SAF-ADAPT

South Africa / Flanders Climate Adaptation Research and Training Partnership

RESEARCH BRIEF
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Assessing the Sensitivity to Climate Change of the Berg River Vöelvlei Abstraction System, Western Cape Province, South Africa

Takalani Rabakali

RESEARCH BACKGROUND

Climate change poses significant challenges globally, impacting water resources through extreme weather events, sea-level rise, altered precipitation patterns, and increased water stress. These changes diminish water quality and quantity, affecting streamflow and reducing reservoir levels. Mitigation and adaptation strategies such as resilient infrastructure and sustainable water management are crucial responses to these challenges.

Southern Africa, including the South-Western Cape (SWC), faces intensified droughts, reduced rainfall, and escalating water demand. The region heavily relies on surface water, with Cape Town as the largest consumer within the Western Cape Water Supply System (WCWSS), where during non-drought periods, it uses over 64% of available drinking water. South Africa ranks as the 30th driest country globally, with highly variable rainfall, shallow aquifers, and erratic runoff. Projections indicate a 1.7% water deficit by 2050, further complicating developmental challenges. Surface water constitutes 77% of the country's water supply, necessitating robust infrastructure and regulatory frameworks.

Cape Town's experience during the 2015-2018 drought underscored vulnerabilities exacerbated by climate change, including a southward shift in westerly winds and reduced moisture influx to the SWC region. This period saw record low rainfall, with dam levels plummeting from 100% in 2013 to 35% by 2018, prompting severe water restrictions and economic losses amounting to R5.9 billion in agriculture alone. The city's population faced significant socio-economic impacts, with around 25% enduring persistent water stress post-drought, highlighting ongoing challenges in water resource management.

PROJECT SUMMARY

The project investigates the impact of climate change (CC) on water resources in the southwest region of the Western Cape Province, South Africa. The Western Cape Water Supply System (WCWSS) is highly dependent on winter rainfall, which fills its six main reservoirs. The 2015-2018 drought, exacerbated by population growth and high water demand, highlighted the vulnerability of the system, with 2017 experiencing the lowest rainfall since the 1880s.

KEY FINDINGS

- **Abstraction Reliability:** Analysis using historical streamflow data and climate change projections revealed that the reliability of the Berg River Voëlvlei Abstraction System (BRVAS) is significantly reduced. This reduction is particularly evident when considering the 2015-2018 drought.
- **Future Projections:** Climate change models predict further reductions in water availability for abstraction in both the near future (2015-2044) and the distant future (2070-2099). The minimum annual abstraction during 2015-2018/19 was 33% lower, with the median annual abstraction amount being 75% different compared to earlier periods.
- **Flow Reductions:** In future projections, the frequency of flows below the 25th percentile ranged from -1% to -13% for the near future and from -1% to -39% for the distant future. Median annual abstraction differences for the near future ranged from 0% to -6%, and from 0% to -29% for the distant future.

Overall, the study underscores the need to reassess the reliability of water abstraction strategies in the face of ongoing climate change.

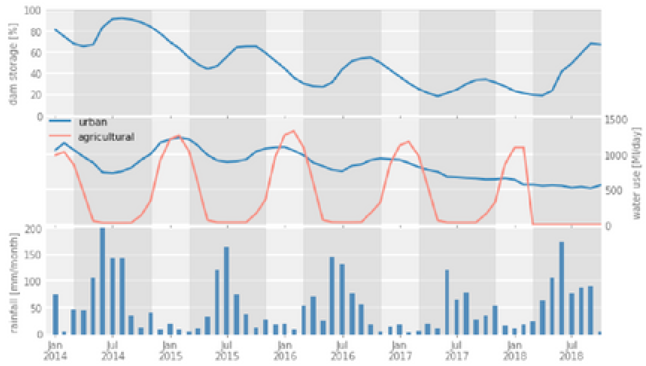

Figure 1. Dam storage levels, rainfall, agriculture, and urban usage in the Western Cape from 2014 – 2018 (Ziervogel, 2019).

ENHANCING WATER RESILIENCE IN CAPE TOWN: STRATEGIES AND CHALLENGES

Cape Town's water supply is primarily sourced from the Streenbras Dam, Riviersonderend, Palmiet, and Berg rivers via the Western Cape Water Supply System (WCWSS), which includes major dams like Theewaterskloof, Voëlvlei, and Berg River. To meet increasing water demands, a reconciliation strategy focuses on short to medium-term options such as removing invasive plants, developing groundwater, and implementing water re-use and desalination projects, aiming to boost the WCWSS's water yield to 126.48 million cubic meters per annum by 2028-2029.

The adaptation strategies involve a systems approach to water management, climate-proofing infrastructure, and integrating surface and groundwater management with rainwater harvesting. Non-conventional options like seawater desalination and aquifer storage are crucial for long-term water resilience due to limited scope for conventional development. The proposed Berg River Vöelvlei Abstraction Scheme (BRVAS) could add 23 million cubic meters annually to the WCWSS, enhancing supply reliability.

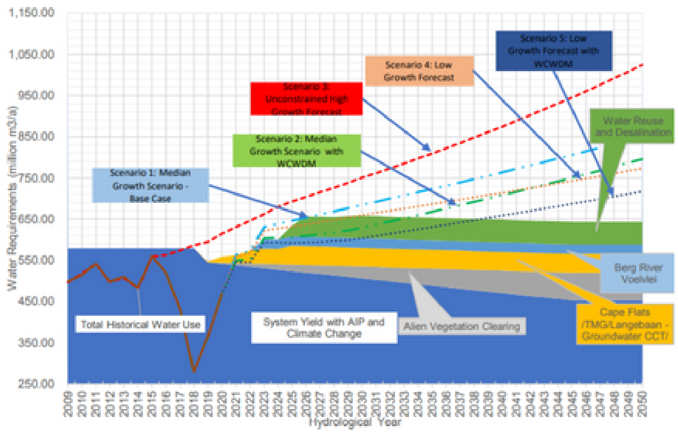

Figure 2. Water balance scenario for the committed abstraction options (DWS, 2020)

RESEARCH QUESTION

Given the recent 2015-2018 drought in the SWC, is it still appropriate to use the earlier dry period of 1968-1972 for calculating drought period abstraction amounts at the Berg River Voëlvlei abstraction scheme when it becomes operational in the 2020s? How will climate change affect the availability of water for abstraction in the future?

METHODS

The Berg River catchment, covering 13,000 km2 in South Africa's Western Cape Province, experiences a Mediterranean climate with 80% of rainfall occurring between April and September. Mean annual precipitation varies spatially, ranging from 300 mm/a in the southeast mountains to less than 300 mm/a in the coastal plains. The region's semi-arid nature is reflected in mean annual runoff of approximately 1094 million cubic meters and monthly evaporation rates ranging from 20-50 mm in winter to 230-250 mm in summer.

ANALYSIS

Daily observed streamflow data from 1967 to 2021 were obtained from the Department of Water and Sanitation (DWS) gauge station website. Projected future daily flow data for different periods (1961-1990, 2015-2044, 2070-2099) were sourced from a hydrological modelling study on climate change (CC) scenarios specific to the Western Cape. Six CC scenario models were developed in a spreadsheet and bias correction was conducted by normalising modelled data against observed data from 1965-1990 using quantile-quantile (Q-Q) plots.

An abstraction model for the Berg River Voëlvlei Abstraction Scheme (BRVAS) was created in Excel, using daily observed flow data to determine daily abstraction amounts based on operational rules. These rules are essential for sustainable water management, balancing abstraction needs with ecosystem and long-term water resource protection.

The study employed monthly abstraction duration curves to analyse simulated abstraction amounts, and flow duration curves to assess river flow variability. Annual total abstraction and monthly abstraction statistics were also calculated to evaluate water resource dynamics.

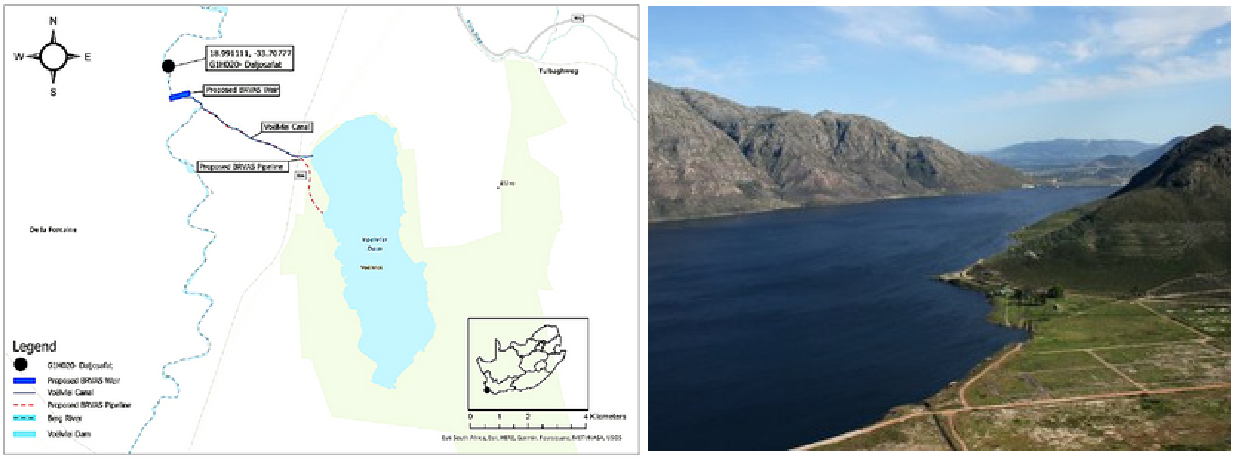

Figure 3. (Left) The proposed BRVAS and the abstraction site (Google Maps; Author), (Right) Berg River Vöelvlei Dam (Unsplashed)

RESULTS AND DISCUSSION

ABSTRACTIONS BASED ON THE OBSERVED STREAMFLOW GAUGE HISTORICAL DATA

The annual results for simulated abstraction using historical gauge data showed that abstraction estimates of the most recent drought (2015-2018) are significantly lower as compared to 1968-1972. The largest relative reductions were in the winter abstraction seasons of August to October, where monthly results are consistent with annual results. The recent drought period has a more significant impact on abstraction potential. For the observed streamflow findings, simulated annual abstraction results showed an annual abstraction over the recent drought period of 31% more than the earlier one. All five years in the recent period were below the long-term average. Results for the abstraction difference exceeded 100% of the time across all months of the year (FDCs) was -71 percent, whereas the 25th percentile of monthly abstraction statistics difference was noticed to be -72 percent. In the recent dry period, the minimum flows were consistently lower than in the earlier period, although in June they were similar.

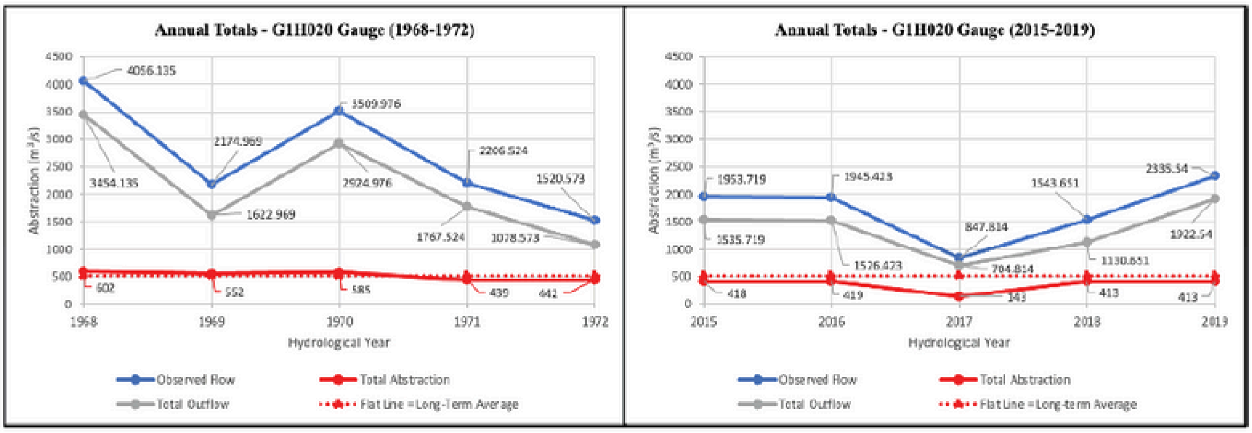

Figure 4. Simulated annual time series hydrograph shows the total abstraction amount (m3/s) from 1968-1972 past drought and from 2015-2021 recent drought winter months of June-October at the streamflow gauging station G1H020 - Daljosafat along the BR Catchment. The blue colour time series graph indicates the observed flow, the grey colour displays the total outflow, the red colour without a dashed dot exhibits the total abstraction and the red dashed dot presents a flat line = the long-term average from 1967- 2021 for each variable (Author).

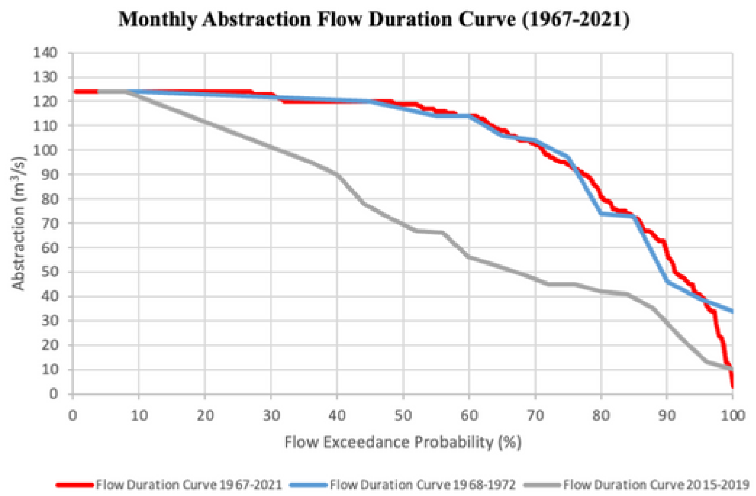

Figure 5. Simulated monthly abstraction duration curves (m3/s) from Daljosafat streamflow gauge from 1967-2021. The three flow duration curves are included in one plot/graph. The red colour curve represents the full duration record, the blue colour curve signifies the past drought of 1968-1972 and the grey curve colour denotes the recent drought of 2015-2019 (Author).

SUMMARY OF KEY FINDINGS

OBSERVED STREAMFLOW HISTORICAL DATA

- **Annual Streamflow Findings for BRVAS**: Historical data analysis identified low flows during previous drought periods in 1969, 1971, and 1972. The most recent severe drought in 2017 significantly impacted streamflow and abstraction amounts in the South-Western Cape (SWC). Using more recent data suggests that the reliability of abstraction estimates for the Berg River Vöelvlei Abstraction Scheme (BRVAS) would likely be lower compared to the original feasibility study.
- **Monthly Flow Duration Curve (FDC) Results:** Analysis of monthly FDC results showed that during recent drought periods, abstraction amounts at lower probabilities were considerably reduced. This highlights the importance of validating abstraction strategies based on recent severe drought data, which could provide better insights for worst-case scenario planning. Previous drought period data may have been less severe and potentially compromised for planning purposes due to higher abstraction yields.
- **Monthly Abstraction Statistics:** Examination of monthly abstraction statistics, specifically minimum flows and the first quartile (Q1), indicated that abstractions during the recent drought period were more severely affected compared to past droughts. Minimum flows were consistently lower in the recent period, impacting abstraction yields more significantly, although similar patterns were observed during winter months.

PROJECTED RIVER FLOWS

- **Bias Correction and Normalisation:** The bias correction using Q-Q plots showed that while sorted values generally fit close to a 1:1 line, normalisation resulted in an underestimation of larger flows and an overestimation of lower flows, indicated by blue dots below the 1:1 line. This suggests that removing the mean bias does not completely eliminate bias across the entire flow distribution.
- **Annual Abstractions under CC Scenarios:** Analysis of annual abstractions under six climate change (CC) scenarios indicated that the distant future (2070-2099) projected the lowest abstraction amounts, followed by the near future and then the recent past. This implies a trend towards reduced water abstraction in the Berg River Vöelvlei Abstraction Scheme (BRVAS) due to climate change scenarios, foreseeing a shift in available water for abstraction.
- **Monthly Abstraction Flow Duration Curves (FDC) under CC Scenarios**: Examination of monthly FDCs for the six CC scenarios revealed that future periods generally showed lower water abstraction amounts across most probabilities compared to the recent past. While the near future FDCs exhibited some overlap with recent past scenarios in half of the models, overall, the results suggest a consistent reduction in water available for abstraction under future climate conditions in the BRVAS.
- **Impact on Minimum and Q1 Flows:** Minimum and first quartile (Q1) flows, particularly during winter abstraction months, were significantly affected across all scenarios, with the Mpi085 scenario showing the most severe impact. Although minimum flows for Mpi085 from June to October were similar, the overall trend indicated lower minimum flows in the distant future period. This underscores the sensitivity of the BRVAS to future changes in winter river flow characteristics due to climate change.

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All opinions, interpretations and conclusions expressed are entirely those of the authors and do not reflect the views of the funder, the Government of Flanders.

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Corresponding author: Takalani Rabakali (tcrabakali@gmail.com) or **Read the full THESIS here**