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Abstract: *This study assesses the influence of the Djorf Torba Dam on the Turonian aquifer system in the Béchar region, southwestern Algeria, focusing on reservoir water infiltration into the underlying Turonian and Quaternary aquifers hosted in fractured limestone formations. Infiltration processes are controlled by aquifer hydrodynamic properties, reservoir water levels, and surface area. Monitoring data from external piezometers show that 72.2% of the instruments screened in the Turonian aquifer exhibit groundwater level variations closely correlated with reservoir water levels, with correlation coefficients ranging from 0.75 to 0.94. Piezometric mapping indicates groundwater levels between 693 m and 697.67 m, forming two recharge domes connected to the main branches of the reservoir. When reservoir levels exceed 695 m, infiltration significantly increases along major Turonian fault zones. Water balance calculations estimate an average infiltrated volume of 22.57 hm³/year, including 17.56 hm³/year recharging the Turonian aquifer and 5.02 hm³/year contributing to the Quaternary groundwater. Hydrochemical analyses reveal that groundwater chemistry reflects reservoir water composition, with higher solute concentrations resulting from leaching processes. These findings highlight the strong hydraulic and geochemical impact of the Djorf Torba Dam on the Turonian aquifer system.*

Keywords: *Djorf Torba Dam; Turonian aquifer; reservoir infiltration; groundwater–surface water interaction;*

1. INTRODUCTION

Dams are works of art constructed across rivers and wadis, aim to control floods, regulate water flows, and store water for different uses [1]. To choose and adopt the right type of dam, the techniques of their construction require detailed studies in topography, hydrology, geology, and hydrogeology [2]. The topography requires the existence of a bank having a high depth to surface ratio in order to minimize evaporation losses. The Geology requires rocks, both resistant and impermeable to prevent water leakage to the depths and downstream of the dam. Large dams like Djorf-Torba inserted in Turonian limestones gorges engender change in the hydrological regime of Guirwadi and in the hydrogeology of the underlying aquifers [3-4]. This dam creates a lake, which straddles a calcareous aquifer of Turonian

age. Faced with this situation, infiltrations to this aquifer through its foundations and its lake, can take place. Indeed, the relationships between surface water and groundwater have been subject to numerous studies in a wide range of hydrological, hydrogeological, hydro-geophysical, or hydro-geochemical fields [5-6].

This study raises the scientific problem, dealing with the lake waters infiltration from Djorf Torba dam to the Turonian aquifer. It aims to examine and analyze infiltration phenomenon from different angles. We base our study on geological, hydrodynamic, statistical and hydro-chemical cross analyzes. The infiltration is quantified based on the study of the hydrological balance of this dam.

2. STUDY AREA

2.1. Geographical Setting

The Djorf Torba Dam is located in the Béchar Province, southwestern Algeria. It lies approximately 60 km west of Béchar city, 37 km west of Kenadsa, 20 km east of the village of Meridja, and nearly 70 km south of the Algerian–Moroccan border [7]. Geographically, the dam site is positioned between longitudes $02^{\circ}46'05''$ and $02^{\circ}46'25''$ W and latitudes $31^{\circ}30'13''$ and $31^{\circ}30'34''$ N (Fig.1).

The dam is built across Wadi Guir, a major ephemeral river draining a vast watershed of about 22,068 km². The wadi originates in the eastern High Atlas Mountains of Morocco and is characterized by highly irregular flows, with long dry periods interrupted by short but intense flood events. Historically, Wadi Guir has been considered one of the most powerful wadis in North Africa.

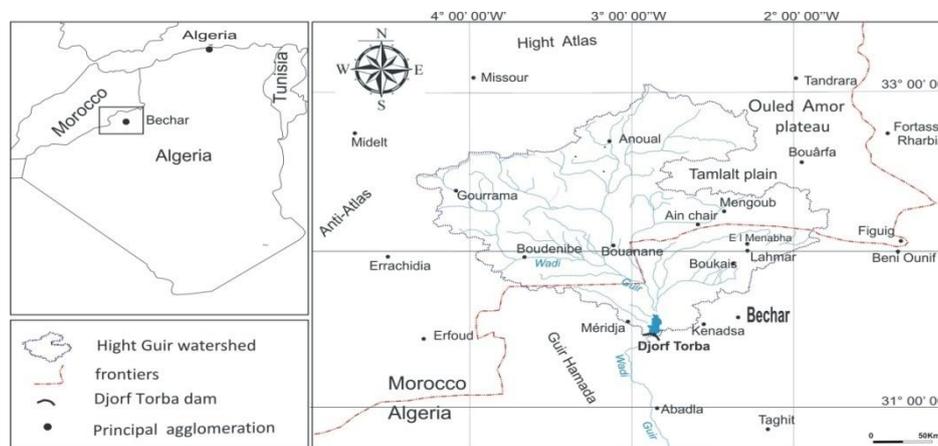


Figure 1: Location of Djorf-Torba Dam and High Guir Watershed

2.3 Geological and Hydrogeological Context

Geologically, the dam site is located on the southern margin of the Béchar Cretaceous basin. The substratum consists mainly of Turonian limestones, with an average thickness of about 35 m. These limestones are fractured, locally karstified, and rest on Cenomanian marls that act as a relative aquitard[8]. The Turonian formation forms both the foundation of the dam and part of the reservoir bottom, making it particularly vulnerable to infiltration.

Below the Cretaceous formations, Carboniferous sandstones, shales, and clays constitute the bedrock. These formations are affected by fault systems with dominant NE–SW orientations, which play a key role in controlling groundwater flow[9]. Above the Turonian limestones, Senonian clays, gypsum, and evaporitic deposits are present, while Quaternary alluvial and travertine deposits occur locally, especially on the right bank of the dam. Hydrogeologically, two main aquifers are identified: the Turonian aquifer, which is regional and highly productive, and a secondary Quaternary aquifer of limited extent. These aquifers are partially hydraulically connected through fracture and fault networks.

3. MATERIALS AND METHODS

3.1. Geological Investigations

Geological investigations were conducted at different spatial scales in order to characterize the geological setting of the Djorf Torba Dam and to assess its influence on groundwater infiltration processes[10]. Field reconnaissance surveys were combined with the analysis of drilling cores and geological maps to identify the main lithological units and structural features. The dam site is located on Turonian limestone formations, which are fractured and locally karstified, favoring groundwater circulation.

Core analyses indicate Rock Quality Designation (RQD) values ranging between 60% and 65%, reflecting a highly fractured carbonate medium. Several fracture families with different orientations were identified, with dominant NE–SW trends associated with regional fault systems. These discontinuities significantly increase the permeability of the limestone formations and provide preferential pathways for water flow (Figure 2) [11]. Satellite imagery interpretation and outcrop observations further revealed the presence of faults and joints extending beneath the reservoir and the dam foundation. The combined geological evidence indicates that the substratum of the reservoir is not perfectly impermeable and is predisposed to infiltration, particularly under high hydraulic gradients generated by elevated reservoir water levels.

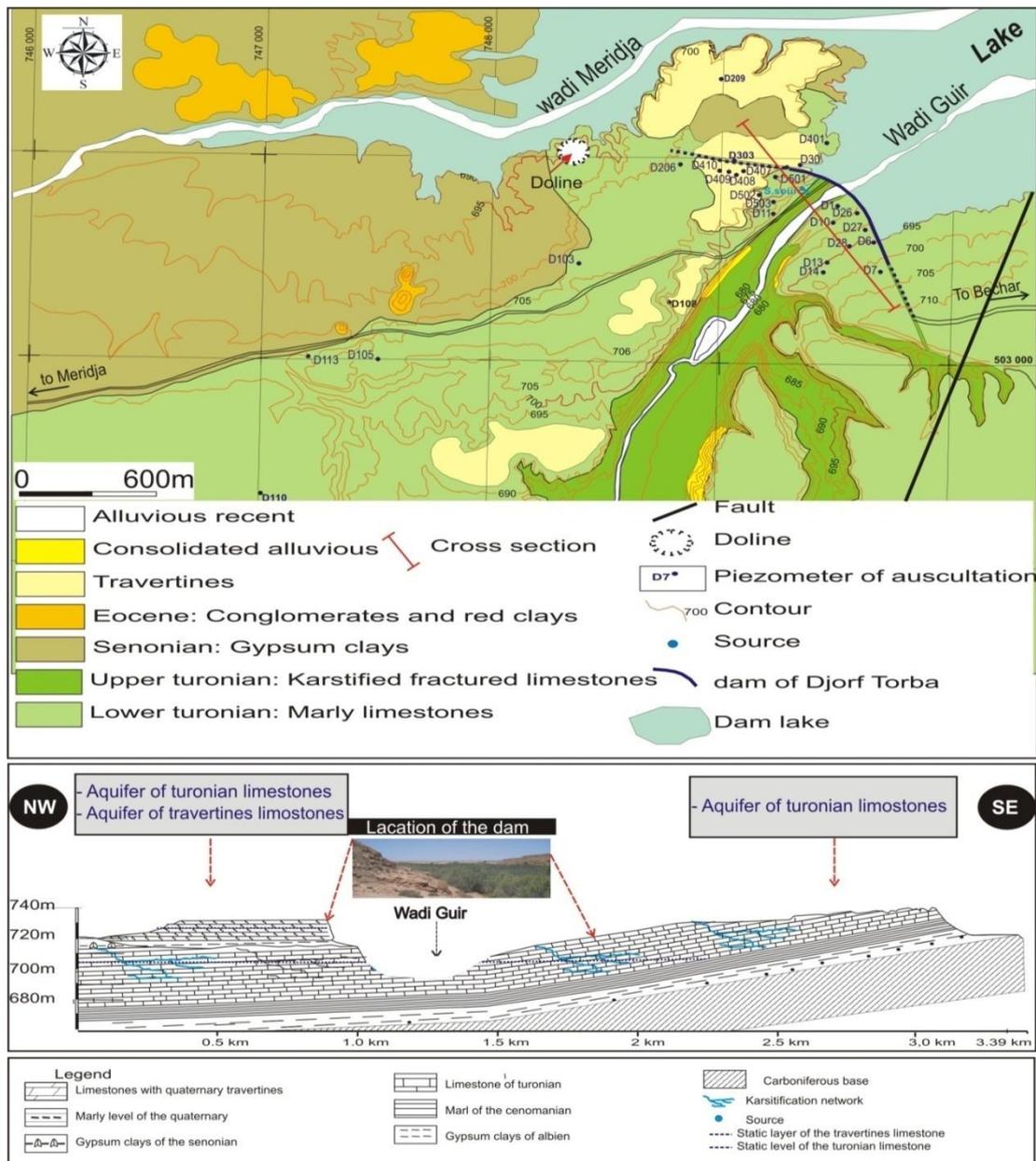


Figure 2: Map and geological cross section of the dam site

3.2. Hydrodynamic Monitoring

Groundwater levels were monitored using 31 functional piezometers installed upstream and downstream of the dam on both banks of Wadi Guir. Static water levels were measured manually using electrical probes with an accuracy of ± 1 cm. Reservoir water levels were recorded daily using a limnometric scale fixed to the dam structure[12].

3.3. Statistical Analysis

Time series of groundwater and reservoir water levels covering the period 2011–2016 were statistically analyzed. Correlation coefficients were calculated between lake water levels and

piezometric levels to assess the degree of hydraulic connectivity between surface water and groundwater.

3.4. Hydrochemical Analysis

Water samples from the reservoir and the Turonian aquifer were collected and analyzed in the regional laboratory of the National Agency for Water Resources. Major ions (Ca^{2+} , Mg^{2+} , Na^+ , Cl^- , SO_4^{2-} , HCO_3^-), pH, total hardness [13], and total dissolved solids were measured. Hydrochemical facies were identified using Piper diagrams.

3.5. Water Balance Method

The infiltrated volume was estimated using the reservoir water balance equation, which considers inflows, rainfall, evaporation, withdrawals, leakage, and changes in storage over a five-year period. This approach provides a quantitative estimate of reservoir-induced recharge[14].

4. Results

4.1. Hydrodynamic Response of the Turonian Aquifer

The analysis of piezometric data shows that the majority of monitoring wells exhibit synchronized fluctuations with reservoir water levels. Head losses between the reservoir and piezometers vary spatially, reflecting lithological heterogeneity, fracture density, and the influence of the sealing curtain[15].

4.2 Piezometric Mapping

Isopiestic maps constructed for maximum and minimum reservoir levels reveal the formation of two recharge domes. These domes indicate continuous groundwater recharge from the reservoir toward the Turonian aquifer throughout the year[16].

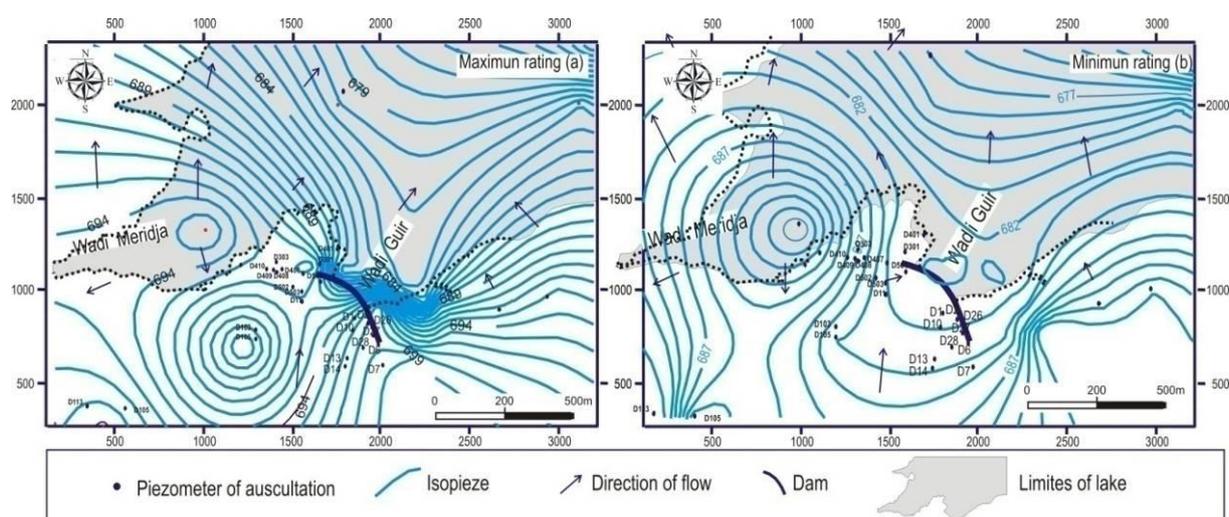


Figure 3: Isopiestic maps of the dam site. A : under a maximal hydraulic gradient of the lake(March,2012), B : under a minimal hydraulic gradient of the lake (August, 2012) .

4.3 Hydrochemical Characteristics

Hydrochemical analyses reveal that both reservoir water and groundwater share similar chemical facies, dominated by chlorinated–sodic and sulphated–calcic types. Groundwater exhibits higher mineralization, reflecting longer residence time and enhanced water–rock interaction (Figure4).

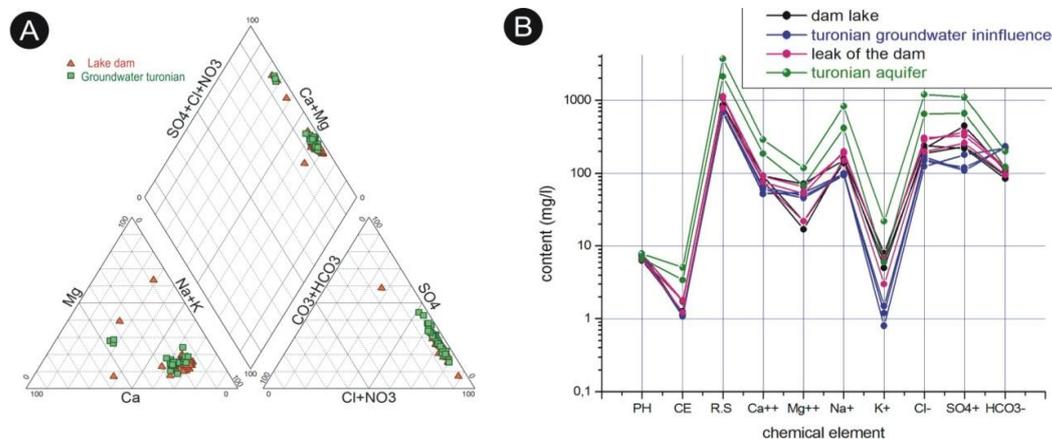


Figure 4 : Hydrochemistry of the lake waters and the waters of the Turonian aquifer

4.4 Estimation of Infiltrated Volumes

The infiltrated water volume was estimated using the reservoir water balance method, based on the principle of mass conservation. This approach considers variations in stored volume, inflows, rainfall, evaporation losses, leakage, and water withdrawals for domestic and irrigation uses. Calculations were performed over a five-year period using operational data from the Djorf Torba Dam. The results indicate an average annual infiltrated volume of approximately 22.57 hm³[17]. This volume mainly contributes to the recharge of the Turonian aquifer, with a smaller proportion feeding the Quaternary aquifer. These findings confirm the significant role of the reservoir as an artificial recharge source in an arid hydrological context[18].

5. Discussion

The results obtained in this study clearly demonstrate a strong hydraulic interaction between the Djorf Torba reservoir and the underlying Turonian aquifer. This interaction is primarily controlled by the geological characteristics of the dam foundation, particularly the fractured and locally karstified nature of the Turonian limestones. Such structural conditions enhance the permeability of the aquifer and facilitate vertical and lateral water transfers from the reservoir toward the groundwater system[19]. The hydrodynamic response observed in most piezometers confirms that groundwater levels are directly influenced by fluctuations in the reservoir water level[20]. The high correlation coefficients indicate that reservoir-induced recharge plays a dominant role in controlling groundwater dynamics, especially during periods of high water levels. The threshold elevation of approximately 695 m appears to be

critical, as infiltration processes intensify beyond this level due to increased hydraulic gradients and direct contact with fault networks.

The spatial distribution of piezometric heads and the formation of recharge domes further support the existence of continuous groundwater recharge from the reservoir. These findings are consistent with the hydrochemical results, which reveal similar chemical facies between reservoir water and groundwater. The higher mineralization observed in groundwater can be attributed to longer residence times and enhanced water–rock interactions within the carbonate aquifer[21].

Overall, the combined hydrodynamic and hydrochemical evidence confirms that the Djorf Torba Dam significantly alters the natural groundwater regime, acting as an artificial recharge source in an arid environment. This dual role highlights the importance of considering both resource benefits and structural safety in reservoir management strategies.

6. Conclusion

This study highlights the significant influence of the Djorf Torba Dam on the hydrodynamic and hydrochemical behavior of the Turonian groundwater system in the Béchar region, southwestern Algeria. The construction of the dam on fractured and locally karstified Turonian limestone formations creates favorable conditions for hydraulic exchanges between reservoir water and groundwater. Piezometric monitoring demonstrates that most observation wells respond synchronously to fluctuations in the reservoir water level, indicating strong hydraulic connectivity between surface and subsurface waters. High correlation coefficients confirm this relationship, particularly when the reservoir level exceeds the elevation of 695 m, beyond which infiltration processes intensify along fault and fracture networks.

Piezometric maps reveal the development of recharge domes directly associated with the reservoir and its secondary branch, reflecting a continuous contribution of reservoir water to the Turonian aquifer. Hydrochemical analyses further support this connectivity, as groundwater and reservoir waters exhibit similar chemical facies, while groundwater shows higher mineralization due to prolonged water–rock interaction processes. Water balance calculations estimate an average annual infiltrated volume of approximately 22.57 hm³, with the majority contributing to the recharge of the Turonian aquifer. In the arid climatic context of the study area, this reservoir-induced recharge represents a valuable groundwater resource. However, it also emphasizes the necessity of integrated management strategies to ensure both dam safety and the long-term sustainability of groundwater resources.

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