WATER RESEARCH COMMISSION

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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

GROUNDWATER

For more than 30 years the Table Mountain Group (TMG) aquifer system has been considered a potential source of bulk water supply for meeting water requirements of both the Western and Eastern Cape Provinces. Information on climate, hydrology, geomorphology and geology has been used to develop conceptual models of recharge in the TMG system, while research has been undertaken to assess realistic recharge rates.

Estimating Recharge of the Table Mountain Group Aquifer System

Recharge estimation and the TMG aquifer system

The TMG is a system of deep-seated fractured aquifers belonging to the Cape Supergroup, which is exposed along the entire length of the Cape Fold Belt (CFB) adjacent to the south and west coasts of South Africa and covers an area of 248 000 km^2 in the Western and Eastern Cape Provinces. TMG outcrops are spread over approximately 37 000 km^2 of this CFB area.

The TMG comprises an approximately 4 000 m-thick sequence of quartz arenite and minor shale layers. The main aquifers within the TMG are located in the Peninsula formation and the Nardouw Subgroup, these being separated by the Cedarberg Formation which acts as an aquitard.

Although groundwater recharge is widely recognised to be the key consideration in the sustainable use of groundwater resources, no comprehensive studies of groundwater recharge in the TMG system had been undertaken prior to the WRC study.

Conceptualising groundwater recharge processes

In support of investigations into groundwater recharge, the TMG aquifer system has been critically reviewed and 19 hydrogeological units have been identified on the basis of geologic, geomorphologic, climate and hydrogeological characteristics.

The interaction of climate, geology, morphology, soil condition and vegetation determines recharge. In particular, an understanding of the geomorphology contributes to a better delineation of the TMG recharge processes and an improved appreciation of the challenges of recharge estimation.

Consequently, field investigations covering the 19 hydrogeological units have been undertaken to underpin development of conceptual models of recharge processes in the TMG area. These studies include consideration of the effects on recharge of topography, fractures, slopes and vegetation, as well as of structural influences with regard to recharge processes in soil (texture, thickness) and various strata (horizontal, upright, inclined) zones.

From the viewpoint of groundwater recharge, five types of aquifer setting have been recognised based on their geomorphologic characteristics. These are the horizontal terrain zone, the inclined strata system, the folded strata belt, the weathered rock (crust) aquifer zones and the fractured rock aquifer outcrop.

The recharge processes are related to topography and fracture networks. Different topographic types show different patterns of surface water runoff and infiltration mechanisms. Interflow occurs in the weathering and preferential fracture zones above the local river levels.

Infiltrate rate is related to characteristics of land surface. The percolation rate to the aquifer is constrained not only by the infiltration rate, but also by fracture characteristics at depth. In most cases, the percolation rate is very small as most of infiltration water seeps out in the form of interflow, especially in mountainous areas.

Fractures in shallow rock layers, together with fissures that are due to weathering near the surface, are the most important factors that promote both rainfall infiltration and groundwater recharge in the outcrop areas of TMG aquifers. These outcrops of the TMG form the main recharge areas of the aquifers as do the foothills and foot-slopes of the mountains where flood fans occur. Deep-seated faults, conducive to preferential flow, that are linked to dense fracture intersections at shallow locations appear to facilitate recharge processes in the deep TMG aquifer system.

Recharge estimation methodology

At the scale of each recognised hydrogeological unit, a water balance model can be used for providing an estimate of groundwater recharge to serve as a departure point for subsequent, more detailed, quantification.

At local scale, estimation is facilitated by considering six recharge-process scenarios, namely for soil zones, horizontal strata zones, vertical strata zones, and three inclined strata zones. In most of the TMG area, a combination of these scenarios would be needed to account for the complex recharge processes that occur.

A preferred approach to quantifying groundwater recharge rates is to use several recharge estimation methods for purposes of cross-checking. Typically, these may include the Chloride Mass Balance (CMB) mixing model, the Saturated Volume Fluctuation (SVF) method, the Cumulative Rainfall Departure (CRD) method, and an extension of the CRD model called the Rainfall Infiltration Breakthrough (RIB) model. Verification through numeric simulation modelling is found to be additionally beneficial.

A hydro-geochemical conceptual model has, furthermore, been developed to qualify and quantify the relationship between rainfall, interflow, springs, surface water and the water in shallow, local and regional aquifers. This model has been applied in the case study described below.

Case study: Kammanassie area

The Kammanassie area has been investigated comprehensively because of the availability of detailed data and its well documented, problematic groundwater supply scheme. The recharge area of the Vermaaks River wellfield in the Kammanassie area lies within the outcrops of the Peninsula Formation that extend over about 40,6 km^2.

There are nine production boreholes, 27 monitoring boreholes and 19 boreholes. The water levels of the production boreholes in the Vermaaks Catchment have been declining since 1984 due to high abstraction rates.

Long-term rainfall records have been analysed to establish rainfall variability and trends, while shorter (1994-2003) records have provided supplementary rainfall data in the area where most of the recharge occurs. Further data used in this study have included existing groundwater and surface water data from the National Groundwater Database, as well newly acquired data derived from samples of rain water, soil, borehole water, spring water and chloride deposits.

Analysis of data has provided new insights into groundwater source areas, infiltration paths, flow paths and residence times. The determination of groundwater recharge in the Kammanassie area using four different recharge estimation methods, has resulted in recharge values of less than 5% of annual rainfall, much lower than the 15% to 20% estimated by previous researchers. A 3-D numeric model simulation has been used to confirm this lower, steady-state recharge estimate. The results obtained are compatible with those obtained elsewhere in southern Africa.

TMG recharge estimates

A soil water balance model has been applied to obtain preliminary recharge estimates in the 19 hydrogeological units of the TMG region. The average recharge rate of the TMG is about 30 mm·a^{-1}. The highest recharge rate is 137 mm·a^{-1} associated with rainfall of 1842 mm·a^{-1}; the lowest is 0.7 mm·a^{-1} associated with 164 mm·a^{-1}. Percentage wise, this variation is from 0,28% to 12,6% of the mean annual precipitation. A recharge map for the TMG has been compiled to provide a departure point with a view to future updating.

Uncertainty and need for future research

As a rule, all recharge estimation methods have their uncertainties and inaccuracies arising from spatial and temporal variability in processes and parameter estimations, measurement errors and validity of assumptions. Error propagation should be kept in mind and minimised as far as possible.

The recharge areas influenced by snowmelt in the TMG are catchment areas above 1 000 m a.m.s.l. Further research is needed to compare snowmelt recharge with that of normal rainfall.

Besides sparse vegetation and mountain fynbos, exotic plants are often dominant in the recharge areas of the TMG aquifer. Several studies on the impact of exotic plant species on surface runoff suggest that similar studies on groundwater recharge may be necessary in the future.

Both the recharge to deep TMG groundwater flows, including 12 hot springs (12 Mm^3/a), and the discharge of TMG groundwater to oceans have yet to be addressed adequately. These aspects need further research attention.

Further reading:
Groundwater Recharge Estimation of Table Mountain Group Aquifer Systems with Case Studies (**Report No: 1329/1/07**). To order this report contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565, E-mail: orders@wrc.org.za