

# **Title:** Long-Term and Step-Drawdown Pumping Tests in Deep Hydrogeological Boreholes, Characterization of Hydrodynamic Properties and Transmissivity of Deep Aquifers: Case of the Fritissa Area (Middle Moulouya Basin, Morocco)

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## **ABSTRACT**

The water sector in Morocco's Moulouya basin faces critical challenges, including decreased natural recharge due to climate change, deteriorating water quality, and unsustainable exploitation of groundwater. This study characterizes the hydrodynamic properties and transmissivity of the deep aquifer system in the Fritissa zone (Middle Moulouya) across three specific locations: Bouyakoubate (F1), Dkikkira (F2), and Fritissa (F3). Accurate estimation of these parameters is vital for sustainable resource management. The methodology utilizes data from three boreholes (IRE N°1212/23, 1231/23, and 48/23), including pumping tests and drilling reports. Flow rates were calculated using the Theis (1935) method, while the specific flow rate ( $Q_{sp}$ ) and critical flow rate ( $Q_c$ ) were determined using the OUAIP tool developed by the BRGM. Descriptive and multivariate statistical analyses were applied to establish prognostic correlation equations between hydrodynamic parameters. Results indicate a transmissivity of  $1.46 \times 10^{-2} \text{ m}^2/\text{s}$  and permeability of  $2.43 \times 10^{-5} \text{ m/s}$  for F1;  $7.72 \times 10^{-4} \text{ m}^2/\text{s}$  and  $1.39 \times 10^{-6} \text{ m/s}$  for F2; and  $1.65 \times 10^{-2} \text{ m}^2/\text{s}$  and  $2.42 \times 10^{-5} \text{ m/s}$  for F3. Specific fluxes were measured at  $91.12 \text{ m}^2/\text{h}$  (F1),  $1.25 \text{ m}^2/\text{h}$  (F2), and  $133.33 \text{ m}^2/\text{h}$  (F3). Critical flow rates reached  $288 \text{ m}^3/\text{h}$  (F1),  $61.2 \text{ m}^3/\text{h}$  (F2), and  $291 \text{ m}^3/\text{h}$  (F3). Established correlation equations are:  $Q_c (\text{m}^3/\text{h}) = 0.63 + 0.61Q$  and  $T (\text{m}^2/\text{h}) = 0.63Q_{sp}^{1.3}$ . The exploratory phase confirms the feasibility of a supply program. The long-term pumpable flow is  $13,896 \text{ m}^3/\text{day}$  for F1 and F3, and  $1,468 \text{ m}^3/\text{day}$  for F2. To preserve the deep aquifer while meeting regional needs, an optimum annual exploitation flow of  $5,607,860 \text{ m}^3$  is recommended. This significantly exceeds the projected peak demand for 2035 ( $70,956 \text{ m}^3/\text{year}$ ) estimated by the ABHMO. This research establishes the aquifer's high productivity and provides a framework for managing groundwater as a strategic relief reservoir against climate hazards through flow modeling and geostatistical tools.

**Keywords:** Pumping Tests; Hydrodynamics; Transmissivity; Specific Flow; Critical Flow.