Frontiers in Scientific Research and Technology

Online ISSN: 2682-297
Print ISSN: 2682-2962
http://fsrt.journals.ekb.eg

FSRT J 3 (2022) 70-77 10.21608/fsrt.2021.112247.1053

Surveying the seepage area in the Dong Do dam by the improved multi-electrode electrical exploration method

Chung Anh Do[1, 2], Minh Duc Vu[2, *], Luan Thanh Pham[2], Ahmed M. Eldosouky[3]

[1] Institute for Ecology and Works Protection, Vietnam Academy for Water Resources, 171 Tay Son, Dong Da, Hanoi, Vietnam

[2] University of Science, Vietnam National University, 334 Nguyen Trai, Thanh Xuan, Hanoi, Vietnam

[3] Geology Department, Faculty of Science, Suez University, Suez, 43518, Egypt

ARTICLE INFO

Article history:
Received 20 December 2021
Received in revised form 23 December 2021
Accepted 25 December 2021
Available online 25 December 2021

Keywords
Seepage area,
Dam,
Improved multi-electrode electrical exploration,
Profile.

ABSTRACT

One of the common dangers of earth dams is seepage, or leakage through either the dam body, the dam foundation, or the culverts. This paper presents the results of utilizing the improved multi-electrode electrical exploration method to survey the seepage area in the Dong Do dam in Minh Tan village, Minh Tri commune, Soc Son district, Hanoi, Vietnam. The obtained results show two possible seepage anomalies in the survey profile along the heartbeat line, one seepage anomaly in the survey profile at the center of roof 1, one seepage anomaly in the survey profile at the center of roof 2 and a large heterogenous area in the first profile from the 185th meter position to the flood spillway staring from the surface down to a depth of 11m that the previous drilling could not reach these areas. These results confirm the effectiveness of the improved multi-electrode electrical exploration method in investigating hidden hazards in general, and the seepage areas in the dam in particular.

1. Introduction

The earth dams of Vietnam, after long periods of operation and exploitation, often develop hidden hazards that may significantly affect safety at many different levels and of many different characteristics. One of the common dangers is seepage, or leakage through either the dam body, the dam foundation, or the culverts.

However, the detection of seepage areas in the dam body is usually done only via observations of the dam roof and measurements of the seepage flow downstream and seepage manifestations on the outside. The functionality of the dam would already have been threatened when signs of seepage are seen. However, external manifestation observations cannot assist in determining the exact location of the seepage from upstream, thus treatment procedures are often of high cost yet low efficiency. In some circumstances, there may be no visible manifestation up until the reservoir has been filled with water and start to seep out, by which it is already too late.

We have used Geophysical methods to identify seepage areas in dikes and earth dams in Vietnam when there have been abnormal manifestations [1, 2, 3] and achieved very useful results.

* Corresponding authors at Vietnam National University
E-mail addresses: minhvd@vnu.edu.vn (Minh Duc Vu)

According to the general dam safety inspection program, we conducted a survey by the improved multi-electrode electrical exploration method to determine if the Dong Do dam has a seepage area or not, as well as their exact locations in order to proactively deal with them in an accurate and effective manner.

2. Survey area and method

2.1. Survey area

2.1.1. Geographical location

The Dong Do Lake is located in Minh Tan village, Minh Tri commune, Soc Son district, Hanoi, Vietnam, at a 45 km distance from Hanoi city. Minh Tri commune lies at a geographical position from 105°45'56" to 105°46'40" East longitude and 21°18'36" to 21°19'36" North latitude, has a total natural area of 2.435 ha surrounded by Bac Son commune to the North, Minh Phu commune to the East, Tan Dan ward of Phuc Yen city in Vinh Phuc province to the South, and Xuan Hoa ward of Phuc Yen city in Vinh Phuc province to the West.

2.1.2. Current status of the Dong Do dam

In the past, there had been a phenomenon of water seeping through the dam body to the downstream rock pile with a relatively large flow. In 2009, injection grouting was

carried out for the dam (3 boreholes drilled from the middle of the dam to the sluice location - Irrigation Project Management Board 402), so the issue above has been resolved, ensuring the seepage through the dam is within the permittable limit, as well as dam stability. According to the lake manager, recently, when the water level reached the height of 38.6m, there was seepage in the left half of dam roof 2.

At the time of survey, the lake water level was at 36.6m, so no seepage was observed:

- The dam surface had no subsidence, damage or deterioration, and was assessed to be stable, ensuring inter-village traffic in Minh Tri commune, as well as stable management and operation of the lake. (Figure 1).

- The downstream dam roof is protected by planting grass beds with vertical grooves along the dam roof located 5m apart, and horizontal grooves running along the dam body, all are made of masonry with a rectangular cross-section sized 0.3x0.3m. The drainage ditch at the foot of the dam was also made of masonry with a trapezoidal cross-section, the width of the bottom is 0.3m, the height of the trench is 0.3m. The current status of the downstream dam roof is stable, there is no subsidence or landslide, ensuring safety. (Figure 2).

Figure 1. Current status at the top surface of the Dong Do dam

Figure 2. Current status of the Dong Do downstream dam roof

Figure 3: Current status of the Dong Do upstream dam roof

- Upstream dam roof is protected by anhydrous paving stones, the footrests of masonry. The current status of the upstream dam roof is stable, with no subsidence or landslide, ensuring safety. (Figure 3)

2.2. Survey Method

- Using the improved multi-electrode electrical exploration method [4, 5, 6] to survey and detect the seepage area, as well as determine the locations of the extrusion circuit, the effervescent circuit and the hollow cavities within the dam body.

- Conduct survey on 3 profiles: profile 1: running along the heartbeat line (passing through 3 boreholes dating back to 2009) (Figure 5); profile 2: in the middle of the downstream roof above the dam; profile 3: in the middle of the downstream roof below the dam.

- Using the device SUPERSTING R8/IP + 56 poles from AGI (USA) [7], has large output power, high accuracy and good anti-interference with a solid structure, easy to use and is suitable for conditions in the field with the output current is from 1mA to 2A continuously and the output power is 200W, using a symmetrical MC electrode array.

- Process and analyze measured data with the software EarthImager 2D [8]. This is a useful software that can be synced with the SuperSting R8/IP device.

- The distance between the measuring points is 3m along the measuring profile. The survey is conducted to a depth of 30m.

2.3. Map of survey profiles

The direction of the measuring profiles is from left shoulder to right shoulder of the dam. The distance between measuring points is 3m. The length of the dam surface profile is 249m. The center profile of roof 1 has a length of 219m and that of roof 2 is 165m. The total survey length is 633m. (Figure 4).

Figure 4. Map of survey profiles for the Dong Do dam

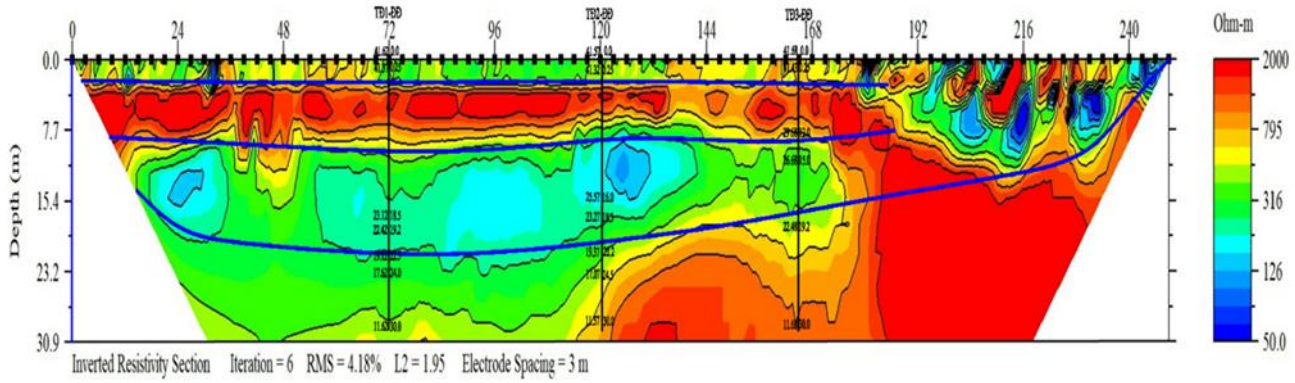


Figure 5. Survey result of the profile along the heartbeat line of the Dong Do dam

3. Survey Results

3.1. Profile along the heartbeat line

The obtained results show that the section from the left shoulder to the 185th meter position in the dam body is made up of 3 layers (Figure 5):

Layer 1: Depth from 0m to 3m, has an average resistivity of 315Ωm.

Layer 2: Depth from 3m to 8.5m, with resistivity greater than 1,000Ωm.

Layer 3: Depth from 8.5m to the deepest point at 23m. In this layer, the resistivity had many fluctuations, specifically: In the passage of the left shoulder with a depth of 8.5m to 18m, from the 18th meter position to the 32nd meter position, and from the 120th meter position to the 130th meter position are two low resistivity anomalies spots with only 50-70Ωm yet located in a layer with resistivity of about 150Ωm. We concluded this could be a seepage anomaly in the dam. In addition, at the profile on the dam surface, the section from the 185th meter position to the flood spillway (250m) with a depth of 0m to 11m is a large heterogeneous area that needs to be investigated more closely at this location.

3.2. Center profile of roof 1

The obtained results from the survey profile in roof 1 shows one less layer of dam composition compared to the profile along the heartbeat line (Figure 6):

Layer 1: Depth from 0m to 6m, has a resistivity greater than 1,000Ωm and extends to the entire survey profile.

Layer 2: Depth from 6m to 15m. Images show that, at this layer, from the beginning of the profile to the 30th meter position at a depth of 3m to 8m, there is a low resistivity anomaly of about 150Ωm yet located in the area with resistivity greater than 800Ωm. This may also be a seepage anomaly for the dam.

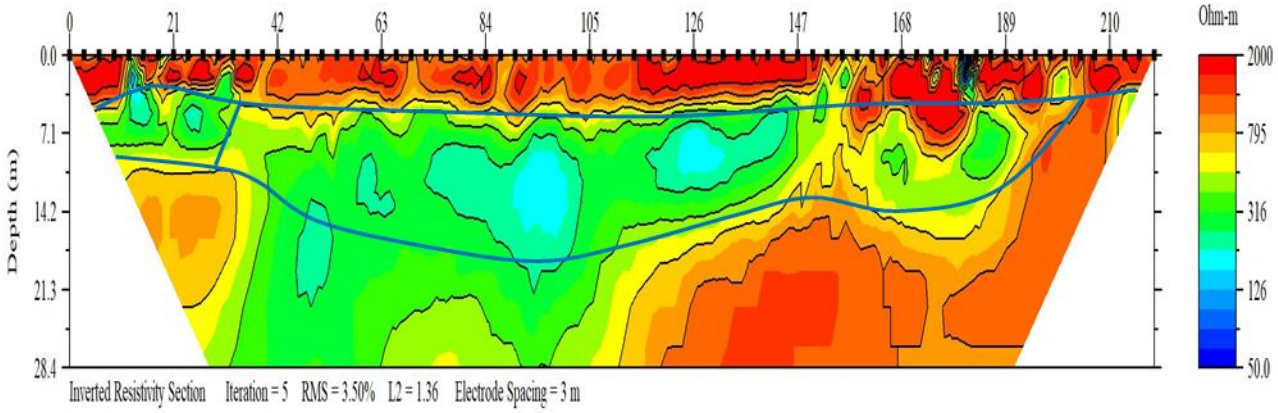


Figure 6. Survey results of the center profile of roof 1 of the Dong Do dam

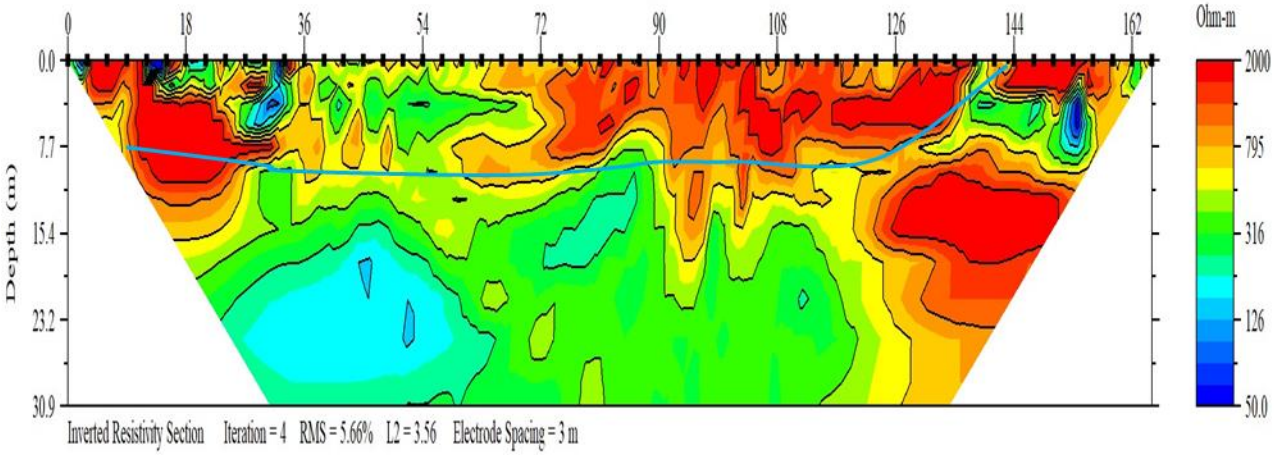


Figure 7. Survey results of the center profile of roof 2 of the Dong Do dam

3.3. Center profile of roof 2

The survey results from the center profile of roof 2 show that there are only 2 layers to distinguish between the embankment and the foundation (Figure 7). The thickness of the embankment is about 8m. In the range from the 12th meter position to the 65th meter position of the survey profile, there is a low resistivity anomaly starting from the surface. According to our assessment, at this location, when lake water level rises, there would be seepage occurring into the dam surface.

3.4. Assessment

3.4.1 About survey Results

After conducting surveys using the improved multi-electrode electrical exploration method with three profiles at the dam surface, roof 1 and roof 2 downstream, in addition to the comments presented above, the conclusions about the current status of the surveyed dam can be summarized as follows (Figure 8):

- The left shoulder of the dam has a seepage line from upstream to downstream of the dam.

- At the dam surface, close to the flood spillway, there is a heterogenous area that needs to be investigated in more detail.

- The depth of seepage as well as the area are determined with heterogeneity on the survey profiles.

3.4.2 About drilling results and geological sections

According to the results of 3 boreholes on the profile along the heartbeat line of the dam and the Geological cross-sections [9], we have linked the survey results using the improved multi-electrode electrical exploration method and the drilling and geology documents into Geological - Geophysical cross-sections. These cross-sections are shown in Figures 8, 9, 10 and 11.

- Comparison of the results between the improved multi-electrode electrical exploration method and the drilling method shows that these results are consistent with each other. The boreholes, however, do not pass through the heterogenous and seepage area so they cannot be detected when using this method.

- The geological cross-section is divided into thin layers. The top layer was considered to be homogeneous, yet results from surveys using the improved multi-electrode electrical exploration method discovered that there is a large heterogenous area located near the flood spillway (Figure 12).

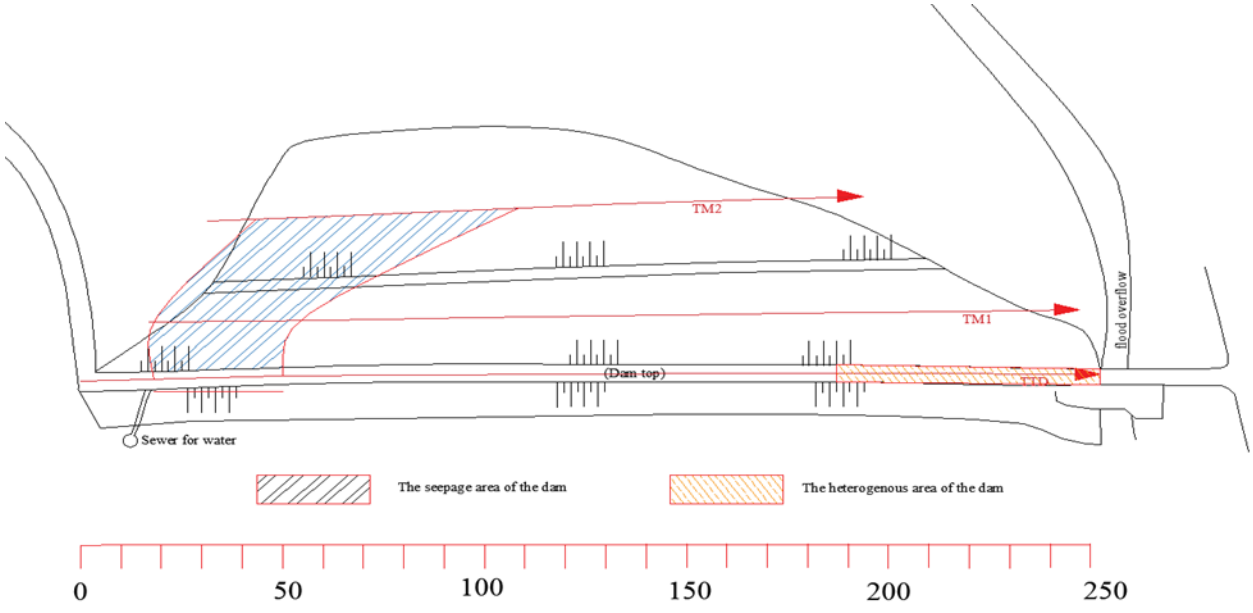


Figure 8. Map of the seepage area on the Dong Do dam

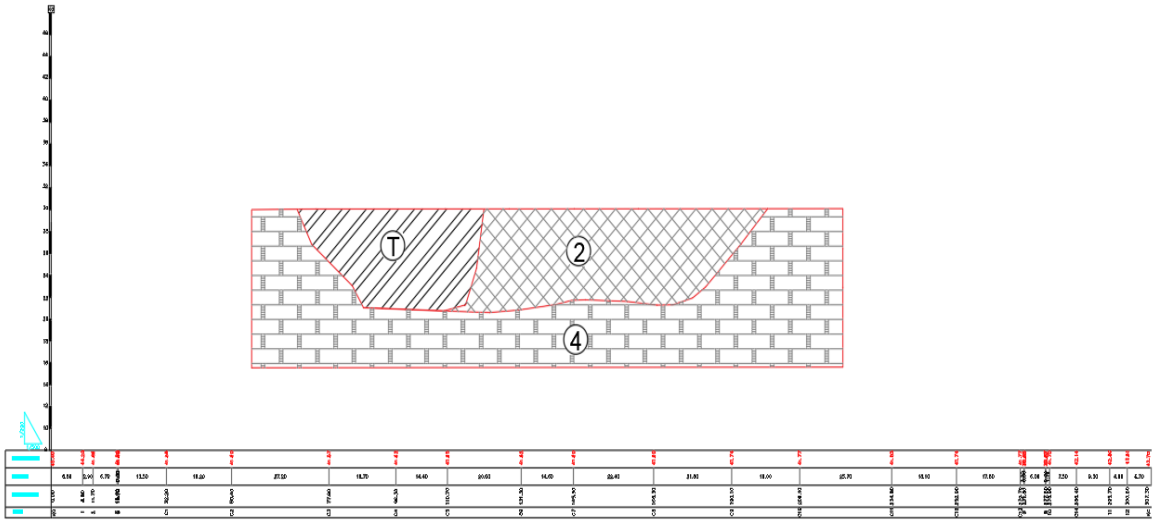


Figure 9. Geological - Geophysical cross section of the center profile of roof 2

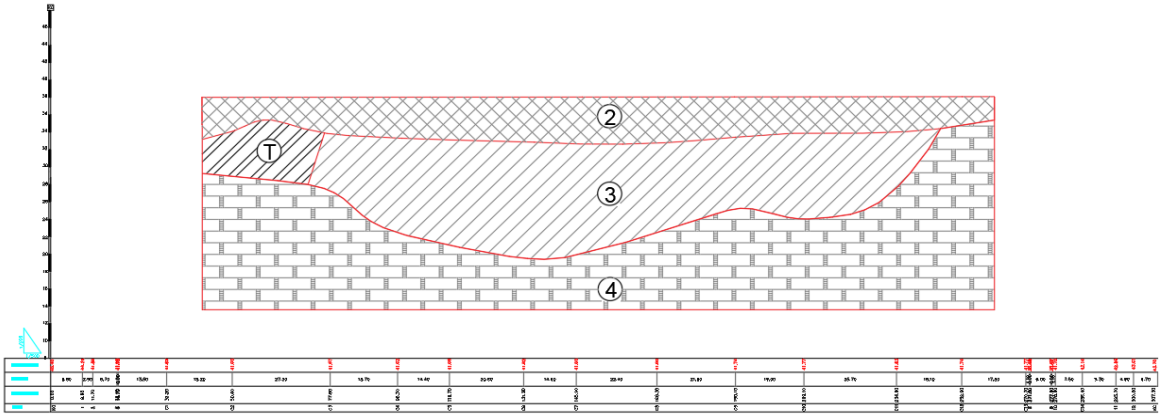


Figure 10. Geological - Geophysical cross section of the center profile of roof 1

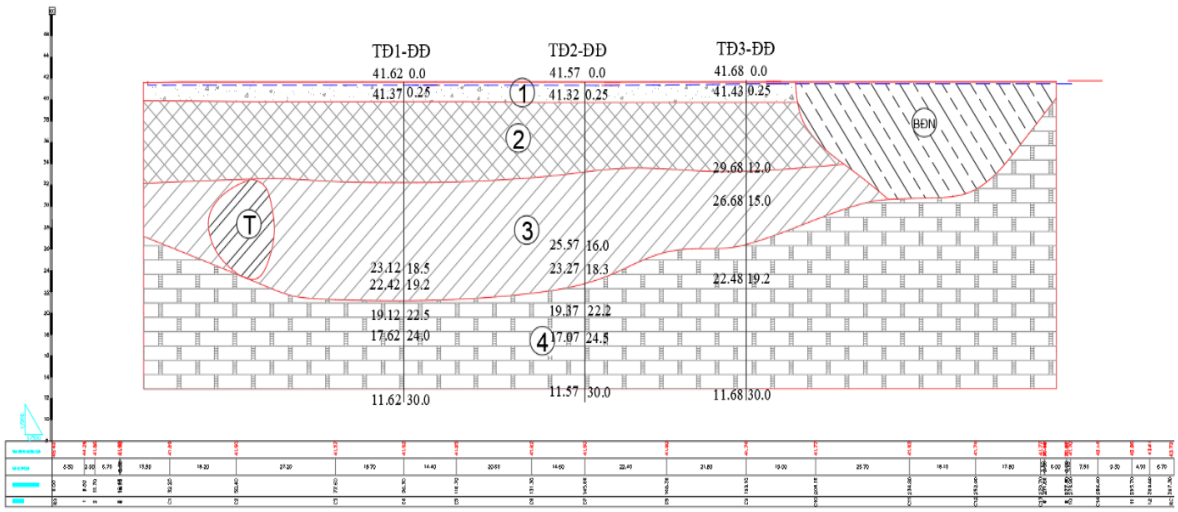


Figure 11. Geological - Geophysical cross section of the profile along the heartbeat line

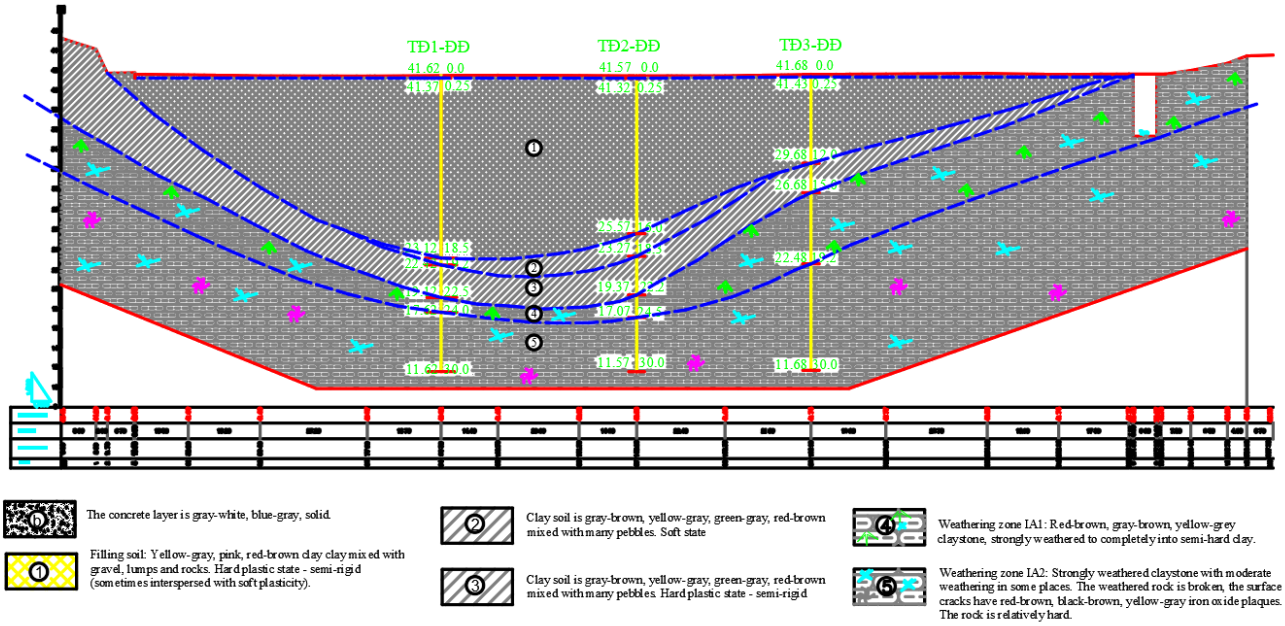
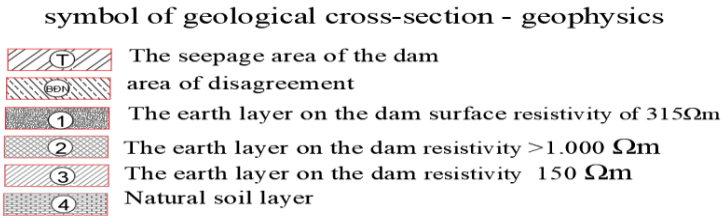


Figure 12. Geological cross-section of the profile along the heartbeat line



4. Discussion

In addition to the detailed comments presented above, it is possible to discuss the obtained results through this survey as follows:

- Geophysical survey using the improved multi-electrode electrical exploration method has been carried out at the site on 3 profiles on the Dong Do dam with a total length of 633m with the distance between the measuring points is 3m.

+ The survey results have identified the distribution and depth of the dam embankment.

+ The survey results found that there is one heterogeneous block located near the flood spillway with a depth of up to 11m, requiring more detailed investigation.

+ The survey results on all 3 profiles along the dam have suggested low resistivity anomaly located on the left shoulder. In our opinion, this is a seepage anomaly from upstream to downstream and will seep into the dam surface when the lake water level rises.

Detail: The obtained results identified the distribution and depth of the dam embankment, showing two possible seepage anomalies in the survey profile in the passage of the left shoulder along the heartbeat line at the depth of 8.5m to 18m from the 18th meter position to the 32nd meter position and from the 120th meter position to the 130th meter position, one possible seepage anomaly in the survey profile at the center of roof 1 from the beginning of the profile to the 30th meter position at 3m to 8m deep, and one possible seepage anomaly in the survey profile at the center of roof 2, most likely when lake water level rises, starting from the surface from the 12th meter position to the 65th meter position. These results also identified a large heterogenous area in the first profile from the 185th meter position to the flood spillway staring from the surface down to a depth of 11m. These findings were compared with data from the drilling method done in the past and the majority of the results were consistent with each other, except for the identification of the heterogenous and seepage area as the boreholes created from the drilling method did not pass through these areas and thus is unable to detect it.

- The Geological - Geophysical cross-section and the map of the seepage area show that with the improved multi-electrode survey method, it is possible to determine the depth, scale of the seepage area as well as the heterogeneity present on the dam.

- It can be very difficult to use the improved multi-electrode electrical exploration method to distinguish between thin layers, or layers with the same resistivity factor.

- With the improved multi-electrode electrical exploration method, it is possible to determine the change of the embankment layer when there is seepage or a certain factor (heterogeneity) that disturbs the dam, whichthe drilling method cannot detect. This has been clearly demonstrated in the Geological- Geophysical cross-section of the profile on the dam surface.

All of these results once again demonstrate the effectiveness of the improved multi-electrode electrical exploration method in detecting hidden hazards in general, and seepage areas in particular in the earth dam body even if there is no sign of hidden dangers and seepage.

Recommendations

It is recommended that related authorities check and monitor the seepage area regularly at the left shoulder of the Dong Do dam and take timely measures if needed. Proceed to carry out detailed surveys of the area near the flood spillway to assess the large heterogeneous anomalies detected.

Reference

[1] Do, C.A., Pham, D.V., Vu, M.D. (2011). Some initial study results of determining seepage area in the earth dam of reservoirs. VNU. Journal of Science, Natural Sciences and Technology 27(3), 154-166. DOI: https://js.vnu.edu.vn/NST/article/view/1322. (in Vietnamese)

[2] Do, C.A., Vu, M.D. (2012). Survey on seepage in dikes with the Multi-electrode Resistivity Imaging method. VNU. Journal of Science, Natural Sciences and Technology. 28(1), 11-18.

DOI: https://js.vnu.edu.vn/NST/article/view/1167. (in Vietnamese)

[3] Vu, M.D., Do, C.A. (2015). Some experiment results of determining saturation line in Dong Mo dam by the Advanced Multi-electrode Electrical Sounding Method. VNU. Journal of Science, Natural Sciences and Technology. 31(3), 23-37. (in Vietnamese)

[4] Vu, M.D., Do, C.A. (2015). Introductions to the Advanced Multi-electrode Electrical Sounding method. VNU. Journal of Mathematics-Physics. 31, 1-14, DOI: https://js.vnu.edu.vn/MaP/article/view/112 .

[5] Vu, M.D., Do, C.A. (2018). Perfecting the Advanced Multi-electrode Electrical Sounding method. VNU. Journal of Mathematics-Physics. 34(3), 90-103. DOI: https://doi.org/10.25073/2588-1124/vnumap.4291 .

[6] Vu, M.D, Xayavong, V., Do, C.A, Pham, L.T, GómezOrtiz, D., Eldosouky, A.M. (2021). Application of the improved multi-electrode electrical exploration methods for underground investigation in Vientiane Province, Laos. Journal of Asian Earth Sciences: X 5, 100056, DOI: https://doi.org/10.1016/j.jaesx.2021.100056 .

[7] Advanced Geosciences, Inc. (2013). Instruction manual for SuperSting™ Earth Resistivity, IP & SP System with Wi-Fi ®. Austin, Texas 78726, USA.

[8] Advanced Geosciences, Inc. (2002-2009). Instruction manual for EarthImager 2D, Version 2.4.0, Resistivity and IP Inversion Software. Austin, Texas 78726, USA.

[9] Institute for Hydraulic Construction. (2021). Geological report on Dong Do dam. (in Vietnamese).