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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

Climate change & water

Practical methodology for assessing the potential impacts of climate change on the yield characteristics of reservoirs.

Reservoir yield analysis: Introducing climate change considerations

Scientists agree that climate change will probably result in more extreme rainfall events (both droughts and floods), and shorter wet seasons in the arid areas of sub-Saharan Africa. Such changes could have severe impact on available water resources, as confirmed by recently completed hydrological studies which indicate that climate change will impact on runoff – albeit in varying degrees.

There is a need for scientific research results to be incorporated into practical tools that will allow water resource planners to take climate change impacts into account in the planning process. In South Africa, water resource planning is synonymous with reservoir planning, as the runoff from almost all catchments is directly or indirectly controlled by reservoirs.

The supply capability of these reservoirs is mostly determined by means of yield analysis, in which the volumetric yield is assessed by making use of stochastically simulated inflow sequences. This allows a yield estimate to be associated with a specific risk of failure. Yield estimates and associated assurance criteria are then compared with water requirements to determine the likelihood that users will experience water supply shortages.

In order to account for possible changes in reservoir yield under various climate change scenarios, it was decided to appropriately adapt the current stochastic yield analysis methodology, which is based essentially on historical climatic characteristics. The adapted methodology would then be tested in three South African reservoirs, i.e., the Berg River Dam, Midmar Dam in the Mgeni River and Grootdraai Dam in the upper Vaal River, representing climatically diverse areas which are expected to experience different climate change impacts.

Climatic change data sets, generated by different circulation models (GCMs) and downscaled to catchment scale using various regional climate models and other downscaling methods, are frequently not in agreement. Consequently, it is to be expected that model predictions of present-day rainfall and surface runoff are often found not in line with naturalised observed data. Also, climate and surface-runoff data sets derived directly from GCM outputs span a period only 19 hydrological years – too short for stochastic yield analysis. Both this non-alignment with present-day conditions and the short GCM-derived runoff time sequences represent obstacles to the direct application of GCM-based data for reservoir yield analysis.

Practical methodology

To address these limitations, a simple, statistically-based, pre-processing method was developed for generating long, stationary runoff data sets, both in line with observed, present-day runoff characteristics and representative of given climate change scenarios. Although the method may be crude and in need of substantially refinement through further research, it does provide a reasonable basis for applying available climate change scenario information in traditional long-term yield analyses and, as such, the means for identifying possible generalised trends in future yield characteristics.

Using the latest available set of downscaled catchment-based surface water runoff derived from GCM data and the above data pre-processing method, long-term stochastic yield analyses were performed for each of the selected reservoirs and for five selected GCMs. In all cases, the present live full supply capacity was assumed for the reservoirs.

Outcomes of using the methodology

The results of the analyses were consistent with expectations, and can be summarised as follows:

- The projected impacts of climate change on long-term reservoir yields vary significantly among climatic regions and also depend largely on the climate model used.
- In the case of the Berg River Dam, results for the intermediate future (2046 to 2065) time-horizon are inconsistent, but for the distant future (2081 to 2100) a significant decrease in yield is suggested.
- In the case of Midmar Dam, results suggest a significant increase in yield for both the 2046 to 2065 and 2081 to 2100 time-horizons.
- For the Grootdraai Dam, results suggest a significant increase in yield for both the intermediate and future time-horizons.

Overall, this exercise represents the first substantial step in developing a practical methodology for assessing the potential impacts of climate change on long-term reservoir yields for various time-horizons, based on runoff time-series data derived from the downscaled products of GCMs. However, further research on the refinement of the preliminary methodologies is considered to be essential.

Recommendations

Within this context, the following recommendations have been made:

- Improved communication channels should be established between water resource planners and climate change researchers in order to ensure that research outputs are better aligned with the requirements of water resource planning tools. Of particular concern is the apparent discrepancy between runoff characteristics derived from downscaled GCM information for the present-day time-horizon and that of observed naturalised historical runoffs.
- The validity of the statistically-based data pre-processing method, developed for generating long, stationary runoff data sets from available climate change scenario information for application in traditional long-term yield analysis methodologies, remains essentially untested. This and other possible approaches, including the development of alternative yield analysis methodologies that accommodate the inherent non-stationarity of a changing climate, should be subjects of further investigation.
- Tested methodologies should be applied in order to provide broad-scale information to the water resources planning community on possible future climate change impacts. Information needs to be presented on a quaternary catchment scale and include possible impacts on reservoir yields for a range of reservoir storage sizes and assurances of supply.
- Such methodologies should also be tested and applied in an integrated water resources system context using more sophisticated yield assessment tools, e.g., the Water Resources Yield Model (WRYM).
- In addition to the daily time-step agro-hydrological model (ACRU) used in this exercise to generate runoff time-series data, the possibility of using other hydrological models, such as the monthly-time step WRSM2000 rainfall-runoff model, to bring about better alignment of results with other planning studies such as those undertaken by the Department of Water Affairs, should be investigated.
- In the interest of greater credibility, methodologies developed to assess the impact of climate change on reservoir yield should be made capable of accommodating data resulting from the application of a wider range of GCMs, greenhouse gas emission scenarios and alternative downscaling methods, with special attention being given to refinements that are continuously taking place.
- Factors considered to be of secondary importance and consequently ignored in developing the current methodology (i.e., climate change-related changes in natural vegetation, land use, migration patterns, socio-economic activities, as well as rainfall received directly on, and evaporation directly from, the reservoir surface) could impact on yield in varying degrees and require further research.
- Specific research required for developing a framework to guide the incorporation of projected climate change impacts into the mainstream water resources planning process includes, for example:
  - The need for and timely implementation of additional augmentation in cases where projections indicate a possible decrease in runoff and reservoir yields.
  - The possible deferment of planned augmentation schemes in cases where projections indicate a possible increase in yield.
  - The possible adaptation of flood emergency plans, flood design parameters and sediment management plans in cases where the frequency and severity of flood flows are projected to change.
  - Managing impacts on water quality resulting from higher air and water temperatures, sediment loads, etc.
  - Assessing the credibility of climate change impact projections and also the associated risk of their consideration in the implementation of planning decisions.

Further reading:
To obtain the report, ***Development of a Practical Methodology for Assessing the Potential Impacts of Climate Change on the Yield Characteristics of Reservoirs*** (**Report No: KV 266/10**) contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; E-mail: orders@wrc.org.za; or Visit: www.wrc.org.za