APAT
Agenzia per la protezione
dell'ambiente e per i servizi tecnici

ICRAM
ISTITUTO CENTRALE PER LA RICERCA
SCIENTIFICA E TECNOLOGICA APPLICATA AL MARE

ARPAL
Agenzia Regionale Protezione Ambiente Ligure

arpa
agenzia regionale prevenzione e ambiente dell'emilia-romagna

arpa sicilia
agenzia regionale per la protezione dell'ambiente

ARPAT
Agenzia regionale per la protezione ambientale della Toscana

ITALIAN ENVIRONMENTAL MISSION IN LEBANON
APAT/ARPA-ICRAM

JIEH POWER PLANT SITE

INVESTIGATION PLAN PROPOSAL

December 2006

For further information on this document please contact:

Valerio Pucci, ARPA Liguria, valerio.pucci@arpal.org
Laura D’Aprile, APAT, laura.daprile@apat.it

INDEX

INTRODUCTION

Following the fire at Jieh power plant and the subsequent demolition activities, a constant release of oil to the sea is occurring.

Before starting the necessary clean-up and recovery of the polluted area of the power plant site, the following activities should be undertaken:

- delimitation of the vertical and horizontal extension of the contaminated area;
- localization of
  - active sources of contamination (pipes, underground tanks, etc.);
  - potential migration pathways of the contaminated plume in relation to an actual and active coastal oil spill evidence; this aspect could be evaluated following an exhaustive geological and hydro geological study of the area ;
  - target of the contamination (workers of the power plant, inhabitants of the surrounding villages, marine ecosystems, terrestrial ecosystems).
- interruption of the active pathways in order to avoid further diffusion of the contamination outside the affected area;
- safe storage of demolition waste;
- application of safety measures for human health protection (i.e. it should be advised against fishing from the rocks in the area of the intake; the workers of the plant should use personal protection devices).

To complete the above described activities samples of soil (top-soil, subsoil), groundwater, should be taken and analysed. Furthermore the geological and hydro-geological information from field measures should be collected. The measured data could support the design of the appropriate remediation strategy.

The present document is aimed to give a proposal of investigation plan for the power plant area.

The authors wish to express their gratitude to the Health Science and Geology Departments at the American University of Beirut .Their thanks and appreciation are also due to Prof. Rima Habib and to Prof. Ali Haidar for their valuable help.

SITE DESCRIPTION

Power Plant

Lebanon is almost completely dependent on oil import for energy needs. The energy sector in Lebanon represents a major burden on country's economy. The electric power industry in Lebanon is one of the largest and most important industries in the country.

The total electricity nominal capacity in Lebanon is 2, 390 MW (1,965 MW of thermal capacity and 325 MW of seasonal hydro-capacity). However the maximum capacity in 2005 is 1,891 MW and the effective capacity in 2005 is 1,512 MW.

In Lebanon there are five power plant:

- Zouk (fuel oil 1% sulphur)
- Jieh (fuel oil 1% sulphur)
- Tyr (gas oil)
- Beddawi (gas oil)
- Zahrani (gas oil)

The Jieh power plant is located about 30 Km South of Beirut. It was built in '70 by Toshiba and operates with steam turbines. Further improvement of the efficiency of the plant were made by BBC. The fuel type used at Jieh is fuel oil (1% sulphur). The installed capacity of Jieh power plant is about 334 MW, while the current capacity is about 295 MW.

The average consumption of fuel of the plant from 1998 to 2001 were:

- 1998: 286 g /kWh
- 1999: 282 g /kWh
- 2000: 287 g /kWh
- 2001: 289 g /kWh

The estimated running hours per year of the power plant are 6.500. The production of MWH is about 2.047.500 with 604.012 tons of required fuel.

Jieh is the fourth power plant in Lebanon for MWH production and the second for fuel consumption. The low efficiency of the plant is mainly due to the age of the plant and the scarce O&M activities. Some studies investigated the possibility of using natural gas in power generation in order to achieve economic savings and higher efficiency levels (El Khoury, 2006).

Geological Features

<u>*Lithology*</u>

Jieh Power Plant has a prominent location to Ras Nabi Younes foreland, located along the southern coastal area (see the picture) of Lebanon as it is situated between Beirut and Saida. It is bounded in the North and South, respectively, by the Damour and Awali Rivers.

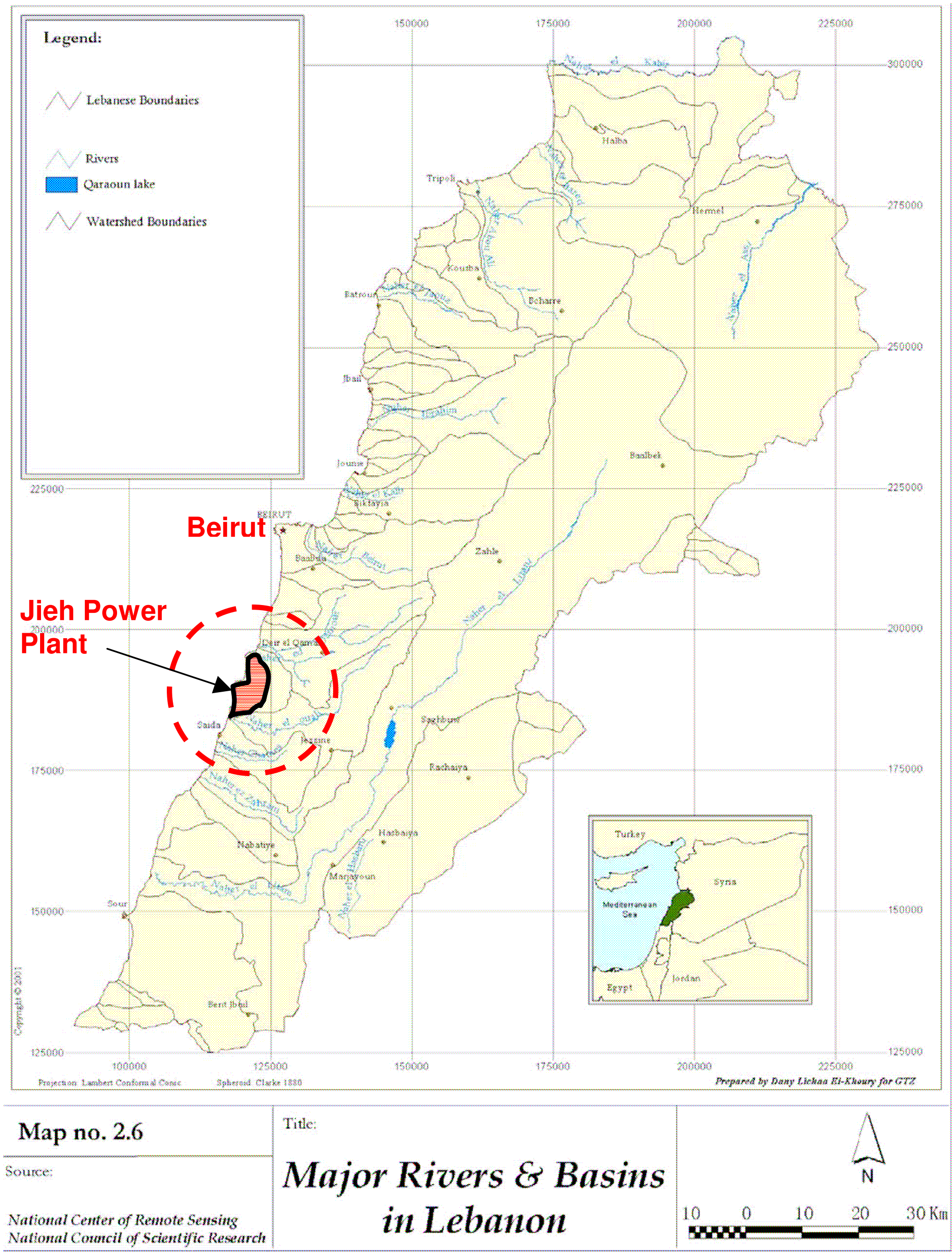


Fig. 1 : Geographic arrangement of Ras Nebi Younes head (Jieh Power Plant site) .

Within the limits of Damour – Awali area (note the above and below picture), all the outcropping formation belong to the Upper and Middle Cretaceous except for the superficial wadi deposits and coastal deposit which are Quaternary and Holocene . The Upper and Middle Cretaceous formations belong to the Cenomanian limestone (C4 – Sannine Limestone) and Senonian marl (C6 – Chekka Marl Formation). They reveal a relatively deep marine environment and clear water in the Cenomanian and slight shallowness and turbid water in the Senonian. The Upper and Middle Cretaceous deposits form the main succession in the study area. They acquire a total thickness of about 500 meters and occupy about 95% of the area.

Particularly, Ras Nebi Younes promontory (where Jieh Power Plant site occurred) is interested only by outcrops of Sannine Limestone Formation (C4), that jetting out into sea as headlands. The Formation refers generally to three carbonate members which distinguish the Cenomanian succession in Lebanon (Guerre, 1969). The members are generally composed of limestone, dolomitic limestone, marl and shaly marl with geodes of calcite, quartz and chert, and bands of chert. There are unconformable relations between the members, the lithology changes suddenly at the boundaries. The members may be unified by the carbonate and siliceous matter. The limestone and dolomitic limestone beds are very hard, and display conchoidal fractures. Extensive joints and random fissures at various level can be observed to be present in high density. The fracture are either open or filled with soil or calcite/ or quartz veins. The solution action along the fractures turned the terrain surface rugged.

The Sannine Limestone Formation outcrops almost everywhere in the area and along most of the coastal ribbon (about 80% with a total thickness of 325 m).

Quaternary deposits can be extensively encountered along the coast, valleys and river mouths areas, especially those of Damour and Awali Rivers. Such deposits form the plains of Jieh and Aalman . They vary in thickness from few centimetres up to several meters and may sometimes reach up to 30 meters in Jieh.

The shore deposits are fluviomarine to marine origin: an example of that is the coastal plain that extends from Ras es Saadiyat to Ras Nebi Younes. The sand deposits along the shores of Rmayleh, Nebi Younes have been reworked by wind to sand dunes (the most conspicuous are those of the Jieh coast).

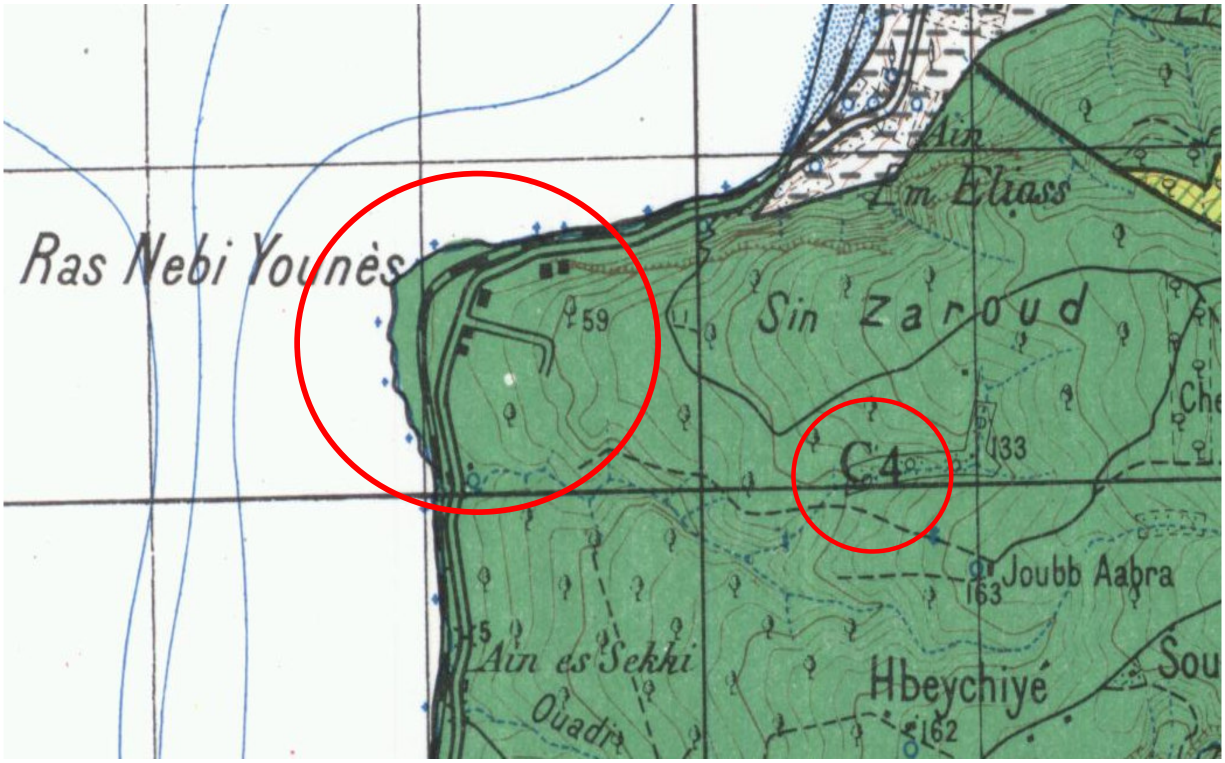


Fig. 2 : Geological arrangement of Ras Nebi Younes head within Damour – Awali area. Power plant site and geological formation are highlighted (from Saida sheet, scale 1:50.000 by Dubertret, 1949)

Geomorphology

Generally within Damour – Awali are present three distinct morphological structures: a discontinuous coastal plain, a sloping terrain east of it, followed by a tilted plateau and narrow valley across the plateau.

The tilted plateau is geomorphic real cuesta as it consists of a gently sloping succession of limestone beds. Parts of the cuesta, merge into the sea in some localities, forming escarpments and heads as Ras Nebi Younes with a slope gradient of 11°. The drainage lines across the cuesta are separated by broad flat divides indicating a young stage in the course of the geomorphologic cycle of the area.

All the valley along the coastal ribbon, except for the Damour and Awali valleys, remain dry for more than 10 months/year. They running from east to west in the direction of the dip slope. Immediately at South of Ras Nebi Younes foreland notes one of these (Ain Quansa). A few other valleys cross this region from north to south along the direction of strike, running along fault lines, thus are subsequent types. Some valleys are deep and appear to be well developed, others appear to be still in their initial stage. In general the valleys are V-shaped and still within the young stage of evolution. The majority of the valleys composed of a main drainage line with short tributaries. This may be related to the nature of the rock in the area, as it is very permeable, as being highly fractured and karstified. Karst features are very well pronounced. They reflect the product of the differential intensive chemical weathering of heavily fractured limestone of the Jurassic and Cretaceous system (Abu el Enin, 1973). The Damour – Awali area is mainly composed of the Cenomanian Sannine Limestone Formation. The karst features are manifested by lapis which are varieties of pits and cylindrical holes (with a diameter of 5 – 25 cm and depth up to 8 cm) and furrows. Other large scale erosive features like caves are most probably related to karstification in conjunction with a specific system of fracturing (fault and joint). Recently an underground cave associated with an underground river was found.

Terraces mark former water level and indicate an instability of the crust. They are partly preserved in almost all localities in Damour – Awali area. These marine terraces were originally at sea coast like beaches or wave cut benches, and by eustatism became relatively higher than the present sea level (Thornbury, 1976). Most of the marine terraces are pertinent to the Pleistocene uplift (Dubertret, 1949). Such terraces are encountered in many localities between Damour and Awali Rivers. They are at different elevations from the recent sea level. They can be arranged and correlated on this basis, into low, middle, and high terraces. The low terraces range in elevation from 5 to 20 m a.s.l.. They are relatively narrow strips bounded by gentle break of slope representing a minor stage of instability combined and followed by a stage of erosion. They appear in the field in series as if along a contour line. The lower terraces, due to their low position, are prone to the erosive action of waves. The terraces are exposed at Ain es Sekke, South of the Electricity Plant of Jieh (as a fossiliferous – Murex, Strombus, Tritonidea - pebbly deposits), and the same site of General Plant is affected. Furthermore notes that Power Plant of Jieh (Ras Nebi Younes head) is today located on a new and planar surface shape obtained by backfilling materials (about 2 meters thick) and remodelled covers .

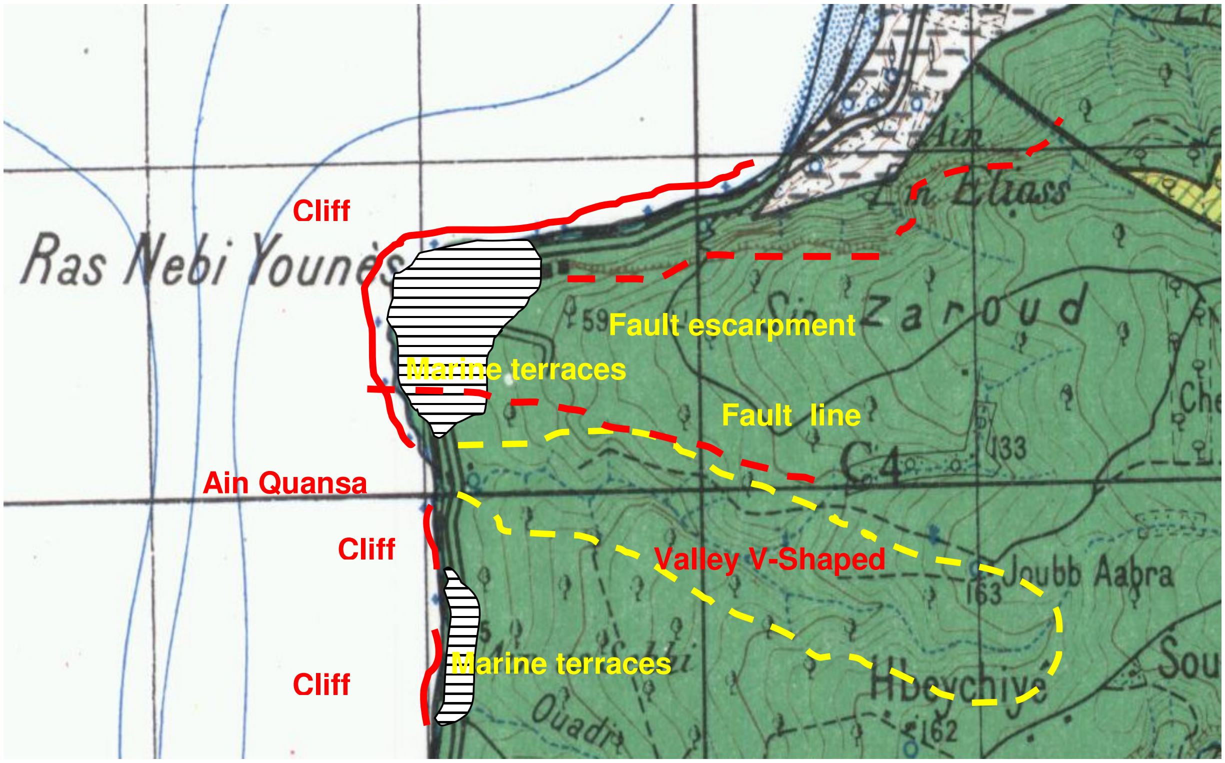


Fig. 3 : Geomorphologic arrangement of Ras Nebi Younes head (Jieh Power Plant site) . Morphological types are highlighted (from Abdul Rahaman M. Arkadan, 1991)

Escarpments are landforms produced in various ways as faulting and/or erosion and encountered at seaside or inland. Sea cliff often mark the land – sea interface. At the base of the sea cliff there is usually a flat rock extension called wave-cut benches. Features resulting from erosion of inclined beds are classified according to their dip angle into homocline along the cuesta at Ras Nebi Younes. Fault escarpment is also observed in Ras Nebi Younes originated by the Jieh fault, modified by man and became a composite escarpment. Moreover another fault line is observed (with a NW –SE course on map) crosses Ras Nebi Younes promontory (A. Arkadan, 1991).

Ras Nebi Younes ‘ shore has characterized to protrusion of thick limestone beds jutting out into the sea. The headland rock is attributed to the Sannine Formation and have gentle slope towards the sea. Today its shoreline is reinforced by an artificial reef.

Structure Analysis

The rock outcrops of Lebanon are greatly affected by the Upper Eocene and Oligocene Alpine Orogeny which gave rise to the development of complicated systems of folds and faults (Beydoun, 1988). The structure of Lebanon, Anti Lebanon mountains and the Bekaa

Plain are the major products of the orogeny (Beydoun, 1988). The general bearing of the main geologic structures lies mainly within the NE – SW. Relatively, a few less important structures have an E – W trend. Damour – Awali area is structurally located on the western middle section of Mount Lebanon. It is influenced by the folds and faults which are related to the major structures of the west of the Bekaa Graben. The structural features presumably have relevancy to the Miocene – Quaternary tectonism (Beydoun, 1988). Faulting is widespread throughout the area, and faults have an approximate distinct general E-W trend, except only one major fault with a N – S bearing. The faults are almost invariably normal , and may acquire a strike-slip component. The normal faults are high angled as the dip of the fault planes is > 45° to subvertical. Faults occurring on the slope of Ras Nebi Younes (Jieh Power plant site) in Sannine Limestone Formation .

The numerous joint systems in the various parts of the Sannine Limestone Formation exposures can be traced for only short distances (3-10 m). They are difficult to describe except that their direction is uniform. They were severely attacked by physical and chemical weathering processes or being masked by soil vegetation. Generally the joint planes are subvertical to vertical, with bearing ranges NE and NW, with strikes N80°W and N30°E and spacing ranging from tight to wide opened. Wide joints are always filled up with lateritic soil . Vertical and subvertical sets of joints are more clearly visible near the Jieh Power plant with spacing between 15-40 cm . Beds in the study area have a general dip slope direction E – W. Local deviation attitude may be due to faulting . The maximum degree of a dip measured reaches up to 20° in the western part near Jieh with a strike magnitudes of N10°E, N25°E. The magnitude decrease gradually eastward to a minimum of 10°. Horizontal beds or beds with very gentle dip are encountered in many localities.

Structure Analysis on site

In November 2006 a specific structure analysis has occurred on Jieh powerhouse site and its bombed tanks area by technicians of Italian Ministry of Environment . Aim of the study is a first valuation of the bedrock insulating properties by leaching from contaminated soil, subsoil and waste.

Observed data field are represented by

- a rocks classification and identification by UNI EN ISO 14689-1(**Annex 1**)
- a geomechanical rocks classification by Bieniawski RMR SYSTEM (Rock Mass Rating system) (**Annex 2**)
- Layer and joint Dip direction, Strike and Dip Angle (**Annex 3**)

- Structural Geological Analysis (**Annex 4**)

and attached to present work .

The data were collected from ten subsites (nominated STOP1, STOP 2, STOP 3 and so on) inside the named area as shown below.

Fig. 4 : Rock outcrops sites for geological structure analysis to Jieh Power Plant (photo by Google Earth , November 2006)

So far, the following outcomes have been carried out :

- rocks classification and identification by specification UNI ISO 14689-1 has highlighted and confirmed that is present a good persistence of joints family with weathering occurs in fracture plane with evidence of karst phenomenon and high alteration in fracture's planes with soil transformation (lateritic fill material);
- rocks classification and identification by Rock Mass Rating system has highlighted a high mechanical strength of the limestone (Sannine' Formation), a low rock quality

design, narrow discontinuities spacing of two family joints, high persistence of joints and bedding (regional diffusion), a strong alteration into joint plane with evidence of cavernous joint , a not good geomechanical overhead quality of Sannine limestone Formation at Ras Nabi Younes cuesta, a specific site attitude of Sannine Limestone sequence .

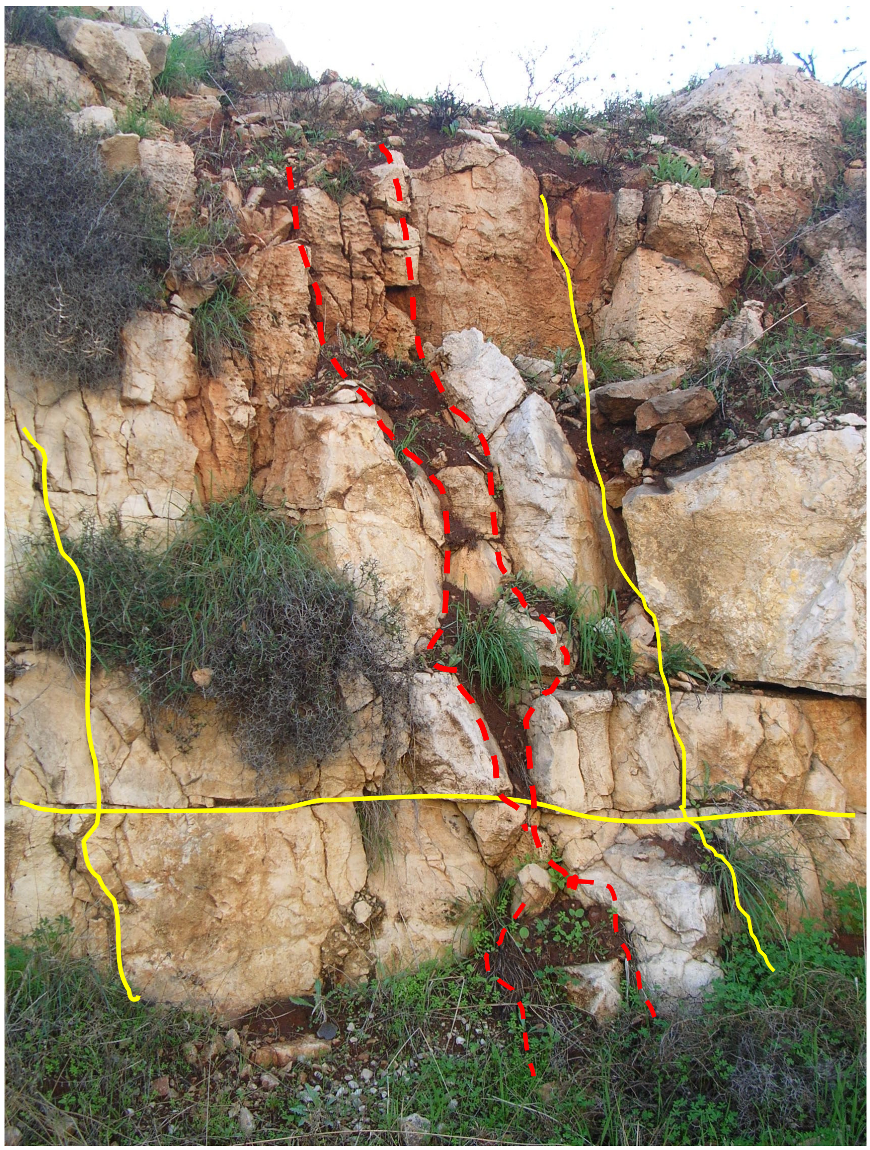


Fig. 5 : Karstified limestone beds. Notes layering in landslide attitude, one family of joint with fracture's plane deep weathering affect and a likely fault plane (STOP 1)

Fig. 6 : Karstified limestone beds. Notes inclinated layering in landslide attitude ("traverpoggio"), one family of joint with narrow persistance and a likely fault plane. The hanging over wall is fault fracture plane affect, too (STOP 4)

Fig. 7 : High fractured limestone beds. Notes layering in landslide attitude ("traverpoggio"), two families of joint with very narrow persistence and cavities in fracture's plane (STOP 5)

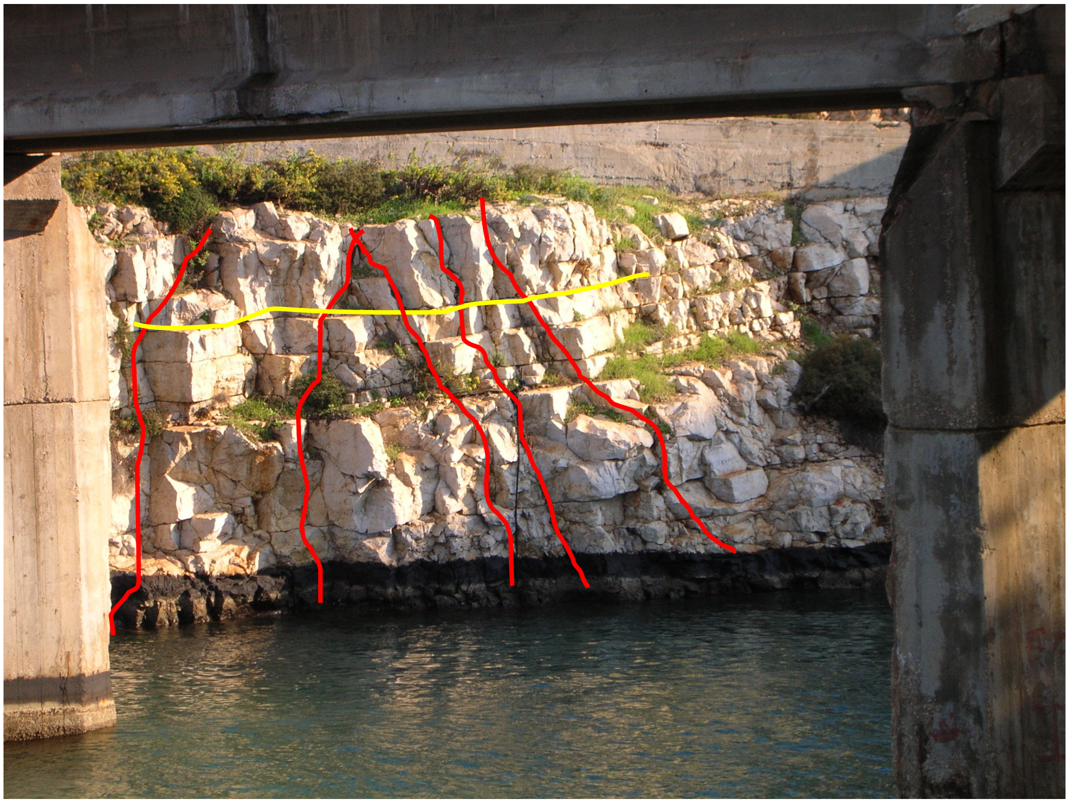


Fig. 8 : Sannine Limestone beds. Notes inclinated layering in landslide attitude ("traverpoggio"), two families of joint with and columnar blocks (STOP 7)

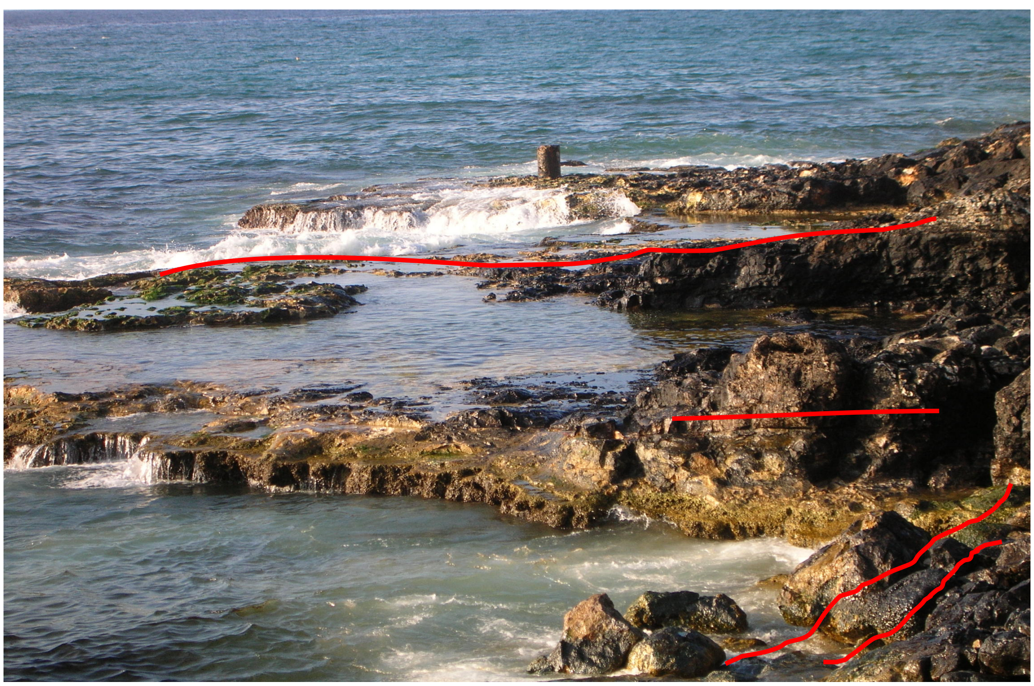


Fig. 9 : Sannine Limestone dipping beds. Notes gentle inclinated layering and family of joints (STOP 8)

Concerning to the specific structural analysis see the structural data field plot in **Annex 4** by GeoDbase software .

On the area of Jieh Power plant site the following outcomes have been carried out by a structural data computing with Equiangular Equatorial Projection - Wulff grid and Rosette diagram :

- The medium layers attitude has a W-NW Dip direction, about 290°, a medium Dip Angle of 10° and a likely N –S bearing (see plotting in **Annex 4**);
- Family joints attitude is generally widespread around a S-SW (J1) and NE - SE(J2) Dip direction with a medium Dip Angle about 80° (see plotting in **Annex 4**);
- Particularly, family joints J1 attitude has a 240° medium Dip direction with a medium Dip angle of 85° and a -30°NW bearing (see plotting in **Annex 4**);
- Particularly, family joints J2 deposition has a 170° medium Dip direction with a medium Dip angle of 80° and a 80° bearing (see plotting in **Annex 4**).

These data confirm outcomes from scientific literature about the study area and demonstrate, if considered together at all observed field data, a bad insulating property of bedrock (with a considerable permeability by karst phenomenon, high alteration in fracture's planes, a very good persistence and a narrow spacing of fractured system) by leaching from contaminated soil, subsoil and waste. Moreover structure analysis shows a likely pollutant course toward the sea, favoured by spatial distribution of bedding and joints (J1) Dip direction. Percolation toward the sea happens trough joints J1 plane, at the first, and then by bedding in landslide attitude. For site structural layout see the following pictures.

Fig. 10 : Spatial distribution of layer dip direction of rock outcrops, toward to the sea with a dip angle about 10°, to Jieh Power Plant (photo by Google Earth , November 2006)

Fig. 11 : Spatial distribution of joint dip direction (family joints J1) toward to the sea, to Jieh Power Plant. Dip angle is subvertical. (photo by Google Earth , November 2006)

Fig. 12 : Spatial distribution of joint dip direction (family joints J2) to Jieh Power Plant. Subvertical dip angle contributes at groundwater circulation and eluate absorption, although the joint attitude is unfavourable for transports pollutant toward the sea (photo by Google Earth , November 2006)

Hydrogeological Features

Sannine Limestone aquifer is equivalent to Sannine Limestone Formation and considered as the most important aquifer in the study area. It is stratigraphically a confined aquifer as underlain by the Hammana Marl aquiclude and overlain by the Chekka marl aquiclude. The aquifer is classified into an upper and lower aquifer members separated by one marly aquiclude. Only the aquifer upper member is outcropping in the area and always referred to as the Sannine Limestone aquifer. The important porosity of this aquifer is represented by fracturing (secondary porosity) which is enhanced by karstification. The tectonic structure has a general control on the hydrocharacteristics of the aquifer. Fractures play an important role in recharging, storing, transmission and discharging of groundwater. It can be said that the potential capacity of the aquifer depend on the dimensions of fractures. Differences in discharge of springs and wells are pertinent to structural differences. Marine springs location show that are associated with faulting or karst phenomenon . The study area shows also twenty two land springs (perennial type) with a discharge magnitude between the fourth and sixth order of Meinzer classification, one of these is located along the coast (altitude 10 m a.s.l.) to Ain Quansa (500 metres far from Jieh Power Plant) and characterized by an average discharge of 2 l/s. The spring issuing from the Sannine Limestone aquifer are of the unconfined type (classification of Guerre, 1969). Some marine springs issuing close to the seashore such as in Ain es Sekke (about 1,5 Km at South to Jieh Power Plant site) are also related to this type. Location of such springs is controlled by structural features such as flexures, faults, joints and fissures. Springs related to the semiconfined aquifer are very frequent and are related to karstic aquifers (Guerre, 1969).

The highest discharge rate from wells drilled in the Sannine Limestone Aquifer is about 15 l/s. This rate of discharge may be a provisional measure to avoid contamination of groundwater by seawater. However the average discharge rate is 8,7 l/s .

The general groundwater flow is represented by flow lines oriented towards the west and Northwest. This is attributed to the configuration of the water table is or to the direction of the hydraulic gradient which is generally oriented from East to West. By measurement taken in 1989 – 1990, notes that elevation a.s.l. of the water table in Ras Nebi Younes, is lower than 0,5 metres a.s.l. (A. Arkadan, 1991).

Where the percentage of fracturing is high the flowing groundwater needs a lower water head to allow through and consequently a flatter hydraulic gradient. Such conditions are present especially in Jieh Electric Power Station site. The permeability and transmissibility in this area are relatively higher (a permeability likely about 10^{-1} - 10^{-2} m/s).

Groundwater in coastal aquifers is subject to saline contamination where seawater comes in contact with freshwater. The contact plane between the saline water and the fresh groundwater is referred to as a mobile interface. Under the condition of hydrostatic equilibrium, the freshwater under coastal assume a wedge or a lens shape, floating on the saltwater. The position of the interface between fresh and saline water is function of the height of the fresh water above sea level , the density of the seawater and existing coastal pumping activities. The first attempt to study the sea water encroachment and depth and geometry of the fresh/seawater interface, along the coastal zone of Lebanon was in 1965, by the Yugoslav team (Geofizika). The team undertook geophysical investigation through the application of geoelectrical resistivity soundings along the southern coastal zone of Lebanon which comprehended all Damour – Awali area . Many boreholes were drilled along straight lines, approximately East-West traverses to measure the resistivity of rocks at different depths. Geoelectrical resistivity sounding results show a fresh/seawater interface, on the interested area, as in the below depiction.

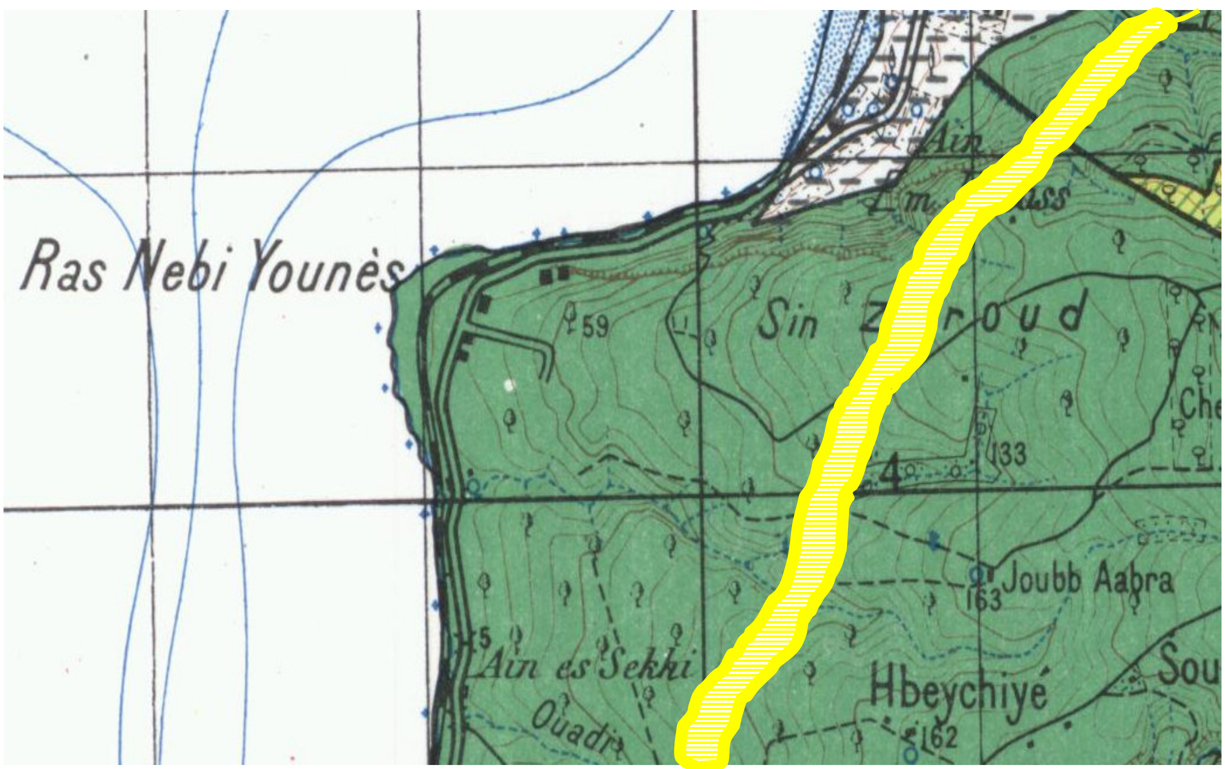


Fig. 13 : Course of fresh/seawater interface in proximity to Ras Nebi Younes head (Jieh Power Plant site) by Geofizika survey, 1965 (from A. Arkadan, 1991)

The illustration describes the configuration of the interface as it extends inland. Notably the contour line (contour line is -150 m in depth) run approximately parallel and at a distance between 500 and 1500 metres from the shoreline. These results are some what in agreement with results obtained in 1989 by the chemical analysis of sample collected from the pumped wells (A. Arkadan, 1991).

Contamination Sources

The potential contamination sources at Jieh power plant are represented by:

- damaged pipelines;
- underground tanks
- bombed oil tanks
- waste
- contaminated soil

Potential Migration Pathways

The potential migration pathways of contamination (oil) can be represented by:

- leaching from contaminated soil and subsoil to groundwater and/or seawater;
- leaching from waste to soil and subsoil;
- leaching from damaged pipelines and underground tanks to subsoil and/or groundwater/seawater;
- migration of the oil contained in the bombed tanks from the fractured bedrock to the sea;
- migration of the contaminant dissolved in groundwater to the seawater;
- wind transportation of contaminated surface soil and dusts;
- vapour migration from soil, subsoil and groundwater to air (only for volatile substances)

Contamination Targets

Potential contamination targets are:

- workers of the power plant;
- inhabitants of the surrounding villages;
- marine ecosystems;
- terrestrial ecosystems.

It is worth mentioning that the contamination of sea water at the intake of the power plant can negatively affect the performance of its cooling systems.

PROPOSED INVESTIGATION PLAN

Contaminants

According to the information collected on the power plant and on the personal experience of the authors of the present document, the presence of the following contaminants in the environmental matrixes (soil, subsoil, groundwater) should be investigated:

ORGANICS

- Benzene;
- Toluene;
- Xilene;
- Ethilbenzene;
- Stirene;
- PAHs;
- HC<12
- HC>12
- PCBs
- PCDDs/PCDFs (only on top-soil samples)

INORGANICS

- Arsenic
- Vanadium
- Lead
- Mercury
- Copper
- Chromium (Total)
- Chromium VI
- Zinc
- Cobalt
- Nickel

Soil

Given the total extension of the potentially contaminated area in the tank park, at least 10 sampling points should be selected, basing on the information on the potential sources of contamination. The location of the sampling points should be selected according to a systematic grid (50x50 m).

At each sampling point (random sampling within blocks) a number of samples that could represent all the geological and artificial layers should be taken. As en example, the following intervals can be indicated and sampled:

- 0-20 cm (top soil) (first medium representative sample collect)
- 20 cm – 100 cm (surface soil) (second medium representative sample collect)
- 100 cm –bedrock bottom (subsoil) (third medium representative sample collect)

Soil borings should reach the first uncontaminated rocky layer.

For soil sampling procedures and a correct medium representative sample formation see US EPA Standard Operative Procedures – Soil Sampling, Response Team , 2000.

Waste

In order to guarantee the representativeness of the waste sample the possibility of excavating trenches (with trench size 3m X 4m and 3 m deep approximately) in the waste pile where surface evidence occurring. The location of the excavate points (at least 2 sampling points should be selected) according to a systematic grid (25x25m). Samples should be collected in according to UNI 10802 standard from the excavated materials heap and classified as hazardous and/or non hazardous waste for the management of the final disposal.

It should be pointed out that, according to the latest EU indications, all the waste containing HC in a certain amount (more than 1000 ppm) should be classified as hazardous waste.

Groundwater

In order to assess the hydrogeological features of the area, at least 3 piezometers (4” diameter) should be constructed around at the bombed tanks site. Each piezometer should be at least 8 m long with the screened length 6 m long, beginning from the bottom of the borehole. Furthermore two bedrock permeability measures by Lugeon test must be carry out in rocky substratum below of bombed area (tanks site), at least 1,5 m in depth inside of body rock. Lugeon tests preferably must be located in central area and in the neighbourhood of oil spill point.

Sampling Recommendations

Soil and waste

During the sampling the following recommendations should be taken into account:

- minimize the possibility of cross-contamination by using disposable sampling equipment that is certified as clean for each sample collected. If disposable sampling tools are not available, specify the cleaning procedures used. Wear clean sampling gloves at each sampling point. When using a split-spoon or similar sampler, wash it with a detergent solution, rinse, and dry it before each use.
- Collect samples from split-spoon samplers or a soil sample liners immediately after opening the sampler, minimizing losses due to volatilization.
- Collect samples using coring devices and either put the "cored" directly into containers provided by the analytical laboratory (verify that the laboratory has pre-weighed these containers) or place the sealed coring device containing the soil in a cooler containing ice/coolants. The correct volume of sample to use in the coring device is established by weighing a similar sample before coring the analytical sample. Do not weigh analytical sample into the sample container because doing so can undesirably aerate the soil sample. The holding time is 14 days for soil samples preserved by methanol or frozen in an approved coring device. Samples in a coring device that is not frozen must be extracted within seven days. Do not retain soil previously used for soil screening or soil classification for analytical samples.
- collect total petroleum hydrocarbons (TPH) and volatile organic compounds (VOC) according to the US Environmental Protection Agency (EPA) Method 5035 (per EPA SW-846). This method requires the use of methanol as a preservative for most sampling. When methanol is used as the preservative, HC and VOC results can be obtained from the same sample. Approximately 25 grams of soil is commonly preserved with 25 ml of methanol in a tared 60- ml vial. A maximum of 35 grams of soil is allowed to enable a 1:1 ratio of soil to extraction solvent in the sample container. Other sample sizes, such as 5 grams of soil and 5 ml of methanol in a 40 ml VOC vial, can be utilized if the 1: 1 ratio is maintained. An approved sampler can also be utilized to hold the samples for 7 days from the date of sampling when held at 4^{o} Celsius, or 14 days from the date of collection when frozen below -12^{o} Celsius

before methanol preservation following these protocols. Collection of at least three vials per sample is recommended for the laboratory to have enough containers for dilutions, and screening analysis. A dry weight vial without methanol preservation is also required for every sample. Clean the vial threads to assure a good seal with the cap provided.

- Label all vials, place in a covered cooler with ice, and transport to the laboratory for analysis. Include a container of water for verifying that sample temperature is stable at approximately four degrees C. The labels should indicate:
  a. Type of analysis;
  b. Name of facility;
  c. Monitoring point identification;
  d. Name of person collecting sample;
  e. Time and date the sample was collected; and
  f. Note whether a preservative was added.
- Samples must be collected, transported, and delivered under chain of custody.
- Samples not transported or analyzed within the accepted holding time will be considered invalid.

Groundwater

Particular care will be exercised to avoid the following common ways in which cross contamination or background contamination may compromise ground water samples:

- improper storage or transportation of equipment;
- contaminating the equipment or sample bottles on site by setting them on or near potential contamination sources such as uncovered ground, a contaminated vehicle, or vehicle exhaust;
- handling bottles or equipment with dirty hands or gloves;
- inadequate cleaning of well purging or sampling devices;
- Special care will be exercised to prevent cross-contamination of sampling equipment, sampling bottles, or anything else that could potentially compromise the integrity of samples. Field personnel will work under the assumption that contamination exists in land surface soil and vegetation near sampling points, wash water, etc. Therefore, exposure to these media will be minimized by taking at least the following precautions:

- minimizing the amount of rinse water left on washed materials
- minimizing the time sampling containers are exposed to airborne dust or volatile contaminants in ambient air
- placing equipment on clean, ground covering materials instead of on the land surface
- Clean gloves made of appropriately inert material will be worn by all field crew. Gloves will be kept clean while handling sampling-related materials. The gloves will be replaced by a new pair when soiled and between each sampling site.

Field methods for groundwater

Specific conductance, pH, temperature, turbidity and dissolved oxygen **[**redox potential**]** will be measured in the field by specific probe immediately before sample collection. Measurement conditions and the steady-state value for each field water-quality parameter will be noted .

Specific procedural details for measurement of individual field water quality parameters are specified below. General care, maintenance, calibration procedures, and operation of each measurement device will also follow manufacturers specifications as detailed in the instruction/owner's manual for each device.

Only wells that were properly installed and developed at least two weeks in advance will be sampled. Before a well is sampled for the dissolved phase, it will be evacuated to ensure that samples contain fresh formation water. While the well is being purged, water quality parameters and the quantity of water evacuated will be recorded on a Well Purging - Field Water Quality Measurements Form. If he turbidity during purging cannot be reduced to 5 Nephelometric turbidity units (NTU) or less, additional well development will commence to reduce turbidity to a level acceptable for sampling. After the monitoring well has been developed to yield water of acceptable turbidity, at a rate indicating good hydraulic communication with the targeted water-yielding zone, a period of two weeks will be allowed to pass before purging and sampling commences. If well completion follows initial well development, the two week minimum waiting period will begin when well completion is finished. During development and evacuation, no water will be added to the well. One or more of the following techniques will be used for well development: mechanical surging with a surge block, cycles of bailing followed by intervals of well recovery, and pumping followed by intervals of well recovery. Air jetting will not be used.

Care will be taken to avoid any significant amount of cascading or turbulence in the well.

Wells with extremely slow recharge rates due to tight formation materials, may require alternate purging and sampling methods. If normal purging is clearly impractical, the well will be pumped to near dryness and allowed to partially recover (a reasonable amount of time) two times before sampling. Sampling will then commence as soon as possible after the third evacuation. The maximum recommended limit is two hours, however, data for sensitive parameters may be considered questionable unless sampling occurs very soon after purging .Purging will be conducted in a manner that, to the extent practical, removes all the "old" water in the well so it is replaced by fresh ground water from outside the well installation.

1. The well will be purged by withdrawing water from within two feet of the top of the water column.
2. Repeated vertical adjustment of the purging equipment intake may be necessary as the water level drops.
3. Positive displacement submersible bladder pumps will be used for both purging and sampling.
4. Sampling will immediately follow purging.
5. Well evacuation will be continuous between purging and sampling.
6. The same pump will be used for both purging and sampling at each individual well.
7. Neither air lift pumps or any other method device that significantly aerates well water or otherwise creates significant turbulence will be used at any time during the purging or sampling of wells.

Field water quality parameters will be measured for stabilization after each water-column volume is purged. One water-column volume is defined here as equal to the volume of a cylinder with a height (h) equal to that of the Static Water Column inside the well and a diameter (d) equal to the diameter of the well casing (Volume = $\pi(d/2)^2h$). The following target criteria for three consecutive measurements (one water-column volume apart) will be used to demonstrate stabilization:

- pH +/- 0.04 units
- temperature +/- 0.1 degrees Celsius
- specific conductance (temperature corrected EC) +/- 5%
- dissolved oxygen +/-0.5 mg/L **[**redox potential +/-20 mV**]**
- turbidity: less than or equal to 5 NTU **(**0 NTU may be acceptable when not sampling for sensitive parameters such as trace metals or trace organics.

Samples for laboratory analysis will be collected only after a minimum of three water-column volumes have been purged and stabilization of field water-quality parameters has been demonstrated by meeting the target criteria defined in the preceding paragraph. If field parameters do not stabilize after approximately five water-column volumes, then field staff will check operator procedures, equipment functioning and well construction information for potential problems. In particular, field staff will re-evaluate whether or not water is being withdrawn from the appropriate depth to effectively evacuate the well.

If all the checks produce no new insight, a decision might be made to collect samples after five or more water-column volumes have been purged even if field measurements have not stabilized. Before authorizing the laboratory to analyze samples, the meaningfulness and value of completing laboratory analysis of the sampling suite will be evaluated by reviewing the results of field measurements, well construction data, site hydrogeology, etc. Where such data is presented, it will be clearly documented that stabilization was not achieved; at a minimum, this fact will be reported in the Sampling and Analysis Report.

Drums will be located at each of the wells to collect water removed from the wells during development or evacuation. No significant amount of well water will be emptied or discharged onto the ground surface unless analytical data are available and indicate that the water is not contaminated. After water analyses become available, and appropriate disposal alternatives are evaluated, the water will be disposed of in an environmentally safe manner that does not conflict with any applicable rules.

A two-inch submersible bladder pump will be used as the default device for sample collection. If well recovery is so slow that a satisfactory water column height (for normal pump operation) is not reached in a reasonable amount of time, a zero submergence bladder pump **[**Teflon® bailer**]** will be used for sample collection. The Sampling Report will show what type of pump **[**or bailer**]** was used to sample each well. If any device other than the one described above is used, it will be reported as a protocol exception.

Following purging, the water level will be checked with a clean measurement device (cleaned according to the decontamination procedures above). The pump intake will be adjusted, if necessary, so it is set inside the screened interval at approximately two feet below the water surface inside the well to collect samples. The water level measurement will be compared to the static water level and the pump intake setting. This comparison will be used to verify that drawdown is minimal at the purge rate and that the pump intake is located approximately two feet below the top of the water column. In very slowly recharging wells, the pump intake will be set approximately two feet from the bottom of the well to minimize aeration problems.

The same pump will be used for sampling as was used for purging. Pumping will be continuous and sampling will immediately follow purging. If pumping is not continuous it will be noted on the Sampling Report. The sample collection pumping rate will be less than or equal to the purging rate.

Any final rinse water remaining in any portion of the sampling pump or discharge lines will be completely purged with fresh well water before filling sampling containers. To insure this, at least two tubing-volumes will be purged from discharge lines before sample collection begins.

Some sample containers will be filled with sample water that has been filtered in the field (for determination of Cr VI, trace metals and alkalinity) . Sample filtration will be completed as follows:

1. The filter holder and new filter will be thoroughly pre-rinsed with laboratory-controlled deionized or distilled water before use.
2. The new filters will be flushed with fresh sample water a minimum of two minutes before collecting samples.
3. The filter will be connected directly to the well sampling pump discharge line using positive pressure to force the sample through the filter.
4. From the filter, the flow will be routed directly into the sample collection container.
5. A **[**0.45**]** micron pore size filter will be used.
6. The flow rate will not exceed 500 ml per minute.
7. Agitation and aeration of the sample will be minimized.
8. Teflon® tubing will be used for the pump and filter discharge lines.

Sample blanks, will be collected to detect background or method contamination. Replicate samples [and split samples] will be collected to evaluate variability in analytical methods. These samples will be collected at sampling points suspected to have relatively higher levels of contamination to provide meaningful information for blank or duplicate sample evaluation.

CONCLUSIVE REMARKS

On the basis of this site specific study relate to control the level pollution off and on/in Jieh Power Plant, with a constant release of oil toward the sea, the following outcomes have been carried out :

- Geological, geomorphologic, hydrogeological, structure analysis studies demonstrate a bad insulating property of bedrock (with a considerable permeability by karst phenomenon, high alteration in fracture's planes, a very good persistence and a narrow spacing of fractured system) by leaching from contaminated soil, subsoil and waste. Moreover structure analysis shows a likely pollutant course toward the sea. Oil spill point can be likely related to an observed fault line or a little marine spring emerging ;
- Consequently are identified and proposed site specific investigation, based on international recommendation, to determine :

- delimitation of the vertical and horizontal extension of the contaminated area;
- localization of active sources of contamination (pipes, underground tanks, etc.);
- localization of potential migration pathways of the contaminated plume in relation to an actual and active coastal oil spill evidence;
- target of the contamination (workers of the power plant, inhabitants of the surrounding villages, marine ecosystems, terrestrial ecosystems).
- interruption of the active pathways in order to avoid further diffusion of the contamination outside the affected area;
- application of safety measures for human health protection (i.e. it should be advised against fishing from the rocks in the area of the intake; the workers of the plant should use personal protection devices);
- a better knowledge of geological and hydro-geological information from collected field measures;
- activities samples of soil (top-soil, subsoil), groundwater.

We underline, in short, that these site specific investigations are absolutely necessary to support the design of the appropriate remediation strategy or to carry out a site specific hazard analysis with possible making safe measures .

REFERENCES

- El Khouri P.T. (2006): “The use of natural gas for power generation in Lebanon: analysis of the proposed solution for the Beddawi & Zaharani power plants”, Project, American University of Beirut, June 2006;

- Environmental Status in Lebanon: National Action Plan;

- Petroleum Remediation Program, Minnesota Pollution Control Agency, April 2005

- RCRA Waste Sampling Draft Technical Guidance, EPA August 2002;

- Ground Water Sampling Guidance, Pollution Control Agency, November 2006;

- The Geology, Geomorphology and hydrogeology of the Damour – Awali Area – Coastal and Hinterland , Abdul Rahman M. Arkadan The American University, Beirut ,1991;

- Bieniawski, Geomechanical classification, Bieniawski, Environmental and Technical Geology, 1989;

- Rock Characterization with experimental survey, Pier Paolo Rossi, Environmental and Technical Geology, 1992;

- US EPA Environmental Response Team, Standard Operative Procedures, 2000;

ANNEX 1

ROCKS CLASSIFICATION AND IDENTIFICATION

SPECIFICATION UNI EN ISO 14689-1

ROCKS CLASSIFICATION AND IDENTIFICATION

SPECIFICATION UNI EN ISO 14689-1

SITE: OUTCROPS ON RAS NEBI YOUNES (JIEH'S POWER PLANT,BEIRUT)

DATE: 17 NOVEMBER 2006 – 20 NOVEMBER 2006

1. ROCK'S IDENTIFICATION

GENETIC GROUP	magmatic Rocks	sedimentary Rocks	metamorphic Rocks	Sign :
1		X		

STRUCTURE	Massico	Bedded	Schistose	Sign :**Presence of joints family with good persistence**
2		X		

GRAIN SIZE (mm)	Texture very fine (< 0.002)	Texture fine (0.002-0.063)	Texture medium (0.063-2)	Texture coarse (2-63)	Texture very coarse (>63)	Sign :
3	X					

MINERALOGICAL COMPOSITION	Quartz, feldspars and silicate ores	Dark ores (ex. biotite, amphiboles and piroxenes	Clayey ores	Carbonate ores (ex. calcite, dolomite)	Siliceous and amorphous material (glass)	Sign :
4				X		

carbonaceous material (ex. coal, graphite)	Salts (ex. gypsum)	Swelling ores (anhydrite and clayey ores)	Sulphureous ores	Sign :

2. LITHOLIGICAL DESCRIPTION

COLOUR	Hue	Chroma	Lightness	Sign :
5	Pink…….. Red……. Yellow……. Brown…. Green……. Blue……… White….**X.** Gray…**X**… Black…….	Pinky…**X**…. Reddish…… Yellowish…… Brown…….. Greenisch…… Dark bluish……. Greysh…..	Bright……. Opaque …**X**…..	

ROCK WEATHERING	unaltered	Colour modification weathering evidence	weathering with disgregated matrix	Decomposed	Sign: **Weathering occurs in fracture plane with evidence of karst phenomenon**
6		**X**	**X**		

CARBONATE CONTENT	Absent	Calcareous	Strongly calcareous	Sign :
7		**X**	**X**	

RAIN ROCK SENSITIVITY	Stable	Little stable with crumbling surface	Unstable with crumbling evidence	Sign :
8			**X**	

SINGLE AXLE PRESSURE NOT CONFINED (Mpa)	It is possible scratch the rock with nails Extremely weak rock <1	It is possible break the rock with the point hammer. Very weak rock 1-5	It is possible scratch the rock with point hammer Weak rock 5-25	It is possible to crush a sample with only one stroke of a hammer. Moderately strong rock 25-50	Sign :
10					

It is possible to crush a sample with two or three strokes of a hammer. Strong rock 50-100	It is possible to crush a sample with several strokes of a hammer. Very strong rock 100-250	It is possible to chip a sample with a hammer. Extremely strong rock >250	Sign
X	**X**		

STRUCTURE	Magmatic rocks	Sedimentary rocks	Metamorphic rock	Sign:
11	Massico……………………… Flow layering…….. Folded……………………….. Lineate structure…………	Bedded………**X**………… Interbedded…………… Banded………………… Folded………**X**………… … Massico………………… … Graded…………………… .	Cleavage structure……… Foliation………………… Schistose………………… Banding………………… … Linear structure…….. Gneiss structure………… Folded ……………………	**Extremely weak folded structure with large fold ray**

STRUCTURAL DISCONTINUITIES SPACING Ex. (cleavages, foliations, schistosity, layering, ecc in mm)	Very large >2000	Large 2000-600	Medium 600-200	Narrow 200-60	Very narrow 60-20	With foliation 20-6	Large intensity of foliation <6	Sign :
12			**X**	**X**				

JOINTS SPACING (mm)	Very large >2000	Large 2000-600	Medium 600-200	Narrow 200-60	Very narrow 60-20	Extremely narrow <20	Sign
13				**X**	**X**		

SIZE BLOCKS (mm)	Very big >2000	Big 2000-600	Medium 600-200	Small 200-60	Very small <60	Sign
14			**X**	**X**		

SHAPE BLOCKS	Polyhedral	Tabular	Prismatic	Cubic	Rhomboidal	Columnar	Sign: **Big columnar blocks sometimes are observed**
15			**X**				

DISCONTINUITIES ROUGHNESS	irregular and rough surface	regular and very rough surface	rippled and irregular surface	rippled and regular surface	irregular and flat surface	regular and flat surface	Sign :
16		**X**	**X**				

DISCONTINUITIES OPENING	Extremely open >1m	Very open 100-10 cm	Open 10-1 cm	Moderately open 10-0.5 mm	Not open 0.5-0.25 mm
17		**X**	**X**		

Tight 0.25-0.1 mm	contact <0.1mm	Sign :

WATER FLOW	Low 0.05-0.5 l/s	Medium 0.5-5 l/s	High >5 l/s	Sign: **Water is not present. Discontinuities are affected by humid fill material**
18				

ROCK WEATHERING SCALE	Weathering not visible	Low weathering with surfaces' decolourization	Moderately weathering: less than of one half of the rocky mass is decomposed and disintegrated .	Sign: **high alteration in fracture's planes with soil transformation (lateritic fill material)**
19			**X**	

High weathering: more than of one half of the rocky mass is decomposed and disintegrated .	Totally damaged : all rocky mass is decomposed and disintegrated. It is possible to see original structure.	Residual soil : all rocky mass has soil transformations with modified volume	Sign:

FORMATION'S NAME: SANNINE LIMESTONE

ANNEX 2

ROCKS CLASSIFICATION AND IDENTIFICATION

RMR SYSTEM (Rock Mass Rating system) (Bieniawski, 1989)

ROCKS CLASSIFICATION AND IDENTIFICATION

RMR SYSTEM (Rock Mass Rating system) (Bieniawski, 1989)

SITE: OUTCROPS ON RAS NEBI YOUNES (JIEH'S POWER PLANT,BEIRUT)

DATE: 17 NOVEMBER 2006 - 20 NOVEMBER 2006

1) Rock Strength			**2) Rock Quality Design (RQD)**			
	Strength to single axle pressure not confined (Mpa)	Strength Index Point-load (Mpa)	Quality excellent Good Medium		90-100% 75-90% 50-75%	**1) Associate index = 9,5**
Very high	>250	>10	Low	**X**	**25-50%**	
High	100-250 **X**	4-10 **X**	Very Low		<25%	
Medium	50-100 **X**	2-4 **X**				
Moderate	25-50	1-2				
Low	5-25	<1				**2) Associate index = 8**
Very low	1-5					

Direction and Dip values

	Type	Direction	Dip Angle	Dip Direction
Family 1 Family 2 Family 3 Family 4 Family 5	**See the further Annex 3**	**See the further Annex 3**	**See the further Annex 3**	**See the further Annex 3**

3) Discontinuities spacing

		Layering	**Joints 1**	**Joints 2**	**3) Associate index = 8**
Very large	>2m				
Large	0.6-2m				
Medium	20-60cm	**X**			
Narrow	6-20cm	**X**	**X**	**X**	
Very narrow	<6cm		**X**	**X**	

4) Groundwater

Water flow pressure (kPa) **0** Litres/min **0** Sign **Water is not present. Discontinuities are affected by humid fill material**
4) Associate index = 12,5

5) Discontinuities Condition

Persistence		**Layering**	**Joints 1**	**Joints 2**	Sign: **Joints aggregates and layering are present in a big area with same**
Very low	<1m				

Low	1-3m				**geometrics and physical characteristics (regional diffusion)**
Medium	3-10m		**X**	**X**	
High	10-20m				
Very High	>20m	**X**			
Opening		**Layering**	**Joints 1**	**Joints 2**	Sign: **Strong alteration in joints' plane with evidence of karst phenomenon (cavernous joints)**
Contact	<0.1mm				
Tight	0.1-0.5mm				
Partially open	0.5-2.5mm				
Open	2.5-10mm	**X**			
Very Open	>10mm	**X**	**X**	**X**	

Roughness	**Layering**	**Joints 1**	**Joints 2**	Sign:
Very rough surface				
Rough surface	**X**	**X**	**X**	
Slightly rough surface				
Smooth surface				
Slickenside				
Filling material	**Layering**	**Joints 1**	**Joints 2**	Sign: **high alteration in joint fracture's planes with soil transformation (lateritic fill material). Several times all kind of fracture' planes are voids**
Type	**No material**	**soft and clayey**	**soft and clayey**	
Thickness	**0.2cm – 10 cm**	**1cm - 40 cm**	**1cm - 40 cm**	
Strength to simple pressure		**very weak**	**very weak**	
Percolation	**Water is not present**	**humid (water is not present)**	**humid (water is not present)**	
Discontinuities Walls	**Layering**	**Joints 1**	**Joints 2**	Sign : **Weathering occurs in fracture plane with evidence of karst phenomenon (cavernous joint)**
Not altered				
Slightly altered	**X**			
Very altered	**X**			
Totally altered		**X**	**X**	
Residual soil		**X**	**X**	
				5) Associate index = 8

Total Associated Index = 45,5
Geomechanical quality of surveyed outcrops : <u>Discrete rock – Class III</u>

RMR BASE	**100-81**	**80-61**	**60-41**	**40-21**	**<20**
Class	I	II	III	IV	V
Description	excellent rock	good rock	discrete rock	inferior rock	very inferior rock

ANNEX 3

STRUCTURAL GEOLOGICAL SURVEY - MEASUREMENT

SITE: OUTCROPS ON RAS NEBI YOUNES (JIEH'S POWER PLANT,BEIRUT)

DATE: 17 NOVEMBER 2006 – 20 NOVEMBER 2006

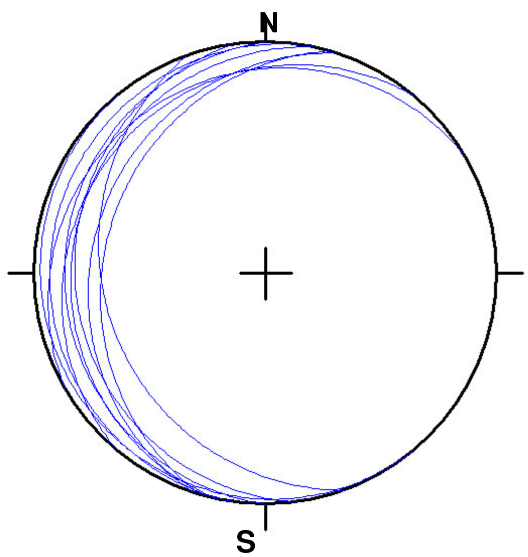
SITE STOP 1	BEARING	DIP DIRECTION	DIP ANGLE	NOTE
S_0	+16°	-74° NW	20°	
J_1	+82°	+172°SE	82°	
STOP 2				
S_0	+20°	-70° NW	10°	
J_1	+106°	+196°SW	88°	
STOP 3				
S_0	0°	-90°W	8°	
J_1	+90°	+180°S	86°	
STOP 4				
S_0	+12°	-78°NW	10°	
J_1	-60°	+30°NE	74°	
STOP 5				
S_0	+28°	-62°NW	16°	
J_1	-54°	+36°NE	80°	
STOP 6				
S_0	-8°	-98°SW	11°	
J_1	-100°	-190°SE	88°	
STOP 7				
S_0	+60°	-30°NW	8°	
J_1	+80°	+170°SE	76°	
J_2	-14°	+76°NE	76°	
STOP 8				
S_0	+8°	-82°NW	4°	
J_1	-38°	-128°SW	88°	
J_2	+80°	+170°SE	74°	
STOP 9				
S_0	-20°	-110°SW	2°	
J_1	+70°	-20°NW	79°	
J_2	-40°	-130°SW	80°	
STOP10				
S_0	+140°	+230°SW	2°	
J_1	-68°	-158°SW	85°	
J_2	+100°	+10°NE	63°	

ANNEX 4

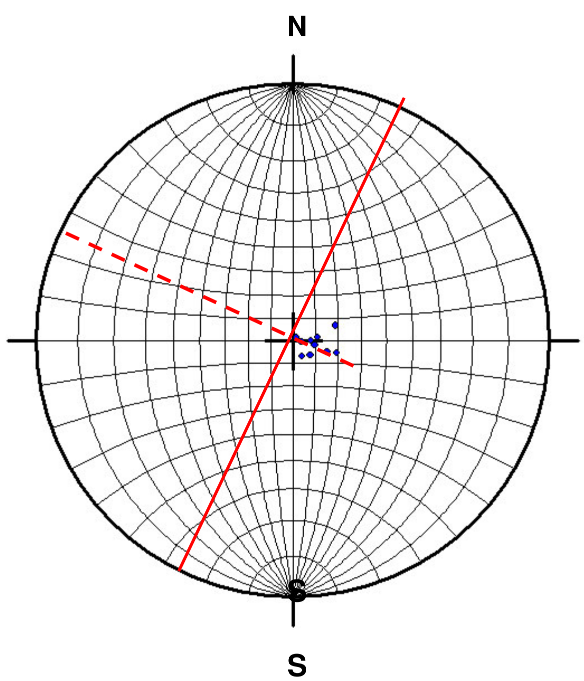
STRUCTURAL GEOLOGICAL ANALYSIS

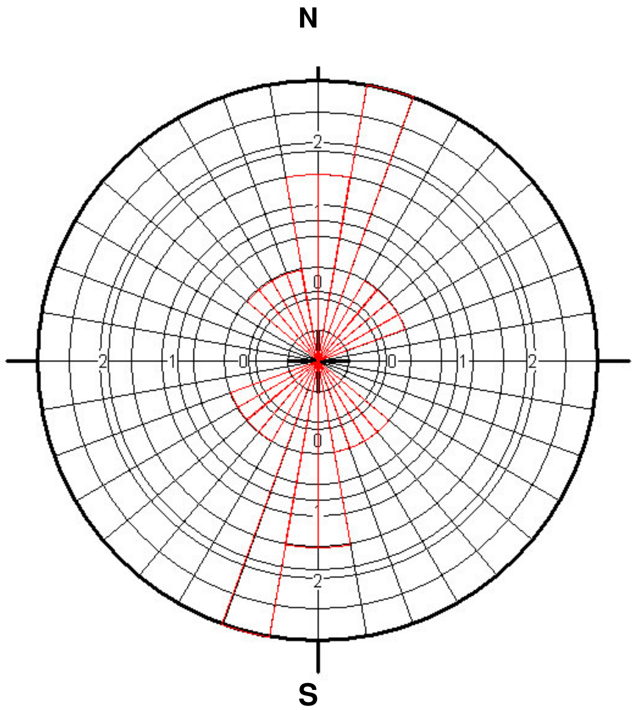
SITE: OUTCROPS ON RAS NEBI YOUNES (JIEH'S POWER PLANT,BEIRUT)
DATE: 17 NOVEMBER 2006 – 20 NOVEMBER 2006

Layers (S_0) attitude plotted by Equiangular and Equatorial Projection - Wulff grid (data are shown in **Annex 3**). **Number of projection data : 10**



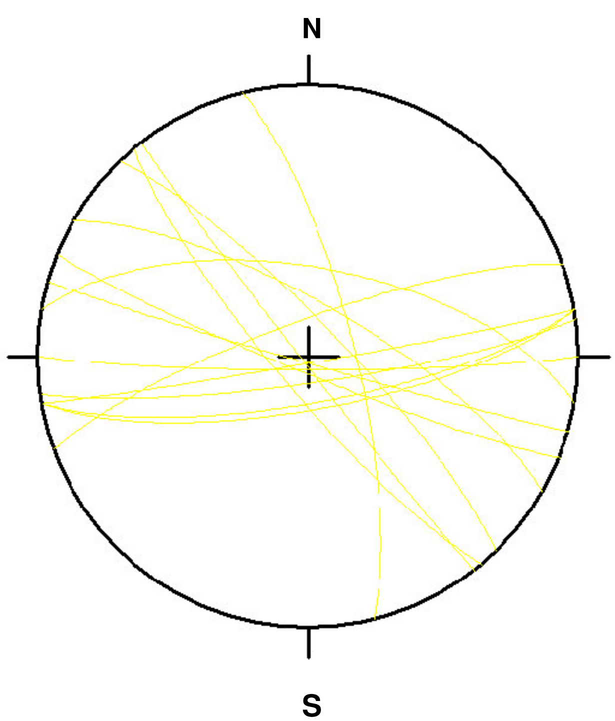
Layers (S_0) poles plotted by Equiangular and Equatorial Projection - Wulff grid (data are shown in **Annex 3**).

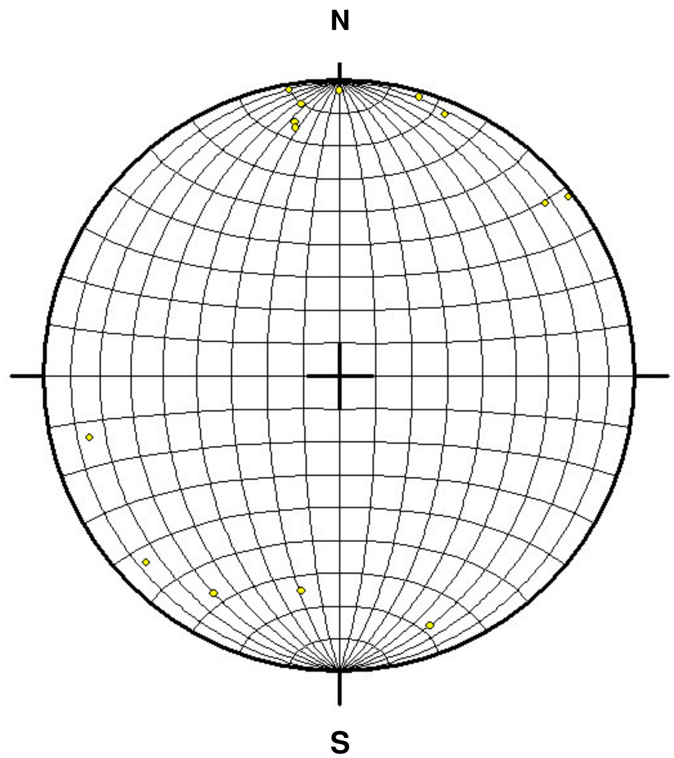




<u>Layers</u> (S_0) strikes plotted by Rosette diagram with Equiareal and Polar Projection - Schmidt grid (data are shown in **Annex 3**). Maximum attitude frequency shows a medium Dip Direction about 290° (strike 20°N) and a medium Dip angle of 10°.

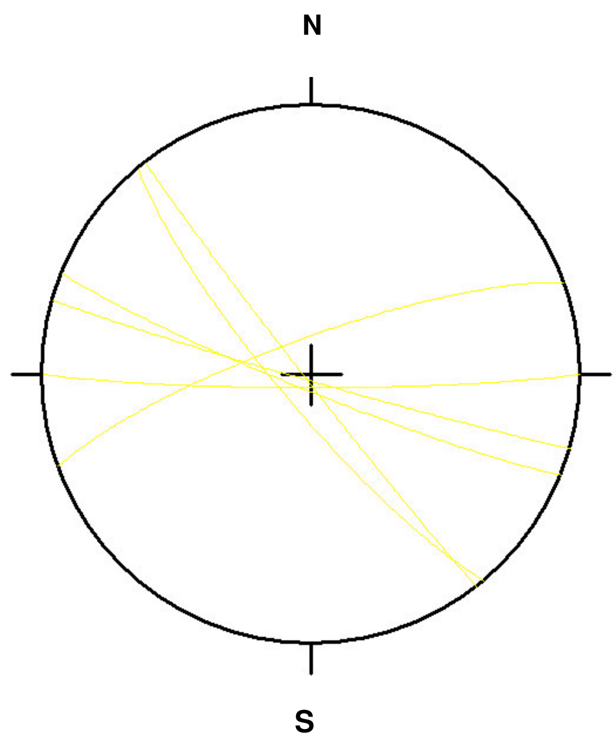
<u>Joints (J1,J2)</u> attitude plotted by Equiangular and Equatorial Projection - Wulff grid (data are shown in **Annex 3**). **Number of projection data :14**

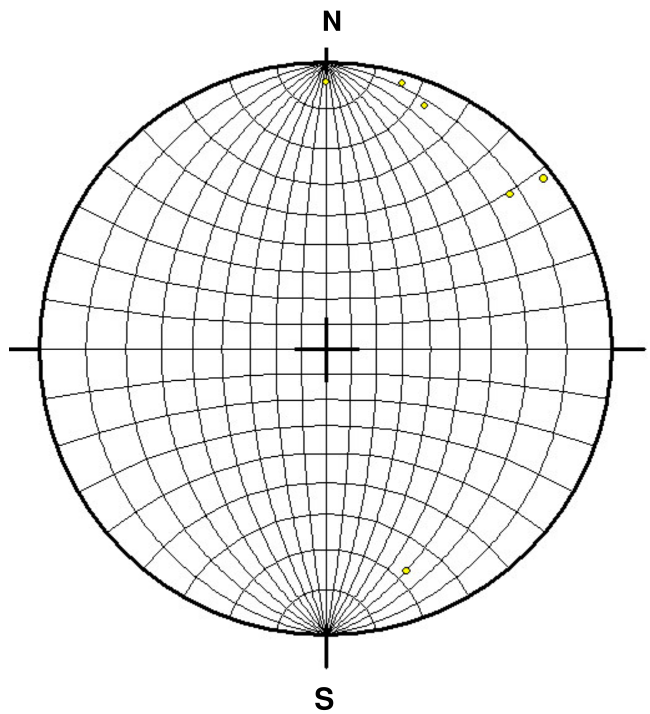




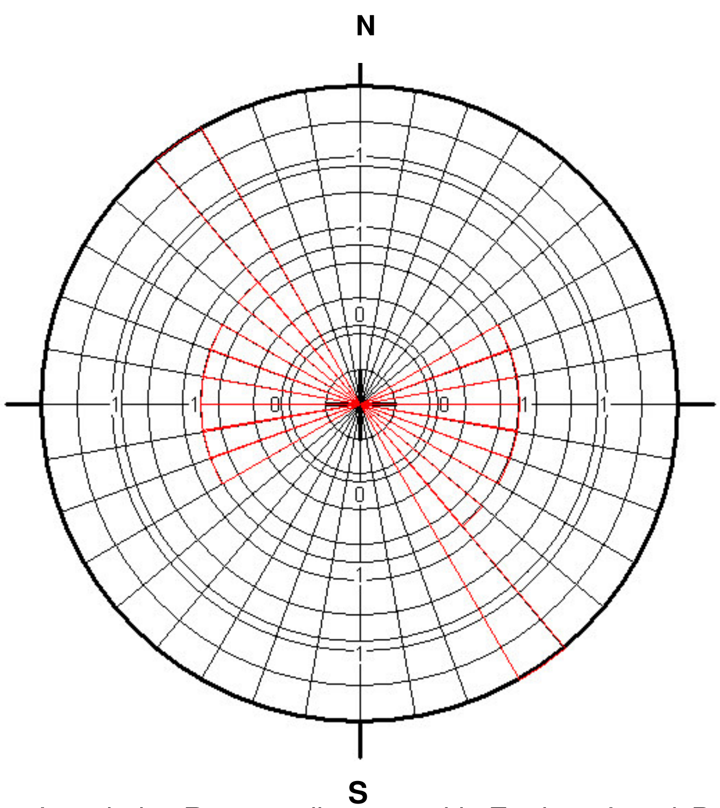
<u>Joints (J1, J2)</u> poles plotted by Equiangular and Equatorial Projection - Wulff grid (data are shown in **Annex 3**)

<u>Joints (J1 with S-SW and NW Dip direction)</u> attitude plotted by Equiangular and Equatorial Projection - Wulff grid (data are shown in **Annex 3**). **Number of projection data : 6**



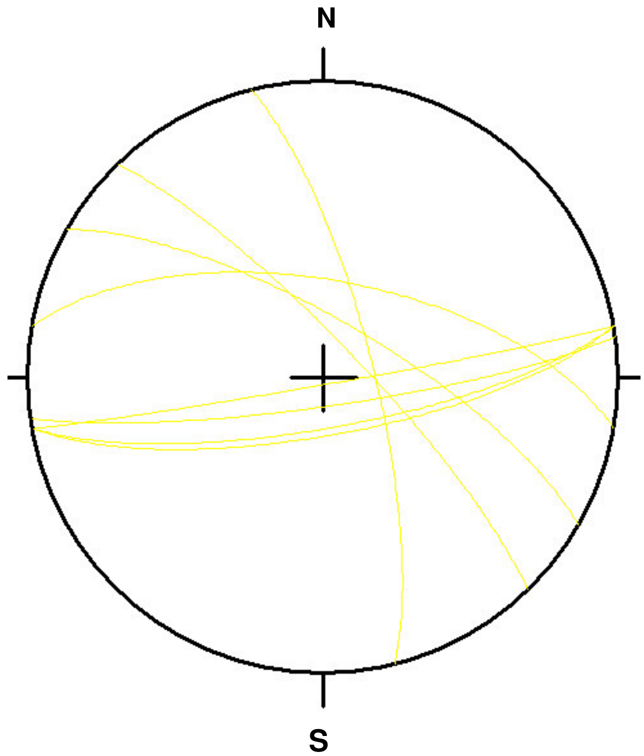


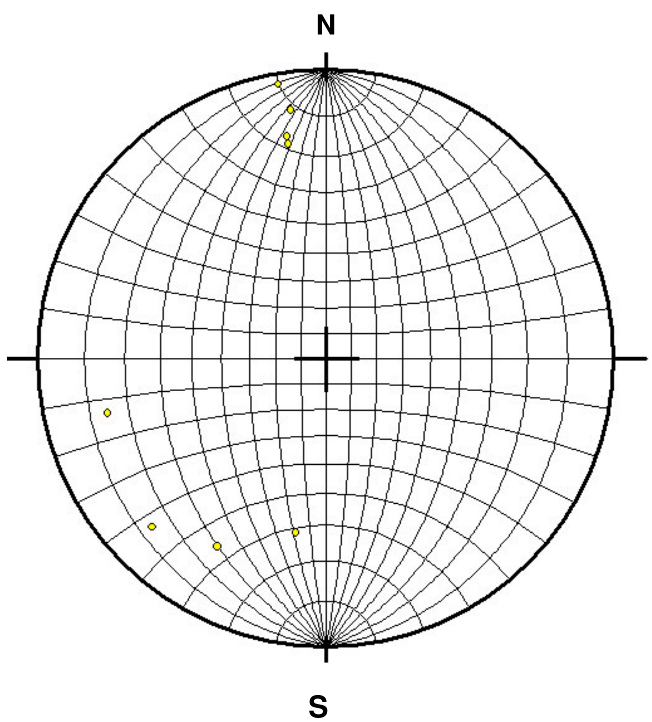
<u>Joints (J1)</u> poles plotted by Equiangular and Equatorial Projection Wulff grid (data are shown in **Annex 3**).



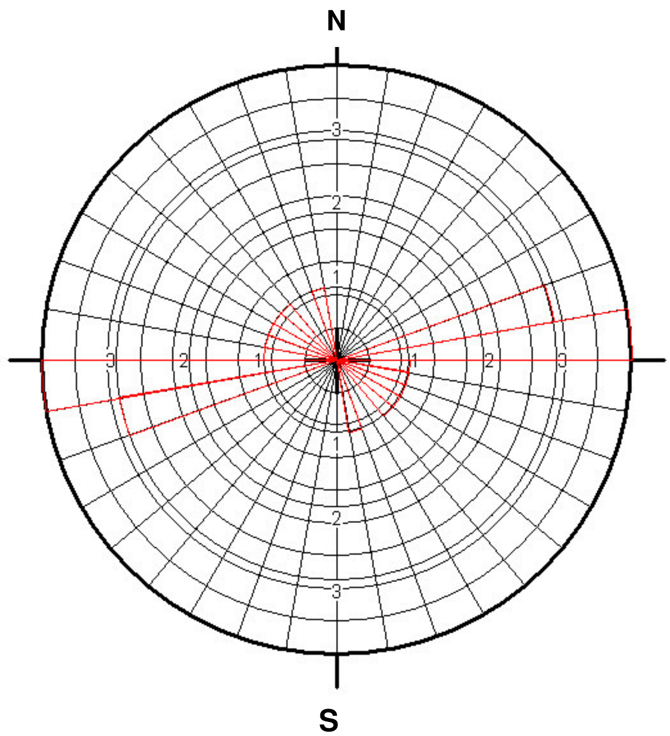
<u>Joints (J1) strikes</u> plotted by Rosette diagram with Equiareal and Polar Projection - Schmidt grid (data are shown in **Annex 3**). Maximum attitude frequency shows a medium Dip Direction about 240° (strike -30°) and a medium Dip angle of 85°.

Joints (J2 with E-SE and NE Dip direction) attitude plotted by Equiangular and Equatorial Projection - Wulff grid (data are shown in **Annex 3**). **Number of projection data : 8**





Joints (J2) poles plotted by Equiangular and Equatorial Projection - Wulff grid (data are shown in **Annex 3**).



Joints (J2) strikes plotted by Rosette diagram with Equiareal and Polar Projection - Schmidt grid (data are shown in **Annex 3**). Maximum attitude frequency shows a medium Dip Direction about 170° (strike 80°) and a medium Dip angle of 80°.