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German-Lebanese Financial Cooperation
KfW Entwicklungsbank

JEITA SPRING PROTECTION PROJECT, PHASE I

FEASIBILITY STUDY

REHABILITATION OF TRANSMISSION CHANNEL JEITA SPRING INTAKE – DBAYE WTP

April 2011

Protection of Jeita Spring

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ABBREVIATIONS

BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources), Germany
BMLWWE	Beirut and Mount Lebanon Water and Wastewater Establishment
BMZ	Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung (Federal Ministry for Economic Cooperation and Development), Germany
BOD	Biological Oxygen Demand
CCTV	Closed Circuit TV
COD	Chemical Oxygen Demand
CDR	Council for Development and Reconstruction Chemical Oxygen Demand
CV	Curriculum Vitae
EDL	Electricite du Liban
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EU	European Union
EUR	Euro (European Currency)
FC	Financial Cooperation
FIDIC	Fédération Internationale des Ingénieurs Conseils International Federation of Consulting Engineers
GHG	Green House Gas
GIS	Geographical Information System
GITEC	GITEC Consult GmbH, Düsseldorf, Germany
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
ha	hectare
IFI	International Financing Institution
IPCC	Intergovernmental Panel on Climate Change
JSPP	Jeita Spring Protection Project
JSP	BGR project “Jeita Spring Protection”
KfW	KfW Development Bank, Frankfurt, Germany
LWA	Litani Water Authority
km	Kilometre
M&E	Monitoring and Evaluation
MHPP	Micro-hydro-power plant
MoEW	Ministry of Energy and Water
NGO	Non-Governmental Organisation
NRW	non-revenue water
O&M	Operation and Maintenance Project Executing Agency
Q_{av}	Average daily flow
P_e	Population equivalent
PST	Pumping Station
SS	Suspended Solids
SPST	Small Pumping Station
TC	Technical Cooperation
TN	Total Nitrogen
ToR	Terms of Reference
TS	Total Solids
TWW	Treated Wastewater
UASB	Up-flow Anaerobic Sludge Blanked
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organisation
WTP	Water Treatment Plant (potable water)
WWTP	Wastewater Treatment Plant
WWE	Wastewater Establishment

0. SUMMARY

This Feasibility Study on the Transmission Main from the Jeita Spring Intake to the Dbaye Water Treatment Plant includes a thorough presentation of the project proposal. It gives a description of the characteristics of the project area and a brief assessment of the environmental situation.

The report is prepared by:

(a) the Joint Venture Consultants GITEC / WE Consult / LIBANCONSULT, responsible for the Jeita Spring Protection Project including the Regional Sewage Plan and the detail design and implementation of Phase I, consisting of Jeita WWTP and sewer networks for Jeita, Balloune, Aajaltoun and Daraiya and

b) the Federal Institute for Geosciences and Natural Resources BGR, Hannover / Germany responsible for the project Protection of Jeita Spring. The tasks of this 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 land use planning:
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*

Project area

The project area is located in the central part of Lebanon, about 12 km northeast of Beirut. The transmission main is passing through two districts, namely Kesrouan and al Metn, involving the municipalities of Jeita, Zouk Mozbeh, Mar Abda, Deir Tamish and Dbaye.

Existing transmission channel

The transmission channel and tunnel was built some 150 years ago most likely as a part of an irrigation scheme. At that time the water was passing around the hill, later when the channel was used for irrigation and water supply the tunnel section was added. The spring is used since 1870 for water supply of Beirut (KARKABI, 2009).

According to some drawings dated 1940 the channel was initially an open, trapezoid shaped channel. Whether the channel was lined with some stone patching, to reduce the water losses, is not known. Later the channel was rehabilitated providing trapezoidal or rectangular cross-section with masonry walls and was finally covered with concrete slabs. Based on the above-mentioned drawing it seems that the intake was some few hundred metres downstream of the existing intake, probably in the region of the Kashkoush spring.

State of environment

The region is characterised by serious pollution problems, having a negative impact on the environment in general. The river courses, finally the coast and the beaches suffer severely from the uncontrolled discharge of wastewater and garbage from whatever sources. Often natural and manmade drainage channels are also misused to dispose of domestic and commercial waste or wastewater. The present practice of disposing commercial or human waste on land or through sub-soil passages[1] (e.g. septic tanks with soak ways) pose a great

[1] *Sub-soil conditions which are rarely existing in karstic formations*

risk to the groundwater quality. Spring or groundwater in the area is often bacteriologically polluted and must undergo disinfection treatment to make it fit for human consumption.

Even if the planed wastewater project on the northern side of the Nahr el Kalb is implemented, there remains a considerable potential of water and especially of groundwater pollution by various sources. Presently solid waste or wastewater can enter the transmission channel after the Jeita Spring Intake since it is not a closed system.

Development prospects

The area will continue to serve as recreational area for the population of Lebanon but especially for Beirut due to its pleasant climate and environment. From the touristic point of view, the area will continue to be developed for summer as well as for winter sport and recreation activities. For this reason, it must be assumed that the presently observed development trends (real estate and tourist facilities) will carry on in the future and if not better controlled by the government will pose a great risk to the infrastructures and the water quality of Beirut Water Supply.

Land ownership

Acquisition of land is time-consuming and may delay the project implementation if not initiated as early as possible. Presently just the width of the channel belongs to the public. To implement the proposed rehabilitation project and to enable an efficient maintenance of the structures it is necessary to acquire the land needed for the proposed twin pipelines and an access road.

Transmission Main - Rehabilitation Project

In order to decide on the most appropriate measures to be proposed for the rehabilitation of the existing transmission channel the following goals have been established by the Project Team:

1. Marked improvement of operational reliability by providing
   - if possible a second transmission line (redundancy) and
   - to renew the old and dilapidated masonry, concrete structures and tunnel ..section and aqueducts.
2. Maintain or if possible increase the flow capacity of the transmission main
3. Eliminating pollution of the spring water from exterior sources like surface run-off during the rainy season, or feeding polluted Nah el Kalb water (sub-standard water) into the transmission main.
4. Not allowing direct access to the water in the transmission pipe by unauthorized persons for irrigation needs.
5. Establishing independent systems for irrigation needs.
   Note: If it is possible to eliminate the OEB water Intake it will be possible to satisfy the irrigation water needs also with treated effluent from the WWTP.
6. Produce if economical justifiable renewable power by utilizing the available hydraulic head for hydropower generation.
7. Provide ample storage to maintain chosen flow capacity throughout the year.

Based on these goals the existing structure was carefully analysed and the Project Team came to the following conclusion:

To carry out partial repair and augmentation work will not solve most of the operational problems encountered today – the risk is actually that it may be the continuation of the presently applied “piecemeal repair approach” without substantially improving the structural condition of the channel.

Based on this conclusion cost estimates and financial analysis were prepared for the complete renewal to the transmission main and for basically two different flow rates of (a) 250’000 m^3/d and (b) 400’000 m^3/d. Furthermore, the possibility of power generation was studied with one plant at the former Harch Station and on the inlet to Dbaye WTP.

Preliminary data indicate that in the long-term the spring yields might decline due to climatic changes and man-made changes in the catchment area. For this reason, a preliminary assessment of potential dam sites has been carried out with estimated storage volumes in order to augment the declining spring yields. For the impounding reservoirs no financial analyses are provided except cost estimates.

Subject of the financial and technical analysis of the various alternatives considered below the Project Team presents the following recommendations:

Recommendation 1: The Consultant recommends to implement Alternative A400, which means twin pipes with a total flow capacity of 400’000 m^3/d. Regarding the pipe material to be used, the final decision should be made at the final design stage. The question of power generation may have its impact on the pipe material to be used. The resulting cost per 1 m^3 water arriving at the Dbaye WTP is approximately 0.026 to 0.042 USD depending on the pipe material (steel or glass reinforced). Comparing with a water tariff of 0.39 USD/m^3 drinking water (ref. Regional Sewage Plan) the proposed rehabilitation costs are representing about 10 % of the presently applied water tariff.

Recommendation 2: Presently, the financial analysis is showing that the installation of power generating sets is not economical. However, since these units can be operated as stand-alone units they can be used as emergency generation set, an advantage that the BMLWWE should carefully analyse before making any final decision. Furthermore, since the study at hand is on a very preliminary level with its usual uncertainties the Consultant recommends to include the possibility of power generation in the detailed design. The present additional cost of power generation is estimated to be less than 1.5 cent (¢ USD) per 1 m^3 water arriving at the Dbaye WTP.

Recommendation 3: To build an impounding reservoir is a mid-term issue, which needs to be commenced as soon as possible due to the required land expropriation. The Planning Team recommend that BMLWWE is undertaking a feasibility study in order to determine the most favourable location for a dam and its cost. This information will provide the inputs required to make a decision whether or not to peruse up the project idea.

1. INTRODUCTION TO JSPP PROGRAMME

1.1 TENDERING AND AWARD OF CONTRACT

The invitation for bids requesting consulting services for the Jeita Spring Protection Project (JSPP) were issued by KfW on 25.06.2010. The project site is located in the Kesrouan district of Lebanon. GITEC was awarded the contract that was signed on 24.06.2011 between the parties concerned.

The project proposal was prepared by GITEC in association with WE Consult, Germany and LIBANCONSULT, Lebanon. CDR is the project-executing agency; KfW had entered into an agency contract with CDR for selecting an implementation consultant and carrying out the program.

1.2 THE PROJECT AREA

The Kesrouan area, situated directly north-east of the City of Beirut is characterized by its numerous small localities spread across its mountainous terrain, with elevations ranging from sea level to over 1,500 meters. The region is bound from the north by the Ibrahim River and from the south by the Al-Kalb River. It is known for its steep gorges and seasonal watercourses that flow during the winter period, especially when mountain snow melts in the springtime. Surface water infiltrates into the underlying highly permeable karstic rock formation, recharging the groundwater aquifer, which feeds the Jeita springs, the main source of drinking water for the City of Beirut. The Jeita spring is situated on the northern bank of the Nahr el Kalb, approximately 4 kilometres east of the point where the Nahr el Kalb discharges into the Mediterranean Sea.

In recent years, the entire area has undergone increasingly serious environmental pollution due to the absence of adequate wastewater collection and treatment infrastructure. Most of the region’s properties and households do not have appropriate wastewater disposal facilities. The wastewater either is disposed of in septic tanks of inadequate design and functionality, or is inappropriately diverted into sinkholes, vertical shafts and watercourses without any treatment whatsoever. As a result, the pollution of the Jeita groundwater aquifer has dramatically increased in recent years, and has already reached levels which are hazardous to the public health and which affect negatively the water treatment of potable water for Beirut.

1.3 OTHER ACTORS IN THE SANITATION SECTOR (EIB, ITALIEN, GIZ + BGR)

Besides this KfW funded JSPP there are two other wastewater projects, which are expected to be implemented in the coming years in Kesrouan region:

EIB / Tarbarja WWTP Project: The design concept for the EIB project was developed in 1995. The project will serve Jounieh area and the coastal strip of Kesrouan region, north of Tabaja. The project will serve (in the 1st phase) 400,000 people with an equivalent of about 50,000 m³/d wastewater. The anticipated total costs of the project amount to about EUR 110 million (70 Mio EUR from EIB and 40 Mio EUR from AFD). With an anticipated total implementation period of four years, it is assumed that the project becomes operational in early 2013.

Italian financed Mairouba Project: The project covers the wastewater collection and centralised treatment of four smaller towns and villages (Mairouba, Hrajel, Faraiya and

Aayoun es Simane) with a total current population of about 25,000 people. The project area is located some 25 to 30 km from the Mediterranean Sea, in the upper reaches of the Al-Kalb River. The investment amounts to US$ 9 million (EUR 6.7million). It was planned that the project will be operational at the earliest in 2011.

The on-going GIZ and BGR assistance programs are briefly described and summarised as follows:

GIZ – Assistance to the Water Sector Reform: The GIZ is assisting the government (MoEW), the four regional water establishments and the communities at various levels of the water supply and wastewater sector. Besides sector reform activities at the government level, the program is mainly meant to foster institutional development and capacity building at the WE level. The coordinated use and integration of the outcome of the GIZ assistance measures into the planning and implementation process of the three envisaged wastewater systems in Kesrouan region would certainly enhance BMLWWE's future operation capability and efficiency.

BGR – Protection of Jeita Spring: BGR is presently implementing a Technical Cooperation (TC) project, which shall complement the KfW financed investment project for the protection of Jeita Spring. Partners of this TC project are MoEW, CDR and BMLWWE as well as the municipalities involved. The project includes besides other issues the following objectives:

- Delineation and implementation of groundwater protection zones for Jeita Spring
- Integration of water resources protection aspects into the investment planning and implementation process in the wastewater sector.
- Support of the partner institutions concerning the implementation of urgent protective measures.
- Sensitization of the population concerning risks of water pollution and connection to the sewage system.

1.4 PROGRAMME'S GOAL AND OBJECTIVES

According to KfW's Terms of References for the Consulting Services

The <u>programme's overall goal</u>

The planned 'Jeita Spring Protection Project' (JSPP) aims to protect the water resources in the area from contamination with sewage water. A safe wastewater disposal being it by wastewater collection and centralized treatment plant or on site wastewater treatment is envisaged for all localities influencing the water of the Jeita spring source, in particular those discharging their untreated wastewater directly into the Nahr el-Kalb gorge. Once implemented, it is expected that the project will reduce adverse health impacts resulting for the contamination of drinking water supply for the residents of the City of Beirut, and that it would considerably enhance the environmental conditions of the project area as watercourses for the Al-Kalb River and its tributaries will once again flow with non-domestic polluted water.

The <u>projects objective</u>

The project is to safeguard the quality of the groundwater from Jeita spring so that the supply of the population of Beirut with hygienically sound drinking water can be ensured.

With respect to the actually planned measures with high priority, the following indicators for measuring the degree of achievement of the projects objectives can be used:

- Two years after commissioning of the WWTP
  80% of the households and commercial establishments of the southern districts of Jeita will be connected to the WWTP and the collected wastewater will be treated in the WWTP
- Operation of the WWTP and the collection networks is ensured continuously and technically appropriate
- The limiting values of the organic pollution and total coliform bacteria's according to WHO standards are fulfilled at 80% of the samples.

The scope of work to be delivered by the Consulting Services for Phase I can be sub-divided into the following stages:

- **Phase I A:**
  - Inception Report
  - Preparation of a Regional Sewerage Plan for Jeita spring catchment area.
- **Phase I B:**
  a) Final design and tender documents for:
     - Jeita Municipality sewer network
     - WWTP incl. immediate (repair) measures on Jeita Spring Intake
  b) **Feasibility Study: Rehabilitation of Transmission Channel Jeita Spring Intake - Dbaye WTP**
- **Phase I C:**
  Assistance to the Employer in Tendering and Contracting of:
     - Jeita Municipality sewer network
     - WWTP incl. immediate (repair) measures on Jeita Spring Intake
- **Phase I D:**
  Supervision of physical construction works for the first phase of the project to achieve the objectives of the Project
     - Jeita Municipality sewer network
     - WWTP incl. immediate (repair) measures on Jeita Spring Intake

The Regional Sewage Plan, which forms the base for the detail planning, focused especial on the sewage collection and disposal within the whole project area. The report did not deal with the internal sewage network of the various municipalities but with the main sewage collectors and the number and locations of required WWTPs in order to arrive at the most economical and technical solution.

In General

In Lebanon, the porous limestone formations throughout the country constitute a principal water resource, which is easily contaminated by surface infiltrations. Consequently, national planning (the water sector reform of 2000 with restructuring the responsibilities in 2005) emphasizes the importance of developments in the sewerage sector.

The sanitary conditions within the project area are to be improved by comprehensive sewage collection, aiming at 100 % connection as far as this is economically justifiable, and transport the collected wastewater to a wastewater treatment plant. In places where sewage collection systems are not feasible, for technical or economic reasons, appropriate off-site wastewater disposal will be considered.

2. PROJECT AREA

2.1 BRIEF INTRODUCTION TO THE GENERAL CHARACTERISTIC OF THE PROJECT AREA

The project area is located in the cental part of the Lebanon, about 12 km northeast of Beirut as shown in Figure 2-1.

Figure 2-1 Project Area in the Centre of Lebanon

Geology

The project area is located in a karstic zone as found elsewhere in Lebanon. The porous limestone formations constitute a principal water resource, which is easily contaminated by surface infiltrations. The favourable climatic and geological conditions lead to a substantial dissolution or karstification of the limestones.

Medium-sized surface features may include sinkholes or cenotes (closed basins), vertical shafts, foible (inverted funnel shaped sinkholes), disappearing streams, and reappearing springs. Large-scale features may include limestone pavements, poljes and blind valleys. Beneath the surface, complex underground drainage systems (such as karst aquifers) and extensive caves and cavern systems may form e.g. Jeita Grotto ref. Figure 2-2 (Photo new7wonders.com).

Figure 2-2 Jeita Grotto

The climate of Lebanon is typically Mediterranean, with heavy rains in the winter season (December to April) and dry and arid conditions in the remaining seven months of the year. However, the influence of the Mediterranean Sea, the topographic features, and the Syrian Desert in the north creates a variety of microclimates within the country with contrasting temperatures and rainfall distribution.

On the coast, the average annual temperature is 20 °C, ranging from 13 °C in winter to 27 °C in summer whereas the average annual temperature in the Bekaa valley is lower at 16 °C, ranging from 5 °C in winter to 26 °C in summer; nevertheless, at higher elevations in the mountain zones the average annual temperature is below 10 °C, ranging from 0 °C in winter to 18 °C in summer.

Average annual rainfall is estimated at 823 mm although this varies from 700 to 1’000 mm along the coastal zones and from 1’500 to 2’000 mm on the high mountains, decreasing to 400 mm in the eastern parts and to less than 200 mm in the northeast. Above 2’000 m, precipitation is essentially niveus and helps to sustain a base yield for about 2’000 springs during the dry period. Precipitation in dry years can be as little as 50 per cent of the average. Rainfall occurs on 80 to 90 days a year, mainly between December and April. About 75 per cent of the annual stream flow occurs in the five-month period from January to May, 16 per cent from June to July, and only 9 per cent in the remaining five months from August to December.

The National Meteorological Service has identified eight eco climatic zones based on rainfall:

- the coastal strip, which includes the northern, central and southern coasts;
- the Lebanon Mountains, which are divided into the northern and central mountains;
- the Bekaa Valley, which is divided into the northern (interior Asi-Orontes), central (interior Litani) and southern (interior Hasbani) regions.

Although there are some meteorological stations located within or nearby the projects area, there are only some few statistical analyses available based on a longer time period. Figure 2-3 shows the Rainfall distribution (1939 – 1970) in the Nahr el Kalb catchment according to UNDP / FAO (1973).

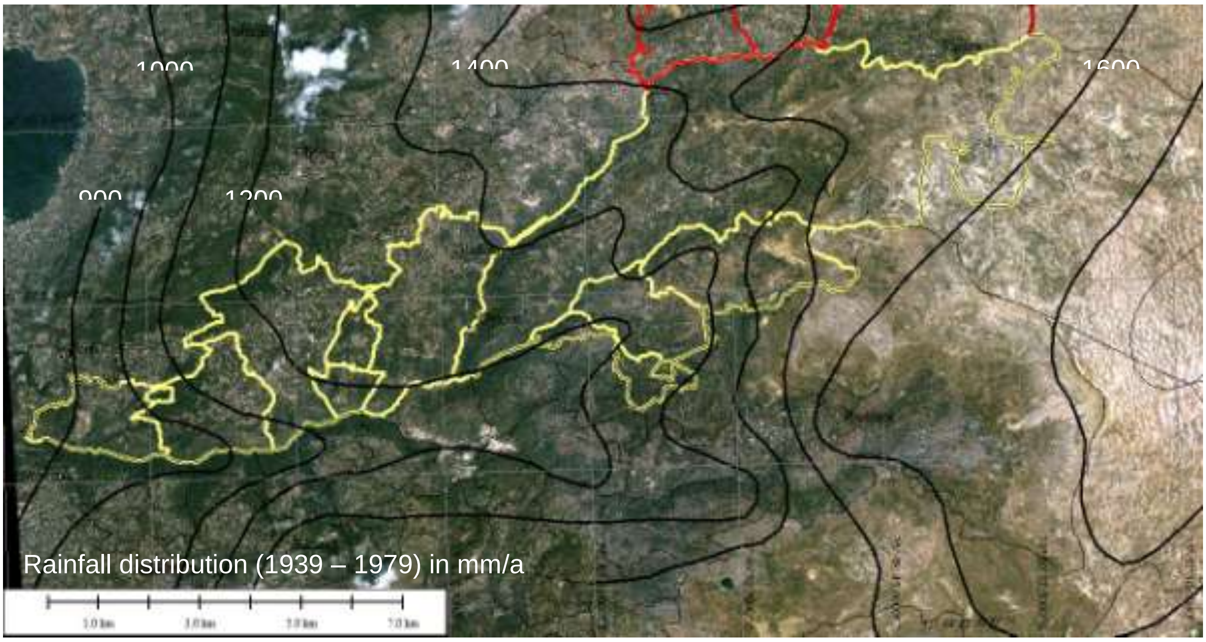


Figure 2-3 Rainfall distribution (1939 – 1970) in the Nahr el Kalb Catchment

Mean annual potential evapotranspiration ranges from 1’100 mm on the coast to 1’200 mm in the Bekaa Valley, with maximum values recorded in July. Generally, fewer adverse effects are observed on the coast than in the Bekaa Valley, where effects due to wind and high vapour pressure deficit are dominant (LNAP, 2002).

3. SOIL INVESTIGATIONS

No specific soil or sub-soil investigations were carried out along the existing or planned transmission main(s).

4. EXISTING TRANSMISSION CHANNEL

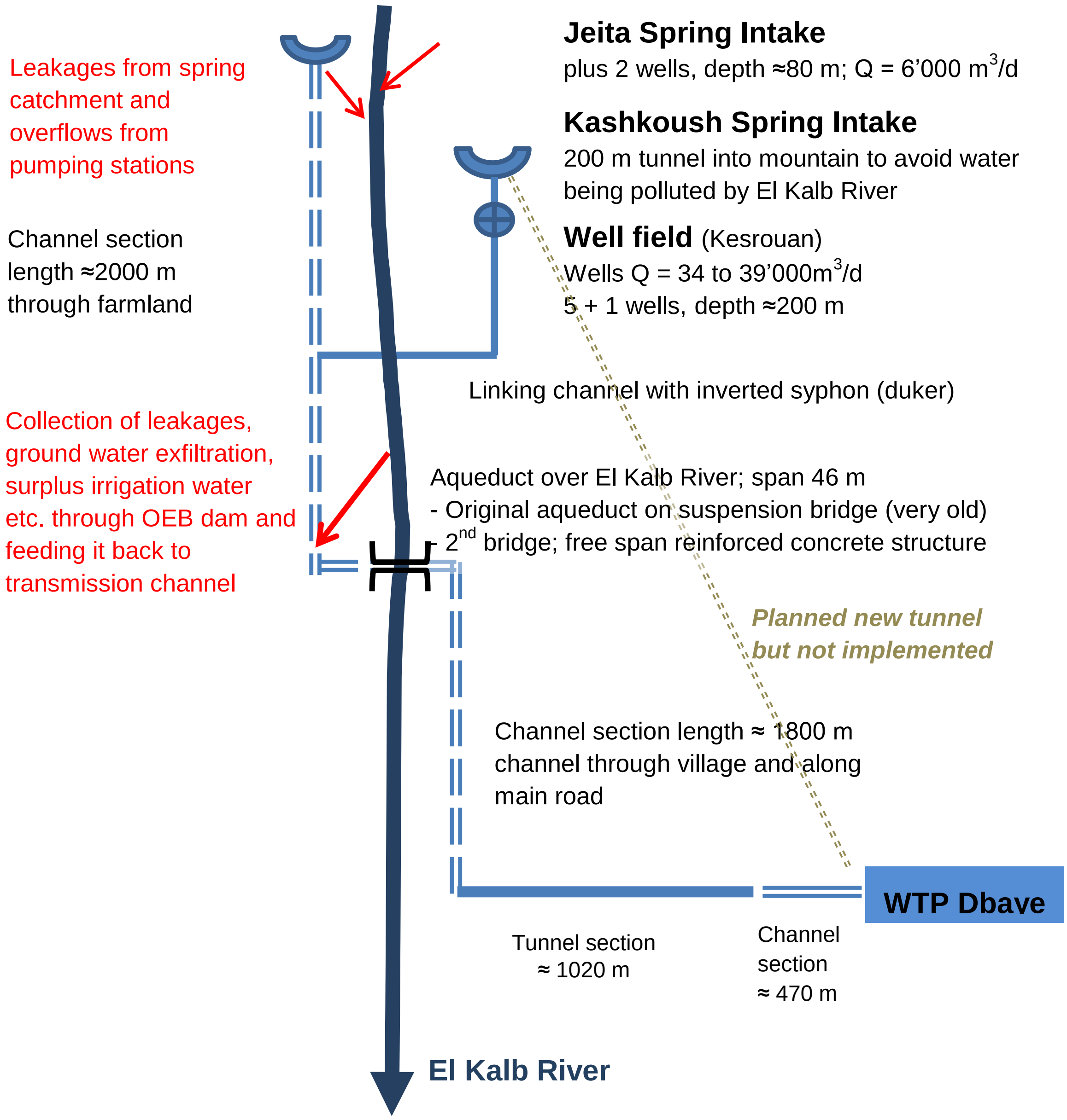
4.1 INTRODUCTION[2]

The transmission channel and tunnel was built some 150 years ago most likely as a part of an irrigation scheme. At that time the water was passing around the hill, later when the channel was used for irrigation and water supply the tunnel section was added. According to

[2] *Source: JSPP Inception Report, Oct. 2011*

some drawings dated 1940 the channel was initially an open, trapezoid shaped channel. Whether the channel was lined with some stone patching, to reduce the water losses, is not known. In any case, at that time the Jeita spring provided sufficient water for the population of Beirut. Later the channel was rehabilitated providing trapezoidal or rectangular cross-section with masonry walls and was finally covered with concrete slabs. Information on the channels foundation slab (concrete or pointed hard-core layer with cement rendering) is not available. Based on the above-mentioned drawing it seems that the intake was some few hundred metres downstream of the existing intake, probably in the region of the Kashkoush spring.

4.2 SCHEMATIC SKETCH OF TRANSMISSION CHANNEL



4.3 BRIEF DESCRIPTION OF THE TRANSMISSION CHANNEL

Section	Comments
General comments of the transmission channel	**Landownership:** The width of the channel is exactly the width of the land belonging to BMLWWE or the Government. Any by-pass arrangement for the existing channel requires the expropriation of land. **Channel Cross Section:** There are different cross sections encountered along the transmission channel.
	Longitudinal Profile: The scarce data available indicate that the longitudinal profile is as ill structured as the varying cross sections.
Intake	Leakage at intake site are taken care by immediate measures proposed and included in the scope of work for the WWTP
Intake – Harch hydropower station	The old hydropower plan is out of order for a long time and due to its age no more repairable. Also in future, during the dry season, the water from the Kashkoush Spring is needed to supplement the Jeita Spring yield. For this reason, the hydraulic grade line of the transmission line must be on such elevation to enable the Kashkoush Spring flow to enter the transmission main. Since there is a difference in elevation between the Jeita and Kashkoush Springs, the available head could be used for hydropower generation by re-furnishing the existing power plant.
Harch hydropower station – OEB dam	• In the upper parts, the channel is prone to be over topped during flush floods by the Nahr el Kalb and heavy polluted river water is entering the channel due to open slab joints. • In the middle parts the channel is damaged on different locations by stones e.g. landslides or river channels. In this part, there are also a lot of the irrigation water draw offs, whose quantities cannot be controlled. • In the lower part, the channel foundation is eroded or even washed away during the rainy season. In the long run and if left unattended the channel structure will collapse.
OEB dam	At this location, the natural ground conditions helped to create a small pond. In the dry season, the dam height is artificial increased to enable the collected and visually polluted water to be diverted into the transmission channel.
OEB dam – Aqueduct	In this area, buildings are placed next to the channel. Proper maintenance and e.g. extension of the channel is not possible.

Section	Comments
Aqueduct	• The originally built aqueduct is a concrete structure placed on a steel frame which itself is connected to the suspension cable. • The newer free span reinforced concrete aqueduct is split into three flow chambers / channels, which are accessible at the bridge supports.
Aqueduct – Tunnel entrance	• The channel passes near and under houses, through short aqueducts or tunnel sections. A great part follows the road with the top of the channel about 1 m above the road level. • Notwithstanding, neither accessibility for O&M is guaranteed nor is it feasible to control illegal use of water.
Tunnel section	The tunnel is an unlined rectangular shaped cross section. The cross sections are varying and there is hardly any slope in the longitudinal profile. The tunnel flow capacity is occasionally further reduced by localized collapse of the tunnel section whereby debris reduce the flow cross section.
Tunnel end to Dbaye WTP	Not inspected, completely surrounded by buildings and roads

4.4 PREVIOUS REPORTS

In the last decades, various studies have been carried out with different objectives, just to mention the most important ones:

- Nahr-el-Kalb – Dbaye Water-Conveyor, Associate Consulting Engineers (ACE), Beirut, 1988
  This report provides a comprehensive picture of the state of the existing channel and makes proposals to increase the flow to Dbaye WTP up to 525’000 m^3/d (6.07 m^3/s) to be reached for 164 to 210 days per year. To achieve this objective an additional transmission channel is proposed.
  The capacity of the existing transmission channel is estimated to be between 240’000 and 280’000 m^3/d.

- Canal d’adduction d’eau de Jeita à Dbaye, Dune Ingénierie et Développement, September 1995.
  As it seems the study’s main objective was the assessment of the existing channel conditions and the proposal of rehabilitation measures.
  The report deals only with 3360 m length of the Transmission main, out of which about 2250 m must be rehabilitated.

- Appui à la réforme institutionnelle du secteur de l’eau au Liban / Action pilote pour la sécurisation de la ressource de Jeita; Burgéap 2005
  The report provides an overview of the different flow regimes adopted by Dbaye WTP and the newest figures on water production and water withdrawal.

4.5 JEITA SPRING INTAKE

The lack of fundamental data, such as for instance spring flow data, from this important catchment in Lebanon is the reason that a meaningful water balance had not been established until recently (SCHULER, 2011; MARGANE et al., in progr.). Even the study carried out by UNDP (1972) did not make any efforts to improve spring discharge monitoring or to determine the groundwater catchment. UNDP assumed that the groundwater catchment is similar to the shape and extent of the surface water catchment which, as recent studies have pointed out, is definitely not the case (MARGANE et al., in progr.).

Discharge of Jeita spring (commonly referred to as Jeita 60) had until recently not been measured correctly. During the time period 1966/67-1973/74 the Office des Eaux de Beyrouth (OEB) had carried out measurements at the canal from Jeita to the Harash hydroelectric power plant. SALIBA (1977) gives the maximum amount to be diverted at this point as 15 m^3/s. Under current conditions this upper part of the canal can convey only a maximum of 4.3 m^3/s (Chapter 4.7). The previous flow measurement of OEB must have taken place at about the same place as the measurements carried out by LRA nowadays. The statement about a maximum capacity of 15 m^3/s, being almost 4 times as high as nowadays would thus seem completely unrealistic. Flow measurements were only made randomly (between once a week to once every two months, even during high flow periods) and amounts exceeding the maximum flow capacity of the canal and thus being discharged into Nahr el Kalb at Jeita could not be measured.

Even measurements at the siphon terminal (commonly referred to as Jeita 140; SALIBA, 1977; UNDP, 1972), located some 5300 m upstream of the boat moorings and accessible through the Daraiya tunnel probably bear a high uncertainty due to the construction of the site. Reports documenting the construction of both sites and the calibration of the discharge measurements could not be found.

Completely unrealistic is the extrapolation by SALIBA (1977) of flows at Jeita 60 and Jeita 140 based on a correlation with flows in Nahr el Kalb, which have absolutely nothing in common.

The Daraiya tunnel was dug in 1971 by Hungarian engineers to divert groundwater from here through a tunnel directly towards Beirut. It was hoped that by raising the water level by a dam (2.5 m) the available amount of groundwater could be increased (UNDP 1972). The concept of this idea is not comprehensible.

In order to finally establish a water balance based on real data for the Jeita groundwater catchment, the following installations have been made by the project in Jeita (500 m upstream of boat moorings; spacing 5 m):

- Multi-parameter probe (InSitu Troll 9500) measuring at 20 minute intervals (since August 2010): water level, electric conductivity, pH, oxygen content, temperature, turbidity. Based on water level measurements and individual discharge measurements a rating curve has been established in order to determine discharge based on water level for this section.
- Acoustic Doppler Current Profiler (ADCP; SonTek Argonaut SW; since August 2011) measuring water level and flow velocity. The complete flow profile has been surveyed and thus discharge can be calculated directly from the ADCP measurements.

Spring discharge measured by the multi-parameter probe using a rating curve (STOECKL, 2011) during 01.09.2010 to 31.08.2011 (water year 2010/11) was 122.6 MCM (Figure 4-1). It should be noted that there are considerable fluctuations in water level and flow and that the recession period after heavy rainfalls is very short (Figure 4-2). Measurements using the ADCP indicate flow velocities of between 2 and 65 cm/s.

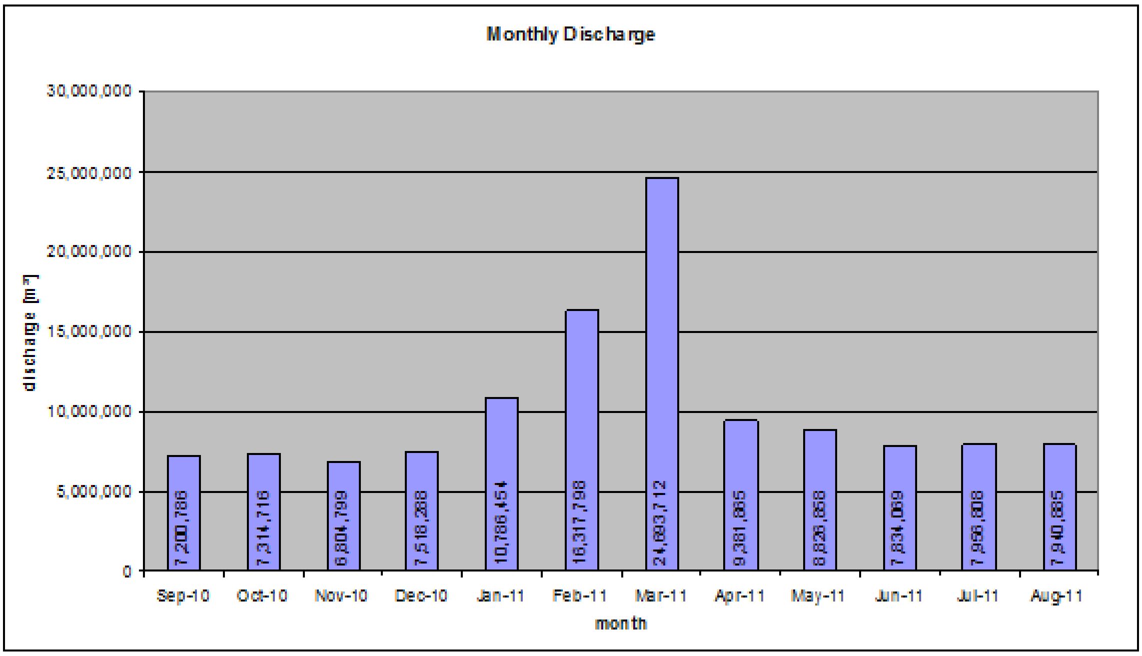


Figure 4-1 Spring Discharge of Jeita Spring during Water Year 2010/11

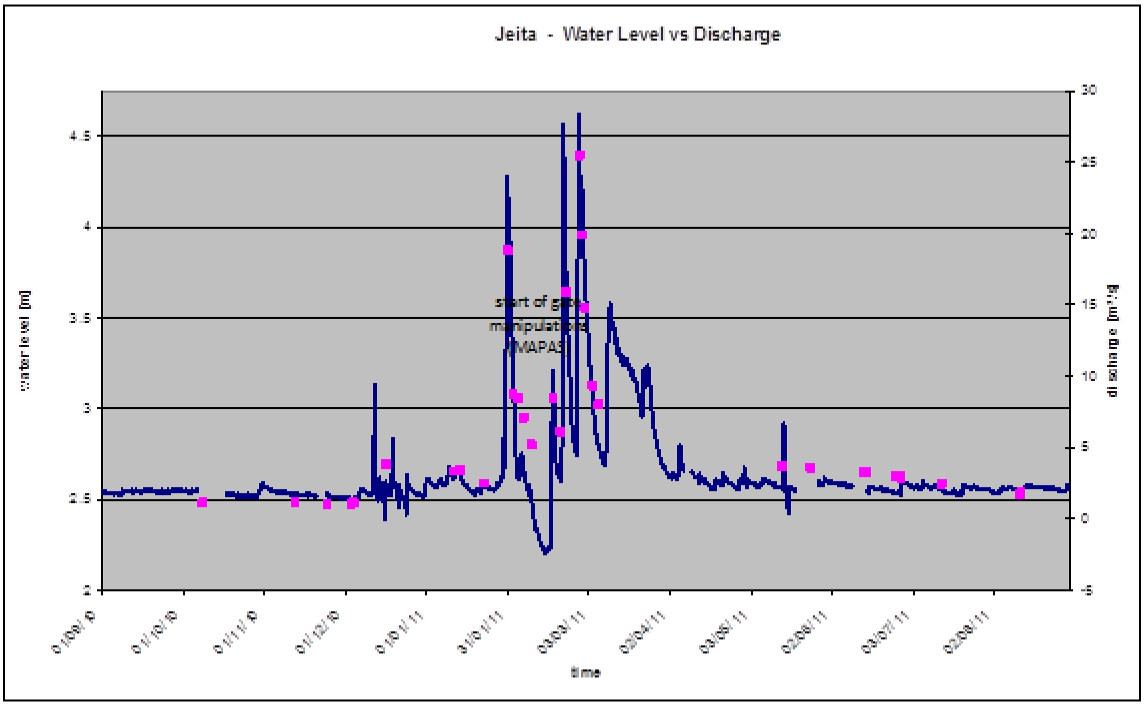


Figure 4-2 Water Level of Jeita Spring during Water Year 2010/11

Flow of Jeita spring is currently measured by LRA in the canal at the lower level of Jeita Grotto parking (Chapter 4.6). This measurement does not represent total flow of Jeita spring, because this measurement takes place after diversion of water exceeding the capacity of the intake (max. 4.3 m³/s; see Chapter 4.7; only a max. of 3.1 m³/s actually arrives at Dbaye). Measurements at this location only give the amount of water at the beginning of the conveyor before diversions and physical losses.

Water Establishment Beirut and Mount Lebanon (WEBML) measures flow at Harch using a Marsh Mc-Birney FLO 450 flow meter (http://www.hach.com/mmi) installed in 2003.

The spring capture in its current configuration is the result of tinker work over almost 150 years. Due to poor upkeep many parts are not operational anymore and only a minor quantity of the spring discharge can currently be captured. All old installations should therefore be removed.

Description of Current System

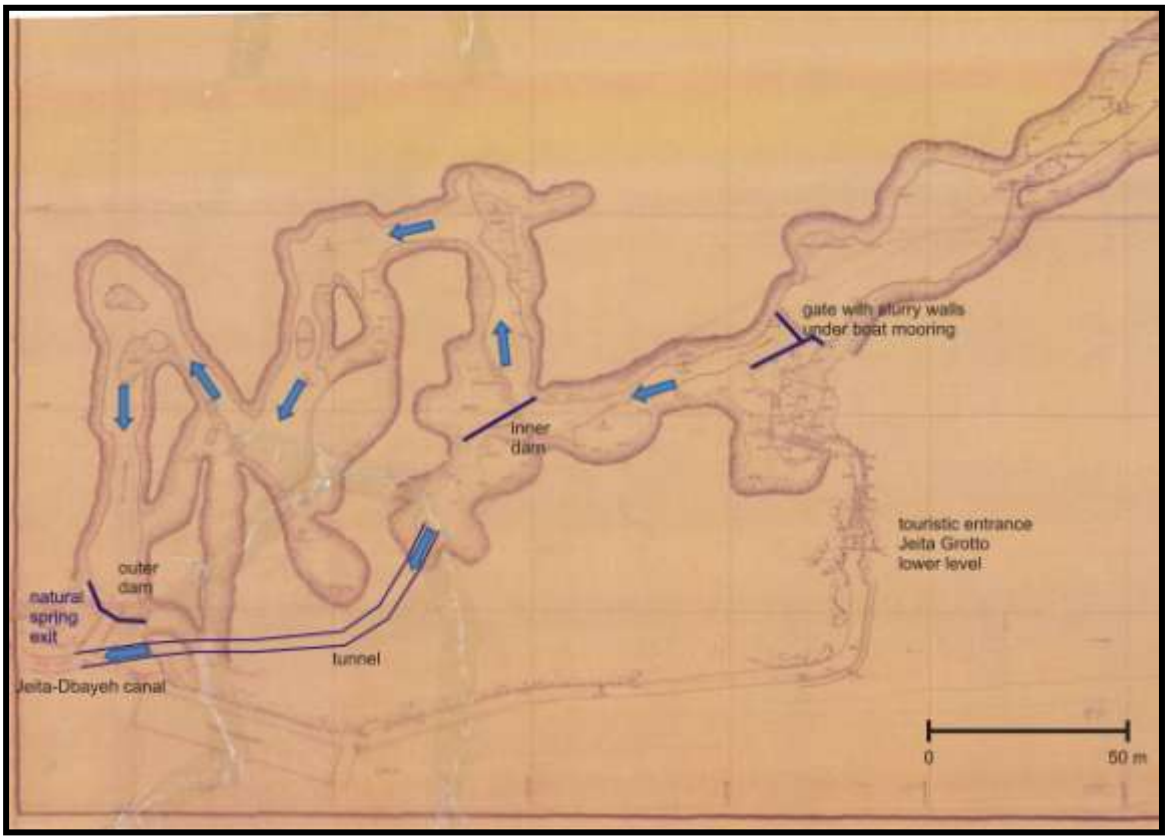


Figure 4-3 Jeita Spring Capture - Current Configuration

The installations related to water abstraction are shown in Figure 4-3. The distance from the boat mooring to the natural exit of the spring is around 200 m. At the boat mooring water level is controlled by two slurry walls (Figure 4-4). The boat mooring becomes flooded at a flow exceeding approx. 10 m³/s. Right after the boat mooring water continues through a narrow passage (Figure 4-5), approx. 50 m downstream of which is a small dam (Figure 4-6). The purpose of this dam is to divert water into a man-made tunnel running towards the natural exit of the spring. In case of high flows the inner dam cannot receive all water and water flows through the natural cave to the outer dam (Figure 4-7 and Figure 4-8).

Figure 4-4 Flooded Boat Mooring and Crane for moving Slurry Walls (arrow)

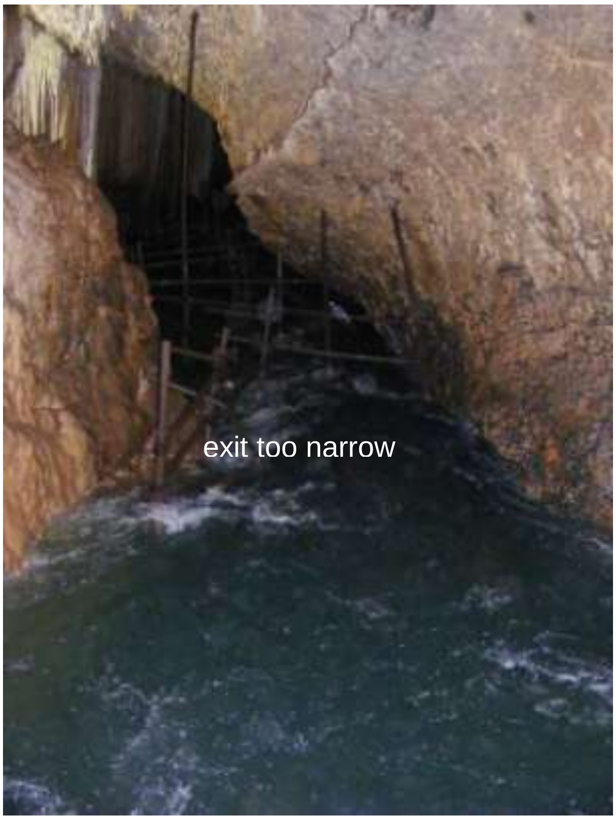


Figure 4-5 Narrow Passage between Boat Mooring and Inner Dam

Figure 4-6 Inner Dam with Intake to Tunnel

Figure 4-7 Natural Exit of Jeita Spring with Outer Dam

Figure 4-8 Natural Exit of Jeita Spring with Outer Dam

Figure 4-9 Jeita-Dbaye Canal and Overflow

Figure 4-10 Overflow from Outer Dam

4.6 WATER SAFETY ALONG THE JEITA - DBAYEH TRANSMISSION MAINS

4.6.1 Introduction

Although used in prehistoric times, Jeita Grotto was rediscovered in 1836 by Reverend William Thomson (http://en.wikipedia.org/wiki/Jeita_Grotto). The spring is used since 1870 for water supply of Beirut (KARKABI, 2009). Parts of the transmission mains still date back to this time. A description of the establishment of the historic water supply has not been mentioned in any previous documents reviewed by the author and it is thus unknown which parts of the transmission mains exactly date back to which time. However, it can safely be assumed that large parts of the infrastructure are more than 100 years old.

The Jeita - Dbayeh transmission mains are the main source of drinking water for the Greater Beirut area. However, its capacity is currently limited to 3.1 m³/s. Limiting factors are not only the tunnel between Nahr el Kalb and Dbaye but also the canal, which has considerable physical leakage losses (Chapter 4.7). This maximum amount, however, is available only during a short time of the year. During the dry season discharge of Jeita spring is often decreasing to < 1 m³/s (MARGANE et al., in progr.; Figure 4-13), while Kashkoush spring yields usually < 0.3 m³/s in the dry season (Figure 4-14).

During the period from mid-June to mid-September, an amount of 60,000 m³/d (0.7 m³/s) has to be made available for irrigation (pers. comm. BMLWWE) from the transmission mains because of existing water rights.

Several proposals have already been made to improve the transmission mains because of water quality concerns and in order to increase the supply capacity (SALIBA, 1977; ACE, 1988; CORAIL & ICEA, 2005) but none of them has been implemented for reasons unknown.

Over the past decade the level of microbiological contamination has increased considerably (BMLWWE; HAKIM, 1993; JURDI, 2011). The reason is the rapid and uncontrolled development, which took place after the end of the civil war in the Jeita catchment.

The inside of the transmission main is inspected once a year in order to clean it from rocks, roots, etc. The last inspection was done on 26-MAY-2011 (pers. comm. BMLWWE).

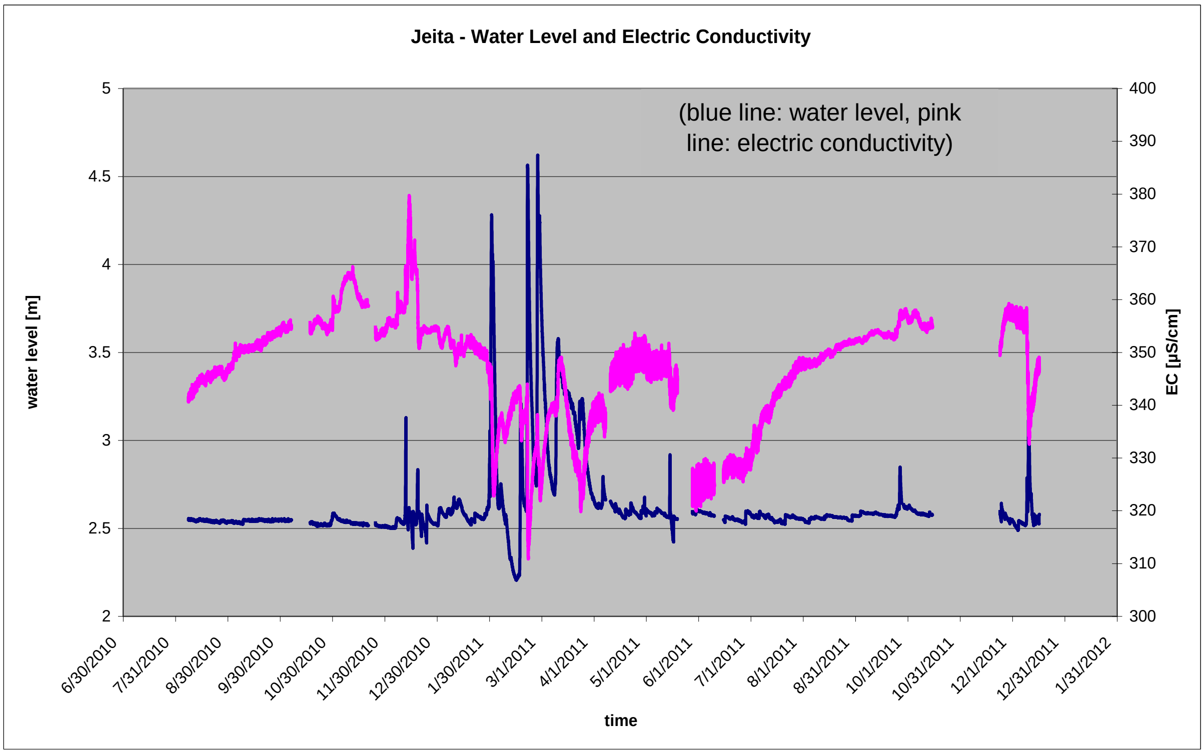


Figure 4-11 Water Level at Jeita Spring measured since 07-AUG-2010

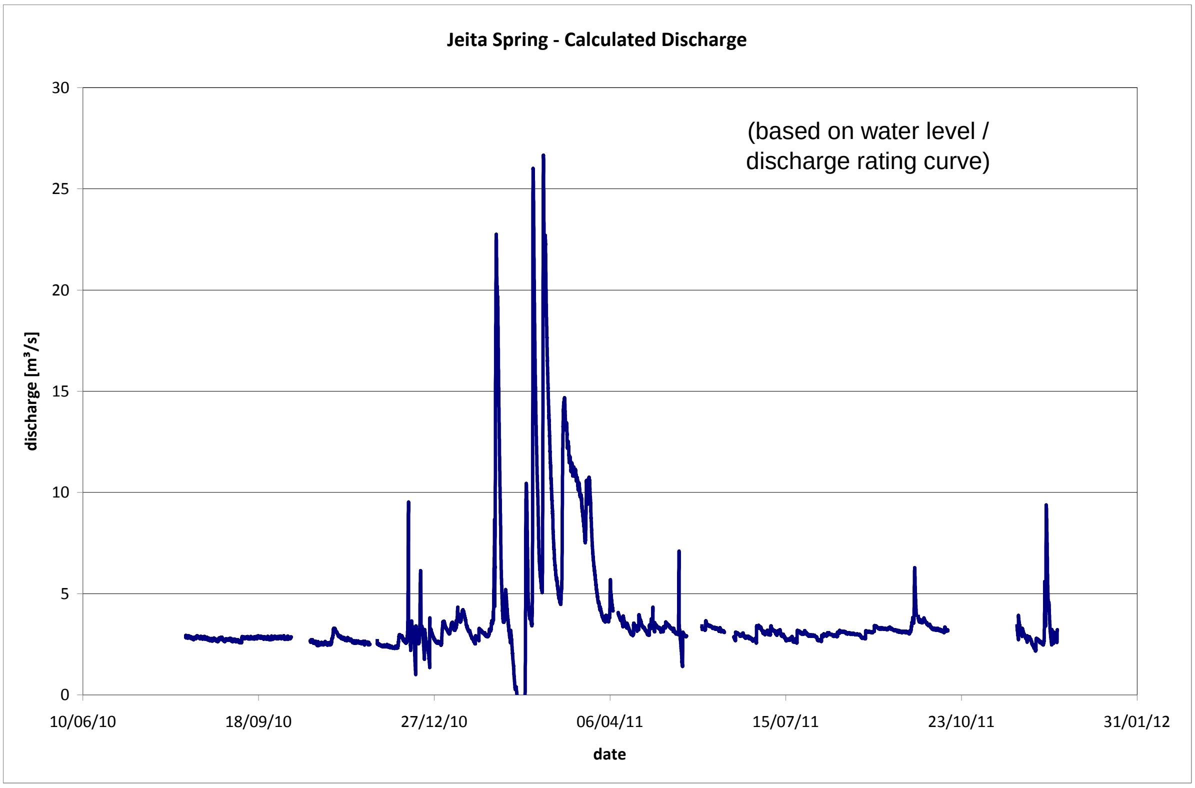


Figure 4-12 Discharge of Jeita Spring

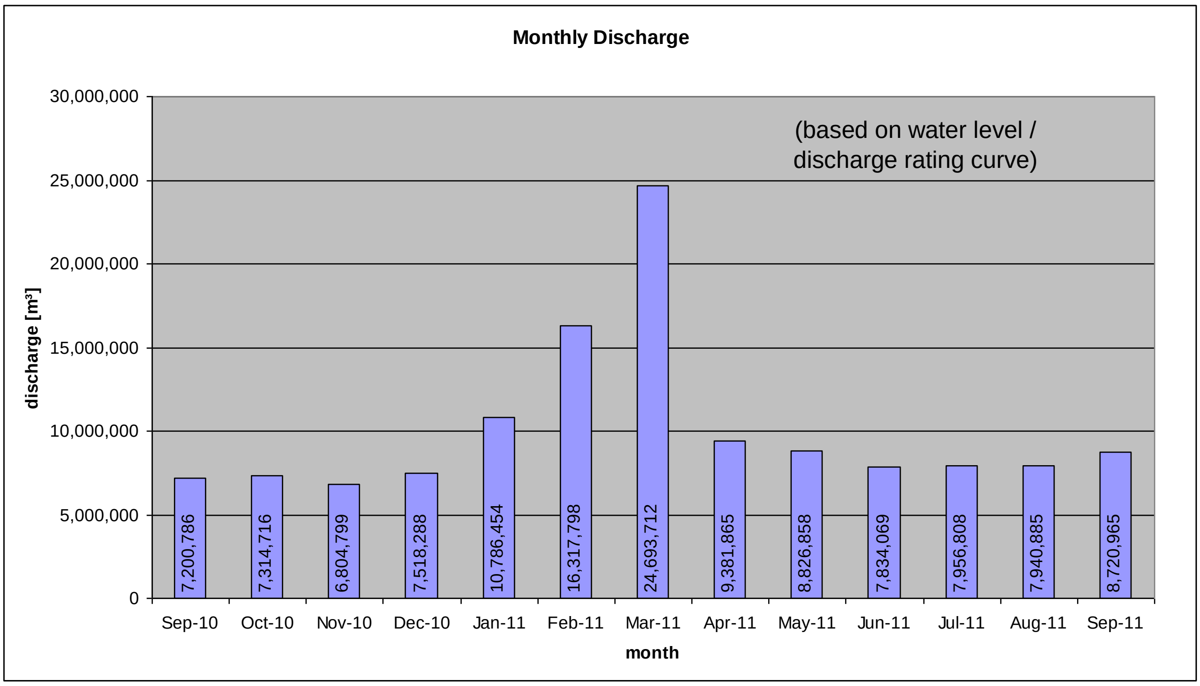


Figure 4-13 Monthly Discharge of Jeita Spring between 09/2010 and 09/2011

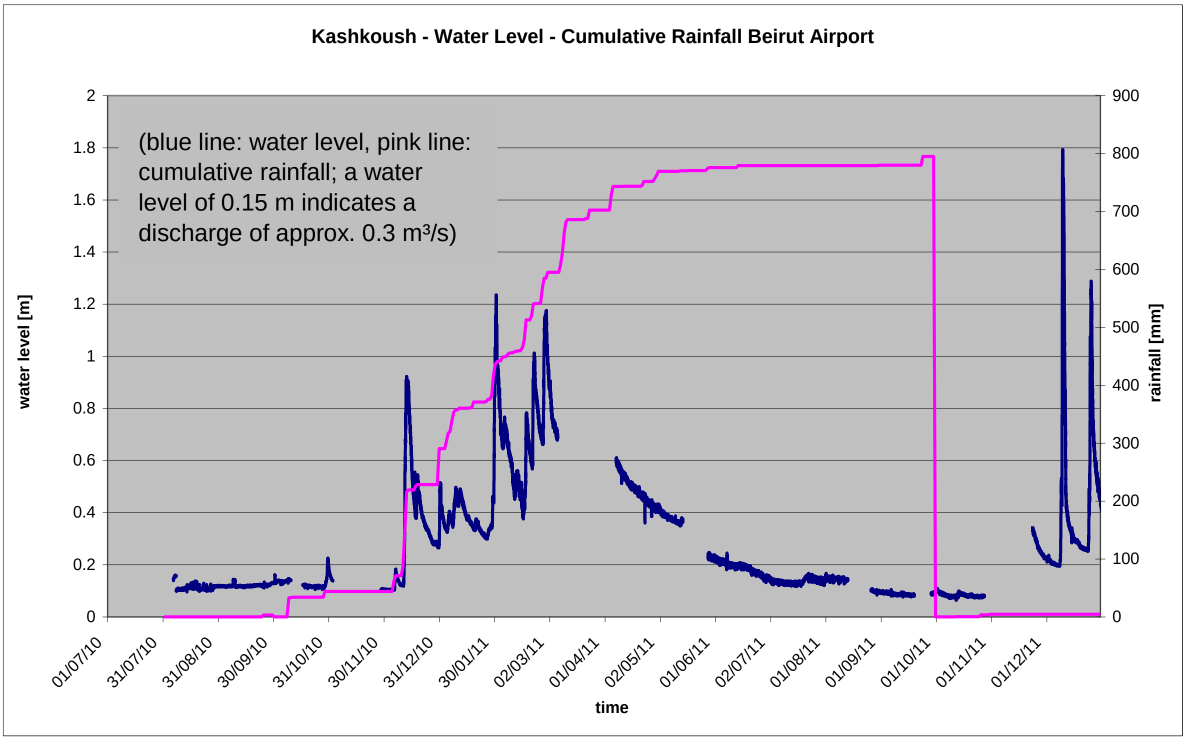


Figure 4-14 Water Level at Kashkoush Spring measured since 06-AUG-2010

The drinking water treatment plant at Dbaye (Figure 4-15) uses aeration / coagulation, sand bed filters and chlorination for treatment. Coagulation with ferric chloride ($FeCl_3$) is used to reduce turbidity in the aeration tanks. The residence time in the treatment plant is less than 1 hours (pers. comm. BMLWWE).

Figure 4-15 Dbaye Drinking Water Treatment Plant

At Dbaye, raw water from the two springs, Jeita and Kashkoush, as well as from 6 wells, located at Kashkoush, are passing through the treatment plant. There are 5 wells at Jeita, which are only partially used for water supply in the Qornet Hamra area and 3 wells in Nahr el Kalb at Mokhada where water is transferred into the Jeita - Dbaye canal. The components of the transmission main related to Jeita spring capture are shown in Figure 4-16, those related to Kashkoush spring capture in Figure 4-17. Dbaye also receives water from 1 well at Antelias and the Faouar Antelias spring.

Figure 4-16 Layout of Jeita Spring and Infrastructure related to Jeita Spring Capture

Figure 4-17 Location Map showing Kashkoush Well Field and Kashkoush Spring

The aim of water safety is to protect a water supply network against contamination. The only effective way to provide a sufficient protection is to ban the public from having access to the transmission mains.

In order to address comprehensively all water safety issues along the transmission mains, all components have to be considered. An overview map showing all components of these transmission mains is given in Figure 4-18. Details of this system, going from east to west, are shown in Figure 4-19 to Figure 4-22.

4.6.2 Components of the Transmission Main

The transmission mains from Jeita / Kashkoush to Dbaye are composed of the following elements:

Figure 4-18 Components of the Jeita - Dbaye Transmission Main

1. Small dam at Jeita spring (approx. 50 m downstream of touristic boats mooring) acting as intake station for the canal;
2. Tunnel from the dam towards the natural exit;
3. Dam and diversions at the natural exit of Jeita spring (Figure 4-19);
4. Canal from the natural exit of Jeita spring to another small dam (Figure 4-20);
5. Dam acting as diversion structure for a) irrigation in the Kashkoush area (Figure 4-21), b) rejection of Jeita water and discharge into Nahr el Kalb river in case excessive turbidity or repair of the canal (Figure 4-22), c) transfer to Dbaye;
6. 2 m diameter pipeline from the dam to the former Harch power plant (Figure 4-17);
7. Transfer into the canal at the former Harch power plant Figure 4-18,
8. Intake from Kashkoush spring (Figure 4-19);
9. Mokhada diversion structure and Mokhada dam (Figure 4-20);
10. Canal crossing Mokhada bridge;
11. Canal passing through the village of Mokhada to the entrance of the tunnel;
12. Tunnel passing through the mountain to the Dbaye WTP.

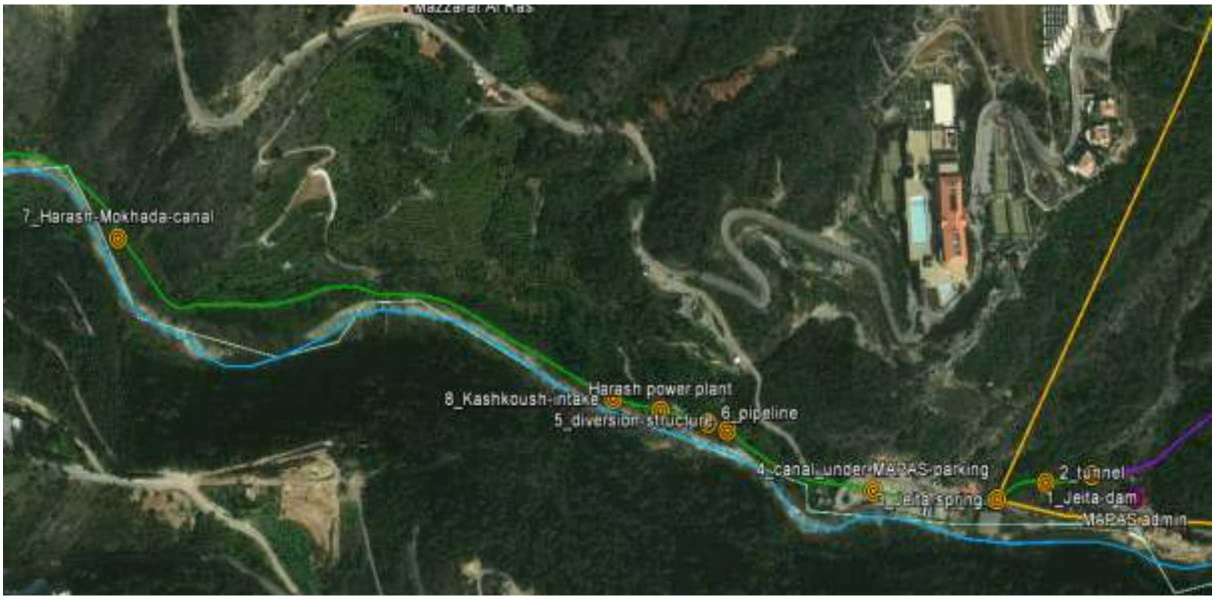


Figure 4-19 1st Part of Transmission Main (Components 1-7)

Figure 4-20 2nd Part of Transmission Main (Components 7-10)

Figure 4-21 3rd Part of Transmission Main (Components 10-12)

Figure 4-22 4th Part of Transmission Mains (Component 12 - Tunnel + Dbaye Intake)

4.6.2.1 Jeita Spring Intake - Transfer of Jeita Spring into the Canal

The dam (Figure 4-23; inner dam) from where Jeita water is transferred through a tunnel into the first part of the canal is accessible and is located approx. 100 m upstream from the gate. At the exit of Jeita spring there is another dam (Figure 4-24; outer dam), which has no function nowadays since its gates cannot be moved anymore.

Components 1, 2 and 3, i.e. the inner dam (Figure 4-23), the inner tunnel and the outer dam are not open to the public and there is therefore no water safety concern. However, the place where component 4, the first part of the canal starts, is right at the gate and is accessible to the public. This part of the canal is not closed (Figure 4-25).

All accessible parts along this flow path need to be closed. There should be no public access to them.

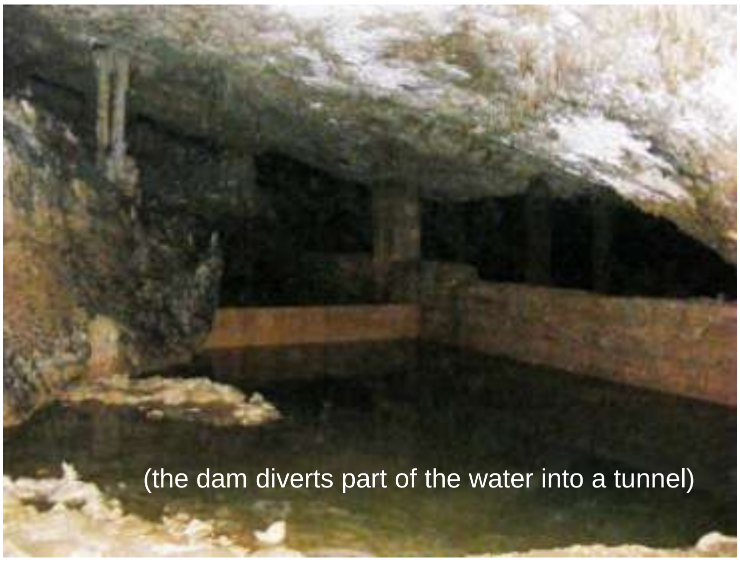

(the dam diverts part of the water into a tunnel)

Figure 4-23 Inner Dam at Jeita Spring (Component 1)


(the gates of the dam cannot be opened anymore)

Figure 4-24 Outer Dam at Jeita Spring (Component 3**)**


(the canal is partly open; the gates cannot be operated anymore)

Figure 4-25 Canal at Jeita Spring (Component 4)

From the gate, the canal passes at the lower parking level, currently used also as a storage place, partly on the canal itself (Figure 4-26). At the western end of the parking, Litani River Authority (LRA) has installed a station monitoring spring discharge (Figure 4-27).

A fence needs to be erected to block access to the canal. No storage of any goods on the canal should be allowed. All open parts need to be closed.

Figure 4-26 Canal at MAPAS parking (Component 4)

Figure 4-27 LRA Discharge Monitoring Station at MAPAS parking (Component 4)

After passing the MAPAS parking, the canal remains parallel to the road until reaching a small diversion structure (Figure 4-28; component 5). This component can only be reached by passing over private property. Here water can be diverted into a canal providing irrigation water to the Jeita/Kashkoush area (15,000 m³/d; pers. comm. WEBML). Water can also be diverted to the Nahr el Kalb, e.g. in case of repair works at the canal, or if the pollution load is too high. A third connection is diverting water through a pipeline of 2 m diameter (Figure 4-29; component 6) through the former Harch hydroelectric power plant into the canal (component 7) that from there on follows Nahr el Kalb for approx. 1,800 m to the Mokhada bridge.

Every time the site was visited, it was observed that the dam was filled with garbage from the tourists in Jeita Grotto. The dam needs to be regularly cleaned.

Approx. 40 m after the former Harch hydroelectric power plant water from Kashkoush spring and wells is diverted into the Jeita - Dbaye canal through an underpass under the Nahr el Kalb riverbed (Figure 4-37; component 8). BMLWWE is measuring flow in the canal immediately after the former power plant (Figure 4-36).

Figure 4-28 Diversion Dam (Component 5)

(irrigation water for the Kashkoush area is diverted into a small canal and water from Jeita can be discharged into Nahr el Kalb)

Figure 4-29 View at the Harch Plant and Kashkoush Spring/Well field

View from Diversion Dam (Component 5) showing Pipeline (Component 6)

4.6.2.2 Kashkoush Spring Intake and Transfer into the Canal

Kashkoush spring formerly discharged into the Nahr el Kalb River around 120 m upstream of the current location of the spring capture. The new capture was constructed in 1995 funded by Kuwait Fund (construction works by GIBBS & partners). It conveys the spring through a 170 m long tunnel to a diversion structure. Before arriving there, flow is measured using ultrasonic methods (Figure 4-32 and Figure 4-37). The BGR project has installed a multipara-meter probe measuring water quality parameters and water level in August 2010 (Figure 4-33).

Kashkoush spring often shows high peaks of pollution and turbidity. BMLWWE manually interrupts diversion to the transmission mains when a certain turbidity level is exceeded.

The Kashkoush well field currently comprises six wells (Figure 4-17 and Figure 4-30), which were drilled by BMLWWE during 2006 to 2009 and are around 200 m deep. During winter, wells are under artesian pressure. All except one well are connected to the Kashkoush spring capture.

Figure 4-30 Kashkoush Well field and Outlet of Kashkoush Spring

(panorama view)

Figure 4-31 Outlet of Kashkoush Spring into Nahr el Kalb

(during peaks of high turbidity and when water from Kashkoush spring is not needed, water is released into the river)

Figure 4-32 BMLWWE Monitoring of Kashkoush Spring Discharge

(since 2003 water level and flow velocity data were sent via telemetric transfer to Dbaye; this system is currently out of order)

Figure 4-33 BGR Monitoring of Kashkoush Spring Water Quality and Discharge

(Data can be sent via telemetric transfer to Dbaye treatment plant for quality control and discharge management)

Figure 4-34 Kashkoush Well field

(During winter wells are under artesian pressure; the well shown is not connected to the transmission mains)

Figure 4-35 Former Harch Hydroelectric Power Plant near Kashkoush Spring

Figure 4-36 BMLWWE Monitoring of Jeita-Dbaye Transmission Man at Harch HPP

(BMLWWE Monitoring station. Formerly water level and flow velocity data were sent via telemetric transfer to Dbaye; this system is out of order)

Figure 4-37 Measurement of Flow Velocity/Water Level at Kashkoush Spring

Figure 4-38 Kashkoush Spring Intake downstream of Harch HPP

4.6.2.3 Canal from Harch to the Mokhada Diversion Station

After the former Harch power plant, water is conveyed in a masonry canal fitted at the top with a concrete slab (Figure 4-39 and Figure 4-40). Over this stretch, the canal is more or less of uniform dimensions. Width varies between 1.5 and 2.2 m, height between and 1.8 to 2.2 m (measured inside), except for the 500 m long part immediately upstream of Mokhada, where the canal is only 1.25 m wide and 1.25 m high.

There are several gates were water can be diverted from the canal to the river. Most of these gates are not functional anymore and due to this water is overflowing from the canal to the river in some places (Figure 4-41). This was observed especially during peak flow at Jeita spring at the Mar Abda Bridge located some 340 m downstream of the Harch plant. At those places where gates block the flow in order to divert water to the river, water can also get into the canal during periods of peak flow in the river (Figure 4-42). Since plastic garbage is observed all along the canal at levels much higher than the canal, it is assumed that after heavy rainfall and during snow melt river water frequently enters the canal.

The canal cannot be accessed at some places because private fences have been erected over it. An inspection is therefore not possible. At several places water is drawn from the canal for irrigation, most likely illegally (Figure 4-46).

Figure 4-39 Canal at Mokhada

Figure 4-40 Inside of Canal at Mokhada Diversion Station

Figure 4-41 Overflow due to Dysfunctional Gate near Mar Abda Bridge

Figure 4-42 Canal between Harch and Mokhada during wet season (22-02-2011)

Figure 4-43 Section were Canal is Publicly Accessible

Wastewater collected at Jeita Country Club is conveyed over the raw water transmission link (Figure 4-44 and Figure 4-45). Due to the conditions of the canal, it is quite possible that wastewater enters the canal.

Figure 4-44 Wastewater overpass of Jeita-Dbaye Canal

Wastewater from Jeita Country Club conveyed over the Jeita-Dbaye Canal, between Harch and the Mar Abda Bridge

Figure 4-45 Same Location as **Figure 4-44** but during summer

Figure 4-46 Irrigation Water drawn from the Canal

At the Mokhada diversion, station (Figure 4-47 and Figure 4-48) water is diverted into the Wata canal. Although formerly intended for irrigation, water is nowadays mainly not used for irrigation but for commercial purposes. The amount diverted, based on irrigation rights, is up to 44,000 m³/d (0.5 m³/s; 22,000 m³/d for Wata, 6,000 m³/d for Dbaye, 6,000 m³/d for Naccache, 10,000 m³/d for Antelias; pers. comm. BMLWWE) between mid-June to mid-September. However, it was observed that the Wata canal is practically open at all times, even in winter when irrigation water is not needed.

Previously water flow in both, the Wata canal and the Jeita-Dbaye canal (after the diversion; LRA station 29) were measured by LRA. Nowadays flow is measured at both places by BMLWWE using ultrasonic devices (Figure 4-49 to Figure 4-51).

After heavy rainfall and snow melt, water level in Nahr el Kalb can reach levels as high as the diversion station (Figure 4-47and Figure 4-48) and there is a high risk of flooding.

Figure 4-47 Mokhada Diversion Station during Wet Season (26-01-2012)

(Water could easily pass through the gates or even overflow during periods of peak flow in the Nahr el Kalb)

Figure 4-48 Gates at the Mokhada Diversion Station

During the dry season, water flow in Nahr el Kalb is blocked by a man-made dam, rebuilt after every winter (Figure 4-52). The purpose is to a) allow for repairs of the canal and b) to divert more water than the canal can convey, due to high physical losses, back into the canal. This bears a high risk of contamination because some villages (e.g. Beit Chebab) discharge wastewater collected in large pools at various times throughout the year into the river. The wastewater from Jeita Country Club and other villages (e.g. Jeita), which have started to construct wastewater collector lines, will as well be mixed with the raw water from Jeita and Kashkoush springs as well as the Kashkoush wells.

Opposite the Mokhada station Animal City, a zoo, is located. At its eastern end a large garbage dump is situated where the zoo gets rid of its solid waste, beyond the public eye. This waste can be flushed downstream reaching Mokhada station and there is thus a high risk of contamination.

Mokhada station can be accessed easily and there were rarely any BMLWWE staffs during our frequent visits.

Figure 4-49 BMLWWE Monitoring of Discharge at Wata Canal Diversion

Figure 4-50 LRA Monitoring of Discharge at Mokhada after Wata Canal Diversion

Figure 4-51 BMLWWE Monitoring of Discharge at Mokhada after Wata Canal Diversion

Figure 4-52 Summer Water Intake at Mokhada "Dam"

(Diverting Water from Nahr el Kalb into the Canal during summer time)

4.6.2.4 Canal from Mokhada Diversion Station to the Tunnel

After the Mokhada station, water is conveyed in the canal to the Mokhada Bridge (Figure 4-53). Here mainly orchards are located, all drawing water from the canal through illegal connections with permanently installed pumps. For this purpose, holes have been drilled into the canal at numerous locations. This is the case all the way from the Mokhada station to the end of Mokhada village (Figure 4-54). From the station on the canal is open to public access at all times.

Apart from the mentioned small illegal connections there is one larger connection at the western end of Mokhada village were irrigation water is diverted, also practically at all times, even during winter (Figure 4-55).

The canal is integrated in the everyday life of the local people, functioning as car park (Figure 4-57) or prepared as a garden (Figure 4-58).

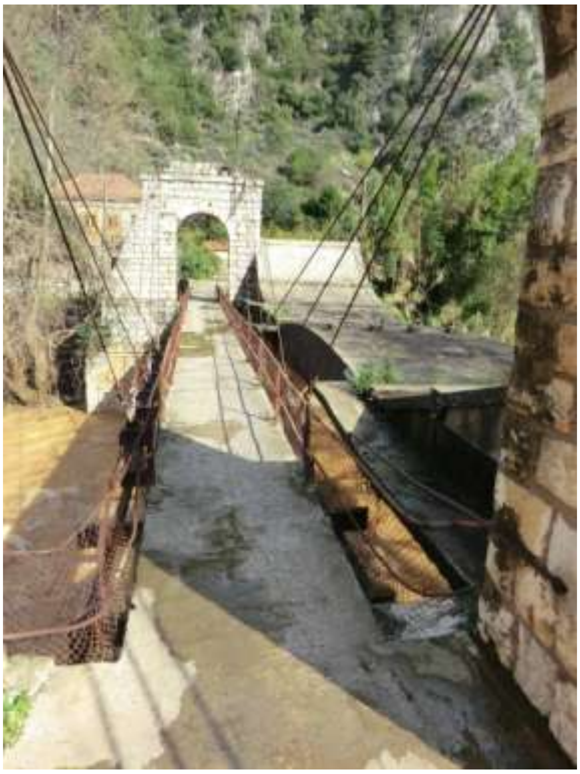


Figure 4-53 Mokhada Bridge

Figure 4-54 Households tapping into the Jeita-Dbaye Canal

Figure 4-55 Irrigation Water drawn from the Canal in Mokhada Village

Figure 4-56 Canal passing through the village of Mokhada

(Engulfed on both sides by private properties)

Figure 4-57 Canal used for parking cars in Mokhada

Figure 4-58 Canal used as a Garden in Mokhada near Aqueduct

From the village of Mokhada the canal follows the main road. Before the entrance to the Nahr el Kalb-Dbaye tunnel (Figure 4-59), flow is measured by BMLWWE using an ultrasonic device.

Figure 4-59 Nahr el Kalb-Dbaye Tunnel

4.6.2.5 Tunnel and Dbaye Intake

The Nahr el Kalb - Dbaye tunnel (Figure 4-60) is 1000 m long, approx. 1.8 m wide with rounded shape. It current conveyance capacity has been determined through tracer tests conducted on 26-JAN-2012 as 3.1 m³/s. The sidewalls have no concrete coating. It formerly had three air vents reaching up to the land surface, two of which have been closed with one still open.

During a recent inspection (26-05-2011; Figure 4-61), it was observed that at several places large blocks of rocks had fallen into the tunnel, which causes turbulences. Due to difficulties in reaching this place, rocks could not be taken out.

The hills in which the tunnel passes are about 100 m high. While the higher part is largely not inhabited, the lower part of the hill is densely populated (village of Dbaye). Here the overburden ranges from about 50 to 0 m. There is no wastewater collection network in this area. It is thus assumed that wastewater infiltrates from cesspits into the canal.

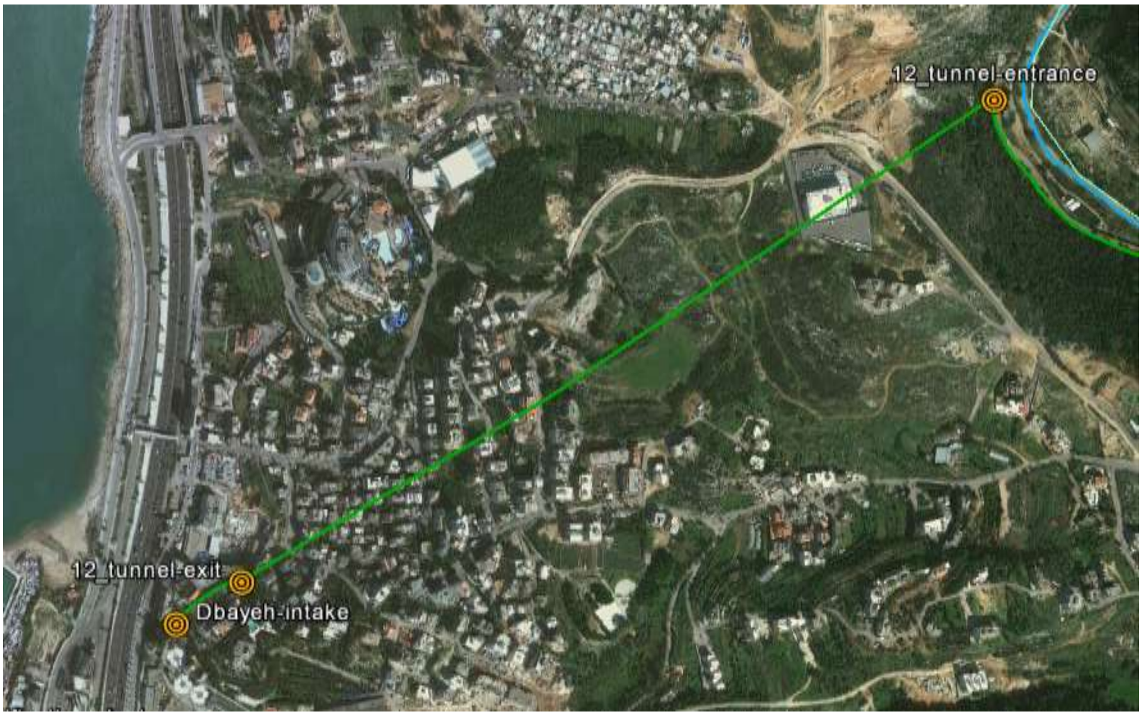


Figure 4-60 Nahr el Kalb - Dbaye Tunnel

Figure 4-61 Rock Falls in Tunnel (picture: BMLWWE)

4.6.3 Georisks

Apart from the above-mentioned risks, there is the risk that the conveyor may be affected by earthquakes, tectonic movements, landslides or rock falls. The entire section is located in a tectonic very active zone, named the Western Flexure, where geological dip of the strata is almost vertical. Over this section, the entire Cretaceous sequence crops out. This sequence contains a number of soft rock units, such as friable sandstones, claystones and marls. Historic and present day landslides, rock slumps and falls are observed all along this stretch.

Due to the very steep slopes on both sides of the valley and the unfavourable geology, the risk is indeed very high that the transmission mains may be interrupted for an elongated time period so that Beirut would be without water.

Smaller landslides could cover the canal or sediments could intrude into the canal. This risk is especially high where steep slopes exist right next to the transmission links, e.g. along the Mokhada - coastal highway road, where this phenomenon has recently been observed.

Flooding from Nahr el Kalb can reach the transmission links easily, causing an infiltration of river water into it resulting in damages to the link and severe health effects.

4.6.4 Summary

Due to the construction and ill maintenance, pollution can easily reach the transmission mains. The main water safety risks results from the following sources and facts :

- the conveyor is open and freely accessible at many places; over most of its length there is no fence to block the public from having access;
- the transmission mains are very old and are not sufficiently maintained or repaired; there are therefore many leaks and open places;
- the transmission mains are not surveyed often enough;
- wastewater is conveyed over the transmission mains;
- there are many illegal connection; people have drilled holes into the transmission mains to get access to water;
- the transmission mains can be flooded so that water can leak into them from the river;
- people living near the transmission mains do not seem to recognize that this is the main water supply of Beirut; they seem to regard it as their property; they know that nobody controls or maintains it and they feel no responsibility for its water safety;
- during the dry season, water is conveyed in the Nahr el Kalb and not in the transmission mains increasing the risk of pollution;
- Large parts of the area under which the tunnel passes are populated. There is no wastewater collection in this area and the geological overburden is low; untreated wastewater can thus easily infiltrate into the tunnel.

There are too many illegal diversions of water from the transmission links. Those connections should be stopped.

4.6.5 References

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4.7 HYDRAULIC CHARACTERISTICS OF CURRENT TRANSMISSION MAINS

Several tracer injections were conducted on 26-JAN-2012 between Kashkoush and Dbaye in order to determine some hydraulic characteristics of the existing transmission mains, such as

- the current capacity of the transmission mains between Jeita and Dbaye;
- the flow velocity between Kashkoush and Dbaye and at different places along the canal; and
- the amounts of overflows and leaks from the canal.

The timing was chosen so that the canal would be charged at Jeita at its full capacity. Discharge at Jeita spring had been 5.0 m³/s on 24-JAN-2012 with a rising trend (approx. 10 m³/s on 26-JAN-2012).

Uranine (ORCO 86%; also named fluorescein) was used as a tracer. The amount of tracer to be injected was chosen to be below the limit of visibility (30 ppb) at Dbaye. Four Albillia GGUN-FL30 portable fluorometers were used for monitoring of tracer concentration at four different monitoring sites.

The location of injection and monitoring sites are shown in Figure 4-62. The injection times and amounts of tracer used are shown in Table 4-1. Distances between injection and monitoring sites are presented in Table 4-2.

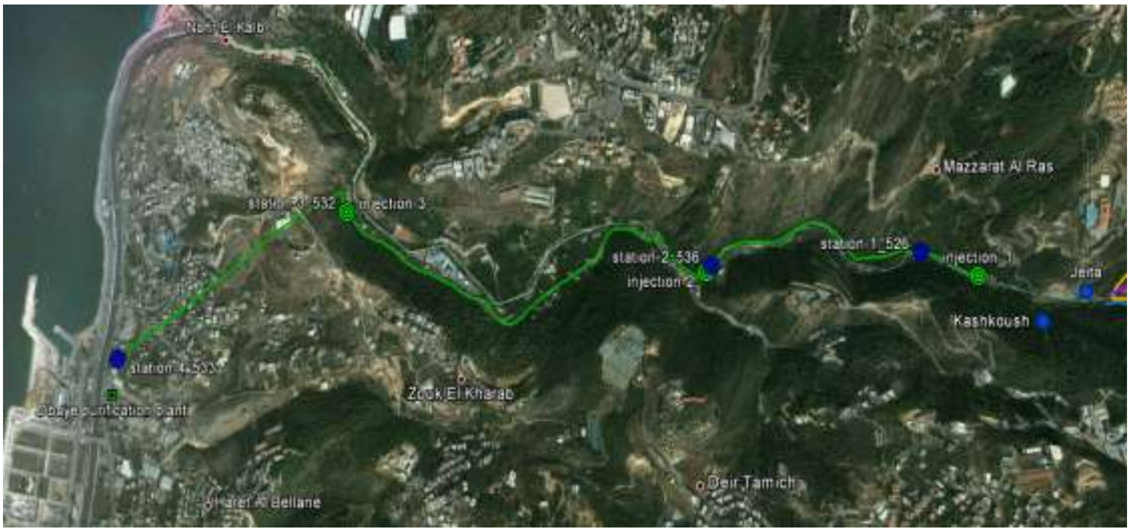

Figure 4-62 Location of Injection and Monitoring Sites

(injection sites: green symbol, monitoring sites: blue symbol)

4.7.1 Injection Sites

Site-1 Harch (injection-1):

The first three injections were done immediately downstream of the Harch (Kashkoush) hydroelectric power plant, using a) 30 g, b) 10 g and c) 10 g of tracer (Figure 4-63). Time interval between injections was a) 90 min b) 60 min.

LAT: 33.944489° / LONG: 35.636829°

Figure 4-63 Injection Site 1

Site-2 Mokhada (injection-2):

One injection was done at Mokhada diversion station, downstream of the Wata diversion at LRA station no. 29, using 10 g of tracer (Figure 4-63).

LAT: 33.945361° / LONG: 35.623142°

Figure 4-64 Injection Site 2

Site-3 Tunnel entrance (injection-3):

Three injections were done approx. 60 m before the tunnel to Dbaye, using 5 g each of tracer (Figure 4-65).

LAT: 33.945361° / LONG: 35.623142°

Figure 4-65 Injection Site 3

Table 4-1 Times and Amounts of Tracer Injections

Location	**Time**	**Tracer**	**Amount [g]**
Site-1 Harch	11:40	Uranine ORCO (86%)	30
Site-1 Harch	13:10	Uranine ORCO (86%)	10
Site-1 Harch	14:10	Uranine ORCO (86%)	10
Site-2 Mokhada	16:30	Uranine ORCO (86%)	10
Site-3 Tunnel entrance	17:27	Uranine ORCO (86%)	5
Site-3 Tunnel entrance	17:40	Uranine ORCO (86%)	5
Site-3 Tunnel entrance	17:55	Uranine ORCO (86%)	5

4.7.2 Monitoring Sites

Site-1: fluorometer 526 (monitoring-1)
Located 290 m downstream of injection site 1 at a non-functional diversion weir.
LAT: 33.945516° / LONG: 35.633998°

Site-2: fluorometer 536 (monitoring-2)
Located 10 m upstream of the Mokhada diversion station.
LAT: 33.945601° / LONG: 35.623429°

Site-3: fluorometer 532 (monitoring-3)
Located 60 m upstream of the tunnel entrance.
LAT: 33.945361° / LONG: 35.623142°

Site-4: fluorometer 533 (monitoring-4)
Located at the entry point of raw water to the Dbaye treatment plant.

LAT: 33.943758° / LONG: 35.592435°

Figure 4-66 Monitoring Site 4

Table 4-2 Distances between Injection and Monitoring Locations

	Injection-1	Injection-2	Injection-3
Monitoring-1 526	290	-	-
Monitoring-2 536	1390	-	-
Monitoring-3 532	3540	2190	-
Monitoring-4 533	4940	3590	1400

Due to technical failure, data from fluorometer 536 at monitoring Site-2 Mokhada could not be recovered.

4.7.3 Results

4.7.3.1 Flow Rates and Physical Losses

Flow rates at the former Harch hydroelectric power plant were approx. 4.3 m³/s. Flow at the Dbaye treatment plant intake was 3.1 m³/s (± 0.1 m³/s). There was therefore a loss in flow due to overflow (Mar Abda bridge), outflow (Wata canal) and leakage (Figure 4-64) of 1.2 m³/s or 28 %.

Table 4-3 Flow Rates in the Jeita - Dbaye Canal

	Hrach	**Dbaye** (intake to treatment plant)
Test-1	[3.6 m³/s]*	3.1 m³/s
Test-2	4.3 m³/s	3.1 m³/s
Test-3	4.4 m³/s	3.2 m³/s

* value not used due to low accuracy of measurement (interval: 10 s instead of 3 s)

Leakages occur at the following locations. The amount of leakage can only be estimated:

Leakage-1 and Overflow

A considerable overflow occurs immediately upstream of Mar Abda bridge (approx. 0.6 m³/s; Figure 4-67). The reason is a non-operational diversion weir in the canal. (Figure 4-68 and Figure 4-69). Downstream of the bridge another significant leakage occurs from the canal, partly because of crack in the canal, partly because of a broken diversion weir (approx. 0.2 m³/s; Figure 4-70).

Figure 4-67 Location of Leakage-1 and Overflow at Mar Abda Bridge

Figure 4-68 Overflow due to Dysfunctional Weir

Figure 4-69 Dysfunctional Weir

Figure 4-70 Leakage-1

Outflow to Wata Canal

Even though only intended for provision of irrigation, the Wata canal seems to be open at all times. During the tracer test, about 300 l/s were diverted into the canal.

The reason is probably a non-functional diversion structure. The Wata diversion should be urgently fixed.

Figure 4-71 Location of Diversion to Wata Canal

Figure 4-72 Outflow to Wata Irrigation Canal

Leakage-2, leakage-3, leakage-4

Smaller leakages occur at the bridge crossing Nahr el Kalb and approx. 150 m downstream of the bridge (Figure 4-73 to Figure 4-75), which could be fixed easily. Another leakage occurs at the bridge in Mokhada (leakage-4; Figure 4-76). Losses at those three places are less than 100 l/s.

Figure 4-73 Location of Leakage-2 and Leakage-3

Figure 4-74 Diverse Leakages from Canal (Leakage-2 and Leakage-3)

Figure 4-75 Location of Leakage-4

Figure 4-76 Location of Leakage-4

Table 4-4 Estimation of Physical Losses on 26-JAN-2012

Name		LAT	LONG	Amount
Overflow	Mar Abda bridge	33.945522°	35.633937°	600 l/s
Leakage-1	Mar Abda bridge	33.945572°	35.633387°	200 l/s
Non-functional diversion to Wata canal		33.945586°	35.623276°	300 l/s
Leakage-2	Mokhada bridge	33.946835°	35.620616°	100 l/s
Leakage-3		33.947211°	35.619138°	
Leakage-4		33.944586°	35.611953°	
Total				1200 l/s

4.7.3.2 Travel Times

Friction losses are resulting in a longitudinal dispersion of around 925 m over the total distance monitored, which was 4940 m (0.19). Mean travel time between the former Harch hydroelectric power plant (Kashkoush) and Dbaye was 80 minutes. The mean flow velocity over this distance was 1.0 m/s. Between Injection-1 (Kashkoush) and Monitoring-3 (60 m upstream of entrance to tunnel) mean flow velocity was 1.15 m/s, while in the tunnel mean flow velocity was only 0.83 m/s. While tracer breakthrough curves are relatively smooth until before the tunnel (Monitoring-3; Figure 4-77), they show a considerable jitter after leaving the tunnel (Monitoring-4; Figure 4-78). It is assumed that this is caused by turbulences resulting from rocks slumps into the tunnel.

Table 4-5 Mean Travel Times and Mean Flow Velocities in the Canal

	Distance [m]	Mean Travel Time [min]	Mean Flow Velocity [m/s]
Injection-1			
Monitoring-1 526	290	4	1.2
Monitoring-2 536	1390	-	-
Monitoring-3 532	3540	52	1.15
Monitoring-4 533	4940	80	1.03
Injection-2			
Monitoring-3 532	2190	35.6	1.03
Monitoring-4 533	3590	63.9	0.94
Injection-3			
Monitoring-4 533	1400	28.2	0.83

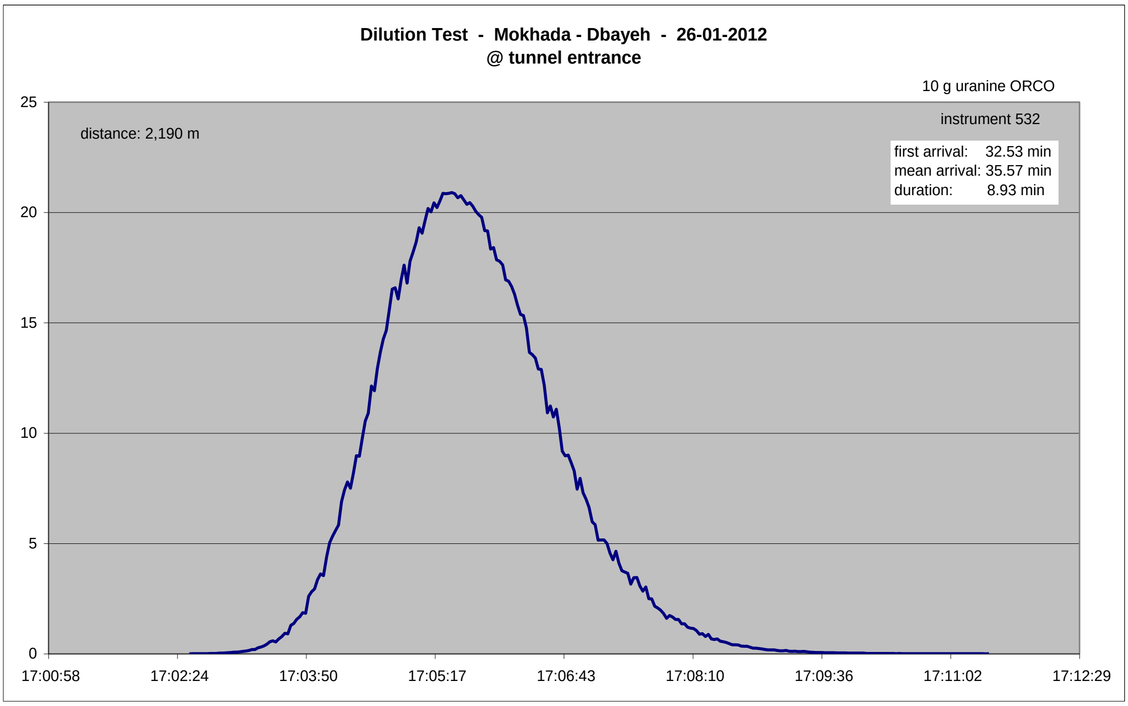

Figure 4-77 Uranine Dilution Test between Mokhada and Tunnel Entrance

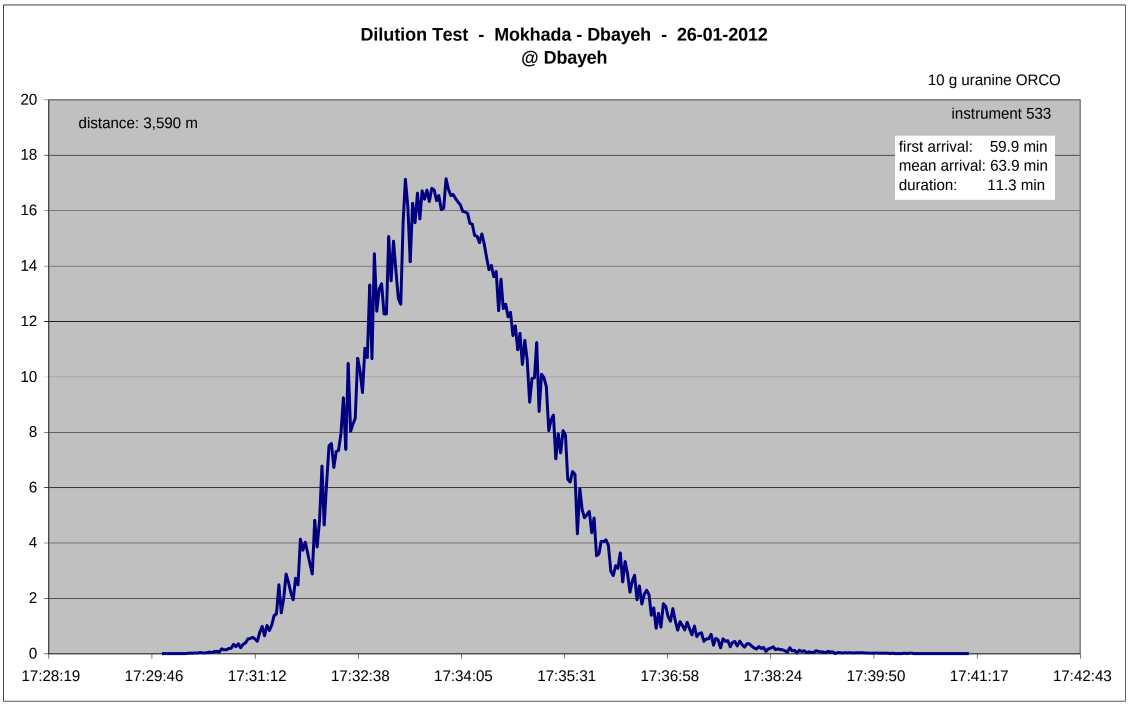

Figure 4-78 Uranine Dilution Test between Tunnel Entrance and Dbaye Intake

4.8 OPERATIONAL PROBLEMS AND POSSIBLE REMEDIAL MEASURES

Jeita and Kashkoush springs are supplying water to a population of ≈1.1 Mio. people. In case of a failure of the intake structures and or transmission channel a great part of Beirut and suburbs will not be supplied with water. To have a supply system of this size without sufficient standby capacity is very unusual.

Below a summary of the most important operational problems encountered and possible measures to rectify them:

Operational Problems	Possible Remedial Measures
Maintenance: The existing transmission main can be taken out of service 24 to a maximum of 48 hours. This limitation makes it very difficult to do any substantial maintenance work along the channel.	Basically it is necessary to construct a second transmission line in order to have redundancy in case of maintenance work on one of the transmission mains. With the construction of a new water source for Beirut the problem will be slightly reduced but not eliminated.
Water pollution: The Jeita spring water is polluted from various sources e.g. surface run-off from adjacent land or Nahr el Kalb itself since the transmission channel is not a closed system (open joints).	Construction of a closed system e.g. with pipes or installing liners in the existing channel.
Water loss Water loss has been quantified (refer to Chapter 4.7) with about 1.2 m^3/s leakages. Theis value was determined during the wet season and might be slightly less during the dry season. Taking into account the construction methods used to upgrade the original channel built about 150 years ago the losses are not excessive but within the range to be expected.	Construction of a closed system e.g. with pipes or installing liners in the existing channel.

Jeita Spring Intake
The spring intake was, originally constructed to capture the spring water for the Beirut water supply. Today there are two tasks (a) spring intake and (b) keeping water level in the Grotto somehow constant. These two functions are to some extend contradictory e.g.
• Spring yield measurements are influenced by the Grotto water level control, and
• Water level in the Grotto cannot be controlled during rainy season due to constraints in the spring catchment structures thereby flooding part of the Grotto and leading to uncontrolled spring discharges through other channels
The present situation is not satisfactory at all for both stakeholders.
	Construction of a new intake structure whereby the needs of the Grotto operation (for the tourists) and the one for the BMLWWE (water quantity and quality monitoring) are separated as follows:
	• Water level control for Grotto operation at the start of the new intake structure and
	  • Actual spring catchment with
	    - necessary water monitoring equipment,
	    - overflow arrangement
	    - transmission main control pen stock(s)
	    - necessary grout curtain to stop suspected leakages

Operational Problems	Possible Remedial Measures
Accessibility of structures: Transmission main Jeita Intake - Aqueduct. There is no access road along the channel for inspection and maintenance purpose. Furthermore in the area of the OEB Dam buildings are directly adjacent to the channel.	Presently only the width of the channel is land owned by the Government. It is mandatory to expropriate land along the channel in order to build a road for maintenance purpose. In the areas where the road cannot follow the channel due to buildings the access road is passing either behind the buildings or on the side of the river necessitating protection walls. Another possibility for the part OEB dam to Aqueduct it to construct a tunnel. Note: Independent of the decision where to build the WWTP for the JSPP area, a pipeline is required along the transmission main for treated or untreated wastewater up to the OEB dam site. For this line it is necessary to expropriate the land required.
Aqueduct Presently both aqueducts are still operational but have outlived their service time since long	Construction of new river crossing either above river with steel structure or below river bed either a siphon (duker) or free flow depending on the alternative chosen.
Transmission main Aqueduct – Tunnel entrance, Tunnel exit – to Dbaye WTP Passing under houses, aqueducts, along the main road and small tunnels Especially in the sections, which are passing under houses, aqueducts and small tunnels, accessibility is not ensured.	Since in this area the channel passes through a build-up area an extension or proper maintenance is not possible. For this area the construction of a new tunnel is the only possible solution. Whether the existing channel is completely abandoned or be equipped with a pipe in-liner must be evaluated.
Structural conditions: The structural safety is no more guaranteed in some stretches e.g. structurally weak covering slabs, cave-in in the tunnel section etc.	Dilapidated channel sections need to be replaced. For the tunnel section, either a new tunnel is constructed or the existing tunnel is provided with a liner of appropriate strength to withhold the overburden pressure.
Water quality: High turbidity and bad water quality of Kashkoush Springs	As it is done today during times of high turbidity the water is drained to waste.
Water abstractions: Water abstraction legal and illegal for whatever need.	Closed system with separate pipe for legal irrigation needs
Using Jeita Spring Water for Irrigation: Feeding the Wata Canal with high quality Jeita spring water for "irrigation purposes" results in the need to collect and feed sub-standard water from the river at OEB Dam into the transmission channel for drinking purposes.	Construct a small permanent dam at OEB dam site in order to feed the collected water into the Wata Canal, which presently is not possible due to elevation problems. If possible Wata Canal water rights should be purchased back by the WE since there is hardly any farming left downstream of OEB dam.

Operational Problems	**Possible Remedial Measures**
Degree of capacity utilization: On an annual basis the assumed the channel capacity of about 255'000 m^3/d is available only for: - 10 months in a wet year - 7 months in an average year - 5 months in a dry year The statement is based on flow measurements 2001 to 2010 provided by Dbaye WTP, ref. Annex 1	To secure a minimum base flow it is necessary to build in the upper catchment area of Nahr el Kalb an impounding reservoir

The following Table 4-6 provides a rough overview on the flow regime along the transmission main.

Table 4-6 Flow Chart of water production / abstraction along the transmission main

Flow in m^3/d		Note: Minimum yield = 10 - years average flow figures
Minimum	**Maximum**	**Spring / Well yield or Abstractions**
110'000	1'000'000	Jeita Spring, yield
0	-700'000	Jeita Spring, overflow
-18'000	-25'000	Supplied to Matan District
-10'000	-10'000	Supplied to Kesrouan District
6'000	0	Well yield, located at Jeita spring intake Note A
29'000	500'000	Kashkoush Spring yield
	-500'000	Kashkoush Spring, not used
36'000	0	Well yield, located at Kashkoush spring intake site Note A
-15'000	0	Irrigation, along transmission channel (estimate by Burgéap) Note B
18'000	0	OEB Dam Note A
-10'000	-10'000	Supplied to Maghada
22'000	0	Wata Canal Note B
4'500	0	Well supply, just after aqueduct Note A
9'000	0	Well supply, before Tunnel entrance) Note A
181'500	**255'000**	**Flow at Dbaye WTP** excl. Antelies spring
18'000	40'000	Antelies spring yield

Notes:

1. Min. flow for Jeita + Kashkoush Springs is the lowest average month for the measuring period 2001 - 2010
2. Jeita spring overflow is adjusted in order that the max. flow at Dbaye WTP is not exceeding 255'000 m^3/d
3. Antelies spring is not located within the El-Kalb catchment area. Spring location southeast of Dbaye WTP.

A Additional water from wells and OEB dam site it used only during dry season (minimum spring yield)
B No need for irrigation water during wet season (maximum spring yield)

4.9 LEAKAGES

4.9.1 Intake site

There are some visual leakages at the intake site like:

- Leaking pen-stock
- Overflow at the pumping station

This leakages can be stopped or at least reduced and the proposed (immediate) measures to reduce the water losses are included in the scope of work for the WWTP.

There are other suspected leakages at the Spring Intake site, which however do not manifest themselves visually. To detect them it is necessary to carry out an extensive search under operational conditions and by utilizing the tracer method (organic colorants). Due to the existing conditions and constraints (e.g. constant water level in the Grotto for touristic reasons) at the intake site, any repair work will be a major intervention and needs to be carefully planned. It is proposed to carry out such work within the overall scope of work for a refurbishing of the compete transmission main.

4.9.2 Transmission Channel

Complete lack of operational and accurate monitoring equipment makes an estimation of water losses along the transmission main a futile undertaking. Also there are some obvious leakages along the transmission channel, some of them visual, some of them suspected, e.g. in the tunnel section.

Theoretically it is possible to install calibrated water flow metering equipment in the channel in order to establish over longer periods:

- The water losses along the channel
- The channel maximum flow capacity.

From the hydraulic point of view such measuring devices must be installed according to strict rules and conditions. This requirement necessitates some structural adjustments in order to secure accurate readings, resulting in high costs for the installation of the measuring devices.

Another possibility to get an idea of the water losses is to carry out a tracer test starting at the intake site and ending at the Dbaye WTP. Such measurements have been carried out by BGR in February 2012, refer to Chapter 4.7. Basically the measurements confirm earlier measurements that the transmission main has a capacity of more than 250’000 m^3/d.

4.9.3 Irrigation Abstractions

Although, the abstractions for irrigations are old water rights which at the time of building the transmission main had its justifications, today, especially in the lower reaches of the Wata Canal, there is hardly any agriculture left and thus no justification of abstraction rights. Besides these legal abstractions there are illegal abstractions or waste of Jeita spring water like:

- There are numerous abstractions, which are illegal, since it is comparably, easy to have access to the channel interior.
- There are legal abstractions, which are abstracting more than their permit allows.

- Some of the users are abstracting more than they need. This wastage is drained back to the Nahr el Kalb, polluted with e.g. pesticides and fertilizers.

The amount abstracted for irrigation, whether legal or illegal, was previously measured by LRA at the OEB dam. However, measurements there have been abandoned. Actual measurements have not been done in the framework of a tracer test carried out by BGR in February 2012. Irrigation water uses should be measured using a tracer test as stated in Chapter 4.9.2 during the dry season.

4.10 CAPACITY OF TRANSMISSION CHANNEL AND CAPACITY CONSTRAINS

Based on the available information received, there are channel sections with limited flow capacities like:

1. Channel sections, up-stream of OEB Dam, as reported with a dimension of e.g. 0.6 x 1.2 m must be extremely short otherwise, the flow rate as conformed by Dbaye WTP of 255’000 m^3/d could not be achieved.
   According to other sources the cross section in questions has a dimension of 1.25 x 1.25 m, which results in a hydraulic gradient of 7.3 ‰ at 4.3 m^3/d on the day of measuring the flow rate, refer to Chapter 4.7. The field survey established the following parameters:
   (a) cross section 1.25 x 1.25 m and (b) average gradient of channel 13.4 ‰. Although, it is the smallest cross section along the transmission main but with the available channel slope the hydraulic capacity is approximately the same as for the other parts.
2. The channel section between the Jeita Intake and the Hrach Hydropower Station is not regarded as a problematic sections since the hydropower plant was designed for a greater flow rate than the 255’000 m^3/d.
3. The tunnel sections, although with a comparable big cross sections is critical since there is hardly any longitudinal slope between entrance and end of the tunnel. Furthermore since the tunnel is not lined, (a) the capacity cannot be increased by pressurizing the tunnel and (b) there are from time to time flow constraints by rock falls blocking flow in the tunnel.
4. Obstructions were built into the channel by legal or illegal irrigation water users in order that their fields can be supplied by gravity water flow. These obstructions reduce the capacity of the channel considerably and may also be the cause for deposits upstream of such obstructions.
5. The flow capacity is often reduced by roots growing into the channel sections. The Water Establishment is removing these roots from time to time but it is a futile undertaking on a masonry channel with many joints. Principally this would need to be done once a year, which currently is not the case. There are not enough entry points to conduct such a maintenance.

For illustration please refer to Annex 2.

The above mentioned flow rate was established with flow monitoring equipment some few year ago, and re-confirmed by the recent measurements carried out by BGR. The existing channel has a capacity which is exceeding the nominal value mentioned by BMLWWE of 255’000 m^3/d, henceforth it is irrelevant whether the information on the channel cross sections are correct or not.

However, there are large parts of the channel having a much greater capacity than the above mentioned 255’000 m^3/d. Flow constraints are therefore rooted in the aspiration of the Water Establishment to increase the flow to the Water Treatment Plant Dbaye. The present WTP has a production capacity of 320’000 m^3/d inclusive the required backwash water. The channel should therefore have a capacity of 350’000 to 380’000 m^3/d. BMLWWE plans to increase the treatment capacity of the Dbaye WTP to 500'000 m^3/d (5.8 m^3/s). Therefore the design capacity of the channel should be the same. However, from the financial point of view, it is doubtful if such an increase is economically justifiable since the actual flow as compared to the nominal flow is less than 55 %.

5. REHABILITATION, AUGMENTATION OF TRANSMISSION CHANNEL

5.1 GOAL OF A REHABILITATION AND OR AUGMENTATION WORKS

5.1.1 Spring Intake

An integral part of any new installation must be the proper measurement and monitoring of the total spring discharge (Jeita 60) before any diversion.

The new spring capture should be designed based on the following conditions:

1. Maximum withdrawal rate of up to 8.7 m^3/s (750,000 m^3/d);
2. Continuous monitoring of relevant parameters like
   - Flow rates - Conductivity - Turbidity
   - pH - Temperature
3. Data should be stored locally in a logger unit and in parallel be transferred by a telemetric system to the treatment plant (Dbaye);
4. The new Intake structure shall provide adequate protection of the water in order to maintain the water quality / characteristic;
5. Sediments should be eliminated with an appropriate device;
6. The abstracted water must be protected from further pollution by a closed system. Illegal or irrigation water abstractions are not permitted along the pipeline. A closed system allows not only higher flow capacities but also power generation if needed.
7. The best solution to avoid illegal connections to this conveyor would be to build a tunnel from Kashkoush spring to the water treatment plant (Dbaye)[3].
8. The new intake structure shall allow tourists to visit the lower part of the grotto by boat until the point accessible nowadays
9. Automatic water level control to keep the water level constant during the whole year, except for some few days during peak flow periods.
10. The narrow passage near the boat mooring should not be enlarged because it slightly reduces the pressure on the future intake;

5.1.2 Transmission Main

The goals of a rehabilitations and or augmentation of the transmission main from the Jeita Spring Intake to Dbaye WTP shall be as follows:

1. Marked improvement of operational reliability by providing
   - if possible a second transmission line (redundancy) and
   - to renew the old and dilapidated masonry, concrete structures and tunnel ..section and aqueducts.
2. Eliminating pollution of the Spring water from exterior sources like surface run-off during the rainy season, or feeding polluted Nah el Kalb water (sub-standard water) into the transmission main.
3. Elimination of direct access to the water in the transmission pipe by unauthorized persons for irrigation needs.

[3] *A tunnel from Kashkoush spring to Dbaye WTP has been proposed by an earlier study, but for unknown reasons the project was not further considered. One explanation might be that the tunnel alignment is passing a fracture zone which needs special attention when planning and implementing the tunnel.*

4. Establishing an independent system for irrigation needs. Between Jeita Grotto and OEB Dam the system will be supplied by spring water in the lower part. The Wata Canal, after OEB Dam will be supplied with water collected from Nahr el Kalb and only in very dry years with spring water.
5. Note: If it is possible to eliminate the OEB water Intake it will be possible to satisfy the irrigation water needs also with effluent from the WWTP.
6. Produce if economical justifiable renewable power by utilizing the available head for hydropower generation.
7. Provide ample storage to maintain chosen flow capacity throughout the year.

5.1.3 Possible Scenarios

Based on the analysis of operational problems in Chapter 4 and the goal of a rehabilitation work as described in Chapter 5.1 the following scenarios are developed to overcome these problems:

- **Scenario A:**
  To establish the most economical flow rates for the transmission mains flow rates have been computed between 200’000 to 600’000 m^3/d. With this input, for some pre-selected flow rates, the preliminary cost estimates and financial analysis are prepared.
- **Scenario B:**
  To augment the flow rates during dry season a balancing basin with a storage volume of 0.5 Mio m^3 at OEB dam site will be evaluated together with a possible hydropower generation. This power generation plant will have a marked influence on the pipe diameter needed and therefore on the overall costs.
- **Scenario C:**
  To ensure a continuous abstraction rate throughout the year for the transmission main an impounding reservoir will be required. The volume is depending on the chosen abstraction rate but will be most likely around 40 Mio m^3.

Scenario A and B. will be evaluated together as mentioned above.

Scenario C: The yield of the springs is directly influenced by the amount of precipitation stored as snow on the higher altitudes an released later during the snow smelting period. Due to the anticipated climate changes it must be assumed that less precipitations is stored in the mountains and therefore more water is drained off during the wet-season, thereby reducing further the dry season low flow. To counter act this development it will be necessary in the mid to long term to build an impounding reservoir up-stream of Daraiya in the Nahr el Kalb. For this scenario no cost and financial analysis are carried out. The scenario shows the amount of water that must be retained in order to maintain a certain flow rate for the transmission main.

5.1.3.1 Scenario A

It is obviously, the greater the flow rate the more water will reach the Dbaye WTP as shown in Table 5-1.

Table 5-1 Annual water discharge to Dbaye WTP

Nominal flow rate of transmission main	**Annual water production for various spring yields in 1000 m³/a**				**Channel utilization in percentage of nominal capacity**		
x 1'000 m³/d	average	Min.	Max.	[1)]nominal	average	Min.	Max
250	77'739	65'040	86'880	91'250	85	71	95
300	87'004	71'040	99'870	109'500	79	65	91
350	96'004	77'040	111'870	127'750	75	60	88
400	105'004	82'230	121'560	146'000	72	56	83
450	111'602	85'230	130'560	164'250	68	52	79
500	117'602	88'230	139'560	182'500	64	48	76
550	123'602	91'230	148'560	200'750	62	45	74
600	129'602	93'420	157'560	219'000	59	43	72

Note 1): Nominal means the amount of water reaching the WTP, if the transmission flow rate can be maintained throughout the year.

The increase of water reaching the WTP e.g. with a channel capacity of 250'000 to 500'000 m³/d is considerable (between 35 - 60 % depending on the annual spring yields) but it has no effect on the shortage of water at the end of a dry season. But with the increase of the channel capacity the utilization of the channels capacity on annual basis is reduced drastically and may pose a problem to the financial viability.

The problem of water shortage at the end of the dry season can only be solved by a balancing basin with an appropriate storage volume as it will be shown in the following Chapter.

5.1.3.2 Scenario B

5.1.3.2.1 Size of retention basin required

If the flow capacity of the transmission channel shall be maintained throughout the year it is necessary to augment the spring yield during the dry season with additional water e.g. from a retention basin. The required storage volume has been computed for different abstraction rates, refer to Table 5-2.

The computation is based on the assumption that the groundwater abstraction and the Kashkoush spring yield are utilized throughout the year. Presently Kashkoush spring is disconnected when the turbidity is exceeding a certain level and the Kashkoush wells are only operated during the dry season. Furthermore the minimum and maximum are based on 10 % resp. 90 % percentile, which means that neither low nor high extreme values are considered.

Table 5-2 Size of retention basin

		Size of retention basin (in 1000 m³)		
	source yields:	Average	Min.	Max.
without irrigation abstraction				
Dbaye Abstraction (m³/d)	200'000	2'866	7'539	510
	250'000	8'931	20'709	3'915
	300'000	16'556	31'830	9'195
	350'000	25'556	X	16'755
	400'000	34'556	X	25'755
	450'000	44'848	X	34'755

		Size of retention basin (in 1000 m³)		
	source yields:	Average	Min.	Max.
with irrigation abstraction				
Dbaye Abstraction (m³/d)	200'000	5'211	11'004	1'635
	250'000	12'261	20'709	6'495
	300'000	20'996	X	12'525
	350'000	29'996	X	21'195
	400'000	38'996	X	30'195
	450'000	50'398	X	39'195

Note: X Source yield insufficient to maintain abstraction rate

The same figures are illustrated in the following graph, Figure 5-1.

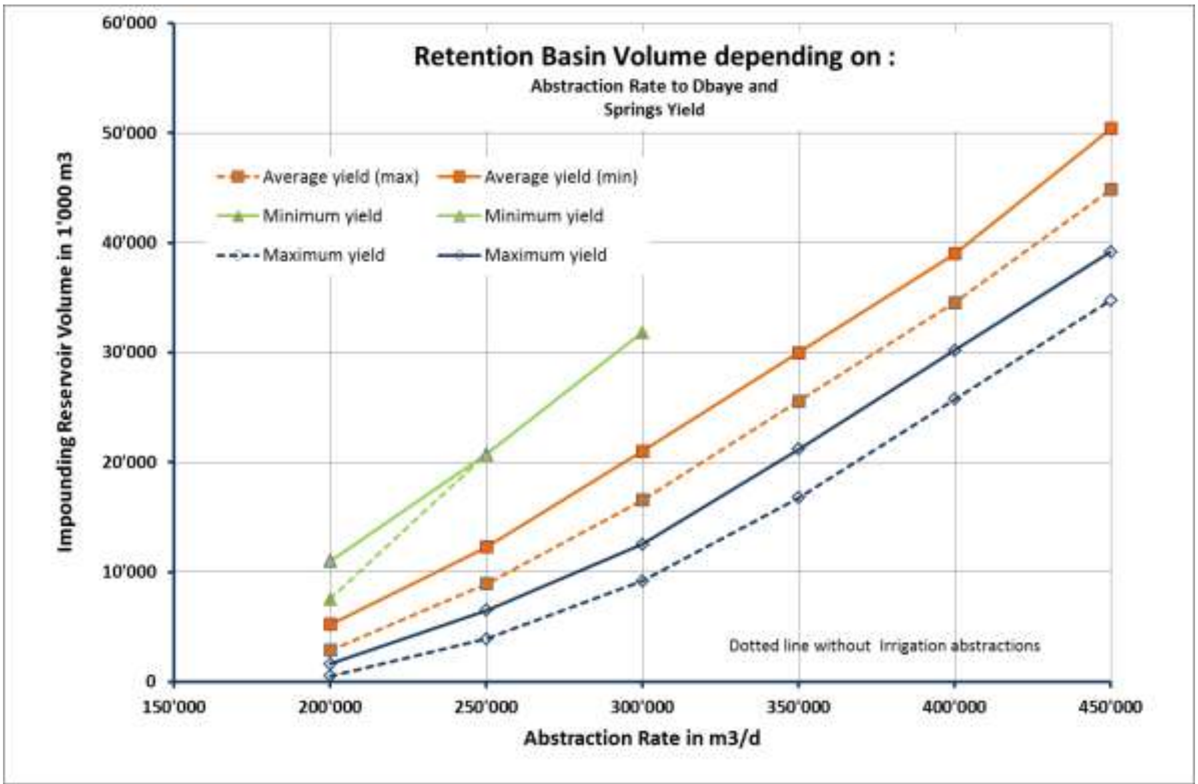

Figure 5-1 Size of retention basin

5.1.3.2.2 Available size of retention basin

As mentioned in the introduction the maximum size of a retention basin, with a dam at OEB dam site is 0.5 Mio m^3 requiring an 16 m high dam and covering about 85'000 m^2. Due to the topographic conditions in the area between Hrach/Kashkoush and OEB dam, 0.5 Mio m³ is the maximum possible storage volume.

The effect of such a small retention volume on the low flow conditions can be summarized as follows:

- At an abstraction rate of 200'000 m^3/d the retention volume of 0.5 Mio m^3 will reduce the period with insufficient flow by one month only
- For all other abstraction rates the stored water will be used up in less than a month e.g. some few weeks

Conclusion: No retention basin at the OEB Dam site is feasible since the topographical conditions do not permit the retention of sufficient water, which would have a noticeable impact on the low flow conditions during the dry season.

5.1.3.2.3 Spring yields depending on the annual variation

Jeita and Kashkoush Springs together with the groundwater abstractions are depending on the annual precipitation within the catchment area and are influenced by the sub-terrain conditions. The more or less complete lack of underground storage for the precipitation due to the karstic underground, results in high spring flows during the rainy season and low flow at the end of the dry spell. Snow or ice in higher altitudes is the only natural storage within the catchment area, which reduces the peak flow of the spring and prolongs the medium flow conditions for some few months. However this kind of storage is extremely influenced by climatic changes as observed today.

The lowest flow observed is approximately 80'000 to 90'000 m^3/d (Jeita and Kashkoush Springs) which means any channel having a greater capacity is under-utilized during some months of the year. The greater the channel capacity the higher the under-utilizing will be, which has a negative impact on the financial viability of a channel to be rehabilitated.

The duration of insufficient available water to maintain the chosen abstraction rate is illustrated in Figure 5-2.

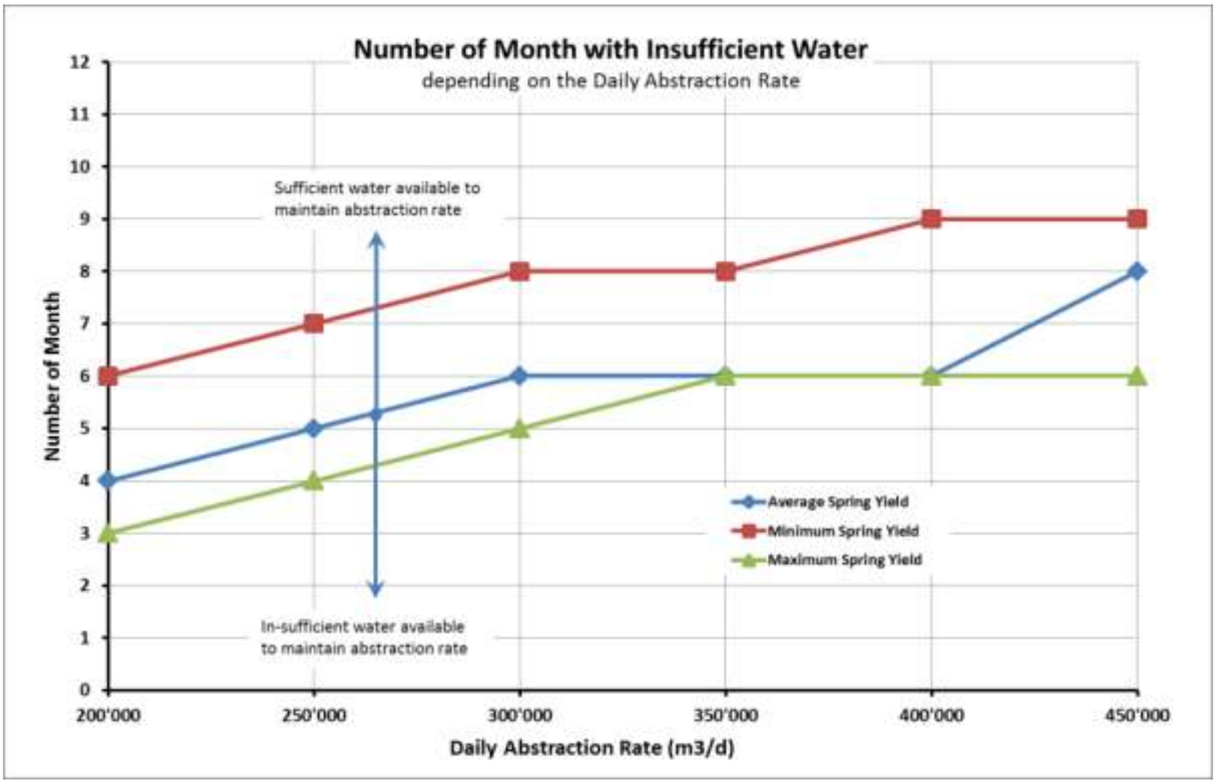

Figure 5-2 Daily abstraction rate versus number of month with insufficient water

Based on the following proposed parameters the maximum abstraction rate can be determined e.g.

- In years with average / maximum precipitation the available flow shall maintain the chosen abstraction rate for at least 6 months and

- In years with minimum precipitation the available flow shall maintain the chosen abstraction rate for at least 4 months and

Under these conditions and the fact that no balancing retention volume is available the abstraction rate will be in the range of:

- 250’000 to 350’000 m^3/d, with irrigations abstraction and
- 300’000 to 400’000 m^3/d without irrigation abstraction.

5.1.3.2.4 Irrigation abstractions

Although the abstractions for irrigations are old water rights, which at the time of building the transmission main had its justifications, today, especially in the lower reaches of the Wata Canal, there is hardly any agricultural land use left. To get an overview of the actual situation, the Consultant strongly recommends that the Water Establishment carry out a detailed survey with the following topics:

- A detailed list of all abstraction permits with the amount of legitimate abstraction must be established.
- Where irrigation rights are no more justified by the title holder such rights should be withdrawn and transferred to BMLWWE, for instance in case that irrigation water rights are used for commercial, industrial or residential purposes and not or less than 75% for irrigation.
- Where irrigation rights are justified but hardly used, such rights should be compensated and transferred to BMLWWE.
- Water abstractions must be monitored / controlled by BMLWWE so that the abstracted amounts are not exceeding the permitted amounts set by the water rights.
- Illegal abstractions from the channel must be abolished. Since the canal is open and easily accessible, anybody can serve his water needs from the channel without any restrictions on the amount abstracted.

The Consultant tried to obtain these information, but failed since it is a very sensitive issue for the irrigation water users concerned.

Notwithstanding, the following measures are recommended to be implemented:

- Upstream of the OEB Dam site a small permanent dam should be constructed which will collect all the leakages and wastages at the intake sites as well as groundwater infiltration along Nahr el Kalb.
- The water collected by this dam shall no more be fed into the transmission channel, but shall be used to feed the Wata Canal. Although the water collected at OEB dam is of inferior quality than the spring water it still can be used for irrigations purpose. Spring water is supplied only if the water rights can no more be maintained by runoff and there is excess water available from Jeita spring which will otherwise not be used for drinking purposes.
  If a small retention basin is viable such a basin would be of advantage to satisfy the established irrigation water demands.
- From the Wata calal intake to the OEB Dam site an independent irrigation pipe shall be laid to which all the justified and authorized irrigation water users are connected. The Jeita-Dbaye drinking water pipeline will be

supplied with Jeita Spring and in the lower part with Kashkoush Spring water, only.

- Abstraction rights from the Nahr el Kalb, which can be replaced by groundwater, shall be promoted by the Water Establishment through drilling and equipping boreholes on appropriate locations on the expenses of BMLWWE. The operation and maintenance of such borehole pumps shall, however, be the duty of the beneficiary.

5.1.3.3 Scenario C:

Another solution to maintain the chosen abstraction rate throughout the year is to build an impounding reservoir up-stream of Jeita Grotto in the area of Daraya.

The size of the reservoir depends on:

- Abstraction rate to Dbaye WTP and
- Spring yield, since the stored water of the reservoir will be used only to augment any deficiency between available spring yield and abstraction rate.

The size of the reservoir as shown in Figure 5-3 depends on the spring yields. In contrast to the dam at the OEB site, in this case the reservoir is not fed by surplus water from the springs but by surface runoff from its catchment area.

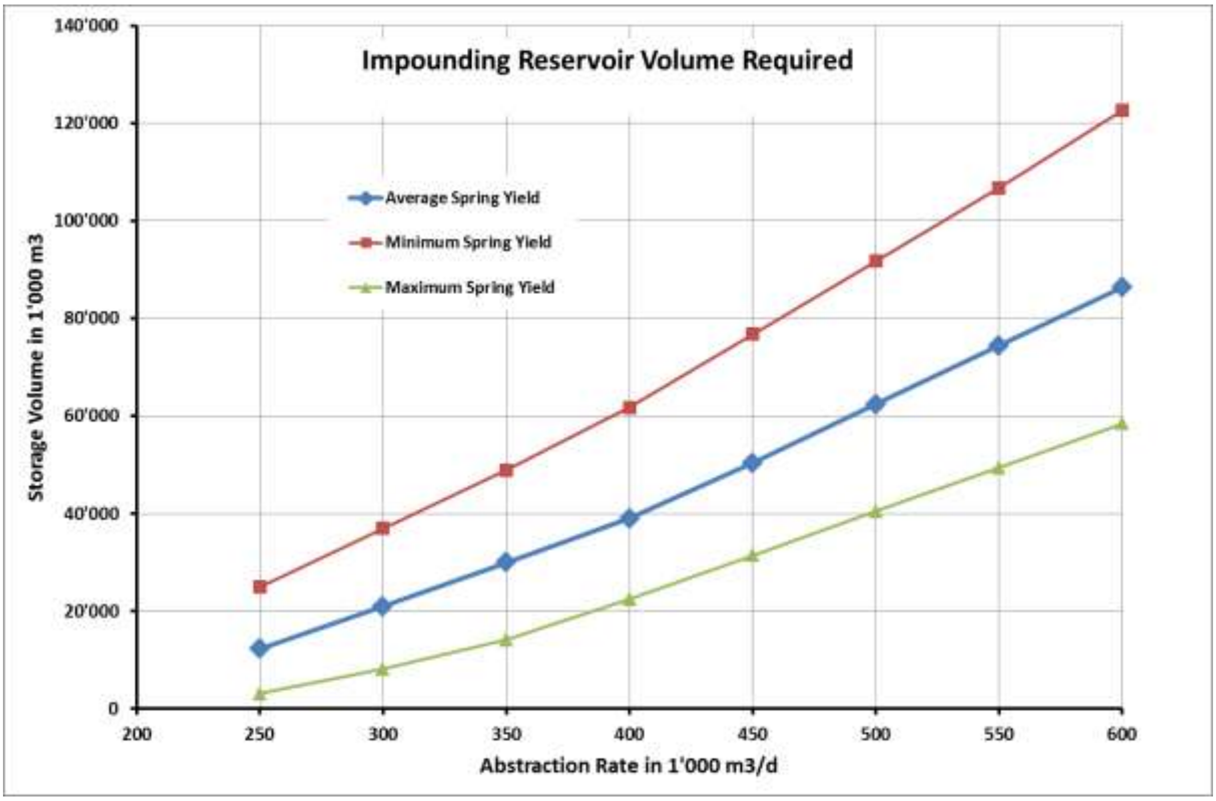

Figure 5-3 Size of impounding reservoir (Net volume)

To maintain an abstraction rate of e.g. 350’000 m^3/d in a dry year and to have ample safety reservoir volume available to reduce the negative impact of the climate changes a net volume of about 60 Mio m^3 is needed. In addition to the net storage volume allowances must be made for evaporation losses and silting e.g. 1 Mio m^3 for evaporation loss and 9 Mio m^3

for silting resulting in a reservoir size of approximately 70 Mio m^3. However, if the site permits greater storage volumes are possible which would allow bigger abstraction rates.

To keep the silting under control the reservoir should be empty at the end of a hydrological cycle and the sediments accumulated in the reservoir should be removed in the dry season. The first floods should be used to de-silt the reservoir. Since the water from such a reservoir will be used for drinking purposes and has great water level variations, it is not suitable for recreational activities. An advantage of such a structure would be that a natural attenuation of surface water pollution will take place in the reservoir.

Possible dam sites within the Jeita Spring Catchment area are discussed in Chapter 6.

5.2 REHABILITATION AND AUGMENTATION OF TRANSMISSION CHANNEL

5.2.1 Proposed New Spring Intake

A new Jeita spring capture (Figure 5-4) would be fairly easy to install. During construction of the new dam and discharge monitoring facility (see below), spring water withdrawal could still be operated through the existing structure. The old system should be removed after the new system became operational.

The only new elements needed are:

- Straight line segment of about 6-8 m width, 4 m height and 50 m length for measurement of spring discharge and water quality parameters and acting as an intake and overflow;
- Access to the monitoring station from the natural exit of Jeita spring, accessible at all times;
- Connection to the new transmission pipeline Jeita-Dbaye and
- Overflow of maximum spring discharge (In case of closed pipeline the complete spring yield of maximum 50 m^3/s).

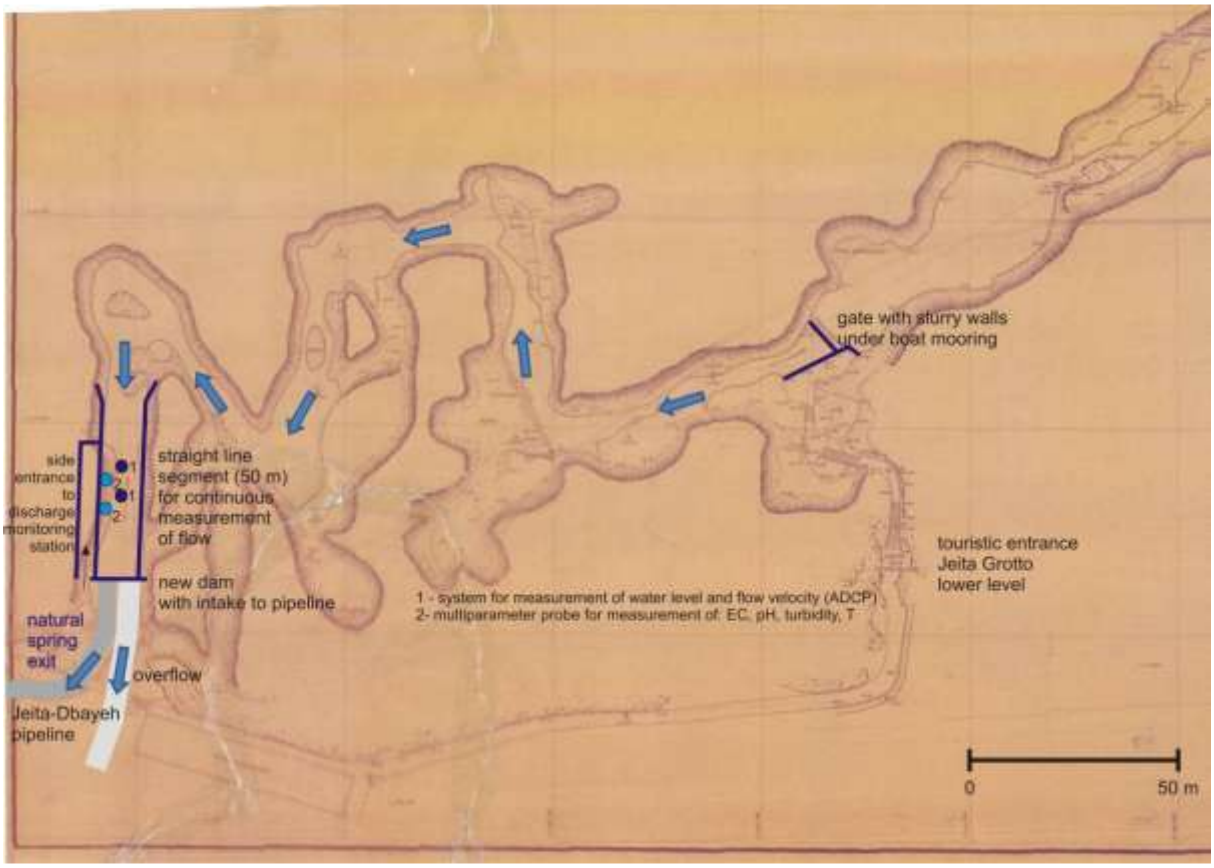

Figure 5-4 Jeita Spring Capture - New Configuration

The proposed spring intake will have the following features:

- Maximum abstraction rate 8.7 m^3/s (750'000 m^3/d)
- Installation of flow and water quality recording and monitoring units as described in Chapter 5.1

  Spring discharge will be measured by two independent systems at 2 different points. Flow velocity should be measured e.g. by ADCPs (3 beams; SonTek or RD Instruments) which need to be installed near the bottom (vertical ADCP) or at the side wall (side-looking ADCP). Flow recording with a measuring range between 0.5 m³/s and 50 m³/s, with recording intervals of 10 to 20 minutes.

  Water quality parameters should be measured by two independent multi-parameter probes to be installed in a PVC casing at the side wall measuring:

measuring:	- Conductivity	- Turbidity
	- pH	- Temperature

  Access to the measuring devices will be provided through the side entrance, where also the data loggers are installed. The side entrance must be lockable in order to avoid leakage in period of peak flows.

  Data recorded will be stored locally in a logger unit and in parallel be transferred by a telemetric system to the treatment plant (Dbaye);
- At the entrance of the intake a gravel / sand trap shall be incorporated into the new structure with the necessary cleaning and flushing devices.

- The water level in the Grotto shall be constantly maintained by an inflatable weir. The automatic controlled weir shall be equipped with a manual operation in case of emergencies.

For construction the following aspects have to be considered:

- Construction of the new intake should be done during low flow period, when average flow is below 2 m^3/s.
- A dry year should be chosen for these works so that there will be enough time to complete all works.
- Construction should not commence later than beginning of August and be completed by end of October.
- During construction the currently used inner dam should be used to convey water into the tunnel and existing canal. After construction of the new intake, the inner dam will be removed.
- The narrow passage near the boat mooring shall not be enlarged because it slightly reduces the pressure on the future intake.

5.2.2 Transmission Channel

As the title of this chapter implies the Consultant, propose the complete rehabilitation of the transmission channel in order to abandon the presently used piecemeal approach by carrying out emergency repairs only. The disadvantage of the present approach is that it is not possible to improve the present not satisfactory situation but just to maintain the status quo. Requirements as defined in Chapter 5.1, just to mention some like,

- Improvement of operational reliability
- Providing direct access to the structures through land owned by BMLWWE
- Eliminating of water pollution
- Elimination of direct access to the channel for the public
- Establishing an independent system for irrigation

cannot be achieved without a complete rehabilitation of the infrastructures.

The proposed measures consist of:

- Renewal of the Spring Intake structures
- Expropriation of land required for the new infrastructure and accessibility for maintenance purpose.
- Replacement of the existing channel by new piped conduits (closed system)
  - where possible pipes will be laid in ground or inside the existing channel
  - tunnel sections are used only where needed for topographical reasons or lack of space available between the river and existing buildings.
- Providing separate pipes to cater for the irrigation needs
- Construction of permanent dam at OEB site to feed the Wata Canal with irrigation water.
- Installation of a comprehensive flow monitoring and telemetric data transfer system to Dbaye WTP for all supply and abstraction points.

- Optional: Installation of Hydropower Plants at former Harch Station and at Dbaye WTP.

The cost estimates and financial analysis for the above mentioned rehabilitation measures are provided in Chapter 9. A longitudinal profile (sketch) of the proposed new transmission main is provided in Figure 5-5.

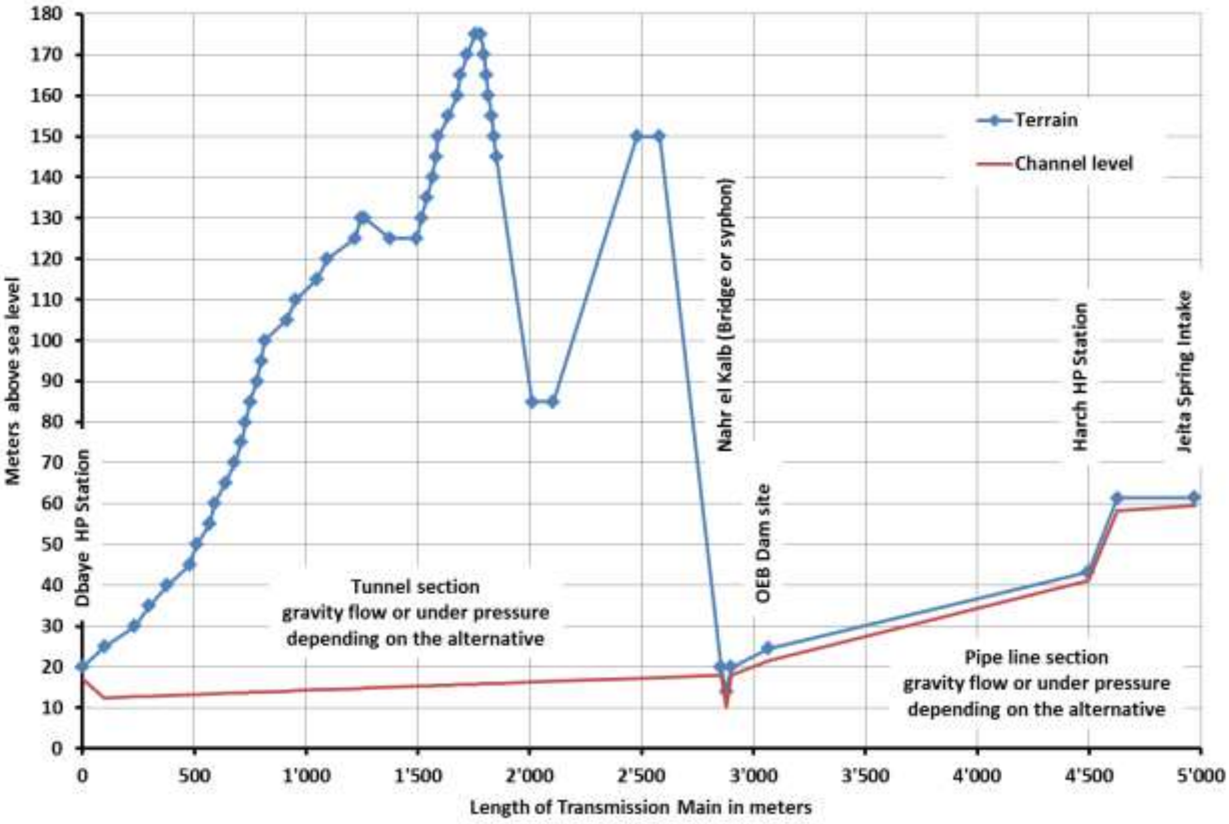

Figure 5-5 Longitudinal profile (sketch) of Transmission Main:

5.3 PRODUCTION AND ABSTRACTION MONITORING

Since the rehabilitation project includes a complete new production and abstraction monitoring system, for the time being, it is proposed to repair the existing required installed measuring devices as deemed necessary. This measures will be included in the Tender Document for the WWTP

6. WATER STORAGE OPTIONS IN THE JEITA CATCHMENT

6.1 INTRODUCTION AND KEY ASSUMPTIONS

The Water Establishment of Beirut and Mount Lebanon (BMLWWE) is in need of additional amounts of water to secure drinking water supply during the end of the dry season.

Currently water supply in the Greater Beirut area depends to about 70 % on Jeita and Kashkoush springs. The construction of the Awali conveyor (approx. 50 MCM/a) and Bisri dam (approx. 120 MCM/a), currently envisioned through a World Bank project, could be an additional source of water for drinking water supply but will not be able to provide the same quality and low mineralization of raw water as is available in the Jeita catchment, once protected through groundwater protection zones. Until any of the above additional World Bank projects become operational, it would be worthwhile investing in the upgrading of the water supply from the Jeita / Nahr el Kalb catchment through artificial groundwater recharge/storage dams. These dams would increase amounts available from the Jeita catchment in the dry season.

The currently proposed Janneh dam, apart from the problem of potential underflow through the around 60 m thick alluvial filling, might, due to the geological and structural conditions in this area, act rather as an artificial recharge dam than as a storage dam. It is assumed (MARGANE et al., in progr.) that groundwater infiltrating in the outcropping upper J4 sequence near the junction of Rouaiss and Afqa branches of Nahr Ibrahim, flows towards Jeita spring. Differential discharge measurements and tracer tests will soon be carried out in this area by the BGR project to prove this hypothesis.

Due to frequent low flows at Jeita and Kashkoush springs, which are the main source of water supply, during the time period from October to December, water demand in the Greater Beirut area at the end of the dry season cannot sufficiently be met. At this time, an additional amount of water up to 60,000 m^3/d is needed. The amount needed is therefore around 5.4 MCM/a. The purpose of this chapter is to point out options to fill this gap. Due to the high amounts currently running off unused, it will be possible to implement several dams, even in the same valley. This would even increase the possibility of infiltration.

As point out in Chapter 4.7, about 30 % physical losses occur along the current transmission mains. In addition, large amounts of water are currently being transferred to the Wata canal without being used for the intended purpose, which once was irrigation (Chapter 4.5). This water transfer takes place even during the dry season, when irrigation water should not be needed. In the Jeita area an excessive amount is being made available for irrigation (15,000 m^3/d; pers. comm. BMLWWE). Also this "irrigation" water is withdrawn even in the wet season. **If some of this transfer, of up to 60,000 m^3/d, would be stopped and physical losses were reduced, less additional amounts of water would be needed for the Greater Beirut area.**

The groundwater contribution zone (or groundwater catchment) has been delineated by the BGR project by means of several tracer tests (MARGANE & MAKKI, 2012; MARGANE et al., in progr.; Figure 6-1).

Also a WEAP model was established providing a water balance (SCHULER, 2011, MARGANE et al., in progr.). Due to the lack of continuous and comprehensive long-term data concerning all individual components of a water balance (MARGANE, 2011), this balance is partly based on old, partly on new data.

The key assumptions are:

- groundwater recharge in the Upper Cretaceous Aquifer (C4) reaches 80 %
- groundwater recharge in the Jurassic is on average around 50 %
- groundwater flow is governed by the complicate geological structure.

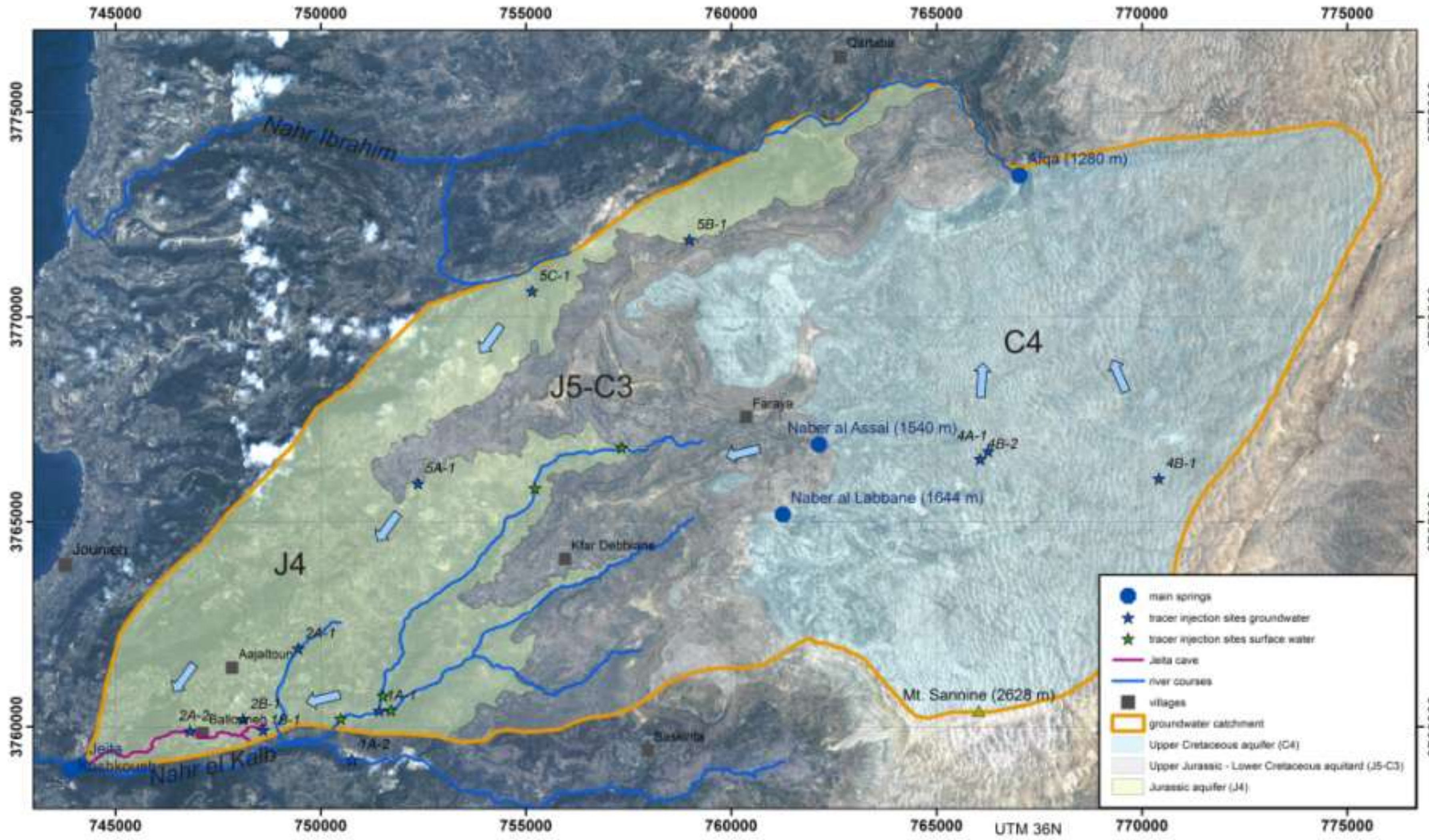

Figure 6-1 Groundwater Contribution Zone of Jeita Spring

Table 6-1 Water Balance for the Jeita Groundwater Catchment (SCHULER, 2011)

Water Balance Component	Amount [MCM]	Amount [%]
Rainfall P	462.5	100
Runoff R	132.1	27
Groundwater recharge GWR	254.2	53
Evaporation E	97.6	20

The main runoff from Jeita catchment occurs in Nahr el Kalb, but since the groundwater catchment considerably extends northwards beyond the surface water catchment, part of surface water runoff is directed towards Nahr Ibrahim or smaller coastal catchments.

Surface water runoff in Nahr es Salib, the northern branch of Nahr el Kalb, is measured by Litani River Authority (LRA; Figure 6-2). LRA Station 226 at Daraya was monitored between 1967 and 1974. After the civil war, measurements resumed in 1997 and are carried out until today, presently using an OTT pressure transducer. Runoff in this northern part of Nahr el Kalb calculated by LRA shows an average of 99 MCM per water year (WY) for all 19 water years with records and of 97 MCM for the continuously monitored time period 1997/98 - 2009/10 (Figure 6-3). Runoff at Kahr el Kalb measured close to the sea mouth (LRA station 228) was measured during a similar time period in the past but flow was much higher in the 1960/70s, compared to the more recent and complete time period of 1997/98 - 2009/10. Here average runoff for all 20 WY was 340 MCM, while was only 170 MCM during the time period 1997/98 - 2009/10. At Daraya, however, average flows were more or less the same during both time periods. The early 1960/70 time period can therefore not be considered. Comparing the flows during the water years 1997/98 - 2009/10, about 73 MCM/a or 43 % of the total runoff constitutes runoff from the southern branch of Nahr el Kalb and the surface catchment between Deir Chamra and Mokhada. In this part of Nahr el Kalb, surface water runoff is not monitored. Surface water runoff in the southern branch of Nahr el Kalb occurs mainly during January to April, while surface water runoff in the Nahr es Salib branch occurs during a longer time period (November to June). During May and June surface water runoff comes mainly from snowmelt in the higher parts of the surface water catchment. Contribution from snowmelt in the southern branch is much less than in the Nahr es Salib branch because due to the geological structure the C4 does not contribute to discharge in this region (MARGANE et al., in progr.).

There is a strong interannual variation of between 38 and 227% at the sea mouth and of only between 36% and 164% at Daraya (Figure 6-3).

The average monthly distribution is shown in Figure 6-4. Peak runoff occurs commonly between February and April.

Figure 6-2 Surface Water Monitoring Stations in Nahr el Kalb

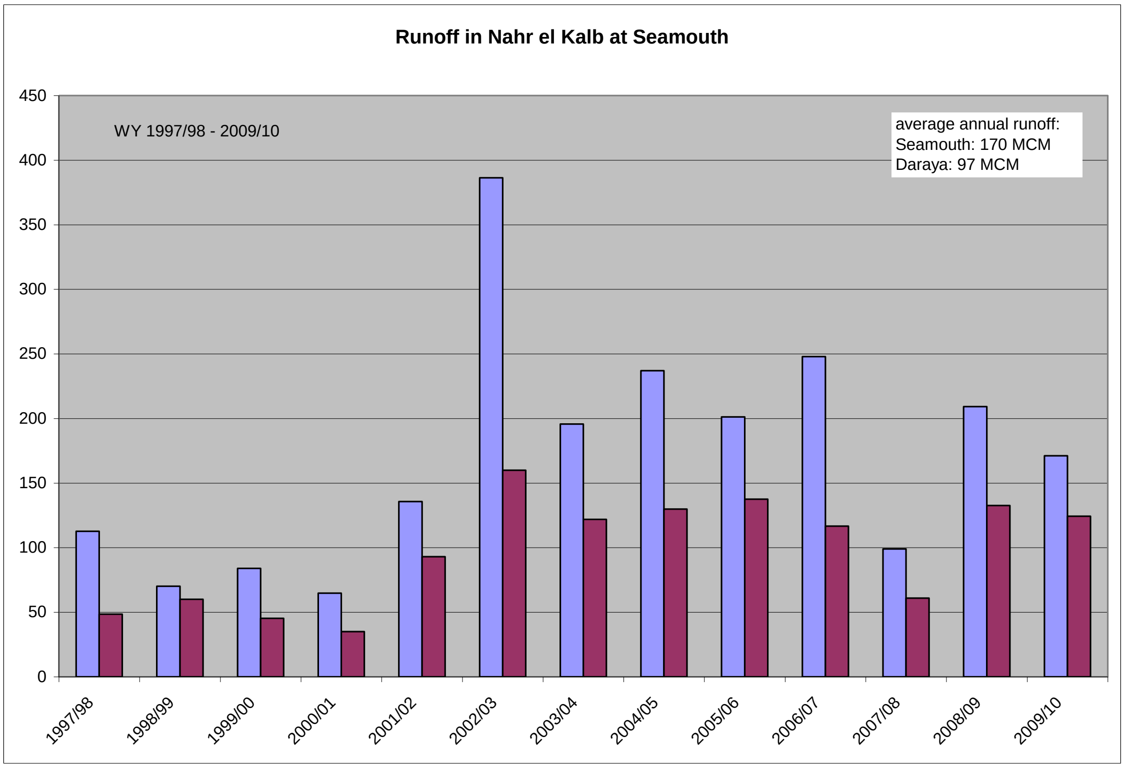

Figure 6-3 Annual Runoff in Nahr el Kalb at Sea Mouth and at Daraya

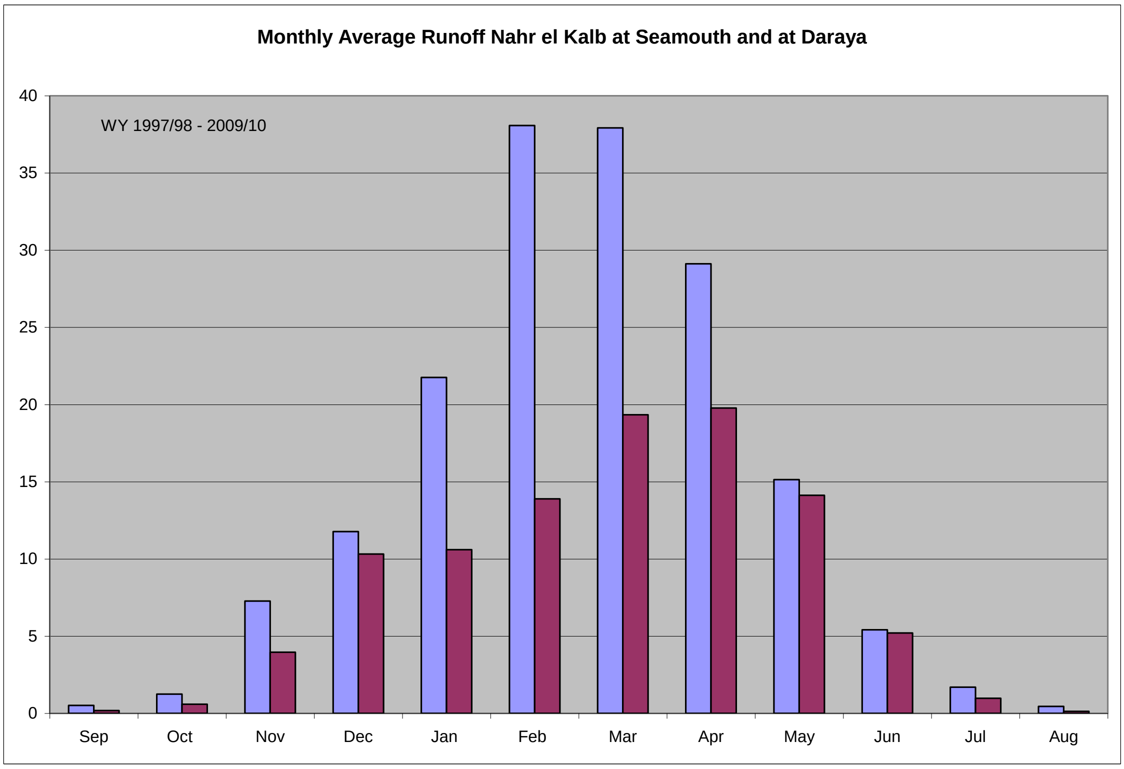

Figure 6-4 Monthly Average Runoff in Nahr el Kalb at Sea Mouth and at Daraiya

The proposed dams will have to be located in the J4 sequence of the Jurassic. It must be assumed that there will be considerable infiltration from the dam into the underlying J4 aquifer, depending on the availability of conduits and fracture pathways in the impoundment area of the dam. This infiltration into the groundwater system is positive as long as it occurs in the groundwater catchment of Jeita spring and thus increases the discharge of Jeita spring. In this respect the proposed dams would act as **recharge dams**. Managed aquifer recharge (MAR) from recharge dams is not an easy task because it cannot be foreseen which share of the impounded water will actually infiltrate, even with the best of engineering geological or hydraulic tests, simply because the location of open pathways and their number cannot sufficiently be determined. It will only be possible to determine the infiltration rate during operation of the MAR dams. In order to do so, the dam sites would have to provide measurements of inflow to the dam and measurements of outflow from the dam.

Nahr el Kalb carries a considerable sediment load. Therefore the proposed dams would fill up with sediments unless operation takes this fact into consideration and the dams are being equipped with an upstream facility to reduce the sediment load before reaching the dam (MARGANE et al., 2009; siltation dams). Sediment accumulating in this dam would need to be removed after every wet season. The proposed dams would have to have several bottom gates at different levels, which would relieve the dam of the accumulating sediments.

When sediments start accumulating at the bottom of the dam, natural infiltration will become less and less over time, even with siltation dams being built. At some dams (e.g. Walla dam in Jordan) therefore injection facilities are available to retain the level of infiltration. Such facilities may be necessary in the long term in the Nahr el Kalb catchment as well and should be planned for from the beginning.

Depending on the rate of infiltration, surface water stored in the proposed dams could, however, also be released into Nahr el Kalb depending on water supply demands. Further downstream, most probably immediately upstream of Jeita, there would need to be an intake structure for conveyance to the Dbaye treatment plant.

Impoundment in the proposed dams would lead to longer residence times of water and thus a lower pollution load (TOC, microbiological constituents). In water bodies nitrogen removal processes take place which lead to a considerably reduction in contents of nitrite, ammonium and nitrate (SEITZINGER, 1988; BURGIN & HAMILTON, 2007). A dam would require setting up a protection zone (MARGANE & SUBAH, 2007) and reducing inflows from wastewater and other hazards to water. **Currently some municipalities discharge their untreated wastewater from large pools (e.g. Beit Chebab) directly into Nahr el Kalb at various times even without notifying the Water Establishment. This practice has to be stopped.**

The calculations in this chapter are based on the following input data:

- DEM based on DAG 10 m contour interval topographic data for around 50 % of the catchment (Daraiya, Zabbougha, Kfar Debbiane, Boqaata);
- SRTM DEM (MARGANE, 2011) for the remaining parts of the catchment.
- Delineation of sub-catchments: SRTM DEM
- Rainfall: pluviometric map (UNDP & FAO, 1973)
- Geology: geological map prepared by the project (HAHNE et al., in progr.)
- Runoff: LRA hydrological data (pers. comm. LRA)
- Water balance components (P, R, E, GWR): MARGANE et al. (in progr.), SCHULER (2011).

The quality of both topographic data sets is principally insufficient for such an accented topographic area. For this reason a new DEM will be generated by the project using TanDEM-X data. Although already acquired, those data were, however, unfortunately still not available at the time this report was prepared. Due to the above-mentioned inaccuracies, the error of volume estimations using the currently available data set is estimated at around 20 %. Any other dataset, even those based on topographic maps, will not be better. This needs to be taken in consideration when using the storage volumes mentioned below. Better estimations can only be based on laser scans or topographic surveys. The latter are, however, extremely difficult in this largely inaccessible land.

6.2 POTENTIAL DAM SITES

From the perspective of availability of a large enough impoundment area, the following six potential sites were selected (Table 6-2):

- Kfar Debbiane dam
- Faitroun dam
- Zabbougha dam
- Boqaata dam
- Daraiya dam
- Baskinta dam

Figure 6-5 Proposed Dam Sites in the Nahr el Kalb Catchment Area

Table 6-2 Base Data of Proposed Dams

Name of Dam	UTM_E	UTM_N	Elevation	Dam crest	Storage	Surface area	Catchment	Rainfall	Rain volume
			m asl	m	MCM	m²	km²	mm/a	MCM/a
Kfar Debbiane	752020	3761940	720	100	7.3	224,721	91.0	1,565	142.4
Faitroun	755210	3765710	1115	65	6.6	459,963	80.1	1,596	127.8
Boqaata	754200	3761500	900	80	4.1	198,025	16.8	1,442	24.2
Baskinta	759060	3758630	1035	100	6.0	157,730	28.5	1,659	47.4
Zabbougha	752120	3760710	635	100	3.0	104,976	46.9	1,454	68.2
Daraiya	748720	3759500	320	100	9.0	235,215	222.0	1,494	331.7

6.2.1 Kfar Debbiane Dam

The proposed Kfar Debbiane dam (Figure 6-6 Location of Proposed Kfar Debbiane Dam and Main Tectonic Elements)
would be located at an elevation of 720 m asl. With a dam crest of 100 m it could store up to 7.3 MCM of water. It would cover a surface area of around 225,000 m². The size of the catchment at the proposed point is 91 km². The rainfall volume over this catchment would be 142.4 MCM/a. However, as tracer tests have proven, a large part of the Upper Cretaceous aquifer contributes to the discharge of Afqa spring. Principally mainly geological units below the C4 limestone could contribute to surface water runoff. Assal and Labbane springs have only small catchments and low discharge, which is used for water supply and irrigation in the catchment. Discharge from C4 currently not used occurs mainly during snowmelt. This flow is difficult to quantify but could reach up to 10 MCM/a.

The catchment of geological units below C4 has a size of about 45 km². Groundwater recharge over the sequence J5-C3 is approx. only 10 %, evaporation around 30 %, so that surface water runoff generated from this part (km²) could be around 19.5 MCM. Together with the surface water runoff generated on the J4 unit (30 % or ~ 4.8 MCM), a total of around 34.3 MCM/a could potentially arrive at the dam site. Storage could thus be met by estimated flow to the dam.

Figure 6-6 Location of Proposed Kfar Debbiane Dam and Main Tectonic Elements

The dam site would be located approx. 1.2 km upstream of the bridge crossing Nahr el Kalb at the road from Daraiya to Abu Mizaine. The dam is situated in a completely uninhabited area. The geological outcrop in this area (Figure 6-7) consists of the J4 Jurassic limestone, approx. 400 m below the top of the formation. Water infiltrating into groundwater at the dam site would certainly reach Jeita spring. Thickness of alluvial deposits at the dam site is believed to be less than 20 m. There is no major tectonic element at the proposed dam but the upper part of the storage area is reached by a major fault with a strike of about 50° (Figure 6-6 Location of Proposed Kfar Debbiane Dam and Main Tectonic Elements).

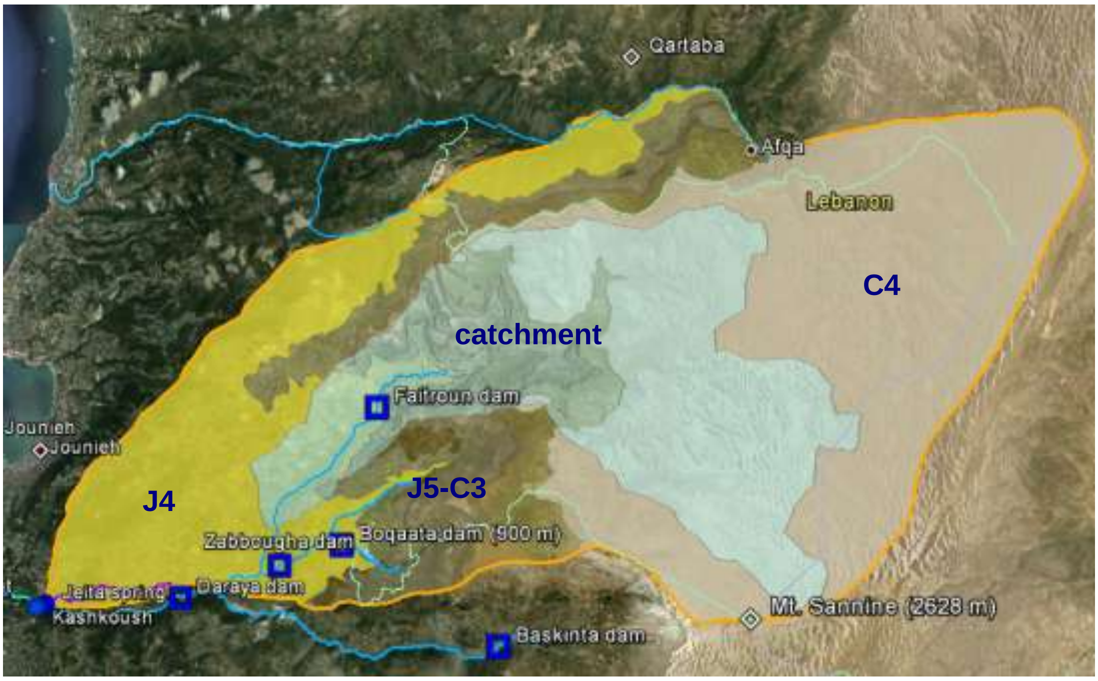

Figure 6-7 Geology and Sub-Catchment of Proposed Kfar Debbiane Dam

6.2.2 Faitroun Dam

The proposed Faitroun dam (Figure 6-8) would be located at an elevation of 1115 m asl. With a dam crest of 65 m it could store up to 6.0 MCM of water. It would cover a surface area of around 460,000 m². The storage area would include only a few houses in Mayrouba. The size of the catchment at the proposed point is 80 km². The rainfall volume over this catchment would be 127.8 MCM/a.

As mentioned above only a small part of discharge from the C4 aquifer could reach this area (approx. < 10 MCM/a). The main surface water runoff would be generated on the J5-C3 aquitard (21.3 MCM/a) and the J4 aquifer (1.3 MCM/a), resulting in a total estimated runoff of around 32.6 MCM/a. Storage would thus be met by expected runoff.

The dam is situated approx. 200 m below the top of the J4 geological unit. There are no major tectonic elements in the dam crest area, however, the upper part of the storage area is crossed by a large fracture zone with a strike of 80°.

Figure 6-8 Location of Proposed Faitroun Dam and Main Tectonic Elements

6.2.3 Zabbougha Dam

The proposed Zabbougha dam (Figure 6-9) would be located at an elevation of 635 m asl. With a dam crest of 100 m it could store only up to 3.0 MCM of water due to the steep topography. It would cover a surface area of around 105,000 m². The storage area would include a quarry, currently not in use. The size of the catchment at the proposed point is 46.9 km². The rainfall volume over this catchment would be 68.2 MCM/a.

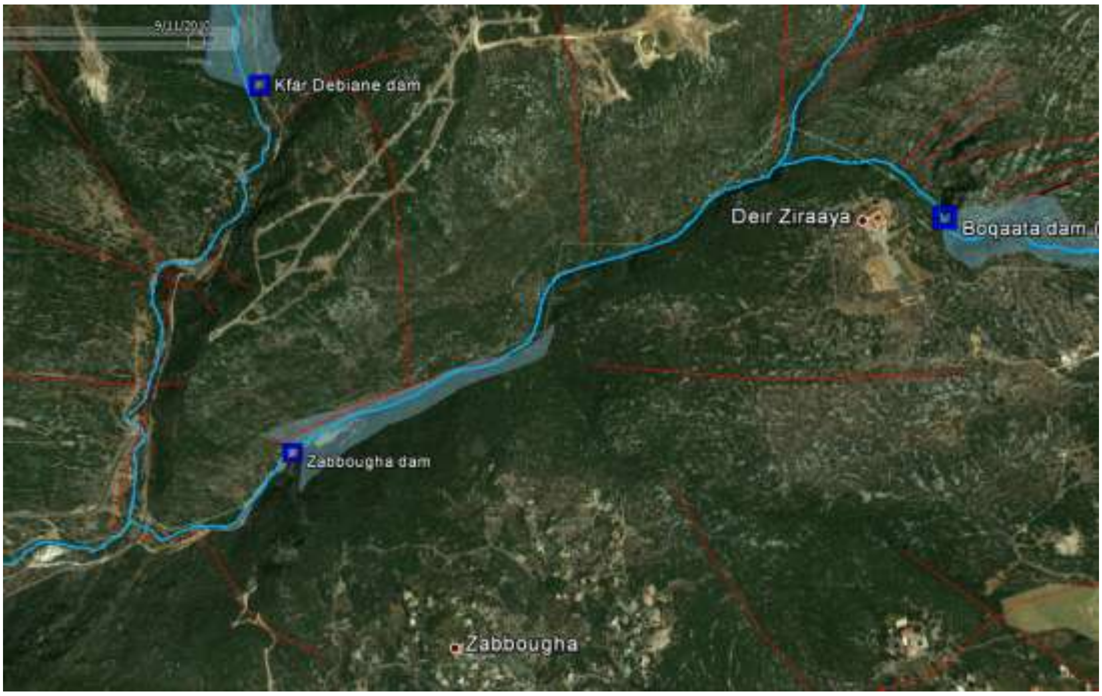

Figure 6-9 Location of Proposed Zabbougha Dam

Although the C4 geological unit covers almost one quarter of the catchment, runoff from this unit is believed to be negligible (see above). The catchment of the proposed Zabbougha dam is considerably larger than that of the Boqaata dam, Figure 6-10. Flow to the site is therefore much higher. Over the J5-C3 aquitard, which constitutes 60 % of the catchment and the J4 aquifer an estimated runoff of around 27.3 MCM/a would be generated.

Figure 6-10 Catchment Size comparison for Proposed Zabbougha and Boqaata Dams

6.2.4 Boqaata Dam

The proposed Boqaata dam (Figure 6-11) would be located at an elevation of 900 m asl. With a dam crest of 80 m it could store up to 4.1 MCM of water and would cover a surface area of around 198,000 m². The storage area would include a few houses in

Boqaata. The size of the catchment at the proposed point is 14.9 km². The rainfall volume over this catchment would be 24.2 MCM/a.

The main surface water runoff would be generated on the J5-C3 aquitard (11.3 MCM/a) and the J4 aquifer (0.3 MCM/a). Total average runoff is estimated to be around 11.6 MCM/a. Storage could thus most likely not be met by expected runoff.

The upper part of the storage area is located on the J5 geological unit (olive colour in Figure 11), while the lower part is on the uppermost J4 limestone, which is highly karstic. It is therefore anticipated that infiltration into groundwater would be significant.

No major tectonic elements are crossing the dam crest or storage area.

Figure 6-11 Location of Proposed Boqaata Dam and Main Tectonic Elements

6.2.5 Daraiya Dam

The proposed Daraiya dam (Figure 6-12) would be located at an elevation of 320 m asl. With a dam crest of 100 m it could store up to 9.0 MCM of water. It would cover a surface area of around 235,000 m². The size of the catchment at the proposed point is 222 km²(Figure 6-13). The rainfall volume over this catchment would be 331.7 MCM/a.

Part of the runoff comes from the Nahr es Salib branch (97 MCM/a), a smaller part from the southern branch of Nahr el Kalb. Runoff will be slightly less than the runoff measured at the sea mouth (170 MCM/a), probably around 150 MCM/a. Storage would be met under any conditions by runoff.

The storage area is located in the J4 geological unit. The top of J4 is most likely around 1050 m asl so that the dam crest would be more than 700 m below the top of J4. In the Daraya tunnel, the entrance of which is located 200 m downstream of the proposed dam, the J4 consists of dolomite at below approx. 200 m asl.

Tracer tests in the river course of Nahr es Salib have shown that the lower part of the J4 is not very permeable. Fractures are mostly closed by clayey material. Groundwater flow in this lower part of J4 is dominated by flow in large conduits and not by fractured flow. Infiltration at the proposed Daraya dam is therefore anticipated to be low. The stored water has to be released when needed into the river and collected through a small intake structure (dam), most ideally directly upstream of Jeita grotto.

The disadvantage of the proposed dam location is that huge amounts of surface water reach this area. Peak flow could be up to 100 m^3/s. To withstand such high pressures, the dam must be built of RCC and be well anchored in the sidewalls. The topography is very steep and the land difficult to access.

Figure 6-12 Location of Proposed Daraiya Dam

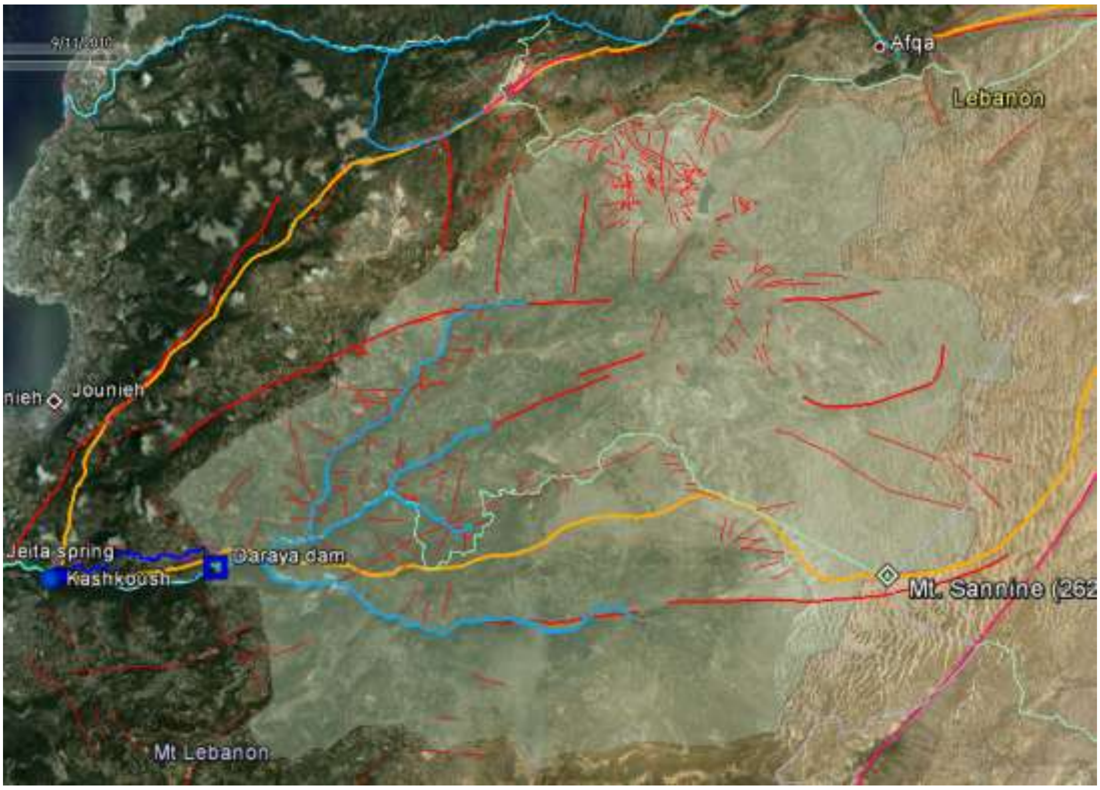

Figure 6-13 Catchment of Proposed Daraiya Dam

6.2.6 Baskinta Dam

The Baskinta dam (Figure 6-14) would be situated in the upper reaches of the southern branch of Nahr el Kalb at an elevation of approx. 1035 m asl. It could serve the water supply for the villages in the southern part of Nahr el Kalb catchment. Water supply to some of the villages would require pumping: Baskinta (1200-1360 m asl), Bteghrine (900-1050 m asl), Marjaba (1100-1200 m asl), Kchenshara (960-1110 m asl), Mrouj and Boulogna (1170-1270 m asl), Dhouar Choueir (1030-1270 m asl), Hemlaya (600-850 m asl), Bikfaya (870-1050 m asl).

Over the catchment of around 28.5 km² rainfall would be approx. 47.4 MCM/a. With groundwater recharge estimated at 50 % of rainfall and an evaporation of around 20 %, runoff to the dam would be around 14 MCM/a. With a 100 m high dam crest, the storage volume of the dam could be up to 6.0 MCM. Storage would thus be met by estimated runoff.

The dam would be located in the uppermost part of the J4 geological unit. Infiltration therefore could be high, most likely up to 50%. Further geological investigations are needed to better estimate the potential infiltration. Currently it is assumed that this area does not contribute to Jeita spring. It may be part of the Faouar Antelias spring catchment. Infiltration would therefore most likely increase discharge at this spring and not at Jeita. However, since Antelias spring also contributes to the drinking water supply of the Greater Beirut area, infiltration in this area would also contribute to the overall aim.

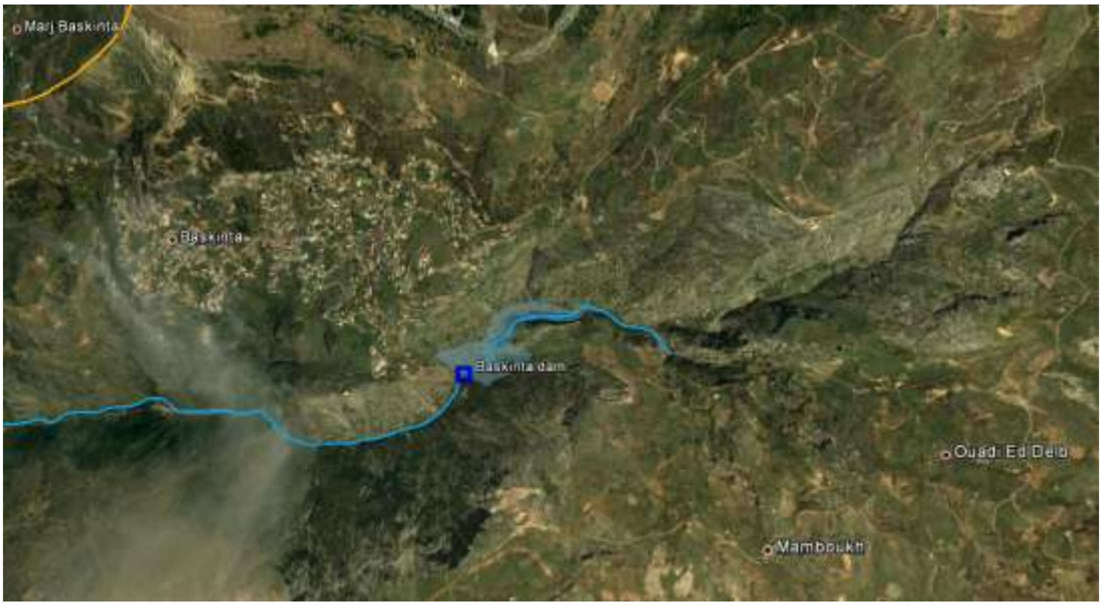

Figure 6-14 Location of Proposed Baskinta Dam

6.3 SUMMARY

Additional amounts of water are needed for water supply of the Greater Beirut area. Up to around 150 MCM/a of surface water are currently running off unused to the sea and would be available for storage or artificial groundwater recharge in the Jeita groundwater or Nahr el Kalb surface water catchment.

Dams could be built in the Nahr el Kalb catchment for the purpose of increasing water resources availability for drinking purposes in the Greater Beirut area during the dry season, filling the gap of water supply that currently often occurs during the months of October to

December. A water supply deficit also exists in large parts of the Nahr el Kalb catchment, especially the southern part between Baskinta and Bikfaya.

These dams could follow different strategies:

a) dam acting as artificial groundwater recharge facilities (Managed Aquifer Recharge or MAR) would retain water especially during snowmelt. Large amounts of surface water would infiltrate into groundwater and discharge at Jeita spring, provided the dams are located in the groundwater catchment of Jeita spring. This would be the case for the proposed Faitroun, Kfar Debbiane, Boqaata and Zabbougha dams. Depending on the distance and on how fast surface water would infiltrate, this could delay the low flow in Jeita by up to approximately 2 months. Several dams could be built en echelon to increase infiltration.

b) dams with a low infiltration capacity, such as the proposed Daraya dam, can only be used to store surface water and release it when needed back into the river.

c) the proposed Baskinta dam would also act as a recharge dam (compare a), however, it would most likely contribute to discharge of Faouar Antelias spring and not to Jeita spring.

Expected runoff could meet intended storage at all proposed sites. Calculations are currently based on a week data basis. A more precise digital elevation model (DEM) or surveying will be needed for more accurate stored volume, surface area and dam dimensions. Due to only few available gauging stations and certain inaccuracies involving flow measurements at these stations, the calculated runoff is not exact but carries an uncertainty factor of 20 %. Rainfall has a large interannual variation which has to be considered for any related decision.

All dams should have sufficiently large bottom gates, which should be operated in such a way that sediment accumulation in the dam is minimized. A siltation dam should be built upstream which must be regularly emptied after each season.

Due to the rather steep topography in the Nahr el Kalb catchment dams will have to be rather high to store sufficient amounts of water. In most cases a dam height of around 100 m is needed. If infiltration at the artificial groundwater recharge sites would function well, the amounts of water which could be gained for water supply would be much higher than the dam storage mentioned in Table 6-2, because a large share of surface water would infiltrate into groundwater.

Table 6-3 Overall Assessment of Proposed Dam Sites

Proposed Dam	Storage [Mio 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
Daraiya	9.0	storage	Low
Baskinta	6.0	MAR > Faouar Antelias spring	Very high

Based on the required storage volume defined in Chapter 5.1.3.3 the above mentioned impounding reservoirs could maintain the following flow rate in the transmission main (ref Table 6-4).

Table 6-4 Channel flow rate depending on storage volume and annual precipitation

Proposed Dam	Transmission flow rate (in 1000 m^3/d) to be maintained throughout the year depending on annual precipitation:		
	Minimum	Average	Maximum
Kfar Debbiane	≈175	≈220	295
Faitroun	≈175	≈220	285
Zabbougha	≈160	≈200	250
Boqaata	≈165	≈200	260
Daraiya	≈185	≈230	310
Baskinta	≈170	≈215	280

Observations regarding the flow rates in the transmission main:

- In a **wet year** it is possible to maintain, throughout the year, a flow rate of approximately 250’000 to 310’000 m^3/d depending on the size of the reservoir, henceforth it is recommended that the transmission main capacity should not exceed 320’000 m^3/d.
- In a **dry year** with the assistance of the impounding reservoirs the minimum flow which can be maintained throughout the year is approximately double the present observed capacity of about 70’000 m^3/d, provided the storage volume is managed accordingly. The Daraya dam is in this respect the most favourable one, since the dam is not used for aquifer recharge a mode of operation, which is difficult to manage.
- The amounts of water withheld in this reservoirs and which is available for the water supply is much greater than the storage volume of the dam.
  The impounding reservoirs are benefiting from a prolonged precipitation period in the higher region of the catchment area as compared to the rainfall pattern along the coast. To make a more accurate forecast concerning the amount of water that can be stored is not possible since no rainfall data are available for the catchment areas.

6.4 PRELIMINARY COST ESTIMATE

The available data material does not allow an accurate cost estimate and financial analysis henceforth the stated investment cost are an indication of the financial requirements for an impounding reservoir.

The Table 6-5 provides an cost overview for the considered impounding reservoirs based on a combination of gravity and arch dam, for more detail refer to Annex 3.

Table 6-5 Cost estimate for impounding reservoirs

Name of Dam	**Cost estimate in USD** Total Mio USD	**Contingencies** (Mio USD) 20%	**Consultancy and preliminary investigations** (Mio USD) 20%	**Total Costs** Mio USD	**Cost per m³ stored water** USD/m³
Kfar Debbiane	95.0	19.0	22.8	136.8	18.7
Faitroun	40.8	8.2	9.8	58.8	8.9
Boqaata	36.5	7.3	8.8	52.6	12.8
Baskinta	159.8	32.0	38.3	230.1	38.3
Zabbougha	71.9	14.4	17.3	103.6	34.5
Daraya	92.1	18.4	22.1	132.6	14.7

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7. PROJECT ASSESSMENTS IN VIEW OF AN OPTIMAL JEITA AQUIFER PROTECTION

The rehabilitation of the transmission channel from the Jeita Spring Intake to Dbaye WTP has no influence on the Jeita aquifer.

8. ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

At this stage, no Environmental Impact Assessment (EIA) for the transmission main is required, which shall be carried out at the detailed design stage. However, some main topics related to the EIA have been listed and commented (refer to Annex 4). The BGR project has developed a guideline on Environmental Impact Assessment in Karstic Areas of Lebanon (MARGANE & ABI RIZK, 2011). It will be used for preparing the detailed design.

Reference:

MARGANE, A. & ABI RIZK, J (2011): Guideline for Environmental Impact Assessment for Wastewater Facilities in Lebanon - Recommendations from the Perspective of Groundwater Protection. - German-Lebanese Technical Cooperation Project Protection of Jeita Spring, Technical Report No. 3, 26 p., Raifoun.

9. ENGINEER'S COST ESTIMATE + FINANCIAL ANALYSIS

9.1 INVESTEMENT COSTS

The investment costs are calculated for two different pipe material alternatives concerning transmission pipes laid either into the existing channel or buried in soil. The tunnel sections and land requirements are in both alternatives the same.

Pipe variant: **STP** – Steel pipe

Pipe variant: **GRP –** Glass reinforced pipe

Abbreviations used in the following tables:

A	= twin pipes	N	= New resp. replacement of existing channel
B	= single pipe, no redundancy	N/E	= One new pipe alignment one pipe using the old and existing channel
250	= to 250'000 m^3/d		
400	= to 400'000 m^3/d	HP	= Hydropower

In addition to the cost of the transmission main the cost estimate includes a lump sum for:

- New measuring and monitoring equipment
  USD 500’000 without and USD 600’000 with power generation
- The new spring intake structure as described in Chapter 5.2.1
  USD 500’000.

Table 9-1 Cost of transmission channel rehabilitation with steel pipes

All costs in: Mio. USD	Total cost		Annual (average) **water production** (1'000 m3/a)	Annual (average) **power production** (1'000 kWh/a)	
Alternative	Investment only	Investment incl. land cost		Dbaye	Harch
Alternative: A250 N	49.95	54.73	77'739		
Alternative: B250 N	29.67	34.46	77'739		
Alternative: A250 N/E	45.19	49.97	77'739		
Alternative: A400 N	51.64	56.43	105'004		
Alternative: B400 N	34.01	38.80	105'004		
Alternative: A400 N/E	56.06	60.84	105'004		
Alternative: A250 N HP	60.23 [10.28]	65.02	77'739	1'147	2'884
Alternative: B250 N HP	42.44 [12.77]	47.23	77'739	1'147	2'884
Alternative: A400 N HP	67.57 [15.93]	72.36	105'004	1'549	2'884
Alternative: B400 N HP	50.90 [16.89]	55.69	105'004	1'549	2'884

Note: [] costs for HP Plants only For more detail refer to Attachments A 2 to A 11

Table 9-2 Cost of transmission channel rehabilitation with glass reinforced pipes

All costs in: Mio. USD	Total cost		Annual (average) **water production** (1'000 m3/a)	Annual (average) **power production** (1'000 kWh/a)	
Alternative	Investment only	Investment incl. land cost		Dbaye	Harch
Alternative: A250 N	44.46	49.24	77'739		
Alternative: B250 N	26.30	31.09	77'739		
Alternative: A250 N/E	35.73	40.52	77'739		
Alternative: A400 N	46.15	50.94	105'004		
Alternative: B400 N	30.43	35.22	105'004		
Alternative: A400 N/E	41.68	46.47	105'004		
Alternative: A250 N HP	53.92 [9.47]	58.71	77'739	1'147	2'884
Alternative: B250 N HP	36.90 [10.60]	41.69	77'739	1'147	2'884
Alternative: A400 N HP	60.65 [14.49]	65.43	105'004	1'549	2'884
Alternative: B400 N HP	43.17 [12.74]	47.96	105'004	1'549	2'884

Note: [] costs for HP Plants only For more detail refer to Attachments A 2 to A 11

Interpretations excl. lines for Hydropower

- The alternative with STP are:
  ≈12 % more expensive than with GRP (Alternatives N lines)
  ≈35 % more expensive than with GRP (Alternatives N/E lines)
- Twin transmission pipe are about
  ≈ 52 to 69 % more expensive than single pipes (Alternatives N lines)
  ≈ 52 to 65 % more expensive than single pipes (STP Alt. N & N/E lines)
  ≈ 35 % more expensive than single pipes (GRP Alt. N & N/E lines)
- The resulting unit investment cost per m^3 is for the smaller transmission flow rate higher than for the greater flow rate.

9.2 ANNUAL COST OF OPERATION AND MAINTENANCE

For the two different pipe material variants the Operation and Maintenance cost are presented in the Chapter 9.3.4 and in Table 9-6.

9.3 FINANCIAL ANALYSIS

9.3.1 General Approach and Assumptions

The financial analysis for the rehabilitation of the transmission main should cover the following issues:

(i) Estimate of investment cost for a variety of project alternatives;

(ii) Split of investment cost by main investment components, showing separately contingencies, consulting services, etc.);

(iii) Estimate of appropriate operation and maintenance cost for the proposed project alternatives by particular project components;

(iv) Allocation of both capital cost and O&M cost for the whole project covering the defined project area over an evaluation period of 20 years; considering reinvestment cost and residual value at the end of the evaluation period;

(v) Calculation of “dynamic prime cost” per m^3 of water for investment, operation and maintenance of the transmission main over the period 2012 to 2033; considering investment cost, re-investment cost, residual value and O&M cost;

(vi) Calculation of “dynamic prime cost” per kWh of electricity for investment, operation and maintenance of the hydropower plants over the period 2012 to 2033; considering investment cost, re-investment cost, residual value and O&M cost;

(vii) Calculation of cost of water arriving at the Dbaye WTP;

(viii) Comments on the influence of the proposed investment measures on the water tariffs, if detailed breakdown of water tariffs to be applied is available.

The main task of the financial analysis within the “FEASIBILITY STUDY: REHABILITATION OF TRANSMISSION CHANNEL JEITA SPRING INTAKE – DBAYE WTP” is to identify the most economical solution and the financial impact on the drinking water tariff.

Within the framework of the Feasibility Study the financial analysis is carried out for an "average annual spring yield" available from the Jeita and Kashkoush springs as well as the groundwater abstractions by various wells.

Subject of the financial analysis are:

- 6 alternatives for different flow rates and pipe arrangements; for each alternative the costs are estimated separately for steel pipes and glass reinforced pipes.
- 4 alternatives for different flow ranges and pipe materials, for each alternative the costs are estimated separately for steel pipes and glass reinforced pipes. The cost estimates comprise only the incremental costs related to the installation of hydropower plants at Dbaye and Harch

The financial analysis is carried out by means of a fully interlinked EXCEL based Financial Projection Model, which is attached on a CD-ROM to the final "Feasibility Study".

All financial projections are carried out in USD, the standard foreign currency in Lebanon, and stated in constant prices at price level 2012 (i.e. in real terms without inflationary price escalation). They are based on the following assumptions and parameters:

- base year for cost calculation and discounting: 2012
- planning horizon: +40 years;
- period for present value analysis: 2012 - 2033
- discount rates applied: 0% to 10%;
- currency: USD;
- exchange rates applied: USD 1.00 = LBP 1500; EUR 1.00 = LBP 2000.

9.3.2 Annual water production and power generation

The annual water passing through the transmission main are determined

a) by the flow capacity of the pipeline and

b) the spring yield since during certain times of the year the spring yield is not able to meet the flow capacity of the pipeline.

The annual amount of water discharged into the pipe is based on records of BMLWWE. For the financial analysis the following recorded average flow rates for the period 2001 to 2011 are used. The annual power production is based on these annual flow rates and an available (net) head of 10.0 m for Dbaye HPP and 13.5 m for Harch HPP.

Transmission pipe capacity (m^3/d) incl. Hydropower Plant Dbaye:	Annual amount of water (1'000 m^3/a)	Annual power production (1'000 kWh/a)
250'000	77'739	1'147
400'000	105'004	1'549
Transmission pipe capacity (m^3/d) incl. Hydropower Plant Harch:		
750'000	144'796	2'884

It should be noted that without additional retention storage volume the annually available water would decline due to climatic changes.

9.3.3 Capital Cost

(1) *General*

Capital costs as required for the calculation of "dynamic prime cost" comprise: (i) the actual value of existing assets to be utilized further by the Project; (ii) the initial investment cost of the proposed project measures; (iii) the reinvestment cost for electro-mechanical equipment and vehicles to be replaced during the evaluation period 2013 to 2033; and (iv) the residual value of the investment components still to be utilised at the end of the evaluation period 2033.

Capital costs are estimated separately for each alternative, as defined in the technical sections of this report.

The total amount and the annual allocation of the initial investment cost, the reinvestment cost, and the residual value of the respective investment components at the end of the evaluation period 2033 are presented separately for each of the alternatives.

The key investment cost data for the 10 alternatives are summarised in Attachments A 2 to A 11.

For the comparison and ranking of the different alternatives (on the basis of dynamic prime cost) the initial investment costs are for each alternative schematically put in year 2013 and the O&M cost spread on an annual basis over the period 2014 to 2033.

(2) Initial investment cost

The initial investment costs comprise the following cost components:

(i) Cost of land
(ii) Transmission main - civil works & pipes
(iii) Hydropower plant - civil works & power connection to main grid
(iv) Hydropower plant - E/M equipment incl. flow monitoring equipment
(v) Physical / price contingencies of 20% on components (ii) – (iv)
(vi) Consulting / supervision cost of 12% on components (ii) - (ix)
(vii) Import duties and cost of shipping and insurance to the final place of destination are included in the unit cost of the foreign investment components.

The initial investment costs of the particular alternatives are summarized in Table 9-1 and Table 9-2.

The overall initial investment costs (including cost of land and appropriate contingencies and engineering/supervision cost) vary between:

(a) Alternatives without power generation
- for STP: Mio USD 34.46 (Alternative B 250 N) and 60.84 (Alternative A400 N/E)
- for GFR: Mio USD 31.09 (Alternative B 250 N) and 50.94 (Alternative A400 N)

(b) Alternatives with power generation
- for STP: Mio USD 47.23 (Alternative B 250 N) and 72.36 (Alternative A400 N)
- for GFR: Mio USD 41.69 (Alternative B 250 N) and 65.43 (Alternative A400 N)

(3) Reinvestment cost

Re-investment costs are calculated for the particular project components according to the assumed "useful life times" as stated in the second column of the Attachments B 1 to B 20.

(4) Residual value of investment

The residual value of the proposed investment measures at the end of the evaluation period (2033) is calculated by using the "useful life times" as stated in the second column of the Attachments B1 to B20.

(5) Value of existing assets

Taking into account the age of the existing transmission main it can be safely stated that the structure has exceeded its useful economical life time. Therefore these assets are not at all relevant for any option analysis and ranking of alternatives within the framework of this feasibility study.

(6) Local and foreign investment cost

As the exchange rate between LLB and USD is fixed for a long period of time, the differentiation by local and foreign currency is not essential. Based on the Consultants assessment the portion of the local currency cost components varies from 30% to 40%.

9.3.4 Operation and Maintenance Cost

9.3.4.1 General Assumptions and Methodology

Operation and maintenance costs are estimated separately for each of the alternatives on an annual basis over the period 2014 to 2033, as defined in the technical sections of this report.

In line with the requirements of the ToR the projection of O&M costs is carried out in real terms (i.e. without inflationary price escalation) for the following cost categories:

(i) Variable O&M cost, dependent on the projected amount of water passing through the new transmission main:
- There are no variable cost but just revenues from sale of electricity produced by the Hydropower Plants; these revenues are considered as negative operation costs.

(ii) Fixed O&M cost:
- Staff;
- Maintenance (materials, services from outside)
- Consumables for Hydropower Plants;
- General cost.

The estimate of O&M costs is based on the following assumptions and considerations:

(i) Revenues from sale of electricity produced by the Hydropower Plants;

BMLWEE is currently charged 0.09 USD/kWh by the Electricity Corporation. This price is increased by the consultant to 0.15 USD/kWh for the fact that the power supply from the public electricity grid is not continuously available; so that for certain periods of time electricity has to be generated by stand-by diesel generators at significantly higher cost.

In order to determine the financial viability of hydropower production the Consultant decided to apply a very conservative electricity selling price of just 0.03 USD/kWh.

A significantly higher price of 0.10 USD/kWh which is based on the following assumptions: (0.15 USD/kWh + 0.09 USD/kWh) / 2 minus 0.02 USD/kWh (for the grid system) = 0.10 USD/kWh, would not lead to another assessment.

- To keep this value over the whole evaluation period seems to be justified, as with the improvement of the reliability of the public electricity grid the electricity prices are expected to increase accordingly.

(ii) Consumables

At this stage of the feasibility study it is assumed that the cost of consumables is included in the overall rates for maintenance, ref. Table 9-5.

(iii) Staff

Estimate of cost of staff for the Transmission Main and Hydropower plant is based on:

- number and category of staff required;
- unit salary cost per staff category:
  The average salary applied for Transmission Main personnel (600 USD/month), respectively Hydropower Plant personnel (700 USD/month) is based on the unit salary cost and the team composition as presented in the following two tables:

Table 9-3 Unit salary cost for Transmission Main and Hydropower Plant personnel

Staff Category	**Monthly base salary** (USD/month)	**Transport allowance** (USD/month)	**Social overhead** (22%) (USD/month)	**Total month cost per staff** (USD/month)	**Total annual cost per staff** (USD/year)
Manager	2000	100	440	2540	30480
Senior engineer	1500	100	330	1930	23160
Technician	500	100	110	710	8520
Operator	400	100	88	588	7056
Accountant	400	100	88	588	7056
Attendants	300	100	66	466	5592
Unskilled labour	200	100	44	344	4128

The average salary is based on the individual salaries and the following team composition:

Table 9-4 Cost for Transmission Main and Hydropower Plant Personnel

	Personnel for:	**Transmission Main**		**Hydropower Plant**	
Staff Category	**Monthly cost per staff** (USD/month)	**Man months** %	**Monthly staff cost** (USD/month)	**Man months** %	**Monthly staff cost** (USD/month)
Manager	2540	0.10	254	0.10	254
Senior engineer	1930	0.10	193	0.40	772
Technician	710	0.10	71		
Operator	588	0.50	294	6.00	3528
Accountant	588				
Attendants	466	0.50	233		
Unskilled labour	344	1.00	344		
	Total	2.30	1389	6.50	4554
		Average salary	604 **≈600**		701 **≈700**

(iv) Maintenance

Cost of maintenance is normatively estimated by applying average percentage figures of investment cost p.a.

As practically all investment components are newly constructed the percentage figures are set at the lower edge of the range usually applied.

Thus for this Study the following %-figures are applied:

Table 9-5 Annual maintenance cost (% of investment cost)

Investment component	**Annual maintenance cost** (% of investment cost)
Transmission, Civil works	1.5%
Hydropower plant - E/M	3.0%
Hydropower plant - Civil work	2.0%
Flow monitoring with telemetric	3.0%

(v) General cost

Cost of administration, insurances, etc. is assumed with 10% of operation cost.

9.3.4.2 Operation and Maintenance Cost for the various Alternatives.

The total amount and the annual allocation of the O&M costs estimated based on the assumptions outlined above are presented for each particular alternative in:

- Attachment B 1 to B 6 and Attachments B 11 to B 16 for the transmission main, and
- Attachment B 7 to B 10 and Attachments B 16 to B 20 for the hydropower plant.

O&M cost are kept constant throughout the economical live time. The summarized results are presented in Table 9-6.

Table 9-6 Annual Operation and Maintenance Cost

Note: O&M costs for hydropower alternatives are just incremental costs; that means just the additional cost related to the hydropower plants.

Operation and Maintenance (O&M) cost

For Steel Pipes

		A250 N STP	B250 N STP	A250 N/E STP	A400 N STP	B400 N STP	A400 N/E STP	A250 N STP HP	B250 N STP HP	A400 N STP HP	B400 N STP HP
		M USD	M USD	M USD	M USD	M USD	M USD	M USD	M USD	M USD	M USD
Annual Operating Costs											
Income from power generation								-0.089	-0.079	-0.100	-0.088
Transmission main		0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
Hydropower Plant		0.000	0.000	0.000	0.000	0.000	0.000	0.050	0.050	0.050	0.000
Administration / other cost	10.0%	0.001	0.001	0.001	0.001	0.001	0.001	-0.002	-0.001	-0.003	-0.007
Total operating costs		**0.016**	**0.016**	**0.016**	**0.016**	**0.016**	**0.016**	**0.062**	**0.063**	**0.061**	**0.007**
Annual Maintenance Costs (% of investment cost)											
Transmission, Civil works	1.5%	0.517	0.315	0.458	0.573	0.370	0.492	0.018	0.018	0.054	0.050
Hydropower plant - E/M	3.0%	0.000	0.000	0.000	0.000	0.000	0.000	0.086	0.085	0.101	0.101
Hydropower plant - Civil work	2.0%	0.000	0.000	0.000	0.000	0.000	0.000	0.116	0.066	0.123	0.133
Flow monitoring with telemetric	3.0%	0.015	0.015	0.015	0.015	0.015	0.015	0.003	0.003	0.003	0.003
Total maintenance costs		**0.532**	**0.330**	**0.473**	**0.588**	**0.385**	**0.507**	**0.223**	**0.172**	**0.282**	**0.286**
Total O&M cost		**0.548**	**0.346**	**0.489**	**0.604**	**0.400**	**0.522**	**0.286**	**0.235**	**0.343**	**0.293**

Operation and Maintenance (O&M) cost

For Glass Reinforced Pipes

		A250 N GRP	B250 N GRP	A250 N/E GRP	A400 N GRP	B400 N GRP	A400 N/E GRP	A250 N GRP HP	B250 N GRP HP	A400 N GRP HP	B400 N GRP HP
		M USD	M USD	M USD	M USD	M USD	M USD	M USD	M USD	M USD	M USD
Annual Operating Costs											
Income from power generation								-0.089	-0.079	-0.100	-0.088
Transmission main		0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
Hydropower Plant		0.000	0.000	0.000	0.000	0.000	0.000	0.050	0.050	0.050	0.050
Administration / other cost	10.0%	0.001	0.001	0.001	0.001	0.001	0.001	-0.002	-0.001	-0.003	-0.002
Total operating costs		**0.016**	**0.016**	**0.016**	**0.016**	**0.016**	**0.016**	**0.062**	**0.063**	**0.061**	**0.062**
Annual Maintenance Costs (% of investment cost)											
Transmission, Civil works	1.5%	0.464	0.279	0.329	0.511	0.328	0.363	0.005	0.007	0.043	0.010
Hydropower plant - E/M	3.0%	0.000	0.000	0.000	0.000	0.000	0.000	0.086	0.085	0.101	0.101
Hydropower plant - Civil work	2.0%	0.000	0.000	0.000	0.000	0.000	0.000	0.132	0.139	0.144	0.147
Flow monitoring with telemetric	3.0%	0.015	0.015	0.015	0.015	0.015	0.015	0.003	0.003	0.003	0.003
Total maintenance costs		**0.479**	**0.294**	**0.344**	**0.526**	**0.343**	**0.378**	**0.226**	**0.233**	**0.291**	**0.260**
Total O&M cost		**0.495**	**0.310**	**0.360**	**0.542**	**0.359**	**0.394**	**0.289**	**0.297**	**0.352**	**0.322**

9.3.5 Dynamic Prime Cost per m^3 of Water Flow

The key purpose of the calculation of “dynamic prime cost” is the comparison of different projects or project alternatives with different cost cash flows, respectively different service volumes. The “dynamic prime cost” can also be considered as a first indication for an “average cost covering price”.

According to standard practice, the calculation of ”dynamic prime cost” is based on a present value approach, according to which the present value of the cost cash flow related to a particular project alternative is to be divided by the present value of the corresponding flow of water over a determined period of evaluation.

The calculation of “dynamic prime cost” per m3 of water flow is carried out separately for

- Six (6) Transmission Alternatives incl. land cost
  Six (6) Transmission Alternatives excl. land cost,
  (each alternative separately for ST and GR pipes)
- Four (4) Power generation alternatives incl. land cost
  Four (4) Power generation alternatives excl. land cost
  (each alternative separately for ST and GR pipes)

It is calculated separately for a “capital cost component” and an “O&M cost component”. It is calculated in real terms at price level 2012 at a discount rate of 0%, which primarily considers preservation of the capital assets and alternative rates between 2% and 10%.

The calculation of dynamic prime cost takes into account:

(i) Projected annual water flows (reaching Dbaye WTP) over the evaluation period;

(ii) Initial investment cost of each alternative, corresponding reinvestment cost and residual value of the investment components still to be used at the end of the evaluation period;

(iii) O&M cost related to the particular alternative .

The present value analyses for all alternatives considered is presented in detail in Attachments B 21 to B 24.

The summarized results are presented in Table 9-7 shows the ranking of the alternatives considered (both including and excluding cost of land) by prime cost per m^3 of water at a discount rate of 5%.

Table 9-7 Dynamic Prime Cost and Ranking (including and excluding land cost)

Comparison and Ranking of Alternatives by prime cost (at a discount rate of 5%)

Ranking of Transmission Main and Hydropower Plant separate!

A: Comparison and ranking by dynamic prime cost per m3 of water - Including land cost

Pipe Material	Alternative	Present Value Water Production Mil m3	Present Value of project cost: Invest cost Mil USD	O&M cost Mil USD	Total cost Mil USD	Prime cost per m3 of water: Invest cost USD/m3	O&M cost USD/m3	Total prime cost USD/m3	Ranking of Alternatives by prime cost
Steel	A250 N	878.730	41.365	6.565	47.930	0.047	0.007	0.055	6
Steel	B250 N	878.730	25.921	4.007	29.928	0.029	0.005	0.034	2
Steel	A250 N/E	878.730	37.741	5.964	43.705	0.043	0.007	0.050	5
Steel	A400 N	1186.922	42.659	6.779	49.437	0.036	0.006	0.042	3
Steel	B400 N	1186.922	29.229	4.555	33.783	0.025	0.004	0.028	1
Steel	B400 N/E	1186.922	46.019	7.336	53.354	0.039	0.006	0.045	4
Steel	A250 N HP	878.730	9.474	1.357	10.831	0.011	0.002	0.012	1
Steel	B250 N HP	878.730	11.358	1.799	13.157	0.013	0.002	0.015	4
Steel	A400 N HP	1186.922	14.056	2.064	16.121	0.012	0.002	0.014	2
Steel	B400 N HP	1186.922	14.775	2.327	17.103	0.012	0.002	0.014	3
Glass Reinforced	A250 N	878.730	37.184	5.872	43.056	0.042	0.007	0.049	5
Glass Reinforced	B250 N	878.730	23.354	3.582	26.936	0.027	0.004	0.031	3
Glass Reinforced	A250 N/E	878.730	38.477	6.086	44.564	0.044	0.007	0.051	6
Glass Reinforced	A400 N	1186.922	26.504	4.103	30.607	0.022	0.003	0.026	1
Glass Reinforced	B400 N	1186.922	26.504	4.103	30.607	0.022	0.003	0.026	1
Glass Reinforced	B400 N/E	1186.922	35.070	5.522	40.592	0.030	0.005	0.034	4
Glass Reinforced	A250 N HP	878.730	8.854	1.254	10.109	0.010	0.001	0.012	2
Glass Reinforced	B250 N HP	878.730	9.703	1.525	11.228	0.011	0.002	0.013	4
Glass Reinforced	A400 N HP	1186.922	12.961	1.883	14.844	0.011	0.002	0.013	3
Glass Reinforced	B400 N HP	1186.922	11.610	1.803	13.413	0.010	0.002	0.011	1

Comparison and Ranking of Alternatives by prime cost (at a discount rate of 5%)

Ranking of Transmission Main and Hydropower Plant separate!

A: Comparison and ranking by dynamic prime cost per m3 of water - Excluding land cost

Pipe Material	Alternative	Present Value Water Production Mil m3	Present Value of project cost: Invest cost Mil USD	O&M cost Mil USD	Total cost Mil USD	Prime cost per m3 of water: Invest cost USD/m3	O&M cost USD/m3	Total prime cost USD/m3	Ranking of Alternatives by prime cost
Steel	A250 N	878.730	38.582	6.565	45.146	0.044	0.007	0.051	5
Steel	B250 N	878.730	23.137	4.007	27.144	0.026	0.005	0.031	2
Steel	A250 N/E	878.730	34.957	5.964	40.922	0.040	0.007	0.047	4
Steel	A400 N	1186.922	39.875	6.779	46.654	0.034	0.006	0.039	3
Steel	B400 N	1186.922	26.445	4.555	30.999	0.022	0.004	0.026	1
Steel	B400 N/E	1186.922	57.304	7.336	64.639	0.048	0.006	0.054	6
Steel	A250 N HP	878.730	9.474	1.357	10.831	0.011	0.002	0.0123	1
Steel	B250 N HP	878.730	11.358	1.799	13.157	0.013	0.002	0.0150	4
Steel	A400 N HP	1186.922	14.056	2.064	16.121	0.012	0.002	0.0136	2
Steel	B400 N HP	1186.922	14.775	2.327	17.103	0.012	0.002	0.0144	3
Glass Reinforced	A250 N	878.730	34.400	5.872	40.273	0.039	0.007	0.046	5
Glass Reinforced	B250 N	878.730	20.571	3.582	24.152	0.023	0.004	0.027	3
Glass Reinforced	A250 N/E	878.730	35.694	6.086	41.780	0.041	0.007	0.048	6
Glass Reinforced	A400 N	1186.922	23.720	4.103	27.823	0.020	0.003	0.023	1
Glass Reinforced	B400 N	1186.922	23.720	4.103	27.823	0.020	0.003	0.023	1
Glass Reinforced	B400 N/E	1186.922	32.286	5.522	37.808	0.027	0.005	0.032	4
Glass Reinforced	A250 N HP	878.730	8.854	1.254	10.109	0.010	0.001	0.0115	2
Glass Reinforced	B250 N HP	878.730	9.703	1.525	11.228	0.011	0.002	0.0128	4
Glass Reinforced	A400 N HP	1186.922	12.961	1.883	14.844	0.011	0.002	0.0125	3
Glass Reinforced	B400 N HP	1186.922	11.610	1.803	13.413	0.010	0.002	0.0113	1

The figures of Table 9-7 indicate that the prime costs per m^3 of water vary for:

- Alternatives with steel pipes between:
  - 0.055 to 0.028 USD/m^3 water (including cost of land);
  - 0.054 to 0.026 USD/m^3 water (excluding cost of land);
- Alternatives with glass reinforced pipes between:
  - 0.051 to 0.026 USD/m^3 water (including cost of land);
  - 0.048 to 0.023 USD/m^3 water (excluding cost of land);

- The incremental prime costs of power generation vary for:
  - Alternatives with steel pipes between 0.012 to 0.015 USD/m^3 water;
  - Alternatives with glass reinforced pipes between: 0.011 to 0.013 USD/m^3 water.

9.3.6 Dynamic Prime Cost per kWh of Electricity Generation

In order to demonstrate the financial viability of hydropower generation the Consultant has carried out in addition a calculation of dynamic prime cost per kWh of energy generation for all Hydropower Alternatives.

In this case the present value of the investment and O&M cost cash flow related to a particular Hydropower Alternative is related to the electricity generation over the period of evaluation.

The present value analysis is presented in detail in Attachments B25 to B26.

- The (incremental) prime costs per kWh of electricity generation vary for:
  - Alternatives with steel pipes between 0.26 to 0.38 USD/kWh;
  - Alternatives with glass reinforced pipes between: 0.25 to 0.30 USD/kWh.

These figures indicate clearly that the installation of hydropower plants for electricity generation cannot be considered feasible from the economic point of view.

10. OPERATION AND MAINTENANCE

In order to carry out “Planed, Routine and Emergency Maintenance” on the infrastructures the following conditions must be observed.

- At the start of the channel, a penstock must be installed to take the whole pipeline out of operation, which necessitates the installation of a by-pass to the Nahr el Kalb.
- On regular intervals, e.g. 1’000 m (except for the tunnel section) lockable and watertight access manhole must be provided (pipe under pressure).
- The hydropower plants must be provided either:
  - with a by-pass or
  - with a kind of turbine where the water can pass through even if the turbine / generator are not operational.
- For the surge prevention, the emergency overflow must be provided.
- Along the whole transmission channel, it is advisable to install a glass fibre line for data transmission and remote control of equipment.
- The transmission main must be equipped with drainage facilities to empty the lines in as short time as possible for inspection and maintenance purpose.

11. RECOMMODATIONS AND IMPLEMENTATION SCHEDULES

11.1 RECOMMENDATIONS

Based on the financial analysis the most economical alternative is B400 N (new single transmission pipe independent of the pipe material). Single pipelines do not provide system redundancy as outlined in the goals to be achieved by a complete rehabilitation of the transmission main, refer to Chapter 5.1. Operational advantage and additional supply security is an important factor when deciding on the rehabilitation of the transmission main, however the advantages are not reflected in the financial analysis.

The alternatives utilizing the existing and a new pipe alignment (N/E) are mostly ranked third place or below and are therefore no more further considered since in addition they do not offer any additional advantages which cannot be assessed in a financial analysis.

Recommendation 1: The Consultant recommends to implement Alternative A400, which means twin pipes with a total flow capacity of 400’000 m^3/d. Regarding the pipe material to be used the final decision, should be made at the final design stage. The question of power generation may have its impact on the pipe material to be used.
Recommendation 2: Presently, the financial analysis is showing that the installation of power generating sets is not economical. However since this units can be operated as stand-alone units they can be used as emergency generation set, an advantage that the BMLWWE should carefully analyse before making any final decision. Furthermore since the study at hand is on a very preliminary level with its usual uncertainties the Consultant recommends to include the possibility of power generation in the detail design. The present additional cost of power generation is estimated to be less than 0.015 USD/m^3 water arriving at the Dbaye WTP.
Recommendation 3: To build an impounding reservoir is a mid-term issue, but which needs to be commenced as soon as possible due to the required land expropriation. The Planning Team recommend that BMLWWE is undertaking a feasibility study in order to determine the most favourable location for a dam and its cost. This information will provide the inputs required to make a decision whether or not to peruse up the project idea.

11.2 IMPEMENTATION SCHEDULE

Conceivable approach to the transmission channel rehabilitation with a flow rate of approximate 400’000 m^3/d:

- **Phase 0**: Detail investigations and design of new transmission main. Expropriation of additional land where required for construction purpose e.g. access road, new construction of channel etc.
- **Phase A:** In this phase, during summer time all the spring water is diverted to the river course in order to carry out the rehabilitation of the channel starting at the Spring Intake to OEB dam. Additional work will be the construction of a permanent dam at OEB dam site and a new diversion chamber for Wata canal.
- **Phase B:** Construction of the section OEB dam site to Dbaye WTP.

  At this stage it must be decided whether: (a)
  - to continue with the pipe lines to the aqueduct
  - construct a new aqueduct
  - and the tunnel section will start just after the aqueduct

  or (b)
  - to start with the tunnel section at OEB dam site

Phase A and Phase B are independent of each and can be executed concurrently or phased, most probably the financial means will dictate the implementation process.

Annex 1 Average Daily Water Production of Jeita and Kashkoush Springs

Average Daily Water Production from Jeita and Kashkoush Springs (in 1000 m3/day)

		Month											
Year	Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	Jeita	500	1000	500	300	225	165	140	125	110	95	125	375
	Kashkoush	200	300	150	100	75	50	41	34	32	30	54	125
2002	Jeita	500	900	750	600	450	250	175	150	125	115	130	600
	Kashkoush	200	200	250	200	150	70	40	35	27	28	31	200
2003	Jeita	750	1000	1000	750	500	300	250	225	150	140	150	300
	Kashkoush	240	500	500	350	150	80	60	37	30	25	33	98
2004	Jeita	1000	1000	725	350	275	230	200	135	115	110	175	400
	Kashkoush	380	420	275	120	86	62	40	30	27	26	105	155
2005	Jeita	1000	1000	600	450	275	240	180	145	120	100	240	375
	Kashkoush	290	420	207	150	95	61	45	35	30	29	80	125
2006	Jeita	750	800	600	600	375	210	170	150	115	105	170	150
	Kashkoush	250	280	200	200	125	72	59	40	30	25	80	70
2007	Jeita	600	850	675	440	300	190	160	130	115	80	100	115
	Kashkoush	200	350	225	160	100	65	40	32	26	25	40	125
2008	Jeita	400	600	450	300	200	160	145	125	110	115	125	200
	Kashkoush	125	250	200	100	60	40	35	30	25	30	40	75
2009	Jeita	300	600	800	700	350	250	200	180	170	160	200	200
	Kashkoush	90	250	400	300	150	95	60	50	45	40	60	70
2010	Jeita	1000	750	600	400	250	180	125	102	85	75	67	150
	Kashkoush	300	250	200	170	100	60	50	38	35	30	28	75

Channel capacity according to Dbaye WTP	255	1000 m3/d
	2951	l/s

(light blue) = overflow of Jeita spring due to insufficient capacity of the transmission channel

(blue) = overflow of Kashkous spring because Jeita spring yield is more than capacity of transmission channel

Source of Information: BMLWWE, Dbaye WTP

Annex 2 Illustration of channel conditions

The following picture were taken by the maintenance personnel of Dbaye WTP on 26.05.11

Structural condition

Structural condition

Roots penetration

Roots penetration

Roots penetration

Roots penetration

Debris in the channel

Debris in the channel

Debris from the OEB Dam intake

Tunnel section

Annex 3 Investment Cost for Impounding Reservoirs

Name of Dam	Elevation	Dam height	Crest length	Storage	Lake surface area	Catchment area	Cost estimate in USD						Contingencies (Mio USD)	Consultancy and preliminary investigations (Mio USD)	Total Costs	Cost per m3 stored water
	m asl	m	m	MCM	1000 m2	km2	Gravity Dam	Grout Curtain	Excavation	Access road	Temporary Water bypass	Total Mio USD	20%	20%	Mio USD	USD/m3
Kfar Debbiane	720	100	440	7.3	225	91	75'996'673	5'500'000	8'218'465	315'000	5'000'000	95.0	19.0	22.8	136.8	18.7
Faitroun	1115	65	300	6.6	460	80	31'262'413	2'625'000	3'382'113	300'000	3'250'000	40.8	8.2	9.8	58.8	8.9
Boqaata	900	80	265	4.1	198	17	26'654'440	2'650'000	2'901'086	300'000	4'000'000	36.5	7.3	8.8	52.6	12.8
Baskinta	1035	100	600	6.0	158	29	132'401'385	7'500'000	14'728'230	150'000	5'000'000	159.8	32.0	38.3	230.1	38.3
Zabbougha	635	100	370	3.0	105	47	56'031'545	4'625'000	5'960'983	330'000	5'000'000	71.9	14.4	17.3	103.6	34.5
Daraiya	320	100	425	9.0	235	222	73'761'570	5'312'500	7'704'458	300'000	5'000'000	92.1	18.4	22.1	132.6	14.7

Trench exaction in rock	20	USD/m3	
Rock exaction big scale	15	USD/m3	
Access road	110'000 to 190'000	USD/km	depending on the amount of rock excavation
Concrete	80	USD/m3	
Shuttering	5	USD/m2	
Reinforcement	1	USD/kg	
Grout curtain	250	USD/m2	
Note:	Daraiya access road partly existing		

Annex 4 Preliminary EIA for Transmission Main Rehabilitation

Criteria	**Transmission main Jeita Grotto – Dbaye WTP**	Location outside of Jeita Spring Protection area Start: Jeita Spring Intake (Grotto) End: Dbaye WTP	Approximate average project coordinates: Start: N: 33° 56' 36" / E:35° 38' 30" End: N: 33° 56' 35" / E:35° 35' 31
	Data	**Advantages**	**Disadvantages**
Location of site with respect to drainage areas	The project site is located between Jeita Grotto and Dbaye town, downstream of Jeita Spring Protection Zone		
Site accessibility (access to site, state of infrastructure, ...)	Access to site: Jeita Grotto to OEB Dam: none OEB Dam to Aqueduct: none Tunnel ends: Through public roads		Need for expropriation of land for the road and construction of road. Section OEB dam - Aqueduct: Due to none availability of land (houses next to the transmission main) infringing into the flow profile of Nahr el Kalb
Land area availability	Area of land required: 1.7 ha	Between Jeita Grotto and OEB dam site, required area of (farm) land is available. OEB dam site to aqueduct, required land may be available on the backside of the houses.	Due to rugged terrain considerable excavation and backfilling works needed. Between Jeita Grotto and OEB dam site, the need for laying sewer pipes alongside of the transmission main increases the required area of land. If land is not available infringing into the flow profile of Nahr el Kalb necessitating protection wall
Geology, nature of substratum	Rocky area	Stable structures	High cost of rock excavation

Criteria	**Transmission main** **Jeita Grotto – Dbaye WTP**	Location outside of Jeita Spring Protection area Start: Jeita Spring Intake (Grotto) End: Dbaye WTP	Approximate average project coordinates: Start: N: 33° 56' 36" / E:35° 38' 30" End: N: 33° 56' 35" / E:35° 35' 31
	Data	**Advantages**	**Disadvantages**
Morphology and stability of the natural ground (slopes, landslide risk, need for retaining walls, settlement risk)	Site located at one side of the river of Nahr El Kalb. Transversal slopes: Moderate slopes at the limit of the bottom of the valley (narrow strip); Sub-surface water courses		Crossing areas prone to landslides. Surface run-off is crossing the channel alignment perpendicular. In some areas river retaining walls required. Washouts of fine material causing structure settlements if not controlled.
Hydrology (distance to and impacts on rivers, water courses, dams, water intakes,) & and hydrogeology (impacts on groundwater in the vicinity of the site)	Site is: - downstream of Jeita grotto - upstream of Makhada village Site is located at a distance of around 100m to the West of the Kashkoush wells.	The construction of the new transmission main will improve the quality of water and will reduce the water losses. With the construction of an access road along the transmission channel, the operation and maintenance will be greatly improved.	The construction of the new transmission channel together with the access road has no negative impact on the hydrology. The use of the access road should be controlled to avoid negative environmental impacts. However, in the areas where river respectively flood protection wall are required the flow profile of the Nahr el Kalb will be negatively influenced.
Availability of backfilling materials		The excavated material of adequate characteristics could be used for backfilling and road execution.	
Location of infrastructure networks (presence and distance to electrical power lines, potable water supply networks and sewer networks)		At Jeita Grotto and OEB Dam site infrastructures are available.	Along the new transmission channel alignment sewer pipes will be laid either conducting raw or treated wastewater.

Criteria	**Transmission main** **Jeita Grotto – Dbaye WTP**	Location outside of Jeita Spring Protection area Start: Jeita Spring Intake (Grotto) End: Dbaye WTP	Approximate average project coordinates: Start: N: 33° 56' 36" / E:35° 38' 30" End: N: 33° 56' 35" / E:35° 35' 31
	Data	**Advantages**	**Disadvantages**
Fauna and flora (presence of fauna and flora and impact)	Agricultural zone, fruit trees No particularly sensitive species.	No particularly sensible fauna and flora.	Elimination of agricultural zone, trees.
Distance to residential zones	The start of the transmission main is located away from the current residential zones, nearest being located at a distance of 300m to the North-East of the Grotto(Jeita Country Club). At Machada and Dbaye the channel alignment passes through and in vicinity of houses etc.	No residential constructions are currently present in the vicinity of the site.	During the construction the population and the tourists visiting the Grotto may experience some disturbances by the construction works. During the construction the population adjoining the channel alignment may experience some disturbances by the construction works. The tunnel construction will be noticeable only at the start and at the end but both entrances are located within residential areas.
Integration of the project into the landscape	Site is located partially in - agricultural zone with fruit trees - residential areas - underground Existing Harch Power Station	After construction of the new channel only the new access road will be partly visible. Architecture compatible with the landscape is necessary and feasible.	Existing Power Station needs to be refurbished since old one is no more serviceable.
Tourist Interest (presence of touristic activities in the area of site)	Jeita grotto is located at the start of the transmission channel.	The improvement of the environmental conditions will generally induce positive impacts on the tourist interest.	The work programme must take care of the tourist seasons as well as the safety of the visitors in order to avoid disturbance.

Criteria	**Transmission main** **Jeita Grotto – Dbaye WTP**	Location outside of Jeita Spring Protection area Start: Jeita Spring Intake (Grotto) End: Dbaye WTP	Approximate average project coordinates: Start: N: 33° 56' 36" / E:35° 38' 30" End: N: 33° 56' 35" / E:35° 35' 31
	Data	**Advantages**	**Disadvantages**
Presence of archaeological monuments	No archaeological monuments are identified in the area of site.	No archaeological monuments are identified in the area of site.	
Compliance with the urban planning regulations	To be checked during the stage of the Environmental Impact Assessment Study, and to be taken into consideration during detailed design stage. This mainly concerns the Power Station.		
Land Ownership (public or private)	Private ownership of land		Land expropriation required for the new transmission channel and access road.
Cost of land	Cost of land is high, but all the construction activities are within an urban planning zoning with low coefficient of built area (i.e. non-residential area, river protection area).		Budget for land expropriation is required. It is relatively high particularly that price of land in Lebanon has increased considerably during the past recent years. However it should be lower than for urban and residential zones.
Political and social attitude		Due to the factors here above and particularly the location of the transmission main away from the residential constructions, the acceptability by the population would be reasonable.	

Annex 5 List of Reports prepared by BGR for the Protection of Jeita Spring

Bundesanstalt für Geowissenschaften und Rohstoffe

Federal Institute for Geosciences and Natural Resources

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

Report No.	Title	Date Published
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 of the Jeita Spring Catchment	In progress
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	In Progress
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	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

Report No.	Title	Date Published
8	Monitoring of Spring Discharge and Surface Water Runoff in the Jeita Spring Catchment	In Progress
9	Soil Survey in the Jeita Spring Catchment	November 2011
10	Mapping of the Irrigation System in the Jeita Catchment	In Progress
11	Artificial Tracer Tests 5C - September 2011 (prepared with University of Goettingen)	February 2012
12	Stable Isotope Investigations in the Jeita Spring Catchment	In Progress
13	Micropollutant Investigations in the Jeita Spring Catchment	In Progress
14	Guideline for Gas Stations - Recommendations from the Perspective of Groundwater Resources Protection	February 2012
15	Tritium - Helium Investigations in the Jeita Spring Catchment	In Progress
16	Hazards to Groundwater and Assessment of Pollution Risk in the Jeita Spring Catchment	In Progress
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	April 2012
3	Jeita Spring Protection Project - Environmental Impact Assessment for the Proposed CDR/KfW Wastewater Scheme in the Lower Nahr el Kalb Catchment	November 2012