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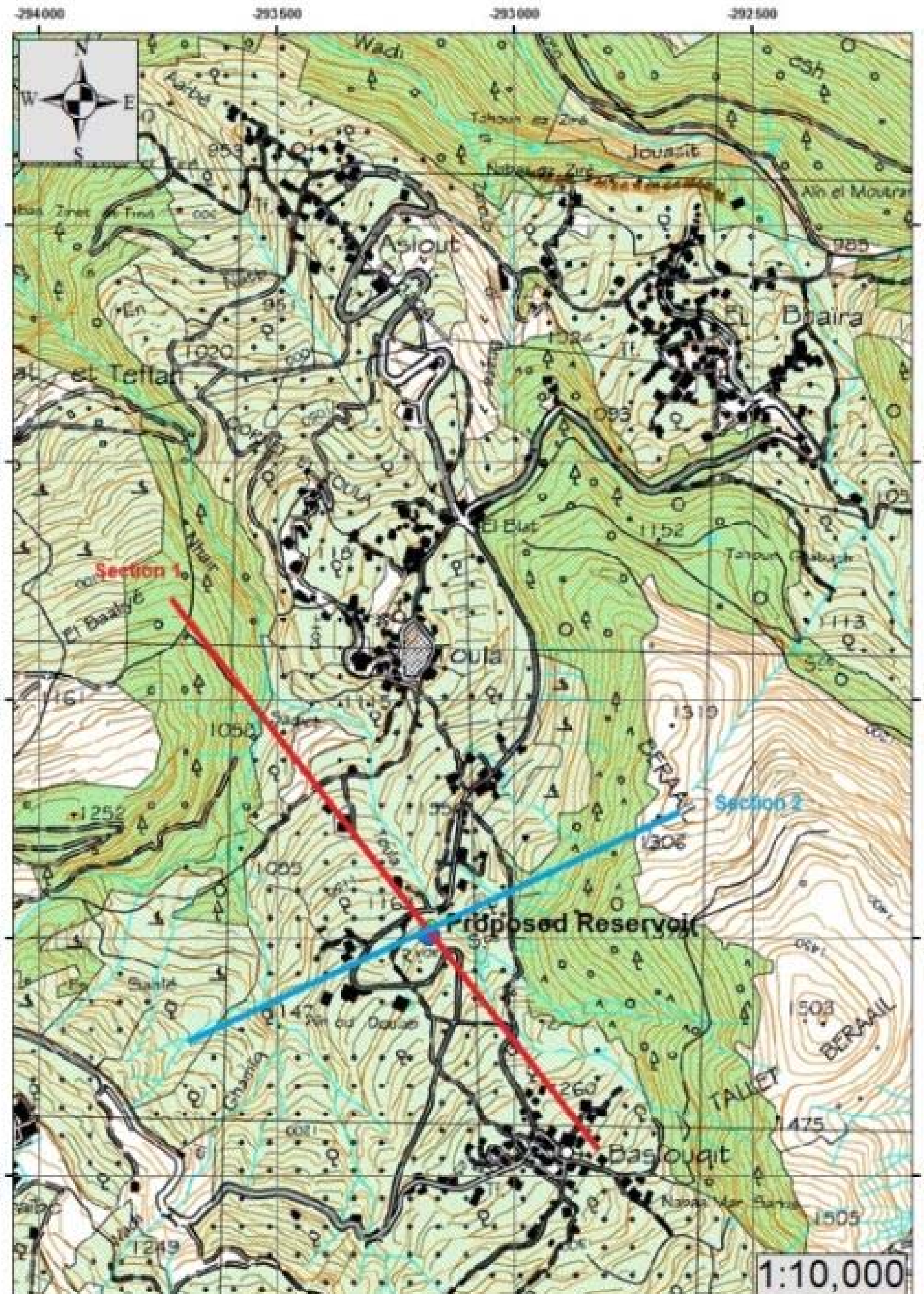
FIGURES

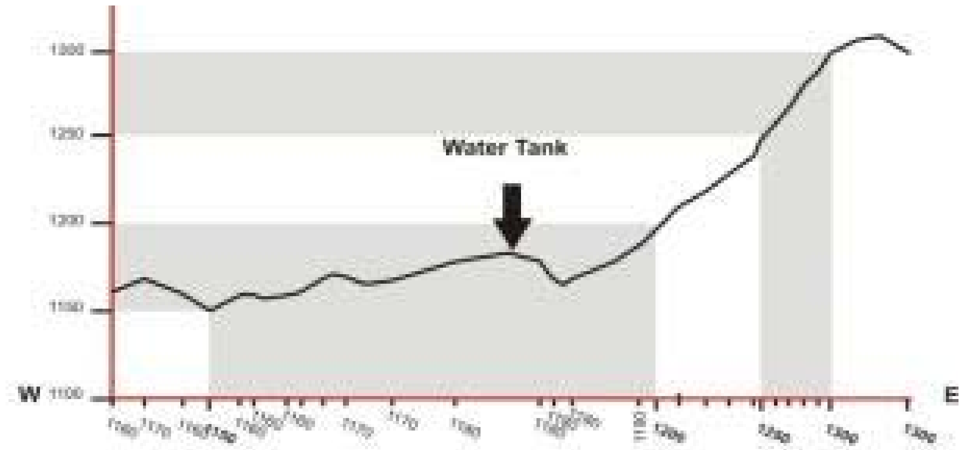
1. Locality and Morphology

The study area is located in the Mohafaza of North Lebanon, in Zgharta District (Caza), East of the village of Toula. The existing topographic features of the project area shows two major trends of dip: the first normal one in the direction to west which gives the stability to land and trap of 10-12 meter of compacted Quaternary debris (soil, marls, gravel of limestones and Basalt) above marl formation of lower cretaceous C3, and the second one (the steep slope) to the North and Northeast direction that is more slumping and sliding (refer to Figure 1: Topographic map and cross sections 1 and 2).

The investigated area features a Mediterranean climate characterized by warm, dry summers and mild snowy winters and normally covered by snow layers that persist on the mountain tops, of a considerable thickness, for a period of approximately two months. Variations in weather conditions and slope position create different reaction of loading and stress - strain deformation under the base deposits.



General Topographic Map of theStudy Area



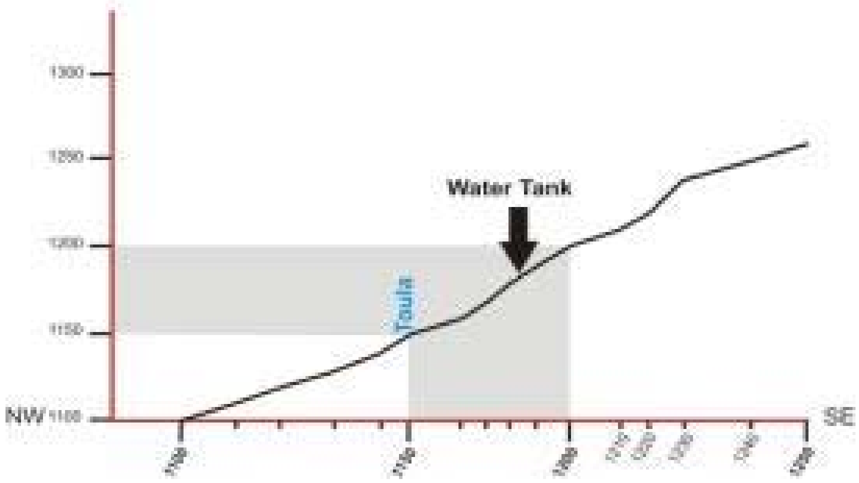


Figure1: Shows the topographic map and two cross section: section 1 present the morphology of the slope from SE to NW, section 1 present the morphology of the slope nearly from E to W.

2. Geology and Tectonics:

The geology of the study area was mapped at the Scale 1:10,000. Interpretation of the geological structures of Lebanon within a coherent structural-tectonic scheme was offered by several authors. The study area is located in the fold system of anticlinal of Mount Lebanon, which cut by faults of every scale. This is a lateral, or strike slip fault and is the Lebanese segment of the Dead Sea Transform Fault.

The normal fault passes south of the water tank at a distance is approximately 100 meters, it is inactive right lateral strike slip fault (E-W) and not dangerous because of plastic deformation of the marls. (Ref Figure 2: General Geologic Map).

Almost all the rocks in the study area belong to the Cretaceous period and most of these rocks composed of Marl, except the upper 10 meters of Quaternary debris and the Basalt of BC2 (the Lower Cretaceous Basalt).

The Geological beds in the study area are dipping toward the North west at angle varies between 20-30°.

(Ref Figure 2: General Geologic Map).

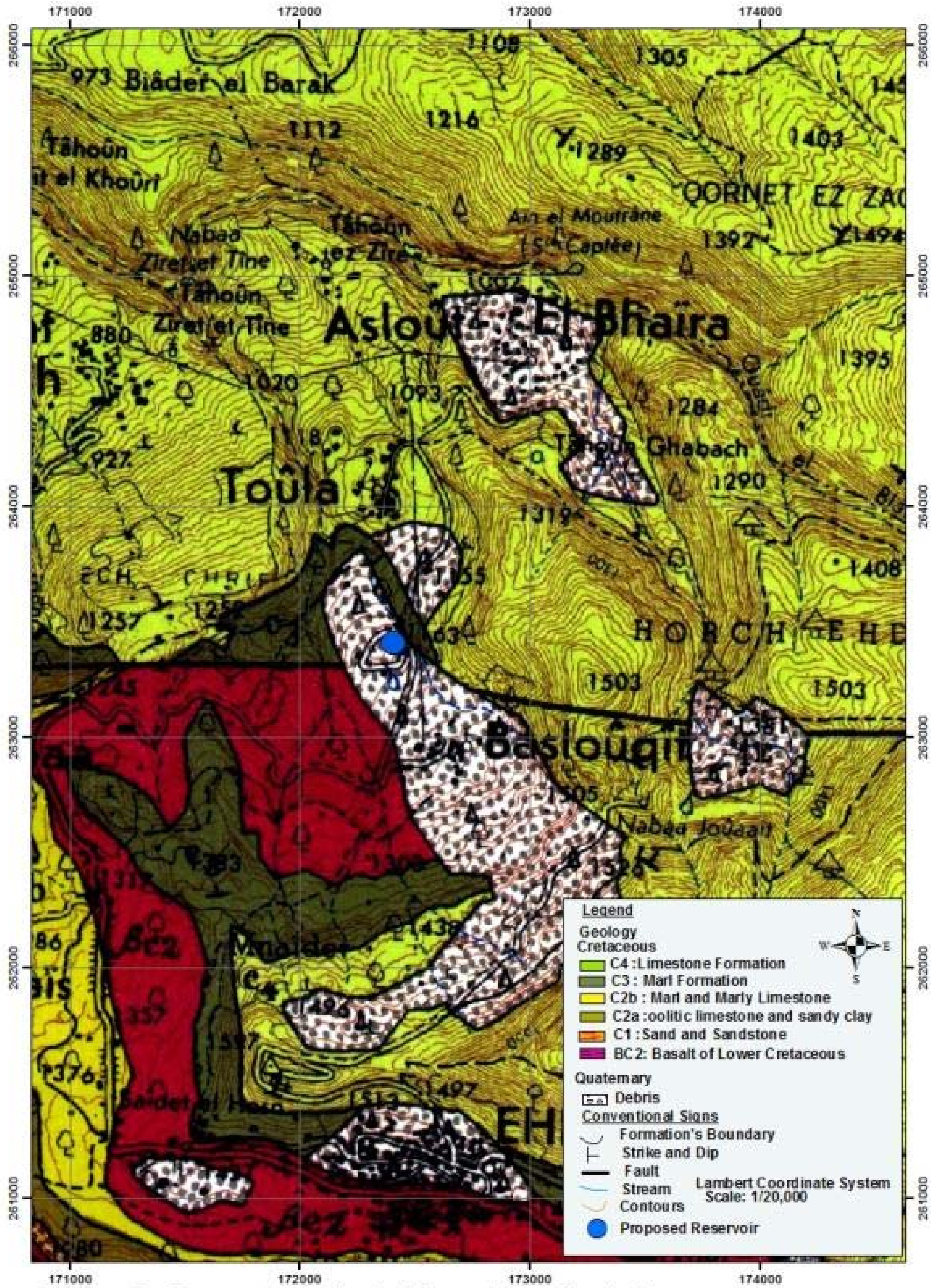


Figure 2 : General Geologic Map of the Study Area

The Water Tank is located above Cretaceous deposits. Where the stratigraphy from the base to the top consists of 150m of Oolitic limestone and sandy clay belong to the lower Aptian epoch (C2a Formation), 120m of marl and marly limestone belong to the upper Aptian epoch (C2b Formation) and 100 meter of Lower Cretaceous Basalt (BC2), and The C3 unconformable overlies the Lower Cretaceous Basalt, it is belongs to the Albian epoch is named in lebanon Hammana marl formation composed of green marl interbedded with thin layers of limestone , the thickness of this formation up to 130 m, the Hammana marl formation is covered by 10 meters of compacted Quaternary debris composed of soil, marl, gravel of limestone and Basalt (See Figure 3).

Figure 3: Quaternary deposits (Clay, Silt, and Gravel of limestone and Basalt)

3. Stability and Loading:

The volume of water tank is approximately 200 m^3. The area of raft foundation is about 50 m^2.Therefore, the weight of water is 200 ton and the weight of concrete walls is equal to 154 ton (weight of raft foundation = 62.5 ton and the weight of concrete walls = 91.5 ton).

The dead loads and over loads of water tank do not exceed 8.7 ton/m^2. The allowable bearing capacity of the soil under the water tank is up to 15 ton/m^2 (Ref. Geotechnical Report – March 2016). Therefore, there is no expected settlement risk under the water tank.

Marl acts in the following two different conditions: a) The behavior of marl mechanics along the ruptured surface is conducted for homogeneous dry slope in weathered clay-marl deposits which will then either deform plastically or brutally, and b) The water logged marls that have a slippery behavior.

for the assessment of potential damages which will be due to the slope movements on the left slope of the water tank, included 10 m debris and marl formation concerning a zone about 800 m long in the North direction. Its width ensured coverage of the concerned slide slopes as well as the inherent areas within the foreland and behind the slope crest in the northern side of water tank.

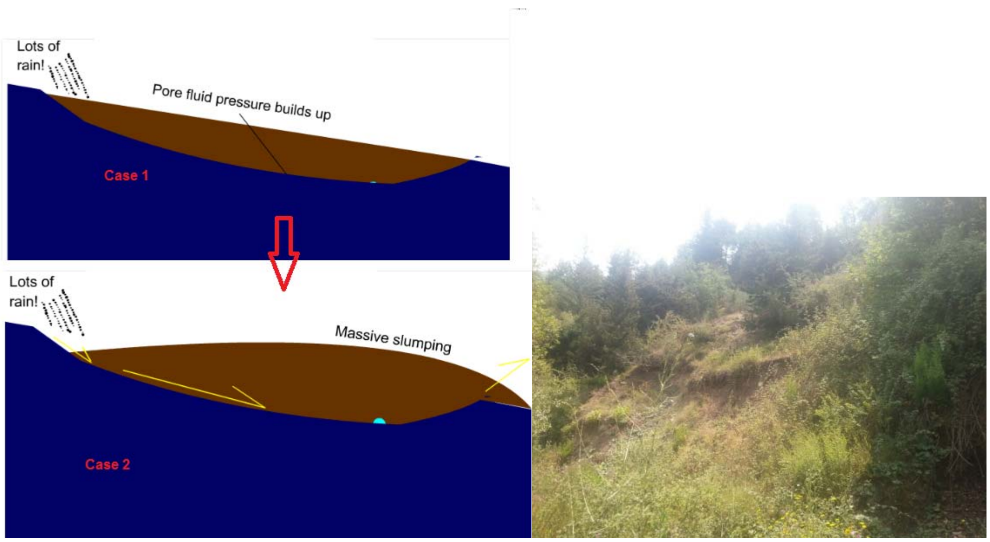


Figure 4 show the abovementioned type of slope deformations. The interpretation contains degree of activity for the slope deformation and the potential risks of conceivable movement

The stress-strain distribution within a slope at the verge of stability is composed of weathered debris and marls. It is assumed that slope stability is controlled by the variation of many main parameters:

- Slope height and
- Angle

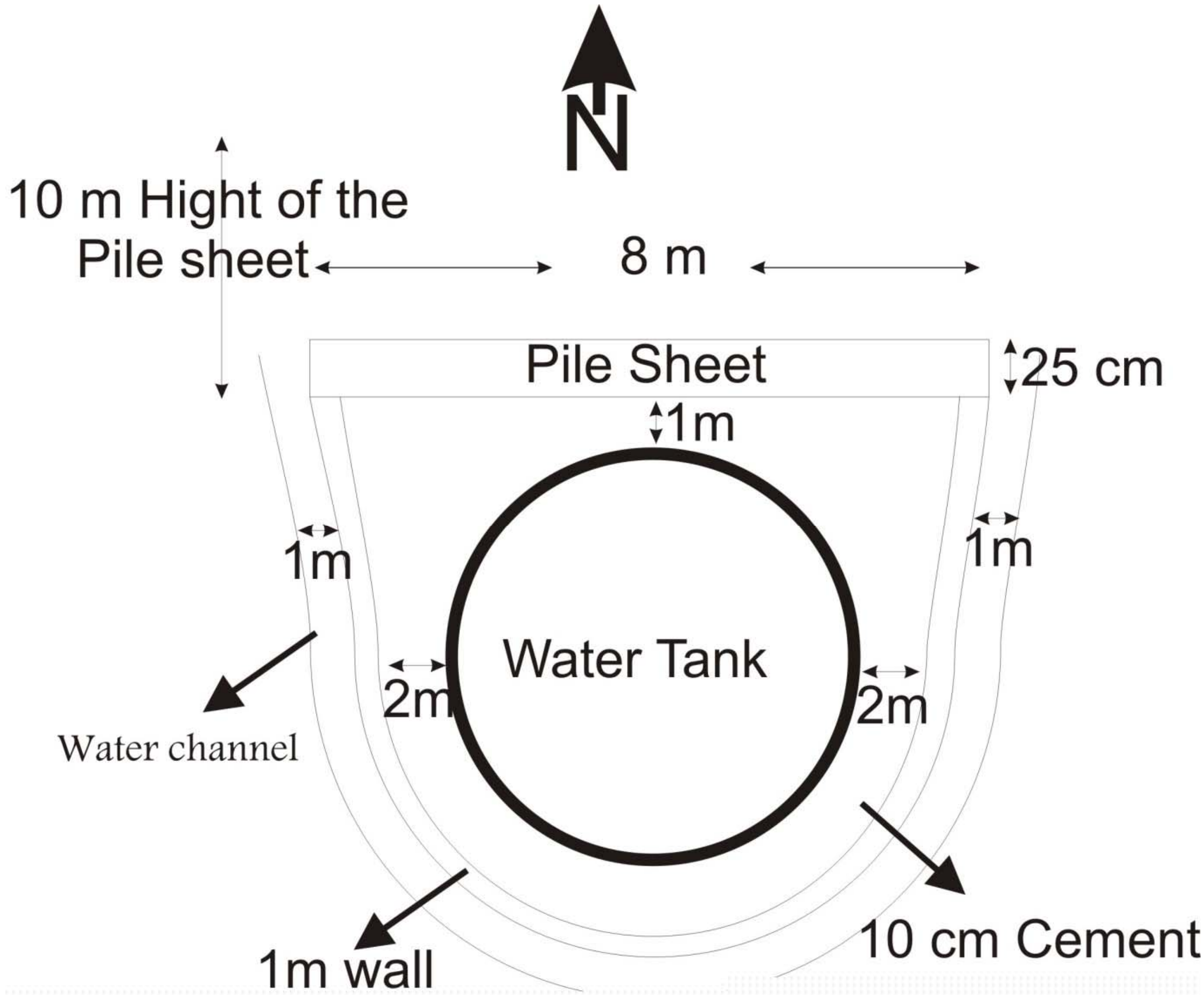
These parameters are satisfactorily met to construct the Reservoir from the West to the North West trend of the slope; however, potential risks may arise in the East to East direction of the slope. This side needs **protection and supporting by the construction of a diaphragm wall. (Further explained in the following section).**

4. Recommendations:

Solutions based on giving the slope the stability to be corroborated by applying shear strength reduction technique and protect marl to be in dry conditions. In this case, factor of safety is obtained by gradually covering the soil and marls and create a network of draining channels.

In order to exclude the possible effect of boundary conditions on the final result, we have to assume a large enough model for the bottom boundary of the water tank. Some of the recommended solutions for providing the slope the needed and secured stability to be corroborated, is by applying shear strength reduction technique and protect marl from dry conditions. In this case, factor of safety is yield by gradually covering the soil and marls and create a network of draining channels.

In order to exclude the possible effect of boundary conditions on the final result, we have to assume a large model for the bottom boundary of the tank.



Above is a presentation of the proposed protection method of the surrounding area of the reservoir / water tank that will secure the slope subjected to sliding. Further methods will include best way to preserve stress-strain distribution in heterogeneous geological conditions and protect the area from the risk of sliding. As such, we recommend constructing the following:

- Pile sheet in the **Northern** side at a distance of one meter from the Water tank in this dimensions (8 m length, 10 m height, and 25 cm thickness).

  It is recommended to make holes of 0.5 inch diameter in the diaphragm wall to discharge rain water under the tank.

- From the other three directions, provide a concrete layer of thickness of 10 cm around the water tank that will be protected by a wall of concrete of a height of 1m and a thickness of 25 cm.

- Around the one meter wall, construct a channel to divert rain water away from the water tank and to protect the base of the water tank