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Investigating the geomechanical properties and permeability of the rocks of the Kurit dam site using geostatistical methods

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Case Study

Keywords
Classification
Kurit dam
Kriging
Lugeon
Permeability
RQD

Abstract

As dams play a very important role in the optimum use of water resources, it is very important to keep them stable and the water stored in the reservoir. It is particularly important to investigate how water moves through rocks and the permeability and quality of the rock mass in structures like dams. Therefore, one of the issues considered in dam stability is monitoring the quantity of leaks. In this research, the engineering geological and geotechnical parameters of the rock mass for the construction of the Kurit Dam located in the city of Tabas in eastern Iran were evaluated. Initially, following the determination of geotechnical parameters, the engineering classification of the rock mass of the study area was carried out. In addition, in order to study and trace the water evacuation routes of the dam construction, two parameters of the RQD and Lugeon were studied and modelled. Analyses have been conducted to examine the permeability and rock quality index in three parts of the left and right abutment, the dam's axis and reservoir with geostatistics and kriging methods. Three-dimensional model of the construction of the Kurit dam was presented and the results were analyzed. Based on the results, the quality of the rock mass in the right and left abutments is arguably better than the dam axis and reservoir. Additionally, as the depth increases, the permeability decreases and the permeability is higher at shallow depths. The highest level of permeability is located at the surface and near the BH_4 borehole.

1. Introduction

Dam construction is one of the largest and most difficult construction projects in the world. In the high-level planning of the countries, the management and engineering of projects such as dams are followed with special precision and insight. Therefore, the construction and implementation of dam projects will be associated with many risks. Studying dams has a particular process that is different from studying other engineering projects. These risks can have a significant impact on operations requiring an unplanned renovation period, leading to significant delays and costs (Nikkhah et al., 2019).

For safe, enforceable and economical designs of a rock engineering project to be built in/ on a rocky environment is nearly impossible without taking into account quantified geological parameters. Engineering design parameters of the rock masses have been derived by considering the quantified values of both intact rock and joint properties. The strength and deformation parameters of intact rock are generally obtained by laboratory studies employed on rock core samples (Sonmez et al., 2022). Engineering geological studies play an important role in dam site studies. In recent years, extensive research has been conducted to assess the properties of the dam site. The quality of the rock mass and permeability is the most important geological characteristics influential in designing and building a dam. (Hedayati et al., 2012).

Rock quality designation (RQD) is an important parameter in evaluating the quality of rock masses. At present, it has been widely employed as the foundational parameter in the rock mass classification system such as a Rock Mass Rating (RMR) and the Rock Quality Tunneling Index (Q-system) (Jun et al., 2021). However, properties of joints considering their origin such as bedding, jointing or faulting should be defined in the field by expert's observations and measurements. On the other hand, Measurement of RQD can be directly conducted by core drilling studies or can be indirectly determined by scanline surveys on rock mass exposures. The measurement of RQD from surface to depth is considered as a standard parameter of core logging for the site investigation (Sonmez et al., 2022).

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Water pressure test or Lugeon permeability test is the most common and appropriate method in order to determine rock mass permeability due to the presence of weak planes, such as faults, bedding planes, joints, fissures, etc. The results of this in situ test are strongly related to the geometric characteristics and weathering degree of the water paths (Foyo et al., 2005). Using the RQD index and a comparison of that with the Lugeon test results is one of the common methods for evaluating the hydrogeological behavior of test section behaviour under Lugeon test (Hedayati et al., 2012). The assessment of the quality of geotechnical characterization has a great impact on the stability of the excavation and structure constructed beneath or on the surface of a specific geological formation. Studies in the field of evaluation of engineering geological and geomechanical properties of rock mass and investigating the state of rock mass permeability in dam projects have been done with different methods. Some of these articles are mentioned below. Many researchers including (Lashkaripour & Ghafoori, 2002; Assari & Mohammadi, 2017; Kanik & Ersoy, 2019; Alipoori et al., 2022; Khodadad-Zadeh et al., 2022; Qureshi et al., 2022) have investigated the mentioned topics in recent years.

In this article, the state of permeability of the rocks of the kurit dam construction in eastern Iran has been investigated. Parallel to a geological investigation of the area, a very important engineering aspect that must be taken into account in the Kurit Dam project is the prediction of the permeability and RQD of rock masses under the dam foundation and reservoir.

In engineering geological investigations, a regular sampling grid with a large borehole's is necessary, due to the high cost of the drilling and rock sampling, using the geostatistical methods such as kriging reduces the cost. Nowadays, geostatistics have been made robust due to its ability to characterize spatial variability through a consistent probabilistic model (Fisonga et al., 2018).

2. Geology of study area

Iran is located in the dry belt of the northern hemisphere, and precipitation levels are lower than the global average. This intensifies the need for efficient use of water resources in the country and dam projects for water storage in this dry climate (Abdollahisharif & Bakhtavar, 2019). The Kurit Dam will be an important reservoir dam to develop the agricultural sector for the southern Khorasan in Eastern Iran. The project site is located 56 kilometers southeast of Tabas, South Khorasan Province and close to the village of Chirok in eastern Iran. This dam is situated on the Kurit River near the ancient Kurit Dam. The Kurit River flows in the southeastern part of the town of Tabas and originates from the heights of Shotori and is one of the tributaries of the Namak River. The survey area is located on the border between the Lut Block and the Tabas Block at the western end of the Shotori Mountain Range. This village is located on the edge of the great salt desert, and consequently the water is of great value (Emami, 2014).

Lut Block has an irregular shape, a north-south process and is surrounded by the mountains of the east and center of Iran. On the north side, the Nayband Fault and Shotori Heights divides this block into two parts. The Shotroi mountain range with the north-south process in the east part of the Tabas block created high altitudes which are situated in a certain direction and at the edge of the plain of Tabas. The highest peak of this mountain range is 2912 meters and is called Shotori and it is made up of limestone, dolomite, sandstone and shale. The Kurit Reservoir is situated at Shotori Heights and the Kurit River runs through the dam site. The heights of the dam area are related to the Shotori Formation and form the abutments of the dam and follow the geological structures of the studied area (Abpooy Consulting Engineering Company, 2000). The new Kurit dam is located upstream of the old dam and in a relatively deep gap, probably caused by tectonic activities and erosion processes (Abpooy Consulting Engineering Company, 2014). The study area location is indicated in Figure 1.

There are many cracks and fissures in this area, and veins filled with white secondary calcite crystals can be observed alongside the cracks. In addition, the Shotori Mountain Range in the study area was impacted by numerous faults, both major and secondary. One of the major problems in the dam is the leakage of the dam reservoir. Figure 2 shows the water outlets in the reservoir of the dam.

Considering the problems with the Kurit Dam, including water leaks and the creation of sink holes in the dam reservoir, further to this article, the engineering geology of the construction of the Kurit Dam was studied using rock mass classifications. In addition, geostatistical methods have been used to study the permeability and rock quality index in dam construction to solve existing problems and to analyze and validate the results.

3. Materials and methods

Library studies as well as field visits to the construction of the dam and the study of geology and geotechnical reports of the construction plan of the dam, which provided an overview of the geological and geotechnical characteristics of the study area, were used in this research. The interactive framework of the existing problems was presented and the results of the interpretation and analysis of the desired sensitivities were obtained. The methodology in this article is divided into two steps.

Firstly, geomechanical parameters and rock mass classification systems in the construction of the Kurit Dam were investigated. In the second phase, analyses were made to check the permeability and quality index of the rock in three parts of the left and right abutment, axis and reservoir by using geostatistics and kriging methods, which will be presented later. The geostatistical models provided a more complete view of the permeability condition and rock quality index in the study area. Therefore, this modelling can be used for better management of water-escaping locations.

Figure 1. Location of research area (Emami, 2014).

Figure 2. The water outlets in the reservoir of the dam.

At the second stage, the Abundance histogram of the RQD and lugeon samples taken was presented and verifications were carried out to detect the presence or lack of trends in three spatial areas. In the following, the best variogram model adapted to the experimental variogram based on RQD and lugeon data is identified and validated. Finally, a three-dimensional model of the construction of the Kurit dam was presented and the results were analyzed.

4. Engineering geology of dam site

According to the designs made during the construction of the Kurit dam, 13 boreholes over 464 meters long were drilled in the dam area and related structures using the continuous coring method (Abpooy Consulting Engineering Company, 1999). The results of the rock quality determination and Lugeon test for boreholes dug at the dam site are presented in Table 1.

The data used for the research were extracted from geological and geotechnical reports from the Abpooy Consulting Engineering Company to Iran Water Resources Management Company. Depending on the location of the boreholes, the dam site is divided into four sections: left and right abutments, dam reservoir and dam axis.

The classification of the rock mass in general depends on the type of rock and the physical and mechanical characteristics of its component minerals and the characteristics of the discontinuity in the rock mass. Typically, the results of the various rock mass classifications can be used to implement engineering programs and plans. As a result, a classification is not assessed on its own and most rock mass classifications were made by selecting the most important and effective parameters in the engineering behavior of the rock masses (Palmström, 2005). One of the most important applications of rock mass classification is the issue of structural stability associated with engineering projects, including dams. The classification of rock masses of the Kurit Dam site is presented below using the RMR classification system.

Bieniawski issued details of a rock mass classification called the Geomechanics Classification or the Rock Mass Rating (RMR). For geomechanical classification of six parameters are used, B_1 : ratings for the uniaxial compressive strength of the rock material; B_2 : RQD; B_3 : ratings for the spacing of joints; B_4 : ratings for the condition of joints; B_5 : ratings for the ground water conditions; B_6 : ratings for the orientation of joints (Palmström, 2009).

$$B = B_1 + B_2 + B_3 + B_4 + B_5 + B_6 \quad (1)$$

In this classification, the rock mass score is calculated from the sum of the first five parameters minus the score of the sixth parameter (Bieniawski, 1989). After applying the discontinuity orientation, the rock mass at the Kurit Dam site is classified as per Table 2.

From the RMR classification results, the rock mass of the right and left abutments is shown to be at the fair and the rock mass of the dam axis is classified as poor rocks.

Table 1. Geotechnical parameters of the boreholes.

Borehole location	Borehole number	Borehole depth (m)	RQD (Average %)	Average Permeability (Lugeon)
Left abutment boreholes	BH_1	40	35.57	48.23
Left abutment boreholes	BH_2	60	43.14	6.11
Right abutment boreholes	BH_4	59	50.75	36.67
Right abutment boreholes	BH_8	35	30.75	55.81
Dam reservoir	BH_5	35	25	6.34
Dam reservoir	BH_6	37.5	25	12.64
Dam reservoir	BH_7	27.5	37.68	17.37
Axis of dam	BH_9	55.7	8.6	-
Axis of dam	BH_{10}	25.10	5.16	2.84
Axis of dam	BH_{11}	55.15	37.4	-

Table 2. Rock mass classification RMR system.

Location / Parameters		Left abutment boreholes		Axis of dam		Right abutment boreholes	
		Ranges of values	Rating	Ranges of values	Rating	Ranges of values	Rating
Uniaxial compression strength (MPa)		59.33	7	45.4	4	31.47	4
RQD (%)		40.7	8	29.22	8	39.35	8
Spacing of discontinuities (m)		0.6-2	15	0.6-2	15	0.6-2	15
Condition of discontinuities	Persistence (m)	01/mar	4	01/mar	4	03/out	2
	Roughness	rough	5	rough	5	rough	5
	Infilling	<5 mm Soft filling	2	<5 mm Soft filling	2	<5 mm Hard filling	4
	Aperture (mm)	01/mai	1	01/mai	1	01/mai	1
	Weathering	Moderately	3	Highly	1	Moderately	3
Ground water Condition		Wet	7	Wet	7	Wet	7
Orientation of joints		Fair	-7	Fair	-7	Fair	-7
Total Rating		45		40		42	
Rock mass class		III		II		III	
Description		Fair rock		Poor rock		Fair rock	

5. Modeling the rock quality designation index and lugeon in dam site

Due to the high ability of the geostatistical method to estimate parameters with space structure and to determine the estimation error in the entire study area, it is suitable for use in rock and soil mechanics. The use of 2D and 3D models can determine the permeability of the area, especially in dam site and on the basis of these models, water leak trajectories can be established (Rahimi Shahid et al., 2016).

5.1 Rock quality designation index (RQD)

Spatial structure refers to the dependency of the value of each variable on its position in space, as a result, which the adjacent samples are spatially related to one another to a certain distance. The existence of spatial structure is demonstrated by variography (Hammah & Curran, 2006). Including spatial parameters defined in geomechanics in soil and rock environments include the index of designation of rock quality and permeability. To justify the use of geostatistical methods in lugeon and rock quality designation index modelling, the spatial dependence of the variables should be determined. The features of the spatial structure need to be properly known. Next, depending on the number of samples and the conditions of the region, the geostatistical estimate that can cover the study area is selected. Finally, by creating a geometric block appropriate to the study area, the values of the variables are estimated and the results of the estimates are checked by different methods.

The abundance histogram of the RQD samples collected, regardless of the location of the harvest, is depicted in Figure 3. As can be seen, the data gathered in Kurit Dam has a normal distribution and the highest abundance of RQD data is concentrated in the range of less than ten and thirty to forty. Based on the results of this diagram, it can be concluded that the Rock quality designation index for the site of the Kurit Dam is of relatively low quality. This diagram does not show the structure of changes in RQD values in various areas of the dam. As a result, such a trend cannot be recognized by drawing a general histogram because the RQD values are not related to its spatial location. As a result, such a trend cannot be recognized by drawing a general histogram because the RQD values are not related to its spatial location.

The dependency of the variable value of the coordinates in various directions is called a trend. One way to recognize the trend is to draw a variable abundance diagram in terms of x, y, and z. If a trend occurs, the corresponding data points come together around the trend line. Based on linear regression, the presence of trends was studied. Figure 4 shows that the relationship between RQD and spatial directions is weak and the points are scattered. Therefore, there is no trend in this data.

After verification of the absence of trends, to obtain more accurate results, the data must be composited. The data composite is a process that turns sample data of different lengths into data of the same length using the weighted average method and is used in statistical calculations (Journel & Huijbregts, 1981). The determination of the rock quality designation index is made at different depths, whereas for modeling, the depth of the rock quality index determination should be the same. Therefore, the range of the composite process must be determined using methods. One way of determining the depth interval of the composite process is by determining the maximum abundance of the depth interval of the measured values. For this purpose, the abundance distribution of the measured RQD depth interval is illustrated in Figure 5. The depth interval of 2 meters measured by RQD has the maximum abundance and this depth interval was applied to composite the data for modelling.

Variography is the most fundamental part of geostatistical studies. The semi-variogram is a variance diagram based on the distance between the samples and the major pillar of geostatistics that shows the structure of the spatial relationship between the samples. The semi-variogram function is defined in Equation 1 (Webster & Oliver, 2007).

$$\hat{y}(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[z(x_i) - z(x_i + h) \right]^2 \quad (2)$$

$\hat{y}(h)$ donates the value of variogram for N sample pairs, which are separated by h (steps) intervals. $z(x_i)$ and $z(x_i + h)$ are regional variable values of x at I and i+h (Webster & Oliver, 2007). Various slopes were utilized to find the best variogram, indicating the spatial structure. Variogram characteristics were altered at every stage to obtain the best model, and the modeling was validated by different methods. Repetition of this step led to the development of a model with the least error. Any mistake in selecting the model is reflected in the following stages. A Gaussian model fitted to the data has the highest acceptability, lowest error, and a correlation of 0.97, making it the best fitting model. Figure 6 illustrates the best variogram model adapted to the experimental variogram obtained from the RQD data.

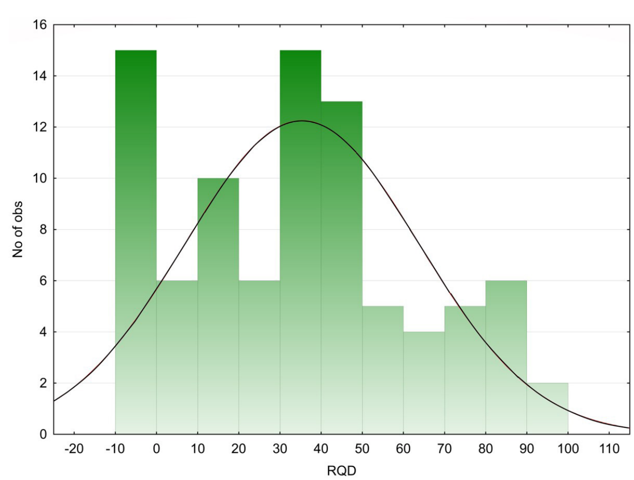

Figure 3. Abundance histogram of RQD.

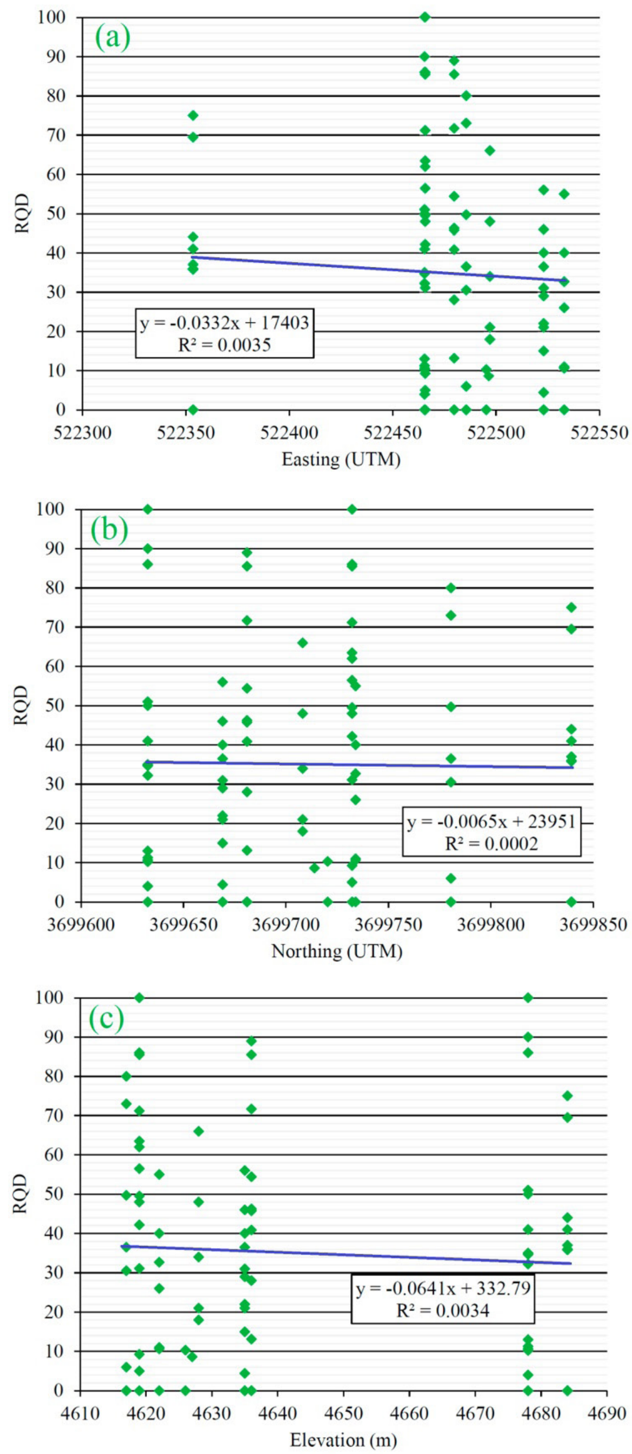

Figure 4. Checking the existence of the RQD trend with a) Easting, b) Northing, c) Elevation.

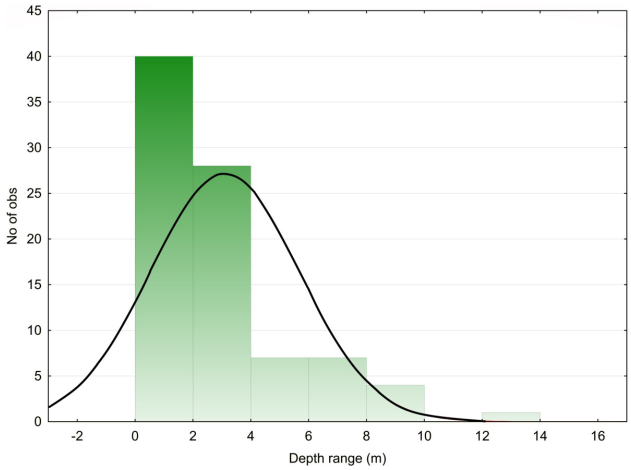

Figure 5. Distribution of the abundance of the measured RQD depth interval.

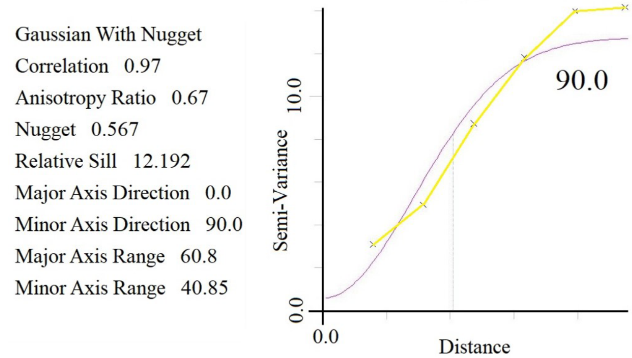

Figure 6. A semi-variogram selected for modeling the RQD data.

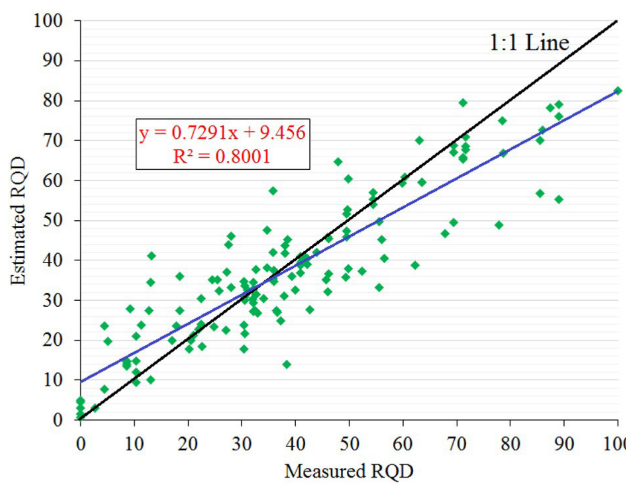

Figure 7. Diagram of the measured values in relation to the estimated RQD values.

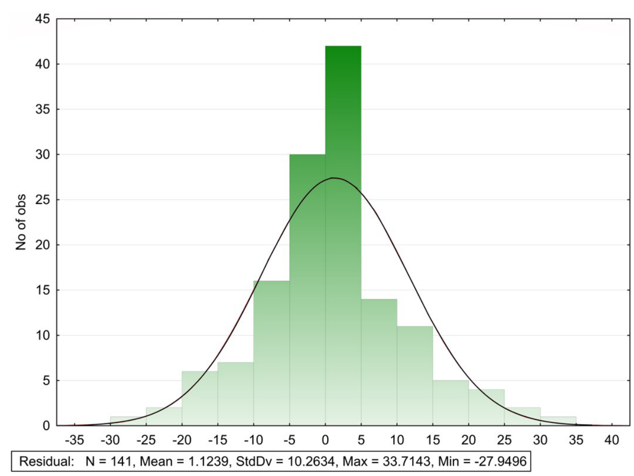

Figure 8. Abundance curve and residue histogram for 3D RQD model.

The Gaussian model passes through near the origin with a parabolic behavior instead of a linear behavior, unlike the spherical and exponential models. In this model, the slope is zero near the origin and gradually increases until a turning point is reached. The slope of the curve changes at this point and climbs rapidly towards its roof. The regional variable is shown to have a high degree of continuity in this model (David, 2012).

There are a number of methods in which estimates are validated. A point or block's estimated values are compared with actual data values as one of the methods used (Rahimi Shahid, 2022; Rahimi Shahid et al., 2022, 2023). For the purpose of validating the presented rock quality models, the input data values were compared with the estimated values in Figure 7. The percentage of correspondence between the measured and estimated values is 80.01%.

The Jackknife error method is used to verify the adjusted variogram. One can obtain the parameters of the variogram by means of Kriging jackknife. To this end, one of the points with known data is removed every time and its value is estimated by Kriging method. Kriging estimation error should be equal to the theoretical estimation error and have zero mean (Lamorey & Jacobson, 1995). The jackknife error variance reflects the estimation accuracy, using the Kriging method. Variogram parameters are selected based on trial and error, so that the variance of jackknife errors is minimized. The residual value is obtained from the difference between the measured and estimated values, and smaller residuals close to zero make the model more valid.

The standard deviation is 10.2634 and the minimum and average residue values are also 1.239 which is around zero and the error histogram is normal. Figure 8 shows the 3D RQD model abundance curve and residue histogram.

After determining the best variogram model, the block dimensions were determined based on the range of interest and the sampling space. Figure 9 shows the properties of the block model of the studied area.

Finally, by using the composition and determining the variographic and topographical parameters of the Kurit dam site, the three-dimensional RQD model and boreholes position are illustrated in Figure 10. In the created model, the rock quality designation index is specified with different color ranges from very low RQD with purple to finally high RQD values with red color. Based on this figure, the changes along the depth can be seen and investigated.

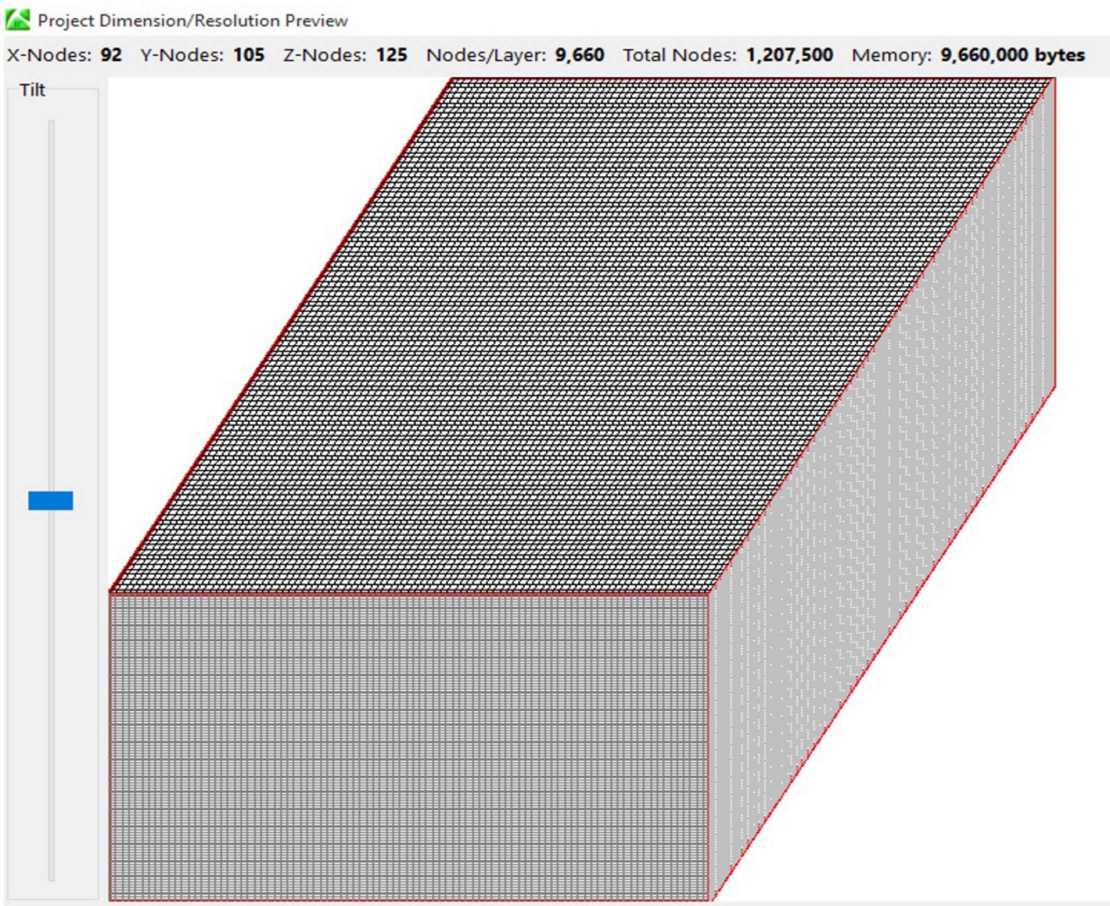

Figure 9. 3D model specifications for RQD values.

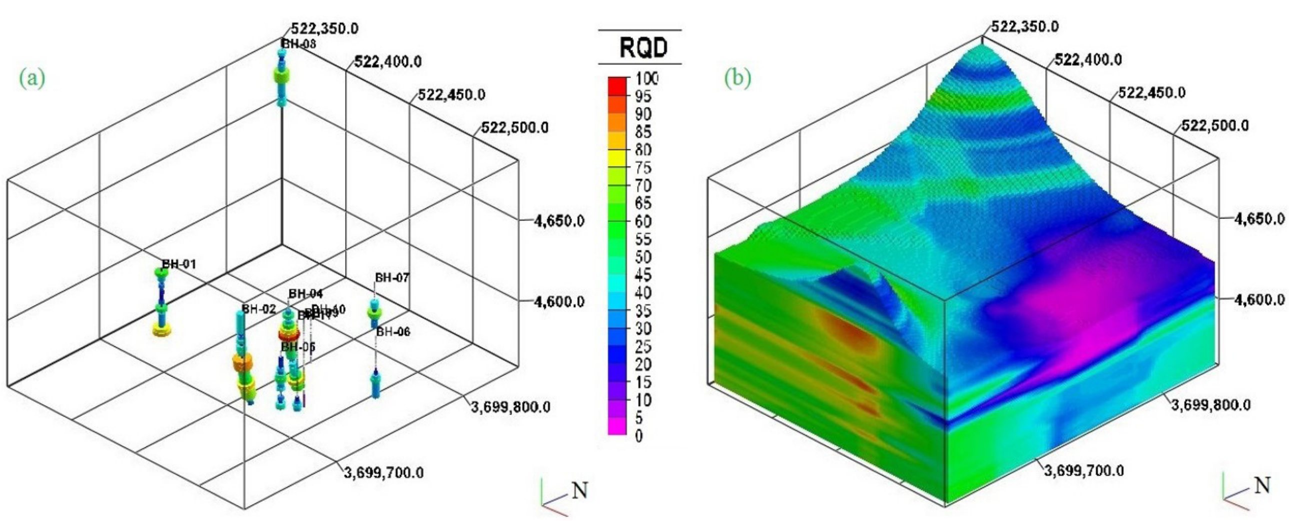

Figure 10. a) Location of boreholes, b) 3D model of RQD.

In Figure 11, the 3D model of RQD < 50 and RQD > 50 is presented. Areas with RQD < 50 are indicated in red and areas with RQD > 50 are indicated in blue. Based on the model presented, the rock quality designation index in the left abutment can be said to be in better condition than the right abutment, axis and reservoir of the dam.

To further examine variations in rock quality designation index relative to depth, the cross-section is shown in Figure 12 and the RQD data fence diagram is shown in Figure 13. It can be seen that the rock quality designation index has increased in the right and left abutments with increasing depth.

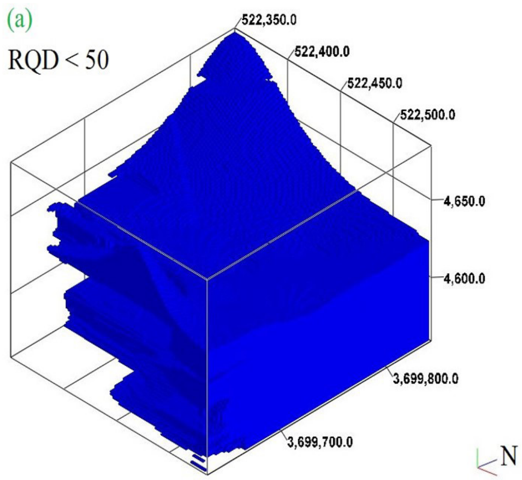

Figure 11. a) 3D model of $RQD < 50$, b) $RQD > 50$

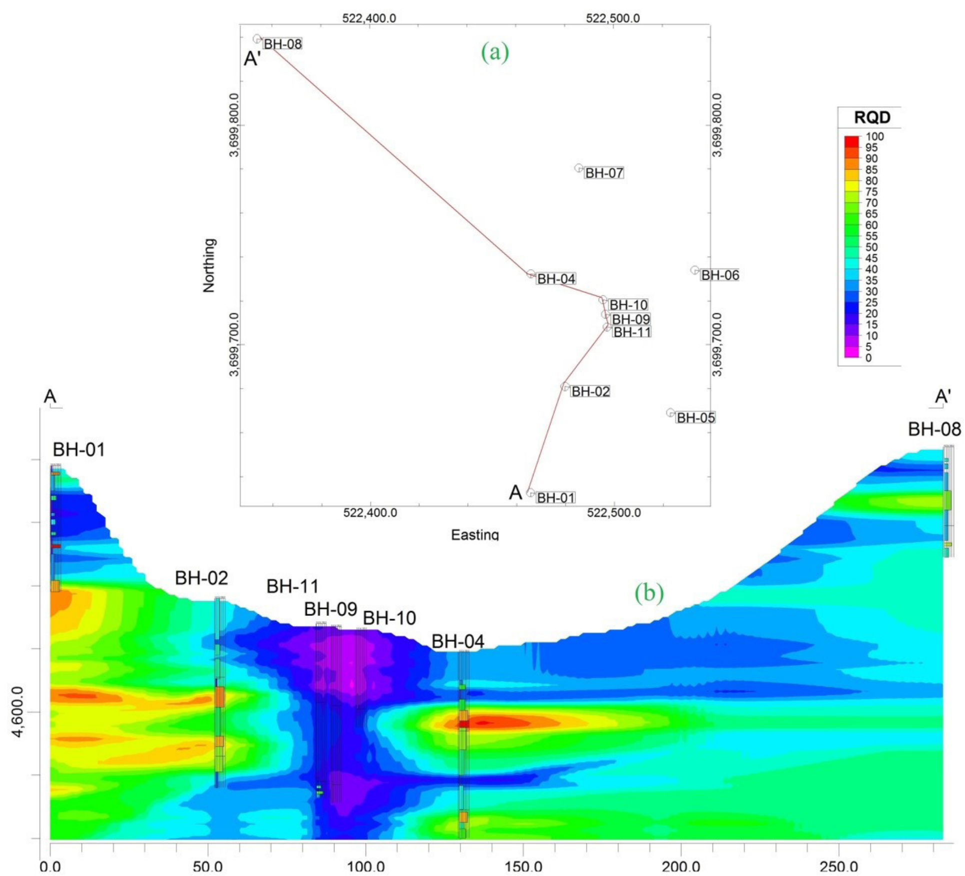

Figure 12. a) Overview of section, b) RQD cross section.

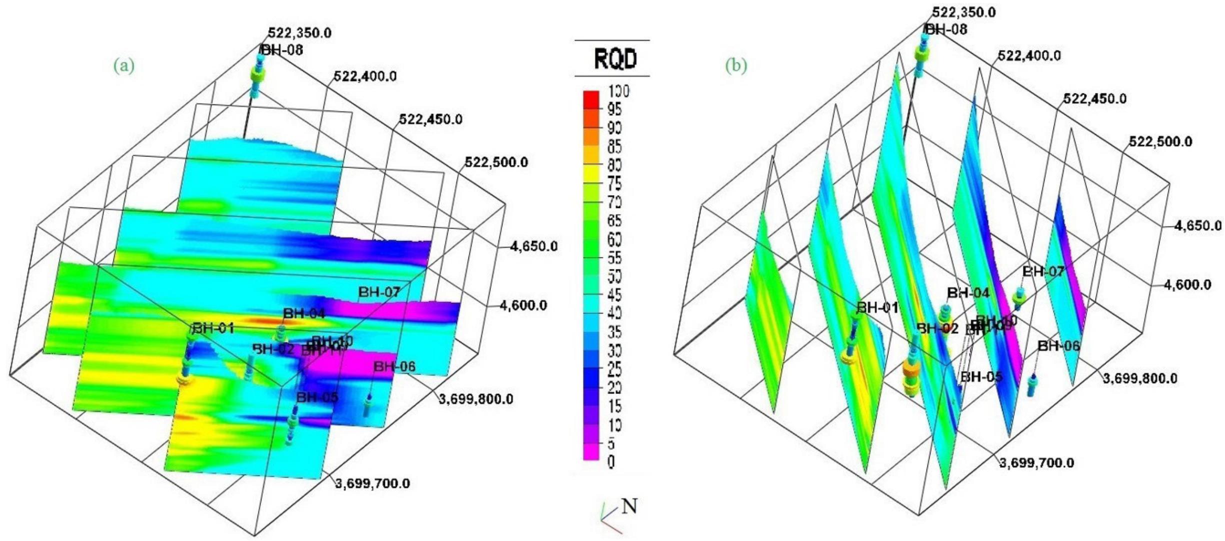

Figure 13. Fence diagram of RQD data a) Northeast-Southwest direction, b) Northwest-Southeast direction

The surface parts of the site in most locations are in the violet to light blue color spectrum (rock quality designation index 0 - 40) which indicates that the rock quality is very poor to poor. With increasing depth and penetration, the colour spectrum of the Rock quality designation Index is in the approximate range from light green to red (Rock quality designation Index 40 - 100), which shows the comparatively good to excellent quality of the rock mass. The state of the rock quality index in two boreholes (BH_9 and BH_{10}) along the dam axis is very poor from the surface to the depth.

5.2 Lugeon

The abundance histogram of the Lugeon samples collected, regardless of the location of the harvest, is depicted in Figure 14. The most extensive Lugeon data are concentrated within the range of less than 30. Therefore, based on the results of this diagram, it can be concluded that the permeability level is low to moderate at the Kurit dam site. This diagram does not show the structure of changes in Lugeon values in different parts of the dam, and Lugeon values are not related to its spatial location.

Based on linear regression, the presence of trends was studied. Figure 15 shows that the relationship between Lugeon and spatial directions is weak, and the points are scattered, therefore, there is no trend in this data.

The abundance distribution of the measured Lugeon depth interval is illustrated in Figure 16. The depth interval of 5 meters measured by Lugeon has the maximum abundance and this depth interval was applied to composite the data for modelling.

Figure 17 illustrates the best variogram model adapted to the experimental variogram obtained from the Lugeon data. An exponential model fitted to the data has the highest acceptability, lowest error, and a correlation of 0.99, making it the best fitting model.

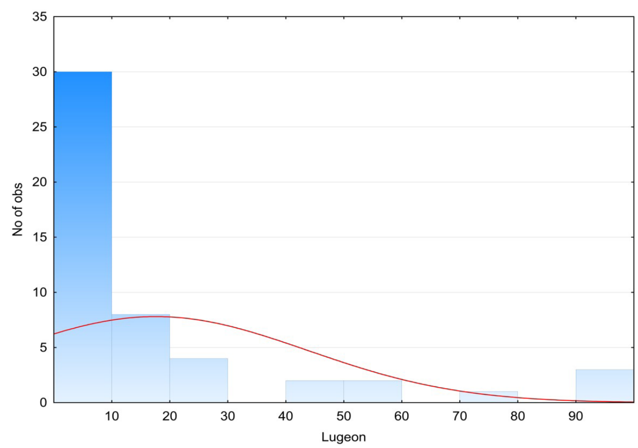

Figure 14. Abundance histogram of Lugeon.

Finally, by using the composition and determining the variographic and topographical parameters of the Kurit dam site, the three-dimensional Lugeon model and boreholes position are illustrated in Figure 18. In the created model, the Lugeon values are specified with different color ranges from very low with purple to finally high values with red color.

For the purpose of validating the presented Lugeon models, the input data values were compared with the estimated values in Figure 19. The percentage of correspondence between the measured and estimated values is 74.07%. The results from this model are therefore valid.

The standard deviation is 14.3635 and the minimum and average residue values are also 0.5896 which is around zero and the error histogram is normal. Figure 20 shows the 3D Lugeon model abundance curve and residue histogram.

On Figure 21, Lugeon's 3D model is shown at different intervals. Based on the models, the site can be split into three layers depending on the permeability depth.

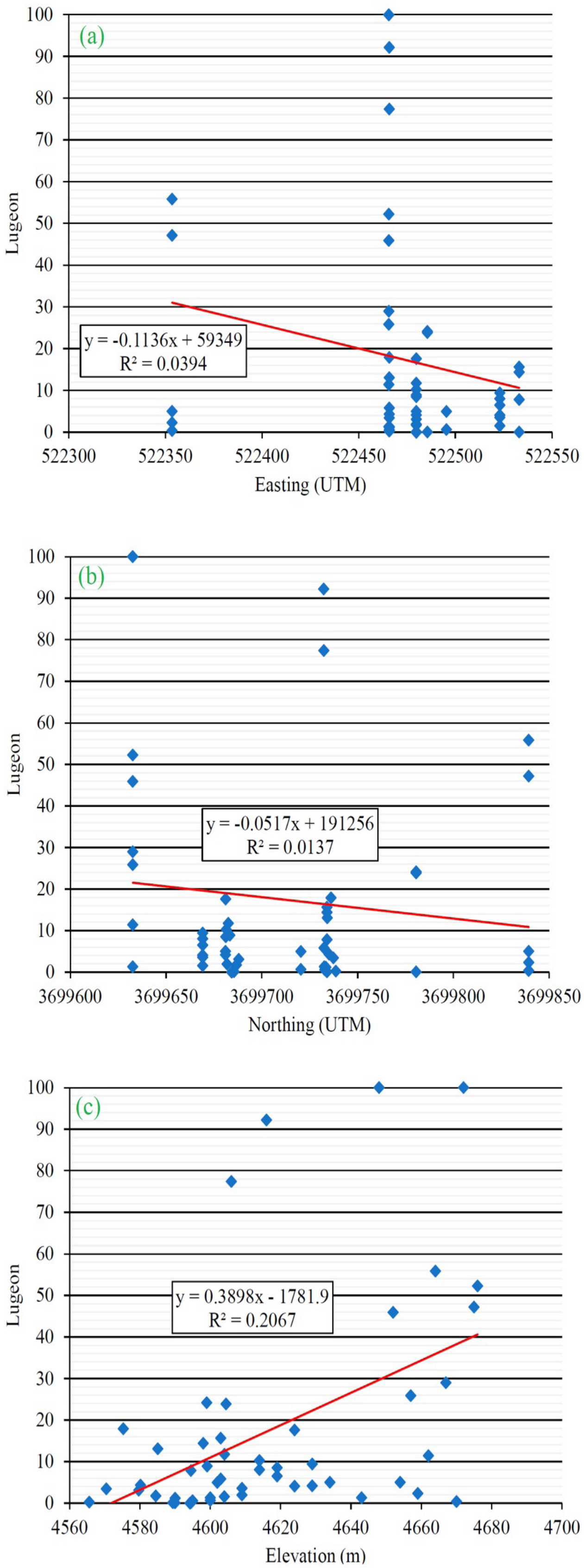

Figure 15. Checking the existence of the Lugeon trend with a) Easting, b) Northing, c) Elevation

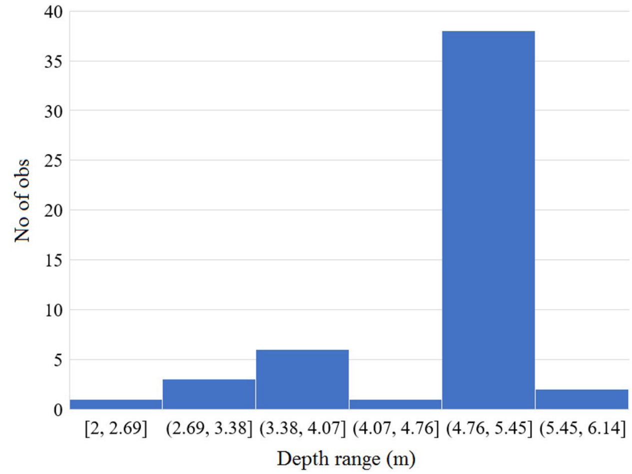

Figure 16. Distribution of the abundance of the measured Lugeon depth interval.

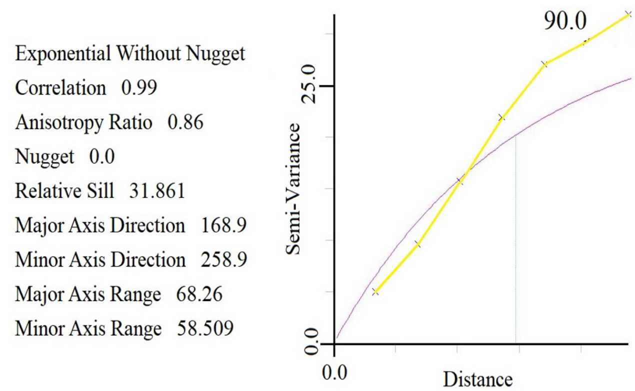

Figure 17. A semi-variogram selected for modeling the Lugeon data.

So, the surface layers at the dam site have a high and very high permeability, which is displayed with yellow and red colors in the 3D model.

As the depth rises, the permeability descends and is shown in green color. The third layer is found at higher depths, and in this layer, the permeability is low and very low, and it can be viewed with a dark blue color in the 3D model.

To further examine variations in Lugeon values relative to depth, the cross-section is shown in Figure 22 and the Lugeon fence diagram is shown in Figure 23. As shown in Lugeon's cross-section and Fence diagram, with increasing depth, permeability decreases throughout most of the area, and permeability is higher at low or medium depth. The highest level of permeability is located at the surface and near the BH_4 borehole. Abrupt Lugeon changes along the perpendicular to axis of the dam are also not seen in this model.

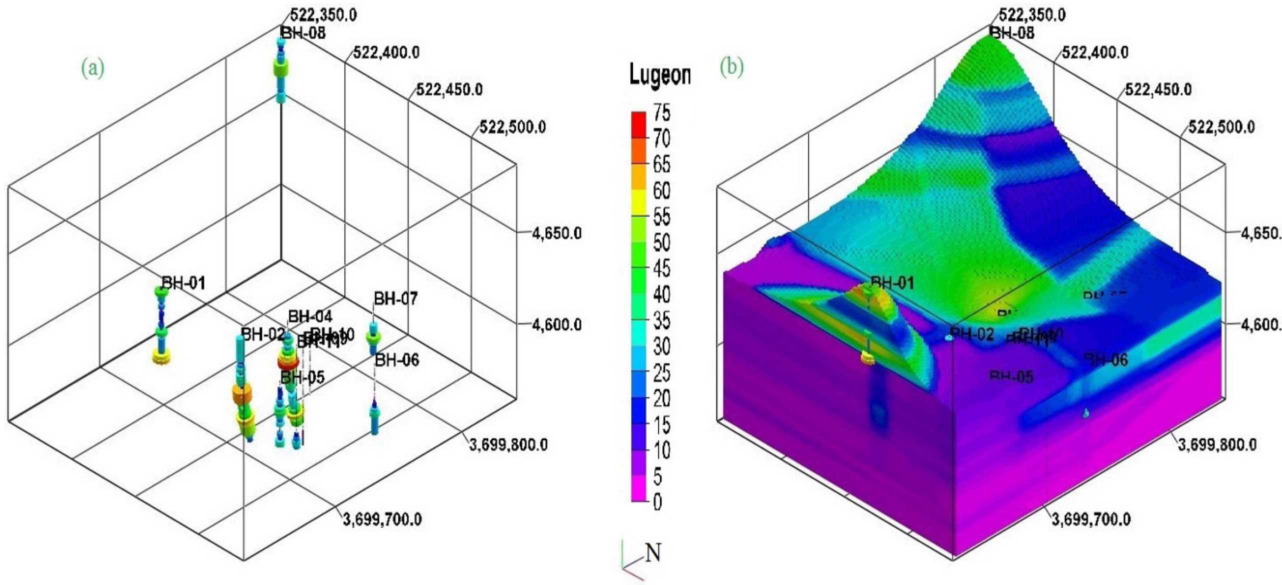

Figure 18. a) Location of boreholes, b) 3D model of Lugeon.

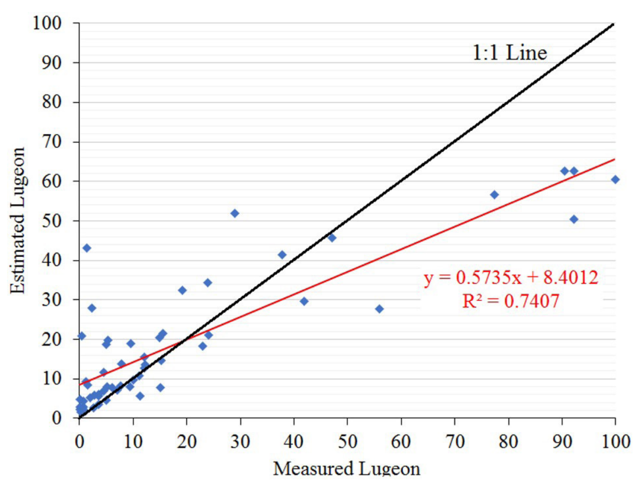

Figure 19. Diagram of the measured values in relation to the estimated Lugeon values.

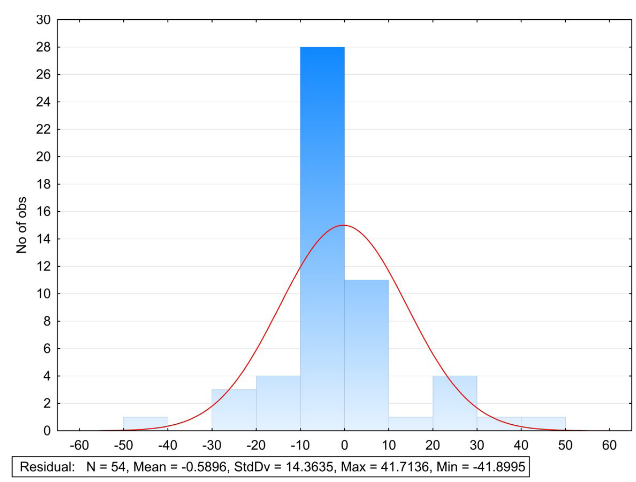

Figure 20. Abundance curve and residue histogram for 3D Lugeon model.

6. Conclusion

The results of this research indicate that:

From the RMR classification results, the rock mass of the right and left abutments is shown to be at the fair and the rock mass of the dam axis is classified as poor rocks. According to the 3D RQD model, the surface parts of the site in most locations are in the violet to light blue color spectrum (rock quality designation index 0 - 40) which indicates that the rock quality is very poor to poor. With increasing depth and penetration, the color spectrum of the Rock quality designation Index is in the approximate range from light green to red (Rock quality designation Index 40 - 100), which shows the comparatively good to excellent quality of the rock mass. The state of the rock quality index in two boreholes (BH_9 and BH_{10}) along the dam axis is very poor from the surface to the depth. In the boreholes related to the reservoir of the dam, including BH_5 , BH_6 and BH_7 , in surface areas, the rock quality designation index is in the purple color spectrum, indicating the very poor quality of the rock masses. Based on the models, the site can be split into three layers depending on the permeability depth. So, the surface layers at the dam site have a high and very high permeability, which is displayed with yellow and red colors in the 3D model. As the depth rises, the permeability descends and is shown in green color.

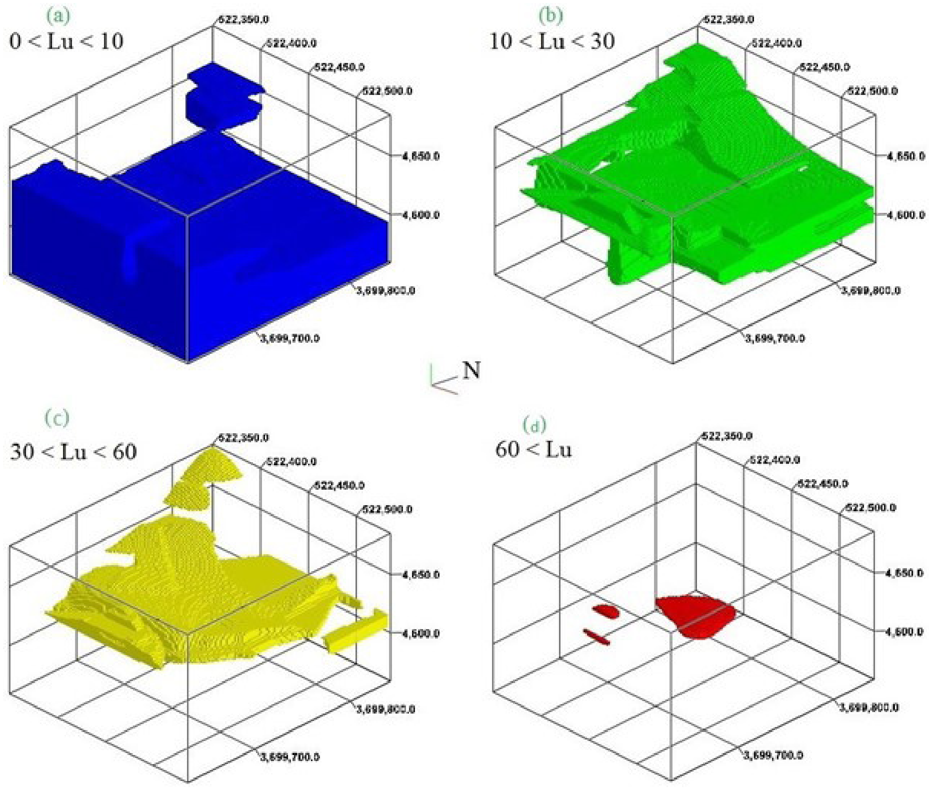

Figure 21. 3D model of a) $0 < Lugeon < 10$, b) $10 < Lugeon < 30$, c) $30 < Lugeon < 60$, d) $60 < Lugeon$.

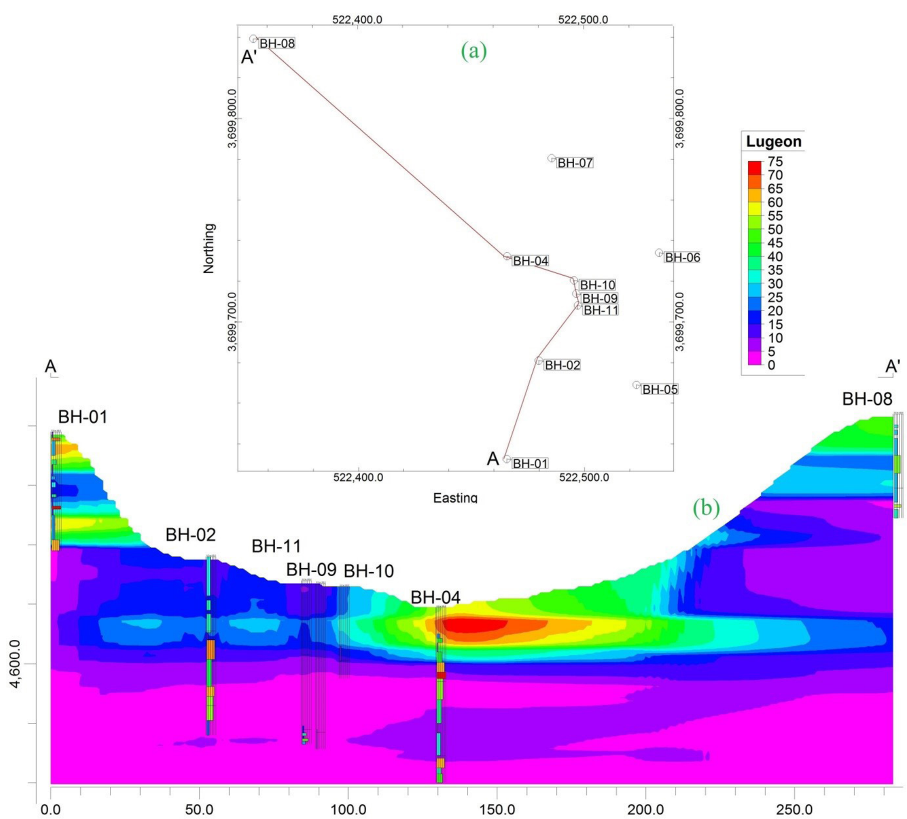

Figure 22. a) Overview of section, b) Lugeon cross section.

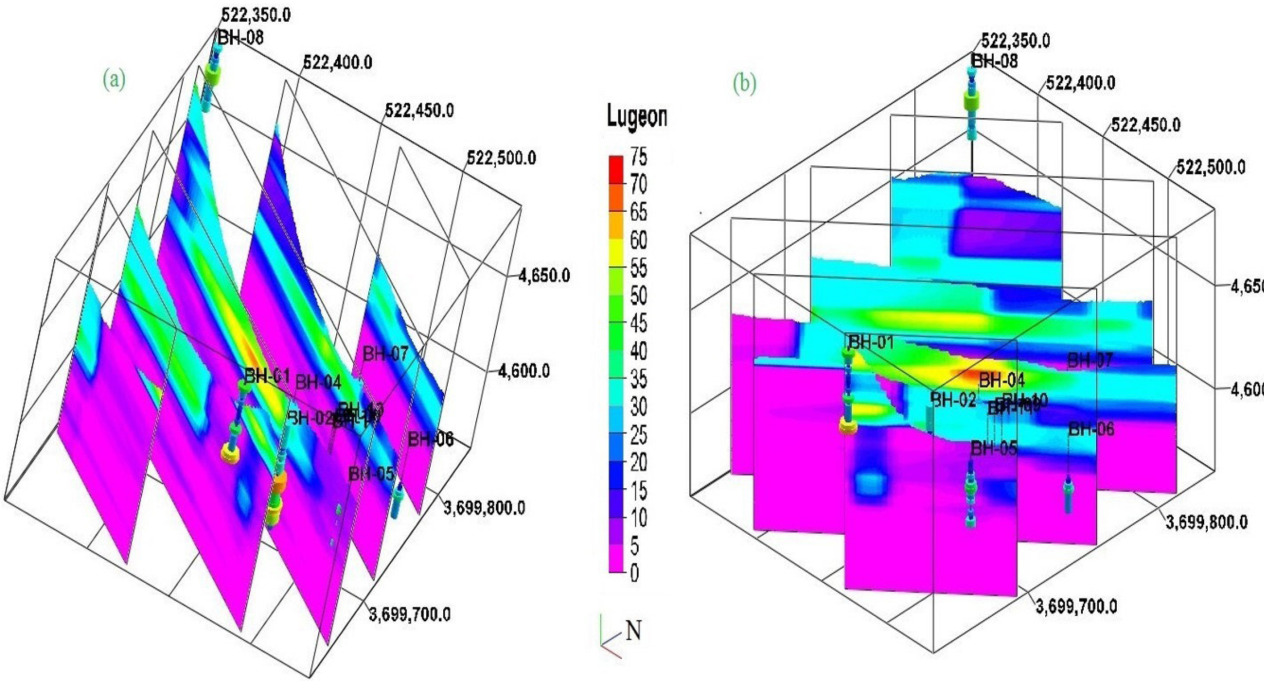

Figure 23. Fence diagram of Lugeon data a) Northwest-Southeast direction, b) Northeast-Southwest direction

The third layer is found at higher depths, and in this layer, the permeability is low and very low, and it can be viewed with a dark blue color in the 3D model. The results of this research showed that the main problem of the new Kurit dam (Tabas city) was to select an inappropriate location for its construction. The technical and engineering aspects may be said to have had little effect on this selection. Field surveys and the use of numerical modelling methods indicate a significant amount of water leakage from the dam reservoir to the underlying strata.

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Declaration of interest

The authors have no conflicts of interest to declare. All co-authors have observed and affirmed the contents of the paper and there is no financial interest to report.

Authors' contributions

Mohammad Amin Ghasvareh: data curation, conceptualization, writing original draft preparation. Mohammad Ali Shahabi: reviewing and editing. Mojtaba Rahimi Shahid: methodology, validation. Maryam Ghavi Panjeh: reviewing and editing.

Data availability

The datasets generated analyzed in the course of the current study are available from the corresponding author upon request.

List of symbols

B_1	ratings for the uniaxial compressive strength of the rock material
B_2	RQD
B_3	ratings for the spacing of joints
B_4	ratings for the condition of joints
B_5	ratings for the ground water conditions
B_6	ratings for the orientation of joints
BH	Borehole
RMR	Rock Mass Rating
RQD	Rock quality designation
LU	Lugeon

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