PAPER 15

WATER MONITORING SYSTEM FOR DATA DRIVEN OPERATIONS IN BARRYDALE

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ABSTRACT
Led by the Grootvadersbosch Conservancy and funded by the Nedbank Green Fund in partnership with WWF, the Barrydale Water System project is a collaborative initiative designed to enhance water security, operational efficiency, and long-term resilience in the small town of Barrydale, located in the Swellendam Municipality, Western Cape. Barrydale is representative of many South African towns that face the dual challenge of ageing infrastructure and limited technical capacity to manage increasingly variable water supply and demand conditions. The project aims to address these constraints through a multi-stakeholder process that integrates community knowledge, municipal operations, and technical innovation. At the centre of the intervention was developing and implementing a locally appropriate water monitoring system. This system was designed to generate near real-time data on river and diversion structure water levels and flows, and estimated usage across the town's water network. The solution leverages low-cost sensors, remote telemetry, and a user-friendly dashboard that allows municipal staff to make timely, informed decisions regarding water distribution and allocation. The system was co-developed with input from Swellendam Municipality, ensuring its usability and sustainability beyond the life of the project. A key strength of the Barrydale project was its inclusive approach to stakeholder engagement. The project team worked closely with local government, civil society, and residents through structured workshops and one-on-one engagements. This process helped build trust, uncover operational bottlenecks, and prioritise context-specific interventions.

By embedding real-time data collection into the town's operations, the Barrydale Water Monitoring System offers a replicable model for data-driven water management in small towns across South Africa. The project is set to demonstrate that targeted technical support, when paired with meaningful stakeholder participation, can unlock institutional momentum and generate practical solutions for long-standing service delivery challenges. The outcomes contribute not only to improved system functionality but also to a growing evidence base on scalable, cost-effective approaches for managing rural and small-town water systems in data-scarce contexts.

INTRODUCTION
Barrydale is a town in the Swellendam Municipality, with an estimated 2023 population of 6,183 which is expected to grow to 7,212 by 2030 (Swellendam Municipality 2020). It is situated in the Langeberg Strategic Water Source Area and relies on the Huis River to meet its water requirements for municipal, domestic irrigation and agricultural use (Swellendam Municipality 2022). The town is surrounded by five commercial farms and a number of small-scale farmers who depend on this river as their primary water source. However, the river has been over-allocated and often runs dry during summer; according to the 2010 Reconciliation Strategy for Barrydale, the safe yield of the Huis River is 0.227 million m^3/a while the estimated water demand is 0.333 million m^3/a by 2020 under a low growth scenario (Umvoto 2010).

FIGURE 1: *Barrydale Redfin caught during the GVBC monitoring (Marais, 2023)*

Water allocation from the Huis River must support not only the town's domestic and agricultural needs but also maintain flows for ecological resilience, most critically, to support the survival of the Barrydale Redfin (*Pseudobarbus burchelli*) (Zutari 2023b). This small, orange-finned freshwater fish, shown in Figure 1, is listed as Critically Endangered on the International Union for Conservation of Nature (IUCN) Red List and is endemic to the Huis and Tradouw Rivers. The species faces existential threats from habitat degradation, poor water quality, invasive species, and reduced flows caused by human abstraction. In 2023, a Framework Plan for Water Security was initiated by the Western Cape Department of Environmental Affairs & Development Planning to identify interventions to improve the water security of Barrydale and thereby protect the habitat of the Redfin (Zutari 2023a).

In response to these water challenges and building on the recommendations of previous work in the catchment, the Grootvadersbosch Conservancy (GVBC), under the leadership of General Manager Aileen Anderson, has initiated a collaborative project to protect the Redfin and manage the river sustainably. Supported by local partners including the Swellendam Municipality, Cape Nature, Gouritz Cluster Biosphere Reserve, and Breed-Olifants Catchment Management Agency, the project aims to improve the base flow of the Huis River and arrest the ecological decline in the Huis River system, which threatens the survival of the Barrydale Redfin. Its conservation is vital not only for biodiversity but also for the ecological integrity of the river system upon which the town relies.

The component of the project presented in this paper contributes to the project goal of improving the base flow of the river. Recognising the role unquantified water abstraction plays in reducing river base flows, it aims to implement a water monitoring system to supply real-time data to a newly developed Water Balance Tool (WBT). The monitoring data collected and analysed will help inform the operating rules for the water system, optimised to maximize base flow while still allowing equitable allocation between urban, agricultural and ecological needs. This balance is particularly

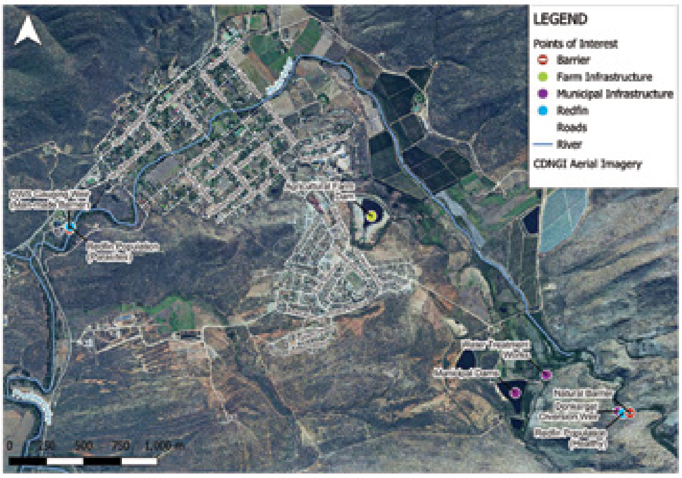

FIGURE 2: *Huis River and Barrydale, the remaining safe habitat for the Redfin*

important to achieve as water scarcity intensifies under future climate change. This work was funded by the World Wildlife Fund (WWF) Nedbank Green Trust.

The monitoring system paired with the WBT is a proactive and practical response to water supply insecurity. By enabling evidence-based water allocation decisions and supporting the adoption of operating best practices, the project aims to build long-term water resilience for Barrydale and the Huis River and offer a replicable model for other small towns and catchments across South Africa.

PROJECT SCOPE AND APPROACH

The overarching project aims to secure the water supply in the Huis River, ultimately to protect the habitat of the Barrydale Redfin. This minnow is closely related to the Breede River Redfin, though its habitat is restricted to the Tradouw and Huis Rivers. Monitoring in recent years shows that the population in Tradouw River has declined. While the Huis River remains safe from predatory invasive fish species, the habitat is under threat from over abstraction, poor water quality and habitat degradation and loss. Figure 2 shows the Huis River; the remaining 6km habitat of the Redfin, flowing through small-scale and commercial farms and the Barrydale town centre.

To address increasing water insecurity, the two encompassing goals of the overarching project are to improve the base flow of the Huis River to meet the ecological flow requirements, and to improve the water quality. Due to the co-dependence of the urban, agricultural and ecological environments on the Huis River, the project includes the following activities: clearing invasive alien plants, restoring riparian areas, constructing a polishing wetland, investigating options for small-scale farm irrigation, improving the mechanism of supply to the commercial farmers and improving the operation of the water supply canal system to minimise diversions. The last activity is the focus of this paper and requires several stages of work to quantify, analyse and propose operating rules for the diversion canals.

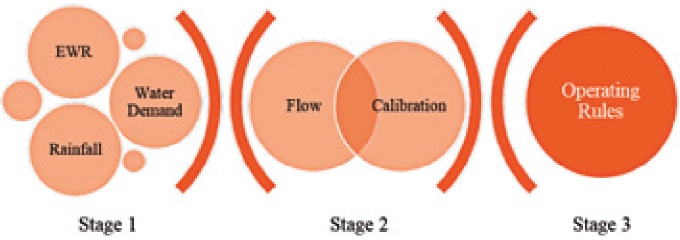

FIGURE 3: *Stages for the Barrydale Water Security project*

There are three stages to this project activity. The first and second stages involve data collection and run in parallel, however, the third stage is dependent on sufficient data collection and analysis conducted during the first two stages.

The first stage is to set up the preliminary version of the Water Balance Tool, an Excel-based programme originally conceptualised by Bruce Paxton and further developed in partnership with Gerald Howard for the Kouebokkeveld Water User Association and adapted for Barrydale. This involves calculating the rainfall for the catchment, the Environmental Water Requirement (EWR) for the river and the water demands from the urban, domestic irrigation and agricultural users.

The second stage is calibrating the WBT using observed data. Water level sensors were installed on 19 June 2025 in three key locations, allowing continuous flow measurements through rating curves developed by in-field measurements and a hydraulic model. This data is used to model the existing water diversion volume and allocation to the user groups.

The third stage is working alongside Swellendam Municipality and local water users to co-develop operating rules. The WBT will be used to evaluate the catchment response to future allocation options under different demand patterns and climate scenarios. The analysis will be iterated until best practices for the operation of the system can be established. These guidelines aim to improve water allocation decisions, promote transparency, and help to proactively address seasonal water shortages.

A collaborative, capacity-building approach underpins all components. By upskilling local stakeholders and supporting effective engagement, the project lays the foundation for more sustainable water management in the future. While the findings and operating rules will not have legal status, they are intended to drive practical improvements toward a water-secure Barrydale.

Note: Progress will continue to be made and will be included at the IMESA Conference in October 2025, allowing for the sharing of key findings and lessons learned from this ongoing work.

DEVELOPMENT OF THE WATER BALANCE TOOL

The WBT is in its second iteration of development. It was conceptualised by Bruce Paxton of the Freshwater Resource Centre to assist farmers in their operation of their water schemes, particularly in dry seasons, where the farmer at the downstream end of the river typically experiences a worse water shortage than the upstream neighbours. The tool is being adapted for Barrydale to include urban and domestic irrigation as water users. The WBT configuration includes the network routing, hydrological fragmentation of the catchment, the farm specifications, and intra-system transfer information. It breaks down monthly data to a series of daily inputs, which allows multiple use-cases, e.g. operating rules, weekly planning, future planning for water user expansion, EWR enforcement and may potentially include water use license allocation and enforcement.

Configuration

For Barrydale, the WBT was configured to represent the existing water supply network represented in Figure 4. An HDPE-lined canal diverts water from the Huis River at the Donkergat weir. The weir has a 100mm pipe positioned lower than the canal invert level, intended to maintain the EWR in the river. See Figure 5a and b. The canal continues along the contours of the western side of the valley until it splits to supply the municipality and the commercial farmers.

At present, the supply directed to the commercial farmers spills down the mountainside back into the river, where it is captured by an earth channel crossing the river and directing into an earth canal on the eastern side of

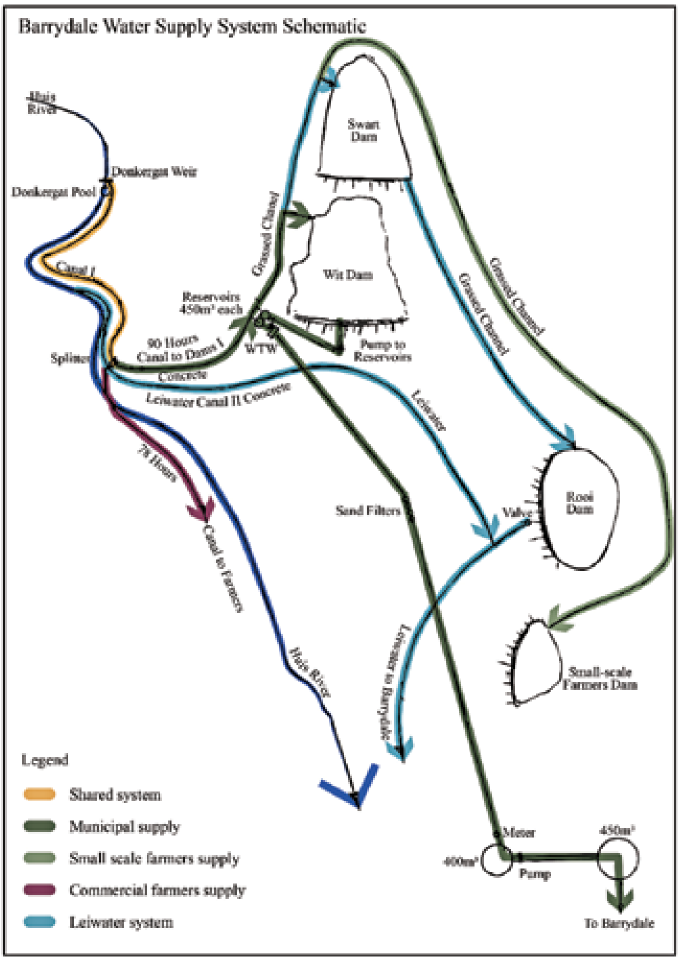

FIGURE 4: *Barrydale Water Supply Schematic, adapted from Zutari 2023a*

the valley. The municipal canal continues to two 450kl concrete reservoirs above the water treatment works (WTW), and thereafter is a grassed channel supplying, in order, the Wit, Swart, Rooi and Small-scale Farmers dams. The WTW can source raw water from either the concrete reservoirs or the Wit Dam. Typically, water is supplied from Wit Dam to stabilise incoming water quality for treatment. The Swellendam Municipality aims to always keep the Wit Dam at full capacity; therefore, the water levels tend to only drop during the dry season in times of significant water stress. The Swart Dam is an overflow dam, which, if full, spills into a grassed channel to direct water to the Rooi Dam. The Rooi Dam is the supply for the leiwater system, a legacy canal network, used to supply erfs within the town centre with domestic irrigation water. The Small-scale Farmers Dam is supplied by a grassed channel capturing runoff from a small catchment above the Swart Dam, as well as any remaining water from the municipal channel. Small-scale farmers manually transport the water from Rooi Dam to their farms.

The canals and channels are controlled by sluice gates, which are opened and closed based on schedules, rotating supply among the users. There is one sluice at the Donkergat weir, controlling the total amount of water diverted from the Huis River. Two sluices at the canal split control the division of supply between the commercial farmers and the municipal, domestic irrigation (leiwater) and small-scale farmers. The leiwater network operates on a similar principle, where each erf on the network is allocated 30 minutes with their sluices open, directing water onto their property.

It should be noted that the sluice gates at the Donkergat weir and on the municipal canal are unable to shift position. The spindle on the Donkergat weir is bent rendering the wheel inoperable and the spindle for the municipal canal has been stolen, leaving both gates permanently wedged partially open. This means water is permanently diverted from the Huis River, and the sluice opening at Donkergat weir, when fully submerged, acts as a control structure for water entering the canal. The sluice gate to the municipality is occasionally blocked by sandbags when the timeslot for the commercial farmers is active; however, there is still flow in the canal. If fully submerged, the sluice again acts as a control structure for both the upstream and downstream sections of the canal.

Inputs

To understand the hydrological behaviour of the catchment, the first task was to split the catchment into sub-catchments which align with the water users, e.g. a commercial farm boundary (agricultural demand) or the urban edge (municipal demand). A rainfall-runoff model was developed in WRSM-Pitman to determine the naturalised flows and the appropriate fragmentation of rainfall across the sub-catchments. The daily rainfall inputs can be sourced from the WRSM-Pitman model, Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), a rainfall station in the catchment and can include precipitation forecasts. Fragmenting the rainfall per sub-catchment can be done in three ways within the WBT. The first is through apportionment according to area of the sub-catchment, e.g. Sub-catchment A has 30% of the total catchment area, therefore receives 30% of the rainfall. In some cases, this is applicable; however, in Barrydale, the mountainous area receives more than the areas method would attribute to them and therefore contributes more flow. Therefore, the second method

FIGURE 5A AND B: *Donkergat weir with diversion canal and 100mm environmental flow pipe*

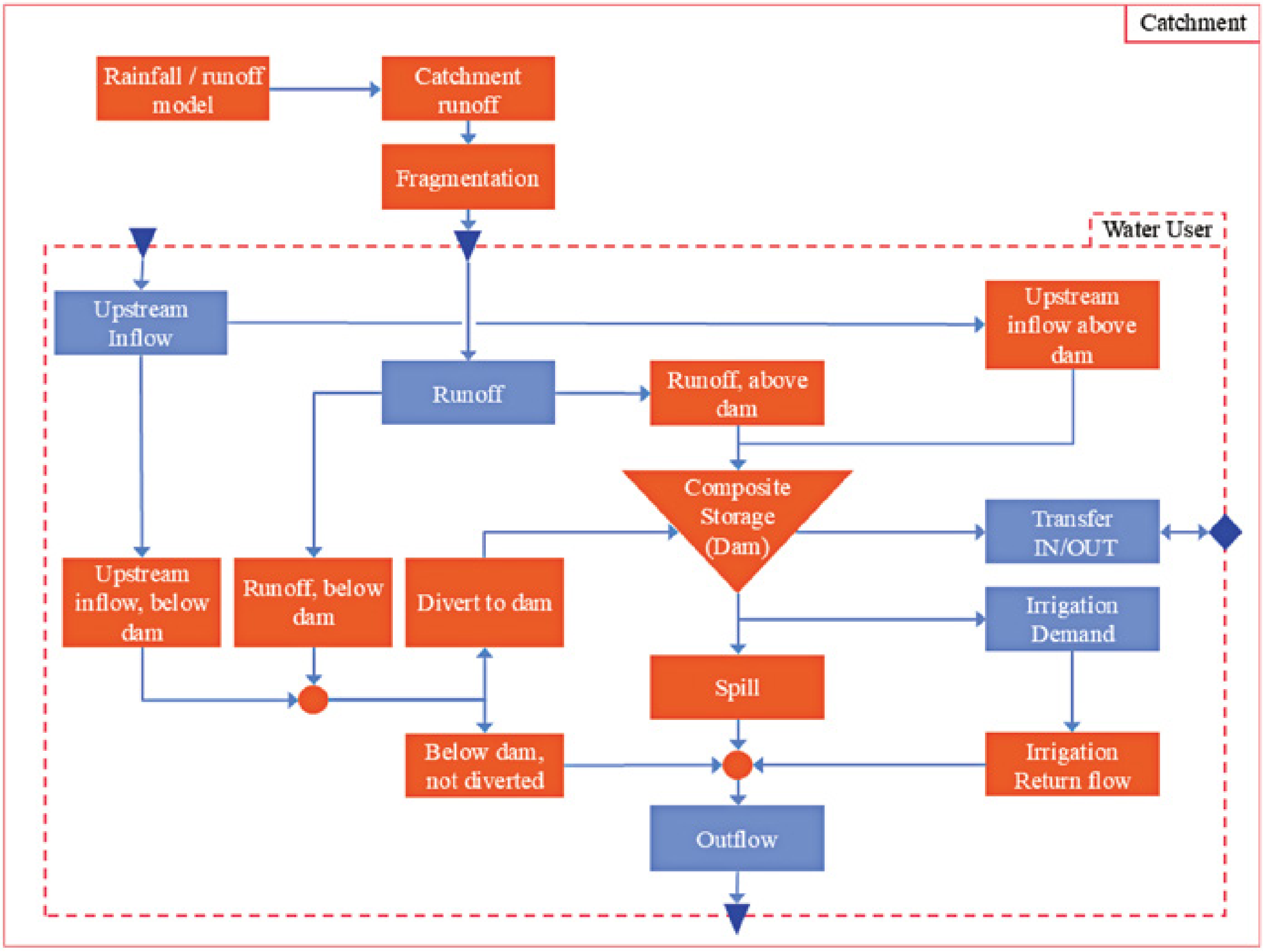

FIGURE 6: *Water user demand configuration*

is used, as the WBT allows the sub-catchments to be split into high and low rainfall zones based on the WRSM-Pitman model outputs for each sub-catchment. The third method is a manual override, which a hydrologist can use their expertise to inform, using the WRSM-Pitman outputs as an informing parameter.

The next input is to determine the water demands placed on the Huis River. As the WTW pumps into storage reservoirs, the urban water demand fluctuation is not translated back to river diversion volumes; therefore, the treated volume recorded by the WTW has a direct influence on the water within the Huis River. Urban demand data, in this case, the volume treated by the WTW, was provided by the Barrydale Municipal Manager. The leiwater system operates through gravity, and a valve at the base of the Rooi Dam controls supply into this canal network; though the network serves a number of erfs within the town, the demand was modelled as a single user to simplify model inputs. Commercial and small-scale farmers were modelled separately, though the principle for determining their irrigation demands is the same. The crop type information was initially sourced from Cape Farm Mapper and verified through discussions with the farmers. The crops are listed in the WBT and assigned crop factors and evaporation values, determined from the ACRU Agrohydrological Model Manual and WR2012 A-pan evaporation data. The irrigation demand per farm is estimated by the formula: Sum of crops (Crop Factor x A-pan Evaporation - Effective Precipitation (Rainfall x Rainfall Conversion Factor)). The configuration for a water user is summarised in the schematic in Figure 6.

The next input is the monthly Gazetted EWR for the catchment which, like rainfall, must be fragmented back to each user. This process avoids unnecessarily penalising users whose catchments receive low rainfall and therefore contribute comparatively lower flows than the users whose catchments receive high rainfall. It is also possible to enter what is called a pragmatic EWR, which is manually set and should be informed by an experienced ecologist who has studied the catchment area.

The final input to the WBT is the transfers between users in the system. However, in Barrydale, there are no internal transfers between the users.

DESIGN OF THE WATER MONITORING SYSTEM

The water monitoring system was designed to provide continuous, site-specific flow data at key points along the Barrydale water network. The aim was to establish a reliable and low-cost solution that would support calibration of the Water Balance Tool and provide operational data for informed decision-making.

The output of the water balance tool is a series of flows. This includes flows for the total catchment as well as per sub-catchment, which correlates to the water demands per user. To ensure that the outputs are based in reality, the model must be calibrated. Therefore, a water monitoring system was designed for the Barrydale system. A gauging station operated and maintained by the Department of Water and Sanitation (DWS) is the downstream end of the water system for the Huis River, measuring the river flow after all abstractions.

Three water level sensors were installed at strategic points in the system: at the Donkergat weir (upstream of the diversion point), before the canal split (to measure total diverted flow) and after the canal split (to measure the amount of water diverted to the municipality, domestic irrigation and the small-scale farmers. Using the collected measurements, it is possible to calculate the flows for the commercial farmers in the system as well as the flow left for the environment. The level sensors were set up to take measurements every 30 minutes to be sent through to a hosting platform, which displays the near-real-time data. These were chosen for their proven reliability in small rural systems and their compatibility with low-maintenance setups. Each sensor was installed in tamper-proof brackets to minimise the possibility of theft or damage. This hosting platform enables the visualisation of river diversion and system flows.

Water depth is measured rather than flow, so it is necessary to convert depth readings into flow rates. Although hydraulic calculations could be used for this conversion, the specific operational conditions of the existing system and the financial limitations, particularly the infeasibility of installing flow-measuring flumes, made this approach impractical. Additionally, the canal system does not operate entirely under gravity. Therefore, it was necessary to conduct in-field measurements using a velocity meter to support the development of accurate rating curves. The procedure used to take the in-field measurements is based on the U.S. Geological Survey area-velocity streamflow measurement protocol. These measurements will be used to develop a rating curve for each monitoring location. The instruments were installed on 18 June 2025, and the rating curves will be developed and refined throughout the project. It should be noted that high flows are difficult to accurately quantify as the water levels become unsafe for in-field measurement, and the cross-section of flow overtopping the weir extends into vegetation and the uneven rock sides, resulting in very turbulent flow and unreliable depth measurements.

The observed flows are the calibration and verification inputs for the WBT. The WBT calculates the flow by using Equation 1, an empirical formula commonly used in hydrology to convert rainfall to runoff irrespective of catchment size and where the relationship is not strictly linear due to catchment characteristic, antecedent moisture, or non-uniform rainfall distribution.

Equation 1: Empirical equation to convert rainfall to runoff irrespective of catchment size

$$Flow = a \times Rain^{b} \times Season\ Factor$$

The flows are calibrated by varying the a, b, and season factors as well as the depth of the rainfall above which runoff is assumed to be generated. There are limitations to the accuracy of the outputs, chiefly associated with the hydrological modelling, the input parameters and the measurements used for calibration. As the data builds over time, it supports refinement of the WBT and provides a foundation for data-informed water management decisions.

OPERATING RULES AND GUIDELINES

The operating rules and guidelines for the Barrydale water system will be developed through an iterative and collaborative process. These rules aim to support more equitable and efficient allocation of the limited water resources across urban, agricultural, and ecological needs.

The WBT will simulate allocation scenarios based on current and projected conditions. It will provide a basis for identifying key operating thresholds and setting priorities under different water availability levels. For example, the sluice gate at Donkergat weir can be managed to maintain a base flow in the Huis River during low-flow periods before allowing further abstraction for water users. Alternatively, during a particularly wet season, the sluice opening at Donkergat weir may be adjusted based on forecasted rainfall to ensure that ecological flow is maximised while ensuring sufficient water is diverted to fill storage dams in the network.

Similarly, guidelines will be developed to prioritise supply to the urban network during periods of water stress while maintaining a minimum allocation for agricultural users and ecological flows. The approach is guided by a "share the pain" philosophy, which recognises that during periods of water scarcity, all users must proportionally reduce demand to sustain the system as a whole.

The WBT will be used to test different allocation scenarios, including dry-season rotations and surplus-sharing mechanisms. The rules are designed to be practical rather than prescriptive. The process includes workshops with municipal staff and water users to interpret monitoring data, understand model outputs, and refine rules based on experience and operational feasibility. The operating rules are not legally binding but serve as a practical framework to support equitable, transparent, and adaptive water management intended to guide local decision-making and foster mutual accountability. The guidelines will continue to evolve as more data becomes available and as stakeholders engage further.

DISCUSSION AND LESSONS LEARNED

The Barrydale Water Security project is currently in its early implementation phase, focusing on data collection and calibration of the WBT. As the project progresses into the third stage, the WBT will be used to simulate allocation scenarios and support the co-development of operating rules. These rules aim to improve transparency and guide the management of the system under average, low-flow and high-flow conditions.

Beyond rule-setting, the tool provides a means to test the potential benefits of various infrastructure and operational improvements. For instance, it can model the effect of fully functional sluice gates or alternative water supply mechanisms to commercial and small-scale farmers. These simulations will allow the project team and the Swellendam Municipality to identify and prioritise infrastructure upgrades that offer the greatest improvement in water security for all users, urban, agricultural, and ecological alike.

A key lesson emerging from this work is that the quality of the input data significantly influences the value of the modelling outputs—'rubbish in, rubbish out' applies. Ongoing calibration and reliable monitoring are essential for meaningful results and sound decision-making. Establishing rating curves, verifying abstraction volumes, and continuously refining the inputs will determine the usefulness of the WBT in practice.

Equally important is the collaborative process underpinning the development of the operating rules. Since the WBT is not being used for compliance or enforcement, but rather to guide shared understanding and adaptive decision-making, the success of the tool depends on trust among stakeholders. Transparent engagement, capacity building, and co-ownership of the process are essential to ensure that users see value in the tool and are willing to act on its guidance.

CONCLUSIONS

The Barrydale Water Monitoring System and Water Balance Tool provide a practical example of how low-cost, site-specific data collection and collaborative modelling can strengthen water security in small towns. These tools allow stakeholders to visualise the impact of different water use patterns, test management interventions, and make informed, transparent decisions about allocation.

While the WBT is still in its early stages, its successful deployment shows that meaningful improvements are possible with the right partnerships and technical support. Data quality and stakeholder trust emerged as key ingredients for success. Accurate and continuous monitoring ensures reliable calibrated model outputs, while inclusive engagement helps foster ownership of the resulting guidelines and decisions.

The Barrydale project demonstrates that proactive investment in monitoring, modelling, and local collaboration can lead to more resilient and equitable water systems. Its lessons are widely applicable to other data-scarce and institutionally constrained catchments across South Africa.

RECOMMENDATIONS

The refinement of the Barrydale WBT is ongoing and will continue under the WWF Nedbank Green Trust project. As additional flow and abstraction data are collected, the model will be iteratively improved to better represent the functioning of the catchment and the water supply system. These refinements are critical to strengthening the reliability of scenario testing and informing the development of context-specific operating guidelines.

To increase the accessibility and long-term sustainability of the WBT, funding will be sought to develop a web-based version of the tool. Transitioning from a spreadsheet model to an interactive web application would allow for real-time data integration and broaden access to users beyond the project team, including municipal operators and water users.

Future iterations of the WBT are going to be aligned with the DWS WR2012 quaternary catchment natural flow estimates to ensure consistency with national hydrological baselines. This alignment will support confidence in the model outputs and strengthen its utility for operational and strategic planning, water use license approval and enforcements, and EWR compliance enforcement.

As the project progresses, attention should be paid to maintaining high data quality through regular calibration of monitoring equipment and verification of diversion measurements. This is essential for ensuring that model outputs remain fit for purpose.

Lastly, lessons from Barrydale should be shared across the sector to inform similar initiatives in other data-scarce and over-allocated catchments. The approach, centred on participatory development and practical tools, provides a replicable model for collaborative water management in rural South African towns.

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