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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

Assessing groundwater availability from streamflows

A completed Water Research Commission (WRC) study developed a novel method for determining allocatable groundwater.

Background

According to the National Water Act (Act No. 36 of 1998) (NWA), water-use licensing, including to groundwater, is to be granted only after defining and fulfilling the Reserve – the amount of water needed to supply basic human needs and preserve ecological integrity.

However, estimating groundwater volumes and fluxes is a major challenge in South Africa due to large hydrogeological variability and complexity and limited groundwater data.

Acknowledging these facts, the generally accepted method for estimating the groundwater quantity part of the Reserve, as an element of defining the so-called groundwater resource directed measures (GRDM) of the NWA, is to use estimates of groundwater recharge and stream baseflow as the upper limit for groundwater exploitation and the upper requirements for groundwater discharge to streams, respectively.

Alternative approach

An alternative approach, which is applied and exemplified in this study, is based on the premise that the baseflow component of streamflow in unregulated basins is a good indicator of groundwater storage and availability in the basin.

Groundwater abstraction or factors impacting groundwater recharge will alter the groundwater storage and consequently the natural baseflow regime. Hence, it is assumed that the amount of water that is available for new groundwater development for use is the baseflow that is in excess of environmental flow requirements.

In order to relate baseflow to groundwater storage, recession flow analysis is applied. Assuming that the recession flows, in the absence of precipitation and direct surface runoff, consist of the cumulative outflow from all upstream phreatic aquifers representing a linear reservoir, the analysis of these flows can infer information on storage of groundwater in these aquifers through a proportionality factor, the drainage time scale.

Similarly, the 'river ecological reserve' or instream flow requirements, when less than river baseflow, can be converted to a groundwater storage in the catchment necessary to maintain them, constituting part of the 'groundwater ecological reserve'.

By analogy, any baseflow in excess of this instream flow requirement represents, when converted to a groundwater storage, the groundwater volume allocatable to all human uses.

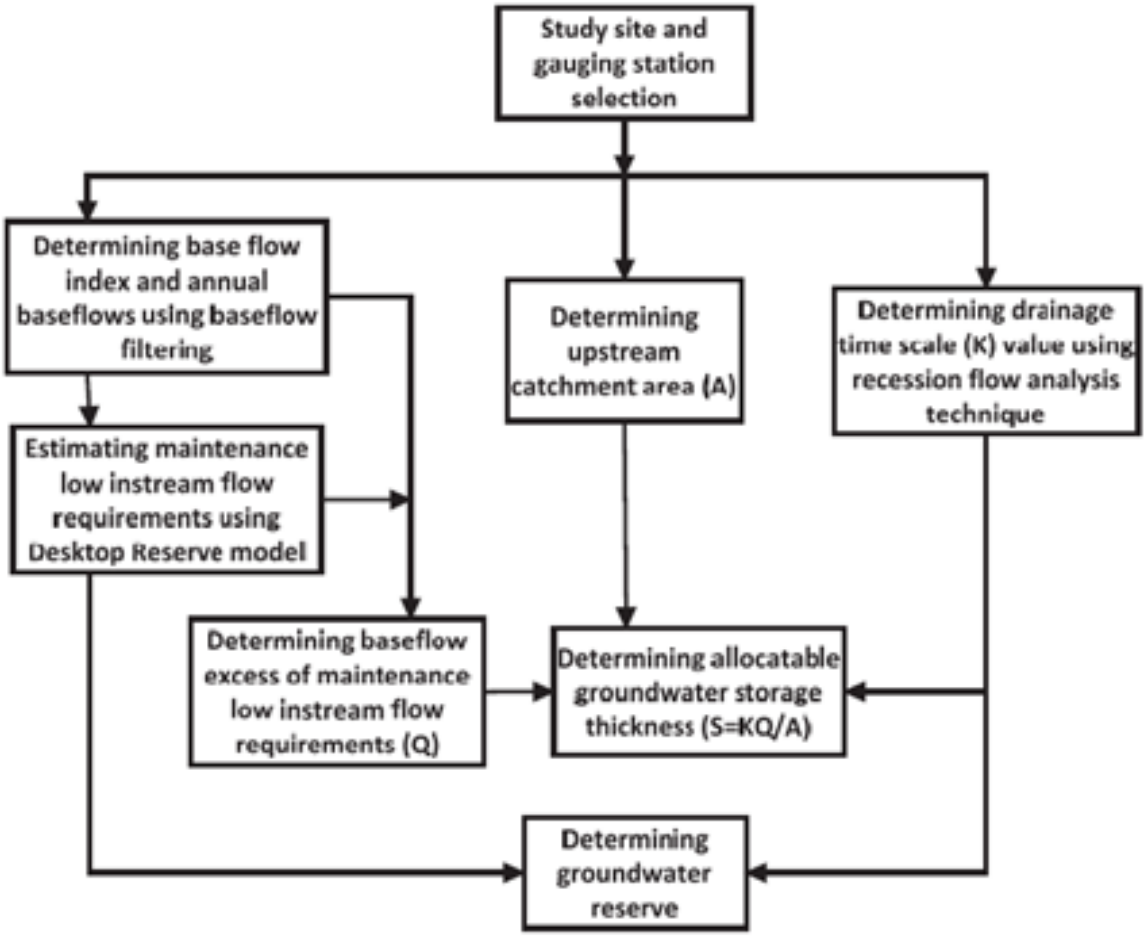
This study proposed to apply this approach for the first time in South Africa as part of the determination of the reserve and resource directed measures.

The overall aim of the project was to contribute to an improved assessment of the groundwater component of the reserve at the quaternary level as part of establishing GRDMs for protection and sustainable development of water resources as well as supporting the development of guidelines for allocation of groundwater resources.

Methodology

The methodology consists of the following seven steps:

1. Find long (> 30 years) streamflow records of perennial rivers in quaternary catchments



2. Determine the river baseflows through a baseflow separation method
3. Determine any temporal trends of the baseflow records.
4. Determine the drainage time scale K from the recessions parts of the streamflow records.
5. Determine the ecological flow requirements in the rivers for predetermined ecological status, based on the desktop model for estimating ecological instream flow requirements.
6. Determine the river baseflow surplus after subtracting from the baseflow the instream flow requirements.
7. Convert the river baseflow and the baseflow surplus to groundwater storage equivalent using the drainage time scale, yielding the groundwater ecological reserve and the upper limit for groundwater abstraction for all human uses in the catchment.

The analysis is based on a daily temporal solution for the baseflow separation and the recession flow analysis, while the instream flow requirements and groundwater availability is based on an annual scale.

Conclusion

This new approach was demonstrated and showcased for 21 perennial and relatively undeveloped quaternary catchments with good and long streamflow records, and using the present ecological status of these streams as targets for instream flow requirements and subsequently for estimating available groundwater.

Results show that groundwater availability varies spatially across the investigated sites and despite groundwater being a buffer, availability also shows variability across the years.

Assuming that an exceedance level of 75% of the years is relevant for the assessment of the groundwater availability on a long-term basis, it was found that the upper limit for

groundwater allocation over the catchments varies between -2.1 and 1.58 MCM/yr.

The ecological groundwater reserve storage, equivalent to present PES-MLIFR, varies from 0.1 to 5.6 MCM, which need to be left in the aquifers to ascertain sufficient river flow. Three out of the 21 catchments have negative storage at 75% exceedance, indicating that the annual baseflow in these catchments is not enough to meet present PES-MLIFR, let alone further groundwater development.

The basic human need reserve was not set aside during the available groundwater storage calculation. Hence the available groundwater calculated in this study needs to be allocated first to fulfil basic human needs.

In general, the approach proved a very useful tool to assist in assessing ecological needs for groundwater as part of determining the reserve and for determining available groundwater for further satisfying basic human needs and other development needs.

Its novelty lies in the combination of various existing methodologies for assessing baseflows, recession flows and instream flow requirements to extract valuable information on groundwater behaviour, such as its drainage characteristics to streams, as well as quantitative estimation of available groundwater volumes and its spatial and temporal variability within South Africa.

Further work is required to refine and further test the method, resolving some of the uncertainties related to the baseflow separation methods, as well as the application to stream to lower baseflow indices. However, this method will not be applicable to ephemeral streams where baseflows are insignificant.

Finally, the method will have to be tested in actual reserve determinations, and contrasted with previous groundwater reserve methods, while ensuring that linking to other components of the GRDMs are taken into account.

Further reading:
To order the report, *Assessment of groundwater availability from recession flows and instream flow requirements of rivers in South Africa* (**Report No. KV 339/15**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.