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ENHANCEMENT OF THE STUDY OF WATER LEAKS ON THE LEFT BANK IN THE OUIZERT ALGERIAN DAM

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ABSTRACT

Water leaks are costly but common issues in the Algerian dam. Whatever their reasons, they progressively threaten the stability of the constructs and reduce the capacity of the reservoir. The Ouizert dam, the focus of this study, was built in an arid zone approximately 35 km from southwestern Mascara city, where water supply deficit is a serious challenge. The dam was designed with a maximum capacity of approximately 100 million m^3 on Wadi El Hammam. It supplies Oran city, Arzew industrial pole, and El Habra agricultural perimeter and contributes to the Bouhanifia dam. However, it never reached its maximum level due to considerable side-leakages estimated at approximately 1 m^3/s. It was thus deemed necessary to perform physisco chemical analyses and piezometric measurements. The data used concerned leakage flow, piezometric coast, distances between the piezometers, physico-chemical parameters (pH, temperature, conductivity), shores of the lake and threshold heights (different water sampling depths of the piezometers) and served to determine the variation between the exfiltration water discharge and the reservoir level. The obtained results can serve as decision-making tools to implement urgently needed dam reclamations.

Keywords: Dams, Ouizert, water leakages, water release, arid zones.

INTRODUCTION

Water leakage at dams results in considerable losses of precious and scarce water and seriously threatens the stability of hydraulic works. In addition, dams are subject to loss of capacity due primarily to water leakage, siltation, and intense evaporation when located in hot areas. The problem is complex, and it threatens the amount of water accumulated in most dams around the world and causes concern about the stability of these structures. Examples include the following dams (Benfetta et al., 2017; ANBT, 2018).

First, the Saint Etienne dam in France is subject to heavy overpressures, especially in winter when the lake coast is high. The opening of cracks in the concrete/rock contact due to hydrostatic tipping is the reason for this phenomenon. The problem is aggravated in the cold season due to thermal removal of the concrete, resulting in a displacement of the dam downstream.

The CAMARASA weight dam is located in Spain on the Noguera Pallasera, tributary of SERGE, and it has a height of 92 m and a capacity of 157 million m^3. In 1920, the partial release of the reservoir was accompanied by water losses of more than 10 m^3/s, a watertight sail of 1100 m of development down to the marl was carried out between 1927 and 1931, and it was necessary to inject more than 190.000 t of dry products to reduce the leaks to 80%.

The BOUVANTE dam is located on the Lyonne in the heart of the Vercos mountain range (Alpes Française du Nord). The water launch in 1926 was accompanied by water leaks on the order of 1100 l/s, and the waters infiltrated in the Urgonian and Cretaceous limestones reached the source of the FREYDIERES. The treatments carried out between 1927 and 1958 reduced the leaks to less than 300 l/s (Benfetta et al., 2017; ANBT, 2018).

Finally, the CANELLES arch dam in Spain was the site of major water leaks across the left bank and near the underground power station. The flow reached 1600 L/s for a water level in the lake exceeding the shore by 75 m. The rise in water level over this coast caused major breakups (Benfetta, Achour, Ouadja, 2017; ANBT, 2018).

In Algeria, we identified fifteen dams whose volume of exfiltered water exceeded 1 M m^3 per year each. Interestingly, six of these dams have a leakage volume exeeding of 5 M m^3. The Ouizert dam is one of the most deeply affected hydraulic constractions in the country. It was installed on a site extremely favorable to water leaks. and a gradual reduction of its storage capacity was then observed over time (Benfetta and Remini, 2008; Benfetta, 2017).

The present study aims to study water leakage in the Ouizert Dam to highlight the underlying mechanism of water leakage flows and perform physico-chemical analyses (ANBT, 2018).

LOCATION OF THE OUIZERT DAM

The Ouizert dam is located in western Algeria approximately 35 km southwest of the Wilaya of Mascara and 17 km south of the locality of Ain Fekan (Fig. 1, Photograph 1). Its coordinates are X: 250.55 Y: 206.80, Z: 396.00 NGA. The study area is part of the Wadi El Hammam basin, which covers an area of 14389 km^2. The site of this dam is located on Sahouet Wadi, 4 km northwest of the village of Ouizert, in the commune of Taria (Wilaya of Mascara). The Ouizert dam was built on the Oued Sahouet, which is the fusion of the Oueds of Taira and Saida. The Sahouet Wadi is one of the main tributaries of the Wadi El Hammam, on which the Bouhanifia and Fergoug dams were built (Fig. 2). The construction of the dam in the gorges of Ouizert created an artificial lake of approximately 10 km in length in the valley of the Sahouet Wadi. It is a heterogeneous earth dam with a height of 60 m and a capacity of approximately 100 hm^3. A volume of water of 12 hm^3 is intended for the irrigation of some 20,000 hectares of agricultural land in the El Habra Plain north of Mohammadia, while 20 hm^3 of water is devoted to the feeding of the industrial area of Arzew and to the drinking water supply (AEP) of the city of Oran. The average annual intake of this dam is approximately 45 hm^3/year (Toran, 1970; ANBT, 2015).

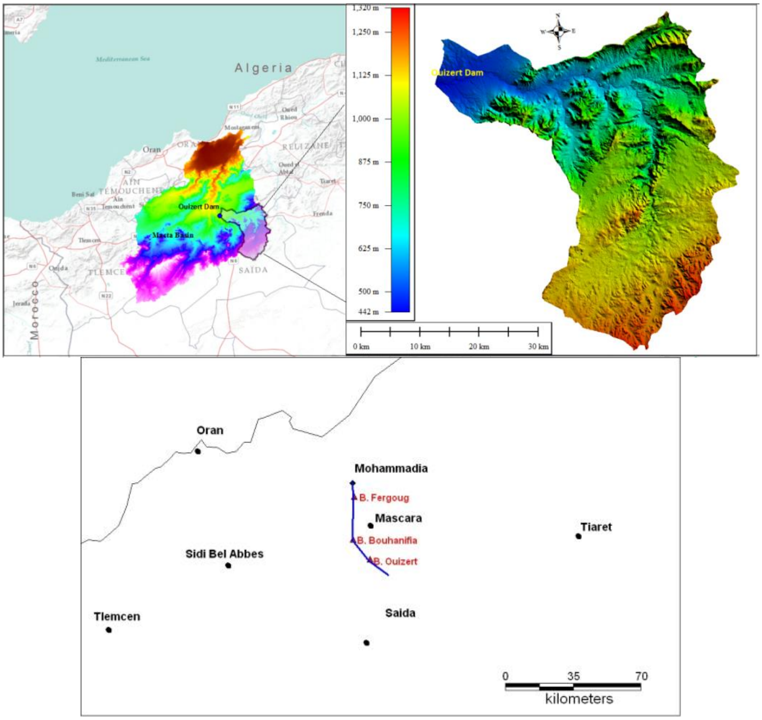


Figure 1: Location of the Foum el Gherza Dam. ***Source: Benfetta and Ouadja, 2021*.**

Photograph 1: General view of the Algerian Ouizert Dam. ***Source: Benfetta, 2021*.**

Photograph 2: Water leaks on the left bank of the Algerian Ouizert Dam. Source: Benfetta, 2021.

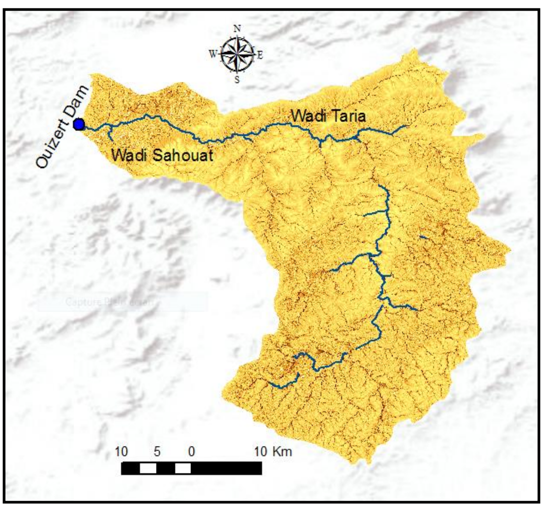


Figure 2: Implantation of the Ouizert dam in the Sahouat Wadi. Source: Benfetta and Ouadja, 2021.

The Ouizert dam is located on a slightly sloping substratum (5°-10°) a few meters thick and composed of a rock mass formed by marl, sandstone, puddle, limestone, colluplane and alluvium. According to data from geological surveys, the limestone layer, approximately 5 m thick, is considerably cracked and thus favors the underground flow of water. The rock mass occupying the area of the profile of the dam is interspersed by a system of oblique cracks almost parallel along the Wadi. In addition, a second system of cracks has been identified almost perpendicular to the course of the Wadi and parallel to the axis of the dam (Figs. 3 and 4, photograph 2). To remedy the problem of water leakage from the Ouizert dam, an attempt was made to consolidate by injection of a seal sail along the axis of the dike, which resulted in the stopping of water leaks on the right bank only. Water leaks still persist across the left bank, with an average interannual volume of 10.42 hm^3 (Toran, 1970; ANBT, 2015; 2017).

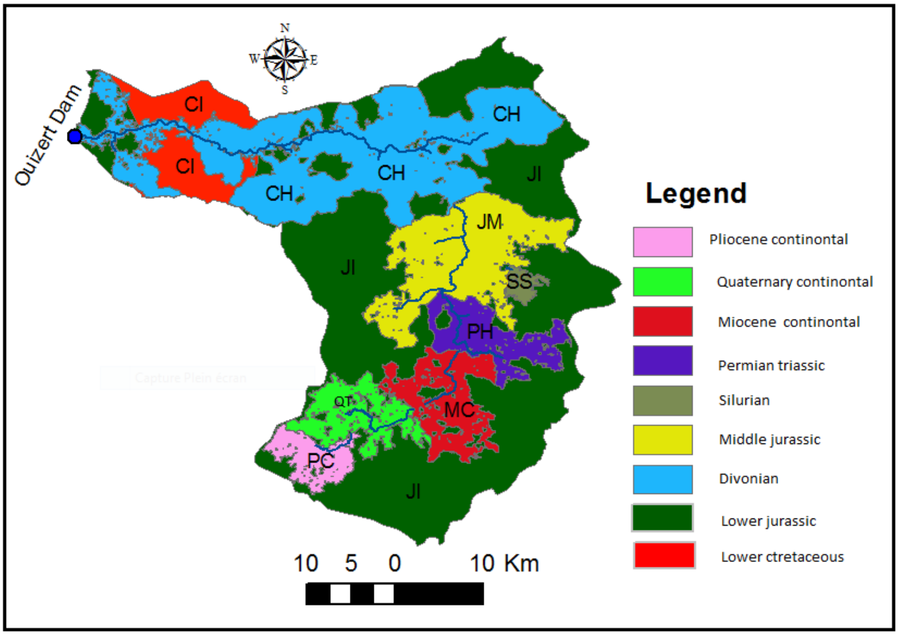


Figure 3: Geological map of the Ouizert Dam site. ***Source: Benfetta and Ouadja, 2021*****.**

Figure 4: Map of the Ouizert Dam location.

DATA USED

To perform our work, we used the following data (Benfetta 2017; ANBT 2017):

- Leakage flow.
- Piezometric coast.
- Distances between the piezometers.
- Physico-chemical parameters.
- Shores of the lake.
- Threshold heights: different water sampling depths of the piezometers (Profiles).

MATERIALS AND METHODS

During the period from 1999 to 2018, we carried out measurements of the physico-chemical parameters (pH, temperature, conductivity) of water samples taken at different depths at the piezometer level. We used hydraulic data made available to us by the services of the Algerian National Dams agency during the period from 1986 to 2018 to monitor the evolution of these parameters as a function of time. The measurements of the physico-chemical parameters were carried out in situ as well as those of the depths of water samples, time and volume taken by awkwarding. To carry out all these measurements, we used the following equipment (ANBT, 2017; ANBT, 2016; ANBT, 2015):

- A limnimetric scale was used to read the level of the lake coast.

- A sounding probe allowed the measurement of the water level in the piezometers. It is composed of two electrodes connected to a multi decameter. The probe emits an audible signal when the electrodes touch the water level in the piezometer, and the multiple decameters then indicate the depth value of the water column.
- A water sampling device was used to carry out water sampling at both the piezometers and the lake.
- A conductivity meter measured the temperature, conductivity and pH of the various samples in situ.
- A water tank was used to measure the volumes of water leakage flows at the left bank.
- A stopwatch was used to measure the filling time of the tank.

DATA PROCESSING AND DISCUSSION OF RESULTS

To address the problem of water leakage in the Ouizert dam, it was necessary to locate the area that should be sealed and to study the hydraulic continuity between the different water bodies. The study included three parts:

The first part concerned the study of the measured hydraulic parameters and their variation over time, particularly the shores of the lake and the piezometric coasts. Figs. 5 and 6 display the variation in the piezometric coast to the lake coast for all the piezometers on the left bank, specifically SB19 and SB16. They clearly indicate a good correlation between the two parameters studied. In general, an excellent correlation was observed for all piezometers. It is then possible to conclude a strong circulation of water between the different piezometers and the restraint. In addition, the slopes of the lines obtained indicate the condition of the areas between the piezometer and the lake. Indeed, the increase in the slopes of the lines shows a movement of water. This is due either to the driving of the clogging materials by the flow created by the hydraulic load or to the chemical dissolution of the components of the rock mass. On the other hand, the diminution of the slopes indicates a low circulation of water, reflecting the fact that the geological layers are less permeable. In addition, the increase in the slopes of the regression lines for some piezometers indicates some deterioration of the layers crossed by the latter. This deterioration can be explained by the break-in due to water-driven sealing of cracks and splines (Benfetta and Remini, 2008; Benfetta, 2017).

The first part also concerned the chronological evolution of the water coast in the piezometers of the left bank compared to the lake coast during the period from 1989 to 2018. This allowed us to distinguish the destroyed, clogged and unaffected areas. Figs. 7 and 8 show an example of the variation in the piezometric coast in relation to the lake coast for one of the piezometers considered. We can thus see that the parameters studied are linearly dependent, which is also the case for all piezometers. In addition, it was found that the slopes of the regression lines obtained were amplified over time, which proves a break-up at the level of the geological layers of the left bank crossed by these piezometers. In addition, when the shores of the lake exceeded 430 m, the slopes of the regression lines increased. This means that the higher the shore of the lake is, the greater the circulation of water in the cracks between the lake and the left bank. This has resulted in the relative deterioration of geological layers through internal erosion (Benfetta, 2017; Toumi and Remini, 2004). The variation in the piezometric line, measured at the level of the piezometers on the left bank, for different shores of the lake was also studied in this first part (Fig. 9). The current lines have a strong curvature. Additionally, the groundwater flow is not uniform and abruptly varies. This reveals the presence of cracks that are preferred routes for water leakage on the left bank of the dam (Benfetta and Remini, 2008; Benfetta, 2017).

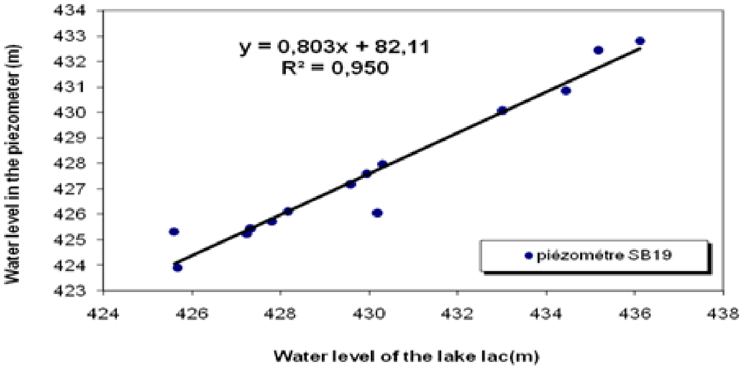


Figure 5: Variation in the water level in the piezometer as a function of the water level of the lake in Piezometer SB19. ***Source: Benfetta, 2021*****.**

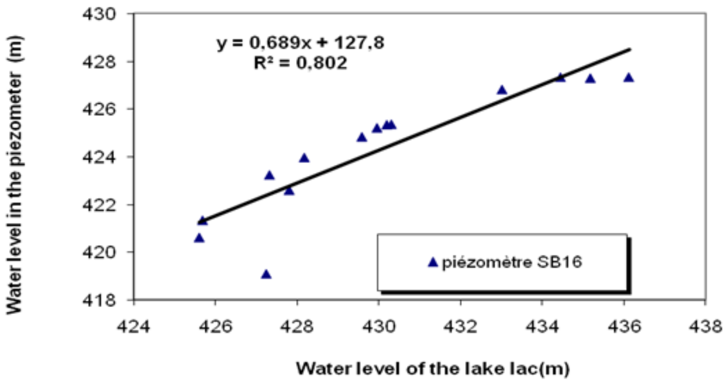


Figure 6: Variation in the water level in the piezometer as a function of the water level of the lake in Piezometer SB16. ***Source: Benfetta, 2021*****.**

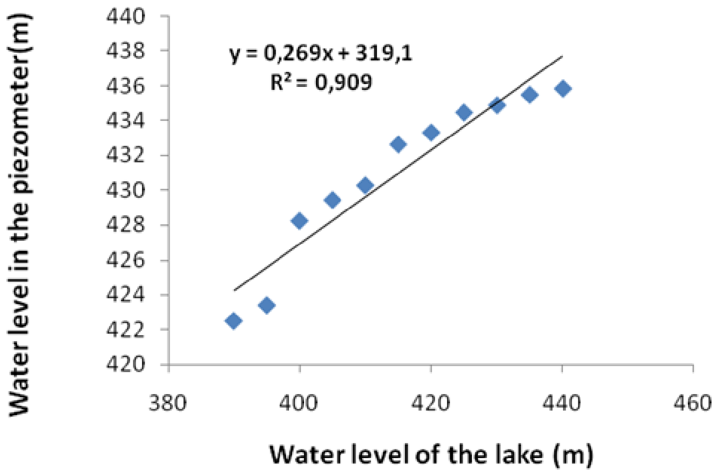


Figure 7: Evolution of the piezometric coast as a function of the coast lake in piezometer SB13 (Left Bank) for the hydrological year 2016-2017. ***Source: Benfetta, 2021*.**

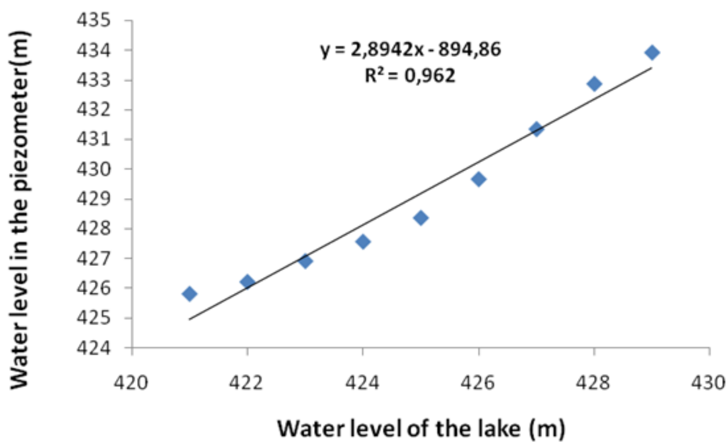


Figure 8: Evolution of the piezometric coast as a function of the coast lake in piezometer SB13 (Left Bank) for hydrological year 2017-2018. ***Source: Benfetta, 2021*.**

It was thus possible to determine the defective areas of the land on the left bank of the Ouizert dam. However, it is still not sufficient to accurately specify either the type of flow or the levels of this flow and the areas it occupies. The flow mechanisms are depicted in the second part of our study. In the presence of thermal stratification in the reservoir, the measurements revealed the relation between the temperature of the water and of the reservoirs at the piezometers and at the lake (Benfetta, 2017; Hocini and Moulla, 2005).

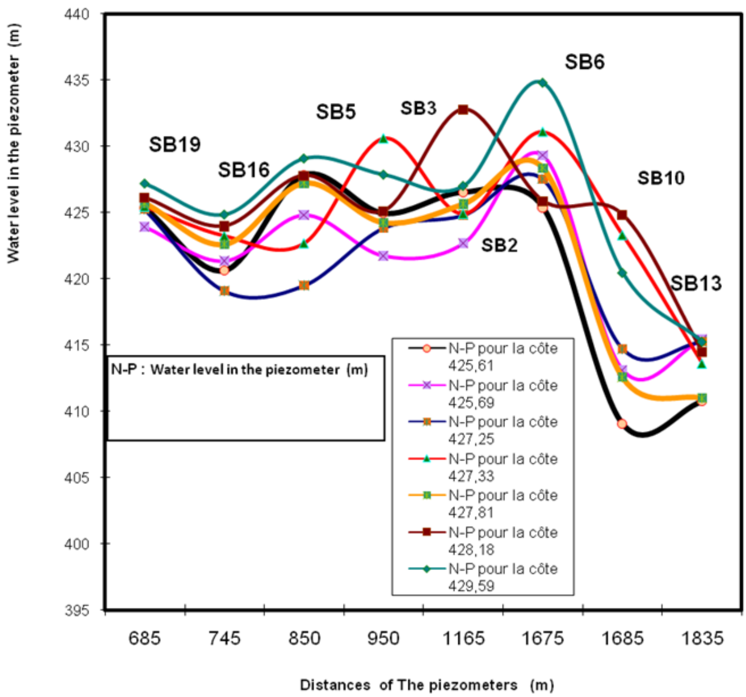
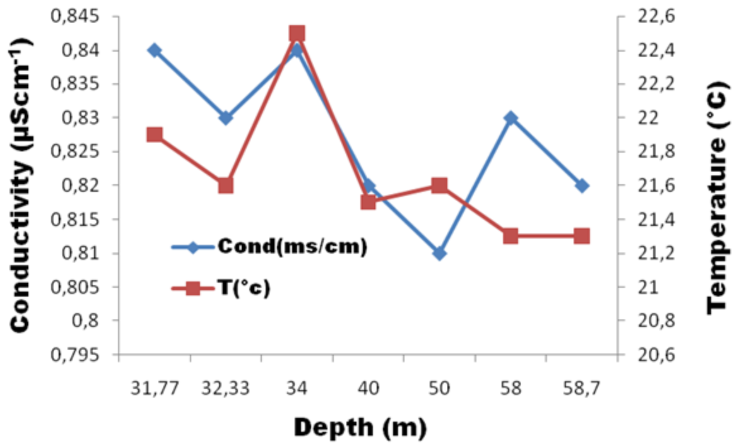


Figure 9: Variation in the piezometric line according to the lake coast of the Algerian dam of Ouizert. ***Source: Benfetta, 2021*.**



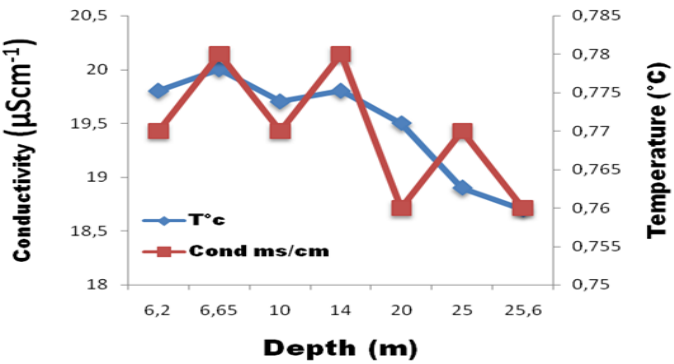


Figure 10: Conductivity profile combined with temperature in piezometers SB5 and SB13. ***Source: Benfetta, 2021*.**

Fig. 10 illustrates the conductivity profiles combined with the temperature profiles at one of the piezometers considered. Two types of flows were depicted in all profiles: the first is vertical downward, represented by the practically constant values of temperature and conductivity, while the second is oblique and almost horizontal from the lake of the water retention at lower conductivity and homogeneous temperature values. This perfectly reflects the degraded state of the geological layers (Benfetta, 2017; Hocini and Moulla, 2005).

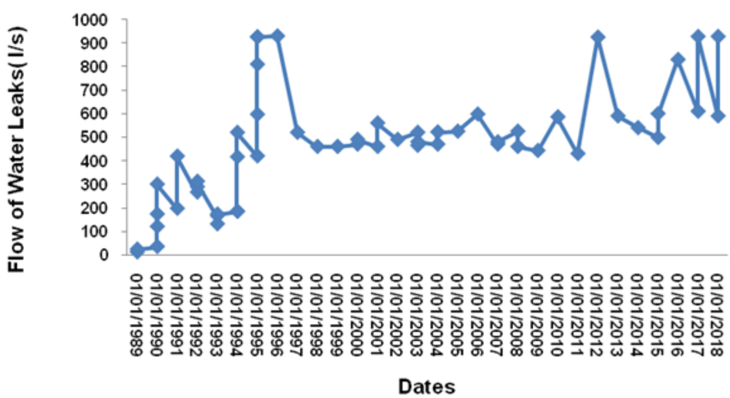


Figure 11: Variation in time of the water leakage flow of the Ouizert Algerian dam. ***Source: Benfetta, 2021*.**

The third part of the study focused on the analysis of leakage flows while examining their variation both over time (Fig. 11) and in relation to the level of the lake coast for two hydrological years taken as examples (Figs. 12 and 13). A review of Fig. 8 suggests the following (ANBT, 2019):

- The flow of water leaks through the left bank increased almost dramatically from 11.6 l/s as of 05/24/89 to 926 l/s as of 05/07/95.
- Due to the reduction in the volume of water in the reservoir, the flow of leaks through the left bank decreased significantly, reaching a value of 460 l/s at the time of sampling on 11/12/2001.
- As a result of the increase in the volume of water in the reservoir, the flow of leaks through the left bank increased almost gradually from 460 l/s as of 11/12/2001 to 925 l/s as of 08/12/2012. It reached the record value of 940 l/s as of 13/12/2013.
- The flow of leaks through the left bank decreased gradually from 940 l/s as of 13/12/2013 to 590 l/s as of 12/07/2018. This decrease is simply explained by the gradual reduction in the volume of water in the reservoir (Benfetta, 2017; Toumi and Remini, 2004).

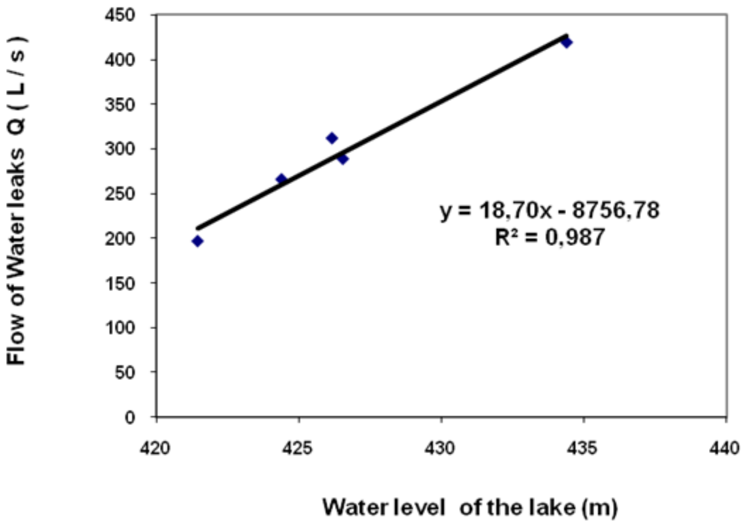


Figure 12: Variation in water leakage flow as a function of the water lake coast (1994/95). ***Source: Benfetta, 2021*.**

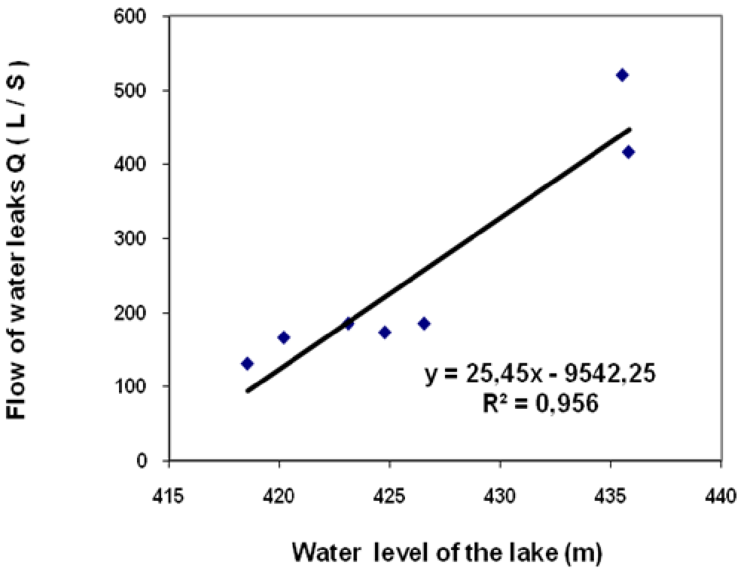


Figure 13: Variation in water leakage rate by lake coast (2011/2012). ***Source: Benfetta, 2021*.**

An examination of the leak flow change through the left bank as a function of the water level in the reservoir led to the conclusion that for all the hydrological years considered, the flow of water leaks increased linearly with the water level in the reservoir lake. The high values of the correlation coefficients (0.987 and 0.956) calculated for the two hydrological years 1994/1995 and 2011/2012, respectively (Figs. 12 and 13) show this fact. Additionally, the flow of water leakage gradually increased to 430 m shore, beyond which it rapidly increased. Variations in the flow of water leaks as a function of the water level in the dam lake can be explained by the fact that when the lake's coast is below 430 m, the flow of water leaks is governed by Darcy's law. It then depends on the permeability of the rock. When this coast exceeds 430 m, the underground flow no longer obeys Darcy's law and involves high permeability layers and even faults. To this is added the flow through the splines whose appearance is due to the reduction of the pressure losses from the coast of 430 m. Beyond this coast, measurements confirmed the continuous increase in the flow of water leaks across the left bank of the Ouizert Dam over time. This increase was remarkable for hydrological years 94/95 and 2011/2012. The increase in hydrostatic pressure due to the progressive raising of the water level in the dam lake resulted in a significant decrease in the load loss. This resulted in the deterioration of the rock mass at the dam site, resulting in a larger crack opening (Benfetta, 2017; ANBT, 2019).

CONCLUSIONS

The Ouizert dam is located on a site formed by a cracked and faulted rocky complex. This cracking is much more pronounced on hard rocks (limestone, sandstone, sandstone and limestone rocks) than it is on marly rocks. Local cracks are also visible on puddle deposits but are of lesser importance.

On the right bank, the rocky complex was dislocated and lowered. It is assumed that the subsidence of the boulder occurred along two lines of fracture approximately parallel to the course of the Wadi. Water leaks are unlikely from the right bank, as the observed faults are virtually parallel to the direction of the layers and as a result to the dam axis.

On the cliffs on the left bank, downstream of the dam, significant discontinuities are visible (cracks and faults), and their extension directions are almost parallel and perpendicular to the course of the Wadi. These discontinuities promote water loss from the reservoir lake.

The correlations between the different hydraulic parameters confirm the presence of horizontal and vertical flows from the reservoir. Based on the analysis of the results obtained, we can conclude that water leaks occur at the left bank downstream of the dam and are favored by the presence of parallel and perpendicular direction cracks along the Wadi. These water leaks are also due to the presence of a strong hydraulic gradient.

The flow of water leaks through the left bank has been increasing substantially over time, particularly when the water level in the dam lake is above the 430 m shore. This could be explained by the fact that the increase in hydrostatic pressure leads to the deterioration of the rock mass by the appearance of large cracks.

The flow of water leaks reached a record of 930 l/s at the end of 1996. Our observations showed that for all the hydrological years considered, the flow of water leaks through the left bank of the Ouizert dam increased linearly as the water level in the dam lake increased. The high values (0.987 and 0.956) of the correlation coefficients calculated for the two hydrological years 1994/1995 and 2011/2012 (Figs. 12 and 13) show this fact. The obtained results can serve as decision-making tools to implement urgently needed dam reclamations.

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