Groundwater resource evaluation of urban Bulawayo aquifer

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Abstract

Judicious management of a groundwater system requires an understanding of its hydrogeology and response to various recharge and pumping stresses. However, in developing countries, groundwater resource evaluations are hampered by a lack of adequate data that will allow for its complete characterisation. Under such circumstances it is not uncommon for *ad hoc* groundwater management measures to be embarked upon, especially during drought conditions. These were the conditions that existed during the 1991/92 drought when the CSIR Stellenbosch evaluated the groundwater resource of an urban aquifer in Bulawayo, Zimbabwe. Their recommendations revealed that about 3.5×10^6 m^3/a could be safely abstracted from the aquifer. In this work, a more comprehensive hydrogeological investigation was carried out which included pumping tests, estimation of abstraction rates and recharge, and numerical modelling of the aquifer. The investigations indicate that the aquifer is unconfined with hydraulic conductivity and specific yield ranging from 0.1 m/d to 2.09 m/d and 0.02 to 0.11, respectively. Recharge estimates indicate an annual recharge of 105.5 mm with 38.4%, 52.1% and 9.5% accounting respectively for direct recharge, water mains and sewer leakages. Furthermore, a long-term sustainable annual abstraction of 6.1×10^6 m^3 or 15% of current city water demand can be obtained from the aquifer.

Keywords: groundwater flow; pumping tests; urban groundwater; numerical modelling; groundwater resource evaluation.

Introduction

Inadequate hydrogeological data continue to present one of the greatest challenges to planning and managing of groundwater resources in many developing economies, particularly under extreme environmental conditions of drought and erratic rainfall patterns. That has been the case with the city of Bulawayo which is located in a water-scarce region of Zimbabwe that is affected by recurrent droughts. The 1991/92 drought prompted *ad hoc* measures to be adopted of which one was a groundwater abstraction programme from the Matsheumhlope well-field that underlies the city to supplement dwindling supplies from surface reservoirs whose levels fell below critical values. In addition a preliminary study of the aquifer was undertaken by the CSIR, and one notable finding was the groundwater potential of the aquifer from which an annual yield of 3.5×10^6 m^3 could be obtained. The study is herein expanded to provide a more comprehensive hydrogeological analysis of the aquifer. The outcome of such an analysis provides for the adoption of a more scientifically-based management policy by the Bulawayo City Council (BCC) which is charged with that responsibility. A management policy for the Matsheumhlope well-field, with the primary objective of optimal utilisation of the groundwater resources without engendering undesirable environmental consequences and meeting other technical and non-technical constraints, has been elusive to the BCC. Failing to achieve this, BCC has relied largely on water supply from Mzingwane, Lower Ncema, Upper Ncema, Inyankun, and Msiza Dams that are all located some 45 km south-east of the city. A small fraction of the total water supply to the city is obtained from groundwater that is pumped from the Nyamandlovu aquifer located 60 km north-west of the city (Fig. 1B). In terms of pumping costs, these will certainly be much higher than those incurred from an aquifer that underlies the city, if it can yield a comparable amount and quality of water. Furthermore, the enormous amount of agricultural activities currently taking place at Nyamandlovu puts that aquifer at great risk of over-exploitation and contamination from fertilisers and pesticides. It is therefore expected that the results of this study will provide the BCC with the basis for a management policy on the Matsheumhlope well-field.

To pursue our objective of evaluating the water resources of the Matsheumhlope well-field, hydrogeological investigations were carried out, including estimating recharge and current abstraction by private individuals and corporate bodies. Pumping tests were carried out on 18 boreholes which produced data that were digitally analysed with the software AQUIFER TEST. The results from these tests confirmed the geophysical investigations of Martinelli and Hubert (1985) that the aquifer is predominantly unconfined. Recharge estimates were carried out using the water balance approach. It is acknowledged that our estimates of recharge are preliminary, having not been verified by another independent method. Because the aquifer is an urban one, the estimate for recharge has not only taken into consideration direct recharge from precipitation but also that due to water mains and sewer leakages. Recharge due to over-irrigation of parks, gardens and lawns has not been estimated because of difficulties associated with its quantification. The city and its environs imports all water for domestic, commercial and industrial activities to the tune of 43×10^6 m^3 from outside the project area and transports its wastes through a network of sewers to treatment works located outside the project area. Recharge estimates indicate that direct recharge accounts for 38.4% of the total annual recharge of 105.5 mm, while water mains and sewer leakages account for 52.1% and 9.5%, respectively.

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