Hazard Mapping Along the Dead Sea Shoreline

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Key words: Sinkhole, Subsidence, Photogrammetry, Orthophoto, GPR.

SUMMARY

Dead Sea is located at the mid west part of Jordan and represents the lowest region of the world. This is a classical region in the course of geological and geophysical studies where topographic, geological and geomorphologic hazard maps should to be prepared covering various economical, environmental and industrial events of high potentials to occur in the near future. Geological and geomorphologic hazard that is developing in this region are affecting the roads, agriculture lands, and buildings foundations by probable collapses of the ground surface forming cracks of different sizes and depths.

This study focus on investigating the hazard detection and mapping based on the development of the Sinkholes and subsidence over the study areas. Data from different sources and research areas that includes Photogrammetric art, Global Positioning System (GPS), Three Dimensional (3D) Geographic Information System (GIS) and Ground Penetrating Radar (GPR) has been integrated for hazard mapping. Photogrammetric adjustment procedures were used to create digital elevation model and Orth-Photo model for Ghoar Haditha area. GPS were used to build spatial network for the study area based on ground control point collections. Finally, a Geophysical technique (GPR) was used to explore the underlying structure of the studied area. For realistic representation of the study area, a three dimensional GIS were prepared for the study area. The system is designed to allow easy and flexible updating of the database, where efficient generation, visualization and interpretation of such special data were recognized.

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1. INTRODUCTION

Hazard mapping is a process of creating a geographic trace for these particular phenomena extents which are likely to pose a threat to people, property, infrastructure, and economics activities. Hazard mapping represents the output of hazard analysis on a map. Recently, this theme has been developed in rapid manner due to vast development in the area of Geometics engineering and geophysics that includes Photogrammetry, global positing system (GPS), Geographic information system, remote sensing and ground penetrating radar (GPR). These disciplines can be used as efficient tools for analysis and interpretation of various geosciences phenomenon (Dewitte, 2006). Dead Sea in Jordan represents a typical example where Geometics engineering techniques could be used to explore the existing hazards at various regions along the Dead Sea (sinkholes, subsidence , shoreline movement and shallow fault) (Damien et al., 2005; Taqieddin et al., 2000).

Dead Sea is located at the mid west part of Jordan, Figure 1, and represents the lowest point of the world. This is a classical region in the course of geological and geophysical studies where topographic, geological and geomorphologic hazard maps should to be prepared for economical, environmental and industrial actions of high potential to occur within this region in the near future.

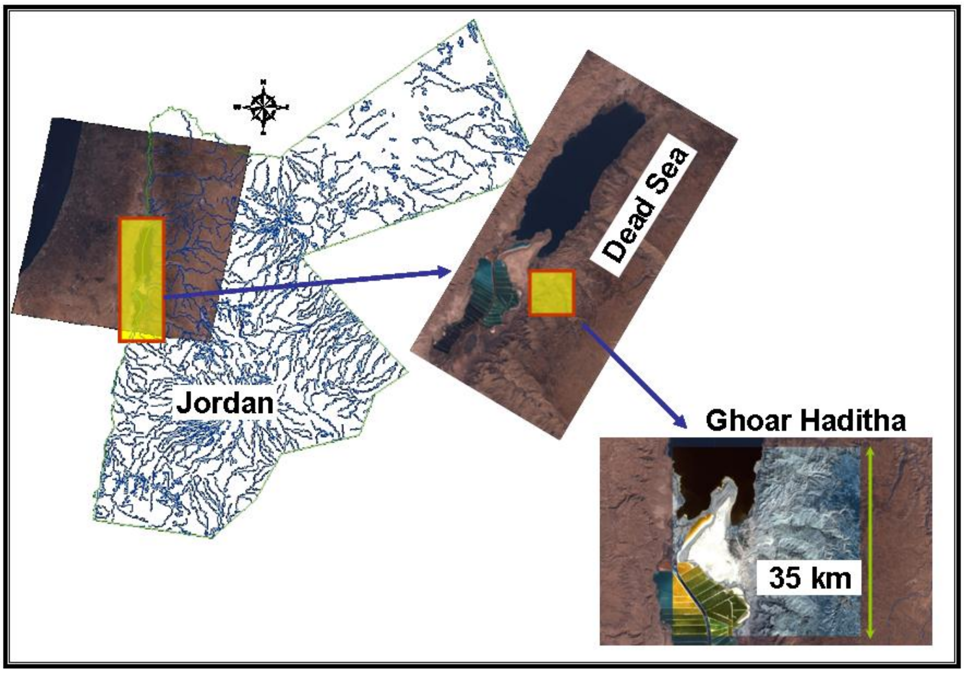

Figure 1. Location of the study area (Jordan - Dead Sea - Ghoar Haditha)

The study area is located along the eastern side of the Dead Sea shoreline, locally called Ghor Al-Haditha, Figure 1. The area is covered by alluvial fan, which consists of fine coarse-grained silica, sand and pebble size gravel with thin intercalations of laminated marl of Holocene age. The alluvial deposit calculated to be good shallow aquifer and one of the primary source, supplies domestic, municipal, agriculture and industrial water to the region. The water in the alluvial aquifer has historically been fresh and suitable for most potable uses. It has been noted that water quality in the eastern side of the Dead Sea shoreline is good and the salinity rarely exceeds 800 ppm; it is slightly alkaline (pH 7.5- 8.0), calcium and magnesium are the predominant cations, and bicarbonate the most important anion.(Al-Zoubi et al., 2007; Khalil, 1992).

Sinkholes and subsidence are natural phenomena that may occur in shallow geology sediments at different regions in the world. Nevertheless Sinkholes hazard assessment is one of the most difficult nearby subsurface investigation process. It is clear that Sinkhole formation is a dynamic process that is occurring over time, of consequential variations in the subsurface properties, such as porosity, fracture density, water saturation, etc. Variations in properties could be detected by geophysical methods as anomalies in the geophysical parameters such as gravity anomalies, seismic velocity, and electric resistivity (Savich et al., 1983, Sharma, 1997, Zhdanov and Keller, 1994)

Figure 2 demonstrates an example of Sinkholes which have been developed in Ghore Haditha area, affecting the roads, agriculture lands, and buildings' foundations by the sudden collapse of the ground surface and forming cracks of different sizes and depths. Different geophysical methods were applied in the study area to detect the presence of any weakness at the overlying materials, which are represented by fractures or cracks, also to detect the subsurface cavities, and any tectonic structures like shallow faults, which tend to affect the Sinkholes' progress within the study area.

Figure 2. Overview of various sinkhole activities in Ghoar Haditha

This study, gathered data from different sources and research areas to be integrated in order to establish a solid base for accurate interpretation of various hazed events that are taking place in Ghoar Haditha. Photogrammetry, GPS, GIS and Geophysical techniques were employed for such purposes. Diversity of data were used for this research, such as LandSat ETM (2002), Aerial Stereo images (2000), Topographic maps, Geological maps, and ground control points collected ,at 2005 and 2008, as grid points using GPS .

In general, Photogrammetry could be used for planning, recording, reconstructing, and revitalizing the study area (Baldi, 2008; Hanley and Fraser, 2001; Paul, 2000). More specifically, in this research the stereo-aerial images of 1/25000 scale were used to generate digital elevation model of the study area where ground control points should to be collected using high sophisticated global positioning systems(GPS) receivers. Moreover, Photogrammetric techniques and Aerial photos with fine ground resolution have been processed to generate high quality Ortho-photo. Geophysical methods such as (GPR) were also used to explore the underlying structure of the study area (Baker,1991; Slater L. and Niemi 2003). Finally, realistic representations of the study area with three dimensional Geographic Information Systems (GIS) were simulated.

Next section will discuss various steps relevant to the spatial data collecting and processing in the Ghoar Haditha to determine the geographic information system for the study area. Including; Photogrammetry processing based on aerial and satellite to be discussed in section 2. Global Positioning System (GPS) to be described in section 3. Various elements of Geographic Information System (GIS) will be discussed in section 4. Geophysical portion represented by Ground Penetrating Radar (GPR) will be discussed in section 5 and finally section 6 dedicated for discussion and conclusion.

2. PHOTOGRAMMETRIC PROCESSING

Photogrammetry and aerial photo is one of the main sources for spatial data. Processing of aerial photos, Figure 3 includes the standard procedures of inner, relative and absolute orientation. The generated stereo model was checked using a set of well distributed check points. The RMS based on the differences between ground and model coordinates of those points was found to be 0.305m. Figure 3 illustrates that the aerial photos have the following properties:

- Aerial photos scanned from hard-copy images, form three strips.
- Overlap between two adjacent photos equal 60 %.
- Photos Scale is (1:25000) with film format (23cm2).
- Spatial resolution is about 50cm where area per photo is about (5.7km2).

In this study, two main photogrammetric products were generated; Digital Elevation Model (DEM) and Ortho-photo.

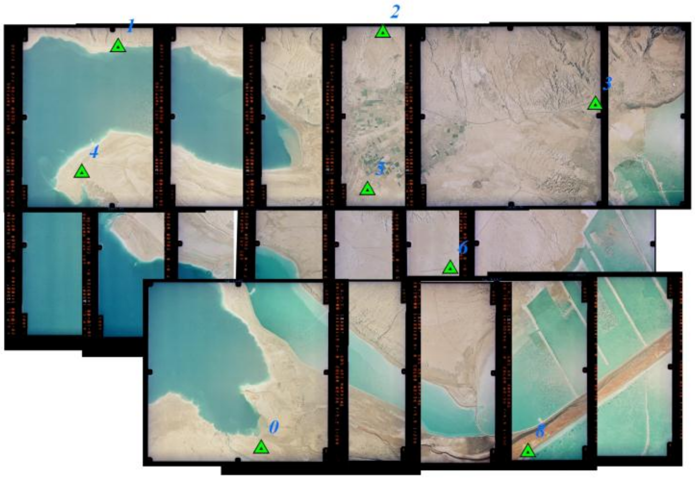

Figure 3. Aerial Photos for North-East Dead Sea Area (Jordan)

2.1 Digital Terrain Model (DTM) Extraction

The concept of creating digital models of the terrain is relatively a recent development. DTM is simply a statistical representation of the continuous surface of the ground by a large number of selected points with known X, Y, Z coordinated in an arbitrary coordinate field. The choice of data sources and terrain data sampling techniques is critical for the quality of the resulting DTM. At present, most DTM data are derived from three alternative sources: Ground surveys, Photogrammetric data capture and global positioning system (Baldi, 2008; Hanley and Fraser, 2001; Paul, 2000).

Figure 4 illustrates the final DTM after editing and processing with (5m x 5m) cell size, which will be used in the Ortho-photo generation. In addition to the above DTM, a TIN surface and contour maps were created. Figure 4 illustrates maps of the location of department of land survey (DLS) place on top on of DTM.

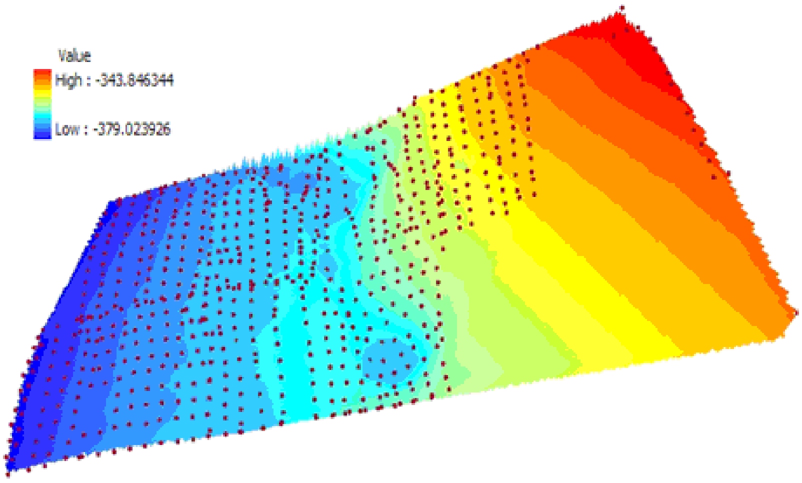

Figure 4. Digital Elevation Model with Elevation Point (Meter)

2.2 Ortho-Photo Generation

An Ortho-photo is a photo with the same characteristics of a map. Thus, Ortho-photo can be used as a map to define measurements and accurate geographic locations of the features. Ortho-photos are generated from aerial photographs and satellite images via a process known as an Ortho-rectification process (Hanley and Fraser, 2001; Paul, 2000). However, normal (uncertified) aerial photographs and satellite images do not show the features in its correct locations due to the displacements caused by the tilt of the sensor and terrain. Ortho-rectification transforms the central projection of the photograph into an orthogonal view of the ground; thus removing the distorting affects of tilt and terrain.

Generation of an Ortho-photo map from aerial photograph requires information about the location of the camera and its orientation in space as well as a model of the terrain elevation. In this study, an Ortho-photo was generated for the study area using information obtained from the photogrammetric processing and the DTM resulted in the previous section. Figure 5 illustrates the final result of the Ortho-photo Generation Process.

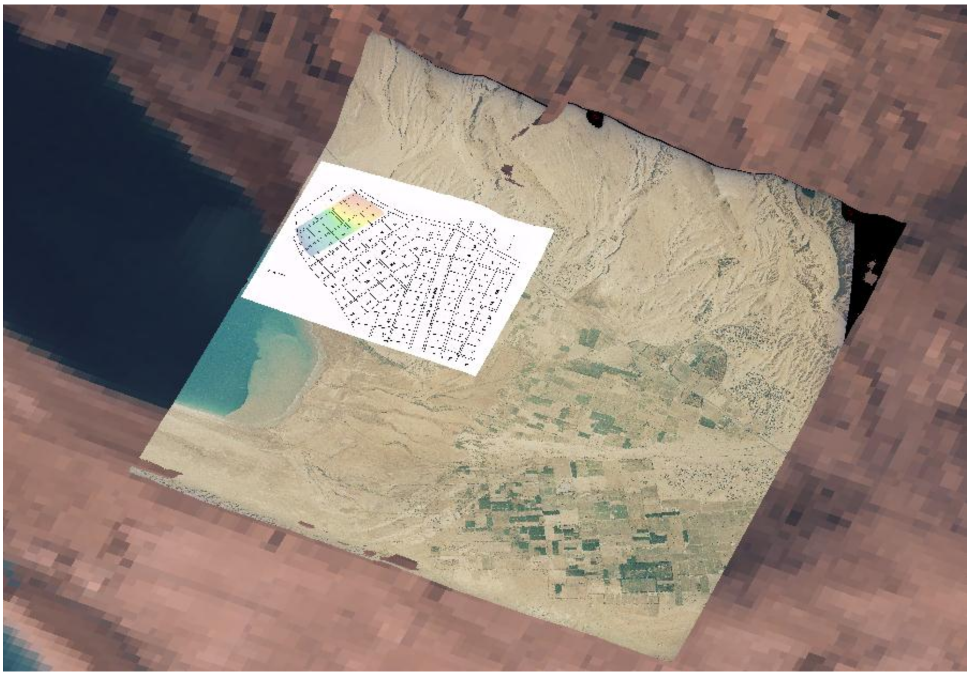

Figure 5. Ortho-photo for the Study Area

3. GLOBAL POSITIONING SYSTEM

Photogrammetric control process consists of any point of which its positions are defined in an object-space reference coordinate system and of which its images could be positively identified in the photographs. In aerial photogrammetry, the object space is the ground surface, and various reference ground coordinate systems are used to describe control point positions. Photogrammetric control, or ground control as it is commonly called in aerial photogrammetry, provides the means for orienting or relating aerial photographs to the ground. After collecting the project aerial-photos, ground control points (GCPs) is needed. Thus, planning and distributing of the GCPs on the photos

(Planning Stage) is essential for an appropriate selection of the GCP over the study area, as shown Figure 6.

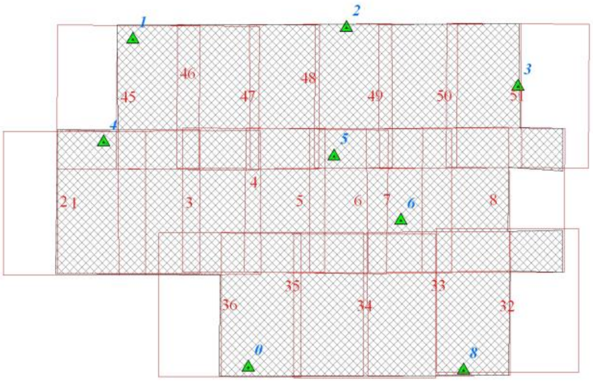

Figure 6. Ground Control Point Distribution in aerial photos

Difficulties during GCP collection process are summarized as follows:

- The topography of the study case is very difficult.
- There were very few interest and sharp features appearing in the aerial and it was not easy to be distinguished.
- About 30% of the aerial photos represent water, therefore the area could not be covered by the GCPs
- The aerial photos are 6 years old, which means that a lot of changes have been occurred in the area typically as the Dead-Sea area is rapidly developed meanwhile many investments were taking place.

It should to be mentioned that a survey has also been conducted to locate the exact position of the Sinkholes in the study area; applying the same method (mentioned above utilizing the GPS positioning of the sinkholes. Figure 7 illustrates the location of these points overlaid on the DTM of the study area.

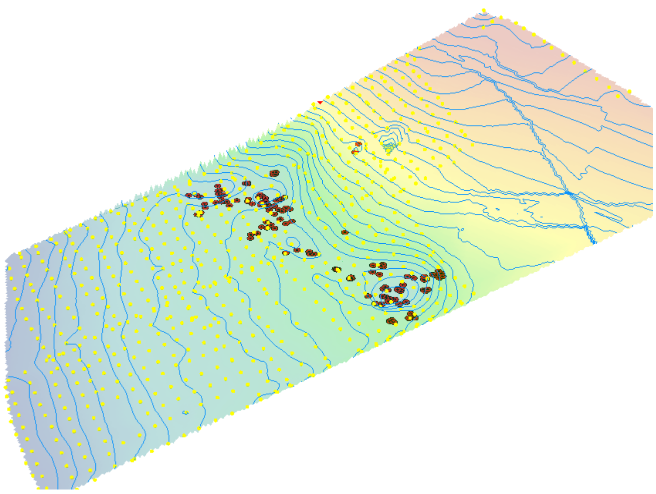

Figure 7. Sinkholes location place on top of the DTM

4. THREE DIMENSIONAL GIS

In general, data entry bears out to be a very time consuming, yet it is the key task at the GIS process. This section discusses the basic organization of entering data, scanning, layers designing, digitizing, georeferencing and projection, (3D) applications in GIS, creating a layout for "Ghoar Haditha Area", and other important aspects.

Most standard and GIS maps are in flat (two-dimensional, 2D) format, but presentation of landscapes as three-dimensional (3D) views is very useful, both as communication from 2D to 3D involving geometric and trigonometric calculations of elevation points to make surface-fitting triangles called TIN (triangular irregular networks). The triangles cover the region and represent the terrain so that a 3D perspective could be provided. Figure 8 illustrates a realistic 3D representation Ortho-photo dropped over DTM with 3D band combination for 4-3-2 LandSat bands.

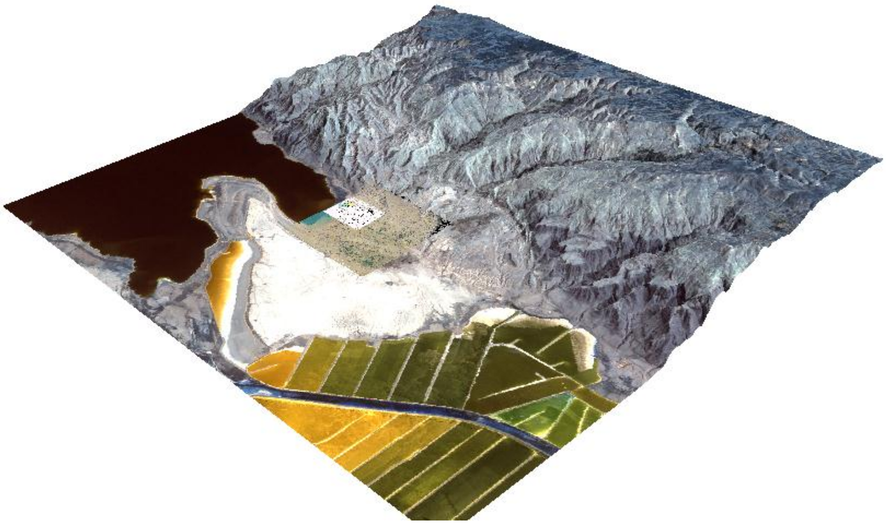

Figure 8. Representation of band 4-3-2 landsat superimpose with Ortho-photo

5. GROUND PENETRATING RADAR

Ground Penetrating Radar (GPR) has become an important non-invasive non-destructive technique for rapid geophysical mapping of shallow subsurface (Abueladas, 2005; Baker, 1991;Davis, 1989). A short pulse of high frequency from 10 MHz to 1 GHz electromagnetic pulses transmitted in to the ground from an antenna towed across. The GPR signal is reflected, refracted and attenuated depending on the distribution of the electrical properties of the subsurface layers which it also depends on water content and the physical properties of the layers (Batayneh et al, 2002). It is a method that is commonly used for environmental, engineering, archeological, and other shallow investigations. Ground Penetrating Radar applications expands to include pipes and utilities, concrete and rebar imaging and inspection, sinkholes, geology (bedrock) and geologic hazards, landfill and burial trenches, unmarked cemetery and grave location and archaeological studies (Abueladas, 2005; Al-Zoubi et al, 2007)

Sinkhole location is potential to be around and under homes and buildings, over roadways, train tracks, and airport runways, and in any other areas where the subsurface materials are subject to collapse. Sinkhole location surveys are conducted most often in karst limestone areas. However, sinkhole locations are potential also in areas with soft soil or where mining or other subsurface disturbance activities happened to occur.

The GPR profiles was situated at the main roads between agriculture units to avoid the noise from the power lines, water buried metallic pipes and water pumps distributed at the study area. Nine continuous GPR profiles were surveyed using SIR-20 system, manufactured by Geophysical Survey System Inc. (GSSI), USA with 400 MHz bow-tie mono-static antennas, Figure 9. Data were recorded at a speed of 50 scans/second, 512 samples per second with 16 bits A/D conversion. Automatic gain was used during data acquisition along all GPR lines. It has to be mentioned that maximum depth penetration was approximately 3 m for 400 MHz antenna where the estimate depth was made using a soil velocity of 0.11 m/nanosecond.

Figure 9. Location Map of the study area showing the GPR lines.

The GPR data is normally displayed with position (distance) along the horizontal axis and time (or approximate depth, if the velocity in the material is known on vertical axis.

- Figure 10 shows the GPR record obtained along GPR Line 1 over a known old filled sinkhole. The anomaly between a distance 21 and 24 m located at approximately 1.2 m depth represent the filled sinkhole with approximately 3 m diameter. The two small collapse features within the buried sinkhole can be noticed at distance 21.5 m and 23 m could be an indicator for new sinkholes along the line.
- Figure 11 shows the main anomaly along this GPR line 2 at distance between 35 m and 37 m located at approximately 1 m deep and may represent a buried sinkhole.
- The GPR line 7 was conducted in active sinkhole area to calibrate the 400 MHz antenna. Two main subsurface targets at approximately 0.4 m depth and located at the horizontal distance 0.7 m and 1.4 m. may represent two shallow parallel dry tunnels Figure 12.

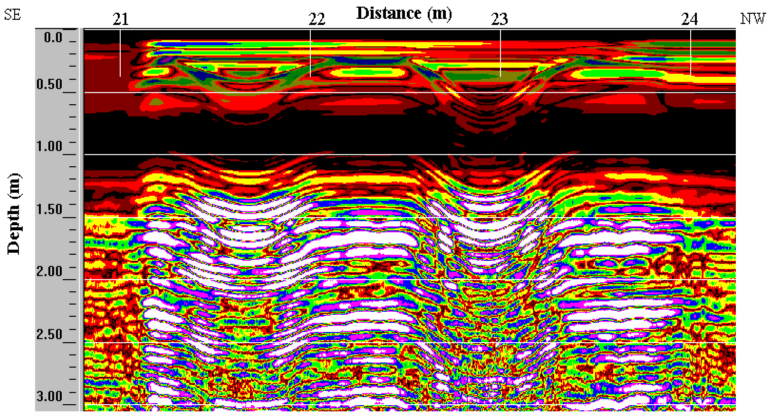

Figure 10. A part of radar cross section along GPR line 1 showing the boundary of known old filled sinkhole with two small collapse features.

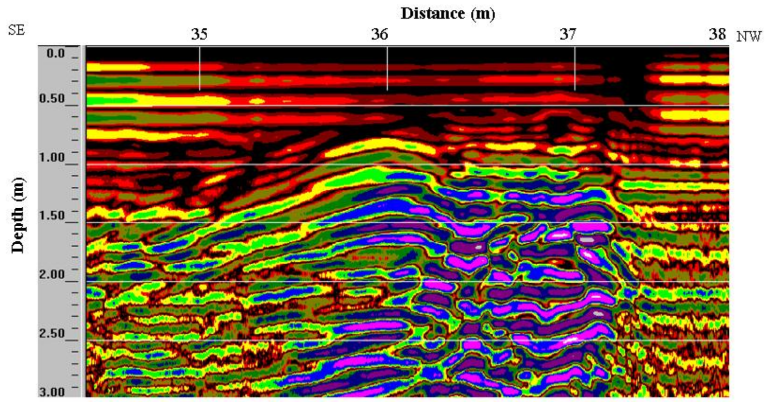

Figure 11. A part of radar cross section along GPR line 2. The main anomaly along this line at distance between 35 m and 37 m located at approximately 1 m deep may represent a buried sinkhole.

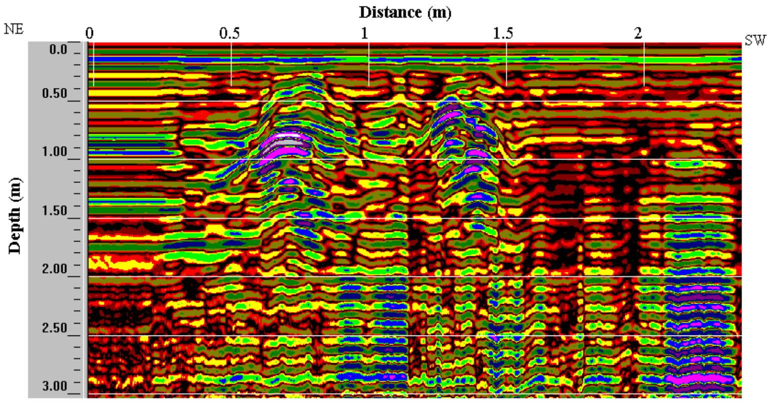

Figure 12. A part of radar cross section along GPR line 7. The two main subsurface targets at approximately 0.4 m depth and located at the horizontal distance 0.7 m and 1.4 m. may represent two shallow parallel dry tunnels.

6. CONCLUSION

Ghoar Hadith Area in Jordan located along Dead sea shore line, represent interesting region for hazard mapping technology. This region combines between hazards that expand to include sinkholes, subsidence, shoreline movement and structural floats. Geometics as well as geophysical science represent efficient tool to prepare accurate spatial database to assess of amount, nature and development of the existing hazard. For this purpose topography (Digital Elevation Model) modeling has been build based on aerial photographs (stereo pair).Moreover, photogrammetric processing was performed in the study area to produce High resolution Ortho-photo image (Image with same characteristics of maps, where it is distortion free image, has constant scale and can be used for actual measurement in GIS systems). Finally, 3D GIS Model or study area was developed that includes (Boundary maps, sinkhole location, DTM, transportation layer, hydrological maps, digital elevation model, and geology of the area).

Ground penetrating radar survey was carried out at Ghor Al-Haditha area at the eastern shore line of the Dead Sea. GPR is a powerful tool for delineation the old buried sinkhole and detect different subsurface target which may represent shallow tunnels which assist the leakage of the surface fresh water to the subsurface layer and washed soft material and salt in the layers that aggregate the formation of the sinkholes in the study area.

Continuous monitoring of the location of the GPR anomaly along the lines will provide us information about what occur beneath the surface with time and to correlate our results with the new events take place in the study area**.**

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