

Determining hydraulic parameters of a karst aquifer using unique historical data from large-scale dewatering by deep level mining – a case study from South Africa

Aljoscha Schrader^{1,2}, Ewald Erasmus² and Frank Winde^{2*}

¹ Faculty of Natural Sciences, Potchefstroom Campus, North-West University, Private Bag X6001, Potchefstroom 2520, South Africa

² Mine Water Research Group, Vaal Campus, North-West University, South Africa

ABSTRACT

Although karst aquifers constitute some of the most important water resources worldwide, generally accepted methods for reliably characterising their hydraulic properties are still elusive. This paper aims at contributing to the discussion by a first-ever attempt to utilise various sets of unique historical data derived from draining a large dolomitic karst aquifer by deep-level gold mines in South Africa. In contrast to conventional pumping tests which only penetrate thick aquifers to a limited extent from surface, this draining took place at the very bottom of the aquifer offering the rare opportunity to capture its entire thickness of nearly a kilometre. The datasets have been treated as analogies to conventional pumping tests applying various types of analytical methods designed for porous media. In order to increase the robustness of the results and to account for specific local conditions a total of four different analytical methods were applied to calculate (horizontal) transmissivity and storage coefficients. The obtained values, in general, compare favourably to previous studies in the area and values reported in literature for similar aquifer types confirming earlier findings that Darcy-based methods can be successfully applied to karst aquifers if the scale of investigation is large enough. Apart from improving the understanding of local karst hydrology the present study also aimed at retrieving and preserving valuable and unique historical datasets that otherwise would have been lost for scientific evaluation and the proactive preparation for mine closure.

Keywords: karst, dewatering, deep level mining, porous medium analytical methods, transmissivity, storage coefficient, Far West Rand

INTRODUCTION

The main purpose of this paper is to explore the usability of historical data gathered over 4 decades of deep-level gold mines dewatering an overlying dolomitic karst aquifer in the Far West Rand (FWR), South Africa, in order to determine hydrological parameters. Based on the conceptual understanding that the set-up under which these data were generated resembles an ultra-large pumping test covering the thickness of the entire karst aquifer, standard analytical methods typically used in pumping tests were applied.

At the same time the study attempts to preserve large sets of unique data that are regarded as most valuable for predicting hydraulic conditions after future mine closure. The latter is particularly important as mining-induced modifications of the natural hydrogeological setting in the FWR will, in all likelihood, have profound impacts on post-mining land use as well as on the long-term availability of surface and groundwater resources.

Hydrogeological conditions of the study area

Geological setting

The karstified dolomites of the FWR goldfield, southwest of Johannesburg, host some of the largest groundwater resources

in South Africa, as well as a range of strong associated karst springs. Gold-bearing reefs below the dolomite have been subject to extensive deep-level mining for many decades. Following a sudden and nearly catastrophic inrush of dolomitic groundwater to the Driefontein Mine in October 1968, it was found necessary to dewater the dolomitic aquifer above the mine void. Owing to the large-scale lowering of the regional groundwater table many of the karst springs dried up. Simultaneously, large quantities of hydrologic data were recorded, some of which are used in this study. The historical and hydrogeological context of the latter data is briefly outlined in this section.

The overall geological situation is depicted in Fig. 1, indicating a north to south cross-section in the FWR as well as the associated stratigraphy.

The dolomite is subdivided into several so called 'groundwater compartments' by approximately north to south-trending intrusive, nearly-vertical dykes, which act as groundwater flow barriers (De Kock, 1964; Brink, 1979). Compartments in the area concerned are the Venterspost, Bank, Oberholzer and, lastly, Boskop-Turffontein Compartments. Data analysed in this study exclusively refer to the Bank Compartment. The northern aquifer boundary is set by granites of the Hartebeesfontein Anticline (Fig. 1). To the south a gradual boundary forms where rocks of the Pretoria Group increasingly overlie the dolomite, preventing pronounced karstification through shielding the underlying dolomite from infiltrating rainfall (Enslin and Kriel, 1968; Brink, 1979). According to Swart et al. (2003), the shielding effect creates a boundary where the thickness of the Pretoria Rocks is at least 150 m. The Ventersdorp Supergroup Lava and Witwatersrand Supergroup Quartzites do not store significant volumes of groundwater

* To whom all correspondence should be addressed.

+27 /16 9103477; e-mail: Frank.Winde@nwu.ac.za

Received 29 July 2013; accepted in revised form 15 July 2014.