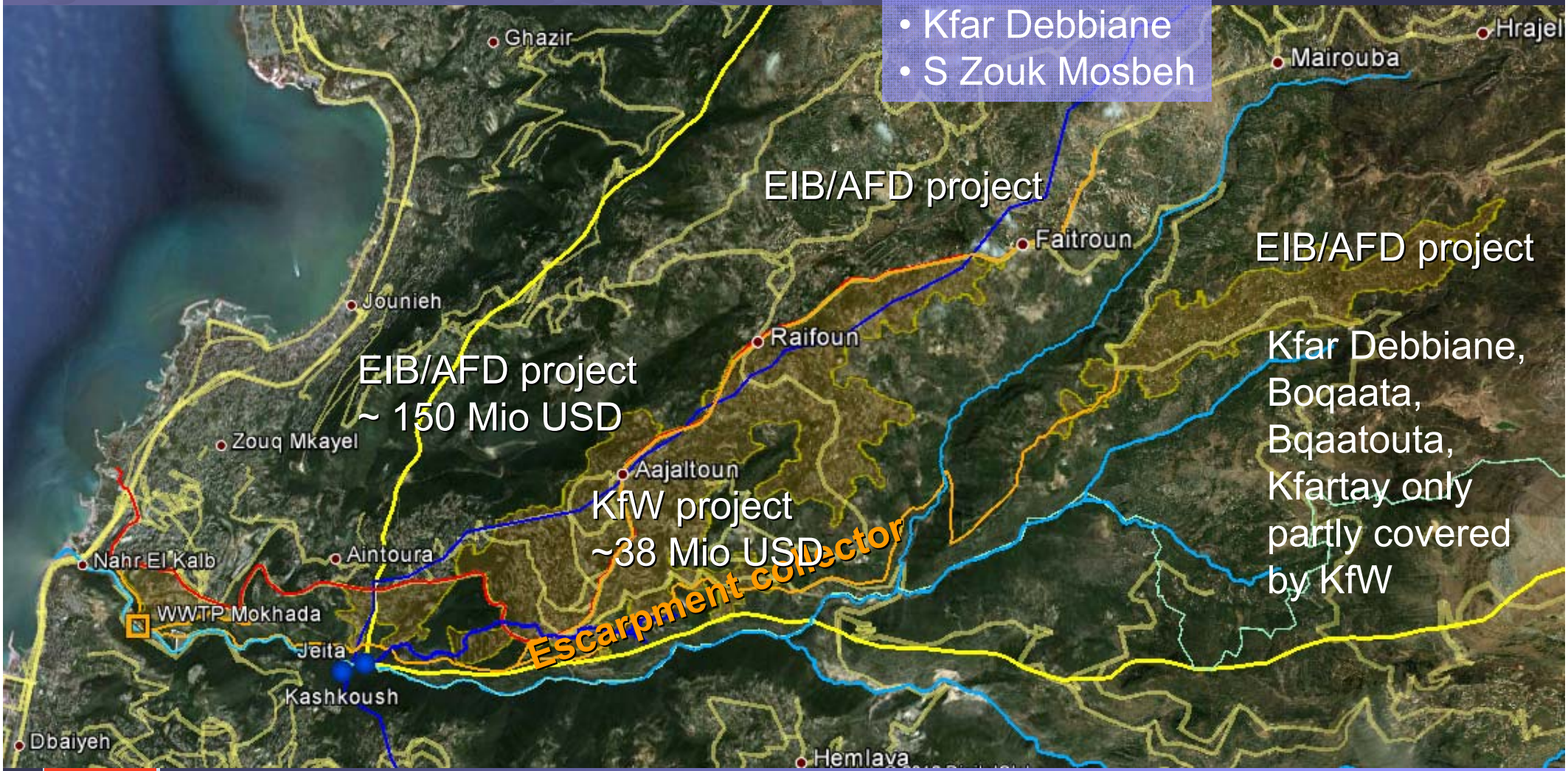


KfW Jeita Project

Without pumpage

Serviced area
- S Jeita
- (S Sheile)
- Ballouneh
- Aajaltoun
- Daraya
- Kfar Debbiane
- S Zouk Mosbeh

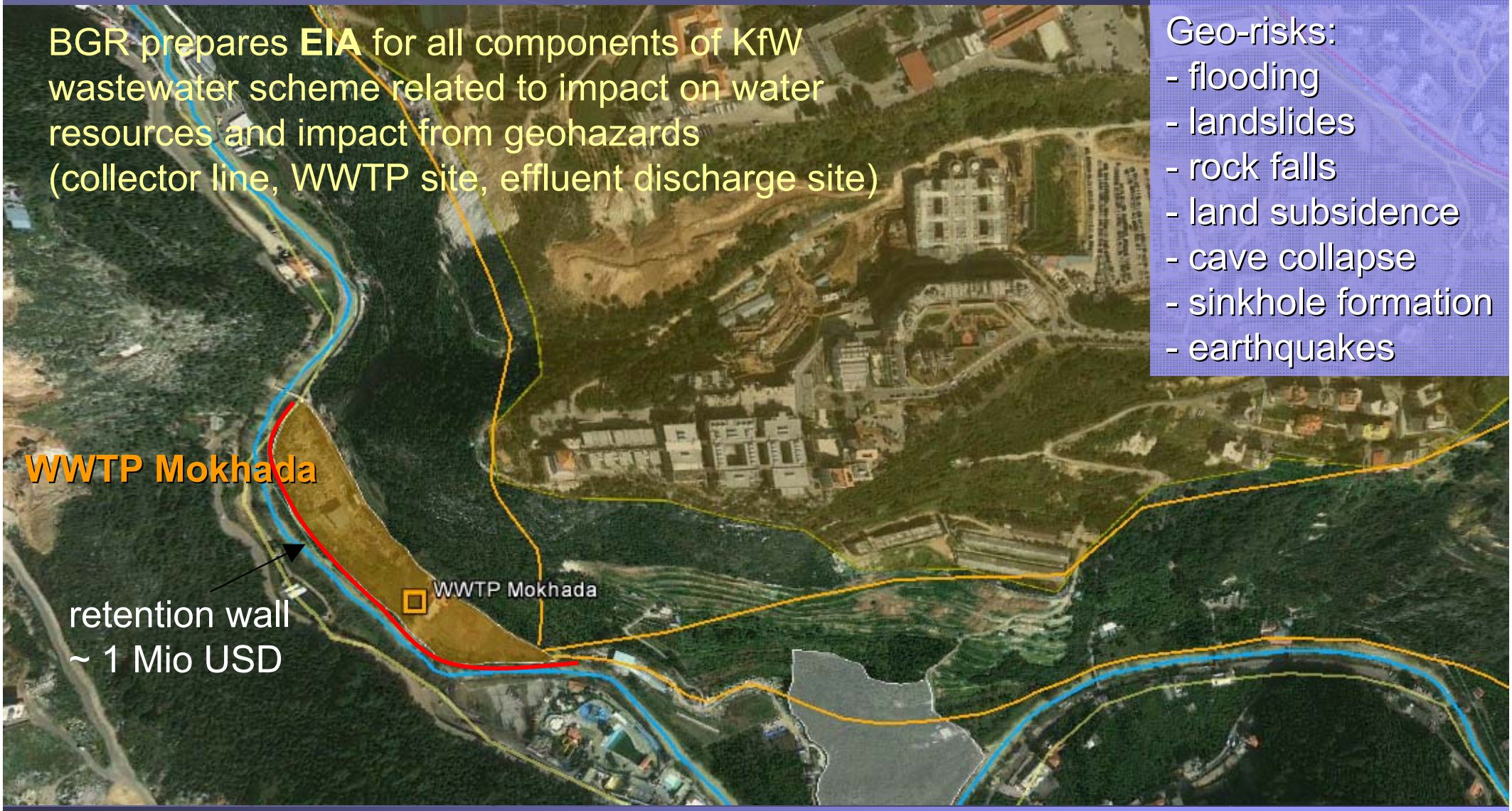
Phase I : 45,000 PE
Phase II: 92,000 PE

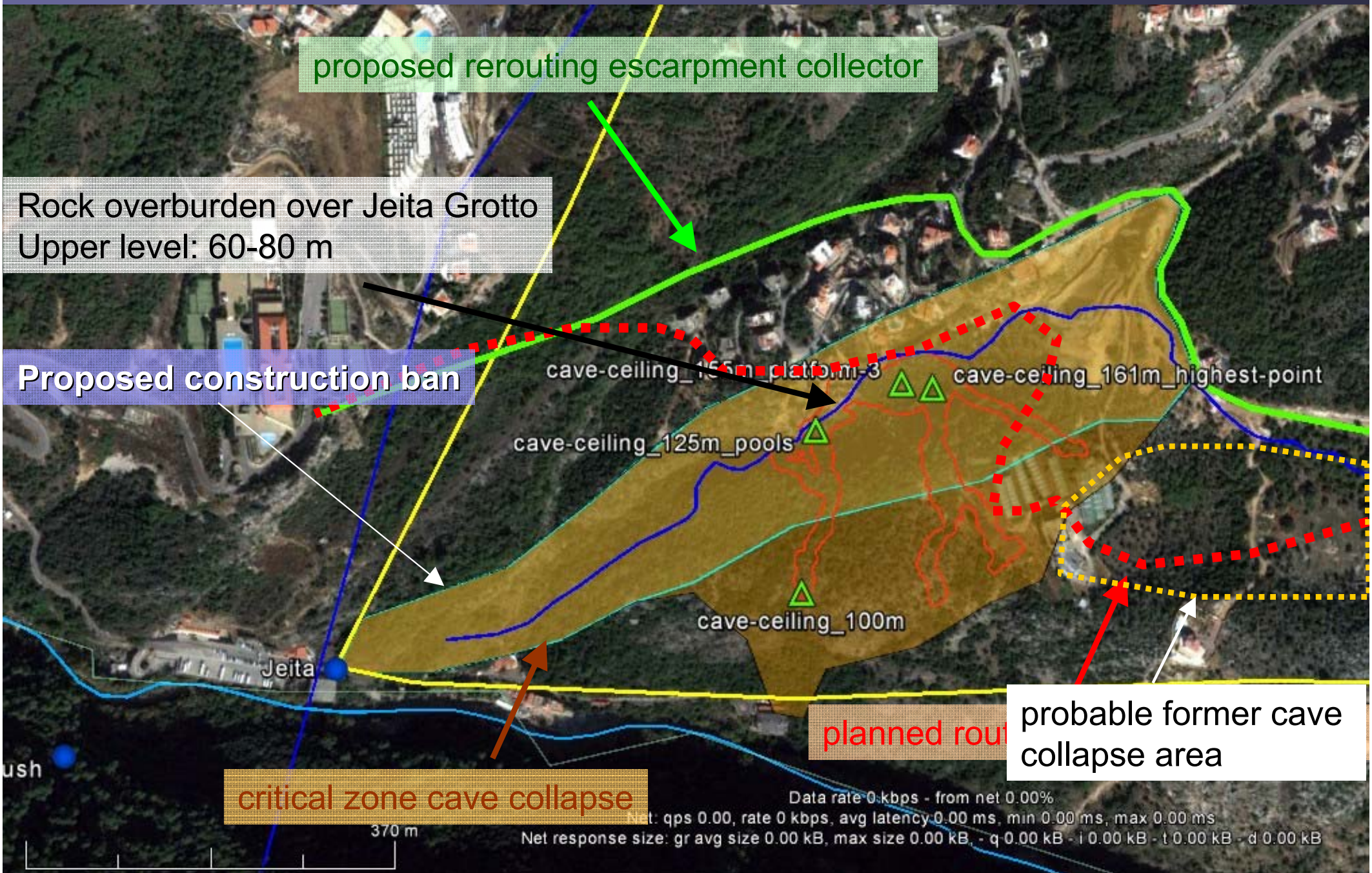


KfW Jeita Project

BGR prepares **EIA** for all components of KfW wastewater scheme related to impact on water resources and impact from geohazards (collector line, WWTP site, effluent discharge site)

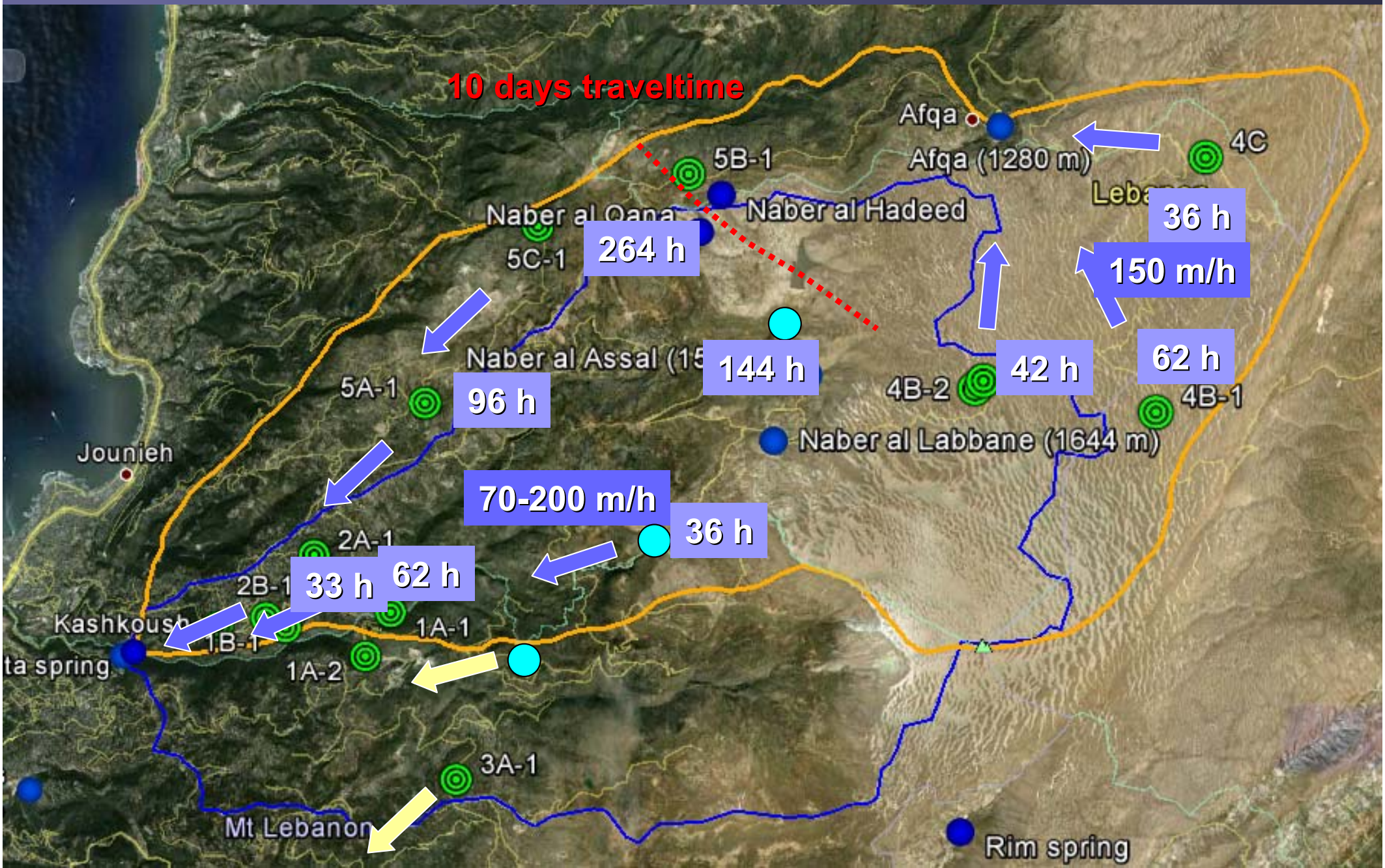
Geo-risks:
- flooding
- landslides
- rock falls
- land subsidence
- cave collapse
- sinkhole formation
- earthquakes




proposed rerouting escarpment collector
Rock overburden over Jeita Grotto
Upper level: 60-80 m
Proposed construction ban
cave-ceiling_161m_highest-point
cave-ceiling_125m_pools
cave-ceiling_100m
Jeita
planned rout
probable former cave collapse area
critical zone cave collapse
370 m
Data rate 0 kbps - from net 0.00%
Net: qps 0.00, rate 0 kbps, avg latency 0.00 ms, min 0.00 ms, max 0.00 ms
Net response size: gr avg size 0.00 kB, max size 0.00 kB, - q 0.00 kB - i 0.00 kB - t 0.00 kB - d 0.00 kB

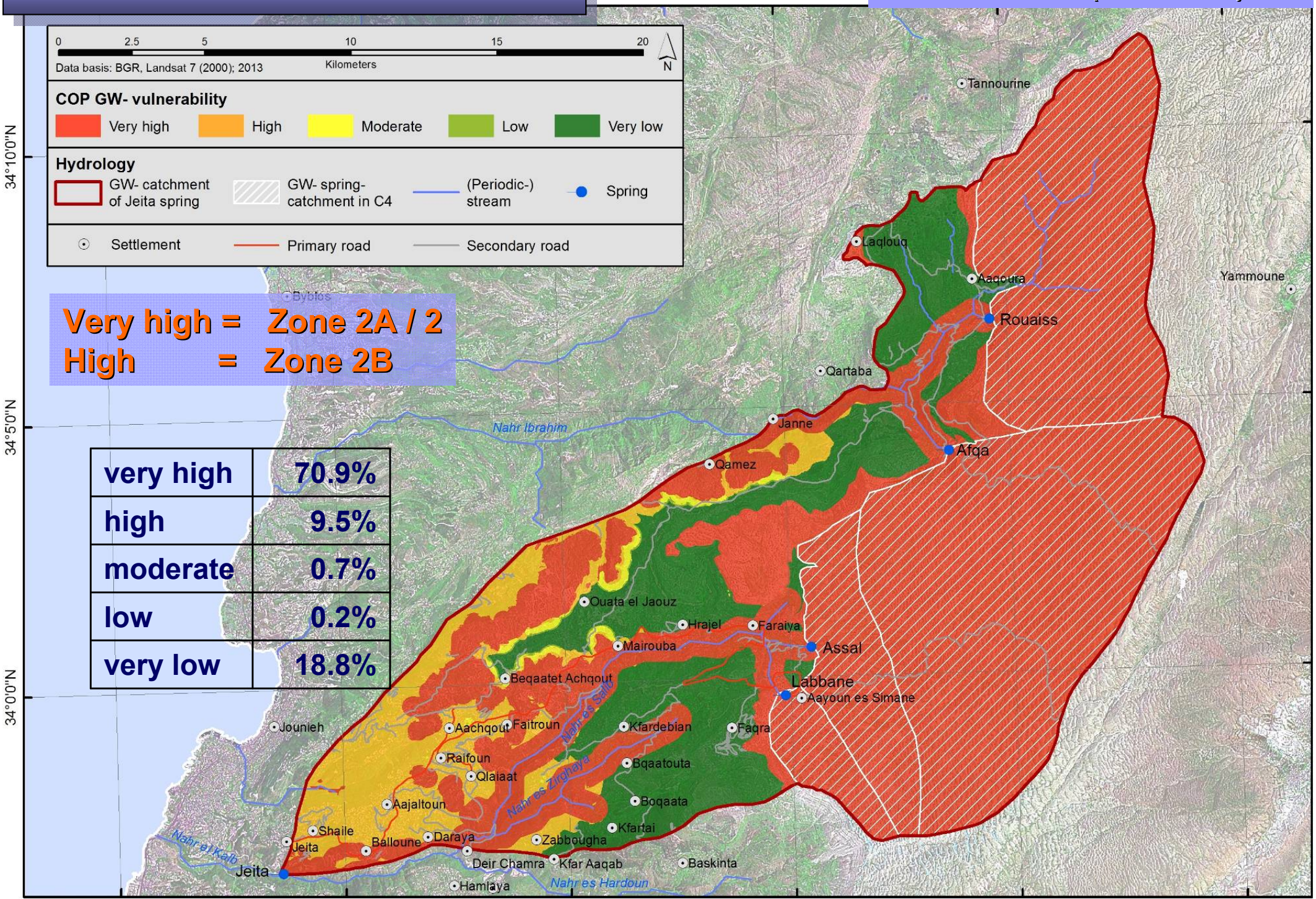
Groundwater Flow

Mean travel times



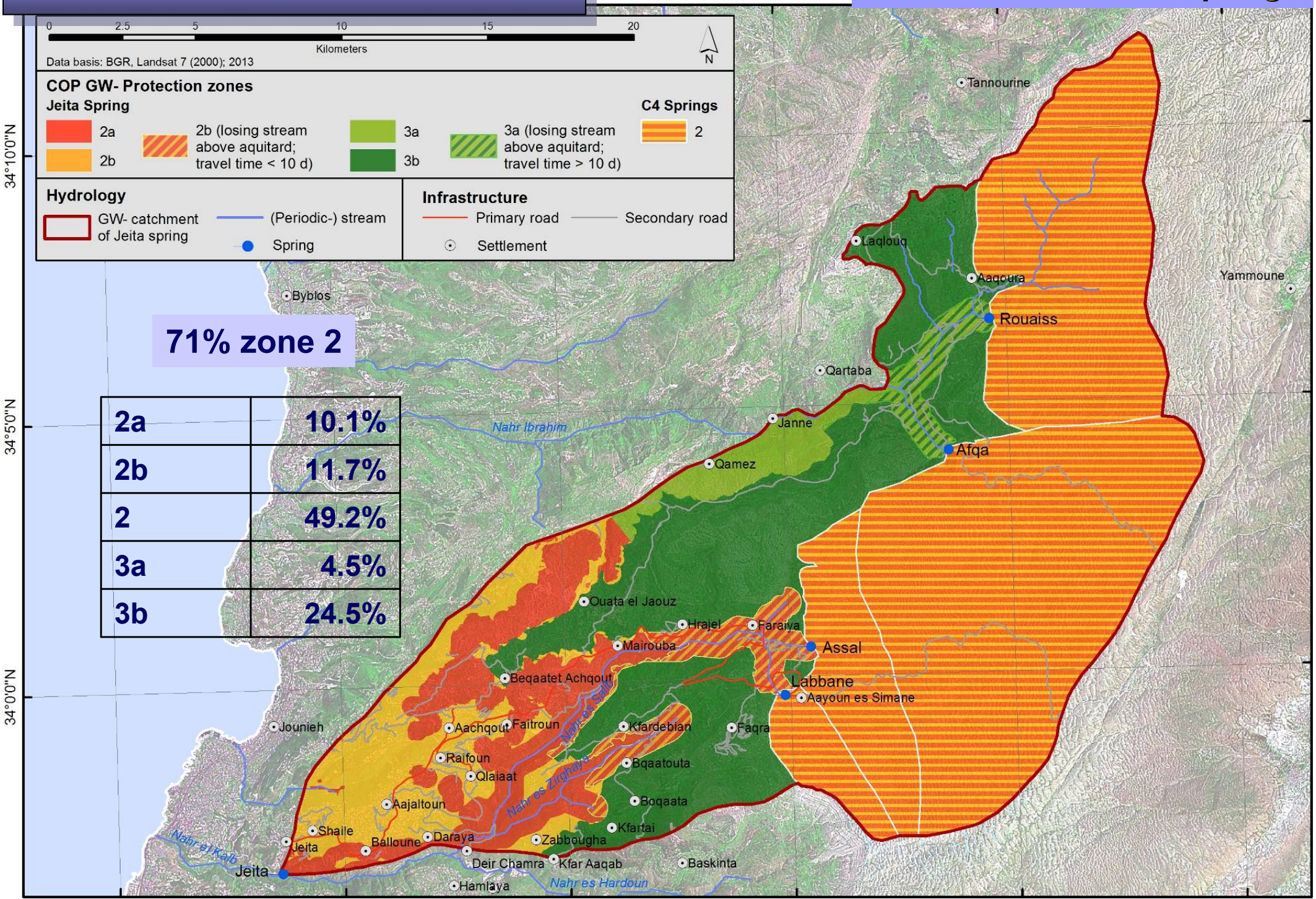
Groundwater Protection Zones

Groundwater Vulnerability COP Method (modified)



Groundwater Protection Zones

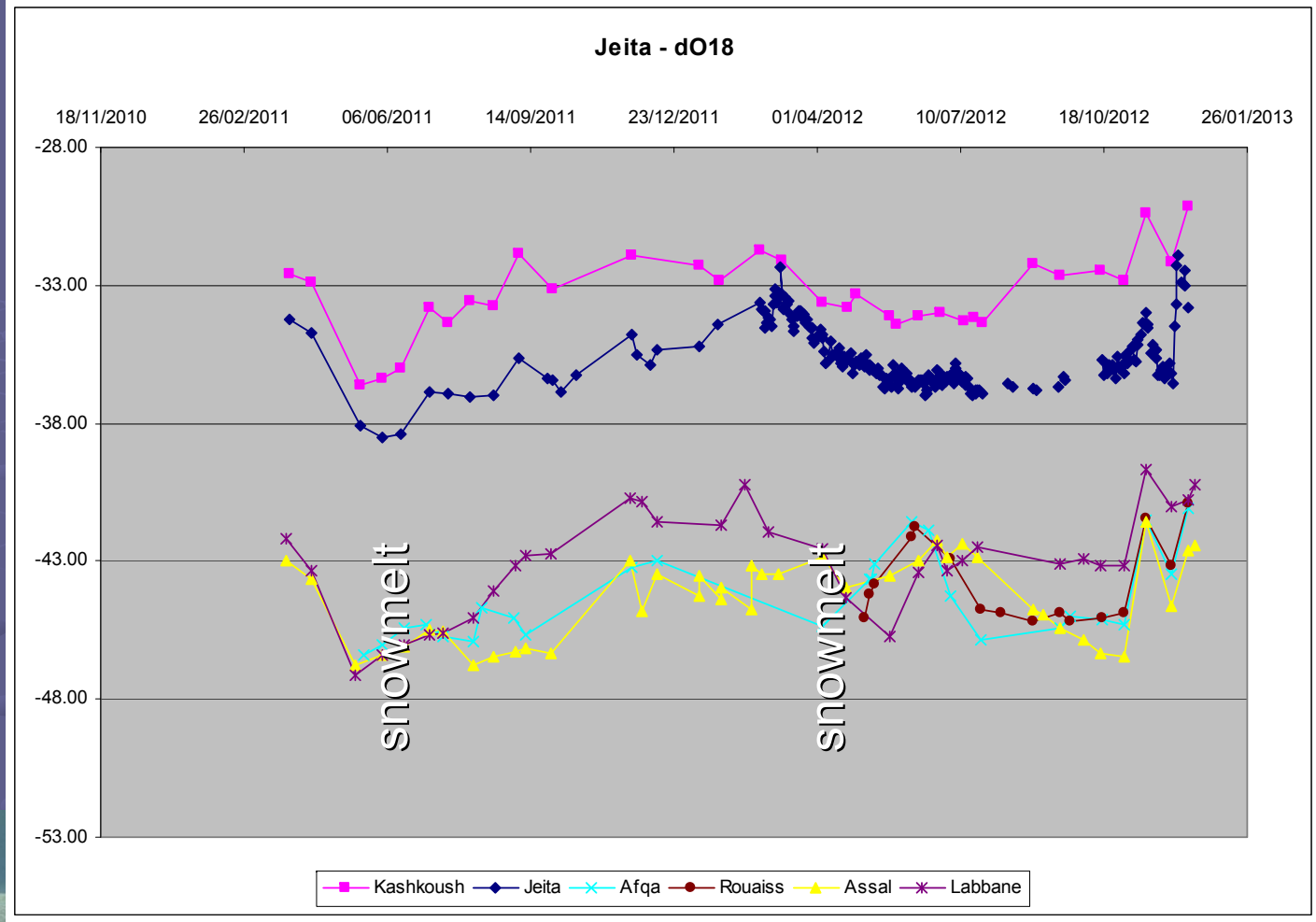
for Jeita, Afqa, Rouaiss, Assal and Labbane springs

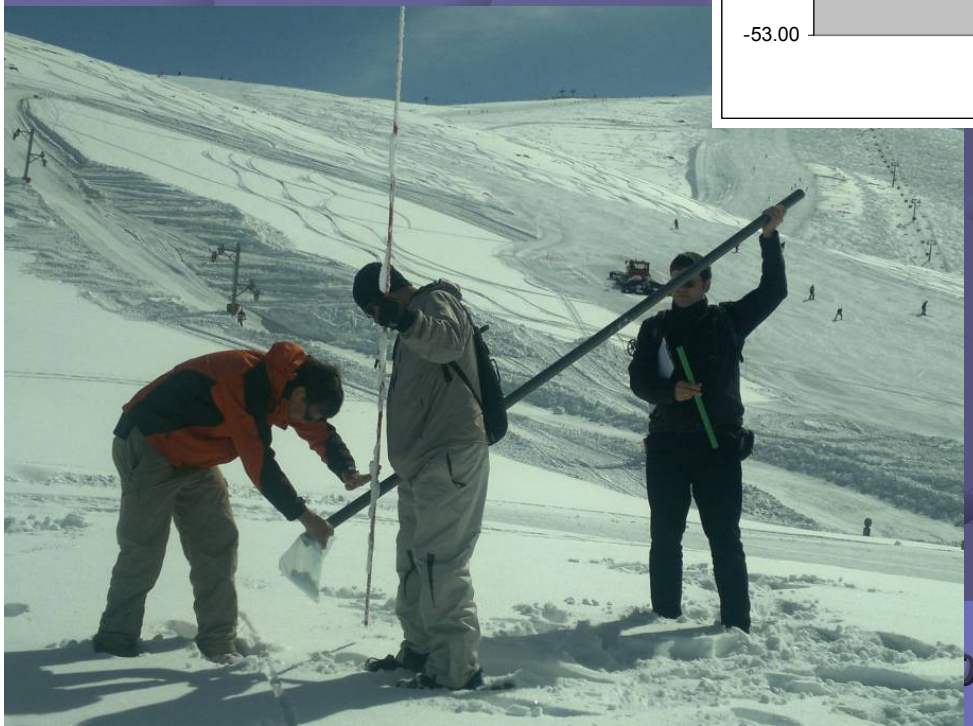


71% zone 2

2a	10.1%
2b	11.7%
2	49.2%
3a	4.5%
3b	24.5%

Isotope data





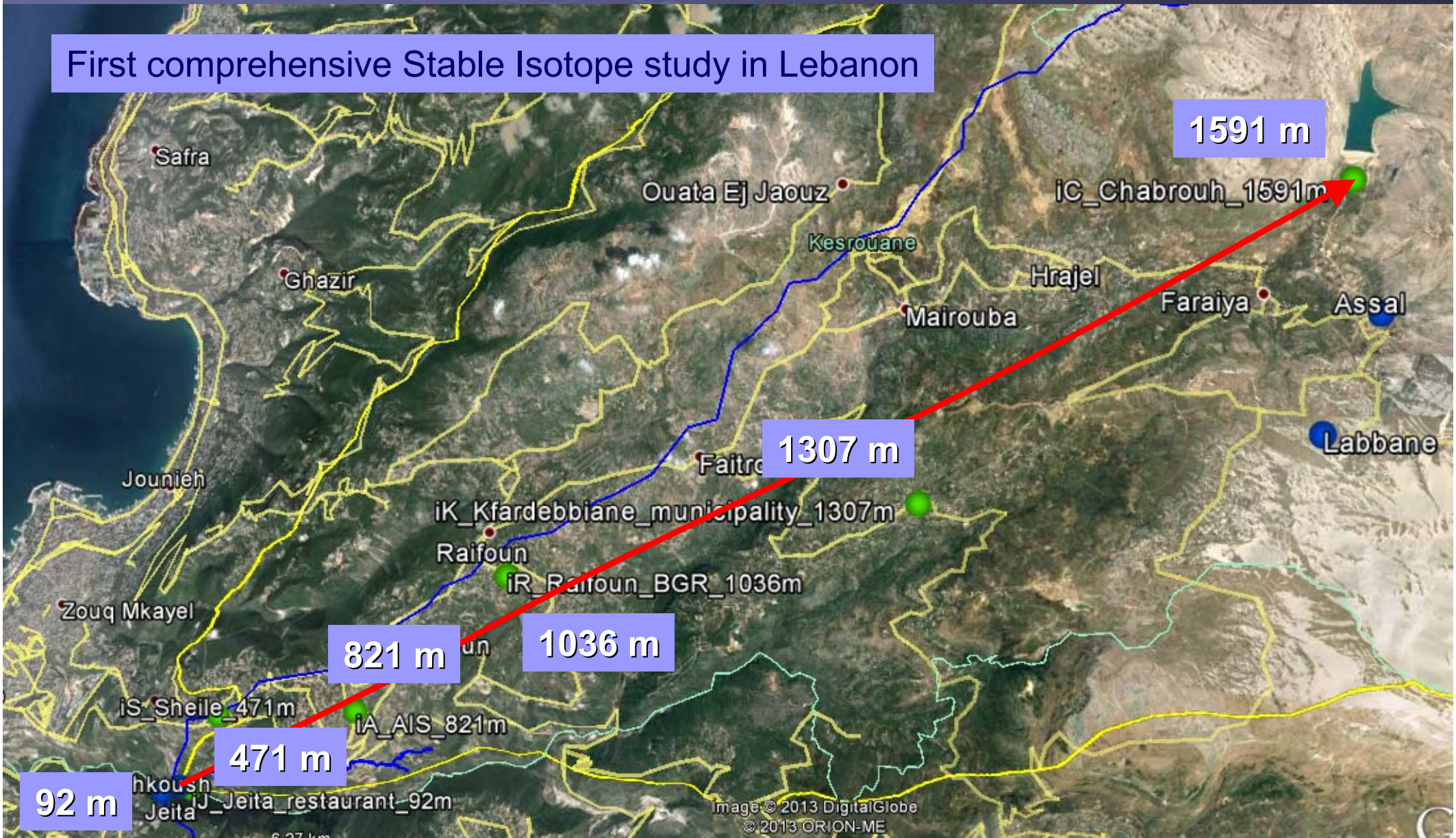
- deuterium/oxygen-18
- tritium/helium
- CFC (chlorofluorocarbon)

D/18O > 800 analyses

- 6 springs
- rainfall – 6 stations @ diff elev.
- snow sampling campaigns

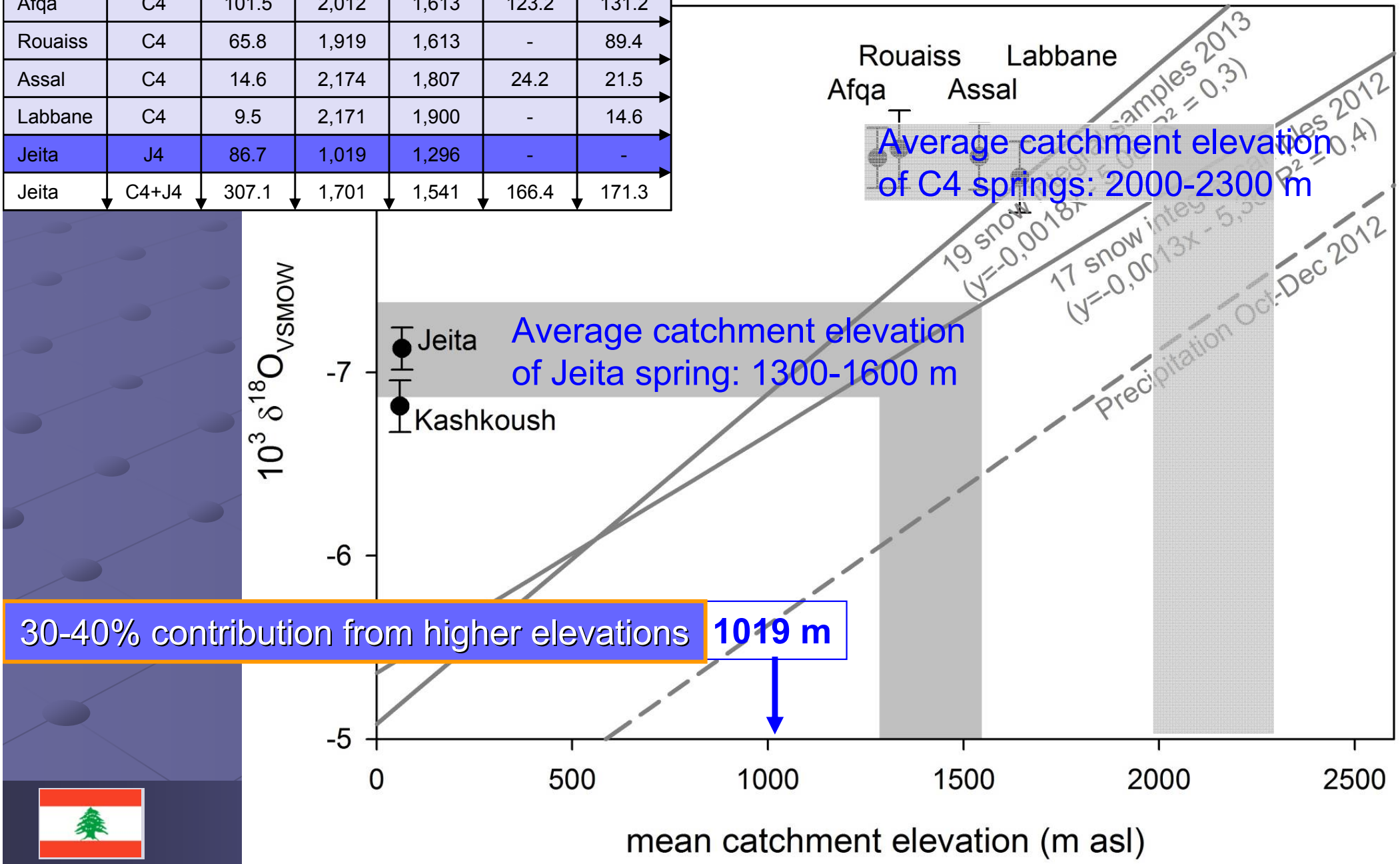
Stable isotope rainfall samplers

decrease in heavy isotopes with increasing elevation



Isotope data

GW Catchment	Aquifer	Size [km²]	Mean Elevation [m]	Mean Rainfall [mm/a]	Mean Discharge Measured [MCM/a]	Mean Discharge WEAP model [MCM/a]
Afqa	C4	101.5	2,012	1,613	123.2	131.2
Rouaiss	C4	65.8	1,919	1,613	-	89.4
Assal	C4	14.6	2,174	1,807	24.2	21.5
Labbane	C4	9.5	2,171	1,900	-	14.6
Jeita	J4	86.7	1,019	1,296	-	-
Jeita	C4+J4	307.1	1,701	1,541	166.4	171.3



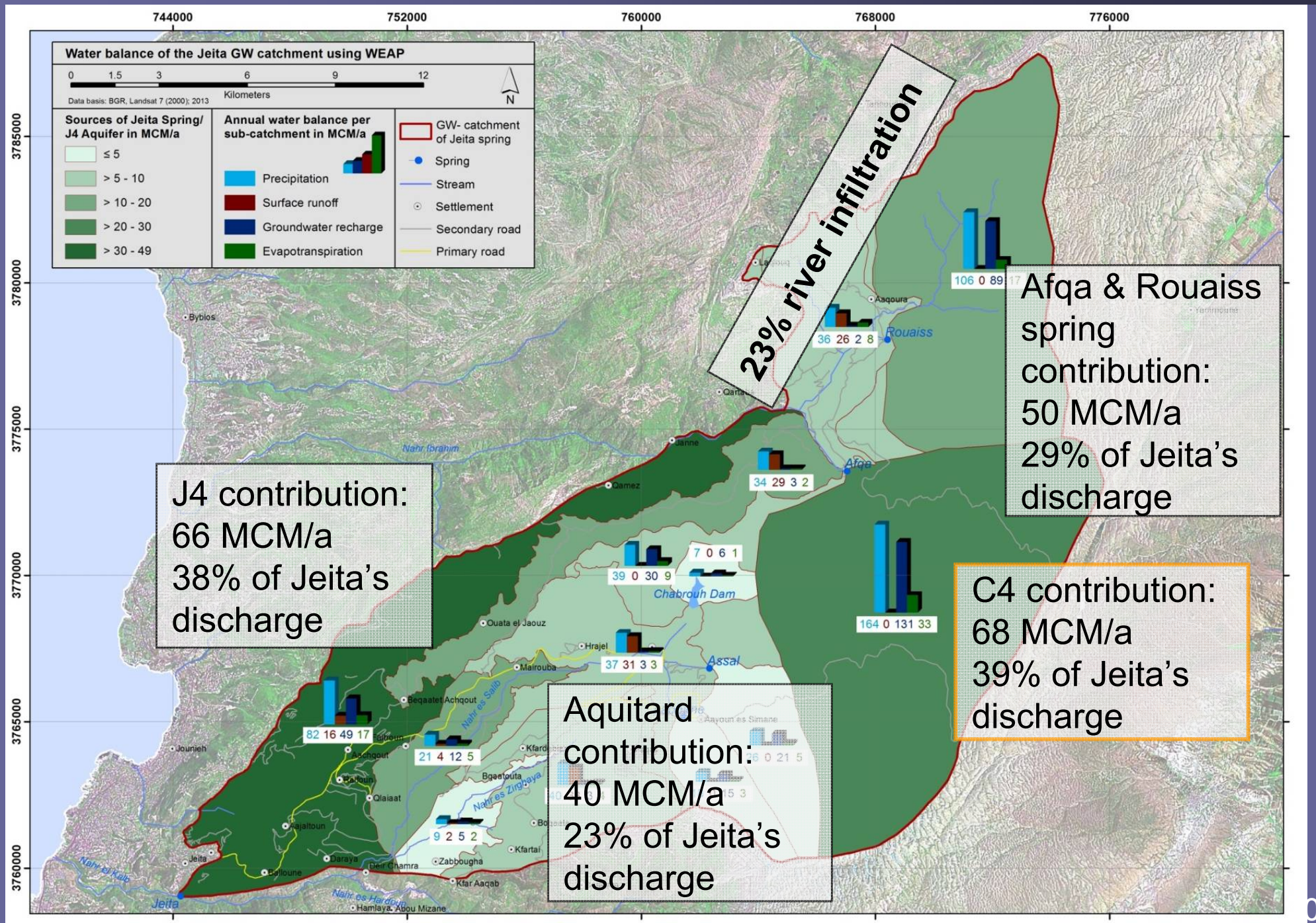
Other Environmental Tracers

Special Report No. 15
(GEYER & DOUMMAR, 2013)

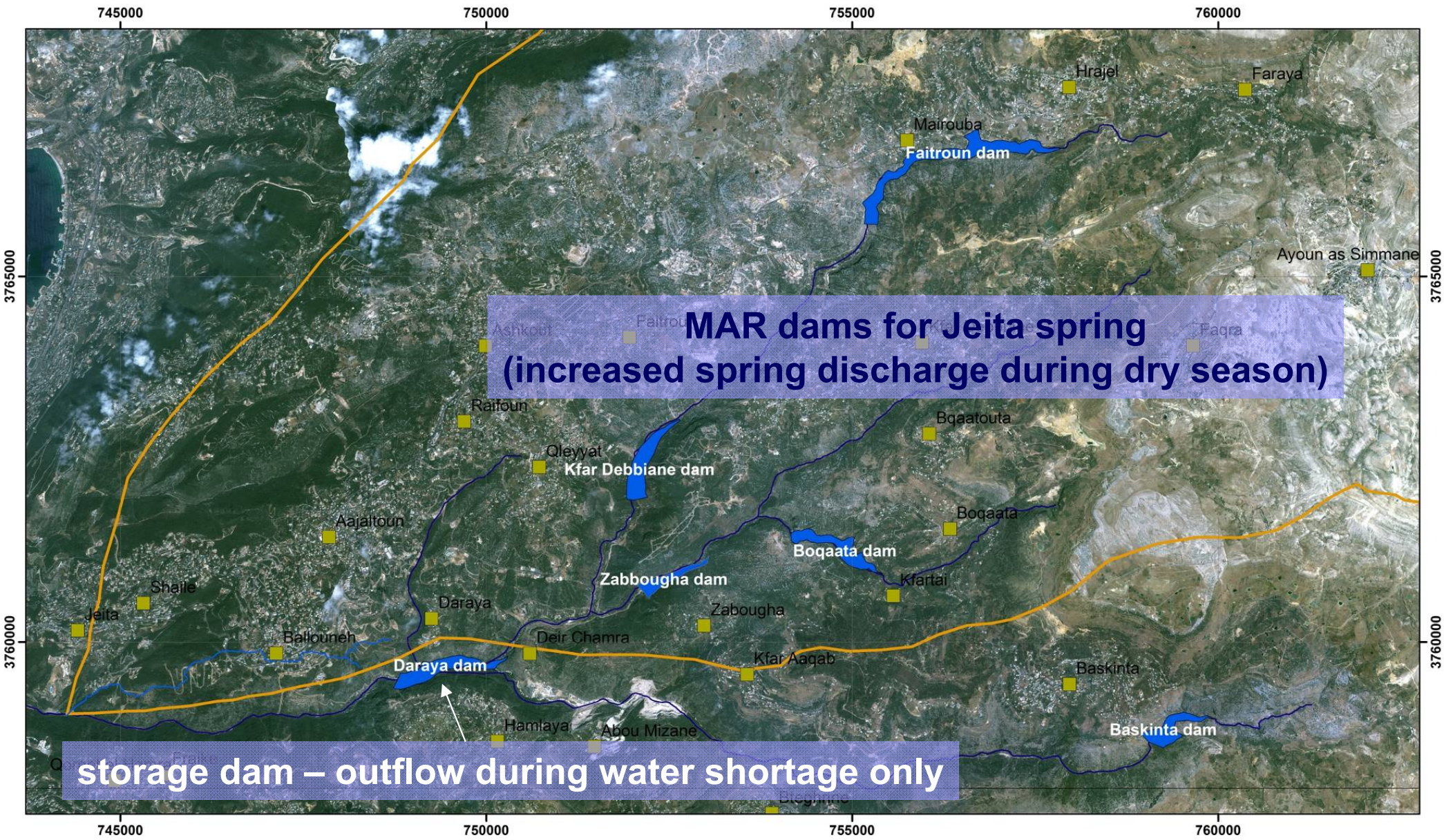
Helium - Tritium
Chlorofluorocarbons (CFC) and SF6 samples from
Jeita, Daraya (Jeita siphon terminale), Assal, Labbane and Kashkoush springs

Location	Date	Tritium	Helium-3	Helium-4	Helium/ Tritium Age
		TU	ccSTP kg^{-1}	ccSTP kg^{-1}	Years
Jeita	17.09.2010	3,03 ±0,31	6.65E-11	4.85E-05	0,9
Daraya tunnel	17.09.2010	3,00 ±0,18	6.85E-11	4.97E-05	1,6
Labbane	18.09.2010	3,26 ±1,32	5.82E-11	4.20E-05	1,7
Assal	18.09.2010	3,27 ±0,23	5.81E-11	4.24E-05	1,5
Kashkoush	19.09.2010	2,99 ±0,24	6.91E-11	5.03E-05	0,9

Water Balance



Proposed Storage & MAR Dams



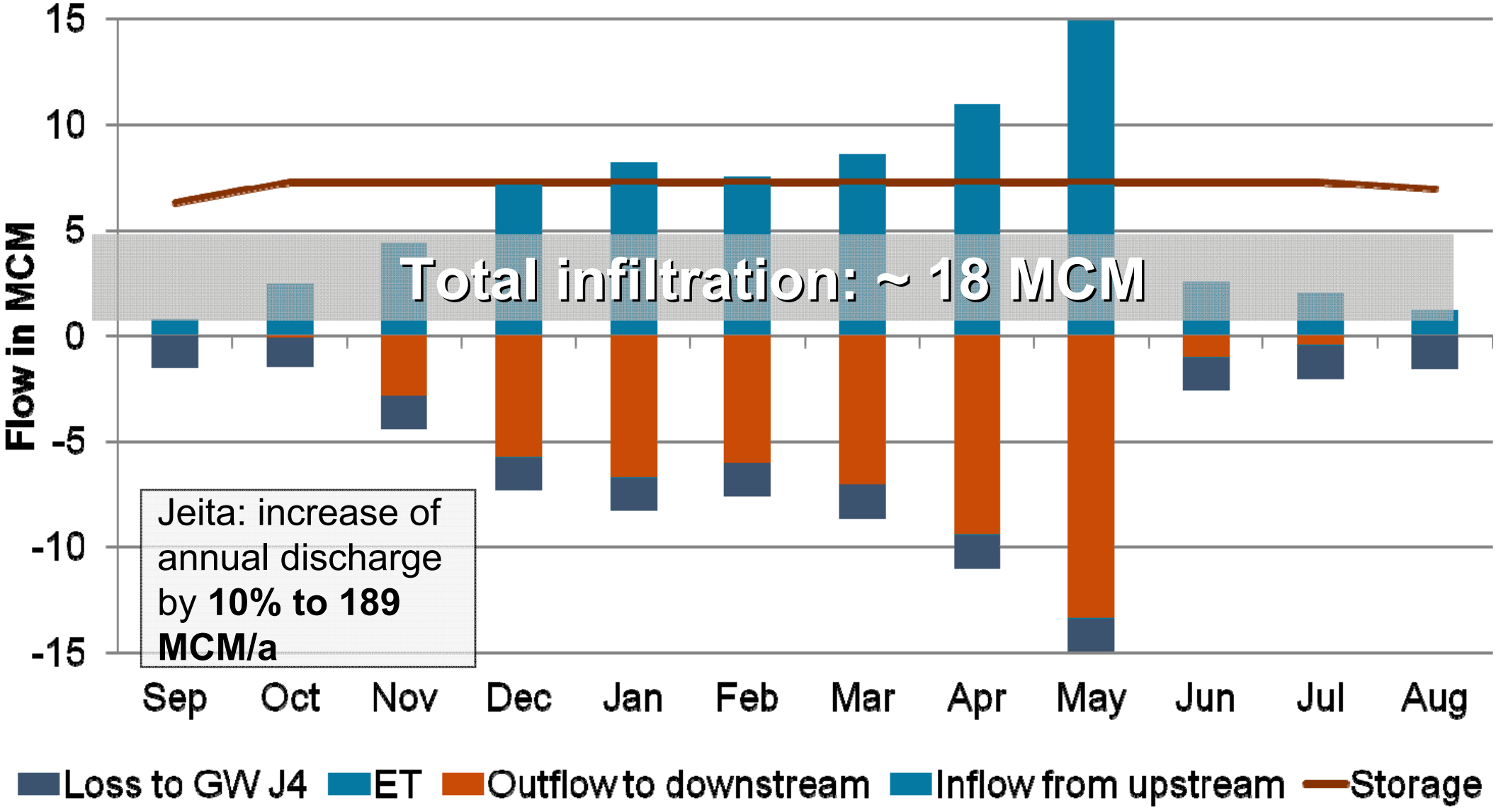
Proposed Storage & MAR Dams

Proposed Dam	Storage [m³] met by runoff	Function	Infiltration capacity
Kfar Debbiane	7.3	MAR > Jeita spring	High
Faitroun	6.6	MAR > Jeita spring	Very high
Zabbougha	3.0	MAR > Jeita spring	High
Boqaata	4.1	MAR > Jeita spring	Very high
Daraya	9.0	storage	Low
Baskinta	6.0	MAR > Faouar Antelias spring	Very high

MAR – managed aquifer recharge

Kfar Debbiane MAR dam

Storage volume and GW infiltration of Kfardebian Reservoir in MCM



WEAP Climate Change Scenario

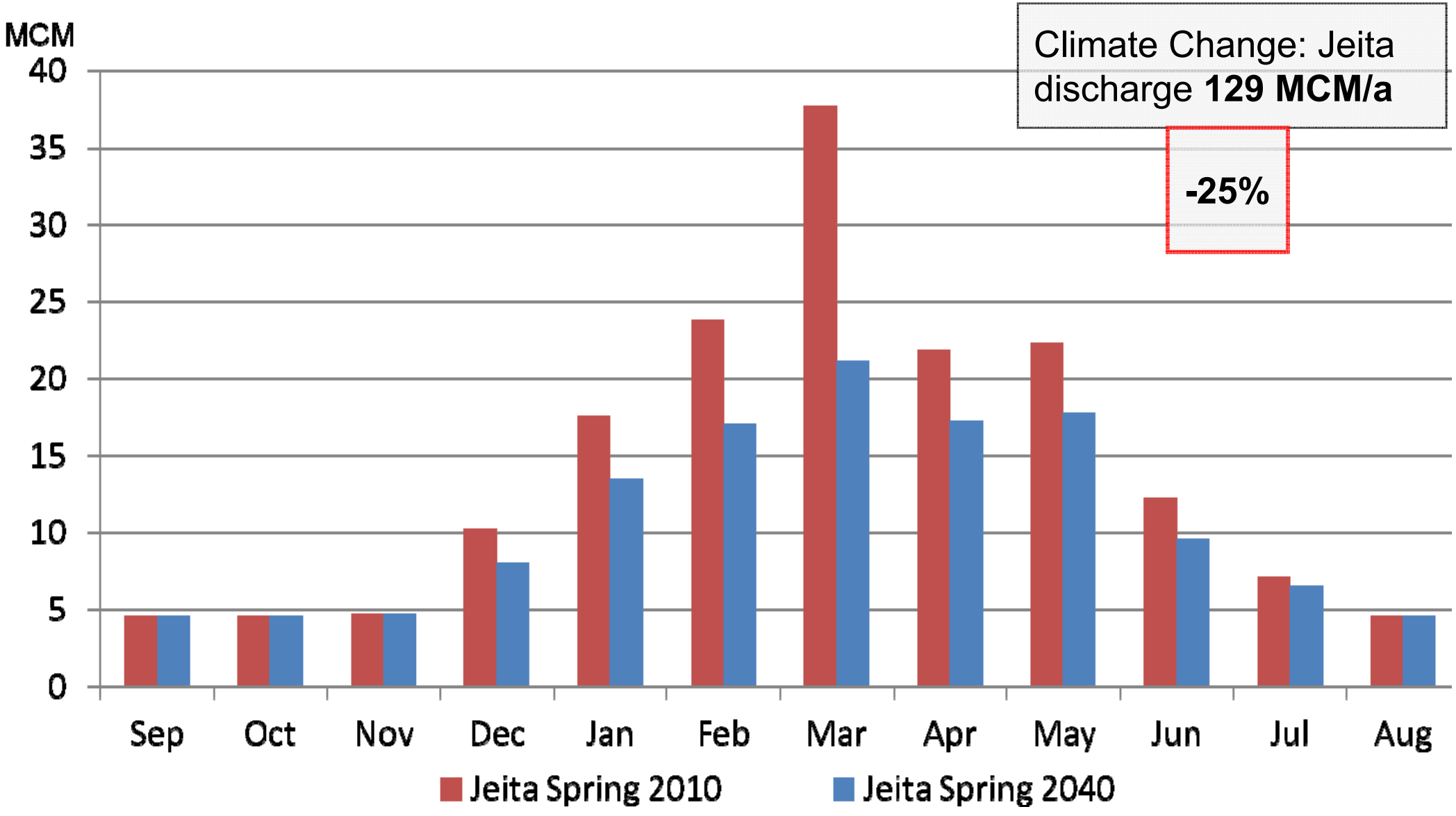
- Modeling period: 2010 to 2040
- Based on the A1B scenario (*)
  - *Most commonly used*
  - *Based on: Beirut, Cedars, Dahr el Baidar and Zahleh*
- Selected forecasts until 2040:

Precipitation (%)		Temperature(°C)		k_c	
Summer	Winter	Summer	Winter	Summer	Winter
-15	-20	+2	+1.75	+4.4	+3.1

(*) MINISTRY OF ENVIRONMENT (MoE) (2011): Lebanon's Second National Communication to the UNFCCC. Republic of Lebanon, Ministry of Environment, 191 p.; Beirut/Lebanon.

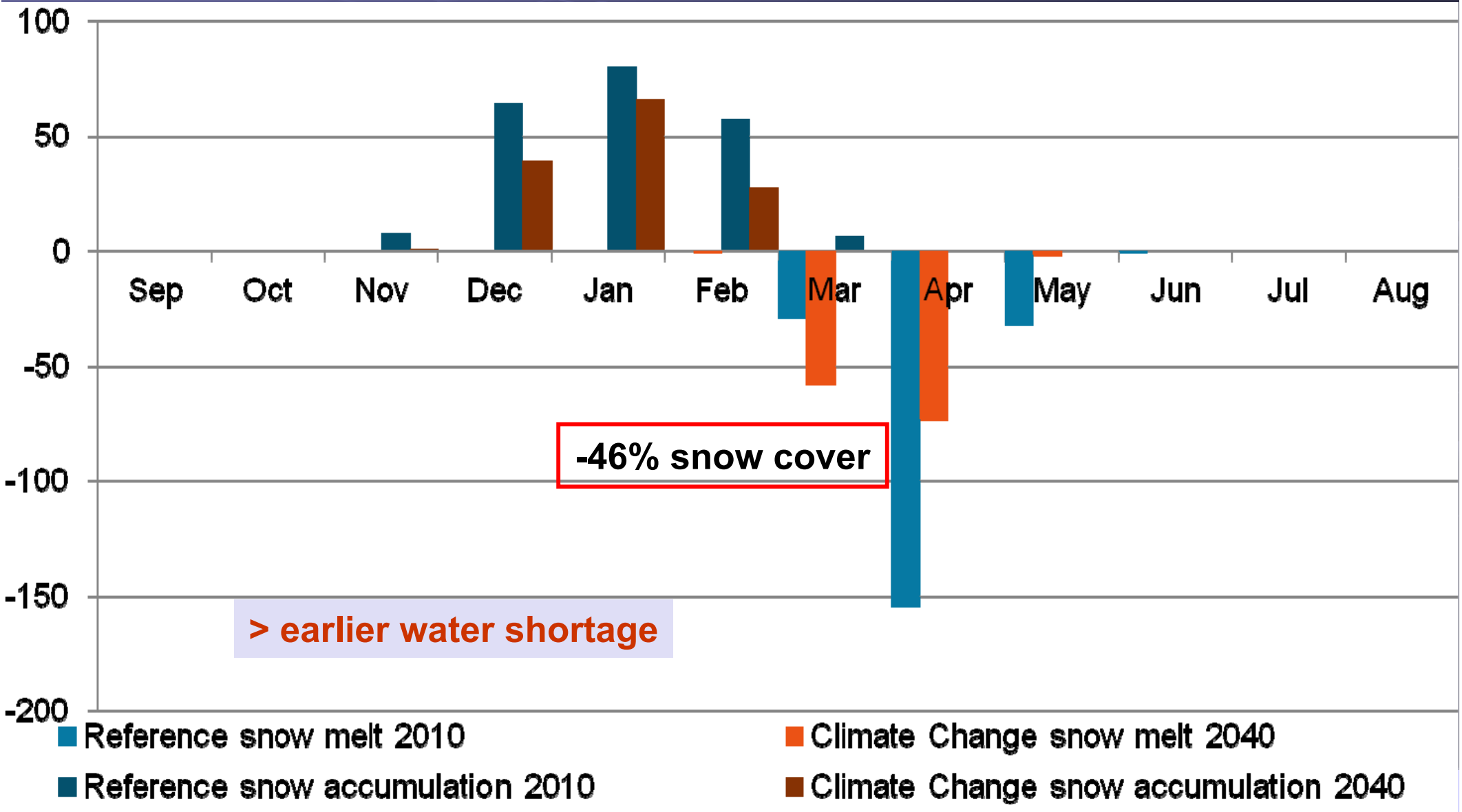
Results WEAP Climate Change Scenario

Discharge of Jeita Spring: Reference vs. Climate Change Scenario in MCM

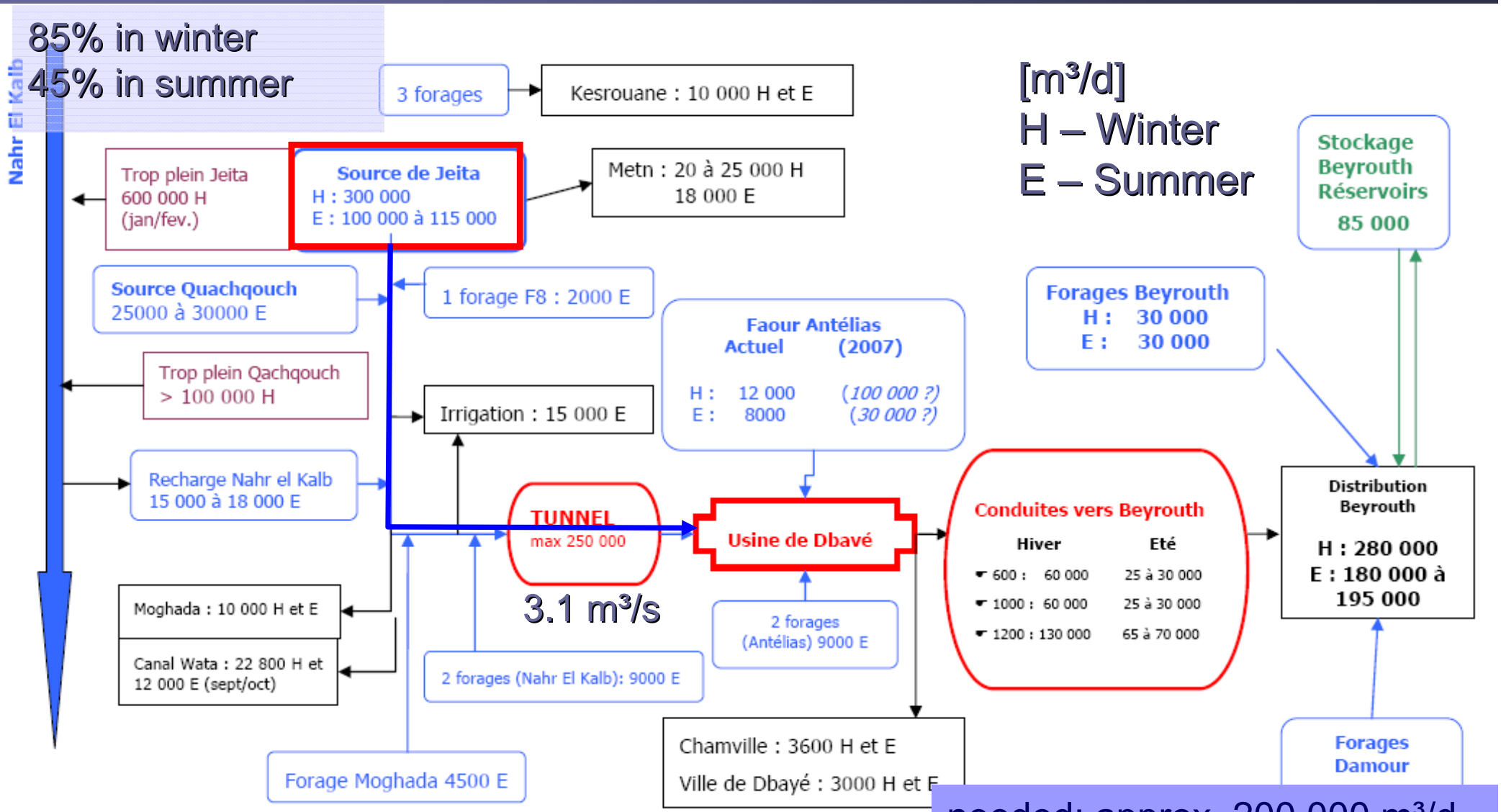


Results WEAP Climate Change Scenario

Snow cover on the C4: Reference vs. Climate Change Scenario in m

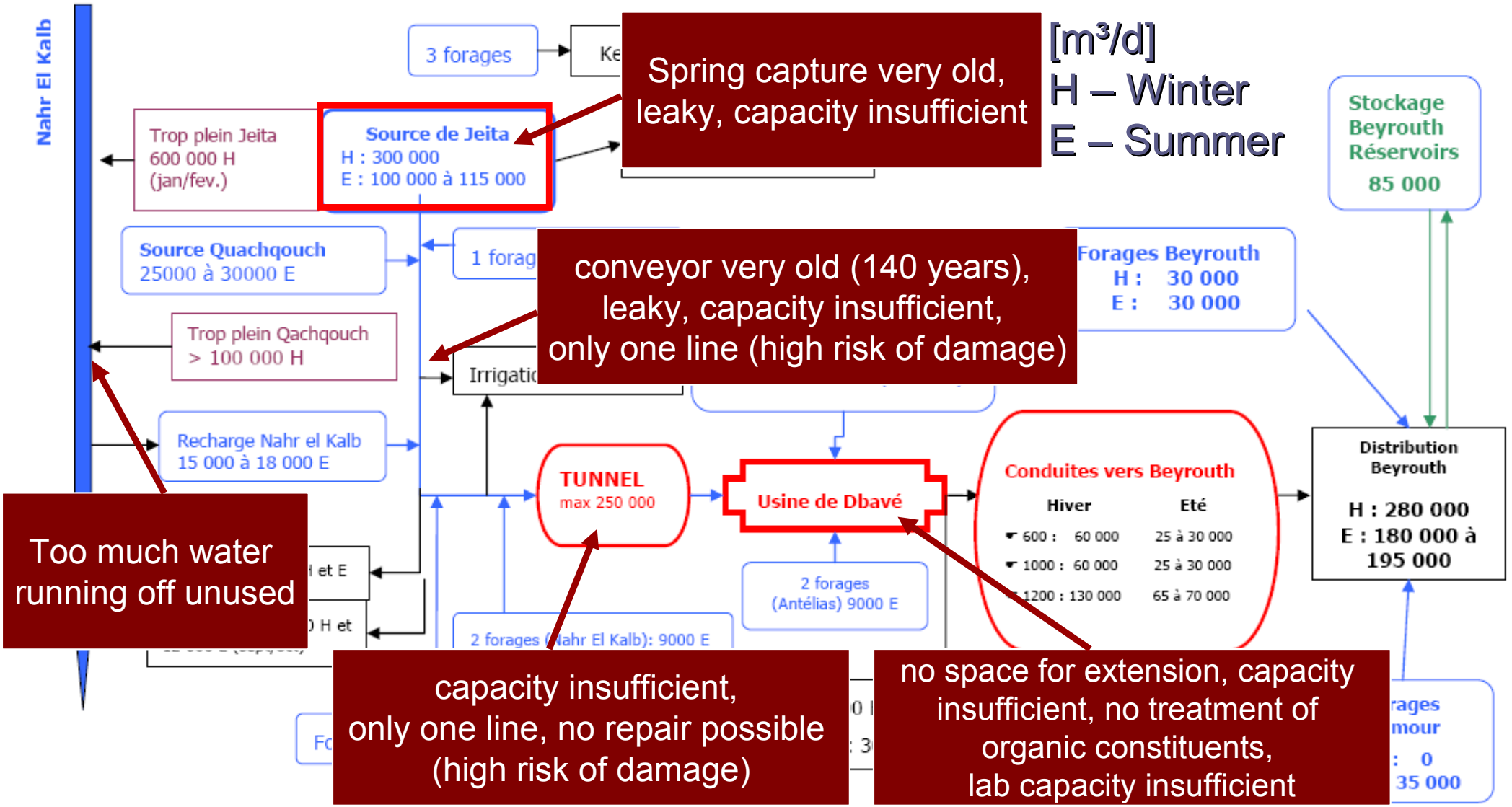


WEBML Water Supply System

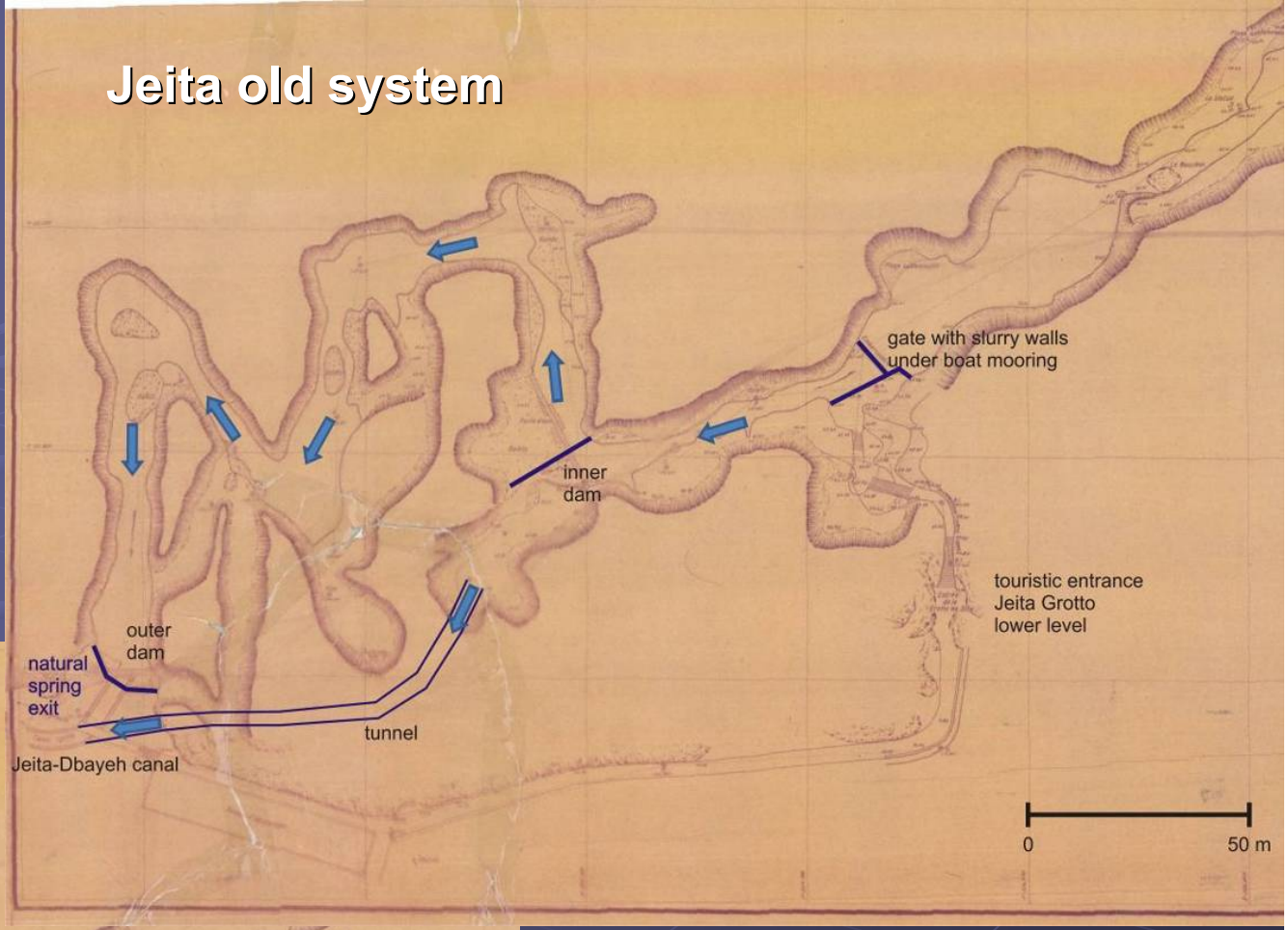


needed: approx. 200.000 m³/d
~ 70 MCM/a
deficit in September-December:
partly < 60,000 m³/d

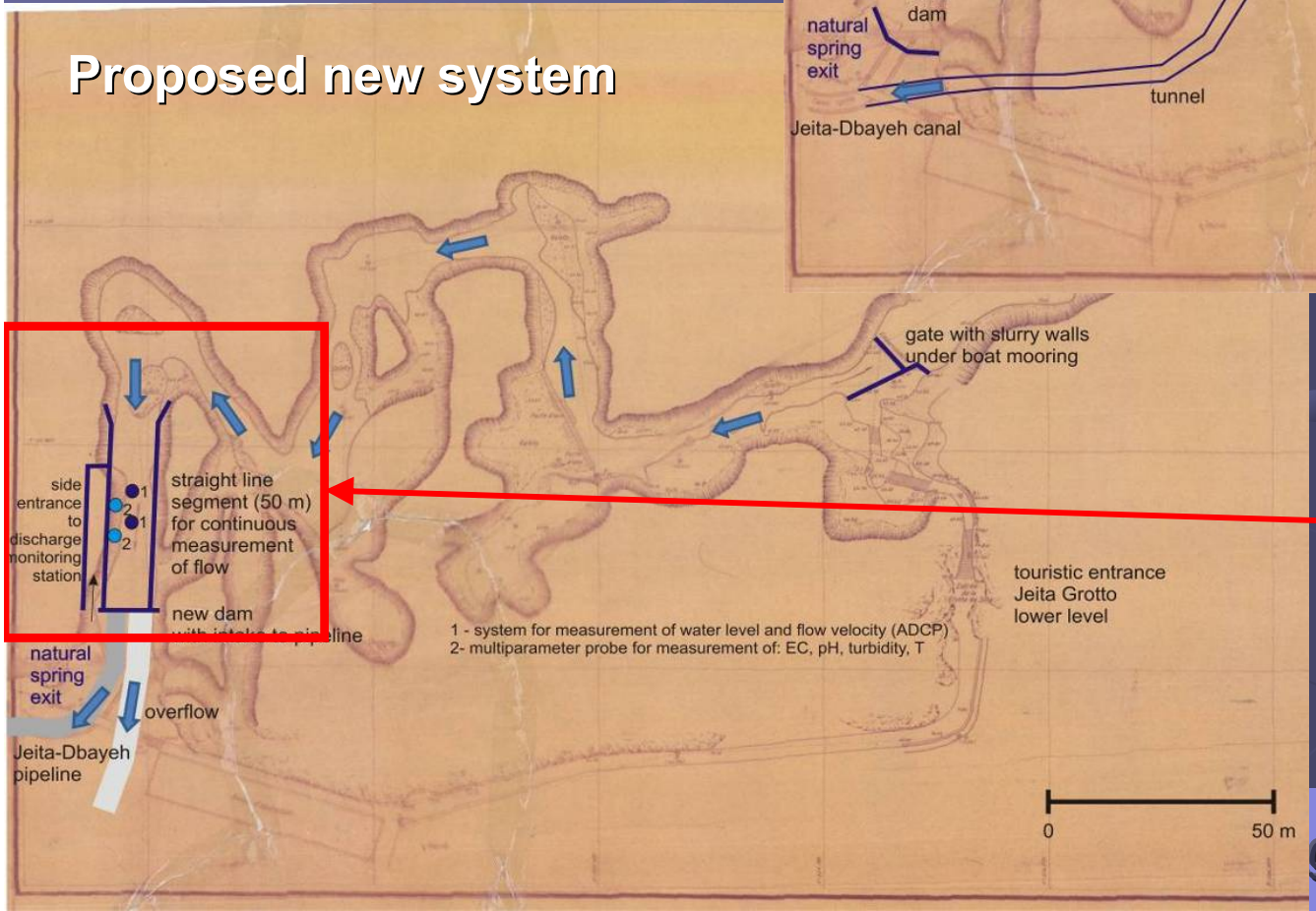
WEBML Water Supply System



Jeita old system



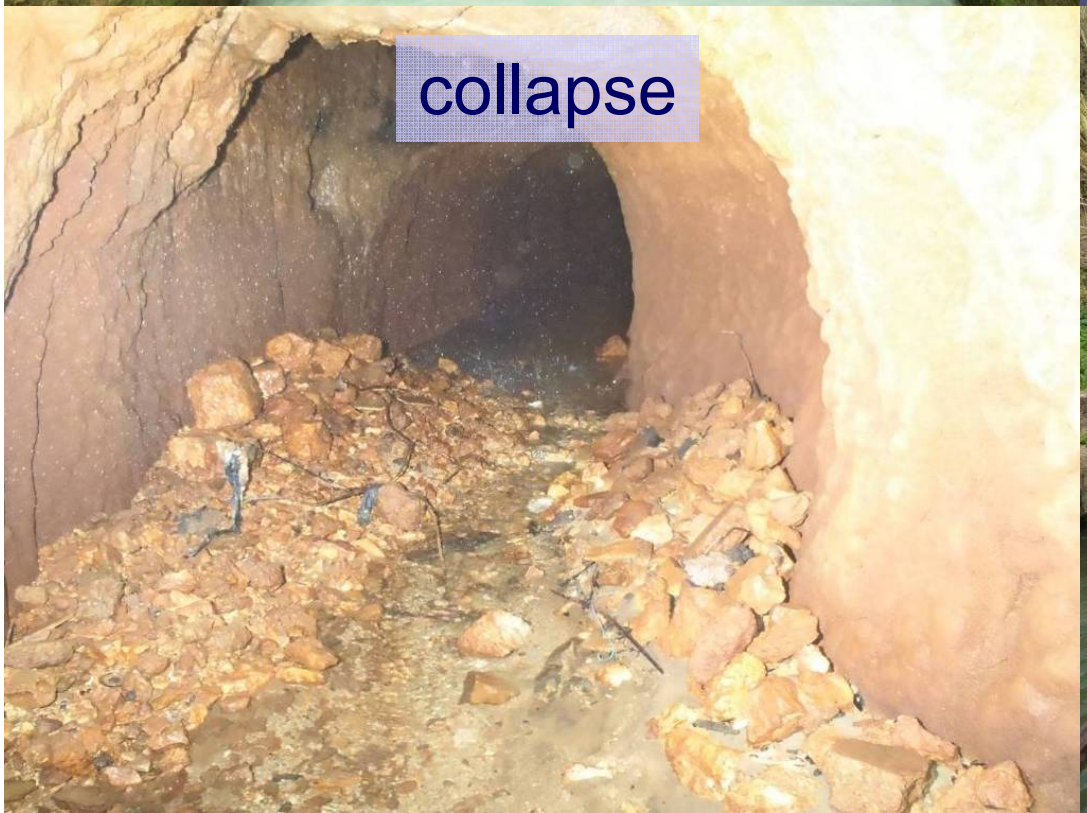
Proposed new system



monitoring

There is only one conveyor line
► in case of damage Beirut may be out of water for months

Conveyor must be protected from flooding

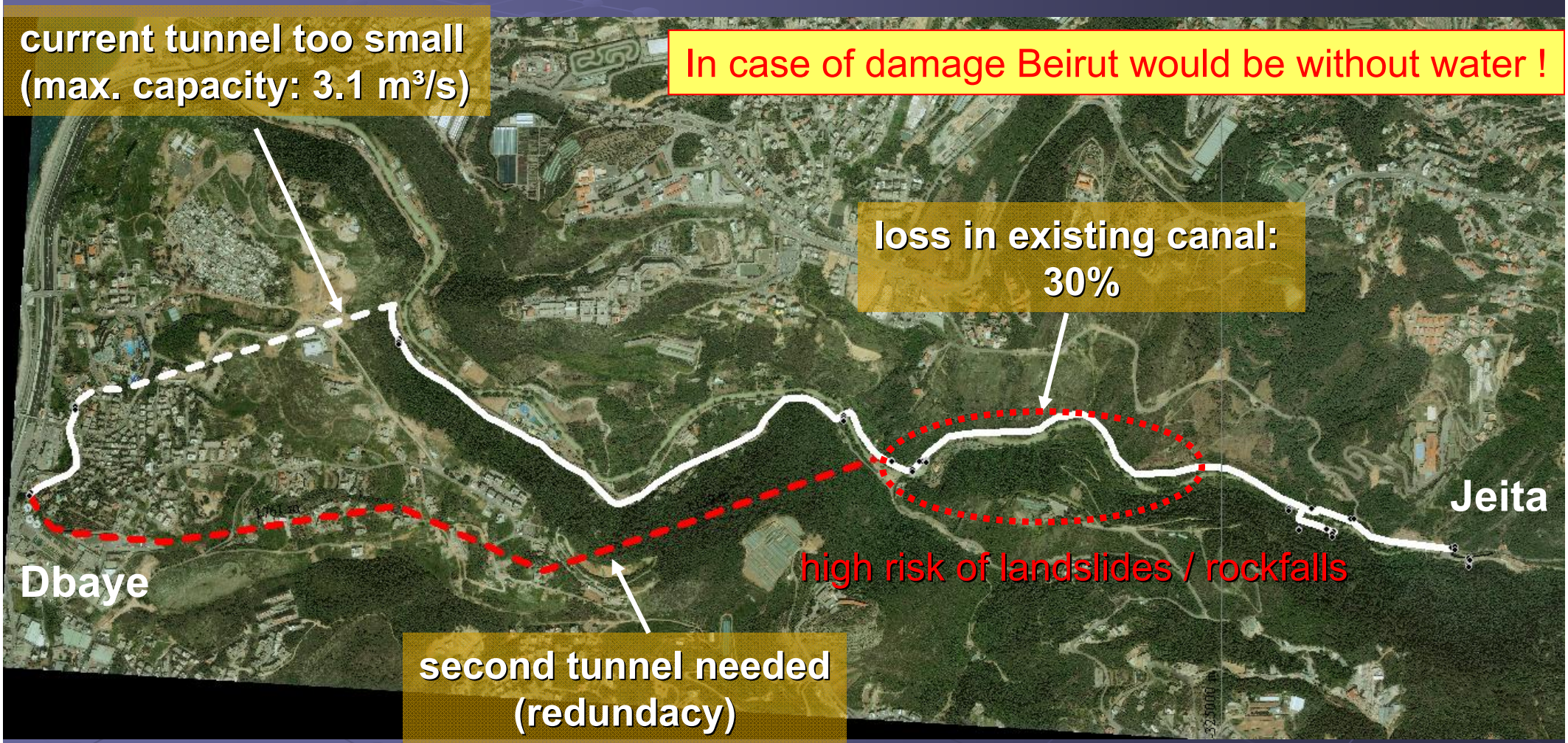


Dbaye treatment plant

116 years old
cannot be expanded (no space)
only sandbed filters (only partly functional) + chlorination
no treatment of organic constituents (pesticides, hydrocarbons) and heavy metals
possible formation of chlorinated hydrocarbons
laboratory not fully functional and too small

WEBML Water Supply System

Study of transmission main Jeita – Dbayeh (GITEC, 2012)



WEBML Water Supply System – what should be done ?

30-50 Mio USD

- Improve capture of Jeita spring
- Establish a new raw water conveyor (pipelines/new tunnel)
  with increased capacity (7 m³/s)
  (2 separate lines because one line could be damaged; redundancy)
- Establish dam with medium capacity (Daraya dam: 9 MCM)
  to overcome water shortages at end of dry season
- Do not allow illegal connections and illegal uses (“irrigation”)
- Increase capacity of treatment & improve treatment process
- Establish **water quality monitoring & increase laboratory capacities**
- Reduce water losses in Beirut

Conclusions

The geological stucture and tectonics are virtually unknown
► a **Geological Survey** should be founded

The amount of groundwater available and the boundaries of GW catchments have never been studied. There is no institution that has the capacity to cover all aspects of water.

► a **Water Resources Agency** should be established to deal with
- water resources monitoring (quality/quantity)
- water resources assessments
- water resources protection
- demand management and allocation
- planning of water projects

Wastewater is the main pollution source, but still no agency wants to deal with it.
► a **National Wastewater Authority** should be created, responsible for:
- planning and implementation of WW projects
- operating and maintaining WWTPs

BGR

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Thank you for your kind attention

www.bgr.bund.de/jeita

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