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Research Paper

An Integrated Geophysical Study of Kraseaw Dam in Thailand

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ABSTRACT

The study was conducted using seismic reflection and electrical resistivity methods including several techniques such as electrical resistivity imaging, seismic refraction and seismic reflection to determine the stability of the dam. The survey used a case study of Krasiao-Dam in Dan-Chang district Suphan-Buri Thailand. Krasiao-Dam is valid for a period of several years, suiting our study. The electrical resistivity data was processed and presented as 2D underground cross section. An integrated data analysis of these two results were verified of possible leakage position or risk location as it needed to be tested by conventional engineering testing methods. Seismic survey results indicate that the dam layers structure; which included compaction soil, is shown with the wave speed as between 400-900 m/sec, ground improved layer and bed rock has a higher signal speed of 1,000 m/sec.

1. Introduction

The principal objective of a geophysical investigation is usually to measure material properties, and locate sub-surface structural features (Telford et al., 1990). An integrated geophysical investigation is widely used for engineering applications to investigate and provide overall underground information (Zhao et al., 1990) and (Inazaki et al., 2008). It can perform quickly on ground surfaces and do not destroy those engineering structures effectively saving costs.The validity of dam safety assessment is largely dependent on mechanical parameters knowledge of the actual construction, as well as its geological substratum. Many dams in Thailand were operated on for long years, and were affected by their mechanical parameters. They suffered a gradual degradation that may cause serious concern today (Bond et al., 2000).

Krasiao-Dam is a typical earth dam and was constructed in 1981 with a length of 4,250 m. This is the second country after the Pa-Sak Cholasit Dam in Thailand. This dam has a height of 32.5 m. and the surface water area or water restoration is 46 sq.km. The capacity of the dam is 240 Mcu.m as shown the cross section in Fig. 1. Krasiao-Dam was situated within a mountainous landform area. The geological profile along the embankment that obtained from the geotechnical investigation is shown in Fig. 2. At the Eastern end of an embankment situated over the Ordovician rocks (THUNG SONG GROUP). this is made up of a grayish black

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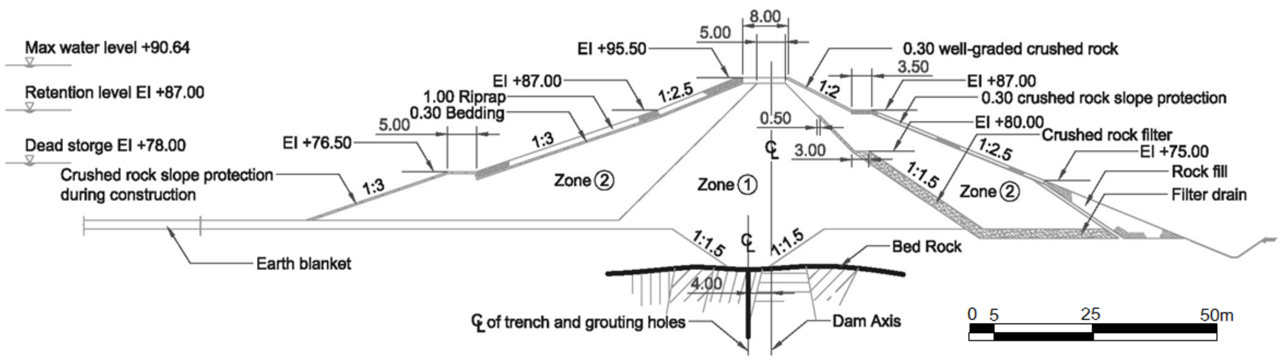


Fig. 1. Cross section of Krasiao-Dam

limestone. At the southern end of the embankment which is located over Silurian-Devonian rocks (KANCHANABURI FORMATION). A type of semi sedimentary-metamorphic rocks which contains Quartzite and brownish sandstone forms, some of the metamorphic rocks has structural qualities like Schist and Gneiss (Geology of Thailand, 2010). This phenomena will take every granted fascinating soil and geologist whoever needed.

2. Literature Review

Assessment of the mechanical properties of the body of the dam, and its geological setting such as, self-potential, electrical resistivity, seismic P-wave and S-wave velocities, etc., are important to identify any risks to the dam.

2.1 Self-potential survey (SP)

Porous pod made from PVC with a diameter of 3 inches and porous ceramic contact at the bottom surface layer and copper electrode on the top. Inside, the pod was filled with copper sulphate solution to perform as non-polarized electrode, as shown in Fig.3a.

NI USB-6009 data acquisition board with laptop computers was used for data acquisition (Fig 3b). The shield cable was connected to two porous pots, one at the base station and one at measurement point. The measurements were performed along three survey lines. Each measurement, 8 channels of data acquisition were performed in single end mode to collect data simultaneously. 8 porous pots were wired to data acquisition unit with referenced to ground at base station.

Measurements points and base stations were located using GPS. These measurement points have a 50m-spacing along the survey line, there survey lines which have a 100 m. offset were conducted within this study. The base stations were located 1,200 m-apart as limited by cable length of 600 m.

Finally, data correction was performed based on base station. Corrected data was plot into grid map based on their position and overlaid on google satellite map.

2.2 Electrical resistivity survey (EI)

EI survey lines were located on one of the self-potential survey lines which are nearest to an embankment. Syscal R1 plus switch 48 resistivity meters with cable and 5 m spacing was employed for this study, as shown in Fig.4. All stainless-steel electrode positions were located using GPS to acquire both position and elevation. In this study we used pole-dipole array as it has advantages in geometric factoring and depth of investigation. The measured data was processed using RES2DINV (Loke, 2010) to have an inversion section.

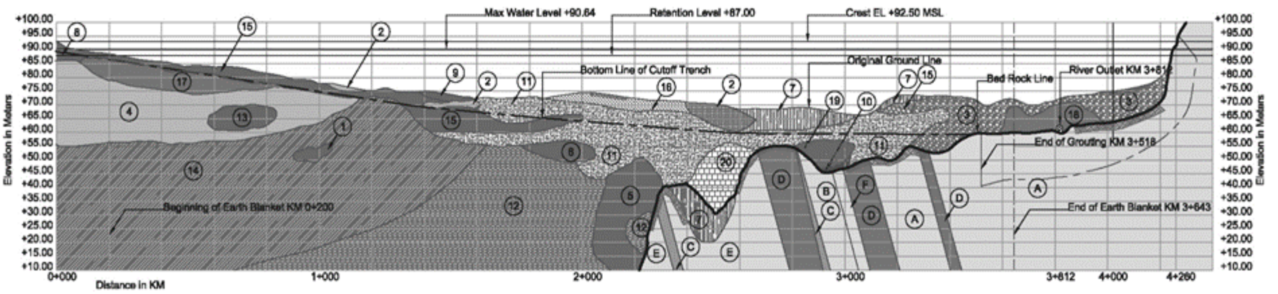
Ground water level was measured from observation wells along the survey line using measurement tapes, as shown in Fig.5. Two additional survey lines were performed perpendicular to the dam embankment over normal location and the self-potential anomaly location. These survey lines were selected after acquiring self-potential data.

2.3 Seismic survey

The seismic survey line which was located on top of the embankment aimed to image each constructed materials layer and initial earth structure underneath the embankment. Markers were made with 5m-spacing along the survey line by GPS. These markers were used for shot point and receiver location.

Seismic data acquisition systems included Geodes24 seismometer with 10Hz geophone (Fig.6a) and 20 lbs sledge hammer with 0.5 inches steel plate were used as a seismic source. To increase survey performance, seismometer was installed on a pickup truck and geophones were installed on a land streamer cable, as shown in Fig 6b.

Seismic survey was designed base on off-end shot pattern to reach 12 folds which the shot point spacing of 5 m and geophone spacing of 5 m. The nearest offset



Legend

- (A) Siliceous limestone-limy quartzite, gray, hard, much broken.
- (B) Shaly LS, light gray-white, soft and brittle.
- (C) LS, light gray-white, hard, much broken.
- (D) Slate, dark grey, hard, some pyrite, severely broken.
- (E) Phyllite, purplish light gray, soft, severely broken, bedding about 30m.
- (F) Shaly, reddish brown, soft.
- (1) Silty clay, high plasticity, dark brown.
- (2) Silty sandy clay, low-medium plasticity, brown.
- (3) Sandy silty clay, medium-high plasticity, yellowish brown.
- (4) Sandy silty clay, some gravels, mostly low-medium plasticity.
- (5) Sandy clay, some Biotite brownish green-greenish gray.
- (6) Sandy clay, some gravels, grayish brown.
- (7) Clayey sandy silt, brown.
- (8) Clayey silty, some gravels, reddish brown.
- (9) Sandy silt, reddish brown.
- (10) Sand, well-graded, brown.
- (11) Sand, well-graded some gravels, with clay binder, brown.
- (12) Clayey sand, some Biotite, brownish green-greenish grey.
- (13) Sand, medium-find brown.
- (14) Sand, med-fine, some gravels, brown.
- (15) Clayey silty sand, brown.
- (16) Silty sand-brown.
- (17) Silty sand, some gravel brown.
- (18) Decomposed limestone with clay binder.
- (19) Decomposed limestone with clay binder reddish brown.
- (20) Decomposed limestone.

Fig. 2. Geological Profile of Krasiao-Dam

and fare offset are 5 and 120 m, respectively, as shown in Fig. 7.

Seismic data set was processed under seismic unix (Seismic Unix, 2015) by Colorado School of Mines, United States of America (USA) for refraction and reflection results, seismic refraction results will be employed for refraction static correction. Pre-Stack Time Migration methods (PSTM) was using for seismic reflection data processing. The same seismic data set was processed by Seisimager/SW for surface wave analysis (Seisimager/SW, 2004) with 25 m interval.

Earth material identification was based on their characteristic of P-wave and S-wave velocity. Soil can classified based on the characteristics of Surface wave seismic velocity into 6 types (BSSC, 1997) as shows all survey lines that were surveyed on this study.

3. Results and Discussion

3.1 Self-potential survey

SP survey results as shown in Fig. 9, indicate a spontaneous potential value range from -150 to 750 mV. General value in ranges from 0 to 150 mV, lower and higher than this range were considered as an anomaly.

a) non-polarized electrode

b) NI USB-6009 14bits data acquisition board

Fig. 3. Self-potential data acquisition system with (a) and (b) options

Fig. 4. Syscal R1 plus switch 48 resistivity meter

Fig. 5. Observation well for ground water level

This anomaly being caused by earth materials, seepage, etc. (Corry, 1985). Two additional EI survey lines at station 0+550 and 3+625 were designed to investigate over anomaly location and normal location, respectively.

a) 10Hz Geophones

b) Land streamer cable

Fig. 6. Seismometer with land streamer system

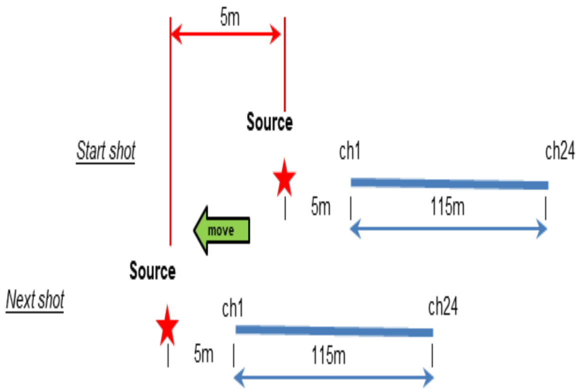


Fig. 7. Seismic survey configuration

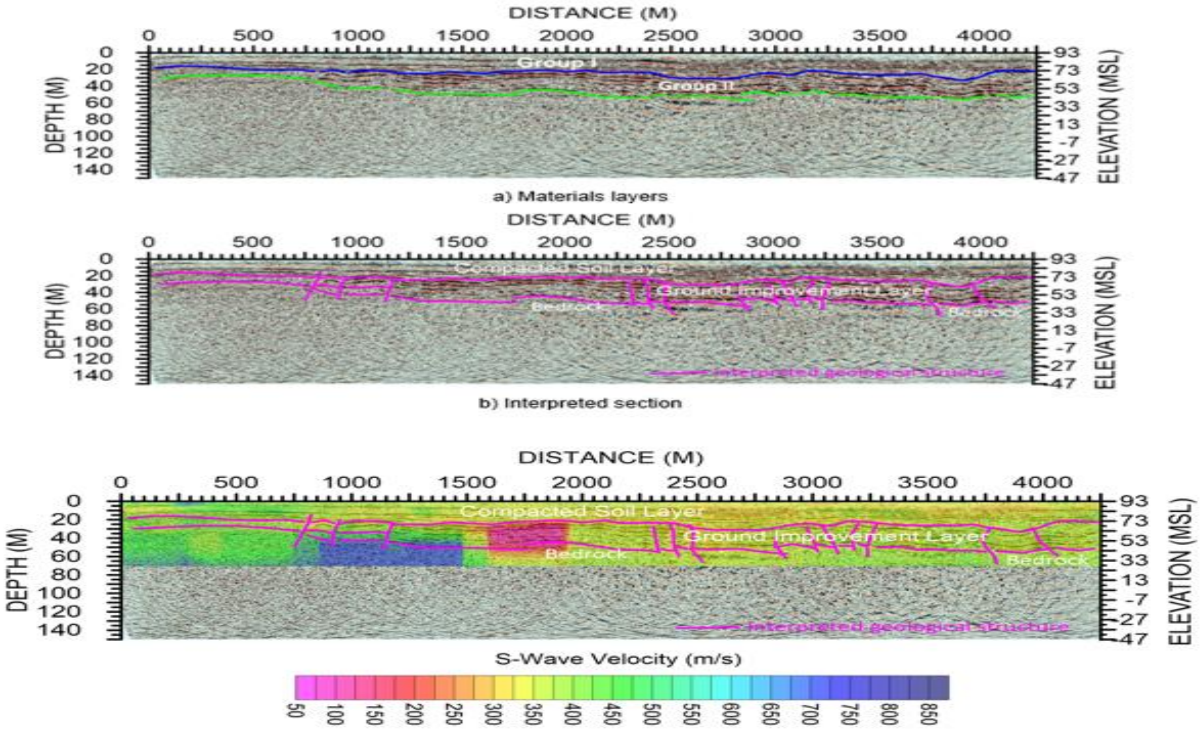


Fig. 8. Resistivity inversion result

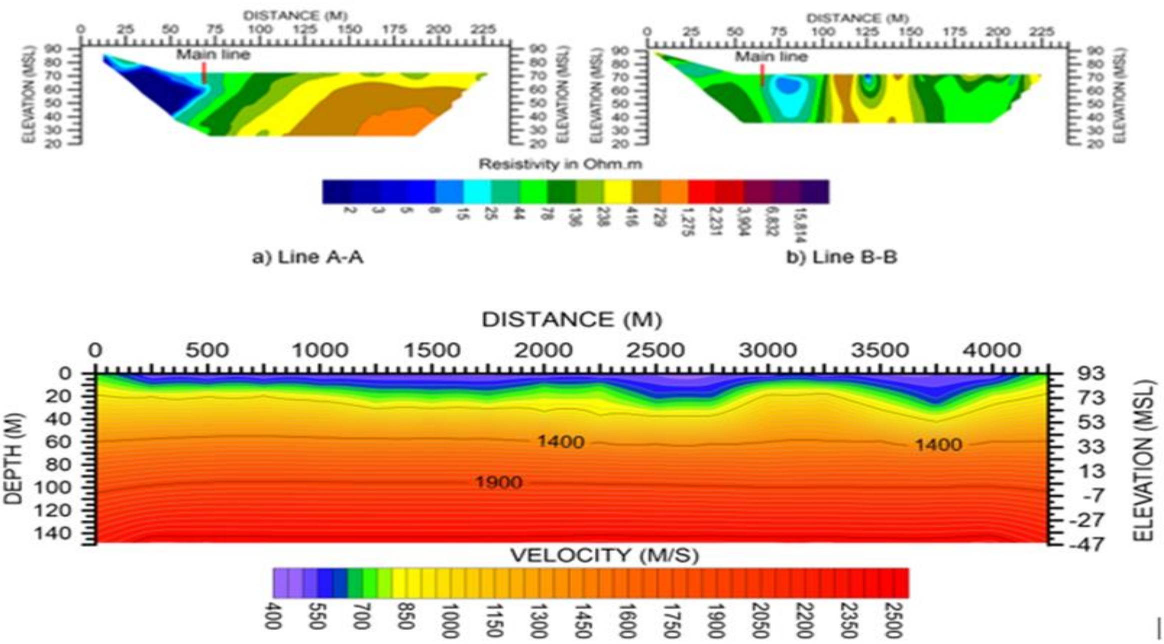


Fig. 9. Additional line resistivity inversion result & Seismic refraction result

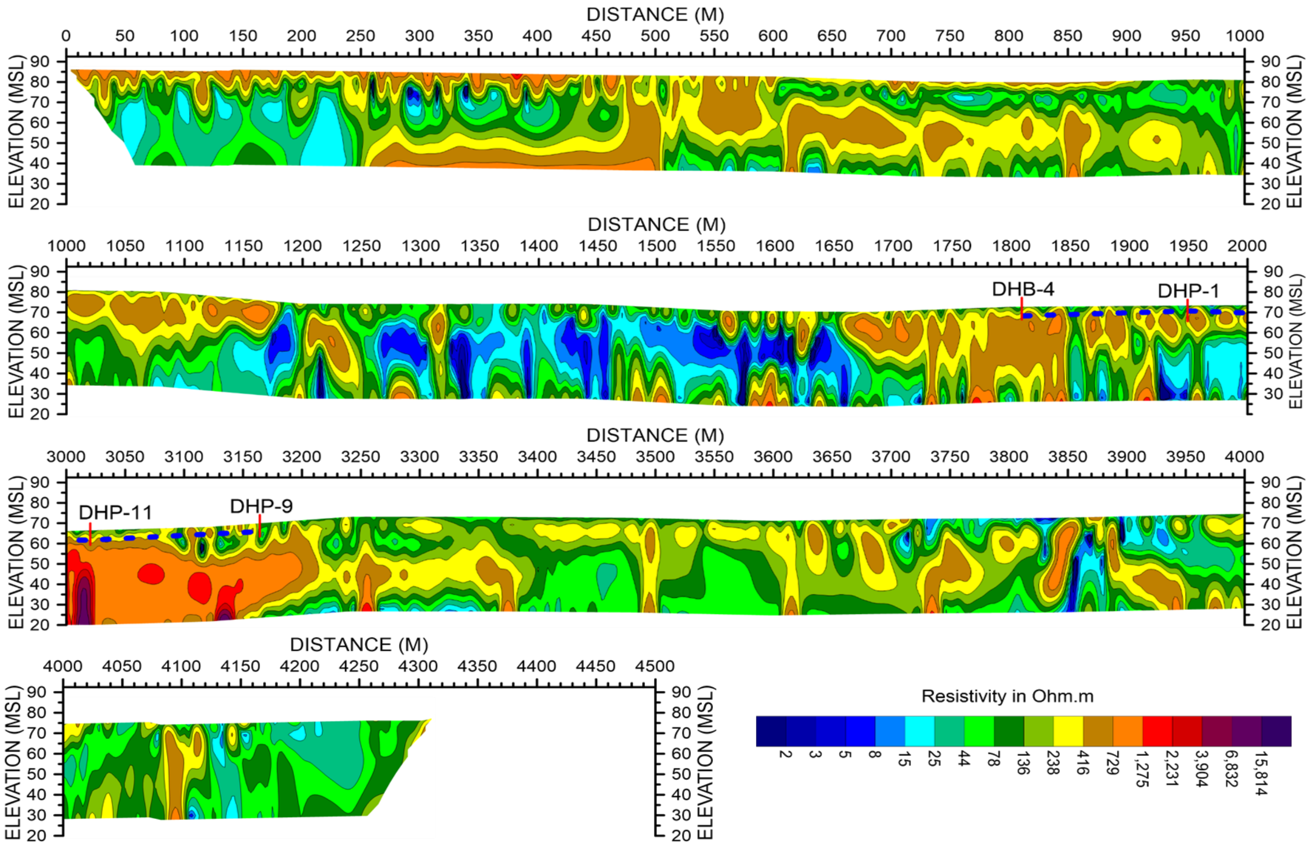


Fig. 10. Seismic reflection result **&** Surface wave seismic result

to verifies these anomalies. From the additional EI survey results of survey line A-A indicate no low resistivity anomaly over the SP anomaly as expected. It is may cause by the laterite soil and garbage dump on this area. The EI survey result of survey line B-B are agreed with SP survey result, the low resistivity anomaly at a distance of 125 m from may cause by a artifact.

3.2 Electrical resistivity survey (EI)

The measured apparent resistivity from the field was in ranges of 1 to 1,500 Ohm.m. The inversion section shows resistivity value from 1 to 20,000 Ohm.m. High resistivity value that was shown in the inversion section may be caused by the contamination with inversion artifacts or by an inversion algorithm (Marios, 2011).

In Fig.8, the rock base layer was identified in the inversion result as shown in range of 120-175 Ohm based on resistivity of earth materials corresponding to limestone Schist and Gneiss that found in the exposures area (Palacky, 1987). The resistivity inversion results of two additional lines perpendicular to the embankment and normal survey lines. Line A-A was located over normal area of self-potential result, which is indicates a low resistance zone inside an embankment. As shown in Fig. 11a. Line B-B was located over an anomaly of self-potential area results, which is indicative of resistance within an earth embankment in the ranges of 40 to 136 Ohm.m, which is an unsaturated compaction material layer.

Low resistance zones, with lower than 10 Ohm.m was identified near to the main survey line, as shown in Fig. 11b. Possible leakage locations were identified at low resistance zones, with resistance lower than 10 Ohm.

3.3 Seismic survey

Refraction seismic result indicates rock base layers with velocities greater than 1,000 m/s. The compacted material layers were identified in velocity ranges of 400-900 m/s and an improvement layer was identified in velocity ranges of 900-1,000 m/s. as shown in Fig.9. The seismic refraction velocity model is agreed with the geological model (Fig.9).

Reflection seismic result indicates two groups of material layers (Fig.110a.); group I was presented at the upper part which this group was identified as compacted soil layers. Group II was identified underneath the group I layer. This group is an improved layer by a cement grouting method, as shown in Fig.10 a&b. The geological features and discontinuity also identified in the seismic reflection results as shown in Fig.10b.

The Fig.10 shows the surface wave seismic survey result overlaid over seismic reflection result, indicates S-wave velocity in ranges of 50 to 900 m/s which corresponding to soil type B to F. The low S-wave velocity zone (50-250 ms) had been identified at sta.1+600 to 1+970 at depth of 20 to 55 m. or 37.5 to 72.5 m. MSL. This low velocity zone is classified in soil profile type D – F, which is stiff to soft layers, especially, type F is special soils requiring site-specific evaluation (Thierry, 1987).

Refraction and reflection seismic survey results were not identified at any risk location. But the surface wave seismic survey shows the location of the low velocity anomaly for further site-specific evaluation.

4. Conclusions

The anomaly those had been identified in each survey methods can be treated as risk locations, which indicated a total score as follows; 1 = risk location and 2= high risk location. Combined applications of electrical and seismic methods allowed us to obtain overall results on the earth dam. Maps of self-potential measured on the dam side, reflect the configuration of the contours of the water flow passing through the dam. This makes it possible to obtain data on the direction and intensity of flow as well as on the presence of heterogeneous grounds filling the dam supporting mass. The electrical resistivity survey method indicates saturated material as a low resistance zone in the inversion result. This confirms the ability of this technique to delineate some critical geological subsurface structures as detected by other methods.

The difference in propagation velocities of elastic waves in subsurface to determining the depth of each layer. Surface wave survey results provide more details on engineering properties of soil and proved their efficiency in the non-destructive testing of the dam as it can detect soft material which shown as low velocity zone.

References

Bond, L.J., Kepler, W.F. and Frangopol, D.M., 2000. Improved assessment of mass concrete dams using acoustic travel time tomography: Part I. Theory. Constr. Build. Mater. 14.: pp 133 – 146.

Building Seismic Safety Council (BSSC)., 1997. NEHRP recommended provisions for seismic regulations for new buildings, Part 1-Provisions (FEMA Federal Emergency Management Agency 302).: pp 290.

Corry, C.E., 1985. Spontaneous polarization associated with porphyry sulfide mineralization, Geophysics 50.: pp 1020-34.

Geology of Thailand. 2010. http://dmr.go.th (10. 6. 2010).

Inazaki, Tomio & Hayashi., Koichi & Watanabe., Fumio & Tokumaru. and Koichi & Imamura Sugio., 2008. Ground Truth Verification of An Integrated Geophysical Investigation For The Assessment Of An Earthen Levee. Conference Proceedings, 21st EEGS Symposium on the Application of Geophysics to Engineering and Environmental Problems, Apr 2008, cp-177-00040.

Loke, M.H., 2010. Tutorial: 2-D and 3-D electrical Imaging Surveys. http://geoelectrical.com (3. 5. 2010).

Marios, K., Panagiotis, T. and Jung-Ho K., 2011. Comparison of algorithms of Time-lapse ERT inversion, Geoelectric Monitoring Current Research and Perspectives for the Future, an International Workshop within the frame of the FWF project TEMPEL (TRP 175-N21) and the 7th FP European project SafeLand November 30th – December 2nd, 2011, Vienna.

Palacky, G.J., 1987. Resistivity characteristics of geologic targets, in Nabighian, M.N., ed., Electromagnetic Methods in Applied Geophysics Theory: Tulsa, Okla., Society of Exploration Geophysicists, v.1, p. 53-129.

Seisimager/SW., 2004. Seismic refraction and surface wave data processing software, http://geometrics.com (18. 8. 2004).

Waves Methods. Journal of Geoscience and Environment Protection, Vol.8, p.55-69.