# HYDROGEOLOGICAL DYNAMICS AND SPATIAL DISTRIBUTION OF GROUNDWATER IN THE KITOB-SHAXRISABZ DEPOSIT UNDER CLIMATE CHANGE CONDITIONS

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**Abstract**

This paper evaluates the hydrodynamic trends and spatial distribution of the Kitob-Shaxrisabz groundwater deposit in Uzbekistan under changing climatic conditions from 2020 to 2025. Utilizing systematic data from 133 optimized high-precision observation wells, the study establishes a direct correlation between volatile regional precipitation regimes and fluctuating water table levels. Structural lithofacies analysis reveals that the deposit is divided into three distinct operational hydrogeological zones: a peripheral foothill recharge belt, a central high-yielding transit core, and a western discharge margin prone to localized soil salinization. The climate-hydrodynamic trend model highlights extreme vulnerability to drought, with the static water table plunging to a depth of 5.2 meters during the severe 2023 dry cycle. This depletion is heavily exacerbated by intensive agricultural abstraction and unmanaged regional drilling. To preserve freshwater security and mitigate saline front encroachment, this study proposes critical management strategies, including the implementation of subsurface drip irrigation, managed aquifer recharge (MAR) structures, and a digital telemetric early warning monitoring model.

**Keywords**

Kitob-Shaxrisabz deposit, Groundwater hydrodynamics, Climate change impact, Aquifer zonation, Water table fluctuations, Managed aquifer recharge (MAR), Telemetric monitoring, Water resource sustainability.

## 1.Introduction

The Kitob-Shaxrisabz groundwater deposit, situated within the eastern intermontane depression of the Qashqadaryo region in Uzbekistan, constitutes a crucial hydrogeological repository. It serves as the primary freshwater asset for municipal drinking water supplies, intensive agricultural irrigation, and industrial applications across the dynamic districts of Kitob and Shaxrisabz. However, ongoing global and regional climate variations, characterized by rising mean annual temperatures and erratic localized precipitation regimes, have significantly altered the recharge rates and spatial stability of these aquifers. Since approximately 59.20% (909.99 thousand $m^3$/day) of the total extracted groundwater volume is rapidly deployed for agricultural irrigation, understanding the direct impact of climate change on water table levels is vital for sustainable water security. This paper examines the hydrodynamic trends of the Kitob-Shaxrisabz aquifers between 2020 and 2025, providing an integrated assessment of structural distribution and climatic correlation.

## 2. Material and Methods

The research utilizes systematic long-term monitoring data obtained from the state hydrogeological network managed by the Qashqadaryo Hydrogeological Station under the State Geological Monitoring Service of 'O'zbekgidrogeologiya' State Institution. Following an intensive network optimization process executed between 2023 and 2024, a total of 133 high-precision observation wells ranging in deep profiles from 10 to 500 meters were continuously monitored. Hydrodynamic parameters, specifically the static water table depth levels, were logged monthly. Meteorological datasets including mean annual precipitation and atmospheric temperature ranges were cross-referenced from regional meteorology stations in Shaxrisabz and Kitob. Spatial analysis and hydrogeological zonation were conducted based on litofacies analyses of the Quaternary (Q) alluvial-proluvial coarse-grained strata, grouping sediment thicknesses, hydraulic conductivities, and boundary parameters into three discrete conceptual operational zones.

## 3. Results

The spatial configuration of the Kitob-Shaxrisabz deposit is highly influenced by the structural architecture of the intermontane basin. Longitudinal hydrogeological profiles reveal that groundwater distribution falls into three well-defined operational zones. Zone I represents the peripheral foothill recharge belt adjacent to the Zarafshon and Hisor mountain blocks, dominated by highly permeable gravels where direct riverbed infiltration from the Qashqadaryo River occurs. Zone II comprises the central transit and heavy extraction core where the unconfined aquifer converts partially into semi-confined high-yielding layers. Zone III forms the western discharge and evaporation margin, where the water table rises close to the topographic surface (0.5 to 2.0 meters), leading to localized soil salinization and mineralized upwelling. The schematic zonation map illustrating these zones and specific active tracking wells is detailed below in Figure 1.

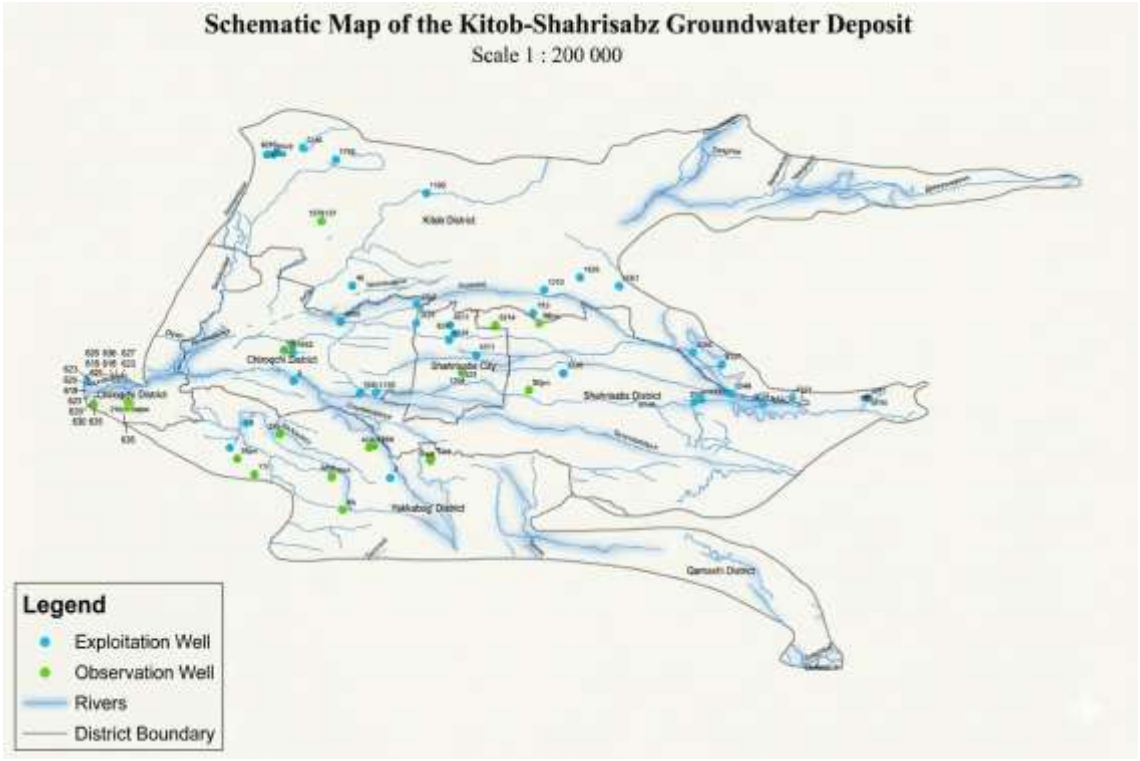


*Fig. 1. Schematic hydrogeological zonation and monitoring well layout of the Kitob-Shaxrisabz deposit*

The quantitative relationship between atmospheric moisture inputs and water table movements demonstrates an immediate and high-magnitude correlation. Table 1 outlines the measured variables extracted from the monitoring network over the 2020–2025 assessment sequence.

| Observation Year | Annual Precipitation (mm) | Mean Static Groundwater Depth (m) |
|---|---|---|
| 2020 | 545.2 | 3.80 |
| 2021 | 412.8 | 4.60 |
| 2022 | 589.4 | 3.40 |
| 2023 | 395.1 | 5.20 |
| 2024 | 462.3 | 4.80 |
| 2025 | 510.5 | 4.10 |

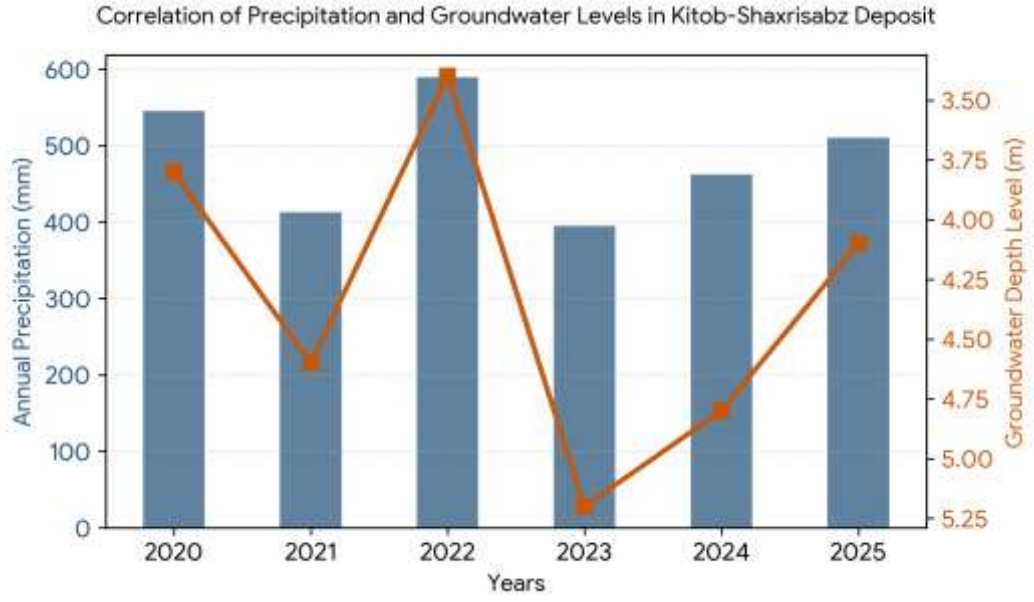


*Fig. 2. Climate-hydrodynamic trend interaction model showing water table fluctuations relative to precipitation*

## 4. Discussion

The empirical findings visualised in Figure 2 expose a synchronous pattern matching precipitation cycles with groundwater depletion trends. During the high-rainfall epoch of 2022, where annual precipitation peaked at 589.4 mm, the intense hydraulic recharge caused the water table to bounce back significantly, reaching an average depth of 3.4 meters below ground surface. Conversely, the severe drought cycle of 2023, which recorded a low of only 395.1 mm of precipitation, led to an aggressive downward trend in water levels, plunging the regional static water table to 5.2 meters deep. This rapid drop indicates a short response lag, highlighting the vulnerability of shallow unconfined Quaternary aquifers to immediate atmospheric drought. Compounding this climatic threat, extensive unmanaged private drilling in the nearby Chiroqchi and Koson districts targets Neogene aquifers to depth ranges of 150-250 meters, pulling lateral groundwater flows from the central Kitob-Shaxrisabz basin. Furthermore, the verified eastward migration of saline frontlines threatens to contaminate adjacent fresh groundwater lenses if depletion trends persist unchecked.

## 5. Conclusion

The detailed investigation into the Kitob-Shaxrisabz groundwater deposit verifies that climate variations represent a primary threat to aquifer sustainability in the Qashqadaryo region. To mitigate accelerated depletion and preserve water quality against saline encroachment, three engineering strategies are proposed: (1) The immediate replacement of standard open flood irrigation with automated subsurface drip irrigation technologies across the agricultural zones to minimize the 59.20% abstraction load; (2) The construction of managed aquifer recharge (MAR) structures in foothill Zone I to capture seasonal flash floods and maximize deep infiltration; and (3) The integration of digital telemetric sensors across the 133 active state observation wells to establish an early warning automation model forecasting groundwater depletion patterns.

## 6. References

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