



Groundwater vulnerability and aquifer recharge modeling by the water table fluctuation method on a nuclear and radioactive facility

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1. Introduction

In a nuclear and radioactive facility (NRF), many safety and security actions must be implemented[1], [2], [3]. Among these actions, geological and hydrological aspects must be monitored [2], [3], [4], [5]. One important aspect is the groundwater regime under buildings and in adjoining areas. That should be monitored to verify the facility design conditions, especially to clarify how, how much, where from and to what direction the water drainage occurs. The monitoring studies are important not only during the study plan for installation, but also during regular operation to assess any chemical or radiochemical undesired release.

Since 1956, Ipen operates inside the campus of Universidade de Sao Paulo, covering a total area of 500,000 square meters. As environmental management actions, IPEN has developed an Integrated Management Policy to minimize any impact on health, to increase safety of its products, processes, and facilities. IPEN's Environmental Monitoring Plans (EMP) seeks to comply with the legal requirements from national and international regulatory bodies [6]. Since 2006, the Environmental Monitoring Program for Stable Chemical Compounds (PMAQ) assesses the impact of metals and stable elements on groundwater from 7 monitoring wells. The monitoring results comply with guideline values from state and country regulations [6], [7], [8], [9]. However, climate variations and changes in the anthropogenic activities could alter groundwater

recharge and flow, hydrological, physical, physicochemical, and biological characteristics governing the transport, diffusion, and retention of stable and radioactive materials[1], [2]. Therefore, the present study aims to identify and quantify the groundwater flow and recharge below Ipen facility. The most common method to estimate groundwater flow and recharge is the Water Table Fluctuation method[10].

2. Methodology

Data collection

One monitoring well was selected to capture the dynamic changes in the water table. This well is located at the low level of the tableland (latitude -23.712194, Longitude -46.7539722, 744,29 m.s.l.). Daily and manually, water table measurements were performed with an electric measuring probe (Hidrosuprimentos, Brasil).

Daily climate data was collected from INMET [11] from three meteorological stations (Mirante, Barueri and Bauru). Precipitation values were registered by event at CETESB monitoring Station IPEN-USP-Cidade Universitaria[12], [13].

All measurements were performed, and data were collected from September to December 2023.

Estimation of ground water recharge

The ground water recharge was estimated by the water table fluctuation method (WTF). Because these was the first recharge assessment no consideration to lateral flow from high water head was done in the present study. Equation 1 was used to estimate the recharge. The main assumption is that water table fluctuations are derived entirely from recharge or discharge and the specific yield of the aquifer remains constant over time[14], [15].

$$R = S_y \frac{dh}{dt} = S_y \frac{\Delta h}{\Delta t} \quad (1)$$

Where R is the aquifer recharge (mm), S is the aquifer specific yield (dimensionless), h is the water table height (in m) and t is time (in days).

Aquifer yield estimate

Considerations on the lithology and soil composition were used to estimate S_y values proposed by Lebreque et al.[16]. As the well is in a sandy-clay bed, the S_y value adopted in the present study was 7% (0.07).

3. Results and Discussion

Figure 1 presents the daily variation of precipitation, water table level, rise and temporal change. The present study adopted the graphical approach. As the measurements started just after the end of a dry period it was possible to observe a brief period of a small and constant decline water table. When the rainfall started at the end of September 2023 with a sequence of very intense rain events (>30mm, n=4), it was possible to observe a significant water table rise of up to 0.2 m. By the end of October up to the end of November 2023 a series of small precipitation events occurred to which no significant (<0.05 m of water table rise or decline) water table level was noticed.

By the reaction time, it was possible to estimate the aquifer recharge occurs rapidly in a couple of weeks after the precipitation event. Aquifers with similar water table level reaction speed are considered relatively vulnerable to pollutants.

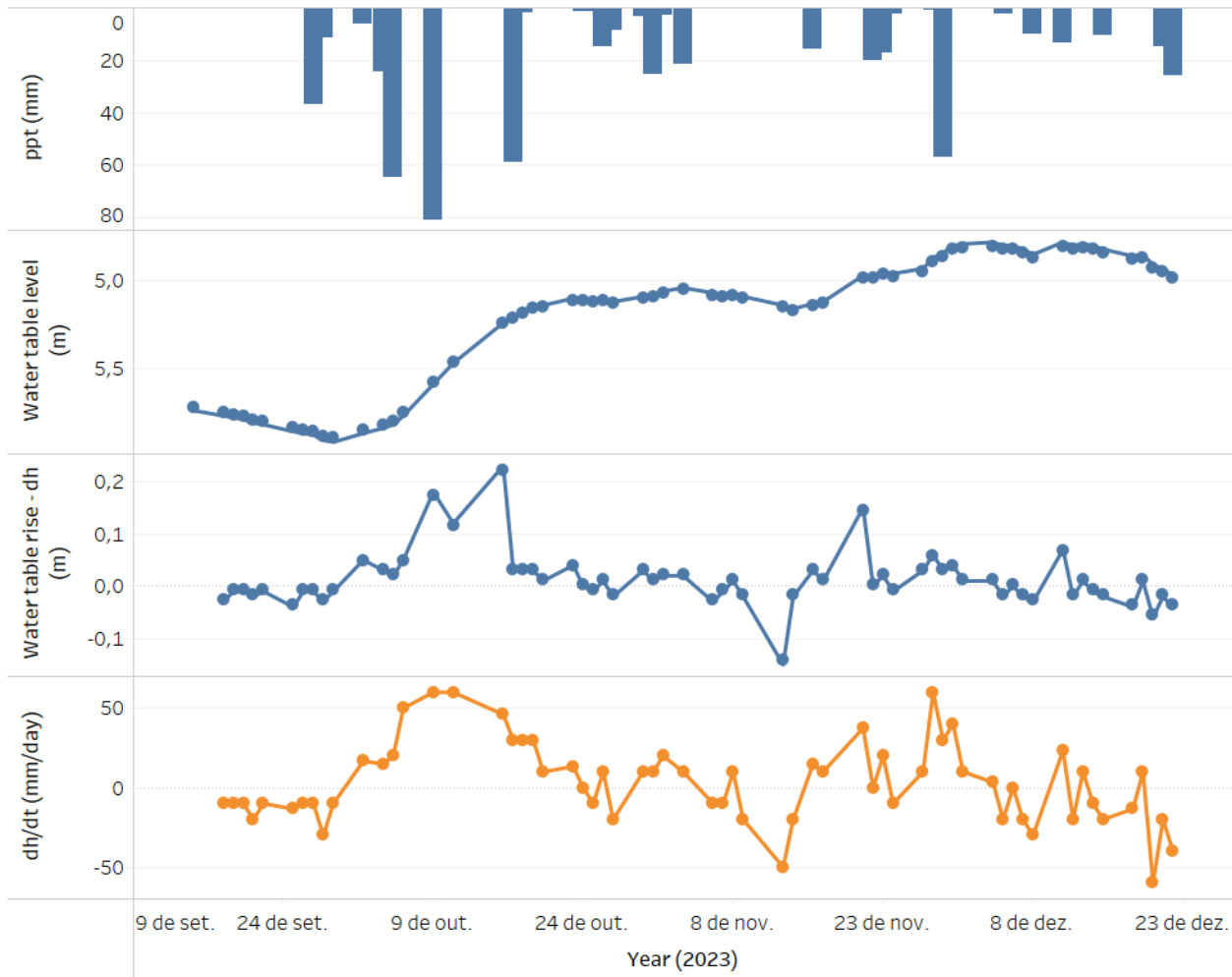


Figure 1 – Daily variation of precipitation, water table level, rise and temporal change.

4. Conclusions

Based on the WTF method, this study presents a first estimate of the local groundwater recharge at Ipen. These results open for discussion about which factors can affect the local water recharge. Temporally, the groundwater presented a fast response time to precipitation events, corresponding to a couple weeks up to one month, with the remark that the monitored well was shallow (water level <10 m). At the moment, no assessment was possible about the size of precipitation event that could contribute to groundwater recharge. But WTF measurements will be performed continuously until correlations to climate and seasonal conditions are possible. As a current study limitation, we state that no spatial recharge variability was performed yet. The present assessment will assist further risk management and groundwater resources management studies in a nuclear and radioactive facility.

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