Integration goes underground: A review of groundwater research in support of sustainable development in South Africa

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INTRODUCTION
The groundwater group of the CSIR has led groundwater research in South Africa in three critical areas during the past three decades: nitrate in groundwater; for ecosystem; and artificial storage and recovery of groundwater.

NITRATE IN GROUNDWATER
South Africa is a water-scarce country and it is believed that current levels of nitrate use may be close to sustainable limits. It is estimated that groundwater supplies 13% of bulk water supply, around 10% of agriculture and over 50% of rural communal supplies (DWAF 2004). Many remote and rural communities use untreated groundwater. High nitrates in drinking water tend to be more common in groundwater than in surface water supplies (Kempster, 2005). South Africa has some of the highest natural nitrate levels in the world (>50mg/L NO3-N). These are shown in Figure 1.

In South Africa, high nitrate levels in groundwater are the single most important reason for groundwater supplies to be declared unfit for drinking, i.e. nitrate N exceeding 10mg/L (Maree, 1991). In 1993, Pretorius reported the nitric oxide results held by the Department of Water Affairs and Forestry (DWAf) showed that 27% of groundwater abstraction points (approximately 5 000) in South Africa yield groundwater with more than 10 mg/L NO3-N. These are shown in Figure 1.

High levels of nitrate in drinking water may cause methaemoglobinaemia or Blue Baby syndrome (WHO, 1993); and death of livestock. In the future the risk is expected to dramatically increase as much of efforts to combat HIV (Coulin and Gamsa, 1999). The South African Department of Health advises HIV-positive mothers to bottle-feed infants to reduce the risk of mother to child transmission of the HIV virus via breast milk. If the water is safe to use. This reduces the risk of infant mortality as a result of AIDS, but may expose infants to other risks from contaminated drinking water.

The distribution of nitrate in groundwater has been studied at Brakwater, Nelspruit and South Africa. Figure 1 shows a simplified map (Tredoux et al., 2001) of areas where groundwater nitrate N exceeds 10 mg/L, i.e. twice the recommended limit of 10 mg/L set by the World Health Organization. Tredoux and Tdhine (2006) used the difference between ratios of nitrogen isotopes in specific environments to discern the sources of high nitrate in environments. They concluded that based on their work to source or potential sources of nitrogen pollution included the following:

1. In unaffected aquifers, nitrate concentrations can be highly variable over short distances due to directly affected by recharge processes (rainfall, infiltration etc.) as well as nitrate pollution activity.
2. Feeding and dairy farming areas, areas that are large potential for nitrate pollution. In agricultural areas that are large potential for nitrate pollution activity.
3. Mosses and ditches, which can have high potential for nitrate contamination by pollution and by the feeding of well water to some extent.
4. Low soil organic carbon in the interior of South Africa. Levels that occur to some extent of natural deionisation; this can result in a large amount of nitrate contamination.
5. Natural enrichment of renewable nitrate content in semi arid and arid environments in southern Africa.

Current research is underway within the CSIR for various applications of deionisation technologies using sodium carbonate sources for deionisation. The CSIR is building capacity in this area and testing the application of this technology to enable the safe use of groundwater in rural areas currently affected by high nitrate levels.

AQUIFER DEPENDENT ECOSYSTEMS
We are now using groundwater sustainably in the future as we need to understand how ecosystems rely on natural flows of groundwater to springs, rivers and wetlands. Aquifer dependent ecosystems are constantly important in sustaining surrounding ecosystems: the oasis effect. Figure 2 shows the riparian ecosystem on the Limpopo River. The oasis effect that is fed by groundwater is the Limpopo. The groundwater group has looked at the wide area of groundwater-linked ecosystems in southern Africa and developed guidelines for their identification and protection within catchment management (Coulin et al., 2007; Coulin and Saityan, 2006).

The CSIR assisted DWAF in developing a policy to enable the protection of ADEs and sustainable management of groundwater. The policy proposes a new Aquifer Health Programme linked to the successful River Health Programme and Working for Wetlands. Initial focus areas will include monitoring and improving our knowledge of aquifer dependency and sensitivity to change; identifying ADEs at a catchment scale; informing decision-Maker determinations and resource quality objectives linked to groundwater licensing.

AQUIFERS AS STORAGE DAMS
In South Africa the rate of potential evaporation is high at about 1 500 mm over the cooler south coast and 3 000 mm in the dry interior. South Africa has a low mean annual rainfall of about 490 mm compared with a world average of about 860 and only 9% of this is converted to river run-off (Midgley et al., 1994). The river of water losses and contamination in surface water storage is significant. Aquifers are often thought of nature’s dams – over 98% of terrestrial freshwater is stored underground.

Unused aquifer storage capacity can for the most part be developed at a significantly lower cost than surface storage facilities, and without the environmental problems frequently associated with surface storage. The overall cost of artificial recharge schemes are often less than the total capital cost of conventional water supply alternatives. Artificial recharge schemes may be considered in areas where there are subsurface water resources at certain times of the year and available unsaturated storage with sufficient permeability for injection and recovery. Opportunities for artificial recharge should also be considered in areas where evaporative losses from open water bodies are excessively high.

During the 1980s Windhoek experienced an acute shortage of water and the CSIR was directly involved in the development of the water reclamation system at Windhoek, which came into operation towards the end of 1988. In the 1990s, the CSIR reported the groundwater-fed treatment plant for artificial recharge of treated wastewater in the Cape Flats (Cape Town). The result of this work makes it possible to us in the Dan Region Project of water recycling at St Elmo. The studies in the Cape Flats proved the way for the Atlantis artificial recharge project that started in 1980.

Research into nitrates in groundwater; for ecosystem; and artificial storage and recovery of groundwater.

Figure 1: The Limpopo riparian aquifer dependent ecosystems uses water stored in the alluvial sediments long after the rains and surface flows have abated.

Aquifer dependent ecosystems (ADEs) require groundwater from aquifers for all or part of their life cycle to maintain a habitat with a water budget, or water quality, that contracts with the surrounding ecosystems (Coulin et al., 2007). ADEs occur throughout the landscape of various ecosystem scales. Examples of known South African ADEs include: in-aquifer ecosystems in the dolomites (North-West province); springs of the Tshoanendere (Western Cape); terrestrial karst species: the oasis effect (Kempster et al., 2005); riparian zones in the seasonal alluvial systems of the Limpopo; seeps on the Karoo dolomite soils.

The identification of ADEs is often difficult and proving links between ADEs and aquifers often requires detailed, multidisciplinary observation and interpretation. At a coarse national scale we can identify areas with a high probability of supporting terrestrial and aquatic ADEs, as shown in Figure 3. Probable vegetation classes have been identified from the National Biodiversity Initiative (nBI) classification by botanists familiar with the different hydrological habitat and rooting habit of the different vegetation types (Coulin et al., 2007).

Figure 2: The Limpopo riparian aquifer dependent ecosystems uses water stored in the alluvial sediments long after the rains and surface flows have abated.

Figure 3: National scale indication of terrestrial ADEs (based on National Biodiversity Institute, nBI vegetation classes) and aquatic ADEs (based on GRAS calculated groundwater-fed baseflow as a percentage of total flows in quaternary catchments in South Africa).