THE STATE OF WATER QUALITY IN SOUTH AFRICA: A CITIZEN SCIENCE PERSPECTIVE

Final report to the WRC

By

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Executive Summary

South Africa faces increasing pressure on its freshwater resources due to population growth, development, and reduced supply capacity. In light of the reality of growing freshwater resources challenges and the country's limited ability to comprehensively monitor the condition of these vital resources, citizen science (CS) has been recognised as a readily available technique for monitoring the state of freshwater resources. In the South African context, the application of CS techniques to monitoring water quality, particularly in rivers, can prove extremely useful considering the capacity limitations impacting monitoring acknowledged by the Department of Water and Sanitation (DWS). South African water management authorities face significant challenges in monitoring water resources due to capacity limitations and a lack of collaboration between government, private sector, and civil society. This project seeks to integrate and collaborate across these sectors to address water resource challenges and contribute to Sustainable Development Goal (SDG) 6—clean water and sanitation. This research aimed to evaluate the potential which innovative citizen-based techniques could have on water resources monitoring, and subsequently, management. This research also evaluated the potential alignment of CS with tertiary education curricula, and future recommendations and plans for CS to explore the continuity of the practice.

The main aim of the study was to evaluate the potential of CS for WQM which included the following objectives:

1. To conduct a situation analysis on the use of CS in SA, including where and how CS is currently being used in SA, its credibility as a water quality monitoring method, as well as a cost efficacy review of CS.
2. To determine what crucial CS data is required to ensure credible and scientific water resource quality to support SDG6 reporting.
3. To determine the barriers to applicability of CS at a national level and for SDG6 monitoring.
4. To determine how youth monitors can contribute to the 'learning to earning' pathway for young people, including incentivisation of CS more broadly.
5. To advise on the adequacy and gaps of CS monitoring tools.
6. To produce a preliminary State of Water Resources from a CS perspective within the current State of Rivers report landscape.
7. To make recommendations on how to strengthen CS in water quality monitoring and to explore the opportunities for scaling CS.

The methodology contained two parts: qualitative and quantitative. Qualitatively, a thorough review of existing literature on CS for WQM was conducted. Stakeholder engagement was prioritized to gain a deeper understanding of the current CS landscape, existing practices, perceived future directions, and challenges faced by the citizen science community of practice (CoP). This engagement included workshops, interviews with key CS practitioners, and ongoing communication. Quantitatively, through national (South Africa) collaborative efforts with some interest from neighbouring countries (Namibia and Lesotho) CS data was collected across river systems with the aim to generate a State of Rivers (SoR) report from a CS perspective. The overall project methodology was structured into four phases: Contextualizing Citizen Science in South Africa, Citizen Science Data Evaluation, Citizen Science State of Rivers Report, and Strengthening and Scaling Citizen Science.

The literature review revealed increasing recognition of CS in South African policy documents which call for public participatory and citizen science-based approaches to WQM. To facilitate this, collaboration was acknowledged as crucial. The project emphasised the importance of communication and collaboration with stakeholders to strengthen the CS CoP. The CS State of Rivers exploration has prompted local participation, encouraged conversations about the current and future state of CS, and highlighted the need for broad intervention from government, society, the private sector, and the educational sector to address water resource challenges. This is over and above the generation of the *2024 Citizen Science State of Rivers Report* which also features examples of CS applications across South Africa.

A key output of this project was the preliminary *2024 Citizen Science State of Rivers Report*, which utilised data collected through collaborative efforts. The report draws from biological data primarily obtained through the mini Stream Assessment Scoring System (miniSASS) technique, as well as physico-chemical data from clarity tube measurements, Freshwater Watch, and WaterCAN techniques. Habitat assessments using the riparian health audit (RHA) were also considered. Over 2700 data entries were used in the generation of the report, representing monitoring efforts across South Africa. The generation of this CS SoR report faced challenges, including the variability in data collection frequency and potential biases in site selection. However, the report demonstrated the feasibility of gaining valuable insights into river health based on CS data.

The study reveals significant insights into the potential and reality of CS applications, the benefits and limitations of CS techniques, and the motivations and reluctance to use CS data for water resource reporting. Interviews with key CS practitioners call attention to the potential for large-scale, real-time river monitoring but also highlight concerns about standardising monitoring methodologies, which limits the view to not using CS data beyond community and project scales. Additionally, despite its potential, sustainable funding for CS efforts remains a challenge.

Overall, this exploration has demonstrated that CS techniques can be used to generate a State of Rivers report, but that this preliminary report can be improved to better show how the applications of biological, habitat, and physico-chemical monitoring techniques used in conjunction can provide a comprehensive overview of river health from a CS perspective. Recommendations include that chemically based CS testing techniques must be more extensively researched and tested.

CS techniques were found to be valuable for their ease of use, reliability as general indicators of river health conditions (acknowledging that they cannot be used to replace conventional monitoring techniques), and large spatial scales of implementation. The latter point being imperative for gathering valuable data to indicate river health conditions across spatial scales which mandated river monitoring departments cannot achieve alone. The analysis of chemical results against laboratory results reveals variations suggesting potential for improvement of techniques in the South African context to be reliably used for reporting, but current potential to be used in aiding tracking point source pollution.

Hesitancy in using CS-based data for reporting stems from uncertainties in tool usage, data submission errors, and concerns about data reliability. Innovations such as online learning materials, the AI-aligned miniSASS application, and online verification systems are encouraging for using sound data in national and international water resources reporting. Reasonable remuneration for data collection is also suggested to motivate citizen scientists to adhere to standard collection techniques. This linked to discussions on the Youth Agency Marketplace (YOMA) pilot study to incentivise youth participation in miniSASS-based water quality monitoring. The pilot explored the 'learning to earning' pathway by offering digital incentives (micro-credentials) for completing miniSASS training and data collection tasks. The study assessed whether incentivizing data collection would motivate participation in CS activities. Findings from the pilot highlighted the importance of focused mentorship, customised learning pathways, and addressing basic digital competency gaps among youth. The insights gained from the YOMA-miniSASS pilot informed recommendations for improving engagement and relatability of online learning platforms for citizen science.

The process of producing the CS SoR report and engaging with the citizen science community highlighted several reflections, challenges, and limitations. Encouraging a cohesive citizen science network requires effective communication, collaboration, and recognition of the contributions of individuals and organisations. Data sharing complexities and varying levels of awareness about the importance of contributing to larger datasets were noted. Biases in data and reporting can arise from the selection of monitoring sites and the application of single monitoring techniques. Despite this, CS has demonstrated its potential as river health indicator techniques to complement conventional monitoring.

Recommendations to strengthen and scale CS include consolidation of CS efforts, alignment with existing environmental programmes, sustainable investment in CS, improved data handling, and for clear governance structures and partnerships to be established to aid in garnering further support.

The preliminary CS SoR report demonstrated the feasibility of generating meaningful insights into river health through collaborative citizen-led monitoring. To fully realise this potential, concentrated efforts are needed to address existing challenges, strengthen coordination, invest in capacity building, and establish robust and structured data management systems. The recommendations outlined provide a roadmap for scaling and sustaining CS initiatives, ensuring their continued contribution to sustainable water management and ongoing investigation into the potential for CS to aid national and international water resource reporting.

Overall, CS has demonstrated great potential in this evaluation study, not only for producing sound datasets for WQM but also for its value beyond data, including as an educational tool, a promoter of environmental conservation, and a tool for advocacy, giving a voice to those vulnerable to water quality challenges. The growing momentum and dedication within the CS community in South Africa offer a promising outlook for its future role in safeguarding vital freshwater resources.

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List of Acronyms

Acronym	Meaning
AaR	Adopt a River
AEN	Amanzi Ethu Nobuntu
AI	Artificial Intelligence
ARUA	African Research Universities Alliance
CAPS	Curriculum Assessment Policy Statements
CAR	Coordinated Avifaunal Roadcounts
CBWQM	Community Based Water Quality Management
CEWQ	Centre for Environmental Water Quality
CGIAR	Consultative Group on International Agricultural Research
CHE	Council on Higher Education
COE	Centre of Excellence
CoP	Community of Practice
CPPP	Community Public Private Partnership
CS	Citizen Science
CSA-SA	Citizen Science Association of South Africa
CSIAF	Citizen Science Impact Assessment Framework
CV	Curriculum Vitae
CWAC	Coordinated Waterbirds Counts
CWRR	Centre for Water Resources Research
DAMS	Data Management Strategy
DBI	Dragonfly Biodiversity Index
DHET	Department of Higher Education and Training
DSI	Department of Science and Innovation
DUCT	Duzi Umgeni Conservation Trust
DUT	Durban University of Technology
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
EFTEON	Expanded Freshwater and Terrestrial Environmental Observation
ELO	Exit Level Outcome
EPWP	Expanded Public Works Programme
FABI	Forestry and Agricultural Biotechnology Institute
FAII	Fish Assemblage Integrity Index
FBIS	Freshwater Biodiversity Information System
GL2E	Green Learning to Earning
GLV	General Limit Value
GT	GroundTruth
IDC	Industrial Development Corporation
IHI	Index of Habitat Integrity
IIE	Independent Institute of Education
IPCC	Intergovernmental Panel on Climate Change
IWMI	International Water Management Institute
IWQM	Integrated Water Quality Monitoring
IWRM	Integrated Water Resources Management
LIMCOM	Limpopo Watercourse Commission
LMS	Learning Management System
MERL	Monitoring, Evaluation, Reporting, and Learning

miniSASS	Mini Stream Assessment Scoring System
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
NAEHMP	National Aquatic Ecostatus Health Monitoring Programme
NDP	National Development Plan
NGO	Non-governmental Organisation
NSoW	National State of Water
NWA	National Water Act
NWRS	National Water Resources Strategy
NWRM	National Water Resources Management
OR	Operational Research
ORASECOM	Orange Senqu River Commission
PGDip	Postgraduate Diploma
PHEI	Private Higher Education Institution
PPE	Personal Protective Equipment
PPSR	Public Participation in Scientific Research
QCTO	Quality Council for Trades and Occupations
REMP	River Ecostatus Monitoring Programme
RHA	Riparian Health Audit
RHP	River Health Programme
RQO	Resource Quality Objective
RVI	Riparian Vegetation Index
SA	South Africa
SADC	Southern African Development Community
SAEON	South African Environmental Observation Network
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks
SAQA	South African Qualifications Authority
SASAqS	Southern African Society of Aquatic Scientists
SASS5	South African Scoring System
SDG	Sustainable Development Goal
SEF	Social Employment Fund
SETA	Sector Education and Training Authority
SLV	Special Limit Value
SoE	State of Environment
SoR	State of Rivers
STEM	Science, Technology, Engineering, and Mathematics
SUWI	Stellenbosch University Water Institute
T&L	Teaching and Learning
TSS	Total Suspended Solids
TVHR	Transparent Velocity Head Rod
UCT	University of Cape Town
UEIP	Umgeni Ecological Infrastructure Partnership
UJ	University of Johannesburg
UKZN	University of KwaZulu-Natal
UN	United Nations
UNEP GEMS	United Nations Environment Programme Global Environmental Monitoring System
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund

UNISA	University of South Africa
UP	University of Pretoria
UWC	University of the Western Cape
VM	Virtual Museum
WaterCAN	Water Community Action Network
WESSA	Wildlife and Environment Society of South Africa
WISA	Water Institute of Southern Africa
WMA	Water Management Area
WMS	Water Management System
WQI	Water Quality Index
WQM	Water Quality Monitoring
WRC	Water Research Commission
WWTW	Wastewater Treatment Works
YOMA	Youth Agency Marketplace

Glossary of Terms

Term	Definition
Blended Finance	A strategic approach to financing that combines public, private, and philanthropic funds to support sustainable development and environmental projects.
Catchment Management	The process of managing water resources within a specific watershed or drainage basin to maintain water quality, biodiversity, and sustainable use.
Citizen Science (CS)	The practice of public participation and collaboration in scientific research to increase knowledge and contribute to environmental and community-based solutions.
Community of Practice (CoP)	A group of people who share a concern or passion for something they do and learn how to do it better through regular interaction.
Enviro Champ	Formally referred to as environmental champions (Enviro-Champs) are a group of community citizens who engage in activities focused on water quality and pollution that benefit the environment, these activities include, inter alia, river clean ups, water quality monitoring, solid waste management and education and awareness. The Enviro Champs model is a community-based initiative that trains local youth to monitor water quality, report environmental hazards, and take action for sustainable water resource management.
Green economy	Green economy refers to an economy that makes efforts to ensure the wellbeing of people, whilst minimizing environmental impacts (Pavlova *et al.*, 2022).
Green Learn-to-Earn (GL2E)	A skills development program designed to provide digital and practical training for individuals seeking opportunities in environmental monitoring and sustainability careers.
Green Skills	Green skills refer to skills, knowledge, and values that are required within the labour market to help employees perform occupational activities that reduce environmental impacts and promote a climate resilient and sustainable economy (Pavlova *et al.,* 2022).
Green Skills development	Green skills development refers to development that equips citizens with the skills, values and knowledge to be prepared for the transition to a green economy, subsequently equipped to perform green occupational activities.
Integrated Water Resources Management (IWRM)	A process that promotes the coordinated development and management of water, land, and related resources to maximize economic and social welfare without compromising ecosystem sustainability.
Low Carbon economy	Low carbon economy refers to an economy that is characterised by sustainable activities that is marked by decreased levels of carbon dioxide emissions and minimized consumption of high carbon energy.
Micro credentials	Micro credentials refer to short learning tasks designed for professional development which are specific to a particular field. They are aimed at upskilling individuals with the skills and knowledge to perform occupational tasks.

Sustainable Development Goals (SDGs)	A set of 17 global goals established by the United Nations to address poverty, inequality, environmental sustainability, and other critical global challenges.
Transboundary Water Management	The cooperative management of shared water resources between different countries or regions to ensure equitable and sustainable use.
Water Resources Management (WRM)	The activity of planning, developing, distributing, and managing the optimum use of water resources.
YOMA-miniSASS	a miniSASS course hosted on the Youth Marketplace Agency (YOMA), which is a global digital marketplace for young people to access and upskill themselves, find micro credentials to earn and create social impact.

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1. Introduction

The increasing pressure on South Africa's water resources due to increasing population, developments and reduced supply capacity, combined with the country's limited ability to monitor the condition of freshwater resources (Statistics South Africa, 2019) provides a justification for the promotion of citizen science (CS) tools and methods to enable a more inclusive model for water resources quality monitoring across South Africa. This project will aim to improve the water resources quality monitoring method in South Africa through the use of CS by consolidating the CS tools, data and information which already exists across the country, and to align this with policy and governmental water resources management structures in hopes to promote the appreciation of the country's water resources across all levels of society and governance. The research, support, and understanding public mobilisation through CS processes will also be investigated and presented in this project.

The field of citizen science is growing field of interest across South Africa (Hulbert *et al.,* 2019). The practice does not require intense or extensive technical training making it a user-friendly, and simple way for people to be trained to accurately monitor water resource quality, and thus river health. This project aims to strengthen and research this capacity in use of CS tools. CS practices should aid in the partnership between agencies who have responsibility over the management of water resources, including the public and communities who live and work along the streams.

The limitations in resources – time, financial, and human – in government river health monitoring programmes has resulted in geographical gaps in the collection of data as well as capacity limitations with laboratory sampling processing. CS can aid in filling in these gaps not only geographically but also conceptually in that it empowers citizens to have a role in the management of water resources. This project also aims to highlight the value and credibility of CS tools and data to be used for both local reporting and international reporting, for the State of Rivers report and Sustainable Development Goal (SDG) 6 reporting, respectively.

In accordance with both national (DWS, 2017a) and international (SDG6) policy and reporting, the efforts to establish and encourage more inclusive, participatory, citizen-based and accessible water monitoring systems at transboundary, national and catchment levels are a driving motivation for this project.

Another driving motivation of this project is to establish the co-ordinated use of CS tools for water quality monitoring across South Africa in a standardised manner, to promote the value and credibility of the incoming data from these CS practices, to be used for the aforementioned national and international reporting. The uncoordinated CS efforts around the country and lack of standardisation of data collection methods has hindered the efforts to upscale the catchment-based CS for water quality monitoring model to a national scale.

1.1 Motivation

Issues concerning the quality of South African water resources are gaining increasing attention. This follows the growing inadequacy of current water and sanitation infrastructure to meet increasing demands on water resources and the challenges being faced. In the 2023 Green Drop Progress Report, the Department of Water and Sanitation (DWS) report that the performance of wastewater treatment works (WWTW) across most provinces "indicates ineffective risk management since the previous 2022 Green Drop audit" (DWS, 2023a). This is evident through recent events in South Africa including the April 2022 floods in Durban (with consequential impacts on water and sanitation across the city), the 2023 Cholera outbreak in Hammanskraal, and the sewage-to-sea-leaks in Cape Town (2022/2023). The capacity of mandated institutions to monitor and report on the quality of water resources across South Africa is limited (DWS, 2021a; Madikizela, 2022). Subsequently, there are insufficient water resources monitoring networks operating across the country to monitor the range of water quality issues by which South Africa's water resources are impacted, as detailed in **Figure 1.1**.

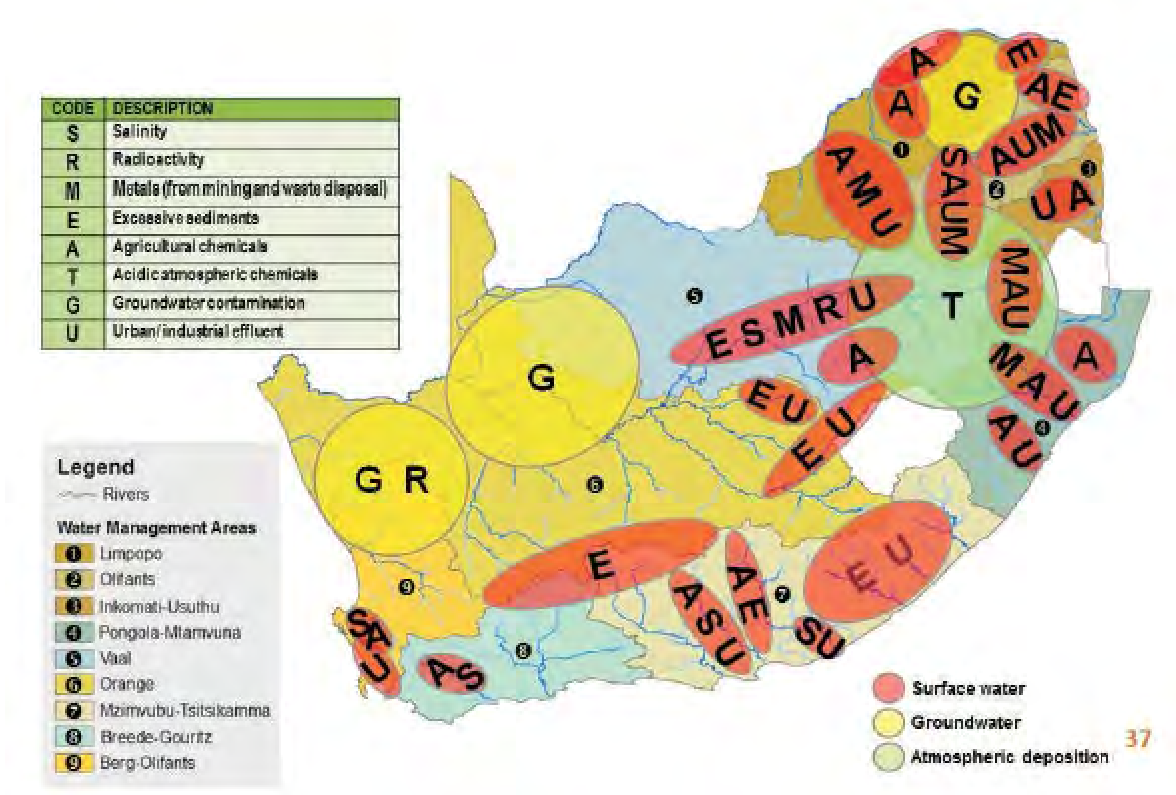


Figure 1.1 Common water quality issues faced across South Africa (DWS, 2017a: p.4).

It is against the backdrop of declining water resources quality monitoring that this project will research the potential for CS to support improvements in the management of South African water resources.

CS has the ability to supplement where these gaps in monitoring exist (San Llorente Capdevila *et al.,* 2020) and has the potential to generate valuable data, provided that the techniques and methodologies for data collection are adhered to. Functioning and reliable CS for water quality monitoring (WQM) networks established prior to the aforementioned events (e.g. the cholera outbreak) could have had the potential to provide advance warning to the authorities regarding the growing environmental issues impacting water resources, thus potentially avoiding or reducing the impact of these events. This is supported by San Llorente Capdevila *et al.,* (2020) regarding citizens' awareness of water resource and environmental issues how their perceptions can be used to inform those who are responsible for the governance and monitoring of these spaces.

1.2 Background

Citizen science is also referred to as community science or crowd-source science and entails the collection of data for a variety of topics by the general public, usually on a volunteer basis (Madikizela, 2022). Citizen science has varying definitions, but a general definition as described by Vohland *et al.,* (2021) defines citizen science as "the active engagement of the general public in scientific research tasks". The United Nations Educational, Scientific and Cultural Organization (UNESCO) Intergovernmental Hydrological Programme Phase Nine define CS as "a process where concerned citizens, government agencies, industry, academia, community groups, and local institutions collaborate to monitor, track, and respond to issues of common community (environmental) concern" (UNESCO, 2021).

Despite the range of definitions, CS through public participation and inclusion not only contribute to research and informing the scientific community but also enhances the public's capacity and understanding of water resource challenges from a scientific perspective. Thakur *et al.,* (2020) detail the value of African indigenous knowledge in the management and awareness concerning water resources and acknowledge that communities have applied indigenous knowledge and practices overtime, preserving and protecting natural resources by respecting the environment and preventing overexploitation. These practices, knowledge and attitudes toward the environment can be considered a type of citizen science in which people use unconventional – or not scientifically-based – methods of approaching and handling environmental issues. Sarabhai *et al.,* (2022) detail how the Nguni people of southern Africa only collect water from lotic river systems with flowing waters as opposed to stagnant waters, and the habitual practice of clearing the water surface with their forearms before collecting the water directly underneath as a way to remove dust. The process of using wood ash as a flocculent to clear surface water before collection is a practice of the Xhosa (Sarabhai *et al.,* 2022). This illustrates that African indigenous knowledge has awareness and consideration of water quality issues, and this understanding indicates a type of citizen science technique which addresses water quality challenges being faced by communities.

South African water management authorities face a dearth of capacity to stay abreast of the water resources challenges being faced in local catchments (Graham and Taylor, 2018). The divide between government, private sector and civil society in addressing water resource issues hinders the process to find inclusive solutions to these water resource challenges. In this research on the state of CS for WQM in a South African context, there is integration and collaboration of these sectors by working towards SDG 6 – clean water and sanitation – through CS practices.

Carlson and Cohen (2018) have noted the growth in CS for WQM (or community-based water monitoring) and make note of various countries where this trend has been noticed, including in South Africa. Carlson and Cohen (2018) attribute this growth in CS to: the affordability of scientifically sound monitoring technique using the appropriate tools; the growing interest or concern which communities have for their local environment; an alternate solution to address the limitations experienced by government and academia in the monitoring of freshwater resources.

Hulbert *et al.,* (2019) have also documented the expected growth in CS projects across South Africa. Upon exploring the challenges and solutions found from establishing CS projects in a South African context, Hulbert *et al.,* (2019) have noted that project redundancy, attracting and maintaining citizen scientists, and data quality are, amongst others, the main challenges with operating and maintaining CS programmes. A proposed solution to the challenge of project redundancy was for those who intend on establishing a CS programme to consider collaborations with existing programmes and tools. This project aims to address this challenge by encouraging the co-ordination of communities of practice (CoP) across South Africa through a sector-inclusive stakeholder network relating to CS for WQM work.

The challenge of attracting and maintaining citizen scientists exists as participants may become impatient or confused if they are unsure of the purpose or methodology of the project, causing them to lose interest and likely not to participate in future (Hulbert *et al.,* 2019). The solution proposed by Hulbert *et al.,* (2019) is to use social media as a tool to promote awareness around CS programmes to better inform participants. This project will address this challenge through a pilot study conducted in collaboration between UNICEF and local NGOs in the uMngeni catchment through an online, incentive-based learning platform called YOMA (Youth Agency Market). The intention is to encourage CS-based learning, particularly for water quality monitoring, and gain an understanding of CS work, as well as to earn incentives for partaking in CS activities, thus aiming to attract and maintain these participants. Another approach is the utilisation of the participatory learning model in which the people who are most affected by a topic being researched should be the people who are involved in the structure, development, design and conduct of that research (Wasserman *et al.,* 2021). In this way, the research is relevant, focused and this participatory approach will allow for insights not previously accounted for to be included.

One of the driving aims of this research and consolidation project is to compare CS-based water quality monitoring data against traditional methods of data collection, to evaluate the credibility of CS-data. Data quality is a challenge for CS programmes (Hulbert *et al.,* 2019) and the incoming data must be high quality to encourage the validity of CS practices; although, here it must be noted that the concern of flawed observations is less so in large, crowd-sourced datasets where the bulk of the data stands to be valid (Holt *et al.,* 2013; Taylor *et al.,* 2022). Hulbert *et al.,* (2019) proposed a solution for improved data collection through organising training sessions for participants and to put in place methods for quality assurance, which this project will also recommend through the use of standardised methodologies for the use of CS tools and techniques. The inadequate water quality monitoring network across South Africa and the resultant insufficient data for informed decision-making is acknowledged in the National Water Resources Strategy revision 3 (NWRS-3) (DWS, 2023b) as one of the key reasons why the country's water resources are in a poor state. One of the challenges with establishing an improved WQM network, as noted in the NWRS-3, is that there is insufficient funding for this network. This may include to monitor all the necessary parameters required to make informed decisions, as well as to the spatial extent required to inform across the landscape of South Africa. In addition to the financial constraints hindering the required operations of WQM networks, the NWRS-3 details the challenges and limitations around water resources knowledge and information management including, inter alia, gaps in the monitoring system and assessment thereof, as well as the technical limitations faced in government institutions (DWS, 2023b). The limitations mentioned here are acknowledged in this project and aim to be addressed through capacitating citizens, assessing the adequacy of CS data to inform government mandated water resources reporting, and the importance of building collaborations across sectors to achieve a common goal. These aims are further echoed by the second, sixteenth and fifth principles of the NWRS-3 guiding principles to improving water quality which are to have a people-centric approach to WQM in line with Integrated Water Quality Management (IWQM), to recognise that data is a strategic asset, and to develop partnerships, respectively (DWS, 2023b).

It is encouraged by Fraisl *et al.,* (2020) that with enhanced support of CS through building partnerships to advance capabilities and greater investment, the full value and potential of CS can be realised and used to accelerate SDG reporting for various indicators. The research in this paper is working to achieve this specifically for SDG 6 reporting in a South African context, and the lessons hereof to potentially be applied in the greater Southern African Development Community (SADC).

1.3 Location of study

This study – set to research, investigate and evaluate CS efforts in South Africa – made of established networks across South African catchments. Upon gauging interest in participating in the data collection aspect of this project, stakeholders from neighbouring countries expressed interest thus **Figure 1.2** depicts South Africa, with its provinces, and neighbouring countries. More specifically, there was participation from stakeholders in Lesotho and Namibia.

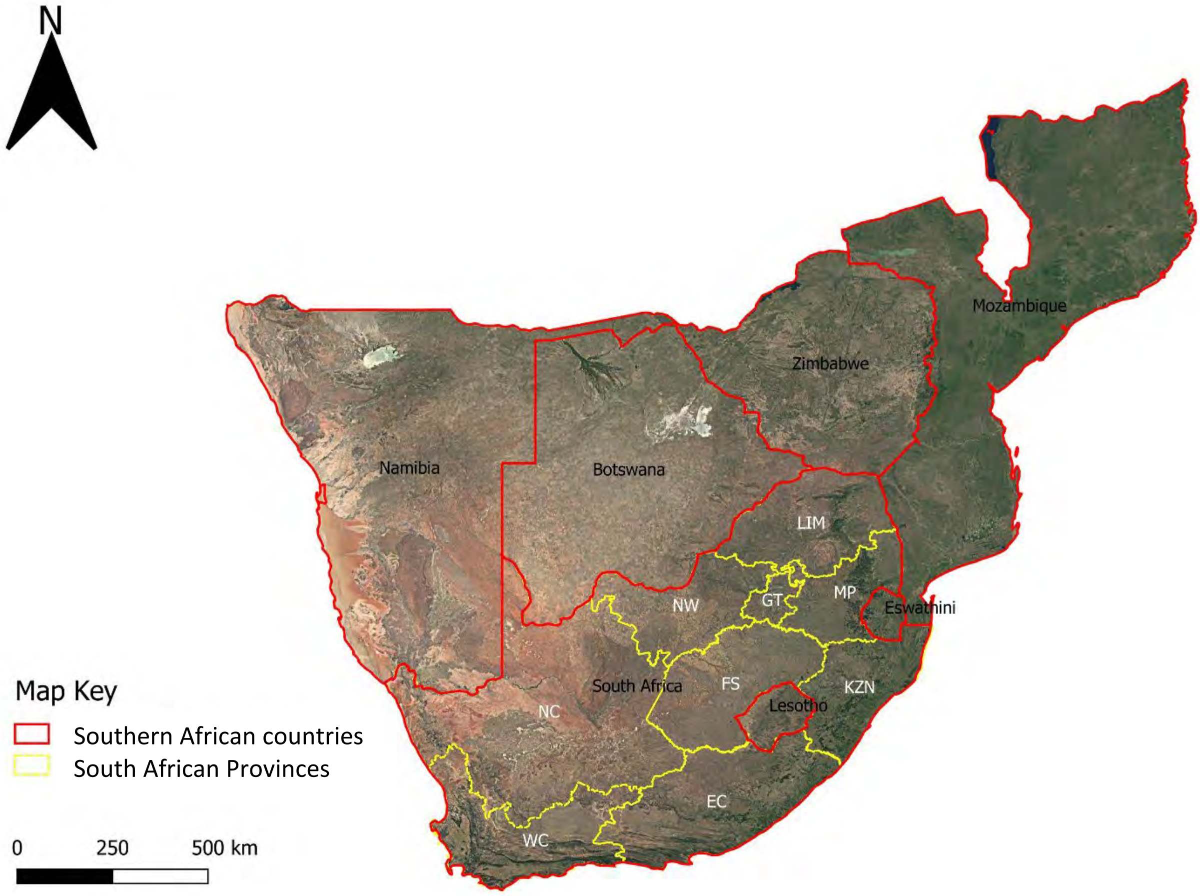


Figure 1.2 Project region focus: Southern African region

2. Research Aims

This project aims to provide a comprehensive overview of what the current state is for citizen science for water quality monitoring in South Africa, relating to the tools and techniques in use, the research efforts, the collaborations, and the applicability of the science in the broader context of water resources management. As such, there are numerous aspects surrounding CS for WQM which would need to be investigated to ensure best practices are being followed, that there is no redundancy of work, and that the organisations and resources needed to support this work are co-engaged. The aims of this research and consolidation project are detailed in **Table 2.1**:

Table 2.1 Project aims for investigating and consolidating the state of citizen science for water resource quality monitoring

No.	Aim
1	To conduct a situation analysis on the use of CS in SA, including where and how CS is currently being used in SA, its credibility as a water quality monitoring method, as well as a cost efficacy review of CS.
2	To determine what crucial CS data is required to ensure credible and scientific water resource quality to support SDG6 reporting.
3	To determine the barriers to applicability of CS at a national level and for SDG6 monitoring.
4	To determine how youth monitors can contribute to the 'learning to earning' pathway for young people, including incentivisation of CS more broadly.
5	To advise on the adequacy and gaps of CS monitoring tools.
6	To produce a preliminary State of Water Resources from a CS perspective within the current State of Rivers report landscape.
7	To make recommendations on how to strengthen CS in water quality monitoring and to explore the opportunities for scaling CS.

An intended outcome from this project is to produce a preliminary CS State of Rivers (SoR) report for all communities of practice (CoP) in the CS space to refer to. As mentioned by Graham and Taylor (2018), CoP are vital to encourage the promotion and use of CS tools. It is also intended for this project to encourage the standardised use of the CS tools and practices being applied across South Africa, with the intention of these CoP to better co-ordinating their efforts at catchment-scale. Alongside the aim to validate the credibility of CS efforts, will be the aim to streamline the incoming data to be incorporated into national (State of Rivers) and international (SDG6) reporting. The project will also explore the efforts to incentivise youth across South Africa to participate in CS efforts and will evaluate this 'learning to earning' model in the South African CS context.

3. Literature Review

Within a South African context, the mandated body which monitors water resources quality is the Department of Water and Sanitation (DWS). The DWS have established a monitoring mechanism to assess the ecological condition of the country's river systems through the River Ecostatus Monitoring Programme (REMP). The parameters which are observed under the REMP are detailed further in **Chapter 6, Section 6.4.** Data from the REMP is used to inform the SoR report ideally on an annual basis however, as the timeline of SoR reports in **Table 3.1** indicate, there are gaps in the reporting of South Africa's rivers overtime.

Table 3.1 Timeline detailing the years which State of River reports were published

Year	Report
1998	State of the Crocodile River
2001	Crocodile Sabie-Sand and Olifants Rivers
	Letaba and Luvuvhu Rivers
2002	uMngeni River
2003	Hartenbos and Klein Brak Rivers
	Diep, Hout Bay, Lourens and Palmiet River Systems
	Free State Region
2004	Berg River System
	Buffalo River System
2005	Crocodile (West) Marico WMA
	Greater Cape Town's Rivers
2006	Olifants/Doring and Sandveld Rivers
	Achievements of the RHP 1994-2004
	The Mokolo River
2007	Rivers of the Gouritz WMA
2008	The Mthatha River
2011	The Breede River
2019	River Ecostatus Monitoring Programme 2017-2018
2021	River Ecostatus Monitoring Programme 2019-2020
2022	River Ecostatus Monitoring Programme 2020-2021

The reports detailed in **Table 3.1** are taken after the publication list found at http://www.dwa.gov.za/iwqs/rhp/state_of_rivers.aspx (as at 01 November 2024) and include the SoR report for 2019-2020 (DWS, 2021a) which has been publicly circulated but not yet published on the webpage linked herein.

From this timeline it is evident that the reporting and, by extension, the monitoring of South African resources is inconsistent. As aforementioned, there are challenges which the DWS face which impact on the ability of the department to continuously and thoroughly monitor the country's river systems. The spatial monitoring gaps which exist can also be seen from the map in **Figure 3.1** which displays the REMP sites for the 2020/2021 annual SoR report (DWS, 2022a). The map depicts spatial gaps in the monitoring networks which gather data for informing the SoR report, prompting concern especially in localities with dense river networks such as western Mpumalanga and the eastern region of the Western Cape.

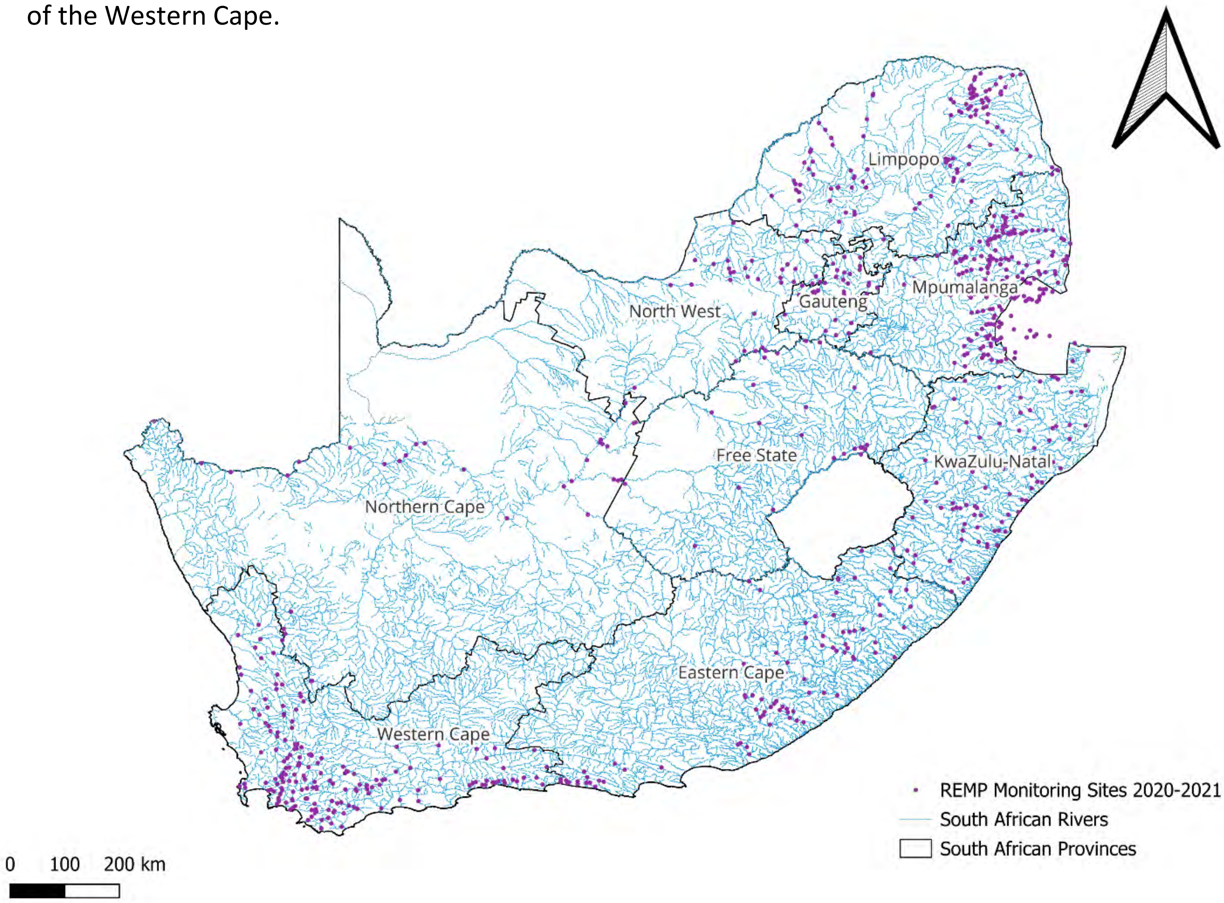


Figure 3.1 River Ecostatus Monitoring Points for 2020/2021

Additionally, Stats SA (2019) reporting on SDGs highlighted South Africa's incapacity to provide the required information to inform the global audience on the country's progress to achieving SDG 6.3.2. Stats SA (2019) accounts for this incapacity by explaining that "South Africa's reporting ability on this indicator has been reduced by the lack of data, limited monitoring because of lack of funding and resource mobilisation, and to a certain degree the inability to coordinate monitoring across various sectors, government departments and public sector institutions".

The conceptual reporting gaps as well as the spatial gaps in river quality monitoring hinder South Africa's responsible bodies from comprehensively evaluating the condition of the country's river systems, thus compromising subsequent decision-making processes. Furthermore, these challenges are hindering the country from the ability to provide data and feedback on SDG 6.3.2 thus not fulfilling global-scale commitments of sustainability target reporting. A solution which can address the spatial gaps and the capacity challenges which exist is required, and CS has the potential to greatly aid in narrowing these gaps.

The NWRS-3 lists water quality challenges which South Africa's water resources are facing, and, of these, there are five which are detailed as the priority challenges: eutrophication, sedimentation, urban pollution, salinisation and acidification/alkalinisation (DWS, 2023b). The NWRS-3 details the pollution sources of each of these issues as displayed in **Table 3.2** and acknowledges that there is substantive knowledge already known on mitigating these challenges.

Table 3.2 Pressing South African water quality issues (taken from DWS, 2023b)

Water Quality Issue	Source of Pollution
Eutrophication	Agricultural sources, domestic wastewater, urban storm-water runoff and diffuse sources.
Salinisation	Natural sources, agricultural sources, industrial sources, domestic wastewater and diffuse sources.
Acidification/Alkalinisation	Mining sources, industrial sources and emissions.
Urban Pollution	Microbial pollution, solid waste, heavy metal contamination, hydrocarbon sources, sedimentation, nutrient enrichment and storm-water runoff.
Sedimentation	Destruction of riparian habitats and wetlands, natural runoff, agricultural sources and urban runoff.

Upon analysing the sources of pollution as detailed in **Table 3.2**, the NWRS-3 notes that these challenges are across socio-economic sectors and, as such, the management of these challenges are beyond that of the DWS working alone. Effective management must include collaborative efforts from government, private organisations, research institutions, educational bodies and civil societies (DWS, 2023b). The latter co-ordinates the potential inclusion of CS in the management of South African water resource quality and supports one of the main aims of this project: to produce a national SoR report from a CS perspective with the intention of showing the value of CS tools and techniques. Along with South Africa's National Development Plan (NDP), the responses of the NWRS-3 integrate working to achieve the relevant SDGs (DWS, 2023b). By working to inform SDG 6.3.2, this project is in alignment with this key legislative strategy.

3.1 Citizen Science in South African Policy

In an investigative study by Lotz-Sisitka *et al.,* (2022), the existing policy in South Africa was thoroughly analysed to identify where there is inclusion of CS, to highlight where the integration of CS can be improved. The main points from the policy review were synthesised and are as displayed in **Table 3.3** below along with an additional review of the National Water Resources Strategy III of 2023 (DWS, 2023b).

Table 3.3 Inclusion of CS for WQM in South African policy (after Lotz-Sisitka *et al.,* 2022 and DWS, 2023b)

Policy Document	Key Points Relating to CS for WQM
The National Water Resources Strategy II of 2013 (DWA, 2013)	Calls for public participatory and citizen science-based approaches to WQM to replace top-down management of water resources, to encourage integrated water resources management
	Water is vital in reducing poverty and inequality and promoting an equitable and just society.
	The development and management of water resources should include input from stakeholders at all levels, from users to those who are involved in high-level decision making.
	The input of those citizens who are of a lower economic class, is vital in ensuring political strategies and policies are applicable and legitimate in ensuring the reduction of poverty.
	The inclusion of citizens in the generation of policies and plans for development is paramount to ensuring that these development plans are impactful and make sense in the local context.
	The inclusion of citizens will aid in encouraging and expanding the sense of responsibility for water resources management.
	This concept of public inclusion in water resources management must be an action-focused approach in order to effectively reduce poverty and inequity.
National Development Plan (NPC, 2011)	The government state, in collaboration with relevant institutions, must work with its citizens, not for them, to achieve sustainable development and advancement of local communities.
Integrated Water Quality Monitoring Policy of 2017 (DWS, 2017b)	Citizen engagement and public participation are integral in the IWQM Policy of 2017.
	Here citizen science is not only seen as a policy to improve WQM but also a means to strengthen relationships between government and private business and society, relating to the enhancement of WQM.
	There are commitments to cross-sectoral relationships and informing policy through latest environmental research.
Integrated Water Quality Monitoring Policy and Strategy of 2017 (DWS, 2017c)	Co-management of water resources is noted here as an integral approach to effective water quality management in South Africa. This co-engagement and management with the public and private sectors aim to be an inclusive and dynamic approach to water quality management.
National Water Resources Strategy III of 2023 (DWS, 2023b)	The primary reason for this revision, *inter alia*, is the inclusion of the development of water-related opportunities and innovative technologies and solutions; both of which are linked to the advancement of WQM CS tools and techniques. Two of the overarching goals of the NWRS-3 highlight "that water and sanitation must support development and the elimination of poverty and inequality…[and]… contribute to the economy and job creation" (DWS, 2023b; p. 3). A principle in the NWRS-III, which set to reinforce the department to work toward their mission, highlights that citizens are to be encouraged to participate in policymaking.

The promotion of sustainable, long-term CS work across South Africa can address unemployment through creating WQM jobs in an under-resourced space with unique skills requirements, while simultaneously establishing a monitoring network to better manage our water resources. CS in the water quality and sanitation space has the potential to encourage this principle as citizens would be involved in understanding the data collection processes and datasets upon which policies are based.

3.2 Citizen Science for Water Quality Monitoring: Tools

Key literature in the field of CS was produced by Graham and Taylor (2018) following a seminal project under the Water Research Commission (WRC) on the *Development of Citizen Science Water Resource Monitoring Tools and Communities of Practice for South Africa, Africa and the World*. Graham and Taylor (2018) collated a toolkit for CS tools which would be most beneficial for informing environmental variables at catchment-scale. The tools included in this toolkit are detailed in **Table 3.4** (after Graham and Taylor, 2018).

Table 3.4 Citizen science toolbox (after Graham and Taylor, 2018)

Citizen Science Tool/Technique	Indicator Observed/Parameter Measured
Aquatic biomonitoring tool – miniSASS	Ecological condition
The Riparian Health Audit	Ecological condition
The Water Clarity Tube	Water clarity as an indication of TSS
The Transparent Velocity Head Rod	Velocity and discharge
The Wetland assessment tool	Wetland ecological condition
The Estuary tool	Estuarine ecological condition
The Spring tool	Spring ecological condition
CS Rain Gauge	Amount of rainfall
Weather monitoring tools	Wind speed and direction
School lesson plans	CAPS compliant environmental literacy building
The Enviro-Picture Building Activity	Contextualising environmental issues

Since this formative toolkit was developed by Graham and Taylor (2018), there have been advancements not only in the use and methodology of existing tools, but also the development of other CS tools in the environmental space.

MiniSASS (mini-Stream Assessment Scoring System) is a simplified, citizen science tool developed from the more complex SASS (South African Scoring System) technique. The development of miniSASS allows for an affordable and easily understandable tool to inform diverse ranges of communities on the health of their rivers. MiniSASS was developed to encourage a participatory approach for biomonitoring of water resources in a simplified manner which provides real-time indication of river health (Graham *et al.,* 2015). Taylor *et al.,* (2022) mention that a case study by Graham and Taylor (2018) on a public participation process on the use of citizen science tools revealed that miniSASS was the tool which appeared easiest to use with the results being immediate and easy to interpret.

Biomonitoring (in the form of miniSASS under this project) as an assessment of water quality gives the user an indication of the health of the water body, provides immediate results which can be easily understood, and possesses the ability to track changes and variations overtime (Jele *et al.,* 2023). This is beneficial as a CS tool as the visible presence of something to measure is more readily understood than chemical or bacterial methods. There is also an instant result in the form of a health condition indication, which the users would be able to immediately contextualise by looking around in that setting and deducing what potentially could be impacting the water quality, thus potentially risking the people who reside near the stream.

It was found, for example, when working with rural farmers from the upper uMkomazi catchment, that their understanding of river health measures was more understood and engaging when dealing with indicators of river health through living organisms (biomonitoring) than when they studied their river using physico-chemical measures even though these were numerical and accurate (Taylor J, pers. comm., UKZN, 2023). In short, a number which one can establish from a chemical test is harder to comprehend than that obtained through studying living organisms and how they cope in different stream circumstances.

This insight takes us further. Where one is seeking to stimulate action from the study experiences, action competence is more likely when the participants are physically engaged in looking, learning and accessing than when they simply extract a figure from a chemical test.

The Water Clarity Tube was designed to measure water clarity as a proxy for water quality parameters when determining the health of a river, wetland or dam (Graham and Taylor, 2018). The water clarity values measured from a water body gives an indication of the total suspended solids (TSS) present in that body of water. DWS (2021a) acknowledge that clarity tube results are a sufficient proxy for TSS. Further to this, Graham *et al.,* (2024) derived an equation to estimate TSS values (mg/L) from known clarity (cm) values and is presented as **Equation 3.1.**

$$y = 10^{2.96-1.05(\log_{10} X)} \tag{3.1}$$

Where $y = \log_{10}$ transformed value for TSS (mg/l)

x = clarity value from the clarity tube (cm)

According to the 2023 Green Drop Progress Report (DWS, 2023a) which reports on the performance of South Africa's WWTW, 66% of all WWTW fall under the high-risk (34%) and critical-risk (32%) categories. There has also been a decrease in the number of WWTW falling under the low-risk category from 168 in 2022 to 74 in 2023. This displays an overall decline in the operational capacity and management of South Africa's WWTW. Here, CS through the use of the water clarity tube would aid in tracking the TSS found in the river upstream of a WWTW, and then just downstream of it, as a way to ensure that water of an acceptable standard is being released from the WWTW. In instances where this is not being upheld, this empowers the citizens to raise these concerns with measured, sound evidence to support their concerns. Graham and Taylor (2018) detailed an example of this where the residents of Shiyabazali community located in Howick, KwaZulu-Natal. Through WQM using a clarity tube and subsequent collection of scientifically-sound data to support their concerns, the community was in a better standing to hold the relevant authorities' attention to the water resource quality issues which they were facing. This case study is a prime example of how CS can be used to inform and to empower people.

A Transparent Velocity Head Rod – or simply, velocity plank – is a meter-long Perspex plank which is used to measure the velocity and discharge of a river, through the measurement of the free-flowing water level, and the difference in water levels between the upstream and downstream sides of the plank when it is used to block flow (Graham and Taylor, 2018). This CS tool is useful to track the impact on downstream flow before and after changes have occurred in the surrounding environment along the river. For example, the velocity plank can be used to indicate how the streamflow is affected after erosion has caused a riverbank upstream to collapse, after a section of alien invasive vegetation has been cleared along a riverbank, or how the construction of a dam impacts on the streamflow downstream of these activities.

A notable mention of another CS technique is the Enviro-picture Building activity. The Enviro-picture Building activity was designed specifically for communities who have no formal education in the environmental sector but are eager to grow their environmental literacy. This activity encourages participants to apply their minds to the environmental issue displayed on the activity card and contextualise it in their own communities (Graham and Taylor, 2018). Although this is not a quantitative CS tool or method, the Enviro-Picture building activities offer a learning process that commences from the real-world reality of the participants and supports them to link their understanding of the environment to other systemic issues that may affect stream quality, quantity and access. It is thus a good example of action learning in context (Taylor, O'Donoghue and Venter, 2018). It is noted here as the impact of the CS work which the public are engaging in should be contextualised so that there is meaning behind the quantitative values being measured and recorded. It also enables the public to gauge their reach of impact and what issues they are directly and/or indirectly addressing through CS work.

Other notable mentions of CS tools are the iLab Water Testing Kit and the Freshwater Watch kit, both of which provide chemically based indications of water quality. The iLab Water Testing Kit encourages citizens across South Africa to test the chemical and bacterial quality of their water resources. These resources include water from dams, rivers, lakes, and even taps. This was designed to enable citizens to be aware of the condition of the country's water and empowers citizens to justifiably make a call for change (with scientific evidence to support them) should the quality of any of the resources be found to be unfavourable. This application of CS is scientifically sound and, with each kit coming with an instruction manual and a tutorial video found online, encourages minimal error (WaterCAN, 2023). The results from this kit range from immediate to three days later, which is quicker and more affordable than sending water samples to an independent laboratory for analysis. A South African organisation which has encouraged the use of the iLab Water Testing Kit is WaterCAN (Water Community Action Network). WaterCAN has launched the "Map My Water" tool which is an online map that gives a visual representation of where water testing has occurred, the testing method and an indication of the quality derived by use of that method, along with other relevant information. A similar kit has been developed in Europe and is called a Freshwater Watch kit which prompts users to record chemical, hydrological, optical and ecological observations of freshwater. The starter kit includes user-friendly apparatus to test for nitrates and phosphates (15 tests each) present in water resources, a Secchi tube to determine turbidity, instruction leaflets, colour charts, a sample cup and a pair of gloves. Additional payments will include other parameters to observe which the user can select, for example a recording sheet to observe the presence of specific aquatic invertebrates (Earthwatch Europe, 2023).

San Llorente Capdevila *et al.,* (2020) note that the difficulty associated with conceptualising chemically based water quality parameters can hinder the citizens involved in the collection of this data from connecting with the science; there is a disconnect between measurements of certain chemicals and how that translates to something of concern or of relief for a citizen scientist. This limitation of chemically based methods is that prior knowledge and understanding of the basics of chemistry and micro-organisms would be favourable to understand what the results are showing. It could also prove difficult for participants to contextualise the results from this kit into the surrounding from which the sample was taken, potentially causing a disconnect between the water quality result and the environmental issues or anthropogenic activity linked to it. There is, however, value to using this CS kit due to the ease in generating scientifically sound chemical results and the affordability compared to laboratory testing; this is better suited for contexts where users have foundational understanding of environmental issues and their impact on water resources. Where conditions would allow, the potential for these kits to be combined or used in conjunction with an aquatic biomonitoring tool, such as miniSASS, would give a more rounded indication of water quality. The combination of chemical and biomonitoring tools for CS work will be explored in this research.

3.3 Cost Efficacy of Citizen Science for Water Quality Monitoring

A strong motivation for the use of CS has been the affordability of the tools and techniques in comparison to the traditional and/or laboratory-based methods for gathering data on water quality parameters. The notion of CS data being collected by either volunteers or low-skilled workers makes for low human resources costs of CS methods.

The practice of using traditional methods and/or laboratory testing for all water quality parameters is not viable over large spatial and temporal scales due to the capacity of responsible bodies and organisations to cover the expenses of frequent sampling and monitoring. The ability of accredited laboratories across South Africa to handle an increased demand for results would also need to be considered. It must be noted that the use of CS in combination with traditional laboratory methods of data collection and analysis is a comprehensive and rounded way of looking at water resources management and reporting. The intention is not to discredit one or the other but rather look at how the techniques can complementarily work. The view of CS being only a cheaper alternate for WQM taints the perception of the validity of the tools and techniques. Carlson and Cohen (2018) call for a change in the perception of CS for it not to just be viewed as a cheaper alternative to collect data, but for the value it brings to be realised and acknowledged hence the need for integration of this information into policy and practise.

Summarised in **Table 3.5** is a cost comparison between the traditional method and/or equipment required to measure a parameter, and its relevant CS tool. It must be noted that these costs do not include the associated human resources costs, operational costs, and the subsequent costs associated with the data handling and analysis.

Table 3.5 Cost comparison between traditions water quality monitoring equipment and water quality monitoring citizen science tools

Traditional Equipment	Cost	Frequency of purchase	Citizen Science equipment	Cost	Frequency of purchase
Laboratory analysis of TSS	R99.00[A]	Per sample taken	Clarity tube	R1798.60[C]	Once-off
SASS5 Kit	R2304.60[C]	Once-off	MiniSASS kit	R2070.00[C]	Once-off
Flow meter	R70 000.00[B]	Once-off	Velocity plank	R894.70[C]	Once-off

[A] Gathered from an independent laboratory (as at August 2023).

[B] According to Graham and Taylor, 2018 (page 54).

[C] Prices are as at August 2023, available from GroundTruth.

The miniSASS kit mentioned in **Table 3.5** includes the following items: a sorting tray, a pair of tweezers, a miniSASS net, a pair of latex gloves, a magnifying glass, three sample bottles, three vials, a pipette, two petri dishes, a scoring sheet and a miniSASS instructional DVD. The SASS5 kit mentioned includes: a SASS net, a sorting tray, a loupe and a pair of tweezers. A cost-effective technique of conducting a miniSASS without purchasing the official kit, would be to create a kit using materials such as a white ice-cream container instead of a miniSASS tray, or buying a small fishing net instead of the net which comes with the kit. In the interest of maintaining the validity of the observations using a low-cost miniSASS kit, research is currently underway to explore the efficacy and credibility of this cost-effective technique (Russell C, pers. comm., GroundTruth, 2023).

The equipment mentioned in **Table 3.5** each has its own training, human resources and/or operational cost associated with it dependent on variables such as the frequency of sampling and the platform for training (where there is a choice). The frequency of sampling relates to how often the tool or equipment must be used which possesses equipment costs each time (for example, in the case of TSS sampling), and the associated cost of human resources (labour costs), commonly based on rates in accordance with the qualification and experience of the individual recruited. The platform of training varies across the equipment listed, but also for tools. For example, training to use CS tools can be conducted in person, online – or "digital learning" (Russell C, pers. comm., GroundTruth, 2023) – or through the manuals which come with each tool. **Table 3.6** summarises these implicit costs of the use of each method. Due to these variables, a total cost figure cannot be assigned to each method, however it is important to note these implicit costs.

Table 3.6 Implicit costs associated with traditional and citizen science techniques for water quality monitoring

Traditional Equipment	Operational and Human Resources Costs	Citizen Science equipment	Operational and Human Resources Costs
Laboratory analysis of TSS	Human resources: Trained individual to conduct sampling and professional to conduct laboratory analysis Operational costs: Travel to and from the laboratory and the procurement of the correct sampling bottles for each sample, and PPE	Clarity tube	Human resources: An individual(s) who has trained and knows how to use to use a clarity tube Operational resources: Travel to and from sites, if the individual(s) are not within walking distance
SASS5 Kit	Human resources: A trained and SASS5 accredited individual to conduct the SASS5 assessment Operational costs: Travel to and from sites, PPE	MiniSASS kit	Human resources: An unaccredited individual(s) who has trained and knows how to conduct a miniSASS Operational resources: Travel to and from sites, if the individual(s) are not within walking distance
Flow meter	Human resources: A trained user Operational costs: Maintenance costs	Velocity plank	Human resources: An individual(s) who has trained and knows how to use a velocity plank Operational resources: Travel to and from sites, if the individual(s) are not within walking distance

3.4 Credibility and Validity of Citizen Science for Water Quality Monitoring

The credibility of CS techniques has been questioned, especially by the broader scientific community. The development of CS across a range of various fields and sectors should be perceived as an innovative way to engage the public and collect valuable data, rather than something counterproductive. Miscommunications, misunderstandings and too-broad-conclusions have been the causes of these criticisms, which hinders the value of CS techniques from being fully recognised. The credibility, validity and quality of CS work has been questioned largely by those who are professionals in the fields which CS can support. The view of CS being below standards of traditional data collection hinders the broader adoption and applications of CS work (Quinlivan *et al.,* 2020). An aim of this project is an attempt to change this perception by evaluating CS data against traditional data collection methods to speak to the credibility of CS-derived data.

Quinlivan *et al.,* (2020) indicated that there has been extensive research conducted which attests to CS being credible where the standard of water quality data collected, after citizen scientists received proper training and with enough resources, was as sufficient as that of professional scientists. The scope of work which the citizen scientists are undertaking must correlate with their abilities to ensure datasets of a higher quality can be generated, as opposed to those which lack training and contextualisation Quinlivan *et al.,* (2020).

Hulbert *et al.,* (2019) gives credence to the credibility, validity, and value for CS-based data with the aim of garnering support and integration of CS-based data in broader contexts such as in the scientific community and South African government environmental reporting bodies. There are measures which need to be implemented to enhance the validity of CS techniques. This includes citizen scientists following standardised techniques and procedures for the collection of data. This can be ensured through a formal training course, facilitated online or in-person. As a suggestion, after undergoing the training process, a subsequent verification of correct practice by a trained practitioner in the field (who has intimate knowledge of the use of the tools) can take place for individuals to be considered expert users with a subsequent certification awarded.

After the development of the CS tools and following the increase in use of the tools, subsequent versions of the methodology have been reviewed and revised with the aim to develop a methodology which aligns with best practice for use of these tools. Ideally, any amendments to the methodology for use of the tools or updates regarding new tools, should be formally communicated to all CS users to ensure everyone in the practice is following the correct methodology and, by extension, collecting reliable data.

Ramírez *et al.,* (2023) acknowledges that CS can collect WQM data over large spatial and temporal scales, and that CS techniques can aid countries to meet the requirements for SDG reporting. It was also noted that upon reviewing the literature around CS for WQM, the ability to collect of WQM data at large temporal and spatial scales through CS techniques was shadowed by the comparisons of the data correlation between CS data and traditional WQM data. Ramírez *et al.,* (2023) emphasises here that it is not only the reliability of data that must be investigated before incorporating a technique in national or international monitoring programmes, but the ability of the data to be tracked over time and space is just as important. In this research project, bearing in mind what has been emphasised by Ramírez *et al.,* (2023), the spatial gaps of CS for WQM work in the country will be identified, as far as possible. Collaborations with key stakeholders will inform optimal frequencies of measurements for the various CS tools to ensure sound science behind the techniques is being adhered to, while simultaneously adhering to the requirements for national and international reporting.

3.5 Encouraging a Citizen Science for Water Quality Monitoring Network

Statistics South Africa (2019) has reported that a lack of data and monitoring around water quality has hindered South Africa from reporting on SDGs, and this can be partly accredited to the uncoordinated efforts within the country. CS in South Africa can benefit from an established network of active citizen scientists, such as the recently established (October 2023) Citizen Science Association of Southern Africa (CSA-SA), with sub-groups for CS around specific issues, such as a CS for WQM network. This research will aim to encourage such a network which will include representatives from public, private and tertiary education sectors to ensure there is sufficient representation and inclusion of key stakeholders in the CS space. The representation in this network has the potential to greatly aid in the sharing and mobilisation of knowledge and resources.

This network will not only aid in co-ordinating the temporal and spatial scales of CS work across South Africa, and potentially the SADC region, but can also serve as a platform for data sharing, information generation, and news in the field. Through this network, the continuity of CS work can be ensured through institutionalising the practice and having the continuity of CS being encouraged by an expanded community of practice.

These networks do not only speak to the connections between professionals in the field, but also between government and society. DWS (2021a) call on state regulators to strengthen their protocols and procedures to monitoring non-compliance especially in tracking point and non-point sources of pollution, which contributes greatly to the poor quality of water resources. A suggestion here, as with the aforementioned case of the Shiyabazali community (Graham and Taylor, 2018), would be to empower communities to be custodians of their water resources – through the use of CS methods. Communities would be on-the-ground monitors to aid in identifying environmental issues caused by non-compliance through using near real-time observations; potentially aiding in identifying point pollution sources. The potential for collaboration between government and society here could firmly set the precedent that environmental issues are to be prioritised and taken seriously across the country, including within all industrial, residential and agricultural communities.

3.5.1 *An evolving stakeholder network and community of practice*

An evolving CS for WQM stakeholder network is displayed in **Figure 3.2** and is based on expressions of interest in this project as at January 2024. This network is also based on the existing networks within the working group on this project as well as past research by Lotz-Sisitka *et al.,* (2022) which had informed the starting links of this stakeholder network.

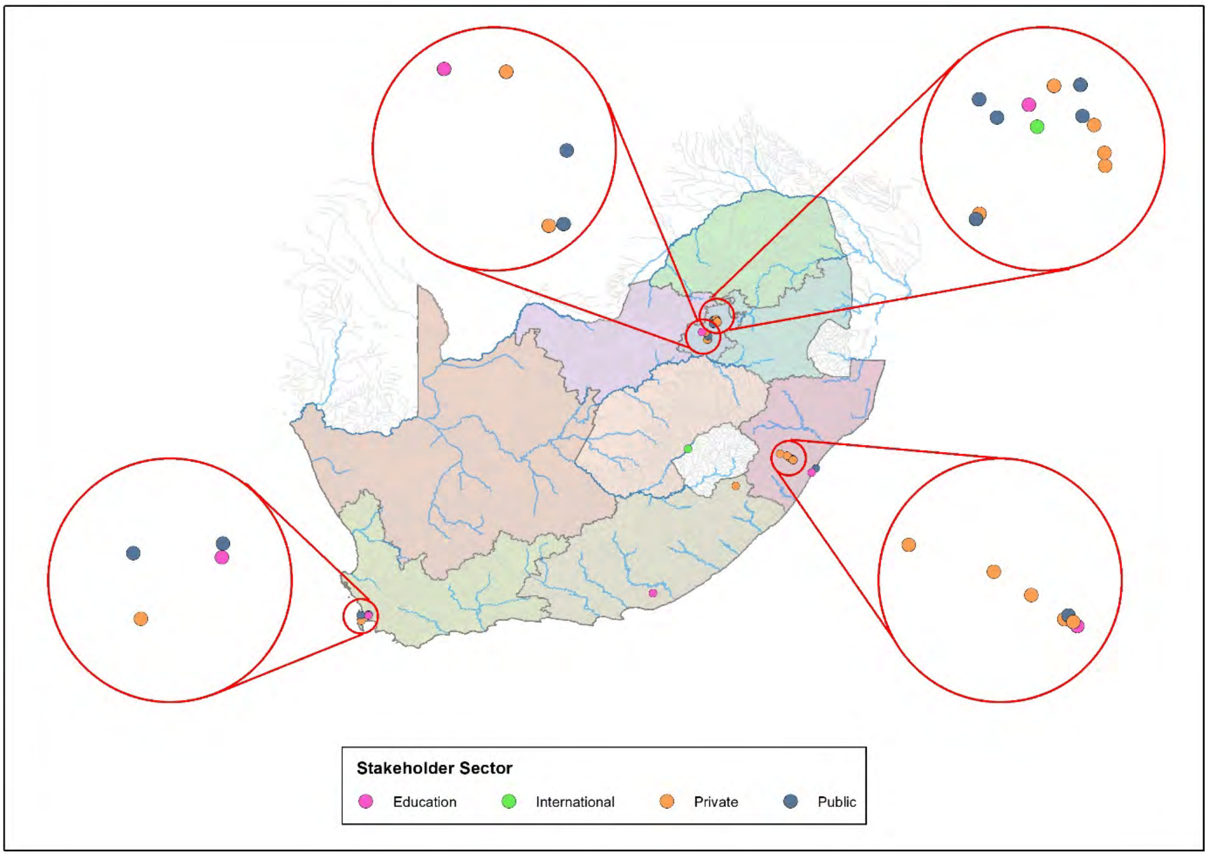


Figure 3.2 Map of stakeholders interested in CS for WQM across southern Africa

It must be noted that with the nature of CS work, this stakeholder network can be updated, names and organisations added or removed, and that this stakeholder network is unlikely to reach a completion point; it is to be continuously updated and here it is acknowledged that there may be individuals, programmes or organisations which have been overlooked, and are invited to contact the lead author in this regard. The *2024 Citizen Science State of Rivers Report* in **Chapter 7** provides an updated figure illustrating where CS has been applied across the region.

3.5.2 *Citizen science for water quality monitoring programmes*

In 2008 the Department of Water Affairs (DWA) initiated the Adopt a River (AaR) Programme which aimed to create awareness around the protection and management of South African water resources through participation by volunteers. These public participation awareness efforts included enlightening the public to water quality issues as well as the concept of Integrated Water Resources Management (IWRM) (Graham *et al.,* 2016). In 2010 the AaR Programme shifted from a volunteer programme to an employment programme. Although this job creation shift (as a step away from poverty) was welcomed, this shift also meant that the focus shifted from water quality monitoring issues to that of job creation. Graham *et al.,* (2016) report that although the objectives of the first two phases of the AaR Programme were achieved, the implementation of these phases was not well achieved. A review of the AaR Programme by Graham *et al.,* (2016) provided suggestions for the implementation of future AaR Programmes which included, *inter alia*, a revised governance framework which encourages a governmental and public-private partnership for the implementation and organisation of the programme, and a mission statement addressing the broad goals of the AaR Programmes. Graham *et al*. (2016) also suggested that there be an emphasis on training and skills development opportunities to be given to participants, in line with the reviewed framework, and that the role of citizen science monitoring integration be explored along with the collaboration with the National Aquatic Ecostatus Health Monitoring Programme (NAEHMP). Graham *et al.,* (2016) also revised a funding framework to support the AaR programme, noting that during the AaR programme operations from 2010-2015, the funding from treasury was situated within government departments. This meant that without the ability to budget beyond stipends, there was no investment in training, skills development or career pathing for individuals, and the programme did not create a sustainable change to communities or the environment.

The Amanzi ethu Nobuntu (AEN) programme stemmed from the uMngeni Ecological Infrastructure Partnership (UEIP) as the entity which will oversee the management of citizen science and environmental programmes across the uMngeni catchment. The AEN programme is founded on the concept, to *work for the common good* which aims to encourage people to partake in activities for the betterment of people and the environment at present and into the future. AEN has seen two phases come to completion. The first phase duration was over three months in early 2021, and the second phase ran just over a year from October 2021 to November 2022. Phase 1 successfully employed 300 people, as Environmental Champions (Enviro Champs), to work for the common good through river health monitoring and environmental work. This work included clearing of alien invasive species along riverbanks, clearing illegal solid waste dumpsites, reporting sewer and water leaks, and spreading environmental awareness throughout their communities through door-to-door visits. All the data collected from conducting this work was recorded using a smartphone application called FieldSurvey, and stored on the platforms server. This model was applied at a larger scale through phase 2 (October

2021 to November 2022), employing over 500 Enviro Champs (through a public-private blended finance model) to work for the common good while accounting for the lessons learned from the previous phase (Amanzi ethu Nobuntu, online, undated). The NWRS-3 (DWS, 2023b) acknowledges the youth employment and capacity development in the river biomonitoring through CS space through AEN as one of the successes of the NWRS-2. This acknowledgment attests to the occupational value which CS possesses in the WQM space.

Programmes such as AEN have displayed how meaningful collaboration between partners who work toward a common goal carries great influence over environmental awareness and actions at a catchment scale, and this can be used as a model for future programmes to draw on, noting the successes and the shortcomings of such a programme (DUCT, 2021). DUCT (2021) reports a shortcoming to note are the impacts of the short-term nature of the AEN programme. First, the short-term involvement can be demotivating for the Enviro Champs involved as the nature of environmental work is continuous, and the impact thereof takes time. Secondly, most staff on programmes such as AEN are often reliant on short-term stipends for income and the skills obtained under these programmes cannot be used to independently generate an income. This issue has prompted the incentivisation of CS work by UNICEF through the YOMA platform, detailed further in **Chapter 8, Section 6**. This UNICEF and YOMA partnership aims to establish a sustainable learning pathway for citizen scientists (Enviro Champs), whilst incentivising their capacity building journey on the YOMA platform. It has also prompted the operational research currently underway through collaborative efforts by Rhodes University, GroundTruth, UNICEF and DUCT. The operational research is intended to document the piloting of a learning pathway on the YOMA platform, with the aim of submitting the research findings to the Quality Council for Trades and Occupations (QCTO) in recognition of the occupational role Enviro Champs play (Russell C, pers. comm., GroundTruth, 2023). This may encourage an occupational uptake of CS-based data collection for WQM. Lastly, the short-term nature of projects also hinders collation of a continuous water resource quality database, consequently hindering the subsequent reporting processes on those water resources.

Through an established network of citizen scientists who work for the common good across catchments and are mandated to report their work and observations, a system of streamlining water quality data for reporting can be established. This speaks to another major shortcoming of the AEN phase 2 programme; the data which was collected over the course of phase 2 was not used beyond programme-level reporting; reporting of selected sewer leaks, water leaks, and illegal dumpsites to relevant municipalities; and reporting back to the Department of Science and Innovation (DSI) who funded phase 2 (Brownell F, pers. comm., AEN, 2023). Through a functional, effective and continuously collaborative network of CS stakeholders, CS data can be better utilised for catchment-scale reporting, further contributing to the improved perception of CS being a valuable practice which possess great ability to account for spatial and temporal gaps in water resource quality data collection.

The data collected during AEN Phase 1 was used to generate a draft State of Rivers report from a citizen science perspective for the uMngeni catchment, working in collaboration with uMngeni-uThukela Water. This project will use that report as a basis to further encourage the potential of CS work to be utilised for reporting on South Africa’s catchments.

3.5.3 *Database on citizen science for water quality monitoring*

A challenge noted by DWS (2023b) is that the current DWS information-system is data-driven instead of information-driven. This is where CS techniques can bring an information-focused perspective, linking the indicators back to the environmental context instead of providing decision-makers and other stakeholders with an array of figures which can be difficult to contextualise from a numerical database. An example here of information-focused over data-focused techniques, is how miniSASS provides an indication of the state of a river without a statistical analysis required, thus is simple for stakeholders to understand.

The National Water Act 36 of 1998 requires that a publicly available national water resource information system should be established providing information pertaining to all facets around South Africa's water resources. This system will not only aid in the high-level water management and decision making, but can also be utilised by public safety representatives, researchers, community environmental groups, and other interested parties. DWS (2021a) State of Rivers report 2019-20 had reported that fish assemblage and macroinvertebrate data prior to 2014, had been stored in the DWS internal database in a Rivers Database, which is now inactive. Upon receiving external funding, the Freshwater Research Centre in Cape Town developed the online Freshwater Biodiversity Information System (FBIS), limited to capturing only fish and macroinvertebrate data, while on a stable internet connection. The data from the Rivers Database has been captured on the FBIS. The DWS (2021a) State of Rivers report 2019-20 calls for a department funded, and well-maintained database, with sufficient storage capacity to host all data related to the quality of water resources across South Africa. The limitation of establishing a functional and well-maintained database for water quality data is similarly being experienced by WQM citizen scientists. In line with the National Water Act (NWA) of 1998, information pertaining to South Africa's water resources should ideally be centralised for ease of access by all relevant stakeholders. These potentially complimentary methods of investigating the ecological conditions of water resources and contributing to an annual South African State of Rivers report will be further investigated in this project. There is potential here for the integration of CS techniques at a departmental level, supporting the efforts for an up-to-date WQM database. DWS supporting the actions of civilians in improving their water quality and encouraging government departments and representatives to link with the public may subsequently lead to assistance in funding opportunities for CS initiatives, and encouragement of the continuation of existing initiatives (DWS, 2021a). Within an established CS for WQM network with varying stakeholders working together, there is potential for sufficient interest and motivation to be generated for a central platform for CS data. This network could mobilise the necessary stakeholders regarding the materialisation of this platform.

Graham and Taylor (2018) worked on such a platform, Capacity for Catchments, which can be accessed at https://capacityforcatchments.org/home. The platform is under construction but was initially developed to host discussion forums, relevant information and documentation on the tools and learning material, details of the various communities of practice, and other relevant CS material.

Hulbert *et al.,* (2019) encourages CS programme leads to subscribe to an online group (found at https://groups.io/g/CitSciSA) to join a network of CS efforts across South Africa. Upon joining this online group on 28 July 2023, it was found to last be active in 2019 with just 13 members. This online group was a start to build a stakeholder network however, the social connections and interactions of relevant stakeholders in the field is what will encourage such a group or platform to be promoted, utilised and expanded.

These valuable attempts justify the need for updated stakeholder networks, particularly focusing on water quality monitoring, to be established for South Africa, and potentially extending into the SADC region. The Citizen Science Association of South Africa (CSA-SA) has recently been established (October 2023), and such an association can aid in the co-ordination of all CS work across South Africa, as well as in the development and maintenance of a CS database. Such platforms should be easily accessible and up to date for current stakeholders to engage with, and user-friendly enough for new CS stakeholders to navigate. A CS platform could host the database for water quality data and greatly aid in streamlining data to inform national and international reporting.

3.6 Potential for Citizen Science to Inform National and International Water Resources Reporting

One of the aims of this research is to evaluate the suitability of and opportunities to incorporate the data and information on the quality of the water resources in South Africa derived from citizen science methods into reporting on a national and international scale. A point of concern for the integration of CS-derived data in national (DWS) and international (SDG) reporting is that currently there exists variability in techniques thus concerns are raised around the reliability of the CS-derived datasets for WQM. Recently published research around the standardisation of a select suite of CS tools can be found under the Water Research Commission project report (WRC Report No. TT 933/23) by Russell *et al.,* 2024. Outputs from that project include simplified online and user-friendly manuals for an array of CS tools, including the clarity tube, miniSASS, and the velocity plank **(Appendix B, C, and D, respectively).**

The standardised use of CS tools will not only improve the credibility of the data being collected but will also ensure reasonable comparisons of parameters across spatial scales. These standardised methodologies are critical in ensuring that reliable data can be used at catchment and national scale, for potential to be streamlined into national and international reporting structures.

3.6.1 *National water resources reporting*

Carlson and Cohen (2018) explored the integration of CS water quality monitoring data into policy against a Canadian-backdrop and had concluded that although standard procedures and protocols were followed, the outputs, data and information generated from most of the community-based work was not used to inform policy and decision-making processes at any level of government. This project has purposefully worked in collaboration with diverse partners across the public and private sectors to avoid the value of CS work being overlooked at higher-level decision-making.

Citizen-led and volunteer programmes have great potential to address challenges around the scale and frequency of data collection however, the methodologies informing these citizen science programmes are often more variable than traditional, professional data collection methods (Holt *et al.,* 2013). This justifies the requirement for standardised methodologies to be developed for CS use which was one of the main aims of a complementary WRC project looking at the accessing the CS toolbox on a wider scale through, digitizing the manuals and creating instructional videos, simplifying the manuals, and having the manuals translated into terms which can be easily understood by laymen. These digital manuals may also be translated into other South African languages to broaden the range of understanding.

In the South African context, there is potential for the parameters observed through CS work to inform the annual SoR report, collated by the DWS. The SoR Report 2019-20 emphasised that in accordance with the South African National Water Act 36 of 1998, water resources management must equitably prioritise the use and protection of the country's water resources, which includes prioritising river health monitoring efforts (DWS, 2021a).

The REMP is conducted by DWS to collect data used to contribute to the annual SoR report and inform the ecological condition of the country's river systems. The REMP work includes the objective to build the capacity of citizens and encouraging environmental awareness, closely aligned with the notions of CS. The initiation of such a programme improves in establishing river monitoring networks throughout the country to ensure continuous monitoring to inform the annual SoR report. Continuous monitoring also allows environmental issues affecting water quality to be detected at early-stages and addressed so that it does not culminate into a larger problem (DWS, 2021a). A study by Hadj-Hammou *et al.,* (2017) in the United Kingdom has shown how CS data can complement and aid in completing a full review of river systems monitoring across catchments. This approach of synergising strategies can be applied in a South African context for the SoR reports to promote the generation of valuable river health monitoring data.

The SoR Report 2019-20 was largely based on the assessment of macroinvertebrates through SASS5 methods, along with other ecological indices such as Riparian Vegetation, Index of Habitat Integrity and Fish Assemblages. From this, the status of a water resources can be determined by placing it into one of the Generic Ecological Categories. A subsequent comparison against previous results can be conducted to track the changes in the condition of the river (DWS, 2021a). The challenge of collecting sufficient data to inform these indices, and subsequently the river ecological categorisation, is mentioned in this SoR report. This national challenge can be addressed at catchment scale through improved capacity of monitoring systems across the country; more specifically, CS networks. Other reasons preventing the monitoring of a large portion of South African river systems included that these systems exhibit flow patterns not suited for monitoring using the aforementioned parameters, there exists too much pollution in these systems for continuous monitoring to take place, or the systems were inaccessible due to the system being located on private (or protected) land (DWS, 2021a). CS practices adopted by the individuals or organisations who have access to these privately (or protected) located water resources can assist in filling in these geographical gaps. An example of this are the portions of rivers which run through the protected South African National Parks (SANParks). There is potential for the mandated and interested authorities to collaborate with SANParks to monitor the water resources. The use of CS is an accessible way to establish this connection through the easily understandable and user-friendly techniques which, when followed correctly, will provide reliable river health data.

One of the major challenges to achieve effective, integrative and sustainable water resources monitoring and management in South Africa is a limitation in the data which covers the full range of the quality of water resources. Graham *et al.,* (2015) notes this limitation due to limitations in skills to collect and analyse water resource quality data. Similarly, DWS (2021a) State of Rivers report 2019-20 highlights that there is a major human and institutional capacity issue for the continuous monitoring of river systems across the country. Specifically, there are limitations with SASS5 accredited practitioners' availability across all provinces in South Africa, with just one practitioner operating per province, or no practitioners in certain provinces. External SASS5 training and accreditation is available at a cost, however DWS has found internal additional SASS5 training prior to undergoing the accreditation process has proven fruitful in certain cases. An example from a CS perspective is the complementary technique of using miniSASS as an ecological condition indicator which has great potential to reliably supplement the ecological monitoring of river systems, contributing to the database for the generation of an annual SoR report.

Lotz-Sisitka *et al.,* (2022) investigated how CS can inform national and international reporting, and inversely how these policies and reporting systems can strengthen CS work. In this comprehensive review, it is noted that the objectives of CS programmes which have been active across South Africa are closely aligned with the SDGs, especially SDG6. Lotz-Sisitka *et al.,* (2022) also note that South Africa is one of the United Nations (UN) member states who are revising national policies and strategies to align with the aims of the SDGs. This is evident from the analysis and in-depth review conducted by Lotz-Sisitka *et al.,* (2022) of the Integrated Water Quality Management Policy and Strategy of 2017 (DWS, 2017c) where the value, impact and potential of CS work is recognised and contributions, collaborations, and bottom-up approaches to WQM are encouraged. Thus, the correlation between the aims of government strategy and CS programmes is evident, proving further justification into researching how credible CS data and information can be streamlined to inform national as well as international reporting.

3.6.2 *International water resources reporting*

Fritz *et al.,* (2019) acknowledge that CS is a non-traditional way of gathering data to inform SDG measurement and reporting, in a way which traditional data collection methods and sources are unable to. It is therefore imperative to note here that CS efforts in SDG reporting has spanned across fields and SDGs. A comprehensive study on the existing CS contributions to SDG reporting was conducted by Fraisl *et al.,* (2020) and revealed that of the five SDG indicators which are already being informed by CS efforts, SDG 6 on clean water and sanitation was included here.

This project aims to address the concerns around the credibility of CS data, specific to WQM, on the basis that previous research has proven that there is value in using CS datasets in broader contexts. For example, Quinlivan *et al.,* (2020) have acknowledged the UN encouraging the potential of CS to contribute to SDG 6 reporting as a proxy for sufficient water quality monitoring data being collected in many countries, due to varying challenges. As such, monitoring of SDG 6 through CS techniques has been recognised by the UN as potentially becoming a necessary practice across countries for the support and contribution to the continuous reporting on these parameters.

SDG target 6.3.2 is set out to monitor the proportion of water bodies which possess good ambient water quality, based on national water quality standards (UNEP, 2018). In a case study by Quinlivan *et al.,* (2020), the study participants used Freshwater Watch citizen science kits to test five parameters of ambient water quality; electrical conductivity, pH, nitrate concentration, orthophosphate concentration, and Chemical Oxygen Demand (*in lieu* of a CS test for dissolved oxygen). The results for electrical conductivity and the concentrations of orthophosphates and nitrate compared well against laboratory results, however the same comparison for chemical oxygen demand and pH revealed significant differences. Acknowledging the differences for the latter parameters, the potential for CS in monitoring Level 1 ambient water quality parameters is apparent from the former three parameters. This study by Quinlivan *et al.,* (2020) to validate the CS water quality monitoring techniques against traditional, laboratory testing for SDG 6.3.2 reporting revealed that the CS-derived data largely compared well against the laboratory-derived data. It was thus suggested that CS would be a valuable contributor to SDG 6.3.2 reporting. Although CS does not give a comprehensive set of parameters, further research and development of the CS tools, kits and procedures used can be most beneficial to integrate CS in SDG 6.3.2 reporting.

Bishop *et al.,* (2020) notes that through the incorporation of CS in national monitoring procedures, CS can aid in contributing to and achieving the SDGs. With specific focus on SDG 6.3.2, Bishop *et al.,* (2020) found that SDG-focused CS data collection methods and procedures can better represent and inform on the state of freshwater resources over a country, more so than traditional water quality monitoring programmes. This can specifically relate to water quality monitoring through citizen science initiatives and biological monitoring techniques being recognised as level 2 techniques, *inter alia*, for SDG 6.3.2 monitoring (UNEP, 2018). Understanding the state of water resources from the perspective of citizens and their on-the-ground observations gives a realistic and informed status of the state of water resources.

Water resources authorities in Zambia use CS water quality monitoring programmes to gather data on the state of their water resources in areas where governmental capacity is lacking and have found CS-derived information on WQM has proven to be reliable in informing SDG 6.3.2 reporting (Dörler *et al.,* 2020; Bishop *et al.,* 2020). Case studies such as this can aid in informing the integration of CS methods for national and SDG reporting in a South African context. **Figure 3.3** (DWS, 2022a) below shows proposed baseline SDG 6.3.2 monitoring sites for South Africa. These sites have been registered on the DWS Water Management System (WMS) and it is planned for sampling for level 1 SDG 6.3.2 parameters to be conducted on a minimum of a quarterly basis (DWS, 2022b).

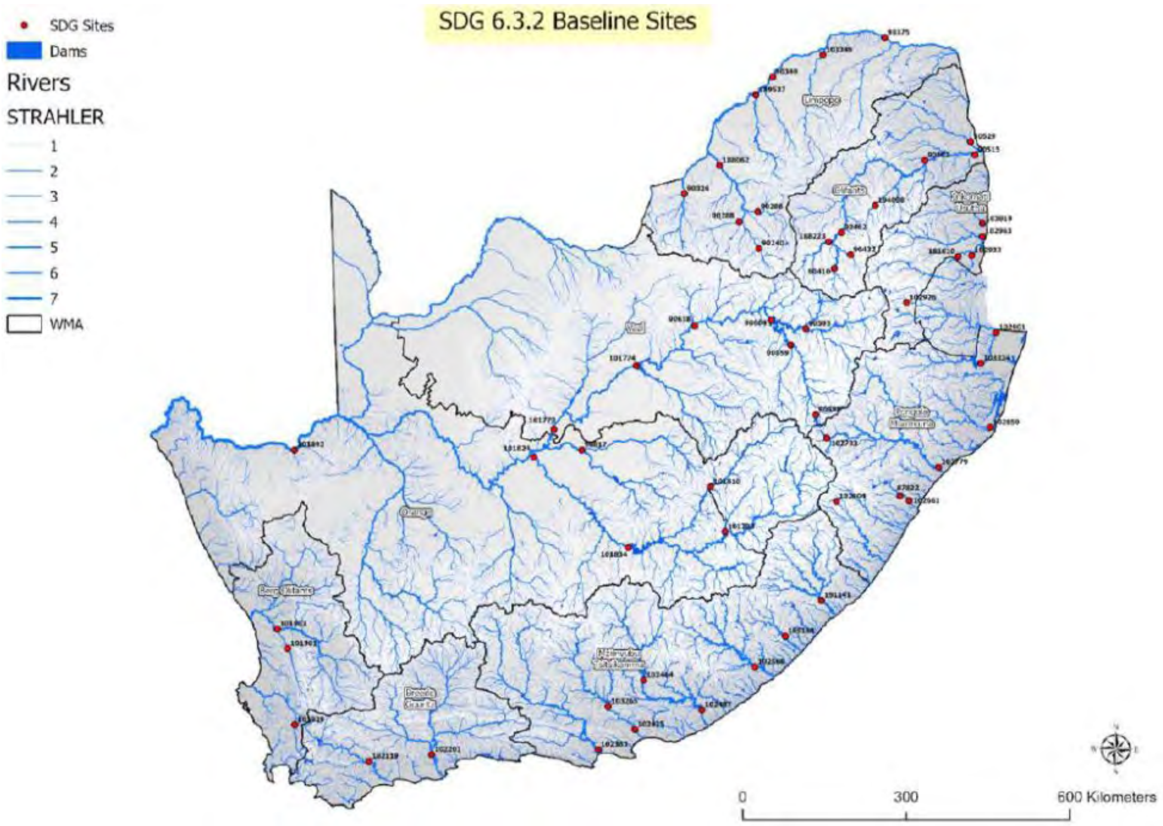


Figure 3.3 Baseline sampling sites for SDG 6.3.2 monitoring (DWS, 2022a)

When CS techniques and methods are co-designed between the private sector and government agencies, and the biases which exist in these techniques and methods are acknowledged (San Llorente Capdevila *et al.,* 2020), then CS can reliably and soundly be used for SDG reporting (Bishop *et al.,* 2020).

3.7 Participation in Citizen Science for Water Quality Monitoring Initiatives

Beyond the quantitative value which CS data generates, the promotion of environmental education and awareness, community empowerment, social mobilisation and increased social participation, and collaborative work for sustainability must also be acknowledged as points of value which CS holds in the South African context (Bishop *et al.,* 2020; Woods *et al.,* 2022). San Llorente Capdevila *et al.,* (2020) touch on the societal benefit of CS projects through the way which communities involved in CS work interact, mobilise and educate each other. This human connection and having people working cohesively together of their own volitions is an invaluable result of CS work.

Fraisl *et al.,* (2020) closely align their perception of what citizen science is with that of Shirk *et al.,* (2012) who elaborate on the paradigm that citizen science projects, termed Public Participation in Scientific Research (PPSR), correlate to one of five different levels of public participation namely: contractual, contributory, collaborative, co-created and collegial. Contractual approaches are entirely led by researchers and professionals in the field, with little to no input from members of the public. Contributory approaches are designed and led by professionals, with the extent of public participation not reaching much beyond data contributions. A collaborative approach is similar to a contributory approach, with the addition of the public being able to work with the professionals beyond just data collection such as the interpretation, information generated and distributed to the wider community. A co-created approach is similar to a collaborative approach, except the public work with the professionals from the design phase of a project right through its inception and duration, and right to completion. This approach is the most inclusive between the professionals and the public. The collegial approach involves projects designed and led by the public and involves little to no input or recognitions from professionals in the field. Graham and Taylor (2018) have also made mention of the contributory, collaborative and co-created approaches for CS projects.

With these levels of public participation in mind, it can be said that not all citizen science projects aim to promote or encourage the concepts of ecological literacy, environmental knowledge building and environmental awareness. However, this project is of the view that these concepts are critical to CS, as the development, educational capacity building, encouragement of behavioural changes are intrinsic to achieving sustainability. Thus, working collaboratively or co-creatively, specifically in a South African context, creates a viable and navigable pathway to encourage changes in perceptions and attitudes toward the environment which the public may currently possess. These perceptions could be due to a lack of education and understanding of environmental processes, perpetuating the degradation and lack of appreciation for our natural resources, specifically water resources. The enhancement of public learning, scientific literacy and community mobilisation through CS is a positive outcome of CS on its own (San Llorente Capdevila *et al.,* 2020; Ramírez *et al.,* 2023), but the subsequent community engagement with the environment and growth in appreciation of the natural environment are extensions of that outcome. When citizens are armed with knowledge and understanding, they can develop their sense of agency to present their own ideas and solutions to tackle issues affecting the environment and communities.

The characteristics and attributes of people who are participating in CS work, the nature of the institutions initiating this CS work, and the interactions between these citizens and the institutions are paramount to the success driving CS activities (San Llorente Capdevila *et al.,* 2020). In terms of the citizens, factors which effect their levels of engagement and enthusiasm are their knowledge and understanding of the data collection process, if they have previous experience in similar work, their awareness and understanding of the issues being faced by their water resources and environment, and if they possess the motivation to partake in CS initiatives. In the instance of CS in South Africa, the option to recruit individuals on the basis that they have previous knowledge, or experience is a major limiting factor for trying to increase the spatial-temporal scales for data collection, and this can also contribute to the disconnect which exists between communities of people and their local water resources. This also contradicts the nature of CS being an inclusive methodology and a compilation of user-friendly tools and techniques. Inclusion here also has the potential to gather knowledge through bottom-up knowledge generation processes. San Llorente Capdevila *et al.,* (2020) also mention that the presence of a CS project in communities, gives a strong catalyst for CS as for member of the public who are not involved, it is hoped that these civilians develop an interest in the CS efforts happening in their community.

The inclusion of citizens in the generation and collection of valuable WQM data not only benefits the institutions who are users of this data, but it informs communities through promoting knowledge creation and capacity building. In this way, relationships between research organisations and institutions, and the community can be developed (Pattinson *et al.,* 2023) and aid in fostering healthy partnerships working toward environmental care and sustainability.

Palacin *et al.,* (2020) explored, through two case studies in Japan and Finland what drives participation in digital CS efforts for the collection of environmental data. It was concluded that although values such as curiosity drove the initial participation in CS efforts, it was a greater sense of belonging and contribution which encouraged the citizen scientists to sustain their CS efforts over a long duration. This sense of contribution to a larger community and the work being done having meaning, impact, and a place in government and society should be made explicit to the citizen scientists in South Africa to encourage long-term participation. It is through the CS CoP to create a space where CS is not only recognised but also encouraged and valued.

3.8 Learn to Earn Model: Incentivising Citizen Science for Water Quality Monitoring Efforts

The idea behind citizen science is in the name; the techniques and tools developed for CS work across various sectors were designed with the citizen in mind, so that someone who does not necessarily have learned knowledge or skills in the field, something they did not have to study for, will be able to follow clear methodology, correctly use the tools, and understand what it is that they are evaluating. Ideally, this would be on a volunteer basis and has been adopted on this basis in numerous fields. CS has the potential to inform environmental decision making through the collection of valuable data. Thus, there are programmes which have been established which remunerate people for manual-labour intensive environmental work where one of the key mandates is to collect WQM data by use of CS tools.

In this research study, the value of CS for WQM work is being explored as well as how key stakeholders across the public, private and tertiary institutions can benefit from collaborative CS efforts. This exploration would be incomplete without an evaluation of those who are on the ground, collecting the data and doing work for the benefit of the environment and people. These workers, such as *Enviro Champs* under the Amanzi ethu Nobuntu programme, are imperative to the structures supporting the monitoring and reporting of South African water resources from a CS perspective. There is more value being realised for WQM data through CS techniques and, by extension, the value of those who are vital for the collection of those data should also be recognised. This has been realised by a working group which includes organisations such as UNICEF, Rhodes University, DUCT and GroundTruth. Members of this working group are currently investigating how the occupational role which Enviro Champs fill through their environmental work and work for the common good can be documented and sent for review to the QCTO. The aim is for the Enviro Champs to gain accredited recognition for the skills which they obtain through environmental programmes, such as Amanzi ethu Nobuntu, and investigating potential career pathways for these skills (Russell C, pers. comm., GroundTruth, 2023).

Through the research in this study, which aims to give value and credibility to CS work, the value in programmes such as Amanzi ethu Nobuntu can be further realised. These green programmes can feed into the streamlining of CS data and information to higher-level decision makers in the private and public sectors. These programmes have addressed unemployment but due to the capacity for funding and resources, these employment opportunities have been short-term and sporadic. Not only does this not translate well economically for Enviro Champs, but this also hinders comprehensive water quality datasets from being generated, resultantly not proving beneficial for potential incorporation into national and international reporting. The start of this recognition is through the learning-to-earning pathways.

3.8.1 *Participation in citizen science practice*

The duration of participation in CS projects can vary in length due to several factors. Two such factors include the ability of the programme to be sustained over the long-term, and the interest of the participants. Lotz-Sisitka *et al.,* (2022) have mentioned that CS projects struggle to find sustainable routes for their work. This does not only pertain to the sustained continuity of WQM work but can also extend to the ability of the staff employed under these programmes to sustain their employment once these programmes have come to an end. Long-term CS participation is not only driven through monetary incentives, but also through the recognition of the valuable work by the participants at catchment-level, which has the potential to form part of national monitoring.

Long-term participation and interest in the objectives of any CS programme can be ensured through recognition of the work done by the individuals involved to build morale and importance. Palacin *et al.,* (2020) suggests that it would be most valuable for CS programmes to explicitly share the recognition and possession of data, in order to build trust in the programme and sustain long-term CS work.

Palacin *et al.,* (2020) appeals for the designers of CS programmes to create strategies which appeal to the participants intrinsic desire to participate, using incentives only to prompt engagements for specific, pressing activities which are required to take the CS programme forward. This method of operation may prove to be fruitful in other contexts however, in the environmental space the inclusion of society is vital from project initiation so that social learning can be facilitated, valuable experience can be gained, and knowledge sharing can begin which all have the potential to improve people's intrinsic motivations to participate.

It is encouraged by Palacin *et al.,* (2020) to design and create content which appeals to the target audience for the CS participants required, in such a way that the programme caters to a diverse range of interests and values, but all centre around the main aim of the programme. In the context of CS, generating reliable datasets on WQM at particular locations overtime is one of the main aims. Having a range of learning material on YOMA and through partnerships with Rhodes University, DUCT and GroundTruth, the programme will have a variety of learning material on environmental education and related modules. Echoing the encouragement by Palacin *et al.,* (2020), this encourages participants with varied interests, which all link back to environmental issues, to participate and invites people to interact with the work over longer time periods and on an ongoing basis. Allowing participants to be equipped with environmental knowledge and understanding of CS programmes has the potential to allow for their connection with the environment and sense of environmental responsibility to be strengthened, potentially encouraging sustainable practices beyond financial intervention.

3.8.2 *YOMA citizen science pilot study*

YOMA is an online learning platform established by UNICEF to encourage youth to participate in learning opportunities. This online platform hosts learning opportunities and tasks developed by partner organisations, referred to as ecosystem partners. These partners make learning courses available through the YOMA platform on a range of topics including both hard and soft skills. YOMA is unique from other platforms in that it uses block-chain technology to build a digital CV (curriculum vitae) for the participants, automatically adding the skills acquired from completed learning opportunities and tasks to these digital CVs. YOMA also offers digital rewards in the form of Zlto (a digital currency, pronounced 'zlato') for completed learning opportunities and these Zlto can be exchanged for airtime and data vouchers. The YOMA platform uses the learning-to-earning pathway however, this is not done through the monetary incentivisation of the learning opportunities. Rather, the learning-to-earning pathway is encouraged by YOMA as the learning opportunities offered can improve the employability of the participants by adding to their hard and soft skills which are verified through the blockchain and displayed on their digital profiles. Upon completion of these learning opportunities the skills gained through the completion of these opportunities are automatically uploaded on the user's digital profile (Zittel K, pers. comm., UNICEF, 2023).

The YOMA-Citizen Science pilot study will be conducted through the Social Employment Fund (SEF) with funding sources through the Industrial Development Corporation (IDC) and UNICEF. The SEF programme will be facilitated through DUCT, working in collaboration with other partner environmental organisations across the uMngeni catchment. Besides the mandated work for each partner organisation which staff (Enviro Champs) will be required to complete, the Enviro Champs are required to monitor a designated water resource(s) for the duration of the ten-month programme using CS techniques. The WQM tool which will be the focus under SEF is miniSASS. The SEF Enviro Champs will be required to engage with the miniSASS training material available through the YOMA platform to be able to use the kit for biomonitoring. The monitoring and evaluation of this pilot study is being documented by DUCT, whereas this project will document the efficacy of YOMA to encourage the engagement with CS work through using digital incentives.

A case study conducted by Aristeidou *et al.,* (2021), on volunteer engagement using the iNaturalist citizen science application showed a positive short-term engagement with the application, but a negative long duration on the platform. The incentivisation efforts through YOMA attempt to have a positive long duration of users participating in CS based data collection.

3.8.2.1 *Objective*

One of the main objectives under this project is to assess whether incentivising data collection using miniSASS, which the Enviro Champs will already have knowledge with from work activities, will motivate people to participate in CS activities in their own free time. From a UNICEF perspective, the main objectives of this YOMA-Citizen Science pilot study are to have encouraged and facilitated youth developing new skills, youth benefitting from incentive-based learning, and have improvements to the digital miniSASS training system through YOMA (Zittel K, pers. comm., UNICEF, 2023).

A benefit of incentivising miniSASS tasks in this YOMA-Citizen Science pilot is that through the encouragement to complete opportunities on YOMA, the development of the miniSASS mobile applications and the upgrades to the miniSASS website can be trialled. This development and upgrading of the miniSASS mobile applications and website, respectively, will be documented under another project.

Currently, there is complementary operational research being conducted (linked to the aforementioned research around the occupational role which Enviro Champs fill) which will document the pilot of the miniSASS training through the YOMA platform. Besides the complementary operational research being conducted, this project team, working closely with UNICEF, will evaluate the potential for miniSASS activities to be promoted and incentivised through the YOMA platform.

3.8.2.2 *Learning to earning*

The application of the learning-to-earning model in the context of CS work stems from the inconsistent nature of environmental programmes which are only able to support CS initiatives over a short-term. The learning-to-earning model follows the notion that an individual, of their own volition, decides to participate in learning opportunities and/or tasks and can gain critical knowledge and/or skills through that opportunity, that will put them in a position to be able to receive a monetary or related benefit from doing so. The miniSASS learning opportunities through the YOMA platform will equip the user to understand the methodology and use it to complete miniSASS assessments as tasks also available on the YOMA platform. The user will then be able to earn the digital currency Zlto (pronounced 'Zlato') for their efforts (Zittel K, pers. comm., UNICEF, 2023).

The concept of the learn-to-earn model is that individuals are given the opportunity to learn new sets of skills and, of their own volition, use those skills in such a way that it aids them in generating an income for themselves. An example of this in the local context is the miniSASS opportunities which are available for South African users. The model appeals to a person's sense of agency and self-reliance as opposed to being dependant and reliant on others. This model is being trialled in a citizen science context with the additional motivation to participate being the ability to earn a digital incentive through Zlto. The Zlto (Z) digital currency is equivalent to the South African Rand (R) on a 1:3 ratio, where R1 = Z3. The Zlto rewards system has previously and successfully been trialled in the South African context with data and airtime vouchers being the exchangeable reward (Zittel K, pers. comm., UNICEF, 2023).

3.8.2.3 *Incentivising citizen science efforts*

The motivations for participation in CS initiatives can be intrinsic or explicit. Intrinsic factors are driven by a desire to know more, grow in awareness and knowledge, and be part of community efforts. Explicit factors are in the form of remuneration or incentives for the work being done (San Llorente Capdevila *et al.,* 2020). A combination of these factors has the potential to sustain an income for staff while growing their sense of environmental responsibility.

The gaps identified in CS work was the human resources to continually monitor set locations over time to track changes, and for monitoring to take place on a large enough scale and at key points throughout a catchment to inform on the state of surface water resources at a catchment scale (DWS, 2021a). Due to the simplicity associated with manual environmental labour and the use of CS tools, the remuneration (where possible) for this type of work is often at a minimum wage rate, as can be supported by the remuneration under the Amanzi ethu Nobuntu programme (2021/2022) and the Social Employment Fund programme (2023/2024) supported by the Presidential Employment Stimulus (Fowler A, pers. comm., AEN, 2023) and the Industrial Development Corporation (Schultz L, pers. comm., DUCT, 2023), respectively. However, the sustainability of these new initiatives remains a concern. The incentivisation of CS learning and tasks through YOMA is beneficial for staff (Enviro Champs) under environmental programmes such as these in that they can explore an extra avenue of income for tasks which they are already well-versed in through work. The data which Enviro Champs are collecting has the potential to be vital for use in catchment, national and international reporting on the state of water resources and, as such, the remuneration of this work at minimum wage can benefit from a review. However, the incentivisation of CS work (specifically miniSASS for this pilot) through the YOMA platform is a step toward improving the Enviro Champs income opportunities.

The incentivisation of the miniSASS activities through the YOMA platform for the 10-month YOMA-Citizen Science pilot had funding sources from the Botner Foundation and the Department of Science and Innovation. The UNICEF team is currently working on establishing a sustainable funding mechanism through partnerships to be able to prefinance the learning opportunities and tasks on the YOMA platform over the long-term (Zittel K, pers. comm., UNICEF, 2023).

3.8.2.4 *Limitations*

Although CS-based work is diverse and can vary across socio-economic classes, Hulbert *et al.,* (2019) notes that can be challenging for projects to be appropriate for varying groups across differing socioeconomic groups. Particularly, initiatives which require online activity, with stable internet connections, or use through a smartphone or computer can hinder wider participation within more rural South African contexts, where this water quality monitoring work would be valuable. Even if the motivation for the completion of learning opportunities is implicit, the feasibility of using the YOMA platform to earn digital incentives will be investigated in this project. It must be noted here that a low-data version of the YOMA platform is being developed for regions, such as South Africa, where data is costly however, this was not the version which was being piloted for CS work during the drafting of this report (Zittel K, pers. comm., UNICEF, 2023).

Technicism is, consciously or unconsciously, a driving force for evaluating the ways in which people think, operate and learn. The technicist idea that issues can, and should, be rationally and linearly addressed (Taylor, 1997) is limiting and can hinder the development of the social fabric in the environmental space, as human interactions are complex and irreplaceable. Social engagement on various issues in the environmental space are fundamental and where valuable connections are made. Technicist approaches without consideration of the value of social learning can cause great disconnects between people, and between people and the issue which they are trying to address.

The balance between keeping up to date with the fourth industrial revolution and technological developments, but still maintaining not being ruled by technicism is a challenge which must be acknowledged in this research. Although the accessibility of training through the YOMA platform has the potential to reach audiences at any time and over geographical space encourages the uptake of the CS methods, it can, however, cause a disconnect between the trainee and the concepts being facilitated.

It must also be ensured that online training material avoids varying interpretations to occur, and all instructions therein must be unambiguous. Particularly for the miniSASS training material being trialled in this pilot, there must be minimal ambiguity in instructions and explanations to ensure a standard procedure to be followed by all who engage with the material.

3.9 Chapter Discussion and Conclusion

South African policy calls for the integration of civil society in the management of water resources. There is also acknowledgement that this inclusion of citizens will work to build an inclusive, and informed society who realise effective water management is vital to alleviate poverty and promote environmental sustainability.

Research conducted by Lotz-Sisitka *et al.,* (2022) highlighted that the existing CS initiatives across South Africa would benefit from improved alignment and co-ordination – emphasising the importance of collaboration and partnerships. It is also emphasised that CS is an under-used resource to aid in informing the governance of water resources. Co-ordinated CS efforts across South Africa will benefit the organisations who monitor and report on the health of river systems based on water quality parameters, and will aid in spatial and temporal comparisons, supporting in tracking trends and identifying points of concern.

Concerns regarding the credibility of CS data will be addressed through the generation of the CS SoR report. This will be by way of emphasising following standardised methodologies and receiving sufficient training prior to beginning data collection.

With citizen science practices growing across South Africa, and permeating into the workforce, there are numerous factors which require addressing including, but not limited to: the employment opportunities to collect valuable data and findings through citizen science work, specifically in the WQM space, and the bodies which should support these opportunities; the remuneration for CS when considering the value which the work can bring to the country's monitoring and reporting structures; the careers which can be establish by generation of skills in the CS space; investigations around the credibility of these skills and the accuracy of the data; and the mechanisms to incentivise efforts, particularly youth, to participate in CS activities for people with concern in-and-outside of the green space. This research will address the last factor mentioned whilst the other complementary research projects mentioned will address the former factors.

The ability to garner interest in the CS activities across South Africa – through appealing to people's implicit motivations to be involved or their explicit motivations to gain something – not only promotes the appreciation and uptake of the user-friendly CS tools and methods but also assists in raising awareness around the state of water resources across the region. This can also support societies to bring the responsible bodies into conversations around environmental health and aids in creating a broad network of both paid and volunteer Environmental Champions.

In response to the sparse state of water quality monitoring networks established across South Africa, this project aims to demonstrate the potential and value which CS techniques possess. This will be through the generation of a preliminary SoR report from a CS perspective, a report to detail how CS practices can be institutionalised for continuity, and a report to detail how CS can inform national and international monitoring systems. These aspects will feed into a final report on recommendations on the application, expansion and consolidation of CS efforts into the SADC region.

4. Methodology

The methodology for this project is separated into four phases, each of which set out to address the aims as set out in **Table 2.1.** These methodologies per phase also correspond to the deliverables which were produced over the project duration as set-out in **Table 4.1.**

Table 4.1 WRC C2023/2024-01399 Project: Outline of Deliverables

Deliverable	Content
1. Project inception report	A report detailing the project aims and objectives, background, and expected outcomes. This report informed the team of the projected project plan, including research methods and procedures that will be adopted in the execution of the project, providing the team with a guiding document to keep track of progress and outcomes.
2. Project initiation workshop and report	A report on the open-invitation workshop, which was hosted on 20 October 2023 on CS for WQM, which aimed to facilitate discussions around the current state of CS for WQM and the future application to chart the appropriate way forward in consolidating the current CS approaches in South Africa.
3. Literature review	This report was a review of the landscape of CS in South Africa, the current state of CS practices, the current applications and limitations, and a reflection of the potential of CS practices and techniques. This review also included a discussion on how CS can contribute to the "learning to earning" pathways for youth.
4. SoR report from a CS perspective	This report collated CS findings from across South Africa to generate a report on the conditions of river systems across the country based on the available CS data.
5. CS research continuity and skills development	This report provides strategies of incorporating CS research into teaching and learning curricula at tertiary level to secure the continuity of CS research, and skills development. This report touches on where future researchers in CS can be trained and incorporated into the field.
6. Report on capacity of CS to contribute to national and international water resources reporting	This deliverable focused on the capacity and capability of CS to generate credible data that can be used at a national and international level to contribute to water resources monitoring systems and meet SDG6 goals.

7. Final report	This deliverable is this document, which encompasses deliverables 1-6 as well as outlining key recommendations to sustain a productive CS community in South Africa, and how to strengthen and consolidate efforts to expand CS further into the SADC region. This report will also outline opportunities for scaling CS.

The sections to follow outline general methodologies implemented to achieve the overall project aims (as detailed in **Table 2.1**). These methodologies provide an overview of the planning and implementation which the project team undertook, with deliverable-specific methodologies detailed in each of the chapters to follow.

4.1 Phase 1: Contextualising Citizen Science in South Africa

This phase focused on aims 1 and 4 which were to conduct a situation analysis of the use of CS in South Africa, and to determine how youth monitors can contribute to the "learning to earning" pathway to incentivise CS efforts, respectively.

Addressing aim 1: reviewing the uptake of citizen science in South Africa

A detailed review of CS efforts across South Africa is presented in **Section 3** of this report, and this was done through desktop literature reviews and initial stakeholder engagement to determine where the active CS nodes are across South Africa. Further to addressing aim 1, interviews were conducted with a group of key CS practitioners to unlock insights on the current use of CS techniques, and perspectives of the future applications of the CS tools, to evaluate the current state of CS, and the applicability of CS as a water quality monitoring tool. The interview questions were structured in a way to gather information such as their experience with the training and uptake of CS methods, experiences with applying CS data, the limitations of CS applications, and the alignment of CS data and information with reporting at local, national and international scales. This was done to encourage the practitioners to share their views on the credibility of CS data for the generators and users thereof. In interviewing the key CS practitioners and engaging with a large pool of stakeholders, the project team strongly encouraged the stakeholders to follow the research efforts to improve CS data collection including data collection frequencies, and technological developments underway to reduce error in data collection.

Phase 1 has also included a comparison between the costs associated with traditional, laboratory water quality testing methods, and the cost of the collection of the same indicators through CS. These comparisons include evaluations between: chemical tests and field indicator analyses; and laboratory wastewater treatment works (WWTW) tests vs clarity tube.

Addressing aim 4: exploring the incentivisation of citizen science in South Africa

Aim 4 was set to investigate how the incentivisation of CS can encourage the mobilisation of youth in the CS space. One of the incentive strategies was by use of block-chain technology through UNICEF as part of a complementary pilot project being run alongside the Social Employment Fund (SEF) through

Duzi-Umngeni Conservation Trust (DUCT). The programme employed 1000 youth in the uMngeni catchment to carry out environmental related activities including water quality monitoring through CS, specifically using the miniSASS technique. This programme ran in parallel to another research project, led by Rhodes University, which is investigating the formalisation of the learning pathways which these youth will be exposed to through training and mentoring towards a micro-credential for a *green skill*. The youth engagement and experience through water quality monitoring using CS will result in the youth having gained a set of skills in an under-researched and under-utilised methodology of river health monitoring, potentially enhancing the employability of these youth as the popularity and investment in CS grows. Their employability can also be enhanced through the professional networks established through the CS CoP which already exists and has been encouraged through this project.

The incentivisation through UNICEF will be through the YOMA (Youth Marketplace Agency) online platform where youth are encouraged to participate in various learning opportunities in the form of online courses, and impact tasks which they will provide evidence of to earn a digital currency through the platform. This digital currency (with which they may purchase data, airtime and shopping vouchers through the YOMA platform) is the incentive for the mobilisation of the youth to engage with the courses on YOMA which are CS related and will support their upskilling and career pathing in a CS capacity.

4.2 Phase 2: Citizen Science Data Evaluation

Phase 2 was outlined to address aims 2, 3 and 5, which are to determine what CS data is required for credible support of SDG 6 reporting, to determine the barriers to application of CS at national level and SDG 6 monitoring, and to advise on the adequacy and gaps of CS monitoring tools, respectively.

Addressing aim 2: reviewing citizen science data for SDG 6 reporting

For the project team to report on the capability of CS data to be used international reporting, a review of the current reporting requirements for SDG 6.3.2 was conducted, with a limitation noted of this project having the capacity to focus on surface water resources only at this stage. This was overlapped with the current suite of CS applications (detailed further in **Figure 6.5** in **Section 6.4**). Currently, for SDG indicator 6.3.2., Level 1 data is based only on in-situ measurements of oxygen, salinity, nitrogen, phosphorus and acidification (pH). Measured values for each parameter are compared to the national target levels and if the values meet targets 80% or more of the time, then the body of water is determined to be classified as good. At present, CS data which represents in-situ Level 1 parameters can be considered Level 1 indicator methodology, and this project aimed to investigate the capacity of CS data to achieve this. Level 2 indicators are for information on physico-chemical parameters, as well as biological/ecosystem data and pathogen data and this project investigated how CS data and initiatives can provide complementary data and information to supplement biological/ecosystem data for this Level 2 indicator, specifically through using miniSASS techniques.

A review of two CS water quality assessments, namely the biological based miniSASS and the physio-chemical based Freshwater Watch kits investigated how these methods combined has the potential to provide users with a more comprehensive water quality assessment.

Addressing aim 3: exploring barriers to citizen science applications

Aim 3 consolidated the findings from aims 1 and 2 and investigated the hinderances to the alignment and incorporation of CS in national and international (SDG) reporting. These discussions are further detailed in parts of **Chapter 5** whilst interviewing key CS practitioners and are further iterated in **Chapter 9** upon evaluating the capacity and credibility of CS in national and international water resources monitoring and reporting. **Chapter 5** also address the shortcoming of South Africa to contribute to the lack of SDG 6.3.2 reporting due to the lack of data, limited monitoring due to lack of funds and resources, and the uncoordinated monitoring efforts across sectors in the country as detailed by Statistics South Africa (2019) through an evaluation of the CS data generated over the project duration, through the *2024 Citizen Science State of Rivers Report.*

Addressing aim 5: evaluating adequacy and credibility of citizen science data

Aim 5 sought to address the credibility of CS data which is affected not only by the user and data collected, but also by how adequate the tools are in collecting data in terms of the extent to which they are able to accurately represent the water quality parameter for which they are designed. This has been evaluated in **Chapter 6** as a comparative analysis between CS data and those data derived from traditional monitoring techniques. This comparative analysis demonstrates the adequacy of the tools for their intended purpose, noting the limitations for each. Furthermore, recommendations were made on how the existing tools can be adapted to improve their credibility and range of use or, where it would be appropriate for a new CS tool to be developed to improve the range of CS tools functionality.

4.3 Phase 3: Preliminary Citizen Science State of Rivers Report

Phase 3 was outlined to address aim 6 which was to produce a preliminary SoR report from a CS perspective within the current SoR report landscape.

Addressing aim 6: producing a State of Rivers report from a citizen science perspective

Aim 6 allowed for a unique product as an output from this project and that is a SoR Report produced from a CS perspective. A detailed framework included in **Chapter 6** on the process which was undertaken to produce the report. The review of active CS nodes across South Africa aided the initiation of this aim, with the project team prioritising stakeholder engagement to achieve the aim but to also encourage the CS CoP beyond project timeframes. It is intended that the successful trial of this report may serve as a model for national application in State of Rivers reporting.

A preliminary plan was drafted for the next phase of Enviro Champ model programmes, and a key focus thereof will be the undertaking of the SoR report on an annual basis. Having Enviro Champ programme(s) across South Africa dedicated to this annual reporting will aid in having a continuous, up-to-date water quality database, resulting in an improved streamlining of data and information to inform decision-making processes as well as international (SDG) reporting (Taylor *et al.,* 2022).

4.4 Phase 4: Strengthening and Scaling Citizen Science

Phase 4 was outlined to address aim 7 which was to make recommendations on how to strengthen CS in water quality monitoring and to explore the opportunities for scaling CS.

Addressing aim 7: recommendations to strengthen citizen science practice

The final aim of this project is addressed in **Chapter 11** and provides recommendations on how to strengthen CS for water quality monitoring in South Africa, with the possibility of upscaling that to the SADC region. These recommendations stem from the information obtained from previous phases of this project (see phases 1-3 above) which analysed CS and its credibility and gaps. Recommendations on the upscaling of CS programmes will also align with the nascent developments in the green economy and impact financing, specifically to use these opportunities to address youth unemployment through skills development.

The recommendations echo the critical point of standardising CS tools training, reiterated by the development of the online learning material (Russell *et al.,* 2024) which encourage knowledge sharing with the aims to improve the overall credibility of users and quality of CS data collected. Other methods of consolidation and knowledge sharing have also been encouraged through the sharing of data through open-source online platforms such at the miniSASS, WaterCAN, and Freshwater Watch websites. Further, these recommendations will reflect on best practice for the use of the tools and elaborate, where possible, on the potential for further research and improvement on the use of the tools.

4.5 Innovations and Products

The following points detail the innovations achieved during the project duration:

- Production of a State of Rivers Report and model using CS to collect key River Health status information to produce the report.
- Use of data (from the Freshwater Watch, WaterCAN and miniSASS websites) which can be used for reporting on the state of South African rivers and within SDG 6.3.2 reporting
- Creating a CS model which can inform policy
- Capacity building initiatives through promoting access to online learning opportunities for CS applications
- The use of social media networks and platforms to promote CS efforts in South Africa
- Promoting the development of the miniSASS mobile application

In the suite of CS tools currently available, there are tools which this project will focus on in terms of evaluating their range of use for different environmental conditions and to be used complementarily in reporting in conjunction with laboratory-based water quality monitoring indicators. **Table 4.2** details these innovative uses of the tools, the target group for these innovations and the application thereof.

Table 4.2 Citizen science techniques and the innovative ways in which they aimed to be researched

Product Name	Target Group	Innovation	Application
Clarity tube as a CS tool to monitor performance of WWTW in SA	Communities close to WWTW	Traditionally the performance of WWTW in terms of their discharge license is measured by a long list of chemically and laboratory tested parameters. This research tested the application of the clarity tube to measure the performance of WWTW	Measurement of turbidity / suspended solids
MiniSASS	All citizens	This project researched the potential application of CS derived biomonitoring and CS derived data to allow more comprehensive spatial representation of SAs water resources for: 1. State of Rivers reporting 2. SDG 6.3.2 reporting via Statistics South Africa	Measurement of SDG 6.3.2
Freshwater Watch kits	All citizens	The applicability and suitability of these kits which provide indications of nitrate and phosphate levels in river samples have been trialled in the South African context.	Measurement of SDG 6.3.2

4.6 Knowledge Dissemination and Research Uptake

The proposed research has been shared through various presentations at local relevant conferences and meetings. These are summarised in **Appendix E,** and do not include the dissemination and promotion of the project and objectives via social media and radio platforms.

5. Perceptions of the State of Citizen Science for Water Quality Monitoring

Various steps in planning and processing were undertaken for the generation of the CS SoR report. This ranged from stakeholder identification, engagement, organising and hosting workshops and training sessions, conducting interviews, to data collection, database management and analysis, and the subsequent drafting of the CS SoR report. This section highlights the qualitative data which has been gathered through the prioritisation of stakeholder engagement to gauge the perceived current state of CS for WQM and its perceived future potential.

A workshop on The State of Citizen Science for Water Quality Monitoring was facilitated by the WRC/UKZN-CWRR project team on 20 October 2023. This workshop was hosted by the University of KwaZulu-Natal (UKZN) and facilitated in collaboration with GroundTruth, with support from the Water Research Commission. Facilitating this workshop in a hybrid (in-person and online) setting allowed for a greater reach of stakeholders to participate and make invaluable contributions. The workshop programme can be found in **Appendix A** and details each session. **Table 5.1** below details some of the organisations, among others, which were represented at the workshop.

Table 5.1 WRC/UKZN *Citizen Science for Water Quality Monitoring* workshop participating organisations

Department of Water and Sanitation (DWS)	Water Research Commission (WRC)	University of KwaZulu-Natal (UKZN), Centre for Water Resources Research (CWRR)
United Nations Children's Fund (UNICEF)	University of South Africa (UNISA)	University of Johannesburg (UJ)
South African National Biodiversity Institution (SANBI)	eThekwini Municipality	KwaZulu-Natal Museum

The purpose of this workshop was to bring together the key stakeholders in the CS for WQM space and having conversations around the potential for growth of CS for WQM practices, the concerns around CS for WQM practices, and to gauge what these participants foresee for the future of CS for WQM practices. Further, this workshop was intended to chart the way forward regarding CS training, uptake of products and research and practice continuity. These participants included representatives from the private, public and education sectors with the intention to broaden the range of input from the workshop participants. Another aim of this workshop was to get an understanding of where there is recent or currently active work around CS for WQM taking place, to gauge where there are interests and research around CS for WQM developing, and where there are potential collaboration opportunities. A key discussion in this workshop centred around the availability and credibility of CS data and the use of these data in WQM. The need to establish the objectivity of CS data was highlighted as a key aspect that requires greater scrutiny.

5.1 Mapping activity

The workshop activities included a mapping exercise to spatially map out where CS for WQM is active, and for everyone – facilitators and participants – to get an idea of where everyone else in the room was based, and where there is CS for WQM work and research currently taking place, localities where there are growing interests in CS, or where there is potential for collaboration. This was also to aid the project team in identifying regions across South Africa which were not represented at this workshop, and to take that forward and research if there are relevant representatives there who can aid in informing the project team about the scope CS for WQM work, or lack thereof, in those regions. Participants illustrated the value of this exercise by indicating various WQ monitoring sites, highlighting communities where CS has either been piloted and/or practiced and indicating locations where CS for WQM can add value, as displayed in **Figure 5.1**.

Figure 5.1 Workshop participants engaging in the mapping activity

5.2 Citizen Science for Water Quality Monitoring Programmes: Past and Present

This participant-led discussion session was facilitated to provide a space to gauge the concerns, queries, lessons learned, points of interest, and other relevant points of discussion from the participants. This session was also conducted to determine if there are any significant points of concern or developments within the CS CoP. This session raised numerous valuable points which are summarised into categories in **Table 5.2**.

Table 5.2 Past and current citizen science for water quality monitoring programmes main discussion points

Category	**Discussion Points**
Citizen Scientists (or Enviro Champs) employed under environmental programmes	Short-term employment: Not financially or environmentally sustainable. Career pathing and professional development: Promoting the development of skills to take forward in work environments; development of learning pathways for the recognition of the occupational role of CS for WQM work. Understanding of the work purpose: What the tool observations are measuring and how this links back to environmental issues. Addressing more than environmental issues: How the environmental work being done can address social issues too *e.g.,* converting illegal dumping sites into vegetable gardens or parks.
Data management	CS data validity, credibility and objectivity: How can this be ensured as it is vital before using CS data in environmental reporting and decision making? Storage: Over the long-term; a database to store the data; a responsible party to host the database; ensuring the data being collected on the ground is collected and submitted to the responsible body for storage. Access: Having the database be accessible for all interested parties. Data quality: Ensuring the consistency and appropriate data quality control procedures to ensure the credibility of CS data.
Tools and techniques	Use of the tools: A standardised methodology of using the tools and simplification of the manuals; the training must be standardised and made available for retraining where necessary. Contextualising tools and techniques for different environments e.g., rural and urban.

Collaboration, Participation and Inclusiveness	Varying companies collaborating and supporting CS for WQM work: Recognition of the importance of CS for WQM; connections to share resources, knowledge and skillsets. Social learning: The efforts by the citizen scientists can be recognised by their community and encourage the community to participate and assist in the betterment of the environment.
Communication and Dissemination	Ensuring that information generated through CS for WQM is rapidly made available to practitioners and is useable to manage WQ.
Ethical challenges	How do we ensure that we experiment *with* communities and not on them? Working with communities to develop, test and use CS tools in a manner that ensures their dignities and involves them every step of the way.
Possible futures for CS for WQM in South Africa	While still in its infancy, CS for WQM has a great potential for expansion in South Africa and may eventually be taught in high schools and tertiary institutions.

Among others, two main points of concern which the workshop participants expressed were the use and credibility of CS derived WQM data, as well as how to define citizen science and citizen scientists.

In terms of the credibility of the data being collected, there was a call for the simplification for instructions on how to use the tools, a standard way to use each tool and the use and sharing of the data collected, particularly for practitioners in local communities.

In this discussion, it was also mentioned that the future of CS across fields must also acknowledge indigenous knowledge systems and practices which have been conducted for years, prior to the Euro-centric notions of citizen science. There are criticisms of CS too often having a Euro-centric definition and not accounting for the indigenous knowledge and Afro-centric practices which exist and have existed. The discussions also cautioned against implying that CS practice should be led by academia or traditional scientists, but that there are varying levels of collaboration between citizens and the traditional scientific communities.

5.3 Breakaway Group Discussions

The breakaway group sessions were with smaller groups of people, to allow the project team to engage in more concentrated discussions with the participants.

This session was initially going to have the participants separated into three groups, one each to represent the public, private and education sectors. Due to the turnout of numerous people representing the same organisations online and in-person, it was decided to rather have two breakaway group discussions with individuals mixed among sectors. Logistically it was simpler to host these discussions with an online group and an in-person group, receiving feedback from each toward the end of the session.

The conversations began with everyone giving a brief explanation of their experiences with citizen science work – not limited to the water sector – and this was to get an understanding of the experience and interest in the room. Thereafter, the groups were asked the same set of questions as detailed in each sub-section below.

5.3.1 *The future of citizen science for water quality monitoring work*

The participants were asked to consider the CS for WQM tools and techniques – based on their recent learning about the tools or their learned experience using the tools – and think about the future of the practices. This open-ended prompt encouraged the participants to think of the current state of the practice and ways in which the practice can be approached going forward.

The central concern around the CS for WQM data was raised in this discussion. One aspect which this concern pertains to is the validity of CS for WQM data, and if it would be a reliable data source for decision-makers to use. The validity is dependent on the use of the tools and the range of information which we can deduct from the observations. It was noted here that the training and instructions on how to use the tools must be standardised and as clear as possible, minimising room for misinterpretations. Here, there is a link to one of the main aims of this project, to produce a SoR report from a CS perspective. This report has the potential to speak to the validity of CS for WQM techniques and data and contribute to the rigorous verification assessments necessitated by government and academia to build trust in the data to be used for monitoring and decision-making. Part of this conversation also brought forward the point that specialist input should be included to support the efforts to verify CS data and speak to its reliability.

There was a consensus that CS-derived data for WQM must be made available for the use of the public and must be fed back to those who collect the data, explaining the meaning and potential uses of the collected data. This is not only to improve open-source WQM databases but also to improve the understanding and capacity of those who are collecting the data, typically as unskilled workers under short-term environmental programmes.

It was noted that the environmental programmes which encourage the use of CS for WQM tools need to be supported and funded to allow them to be sustained over longer time-periods. The point was also raised that each time these programmes stop-and-start, the field workers are starting from a new baseline for that locality each time, making the monitoring a less sustainable practice and making it more difficult to track change overtime.

It was also discussed that there is a need for an integration of CS for WQM tools and techniques in the environmental education space, particularly at school-level. Beside the intention of institutionalising the practice, this will also give children hands-on experience on water quality monitoring techniques as well as experiential learning on water quality parameters, and the factors by which they are affected.

5.3.2 *Citizen science for water quality monitoring in environmental reporting*

This discussion centred around the participants' views of how CS for WQM can contribute to and be integrated into environmental reporting. The discussions centred around how the current CS for WQM tools can be used.

The participants were asked to detail how CS can potentially feed into environmental reporting. The point that departmental water quality monitoring networks are sparse, with reference to the few networks across KwaZulu-Natal, was raised and that the CS for WQM work programmes should aid in generating valuable data to broaden these sparse networks. This led back to the concerns around the short-term nature of CS monitoring programmes and how this hinders long-term databases from being developed.

At an international level, there was a point raised around SDG reporting, particularly for SDG 6.3.2 and 6b[1], where CS for WQM data is required for a large spatial range across South Africa to give a comprehensive indication of the country's ability to meet those SDG targets.

The point of feeding these reports back to the communities – in formal, governmental formats or in simplified, relatable formats – was raised and it was mentioned how the recognition of the communities' contributions to these vital reports can have the potential to motivate the citizens and mobilise more CS participation.

5.3.3 *Expansion of the citizen science for water quality monitoring tools functionality*

In a discussion around the broadened functionality of the tools, it was mentioned here that the tools can be used as a basis for experimental design, clearly understanding the intended use and applications and expected observations, under different conditions, and then using that to test for expanding use of the tools. Here, the tools could also be used against the development of other methodologies attempting to observe the same or similar parameters.

A concern raised in this section was not to do with the functionality as much as the understanding of the tools. An example was made of the clarity tube and how easily it can be misunderstood by citizen scientists; just because the water clarity is high according to a low turbidity score, does not necessarily mean that the water is potable. Thus, there was a call for a simple indicator pamphlet or booklet to be received with each tool to aid in the interpretation of the data. For the clarity tube example, this could explain what turbidity is, cases where clear water is deemed safe or unsafe, explanations of how these tools should be used in conjunction for a more comprehensive indication of the water quality at a point of the rivers. This data interpretation aid would also contribute to capacitating the citizen scientists on what the data means, what they can – with a degree of certainty – deduce about the river health, and what environmental issue the tools are linking back to. A note here is to consider the range of languages in South Africa when developing this material to promote a more inclusive practice.

[1] SDG 6b: 'Support and strengthen the participation of local communities in improving water and sanitation management.' (UN Water, 2025)

5.4 Investments in Citizen Science for Water Quality Monitoring

It was discussed that CS for WQM has both social benefits and data-related benefits. As such, there are investments which have been made in this space supporting the promotion of the practice with consideration for improved data management and social developments. These investments stem from various sources of funding and under different projects, the outline of which is displayed in **Figure 5.2**.

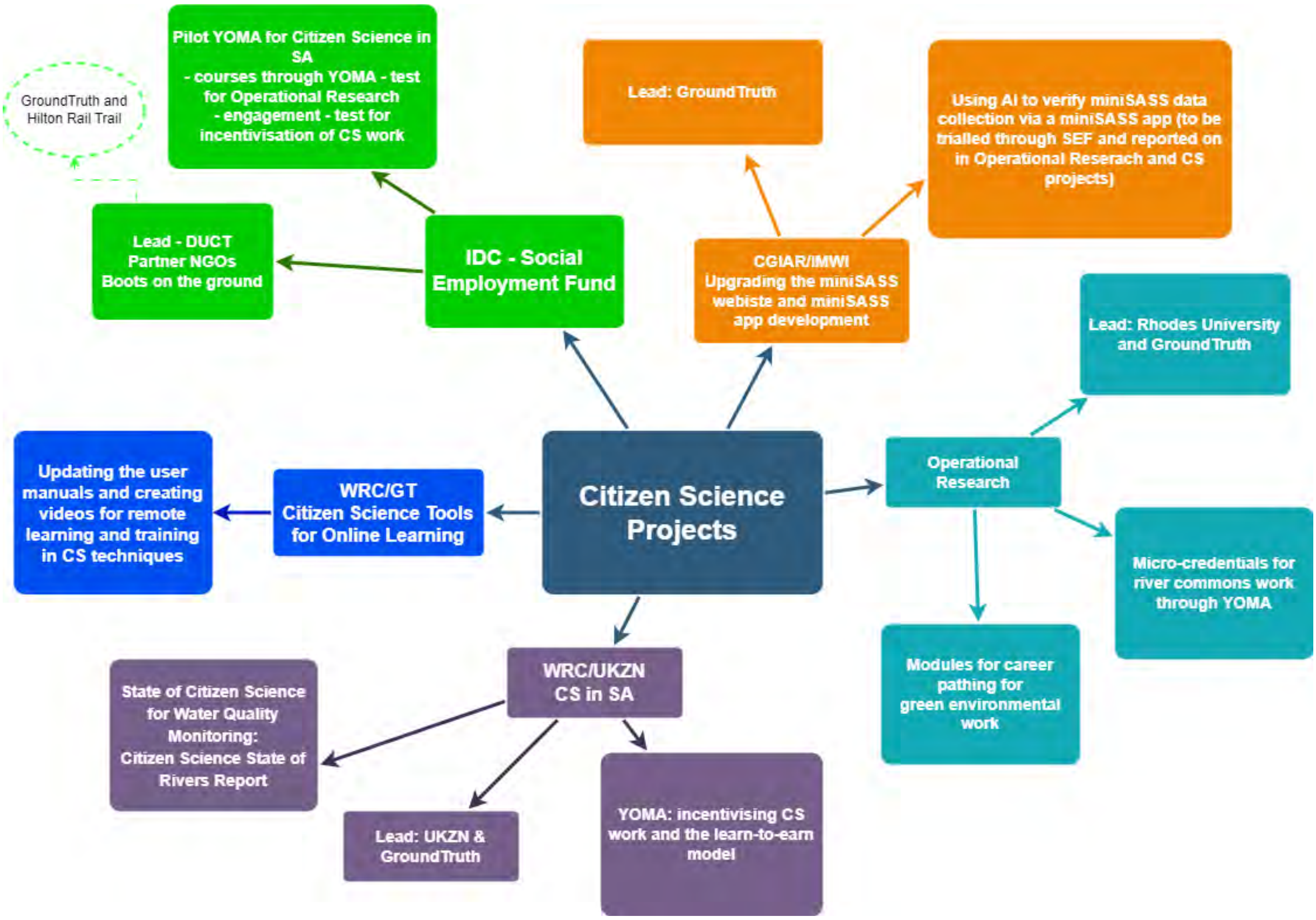


Figure 5.2 Mindmap outlining the linked projects around the YOMA platform

5.4.1 *YOMA platform*

The fourth session of the workshop began with an introduction to the research around the YOMA platform. The purpose of this session was to highlight the investment in research and operations around CS for WQM work. This session also answered queries around the professional development of Enviro Champs, as well as the simplification of the manuals and instructions on the use of the CS for WQM tools.

The YOMA platform was introduced and the relation around the relevant projects was shown as in **Figure 5.2**.

5.4.2 *Opportunities for citizen scientists: operational research*

Concerns which were raised in the session leading up to this included the credibility of the data, the career options and professional development for the staff under environmental programmes who are taught CS for WQM skills, and these concerns were addressed during the introduction to the UNICEF-Rhodes University lead operational research around the career pathing and occupational role which Enviro Champs (referred to as such specifically under that project) fill.

The operational research acknowledges that the CS for WQM skillset is unique and aims to find the gaps in occupations under which these skills can potentially fill. This will be done through creating the relevant modules and learning content for the staff to engage with. These completed modules and learning opportunities will be made available to the public through the YOMA platform and once completed and verified by the YOMA team, this learning opportunity and the skills gained will appear on the participant's digital CV on YOMA.

This research will use those learning opportunities (termed micro-credentials) to build a portfolio to take forward to the QCTO for the recognition of the occupational role which Enviro Champs fill. The aim here is to get the QCTO to recognise citizen science for water quality monitoring as a recognised occupation in South Africa.

Using YOMA requires engagement with online platforms and digital spaces, which obliges the staff to become digitally literate to participate, a step to keep the participants up with the fourth industrial revolution.

5.4.3 *MiniSASS website and application*

The upgrade of the miniSASS website and development of the mobile application are significant developments in the CS for WQM space. This session answered a great deal of the queries around the validity of CS data, specifically the miniSASS data, and gave the participants an acknowledgement that there is room for error in CS, which is challenging to measure, but these uncertainties are being acknowledged and accounted for as far as possible.

The session detailed the developments behind using artificial intelligence (AI) to improve the identification of macroinvertebrates thus improving the credibility of the miniSASS data being collected. This will be facilitated through the miniSASS mobile application and will allow the users to upload their collected observations to the miniSASS website. Such efforts will aid in building a miniSASS data repository with the added functionality to also use the application to submit clarity tube data.

The use of technological advancements (such as mobile applications and the use of AI) is line with the fourth industrial revolution, as with the YOMA and Operational Research, which is reassuring for use of CS for WQM in the future.

5.5 Reflections on Citizen Science: Interviews with Key Citizen Science Practitioners

Globally, the uptake of citizen science (CS) practices is becoming more widespread (Ramírez *et al.,* 2023). In the context of CS for water quality monitoring (WQM) across South Africa, stakeholder interest is growing as evident from environmental programmes which increasingly promote CS such as the Amanzi ethu Nobuntu programme and the uMngeni-uThukela Water: Water Security Action Hub in KwaZulu-Natal; the Friends of Groups, Hennops River Revival, and the WaterCAN monitoring in Gauteng; and the Mbeko Eco Club and the Gouritz Cluster and Cape Winelands Biosphere Reserves in the Western Cape. These are a few of the numerous organisations and/or groups who have engaged on this Citizen Science State of Rivers project and are actively involved in data collection contributing to the drafting of this report.

Interviews with select experienced CS practitioners were conducted to gain an understanding of the perceptions which exist on the current landscape of CS practices. This included perspectives on the application of CS techniques, the limitations which the practices possess, and concerns around the credibility of CS data and gaps in reporting. These interviews were conducted to provide insight on these aspects of CS work and inform the project on the knowledge gained, observations, and lessons realised through experiential learning by various people in the CS space, to assist in gaining an understanding of the current state of CS for WQM.

The perceptions of the current CS landscape have also been informed by participation of a diverse group of stakeholders who attended a workshop hosted by the project team on 20 October 2023 on *The State of Citizen Science for Water Quality Monitoring*. The workshop provided attendees with an opportunity to share their experiences with CS as well as become informed on some of the developments and research which were underway in the CS for WQM space.

Note: From this point forth, the term “citizen scientists” refers to people who are/were employed under a project and/or organisation under which they participated in monitoring rivers using CS techniques. Any use of the term “citizen scientists” which does not align with this definition will be noted as such.

5.5.1 *Methodology*

The eight CS practitioners were selected from the developing network of collaborators which had been growing over the project duration (just over a year). These practitioners were interviewed due to their experience in the CS space, particularly pertaining to river health.

The practitioners who contributed to this report range in their years of experience with CS techniques and when they were first introduced to CS concepts. These practitioners remain actively involved in CS efforts, either directly or indirectly, and have been responsive in the overall efforts of this project. These interviewees also cover a wide range of involvement in the CS landscape in South Africa from management of programmes, training facilitators, and citizen scientists who have themselves been involved in on-the-ground monitoring. This range in roles was deliberately chosen for variation in their perspectives and experiences. Details of the interviewees are contained in **Appendix F.**

The interview sessions were facilitated in such a way that the interviewee had room to bring in their own experiences, opinions, and points of interest. This semi-structured interview style (Petrescu *et al.,* 2017) allows for learning and knowledge exchange to occur organically under a particular topic. The preamble to each interview included a brief background of the interviewee such as their current position within their organisation (where applicable), their experience with CS including first exposure and current use, the CS tools and techniques which they've used, and some detail on how they store and use their CS data. The questions posed are summarised in **Table 5.3.**

Table 5.3 Citizen science practitioner interview questions and motivations for asking each question

Interview Questions	Motivation behind asking this question
1. What benefit do you see from the use of CS?	To highlight the benefits which the practitioners believe CS possesses as motivation to further research and implementation efforts.
• What benefit have you/citizen scientists whom you've worked with or trained, seen in their efforts, if any?	To gain an understanding of the motivations which drive participation in CS for WQM efforts.
2. Do you have a suggestion on how to better integrate CS into varying communities and societies?	To explore the first level of potential barriers of the application of CS methods before exploring the potential barriers in integration into national and international reporting.
3. What gaps, if any, do you believe exist in CS reporting?	To evaluate if key CS practitioners are engaging with CS reporting and to identify where there are gaps in reporting processes.
4. At what spatial scale do you think it best to report on the state of water quality?	To gain an understanding of the scales for reporting which currently exist and use these answers to give thought to scales for CS monitoring and reporting.
• What suggestions do you have to maintain the balance between CS being an accessible practice while maintaining the credibility of the practice and data being collected?	To prompt the interviewees to share ways in which errors in data collection can be minimised for improved credibility of CS practices.
• Throughout your time monitoring using CS techniques, have you noticed any patterns, gaps or trends in the data?	Prompted interviewees to reflect on any trends which they've noted over their involvement in CS which would be useful to comment on the continuity of practices, context of applications, and continuous

Interview Questions	Motivation behind asking this question
	capacity of their involvement to be able to track trends overtime.
5. In your opinion, does CS for WQM have any potential to aid in national water resources management, monitoring, and reporting on the state of South African water resources?	This question was strategically posed last in each session to give the interviewees a chance to answer this having just reflected on both the potential and limitations of CS practices from the previous questions.

In a few instances, supplementary questions which arose during the discussions were asked such as:

- In your experience, who have been a willing, engaging, and enthusiastic target demographic in CS activities?
  This question arose from a conversation around the engagement of people in CS for water quality monitoring efforts being dependent on the affordability, monitoring locations, and user interests.
- What gaps, if any, do you see CS filling in the water resources space in South Africa?
  This question was posed to guide the final question around the potential for CS to aid national water resources reporting. This question was posed particularly to those with experience with water quality reporting.

5.5.2 *Emergent themes from the interview responses*

Responses from the interviewees and workshop attendees have revealed trends in CS practices as well as unique observations from experiences. These emergent themes were noted and are discussed in each section below, as well as added to the table in **Appendix G** to generate a quantitative analysis of the responses. This was based off the eight interviews conducted and does not include discussions or feedback from *The State of Citizen Science for Water Quality Monitoring* workshop.

5.5.2.1 *The perceived value of citizen science*

The practitioners were asked about what value they believe CS possesses. Responses indicated two perceptions of value: value of the CS practice itself, and the value which CS has for the citizen scientists themselves.

The value of citizen science practices

Discussions at the workshop and seven of eight interview responses acknowledged that CS techniques are useful for environmental awareness and education, with various programmes, community engagements, and workshops being mentioned as opportunities for awareness and education. At a fundamental level, CS techniques are tools for understanding the links between humans and their impacts on the environments toward creating informed citizens. Beyond this, an advantage of CS data was the volume of data for a particular issue which could be collected by a large network of users, as mentioned by all interviewees. This large volume of data could prove useful in determining the conditions of rivers in localities across the country and give an indication of sites which may need more immediate intervention than others. It has been acknowledged that at both levels, using CS for awareness and data collection, CS provides tools for empowerment and knowledge creation.

CS was noted as a valuable methodology to expand the spatial scale of WQM and to generate a larger database through crowd-sourced methods. The limitations noted here by six of the interviewees and discussions at the workshop were around standardisation of the methodologies being followed and a point of concern mentioned was for mechanisms to ensure this standardisation. This is to ensure that the data which is being collected by citizens can be relied upon for reporting, monitoring and decision-making at varying levels of WQM.

A notable benefit of CS practices is the broad range of the applications for citizens from varying backgrounds. Included in the examples given were farmers who were able to take the CS practices and lessons to monitor local rivers for application in the management of their activities. This reflection touched on the application of the transparent velocity head rod (also referred to as the velocity plank) in tracking flow changes over time and to check impacts of abstractions on the flow of a stream. The farmers in this instance were able to use the CS technique to confirm their intuitive observations of streamflow reduction activities. The information gathered through the applications of CS practices allows people to become better informed, aiding their decision-making and choices. For example, one of the interviewees noted that CS helped a community decide when would be best to plant certain crops depending on water flows and river conditions, linked to the volume and quality of water to use on those crops, respectively. Another example provided by several interviewees was that of CS having the potential to generate an interest in the aquatic monitoring field, and how CS aided in directing their careers to freshwater monitoring, environmental management, and related fields. A recurring example was the application of CS techniques as an educational tool, for both children and adults alike. For schools in particular, the observed data can be used to feedback to scholars and staff and spread awareness around the condition of local rivers.

Linked to this is the value which CS can have in supplementing existing environmental efforts, which every interviewee acknowledged to be beneficial. An example of this provided by one of the interviewees is that they introduced CS methodologies to an existing *environmental monitors* model. The *environmental monitors* model entailed groups of young citizens patrolling local communities on the lookout for issues which have, or potentially could have, an impact on the environment including illegal disposable nappy dumping, general illegal dumping of solid waste, illegal sand mining, and the spread of alien invasive plants. The incorporation of CS WQM can have the potential to produce river health data which the monitors can link to one or more of the environmental issues observed and communicate this back to the community. This interviewee also mentioned that there was recent acknowledgement from the community of the efforts by the monitors to reduce the nappy dumping along rivers. This is a useful case which shows how bringing science to the communities can aid in building awareness as well as igniting changes in behaviour.

The value of citizen science for practitioners

An overview of the state of CS for WQM would be remiss without investigating the value which the practice brings to the citizen scientists themselves. The interviewees had all worked with and/or as citizen scientists and shared their experiences noting the value of engaging in CS initiatives which has been gained by citizen scientists, and what can be improved to add more value.

An improvement suggested by the interviewees was around the continuity of CS practices relating to the sustainability of paid opportunities for CS practitioners. In a separate current project lead by Rhodes University, the occupational value of the work which citizen scientists possess in the green space is being investigated (Sithole, N., pers. comm., GroundTruth, 2024). That body of research will provide deeper investigation into the occupational value of CS, which is something which had been mentioned by several of the interviewees and workshop attendees. Another point raised was of the value which CS data can have to contribute to water resources monitoring, especially in a South African context where resources for monitoring are limited (DWS, 2021a; DWS, 2022a). Here, all interviewees made mention of opportunities for CS to supplement broader water resources monitoring by government departments. This could be through the potential for funding through those offices and the monitoring being either managed by government or through partnerships between government and private environmental organisations. Another example of a sustainable funding model is through academic institutions through grant funding to develop research relating to various fields such as ecology, hydrology, environmental management, public health, and other relevant courses or modules.

Improved funding mechanism for CS initiatives may have the potential to prioritise skills development for staff under these programmes. It was noted by three of the interviewees, who work closely with citizen scientists employed under CS projects, that short-term projects often did not provide opportunities to develop in-demand skills which could aid finding employment after the project comes to an end. This particularly relates to those seeking employment opportunities and do not possess a tertiary education qualification. It was emphasised that after a short-term CS project is concluded, the workers would have to start over in the search for job opportunities, not having gained skills which would allow them to grow professionally and contribute to their career path. This is due to the nature of CS projects being short-term and lacking sustainable funding for over the long-term, and the limited job avenues in the CS space so these CS opportunities have scare offerings in terms of career paths for people, specifically for youth. A possible solution to this challenge would be to avail training courses to staff to do of their own volition, on both hard and soft skills which they could add to their CVs and apply in future workplaces e.g., courses on time management, conflict resolution, facilitating meetings, etc.

Although the opportunities for career development based on CS projects and experience are limited, five interviewees revealed instances where there were successful career development opportunities or the development of an interest in pursuing a career in the environmental field. This included involvement in CS practices sparking an interest in freshwater monitoring and influenced two separate individuals to pursue studies in freshwater technology and environmental management, respectively. In both instances, the individuals had also gone through SASS5 training courses and intend on becoming accredited SASS5 practitioners. There was also an example provided by an interviewee of a citizen scientist gaining experience in his role and working his way up in the company to his current role of managing all monitoring projects.

Recognition of the efforts made by citizen scientists can give them a sense of pride in the work and the message behind it. In this way, people have been motivated to keep efforts up even beyond the duration of a contract. This recognition had been mentioned by the interviewees and workshop attendees in the form of praise and approval from local ward councillors and communities, especially in those instances where the CS practitioners were able to communicate their observations back to their community, and where they were able to link the CS work with other efforts to address environmental issues such as the removal of alien invasive plants, the collection of solid wastes, reporting sewer and water leaks, and promoting awareness around general and specific pollution impacts on water quality.

Another positive experience shared was that through these CS and environmental awareness initiatives, the CS practitioners were able to garner the interest of young children and play a role in developing their senses of responsibility toward the environment through involving them in the activities or simply communicating the issues and lessons learned in a way which allows them to understand and engage. This was echoed by the workshop attendees and five of the interviewees who reflected that scholars were engaged and enthusiastic to be involved in CS activities and learning. It was also noted here that the incorporation of CS in the school curriculum could be a useful way for scholars to engage in experiential learning, noting that it would be especially useful to incorporate CS practices for those grades and subjects which already have river health in the curriculum. One interviewee in particular runs environmental club programmes for local schools, and found that engaging children in CS helps them to appreciate life in different forms, appreciate nature, and gives a mechanism to facilitate learning about ecosystems and environmental health in a relatable format. It was noted here that despite the results obtained, the learning experience in some cases is more important in allowing children (and adults) to understand their impacts on river ecosystems. In terms of the school curriculum, engaging in CS techniques can also be a practical experience on how to make a scientific enquiry and apply the scientific method, staring with a hypothesis and investigating to come to a sound conclusion. This exploration can be useful where laboratory equipment is limited, but an accessible scientific enquiry would supplement their learning.

5.5.2.2 *Trends, use, and understanding of citizen science data*

It was strongly emphasised that the standardisation of data collection methodologies was needed to generate a CS database which is reliable and can grow over time. Interviewees and workshop attendees mentioned that the credibility of data is largely dependent on the way in which the observations were carried out and how the CS tools were used. Here, it was emphasised that CS must be resourced to ensure the provision of enough training, time and tools to conduct the monitoring in ways which comply to standard procedures.

An interviewee who has been involved in CS training noted that guidance on what to do with the data after collection, such as uploading to the miniSASS website, was often omitted from the training sessions as the focus was placed on getting the methodology correct. This omission can be considered as contributing to the gap in understanding the full application of CS data, as there is no motivation or impetus for citizen scientists to consider sharing their data beyond their immediate superiors or community. Other limitations noted were the lack of access to the internet due to mobile data and network issues, as well as the low levels of digital literacy which exists amongst the citizen scientists who are often involved in projects, typically relating to older individuals.

This uncertainty of the usage and applications of the data after collection was a recurring point of concern mentioned by seven of the eight interviewees and revealed how the lack of feedback loops contributes to a lack of understanding the purpose and reasoning for data collection. This also revealed the disconnected ways in which CS data is stored across users. The storage of data varies across groups or organisations in ways which it is either straightforward for their teams of citizen scientists to feedback the data (an example provided was through communication on a WhatsApp reporting group), or in ways which align best with their systems, for example those who have developed digitised datasets where data is added manually or automatically via linked mobile applications. The interviewees were also asked about the subsequent use of these datasets, and three responses indicated that the data is used to inform just themselves and their immediate communities. In a few of the instances, the relationships with local municipalities had been established better than for other groups, so there'd be an existing way to connect and feedback data to these local authorities. However, five of the eight interviewees indicated that they do share their information with their local municipality. One of the interviewees mentioned that they report back to local municipalities to persist in further building and developing their relationship with the local municipality in case opportunities for collaboration do arise. An interviewee mentioned bringing local offices of regional waterboards into the conversation around CS data, and finding links to how the practices and data could benefit them and the citizen scientists. Expectantly, the diligence in reporting came from those who were required to feedback progress and findings to funders of these monitoring efforts under an environmental programme or project. Two interviewees also mentioned feeding this data back to local traditional authorities in an accessible format is key to mobilising and encouraging CS practices in communities. This feedback channel can also allow for finding solutions to address issues impacting environmental health to be considered by the broader community, and not just a smaller group of environmentalists. Responses from interviewees and workshop attendees included support for having central, public platforms to submit and share data so that CS practitioners can see that their efforts are part of larger developments in the river health monitoring space, that their data will be stored for future reference, and that the data is adding to a collective for use in research, decision-making, and collaborations.

Conversely, an interview and conversations from the workshop revealed that there are CS practitioners who advocate for the practice but prefer not to share their data beyond use for their own knowledge and applications. The reasons provided included concern around impacts on trusting products farmed from areas where the data has been shared and has been shown to have rivers in unfavourable conditions. This could have an impact beyond local trade extending as far as exports to outside of South Africa. Hesitancy to share data also stems from the possibility that data shared could be misunderstood or misinterpreted, and that people may draw too-broad conclusions from the shared datasets. The preference not to share data also has links to the monetary value which the data and the collectors thereof possess, and where there should be mechanisms for payment for the data and to remunerate the collector of that data. This will also be addressed in the aforementioned operational research led by Rhodes University.

The balance between allowing CS to be an accessible practice while still maintaining the credibility of the data was posed to the interviewees. Workshop discussions and all but one of the interviews indicated that thorough training is essential to ensure that the data which is being collected has been done so following standardised methodologies. There was also mention of in-person training being preferred over online or video sessions. An interviewee also mentioned that the training cannot be once-off and there should be a mechanism in place for trainers to check that their trainees are still conducting their assessments correctly a month or two after training. Beside improved reliability of data, these check-ins would also ensure that the CS practitioners are appropriately training others, where applicable.

Interviewees were asked about the trends which they have noticed in CS data which they have collected. It was noted that the monitoring has not been consistent enough to track trends and patterns in the data. This has links to unsustainable funding sources which exist for CS projects over shorter time periods, mentioned by both the workshop attendees and half of the interviewees. Interviewees mentioned that CS practitioners had developed an expectation of the data to be unfavourable and indicate that the rivers are in a poor state, such as the miniSASS scores and clarity values both scoring low. So, the trend noted was the consistently poor results. When queried on what drives the citizen scientists to keep monitoring if they always expect poor results, the responses included that it was a requirement of the job they were employed to do, but others mentioned that they wanted to keep hope that conditions would improve (especially those who engage in other linked environmental efforts such a reporting sewer leaks, clearing illegal dumpsites, and the removal of alien invasive vegetation), and to keep monitoring to check that the conditions were not getting worse. Seasonal trends were noted through miniSASS monitoring in the Western Cape, specifically that there are typically more macroinvertebrates per group found in warmer seasons than in the colder seasons, however the groups of macroinvertebrates found are generally the same. This again echoes the observations by other interviewees that there is no significant variance in results each time. Two of the interviewees had experience in monitoring rivers through CS techniques over larger spatial scales, and in each instance, there was a notable improvement in river health closer to the source of the river than further downstream where there were occurrences of agriculture, industry or residential use of land along the river.

5.5.2.3 *Use of citizen science data for reporting*

When queried regarding CS reporting, every interviewee described uncertainties regarding using CS data for reporting. This uncertainty is justified based on the disconnected nature of data collection and storage, and the uncertainty in the applications and meaning of the data collected. Reporting often occurs as a result of a contractual obligation more than an exercise used to inform the CS practitioners and community. The other concerns and suggestions which arose during these interviews all linked to reporting for feedback loops to CS practitioners, the community of practice, and the public around or reliant on those water resources. These concerns are detailed further in **Section 5.5.2.5.**

Another consideration which was posed to the interviewees was their opinions on the spatial scales at which water resource quality reporting should take place. This prompted the practitioners to think about the scales at which they have already reported or are currently reporting. The answers varied from smaller scales (within a particular city or town, local scales smaller than primary catchments, and along the stretch of a river) to bigger scales such as at a primary catchment level, provincial, national and regional. A few interviewees had multiple answers, providing their opinions on the justification for each. The motivation behind posing this question was for the interviewees to reflect on the audiences which they are already reaching or trying to reach, or which they think CS practices should be reaching. The latter point links to those audiences of existing formal reporting, and initiates thinking around the potential for CS to contribute to this reporting.

An interesting observation was that only two interviewees answered from the perspective of conventional water resource quality monitoring and reporting. Two lessons can be deduced from this. Firstly, the practitioners who answered from a conventional perspective do have experience with conventional style of water quality reporting and an understanding of hydrological catchment sizes (such as primary and secondary catchments). They had started linking CS monitoring to existing conventional reporting, finding overlap between the two and where CS could support and contribute to broader water resources reporting. Secondly, the remaining interviewees answered this question from a CS perspective which helps in understanding suitable reporting scales as determined by experienced practitioners. Again, these spatially based reporting scales varied which could be for several reasons such as that practitioners' levels of engagement (for example local or regional), years of experience, and availability of resources. Although it was an open-ended question, this prompted reflections on how these questions were answered, and what these varying answers meant.

5.5.2.4 *The importance of feedback loops*

A common concern raised was around the lack of a feedback loops and the concern around how this would impact the continuity of CS practices. These feedback loops were mentioned as two different types. The first is feedback to those who have engaged in CS activities as part of a programme or project, and shared the data observed with their superiors. The interviews revealed that this data has been collected and the meaning behind it has not been communicated back to those who collected it; either not at all or in a way where there is still a degree of uncertainty in the meaning of the data and its relevant applications. This raised the point that CS practices and programmes must develop people into citizen scientists, not just data collectors. Fraisl *et al.,* (2020) detail the five different approaches to CS, and this project is of the perspective that CS approaches can only be sustainable if they are collaborative, co-created or collegial. These approaches would be included to ensure that accessible and understandable feedback loops are in place for citizen scientists to understand the rationale for the practices and reveals why it is vital for CS practices to be adopted and developed further.

The second feedback loop entails feedback to broader communities and communities of practice on what CS efforts are aiming to achieve and the meaning of the observations. One of the challenges noted here is the indifference shown by some communities which is possibly accredited to the lack of understanding of the issues which are being addressed by a smaller portion of a community (i.e. those who are engaging with CS and supporters thereof). Reliable and inclusive channels to communicate and disseminate valid information in an accessible manner has been highlighted as vital here, which may also aid in the awareness and potential up-take of CS practices.

The effectiveness, importance, and applicability of these feedback loops depend on the communities of people which are being informed. The interviews and conversations during the workshop noted that in some instances the members of a community or society in an area who are more dependent on water directly from a stream (such as for business, domestic use, or recreation) are more likely to be concerned with the quality of that water and health of the overall stream. Those who are not as directly cognisant to river conditions (such as those who live further from rivers and access water through taps) are less likely to engage with the efforts and objectives of CS. This links to the levels of environmental awareness and education which exist in some communities and reveals that there could be improvement to emphasise the importance of environmental health for all. Two interviewees highlighted that more provocative and intensive environmental awareness campaigns could better prompt people into action and to provoke a real change in behaviours and perspectives.

5.5.2.5 *Potential alignment of citizen science with national water resources management*

The one question which every interviewee responded the same to was: "In your opinion, does CS for WQM have any potential to aid in national water resources management, monitoring, and reporting on the state of South African water resources?". Every interviewee responded that CS does have its place in national water resources management (NWRM), however, this question was phrased broadly to allow for each interviewee to elaborate more on their views.

The motivations mentioned by interviewees for identifying that CS can have its place in NWRM include: the wide reach of citizens to conduct monitoring where there are sparse monitoring networks by mandated departments; the volume of data being fed to decision-makers will also be increased with wide networks being reached; wider monitoring networks through CS techniques can give a broad view of the condition of rivers across the country and aid in identifying where there are issues at particular locations which could require more urgent intervention than other locations; and, the techniques are accessible and cost-effective which is beneficial for departments or municipalities where there are budget constraints. One interviewee identified CS as having a unique position and opportunity to facilitate bottom-up planning and bridging the gaps between civil society and national-level decision-makers. A recurring concern was uncertainty around how CS can aid NWRM in a co-ordinated and strategic way which uses resources efficiently and has focused aims and outputs. There was also emphasis on the engagements with communities being conducted in productive and community-inclusive ways and not done in exploitive and exclusive manners. This inclusivity extends to others in the private sector, who may have access to communities and private landowners to aid in facilitating collaborations in these spaces. Several interviews and discussions at the workshop also mentioned the valuable role which catchment management forums and ward councillors can play in encouraging and/or establishing collaborative efforts and local communities of practice.

An interviewee responded with concern that the CS model needs to be revised from the current volunteer-dependent model before it can aid NWRM. In this revision, mechanisms must be put in place to ensure that data collection does not only adhere to standardised methodologies, but that the efforts are also coordinated and systematic in that they align with gaps in conventional monitoring systems, the monitoring locations are strategically selected and not at random, the individuals who are employed to monitor are employed over a long-term, and that the efforts align with the aims of water resources policy and legislation. The notion echoed here is that CS techniques should be taken up by people who conduct monitoring for remuneration as well as those who do so voluntarily, but the people who are remunerated should feed into the revised CS model where their data should be used for NWRM, whereas volunteers can use the techniques to inform and educate themselves and their communities, but due to the uncertainty in adherence to methodologies, this data should not be used in NWRM. Those who would be gathering data under the revised model would no longer be considered citizen scientists but rather hold another title as trained monitors. A suggestion proposed here to fund employment under this revised model was to have companies in industries whose activities can have a potentially harmful impact on a river system (such as agriculture or mining sectors) to invest in funding these freshwater monitors. Another interviewee made a point linked to this suggestion, that there should be a core team of trained monitors driving the CS and linked work in a locality, but this core team can also promote environmental literacy and CS skills development within the broader volunteer community.

It can be argued that having to go through various trainings to be a qualified citizen scientist is somewhat contradictory to the inclusive nature of CS, however in the plans to take CS techniques forward and scale-up the practice for informing NWRM, best practice and adherence to standard procedures would be vital to be enforced. This would reassure those reluctant to advocate for CS as anything more than an educational tool as the emphasis on following standard procedures can assist in building their confidence in the techniques adopted.

A suggestion posed by one of the interviewees was to incorporate CS into existing government-based environmental programmes so give more meaning to the work which is being done. The examples provided were through the Expanded Public Works Programme (EPWP) work around clearing water ways, including the cleaning solid waste pollution and the removal of alien invasive plants. Here, the CS practice can supplement the purpose of their activities while holding a structure in the government department. The point made here is that there are synergies which already exist, and which CS can be integrated into.

5.6 Chapter Discussion and Conclusion

The workshop managed to achieve the goals of bringing different sectors in the CS for WQM space together to engage in conversations around the state and future of CS for WQM, gaining insight on perspectives of people who have varying experience with the practice, and differing opinions on the future of CS for WQM. Here, the gaps, uncertainties and concerns around the practice could be noted and addressed in real-time or during this project.

The next steps are to consolidate the mapping activity onto a digital map, as well as the online responses and the responses received via email communications, to identify and acknowledge the spatial gaps in CS for WQM work.

The project team are to use the feedback on the training and engagement with the tools in drafting the strategy for the facilitation of the SoR from a CS perspective report. The workshop aims and outputs are also to be used to inform this strategy.

Also, based on the conversations from the workshop, the project team are to acknowledge the conceptual gaps which are present and are pressing points of concern for stakeholders who are active in the practice.

A consistent benefit of CS applications, reflected upon by all interviewees, is to create a way to link accessible, real-time water quality data to the habits of the people who live in close proximity to water bodies, in an effort to change people's behaviours and attitudes toward the environment. This links to the acclaim which CS receives as an educational and awareness building tool.

However, CS practices are still met with reluctance to incorporate the data observed in reporting beyond community or project-based levels and decision-making. This lack of confidence in the datasets can be linked to concerns around the data collection methods being followed, and the uncoordinated and inconsistent monitoring which limits applications of the data observed.

A suggestion to address the challenges surrounding understanding CS data, having it contribute to a database for wider application, and generating information to create feedback loops would be to have the data management and interpretation as a mandatory part of training sessions on CS practices. This would ensure that data are not being arbitrarily collected, with no learning nor exploration of applications being facilitated. Another suggestion made, was for the online, central CS data platforms to present the data in layouts which are useful and make sense for various users, not only data for use in Microsoft Excel, but also in automated pie charts or bar graphs for simplified methods of interpretation.

Overall, there is an agreement that there is potential for CS to aid NWRM however there is also an agreement that this must be done in a strategic, inclusive and co-ordinated way. The suggestion here is that there should be provincial representatives to champion the uptake of CS techniques and assist in the co-ordination, training, and management of these efforts, and to also ensure that correct methods are being practiced, so that the data being observed is reliable and can be used for decision-making. Once these essential issues are addressed to conduct CS practices in co-ordinated and strategic ways, with sustainable financing, then it is believed that CS will have great value in NWRM structures.

6. The State of Rivers from a Citizen Science Perspective Framework

The use of CS to aid in WQM has been widely accepted as useful and inclusive tools and techniques which have the potential to aid in water resources monitoring and management (Bishop *et al.,* 2020; San Llorente Capdevila *et al.,* 2020; Warner *et al.,* 2024). This is echoed by the WWQA (2024a) who promote CS techniques as readily available methods to collect valuable data on the quality of water resources, and specifically to aid in achieving SDG targets 6.3.2 and 6b, where there exists "huge potential for citizen science to be applied directly to monitor ambient water quality (SDG indicator 6.3.2) while simultaneously increasing the participation of local communities in water resource management (SDG target 6b)" (WWQA, 2024a: p. 2).

In the South African context, the Amanzi ethu Nobuntu programme can be used as a useful case study of a citizen-centred river health monitoring programme which worked to promote the uptake of CS to monitor river health and use those observations to grow and benefit the local knowledge of environmental issues. In the second phase of this programme, which ran between 2021 and 2022, CS monitoring resulted in a substantial database of river health monitoring data being generated over the Umgeni catchment in KwaZulu-Natal. Similarly, the river monitoring programme run by the Duzi-uMngeni Conservation Trust (DUCT) through the Social Employment Fund (SEF) has promoted the uptake of CS practices through incentivising youth to engage in river health monitoring. Not only does the programme motivation recognise the value of river health data and monitoring, but it also prompts youth to engage with the state of their local rivers (Brownell, pers. comm., 2025).

Acknowledging the above adoption of CS practice and the support for CS to aid WQM, this chapter will be evaluating the potential of the use of CS for WQM to produce a CS SoR report. The report will cover the conditions of rivers across South Africa. The CS SoR report will provide a CS perspective while conventional monitoring will inform a mandated formal SoR report from the DWS (based on specialist monitoring under the REMP).

Prior to the generation of the CS SoR report, procedures were drafted for effective stakeholder engagement and the development of guides to assist in motivating stakeholders to play a role in contributing to the CS SoR. These engagement procedures and practises were put in place for the project team to better facilitate and streamline communication, ensuring that all stakeholders received the same information and access to training materials.

6.1 Introduction

The monitoring of water resources is essential to gain a sound understanding of the actions which need to be taken to best manage these resources. In South Africa, the DWS provides the country with feedback on the conditions of river systems through the SoR Report. The SoR reporting structure was developed with the intention to support the State of Environment (SoE) reporting and to be used as a communication mechanism to convey important information pertaining to the country's water resources to the citizens of South Africa (Strydom, 2003).

Originally, the SoR was the reporting mechanism which followed the River Health Programme (RHP) under the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP) and was conducted to collect biomonitoring data from river ecosystems nationally. The first SoR report was published in 1998 and included the work which formed part of the pilot RHP in the Crocodile River (Strydom, 2003). The RHP was then superseded by the River Ecostatus Monitoring Programme (REMP) as the RHP did not align completely with the National Water Act. The REMP monitors the ecological condition of river ecosystems across South Africa to support the management of the river systems, and informs the SoR report (DWS, 2021a).

The SoR report is informed by the REMP (DWS, 2021a) which utilises techniques such as the South African Scoring System version 5 (SASS5) aquatic biomonitoring technique and the Index of Habitat Integrity (IHI) riparian and instream disturbances assessment to monitor river health, and which only qualified personnel with the relevant accreditations can conduct. The rise in water quality challenges bring to the forefront the need for innovative and alternate solutions to address these challenges.

Citizen Science and River Health Monitoring

The 2020/2021 SoR Report monitoring locations are illustrated in **Figure 6.1** and although there is an established network, there are still notable spatial gaps in these networks. Whilst the figure shows the intended monitoring locations, there are instances where some locations could not be monitored as "a lack of human capacity remains a major challenge with implementing the REMP" (DWS, 2022a: p.155).

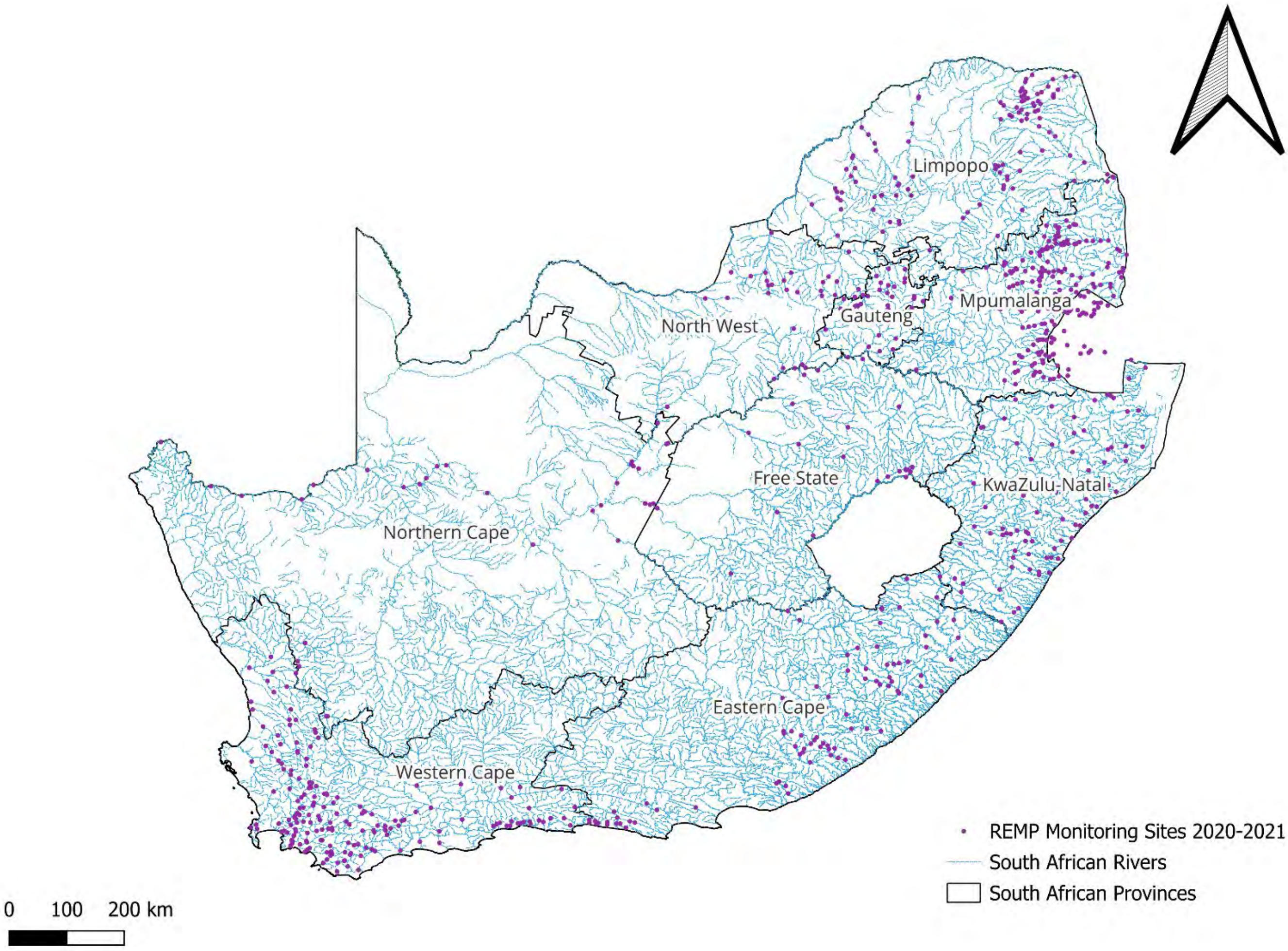


Figure 6.1 River Ecostatus Monitoring Programme (REMP) monitoring locations for 2020/2021

Water resources and aquatic ecosystems are under strain thus a greater spatial distribution of monitoring and broader involvement by civil society in the management of water resources is encouraged. Taylor *et al.,* (2022) emphasises that co-engaged learning, such as through CS approaches to river health, are effective techniques in prompting behavioural and attitude changes towards environmental issues. Further, the involvement of civil society in the monitoring of water resources has the potential to mobilise a large monitoring network across the country which would greatly inform the nation of the state of rivers. This is provided that the techniques are applied with adherence to standard methodologies, and that the data is captured correctly, and shared.

The World Water Quality Alliance (WWQA) (2024a) has recognised CS as a readily available solution to address the unavailability of data to inform the progress on the SDG indicator 6.3.2 regarding ambient water quality of bodies of water. This report will establish where the active CS communities of practice (CoP) are located across South Africa to determine where the applications of CS can be used for water resources reporting.

This report has evaluated the current state of CS for WQM through interviews with key CS practitioners and through the generation of a SoR report from a CS perspective. These insights will inform the capability and capacity of CS in reporting on river health at national and international levels.

6.2 Citizen Science Practitioners Engagement: Fundamentals

CS projects and efforts should be collaborative, and therefore, as part of this research, stakeholders were invited to voluntarily collaborate on the project through the collection of data that would contribute to the 2024 CS SoR Report. The call for collaboration was aimed at stakeholders across South Africa (**Appendix H**). In the process of engaging with this research, it was identified that there is great interest and efforts in the CS space nationally. In these engagements, interest was additionally received from a few stakeholders in Lesotho and Namibia.

The effort to produce this South African CS perspective on water resources generated great interest in the environmental and water management landscape. This is evident from over 200 attendees of the CS SoR initiation workshop which was hosted online on 01 February 2024 as shown in **Figure 6.2**. The workshop was attended by stakeholders from inside and outside of South Africa, comprising various organisations from the public, private, non-profit, and academic sectors. The workshop proved to be fruitful in promoting the CS SoR efforts and as a testament to the scale of interest in CS for WQM.

Figure 6.2 Introductory presentation by Dr Mark Graham at the online CS SoR workshop on 01 February 2024

6.2.1 *Encouraging a citizen science community of practice*

As highlighted by Gold and Wehn (2020), stakeholder engagement is a vital and time-consuming aspect of CS projects. Thus, the project team prioritised stakeholder engagement over a year, up until the *2024 Citizen Science State of Rivers* report was drafted with the intention of disseminating the final published report to collaborating stakeholders. This project encouraged collaboration from inception with individuals representing the public, private, and education sectors on the project reference group. These collaborative efforts were carried throughout the project with the project team liaising with stakeholders from the different sectors in the project planning (**Appendix I**) begin to develop a network of organisations and stakeholders who have an interest in CS for WQM. This network was used to circulate invitations to attend the project initiation workshop (**Appendix L**), to continue gauging the interest of potential collaboration (**Appendix H**), and to invite the network to the workshop hosted to launch the CS SoR efforts (**Appendix M**).

6.2.2 *Channels of communication*

The critical first step in the stakeholder engagement process was the creation of a CS practitioners database. This database contained a list of stakeholders whom the lead organisations (GroundTruth and the University of KwaZulu-Natal - UKZN) had worked with before in CS-related spaces, as well as those who may be interested in learning more about CS. This database of over 1 000 contacts was kept updated with the names, organisations, and contact details of the CS stakeholders.

The primary means of communication for this project was via email. The email communication was sent from a dedicated email address – sor2024@groundtruth.co.za for recipients to easily recognise communications as associated with this project. To get an understanding of the CS network, a general email (**Appendix I**) was sent out to stakeholders early in the project duration to gauge their interest and experience in the CS space.

With the aim to reach as many potential collaborators as possible, social media accounts for the project were created on Facebook, Instagram, and LinkedIn in early January 2024. The accounts all shared the name *Citizen Science for Rivers* and the engagement figures per platform as at 28 November 2024 are as shown in **Table 6.1**, demonstrating the growing public interest in CS efforts.

Table 6.1 *Citizen Science for Rivers* social media engagement as at 28 November 2024

Platform	**Followers**
Facebook	111 followers, 54 likes
Instagram	159 followers
LinkedIn	635 followers

The specifics of the SoR report, methodology and details were discussed through a virtual workshop on 1 February 2024. The workshop focus was to inform potential collaborators of the role they would potentially play if they chose to volunteer to be part of this project. Participation could be on two levels where stakeholders could either contribute to the data collection aspect or could expand on their participation by using the data which they've collected to generate their own local SoR reports. If stakeholders were unable to participate on either level, they were still encouraged to share the opportunity for collaboration within their networks and to those whom they believe have had an interest in participating or in the CS space.

The specifics of collaboration were all documented and included in a guiding document for the participants to refer to: *CS SoR Collaborators Roadmap*. This document included sections such as information on the tools and training, data collection, and the SoR reporting. The guiding document also included a process flow, shown in **Figure 6.3**, of the steps and intended direction of the CS SoR efforts.

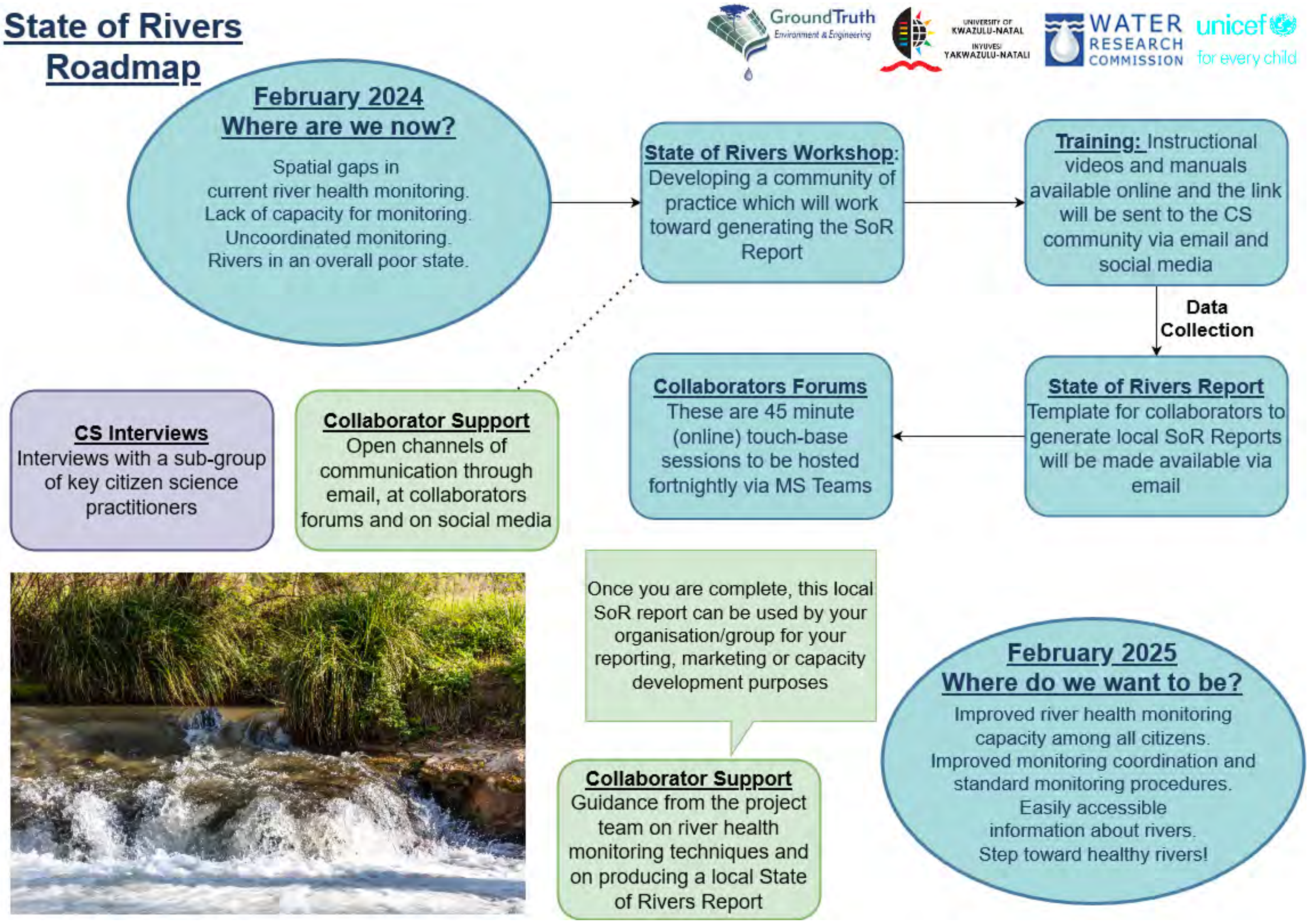


Figure 6.3 Flow diagram of the intended steps and direction of the CS SoR efforts

This project was also promoted by various groups and organisations such as features in the Strategic Water Partners Network newsletter, the eThekwini conservancies communique, the UKZN Centre for Water Resources Research (CWRR) newsletter, the Southern African Society of Aquatic Scientists (SASAqS) newsletter, a presentation to the DWS National Water Monitoring Committee, a radio interview on Bush Radio, and presentations at the Ripples for Change Water Security Event hosted by Varsity College, the Water Security Symposium on Citizen Science hosted by IIE MSA, and the Women in Citizen Science Webinar hosted by WaterCAN.

Stakeholder engagement continued to be prioritised including email communication, interviews, and collaborator's forums as detailed below. This resulted in a collective and collaborative effort to assist in monitoring rivers across South Africa, the findings of which to be incorporated in this SoR report.

6.2.3 *Forums: collaboration and guidance*

The collaborative nature of this work involved convening interest and participation from various stakeholders in the form of a regular *Collaborators Forum.* These stakeholders had differing types and levels of experience in data collection, project co-ordination, research, and advocacy in the CS space, and ranged from novice to well-experience. These forums were online meetings for the collaborators to connect, go through training materials for the different tools and techniques, and raise any questions or queries, covering the following topics:

- The 2024 CS SoR Collaborators Roadmap (link in **Appendix J**)
- Navigating training platforms
- Riparian Health Audit (RHA) training (link in **Appendix J**)
- Exploring monitoring locations (to encourage co-ordinated monitoring and connections)
- Local SoR reporting – use of local SoR reporting templates (link in **Appendix J**)
- Results interpretation guidance (link in **Appendix J**)

6.2.4 *Provincial citizen science networks*

Collaborators were separated per province and an email went out to each provincial group. An example of this can be found in **Appendix K**. This email served as an introductory email to connect the stakeholders based on proximity – working in the same or nearby catchments and/or river systems – if they had not already done so. These connections would then allow these stakeholders to better co-ordinate monitoring efforts. These connections would not only be beneficial for collaboration under this project, but also for other projects and efforts in the future.

6.3 Lessons learned

A great amount of interest and enthusiasm was garnered in the early stages of promoting the idea for the CS SoR report and the opportunities to get involved. However, there were challenges in translating the interest which was expressed into commitments to play a role in CS monitoring for the generation of the CS SoR report. The recurring reason for this challenge was related to the capacity for potential collaborators to voluntarily allocate time and resources to train for and conduct CS monitoring.

The stakeholder engagement process can become complex when there is a large number of stakeholders involved. Although the dedicated project email account did assist in building recognition of the project, especially through social media, this also appeared to hinder communication. It was found that stakeholders who were contacted about the project from a personal connection were more likely to respond to calls to collaborate and less likely to respond to communication from a project email account. The project team experienced this through personally addressed emails and calls between those who are experienced and well-connected in the CS and WQM field. These personal connections assisting in mobilising support for the SoR project show the value in building, encouraging, and partaking in the CoP in the CS and WQM space, and highlight the value of maintaining communication in the CS CoP beyond project objectives.

6.4 Citizen science tools and techniques

As detailed in *Compiling State of Rivers Reports and Posters: A Manual* (Strydom, 2003), the main indices used in the compilation of a SoR report are the South African Scoring System version 5 (SASS5) biological monitoring technique, the Fish Assemblage Integrity Index (FAII) biological monitoring technique, the Riparian Vegetation Index (RVI) vegetation assessment, and the Index of Habitat Integrity (IHI) habitat assessment. These scientifically verified indices are practical to regularly measure and represent environmental and ecosystem changes over time (Strydom, 2003). The Water Quality Index (WQI) have also been used in conventional SoR reports such as the *State of Rivers Report Greater Cape Town's Rivers 2005* (RHP, 2005b), *and the State of Rivers Report uMngeni River and Neighbouring Rivers and Streams* (WRC, 2002). Notably, all these parameters require accredited professionals to observe and report on.

Two of the project aims were "to determine what crucial CS data is required to ensure credible and scientific water resource quality to support SDG 6 reporting" and "to produce a preliminary State of Water Resources from a CS perspective within the current State of Rivers report landscape". SDG indicator 6.3.2 – the proportion of bodies of water with good ambient water quality (UNEP, 2018) – reporting operates on two levels of reporting where level 1 focuses on in-situ physico-chemical data for phosphates, nitrates, dissolved oxygen, acidification (pH), and salinity, and level 2 data can be either in-situ or remotely observed data, on physico-chemical parameters as well as biological/ecosystem, and pathogens. Both levels recognise citizen approaches as acceptable data sources. Level 2 reporting additionally recognises biological indicators as an acceptable data type to inform progress on SDG indicator 6.3.2 (UNEP, 2024). This is depicted in **Figure 6.4** below from UNEP (2024).

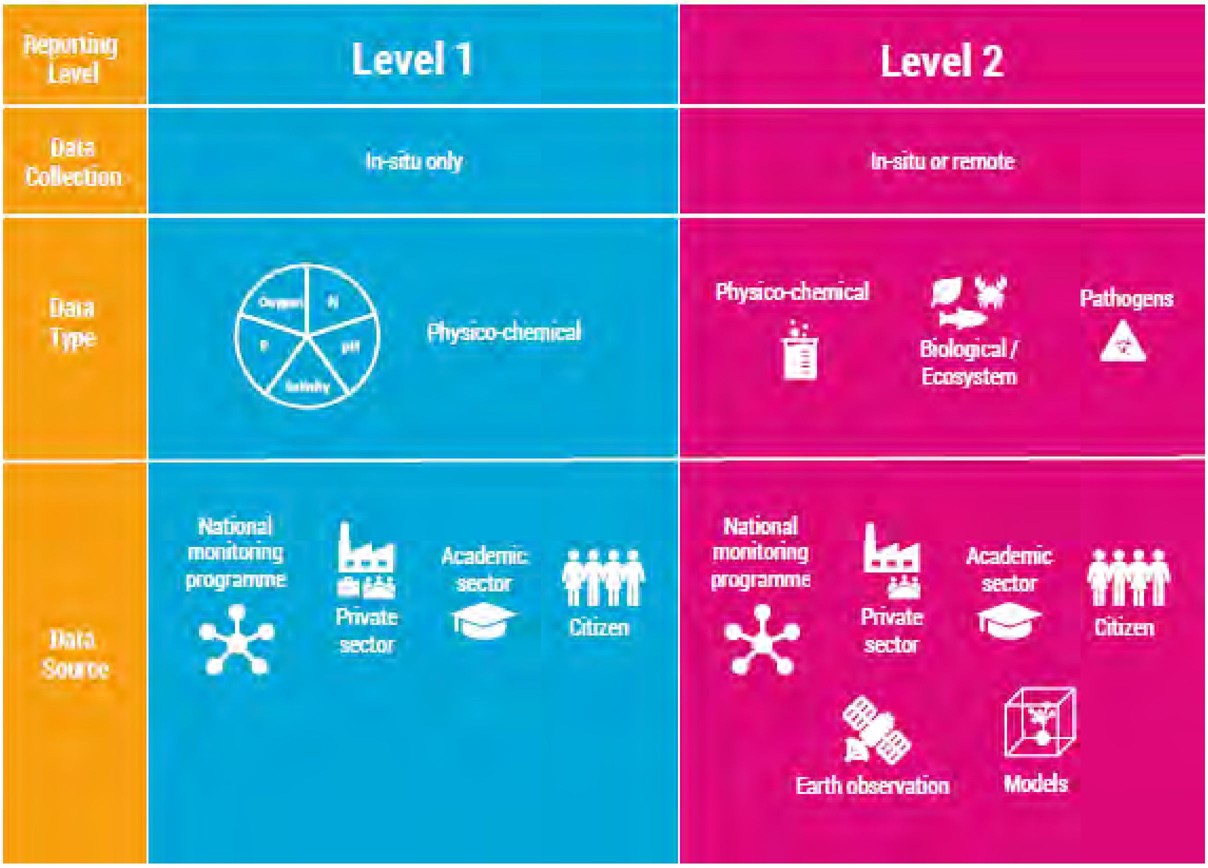


Figure 6.4 Level 1 and 2 reporting levels for infomring SDG 6.3.2 (UNEP, 2024: p.11)

The aims to investigate the potential for CS data to inform both the national SoR report as well as reporting for SDG 6, specifically SDG 6.3.2, led to a comparison between the entire suite of CS tools (as per Graham and Taylor, 2018), the main SoR indices (WRC, 2002; Strydom, 2003; RHP, 2005b) and all the SDG 6.3.2 monitoring parameters (UNEP, 2024). The techniques are represented in light orange, blue, and green, respectively, in **Figure 6.5.** This comparison yielded the overlapping monitoring parameters as the clarity tube, miniSASS tool, and the Riparian Health Audit (RHA) tool. The collaborators were also encouraged to use other CS-based tools or techniques which they have available.

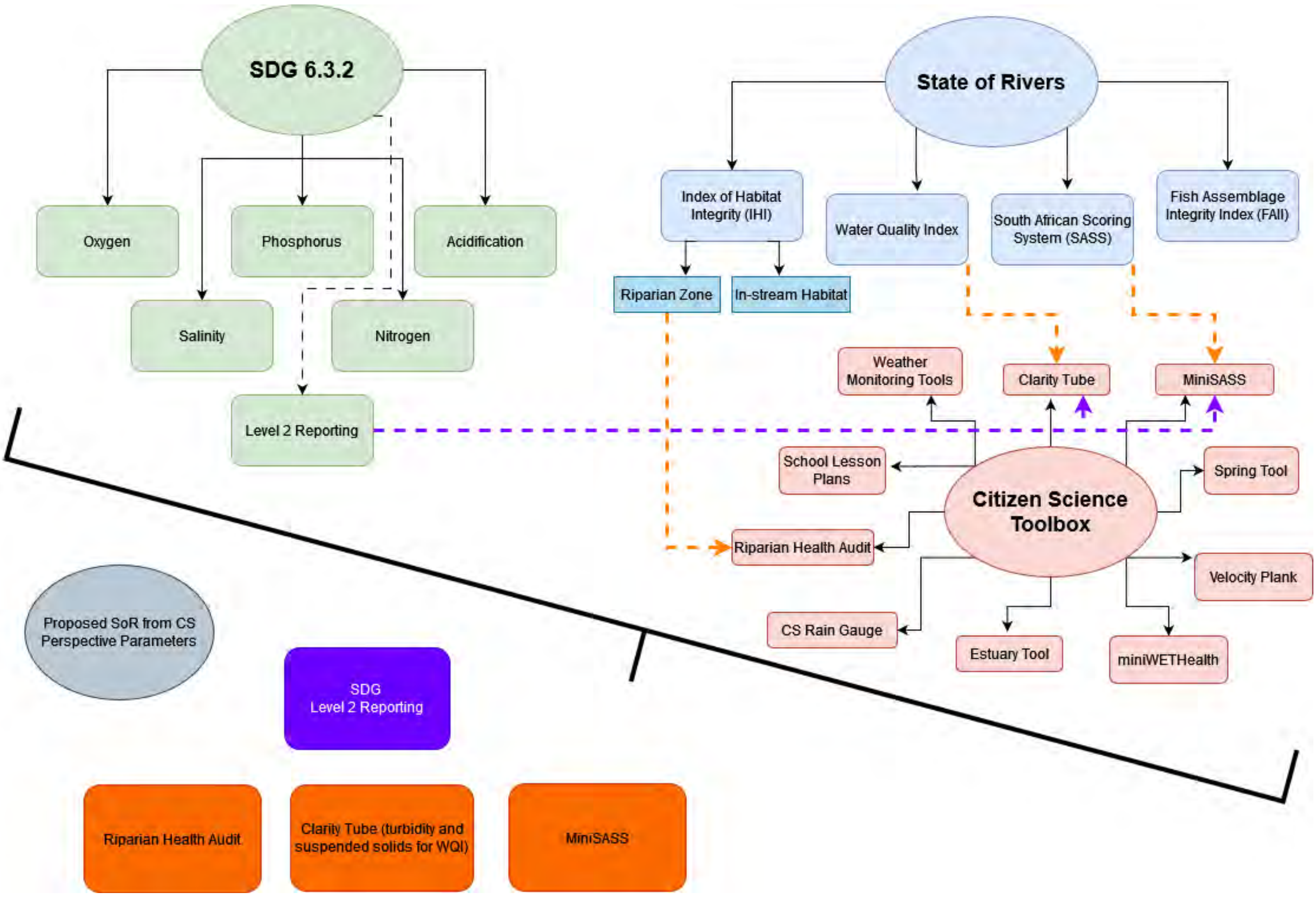


Figure 6.5 Determination of CS monitoring techniques considering SDG 6.2.3 reporting parameters, existing SoR reporting parameters, and the CS toolbox

With specific focus on the parameters used to inform SDG 6.3.2, chemical CS kits can assist in informing Level 1 reporting. This prompted the inclusion of the CS WaterCAN iLab test kits and the Freshwater Watch test kits for chemically based observations. The Level 2 parameters to inform SDG 6.3.2 reporting includes biological techniques (UNEP, 2024) which is where the biomonitoring tool, miniSASS, is considered a potentially valuable technique to inform SDG 6.3.2 (Taylor *et al.,* 2022).

Thus, based on the above, the CS techniques which were selected as the focus techniques for this project include miniSASS, clarity tube, RHA, and physico-chemical based testing by use of the Freshwater Watch and WaterCAN iLab kits. These tools and techniques which have been applied in this project CS SoR report are as detailed further in **Table 6.2.**

Table 6.2 Focus citizen science tools and techniques used

Conventional Monitoring Tool/Technique	**Citizen Science Tool/Technique**	**Indicator Observed/Parameter Measured**
South African Scoring System version 5 (SASS5) aquatic biomonitoring technique.	Mini Stream Assessment Scoring Systems (MiniSASS)	The ecological condition of a river system (Graham and Taylor, 2018).
Sampling for laboratory analysis of total suspended solids (TSS).	Clarity Tube	Water clarity as an indication of TSS (Graham *et al.,* 2024).
Sampling for laboratory analysis to determine the presence of particular or a range of chemicals. In-situ testing for certain characteristics (e.g. pH) using a calibrated meter (e.g. YSI probe).	Chemically based kits (WaterCAN and Freshwater Watch)	WaterCAN: levels of phosphates, nitrates, nitrites, total hardness, chlorine, bromine, alkalinity and pH, as well as tests for the presence of coliforms and *E. coli.* (WaterCAN, 2023) Freshwater Watch: Levels of nitrates and phosphates (Earthwatch Europe, 2023).
Sampling for laboratory analysis of *E. coli* count.	*Escherichia coli (E. coli)* test	Level of *E. coli* present.
Index of Habitat Integrity (IHI) riparian and instream disturbances assessment.	Riparian Health Audit (RHA)	The ecological condition of a river system (Graham and Taylor, 2018).

The tools and techniques detailed in **Table 6.2** were chosen for their applicability to determine the state of river systems, and their accessibility in terms of affordability and training. It must be noted that all the techniques except the *E. coli* tests provide data to inform on the ecological condition of rivers. *E. coli* testing provides information on *E. coli* levels in rivers which is more pertinent to human health than its impact aquatic ecosystem and riparian health (Graham, pers. comm., 2025). Thus, the CS SoR report does not include *E. coli* results, but these results are included in **Chapter 6 Section 6.4.3.1** for comparative analysis against laboratory results to evaluate the application of these CS kits to use to inform on threats to public health. For the miniSASS technique, use of the clarity tube, and the RHA, training material was made available to users in the form of online learning tools i.e. instructional videos and easy-to-follow manuals. The training materials for the use of WaterCAN and *E. Coli* test kits were also provided in the form of a training video and instructional manual, respectively.

It was important for this project to prioritise accessible and easy-to-learn tools and techniques as the timeframes for data collection meant that some collaborators had capacity to collect data over a few months while others had just over a few days. The main focus areas and/or interests of the various groups or organisations were also considered for the selection of the tools and techniques to be used in this project. This was also to encourage and urge the continuity of the use of CS techniques after this project has been completed.

The collaborators were guided to the training locations through the CS SoR Roadmap (linked in **Appendix J**) which included the overview and aims of this project, a guide on the different CS tools to be used, links to training materials and courses, data submission platforms, and an introduction to creating local CS SoR reports.

From **Figure 5.3** the limitations of the current CS toolkit are evident in that there are no tools which align with certain traditional SoR reporting parameters. Examples of this are the Fish Assemblage Integrity Index (FAII) as well as a complete suite of tools to inform the SDG 6.3.2 Level 1 parameters such as oxygen and salinity.

Qualitatively, the project team conducted interviews with key CS practitioners (**Chapter 5, Section 5.5**) to gather information and insights on the state of CS for WQM. Environmental efforts linked to CS by collaborating stakeholders were identified and a select few of these endeavours are included through a brief feature in this report (**Chapter 7, Section 7.5**). These efforts also speak to the continuity of CS practices, the value in CS applications, and may highlight to others the potential opportunities for the uptake of CS practices.

Other CS techniques were also explored by CS SoR collaborators which included the Dragonfly Biodiversity Index (DBI), wetlands assessment tool (miniWET-Health), and other chemical-based testing techniques which provided real-time results and did not require laboratory analyses. The use of the other techniques, especially those for which training material was made available, were encouraged for the CS practitioners to explore for their own interest. However, the collaborators were urged to use the tools and techniques in **Table 6.2** to encourage application of standard approaches and practices. This approach helped achieve a degree of monitoring uniformity across localities for comparisons and to develop a comprehensive CS SoR report; this while still balancing the dynamics of promoting the uptake of CS techniques which would be useful for long-term operations and interests of stakeholders.

Prior to the compilation of the CS SoR report, stakeholder engagement and an analysis of existing SoR reports was conducted to understand the reporting requirements as well as generate reporting templates (**Chapter 6, Section 6.8**). These templates did not only inform the project team but also the collaborating partners who also compiled CS SoR reports for their own localities.

Data management

In terms of the data for this project, the collaborators had been encouraged to share their data on the various open-access platforms or to send it directly for inclusion in the CS SoR report. However, a reluctancy to share data was observed particularly from those collaborators who have been part of CS monitoring programmes before. The rationale here was linked to the value of the data for both the collectors, in this case citizen scientists and users from which the following questions emerged: *what monetary value does the data possess, and to whom does the data belong?* These are complex and important questions of which the answers are currently multi-faceted and variable dependant. It can be argued that the value (monetary and knowledge) and possession of the CS data may depend on what and who the data was collected for. These questions are particularly important for the currently in-progress UNICEF-Rhodes Operational Research project, which seeks to develop a sustainable learning pathway for citizen scientists in the River Commons, which is the first step towards assigning monetary and institutional value to citizen science data and its collection" (Sithole, N., pers. comm., GroundTruth, 2024).

Although there are a host of CS techniques available for use, not every technique has an online, open-source database associated with it. For continuity of CS practices beyond this project, the collaborators were encouraged to share their data and observations on the relevant platforms to feed into those larger databases.

Data between 01 August 2023 and 15 November 2024 were included in the data analysis to inform this report. Before the data were included for further analysis, the co-ordinates in each database were checked to remove entries where co-ordinates were erroneously recorded when checking against the organisation and site names. The data was also checked for duplicate entries which would skew reflections of the total number of observations recorded. Additional data cleaning was conducted for each dataset set specific to those data and are detailed in the sections to follow.

6.4.1 *Biomonitoring datasets and results*

The mini Stream Assessment Scoring System (miniSASS) biological monitoring technique was used to gather observations for the generation of this report and **Figure 6.6** illustrates some steps of that process.

Figure 6.6 MiniSASS identification, miniSASS sample collection, and a stonefly in a sample tray (from left to right)

Data entries for miniSASS observations were sourced either from the miniSASS website, manual submissions, or through conversions of SASS5 results from the Freshwater Biodiversity Information System (FBIS). The SASS5 dataset was downloaded in bulk from the FBIS website (https://freshwaterbiodiversity.org/) from August 2023 to October 2024. FBIS is an open-access online platform dedicated to hosting, analysing, visualising, and sharing South African freshwater biodiversity data, encompassing a wide range of taxa such as fish, amphibians, algae, plants, and invertebrates.

Prior to conversion of SASS5 results to miniSASS results, a desktop assessment was conducted for each site individually. This involved examining the biotopes chart to classify each river as either rocky or sandy for categorization within miniSASS. For the conversion process, all taxa recorded at each river site were reviewed. Each family-level taxon within the SASS5 dataset was then translated to its miniSASS equivalent (for example, *Gomphidae* was classified under "Dragonfly" in miniSASS). Each group was assigned a sensitivity score as per the miniSASS scoring sheet, allowing for standardised assessments across sites. From this conversion, the ecological condition according to the miniSASS scoring methodology could be determined and added to the miniSASS database.

In cleaning the data, the calculated miniSASS scores and classes submitted were checked, and duplicates were removed from the dataset.

Biomonitoring results

A total of 1056 miniSASS data observations were recorded where 86% of these observations were gathered from the miniSASS website or manually submitted to the project team, and 14% were converted from SASS5 results gathered from FBIS. The spatial distribution is illustrated in **Figure 6.7**.

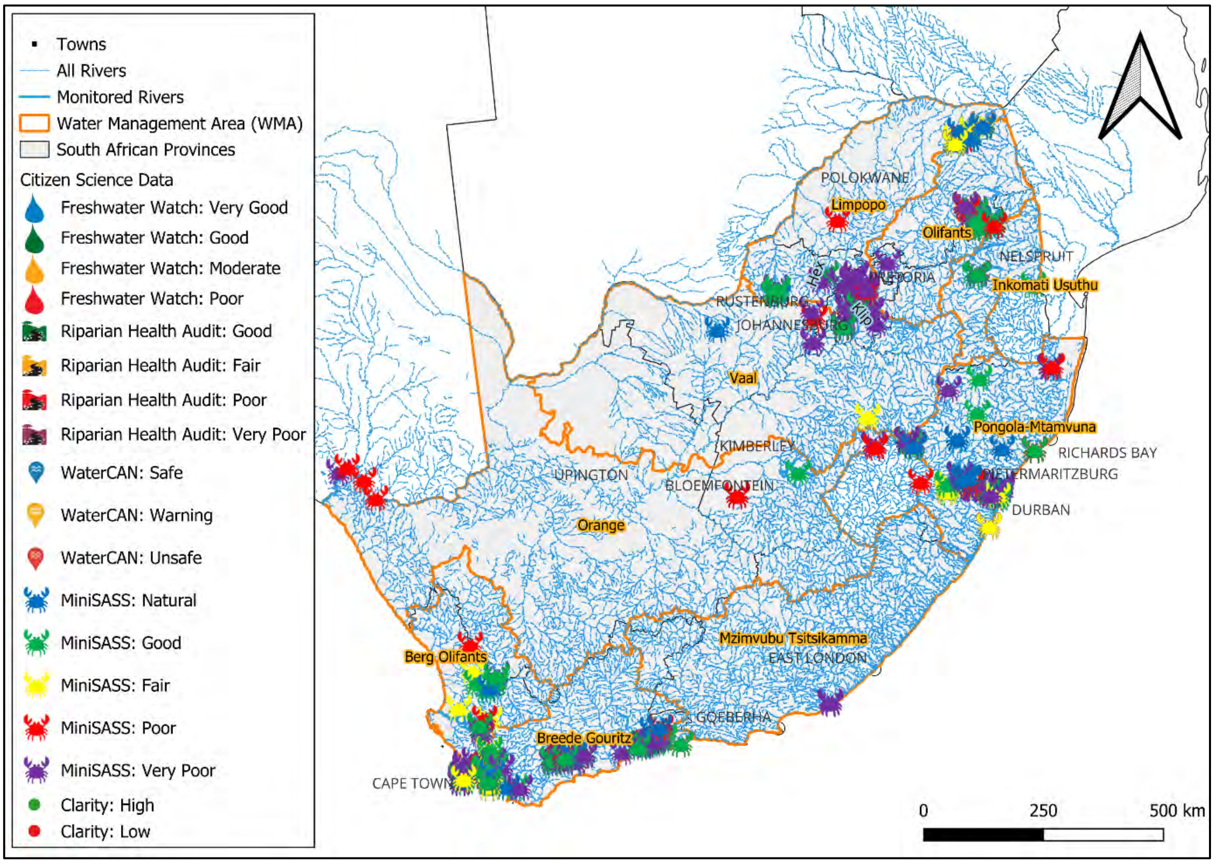


Figure 6.7 Biomonitoring locations across the region

The proportions of these data in the miniSASS categories are summarised in **Figure 6.8.**

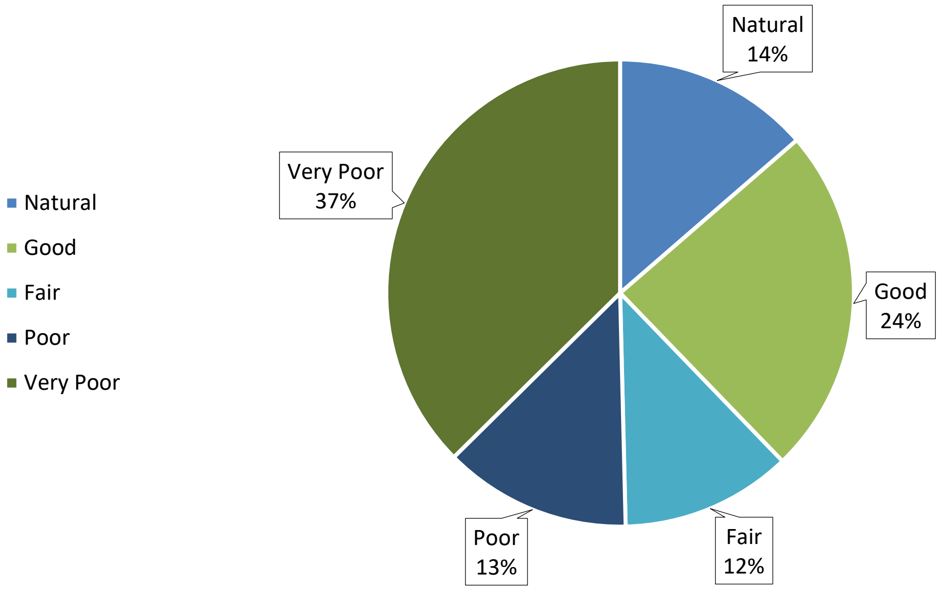


Figure 6.8 Proportions of differing river conditions determined through use of the miniSASS technique

From **Figure 6.8**, the majority of rivers have been found to be in very poor ecological condition through the application of the miniSASS technique.

A comparative analysis was not conducted under the scope of this project as past literature (Graham *et al.,* 2004; Graham, 2012) has demonstrated the comparability of the miniSASS technique to the SASS5 technique.

6.4.2 *Clarity datasets and results*

The clarity of waterbodies was determined using the clarity tube (**Figure 6.8**). The clarity values can also be used to determine an estimate of total suspended solids (TSS).

Figure 6.9 Use of the clarity tube

The clarity tube observations were gathered from different sources. The miniSASS portal hosts miniSASS data with a space for users to record supplementary data, including clarity tube values. The limitation here is that users cannot record clarity values without a miniSASS entry. Thus, data was collated both from the miniSASS submissions as well as manual submissions of data from collaborators. Those collaborators who used the Secchi tube as part of the Freshwater Watch kits also noted their clarity tube values in their submissions on the Freshwater Watch portal, thus clarity data was also pulled from there. In cleaning the data, it was ensured that only entries which are under 100 cm were included as those which are over 100 cm are invalid and could have been typographical errors in data entry. A total of 754 clarity tube observations were recorded. Clarity observations which were 50 cm or above were considered as high clarity scores, while those below were low clarity and these proportions are depicted in **Figure 6.10**.

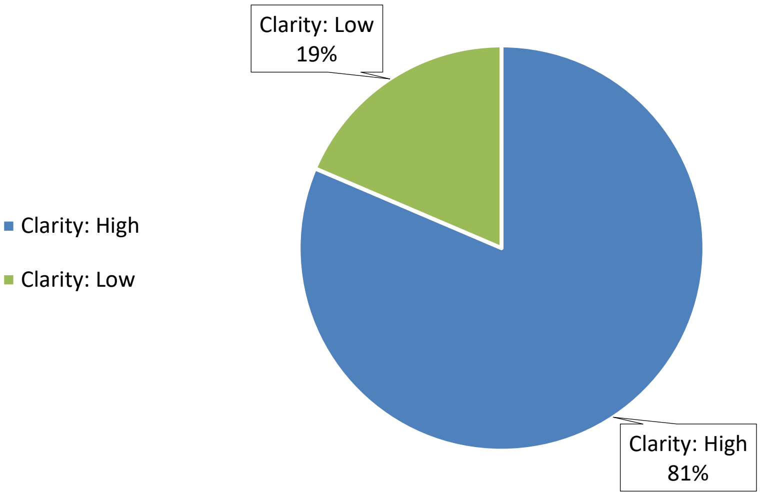


Figure 6.10 Proportions of clarity conditions observed

The spatial distribution of the clarity observations is illustrated in **Figure 6.11**.

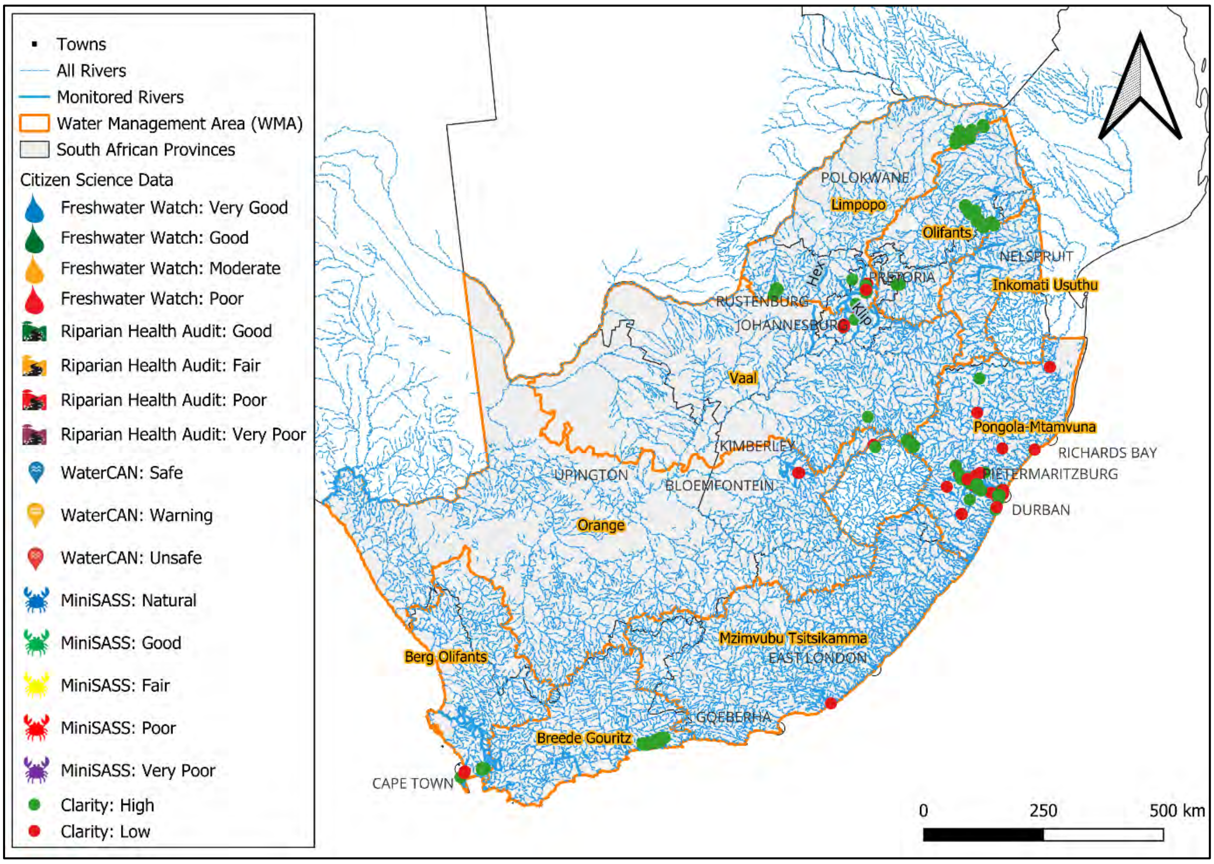


Figure 6.11 Clarity monitored locations across the region

After Graham *et al.,* (2024), **Equation 6.1** was used to determine an estimate of total suspended solids (TSS) using clarity tube values.

$$y = 10^{2.96-1.05(\log_{10} X)} \tag{6.1}$$

Where y = $\log_{10}$ transformed value for TSS (mg/l)

x = clarity value from the clarity tube (cm)

The estimated TSS values determined can be compared to limit values (**Table 6.3**) for TSS in wastewater discharge as set-out by the DWS. From this, the performance of wastewater treatment works (WWTWs) situated along local rivers can be determined with reference to the standards for wastewater discharge into streams (after DWS, 2013).

Table 6.3 Limit values for wastewater treatment works discharge (after DWS, 2013)

Parameter	**General Limit Value (mg/l)**	**Special Limit Value (mg/l)**
TSS (mg/l)	25.00	10.00

TSS is to be compared against either the General Limit Value (GLV) or the Special Limit Value (SLV) depending on the water resource into which the wastewater is discharging. There are conditions for the comparison of results against GLV or SLV, and these conditions are as follows (after DWS, 2013: p. 13):

"2.6. (1)… (i) discharge up to 2 000 cubic metres of wastewater on any given day into a water resource that is not a listed water resource set out in Table 2.3, which may be amended from time to time, provided the discharge-

(a) complies with the general wastewater limit values set out in Table 2.1, which may be amended from time to time;

(b) does not alter the natural ambient water temperature of the receiving water resource by more than 3 degrees Celsius; and

(c) is not a complex industrial Wastewater.

(ii) discharge up to 2 000 cubic metres of wastewater on any given day into a listed water resource set out in Table 2.3, which may be amended from time to time, provided the discharge -

(a) complies with the special wastewater limit values set out in Table 2.1, which may be amended from time to time;

(b) does not alter the natural ambient water temperature of the receiving water resource by more than 2 degrees Celsius; and

(c) is not a complex industrial wastewater,

if the discharging of wastewater -

(aA) does not impact on a water resource or any other person's water use, property or land; and

(aB) is not detrimental to the health and safety of the public in the vicinity of the activity." (DWS, 2013: p. 13).

In the extract above, the information required from Table 2.1. as referred to has been extracted as **Table 6.3** of this report. The table as referred to as Table 2.3. of the DWS General Authorisations can be found on page 17 of the General Authorisations document.

An example of this is a case study in which samples were taken at the effluent discharge points of WWTWs over a month. As per conditions of sampling, the locations and names of these WWTWs will be autonomised with the intention being just to use the effluent samples to determine compliance by application of **Equation 6.1**. An extract of the clarity tube, estimated TSS, and compliance based on the TSS values results are displayed in **Table 6.4**. The conditions as per the DWS (2013) extract above were taken into consideration when comparisons were done against the GLV and SLV.

Table 6.4 Compliance of wastewater treatment works based on estimates of total suspended solids derived from clarity tube values – extract of results

Date	WWTW Code	Clarity tube (cm)	Estimated TSS (mg/L)	GLV or SLV	Value Limit (mg/L)	Compliance
23/09/2024	WWTW 29	37.50	20.29	GLV	25.00	Compliant
25/09/2024	WWTW 32	59.00	12.61	GLV	25.00	Compliant
25/09/2024	WWTW 29	30.50	25.20	GLV	25.00	Non-compliant
26/09/2024	WWTW 28	58.50	12.72	GLV	25.00	Compliant
30/09/2024	WWTW 29	28.00	27.57	GLV	25.00	Non-compliant
30/09/2024	WWTW 32	54.00	13.84	GLV	25.00	Compliant
01/10/2024	WWTW 28	64.50	11.48	GLV	25.00	Compliant
01/10/2024	WWTW 28	67.00	11.03	GLV	25.00	Compliant
01/10/2024	WWTW 34	20.00	39.26	GLV	25.00	Non-compliant

01/10/2024	WWTW 35	55.00	13.57	SLV	10.00	Non-compliant
01/10/2024	WWTW 36	17.00	46.56	GLV	25.00	Non-compliant
01/10/2024	WWTW 41	28.50	27.07	GLV	25.00	Non-compliant
03/10/2024	WWTW 28	69.00	10.70	GLV	25.00	Compliant

Table 6.4 provides insight to the ability of the clarity tube to determine the compliance status of WWTWs after a month of monitoring. **Figure 6.12** will elaborate on this further with specific focus on three WWTW for which the most samples were collected and will illustrate the occurrences of compliance determined.

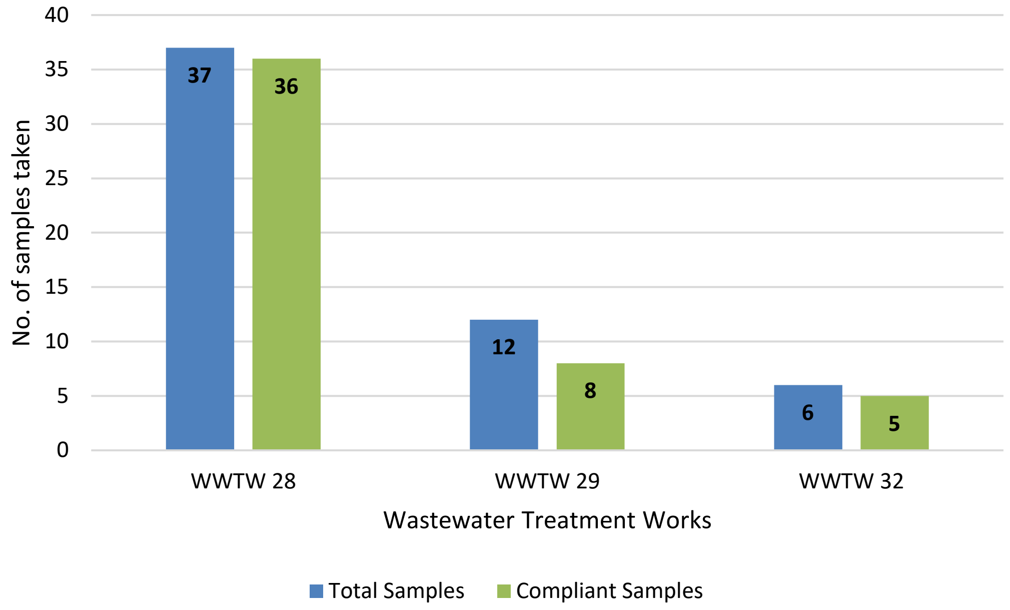


Figure 6.12 Proportions of compliance of three monitored WWTWs

Figure 6.12 illustrates the three most frequently monitored WWTWs which had compliance percentages of 97.30 % for WWTW 28, 66.67% for WWTW 29, and 83.33 % for WWTW 32. These are preliminary results which are used to demonstrate the application of the clarity tube in determining the compliance status of WWTWs as per their discharged TSS values.

Similarly, the results in **Figure 6.13** are preliminary as they are infrequent and would require more frequent monitoring to determine compliance of these WWTW overtime. Rather, these preliminary results are illustrated here to demonstrate that the clarity tube can be used to determine non-compliance as well.

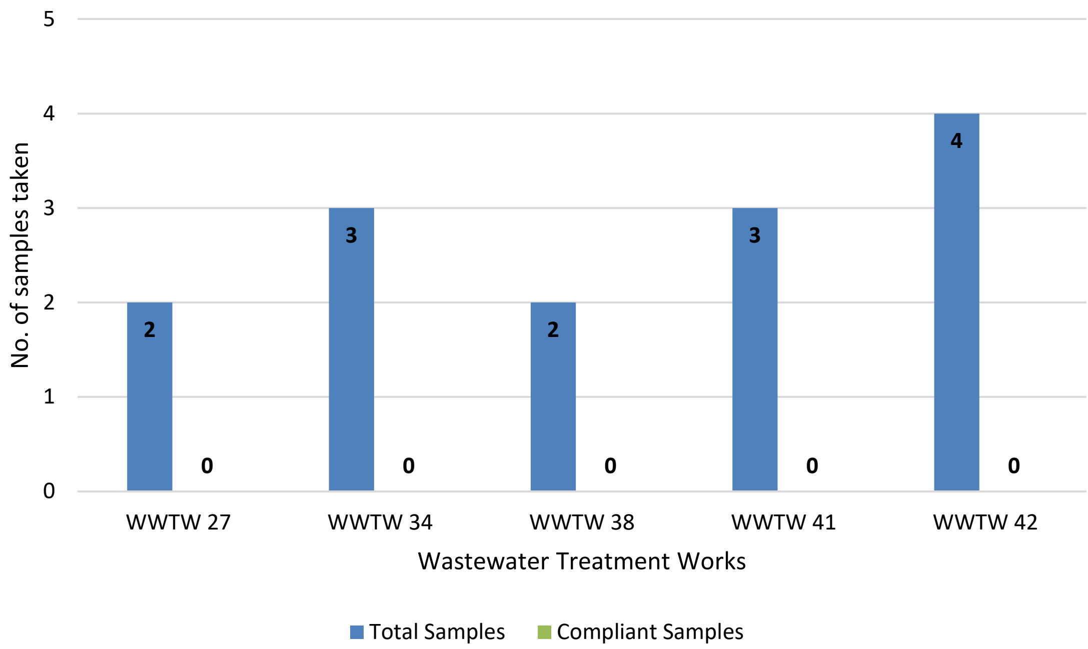


Figure 6.13 WWTWs with no occurrences of compliance

6.4.3 *Physico-chemical datasets and results*

The physico-chemical monitoring for results for the generation of this report includes the use of the WaterCAN iLab test kits and the Freshwater Watch test kits. It is worth noting that although these techniques are used, neither of them has been endorsed by the DWS. The use of physico-chemically based monitoring techniques provides supplementary data on water quality, where routine laboratory testing may inaccessible. The WaterCAN iLab test kits (the use of which is illustrated in **Figure 6.14**) provide indications of a host of parameters including nitrates, nitrites, phosphates, free chlorine, total chlorine, hardness, bromine, alkalinity, pH, as well as indicators for the presence of *E. coli* (human waste) and coliforms (animal waste).

Figure 6.14 WaterCAN iLab 6-in-1 test, *E. coli* petri film, and coliform aqua screen test (from left to right)

The parameters observed through use of the Freshwater Watch kits are indications of nitrates, phosphates, and the turbidity of the water using a Secchi tube (the use of which is illustrated in **Figure 6.15**). These kits were made available to the project team and collaborators through a partnership between GroundTruth and the WWQA.

Figure 6.15 Freshwater Watch phosphate test, Secchi tube, and nitrate test (from left to right)

This body of research has evaluated the use of these kits in three ways. First, through the spatial uptake of both the Freshwater Watch and the WaterCAN iLab kits. Second, through comparing the results from the WaterCAN iLab kits with those from the Freshwater Watch kits and evaluating how these results compare. Third is a comparison of the Freshwater Watch kits against paired laboratory data.

The physico-chemical results which were observed were either by the use of the WaterCAN iLab kits or the Freshwater Watch kits. Both of these kits have their respective online portals for the submission, storage, and viewing of data. The data entry pages for both portals are set-up in a way which does not allow the user to type values manually but rather choose from preloaded options. This selection option over a manual entry minimises error in the results which are recorded. Both portals also do not allow users to submit their observations unless all required fields of the data submission form are populated. This ensures that only those entries which are complete can be submitted and added to the public domain.

The WaterCAN portal does not allow for a bulk download of data, but rather the option to download per record. The Freshwater Watch portal does allow for public bulk data downloads (https://www.freshwaterwatch.org/pages/explore-our-data) however the project team were able to download data from South Africa which was collected during the trial of the kits.

Freshwater Watch data

The Freshwater Watch data was exported from the Freshwater Watch platform (https://www.freshwaterwatch.org/pages/0db6cdd7b4f347d1986fcbf35954810d) and included in this report.

The trial of these kits (under the mentioned GroundTruth and WWQA partnership) as indicators of nitrates, phosphates, and turbidity values commenced in July 2024 across South Africa. An overview of the results from monitored rivers are illustrated in **Figure 6.16**.

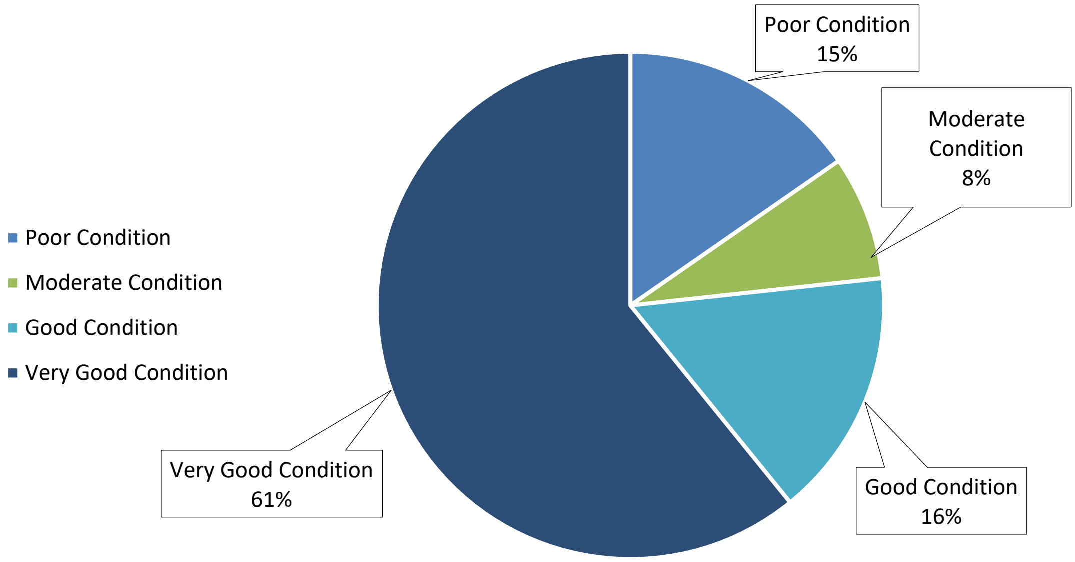


Figure 6.16 Proportions of Freshwater Watch results from monitored rivers

WaterCAN iLab data

The results observed and submitted on the WaterCAN online portal (https://watercan.org.za/map/) were sent to the project team by WaterCAN in Excel format for inclusion in this report. The team selected data across South Africa from August 2023 to October 2024. The data was then cleaned by ensuring that the water source indicated was either a "river" or a "dam". Dams were opted as acceptable to include in this report to aid spatial continuity along the stretches of river systems. An overview of the results from monitored rivers are illustrated in **Figure 6.17**.

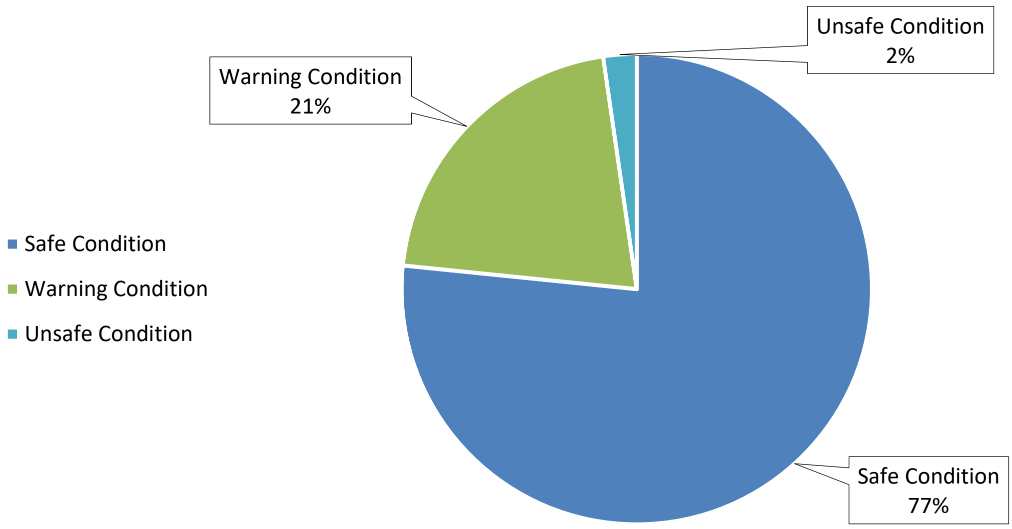


Figure 6.17 Proportions of WaterCAN results from monitored rivers

Physico-chemical results

When the overall safety indicator for the WaterCAN iLab kits was used in mapping the conditions of rivers, the results between the Freshwater Watch and the WaterCAN results appeared contradictory due to the range of parameters tested with each kit. The Freshwater Watch kits can be used to report on nutrients (nitrates and phosphate) levels in river with a focus on environmental (ambient) water quality. However, the WaterCAN kit has a focus on the safety-factor for humans who can be in contact with water, and the overall safety rating includes indicators other than nitrates and phosphates. This includes *E. coli* which would weigh on the overall safety rating of the sample to drop to 'warning' or 'unsafe' dependant on results of the other parameters. Although these kits reveal different overall indication results, the application of both would be useful from a public health perspective to gauge an understanding of the state of the river. However, in terms of using both methods to indicate (and compare indications of) nutrient levels for this study, only the nitrate and phosphate indicators from the WaterCAN iLab kits were considered in the CS SoR mapping (where "Safe" indicates both nitrate and phosphate levels were indicated to be safe, "Warning" means one or the other was indicated as "Warning" or "Unsafe", and "Unsafe" means that both nitrates and phosphates were indicated as at unsafe levels). This focus on only nitrates and phosphate was also to align the findings from WaterCAN iLab datasets to the specific parameters used to inform SDG 6.3.2, i.e., nitrates and phosphates.

A total of 843 physico-chemical results were recorded either through the Freshwater Watch or WaterCAN portals or submitted manually. The spatial distribution of these results is illustrated in **Figure 6.18**.

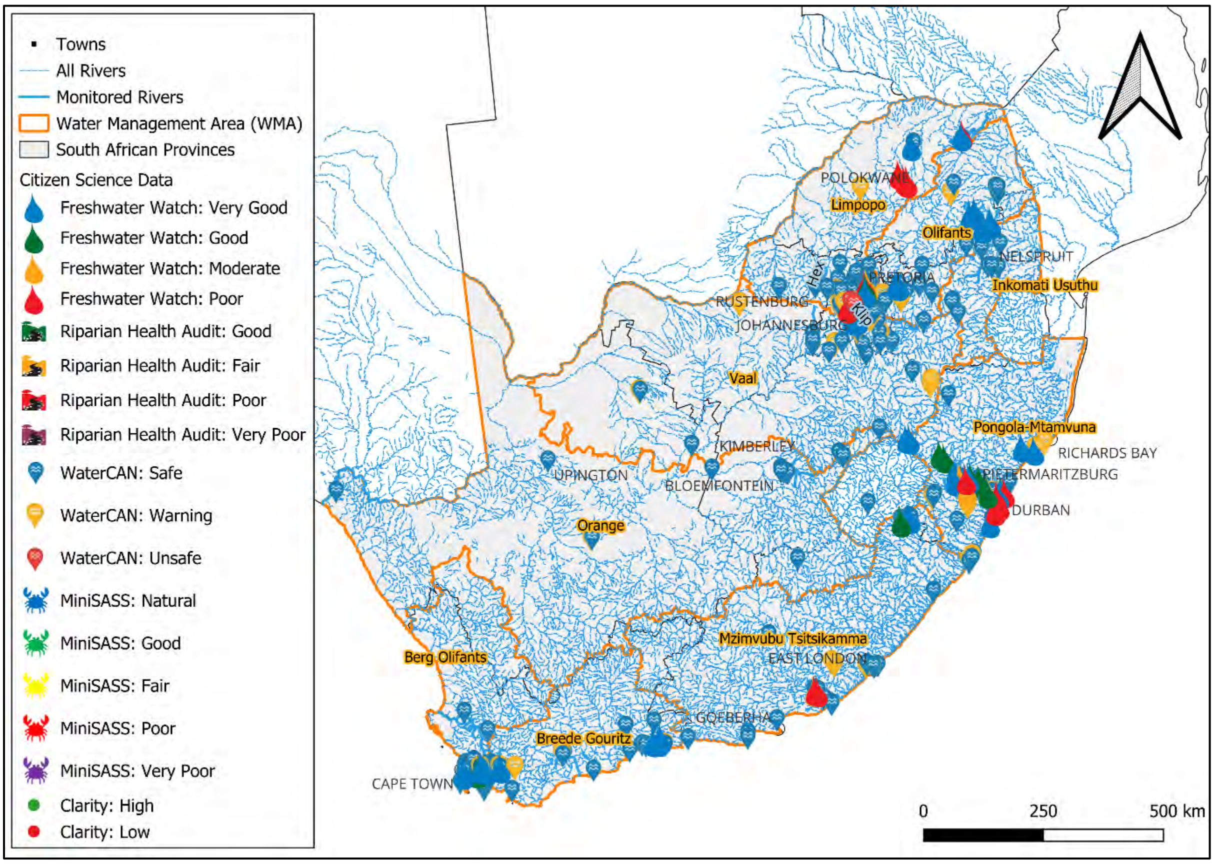


Figure 6.18 Physico-chemical monitored locations across the region

The WaterCAN iLab kits do provide an indication of pH level of the sample tested. These results are not included in the SoR mapping, as they do not provide an indication of the river conditions beyond the acidity level of the water at the time of sampling. However, it is worth noting that pH is another useful parameter collected through use of the WaterCAN iLab kits and can be used to aid in informing the SDG indicator 6.3.2 physico-chemical dataset.

Although the WaterCAN iLab test kits provide a safety indication when testing for *E. coli*, these results were not included in the SoR report maps. This is due to the threat of *E. coli* presence pertaining more so to human health than aquatic river health. The safety indicators are based on an estimated *E. coli* count depending on the number of blue spots present on the petri film. The application of these kits is valuable for citizens to test and track *E. coli* levels in water resources for their own safety. Thus, a comparative analysis of CS-based *E. coli* techniques and laboratory testing is included in **Section 6.4.3.1.** It must be noted that there was greater uptake of the WaterCAN iLab kits than *E. coli* count test kits under this project, which could be accredited to the range of other parameters users are able to test for with the WaterCAN iLab kits. Another factor to consider is that there is an existing national network of volunteer WaterCAN users, adding to this database.

6.4.3.1 *E. coli datasets comparative analysis*

A comparative analysis was conducted between the CS *E. coli* testing methods and laboratory results for *E. coli* count. The CS methods tested were both the WaterCAN iLab petri film method and the Praecautio colorimetric tests. The CS tests were conducted in field and a sample was collected for analysis along the uMthinzima River in Mpophomeni, KwaZulu-Natal. The river source rises in Emashingeni (southwest of Mpophomeni), flows through the community, and then through a wetland before it flows into Midmar Dam – a major dam which feeds water supply to Pietermaritzburg and Durban. The uMthinzima River was specifically selected for *E. coli* analysis as the Mpophomeni community has long faced challenges with sewerage infrastructure including frequently surcharging manholes (Ward, 2016; Sithole, 2023). Five points along the uMthinzima River (and a tributary) were monitored using all three techniques (laboratory sampling, WaterCAN iLab petri film, and the Praecautio colorimetric techniques), the locations and results of which are illustrated in **Figure 6.19**.

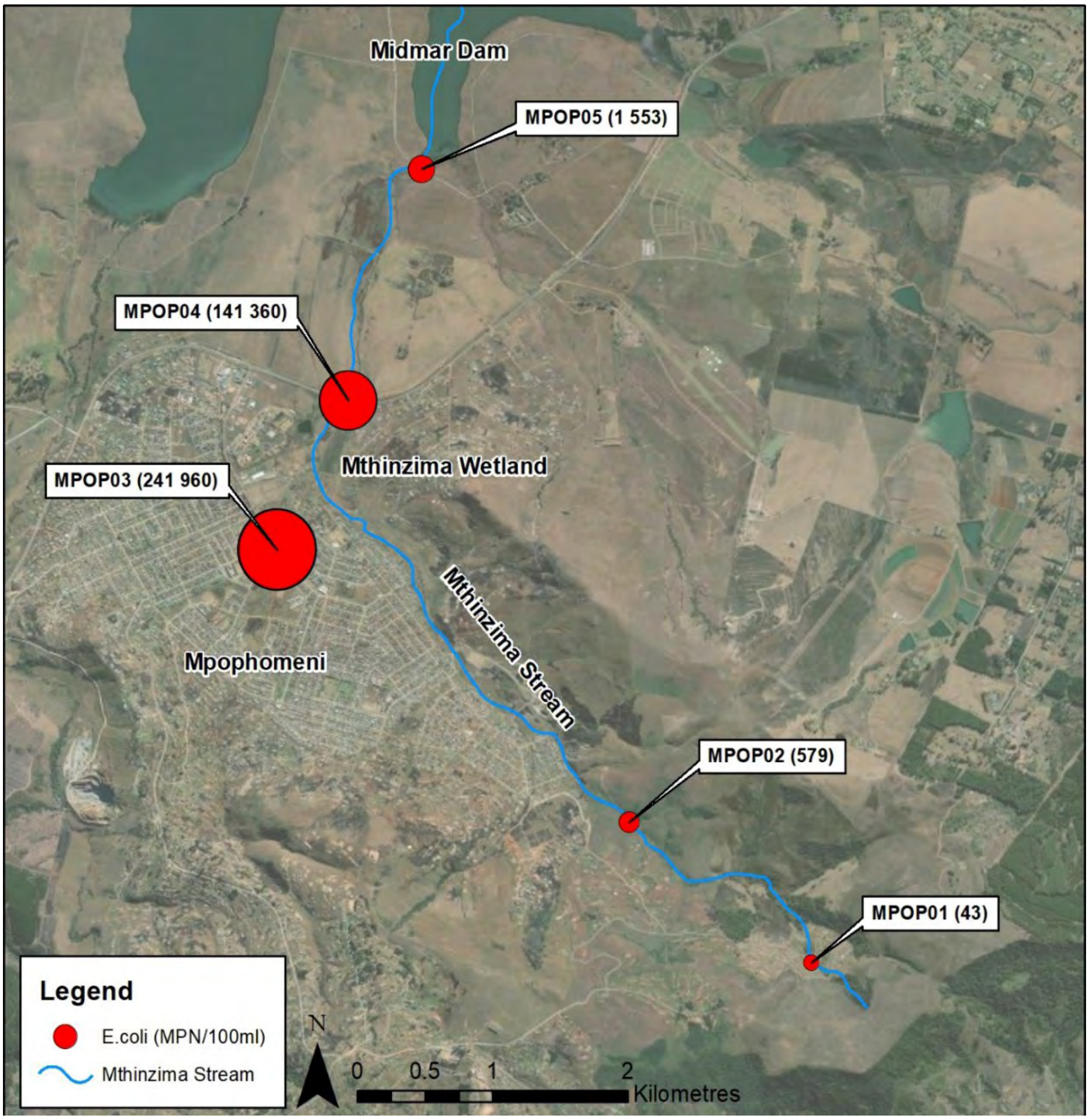
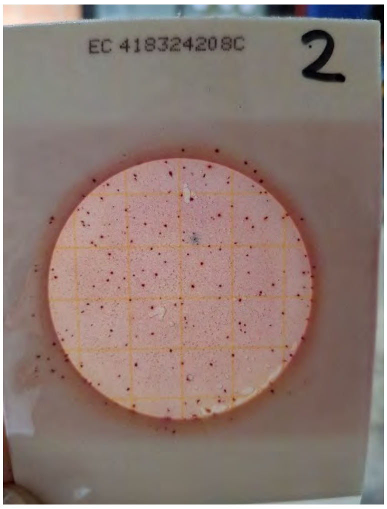
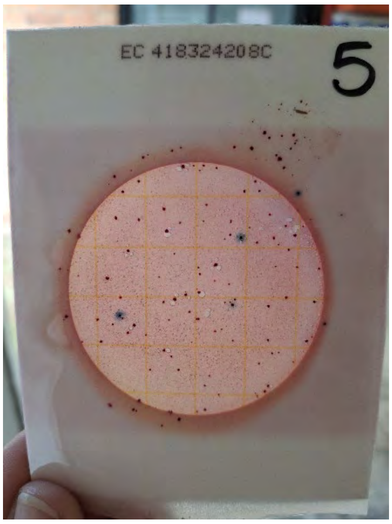


Figure 6.19 Laboratory *E. coli* results along the monitoring locations on uMthinzima River and tributary

Due to the variability of the techniques, the results from each technique cannot be quantitatively compared but rather compared for their overall indication of *E. coli* extent present at the sampled sites. The biological nature of the *E. coli* bacteria, the differing sample sizes (volume), and measurement approaches makes it challenging and complex to quantitatively compare *E. coli* results sampled through different techniques (Sewcharran, pers. comm., 2025). Thus, this comparative analysis will focus on the information which each technique provides, and the overall applicability of these techniques for citizens to use. **Table 6.5** provides an overview of the results from each technique at each sample site.

Table 6.5 *E. coli* results from the petri film, colorimetric, and laboratory testing techniques

Site	Petrifilm Visual Assessment (blue spots indicate *E. coli*)	Colorimetric Test (cfu/ml) (cfu – colony forming units)	Laboratory (MPN/100ml) (MPN – most probable number)
MPOP01		1 – 10	43
MPOP02		10 – 100	579

MPOP03		1 000 – 10 000	241 960
MPOP04		1 000 – 10 000	141 360
MPOP05		1 000 – 10 000	1 553

The colorimetric (Praecautio) tests revealed a positive presence of *E. coli* at every site monitored as indicated in **Table 6.5** and displayed in **Figure 6.20**. Based on the time taken for the sample to change colour to green, a range under which the results would fall was determined. The site with the lowest E. coli count was determined to be MPOP01 (1-10 cfu/ml) followed by MPOP03 (10-100 cfu/ml). The remaining three sites were all determined to have a count between 1 000 – 10 000 cfu/ml.

Figure 6.20 Colorimetric *E. coli* results for all monitoring sites

Through use of the petri film technique (WaterCAN iLab kits), the appearance of blue dots on this film indicated the abundance of *E. coli* in the samples (**Figure 6.21**). Visually, the lowest to highest *E. coli* concentrations were found as follows: MPOP02, MPOP01, MPOP05, MPOP04, and MPOP03. This order of ascending *E. coli* presence has similarly been determined from the laboratory analysis of the samples where this technique provided an exact *E. coli* count with the exception of MPOP01 found to have a lower count than MPOP02.

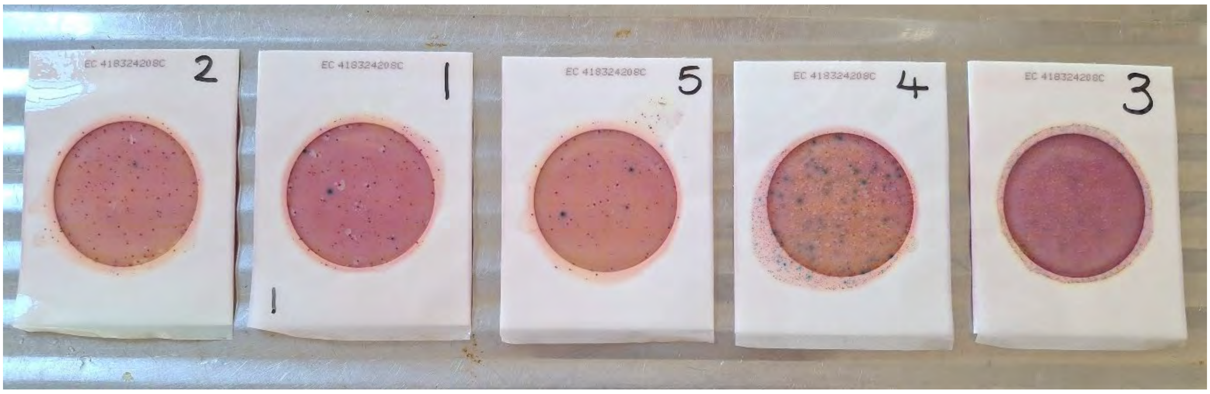


Figure 6.21 Ascending order of abundance of *E. coli* based on a visual assessment of petri film results

The changing *E. coli* conditions provides commentary on the impact of anthropogenic activities along this stretch of river. Focusing on land uses on either side of the riverbank to the monitored locations, starting with MPOP01 which is closest to the source, there are a few settlements in this locality. Downstream at MPOP02, the immediate land use (within 50 m from the river on either side) is grassland, which may be used for grazing, but there are only settlements further away. This demonstrates the ability of the river to replenish itself when left relatively undisturbed by anthropogenic activities. The increase in *E. coli* levels present at MPOP03 brings into view the effect that one stream condition has on another, as this tributary flows into the uMthinzima River and prompts queries around the source of pollution, possibly to investigate the conditions of the manholes upstream of MPOP03. At MPOP04, the *E. coli* count is the second highest, as shown by the laboratory testing and the petri film. This is downstream of the Mpophomeni community, after the main road bridge, and downstream of a wastewater treatment plant. The river continues to flow through the uMthinzima wetland where the *E. coli* count is reduced, according to visual assessment of petri film and laboratory results, before the river flows into Midmar Dam. The decline in *E. coli* count between the points above and below the wetland is a useful example of the value of ecological infrastructure through the filtration of this bacteria, improving the water quality before it enters Midmar Dam, improving the conditions for the dam to be used recreationally by the public. Although the colorimetric range did not reveal a difference between MPOP04 and MPOP05, the laboratory count does, and a visual assessment of the petri film effectively portrays this finding. This ecological infrastructure benefit is supported further through the application of the Freshwater Watch physicochemical monitoring kits at these points, where results for nitrates and phosphates were between 2 – 5 ppm and 0.2 – 0.5 ppm, respectively, at MPOP04 (above the wetland) and <0.2 ppm and between 0.02 – 0.05 ppm at MPOP05 (below the wetland).

E. coli results above 130 counts/100ml should not be used for recreation as it poses a threat to public health through risk of contracting a gastrointestinal illness (DWAF, 1996). In the application of CS monitoring techniques (the colorimetric *E. coli* test) would necessitate users to be cautious of any tests falling above the 100 – 1 000 cfu/ml range. Thus, although the exact value in between one of the larger ranges (such as 10 000 to 1 000 000 cfu/ml) is challenging to determine, it is not necessary to determine the exact value to inform the public to exercise caution but does have the potential to assist with track *E. coli* levels of the water body in question. Similarly, the WaterCAN results portal (after submitting petri film results) cautions against the recreational use of a water body with results of over 10 blue spots (representing *E. coli* levels) visible on the petri film.

6.4.3.2 *Nitrate and phosphate comparative analysis*

In a few cases, the collaborators used the WaterCAN iLab kits and Freshwater Watch kits to collect paired results from the same samples. The results for nitrates and phosphates were then compared with each other to determine the agreement between these datasets. A point to note is that the sensitivity of the Freshwater Watch kits is higher than that of the WaterCAN iLab kits (and more so for phosphates than nitrates) and they give indications as a range and an estimated value, respectively. The possible nitrate and phosphate ranges (Freshwater Watch) or closest values (WaterCAN iLab) from which users would select their observed results are displayed in **Figure 6.22** and **Figure 6.23,** respectively.

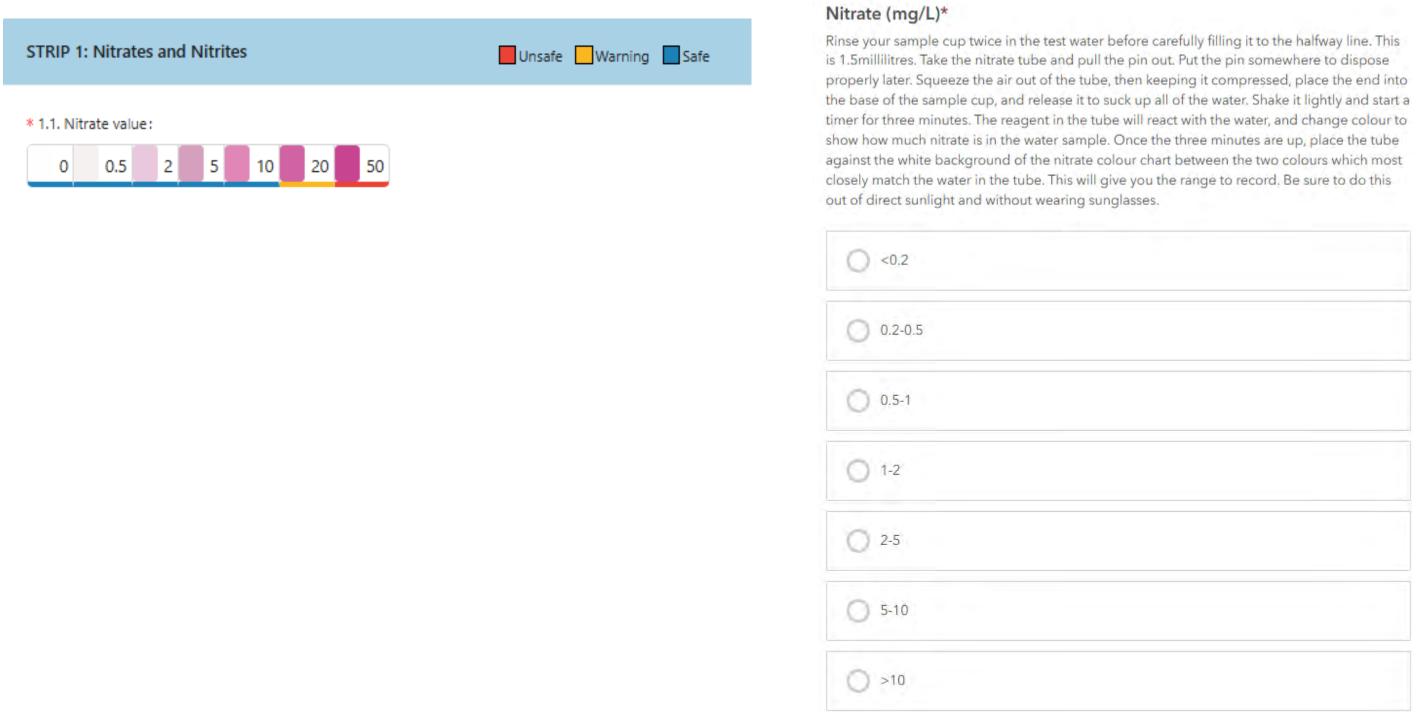


Figure 6.22 WaterCAN iLab (left) and Freshwater Watch (right) nitrate values and ranges

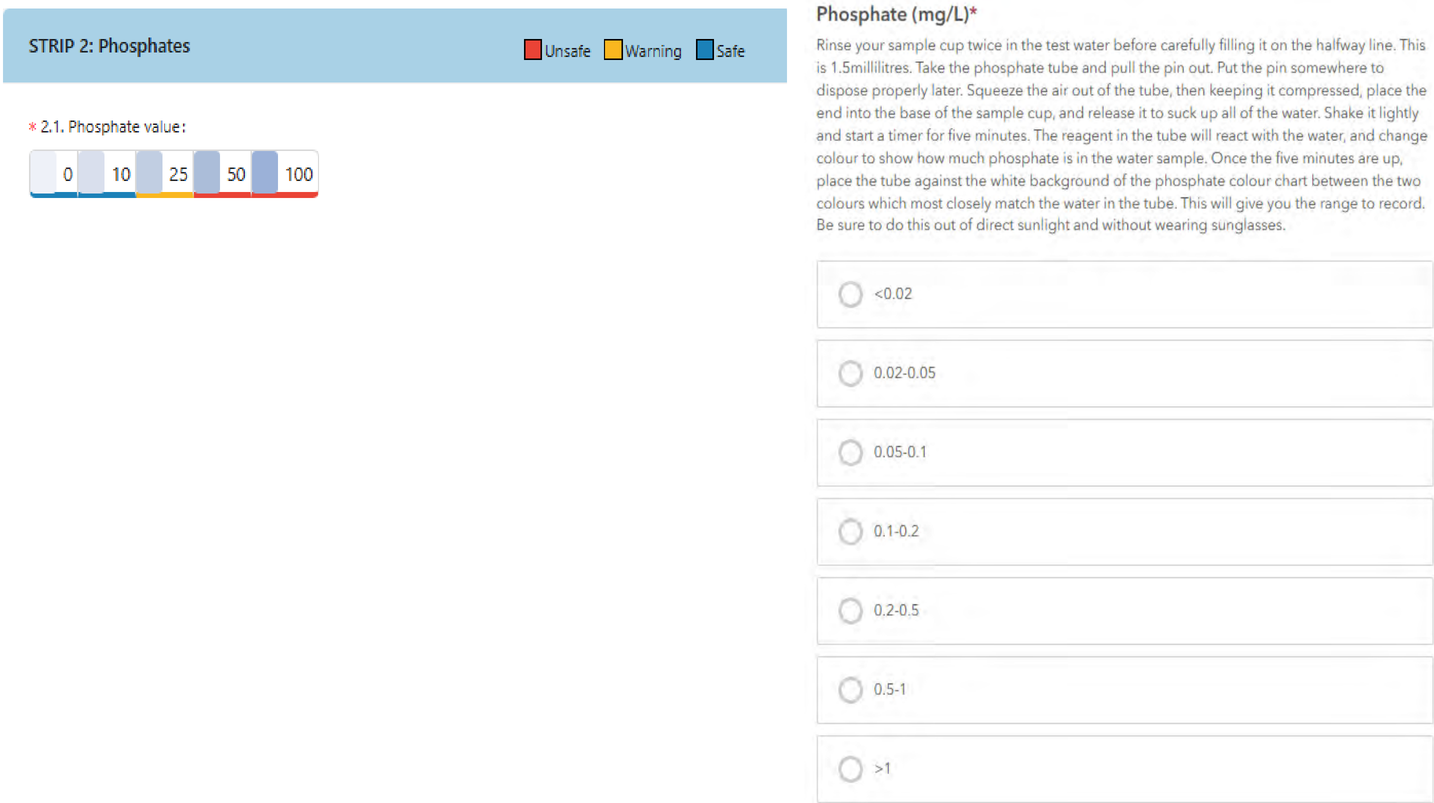


Figure 6.23 WaterCAN iLab (left) and Freshwater Watch (right) phosphate values and ranges

The midpoint value of each of the Freshwater Watch (referred to as FWW in the figures to follow) ranges were considered for comparisons to the WaterCAN (referred to as WC in the figures to follow) data values. As indicated on the Freshwater Watch portal, the nitrate midpoint value for the lower range (<0.2) is 0.1 and the midpoint value for the upper limit (>10) is 10. For phosphate the lower range (<0.02) midpoint value is 0.01 and the upper range (>1) midpoint value is 1. The comparisons between the WaterCAN iLab kit and the Freshwater Watch kits were based on a set of 33 data entries collected by volunteers who were provided with training materials on the WaterCAN kits and an online training session on the Freshwater Watch kits by representatives from GroundTruth who were trained by the Freshwater Watch team. This comparison revealed that there is a positive correlation between the nitrate results (**Figure 6.24**), but a negative correlation between the phosphate results (**Figure 6.25**).

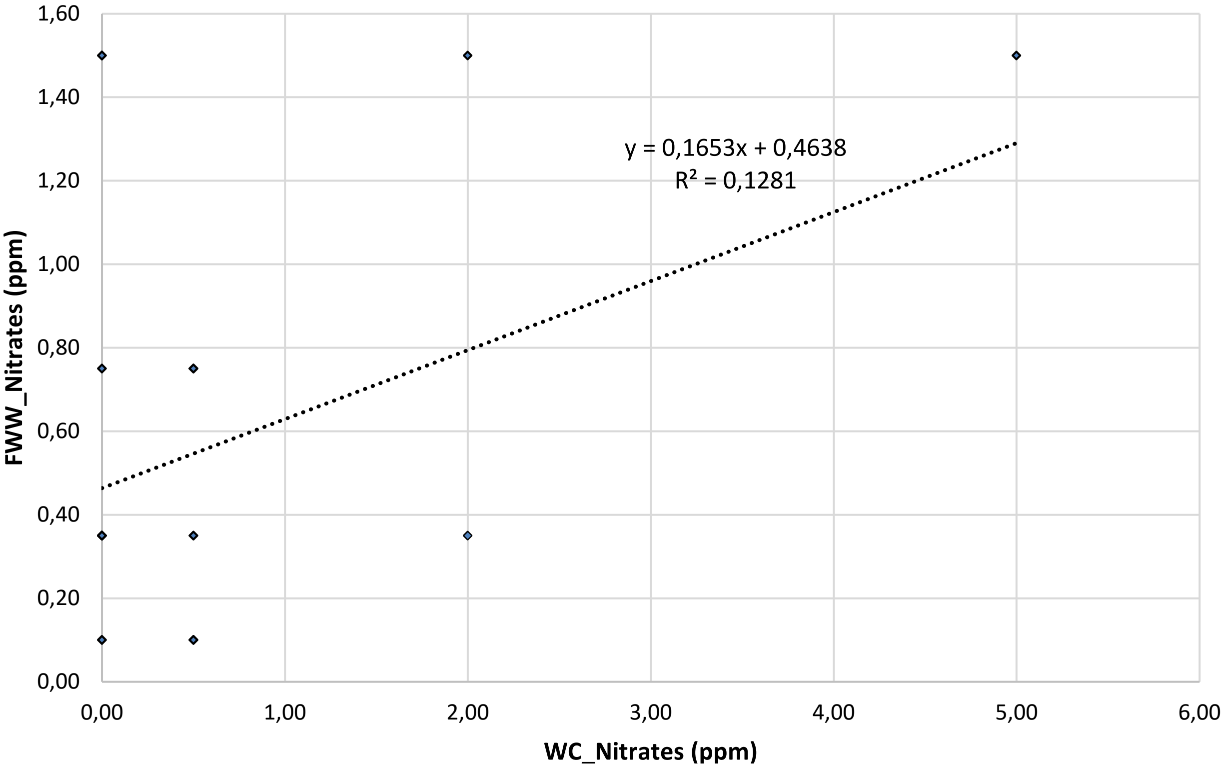


Figure 6.24 Freshwater Watch (FWW) nitrate results compared to WaterCAN iLab (WC) nitrate results

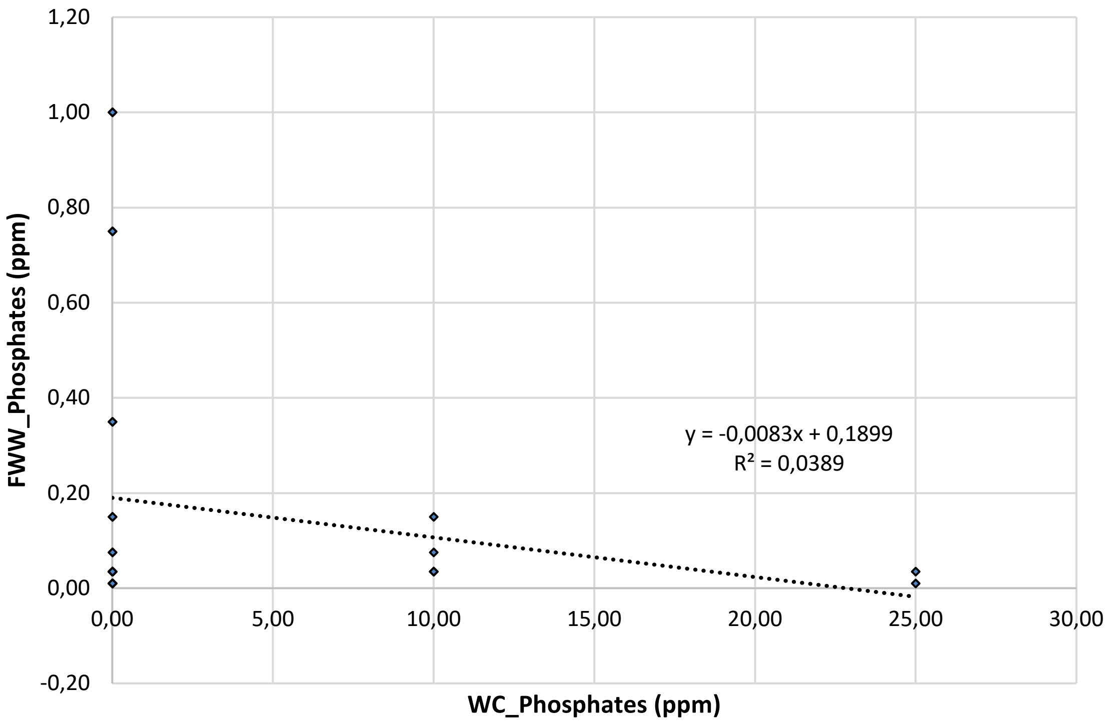


Figure 6.25 Freshwater Watch (FWW) phosphate results compared to WaterCAN iLab (WC) phosphate results

The correlation coefficient between the nitrates datasets was found to be 0.36 and between the phosphates was -0.20. Both correlations are weak, revealing the difference in results which are determined from these techniques. The kits have different sensitivities to the presence of nitrates and phosphates, where the Freshwater Watch kits detect nutrients within a range at a higher sensitivity than the WaterCAN iLab kits, thus the results gathered from each would differ. It must also be considered that although both techniques are colorimetric, the Freshwater Watch technique prompts users to select within which range of the possible nutrient values the result falls, whereas the WaterCAN iLab technique prompts users to determine the closest colour match to an exact value. Further research is recommended to focus specifically on the sensitivity which each of the techniques can detect, and if there are certain environments which would be better suited for the use of each technique.

This comparative analysis was repeated but only focused on a smaller dataset of 5 observations collected by an individual who had been trained by representatives from WaterCAN and Freshwater Watch. These results are provided as a controlled comparison to the set of results above, for a comparison to factor in potential for human error in sampling and/or colour matching. **Figure 6.26** illustrates this comparative analysis for nitrates results and **Figure 6.27** for phosphate results.

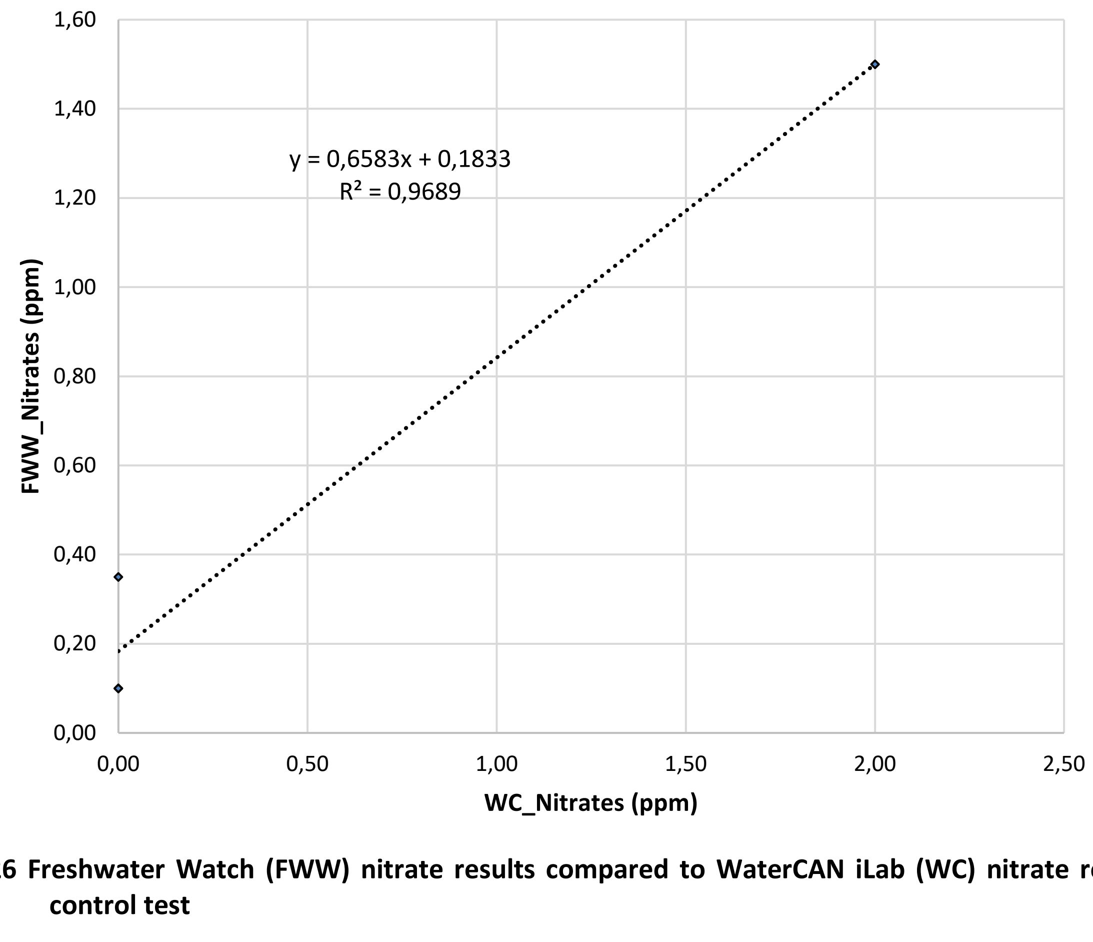


Figure 6.26 Freshwater Watch (FWW) nitrate results compared to WaterCAN iLab (WC) nitrate results – control test

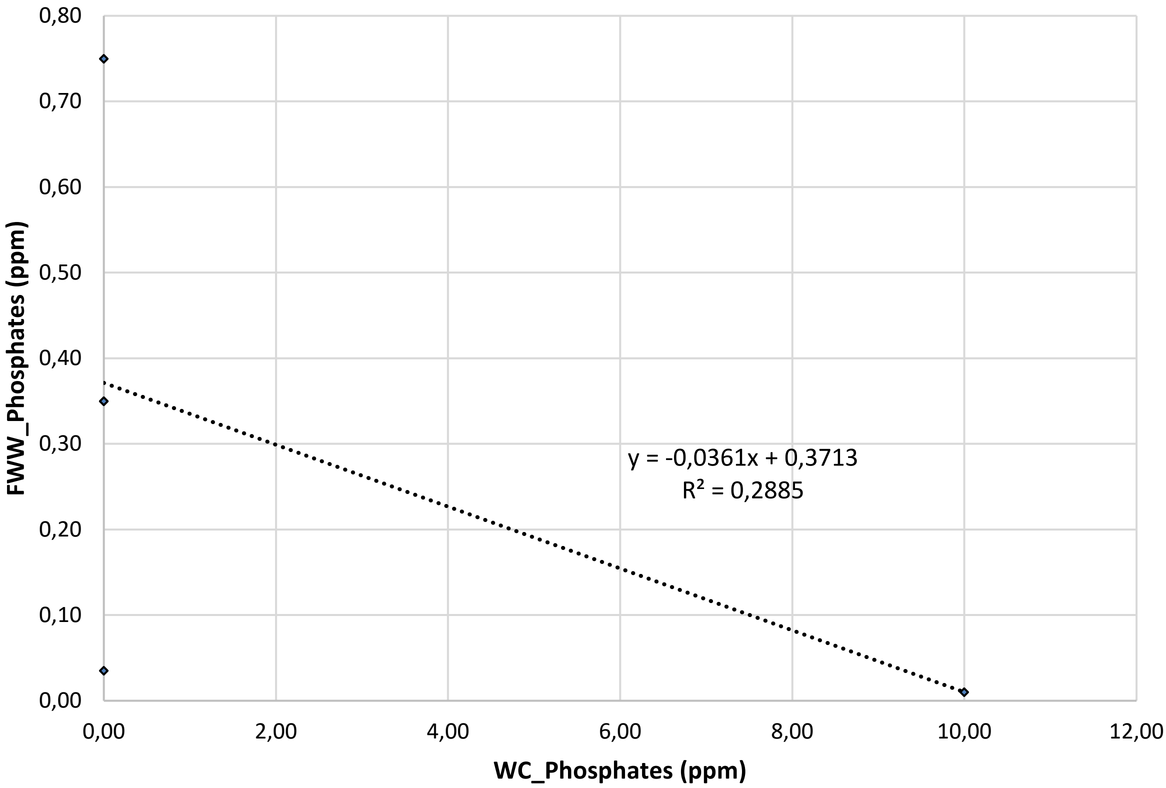


Figure 6.27 Freshwater Watch (FWW) phosphate results compared to WaterCAN iLab (WC) phosphate results - control test

The correlation coefficient between the nitrates datasets was found to be 0.98 and between the phosphates was -0.54. This improvement in correlations demonstrates that there is potential for the two techniques to be complementary in their findings, with the consideration that this is based off a limited dataset.

For 16 select sites, samples were taken to obtain paired results from the Freshwater Watch kits and for laboratory analysis. Once more, the midpoint of the Freshwater Watch results ranges was considered for comparison with the laboratory data. **Figure 6.28** illustrates the relationship between the laboratory nitrate results and the Freshwater Watch nitrate results and reveals that there is a strong, positive correlation. However, **Figure 6.29** reveals a weak, positive correlation between the laboratory and Freshwater Watch phosphate results.

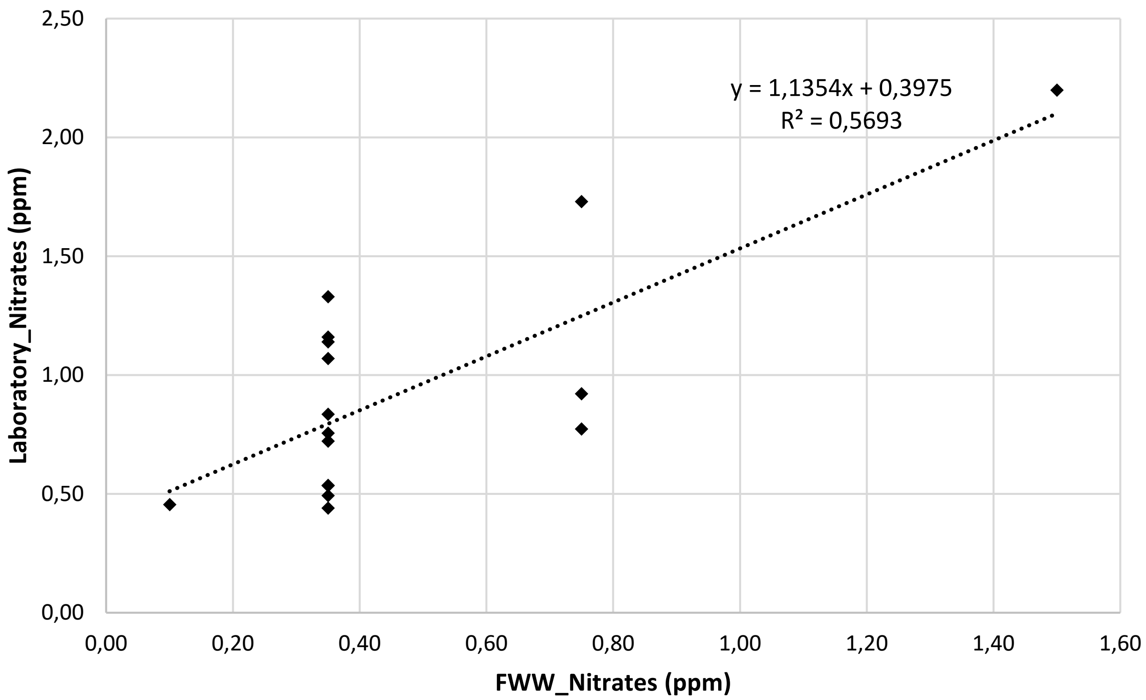


Figure 6.28 Laboratory nitrate results against Freshwater Watch (FWW) nitrate results

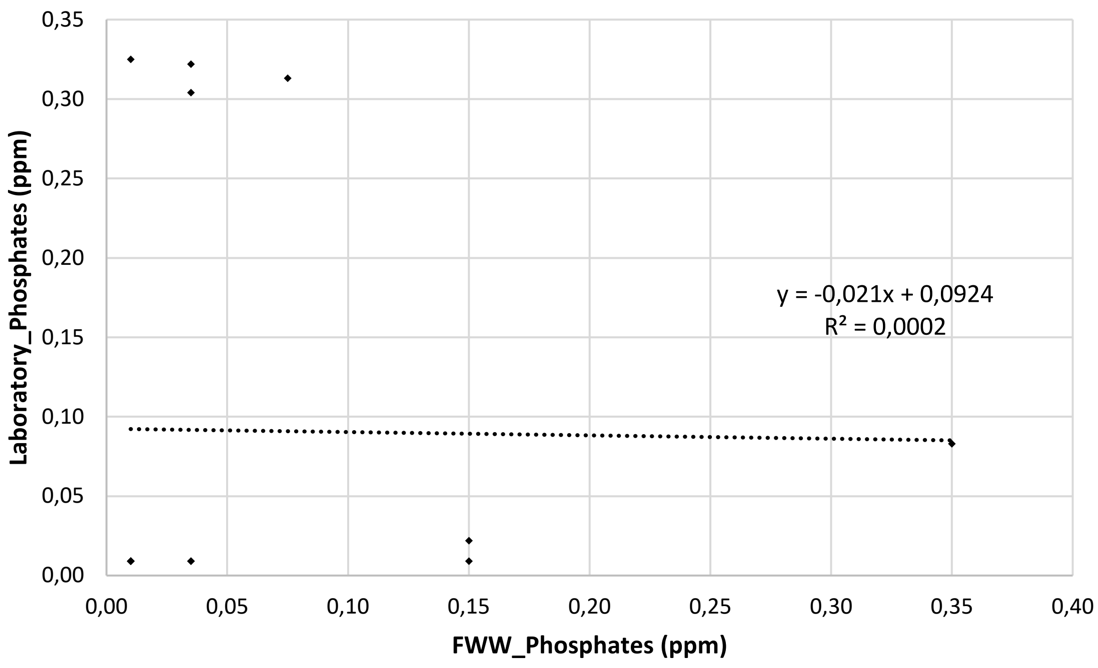


Figure 6.29 Laboratory phosphate results against Freshwater Watch (FWW) phosphate results

The correlation coefficients were found to be 0.75 for nitrates and -0.01 for phosphates. The strong, positive correlation coefficient for nitrates indicates that there is high similarity between the laboratory and Freshwater Wath datasets. However, this is not true in the case of phosphates which have a weak, negative correlation coefficient indicating low similarity between the datasets. The points in the top left corner of Figure 6.25 indicates an underestimation of phosphate values by the Freshwater Watch kits, which skews the overall relationship and correlation coefficient of these two datasets.

This comparative analysis was repeated but only focused on a smaller dataset of 9 observations collected by an individual who had been trained by representatives from Freshwater Watch. These results are provided as a controlled comparison to the set of results above, for a comparison to factor in potential for human error in sampling and/or colour matching. **Figure 6.30** illustrates this comparative analysis for nitrates results and **Figure 6.31** for phosphate results.

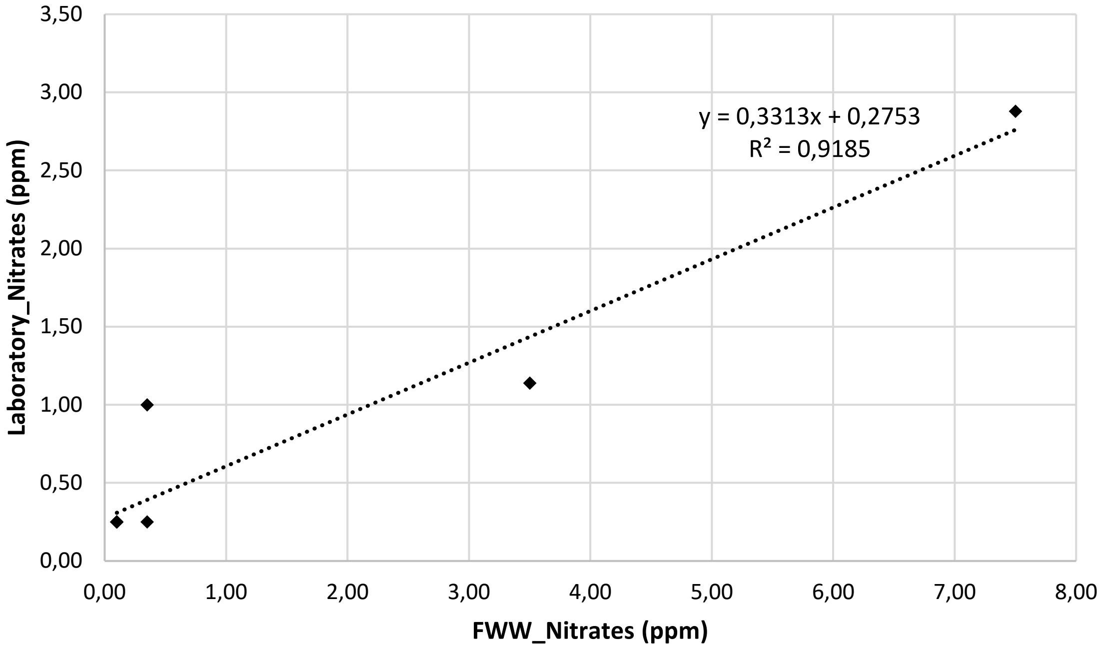


Figure 6.30 Laboratory nitrate results against Freshwater Watch (FWW) nitrate results - control test

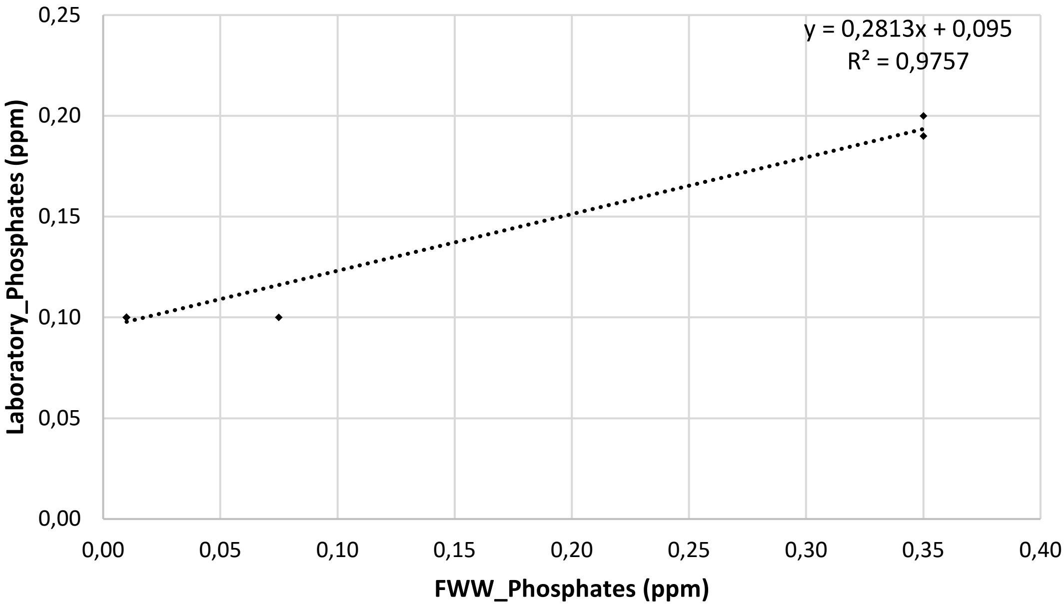


Figure 6.31 Laboratory phosphate results against Freshwater Watch (FWW) phosphate results – control test

The correlation coefficients were found to be 0.96 for nitrates and 0.99 for phosphates. The strong, positive correlation coefficient for both nitrates and phosphates indicates that there is high similarity between the laboratory and Freshwater Wath datasets. These correlations have improved from the previous comparison however it is to be noted that this comparison is based on limited data entries. **Figure 6.29** depicts a very low coefficient of determination (R^2) for phosphate values with less than 1% of the values accounted for in the comparison dataset, however this improved to 98% in **Figure 6.31** (control test). Based on this low value and limited control test observations, it is recommended that further applications of CS-based tests for phosphates could be investigated with focus on a range (very high to very low) phosphate presence, and it is also recommended that these tests be developed further to be able to more accurately detect traces of phosphates in rivers. The nitrate values with coefficients of determination of 57% in **Figure 6.28** and 92% in **Figure 6.30** are higher than phosphates which can be improved to be used as a reliable indicator at broader scales, as are the nitrate tests.

6.4.4 *Habitat assessment datasets and results*

The riparian health audit (RHA) is a technique which translates qualitative observations of the negative impacts on riparian zones to quantitative ratings of the extent and intensity of these impacts. The RHA training is largely based on theoretical understanding, more so than the other techniques mentioned, but it provides users with a way of connecting and linking river systems with impacts on the surrounding environments. Through these audits, users can earnestly consider the impacts which anthropogenic activities and land uses have on riparian and riverine health. The RHA field sheet (**Figure 6.32**) lists the negative impacts which are evaluated, and these results were all submitted manually. Due to the nature of the RHA data being based on ratings of observations, the data could not be subjected to a cleaning process as straightforward as the other parameters except for a check of the total scores, percentage change, and assigned ecological conditions.

Riparian Health Audit Field Sheet

Date:	Upstream boundary longitude (dd):	Downstream boundary longitude (dd):
River:	Upstream boundary latitude (dd):	Downstream boundary latitude (dd):
Project name/no:	General observations/comments:	

Rate each impact from 0-5
Please refer to the manual for rating guidelines

Site Name	Exotic Vegetation	Rubbish Dumping	Bank Erosion	Inundation	Flow Modification	Channel Modification	Evidence of decreased water quality	Vegetation Removal

Figure 6.32 Riparian Health Audit field sheet

A total of 13 RHAs were conducted across the region (**Figure 6.33**). Of the limited RHAs which were conducted, the majority revealed good ecological conditions with none reporting natural nor critical ecological conditions as illustrated in **Figure 6.34.**

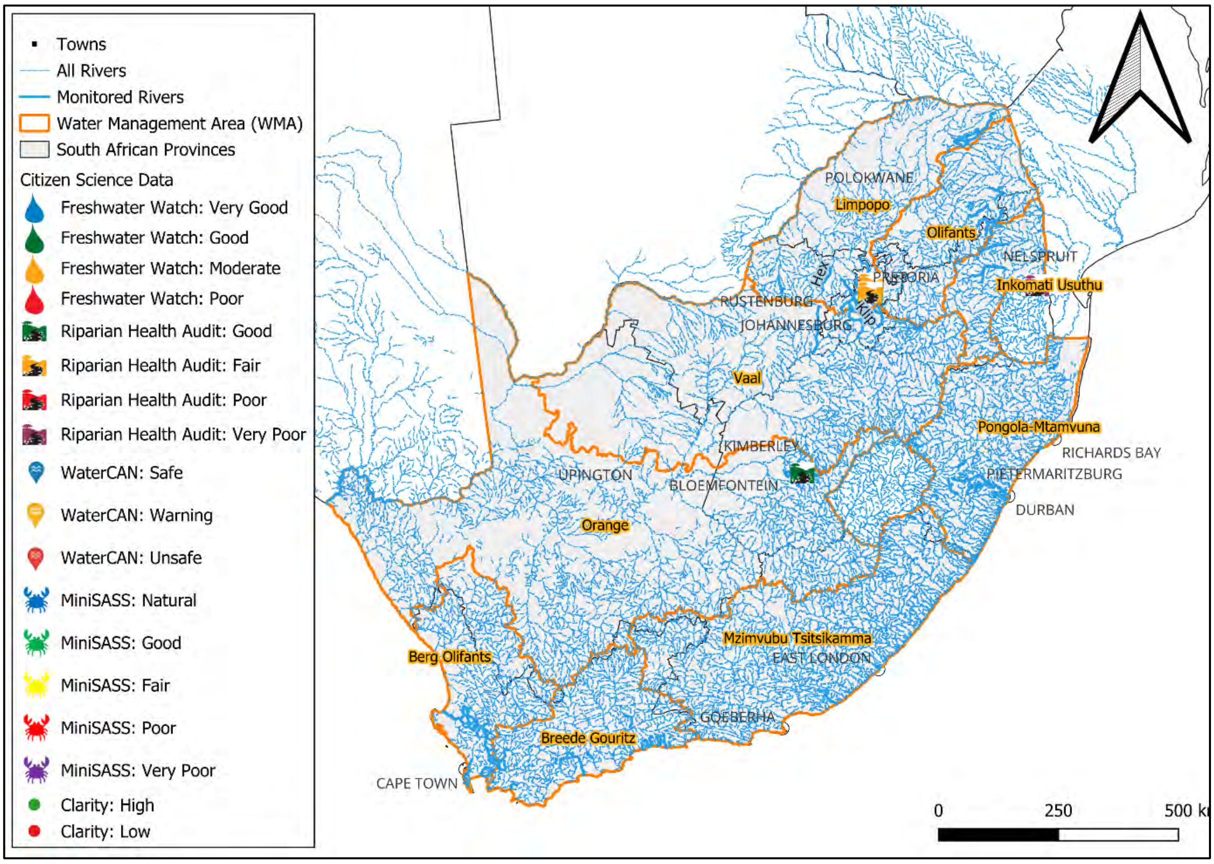


Figure 6.33 RHA monitored locations across the region

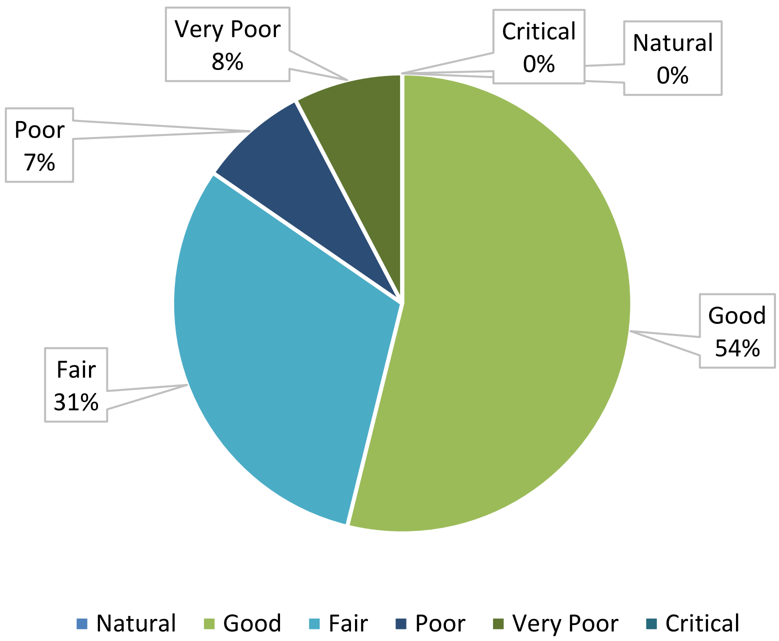


Figure 6.34 Proportions of RHAs per ecological condition category

The collaborators were advised that the RHA was a technique which is not used as frequently as the other methods, and is useful to conduct twice a year, or before and after events which would impact the riparian zone such as construction or flooding.

A possible reason for the low submissions of the RHA can be attributed to the necessity for the users to go through thorough and theory-based training material with explanations of the purpose, the impacts, and technique. Additionally, this habitat assessment would be suited to locations with which the user is familiar and has an understanding of how the impacts have affected the riparian zone. A discussion in the collaborators forum on the RHA training revealed that some collaborators opted not to use the RHA tool as it tends to be subjective and prefer more objective techniques, providing further reasoning for low uptake of this technique.

6.5 Coordination of citizen science monitoring

As revealed from discussions and interviews with CS practitioners, there is a consensus that CS efforts appear to be scattered and uncoordinated, with CS practitioners being unaware of other CS efforts occurring in their catchments. This CS SoR project has provided a space for CS practitioners to connect and has encouraged a CS CoP of CS advocates and practitioners to link together. Through this CS network and CoP, individuals and groups can plan and work collaboratively, thus streamlining the CS efforts and processes, for efficient environmental and water resource management.

For this project, a participation guiding document was compiled and circulated to CS stakeholders. This guiding document was referred to as the *2024 Citizen Science State of Rivers Report Collaborators Roadmap to Success*. This roadmap contained all the relevant information which the stakeholders would have needed to be familiar with, and to understand the project objectives, expectations, methodologies, and the process set out to produce a CS SoR report. Once the stakeholders expressed that they understood and would like to be involved, they were considered as CS SoR collaborators. This guiding document was compiled with the intention of streamlining the onboarding process allowing the stakeholders to understand that this project was set out to take CS beyond just data collection, and to understand how CS data was going to be applied and used for reporting. This roadmap also allowed the stakeholders, whether they opted to collaborate or not, to freely access reliable training material on CS tools and techniques which was published by the Water Research Commission (WRC) (Russell *et al.,* 2024) a few weeks prior to the initiation of data collection for this project.

6.6 Verification of data credibility

The quality of data obtained through CS techniques has been challenged in terms of its validity (Carlson and Cohen, 2018; Hulbert *et al.,* 2019; Ramirez *et al.,* 2023). The concern over the credibility of CS data has been similarly echoed during conversations held at the project initiation workshop for this project, and during interviews with key CS practitioners in South Africa. For this data to be used for CS reporting and decision-making, the concerns around data credibility must be addressed.

Measures to improve the credibility of CS observations have been set into place. The first is the simplified and accessible training which was made available to all collaborators. The development of the miniSASS mobile application which utilises artificial intelligence (AI) is another innovation which aims to reduce error in the identification of macroinvertebrates.

Collaborators forum sessions on the various techniques also aided in facilitating the experiential learning process for the trainees, in which they were guided on best practice for using the tools and techniques. The point of preference for in-person training was raised during the hybrid training session on the use of the Freshwater Watch kits for a select group of collaborators to trial in South Africa. However, open channels of communication with the collaborators were ensured in the case of any queries which arose, and the project team were provided with support from the WWQA Earthwatch Europe team.

Submission of data on the online platforms (such as the miniSASS, Freshwater Watch, and WaterCAN websites) do not allow users to submit data without certain critical information fields being completed. This ensures that all the relevant information to complete an observation is collected. This is a simple but effective measure to ensure only complete datasets are being shared. Further, the data used to generate the CS SoR report were all subjected to a cleaning process (detailed in **Chapter 6, Section 6.33** of this project report).

Regarding the validity of data Holt *et al.,* (2013) note that the concern of flawed observations in a bulk CS dataset is less so in these large CS datasets where majority of the data holds validity. With the consideration that online training materials were made available to collaborators who voluntarily wanted to learn more about CS and play a role in the production of the CS SoR report, it can be assumed that the bulk of the dataset has been collected in accordance with standard practice. However, there is always the possibility of misunderstandings or flaws to occur.

Collaborators were also offered the opportunity to participate in online training courses through the Pluto Learning Management System (LMS) to learn about the CS tools by either accessing the *Tools for Citizen Science* or *YOMA Opportunities* (which is an open-source detailed course on the miniSASS technique and social learning, developed under another project). Access to both these courses was free-of-charge and participants could earn a certificate of theoretical competency for each module under these courses.

6.7 Citizen science impact assessment framework

This evaluation of the effort to generate a CS SoR report is based on the Citizen Science Impact Assessment Framework (CSIAF) as outlined by Wehn *et al.,* (2021b). Wehn *et al.,* (2021b) have emphasised the necessity for CS initiatives to be evaluated against a framework to better comprehend the impact and influence which CS has had on environmental policy and subsequent decision making. The intention of using an evaluation framework is to feed into a broader approach which aims to capture and communicate case studies of CS impacting policy, and to encourage and strengthen relations between policy makers and CS practitioners.

The CSIAF was selected to ensure that the different aspects of this CS SoR initiative have been considered and reported on and can be held to comparisons to subsequent initiatives of this nature, or comparisons to other initiatives in the CS space. The aspects considered in the CSIAF, as outlined in Wehn *et al.,* (2021b), are society, environment, science and technology, economy, and governance.

6.7.1 *Societal impact*

The encouragement of a CS for WQM CoP allows for communities to connect with each other and with other communities over common points of interest or concern. Through these CoP, stakeholders have been able to connect with other CS practitioners. An example of this is through the collaborators forums in which the CS practitioners were encouraged to share their names, affiliated organisations (where applicable) and interest in the CS space in the online meeting chat space, while the informative and interactive session was running. The conversations often led to exchanging of contact details, which is a step toward strengthening the connectivity of the CS network.

Through this project, there has not only been encouragement of connectivity in the CS CoP, but also the promotion of this research serving as an opportunity for professionals in the water sector to learn more about CS, and an opportunity for the CS practitioners to use the connections made to facilitate conversations around improved co-ordination of CS efforts.

The societal impact of this CS SoR project also aided in facilitating a space for academia to connect and share their reflections of where CS is already or where it potentially can be incorporated in the teaching and learning curriculum at institutions of higher learning.

Most notably, outside of the existing CS CoP, the public and inclusive call for all interested parties to take part in CS efforts was met with great interest. Although this interest could not always be translated to action, there was a notable enthusiasm amongst those who were new to the CS space to learn more and apply these techniques beyond this research project. An example of those who were new to the CS space but intend on continuing monitoring and sharing their observations with their local community include members of the Peacevale Conservancy in KwaZulu-Natal and Owe 2 Green Economy in Gauteng.

Beyond the use of CS techniques to generate bulk datasets and as an environmental education tool, scientifically sound CS techniques can be used to support advocacy efforts, giving those who are vulnerable to the impacts of poor water quality a strong case to raise their concerns with data to support them. This also has the potential to assist in building an improved relationship to work with local authorities in identifying and taking steps towards addressing issues of common environmental concern, and particularly those which may pose risks to public health. An example of working toward these synergic relationships which was demonstrated through this CS SoR project was revealed during interviews with key CS practitioners where half of interviewees indicated that they share their CS data with local authorities, and a few share their data with traditional authorities.

6.7.2 *Environmental impact*

Environmental challenges, with particular focus on water quality challenges in the context of this research, must be closely monitored to facilitate improved and efficient management of these challenges.

As previous chapters of this report have touched on, the uptake of WQM through CS techniques can potentially increase the frequency of monitoring at locations which would otherwise be unmonitored by mandated institutions due to the reality of capacity limitations. A network of more frequently monitored points can aid in the identification of points of concern which may need more urgent intervention and prioritisation than others e.g., where there are multiple sewer line leaks or where chemicals are being illegally discharged into the river system.

Apart from the increase in the spatial and temporal resolution of monitoring river systems, CS monitoring has the potential to reveal environmental challenges and/or assist in tracking the efficacy of mitigation measures. In instances where CS is being used for the first time, this can assist communities to develop a baseline of the river conditions and use this baseline to track changes and impacts over time.

The monitoring of freshwater resources through CS techniques has been acknowledged as valuable to assist in informing reporting on SDG indicator 6.3.2 on the proportion of bodies of water with good ambient water quality (UNEP, 2018). Through this CS project and partnership between GroundTruth and the WWQA working group on CS, contributions have been made to the online, open-source, and global Earthwatch Europe (Freshwater Watch) database (https://www.freshwaterwatch.org/pages/groundtruth) aiding information which could be used to inform SDG 6.3.2 through monitoring the levels of nitrates and phosphates by using Freshwater Watch kits.

Linked to the societal benefit, the accessibility and usability of CS techniques facilitate educational experiences that help promote awareness around the protection of the environment. Examples of this, within this project include conservancies and educational groups, such as One Planet and the Mosselbank River Conservation Team, sharing environmental knowledge with their communities through CS practices. The miniSASS-YOMA pilot project also drives this point through the incentivisation of biological CS monitoring using the learn to earn model (details of this pilot project and model are elaborated upon in **Chapter 8, Section 8.6**).

6.7.3 *Contributions to science and technology*

Wehn *et al.,* (2021b) evaluate the impact which CS projects have had on science and technology by how scientific processes, technological advancements, and scientific institutions have been impacted or influenced by these projects.

Although not directly a product of this project, the upgrade and development of the miniSASS website and mobile application, respectively, have been used by the collaborators of this project. Similarly, the online learning materials which were released in early-2024 for various CS tools and techniques have also been the primary medium of training those who are new to the space, and as a refresher for those who are familiar with CS monitoring. Feedback from CS SoR on the online learning materials has been positive as it has allowed collaborators to access the training at their convenience, and at virtually no-cost outside of mobile data to access the materials.

This project in itself has influenced scientific processes and institutions through the support of research at both Bachelor of Science and Masters in Science levels by three students in the discipline of Hydrology at the University of KwaZulu-Natal.

6.7.4 *Economic impact*

This project did not have provision of remuneration for the involvement of collaborators outside of the core project team. The collaborators have either volunteered their time to get involved or have introduced or continued CS monitoring as part of their organisation's operations.

The training materials provided had the potential to aid in the integration of CS efforts in existing structures or operations of those who are working in green spaces. The upskilling of staff from participating organisations could have the potential to catalyse an interest in CS and allow those organisations to explore funding and project opportunities in the CS space in future.

Under a separate but linked project, participating South African youth had the opportunity to earn a R100 voucher to use on the YOMA (Youth Agency Marketplace) platform upon the successful completion of a miniSASS assessment and upon the provision of evidence of having successfully uploaded their result. The duration of the first phase of the YOMA-miniSASS project was within the timeframes for data collection for this CS SoR project (under a year). Thus, these projects worked together to promote miniSASS monitoring during this time.

6.7.5 *Influence on governance*

Governance in this context has been identified by Wehn *et al.,* (2021b) as the impact which CS projects have had on informal and formal decision-making processes.

The potential for CS monitoring to contribute to informing aspects of SDG indicator 6.3.2 as mentioned above links to the potential for CS practices to impact on formal decision-making procedures, such as the cases in Sierra Leone and Zambia where, for the first time, CS data was used to aid in informing on the progress of SDG 6.3.2 (UNEP, 2024). There are also governance lessons to be taken from CS applications in terms of how CS data has influenced decision-making at a local scale. An example of the influence which CS has on governance was demonstrated by Zongile Ngubane in the Shiyabazali community in Howick, KwaZulu-Natal who, through consistent monitoring of the Howick wastewater treatment works with a clarity tube, was able to demonstrate the non-compliance of this system, and develop a relationship with local authorities to work toward rectifying the issue (Graham and Taylor, 2018).

6.8 State of rivers reporting styles

The collaborators were presented with the option of developing their own local SoR reports to allow them to take their involvement a step beyond data collection. Three different templates were created for collaborators to select from to use for their local SoR reporting. By encouraging the production of these local SoR reports, it was also hoped that these collaborators would find value in taking these into the future to monitor and produce the reports frequently, for their own benefit and interest. The different formats were designed to assist the collaborators in generating local SoR reports in a format which would suit their audience, their reporting needs, and the volume of data which they have available to report on dependent on their capacity for monitoring. The first two templates are a timeline of conditions and a landscape of conditions which could both be useful as poster formats. The timeline of conditions would be useful to show changes in the results at a specific location overtime as displayed in **Figure 6.27.** This can also include the different parameters which were observed at that point at different times and can also include an average condition determined over the indicated monitoring period. With a reference to the location of the monitoring point, this format can be useful for a broad range of audiences to view and for comparisons over time e.g. from year-to-year or between seasons. Collaborators were encouraged to note possible causes for the results observed each time to assist in adding to their local SoR report.

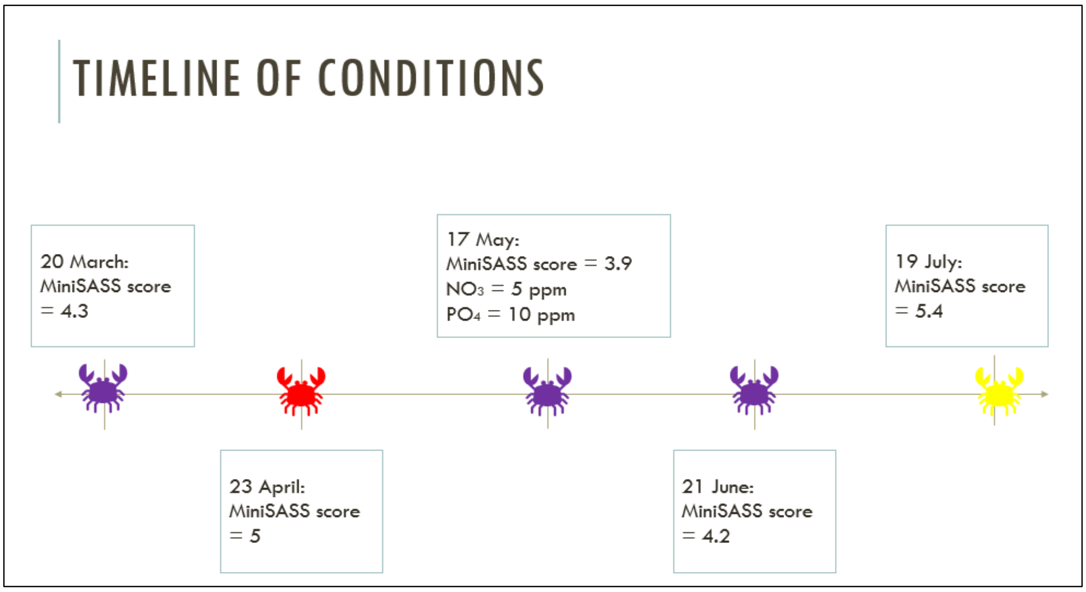


Figure 6.35 Hypothetical example of a timeline of conditions to represent the condition of a river at the same point over time

The landscape of conditions format, as displayed in **Figure 6.28**, provides a summary of results for multiple locations being monitored either once-off or periodically over time. This format can provide audiences with a simple overview of the average conditions at different locations over a landscape and displays changes in the river system over the landscape. If the locations are clear, this can be useful for a wide range of audiences however, this format may be better suited for an audience that is familiar with the landscape and land uses around the monitoring points. The monitoring points can each have their own timeline of conditions with the latest data displayed on the landscape map preceding the timeline for each point.

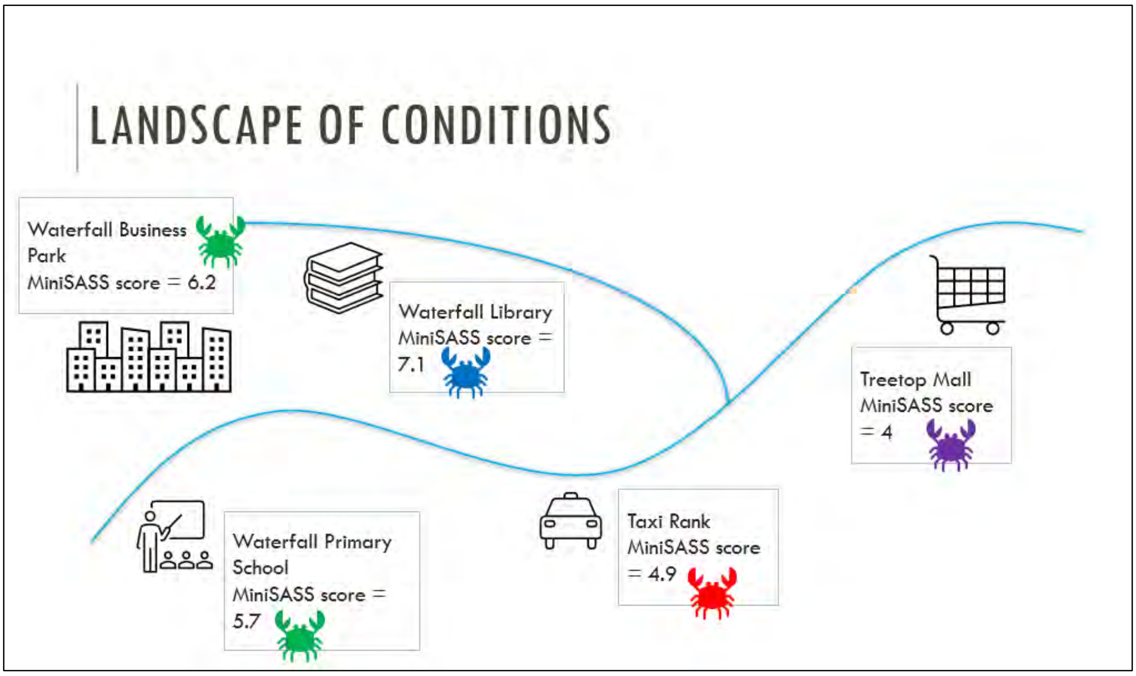


Figure 6.36 Hypothetical example of a landscape of conditions to represent the condition of a section(s) of a river at different points

A report template for a formal style SoR report under this project was created, predominantly following the structure of a DWS SoR report, with amendments which would allow collaborators on this project to create a local SoR report that is understandable, appealing to a large audience, and easy to compile. The template for a SoR report was generated, mainly referencing the *Compiling State of Rivers Reports and Posters: A Manual* by Strydom (2003).

The barriers to the application of this template included that the traditional reporting template required information which would not be easily available for collaborators to access, and it would be information that may not be necessary to include for the aims of this project/collaborative effort. An example included in Strydom (2003), which was excluded from this template, would be the overview information on the population, economic profile and development priorities of the area. This information would be included in the DWS SoR report and would be made available through the department to the interested parties. In the context of this project, the SoR report need only assess the ability of citizen science tools and techniques to produce a SoR report which can inform all communities of water users.

The formal-style report would be suitable for those who would generate reports for the purpose of reporting back to superiors, for academic writing, or as part of a programme (i.e. for operations reporting or as feedback to funders). This type of report would include details of the results including interpretation of the observed data. It would be helpful to include current satellite imagery maps, notable events or developments, and methodologies which were used in the data collection and reporting process, in this type of report to reflect upon in the coming years.

6.9 Chapter Discussion and Conclusion

Apart from the use of the CS tools, the engagement with stakeholders was paramount to the fruitful progression of this project. Without the participating collaborators, the content of this body of work would be lacking. As such, effective and relevant communication was key to generating interest which translated to joining the CS for WQM networks and commitment to assisting with contributing to this body of work.

The project team aimed to make the collaborators' participation in this CS initiative easy to follow, rewarding, and worthwhile. This was done through the guides that were developed, the forums that were held, and the open channels of communication that were maintained to assist. These guiding points and materials assisted in streamlining communication to a large group of stakeholders and provided the resources to further the collection of reliable data.

The evaluation of this project against the CSIAF revealed that this project had varying degrees of influence on society, the environment, science and technology, economics, and governance. However, a recommendation would be to reevaluate these influences once the project reports and contents have been publicly distributed, and feedback from stakeholders has been received.

7. 2024 Citizen Science State of Rivers Report

"Freshwater is the bloodstream of the biosphere's capacity" – RHP, 2005a

River systems are complex and have "developed their own self-sustaining balance" (RHP, 2005a). However, the impacts of anthropogenic impacts cause this balance to shift and can result in a decline in river health. Rivers provide mankind with various goods and services (RHP, 2011) which are essential for human wellbeing such as water for drinking, cleaning, and farming, and provides a habitat for fishing, tourism, and recreation (RHP, 2003). However, anthropogenic actions have impacts on the health of river systems thus it is essential to monitor the quality of these water bodies so that they can be better managed. These activities include, but are not limited to, agriculture, deforestation, abstractions, constructions and activities which lead to increased discharge of runoff, wastewater and effluents into rivers. These detrimental impacts may potentially be detrimental to the health of both humans and the environment. It is through the routine monitoring of river systems that the overall health of these systems can be tracked, pollution sources can be traced, and intervention measures can be evaluated. This chapter aims to draw from the concept of the national SoR reporting by DWS, but using data generated through CS techniques to inform on the conditions of river systems.

The condition of rivers across South Africa are to be determined based on the available CS data and reported herein. The overall condition categories are based on the River Health Classification system as detailed in the 2002 uMngeni State of Rivers report (WRC, 2002) and 2011 Breede State of Rivers report (RHP, 2011). The River Health Classification tables from these reports have been adapted and summarised in **Table 7.1** and include explanations of the river health classes from both ecological and management perspectives.

Table 7.1 River Health Classifications (modified from WRC, 2002 and RHP, 2011)

River Health Class	Ecological Perspective	Management Perspective
Natural (N)	Modification to the system is either none or negligible.	Protected rivers. Minimal human impact on the system.
Good (G)	The system is in a good state with biodiversity and integrity largely intact.	Low-impact human disturbances to the system but it is still in good state.
Fair (F)	Potential loss of sensitive species with tolerant species dominating.	Socio-economic development caused multiple disturbances e.g., impoundment, habitat modification and water quality degradation.
Poor (P)	Declined habitat diversity; present species are often diseased; tolerant species dominating and alien invasions present; population dynamics are disrupted.	High human disturbances and extensive exploitation of resources. Interventions needed to improve river health.

This *2024 Citizen Science State of Rivers Report* will:

- Detail the focus CS techniques for monitoring river health included in this report,
- Explore the conditions of monitored river systems across South Africa based on the available data derived through CS techniques, and
- Feature applications of CS practices across South Africa through case studies compiled by the featured organisations

7.1 How to Read This Report

This report provides an overview of the tools and techniques used, a regional overview, and the results which are mapped out in sections which correspond to the Water Management Areas (WMAs) of South Africa, with additional sections for international boundaries. Provincial boundaries were applied during planning, communication, and execution of this project for simplicity and ease of communication. This was also done for relatability to allow citizens to easily situate themselves per province as opposed to the WMAs. The relationship between the WMAs and provinces of South Africa is displayed in **Figure 7.1.**

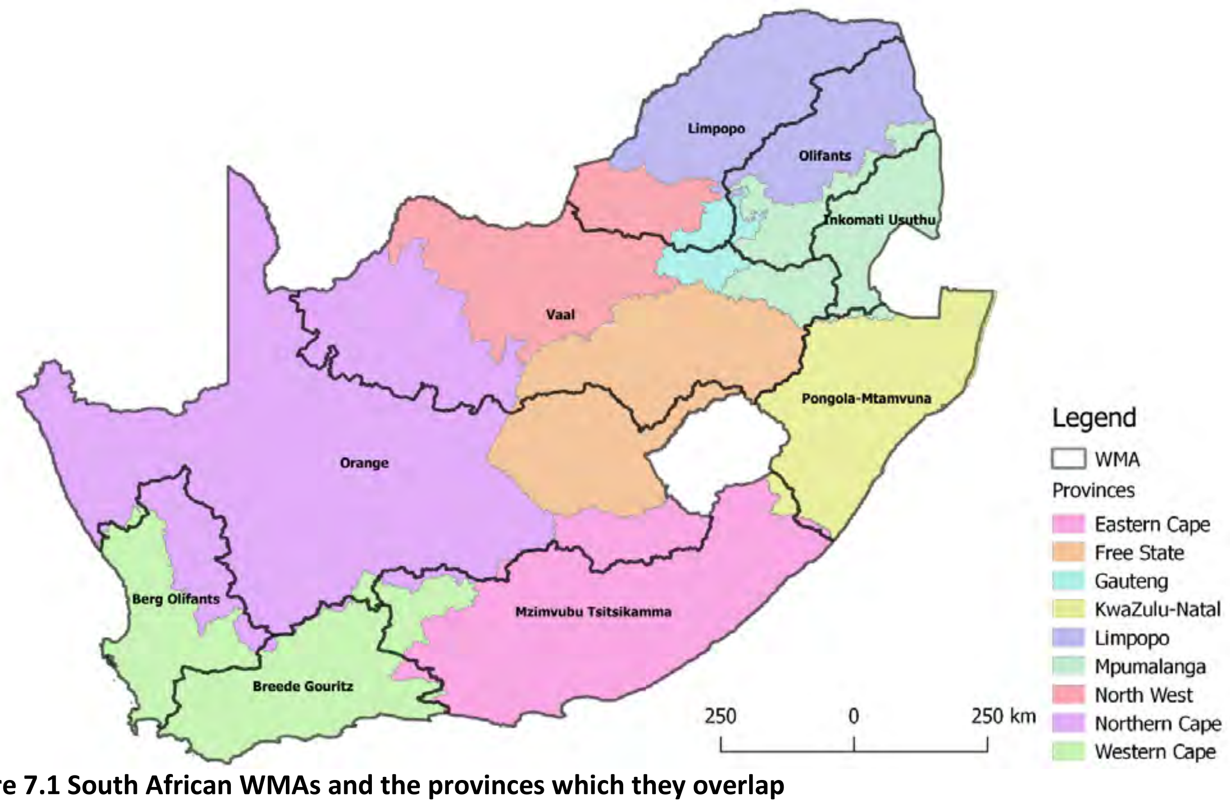


Figure 7.1 South African WMAs and the provinces which they overlap

However, the decision to report the results within WMA boundaries was taken to streamline the discussion for potential alignment with the conventional reporting by the DWS such as the State of Rivers Reports, an example of which from the State of Rivers Report 2020-2021 (DWS, 2022) is shown in **Figure 7.2** where the reasons for not sampling are indicated by different markers in the legend (e.g. health and safety concerns, access limitations, capacity limitations, amongst others) and STRAHLER indicates the stream order.

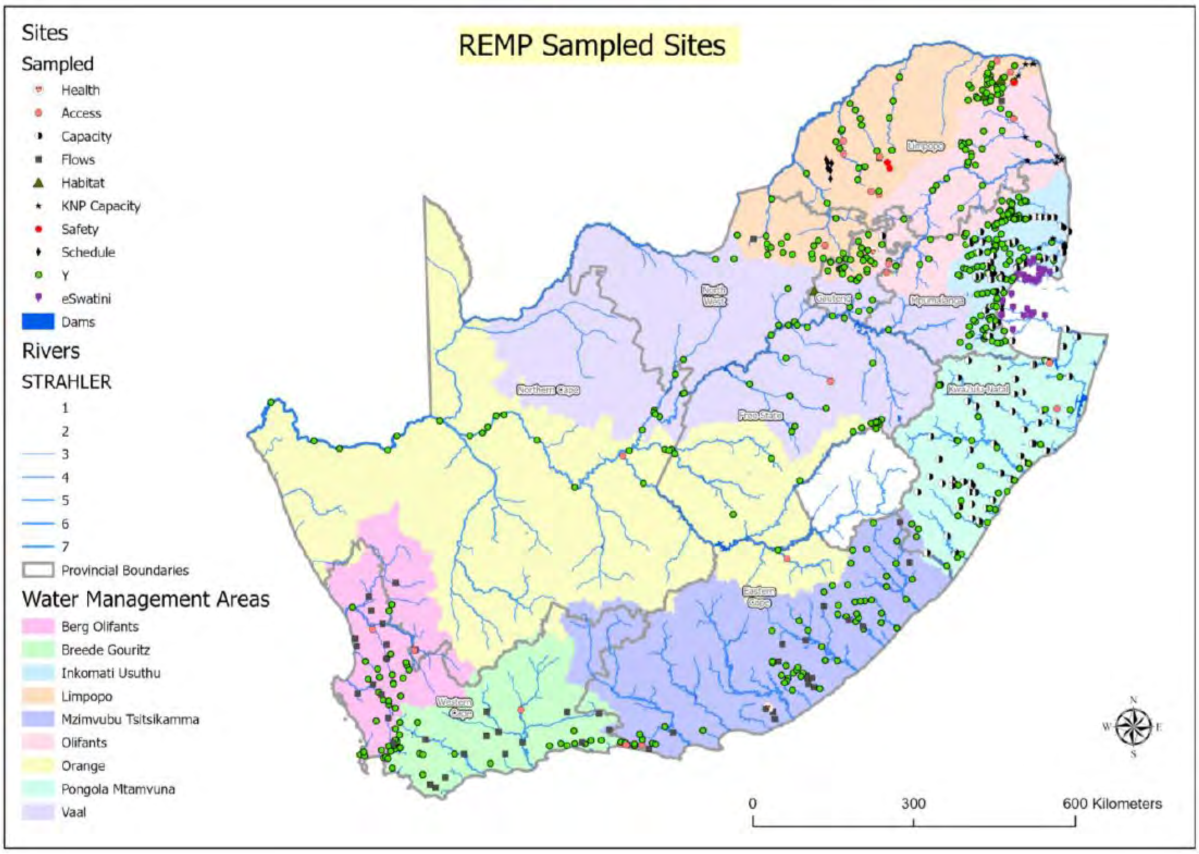


Figure 7.2 River Ecostatus Monitoring Programme monitoring sites for the 2020-2021 hydrological year (from DWS, 2022: p. 3)

The CS techniques used provided insight into the condition of rivers from biological (miniSASS), physico-chemical (clarity tube, Freshwater Watch, and WaterCAN techniques), and habitat (RHA) assessment perspectives. This report provides the most recent results from each of these perspectives along monitored rivers. Thus, the parameters were not all necessarily observed at the same time. Critical to note, is that these perspectives all provide insight into the overall condition of these water resources and are not to be used in isolation to determine an overall condition of the river system. This point highlights the complexities of river and ecosystem health and additionally highlights how CS techniques can provide insights into these perspectives. For example, poor ecological conditions but low nitrates and phosphates may seem contradictory, but this reveals that there are other factors could be impacting river health. Thus, it is encouraged that readers of this document exercise discretion and do not interpret results out of context.

7.2 Data Collection

The volunteer groups, organisations and individuals who contributed data to this body of research were guided to reference and training material on each of the tools or techniques. The project team compiled the *2024 Citizen Science State of Rivers Collaborators Roadmap* (link to this document found in **Appendix J**) which served as a guiding document for participation in this collaborative effort. Herein, links were given to the training materials for each technique mentioned. Every collaborator was encouraged to go through the training material – which was available in written manuals, written summaries, video format, or all or a combination of these – prior to selecting the technique they'd like to use and prior to data collection. This was done to aid in ensuring that the data which was collected was done so with adherence to standardised methodology.

7.3 Regional Overview

The focus for this report is South Africa but it is worth noting that interest was received from CS communities in neighbouring countries Lesotho and Namibia. It must be noted that this report reflects those who the project team could connect to over the project duration (approximately a year), those who did not connect with the project team but did share their data on open-source platforms which the project team included in the datasets, and this only reflects those who opted to share their data. In other words, there are likely other CS efforts, in various phases from ideation to implementation, active across the region which are not represented in this report. For this region (South Africa and the surrounding countries mentioned) the uptake of CS practices has fair representation across most provinces in South Africa. The sites which were monitored are displayed in **Figure 7.3** and include miniSASS, clarity tube, physico-chemical and RHA observations from the various data sources mentioned.

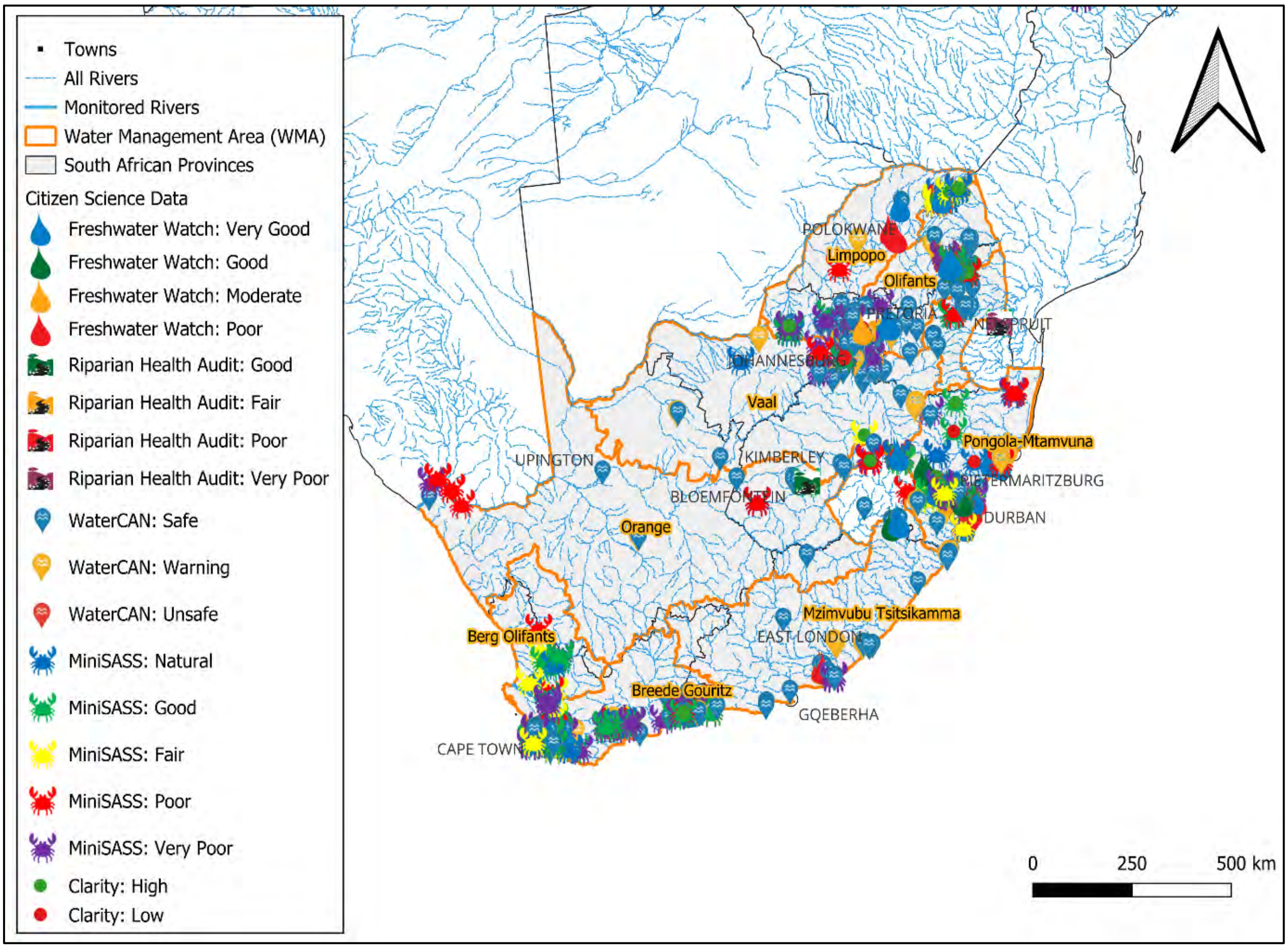


Figure 7.3 All citizen science data points across the region

From **Figure 7.3**, there is a fair spatial spread of CS activities across the region. The research for this project came to identify clusters of CS activity in the various CoPs at catchment and/or provincial scales including parts of KwaZulu-Natal, the Western Cape and Gauteng. It has been through environmental groups, conservation teams, and both funded and voluntary environmental programmes which have contributed to developing CS CoPs in these clusters.

However, in provinces such as Northern Cape, North West, and Free State there is a low representation of the CS community. This could be for several reasons but can be inferred to either a lack of connection to the CS network there by the project team, or a CS community which is not as established as others. Research, such as this project, has the potential to provide communities with information to use when deciding to assign time and resources to CS practices. Overall, there were 2725 data entries used in the generation of this report.

Bias also exists in the sites which were selected to be monitored. An England-based CS case study by Loiselle *et al.,* (2024) noted a limitation of voluntary CS data collection was that site selection was limited to where the volunteer citizen scientists frequent, typically either for work or hobbies. Predetermined monitoring sites were not used for this research but rather, the sites were determined by the collaborators. This was to align with their routine work, monitoring, or recreation, or an area in their local community about which they are concerned. This approach was also taken to encourage the continuation of monitoring at these locations. The uptake of CS in the areas between the existing monitoring sites was encouraged, with specific focus on those areas which would aid in building a continual dataset along rivers.

However, other reasons for gaps in spatial datasets are factors such as safety for civilians to enter the stream either due to the presence of animals in the water (e.g. crocodiles) or hazardous substances (e.g. if civilians can see and smell chemicals or faecal matter in a river they do not need to conduct assessments to know it is in an unfavourable condition), and the accessibility of sites (e.g. deep or fast flowing streams, or stretches of river systems which are located behind fences on private property).

The sections to follow zoom in to each of the WMAs of South Africa and sections of the neighbouring countries where CS monitoring was applied along particular stretches of river systems within these managerial and/or political boundaries. These analyses are to provide a brief overview of the condition of river systems from a CS perspective in the localities within these WMAs.

7.4 State of Rivers: Water Management Areas

The sections to follow focus on stretches of river systems in the WMAs (and neighbouring countries) where two or more points along the rivers stretch were monitored from CS perspectives from August 2023 to October 2024. The data which was gathered will be used to represent the state of the river systems at the respective monitoring points with reference to the river health classification set out in **Table 7.1**. It must be noted that routine monitoring was conducted at some monitoring points which would not be clearly depicted on the maps due to the points overlapping where the same coordinates were recorded. Thus, the average condition and/or changes in conditions were determined using a QGIS file of data points where all data points were made visible and are not based on a static map.

7.4.1 *Berg Olifants Water Management Area*

The Berg-Olifants WMA covers portions of the Western Cape and Northern Cape provinces of South Africa. The rivers systems which were monitored in this region are displayed in **Figure 7.4**.

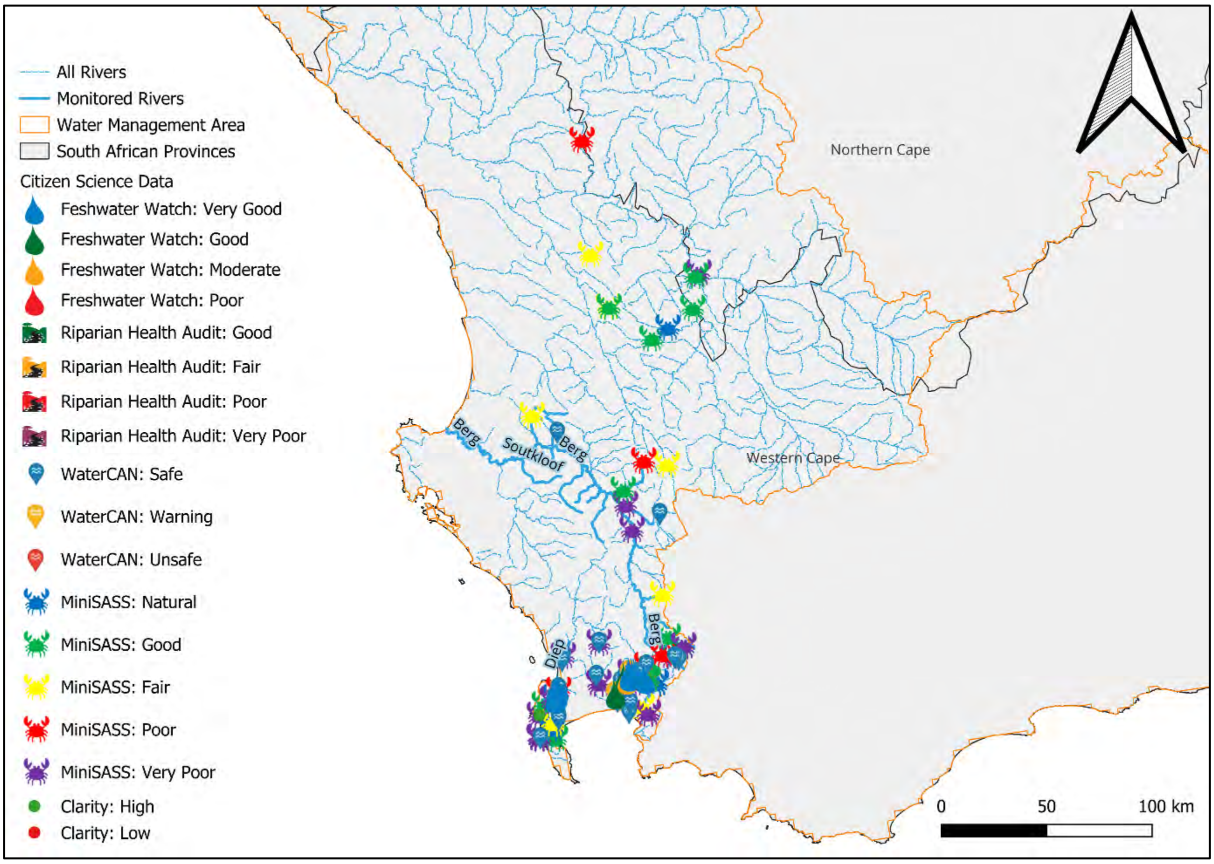


Figure 7.4 Citizen science monitoring in the Berg Olifants Water Management Area

Berg River and tributaries

The Berg River (flowing east to west), and a few of its tributaries were monitored including the Franschhoek, Krom, Klein Berg, Vier-en-Twintig, and Boesmans In the upper reaches of the Berg River close to the source (southeast), the Berg River is fed by the Franschhoek tributary (**Figure 7.5**). Biomonitoring along this tributary indicates very poor conditions. However, from a physico-chemical perspective, the tributary is found to be in safe condition based on testing from three months after the biomonitoring. The Franschhoek tributary then joins the Berg River and downstream of this confluence where the ecological condition is found to be poor. The Krom tributary is found to have a fair ecological condition based on biomonitoring observations and joins the Berg near Wellington. However, biomonitoring conditions further downstream indicate very poor quality both on the Berg, and on the Klein Berg tributary before its confluence point with the Berg. Closer to the river mouth, the Berg is fed by the Boesmans tributary which biomonitoring indicates to be in fair condition. Google Earth satellite imagery reveals that the river passes through extensively cultivated land is found to be in a very poor condition downstream of the Voëlvlei Nature Reserve. Further downstream, the Berg and Boesmans tributary flows through land which has gone through extensive agriculture.

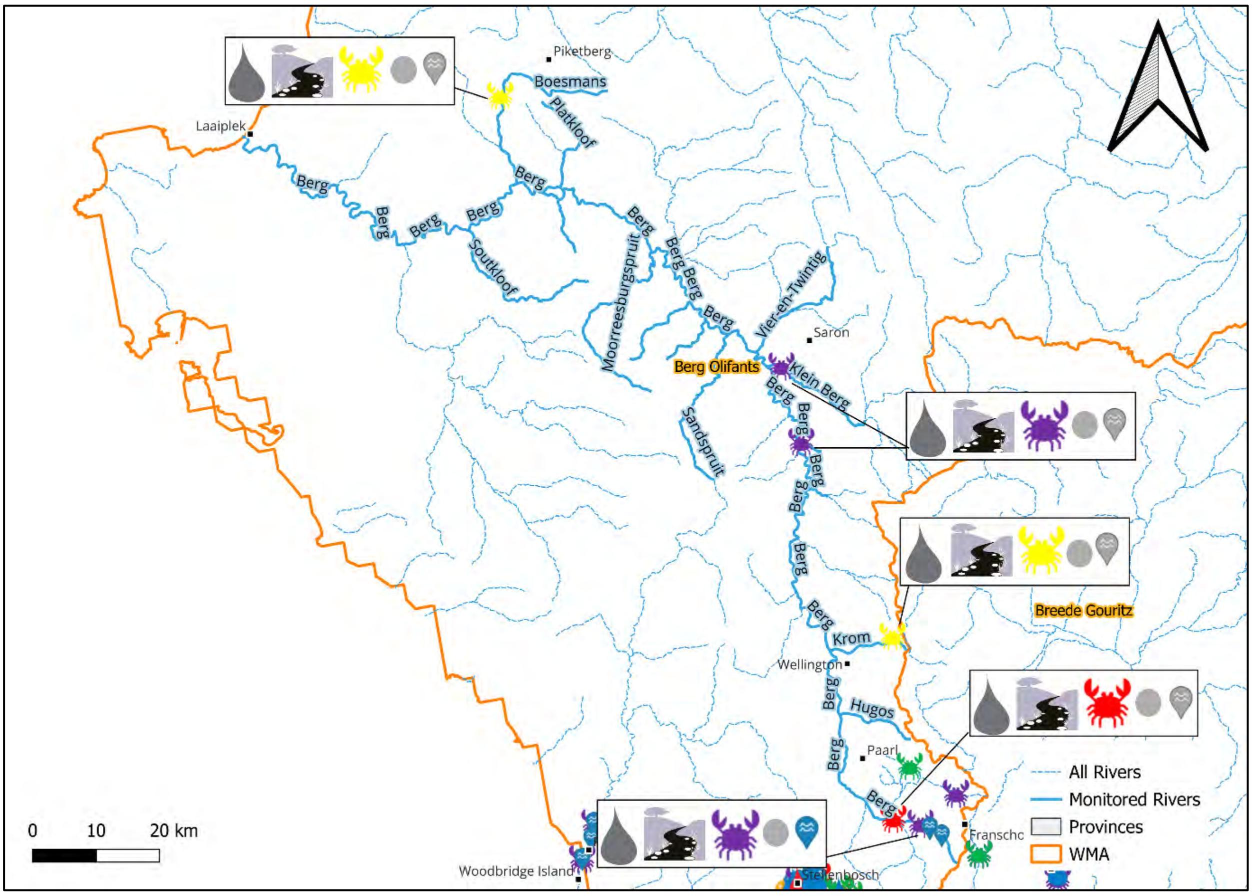


Figure 7.5 Citizen science monitoring along the Berg River

Lower Berg Olifants WMA Rivers (Diep, Window Stream, Hout Bay River, Silvermine River, Bokramspruit, and the Eerste River) – Figure 7.6

Diep River

From a biological perspective, this lower portion of the Diep River close to the river mouth is found to be in very poor condition, and the physico-chemical results reveal an overall safe condition.

Window Stream (Liesbeek)

The most recent biomonitoring in the upper portion of the Window Stream indicates natural conditions, with very good and safe physico-chemical conditions observed based on Freshwater Watch and WaterCAN testing, respectively. However, low clarity is observed. Downstream, before the Window Stream joins the Soutvlei river and flows out to sea, biomonitoring data from earlier in the year indicates poor conditions with low clarity, however the very good and safe conditions observed based on Freshwater Watch and WaterCAN testing, respectively, remain as well as the low clarity observed.

Hout Bay

Biomonitoring results in the upper reaches of the Hout Bay River reveal a good condition however this declines to a very poor condition before the river mouth. The clarity of the river is found to be high at the river mouth.

Silvermine

The most recent biomonitoring results along the short stretch of the Silvermine River indicates fair conditions of this river.

Bokramspruit

Biomonitoring observations indicate that this lower portion of the Bokramspruit is in an overall poor condition. From a physico-chemical perspective, the condition is found to be safe.

Eerste and Jonkershoek tributary

The Jonkershoek River (flowing from the right) flows down and joins the Eerste River which flows out to sea. Biomonitoring close to the source of the Jonkershoek River indicates natural conditions which decline to good in the middle reaches after flowing through a small dam and past a small settlement, according to Google Earth imagery. Physico-chemically, the clarity in these middle reaches in found to be high and the condition is indicated by Freshwater Watch testing as very good.

Ahead of the confluence with the Eerste River, biomonitoring indicates the Jonkershoek to be in a very poor condition with Google Earth imagery indicating densely urbanised land as the dominant adjacent land use. From a physico-chemical perspective, the clarity remains high and poor and safe conditions are indicated by the Freshwater Watch and WaterCAN results, respectively. However, monitoring at the confluence point a month later reveals an improvement in the Freshwater Watch condition indicated to very good.

Downstream, the most recent physico-chemical monitoring indicates good, and warning conditions observed based on Freshwater Watch and WaterCAN testing, respectively.

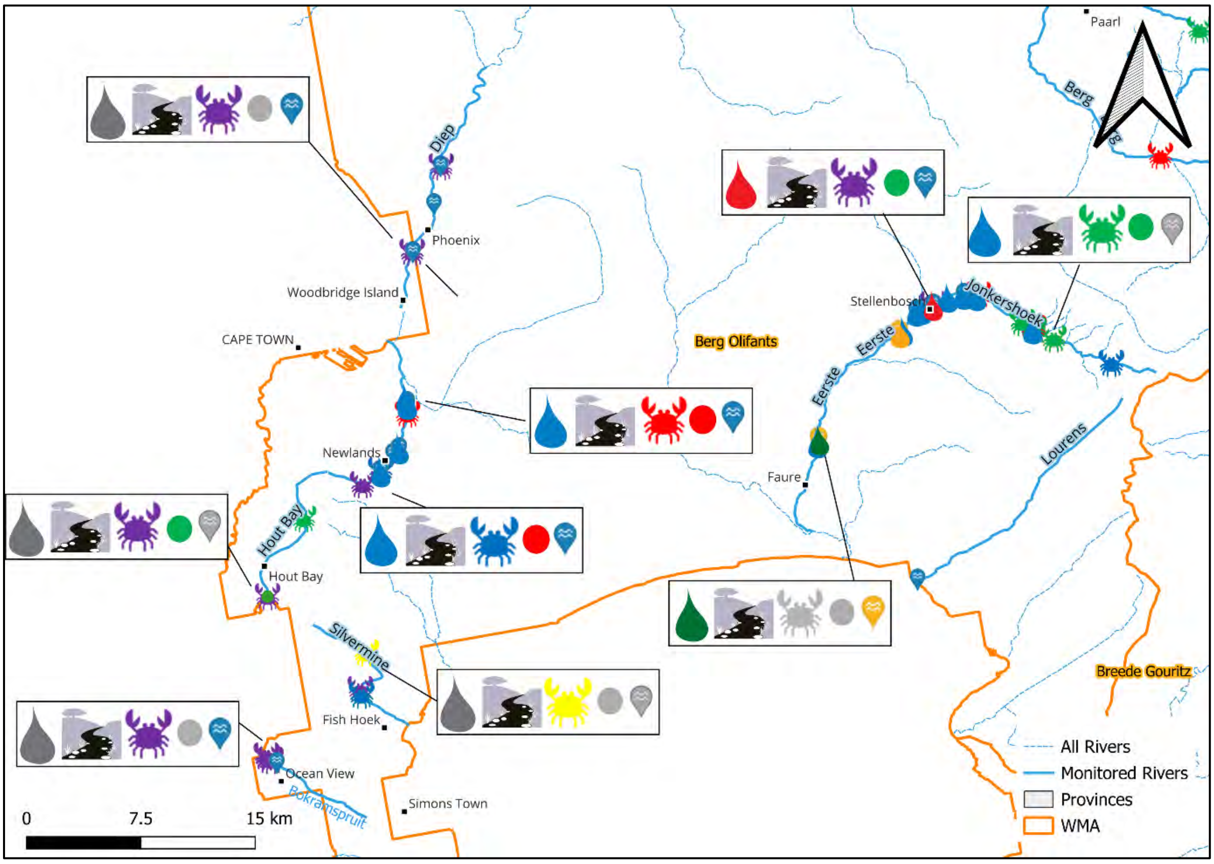


Figure 7.6 Citizen science monitoring along rivers in the lower portion of the Berg Olifants Water Management Area

7.4.2 *Breede Gouritz Water Management Area*

The Breede-Gouritz WMA covers portions mainly encompassing the Western Cape province but does extend into parts of the Northern Cape and Eastern Cape provinces of South Africa. The rivers systems which were monitored in this region are displayed in **Figure 7.7**.

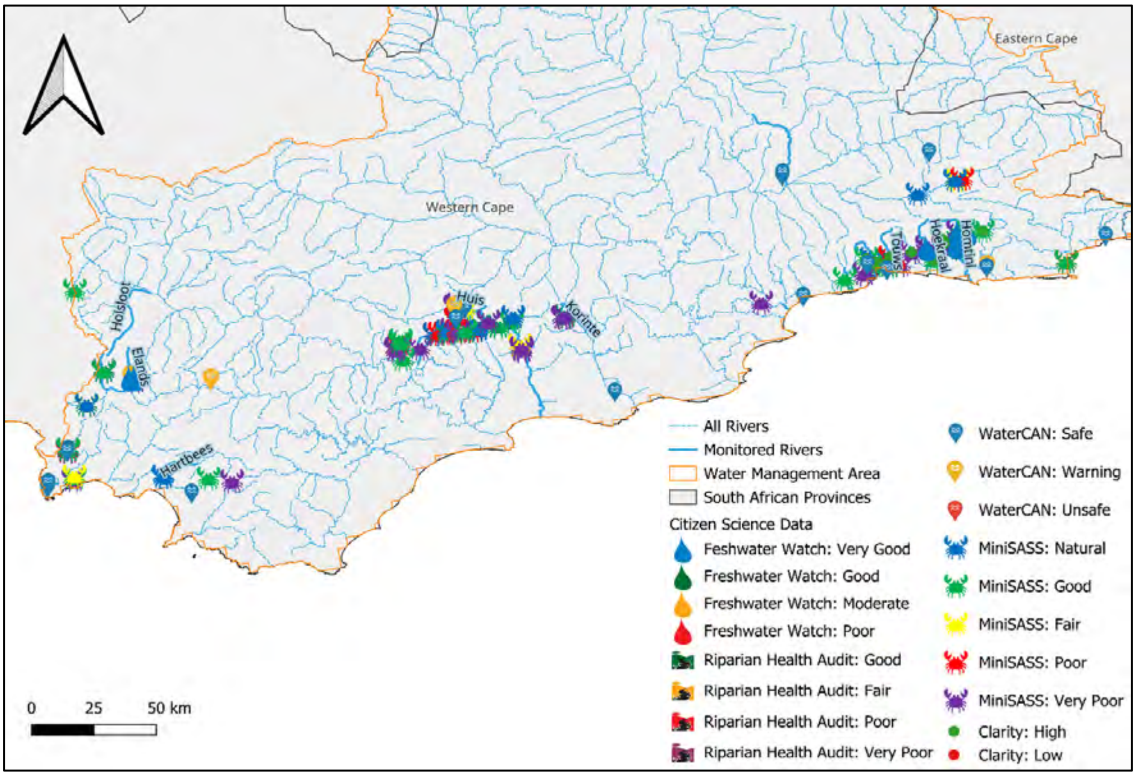


Figure 7.7 Citizen science monitoring in the Breede Gouritz Water Management Area

Lower Buffels River

From a physico-chemical perspective, the condition of the lower Buffels River is determined to be safe (**Figure 7.8**).

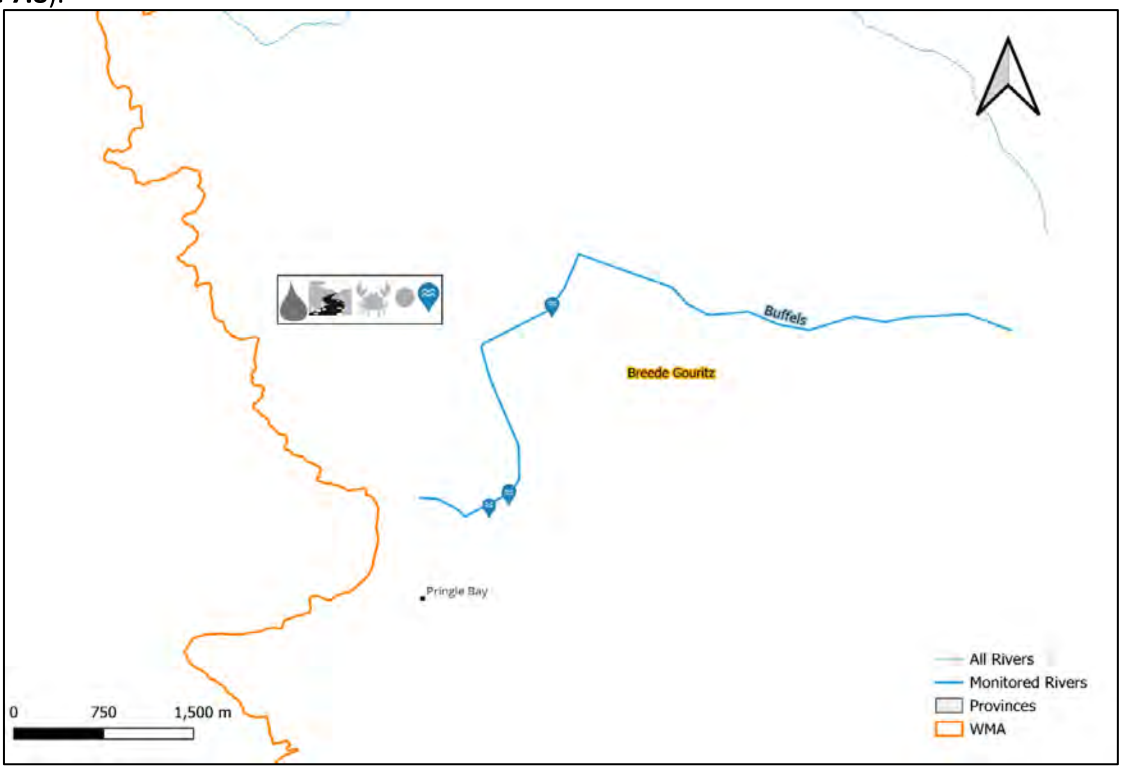


Figure 7.8 Citizen science monitoring along the lower portion of the Buffels River

Mizpah Rivers

This series of rivers all enter the Kogelberg Dam to the east. Biomonitoring results indicated the following overall results for each of the rivers starting with the northernmost river going south, the overall biomonitoring conditions of each were found to be good, very poor, and poor. The physico-chemicals results indicate safe conditions along all three streams (**Figure 7.9**).

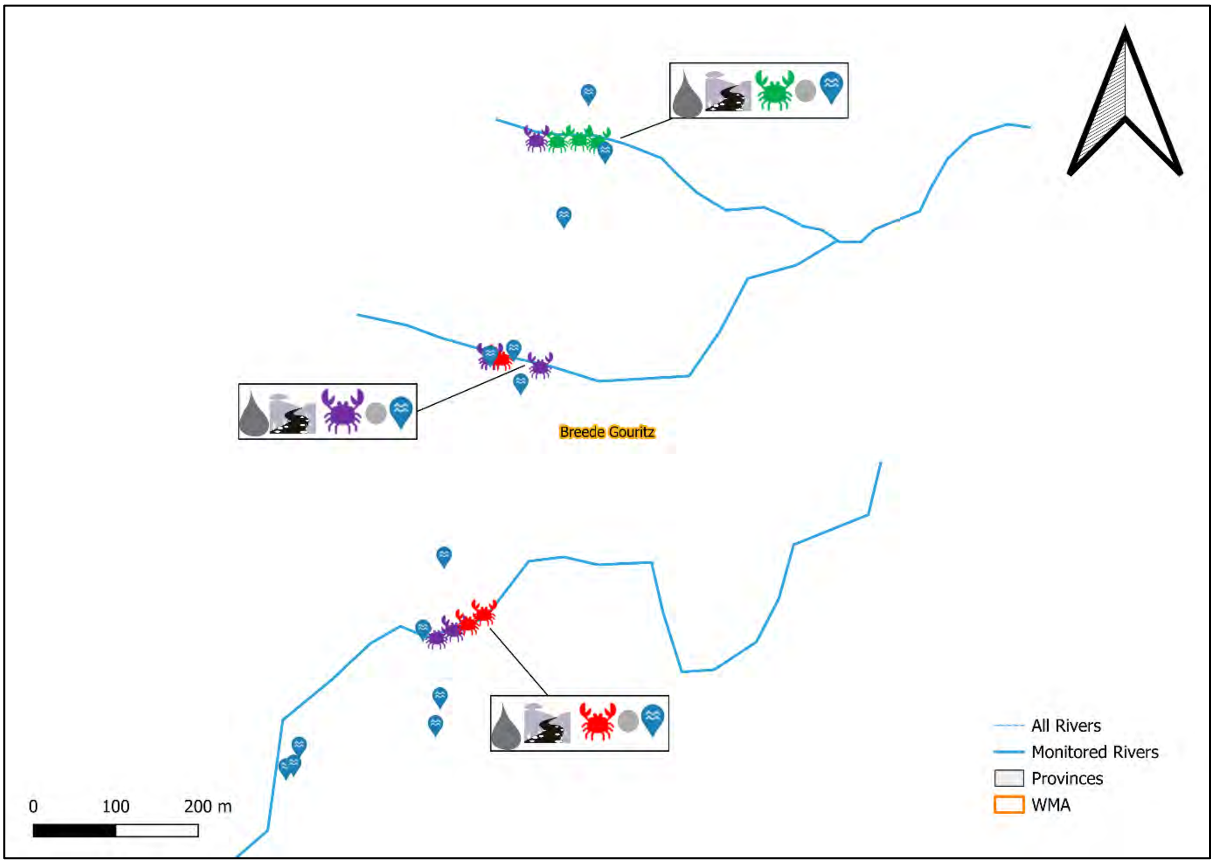


Figure 7.9 Citizen science monitoring along the Mizpah Rivers

Elands River and Hartbees River

The physico-chemical monitoring on the Elands River (**Figure 7.10**) indicates very good and safe conditions from the Freshwater Watch and WaterCAN testing respectively. However, biomonitoring data indicates very poor ecological conditions, before it enters the Theewaterskloof Dam. Google Earth imagery revealed the land uses adjacent to this stretch of the river to be urbanised upstream and widely cultivated downstream before entering the dam. In the south, biomonitoring on the Hartbees River indicates natural conditions.

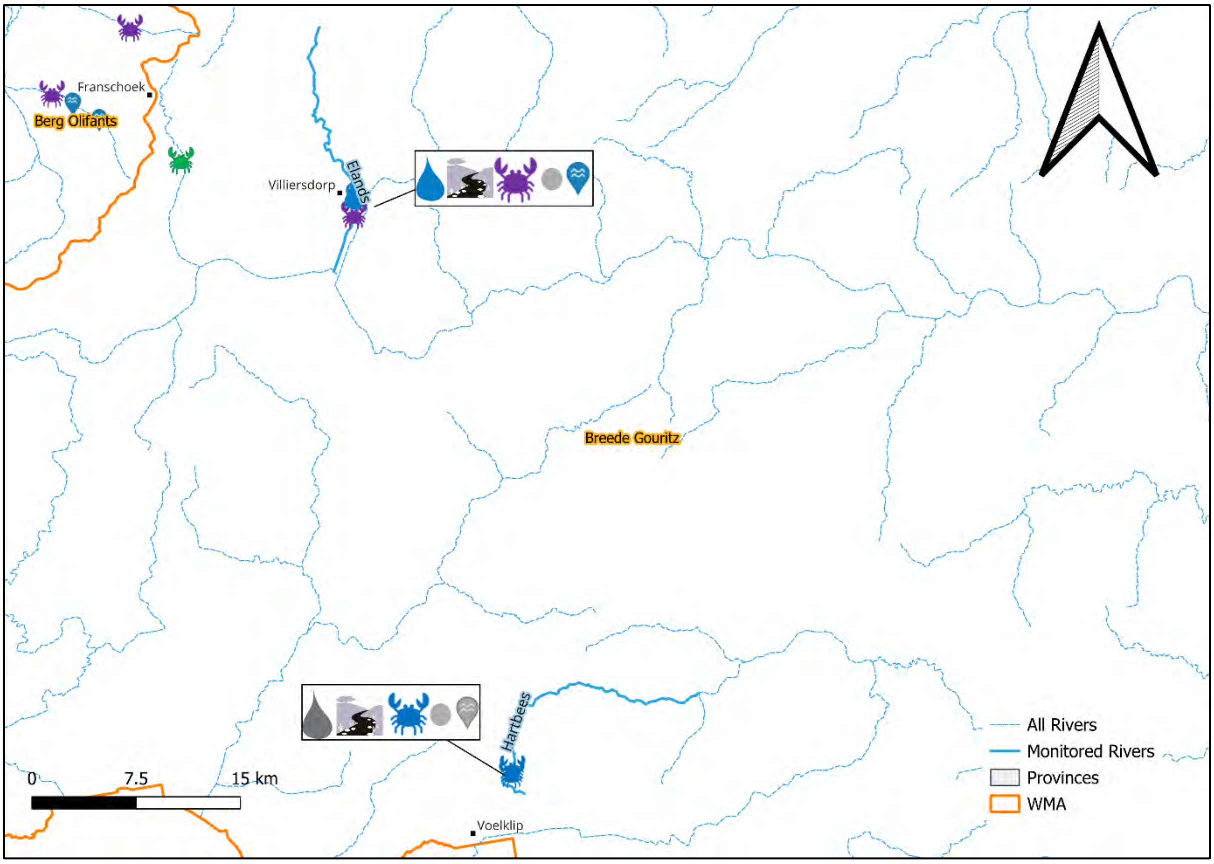


Figure 7.10 Citizen science monitoring along the Elands and Hartbees Rivers

Buffeljags River and tributaries, and Duiwenhoeks River

The Buffeljags is fed by the Grootvaderbos and Tradou (which is fed by the Huis) rivers where there are multiple biomonitoring monitoring locations, and multiple observations recorded at each point (**Figure 7.11**). However, only the most recent scores were considered to determine the overall condition. Biomonitoring on the middle reaches of the Huis (flowing east to west) indicated a fair condition with physico-chemical observations indicating safe conditions. Biomonitoring data shows a decline in ecological conditions to very poor condition of the Huis just before its confluence with the Tradou, with WaterCAN data indicating warning conditions. Google Earth imagery also indicates that the cultivated and urbanised land before the confluence point. The middle reaches of the Tradou are found to be in poor ecological conditions from biomonitoring observations, but in a safe condition from a physico-chemical perspective. Biomonitoring indicates that the poor ecological conditions of the Tradou remains as it enters the Buffeljags.

Biomonitoring along the Grootvaderbos River indicates that this river starts in a natural condition then declines to fair as it enters the Buffelsjags River. The most recent biomonitoring data then indicates that the Buffeljags is in poor condition along its stretch (where Google Earth imagery reveals the surrounding land use to be largely agricultural) declining to very poor toward the lower reaches (after passing through a settlement).

There are multiple biomonitoring points along Duiwenhoks River each having been monitored multiple times. However, the most recent biomonitoring observations reveal that the ecological conditions of the river changes from good condition upstream, to very poor further downstream, after passing through extensive agricultural land and a settlement, as revealed from Google Earth imagery.

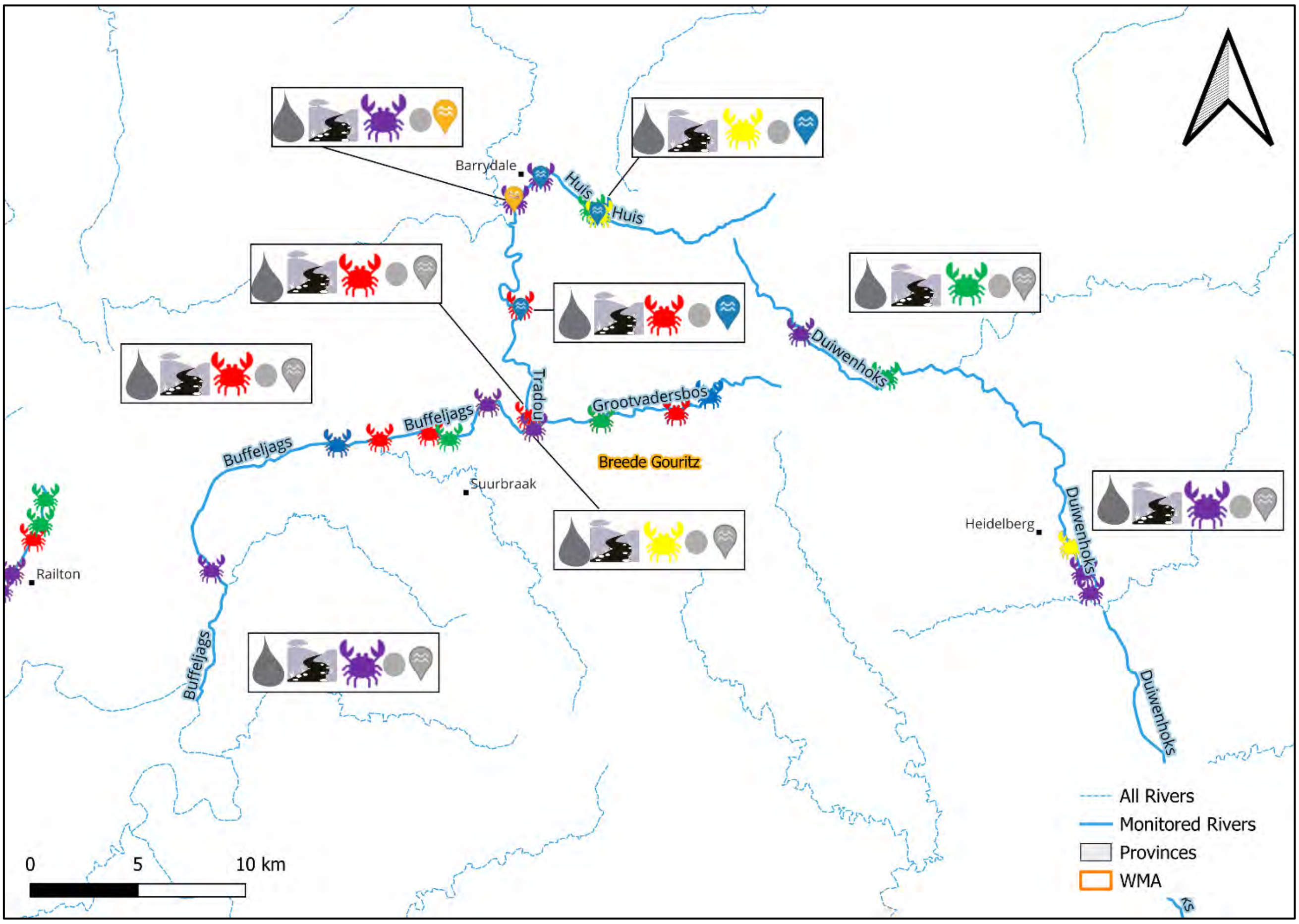


Figure 7.11 Citizen science monitoring along the Buffeljags Rivers and tributaries, and the Duiwenhoeks River

South East Breede Gouritz Rivers (Kaaimans, Touws, Hoekraal, Karatara, and Homtini) – Figure 7.12

Biomonitoring along the upper reach of the Homtini River indicates very poor ecological conditions with physico-chemical monitoring indicating very good conditions with high clarity. Toward its middle reaches, biomonitoring indicates the ecological condition of the Homtini Rivers to change to good condition with high clarity observed.

The Karatara Rivers feeds the Hoekraal River before it joins the Swartvlei Rivers then flows out to sea. Although biomonitoring has indicated a good ecological condition of the Hoekraal River closer to the confluence point with the Karatara river, the most recent data from upstream indicates a very poor ecological condition, with physico-chemical data indicating very good conditions and high clarity. The most recent biomonitoring data indicated that the Karatara River is in a very poor ecological condition with high clarity observed, adjacent to agricultural land and settlements (revealed by Google Earth imagery).

Although biomonitoring in the Touws River indicated a poor ecological condition with high clarity, the most recent biomonitoring further downstream and closer to the river mouth indicate a good ecological condition with high clarity observed. Additionally, monitoring slightly closer to the river mouth indicates a safe condition. Google Earth imagery reveals the adjacent land use to be largely agricultural at the upstream monitoring point, with settlements adjacent to the lower reach.

Biomonitoring along the Kaaimans River indicates natural conditions upstream which decline to good downstream as revealed by more recent observations. However, the clarity remains high. The small tributary southwest of the Kaaimans River is found to be in very poor condition based on biomonitoring observations. West of this, the Gwaing River is found to be in good conditions based on biomonitoring observations.

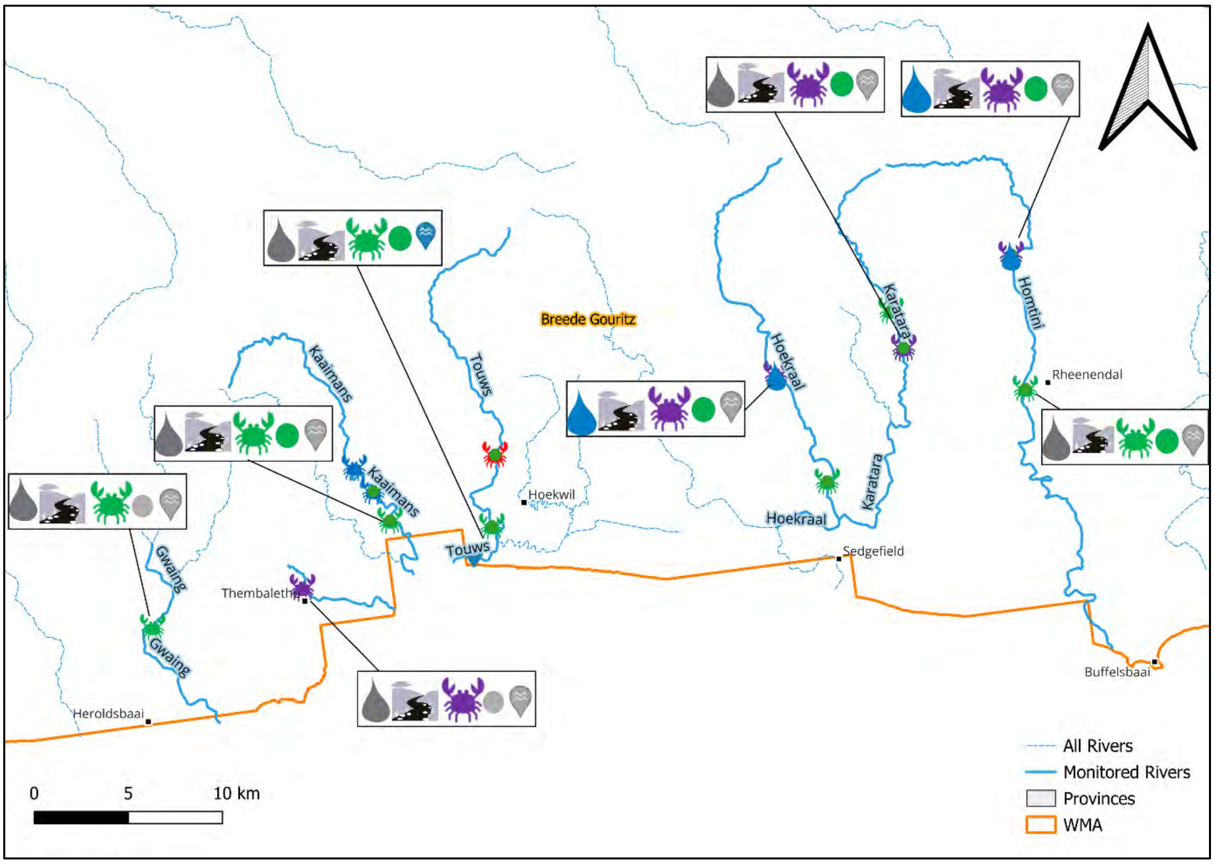


Figure 7.12 Citizen science monitoring along the rivers in the southeast area of the Breede Gouritz Water Management Area

7.4.3 *Inkomati Usuthu Water Management Area*

The Inkomati Usuthu WMA covers a large portion of Mpumalanga province of South Africa. The rivers systems which were monitored in this region are displayed in **Figure 7.13**.

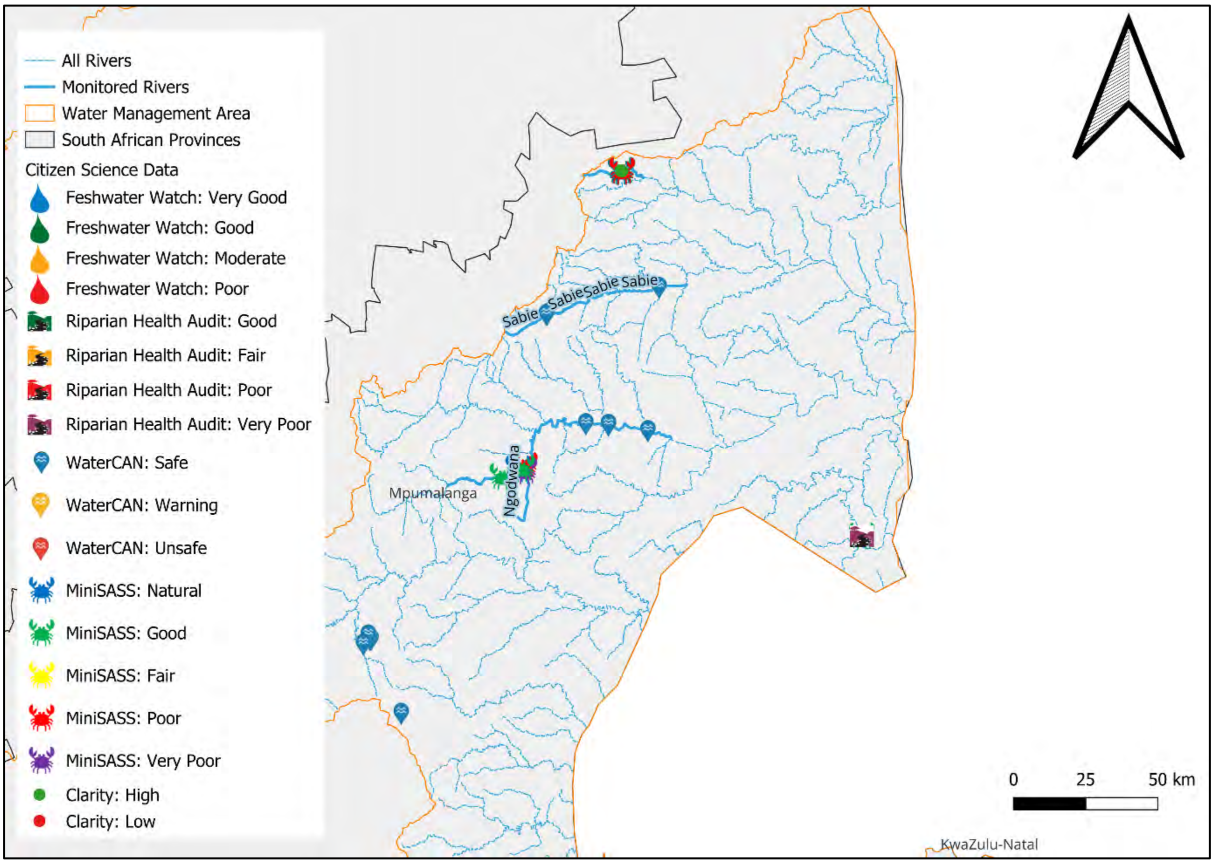


Figure 7.13 Citizen science monitoring in the Inkomati Usuthu Water Management Area

Motlamogatsana River

The most recent biomonitoring in the middle reaches of the Motlamogatsana River (flowing west to east) indicate a natural condition upstream with high clarity observed (**Figure 7.14**). Although the clarity remains high downstream, the condition of the river changes to poor.

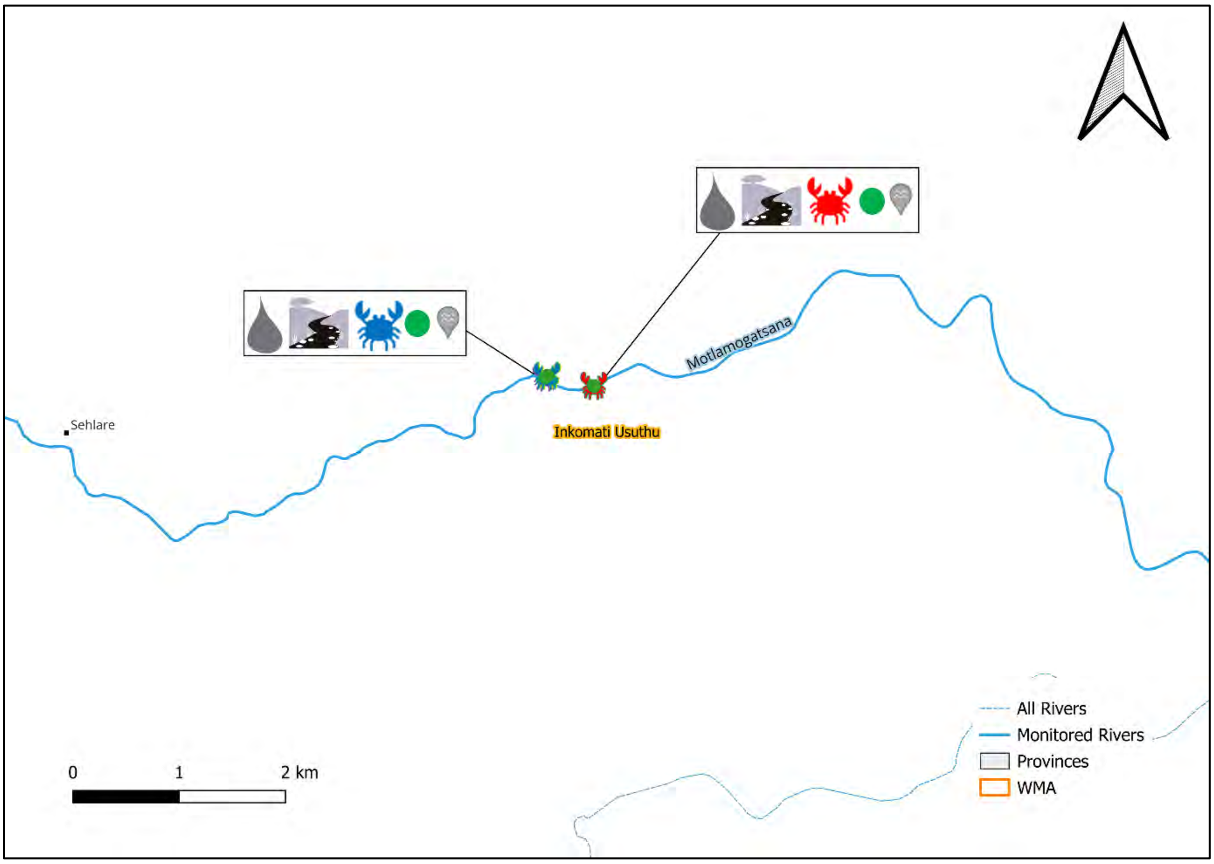


Figure 7.14 Citizen science monitoring along the Motlamogatsana River

Crocodile River and Elands tributary

The Crocodile rivers is fed by many tributaries including the Elands River (**Figure 7.15**). In its upper reaches, biomonitoring results indicate the Elands River to be in good condition and improves to natural condition before its confluence with the Ngodwana River. Biomonitoring on the Ngodwana River indicates how the conditions changed from very poor to good before the confluence point. After the confluence of the Elands and Ngodwana rivers, biomonitoring results indicate that the ecological condition of the Elands declined to poor. The Elands then flows into the Crocodile River where WaterCAN monitoring along a few points on this stretch of the Crocodile River indicate safe conditions.

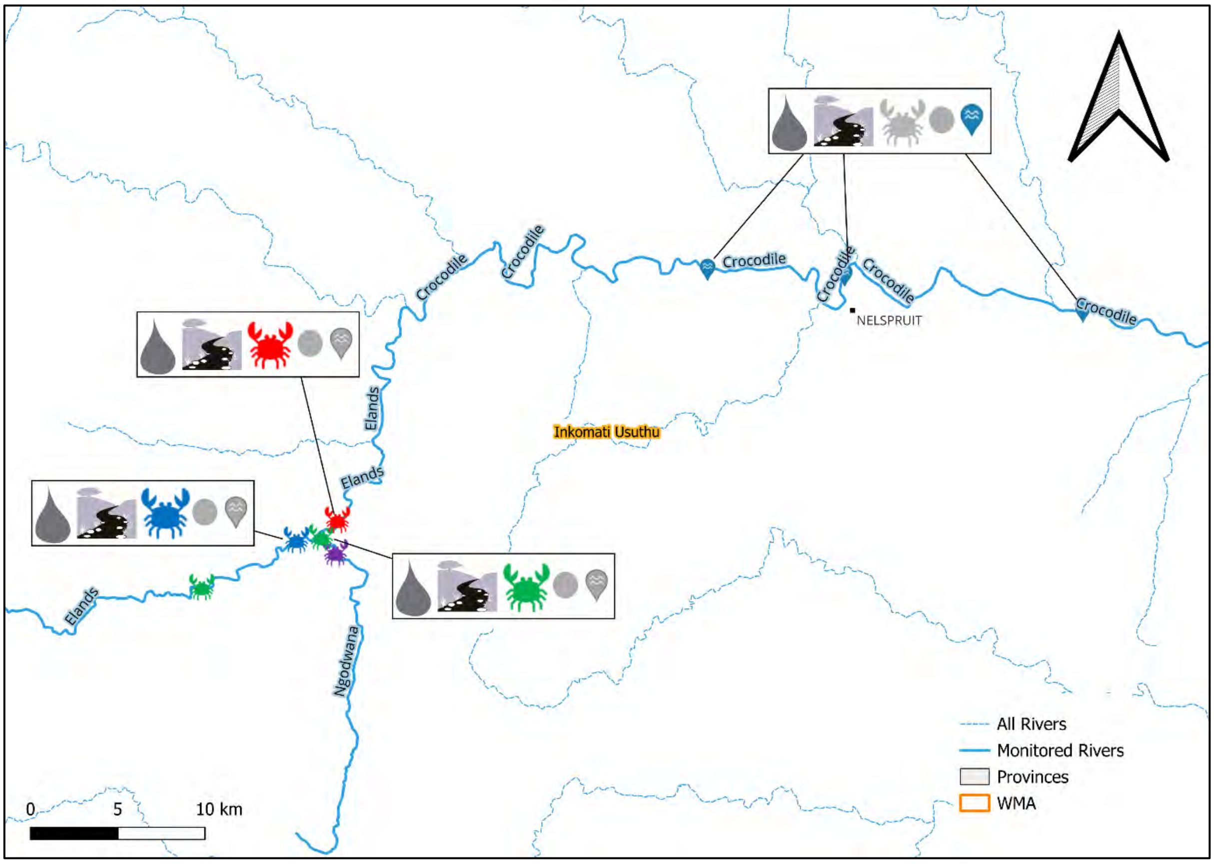


Figure 7.15 Citizen science monitoring along the Crocodile and Elands Rivers

Sabie River

WaterCAN monitoring in the upper reaches of the Sabie River (flowing west to east), close to the source, indicate safe conditions from a physico-chemical perspective (**Figure 7.16**).

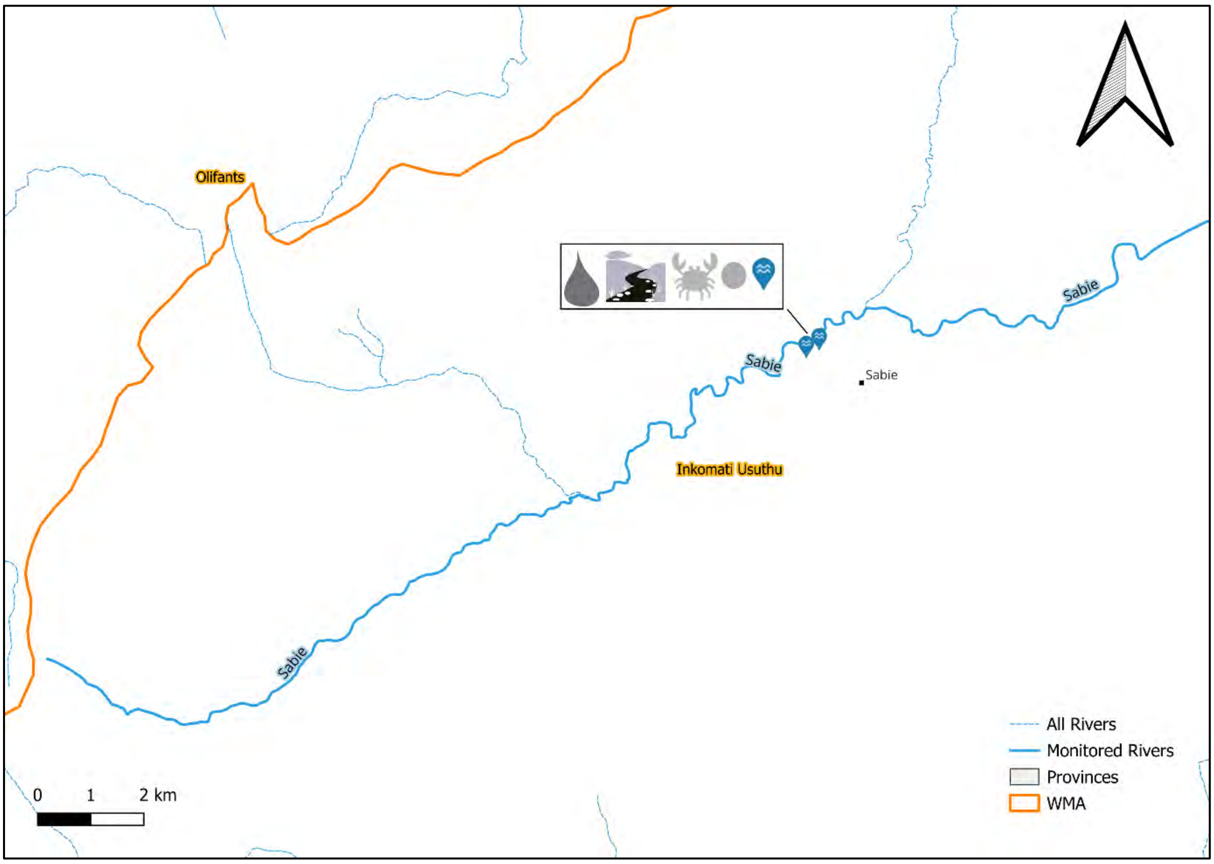


Figure 7.16 Citizen science monitoring along the Sabie River

7.4.4 *Limpopo Water Management Area*

The Limpopo WMA covers portions of the Limpopo, North West, and Gauteng provinces of South Africa. The rivers systems which were monitored in this region are displayed in **Figure 7.17**.

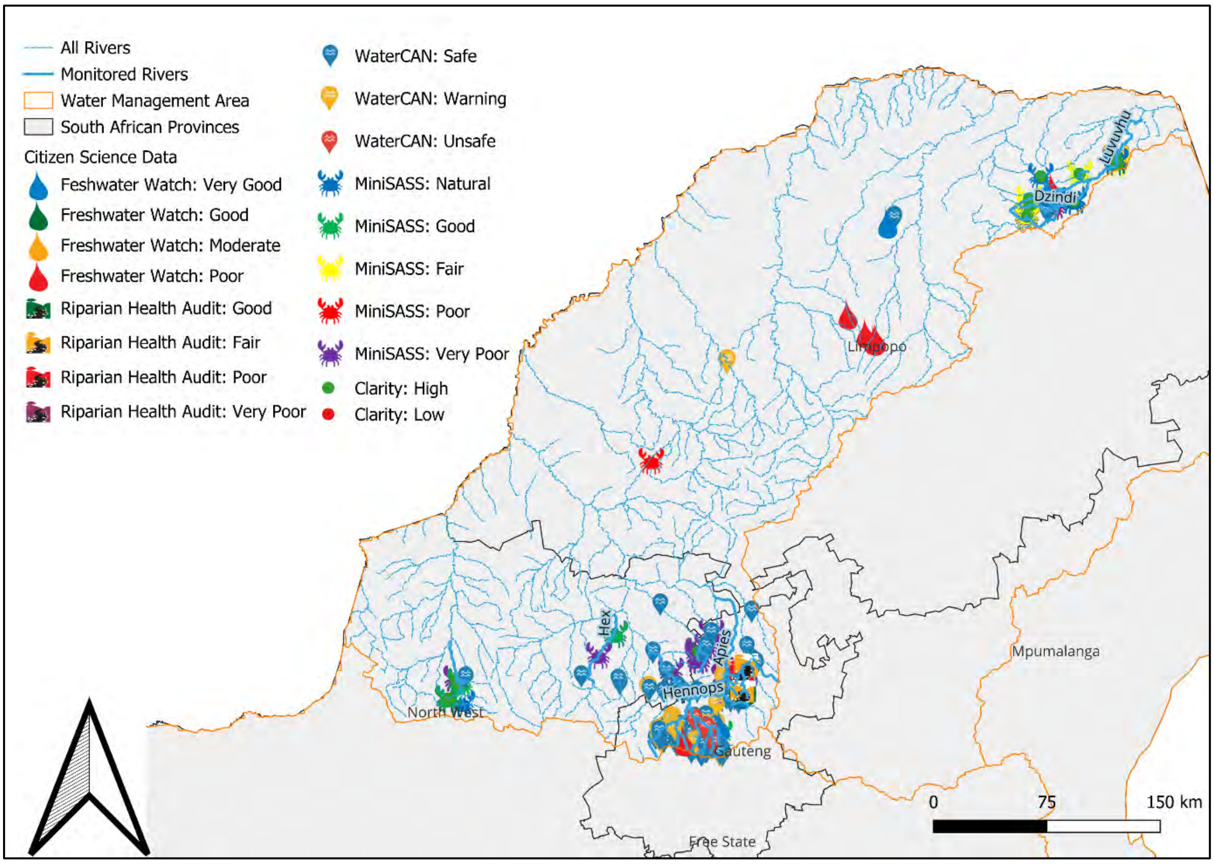


Figure 7.17 Citizen science monitoring in the Limpopo Water Management Area

Crocodile and tributaries (Jukskei, Bloubankspruit, and Hennops) – Figure 7.18

Biomonitoring in the upper reaches of the Hennops River indicate very poor conditions and physico-chemical testing using the WaterCAN tests indicate safe conditions, as it exits the Rietvlei Dam and through the adjacent densely urbanised area. These conditions remain the same downstream, closer to the confluence of the Hennops and Crocodile Rivers.

Physico-chemical observations through WaterCAN testing indicates safe conditions in the upper reaches of the Jukskei (south east), however these conditions decline downstream. West of this, two smaller rivers, the Sandspruit and the Braamfonteinspruit, join before the confluence point where they feed into the Jukskei River. At the Sandspruit and Braamfonteinspruit confluence point, biomonitoring indicates very poor conditions with high clarity, and the chemical results are indicated to be safe. Downstream of the confluence with the Jukskei River, the chemical conditions are found to be unsafe. Chemical monitoring along the Klein-Jukskei indicate the river to be in an overall safe condition, and this condition remains the same according to the most recent test conducted at the confluence of the Klein-Jukskei and Juksei Rivers. Google Earth imagery reveals that the land use along the Jukskei and tributaries is densely urbanised, which potentially contributes to the conditions observed.

To the west, the most recent biomonitoring in the upper reaches of the Crocodile River indicate very poor conditions and chemical testing indicates poor conditions. However, after being fed by a small tributary, the chemical conditions improved to safe. Ahead of its confluence with the Crocodile River, the most recent chemical data for the Bloubankspruit indicates warning conditions. Further downstream, and after passing through the Hartbeespoort Dam, chemical testing indicates that the condition of the Crocodile improves to safe.

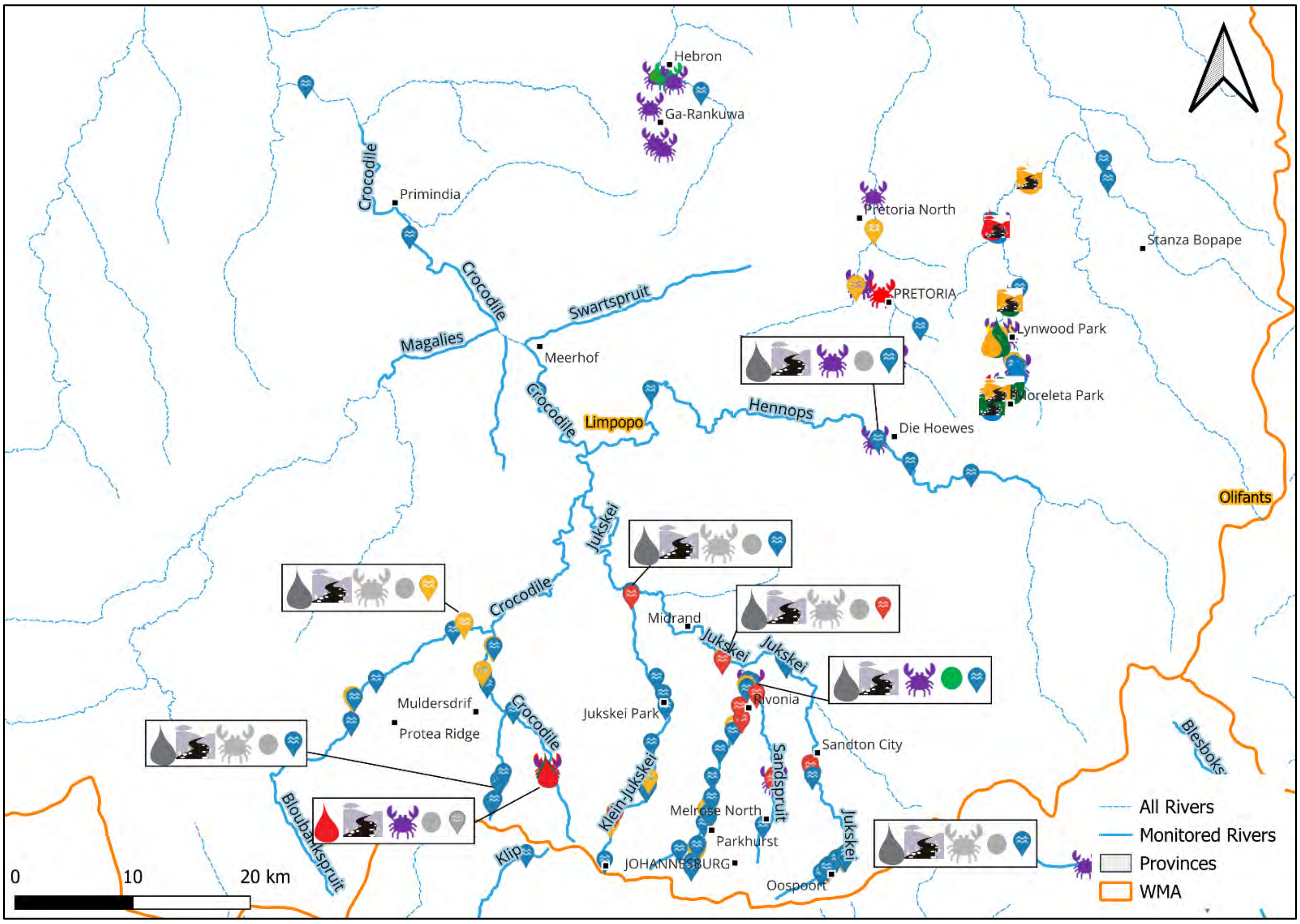


Figure 7.18 Citizen science monitoring along the Crocodile River and tributaries

Sand River and Upper Tolwane tributary

The most recent WaterCAN observations indicate that the upper reaches of the Sand River is in a safe condition, however downstream of this point, biomonitoring data from three months prior indicate very poor conditions, which change to good conditions, around the same timeframe, closer to the confluence point with the Tolwane River (**Figure 7.19**). Biomonitoring results indicate that the Tolwane River remains in a very poor state from its upper reaches to just above the confluence point, with high clarity observed. Google Earth imagery has revealed the surrounding land use adjacent to the upper Tolwane to be densely urbanised and industrial, before it joins the Sand and flows into the Nooitgedag Dam.

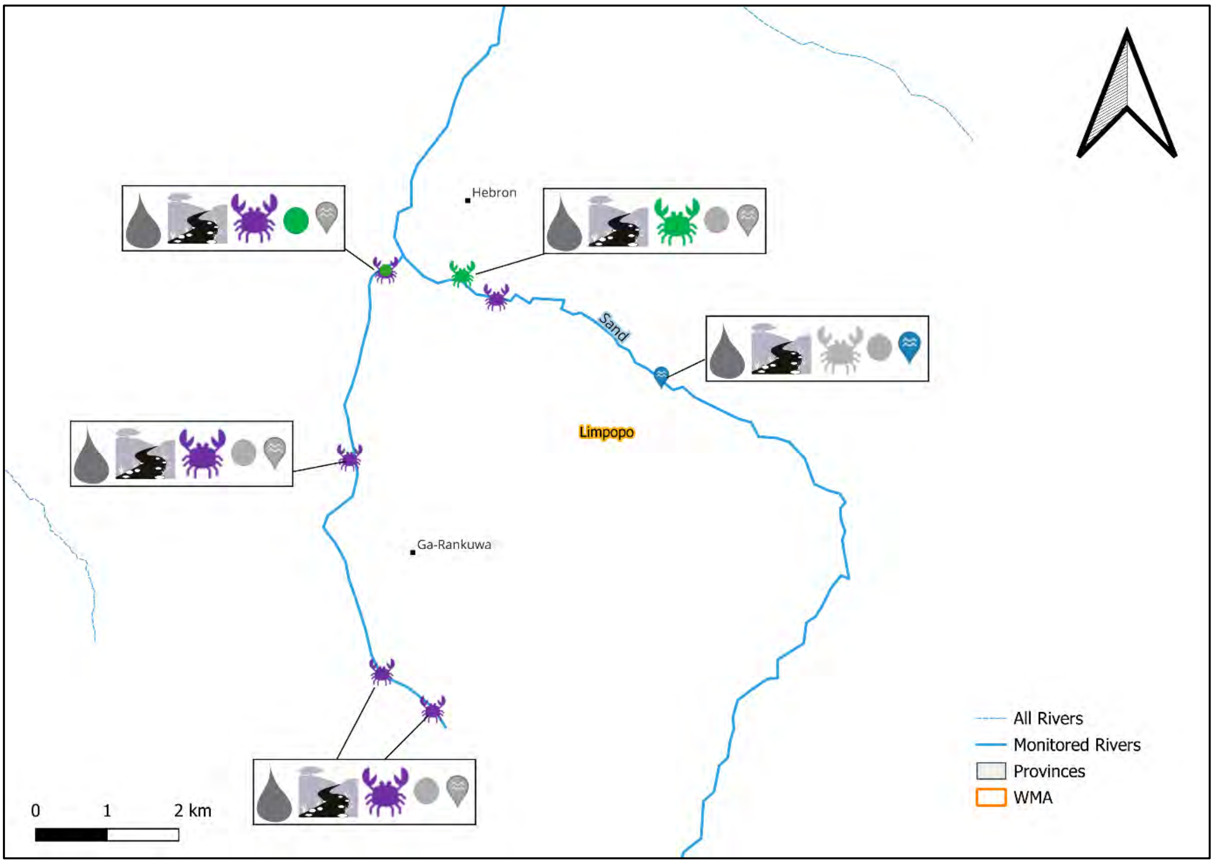


Figure 7.19 Citizen science monitoring along the Sand and Tolwane Rivers

Apies River and tributaries (Figure 7.20)

The most recent biomonitoring data along the upper reach of the Apies River indicates that the river is in very poor conditions, with Google Earth imagery revealing the dominant adjacent land use as densely urbanised. The Apies is fed by the Walkerspruit which WaterCAN testing indicated to be in safe condition. Downstream of the confluence of the Apies and Walkerspruit rivers, biomonitoring indicates that the river is in poor condition. Downstream of the confluence with the Skinnerspruit (unmonitored), biomonitoring indicates that the Apies River is in very poor conditions and the WaterCAN testing indicate warning conditions. Google Earth imagery over this confluence point revealed the adjacent dominant land use to be industrial. These conditions remain the same at points downstream, after the Wonderboomspruit joins the Apies, where Google Earth imagery indicates that the adjacent land use is a heavily urbanised settlement. The Apies progresses past more industry and plots of agricultural land before crossing under a freeway, before flowing into the Bon Accord Dam. Google Earth imagery shows that this dam is either experiencing invasive aquatic plant invasion, or algal blooms on the surface, further indicating the unfavourable conditions of this river system.

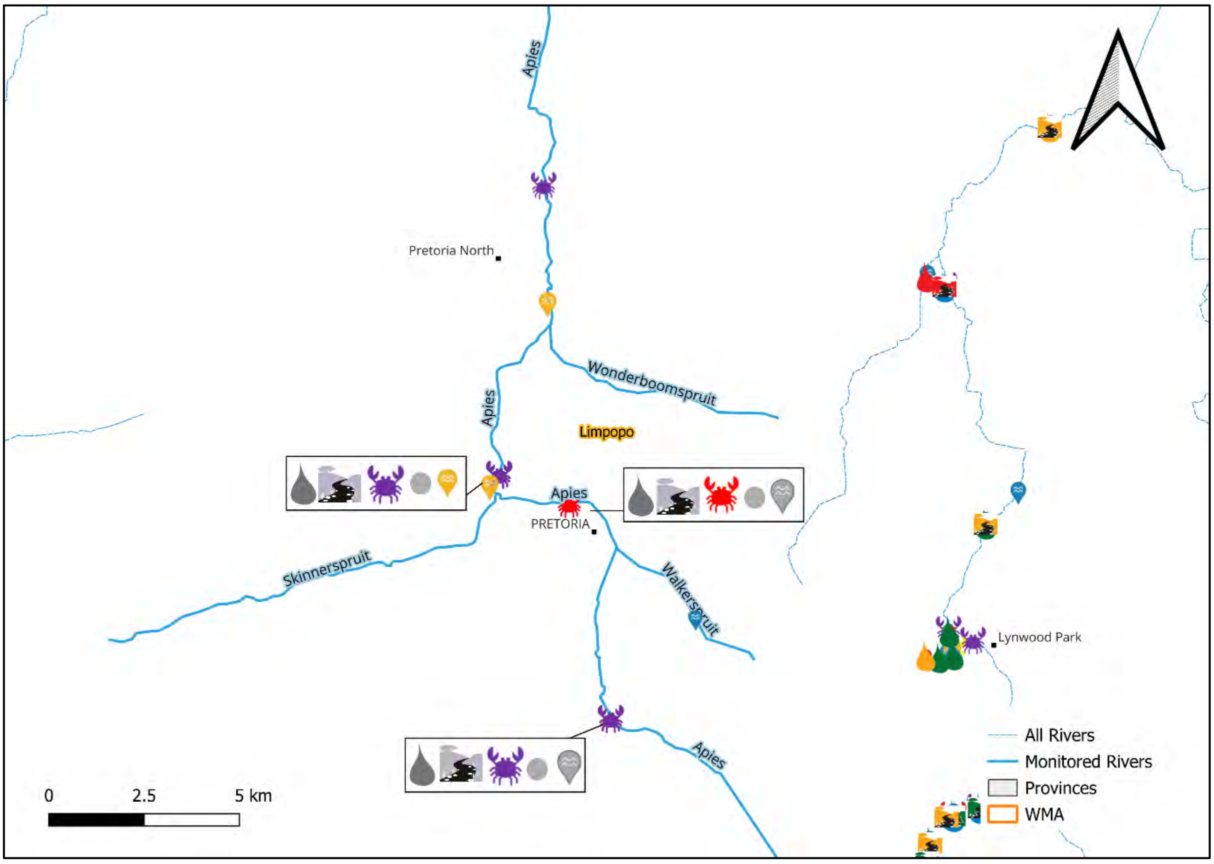


Figure 7.20 Citizen science monitoring along the Apies River and tributaries

Pienaars River tributaries (Edendalespruit, Hartbeespruit, and Moreleta) – Figure 7.21

The Moreleta River is fed by a small tributary, the Rademeyerspruit, which runs through the Moreleta Kloof Nature Reserve. Before its confluence with the Moreleta River, the most recent biomonitoring data indicates the Rademeyerspruit to have an overall very poor condition. Physico-chemical observations indicate high clarity, and good and safe conditions based on Freshwater Watch and WaterCAN testing, respectively. The RHA habitat assessment also indicated an overall good condition of the riparian zone here. Downstream of this confluence point, biomonitoring results indicate that the very poor conditions remain, however physico-chemically the conditions are found to be very good and safe based on Freshwater Watch and WaterCAN testing, respectively, with low clarity observed. Monitoring closer to Lynwood Park indicated very poor ecological conditions based on biomonitoring, however the most recent Freshwater Watch observation indicates good conditions, and high clarity was observed. Downstream of this point, the RHA indicates fair ecological conditions, with physico-chemical techniques indicating high clarity and good conditions as per Freshwater Watch testing. Closer to the confluence point with the Hartbeesspruit, biomonitoring indicates that the ecological condition remains very poor. The clarity observed here is high, with physico-chemical testing indicating very good and safe conditions based on Freshwater Watch and WaterCAN testing, respectively, with the RHA indicating poor ecological conditions. Physico-chemical monitoring along the Hartbeesspruit above the confluence point with the Moreleta, indicated poor conditions by use of the Freshwater Watch testing, with high clarity observed. However, the WaterCAN test conducted just downstream of this point (still before the confluence point) shows safe conditions. After the confluence point, the RHA indicates fair ecological conditions. Physico-chemically, the Freshwater Watch testing indicates moderate conditions, with low clarity observe before joining the Pienaars River. To the west, the Edendalespruit is found to be in an overall safe condition as indicated by WaterCAN testing, before entering the Pienaars River.

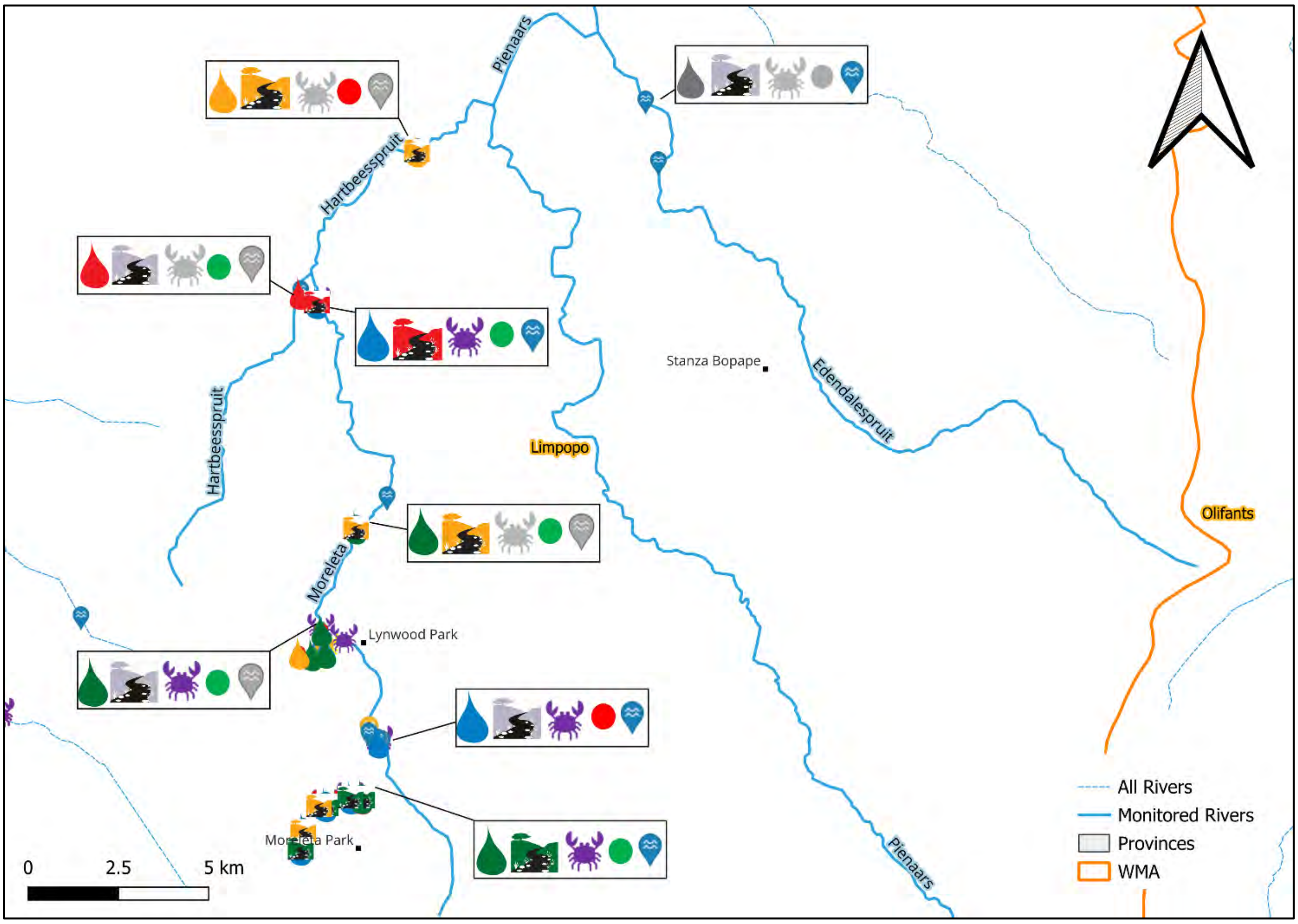


Figure 7.21 Citizen science monitoring along the Pienaars River and tributaries

Luvuvhu and tributaries (Mukhase, Dzindi, and Latonyanda)

Points along the Luvuvhu River and tributaries (namely, Mukhase, Dzindi, and Latonyanda) were monitored as illustrated in **Figure 7.22.** In the upper reaches of this stretch of the Luvuvhu River (to the west), the Latonyanda River feeds into the Luvuvhu. Latonyanda River was monitored frequently however the most recent biomonitoring data indicates very poor conditions and high clarity observations. Google Earth imagery reveals that the adjacent main land use are agricultural and urbanised. The upper portion of the Dzindi tributary is found to be in fair ecological condition from a biomonitoring perspective and has high clarity, before entering a dam. The Dzindi is fed by a smaller tributary further downstream before it joins the Luvuvhu River. The overall conditions of this tributary ahead of the confluence point are found to be in very poor conditions from a biomonitoring perspective, with high clarity observed and safe conditions indicated by WaterCAN testing. Biomonitoring downstream of this confluence point indicate the river is in natural ecological conditions with high clarity observed.

Downstream, the Luvuvhu River is fed by the Mutshindudi. The upper reach of the Mutshindudi is found to be in fair ecological condition from a biomonitoring perspective and has high clarity. The Mutshindudi is fed by the Tshinane tributary which is found to be in very good conditions from Freshwater Watch monitoring. Before its confluence with the Luvuvhu River, the Mutshindudi is fed by the Mukhase River which biomonitoring has indicted to be in good condition with high clarity observed. Google Earth imagery reveals that the dominant adjacent land use is agricultural.

Biomonitoring of the Luvuvhu River near Madandila indicates the river is in natural ecological conditions with high clarity observed.

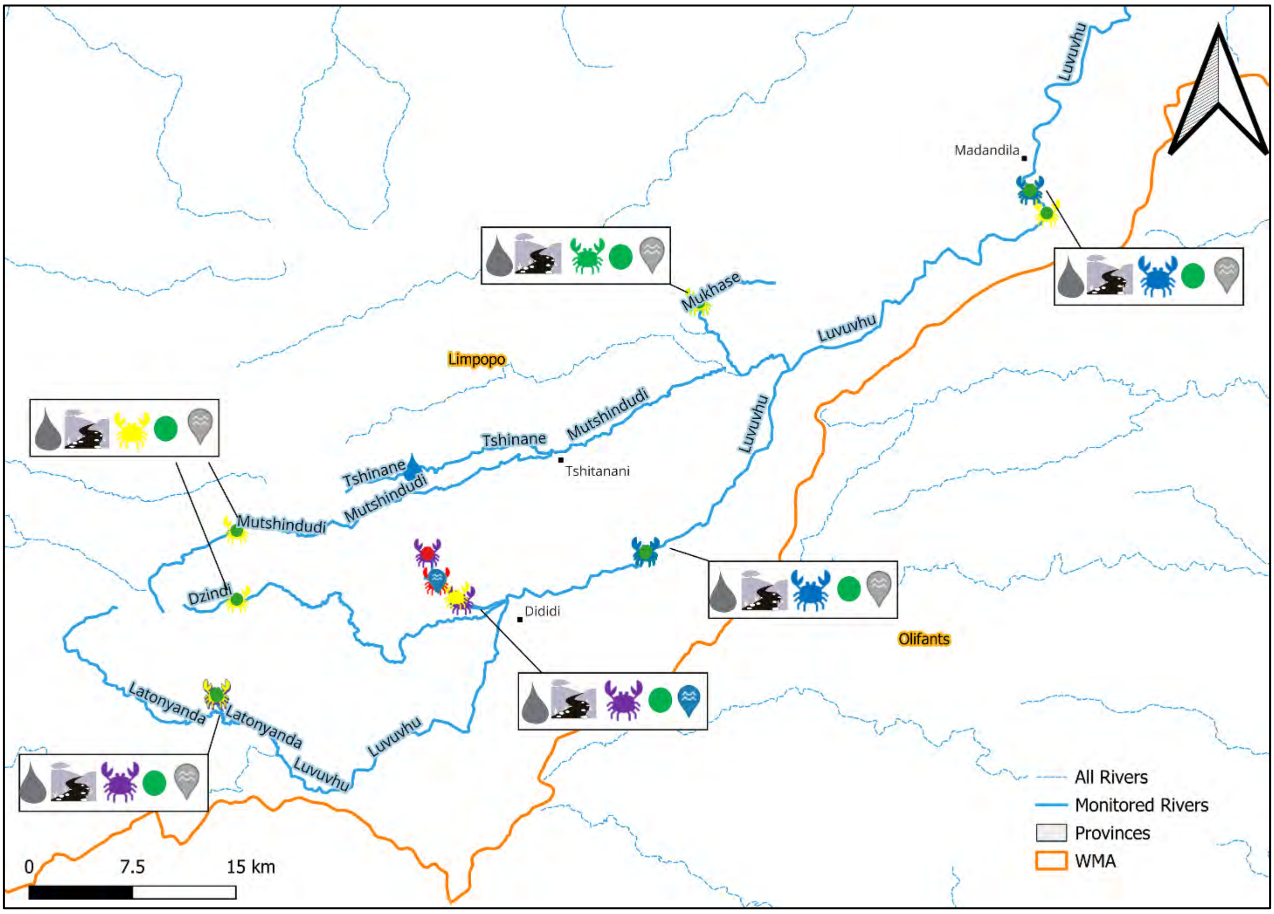


Figure 7.22 Citizen science monitoring along the Luvuvhu River and tributaries

7.4.5 *Mzimvubu Tsitsikamma Water Management Area*

The Mzimvubu Tsitsikamma WMA covers a large portion of the Eastern Cape and small portions of KwaZulu-Natal, Western Cape, and Northern Cape provinces of South Africa. The rivers systems which were monitored in this region are displayed in **Figure 7.23**.

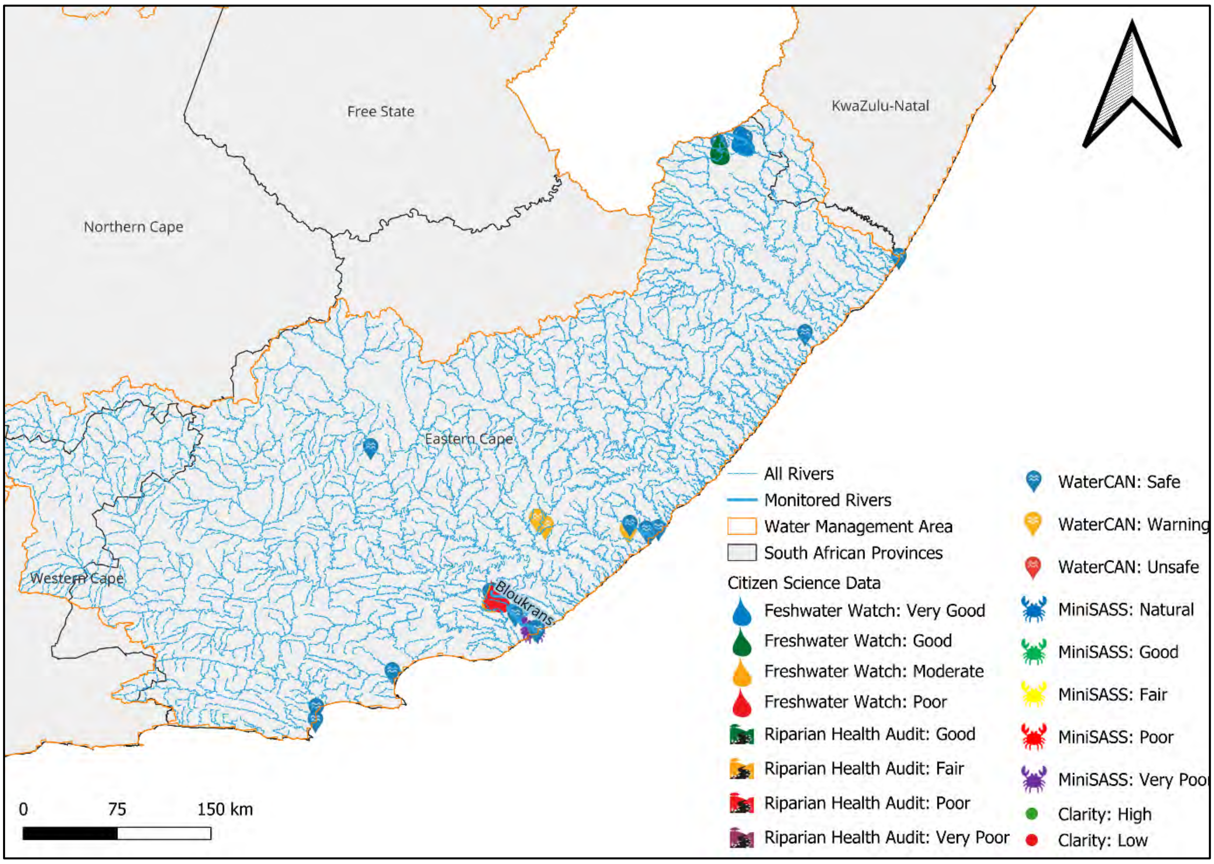


Figure 7.23 Citizen science monitoring in the Mzimvubu Tsitsikamma Water Management Area

Bloukrans and Kowie Rivers – Figure 7.24

The upper portion of Blokrans tributary (which joins the Kowie River) has a most recently monitored safe WaterCAN condition, however, the Freshwater Watch result indicates that the river is in poor condition. Downstream of the confluence point, the WaterCAN test reveals safe conditions. Before the river mouth, biomonitoring reveals very poor conditions with low clarity recorded. However, the WaterCAN test conducted the following month indicates safe conditions. Google Earth imagery reveals farming on adjacent banks after the Bloukrans joins the Kowie, and dense urbanisation downstream.

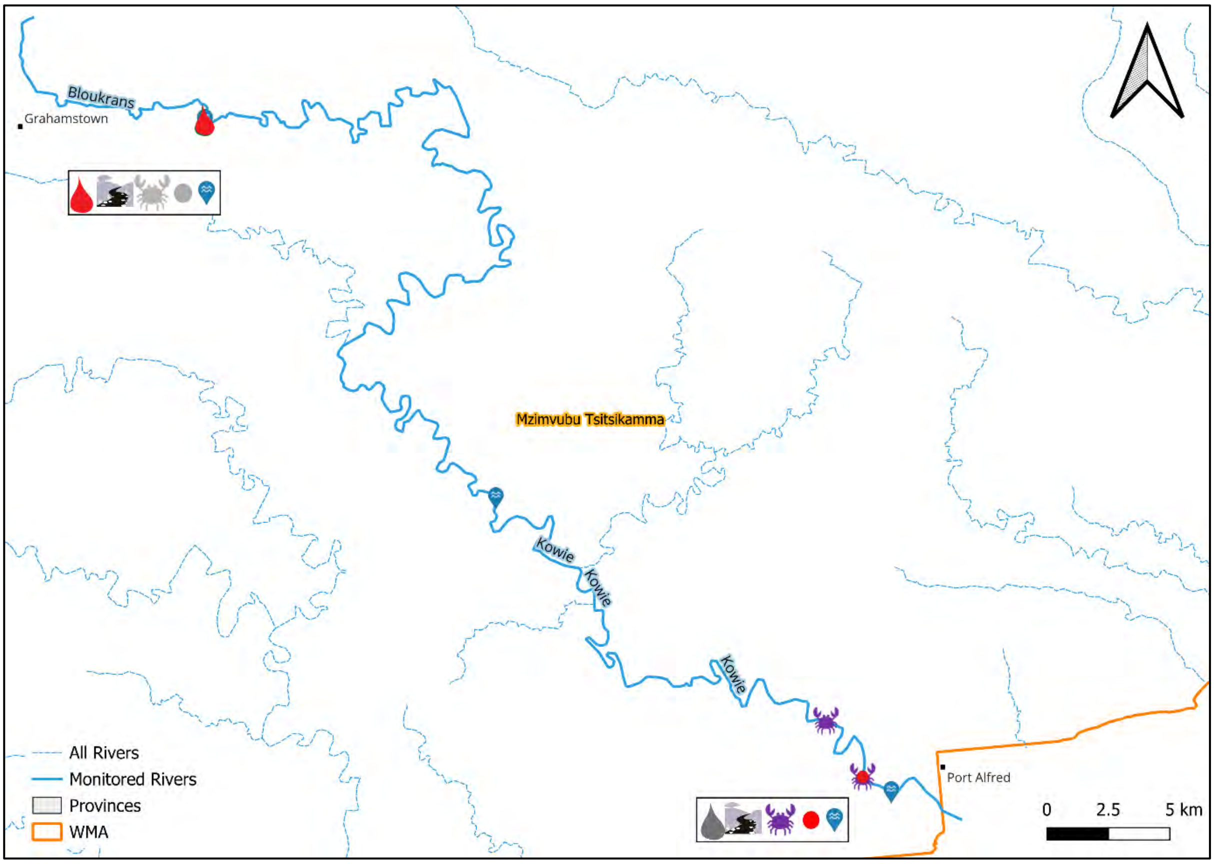


Figure 7.24 Citizen science monitoring locations along the Bloukrans and Kowie Rivers

Nahoon River

The physico-chemical data available for the Nahoon River indicates an overall safe condition of the river (**Figure 7.25**)

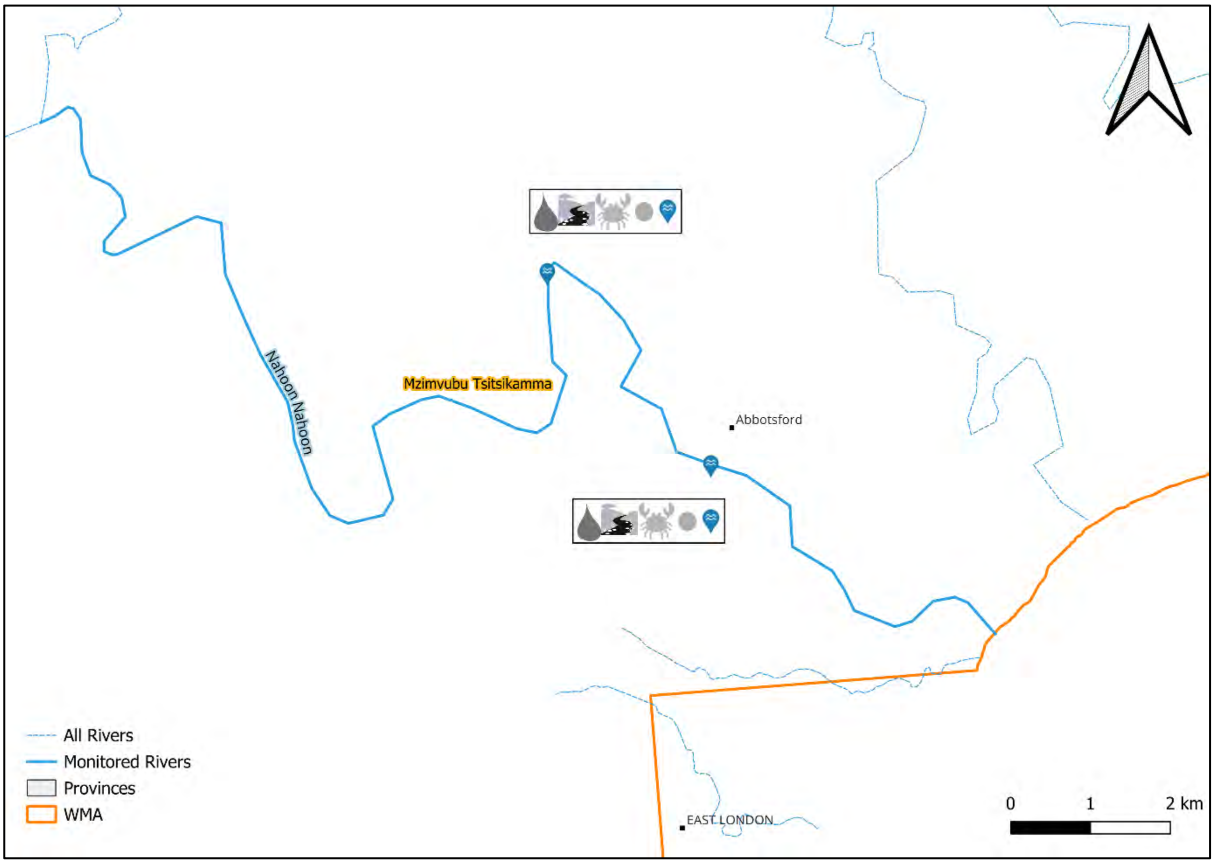


Figure 7.25 Citizen science monitoring locations along the Nahoon River

Tswereka and Mafube Rivers (Figure 7.26)

Physico-chemical data is available for the Tswereka River and indicates safe and very good conditions from WaterCAN and Freshwater Watch testing, respectively at both monitoring points.

Along this short stretch of the Mafube River, physico-chemical tests revealed that the river is in safe and good conditions from WaterCAN and Freshwater Watch testing, respectively.

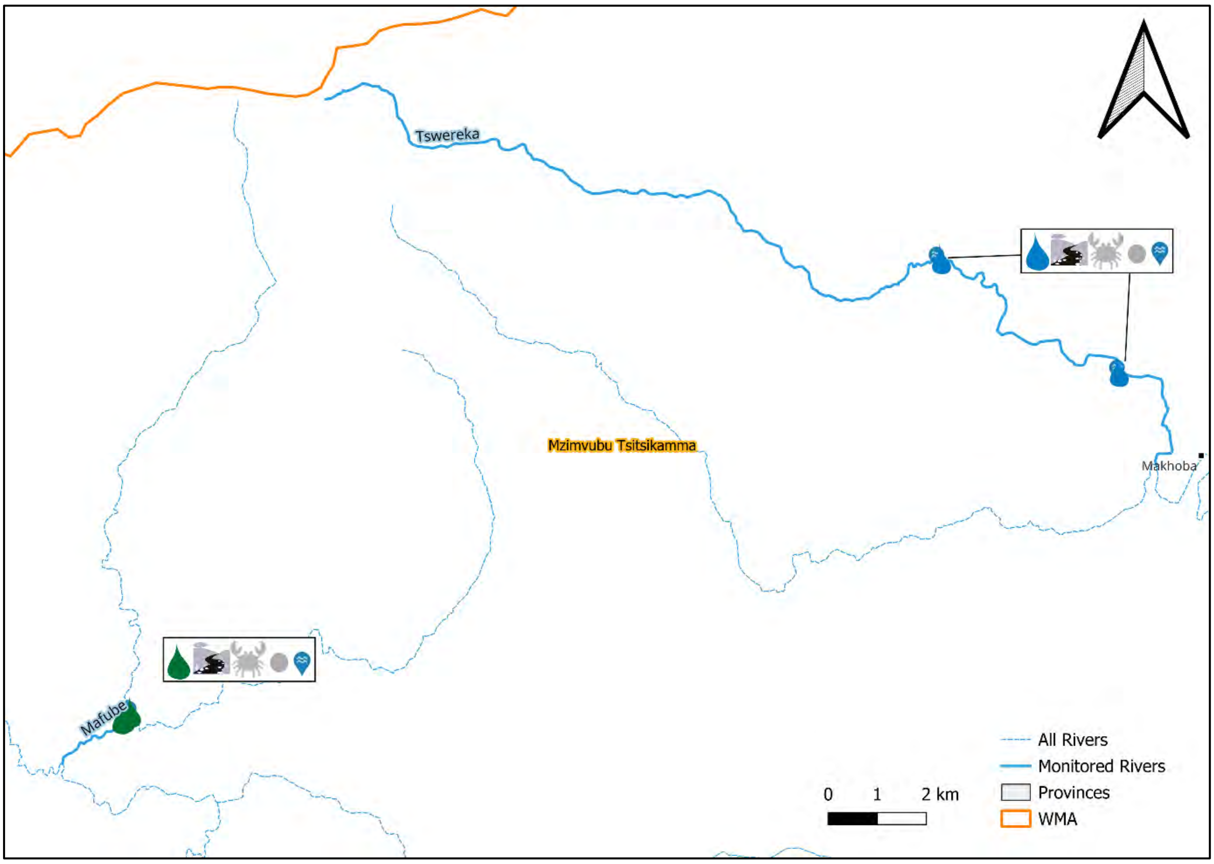


Figure 7.26 Citizen science monitoring locations along the Tswereka and Mafube Rivers

7.4.6 *Olifants Water Management Area*

The Olifants WMA covers portions of the Limpopo, Mpumalanga and a small portion of Gauteng province of South Africa. The rivers systems which were monitored in this region are displayed in **Figure 7.27**.

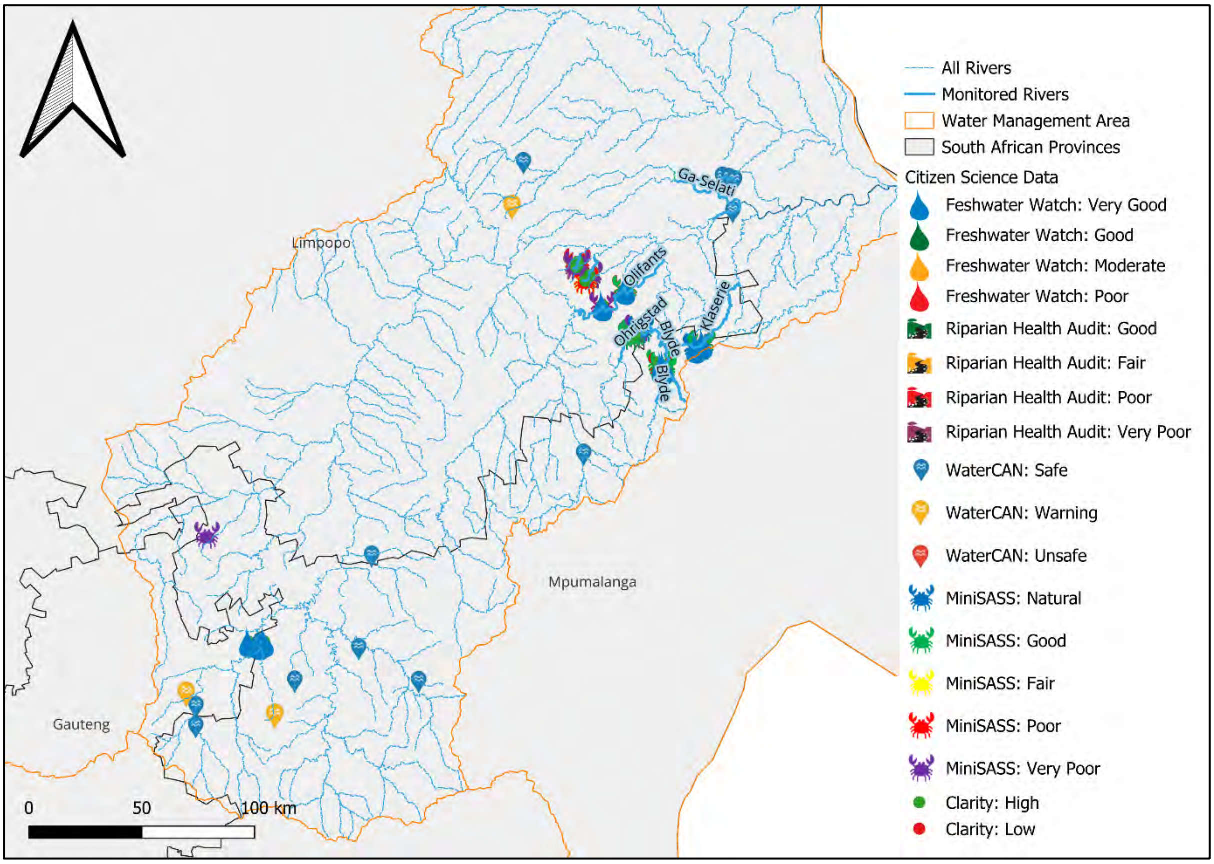


Figure 7.27 Citizen science monitoring in the Olifants Water Management Area

Olifants and Ga-Selati tributary (Figure 7.28)

To the west, the furthest upstream monitoring point of the Olifants River was monitored through physico-chemical techniques which indicated very good conditions using the Freshwater Watch kits and high clarity by use of the clarity tube, however, the latest biomonitoring results indicate a very poor condition. Downstream, the Freshwater Watch technique indicates very good conditions, with high clarity, and the most recent biomonitoring result indicating good conditions.

The Olifants Rivers is fed by the Makhutswi River which is fed by smaller tributaries namely the Moungwane and Malomanye tributaries. The Moungwane has multiple monitoring points which were monitored frequently however the most recent biomonitoring data indicates poor conditions with high clarity observed. Similarly, along the Malomanye multiple monitoring points which were monitored frequently however the most recent biomonitoring data indicates very poor conditions with high clarity observed. Agriculture is the main land use for a large portion of this stretch of the Olifants, with Google Earth Satellite imagery also revealing eroded land around the settlements along parts of the stretch.

The WaterCAN results along the Ga-Selati River indicated an overall safe condition of this tributary which flows into the Olifants River. Google Earth imagery shows that the dominant land use in this area is agricultural use and mining.

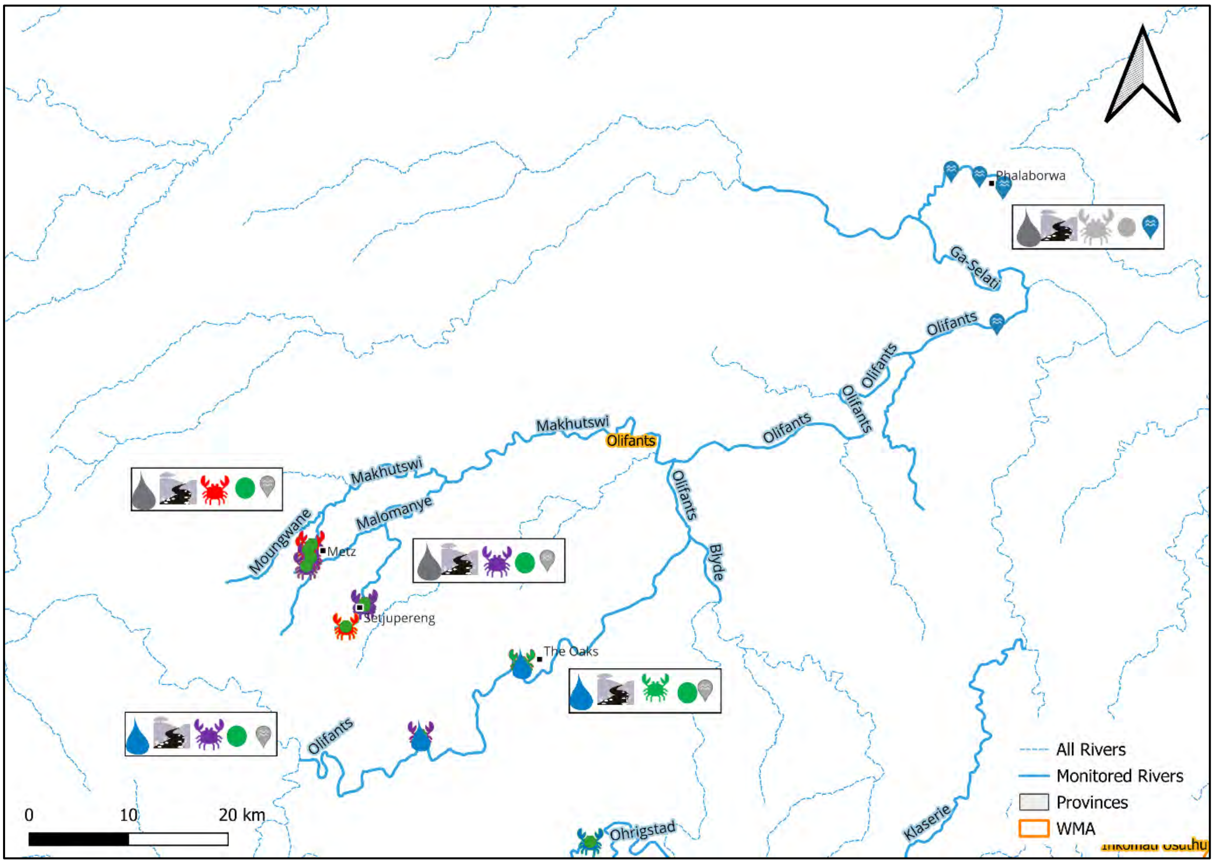


Figure 7.28 Citizen science monitoring along the Olifants River and tributaries

Blyde and Treur Rivers

Points along the Blyde and Treur Rivers were monitored as illustrated in **Figure 7.29**. The Blyde River is fed by the Ohrigstad tributary in the north which biomonitoring data indicated to be in a natural condition with high clarity. The Treur tributary joins the Blyde River in the south and has multiple monitoring points which were monitored frequently. However, the most recent biomonitoring results indicate good conditions with high clarity just before the confluence point, where it joins the Blyde River. Freshwater Watch observations also indicate a very good condition here. The condition of the Blyde River before the confluence with the Treur tributary is found to be good according to the most recent biomonitoring results, with high clarity and Freshwater Watch data indicating very good conditions.

The Klaserie River to the east has multiple monitoring points which were monitored frequently. However, the most recent biomonitoring results revealed good conditions with high clarity. The Freshwater Watch data indicated very good conditions.

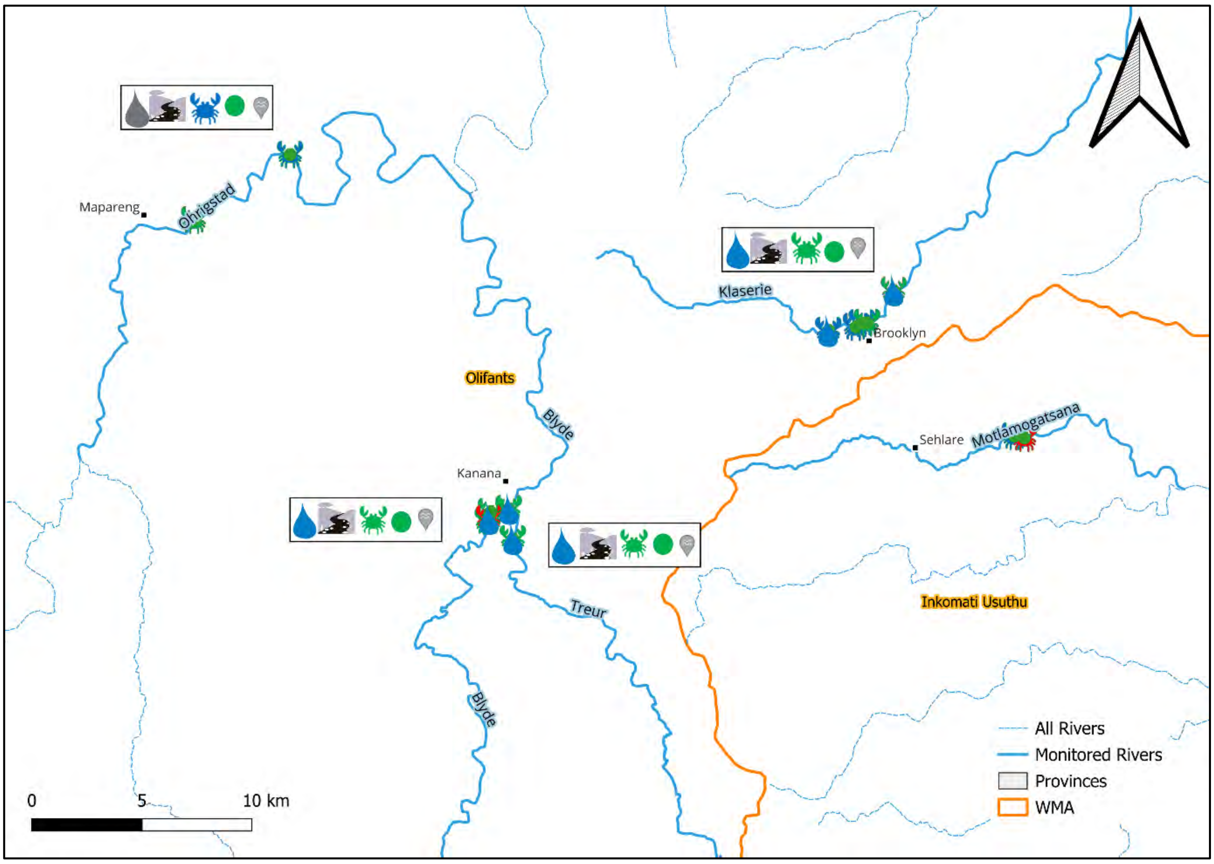


Figure 7.29 Citizen science monitoring along the Blyde River and tributaries, and the Klaserie River

7.4.7 *Orange Water Management Area*

The Orange WMA covers a large portion of the Northern Cape, Free State, and a smaller portion of the Eastern Cape and Western Cape provinces of South Africa. The rivers systems which were monitored in this region are displayed in **Figure 7.30.**

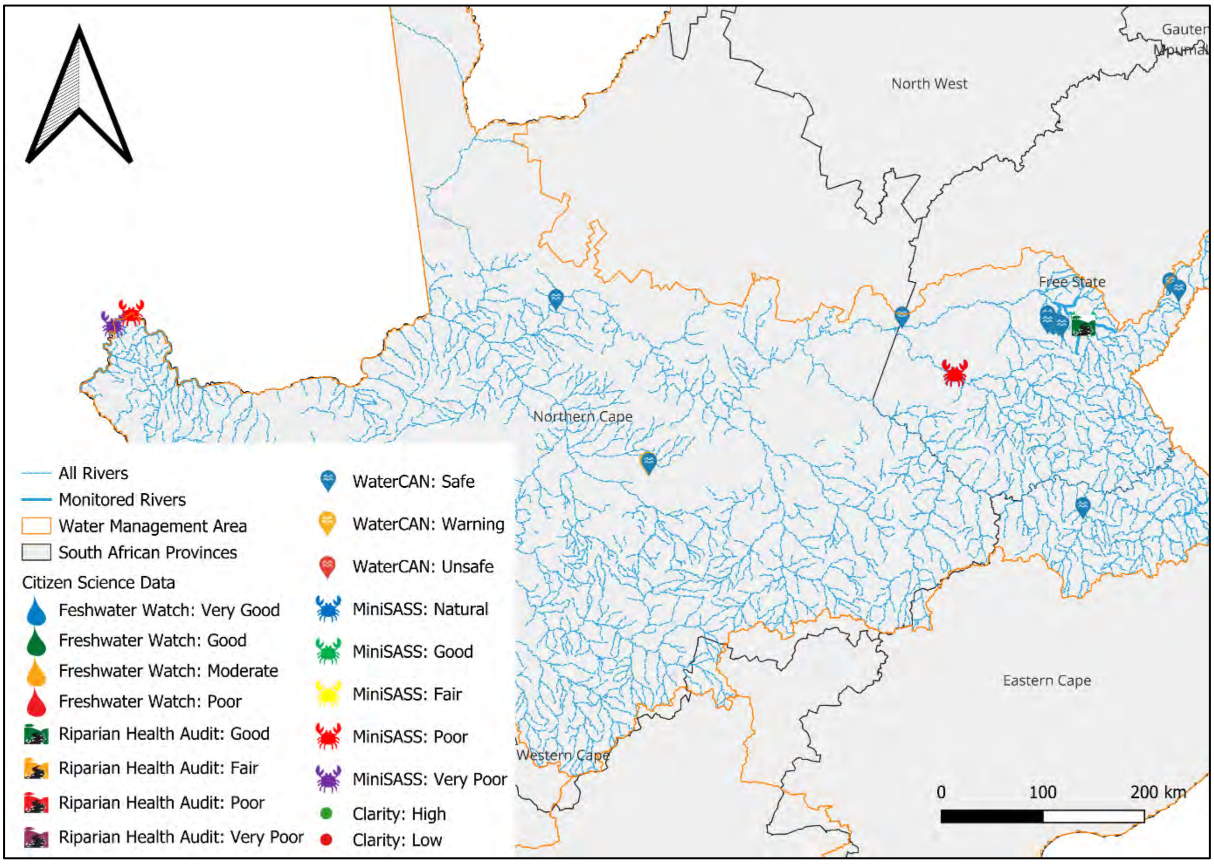


Figure 7.30 Citizen science monitoring in the Orange Water Management Area

This drier part of the region did not have as many monitoring networks as other parts of the region and, as such, only the Modder River and tributaries could be considered to determine the state of a stretch of the river.

Modder River and tributaries

Points along the Modder River and tributaries (Sepane, Bloemspruit, and Renosterspruit) were monitored as illustrated in **Figure 7.31.** Google Earth imagery revealed that the dominant land use in this area is densely urbanised land, and agricultural land, and the Sepane and Modder Rivers on the east, have also been subject to soil erosion on the riverbanks which impacts on the river condition. The riparian health audit reveals good ecological conditions in the upper reaches of the Modder River, and the Renosterspruit entering the Modder River is found to have safe conditions from WaterCAN results.

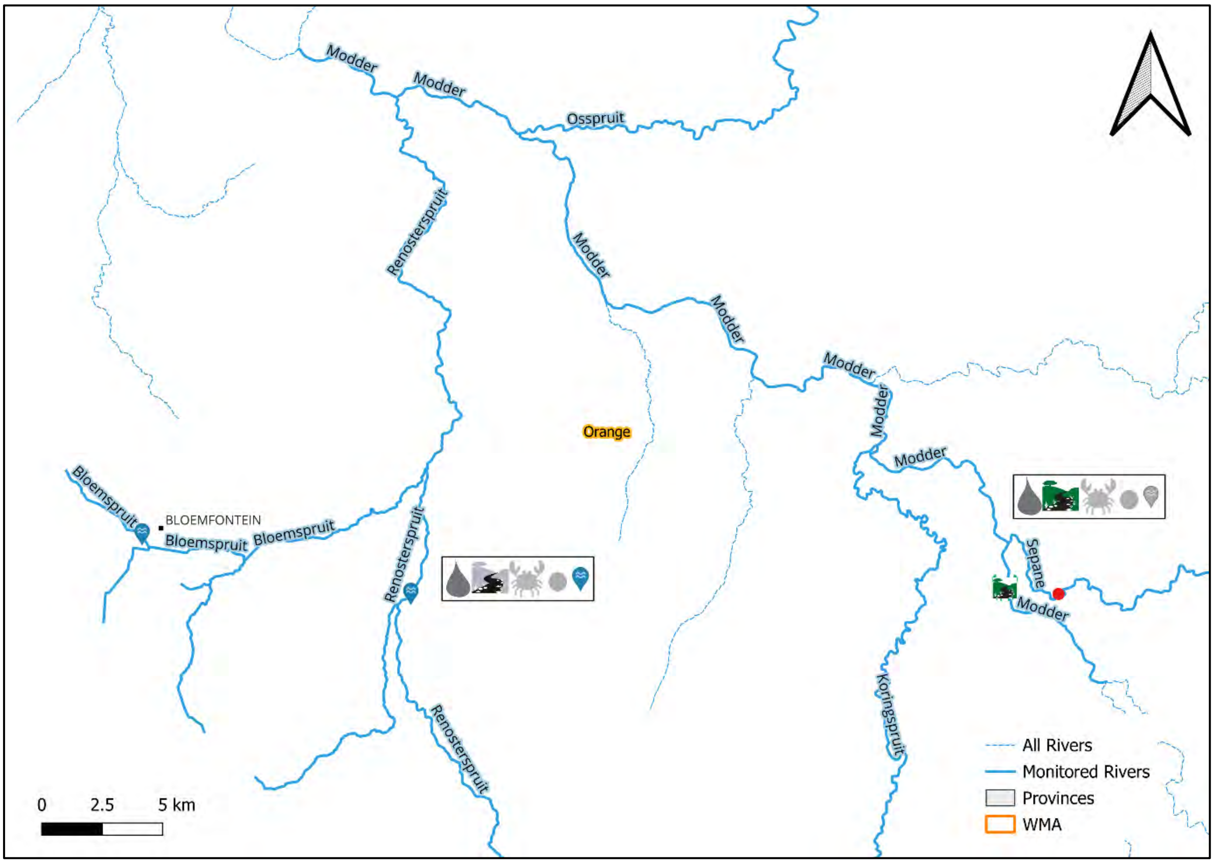


Figure 7.31 Citizen science monitoring along the Modder River and tributaries

7.4.8 *Pongola Mtamvuna Water Management Area*

The Pongola-Mtamvuna WMA covers majority of KwaZulu-Natal and a small portion of Mpumalanga and the Eastern Cape provinces of South Africa. The rivers systems which were monitored in this region are displayed in **Figure 7.32**.

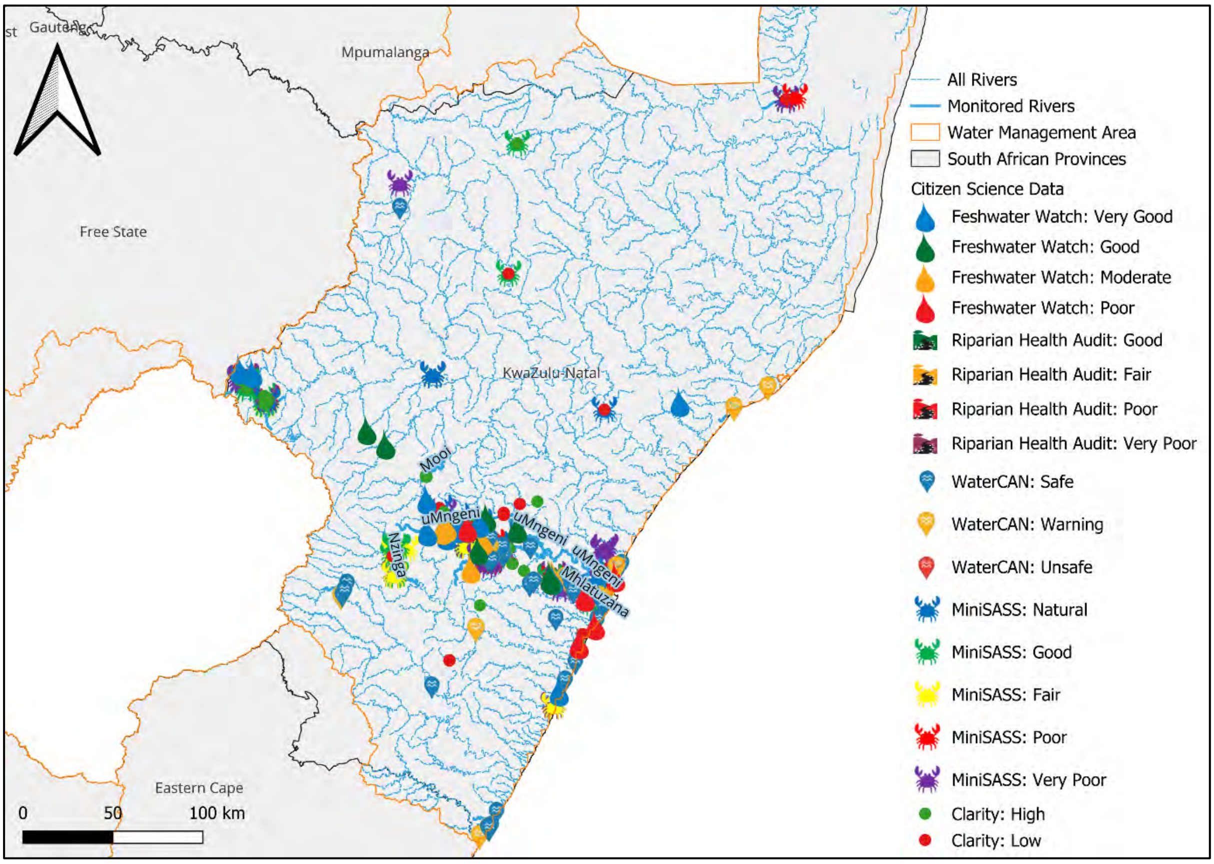


Figure 7.32 Citizen science monitoring in the Pongola Mtamvuna Water Management Area

Lower Pongola Mtamvuna Rivers (Little Mpenjati, Tongazi, and Zolwane) – Figure 7.33

These rivers are found along the coast of KwaZulu-Natal and flow out to sea to the east. Although the data along these rivers was limited, the most recent WaterCAN testing indicated that the Little Mpenjati has a warning condition while the Zolwane and Tongazi Rivers were in safe conditions.

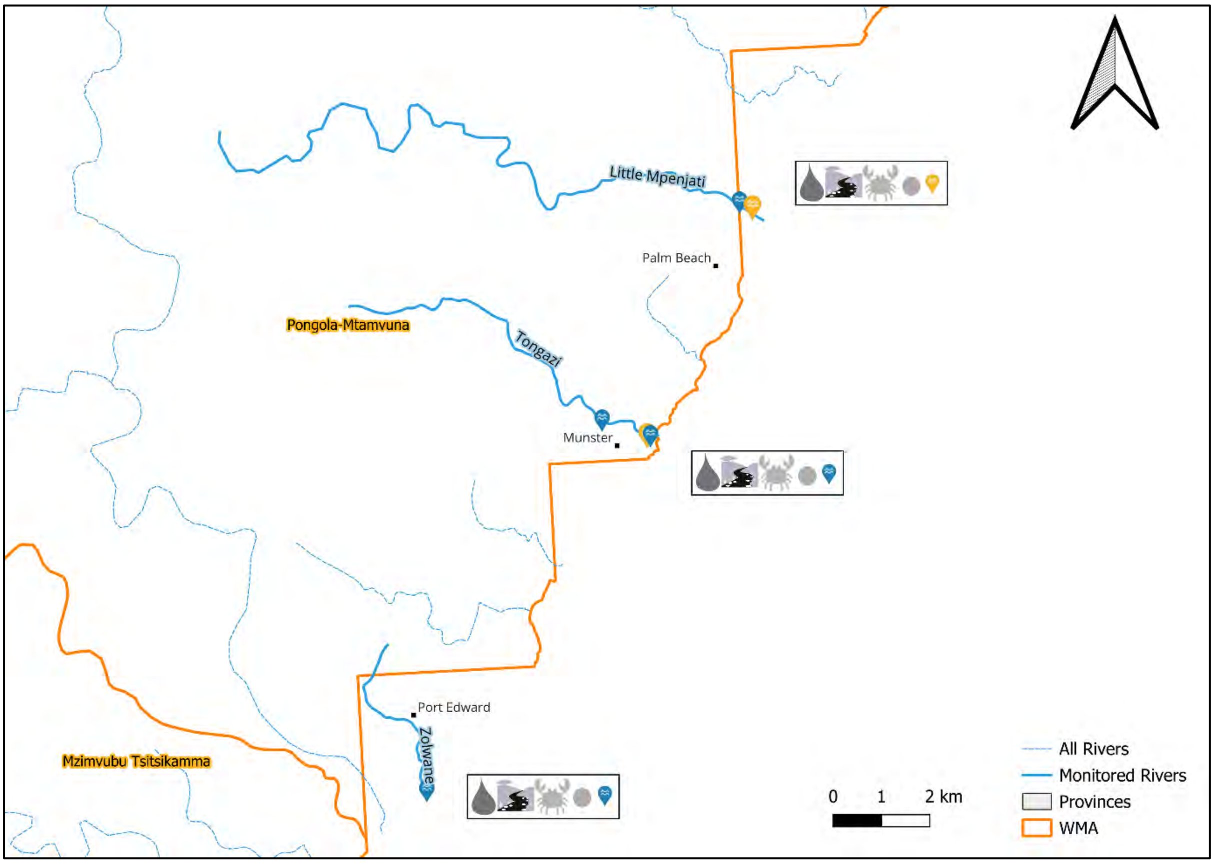


Figure 7.33 Citizen science monitoring along the rivers in the lower section of the Pongola Mtamvuna Water Management Area

Mhlatuzana and Umbilo tributary

The Mhlatuzana River is joined by the Umbilo River before it flows out to sea through the Durban harbour (**Figure 7.34**). Physico-chemically, the most recent WaterCAN testing in the upper to middle reaches of the Umbilo River are found to be in safe conditions. Biologically, the condition found in the middle portion of the reach is fair condition, with high clarity. Google Earth imagery reveales this portion of the stream to be flowing through the Paradise Valley Nature Reserve. However, the Freshwater Watch data which was collected 4 months after the biomonitoring result indicated poor conditions. Further downstream, before the confluence point with the Mhlatuzana River, WaterCAN testing revealed the Umbilo to be in safe condition.

From a biological perspective, the results along the Mhlatuzana River vary from natural conditions closer to the source with low clarity. The biomonitoring results shows that the river changes to very poor conditions (and low clarity) in the middle reaches of the river (Google Earth imagery reveals the dominant land use to be industrial), supported by the Freshwater Watch physico-chemical results which determined poor conditions. However, safe conditions were determined from the WaterCAN testing. The condition then improves to good further downstream from a biological perspective with high clarity. The WaterCAN results indicate that the river is found to be in a safe condition close to the confluence with the Umbilo River before flowing out into the harbour.

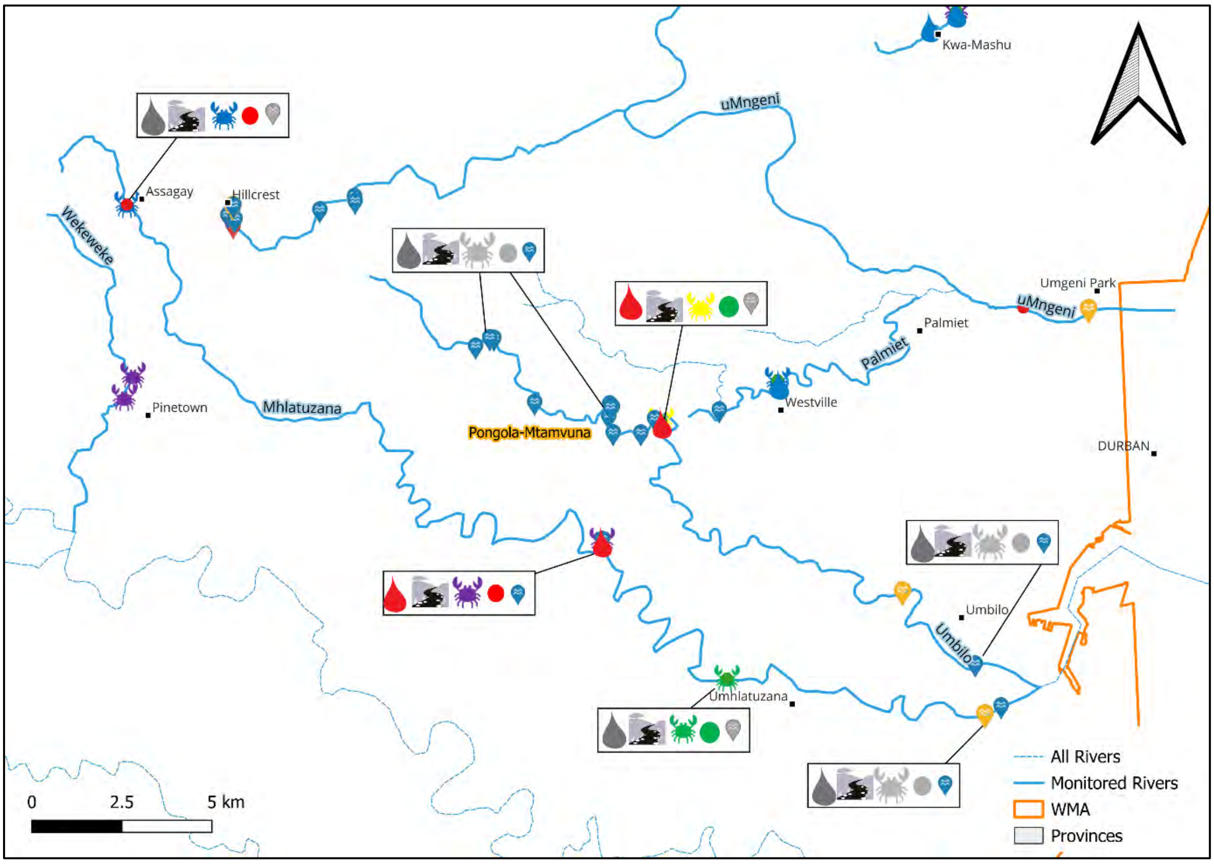


Figure 7.34 Citizen science monitoring along the Mhlatuzana and Umbilo Rivers

Lower uMngeni and tributaries (Palmiet and Molweni), and Ntuzuma Stream – Figure 7.35

WaterCAN tests along the upper reach of the Molweni tributary indicate overall safe conditions. The upper reaches of the Palmiet tributary were found to have a natural condition from a biological perspective, and this is supported by the physicochemical results with high clarity values and very good Freshwater Watch results. Lower down the uMngeni River, close to the river mouth, WaterCAN results reveal that the river is in a warning condition.

The Ntuzuma Stream in KwaMashu is in very poor condition from a biological perspective, however from a physico-chemical perspective, the clarity is high, and the Freshwater Watch test reveals very good conditions.

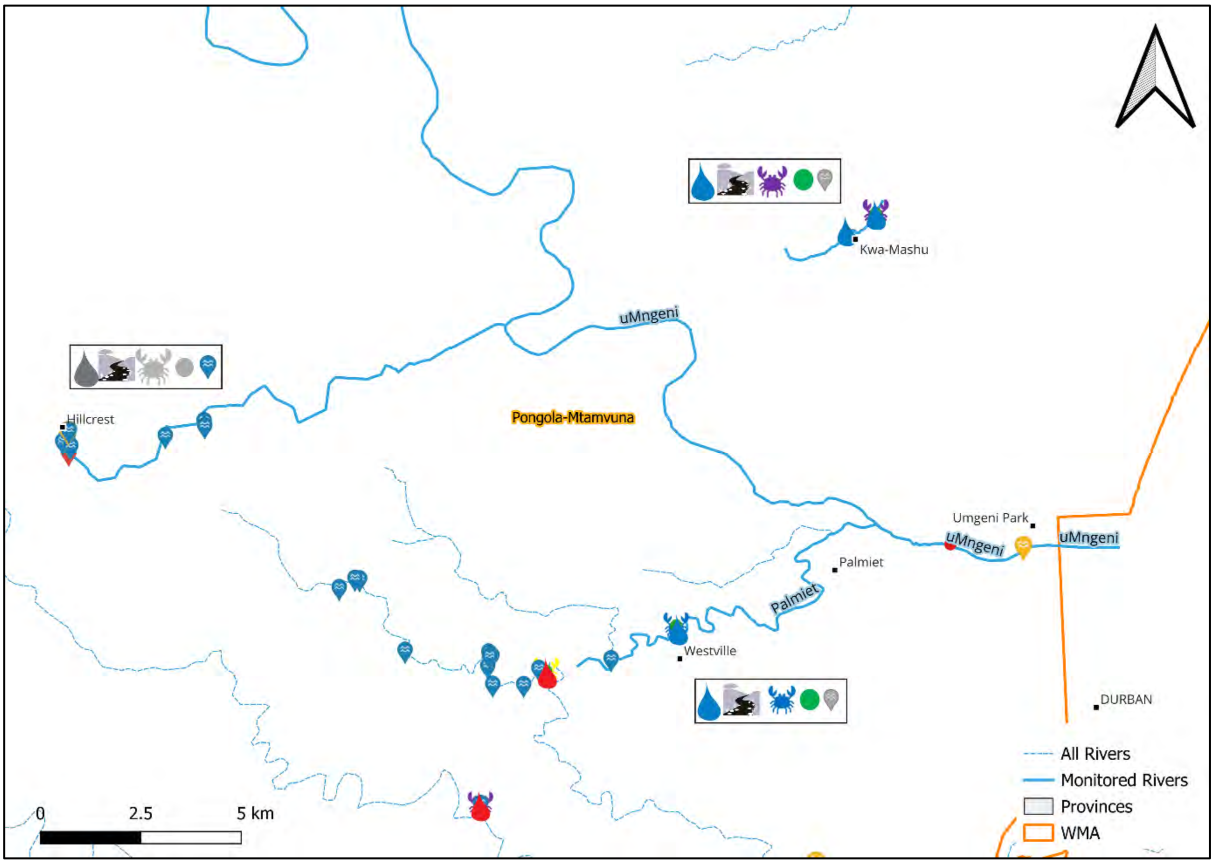


Figure 7.35 Citizen science monitoring along the lower portion of the uMngeni River and Molweni and Palmiet tributaries

Upper uMngeni and tributaries (Lions and uMnsunduze) – Figure 7.36

The Freshwater Watch results in the upper reaches of the uMngeni river, close to its source, indicate overall very good conditions, including after the confluence with the Lions River. The biomonitoring results for the upper stretch of the uMngeni River reveal a very poor condition, however, at the confluence with the Lions River this condition improves to natural. The Mpofana River flows into the Lions River with a very poor ecological condition according to the downstream biomonitoring score, but high clarity. This high clarity is maintained after the Lions River confluence with the uMngeni, and the biomonitoring ecological category improves to natural condition downstream of the confluence. At the confluence, the physico-chemical results are safe and very good for WaterCAN and Freshwater Watch testing, respectively. This confluence point is located just above Midmar Dam, with the outflow located in Howick town. Downstream of Midmar Dam, the most recent biomonitoring results indicate a natural condition of the stream, however a more recently observed Freshwater Watch result indicates a poor condition of the river. Further along the uMngeni, as it passes through the Umgeni Valley Nature Reserve, the biomonitoring condition remain natural with high clarity, and an improvement in the Freshwater Watch result to very good condition. The point monitored below Albert Falls is located in Cumberland Nature Reserve. Here, the WaterCAN test indicates safe conditions, and the Freshwater Watch result indicates good conditions.

The tributaries of the uMnsunduze present overall very poor conditions from biomonitoring observations, with the WaterCAN results indicating mostly safe conditions further downstream but the clarity results remain high. The WaterCAN test upstream of the confluence of the uMsunduze River with the uMngeni River indicates safe conditions.

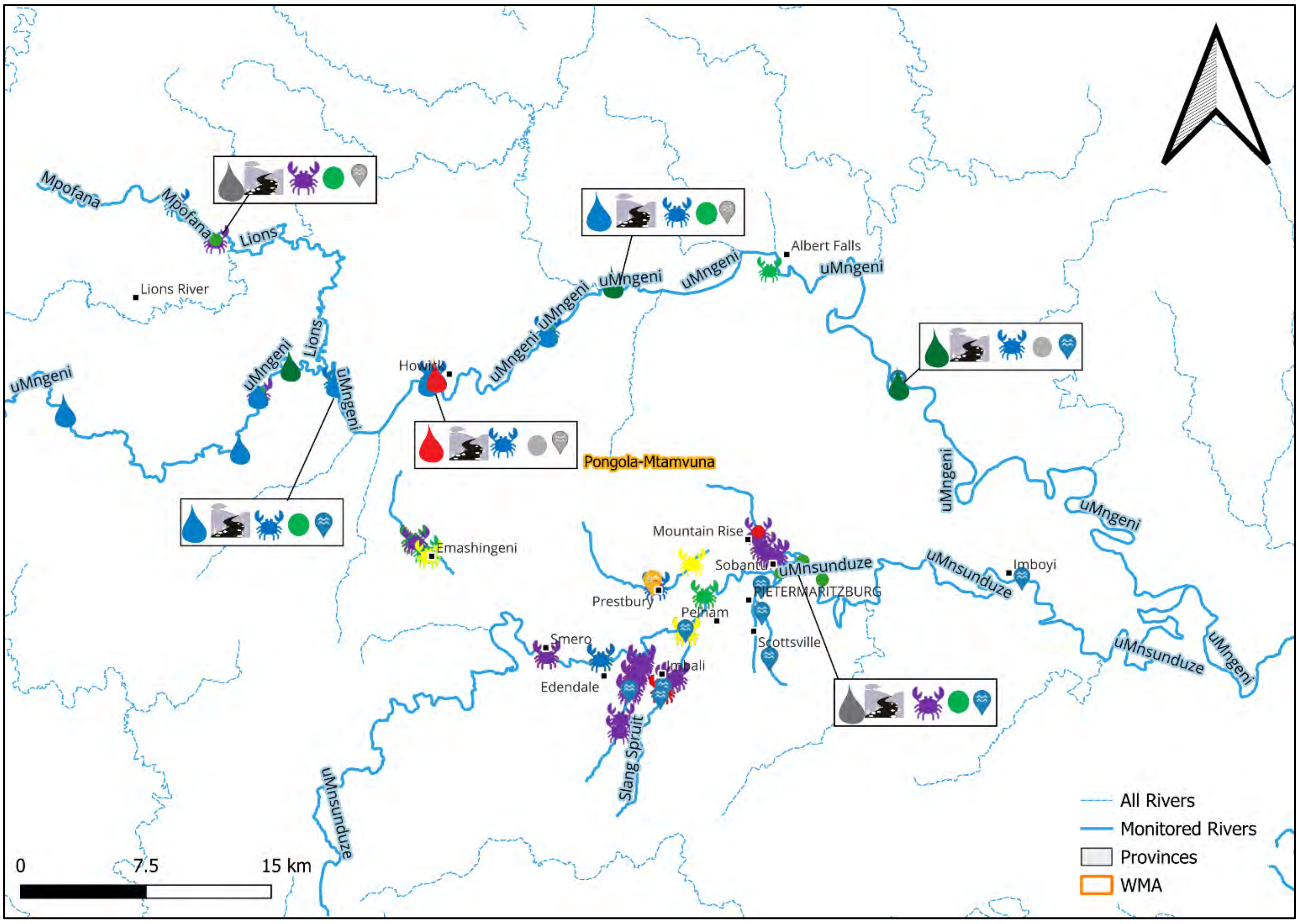


Figure 7.36 Citizen science monitoring along the upper portion of the uMngeni River and Lions and uMsunduze tributaries

Upper Mkomazi and Upper Mzimkhulu – Figure 7.37

The data available to report on the condition of this stretch of the upper Mzimkhulu River is physico-chemical data, the more recent of which indicates an overall safe condition for this stretch of the river.

The Mkomazi is fed by the Nzinga tributary which biomonitoring data indicates is in a good condition with low clarity before it joins the Mkomazi River. The most recent biomonitoring data indicates that the Mkomazi is in fair condition.

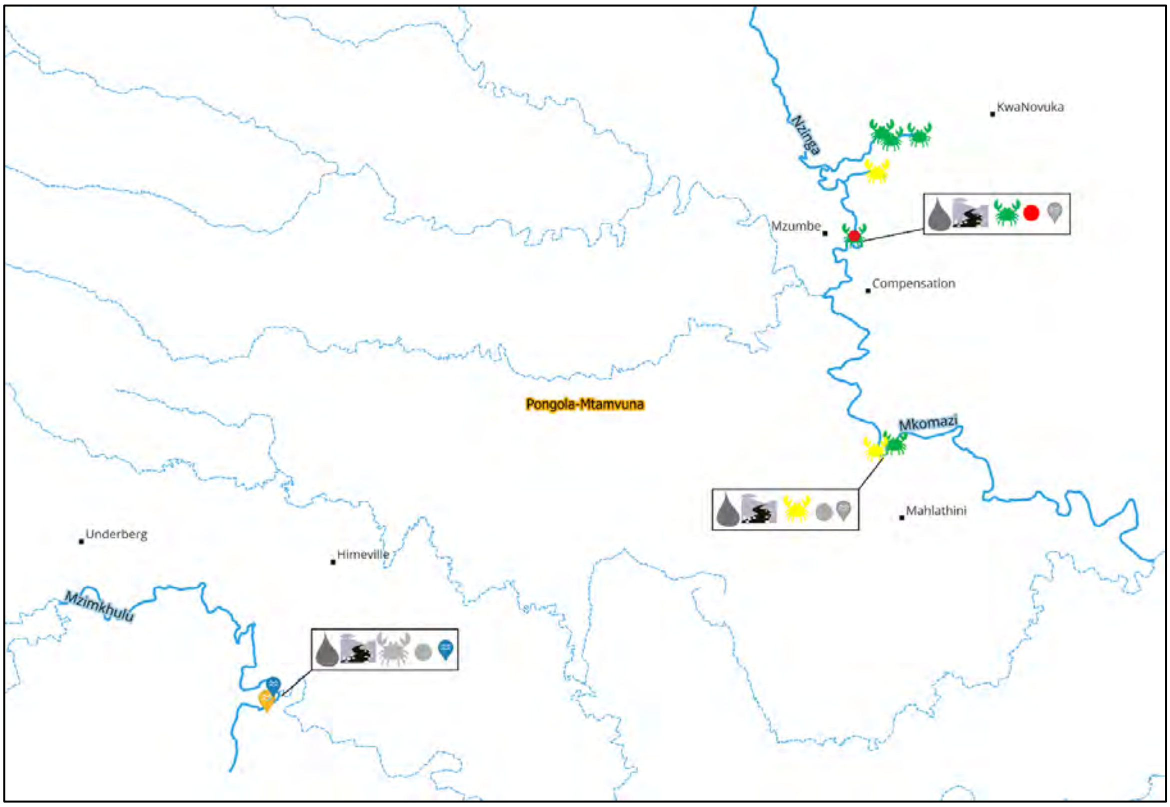


Figure 7.37 Citizen science monitoring along the upper Mkomazi and upper Mzimkhulu

Manzamnyama and uMlalazi Rivers

The most recent WaterCAN indicator for the uMlalazi River has an overall warning indicator. The biomonitoring data for the Manzamnyama River indicates an overall poor condition despite the high clarity tube result (**Figure 7.38**). Google Earth imagery reveals there has been extensive vegetation removal adjacent to the Manzamnyama River.

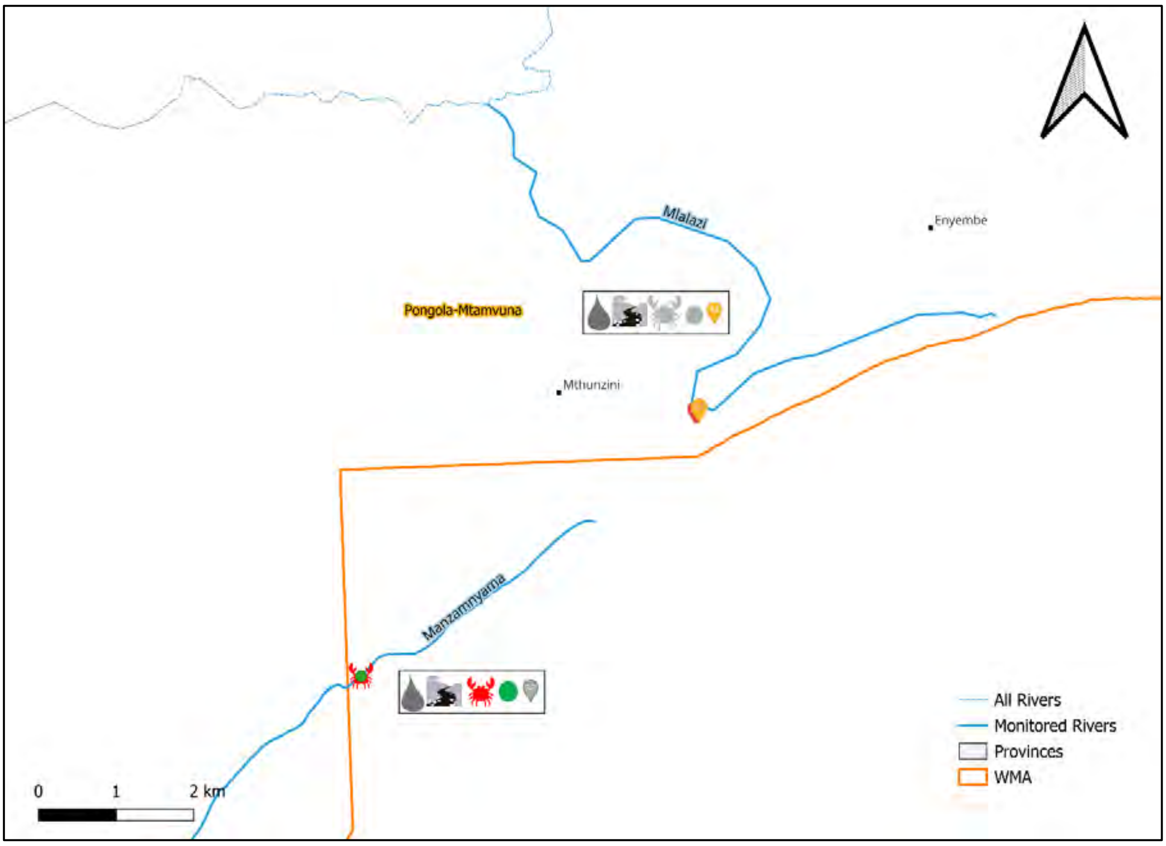


Figure 7.38 Citizen science monitoring along the Manzamnyama and Mlalazi Rivers

Upper Thukela and Mweni tributary

Points along the Upper Thukela River, and the Mweni tributary, were monitored as illustrated in **Figure 7.39**. Google Earth imagery revealed that there is extensive agriculture found along this stretch of the Thukela River, and settlements along the upper portion. The biomonitoring data along the upper reaches of the Thukela River shows an overall very poor condition after it is joined by a tributary, however the clarity value remains high along this stretch. Before it is joined by the Putterill tributary, a Freshwater Watch test indicates very good condition. Biomonitoring along the Mweni River and a tributary, reveal the Mweni to have an overall good condition before it is joined by a tributary with an overall poor condition, resulting in the confluence point to have an overall fair condition. The Mweni then flows through the Woodstock Dam and joins the Thukela downstream however there is no data available to report on the condition at this confluence.

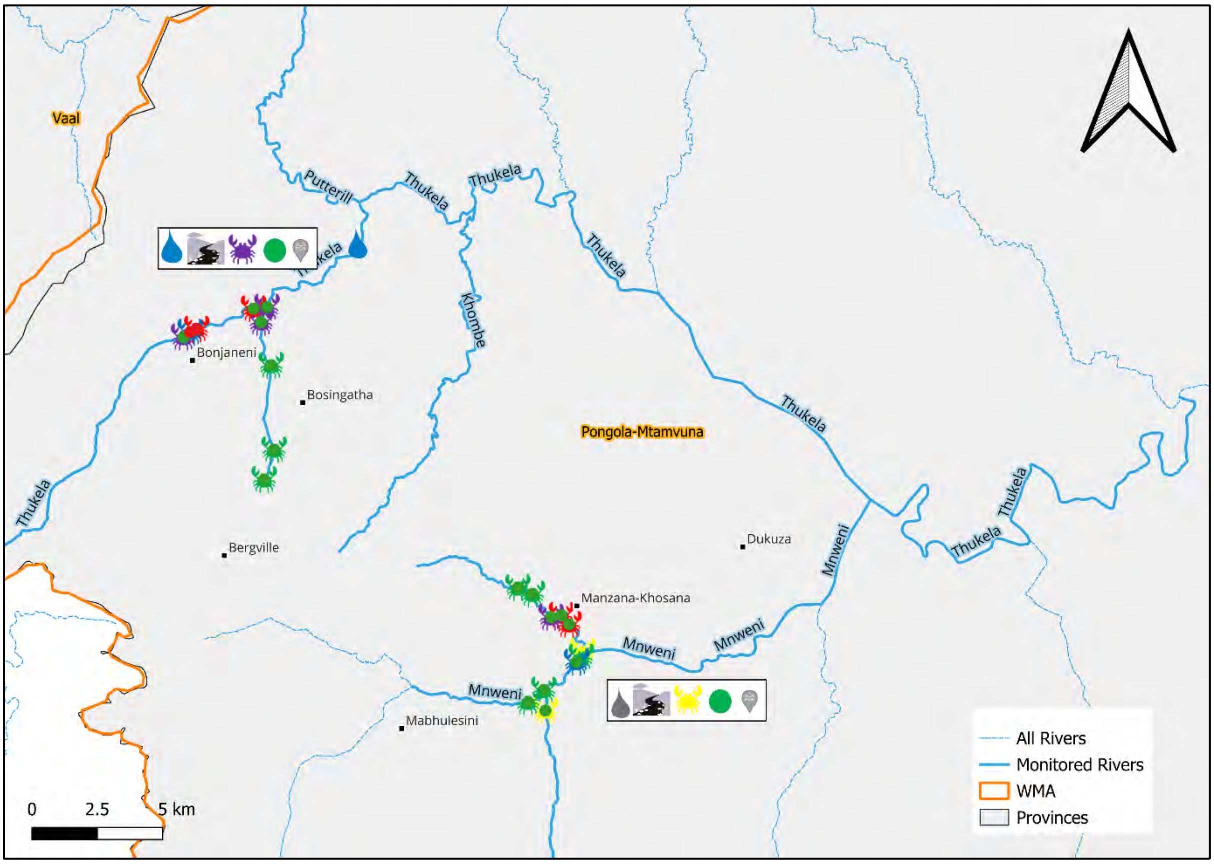


Figure 7.39 Citizen science monitoring along the upper Thukela River and Mweni tributary

7.4.9 *Vaal Water Management Area*

The Vaal WMA covers portions of a few provinces including North West, Gauteng, Mpumalanga, Free State, and the Northern Cape provinces of South Africa. The rivers systems which were monitored in this region are displayed in **Figure 7.40.**

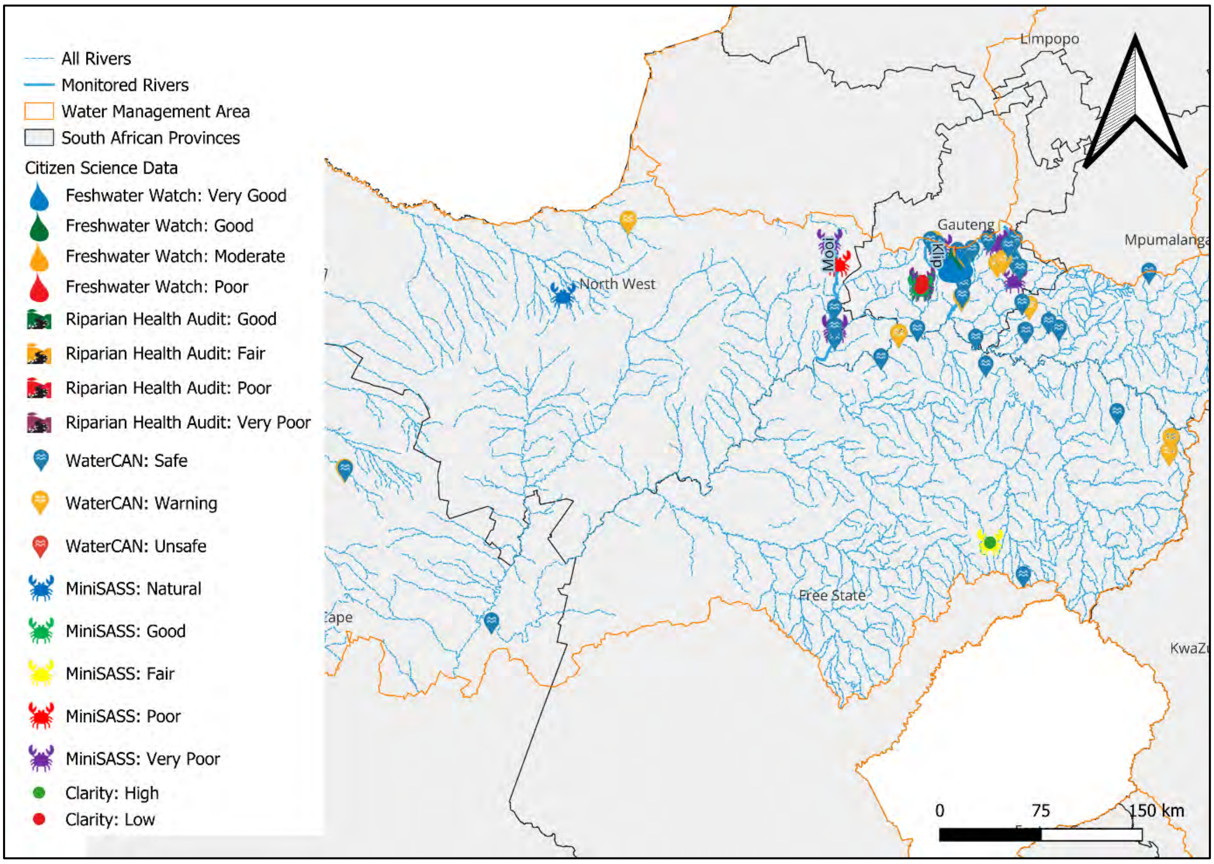


Figure 7.40 Citizen science monitoring in the Vaal Water Management Area

Blesbokspruit, Klip, and Poortjie Rivers

The biomonitoring results along this stretch of the Blesbokspruit reveal very poor conditions however the WaterCAN results indicate safe conditions (**Figure 7.41**).

The WaterCAN results indicate an overall safe condition of the Klip River, with the Freshwater Watch results varying between poor and very good, and the clarity also varying between high and low. Google Earth imagery reveals that the dominant land use adjacent to the river is densely urbanised.

There are multiple monitoring points along the Poortjie River, each having been monitored multiple times. However, the most recent biomonitoring observations reveal that the overall ecological condition is very poor. The clarity tube values also remain low along the stretch of the river.

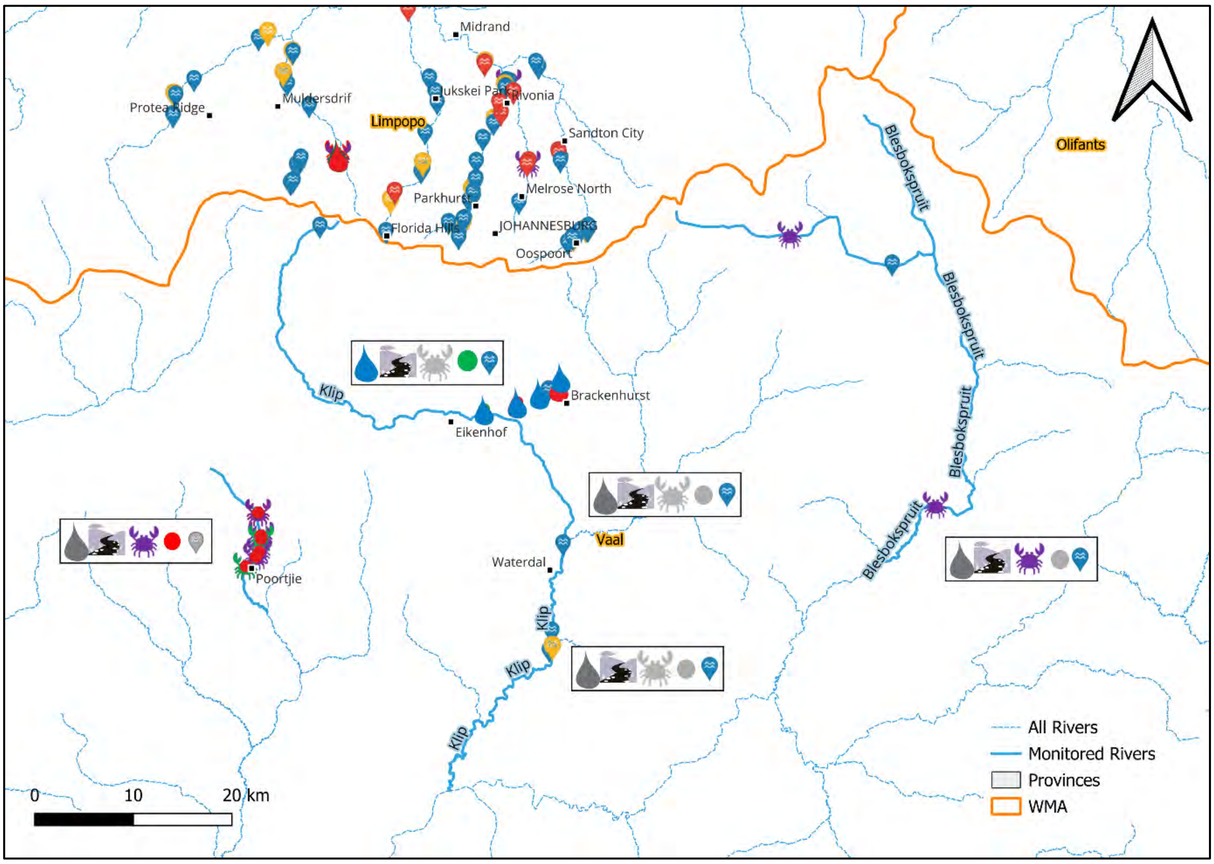


Figure 7.41 Citizen science monitoring along the Blesbokspruit, Klip, and Poortjie Rivers

Mooi River

The upstream (north) portion of the Mooi River is found to be in poor condition based on biomonitoring results. The biological condition decline to very poor in the lower portion of the Mooi River. However, safe conditions are determined through WaterCAN physico-chemical testing for this stretch of the Mooi River (**Figure 7.42**).

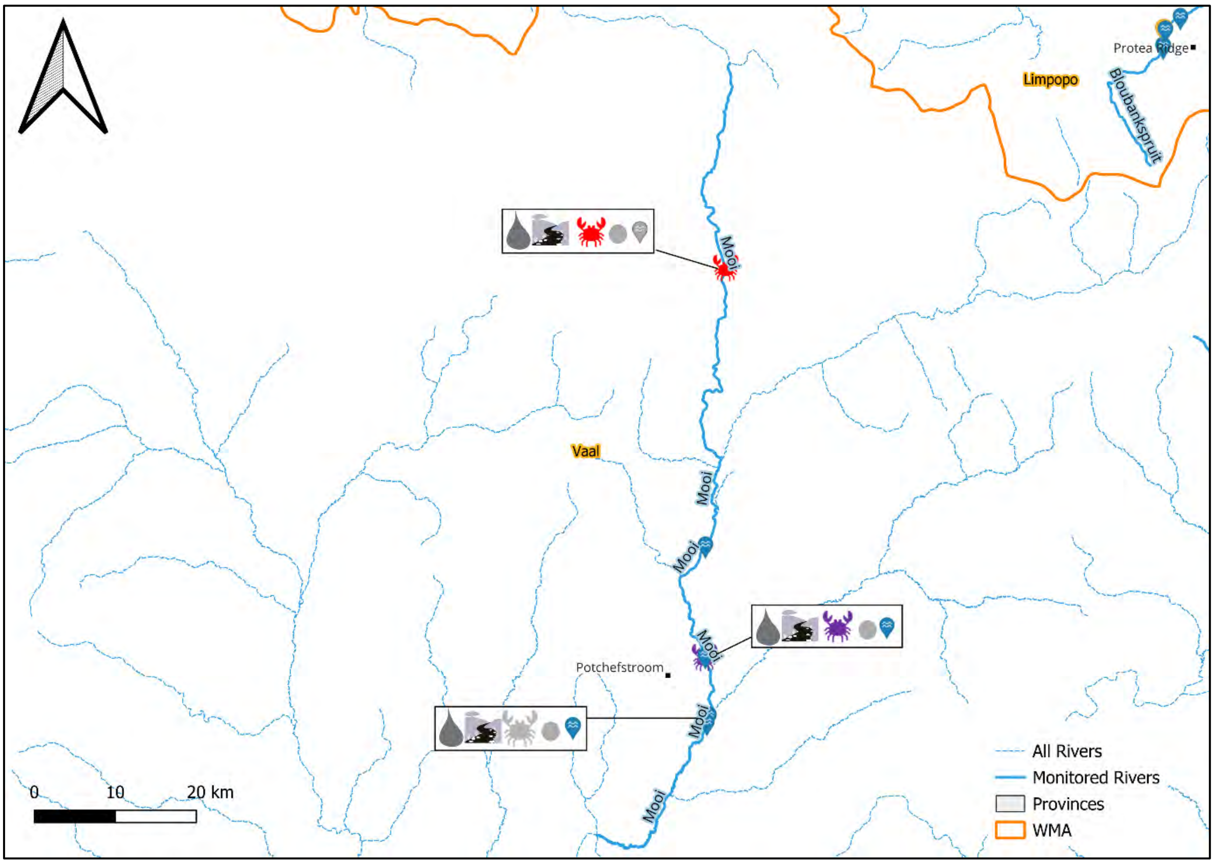


Figure 7.42 Citizen science monitoring along the Mooi River

7.5 Citizen science on the ground: applications in South Africa

There have been great CS efforts around southern Africa during 2023/2024, and numerous participating collaborators as part of this body of work. Below are a few of many cases which demonstrate real applications of CS practices, represent where some of the data discussed above came from, and provides cases of continuity of CS practices. These impact stories are included to strengthen awareness of CS applications for decision-makers (Gold and Wehn, 2020) as well as to build knowledge of the uptake of CS for all citizens.

7.5.1 *Kruger to Canyons Biosphere Region*

KRUGER TO CANYONS
BIOSPHERE REGION

At Kruger to Canyons Biosphere, we are committed to monitoring and improving river health through our Freshwater Monitoring Initiative. In response to the increasing pressures of pollution, climate change, and unsustainable land use, we focus on key rivers like the Blyde, Klaserie, and Olifants. Using citizen science as a core element, we engage local communities in collecting critical water quality data, such as pH, Dissolved Oxygen, and nutrient levels (Phosphates and Nitrates). Citizen science monitors play a vital role in our project, using tools like miniSASS for biological assessment and Freshwater Watch equipment to measure pollutants. By fostering community participation, we aim to create a long-term impact on conservation and river health.

We actively engage with stakeholders, including traditional authorities, to raise awareness of river conditions and involve communities in conservation. Participating in the Science for Society Symposium and IIEM Water Symposium has enhanced our capacity and strengthened citizen science. Going forward, we aim to expand community involvement and improve data use for long-term river conservation.

Freshwater Monitoring Initiative
Project Lead: Phomolelo Malatji
phomelelo@kruger2canyons.org
www.kruger2canyons.org
@k2c.biosphere




7.5.2 *Friends of the Liesbeek*

The Friends of the Liesbeek (FoL) is a Cape Town-based non-profit dedicated to rehabilitating, enhancing and conserving the Liesbeek River, while raising awareness of its value as a green corridor in an urban environment. In August 2024, FoL joined the citizen science initiative, contributing essential water quality data to South Africa's State of the River report. The Liesbeek River, recognised as one of Cape Town's cleanest urban rivers, benefits from community-driven efforts such as the Upper Liesbeek River Garden and FoL's artificial wetland near Rosebank, which treats polluted stormwater. This initiative allows FoL to monitor the river's health and actively engage the community in activities like miniSASS, Riparian Health Audits, and water quality testing using WaterCAN kits funded by WESSA. FoL aims to continue these bi-monthly efforts, building a valuable database to track water quality changes over time and setting an example of citizen science in urban river stewardship.

FRIENDS OF THE LIESBEEK

Website: https://fol.org.za/

Email: info@fol.org.za

Social Media:

Facebook (@Friends of the Liesbeek)

Instagram (@friendsof_theliesbeek)

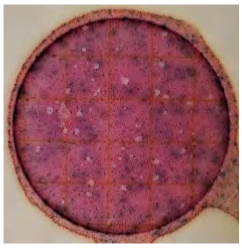
7.5.3 *River Rescue*

River Rescue works to clean the rivers in the city of Makhanda/Grahamstown and to restore the local watercourses to a state where they can be used by the citizens of the city, Makhanda, in the Eastern Cape, South Africa.

Since 2020, volunteers from the full spectrum of residents – University students, local residents, city councillors, businesspeople and, most especially, children – have been regularly involved in the 'housework' of cleaning rubbish out of the watercourses. Changes have been small, but significant, and participants have learned a great deal as they've worked.

'Pop-up' schools provide an opportunity to share knowledge about the rivers, the creatures that live in them, the plants that grow along the banks, and to begin to understand the connections rivers create between us all and the planet we call home.

River Rescue
Uthando lwemilambo



Website:
www.riverrescue.co.za

Facebook:
www.facebook.com/RiverRescueMakhanda

Email:
riverrescue6140@gmail.com

7.5.4 *SANParks Garden Route*

South African
NATIONAL PARKS

Using miniSASS as a tool in SANParks' environmental education programmes

https://www.sanparks.org/

https://www.facebook.com/South.African.National.Parks

Over the years, SANParks Scientific Services have been conducting and participating in various science outreach events with lessons covering various aspects of biodiversity and conservation. These are linked with practical exercises to give participants hands-on experience in the field of conservation and shows them the fun side of science. The miniSASS citizen science tool has been invaluable in providing these practical opportunities while still contributing to our biodiversity monitoring databases. It has been easy enough to use with groups of all ages as well as with colleagues who have varying education and experience levels. Most importantly, it exposes everyone to the world of the often unnoticed yet vital parts of biodiversity!

7.5.5 *Deep Water Movement*

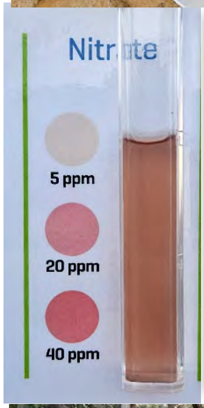
The Deep Water Movement's recent citizen science project has revealed the critical condition of Gauteng's rivers. Water quality tests on rivers such as the Hennops, Jukskei, Rietspruit, Sandspruit, Diepsloot, Rietvlei River and Braamfontein Spruit show alarming results, calling for urgent action.

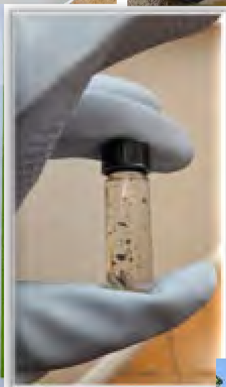
All rivers tested positive for coliform bacteria, including *E. coli*, indicating severe faecal contamination. High nitrate and phosphate levels were observed in all the rivers suggesting nutrient pollution, leading to eutrophication and low oxygen levels. Dissolved oxygen levels were below the healthy threshold, stressing aquatic life.

While low turbidity indicates clear water, it doesn't address dissolved pollutants. The presence of coliforms signals possible contamination by harmful bacteria, viruses, or parasites.

With only 7.8% of South African water safe for consumption, the poor state of rivers underscores the broader issue of water quality in South Africa. Immediate intervention is needed to reduce pollution and restore oxygen levels, ensuring aquatic life's and human communities' health.

STOP POLLUTING OUR WATERWAYS!





DEEP WATER MOVEMENT

Contact Details: +27 82 460 2899

LinkedIn: Deep Water Movement

7.5.6 *Owe 2 Green Economy*

079 176 4751

Restoring Rietspruit: A Pathway to Heritage, Healing, and Sustainability

OWE2 Green Economy is honoured to contribute to water monitoring and restoring the Poortjie Rietspruit Catchment Management Area, a site of immense cultural, spiritual, and ecological significance. Through our Citizen Science water monitoring, we've seen how community-led efforts can combat pollution and biodiversity loss while preserving cultural and recreational spaces.

The Rietspruit, once a hub for rituals and healing, now symbolises environmental degradation. Our work seeks to reconnect communities with this vital resource, empowering them to restore its health and reclaim its role in their heritage.

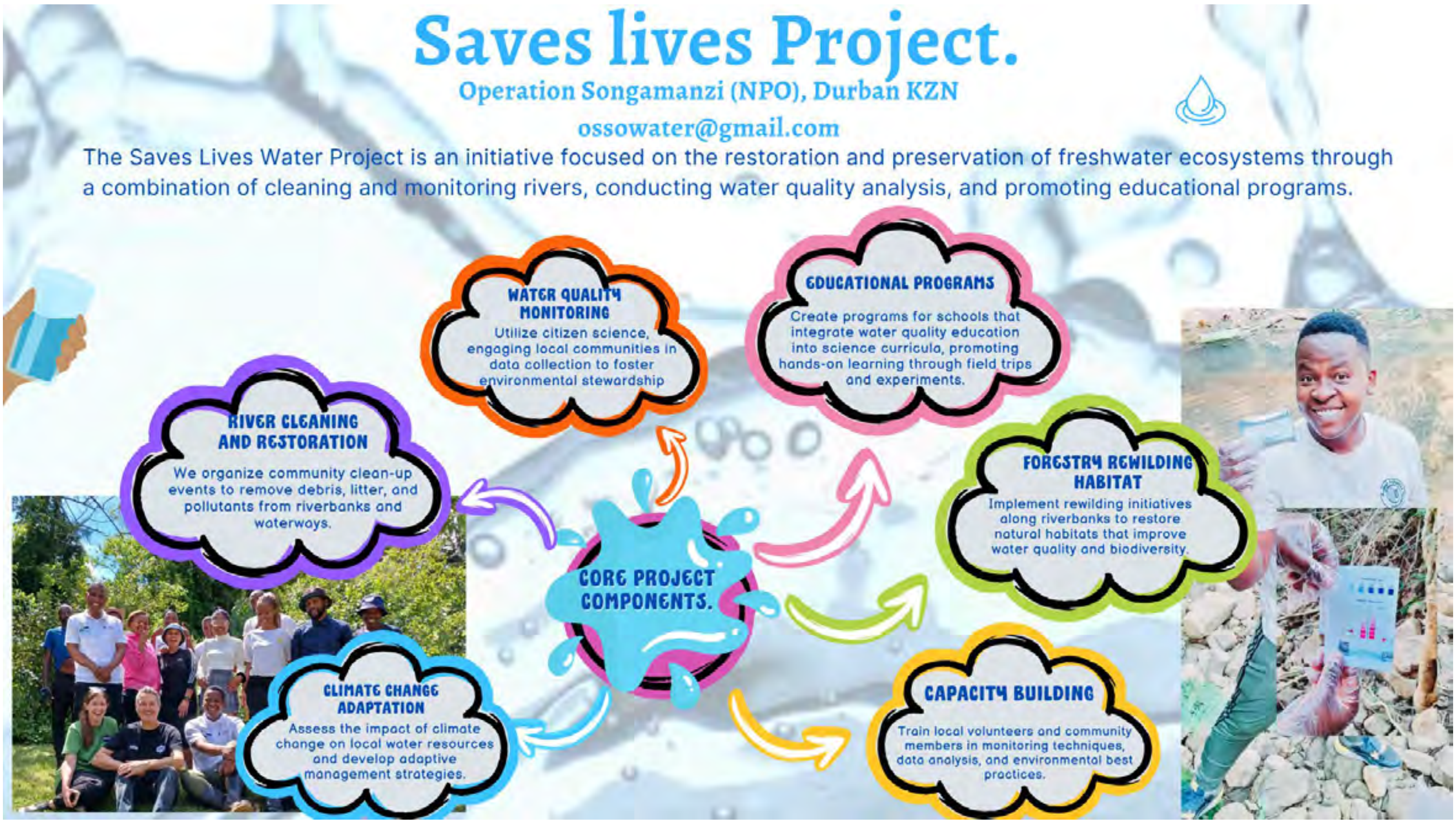
We envision the Rietspruit as a sanctuary for reflection, cultural preservation, and eco-tourism, driving both environmental renewal and sustainable economic opportunities. OWE2 Green Economy remains committed to continuous monitoring and fostering stewardship for a thriving, resilient future.

DON'T BE LEFT BEHIND! - OTLA E NYANYA E MATHA!

OWE2 Green Economy, CEO
Nkosinathi Hlabeni.

nkosihlabenii@gmail.com

7.5.7 *Operation Songamanzi*



7.5.8 *Environmental and Rural Solutions*

In our mission to secure resilient landscapes, Environmental and Rural Solutions (ERS) has been involved in monitoring river health and water quality adopting an active CS approach within the wider uMzimvubu Catchment Partnership efforts and participating in data gathering initiatives with various research institutions and partners, including GroundTruth and DWS.

ERS is a grassroots NGO, based in Matatiele (Eastern Cape). Our mission is to secure healthy landscapes to support resilient rural livelihoods, and we work closely with traditional and local authorities and a range of natural resource users, including farmers and traditional healers. The SoR 2024 initiative involved a group of enthusiastic river monitors, including ERS's eight field-based Ecochamps who are multi-skilled local youth providing a vital extension and liaison arm to amplify the NGO's reach and impact in the upper Umzimvubu catchment. The SoR 2024 voluntary efforts contributed to our overall mission by helping to understand drivers and issues in our strategic water source area through providing river data: identifying pollution sources, along with aquatic life, flow rates, and water colour as indicators of freshwater health status. Importantly, local water users and potential risks were identified and many learning conversations were stimulated.

Our monitoring revealed excessive levels of nitrate and phosphates due to agricultural runoff, poorly managed developments, and disposable nappy and other dumped solid waste pollution leading to eutrophication, algae blooms, and the degradation of aquatic habitats. Ongoing monitoring and active community engagement is vital and CS water quality monitoring projects contribute towards restoring and maintaining the health of river ecosystems and encouraging citizen responsibility in preventing pollution and negative impacts. This underscores the need for ramping up WASH outreach and river clean ups which ERS tags onto our rangeland health related work, especially spring protection and a smart nappy promotion pilot.

Together we can do more to secure the future!

7.5.9 *Duzi-uMngeni Conservation Trust and the Social Employment Fund*

The Duzi-uMngeni Conservation Trust (DUCT) is a non-profit organization dedicated to restoring the health of rivers and promoting environmental sustainability. We tackle pressing challenges such as pollution, invasive alien plants, and solid waste through community-led initiatives. At the heart of our approach is the "Enviro Champs" program, which empowers individuals to become active stewards of their local environment. By combining capacity building, environmental education, and community-based water quality management, we deliver people-centred solutions to environmental challenges.

In partnership with the Social Employment Fund (SEF) and DUCT is amplifying the power of citizen science to drive meaningful change. Over 1,000 Enviro Champs over 10 community-based organizations are engaged in critical activities such as river health biomonitoring, invasive plant clearing, and waste management. This initiative not only generates valuable environmental data but also equips participants with practical skills, creating employment opportunities and empowering communities to safeguard their natural resources.

Tel: 033 345 7571
Website: www.duct.org.za
Facebook: Duzi uMngeni Conservation Trust
LinkedIn: @DUCT RIVERS

7.6 Reflections on Producing a Citizen Science State of Rivers Report

The research conducted provided both quantitative and qualitative findings. With stakeholder interactions comprising a large component of this research, there were learnings and reflections which occurred outside of focused quantitative data collection. The sections to follow detail some of these reflections.

7.6.1 *Encouraging a citizen science network*

This report was generated through the efforts of many people in the CS network across South Africa, and neighbouring countries. Collaborators ranged in their demographics including their levels of experience using CS techniques, their levels of education and affiliated sectors. These volunteer efforts were vital in gathering observations to inform this report. When challenges were encountered, the collaborators and project team tried to mitigate and/or resolve these challenges, where possible. A few of the recurring challenges faced are detailed in **Table 8.1**.

Table 8.2 Recurring challenges with citizen science data collection

Challenge	**Proposed mitigation/solution**
MiniSASS application and website technical difficulties due to the recent (at time of participation) website upgrade and application development.	Open lines of communication between the collaborators and the project team were available to report any issues experienced. The project team also sent follow-up emails to check if the collaborators had any issues after being assisted or if they had success in using the platform(s).
Provision of tools – affordability for smaller organisations or individuals.	Collaborators were advised on lower cost alternates to monitoring for each tool (linked in **Appendix J**) and were encouraged to reach out to other CS practitioners in their area to possibly connect to share resources. This was facilitated through sharing a Google Earth file of locations and contact details where other CS practitioners are active. The project team also facilitated a space for the practitioners to link through sending out an email per province to allow everyone to introduce themselves and encourage these members of the CS CoP to connect.
Monitoring in local rivers which are in very poor conditions such as rivers which smell foul and have discoloured waters, possibly due to the high levels	The collaborators were strongly advised to exercise extreme caution if they opted to monitor those rivers and to do so with appropriate personal protective equipment (PPE) on. However, where this was not possible the project team would advise against getting into those

of raw sewerage or chemicals in the system.	rivers, but noting those locations for their local reporting to authorities.
Uncertainties in the methodology of tools.	The project team provided the collaborators with the appropriate links to view videos and/or manuals on the use of the relevant tools and provided follow-up calls/emails to ensure clarity.

7.6.2 *Citizen science limitations*

The concepts of river health and water quality are multifaceted, and each take various parameters into account. The capacity a CS counterpart for each conventional monitoring technique, such as the VEGRAI or MIRAI (recall **Chapter 6, Section 6.4**), has not yet been developed.

Thus, it must be reemphasised that CS techniques can contribute where monitoring systems are lacking and supplement in filling gaps in these monitoring systems but are not intended to replace conventional monitoring. Each has its place and beyond using CS for monitoring, the collaborations through this research have shown the contribution of CS to research, spreading awareness of environmental issues, a tool for advocacy and environmental education, and to promote conservation efforts.

7.6.3 *Complexities of data sharing*

The data which was used to create this report was gathered from many sources and all comprised of people who are part of the CS community who were willing to publicly share their data and findings. However, there were some instances where data was opted not to be share due to commitments under project contracts, or agreements with sponsors who are funding CS projects.

As mentioned, CS has been greatly promoted as a tool for environmental education and, as such, another point to note is that the data collected during observations for educational purposes was not always recorded as an observation. This should be true for demonstrations which deviate from the standard methodology, but this can be noted as an opportunity to note observations while using CS tools for education.

The collaborators were encouraged to share their data on central, open-source, online platforms where applicable. A limitation noted was that not everyone was aware of the importance of contributing to a larger dataset to be used beyond projects, and to rather feed into the broader CS efforts and used to show the uptake of CS practices. It is noted that this point should be emphasised in future.

7.6.4 *Biases in data and reporting*

There are biases which are to be acknowledged in this research. The applications of just one technique across a river system would provide a bias toward reflections based on that dataset, thus the inclusion of other techniques was encouraged. However, this was not viable at every site monitored thus bias does exist where a single technique was used.

As mentioned in the regional overview (**Chapter 7, Section 7.3**) the monitored sites were not predetermined by the project team, but rather by collaborators. Thus, a degree of bias must be considered here in that people are likely to choose to monitor at sites which are near where they work, live, and enjoy recreational activities. The selected monitoring locations could also be in areas where people would like to conserve or raise awareness of the declining state. The motivations for site selection vary per site and citizen scientist, however there is bias in cases where collaborators would have intentionally prioritised objectively very poor or natural sites. For example, if the intention was to use CS as an educational tool for scholars the preference may have been to go to a local nature reserve where rivers tend to be in more favourable conditions. Conversely, if the intention was to demonstrate the deteriorating condition of river systems using CS, site selection may have focused on river systems near those WWTWs which are known to be dysfunctional thus are negatively impacting the adjacent river systems.

Instances where paired biomonitoring and physico-chemical data were collected at different times of the year may cause the conditions to appear contradictory when visually determining the overall condition from a map. This also applies for when entire data types are collected at different times of the year, so these results cannot be soundly compared. For example, if biomonitoring scores along a stream are observed in April but the Freshwater Watch results are from August, it would not be sensible to compare these results with each other. A suggestion to resolve this would be seasonal maps, which show results to be compared when climatic conditions are similar for a certain period thus that variable would be partly controlled in data interpretations. Conclusion statement: to better co-ordinate monitoring to be done within a specified period in order to gain a clearer and more comprehensive overall condition of rivers. Logistically, this may theoretically be easier to enforce in funded, structured programmes than on a volunteer basis. It is therefore strongly recommended that South Africa designs a structured and credible CS monitoring programme.

Although stakeholder engagement was prioritised and collaboration was widely encouraged, there is a degree of bias which must be considered in the value of existing connections. Through their own networks, the project team and reference group members aided garnering support for and participation in this project through data collection. These personal connections and working relationships often resulted in more responses than those calls from the project account. Notably, not all responses resulted in participation, but some did help aid communication and others did assist in disseminating the project information within their networks.

7.7 Chapter Discussion and Conclusion

Through the collaborative efforts of many organisations across South Africa (acknowledged in **Appendix N**) and the growing CS network in the region, the state of over 73 river systems were determined through CS monitoring, with single monitoring points spread over other river systems, and over 2700 observations made over these rivers. Through the application of CS techniques, the spatial distribution of river health conditions was fairly represented across each WMA. These observations are spread throughout South Africa, with most of the monitoring data found within the Pongola-Mtamvuna, Breede-Gouritz, and Limpopo WMAs. These WMAs have established CS programmes and monitoring networks present such as: the Amanzi ethu Nobnutu Programme and the Enviro Champs model in the Pongola-Mtamvuna WMA; the Friends of Groups and biosphere reserves in the Breede-Gouritz and Berg-Olifants WMAs; and the environmental advocacy groups such as Deep Water Movement and WaterCAN in the Limpopo WMA. It is acknowledged that without these efforts, the generation of this report would not have been possible.

Recognising the biases present in CS datasets, as with any type of dataset, is crucial for effectively using this large and reliable indicator dataset to inform decision-making, with the context providing guidance throughout the process. Further, sampling location biases can influence the perception of rivers monitored across the country e.g. 37% of rivers monitored were found to be in very poor condition from an ecological perspective, but this is just for those rivers monitored, not for all rives across South Africa. This also highlights why it is crucial to only consider data in context.

Given that the data collection was carried out by volunteers who willingly opted to use CS techniques to monitor river health, it is reasonable to assume that majority of the data adheres to standard collection protocols, ensuring its overall validity. This further strengthens the case of validity of the bulk CS datasets to be used for reporting and decision-making.
Imperative to the understanding of this report is the acknowledgement of viewing rivers health from different perspectives – namely biological, habitat, and physico-chemical in this case - given the available information. Having data from different perspectives provides insights into how these aspects all interact and impact on each other, and overall river health.

Both the physico-chemical monitoring techniques and the miniSASS technique was used to monitor river health and each possess their own background factors which are indicative of river health. Most of the entries used for the generation of the CS SoR report were miniSASS observations. The ecological conditions from these observations provide a real-time river health indication making this suitable for potential use in reporting on SDG 6.3.2. This can be further supplemented by the in-situ physico-chemical observations using the WaterCAN iLab and Freshwater Watch kits. However, it is recommended that the sensitivities of each kit is investigated further using more entries and over a larger spatial scale to determine its suitability for SDG 6.3.2 monitoring in the South African context.

Thus, in determining if a State of Rivers Report can be produced from a CS perspective, this report has demonstrated that there is potential for this to be done. However, this approach would benefit from further refinement of organisational techniques to gather data to produce this report. This includes gathering data at wider scales, and measures to ensure (as far as possible) that monitoring using various techniques at a singular point is optimised.

Beyond the ability to generate bulk sets of data, the value of applying and promoting the use of CS techniques is highlighted through the featured CS programmes and/or initiatives. Each feature provides recognition of the perceived value gained through CS explorations, such as the knowledge acquired based on the data observed, the demonstrational applications to emphasise declining river health, and the ways in which the CS techniques have aided in environmental education and awareness.

It must be reemphasised that this project did not hold a budget to remunerate collaborators outside of the project team for their time and efforts, but it based entirely on volunteer efforts and collaboration with monitoring programmes which are already established during 2023/2024. This highlights the value what CS has been able to generate, both in terms of information and encouraging a CS CoP, with limited resources and time.

8. Citizen Science Research Continuity and Skills Development

The growing interest in environmental issues by communities of people has been a motivating factor for the growth in CS practices (Carlson and Cohen, 2018). The growing interest by society in actively participating in efforts to improve environmental sustainability has allowed for a growth in interest in CS tools and techniques. This is not only through CS monitoring, but also through engagements with developing communities of practice (CoP). One such CoP is in academia. This research will evaluate the potential for continuity of CS practices through integration in the teaching and learning curriculum at tertiary institutions in South Africa. Considering the value which CS possesses in contributing to reporting on SDG 6.3.2 (Taylor *et al.,* 2022), the inclusion and exploration of CS for environmental applications would be beneficial in the curriculum for tertiary students.

In South Africa, the environmental sector and green job market are expanding swiftly, driven by the global transition to a green economy attributed to climate change and the urgency to achieve the SDGs by 2030. However, despite skills development for green jobs being the crucial component required to enable the transition to a green economy, the current landscape for training and skills development is not adequately prepared to meet the anticipated increase in demand for green skills training. According to Ramasarup *et al.,* (2024) learning pathways for green jobs are often poorly catered for and disjointed. One of the challenges attributing to this is the disconnect between green skills development and labour market requirements in the green economy. This gap is due to several factors, including, inter alia, the lack of a dedicated skills body to lead green skills development, insufficient Sector Education and Training Authority (SETA) funding for retraining and upskilling within the green sector, and a shortage of skills development initiatives that offer training options addressing emerging climate-related environmental concerns (Ramup *et al.,* 2017). It is urged that, to achieve the SDGs by 2030, there must be a substantial increase in green skills development, which is a key objective of UNESCO's 2030 Education Agenda (Pavlova *et al.,* 2022).

Furthermore, the transition to a green economy is expected to lead to economic restructuring, potentially creating job opportunities for youth. These opportunities can arise from the development of green practices and production processes in businesses through green technology and climate change adaptation strategies (ADI, 2023). To prepare young people for the technical green skills required for these jobs, a robust and appropriate green skills development initiative is essential. This study aims to document the green learning-to-earning pathways within the YOMA-miniSASS pilot and test innovative finance models to support youth. By focusing on the learning pathway for citizen scientists in the River Commons using the YOMA-miniSASS pilot as a case study, this research contributes to strengthening green skills development initiatives.

This report also provides a detailed account of how the YOMA-miniSASS course was piloted (i.e. background, methodology and key findings); and the evaluation and adaptations that were made during the pilot study to the course to suit the learning needs of the participants. Furthermore, the report highlights the principles and activities that informed the design of the YOMA-miniSASS course and provides recommendations on how to improve the engagement and relatability of the YOMA-miniSASS content to encourage uptake of CS methods for water quality monitoring outside of project-based programmes.

Research in South African Higher Education institutions is conducted in the service of the citizens of the country to respond to an ongoing or emerging relevant issue that requires intervention based on sound scientific approaches. This research can be conducted in the context of a strategic research theme such as the long-term management of water resources or the need to align research outputs with policy development and the promulgation of legislation. CS may be considered as one of these strategic themes in which members of the general public are invited and included in most aspects of the research process. Like any other research exercise, CS projects should be driven by a clear research question or monitoring agenda intended to fulfil a strategic objective, in this instance, water resource quality monitoring. While CS is an accessible science, there remains a need to ensure that the theoretical basis is well established in order to safeguard the integrity of the results garnered from its outputs. In academia, educators or lecturers must set clear curriculum criteria that will allow the dissemination of acceptable knowledge that will generate real benefits for its otherwise untrained students. The same notion can be applied to CS.

8.1 Citizen Science Research Continuity

South Africa urgently requires equitable and sustainable use and management of water resources for poverty alleviation and socio-economic development. The dearth of appropriately trained researchers, managers and practitioners necessitates the inclusion of observers that may be situated outside the academic enterprise. That implies the inclusion, as far as possible, of stakeholders from the public who can make meaningful contributions to water resources management. This, of course, is predicated on the development of a robust and inclusive teaching curriculum that can be disseminated to the public and simultaneously to students and researchers in institutions of higher learning. It is now well understood that increasing climatic variability and the impacts of climate change on water resources will enhance the already complex and alarming challenges in water resources management. For instance, the latest Intergovernmental Panel on Climate Change (IPCC) report (Hennessy *et al.,* 2022) has noted that South Africa (and Africa) is one of the most vulnerable countries to the impacts of climate change on water resources and responding to this observation is critical. However, as aforementioned, inadequate human and institutional capacity to respond to the challenges related to water resources further highlights the need to train a critical mass of skilled or even semi-skilled researchers and professionals. CS offers a unique opportunity to develop this critical mass. Some of the key research questions that CS needs to respond to include:

1. How can CS be meaningfully incorporated in hydrology education?

- What are the educational models that can include training programmes from school through undergraduate and postgraduate and even relevant stakeholders from the general public?

2. What are the benefits and pitfalls of CS focused education on water resources education?

- What is the expected throughput regarding graduates trained in CS?

Responding to these questions will require clear guidelines related to the teaching philosophies related to CS, outlining the approaches adopted by other universities across South Africa and abroad that offer CS teaching, the availability of depth and breadth with regard to teaching staff and, potentially, the use of technology as a tool to further teaching capabilities in the CS space.

In response to these questions, the project team has engaged with a group of lecturers from a few universities across South Africa to gain the perspectives of other institutions on the incorporation of CS in the T&L curriculum.

8.2 Citizen Science in Teaching and Learning

This section will collate reflections received by academia who either have aspects of CS already incorporated in their T&L curriculum, or how the potential integration of CS could be best situated in their teaching.

8.2.1 *Hydrology*

In hydrological teaching and learning and, by consequence hydrological research, the emphasis has been to provide support of the prescriptions of the National Water Act (NWA) and implementation of water resources management policy. The current ongoing water crises across South Africa underscore the need of adopting transdisciplinary approaches which go beyond the confines of the hydrology discipline. It is therefore imperative that CS become incorporated in hydrology teaching and learning (T&L) in a way that protects the integrity of hydrological research whilst meeting the strategic objectives of supporting the NWA. To incorporate CS in hydrology in T&L, a careful and measured analysis must be conducted to "promote excellence in teaching and learning through creative and innovative curriculum design and development, pedagogical strategies, and assessment practices in accordance with the highest quality management principles" (UKZN Teaching and Learning Office, 2013). This implies that while CS can be introduced into the hydrology curriculum, this can, for the time being, be most effective by recruiting students at the postgraduate level. The reasons for this are multifaceted and they include:

1. The strong emphasis on the theory of physical hydrology and hydrological modelling at undergraduate levels.
2. The currently nebulous definition of CS in a South African context which does not effectively lend itself to the teaching of this concept at undergraduate levels.
3. The educational rationale informed by relevant current research in theory and practice of CS.

- The need to develop key generic competences in T&L to an appropriate level to improve student employability and encourage responsible citizenship;

4. The requirement of including valid and reliable assessment as an integral part of the teaching/learning cycle and enhance engagement with the learning task, and self-assessment.

In that regard, a carefully structured curriculum needs to be designed in a way that builds interest in CS and can build the critical mass of researchers that will adopt CS as a key component of their research careers. This is not to suggest that CS cannot be introduced and taught at the undergraduate level but that the necessary competences will require a higher level of understanding that is often achieved at the postgraduate level.

It is acknowledged that this treatise focuses on the hydrology discipline; however, the conclusions regarding curriculum design can be applied across most T&L programmes in South African universities should they adopt CS in their teaching. Subsequent sections will detail the CS curricula on offer across other major South African universities and their relevance to the overall CS space in the country.

8.2.2 *Water management*

The integration of CS in modules and courses on water management provides students with real-life examples of integrated water resources management, and the inclusion of civil society in the management of water resources, in line with South African legislation.

Water management content and modules hold a place across a range of qualifications at tertiary institutions such as postgraduate diplomas to doctorate level. These modules provide students with the knowledge and skills to manage water affairs and services, including meeting the water needs of society. Through modules which focus on catchment health, the capacity to understand, thus better manage, water resources are built through practical experience such as through CS practices.

8.2.3 *Environmental planning*

There is also value in the incorporation of CS more broadly, such as in environmental management, planning, and science courses. There are CS tools and techniques which can be used for education on environmental health, sustainability, and impacts of anthropogenic activities. CS can also supplement carrying out baseline studies for assessing environmental impacts of particular activities on natural systems such as rivers or wetlands.

From a social perspective, students can actively engage in practical applications of their studies through using CS to explore the role which CS plays in community empowerment and development, and livelihoods.

8.2.4 *Natural sciences*

CS can facilitate or supplement experiential learning under natural sciences such as ecology, biodiversity studies, horticulture, and freshwater technology. Depending on the qualification level, CS can be integrated in various ways such as part of a semester module, or through scaffolding the CS content from first-to-final year of a qualification would be an option. CS here can provide students with practical applications of the content which they have learned.

8.3 Curriculum design for Citizen Science Teaching and Learning

There are four recurrent orientations on curriculum thought which include, *viz*., the intellectual traditionalist, social behaviourist, experientialist and critical reconstructionist (Biggs and Tang, 2011; Spiller, 2012); the most dominant and valued positions remain the social behaviourist and intellectual traditionalist in modern educational ethos. This is owing to the traditionally accepted, albeit outdated, notions regarding the meaning of knowledge, education and the development of individual and societal characters. The perspectives are summarised in **Table 9.1** below specifically in the context of CS.

Table 9.1 Four Perspectives on Curriculum Design Related in Teaching and Learning

	Social Behaviourist	**Intellectual Traditionalist**	**Experientialist**	**Critical Reconstructionist**
What knowledge is most valued?	Emulation of morally successful members of society.	Knowledge derived from the classics of human thought. The so-called “great works”.	Knowledge that is based on personal and interpersonal experiences and values which shape the individual’s character.	Knowledge that is based on the struggle for social equity, justice and reform.
Where does the content/ body of knowledge that is taught come from?	Scientific evidence provided in research literature on the design of learning activities.	Based solely on discourses contained in great works.	It comes from the experiences of both the teacher and the student/researcher. Since experiences and values are shared a dynamic curriculum and learning environment is thus created.	The body of knowledge is predicated on the struggle for social and economic equality. T&L is based on the realities of the injustices of race, gender, class, health, *etc.*
What is the dominant worldview, perspective or orientation?	Curriculum needs to be designed and organized around discovering and understanding what successful people *need to know* in order to *do* what they spend their time doing.	Curriculum needs to be designed around a deep appreciation of the classics or disciplines and character is built upon this basis.	Student interests and concerns should be the hub around which curricula is designed. Further, learning should be interdisciplinary, integrated around emerging life interests of learners and their concerns about who they are becoming.	Character education differs from school to school along social and economic hierarchies.

How do/should teachers from this perspective teach?	Encourage their students to observe and report on what morally successful individuals do.	Teachers must expose students to the great ideas that human beings have created throughout history.	Teachers need to be aware of the funds of knowledge that exist and add meaning to these life projects by showing how various learning systems can deepen and broaden the *shared* interests of learners.	Teachers need to be sensitive to the reality presented by these hierarchies and thus design curricula which cuts across these lines and presents a coherent and holistic learning environment.
How strong is the link with labour market?	Very strong. Student employability is based primarily on the demonstration (*i.e.* CV) of their potential to either match or surpass the expectation and definition of success in the workplace.	Weak. This approach has limited relevance in the workplace owing to its strong philosophical basis and limited application relevance.	Very strong. In a rapidly changing world, the requirement of interdisciplinary approaches to problem solving is paramount. Students who are able to demonstrate (*i.e.* CV) that they can understand and appreciate shared interests and concerns with their broader community can be expected to create sustainable solutions to local and global problems.	Very strong. Although a progressive, non-discriminatory narrative is espoused in the workplace, students from diverse social and economic backgrounds will still demonstrate vastly different character traits. Thus, their transition into the labour market and their success thereof will hinge on how their character education differed based on the aforementioned social and economic hierarchies.
Other relevant points	This model follows a rigid, scientific approach which ignores student individuality and encourages the "mass-production" of individuals	None.	The experientialist is, without a doubt, an important the most crucial orientation in modern society. Innovative problem solving requires hindsight and foresight, both	The approach of the critical reconstructionist is particularly important when the history of education in South Africa is considered. Educators have to even the playing field with regard

	whose success is defined by societal norms.		of which require extensive learning experience.	to their teaching methods in order to foster social reconstruction.
Comments in relation to the Hydrology curriculum	In Hydrology, scientific innovation is encouraged; and such innovation rests solely on the ability of students to creatively approach and solve problems. In that sense, the idea of emulating successful individuals is encouraged only as far it allows the application of correct principles and for purposes of motivation. Beyond that, the idea of a social behaviourist is detrimental to scientific progress as it prevents the generation of original ideas.	Although appreciation of the classic works of science is imperative in the teaching of scientific theory, it is perhaps more relevant to focus on current developments in the field of Hydrology. This is to permit the design of relevant and current solutions in the field of Water Resources Management.	Students are taught to be keenly aware of the environmental problems plaguing the country and the world. They are further encouraged to use their personal and academic experiences to consider their possible contributions to these problems and how they can creatively solve them. In that way, character development through experience is highlighted and is focused on the individual student.	T&L in Hydrology is underpinned by a particularly strong social redress approach through integrative curricula. Having a large practical work component, Hydrology students are encouraged to work in groups with peers from diverse social backgrounds. Although this is not strictly imposed upon the students; it is nonetheless deeply encouraged. In this manner, character education is not solely the responsibility of the teacher but also that of the learner. This, it is believed will develop more socially conscious and responsible citizens.

The table above shows that a CS curriculum would need to align closest to the "Experientialist" and "Critical Reconstructionist" models. Emerging researchers or students would need to be encouraged to align their learning outcomes with their own personal experiences and worldviews related to the CS agenda. Further, the approach of teaching would need to be highly transdisciplinary as students are prompted to draw lessons across the Earth Sciences spectrum. For instance, the major 2015-2016 drought across South Africa had a profound impact on how water resources are managed in this country. Students experienced this drought first-hand through water shortages and supply curtailment. Students would subsequently be asked to conduct a research project in the form of a research paper and draw from this experience to describe how this drought was propagated, the impacts it had on South African water resources and how future droughts can be managed such that adequate water supply is secured. In this manner, this would facilitate research on climatology, hydrology, atmospheric science and even economics and added their own personal narrative to describe the impacts of the drought.

As mentioned above, that the level of cognitive development required to grasp the concepts that would be taught in a CS course would potentially be beyond the scope of undergraduate students (*i.e.* conducting research and communicating CS information). Further, attempting to standardise the teaching methods in CS for students from diverse learning, cultural, and social backgrounds would be a challenging endeavour. Regardless of these arguments, the core curriculum approach can be designed in a way that emphasises experiential learning overcomes these challenges. Thus, the curriculum may call for higher level cognitive skills and the crop of students involved in a CS course would need to have been guided from undergraduate levels to "think appropriately" regarding CS.

CS is well suited to support multidisciplinary collaboration in a world changing at a staggering pace. Thus, a CS curriculum would need to maintain pace with global and local changes such that students are taught current and relevant theories and concepts. In a country still struggling for social equity, justice and reform; the importance of integrating social reconstructionism in the curriculum is crucially important. CS is a concept which encourages social agency as a tool of understanding and mitigating negative environmental impacts stemming from anthropogenic global change. The only way this concept works (and it does work) is if diverse communities work together to manage water resources (or any other natural resource). This way, community interaction is encouraged, and people are better able to understand one another as they work for a common goal. This is key to social reform and reconciliation.

It is important to note that CS is already being taught in the Hydrology Honours programme and it can, over time and with further refinement based on research outputs, gradually be introduced at undergraduate levels. T&L across courses is necessarily transdisciplinary. This is because global environmental change is not confined to the Hydrological Sciences but spans a wide range of related Earth Sciences such as Climatology, Geology, Soil Science and Environmental Engineering. The curriculum, therefore, would need to adopt an interdisciplinary teaching approach and one which encourages experientialist learning.

8.4 Current Citizen Science Academic Programmes Within South African Universities

This section provides an overview of the citizen science academic programmes currently on offer across major South African universities and outlines how these programmes can be leveraged to meet the research continuity objective of this project. Further, this section will detail the models of CS T&L based on the levels of collaboration between scientists and practitioners in South Africa. It is important to note that, as of this writing, there is not an explicitly stated, structured or accredited CS tertiary qualification offered in any university in the country. CS is mainly offered as a component of existing modules or courses as part of broader qualifications, or as an offshoot of an umbrella of projects often housed under a variety of research Centres of Excellence. These projects often have the intention of mainstreaming CS to encourage science communication and engagement to enhance the societal value of the outputs from research projects. It is important to note that while the theory and practice of CS is not explicitly taught in most local universities, it retains a significant and highly active community of practice across numerous research centres hosted within these universities. These research centres often rely on the recruitment of postgraduate students who often have limited exposure to CS and can only gain a more complete understanding of this field through their research efforts.

8.4.1 *Stellenbosch University*

The Stellenbosch University Water Institute (SUWI) and the Department of Earth Sciences have a range of projects with a strong emphasis on CS. These include the Iimbovane Outreach Project (Exploring South African biodiversity and change), Cape Citizen Science (Go hiking for science), the Namibian Dolphin Project (a research and conservation project), the rePhotoSA project (a repeat photography project looking at landscape change), Monitoring water quality of the Apies and Crocodile rivers, and the South African National Biodiversity Institute's iNaturalist project. These projects are, by their definition, transdisciplinary CS projects since they encourage the involvement of school learners, teachers, researchers and policy-makers with an overarching goal of mainstreaming CS. The ongoing projects in SUWI, particularly the project on assessing the water quality of the Apies and Crocodile rivers uses CS tools to gather water quality data. This project involves students who, presumably, receive extensive training in the use of these tools. However, SU and SUWI do not, at present, have a CS T&L curriculum in undergraduate or postgraduate levels. The students involved in comparable CS projects have the necessary skills to conduct CS research, but they are not, or do not, identify as citizen scientists.

It is worth noting that the SU Earth Sciences undergraduate programme combines observational and field skills with the necessary scientific background and strives to develop teamwork and provide students with sound communication skills. This implies that while CS is not part of the undergraduate T&L programme, the various courses on offer provide the necessary academic grounding to allow students a pathway to become involved in CS projects in the postgraduate academic careers.

8.4.2 *University of the Witwatersrand (Wits University)*

While CS is not directly taught at Wits University, there are courses such as Applied Ecology and Global Change IIIA: Individuals, Populations and Communities, which equip students with the necessary research and communication skills that can be transferred to CS research. Courses such as this one are offered to undergraduate students in the Faculty of Science (specifically in the Schools of Animal, Plant and Environmental Sciences, Geography, Archaeology and Environmental Studies, and

Geosciences) and they develop the necessary skillsets such as scientific communication, data collection, and basic research. However, these skills can only be leveraged in advanced research projects that, nonetheless, offer a clear pathway into CS research and collaboration.

Although Wits University does not offer an undergraduate or postgraduate CS T&L programme, similar to SU, there are a number of CS projects (most notably the Jozi Bee Hotel project spearheaded by the School of Animal, Plant and Environmental Sciences) that directly involve both postgraduate students and Johannesburg residents in urban bee monitoring. There are also ongoing research projects that have a clear CS focus in a variety of Centres of Excellence including the Centre for African Ecology, Urban Ecology and Sustainability Lab and Sustaining Natural Resources in African Ecosystems research unit. The various research projects currently underway at Wits conduct CS research that, while on the periphery, still conform to the stated goal of CS which is to strive toward generating scientific outputs that have wide societal relevance and benefits. Regardless of direct undergraduate and postgraduate CS teaching, there is tremendous value that can be extracted to advance CS in South Africa.

8.4.3 *University of Pretoria*

CS does not form part of any curriculum at the University of Pretoria (UP). However, UP has taught and participated in CS projects, most notably the project by the Forestry and Agricultural Biotechnology Institute (FABI) that involved the public in a plant disease survey in the Fynbos Biome. The project encouraged citizens to contribute observations of dying plants on Ispot and WhatSpecies and through the Cape Citizen Science (https://citsci.co.za/) initiative, encouraged members of the public in the Western Cape Province to become “pathogen hunters” regardless of their age or qualification.

8.4.4 *University of the Western Cape*

While the University of the Western Cape (UWC) has a strong Citizen Science research focus within the Department of Biodiversity and Conservation Biology, the Department of Earth Science, and the Institute for Water Studies, the theory and practice of CS is not explicitly taught in undergraduate T&L programmes. Regardless, there are a number of research initiatives that directly work with communities across South Africa in the pursuit of advancing CS. For instance, through the project termed Integrating Human Perspectives and Citizen Science in Water Resources Management project and the Diamonds on the Soles of Our Feet initiative, more than 200 schoolchildren in Limpopo have been trained to collect data about water quality from boreholes? and rivers near their schools. The project links academics, citizen scientists and learners to monitor borehole and river water. Another notable example is a project which seeks to understand the functional role of snakes in African ecosystems. This project termed Sharing for Science: High-Resolution Trophic Interactions Revealed Rapidly by Social Media (part of the Quantitative Snake Ecology in Southern Africa programme) investigated the utility of social media for rapidly collecting observations of ephemeral ecological phenomena with low spatial and temporal predictability by using a Facebook group dedicated to collecting predation events involving reptiles and amphibians in sub-Saharan Africa. The outcomes of these projects/initiatives have been valuable in allowing academics and practitioners to explore ways in which a common language can bring together a community of practice.

It is important to highlight a unique feature of the UWC respect to CS: the university hosts a Centre of UNESCO Chair in Groundwater Earth Sciences which is affiliated with Citizen Science South Africa and Citizen Science Association Africa. This is relevant because within this Centre, a few programmes are offered which include the BSc and BSc (Honours) degree in environmental and water science, a postgraduate diploma and taught MPhil in Integrated Water Resources Management, and research Masters and PhD degrees. This implies that the UWC trains a group of students that are uniquely trained in CS and thus ideally positioned to contribute to the South African CS community of practice.

8.4.5 *Rhodes University*

Although Rhodes University offers an Honours course in Environmental Management which involves freshwater ecology, environmental water quality and hydrology and the erstwhile Open Science course on CS, there currently is no structured CS T&L programme at this institution. The Rhodes University Institute for Water Research which incorporates the African Research Universities Alliance (ARUA) Water Centre of Excellence (COE) and the Centre for Environmental Water Quality (CEWQ) have an array of CS research projects which include, *inter alia,* A stakeholder-driven process to develop a more equitable and sustainable water resource management plan, SDG-pathfinding: co-creating pathways to sustainable development in Africa (SDG-pathfinding), exploring rangeland integrity to support ecosystem-based livelihoods in the Eastern Cape and Equity dimensions of the Nelson Mandela Bay water crisis and the implementing context as enabler or barrier for uptake of translatable lessons from the Cape Town water crisis.

Despite the alignment of these projects CS directives, students can only develop their CS research and communication skills through hands-on experiences in CS research. A Rhodes University lecturer and research noted that, (sic) “there probably is scope to include Citizen Science in the Honours course, but the students themselves would need to do some of the work of being a citizen scientist, rather than just learning the theory. I think many students do not really understand what citizen science is as they do not undertake any citizen science work themselves” (Wolff, pers. comm., 2024). This observation illustrates that Rhodes University graduates may not have the skillsets required for CS research but that they can develop these skills through their direct involvement in CS research.

8.4.6 *University of Johannesburg*

The theory and practice of CS is currently not part of the T&L curriculum in the Department of Geography, Environmental Management and Energy Studies at The University of Johannesburg. However, students are introduced to CS tools in the Environmental Management 3A course which involves practical exercise in the field in the use of miniSASS, clarity tubes and velocity planks. Additionally, there is an honours course in strategic environmental planning in which students are trained to compare CS tools with state-of-the-art environmental monitoring tools run by SAEON/EFTEON. While CS is not explicitly taught at UJ, students are exposed to the various tools and methodologies involved in CS. Most notably, a new MSc module set to commence in 2025 will have a theoretical lecture/theme on the role of CS in water resource management. This course, termed MSc in Water and Sanitation: Water and Community Development, will focus on the role of citizen science in empowering communities and engaging them in monitoring progress/achievement of SDG6. Some of the key outcomes from this course will include monitoring progress on SGDs, the role of citizen science in SDG monitoring and the Potential of Citizen Science for community engagement with water and sanitation: role of NGOs.

The University of Johannesburg (UJ) is part of the Consortium for Comparative Research on Regional Integration and Social Cohesion-Social Elevation (RISC-RISE) which integrates citizen science, community engagement, and policy-impact as part of its objectives.

8.4.7 *Independent Institute of Education*

IIE MSA is a private higher education institution (PHEI) and not one of the 23 public universities. All qualifications offered through the IIE and IIE MSA are fully accredited by the Council on Higher Education (CHE), the South African Qualifications Authority (SAQA) and DHET– the same centralized bodies who accredit all south African university curricular. The IIE's strategic intent aims to inspire individuals to develop a sense of self as citizens of change in a complex world through its commitment to transformation and excellence in learning and teaching, scholarship, and community engagement. As part of this, the institution values a transformative mindset characterized by the acronym "CHANGE" which includes the following key concepts:

- **Co-creation**: Collaboratively pursuing knowledge that transforms individuals and society.
- **Holistic thinking**: Approaching challenges from a systemic viewpoint acknowledging the interconnectedness and interrelatedness of all the parts.
- **Advocacy**: Championing meaningful, positive, and sustainable change ethically and mindfully.
- **Nation building**: Promoting social cohesion that celebrates and embraces diversity, equity, and inclusion.
- **Grit**: Navigating challenges that accompany learning and transformative change with passion, perseverance, and resilience.
- **Empowerment**: Enabling individuals to participate actively in shaping their own lives and the world around them (The Independent Institute of Education, 2024)

Whilst the institution offers over 130 accredited qualifications and programmes, citizen science only currently features in two existing qualifications, namely, the Postgraduate Diploma in Water Management and the Master of Philosophy (PGDip) in Integrated Water Management. These two qualifications therefore form the basis of this document. However, in addition, a Bachelor of Science in Environmental Science is currently being developed (to be offered in 2026) and will also feature citizen science tools and techniques.

A key focus of the PGDip Water Management is to build capacity in the water sector in South Africa, with the qualification purpose stating:

"The purpose of this qualification is to equip learners with knowledge and skill to manage water affairs and engage them in the development of water resources and in the delivery of water services."

The qualification was initially developed in order to meet the challenge of critical skills shortage in the water sector and has a specific focus on interdisciplinary approaches in the field of water management in order to ensure effective management and good governance of water resources. The Rationale for the qualification also speaks to "*application of professional skills and knowledge in water management as a basis for solving many of the societal problems related to water resources and service delivery*." Six exit level outcomes are associated with the qualification, including:

- ELO1: Apply the basic principles of catchment management and aquatic ecosystem health, collaborative water planning and project management in managing water resources.
- ELO2: Analyse the key concepts, definitions and practices of water supply and sanitation systems.
- ELO3: Critique the approaches and frameworks used in community water development.
- ELO4: Integrate the theory and practice of urban water design.
- ELO5: Evaluate the relationship between climate change and water resources.
- ELO6: Apply the basic principles and techniques of Geographical Information Systems (GIS) in managing water resources.

In ensuring that students meet these ELOs, the IIE MSA tries to provide students with practical experiences. In particular, one of the modules offered as part of the PGDiP qualification is Catchment and Aquatic Ecosystem Health lends itself to this as it aims to introduce the students to the concept of resilience, social-ecological systems, and its application to the management of freshwater ecosystems. It is a blended module and as such, it is delivered in a mix of face-to-face and online instruction. The students are postgraduates and are working professional students, in other words they have full time jobs as professionals mostly in the water sector. They are also everyday citizens. Many of them work for municipalities, wastewater treatment works, bulk water providers as process controllers, water technicians or environmental specialists.

By providing students with authentic learning experiences like miniSASS and wetland health assessments (miniWET-Health) students are exposed to and get to experience/ practice ways of river health monitoring which they can use within their organisations to build capacity within the water sector.

In addition to the PG Dip in Water Management, the IIE MSA also offers a Masters in Philosophy in Integrated Water Management. This coursework Masters aims to build the capacity of future leaders in water resource management and includes 4 modules, namely, Science of Water, Water, sustainability and development, Water governance and policy and Project Management and Research Design. In addition, research is a key component and carries the bulk of the degree weighting. Students select a research project in which the ideas and principles of integrated water management feature prominently. Research projects should ideally allow a significant degree of cross-disciplinary integration and address an issue related to a real sustainability challenge. Through both the research mini-dissertation and coursework modules, the qualification focuses on building skills such as critical thinking, problem solving, statistics and data management, knowledge transfer and effective leadership.

An important part of the IIE's rationale is the inter-disciplinarity of the programme and the need to involve experts from fields ranging from water law to aquatic biology, community development to water supply and sanitation engineering. The aim of the programme is to provide students with a deep understanding of the interconnectedness of water problems so that they are not only able to tackle water problems from a technical position, but also understand environmental, social, and economic factors involved. Throughout the programme there is an emphasis on the whole-of-water cycle, with the following exit level outcomes (ELO) expected:

- ELO1: Students will be able to appraise freshwater ecosystems.
- ELO2: Students will be able to evaluate the imperative of sustainable development in relation to the planning and management of water resources.
- ELO3: Students will be able to design an integrated water resource management plan.

- ELO4: Students will be able to develop a research project proposal.
- ELO5: The students will be able to execute an integrated water management research project.
- ELO6: Students will be able to do verbal presentations on their research project.
- ELO7: Students will be able to prepare a manuscript (academic paper) ready for submission for publication.

CS is also integrated into this qualification, specifically in the Science of Water module, where students are taken to the field and exposed to some of CS tools such as miniSASS and wetland health assessments (miniWET-Health). The water, sustainability and development also include a focus on participation in water management and showcases citizen science as an efficient means of community involvement in water management.

Whilst the BSc in Environmental Science is still under development, it provides an interesting example of how CS can be integrated at the undergraduate level.

The purpose of the Bachelor of Science (BSc) in Environmental Science is to prepare students to be informed, engaged and effective environmental scientists who can contribute positively to the sustainable management and conservation of the planet's environmental resources and ecosystems. The qualification has a clear focus on the concept of sustainability and aims to produce graduates which will have a keen understanding of sustainability and the need for a sustainable future. Concepts such as ethics, interconnectedness, communication and problem solving are key and form the basis for the exit level outcomes, which include:

- ELO1: Demonstrate knowledge and understanding of the interconnectedness between various environmental approaches.
- ELO2: Demonstrate the ability to think critically, holistically, systemically, systematically, spatially and in an integrative manner to inform environmental decision making within various legislative frameworks.
  - ELO3: Apply environmental approaches, legislative tools, procedures, and methods to propose solutions to complex environmental problems.
- ELO4: Demonstrate the ability to manage and monitor environmental resources and implement environmental projects ethically within various legal frameworks.
  - ELO5: Conduct applied research on an identified research problem in a specific environmental context.
  - ELO6: Engage and collaborate effectively and professionally with diverse stakeholders using a range of communication skills.

In the first year, students all take several foundational modules which will provide the necessary scientific basis for Year 2 and 3. From the second year of study the programme is designed with three learning programmes; namely environmental management, water resource management and ecology. CS techniques will be included in various modules in Environmental Science 3a, Environmental Science 3b, Introduction to Research and Development, Livelihoods and Sustainability. In addition, all third-year students will be required to undertake an Environmental Science Practical Research Project. As part of this students will be provided the opportunity to work on identified environmental science problem that interests them in their area or community and will develop a research proposal to research this issue. They will collect environmental data, analyse this data and write a report on their findings. CS methods and tools will be part of the suite of techniques that will be available to students.

CS can be taught in a formal university setting - if the lecture theatre can be extended and reimagined landscapes are classrooms, river scapes are classrooms – the idea of a university lecture theatre being 4 walls needs to be reimagined. We need to include practical components – you cannot teach a love for the environment outside of the environment. We need to make sure that our qualifications include practical components and that these components include CS.

8.4.8 *Durban University of Technology*

The Horticulture programme at Durban University of Technology (DUT) exposes students to a few CS tools and encourages student to actively engage in using some of these CS tools. However, this content is a small percentage of a broader programme. Thus, while CS is a limited part of the T&L curriculum at DUT, students are exposed to CS, albeit to a limited degree. Specifically, two modules are offered, *viz.,* Environmental Sustainability 2a (EVSA201) and Environmental Sustainability 2b (EVSB201). Per the DUT Handbook, these modules enable students to understand a wide range of environmental issues, both locally and globally, and the significance of these issues in practising sustainable horticulture with emphasis on natural resource management and conservation. The students are trained to develop an appreciation for environmental and conservation issues, the impacts of their actions and thus the contribution of their actions to complex local and global environmental concerns, while developing an ethos of making environmental issues a fundamental consideration in everything that they do, in the workplace and in their lives in general to achieve sustainability. In addition, the students gain knowledge of the complexities of environmental issues and their relationships to development, poverty, community issues and horticulture. Focus is on the policies, programmes, tools and methods employed to manage environmental problems.

The module content includes:

- Environmental conservation (The value of nature conservation; Conservation in South Africa; Biomes of South Africa; Importance of biological resources and biodiversity; Factors that threaten biological resources and biodiversity; Ecotourism and the promotion of conservation; The role of business in conserving biodiversity; Red data species)
- Managing our natural resources (Conservation versus development; Sustainable development; Challenges to sustainable development; Resource management in South Africa; Land-use management)
- Ecological disturbance: Restoration and rehabilitation (Ecological disturbance/degradation; Restoration and rehabilitation; Establishment and management of self-sustaining vegetation)
- Evaluating Environmental and Development projects (Environmental Impact assessment; Social impact assessment; Integrated environmental assessment; Environmental Management plans; Auditing; Local and international laws of relevance)

8.4.9 *University of South Africa*

The University of South Africa (UNISA) offers two courses on CS, *viz.,* Citizenship, Identity and Citizen Science (AD21ST1) and Qualitative and Quantitative Research Methods for Inter-Disciplinary Citizen

Science (AD21ST4). The AD21ST1 module This course explores the global and local context of African citizenship in the 21st century and has as its stated learning outcomes:

- The global and local context of African citizenship in the 21st Century focusing on key global problems; post-Independence Africa.
- Theory of 'Glocalization': African challenges in different sectors of Development.
- Engaged Citizenship and Active Citizenship.
- South African key challenges.
- African Alternatives and Post-Apartheid Development Programs.

AD21ST4 covers the main research paradigms for qualitative research methods in the social and humanities sciences and its outcomes include:

- Dominant and mainstream research paradigms for qualitative research methods in the Humanities and Social Sciences.
- Basic instruments for reading quantitative information and compiling and conducting quantitative research in relevant areas.
- Ethnographic case studies from different South African and African contexts that demonstrate indigenous experiences and realities of Citizenship at different geographic scales.
- New and cutting-edge research methods that use indigenous rituals and practices in the conducting of data-gathering for Qualitative Research Methods.

The value of these courses in teaching CS is apparent and while they are not necessarily part of Earth Sciences, it is clear that the course content provides a good foundation for training citizen scientists and opens valuable avenues for collaboration.

8.4.10 *University of Cape Town (UCT)*

The Citizen Science community is fairly strong at UCT; however, it is unclear if CS is directly taught in undergraduate or postgraduate T&L programmes. Regardless, CS research initiatives which include the Coordinated Waterbirds Counts (CWAC), Coordinated Avifaunal Roadcounts (CAR) and the Virtual Museum (VM) form part of an overarching CS research theme under the Fitpatrick Institute of African Ornithology. CWAC counts are conducted by volunteers; people and organisations and is one of the largest and most successful citizen science programs in Africa, providing much needed data for waterbird conservation. Currently the project monitors over 400 wetlands around the country, and curates waterbird data for over 600 sites. Similarly, the CAR project participants submit a summary of the population trends along their routes and these data have been used in several conservation assessments. Finally, the VM is a database system and web front-end designed to provide a platform for citizen scientists to contribute to science driven biodiversity projects. VMs serve as repositories for the long-term curation of distributional data sets. These data are made freely available in the form of maps and lists through the internet. VMs have been used as the platform for national Conservation Assessments of reptiles, butterflies, mammals and birds. While these initiatives have generated useful CS data and conservation insights, they are guided by standard research practices and not based on the theory of CS as can be taught to undergraduate or postgraduate students as part of a standard T&L curriculum.

8.4.11 *Concluding Remarks*

It is clear that CS is gaining traction in South Africa, both as a method for scientific inquiry and a tool for education. There is a significant CS community of practice that directly engages in CS research across a wide spectrum of Earth and Social Sciences. However, teaching the theory and practice of CS in institutions of higher learning as part of a recognised and accredited curriculum is largely missing. Students and public participants only gain the skills relevant in practicing CS when they join an already-existing research project or Centre of Excellence that already employs CS tools. This implies that, at present, the majority of participants who can be referred to as “citizen scientists” do not have a formal introduction to the definitions and theoretical basis delivered through standard T&L curricula and settings. Consequently, the capacity to teach and thus impart CS knowledge remains mainly the domain of advanced researchers and, to some degree, postgraduate students. This is not to suggest that CS cannot be effectively incorporated into undergraduate T&L curricula because, as demonstrated by IIE, UKZN, and UNISA, this is an entirely achievable objective. It is to emphasise that, at present, there are significant challenges that need to be overcome to enable the introduction of CS at appropriate level in institutions of higher learning. For instance, a very limited number of CS researchers and practitioners have the training or professional development required to teach CS theory effectively at a university level. The lack of this intersection between teaching, research and practice suggests that the development of clearly structured T&L curricula that will train distinctly qualified citizen scientists will remain difficult.

At present, CS is integrated into existing T&L programmes not as a main focus (*e.g.* as a module or structured degree programme) but as a component of a broader teaching and/or research themes. Commonly, these themes include environmental conservation, biodiversity monitoring and climate science. While research organizations who engage directly in CS practices are widespread in South Africa (*e.g.* SANBI’s iNaturalist, CitSci Africa and SARAO/MeerKAT among many others), they primarily focus on data collection and present their outcomes to a limited number of participants who are already engaged in CS work. These further hamstrings the development of CS T&L curricula as there is very limited feedback from these research organizations directly into teaching and learning programmes.

Citizen science offers a powerful, hands-on way for South African students to engage with real-world scientific problems, fostering both curiosity and community responsibility. With proper developments of the links between research, teaching and policy backing, it holds immense potential for transforming T&L in institutions of higher learning.

8.5 Incorporating Citizen Science in Higher Education Teaching and Learning

This section provides an example of how CS can be implemented more effectively in Higher Education Teaching and Learning based on current advanced modules/course currently on offer at the University of KwaZulu-Natal. The outline of this section can be applied to other courses at institutions looking to incorporate CS in the curriculum.

8.5.1 *Potential student profile*

Students would need to have enrolled for and completed a BSc Degree with a Hydrology or other related major in the Science, Technology, Engineering, and Mathematics (STEM) field.

8.5.2 *Teaching and learning philosophy*

1. **Lectures:** Formal note taking of theoretical material.
2. **Tutorials/Practical Sessions:** Interactive problem-solving exercises designed to reinforce basic concepts discussed in lectures.
3. **Research Assignments:** Research, preparation and presentation of research projects.
4. **Consultation:** Ad-hoc meetings with academic staff and tutors.

8.5.3 *Required knowledge, attitudes, skills and values (i.e. learning outcomes)*

Students taking this module would develop an understanding of CS and particularly how humans have altered the global and local environment and strategies to respond; they will be taught to understand the underlying concepts of CS; they would develop critical and analytical thinking skills; and develop the ability to communicate scientific information in a written and verbal form to peers. After successful completion of this CS course, students will be able to better understand and interact with the world they currently live in and the people they share it with. This will develop graduates and researchers who can generate innovations and solutions which are relevant and useful in the current world based on their profound understanding of how the world actually works as opposed to how the world ought to work.

8.6 Citizen Science Skills Development

This section provides an evaluative summary of the current learning to earning pathway of citizen scientists in the *River Commons* by drawing lessons from the YOMA-miniSASS pilot as a case study. Additionally, the section proposes strategies that can be leveraged upon to provide a brief overview of how the YOMA-miniSASS pilot contributes to advancing CS practices in South Africa, particularly those linked to the *River Commons*.

River Commons are built on the notion that river systems belong to everyone, thus it is everyone's responsibility to manage and govern these systems. The objective of the *River Commons* concept is to encourage protection, conservation and sustainable management of our rivers through co-governance across stakeholders (i.e. communities, government, private businesses and organizations). The *River Commons* concept can be practically implemented across several strategies, including:

- **Participatory decision making** alludes to the public participation of community members in water related decision making and subsequently water management. Through this approach, communities can be involved in making decisions that affect their wellbeing and provides opportunity for diverse perspectives to be considered. Additionally, this process allows communities to voice the challenges they are facing, resulting in context specific solutions that communities also benefit from.

- **Promoting sustainable practices:** *River Commons*, can include activities that create a source of livelihood for communities whilst protecting water resources (i.e. rivers). A prime example of this, is the Enviro Champs model, which gained recognition through the infamous Mpophomeni Enviro Champs project. The Mpophomeni Enviro Champs project has been pivotal in pioneering civil action in addressing water quality challenges in their community, through CS. The project also provided a financial incentive for the Enviro Champs throughout the duration of the project, which contributed to sustaining their livelihood.
- **Equitable access to natural water resources (i.e. rivers):** A key component of the co-governance of river systems encourages the equitable access of rivers and associated ecosystem services to communities, more particularly the most marginalized.

These strategies are key in informing the design of a learning pathway for citizens within the *River Commons*, as they can be leveraged upon to promote CS skills development for water quality monitoring and management.

Background

The development of the YOMA-miniSASS course forms part of a broader project funded by the United Nations Children's Fund (UNICEF) in partnership with Rhodes University, which seeks to undertake formative research to map out water security Green Learning to Earning (GL2E) pathways in peri-urban catchments. The GL2E project was initiated through the growing recognition and need to prepare youth to leverage off the benefits of a growing green economy. The following knowledge gaps were identified as critical areas that needed to be addressed through the project,

(a) the translation of green skills into an inclusive green economy,

(b) tangible economic opportunities for youth in the green economy and

(c) sustainable investment models to support green growth.

The focus of the broader research has been the co-development of knowledge for enabling the conceptualisation of more sustainable learning pathways that are also integrated into the national system of occupations and qualifications such the SETA body. The intention of the overall research project is to pilot a blended learning course targeted at youth in South Africa, using 1) the YOMA digital platform (https://yoma.world) to host the learning and earning opportunities; and 2) a digital learner management system (LMS) to support and track the course work. The YOMA-miniSASS course aims to help young people develop critical skills needed in the South African green economy and contribute to developing a new generation empowered to address environmental crises.

The GL2E project, consists of two components running in parallel - the development of course material, and the documentation of the learning experiences of the participants. The development of the short course (YOMA-miniSASS) to equip citizen scientists in the *River Commons* was informed by operational research led by GroundTruth in collaboration with Duzi uMngeni Conservation Trust (DUCT). The primary objective of this research is to explore how digital initiatives, like the YOMA-miniSASS pilot, can equip youth with essential green skills through micro-credential learning, and connect them with current and future income opportunities in the green economy. The findings will outline viable green occupational pathways for South African youth and support the creation of a QCTO accredited course for citizen scientists in the *River Commons*. The documentation of the learning journeys of the course participants informed the refinement and adaptation of the pilot course to suit the learning needs of the participants

8.7 Methodology

To inform the design of the YOMA-miniSASS course, several qualitative data collection methods were utilised. Qualitative data collection methods are useful in providing an in-depth understanding of social phenomena or human experiences within their social context (Astalin, 2013). Semi structured interviews, a document analysis, periodic surveys, a focus group discussion, and reflection of learning engagements were all undertaken. These data collection methods are discussed in further detail below (dataset 1 to 5).

Dataset 1: semi structured interviews

We conducted semi-structured interviews with selected participants to gain insight into the current learning journey of participants. Furthermore, the interviews were aimed at understanding the current obstacles of aligning green skills training with the labour market in the green economy. The selected participants, representing various roles within the *River Commons*, offered diverse perspectives on their organizational roles and activities. This method aimed to inform and refine the learning pathway mapping for citizen scientists in the *River Commons* and attempt to address the misalignment of green skills training and green jobs. **Table 9.2** provides a brief description of the participants that were interview and their roles within the *River Commons* workstream in relation to green skills development.

Table 9.2 Description of participants

Participant	**Reason for interviewing participant**
Participant A	This participant is currently working as an ecological technician at GroundTruth and was previously part of the first group of the Mpophomeni Enviro Champs. The participant has extensive experience in training citizen scientists involved in *River Commons* work, thus is integral in informing the design of the first iteration of the learning pathway for citizen scientists.
Participant B	Previously employed as an Enviro Champ and has progressed to being part of the DUCT team. She is currently working as a project coordinator at DUCT.
Participant C	Is a GroundTruth manager of the wetlands division and has extensive experience in implementing and overseeing wetland rehabilitation projects. He has been involved in overseeing and supporting staff development through workplace-based trainings.
Participant D	Previously part of EWT as a regional coordinator. The participant is very experienced in developing a range of formalized environmental training courses for interns and learners at EWT.

Dataset 2: Document analysis

A document analysis of mainly grey and scientific literature was undertaken to gain insight on the current occupational activities of Enviro Champs in the *River Commons.* Additionally, this analysis provided insight of the existing learning pathways of citizen scientists within water-related CS projects or programmes. The insights emerging from this data source informed the mapping process of a learning pathway for citizen scientists in the *River Commons.*

Dataset 3: Periodic surveys

A survey was included at the beginning and end of the YOMA-miniSASS course to capture the participants' learning experiences. The feedback from the participants contributed to improving and adapting the pilot course, enhance and support the learning journey of participants.

Dataset 4: Reflection of learning engagements

In collaboration with Rhodes University, GroundTruth hosted two learning engagements intended to map existing workplace-based learning pathways for citizen scientists in *River Commons* and Community Based Water Quality Management (CBWQM) projects. The first workshop was held in October 2023 at GroundTruth, with attendance from a range of stakeholders, including *inter alia*, Endangered Wildlife Trust (EWT), DUCT, SANBI, Rhodes University, and current Enviro Champs. This workshop provided insights on the occupational activities of the Enviro Champs along with the knowledge, skills, and values required for them to carry out their activities effectively. The outcomes from these learning engagements informed the development of a series of micro-credentials (short theory lessons and practical tasks) and mapping out the learning pathway for citizen scientists in the *River Commons.* These insights informed the design of the YOMA-miniSASS course and the subsequent learning engagements.

A second learning engagement was held in February 2024, which also included a diverse group of stakeholders, including representatives from Rhodes University, DUCT, SANBI, Imagine If, Institute of Natural Resources (INR), and Love Howick. The workshop was aimed at further distilling the occupational activities and associated skills, knowledge and values required by an Enviro Champ to competently and effectively fulfil their role. Additionally, the learning engagement aimed to refine the mapping of a learning pathway for citizen scientists in the *River Commons*, and how this can be aligned to QCTO accreditation requirements. The outcomes of both these workshops informed the initial design of the YOMA-miniSASS course.

Both learning engagements aimed to inform the following questions:

I. Who is currently involved with CS training/learning?
II. What activities are Enviro Champs/CS monitors currently involved in?
III. What are the obstacles/disruptors to Learning and Earning?
IV. What is driving the need for this work?
V. What are the opportunities that are emerging?
VI. Who else needs to be involved?

Dataset 5: Focus group discussions

A focus group discussion was held at the Social Employment Fund (SEF) partner close-out workshop, hosted by DUCT. The discussions were aimed at gaining comprehensive insight of participants' experiences with the YOMA-miniSASS pilot and use these insights to refine the learning-to-earning pathway for citizen scientists in the *River Commons*. This data will help further improve the YOMA-miniSASS pilot.

8.8 Key findings

This section provides a summary of the emergent themes derived from the five datasets, as presented in **Table 9.3.** The results presented in this section are based on the data analysis conducted for the Rhodes University-UNICEF project (Sithole, 2024). The project aimed to gain an understanding of the learning journey of participants who partook in the YOMA-miniSASS course, to inform the current learning pathway of citizen scientists in the *River Commons*.

Table 9.3 Emergent themes from datasets 1-5 (not in order of importance) (Sithole, 2024)

Emergent Themes	**Data sources**
Critical basic competencies and skills are required for citizen scientists to effectively do their occupational activities: **basic report writing, digital, workplace professionalism, communication (verbal and email) and computer literacy skills.**	Dataset 1,3 and 5
Focused mentorship with a **shared value** is a critical need in supporting the learning pathway of citizen scientists within the *River Commons*.	Dataset 3 and 4
Indigenous knowledge is essential in fostering a connection between individuals and the natural environment, particularly in rural communities where there are numerous cultural beliefs held around water.	Dataset 1,3 and 4
Accredited or formalized trainings are a critical need to access the green economy for citizen scientists.	Dataset 1,3 and 4
Aligning green skills with labour market requirements particularly where there are critical green skills shortages is important in helping citizen scientists transition from formal to informal work.	Dataset 1, 3 and 4
Learning pathways are not a one size fits all – thus should be customized to suit the learning journey of an individual.	Dataset 3 and 4

8.8.1 *Current occupational activities of citizen scientists in the River Commons*

To inform the design of the YOMA-miniSASS pilot course and the mapping process of the learning pathway for citizen scientists in the *River Commons*, it was important to first gain insight of the current occupational activities of the Enviro Champs, and the associated skillset required for them to effectively perform their occupational activities (**Figure 9.1**). This formed the foundation on which the initial mapping process could be undertaken. In addition to this, a gap analysis was conducted, to identify what technical or soft skills were missing in the current workplace-based trainings being offered to the Enviro Champs which they require for their occupational activities. The most common skills that were highlighted as underdeveloped or missing, and evident in emerging themes from datasets 1,3 and 5 include:

- **Basic communication skills (verbal and email):** Good communication skills are critical in building positive work relationships. While clear and effective communication avoids misunderstandings and ensures that a message is conveyed effectively. This is a critical skill for Enviro Champs to possess as communication is required at all levels of one's professional growth.
- **Basic digital skills:** These are critical as the Enviro Champs use mobile based applications such as FieldSurvey to collect monitoring data. If an Enviro Champ lacks this technical skill it is likely to affect the quality of data collection.
- **Computer skills:** Team leaders (Enviro Champs who assume the role of team leader) are often required to check the back end of mobile based applications to ensure that data is captured correctly. Additionally, Enviro Champs are required to have email addresses, to be able to sign up to mobile based applications on a computer. The lack of computer skills within most Enviro Champs poses a challenge to the quality of the data collected and potentially the possibility of them being promoted to team leader.

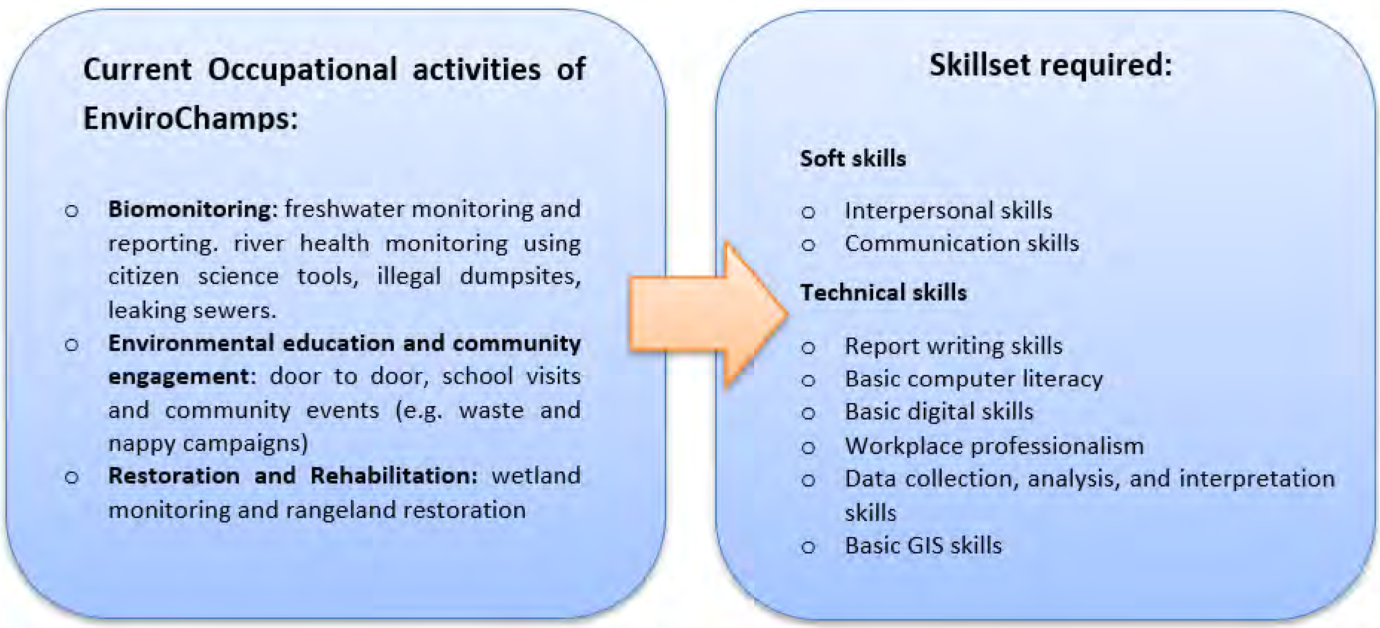


Figure 9.1 Current activities (and associated skills) citizen scientists in the *River Commons* currently engage in (Source: Sithole, 2024).

Within the second learning engagement (dataset 4), the first iteration of a learning pathway for citizen scientists in the *River Commons* was mapped. This mapping process was informed primarily by previous Enviro Champs who highlighted which of the workplace-based trainings best equipped them to conduct their occupation activities and the skills an Enviro Champ would need to progressively transition from their role as an Enviro Champ (informal) to more formal employment within the green economy. Each tier in **Figure 9.2** provides evidence of an increase in complexity of skills required for an Enviro Champ to acquire to competently perform the occupational activities associated with the role assigned to each tier. For example, for an Enviro Champ to transition to a data technician role (second tier in **Figure 9.2** – top-to-bottom), they would require basic project management and data management and reporting skills, which are not included in the first tier of **Figure 9.2** (of the Enviro Champ role). This provides evidence that Enviro Champs require learning pathways and trainings that anticipate the learning journey and personal interests of the Enviro Champ, equipping them with the skillset required to move up into more formal occupations within their learning pathway. Stakeholders within dataset 4 highlighted that accredited trainings which equip Enviro Champs with skills such as basic ecology and advanced GIS mapping skills would be beneficial for their professional development.

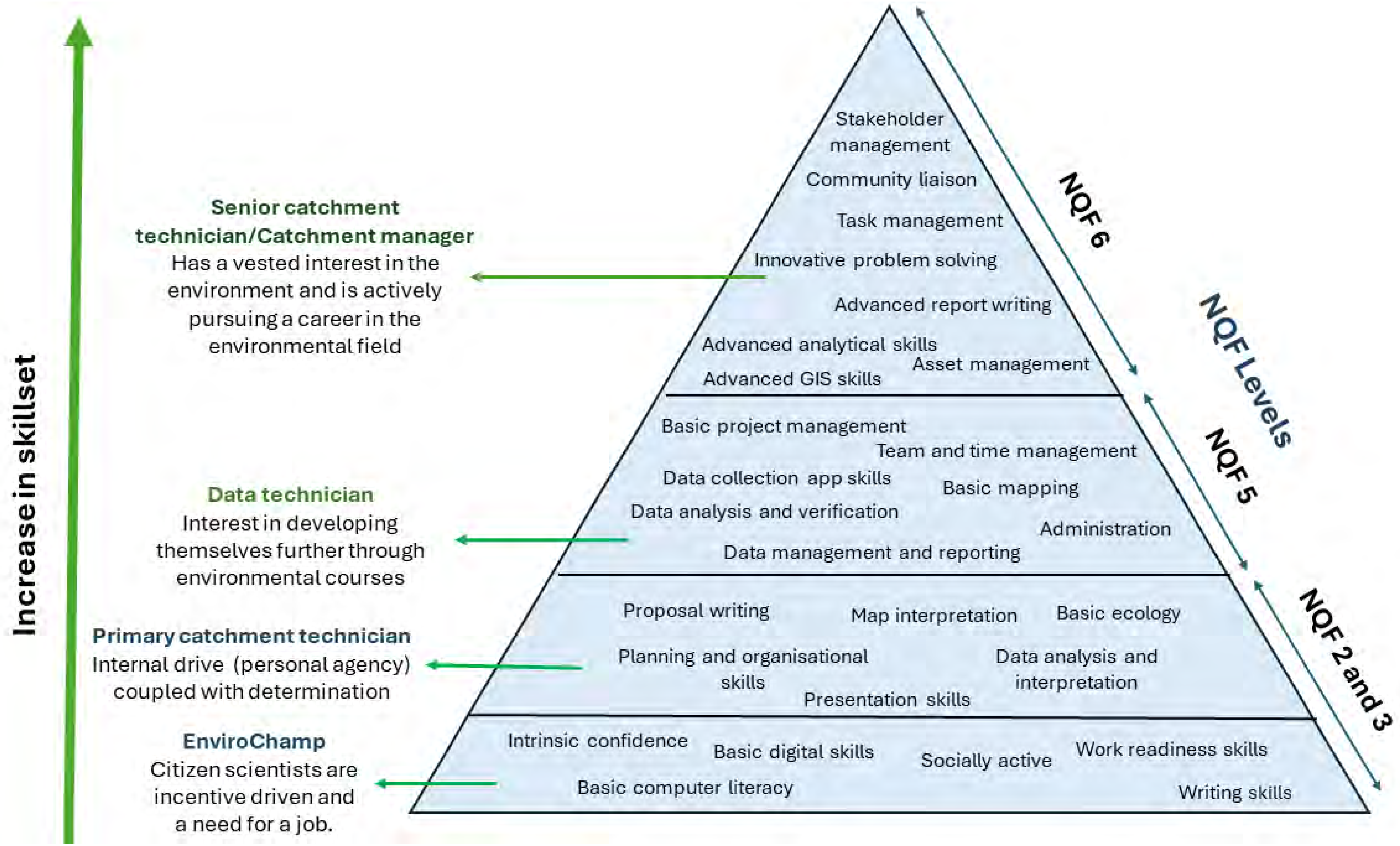


Figure 9.2 First iteration of a learning pathway for citizen scientists in the *River Commons* (Sithole, 2024)

8.8.2 *The design of the YOMA-miniSASS pilot programme*

Micro-credentials were developed based on these occupational activities (**Figure 9.1**), forming the foundation of the course design. The design of the YOMA-miniSASS course material and structure drew from the Water Research Commission (WRC: TT/933/23) project titled *Citizen Science Online Training and Learning System*, which aimed to create a remote learning system for CS in the *River Commons*. This system was piloted with participants from a marginalized community, and their learning journey was assessed to understand how CS learning occurred, and which elements were beneficial to retain. From this assessment, the following guiding principles for online CS learning were established, informing the design of the YOMA-miniSASS course (Russell *et al.,* 2024):

- **Contextual Relevance**: Learning must be relevant to the participants' needs and lived experiences.
- **Action Learning Approach**: Common environmental concerns should be investigated using this approach, linking back to indigenous or historic practices to address these concerns.
- **Monitoring and Evaluation**: CS should be introduced as a tool to assess environmental changes.
- **Hands-On Learning**: Learning about CS tools should involve real-life experiences, hands-on use, diverse field-based encounters, and repeated practice.
- **Scaffolded Learning**: Learning should build on participants' prior knowledge, involve questioning and probing assumptions, and allow time for peer discourse.
- **Community Impact:** Participants need to feel they are making a significant difference in their community.
- **Accessibility:** The remote learning platform should be user-friendly and include internet usage charges.

The course was structured into seven opportunities (micro-credentials detailed in **Table 9.4**), each including:

- **Quizzes**: To gauge participants' understanding.
- **Forums**: For discussions and shared learning, deepening understanding of miniSASS.
- **Instructive Videos and Textual Content**: To guide participants on using the tools.

These elements collectively supported the participants' learning journey, ensuring they gained the necessary skills and knowledge to effectively engage in CS.

Table 9.4 Details of microcredentials on the YOMA-miniSASS course

Micro credentials	Description
Opportunity 1: the miniSASS course	This opportunity provided an overview of the miniSASS course content of how to use the miniSASS tool.
Opportunity 2: miniSASS field test	For this opportunity participants had to take a miniSASS sample at a nearby stream, calculate their miniSASS score, and upload it to the miniSASS website. Thereafter, participants had to take a screen shot of their upload and submit it as their assignment.
Opportunity 3: Monitoring Plan	For this opportunity participants had to go through the course content and create a monitoring plan for their stream. Thereafter they needed to upload a monitoring plan as their assignment submission to complete the opportunity.
Opportunity 4: Stream monitoring	For this opportunity participants needed to implement their monitoring plan by taking 6 miniSASS samples over a period of 2 months.
Opportunity 5: Change Project	For this opportunity needed to develop a "Change Project". They had to reflect on the impact their miniSASS data collection may have had on the community and their local stream. Thereafter they had to create a video, photo journal, or write about their reflections. Participants were also required to share their reflections as a social media post.
Opportunity 6: Social Learning Course	This opportunity taught participants to teach others about the miniSASS tool.
Opportunity 7: Teach others	For this opportunity participants had to share their learning experience with others and develop a report from this.

8.8.3 *Way forward*

Currently the YOMA-miniSASS course is being redesigned to further define the learning pathway of citizens interested in becoming a registered water monitor, within the field of CS. The redesign of the course has been informed by the skills gap that emerged from the evaluation of the learning journey of participants on the YOMA-miniSASS course, and the labour market needs, within CS. The aim of the new course is to get citizens interested in becoming registered water monitors, with skills to effectively collect biomonitoring, physical and chemical water quality data using the miniSASS, velocity plank, clarity tube and WaterCAN CS tools. The course is currently under development and will be informed by the assessors' workshop [2]that is to be held in early 2025. The assessors will include technical staff (comprising of experienced SASS 5 or accredited SASS 5 practitioners) who will be responsible for assessing and verifying the competency of water monitors, to effectively collect water monitoring data using the CS tools. The course structure is still currently under development and will be further informed and refined by the outcomes of the assessors' workshop. The first iteration of the course structure for the water monitors course is outlined below:

- Module 1: Basic introduction to aquatic ecology
- Module 2: Significance of data collection
- Module 3: Developing a monitoring plan
- Module 4: Change project

8.8.4 *Recommendations for future work*

This section highlights recommendations that will guide the mapping of the learning pathway for citizen scientists in the *River Commons* project and enhance the YOMA-miniSASS pilot course.

- **Aligning Training with Skills Needs:** It's crucial to align green skills development programs with labour market demands. Training developers should create programs that meet the anticipated needs of the green economy. This alignment can be achieved through conducting a needs analysis for skills currently in demand in the labour market and tailor courses to fit these needs.
- **Developing an Evidence-Based Business Case:** Demonstrating the effectiveness and impact of formalized and accredited training for citizen scientists is essential. Building an evidence-based business case can support the formalization of green skills development and training, showing the positive impact on participants' learning journeys and environmental conservation.
- **Building Accreditation Partnerships:** Partnering with accredited institutions, such as those recognized by the South African Qualifications Authority (SAQA), can help provide recognized and accredited training for water-related citizen scientists. This partnership can facilitate the transition to more formalized training programs. Additionally, learning from organisations that have undergone the same experience of getting citizen science training programmes accredited, can be invaluable for this project or those interested in developing a learning pathway for citizen scientists in the River Commons. This project has benefitted greatly from the experience of the Endangered Wildlife Trust (EWT) who have growing experience in developing learning programmes for their citizen scientists and getting those learning programmes to a standard of being accredited.
- **Accreditation and Alignment with SAQA:** Ensuring training programs are accredited and aligned with SAQA standards involves conducting a needs analysis, identifying required skillsets and aligning the program with specific unit standards to guarantee quality assurance. In South Africa, accredited qualifications are considered more important and hold significance in formal

[2] The assessors' workshop will be aimed at equipping the assessors (accredited SASS 5 and experienced SASS 5 practitioners) with the skills to assess the competency of the water monitors in collecting, analysing and interpreting water-related citizen science data. To achieve this, an assessment criteria for the data collectors' verification process will be co-developed at the workshop with the assessors.

organisations and thus efforts should be made to provide Enviro Champs or water-related citizen scientists with formalized/accredited trainings.

These lessons will inform the development of effective learning pathways and training programs, ensuring that water-related citizen scientists are well-equipped to advance into more formal job opportunities in the green economy.

8.9 Chapter Discussion and Conclusion

CS has been identified as a valuable and accessible tool for informing river health monitoring (WWQA, 2024a) and to actively engage civil society in water resources management (Taylor *et al.,* 2022). The YOMA-miniSASS pilot study provided a useful case study of CS integration into a learning pathway through a skills development opportunity. The engagements and discussions throughout the process to develop and trial the YOMA-miniSASS pilot revealed valuable reflections of some of the requirements to advance skills in the CS space, and guidance on how to facilitate the opportunities for these skills to be developed and used. This research aligns directly with the call for continuation of CS skills development, ensuring that the practice continues beyond project-scale, and benefits both the environment and communities.

Further, there exists great potential for CS integration into the T&L at tertiary institutions which encourages the continuity of CS. This could range from practical sessions which are drafted into the curriculum, or something as simple as referencing CS examples in coursework when appropriate. This evaluation highlights that there is great potential to integrate CS applications in tertiary education as it provides real-life, practical, and accessible applications and examples of the content which students are learning about. “Experientialist” and “Critical Reconstructionist” perspectives of curriculum design call for reality and experience to form part of teaching. CS applications and the issues which these practices are aiming to highlight, monitor, and address link well with these perspectives.

9. Evaluation of Citizen Science for National and International Water Resources Monitoring

The development of CS across a variety of industries and specializations represents an excellent opportunity and a creative means of interacting with the public to facilitate the collection of valuable water resources data. CS offers a variety of avenues that can permit the generation of high-quality datasets provided the appropriate quality control guardrails are in place. To further promote the adoption and use of CS data to support policy, there is a need to increase the connectivity of CS data with traditional laboratory-derived data to lend increased reliability of CS datasets. This highlights the need of strengthening CS data collection and management procedures and methods.

This can be facilitated through structured training programmes, either conducted online or in-person. Alternatively, trained professionals can be part of field surveys to verify data collection practices by CS practitioners. The emergence and increasing use of CS tools has seen a parallel evolution of methodologies which seek to further bolster the credibility of CS-derived datasets (Cooper *et al.,* 2012). The development of CS in an international context is well document; however, South Africa still must establish its own identity regarding the theory and practice of this field of study. This is particularly critical if CS is to form a key role in supporting water resources management policy.

Involving communities in environmental management assists communities understand their environment and offers them an opportunity to have a 'voice' in water governance. However, as mentioned before, the use of CS in river health reporting in South Africa has not yet received much recognition by the concerned government departments, although it has demonstrated potential to contribute to decision-making in these departments. Although citizen science has made significant contributions to river health monitoring in South Africa, there has been limited use of the data collected in supporting these departments' governance structures (Graham *et al.*, 2004).

Monitoring the quantity and quality of water resources is essential to the effective management of these resources in terms of the risk factors faced, the quantities available for various uses, and the climate change impacts on water resources (WWQA, 2024a). Informed decision making is hindered by limited sound and reliable water resource monitoring data and information for communities, decision makers, and water resource managers. This research has aimed to evaluate how CS can aid in overcoming limitations in water resources monitoring and gathering relevant valuable data.

This evaluation of the use of CS data for water resources management draws motivation from existing policy. At a national scale the South African DWS highlights that the South African National Water Act (Act 36 of 1998) emphasises that there must be a balance between using and protecting water resources, acknowledging that there are various monitoring and protection techniques which can be applied (DWS, 2021a) and that people-centric water quality monitoring approaches are vital to improving water quality, in line with IWRM (DWS, 2023b).

This is a useful example of alignment of CS with policy, however Wehn *et al.,* (2021a) note a lack of literary evidence of the impact which CS has on policy and partially accredit this to difficulties in linking CS impact with the dynamic and complex policy and decision-making procedures. Further, Wehn *et al.,* (2021a) note that although recent studies show the value in CS data for reporting on the SDGs, this links closer to CS aiding water resources monitoring more than influencing policy, decision-making, and management. Carlson and Cohen (2018) reflect similar findings of CS techniques being applied for monitoring but not being used in informing policy and government-level decision-making processes. This evaluation explored this notion further by assessing the potential for CS to inform national and international monitoring processes and policy.

A challenge recently noted by the DWS is that their current information-system is data-driven instead of information-driven (DWS, 2023b). This is where CS techniques can bring an information-focused perspective, linking the indicators back to the environmental context instead of providing decision-makers and other stakeholders with an array of figures which can be difficult to contextualize from a numerical database (Buytaert *et al.,* 2014). An example of information-focused over data-focused techniques, is how miniSASS provides an indication of the state of a river without a statistical analysis required, thus is simple for stakeholders to understand. The National Water Act requires that a publicly available national water resource information system should be established providing information pertaining to all facets around South Africa's water resources (DWAF, 1998). This system will not only aid in the high-level water management and decision making, but can also be utilised by public safety representatives, researchers, community environmental groups, and other interested parties. The limitation of establishing a functional and well-maintained database for water resources data is similarly being experienced by WQM citizen scientists. In line with the NWA, information pertaining to South Africa's water resources should ideally be centralized for ease of access by all relevant stakeholders.

Issues related to data quality are rarely shared between citizen science projects (Sackey *et al.,* 2024). There is often little scope for new projects to learn from existing projects in terms of best practice approaches. In addition to establishing credibility and trust, communicating data quality practices can help citizen science collaboration by identifying shared issues and concerns. The most important factor that defines citizen science is that non-professional scientists contribute to scientific research. Therefore, it is important to recognize the perspectives and experiences of these participants. Projects may provide ways for participants to contribute to scientific research at different stages of the scientific process according to different levels of engagement. It is important to understand what benefits participants gain from engagement in citizen science projects. This will help ensure that scientists as well as participants benefit. Participants may also encounter challenges during their engagement with citizen science projects.

9.1 National Water Resources Management

The generation of the *2024 Citizen Science State of Rivers Report* provides an indication of the capacity and capability of CS to provide information on the condition of river systems across South Africa. The generation of this report is considering the budget limitations and acknowledges the data collection on a volunteer basis in under a year. This highlights the potential for CS to be integrated into existing workplaces and already-existing routine monitoring.

In the State of Rivers (SoR) Report 2020-2021, DWS has encouraged that government should champion community-based initiatives to monitor and protect water resources, and calls for funding and support of these CS initiatives, such as the Adopt-a-River programme which engages communities in CS. Thus, the necessity for CS initiatives and the support for CS has been acknowledged at national department level (DWS, 2022a). Furthermore, Lotz-Sisitka *et al.,* (2022) have explored the alignment of CS with South African policy where CS in South Africa is situated in a beneficial position in which it can draw support and motivation from a range of South African policies and legislations. The encouragement of the government-based Adopt-a-River programme (DWS, 2022a) and related governmental support of CS initiatives across the country also highlights that there is an influence by CS on government-based decision making, supporting existing policy, and having fair potential to impact on future policy.

One of the main recommendations provided by DWS at the end of the State of Rivers Report 2020-2021 (DWS, 2022a: 157) page encourages readers to “be part of the solution” linking to the impacts which CS has already had, for example allowing citizens to observe and hold their own data for decision making and aiding in engagements with government and corporate companies. Further, DWS encourages broader uptake of CS techniques by public and private entities and recommends CS for its potential to close gaps where there are capacity limitations in government (DWS, 2022a). This research has aligned with this encouragement of CS uptake and solution-oriented approaches through having engaged with CS stakeholders across public and private sectors in producing the CS SoR report.

The UNEP 2021 Progress Report drew a connection between low-income countries and a low capacity to monitor their freshwater resources (WWQA, 2024a). It is in these instances that the applications of CS would be useful. An example to support this can be taken from DWS (2022a) for the monitoring locations under the REMP for the secondary drainage unit Umgeni (U2) in the primary drainage region U (Pongola-Mtamvuna water management area). In this primary drainage region, there are 27 monitoring sites but only 9 were monitored to inform the SoR Report 2020-2021. In the secondary drainage unit, U2, the main river (uMngeni River) was monitored at just one location along its approximately 230 km stretch. These monitoring restrictions are accredited due to “limited human and financial capacity” (DWS, 2022a: 129). Considering the reality of resource limitations, this research has explored the scope of monitoring through CS techniques and from the *2024 Citizen Science State of Rivers Report* generated, 306 CS observations were made in the Umgeni (U2) secondary drainage region during 2023-2024 (**Figure 10.1**), with 47 of these observations located along the uMngeni River.

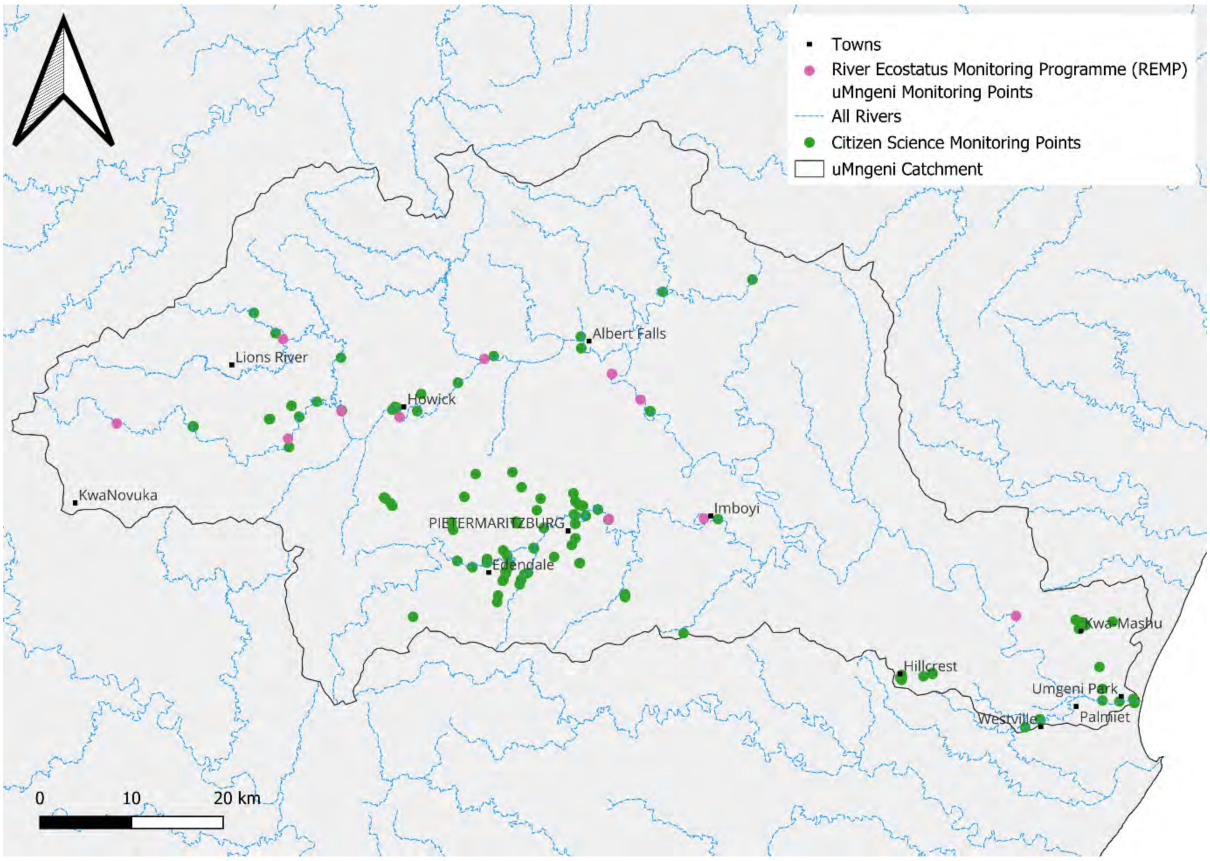


Figure 10.1 River Ecostatus Monitoring Programme points during 2020/2021 compared to citizen science monitoring points during 2023/2024 in uMngeni Catchment, KwaZulu-Natal

The WWQA (2024a) elaborate on action pathways which can be taken towards effectively monitoring ambient water quality based on the data which is available and how CS can be integrated to aid in the monitoring capacity. These pathways are summarised in **Figure 10.2** below (taken from WWQA, 2024a).

Figure 10.2 Action pathways for monitoring ambient water quality based on the availability of data (taken from WWQA, 2024a)

These pathways provide decision-makers from both public and private sectors with a guide to initiate strategic plans for water resources monitoring in a way which optimises resources dependant on the availability of data. These strategies can be applied at the relevant scales, such as locally, per the water management area, provincial, and national scales. Technical challenges to consider would be the strategic, methodical, and unified integration of the data, drawing from the various sources into a central database.

One of the benefits of CS is its potential to be applied across wide spatial scales in areas where communities live, work, host recreational activities, and aim to conserve. This places CS in a unique position to potentially be applied at greater spatial scale than mandated river monitoring bodies would be able to reach by using conventional monitoring methods. Pattinson *et al.,* (2023) highlight that technological advancements in the modern age have aided the collection of real-time, variable data collection, and further link this technology to advancing CS practices. Through the collaborative data collection efforts towards the *2024 Citizen Science State of Rivers Report*, this research has provided a valuable case of modern technology aiding data collection through the miniSASS technique and website with open-access data viewing. The miniSASS technique also has its own mobile application which users can access in-field and submit their data in real-time. From this portal, valuable CS data can be shared and fed into a national database for local and global water resources reporting. The streamlining of data can aid national water resources monitoring, providing supplementary motivation for CS practices to be further incorporated in policy.

Proden *et al.,* (2022) highlight that in order for CS data to feed into policy, the CS practitioners must be knowledgeable of the type and quality of data which is required for considerations in policy applications. As such, the training on the use of the techniques is essential. Technological advancements of mobile applications and websites for data entry aid in the submission of reliable data by only allowing those data which results can be submitted on those portals. As an example, the Freshwater Watch portal only allows users to select from a predetermined list of results for nitrate and phosphate tests. This is also helpful in minimising typographical errors. Similarly, the miniSASS website does an automated check that the co-ordinates entered are located on a land mass, and not over the ocean. These technological precautions all contribute to the reliability of CS data.

The WWQA (2024b) demonstrated successful cases of the integration of CS-based data with conventional national data and, from this, defined three conditions for national authorities to meet toward the success of this data integration and subsequent SDG 6.3.2 reporting. These conditions are: "(1) Data can be produced that meets the requirements of SDG indicator 6.3.2. (2) Citizen science participants are willing and able to collect the data. (3) There is an enabling framework that allow both the participants and the data they produce to be incorporated into integrated water resource management" (WWQA, 2024b: 9). The generation of the 2024 CS SoR aligns with these three points in that the miniSASS technique produced data which is readily available for SDG 6.3.2. reporting, the spread of collaborators who were involved in CS on a voluntary basis, and that the data collected has been acknowledged as a collaborative effort.

The effective adoption and use of CS-based data requires a sound, implementable data management framework that is informed by well executed environmental research which includes monitoring and evaluation. In many instances, particularly in South Africa, there is a significant disconnect between CS theory and practice. This disconnect can be attributed to several reasons, including significant time constraints for detailed catchment scale CS investigations which inform policy, information is usually disconnected in time, space, and function, and knowledge cannot be effectively generated from environmental studies due to the disjointed nature of the information collected. The result of this will potentially be the development of inadequate policies, redundant water resource management instruments, inappropriate or inadequate catchment biophysical process knowledge, missing or inadequate monitoring programs and unclear institutional responsibilities. This can create an environment where the adoption of CS-based data is limited and this can further limit the development of CS monitoring tools thus, ultimately, undermining accessible water resources management. If the proper frameworks designed to enhance the uptake of CS-based data are not in place, it is highly unlikely that any policy development informed directly by CS research can be undertaken.

9.2 International Water Resources Management

WWQA (2024a) calls for international and local communities and policy makers to recognise, support, and utilise CS as tool which contributes to effective water resources management. This call is under the WWQA 2024 policy brief on "*The role of citizen science in improving ambient water quality*" (WWQA, 2024a) which motivates for CS as a solution to provide opportunities for data collection and public engagement, which link to improved data availability assisting decision makers and promotes more inclusivity in water resources management. Furthermore, the WWQA emphasise that the "2030 target for ambient water quality…will not be met without the use of citizen science" as an available alternate for water quality monitoring due to limits in conventional monitoring (WWQA, 2024b: 8).

SDG 6 focuses on clean water and sanitation. CS monitoring and engagement with communities have been recognised as contributing methodologies which can be applied to SDG indicator 6.3.2 and SDG target 6b, respectively (WWQA, 2024a). With specific focus on SDG 6.3.2, **Figure 10.3** (UNEP, 2024) shows that both level 1 and 2 reporting data can be fed by citizen-focussed approaches to both physico-chemical and biological data. In the context of this research, the WaterCAN iLab kits or Freshwater Watch kits, and the miniSASS technique, respectively, provide illustrations of such approaches. This also speaks to the recognition of the capability of CS data at an international scale.

Figure 10.3 Summary of Level 1 and Level 2 data collection methods, data types and data sources that can be used for SDG Indicator 6.3.2 reporting (from UNEP, 2024)

Literature and the practical approaches to the generation of the *2024 Citizen Science State of Rivers Report* have shown the reach that CS has had in its applications at international and local scales, respectively, and thus, have highlighted the capability of CS. The United Nations SDG 6.3.2 progress on ambient water quality report has included CS-based data from SDG 6.3.2 reporting from Sierre Leone and Zambia reporting that these countries are the first to use citizen-generated data to inform and report on the progress of their respective countries on SDGs (UNEP, 2024). Referencing the dataset from Sierra Leone specifically, UNEP (2024) reported that the inclusion of CS data with conventional, national data doubled the available data records, thus, motivating for the capability of CS practices.

Drawing from the data used to generate the *2024 Citizen Science State of Rivers Report* there is a total of 843 physico-chemical observations made through the use of CS techniques and 1056 total miniSASS observations. These data combined with national, conventional monitoring can contribute towards a well-established database for the year, with the potential to reflect on areas not sufficiently covered by conventional monitoring as is in the example of the Umgeni catchment. Specifically, the wealth of physico-chemical and miniSASS data collected directly contributes to a database which can be used for SDG 6.3.2 reporting.

As acknowledged in the *2024 Citizen Science State of Rivers Report* there are limitations in the applications of CS techniques to provide a fully comprehensive review of river systems however, as in the case of applications in Sierre Leone and Zambia (UNEP, 2024), the CS data which is collected possesses the capability to be integrated with conventional data to enhance the frequency and spatial coverage of monitoring information

9.3 Chapter Conclusion

The value of CS has been acknowledged at both national and international levels, and the ongoing projects, such as those lead by the WWQA (UNEP, 2024) investigating the integration of these CS data with conventional national data, have the potential to unlock more capabilities of CS practices.

Through practical applications of CS and literature supporting the uptake of CS practices for informing water resources monitoring, a strong case can be made for the value of CS data and the integration of these data for water resources management. This is provided that training, quality control, and standardised methodologies for data collection are adhered to. These practical and literature-based cases have demonstrated the potential and value that citizen-generated data can have in broader water resources management at both national and international levels.

10. Looking Ahead: Developing Research and Investment in Citizen Science

Southern Africa is facing severe water quality and quantity challenges attributed to extreme weather-related events linked to climate change, a rapidly growing population, poor management of water and wastewater infrastructure by municipalities, and poor land use practices leading to biodiversity loss and environmental degradation (Petersen *et al.,* 2020). According to Skowno *et al.,* (2019) an estimated 64% of rivers in South Africa are categorised as threatened due to declining water quality, with 42% of river ecosystems not protected.. In addition to this, 98% of available water, categorised as mainly freshwater has been allocated for use (DWS, 2021b). This poses a significant threat to the country's rapidly growing population and increased economic growth which requires consistent and high levels of water demand. Although the nation boasts some of the most progressive water policies globally, the practical implementation of these policies on the ground in both national and local contexts has often fallen short. The National State of Water Report (DWS, 2023c) highlights severe challenges related to microbial contamination in dams and rivers across South Africa. The 2022 Green Drop report (DWS, 2023a) shows that about half of South Africa's wastewater treatment works are failing to properly treat sewage. This means that much of the sewage and industrial waste is either not being treated at all or is spilling into the environment before it reaches the treatment works. It is thus very concerning that the country has both high water losses in our supply systems, as well as deteriorating water quality in our rivers and dams. Significant boost in capacity for enabling better water resources management is desperately needed in southern Africa.

Citizen science is a growing practice in southern Africa and holds great potential to address water quality and management challenges in many communities faced with poor service delivery and socio-economic issues. Citizen science has potential to increase public participation in water quality management and monitoring at a local scale, whilst providing beneficial socio-economic outcomes such as increased scientific literacy, increased data collection and the development of integrative and context-specific solutions to water quality issues within communities (Graham and Taylor, 2018). Citizen science processes have been recognised as key to addressing challenges such as weak cooperative governance amongst water users (NGOs, civil society, private sector and government institutions) and the poor management capacity of water authorities (Graham and Taylor, 2018). Through participating in citizen science processes, citizens are capacitated with skills and tools to respond to water quality issues at a local level and subsequently address municipal hurdles, and more broadly urban governance issues in a concerted and effective manner (Graham and Taylor, 2018).

Along with the water crisis South Africa is facing, the rise in unemployment levels of youth, remains a top concern. South Africa has the highest official unemployment rate in the world, which is >45% unemployment among youth (18 – 35 years old), with black Africans (especially young women) being most affected (Stats SA, 2024). Unemployment has cumulative devastating impacts on individuals, households and communities, including inter alia, prolonged poverty in communities, increased crime rates due to desperation for basic needs and stunted economic growth. Thus, unemployment requires a complex, multidimensional effort that addresses social, economic and environmental issues. It is anticipated that the transition to a low-carbon economy holds great potential to contribute to the increase of employment in developing countries. The transition to a green economy is anticipated to result in businesses adopting sustainable and environmentally friendly production processes that will require basic and advanced technical skills, thus creating work opportunities (Maclean *et al*., 2013). However, gaps in skills development bodies/institutions for green skilling have been identified and need to be filled to enable the transition to a low-carbon economy. These gaps include the lack of a designated SETA to pioneer green skills development in the green sector, the lack of available SETA funding to retrain and upskill existing staff within the green sector and the absence of development initiatives that respond to novel climate change related challenges. Furthermore, existing skills development initiatives contribute to the rising levels of unemployment as they result in poor skills training and ineffective learning outcomes (Ramasarup *et al*., 2017). To address unemployment challenges and create work at a scale that addresses the unemployment issues, it is necessary to embrace a paradigm of green income opportunities that include 'work for the common good'. This paradigm speaks to work that allows for the development of civic action skills, values and practices of sustainable development, and competences for improved social-ecological security and well-being. Social and economic innovations are required to not only produce more employment opportunities but also to produce more skilled, confident and engaged youth; youth who are able to learn, work, and contribute positively to their communities for the future.

Many innovations for employment creation ultimately fail to support a whole social system approach and several employment initiatives lack sustainable skills development and civic action for the common good during or following a typically temporary job opportunity. Developing and implementing a transboundary transformative innovation 'work for the common good' programme within a systems-based, citizen science and civic action initiative presents a nexus solution that addresses the urgent need to improve natural resource monitoring and management and the need to implement just, equitable, and sustainable solutions to serious unemployment issues.

The economic shut down that occurred in 2020 due to the COVID-19 pandemic, resulted in the urgent need for innovation in job creation in South Africa. The "Enviro Champs" model of youth working for the common good in catchment management was one of the programmes supported by the Presidential Employment Stimulus Programme to scale new work opportunities in the green economy. This 'pressure cooker' scenario resulted in rapid scaling and experimentation in community-based water resources management with youth as the core agents of change. The model has been adapted over time, to try to find solutions for multiple environmental and social challenges. The conclusions after nearly 5 years of experimentation, are that 1) there is a vibrant, extensive resource in our youth who are struggling to enter learning and earning pathways; 2) the environmental challenges related to water are urgent, and increasing; 3) there is a potential solution to both challenges in community public private partnerships for water resources management; and 4) we cannot continue to rely on grant funding if this solution is to be long-term and scaled across the catchments of the SADC region.

The role of citizen science in the green economy is a developing and innovative space with experimentation across many projects, dynamic research, and collaborative conversations revealing learnings on what is suitable and unsuitable in the citizen science context. The reflections in this report draw from experience in past and current initiatives, some of which has been formally written up but most of which stems from conversations within the CS Community of Practice (CoP) across South Africa, including the uMngeni Enviro Champs programme. There are also reflections which draw from current trends in the CS space regarding how to advance the field further with consideration of the lessons learned from previous efforts. In **Chapter 5, Section 5.5**, the interviews from key CS practitioners brought up the recurring point that CS is a growing space, further emphasising the necessity to evaluate and give key recommendations for the future of CS practice. It is hoped that this report provides a pragmatic guide on how to upscale the use of citizen science as part of the urgent need to understand the state of our rivers, whilst providing much needed purposeful work and income to youth in the SADC region.

10.1 The Future of Citizen Science in South Africa

The view of IWRM is shifting to acknowledge that it fundamentally relies on community participation. Engaging local communities ensures that water management practices are tailored to the specific needs and incorporate situated local knowledge (Graham and Taylor, 2018).

10.1.1 *Community at the heart of water resources management*

Community members often possess valuable local insights and traditional knowledge about water sources, usage patterns, and environmental changes. Their involvement fosters a sense of ownership and responsibility, encouraging sustainable practices and compliance with water management policies. Additionally, community participation helps in the identification and implementation of practical, context-specific solutions, enhances transparency and accountability, and builds resilience by leveraging the collective efforts of diverse stakeholders.

Citizen science initiatives play a pivotal role in contributing to water quality monitoring and reporting at a local level. Empowering communities to act as custodians of their water resources through CS methods is a promising strategy. Communities can serve as on-the-ground monitors, using near real-time observations to identify environmental issues caused by non-compliance and potentially pinpoint pollution sources. Collaboration between government and society, encompassing all industrial, residential, and agricultural communities, could firmly establish the importance of prioritizing environmental issues

A well-known example is the Mpophomeni Enviro Champs [3]initiative, which was catalysed by the urgent need to address water quality issues in the Mpophomeni community near Midmar Dam in the uMngeni Municipality of KwaZulu-Natal. Efforts were directed at restoring and protecting the water quality of the uMthinzima stream that flows through the Mpophomeni settlement. This stream is a critical area of ecological infrastructure that plays a key role of preserving the health of the water entering the Midmar Dam and protects it from the water-polluting urban activities in the Mpophomeni settlement. The Mpophomeni Enviro Champs initiative aimed to (1) raise community awareness of environmental issues, and (2) monitor and report pollution sources that impact key water resources in the Mpophomeni community (particularly leaking sewer manholes and illegal dumping activity) (Sithole *et al*., 2024). One of the milestones achieved was the drastic decline of surcharging manholes from 180 in 2015 to 40 in 2017. This decrease in surcharging manholes

[3] Enviro Champs refers to a group of 'environmental champions' who are local citizens concerned about the health of their local water resources. This group of individuals is trained to monitor and report on water quality using citizen science tools, and work with diverse stakeholders (municipal and local) to address these water quality challenges in their community (Pattinson *et al.* 2023).

demonstrates the impact of the sewer monitoring work of the Mpophomeni Enviro Champs and ultimately the impact of citizen science action in addressing water quality issues.

10.1.2 *Youth as active citizens*

Upskilling local youth as citizen scientists aims to introduce and accelerate fresh perspectives, technological savvy, and innovative solutions. Enviro Champs can use digital tools and social media to collect, analyse, and share data on water quality, usage, and conservation practices. Their active engagement in monitoring water resources and pollution, in addition to advocating for sustainable practices, enhances community awareness and drives local evidence-driven policy changes. By harnessing the enthusiasm and skills of youth, IWRM initiatives can become more effective, inclusive, and responsive to local needs, helping transition towards a more sustainable, just, and equitable approach to managing water resources and environmental health.

10.1.3 *Citizen science networks to foster knowledge sharing: across boundaries and disciplines*

In light of the existing water security challenges South Africa is facing, the country stands to gain from establishing a network of active citizen scientists. The newly formed (October 2023) CSA-SA includes sub-networks focusing on specific issues like a CS for WQM, could be central to the establishment of such a network. A network should incorporate representatives from public, private, and tertiary education sectors to ensure comprehensive representation and inclusion of key stakeholders in the CS domain. This network could significantly facilitate the sharing and mobilization of knowledge and resources across disciplines. Such a network will not only coordinate the temporal and spatial dimensions of CS efforts across South Africa, and potentially the SADC region, but also serve as a platform for data sharing, information generation, and updates in the field. By institutionalizing the practice and encouraging continuity through an expanded community of practice, the ongoing CS work can be sustained. These networks foster connections not only among professionals but also between government and society.

Water resources know no political boundaries, and thus transboundary approaches to WRM are not only encouraged but necessary - evident by the existence of entities such as the Orange Senqu River Commission (ORASECOM) and Limpopo Watercourse Commission (LIMCOM). This CS SoR report provided useful transboundary data through monitoring along the portion of the Orange River which forms the border between South Africa and Namibia.

10.1.4 *Citizen science for SDG reporting*

South Africa's efforts to report on water-related SDGs have been hampered by a lack of data and monitoring of water quality, as highlighted by Statistics South Africa (2019). This is attributed to several factors, including inter alia, poor coordination of government departments, stakeholders and civil society, the lack of skills and resources to timeously and comprehensively collect water quality data and inconsistent data collection methods which make it challenging to assess progress for some of the SDGs (Stats SA, 2023). Additionally, the Statistics South Africa (2019) report highlights inadequate reporting on the lawful discharge of treated wastewater from sectors such as mining. This deficiency impacts on reporting against SDG 6, specifically indicator 6.3.1 D, which measures the proportion of water containing waste that is safely treated and lawfully discharged. Citizen science has been recognised as an enabling approach to meeting the SDGs. According to Taylor *et al.* (2022) to meet the SDGs by 2030, an approach that enables public participation and environmental education is required. Citizen science tools like miniSASS, have been highlighted as one of the tools that meet these objectives, as they hold great potential to increase reporting against Target 6.3. MiniSASS has gained popularity in southern Africa as a cost effective and simple data collection tool to use (Taylor *et al*., 2022).

10.2 Scaling Citizen Science in SADC

A recent study by Lotz-Sisitka *et al.*, (2022) on scaling CBWQM practices offers valuable insights derived from an in-depth review of seven best-practice South African CBWQM cases. The study's outcomes and recommendations have significantly influenced the scaling of the Enviro Champs program from 2021 to 2025, informing the action research planned for 2025-2027. Additionally, it has guided the formalization of funding mechanisms and supported the establishment of CBWQM communities of practice across South Africa. This section provides a summary of the main findings and recommendations drawn from the review, providing context for potential scaling pathways for CBWQM practices across the SADC and building on developments and lessons learned since the completion of that study.

10.2.1 *Key definitions and findings*

Scaling can be defined as a learning process that extends activities from a small to large scale (Lotz-Sisitka *et al.,* 2022). Scaling can take place through various mechanisms, which are identifiable in CBWQM practices, including,

- **Scaling Objects**: refers to specific activities being scaled, including norms, values, principles, and social learning
- **Scaling Subjects**: Individuals or entities executing the scaling process, such as NGOs, researchers, policymakers, and community members (e.g. Scaling of the Enviro Champs programme through the Amanzi Ethu Nobuntu programme and led by DUCT in partnership with the uMngeni Ecological Infrastructure Partnership).
- **Scaling Sites**: refers to the locational contexts from which and to which activities are moved (i.e. from a local scale, in the community of Mpophomeni to a national scale, or within a different province).
- **Scaling Pathways**: Mechanisms through which scaling objects travel, across different contexts like CBWQM projects.
- **Scaling Resources**: Enabling factors like funding, frameworks, and policies supporting broader scaling.
- **Scaling Drivers**: Partnerships and other entities facilitating scaling over time.

Through the initial review of seven (7) South African CBWQM initiatives in South Africa, several scaling mechanisms and pathways were identified as necessary to explore to scale CBWQM practices in South Africa. These scaling mechanisms and pathways informed the development of an analytical framework (**Figure 11.2**), which allowed for further analysis of the selected CBWQM initiatives, to distil enabling and constraining factors that support scaling of the practice of CBWQM.

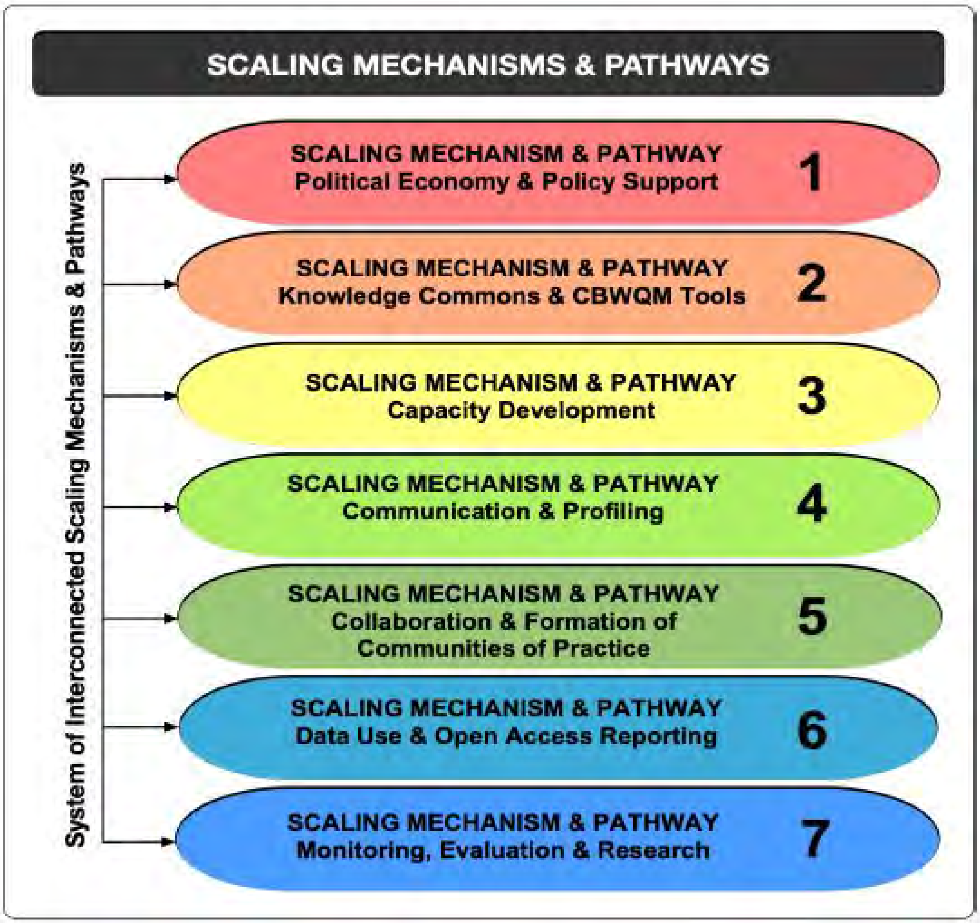


Figure 11.1 Analytical framework for scaling pathways and mechanisms (Lotz-Sisitka *et al.,* 2022)

The review provided the following recommendations for scaling CBWQM initiatives across several of the 7 scaling pathways and mechanisms (**Figure 11.2**) (Lotz-Sisitka *et al.,* 2022):

Scaling mechanism and Pathway 1: Political Economy and Policy Support

This scaling pathway focuses on engaging policies at global, national, and local levels concerning water resource management and establishing a political economy to better support Community-Based Water Quality Management (CBWQM) practices. Several scaling strategies are proposed for this scaling pathway including inter alia,

- ***Policy Dialogue for CBWQM Integration:*** A policy dialogue should be convened by the WRC, involving key stakeholders, to discuss research findings and their implications for Integrated Water Quality Management (IWQM). This should lead to the development of policy briefs and integration into national water strategies like the NWRS3.

- *Government Budget Integration for Sustainability*: CBWQM should be embedded in government budgets at all levels for long-term sustainability. The initiative can be linked to job creation efforts, such as Groen Sebenza, to support youth employment and capacity building.

Scaling mechanism and pathway 2: Knowledge Commons and CBWQM Tools

Refers to the sharing of knowledge and tools used within the CBWQM practice. This includes leveraging off technological advancements that upscale and increase use and access to citizen science tools. An example of this is the miniSASS website (https://minisass.org/) which allows for sharing of miniSASS data across a wider audience. The following scaling mechanisms were proposed along this scaling pathway,

- *Enhancing CBWQM Tools for Wastewater Monitoring:* Existing CBWQM tools should be improved and widely adopted to monitor wastewater treatment works (WWTWs). Citizen science efforts should align with SDG Targets 6.3 and 6.b to ensure better water quality and community involvement.
    - *Advancing ICT-Based Citizen Science Tools:* Expansion of citizen science tools, including digital innovations, is essential for improving monitoring practices. Investments should also be made in training and support systems to maximize tool effectiveness.

Scaling mechanism and pathway 3: Capacity Development

This scaling pathway focuses on offering both formal and informal training and support to individuals engaged in Community-Based Water Quality Management (CBWQM). The aim is to enhance their technical skills and expand their knowledge of water resource management. This approach not only aims to achieve CBWQM project goals but also fosters the personal and professional development of its participants. A suggested approach to implementing this scaling pathway includes *inter alia*,

- *Developing Capacity Building Programs*: Courses and training programs should be developed in collaboration with institutions like SETAs and the WRC. Accreditation frameworks should be established to create meaningful learning pathways for young professionals in CBWQM.

Scaling mechanism and pathway 4: Communication and Profiling

This scaling pathway involves communicating citizen science data to relevant stakeholders, including government, businesses, and civil society, at both national and international levels. Sharing and utilizing citizen science data not only raises the profile and importance of Community-Based Water Quality Management (CBWQM) practices but also has the potential to garner support from external stakeholders. This support can lead to increased resources, both financial and skills-based, for CBWQM initiatives across South Africa. Below are proposed scaling mechanisms that can be implemented across this scaling pathway;

- *Communication of the results and outcomes* of the CBWQM practice is crucial for raising awareness of the importance of the work being done and for data generated to facilitate improved governance. The communication approach should be aligned with the reporting of results and mobilising of further agency for change and not be a tick box KPI exercise.
- *Cross community learning:* The role of different partners, and achievements along the way will also be important to share across different communities of practice and into the capacity building programme.

Scaling mechanism and pathway 5: Collaboration and Communities of Practice

This scaling pathway emphasizes the importance of relationship building and collaboration among key stakeholders, driven by a shared concern, as a crucial factor for the sustainability of CBWQM practices. The Mpophomeni Enviro Champ initiative serves as a prime example of how collaboration with diverse stakeholder groups can strengthen and enhance the sustainability of CBWQM practices. The Mpophomeni Enviro Champs have successfully engaged a wide range of stakeholders from government, academia, and civil society to raise the profile of their work and disseminate the citizen science data they collect. Their relationships with academic institutions, such as the University of KwaZulu-Natal and Rhodes University, have significantly contributed to the recognition and impact of their efforts. This collaboration has enabled the pooling of diverse resources, funding, and expertise to upscale the outcomes of the Mpophomeni Enviro Champs' work. Alternative ways in which this scaling pathway can be actioned include, inter alia,

- *Multi-Stakeholder Approach for Scaling CBWQM:* A collaborative, multi-stakeholder approach is necessary for scaling Community-Based Water Quality Monitoring (CBWQM). An interim support structure (e.g., Amanzi Ethu Nobuntu learning network) should facilitate early-stage mobilization.
    - *Strengthening Communities of Practice*: Capacity-building efforts should focus on integrating CBWQM data into local government compliance systems. Communication strategies should be aligned with data reporting to ensure informed decision-making.
    - ***Diversified Resourcing for CBWQM Sustainability*****:** A coordinated funding approach is required, engaging government, businesses, international funders, and research institutions. Each stakeholder should contribute to capacity-building, tool innovation, and policy integration for sustainable CBWQM practice.

Scaling mechanism and pathway 6: Data Use and Open Access Reporting

This scaling pathway involves presenting or packaging citizen science data in an accessible and user-friendly manner for a wider audience. Originally, citizen science data was collected using pen and paper. However, as the practice of Community-Based Water Quality Management (CBWQM) has evolved, data collection now utilizes cell phones and spreadsheets. The internet has also played a crucial role in sharing and collecting citizen science data, raising the profile of CBWQM projects and making them more accessible to a diverse range of stakeholders. This increased accessibility enhances the ability of CBWQM projects to inform decision-making. Several other scaling mechanisms can be implemented across this learning pathway, including inter alia:

    - ***Sustaining CBWQM Platforms with Resources:*** CBWQM reporting platforms require continuous support and resources to scale effectively. Funding should be sought for digital tools that enhance community participation in environmental monitoring.

- *Data Management and Open Access Innovation*: CBWQM data should be managed as a shared resource, maintaining open access and avoiding commercialization. A robust data framework can attract funding while ensuring collaborative knowledge-sharing.

Scaling mechanism and pathway 7: Monitoring, Evaluation and Research

Monitoring, evaluation, and research are critical components for elevating the profile of Community-Based Water Quality Management (CBWQM) initiatives. These processes not only highlight the impact of CBWQM efforts but also facilitate the sharing of knowledge and collaboration across various projects. The scaling pathway can be implemented through the following mechanism:

- ***Monitoring and Evaluation Framework for CBWQM:*** A sector-wide Monitoring, Evaluation, Reporting, and Learning (MERL) framework should be developed. This framework should align with the scaling model and involve CBWQM stakeholders to ensure continuous improvement.

The sections to follow provide an overview of the proposed national blended funding mechanism in South Africa (Pathway 1), aimed at building a sustainable economy for CBWQM. This mechanism will support the development and alignment of key tools such as digital innovations, reporting platforms, data management, and MERL (Pathways 2, 4, 6, and 7). The report then introduces occupationally driven learning pathways for best practice skills development for thousands of youth across the SADC (Pathway 3). Finally, it explores Scaling Mechanism and Pathway 5: Collaboration and Formation of Communities of Practice as a practical approach to addressing recommendations in any catchment area.

10.3 Building Diversified, Sustainable Resourcing for Community Based Water Quality Management

From several discussions with the banking and investment sector, it has been made clear that there is significant opportunity for attracting sustainability investments in programmes that show a positive impact on water quality and quantity. However, these investment opportunities are for $30 million or more, and thus rarely suited to catchment scale programmes. Rather, there is an indication that investment needs to be sought, and managed, at a country level, and aggregate the impact across many catchments. For this to happen, there need to be mechanisms for attracting and managing investment, M&E systems to track impact, and local partnerships with the level of maturity to be able to work with, and report into a national system.

Figure 11.2 Cover page of the proposal to establish a fund to support catchment management

In South Africa, the establishment of a Catchment Management Fund was tabled with the National Treasury in 2024, for the potential inclusion in the budget for 2025 (proposal cover illustrated in **Figure 11.3**). The Fund is to support integrated, collaborative and multi-stakeholder approaches to maintaining and/or restoring natural systems that sustain life on earth. This will catalyse climate change adaptation and respond to increasing pressures on natural ecosystems through catchment and landscape management interventions. Central to this is the establishment of sustainable finance solutions (innovations, mechanisms and instruments) that focus on, amongst others, employment and linked learning opportunities, and the realization of tangible economic opportunities. This will contribute to South Africa's just transition pathway, promoting a robust infrastructure and institutional network that integrates nature-based solutions into the mainstream of development processes, and is inclusive of marginalized communities, particularly women and youth**.**

The nature-based and nature-inspired workstream potential is huge and well suited to a marginalized largely unskilled labour pool. These include:

  - Invasive alien plant removal and control, and value-add of harvested material (for example, charcoal)
- Restoration of degraded landscapes, wetlands and riverbanks
  - Waste removal from water bodies and stormwater systems
  - Integrated flood prevention and mitigation
- Citizen science initiatives to monitor water quality
  - Community development and education relevant to water quality issues, including in relation to sanitation.
  - Rangeland management initiatives
  - Community-based ecotourism

The creation of a fund and supporting mechanisms for the purposes set out is considered the best and perhaps the only way to achieve an integrated, inclusive, multi-stakeholder, area-based response to the challenges, based on experience to date.

Objectives:

- To establish an institutional funding mechanism that rewards integrated, collaborative, multi-stakeholder approaches to building, maintaining and/or regenerating the natural systems required to enhance water quality and/or quantity, and/or to limit flood risks
- To do so in ways that optimizes employment potential from such activities, including forms of public employment.
    - To select a cost-effective funding mechanism drawing on institutional knowledge and strengths of partnerships
    - To crowd in complementary forms of funding and investment, and secure increased and sustained support for landscape and catchment-based initiatives, with a view to experimenting with and supporting payments for environmental services models over time.
- To establish learning pathways that catalyse expanded capacity and improved contributions from all stakeholders.
    - To integrate social, environmental management and technical innovation into the process.
- To enhance monitoring, evaluation, reporting and learning through investment in research to be able to measure quantitative and qualitative social, environmental and economic impacts of the interventions.

The proposal for the Catchment Fund is for R750 million in the first three years from the Employment Stimulus / Just Transition; with commitment from DFFE for a further R250 million per annum, and interest from DWS to allocate some of their Adopt-a-River funds to this Fund.

This Fund is an example of a potential mechanism for scaling community-based water resources management - with citizen science, and the Enviro Champs model, is one of the core initiatives included in the proposal. At present only grant funding has been sought, but the intention is to develop output and impact measurement mechanisms so that multiple funding streams can be aligned towards impact, as shown in the diagram sourced from the OECD (**Figure 11.4**) (Horrocks *et al.,* 2020).

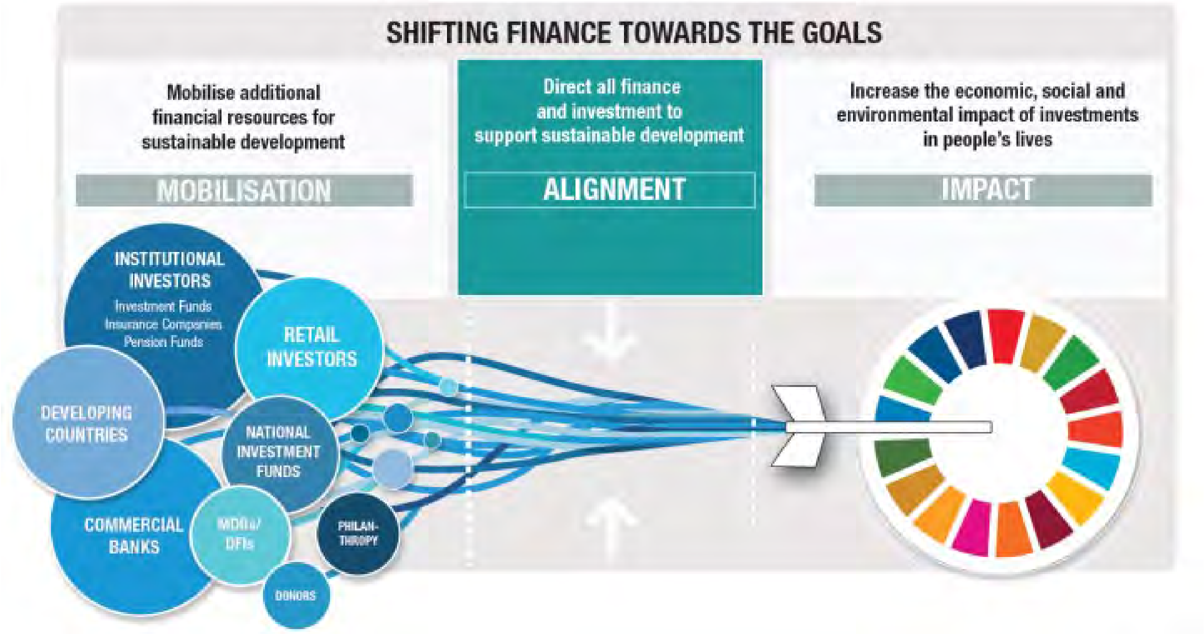


Figure 11.3 Alignment of resources to increase impact (after Horrocks *et al.,* 2020)

10.4 Developing Capacity Building Programmes: Green Learn to Earn Skills Programme

South Africa faces the triple challenge of 1) racial and gendered inequality and poverty with extreme levels of youth unemployment with limited pathways out of poverty into employment, 2) an education, training and skills system that lacks responsiveness and the ability to create flexible pathways to empowerment and economic agency for the most marginalised in the Just Transition, and 3) severe environmental degradation and significant crises in the energy, water, waste and food systems with injustices that most impacts the poor.

The impact of the triple challenge on those most marginalised is further marginalisation and social exclusion, long-term socio-economic hardship, higher risks of poor health, and ongoing environmental degradation. Evidence shows that failure to create opportunities for work and work experience for those who are unemployed but still motivated to seek work, can lead to extended exclusions (Stats SA, 2022). While there has been progress in reducing poverty levels since 1994 mainly through the social grant system, it is a concerning reality that by 2018, almost one third of South Africans were dependent on government support. The statement by Stats SA (2022) that *"A reduction in the number of individuals requiring government aid would signify a better economic state for the country",* supports the establishment of viable green learn to earn skills partnerships and Enviro Champ work opportunities for currently unemployed young people and women in the South African Just Transition to sustainability.

This cannot be done without adequate investment in occupationally directed training and learning pathway development that mobilises digital tools for learning, and that is accredited and recognised in the national system of work and skills. Evidence from the global South shows that digital learning programmes (e.g. micro-credential programmes) need to be supported with a) digital skills development support, and b) communities of practice for the digital innovations to take root and lead to sustainable outcomes.

There is need to build adequate skills ecosystems that involve both digital and practice-based components for the green transition to sustainability. Such learning programmes should be built 'from the grassroots up', as much online learning fails to connect with the contextual realities of learning and earning in African contexts.

UNICEF is supporting Rhodes University and DUCT in an operational research project (detailed in **Chapter 8, Section 8.6**) aimed at improving and increasing access to digital/blended learning to earning opportunities and solutions, with a focus on green pathways, in South Africa. In 2024-2025 the partners pioneered 16 online micro-credentials which are part of 3 GL2E pathways (community-based water quality monitoring, agro-ecology, and waste management), and in 2025-2027 this will increase to 6 pathways. Importantly, the micro-credentials are co-designed by youth who participate in the GL2E pathways, together with a team of young people have been involved in the online course design and development of the micro-credentials. Six of these micro-credentials – specifically on miniSASS, and the creation of a water monitoring programme at a local level - have been tested in-field by DUCT as part of a Social Employment Fund programme. An illustration of a potential GL2E pathway is illustrated in **Figure 11.5.**

Figure 11.4 Example of the Green Learn to Earn pathway piloted on the UNICEF digital platform - YOMA

As stated above, a successful skills programme not only includes the micro-credential learning programmes but also involves the development and support of a CoP (or ecosystem) to support thousands of (primarily) young, unemployed people to make a difference in their local neighbourhoods through environmental action. In order for this work to be meaningful, the work is accompanied by a range of training programmes, and support mechanisms for all those involved - from the participant working on the ground, to the leaders of the teams, the programme management team, and youth-led innovation teams in the office facilitating training, media management, administration, mapping, and technological support.

This community of practice provides an incubation system for green entrepreneurship and draws on the digital online micro-credentials and courses, as well as mapped out workstreams for the GL2E pathways. In the DUCT-led SEF programme, the CoP supports 1 000 youth (employed part-time via the SEF) by providing intensive support to all participants in their learning journey through online support, in-person training, surveys and feedback mechanisms, and the development of peer leaders that provide local, relatable role models for participants. The SEF work and skilling opportunity is for a maximum of 18 months, however, and for many people this is just the first step in their journey to a sustainable livelihood. Following this, what is needed is a further 18 months (average) of support to assist people in further skills development, and work experience before they feel able to step into independence. The proposed ecosystem of support for young people is shown in **Figure 11.6**, and summarised as:

- **Pre-incubation, incubation, and transition phase**: In this phase, participants complete their first micro-credentials and develop initial skills with funded support (part time employment). Here the project will identify and support emerging young leaders who will move into the next phase.
- **Post-incubation phase**: In this phase young leaders will be providing leadership and will be supported with a more intense mentorship programme in communities of practice, with some of the practical costs that make work possible – communications, transport, technology, equipment, etc – provided in order to move into the next phase.
    - **Independence** of incubated activities and workstreams (formal / informal jobs and work) in local economies.

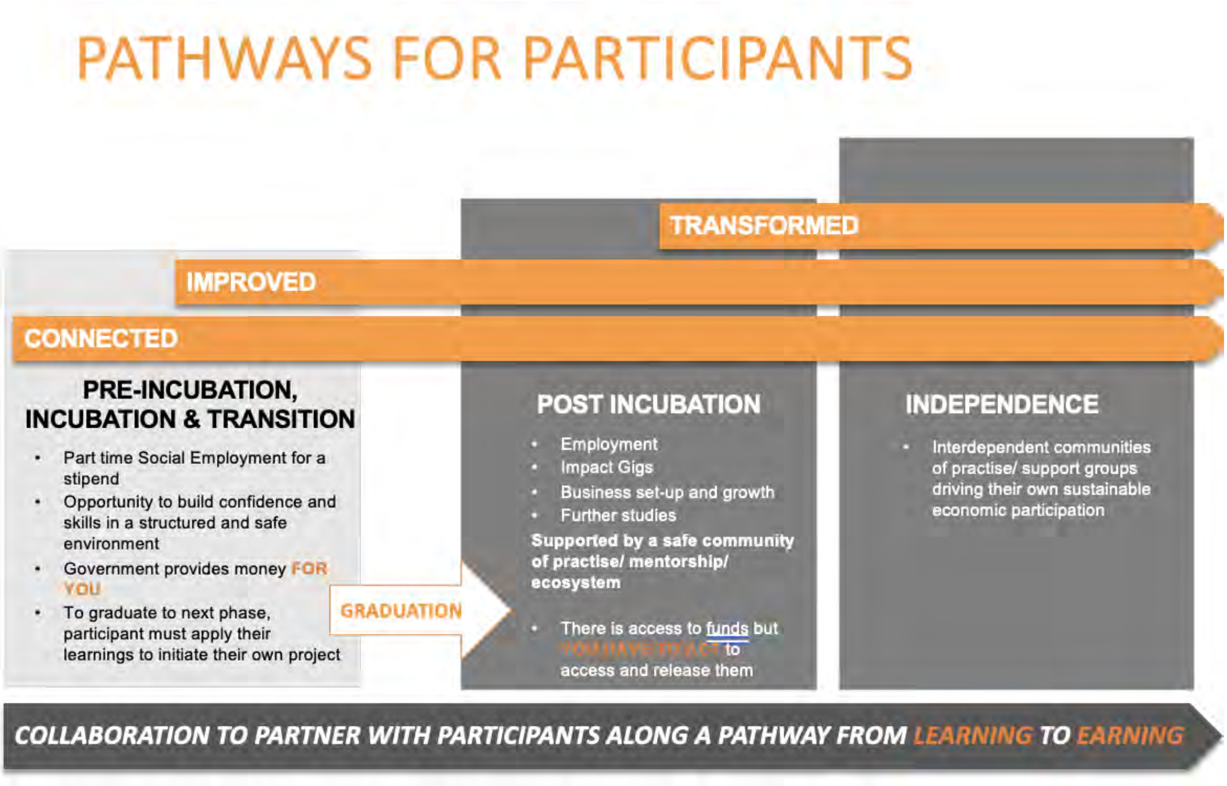


Figure 11.5: Learn to Earn pathway supported via Communities of Practice

In this process, there is need for a strong MERL component. The team need to learn from and with the participants, and ensure their successes and challenges are heard so that pathways can be improved. It is also key to accurately record the impact of the environmental action on the ground in order to clearly communicate the impact of the work, and for the value to be recognised by society. This is crucial to ensure that the workstreams are recognized as viable contributors to the economy, to the just transition, and to climate change resilience.

10.5 Community Public Private Partnership in Catchment Management: Entry Point for Scaling

Building on the Enviro Champs blended finance, action-learning, citizen science-driven environmental monitoring model successfully deployed in the uMngeni catchment[4], it proposed the future of expanding citizen science in South Africa and SADC is in the establishment of community-public-private partnerships (CPPP) for IWRM at catchment/basin levels. Every CPPP will look slightly different, depending on the context, but the essence remains the same – community (predominantly youth) at the heart of the solution. These various basin-level partnerships should then be linked together through policy dialogues, mainstreaming into government budgets, common tools (digital and physical), common training programmes, common data management systems, common MERL frameworks, and co-ordinated funding mechanisms.

[4] Please refer to **Section 3.5.2** for a detailed account of the Enviro Champs programme in the uMngeni Catchment

The key elements and implementation framework outlined below are based on the innovative solutions to roadblocks that were encountered during the scaling of Enviro Champs from 2021-2025 (and ongoing) in the uMngeni catchment. Considering all these hard-earned lessons, the systems and framework suggested are what is now being gradually put in place, in order to move from the current grant-dependent stop-start model, to one that is supported and funded indefinitely through mainstreaming into government budgets, and co-ordinated funding mechanisms.

It is important that a progressive approach is taken, building each of these in parallel, and in a reflexive approach of planning and action. Scaling is not solely based on rapid expansion, but it intends to connect multiple smaller networks and systems to allow vertical scaling[5] (adding complexities by adding new aspects and partnerships), horizontal scaling (through adding more functions, tasks, and roles), and depth scaling (including reflections and gaining deeper understandings of practice) occurring simultaneously. At no time should the systems be developed in isolation to practice, but it is also important that practice does not happen without a framework to guide it.

10.5.1 Communities of Practice

Communities of Practice can drive innovation by bringing diverse perspectives, and expertise, leading to creative solutions that may not emerge out of isolation. Organisations can also share risks and costs, making it easier to undertake ambitious programmes and markets can open up due to the innovation and scale, benefiting all parties. It is therefore imperative that we are intentional about setting up mechanisms for effective collaboration, aligning goals, building trust, and leveraging strengths (illustrated in **Figure 11.7**). There is a sound body of research and practice in the establishment and operation of a CoP to mainstream collaboration.

Figure 11.6 Critical success factors for a community of practice (Blutoc et al., 2021)

Communities of practice at different levels are important in the scaling of citizen science in community-led water resources management. At a catchment/landscape level there are many

[5] Scaling of community-based water quality management is detailed in Lotz-Sisitka *et al.,* (2022) with further explanations of vertical, horizontal, and depth scaling found on pages 103 and 104.

successful partnerships in South Africa – both formal and informal. These all take different forms, and operate at different scales, but in essence all have been established in recognition that collaboration is essential for enabling impact at scale over the long term. Many of these partnerships have citizen science initiatives being implemented by core partner organisations.

For example, members of the UEIP use citizen science as part of their programmes:

- DUCT is implementing the Enviro Champ programme with 1000 people – all who are trained in citizen science tools.
- uMngeni-uThukela Water is rolling out their own programme with young champions – Amanzi Champions – using citizen science tools to monitor pollution and services delivery challenges.
- EThekwini Metropolitan is now starting to use citizen science tools in its Transformative River Management Programme with co-ops and Enviro Champs
- The Institute of Natural Resources uses citizen science to measure changes in soil erosion and water quality with their conservation agriculture and catchment restoration projects

In the uMzimvubu Catchment Partnership, citizen science tools are used by Eco Rangers to test the water quality of springs, monitoring soil erosion in grasslands, and monitoring their rivers.

In the Kruger to Canyons Partnership, linking with the Limpopo Commission there is a programme to increase community participation in the transboundary system through education in citizen science.

Each of these examples are not projects by individual organisations, but rather a growing catchment management approach across multiple organisations, that facilitates sharing of data and includes citizens in decision making tools.

The stakeholder engagement process for this State of CS for WQM research project saw representatives from different organisations connecting through their interest and efforts toward the 2024 CS SoR report. These organic connections were made through sharing the common interest of protecting water ways and monitoring through CS. These connections were based on shared topics of concern, opportunities for collaboration, and due to proximity, *inter alia*. Through the stakeholder engagement process, it was ensured that a space was held for the CoP to organically and informally connect.

However, for CS to become a widespread tool for water monitoring and management, there needs to be an organised CoP at the scale which makes sense for operational management. The CoP should be inclusive, and adaptive, and well-resourced with a core team that can ensure it is relevant and active.

In South Africa, at a national level the recently developed CSA-SA has the potential to stand as the lead organised CoP, promoting and co-ordinating CS efforts across the country. As mentioned in **Chapter 3, Section 3.5**, the CSA-SA intends to have sub-groups which focus on different aspects of CS, and the CS for WQM group would be ideally placed to assist in co-ordinating smaller CoPs and connecting CS practitioners across South Africa, and potentially into other SADC countries through their networks.

10.5.2 *Formal Partnerships*

Out of an active CoP, a formal partnership arrangement needs to evolve with a recognised institutional structure for governance, and implementation oversight. Wherever possible, an existing, functional structure should be the starting point, with some adaptation based on the needs of the new partnership model.

The formal partnership Memorandum of Agreement (MOA) / contract is to primarily govern the financial model. Therefore, this partnership needs to include regulatory oversight institutions, the water supply and water treatment authorities and services providers, and other significant stakeholders. The aim is to establish a long-term performance-based, and impact finance model that collaboratively assists stakeholders to meet their mandates at an affordable cost.

The alignment and integration of CS data with national conventional data is a point to consider in these partnerships as government can benefit from the valuable data and information gathered through CS monitoring programmes. Ideally, national government would buy-in to this model to encourage monitoring at a national scale which would assist in meeting international (SDG) reporting requirements.

10.5.3 *Sustainable Financial Model*

One of the main challenges with CS programmes is the unsustainable financing of these programmes. Short-term programmes are not only unsustainable for finances of the staff employed under these programmes but are also unsustainable to lasting environmental change and to developing longer-term monitoring programmes and bulk sets of data from which to gather information. During CS SoR data collection, most CS efforts were on a voluntary basis or cases where participating organisations incorporated CS monitoring with their routine work. Apart from voluntary efforts and independently funded work, the funding mechanisms were often mentioned to be project-based. Notably, a few responses to excuse participation were due to lack of overall organisational funding to support participation.

As mentioned in the section above, the potential model is an outcomes-based payment system, whereby various stakeholders are willing to pay for/buy certain outputs or impacts generated by Enviro Champs. For example:

- How much is a one data set of water quality results worth? What does it cost to gather that data with a team of trained Enviro Champs using recognised citizen science tools?
- How much is one ton of waste removed from the environment worth? To whom?
- How much does it cost to clear and restore a hectare of green open space? Is someone willing to pay for that environmental and social impact created?
- How much is the data on sewer spillage locations worth to a municipality for improving their turn around times? Or to the catchment management agency for enforcement?
- How much social and economic benefit can be realised by implementing a citizen-led early warning system for potential flood events?
- How much would a national authority pay for accurate, widespread data across a catchment for their SDG 6.3.2 annual reporting?

Each partnership will need to build their own, context-specific blended finance model that shows that the programme is self-sustainable – and determine for themselves the scale at which it becomes viable. Developing these models at catchment scale allows for those on the ground, affected by the management of the water, to be integrally involved in planning, decision-making, and implementing appropriate solutions. However, in order to tap into global opportunities for blended finance, and impact investment, there needs to be collation, and collaboration at a national level if the Enviro Champs model is to truly be scaled across South Africa and the SADC region.

The Enviro Champs Programme in the uMngeni catchment of KwaZulu-Natal started more than 10 years ago (before 2015) but has been growing significantly since the involvement of the Presidential Employment Stimulus Programme in 2020. The programme is currently funded by the South African Government with R23 million per annum, and co-funded by UNICEF South Africa with R2 million per annum and involves 1000 people. Each person is contracted for part-time employment and carry out catchment-related labour-based activities (solid waste management, invasive alien plant control, environmental education, eco-tourism, etc), whilst being provided with a variety of learning pathway opportunities that build their skills and confidence to continue their careers after the 18-month limited duration contract.

It should also be noted that long-term grant funding for such introductory, labour-based programmes has immeasurable positive impact on the people and natural environment. These programmes provide the first steps from unemployment / inexperience, into the economy so that thousands of people can continue their careers with confidence. In addition, the mass work force undertakes essential environmental cleaning and greening services that help improve the state of our river catchments. The key difference is that these programmes should be viewed as the initial phase of work for youth, and not long-term grant dependence. The learn to earn pathways should be designed around the move from dependence to independence over a period (on average) of 3 years. It is important that over this time, the work force is sufficiently trained to then move into other fields of work, or to stay within the community-public-private water resources management model, earning an income as an Enviro Champ. It is this latter model for which requires a sustainable financial model that generates a return on investment that pays for itself and is no longer reliant on grant seed funding.

10.5.4 *Scalable Water Resources Monitoring Programme*

This project has acknowledged that although there are conventional water resources monitoring programmes in place across South Africa, capacity limitations present challenges to monitoring all intended locations in the monitoring network (DWS, 2022b). **Chapter 3** of the CS SoR project report focuses specifically on the current REMP and gaps in monitoring across South Africa. There are large areas where data is not available for planning, management, or reporting. The establishment of supplementary CS-based water monitoring programmes co-designed with authorities, implementers and communities, utilising Enviro Champs, can have significant potential to help monitor all catchments. The 2024 CS SoR report demonstrates this potential through the generation of valuable insights into the state of freshwater across the region gathered on a voluntary basis. However, well trained Enviro Champs, with oversight from young scientists, working with smart technology can provide accurate, reliable data to interested and affected parties. Data points need to be prioritised based on key environmental factors (pollution sources, accessibility, representative sites, flow, etc), as well as funding available to pay for each monthly data set. It is key to start with only a few data points, and build them up as the systems, and support grows. As this is a monitoring programme that relies on monitors in communities (not employees), it is important to not raise expectations that cannot be me regarding payment/remuneration. The monitoring programme is as much a social initiative as a data gathering initiative.

10.6 Water Resources Monitoring Programme: Implementation Framework

The proposed implementation framework, together with the indicative costing and timeline is intended to assist citizen science communities of practice to plan for scaling in a methodical manner. This methodology could be used as the starting point for proposals to secure seed funding for the establishment of a community public private partnership for water resources monitoring.

10.6.1 *Secure seed funding*

It is essential to have grant funding to set up the systems, the support structures, the networks, and the future long-term Enviro Champ work force for citizen science-based water monitoring. A significant investment is needed for this establishment, and in a new catchment/basin, grant funding would most likely be required for at least 5 years for the partnership to develop, mature, and put sustainability mechanisms in place[6].

10.6.2 *Establish governance and partnerships*

- **Stakeholder Identification**: Identify and engage existing appropriate catchment partnerships in the area. Ensure that diverse stakeholders, including local communities, government agencies, NGOs, and academic institutions are all included.
    - **Governance Framework**: Develop a governance structure as part of the partnership to manage the programme, ensuring representation from all stakeholders. Overall governance will be according to the legislative framework of the country/catchment. However, at a more local level, communities of practice need to be formalised to create the framework for a community-public-private partnership. Existing partnerships/networks will be the basis from which the programme works.
    - **Partnership Agreements**: Formalise partnerships through Memorandums of Understanding (MOUs) outlining roles, responsibilities, and collaboration mechanisms.

10.6.3 *Define objectives and scope*

- **Programme Objectives**: Clearly define the goals of the water resources monitoring programme, such as tracking pollution sources, assessing ecosystem health, and informing policy decisions.
- **Geographical Scope**: Determine the specific areas within the catchment where monitoring will take place, considering ecological, social, and political factors.

[6] . The programme in the uMngeni has been severely hampered by stop-start funding. First only 3-months of funding, then 6 months, then 10 month cycles for two years. All with breaks in between. The hope is that soon, 3-years of funding will be secured so that true, consistent growth and maturation can occur. From this experience, and the severe impact it had on many people's livelihoods, and mental health, it is NOT recommended that a large-scale programme be initiated without at least 3 years of seed funding secured.

10.6.4 *Set parameters and intentions for financial sustainability model*

- **Assess the current and potential funding sources**: Before initiating any programmes, identify and secure seed funding for 3-years that will cover the establishment of the programme, and its running costs.
- **Identify stakeholders who need the data/work:** Enviro Champs do essential basic services in monitoring water resources, and positive environmental action. Core to a sustainable model is identifying the partners for whom this data/work is part of their mandate or business service who would be willing to buy the output or impacts generated by Enviro Champs.
- **Develop a transitional economic model:** At the outset, a gradual move from reliance on seed grant funding to a blended finance model, needs to be agreed upon in principle. It is imperative that stakeholders/partners don't expect the programme to be free. A practical, resource economist then needs to work alongside the implementers to develop an appropriate, context specific finance model to show how all the Enviro Champs, tutors, and implementing organisations will be paid.

10.6.5 *Develop a monitoring plan*

- **Parameter and Tool Selection**: Identify key water quality and river health monitoring parameters, and the appropriate, scientifically proven citizen science tool to utilise with access to most appropriate and updated training material. The platform or medium for data recording should also be identified.
- **Monitoring Plan**: Map the intended water monitoring points that citizens should monitor, as well as key control points for sampling by professional scientists.
    - **Incremental Phasing**: Plan the rollout in phases, starting with a pilot phase in selected areas, followed by gradual expansion based on lessons learned.

10.6.6 *Set up online learning platform and support systems*

- **Course design and train the tutors:** Universal access to excellent, best-practice learning content is an important element for scaling. Much work has been / is being done with Rhodes University and other partners to develop a fully-fledged online learning system with a full suite of programmes for emerging "green work"- The GL2E skills programme. However, it should be recognised that this will need to be adapted for local language and context. Course experts will also be required to train a cohort of tutors and provide support throughout the programme as and when needed.
- **Recruit and train tutors:** A network of young tutors who are studying or graduated from appropriate degrees/diplomas will need to be established to provide the online training support and course marking and approval on the learner management system. Tutors will need to earn an income for their work.

10.6.7 *Recruit and Train Citizen Scientists*

- **Community Engagement**: Conduct outreach to engage local communities to build understanding of the programme and clearly define the role of an Enviro Champ. Garner support for the concept of a community-public-private partnership in water resources management. Identify potential Enviro Champs for the programme. Introduce the concept of the GL2E potential, and gauge readiness to participate in such digital opportunities.

- **NGO Training**: Develop and implement training sessions to equip local NGOs with the skills needed for accurate water sampling and data recording, and the support of Enviro Champs. These local communities of practice are essential complements to the online GL2E mechanism.
    - **Training Programs**: Potential Enviro Champs to sign up and engage on the online learning career path to qualify as a water quality monitoring Enviro Champ. Learning consists of course modules and practical tasks.
- **Support and Supervision**: Establish a system of ongoing support and supervision to maintain data quality and Enviro Champ motivation. This will be achieved through a network of peer leaders who have emerged in the online training programme and linking with the local NGO community of practice. Peer leaders will be the top performers who are then further trained to lead a small local network of Enviro Champs.

10.6.8 *Implement Data Collection and Management Systems*

- **Data Collection Tools**: Provide Enviro Champs with necessary tools and equipment, such as sampling kits, phones and mobile apps for data recording.
- **Data Management Platform**: Identify existing water resource monitoring systems in the catchment, and what the gaps are, and the potential complementarity with citizen science data. Work on the integration of these existing systems with a centralized data management platform to store, analyse, and share collected data. Ensure it is accessible to all stakeholders.
    - **Quality Assurance**: Implement quality assurance protocols, including periodic validation of citizen-collected data by professional scientists.

10.6.9 *Data analysis and reporting*

- **Data Analysis**: Analyse collected data to identify trends, pollution hotspots, and areas requiring intervention.
    - **Reporting Mechanisms**: Develop regular reporting mechanisms to share findings with stakeholders, including visual reports, maps, and summaries.
    - **Feedback Mechanisms**: Create feedback mechanisms to inform Enviro Champs of the results and the impact of their contributions, fostering continued engagement.

10.6.10 *Policy integration and advocacy*

- **Policy Linkages**: Integrate findings into local, national, and transboundary water management policies. Advocate for evidence-based policy changes and resource allocation based on monitoring results.
- **Stakeholder Workshops**: Organize workshops and meetings to discuss findings, policy implications, and future actions with all stakeholders.

10.6.11 *Continuous improvement and scaling up*

- **Evaluation and Adaptation**: Periodically evaluate the programme's effectiveness and make necessary adjustments to protocols, training, and governance structures.
- **Scaling Up**: Expand the programme to additional areas within the catchment and replicate successful approaches in other transboundary water systems.

10.7 Indicative Costing and Activities Timelines

In 2024 a proposal for seed funding for the implementation of the Enviro Champs model in the transboundary Limpopo basin was developed. As a part of this process, an operations costing exercise was undertaken to upskill and engage 500 community water resources monitors in strategic points across the basin. The **Tables 11.1 to 11.5** show how some of the baseline costing for the proposal was built up. This is not costing based on an actual functioning programme, and should be used only as a starting point, but may be helpful to others considering scaling citizen science across a catchment, and the long-term costs of training and supporting a scattered group of Enviro Champs who are working fairly independently and paid for each set of water quality monitoring data they submit.

This costing does not include any of the management, systems development, research, communications, and such required. It is purely the cost of the Enviro Champs and their support system – both online, and at ground level. The rates used for the different categories of participant on the ground, are based on what is viewed as the minimum viable rate to keep a person engaged in the programme as a supplementary income source. **Table 11.1** accounts for the potential data cost for youth to participate in the online learning system. This should be set up as a platform cost, and not monies distributed to learners – zero rating of sites, or reverse billing is ideal.

Table 11.1 Potential data cost for youth to participate in the online learning system

Online learners	**Year 1**	**Year 2**	**Year 3**
Learners	200	600	1000
Data	R100.00	R100.00	R100.00
Estimated months	6	6	6
Data per learner	R600.00	R600.00	R600.00
Cost per annum	**R120,000.00**	**R360,000.00**	**R600,000.00**

For the youth to complete online courses, there need to be trained tutors (also youth) who are providing support, and review of work. They will need to be trained and then remunerated for their role. The potential related costs for tutors are as detailed in **Table 11.2.**

Table 11.2 Potential data cost for youth to participate in the online learning system with tutors

Online tutors	Year 1	Year 2	Year 3
Learners (in take every 6 months	100	300	500
Tutors (1 tutor per 20 learners)	5	15	25
Rate per hour	R50.00	R50.00	R50.00
Estimated hours per month	40	40	40
Income per tutor per month	R2,000.00	R2,000.00	R2,000.00
Data cost per tutor per month	R100.00	R100.00	R100.00
no. of months	6.00	6.00	6.00
Intake per annum	2.00	2.00	2.00
Cost per annum	**R126,000.00**	**R378,000.00**	**R630,000.00**

The community citizen scientists or Enviro Champs need to earn sufficient income per month for monitoring several data points. A recommendation of 10 points per Enviro Champ. This is yet to be tested for practicality in terms of the walking time to points, and whether it is viable. However, the basic calculations in **Table 11.3** for Enviro Champs and **Table 11.4** for Enviro Champ leaders shows how costs for a water quality programme can quickly escalate and need to be carefully considered. Communities of practice are not just for NGOs, or catchment level stakeholders – they are also for Enviro Champs. Due to the remote nature of the work, it is very important to have a support system for continuous learning, accountability, and data verification. It is thus recommended that Enviro Champs work in networks of 10, with one being a leader with additional duties alongside their water data collection.

Table 11.3 Costs for recruiting Enviro Champs in a water quality programme

Community Citizen scientists	Year 1	Year 2	Year 3
Data Points	1000	3000	5000
Citizen scientists (10 data points per person)	100	300	500
Rate per data point	R100.00	R100.00	R100.00
Income per person per month	R1,000.00	R1,000.00	R1,000.00
Data cost per CS per month	R100.00	R100.00	R100.00

No. of months	9.00	12.00	12.00
Cost per annum	**R990,000.00**	**R3,960,000.00**	**R6,600,000.00**

Table 11.4 Costs for recruiting Enviro Champ leaders in a water quality programme

Community Peer leaders	**Year 1**	**Year 2**	**Year 3**
Monitors	100	300	500
Peer Leaders (1 leader per 10 citizen scientists)	10	30	50
Rate per hour	R40.00	R40.00	R40.00
Estimated hours per month	25	25	25
Income per leader per month	R1,000.00	R1,000.00	R1,000.00
No. of months	9.00	12.00	12.00
Cost per annum	**R90,000.00**	**R360,000.00**	**R600,000.00**

The support from a local NGO is also critical in the community of practice, accountability, and data verification. One youth mentor that supports 100 Enviro Champs is recommended. Ideally this person also has deeper scientific understanding of water resources (perhaps SASS 5 accreditation), can verify the data of the 100 Enviro Champs, and provide ongoing training to the peer leaders. The costs associated with having a youth mentor are detailed in **Table 11.5**.

Table 11.5 Costs for an NGO youth mentor in a water monitoring programme

NGO support	**Year 1**	**Year 2**	**Year 3**
Monitors	100	300	500
Mentor/admin (1 per 100 citizen scientists)	1	3	5
Rate per hour	R100.00	R100.00	R100.00
Estimated hours per month	167	167	167
Income per leader per month	R16,700.00	R16,700.00	R16,700.00
No. of months	9.00	12.00	12.00

Cost per annum	**R150,300.00**	**R601,200.00**	**R1,002,000.00**

The activities in the programme set out in **Figure 11.8** below are indicative of the process of establishing a monitoring programme in a catchment. The focus is not just the data, but rather the learning ecosystem for the youth. There is high attrition in such learning and earning programmes, and this is designed for a new intake of youth into the online learning course every 6 months. Not all learners would progress into income earning opportunities as monitors. The course graduation results, and the relationship built by learners in their areas of residence are all factors in the selection of monitors that are likely to be the most reliable. It is hoped that many youths who graduate use this as a stepping stone to other income opportunities, and thus the CS training programme is just as important an impact as the community-based water monitoring programme that is established.

Activities	Year 1				Year 2				Year 3			
	1	2	3	4	5	6	7	8	9	10	11	12
Citizen Science based Water Resources Monitoring Programme												
LIMPOPO:												
1.1 Data management agreement with each country		■										
1.2 LIMIS integrated incremental monitoring plan			■									
1.3 Monthly citizen science data								■	■	■	■	■
1.4 Citizen science annual state of rivers report												■
Communities of practice for environmental action												
LIMPOPO:												
2.1 Identification and MOAs with key local NGOs		■	■									
2.2 In-person training of local NGOs in priority zones				■								
2.3 Quarterly community of practice engagements					■	■	■	■	■	■	■	■
2.4 Youth green entrepreneurs network online events								■		■		■
Green Learn to Earn Online Skills programme												
LIMPOPO:												
3.1 MOA with local universities (one per country)		■										
3.2 Learn to Earn Plan (agreed by country reps) with incentive		■										
3.3 Translation of online programme into local languages (2 per annum)		■	■									
3.4 Establishment of a team of online youth tutors		■	■	■								
3.5 Online recruitment and training of potential Enviro Champs and Peer leaders					■	■						
3.6 Selection of Peer leaders from online graduates							■					
3.7 In person training of peer leaders (Train the trainer)							■	■				
3.8. Graduation ceremonies and awards every 6 months							■		■		■	
3.9 Ongoing earning and learning opportunities for added skill sets and environmental actions									■	■	■	■
3.10 Online recruitment and new batch of potential Enviro Champs and Peer leaders every 6 months							■		■		■	
Reporting				■				■				■
Managing Staff		■	■	■	■	■	■	■	■	■	■	■

Figure 11.7 Programme activities for establishing a water monitoring programme in a catchment

10.8 Conclusion

This report provides an analysis of the current state, challenges, and future directions of CS for WQM within South Africa. The findings and recommendations presented in this report highlight the critical role of citizen science in addressing water quality issues, fostering community engagement, and promoting sustainable development.

Key Findings

- **Water Quality Challenges**: Southern Africa faces significant water quality and quantity challenges due to climate change, population growth, poor infrastructure management, and environmental degradation. The report underscores the urgent need for improved water resources management to address these issues.
- **Role of Citizen Science**: Citizen science has emerged as a vital tool for enhancing public participation in water quality monitoring and management. It empowers communities to take an active role in environmental stewardship, thereby increasing scientific literacy and fostering local solutions to water quality problems.
- **Youth Engagement**: The involvement of youth as citizen scientists is particularly emphasized. Programs like the "Enviro Champs" model demonstrate the potential of engaging young people in meaningful environmental work, providing them with skills and opportunities while addressing critical water quality issues.
- **Community Public-Private Partnerships (CPPP)**: The establishment of CPPPs at the catchment level to ensure sustainable and scalable water resources management is key. These partnerships should blend grant funding, corporate social investment, and other financial models to create long-term, self-sustaining programs.
- **Implementation Framework**: A detailed implementation framework is provided, outlining steps for securing seed funding, establishing governance structures, defining objectives, developing monitoring plans, and integrating policy advocacy. This framework serves as a practical guide for scaling citizen science initiatives across the region.
- **Green Learn-to-Earn (GL2E) Skills Program**: Integrating skills development into citizen science programs is essential. The GL2E program aims to provide youth with digital and practical skills, creating pathways to employment and contributing to the green economy.

Recommendations

- **Strengthening Community Engagement**: It is essential to continue fostering community participation in water quality monitoring. This involves building trust, leveraging local knowledge, and ensuring that communities are actively involved in decision-making processes.
- **Expanding Youth Programs**: Scaling up youth engagement initiatives like the Enviro Champs model is crucial. Providing training, mentorship, and employment opportunities for young people can address both environmental and socio-economic challenges.
- **Establishing Sustainable Financial Models**: Developing blended finance models that combine grant funding, payments for data, and other innovative financing mechanisms is necessary to ensure the long-term sustainability of citizen science programs.
- **Enhancing Data Collection and Management**: Implementing robust data collection and management systems is vital for the credibility and effectiveness of citizen science initiatives. This includes providing citizen scientists with the necessary tools and training to collect accurate and reliable data.
- **Policy Integration and Advocacy**: Integrating citizen science findings into local, national, and transboundary water management policies is essential. Advocacy efforts should focus on evidence-based policy changes and resource allocation to support citizen science initiatives.
- **Continuous Improvement and Scaling Up**: Regular evaluation and adaptation of citizen science programs are necessary to ensure their effectiveness. Scaling up successful models to

additional areas and replicating best practices across the SADC region will enhance the impact of these initiatives.

The report underscores the transformative potential of citizen science in addressing water quality challenges in Southern Africa. By empowering communities, engaging youth, and fostering innovative partnerships, citizen science can play a pivotal role in promoting sustainable water management and contributing to the broader goals of sustainable development. The recommendations provided offer a clear roadmap for scaling and sustaining citizen science initiatives, ensuring that they continue to deliver meaningful environmental and socio-economic benefits.

11. Recommendations

Through this exploration of the state of CS for WQM, several insights have been revealed which touch on the future of CS for WQM. These insights have further provided recommendations for future research, developments, and CS applications in a South African context. These recommendations are categorised in the sections to follow.

11.1 Future research suggestions

The correct use of the CS tools is vital for the CS data observed to hold credibility. The procedures on the use of the tools should be standardised across all users. Under the WRC project on Citizen Science Online Training and Learning System (WRC C2022/2023-00841; Russell *et al.,* 2024), the open access materials on the use of the tools are encouraged to be used by the CS CoP to use to adhere to standard procedures. However, through the engagements with collaborators during the data collection phase of this project, it was apparent that the availability of these resources is not well known, and there were still hesitancies with beginning to use CS tools due to uncertainties around training costs. The recommendation here would be for the CS CoP to be made aware of these resources through greater promotion by the organisations who played a role in producing these resources and other keen individuals, NGOs, groups and institutions who have used these resources. This promotion would not only be a step in making CS more accessible, but it would also aid in encouraging the standardised uptake of techniques, leading to credible data collected.

Another insight which was revealed was the capability of CS tools and techniques. Notably, it is recommended that focused and extensive research and testing of the WaterCAN and Freshwater Watch kits in varying river conditions and across season is conducted and potentially reconciled into a new CS chemical monitoring tool. It is also strongly recommended that the users are trained, and the usage is verified by experience users in-person, where possible. Although there is a suite of tools for CS for WQM, the further development of tools for other aspects around river health can also be developed. Such examples could be an exploration of the potential for CS to aid in informing fish monitoring in South Africa such as the techniques considered by Aura *et al.,* (2021) in Kenya and DiBasttista *et al.,* (2021) across Australasia. These innovations and further research can be hindered by the existing uncertainties around funding, resources, and data ownership – all of which are valid concerns for further investment of time and resources. However, the potential for large volumes of data to be produced and wealth of knowledge generation can encourage the motivation for investment in CS.

11.2 Consolidation of citizen science efforts

Statistics South Africa (2019) make mention of the uncoordinated government monitoring efforts as a reason for lack of data to report on SDG 6.3.2. In the case of CS, during the stakeholder engagement with CS SoR collaborators, the CoP which have formed over localities across the southern African region reported that there is lack of connection with other CS practitioners around the, and uncertainties in who else could possibly be monitoring along the same or nearby river systems. This incoordination carries true in CS and hinders progression where efforts can potentially be duplicated. Through this short-term CS exploration, the collaborators with which the project team were liaising, the connections between CS practitioners were encouraged, and the spatial distribution of these practitioners and their monitoring locations was communicated through a Google Earth with metadata (including contact information) for collaborators to use. However, this is a temporary solution requiring the file to be updated frequently and locations and practitioners involved change. The broader CoP could benefit from a dynamic system to use to connect. A recommendation here would be for the CSA-SA to develop such a system, perhaps through membership and using social media platforms to encourage connectivity. This lack of co-ordination in monitoring could also be a contributing factor to the reluctancy to share data.

Throughout the project, the project team has encouraged collaboration with stakeholders from varying sectors to connect – this includes public, private, civil society, and education. In the exploration of the potential for CS to aid national and international WRM, there is a recommendation for the CS data to be used by the relevant government departments as supplementary data for water resources monitoring and reporting. However, it is encouraged that these departments must support the data collection process be it through training, finance, data management, or other. This condition is to support a mutually beneficial working relationship between government and non-governmental organisations. This also aligns with the nature of CS to be inclusive.

11.3 Alignment with existing environmental programmes

During the generation of the 2024 CS SoR report, the collaborating organisations or groups varied in terms of experience with CS. Several of the collaborating organisations had already been part of existing CS programmes (previously or at the time) however there were other organisations which found CS to be a worthwhile addition to routine monitoring. One such example are those groups who were already conducting monitoring using conventional methods, and added in CS methods, and another which led river clean-ups found it useful to get local volunteers to engage with environmental issues. A recommendation here would be an exploration of the benefits for existing environment-related programmes to incorporate CS as part of their key activities such as conservancies, environmental tourism agencies, and environmental education organisations. These explorations could aid organisations in unveiling new practices which they'd have interest in taking up as well as the potential to unlock other funding opportunities which are aligned with CS.

Another recommended exploration is into the potential incorporation of CS applications in the existing EPWP structures in South Africa, aiming to democratise water resources management and promote the notions of environmental stewardship. However, this approach is encouraged to align to the notions of sustainable partnerships for catchment management, so that the programme does not only benefit environmental monitoring but has socioeconomic benefits too through providing people with learning and earning pathways. This exploration can also drive the continuity of CS practices through this EPWP approach. An example of such has been demonstrated by SEF project led by DUCT and elaborated in **Section 7.5.9.** This suggestion of incorporation of CS in existing EPWP structures is not new and has been detailed in the revised Adopt-A-River framework (Graham *et al.,* 2016). However, considering the advancements in the green financing and the learn-to-earn space, it is recommended that these leading parties connect and explore opportunities to advance CS monitoring efforts, and career pathing in the green space.

@Another alignment which became apparent during the exploration of CS continuity in tertiary level research, is the alignment of CS with the curricula at basic education level. This includes primary and high school considerations in subjects such as Life Science, Natural Science, and Geography. CS focused local field trips have the potential to provide scholars with a practical experience of the content which they're learning about in the classroom and immerse them in an experiential learning experience. Outside of the curricula but still at the primary or high school levels is the uptake of CS applications in extra-curricular activities such as part of eco or environmental clubs. Further is the exposure to CS through youth groups outside of the school setting such as the Scouts.

11.4 Investment in citizen science

CS applications can be used as a research tool in research topics at tertiary education level. This approach aids in the continuity of CS practices as well as the encouragement of recognising the value of CS. These approaches can be applied to aid advancements in a particular research topic, or the topic can be on advancing a specific CS approach(es).

Corporations and businesses may also opt to become involved in CS through their corporate social investments through working with schools, their own programmes to adopt a portion of the river to monitor, or use days of recognition to promote CS, e.g. conducting a clean-up and monitoring at a local river on World Water Day on 22 March each year.

11.5 Citizen science data handling

A recommendation for further research would be into the cost, logistics, ownership, and other factors to consider for the development and maintenance of a central database for CS data. The WWQA (2024b) have highlighted the exploration of data integration methods as a focal point in instances where both conventional, authority data and CS data are available. Thus, a central database would be essential for this exploration as a step towards using CS data for national and international reporting.

The suggested ideal scenario would see all types of CS WQM data to be hosted on a central platform for access by the broader CS CoP. This CoP would include all practitioners from private, public, civil society, and education spaces. However, other explorations on how best to integrate the data are encouraged as the integrations will vary as they are contextualised.

Another consideration would be how the database would be structured to be able to feed the data to all users including government for use in national and international reporting. Further, a suggestion mentioned was to have the data already being presented in a dashboard with simplified graphs and tables which users can easily interpret and use for their purposes.

A recurring insight throughout this project has been around the value of CS data which often led to a discussion around the ownership of data, and the access and sharing of these data. This forms part of a bigger conversation around sustainable funding models for CS work, and the stakeholders who would finance these models.

In terms of national reporting, the generation of the bulk set of CS data across South Africa (and neighbouring countries) demonstrates the potential for the DWS to further support this readily available solution to water resource monitoring limitations. The alignment of CS data in policy and reporting, particularly the DWS NWRS-3, has been highlighted and the data generated strengthens this point to encourage the integration of CS with regulatory data in DWS reporting and monitoring objectives. It is therefore recommended that this project be used as a case example for the application of CS, and the potential wealth of data which can be unlocked through strategic, supported, and sustained CS monitoring.

12. Conclusions from Overall Study

The growing water resources quality challenges and the decline in capacity to fully monitor river systems in South Africa led to this evaluation of the potential of CS to aid in water resources monitoring and management. The vast stretches of rivers across southern Africa, the dynamics of rivers flowing through inaccessible or private spaces, and the complexities of conventional monitoring are hinderances to river health monitoring which cannot be undertaken by government alone. The water resources challenges which are being faced nationally require broad intervention from government, society, the private sector, educational sector, and more. This motivates for the adoption of CS techniques characterised by their ease of use, reliability as an indicator, and their applicability across large spatial scales. Literature and practical applications on CS in the generation of the *2024 Citizen Science State of Rivers Report* have demonstrated that there is great potential for CS techniques to be used as indicators for river health. This evaluation of the state of CS for WQM has revealed many insights regarding the current reality and future potential of CS applications, the benefits and limitations of CS techniques, and the motivations and reluctance to use CS data for water resource reporting.

Engagements with the currently active CS community revealed the perceptions of the current state of CS for WQM. The overall view is that of acknowledgement of the great potential for CS to contribute to informing on the state of rivers, and its capacity to be used as a tool for environmental education, awareness, and advocacy. Further to this, stakeholder engagements prompted discussion around the availability and monetary value which should be assigned to CS data; although this exploration does not fall within the scope of this study, it is a vital aspect to explore in further research which some of the other mentioned current CS research will be aiming to investigate. Although the overall perception is in support of CS applications for WQM, the concern of standardised data collection was highlighted, emphasising the impact this would have on data credibility. There exists an overall call for more strategic, inclusive, and co-ordinated CS monitoring to allow for reliable, comprehensive datasets to be gathered whilst fostering connectivity of the CS CoP.

Interviews with key CS practitioners highlighted the great potential for river monitoring on a large spatial scale and in real-time but expressed concern over practical standardisation of monitoring methodologies for the techniques applied, thus hesitancy to use CS for reporting beyond community and project scales. This point has been greatly considered by Russell *et al.,* (2024) through the creation of online, freely available, and simplified instructional materials and tools. The interviews also touched on the sustainability of CS efforts both in terms of the lack of long-term funding mechanisms and ongoing skills development for those who are hired to collect CS data. These limitations require further research and innovative solutions for CS efforts to be strategic and benefit broader NWRM.

Further to benefitting NWRM, the alignment of civilian involvement in WRM with South African policy and legislation provides impetus on the recognition of CS techniques as valuable in the WQM space. Within the suite of CS tools available, there does exist limitations of CS equivalent techniques comparable to conventional monitoring techniques (for example, a CS technique which can be used as an equivalent to collecting data on fish or vegetation) and in the range of tools (for example, the clarity tube clarity values could be easier to compare to the Secchi tube turbidity values if these turbidity readings could also be indicated on the clarity tube). Although the applications of CS beyond data collection and language barriers have been noted as limitations to CS, steps to resolve this have recently and/or are currently being explored such as online learning tools for remote CS learning and the translation of CS material into other languages. However, it must be emphasised that the encouragement of CS is for it to supplement conventional monitoring models (spatially, temporally, and conceptually in terms of inclusion of civilians in WRM) and not to replace it. CS has great potential to aid existing processes, as evident from the generation of the CS SoR report for select rivers across the region. However, it cannot replace conventional monitoring but rather aid in filling spatial gaps in monitoring and conceptual gaps in encouraging citizens to play a role in NWRM.

Throughout this project, the communication and connection with collaborators has been essential in encouraging and strengthening the CS CoP and developing this case study toward evaluating the potential of CS. Furthermore, this CS SoR exploration prompted the developing CS CoP to connect, encouraged local participation in CS engagements, and sparked conversations around the current and future state of CS with stakeholders with varying experience in the CS space. This research demonstrated that co-ordinated efforts and shared engagement of the proactive CS community has huge collaborative potential to support WQM. The voluntary endeavours which have assisted in generating the *2024 Citizen Science State of Rivers Report* highlight the ability to mobilise the CoP across the region. It is through these networks that applying standardised data collection methods can also be encouraged, and refresher training sessions could be facilitated within local CoP. Undoubtedly, CS has also been recognised as an educational tool to spread environmental awareness and knowledge of the state of river systems and holds a power in facilitating experiential learning. Further, CS has demonstrated to be a useful tool to facilitate experiential learning and an interactive way to highlight environmental issues by getting citizens involved in the monitoring of wate resources. This evaluation has revealed an undeniable benefit of using CS for engaged learning, and the CoP across southern Africa have been testament to that.

Through comparative analysis of CS datasets against conventionally collected datasets, the scepticism surrounding the validity of CS practice can, to an extent, be alleviated given the agreement between these datasets. This is also considering the prioritisation and emphasis on collaborators to follow standardised methodologies when using CS techniques, as with conventional monitoring protocol. This analysis sought to shift the attention from concern around the validity of data to focus on the potential CS applications in water resources monitoring and management. However, prevailing hesitancy with using CS-based data for reporting is based on uncertainties in how the users use the tools, errors in data submission, and concerns over the capacity of the tool to efficiently produce reliable data. The innovations of online learning materials, the development of the AI-aligned miniSASS application, and the online verification systems act as interventions that validate the use of sound CS data for national and international water resources reporting. Reasonable remuneration for the collection of CS data has also been called upon to motivate citizen scientists to ensure that the data being collected is valid by adhering to standard collection techniques.

Having been recognised as an acceptable and readily available alternate to WQM of parameters to inform SDG 6.3.2, the uptake of CS methodologies has been encouraged at an international level. As part of informing SDG indicator 6.3.2, the CS data collected covers parameters on both Levels 1 and 2. Level 1 includes the nitrate and phosphate results. At a Level 2 reporting, biological approaches have been acknowledged and here exists potential for miniSASS to become recognised as an acceptable approach. It is recommended that the Freshwater Watch and WaterCAN kit applications be investigated further in a South African context, to enhance obtaining data of higher reliability which can then be used with more confidence in national and international water resources reporting.

To evaluate the state of CS for WQM without consideration of the funded programmes which promote, participate in, and support CS efforts would be remiss. This work has revealed uncertainties which exist in the sustainable financing of CS efforts, even though the value of CS for monitoring and education has been acknowledged. Impact financing models are being considered for funding opportunities in the green space, and this appears to have promise. However, the ownership and monetary value of CS data is still a contentious topic. Factors to be considered here are where the data would be stored, how would transactions be facilitated, how much is each dataset worth, and how would the buyer be ensured of quality in the dataset which they would intend to purchase. The generation of the *2024 Citizen Science State of Rivers Report* highlighted both spatial and conceptual gaps in the current national water quality monitoring programme. With sustainable funding mechanisms and, much requested, streamlined data handling systems in place, including a central database which pulls CS data through from other platforms, programmes such as the DWS Adopt a River programme, Amanzi ethu Nobuntu, and the various efforts around the country, South Africa has great opportunity to unlock WQM data across river networks throughout the country, while promoting the active involvement of citizens in WRM and capacitating people with skills to monitor impacts on water resources.

While the research and investigation continue on the matters above by CS researchers and investors, the facilitation of CS initiatives continues. The research which is being led by the Rhodes University team are eager to establish the learning pathways which can be facilitated for the Enviro Champs model. These pathways are being established to motivate for the Enviro Champs to be able to receive credentials for the CS work and skills related to their experience which they have gained through participation in the CS programme. Current and upcoming research in the CS space demonstrates the current and proposed investment in exploring applications of CS in addressing issues beyond WQM, such as using CS practices as a basis from which to unlock a new career pathway. The miniSASS-YOMA pilot programme formed part of this exploration encouraging the development of green skills through incentivised youth participation in CS biomonitoring. Through those ongoing research efforts, the concern around the continuity of CS practices will be addressed.

However, this research project has highlighted the alignment between CS and curricula at higher education institutions in South Africa. The demonstrated potential for integration and incorporation of CS theory and/or practice in these curricula revealed opportunities for continuity of both CS practices and research.

Upon evaluating this project against the CSIAF, this project (and other linked research projects) had varying degrees of influence on society, the environment, science and technology, economics, and governance. A recommendation for future iterations of efforts to produce a CS SoR report would include a focus on connecting with the existing CS CoP, using the information provided through this project, to aid in co-ordinating monitoring and prompt concentrated efforts in CS WQM. Another recommendation would be for the project in its entirety to be evaluated through a review against the CSIAF after the project contents and report has been publicly distributed, and feedback has been received.

While acknowledging the challenges and limitations in CS applications, the current uptake, reach, and use of these applications demonstrate significant potential, with room for improvement through focused research efforts.

Future research can evaluate a State of Rivers reports from a CS perspective against that from a national, conventional perspective for the exact same time and location. This would further evaluate the potential for CS applications in the locations which government has already deemed priority points. This could also have the potential to initiate engagements between government and society on the prioritisation of certain monitoring points over others, and aid in facilitating a dialogue for environmental and water resources related concerns.

In the application of CS to align and support national water resources monitoring, a recommendation would be catchment-based intervention mapping to identify problem areas motivated by community groups who have invaluable first-hand knowledge and experience of these spaces. Using and encouraging CS in these spaces to generate data which can be brought to the forefront to motivate for change

Overall, CS has demonstrated great potential through this evaluation study. Not only for its ability to produce sound bulk datasets for WQM to aid reporting and research, but also in its value beyond data. This includes as an educational tool, as a tool to promote environmental conservation efforts, and as a tool for advocacy, giving a voice to those who are vulnerable to water quality challenges.

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Appendix A

WRC/UKZN Workshop: The State of Citizen Science for Water Quality Monitoring (CS for WQM)

Participants Programme

Date: 20 October 2023

Time: 08h30 – 15h00

Venue: UKZN, Pietermaritzburg or Microsoft Teams (MS Teams) Meeting

Time	Session	Facilitator
08h30 – 09h00	Registration and tea	
09h00 – 09h10	1. Welcome and introduction. Objectives for the day. *MS Teams Meeting to begin at 08h55*	Simphiwe Ngcobo (UKZN)
09h10 – 09h50	2. Mapping activity: Mapping out where CS for WQM work is underway	Sim'lindile Mahlaba (GroundTruth)
09h50 – 10h40	3. Past and current CS for WQM programmes: lessons learned, engagement with the tools, connections back to environmental issues, etc.	Tanisha Curtis (GroundTruth)
10h40 – 11h10	Tea	
11h10 – 12h00	4. Investments in the future of CS for WQM: UNICEF partnerships with DUCT (YOMA) and Rhodes University (Operational Research)	Tanisha Curtis (GroundTruth) Charlene Russell and Nkosi Sithole (GroundTruth)
12h00 – 13h00	Lunch	
13h00 – 14h00	5. Break-away group discussions on CS for WQM work in the future. Each sector (public, private and education) to discuss their thoughts on the future of CS for WQM, how it can be useful in environmental reporting, how the tools can be expanded. Feedback will be given by a representative from each group.	Private: Ayanda Lepheana (GroundTruth) Public: Tanisha Curtis (GroundTruth) Education: Simphiwe Ngcobo (UKZN)
14h00 – 14h45	6. MiniSASS developments and platform brainstorm for CS for WQM content	Nicholas Pattinson (GroundTruth)
14h45 – 15h00	Closing and thanks	Simphiwe Ngcobo (UKZN)

Appendix B

How to use the Clarity Tube

STEP 1:

Place the clarity tube with the open end facing upstream. Make sure the disc is pushed to the end of clarity tube, so that it doesn't stop the water flowing into the tube.

STEP 2:

Fill the tube with water from the river or stream. Make sure that the tube is completely submerged under the water. Tap the tube to get rid of the bubbles, then close the tube. Close the tube with the stopper cap- make sure it is completely on.

STEP 3:
To hold the tube:

(i) With the sun on your back, stand facing towards the sun.
(ii) Put your left or right arm out your side.
(ii) Position your Clarity Tube in the direction of your outstretched arm, to make sure that the sun is shining in the tube.

STEP 4:

To find the disappearing value:

Pull the disc away from you until you can't see it. Record the value at the place it disappears.

STEP 5:

To find the appearing value:

Pull the disc toward you until it appears. Record the value at the place it appears.

STEP 6:

Use these 2 values to calculate and average. Add them together and divide by two. This final result is the clarity measurement of the river.

How to use a Clarity Tube

Taken from WRC Project 2022/2023-00841

Appendix C

GroundTruth

How to use the miniSASS toolkit

WATER RESEARCH

STEP 1: SAMPLING FOR ROCKY HABITAT

- Shuffle your feet and kick the bigger rocks inside the water.
- As you do this your net should be placed in front of you, to catch anything that has knocked off the rocks.

- As you sample in this habitat ensure that you are not standing in the way of anything that would flow into the net.

STEP 2: SAMPLING FOR GRAVEL,SAND AND MUD (GSM) HABITAT

- Wiggle your feet into the mud and make the sand and mud float into the water.

- Sweep and scoop up the net through the dirty and muddy water; careful not to get too much mud and sand in the net.

STEP 3: SAMPLING FOR VEGETATIVE HABITAT

Choose patches of plants that are different from each other to sample. Push your net under your vegetation and scoop it up in a circular motion, splashing and catching the water under your net.

Sampling of the 3 all different habitats should take 5 mins in total.

STEP 4-6:IDENTIFYING MACROINVERTERBRAE

Using the key to identify macroinverterbrae

- On the score sheet (image 5), circle the sensitivity scores of the identified organisms).
- Add up all of the sensitivity scores.
- Divide the total of the sensitivity scores by the number of groups identified.
- The result is **the average score**, which can be interpreted using the ecological condition table (image 6).

GroundTruth

How to use the miniSASS toolkit

WATER RESEARCH

Taken from WRC Project 2022/2023-00841

Appendix D

How to use the Velocity Plank

At 3 points across the river, measure depth and change in height

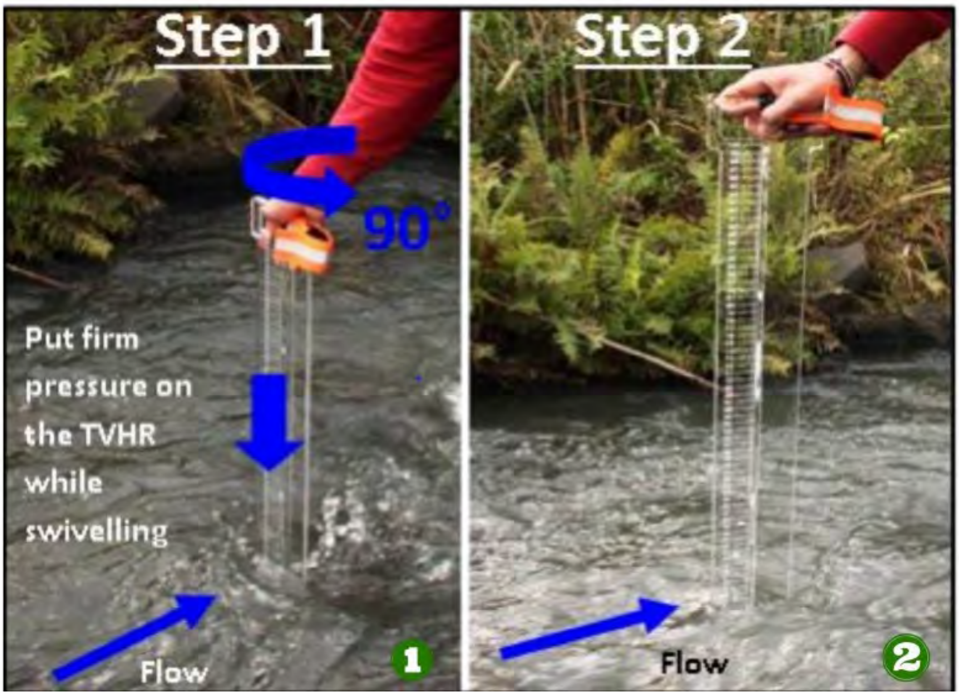
STEP 1: HOW TO MEASURE DEPTH

- Measure the depth at 3 points in the width of the stream.
- Place the velocity plank in the flow of the river so that the narrow side is facing the moving water. The water should easily wash around it.
- Record the depth of measurement.
- Do not stand in front of the Velocity Plank, as this will alter the stream flow which will influence the readings you take.

STEP 2:HOW TO MEASURE CHANGE IN HEIGHT

- Place the velocity plank perpendicular (at 90 degrees) to the stream flow.
- Observe the maximum and minimum height reached by the water on the V.Plank for 20 seconds.
- **(Max height of water - lower point)= difference in height.**
- Do this process for the same 3 points in the width of the stream.

How to use the Velocity Plank



Taken from WRC Project 2022/2023-00841

Appendix E

Date	Event/Meeting Title	Key Meeting Attendees	Key Relevant Discussion Points	Est. no. people
2024/02/13	DWS National Water Monitoring Committee (NWMC)	Task team members including government and private sector representatives	Presentation of State of Rivers project and appeal for support. Points raised in the effort for this project to contribute to CS research and broader water resource monitoring and management	Unknown
2024/02/21	Bush Radio: Community Farmers Radio show	Tanisha Curtis presented on the Women of the Soil segment	Encouraging participation in the CS SoR efforts	Unknown
2024/07/04	IIE MSA Water Symposium	Public event and presenters included representatives from UNICEF, UKZN, GroundTruth, SANBI, CSA-SA, WaterCAN, UJ, and EEIA	Presenters covered varying topics. Opportunity was used to promote participation in the CS SoR data collection efforts	100
2024/08/07	WaterCAN Women in Citizen Science Webinar	Panellists included Tanisha Curtis (UKZN/GroundTruth), and representatives from WaterCAN and Carolina Eco	Discussions were around what is CS, how has it been applied, what does it mean for different users and how it has supplemented what the different organisations are trying to achieve	40
2024/10/20	WRC/UKZN Citizen Science Workshop	Various	Discussions were facilitated to gain an understanding of the current CS landscape and the potential for the future of CS from experienced practitioners	60

2024/02/01	WRC/UKZN Citizen Science State of Rivers Workshop	Various (public meeting) with over 200 attendees	Introduction to the phase of the project which aims to produce a State of Rivers report from a citizen science perspective	200
2024/10/30	UKZN PRIS 2024	UKZN students, staff and representatives from uMngeni-uThukela Water	Presentation of the evaluation of CS for WQM as part of MSc (Tanisha Curtis)	40
2024/09/27	UNESCO Photo Story Competition Launch	DWS, Hennops River Revival, SANBI, Friends of Toloane	To facilitate discussions around our relationships with our water resources and to introduce the photo story competition	in-person and online approx. 40
2024/10/17	Fountainhill Research Symposium	Various	Various recent and ongoing research in the greater Umgeni area	50
Sept/Oct 2024	Europe Study Tour	Various	Workshops, guest lectures, and meetings to speak about CS developments in South Africa and potential collaborations	Unknown
2024/03/14	WWQA Meeting	International Members of the WWQA	Discussions on trailing the use of Freshwater Watch kits in South Africa and the potential for CS to aid SDG 6.3.2 reporting. Progress on the CS for SDG 6.3.2. technical and policy briefs	12
2024/11/07	WWQA Meeting	International Members of the WWQA	General including updates on applying the use of the Freshwater Watch kits for the CS SoR work	30

2024/03/25	Meeting with St Charles' College	SCC and GroundTruth representatives	Discussion of the potential for PMB schools (and beyond) to align aspects of CS in the curricula and how to encourage uptake of CS by schools	4
2024/03/15	Ripples of Change	Various - hosted at Varsity College PMB	Water security in PMB and Umgeni catchment	45
2024/05/20	Student Session at Varsity College with DUCT	GT and DUCT representatives	Promoting the miniSASS-YOMA opportunities to students which would also contribute to SoR data collection	40
2024/05/22	SANBI Biodiversity Day	Umgeni Water, Eskom, Primary Schools from across PMB, Ezemvelo KZN Wildlife	Various	300
2024/03/14	Planning meeting with UUW	Representative from UUW, GT, and UKZN	Various including support for the SoR project	6
2024/08/03	Learning Pathways for Citizen Science: Workshop	Rhodes learning pathway for river commons stakeholders including stakeholders from GroundTruth, UKZN, DUCT, Rhodes University, Mpophomeni Enviro Champs, Conservation Outcomes, SAEON, Palmiet Enviro Champs, WESSA, WWF, UNICEF	• Learning to earn pathway is taking place digitally – but a permanent home for this training content beyond the pilot is undetermined. A potential solution to this could be linking it to the proposed CS in SA platform mentioned in the meeting on 01 August 2023. • Reasonable remuneration for the work being done on the ground which will create valuable data to be used for government and international reporting. • Conversations with the Enviro Champs on their experiences – continuity being a major issue for them not only financially but also in having their efforts feel as if they are in vain when they start over again with their environmental work and community mobilisation. Community mobilisation is difficult when the community sees no authority or justification to engage with the Enviro Champs if they are not wearing a uniform or badge of some sort.	30

2024/08/17	13th African Regional RCE Meeting	Various (global)	Brief mention of the CS SoR project and the aims of the project	150
2023/08/01	Touch base with UNICEF/GT/DUCT	Representatives from GroundTruth, UKZN, UNICEF and DUCT	• Highlighting the importance of housing all the CS in SA information on a central platform to allow for the public accessibility of this methodology/technique. Suggestion for this platform to house literature, past work, present work, interested individuals/groups/institutions (communities of practice) and their work areas and contact details, link to be able to purchase the CS tools, links to other relevant websites (such as the miniSASS website). • An outcome from this was potentially using the WRC/UKZN workshop in October/November 2023 to flesh out this platform idea and get a proposal for it in motion while we have relevant stakeholders and professionals in the room. • General points on efforts around SDG reporting in SA, how the indicators are being reported on and where CS work can supplement this reporting. This conversation looped in various key players and an ongoing conversation around the SDG6 monitoring and reporting landscape in SA is unfolding.	7
2024/08/15	CS for WQM work, research and areas of interest in SA	Representatives from GroundTruth, UNICEF, WRC, DWS, UN-GEMS	• The purpose of the meeting held was an informal chat through the CS for WQM related work which everyone is involved in, to get everyone on the same page and have everyone understand what work is being done in the field. This was to have the CS for WQM network try to keep connected with each other as well as gauge who else should be part of such discussions and engagements. • The outcome was a working document detailing the CS for WQM work each organisation currently has underway.	20
2023/08/29	CS in Africa Caucus meeting	Representatives from CitSciAfrica, UN-GEMS, WESSA, UWC, GroundTruth, and more	The meeting purpose was like that of the meeting on 15 August 2023, with some attendees present at both. There were discussions about what we need and what we are working toward as the CS in Africa community. There was also mention that this working group was largely bias toward CS for WQM work, so it was decided to make that the focus of this caucus tentatively with potential to expand and include other areas in the future.	
2024/02/21	UFS Science Session guest speaker	UFS post graduate students	Presented similar presentation to 1 Feb workshop on introducing the project, and how to get involved	120

2024/02/21	CitSci Africa - SA Slot	Various	Presented similar presentation to 1 Feb workshop on introducing the project, and how to get involved	60
2024/04/19	Meeting with Nature Connect	Representatives from GroundTruth and Nature Connect	Exploring ways to connect through the citizen science SoR project	4
2024/04/02	Meeting with DWS Western Cape	Representatives from GroundTruth and DWS Western Cape	Exploring ways to connect through the citizen science SoR project	4
2024/04/02	Meeting with DUT	Representatives from GroundTruth and DUT	Exploring ways to connect through the citizen science SoR project	3
2024/04/18	Meeting with UFS	Representatives from GroundTruth and UFS	Exploring ways to connect through the citizen science SoR project	3
2024/05/07	Meeting with Umuzi	Representatives from GroundTruth and Umuzi	Profiling the CS water monitoring project	4
2024/05/21	Meeting with The Shark Research Unit	Representatives from GroundTruth and The Shark Research Unit	Exploring ways to connect through the citizen science SoR project	2
2024/06/24	Meeting with WWF	Representatives from GroundTruth and WWF	Exploring ways to connect through the citizen science SoR project	3

2024/07/18	Meeting with Wildtrust	Representatives from GroundTruth and Wildtrust	Exploring ways to connect through the citizen science SoR project	2
2024/08/28	Meeting with Hilton College	Representatives from GroundTruth and Hilton College	Exploring ways to connect through the citizen science SoR project	3
2024/09/03	Collective Data Sharing for Good Ambient Water Quality Workshop	Various (public and international workshop)	Report back on the trial of the Freshwater Watch kits in the South African context, and the contributions of these results to the CS SoR report	40
2024/04/10	Kloof Conservancy MiniSASS Day	Kloof local high schools and volunteer environmental practitioners	Field trip to the local school to demonstrate and teach the scholars about river health and using CS techniques to monitor it	40
2024/10/05	MiniSASS Demonstration with Carter High School	Carter High Eco Club and GT representatives	Demonstration of miniSASS and clarity tube	11
2024/06/08	WESSA YERA	High school scholars and teachers from 10 school across KZN, DBE, UNICEF	MiniSASS explanation and demonstration	150
2024/06/22	Geography Teacher's Association Meeting	IEB Geography teachers	MiniSASS explanation and demonstration	65

2024/03/26	Mpumuza Traditional Authorities	Traditional authority, scholars, Enviro Champs and community members, DWS	To demonstrate the necessity and support of CS monitoring and investment in environmental responsibility efforts to the traditional authorities for their support	100
2024/09/12 and 2024/09/13	UKZN Careers Day	UKZN students	Encouraging participation in the CS SoR efforts and promoting the miniSASS-YOMA incentivised biomonitoring opportunity	100
2024/10/06	Umgeni Day at Hilton College	Hilton College fishing club students, teachers and parents. Representatives from UKZN, INR, and Umgeni Municipality.	MiniSASS explanation and demonstration	50
2025/01/30	KZN Provincial Water Monitoring Plan Workshop	DWS, UUW, SAEON, UKZN, GT representatives	Discussions on water monitoring in KZN and presentation on CS in KZN	45

Appendix F

The CS practitioners who were interviewed are listed below with their affiliated organisations. The project team hereby duly acknowledges their valuable insight and contributions to this report.

The interviewees are as follows, in no particular order:

- Ayanda Lepheana (GroundTruth)
- Mlungisi Ntuli (Liberty NPO)
- Nontutuzelo Pearl Gola (South African National Biodiversity Institute; Citizen Science Association of Southern Africa)
- Bridget Ringdahl (One Planet South Africa)
- Kruger to Canyons Biosphere Reserve team: Marie-Tinka Uys, Romy Antrobus Wuth, Phomelelo Malatji, Mokgale Merchatte, Nick Theron and Dimakatso Nonyane
- Larette Schultz (Duzi Umngeni Conservation Trust)
- Nelisiwe Khusi (Gouritz Cluster Biosphere Reserve)
- Marlé Kunneke (Independent; former Western Cape Government)

Appendix G

A quantitative analysis of the interview responses is displayed in **Table B** below. The total number of interviews conducted was 8 and does not include discussions from the workshop on *The State of Citizen Science for Water Quality Monitoring* on 20 October 2023.

Table 14.1 Quantitative analysis of citizen science interviews

POINT RAISED	A	B	C	D	E	F	G	H	TOTAL	PERCENTAGE
CS as a tool for environmental awareness and education	1	0	1	1	1	1	1	1	7	88
CS is useful in connecting people to the environment	1	1	1	1	1	1	1	1	8	100
CS is useful in collecting large volumes of data over a large spatial scale	1	0	1	1	1	1	1	1	7	88
Practitioners highlighted the importance of standardising the methodologies	1	0	1	0	1	1	1	1	6	75
CS had the potential to generate an interest in the environmental field	1	1	1	1	0	0	1	0	5	63
CS supplements existing environmental efforts	1	1	1	1	1	1	1	1	8	100
Expressed concern around sustainable funding for CS work	0	1	1	0	1	0	1	0	4	50
CS has the potential to aid in broader water resources monitoring	1	1	1	1	1	1	1	1	8	100
Short-term CS projects are not sustainable for career development	0	1	1	0	0	0	1	0	3	38
CS is a useful tool for teaching in schools	1	0	1	1	1	1	0	0	5	63
There exists uncertainty in the usage and applications of CS data	1	1	0	1	1	1	1	1	7	88
CS datasets are used just to inform themselves and/or immediate communities	1	1	0	0	0	1	0	0	3	38
Practitioners share their data with their local municipalities	1	0	1	1	1	0	1	0	5	63
Practitioners share their data and findings with traditional authorities	1	0	0	0	0	0	1	0	2	25
Thorough training is key to ensure the collection of credible CS data	1	1	1	0	1	0	1	1	6	75
Inconsistent CS monitoring hinders trends in CS data from being detected	0	0	1	0	0	0	1	1	3	38
Uncertainties on how to use CS for reporting	1	1	1	1	1	1	1	1	8	100
Experience monitoring with CS at large spatial scales	0	0	0	1	1	0	0	0	2	25
River health needs more provocative campaigns to show the state of our water resources	0	1	1	0	0	0	0	0	2	25

Appendix H

Good day fellow Water Resource Enthusiasts!

We trust that this email finds you well.

As an interested and passionate supporter of water resources in our country, **we need your help.....** 😊

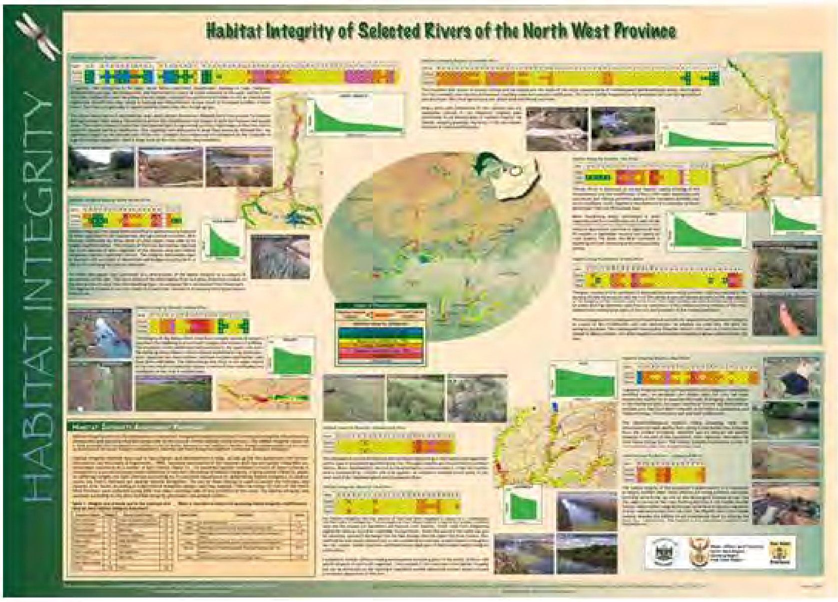
GroundTruth, in collaboration with the University of KwaZulu-Natal (UKZN), are undertaking a project commissioned by the Water Research Commission (WRC), and with funding and support of UNICEF, on *The State of Citizen Science for Water Quality Monitoring in South Africa.* This project aims to generate data that can be used to develop a national State of Rivers (SoR) report from a citizen science (CS) perspective, as well as generate data to inform SDG reporting, specifically targets under SDG 6.3.2 (which monitors the proportion of bodies of water with good ambient water quality).
https://www.unwater.org/our-work/integrated-monitoring-initiative-sdg-6/indicator-632-proportion-bodies-water-good-ambient

Reporting on SDG 6.3.2, Stats SA in 2019 reported that ***"South Africa's reporting ability on this indicator has been reduced by the lack of data, limited monitoring because of lack of funding and resource mobilisation, and to a certain degree the inability to coordinate monitoring across various sectors, government departments and public sector institutions".*** We need to, and can do, much better and tell a fuller story...
https://www.statssa.gov.za/MDG/SDGs_Country_Report_2019_South_Africa.pdf

This novel undertaking of producing the State of Rivers report from a CS perspective has the potential to bring CS techniques to the forefront of water quality monitoring by demonstrating how CS can assist in accounting for gaps and challenges that exist in national river health and water resource monitoring. Moreover, this project will highlight the significance of the inclusion of civil society in water resource management – another critical dimension in meeting SDG target 6.b: ***'Support and strengthen the participation of local communities in improving water and sanitation management.'***(https://www.sdg6data.org/en/indicator/6.b.1).

The SoR report from a CS perspective is intended to show the application of CS techniques across South Africa as case studies, and as a potential model for application in other localities in the future.
As you are probably aware the SoR reporting in South Africa has been inconsistent (see images below and http://www.dwa.gov.za/iwqs/rhp/state_of_rivers.aspx for the most recent reports).

Through this project, we aim to change that narrative by demonstrating how CS can contribute to national monitoring parameters and improving water resource monitoring around the country.



The success of this conceptual report is paramount to encourage the uptake of CS tools and techniques at larger scales, and to feed into national as well as international (SDG 6.3.2) reporting – something that SA has committed to at the national level – and we need your help to achieve this.

You have been identified as a key stakeholder that may be able to contribute toward the development and completion of this report.
You may be asking yourself, "how can I assist/get involved?"

This may translate to assisting the project team to identify staff, students and/or volunteers on the ground who can commit their time to aid in the CS data collection aspect of this undertaking. This is a vital first step in this approach to national water monitoring and river health sustainability. The subsequent data handling and report writing will be completed by the internal project team, who will then share and circulate the collated information and data once reviewed and assessed.
However, if your organisation is interested and able to participate in developing a SoR for your locality as part of the project, we certainly welcome and encourage your continued engagement and interest!

Next steps:

1. Host a virtual workshop with key stakeholders who have a keen interest in this project to detail the roadmap for this undertaking
2. Collate information pertaining to interested stakeholders, working locations, human resources and capacity toward the collection of citizen science data

If you, or colleagues in the field, have the capacity to assist in this innovative community-inclusive project, we strongly encourage you to contact us, so that we can get this project underway in early 2024.

We look forward to your response and working with you further on this project!

Kind regards

Tanisha Curtis
Citizen Science Researcher
MSc Hydrology Candidate

GroundTruth
Environment & Engineering

Appendix I

Good day

I trust this email finds you well.

GroundTruth is currently undertaking a project to consolidate the state of citizen science for water quality monitoring (or community-based water quality monitoring) across South Africa, and is working toward mapping out the future of citizen science river monitoring efforts across the country.

Our project team has identified you as a key stakeholder with your experience and involvement in recent activities as well as current and past projects around citizen science work in South Africa. This email serves to kindly request:

1. You please indicate if you are still active in work around/towards river health.
2. If you have a keen interest in citizen science for water quality monitoring research, activities and developments. If so, please elaborate.
3. If you would be willing to be included as a key stakeholder in our network database and open to engaging with us on matters relating to citizen science and river health monitoring.
4. If you would be able to share the contacts of other stakeholders whose input would be valuable for this work.

I thank you in advance for your time and assistance and look forward to engaging with you more on this project.

Kind regards

Tanisha Curtis

GroundTruth
Environment & Engineering

Appendix J

This appendix contains links to the various guides and training documents which assisted in facilitating training and involvement of stakeholders. All these materials are available on the Google Drive set-up for this project and found at: https://drive.google.com/drive/folders/1TchgQVnlj--nRnfbN6z4bfnophDttv8S?usp=drive_link

- Riparian Health Audit (RHA) training
    - https://drive.google.com/drive/folders/1ufmuHqh4z6Uu5QdtdSLjYBR-faVQ5iXW?usp=drive_link
- 2024 CS SoR Collaborators Roadmap
    - https://drive.google.com/file/d/1e4xEHYD0vV5wjgZbj8Sd5mjeJvZR_446/view?usp=drive_link
- Results Interpretation Guide
    - https://drive.google.com/file/d/1VQrLqaQqFgrc3iYBRmlDm2WU9bECdG-H/view?usp=drive_link
- Local CS SoR Reporting Templates
    - https://drive.google.com/file/d/1YS6qO4aL8paE8CFiN2HMVDFFmetaaOEs/view?usp=drive_link
- CS SoR Frequently Asked Questions (FAQs)
    - https://drive.google.com/file/d/1x3lL5y6V7fcEBCSnywzQnhJdP-Uc43Sm/view?usp=drive_link
- CS Tools: Lower cost alternates
    - https://drive.google.com/file/d/1uei6oUHa2fFChbzjDUU5x9AFk3LffeEC/view?usp=drive_link

Appendix K

Good day, all

I trust that this email finds you all well.

Thank you all for your interest and efforts toward the *2024 Citizen Science State of Rivers* initiative.

In the spirit of building our citizen science network, and connecting with each other, this email serves as an introductory email for you all as part of the KwaZulu-Natal cluster. The purpose of this is to facilitate a space for you all to connect, co-ordinate monitoring, potentially sharing resources/information, and to collaborate with each other not just for this initiative but for future opportunities which may arise.

In lieu of an in-person opportunity to connect, please feel free to use this thread to connect, perhaps by introducing yourself, your organisation, and your interest in the citizen science space. For your convenience, I have also linked the Google Earth file of updated monitoring locations for the *2024 Citizen Science State of Rivers* initiative as of 22 July 2024 here. We hope that this will be a productive and beneficial exercise and will be a step toward further encouraging the development of the citizen science community of practice.

Once again, thank you all for your support on this!

Tanisha Curtis
Citizen Science Researcher
MSc (Hydrology Candidate)

20 GroundTruth

Appendix L

Good day

I trust that this email finds you well.

The University of KwaZulu-Natal in collaboration with GroundTruth are hosting a workshop under the Water Research Commission funded project, "The State of Citizen Science for Water Quality Monitoring". The aim of this workshop is to engage with key stakeholders in the citizen science for water quality monitoring (CS for WQM) space, and unpack the aims, objectives and directions of CS for WQM work in South Africa.

You have been identified as a key stakeholder in this space and we extend an invitation for you to join the workshop. We would greatly appreciate your attendance and participation at this hybrid workshop.

Details:
Date: 20 October 2023
Time: 08h30 – 15h00
Venue: Online or in-person (University of KwaZulu-Natal, Pietermaritzburg)

Kindly find attached an invitation to view further details and RSVP via a Google Form link.
We request that you RSVP before 29 September 2023.

Many thanks!

Kind regards

Tanisha Curtis

GroundTruth
Environment & Engineering

Appendix M

WRC/UKZN Citizen Science State of Rivers Workshop

SOR2024

Accept | Tentative | Decline | ...

2024/01/12 14:51

Citizen Science SoR Opportunity.pdf
6 MB

Thursday, 01 February 2024 10:30-13:30, ~~*(Wednesday, 24 January 2024 10:30-12:30)*~~ Microsoft Teams Meeting

2024: The Year of the Citizen Science State of Rivers Report

Good day, fellow water resource enthusiasts!

Thank you for your interest in being part of this citizen science for water quality monitoring network, and potentially assisting in this undertaking. Your support will be all-important not only in producing a Citizen Science State of Rivers Report, but also in showcasing the value of citizen science techniques – both in the data and socially.

Kindly find attached a flyer for this opportunity for your convenience. Please feel free to circulate this within your networks!

The next step is participation in a virtual workshop which will provide further details of this opportunity and collaborators involvement.

The workshop details are as follows:
Date: 01 February 2024 *(kindly note the change in date, apologies for any inconvenience caused)*
Time: 10h30 – 13h30
Kindly find the Microsoft Teams meeting link below.

We look forward to collaborating on this exciting opportunity!

Microsoft Teams meeting

Appendix N

The following organisations are hereby acknowledged for all their efforts and support for the *2024 Citizen Science State of Rivers Report*:

Adopt a River	M2 Environmental Connections
Adopt Moreletaspruit	Machabeng College
African Waters	Magalies Water
Agricultural Research Council	Mangosuthu University of Technology: Bachelor of Applied Science in Nature Conservation students
AHL Water	Mbeko Eco Club
Alexandra Water Warriors	Midlands Conservancies
Amanzimtoti Conservancy	Midlands Development
Aqua-Amanzi Engineering Solutions (Pty) Ltd	Ministry of Agriculture, Water and Land Reform
ARKYS Outreach NPC	Mogalakwena Research Centre
ARMOUR	Moi Marico Biosphere Reserve
Arrayza	Moreleta Kloof Nature Reserve
Blue Science	Mosselbank River Conservation Team
Boys & Girls Foundation Youth Club	Msinsi Holdings
Bureau Veritas Laboratory (JHB)	Myra Consulting
Cape Winelands Biosphere Reserve	Mzamba Youth
Carter High School	NACSSA
Centre for Ecological and Sustainable Advisory	Namibia Ministry of Agriculture, Water and Land Reform
CES - Environmental and Social Advisory Services	Namibia University of Science and Technology
Citizen Science Association SA	National University of Lesotho. Thaba-Khubelu Conservation & Tours & RCE-Lesotho
City of Joburg	Nature Connect

City of Tshwane	NHL Stenden University of Applied Sciences
Clean Catchments Consulting	North West University
Clean Stream Biological Services	Northern Cape Convervancy
COHWHS Association	Ntuzuma Conservancy
Conservancies KZN	Oasis Environmental Specialists (Pty) Ltd
Conservation Outcomes	OMI Solutions
Cowies Hill Estate	One Planet SA
Curry's Post Conservancy	Operation Songamanzi
Dargle Conservancy	Oppenheimer Generations Research and Conservation
DEA&DP Western Cape	Orange-Vaal WUA
Deep Water Movement	Owe2 Green Economy
Department of Forestry, Fisheries, and the Environment	Peacevale Conservancy
Department of Water and Sanitation (DWS)	Perlidae Aquatic Consulting
Diamonds on the Soles of Their Feet	Pongola- Umzimkhulu Catchment Management Agency
Durban Green Corridors	Praecautio
Durban University of Technology	Randwater
Duzi-uMngeni Conservation Trust (DUCT)	Renew the Elsieskraal
Earthwatch Europe	Rhodes University
Eco Elementum	River Rescue NPO
Ecoglen Association	Rivers of Life
Ecology International	SAEON
Eco-pulse Environmental Consulting Services	SANBI
Ecotone Freshwater Consultants	Sappi
Emanti Water & Environmental Engineering Services	SASAqS

Emaplatini Heritage Forum (EHF)	SCOUTS National
Environmental and Rural Solutions (ERS)	Soulbent Project (NPO)
Environmental Education Association of Southern Africa	South African National Parks (SANParks)
ESENeL	Southern African Society of Aquatic Scientists
Eskom	Southern Estuarine Rehabilitation Action Group (SERAG)
eThekwini Conservancies	St Anne's Diocesan College
eThekwini Municipality	Strategic Water Partners Network
Federation for a Sustainable Environment	Table Mountain National Park SANParks Honorary Rangers
Fransmanshoek Conservancy	Tanja van der Merwe
Freshwater Research Centre	Thaba-Khubelu Conservation & Tours & RCE-Lesotho
Friends of Elizabeth Park - Elsieskraal River	The Shark Research Unit
Friends of Moreleta Kloof Nature Reserve	Thirst
Friends of Rietvlei	Tshwane University of Technology
Friends of the Liesbeek	UJ PEETS
Friends of Toloane	uMngeni-uThukela Water
Future Farmers	uMsunduzi River Crisis Committee
Garden Route Dam Action Group	Umvoto
Gauteng Conservancy and Stewardship Association	UNESCO
GIBA GROUP (PTY) LTD	UNICEF
Gouritz Cluster Biosphere Reserve	University of Cape Town
Great Brak River Conservancy	University of Johannesburg
Grootvadersbosch Conservancy	University of Mpumalanga
GVb Conservancy Trust	University of Pretoria
GWP SA	University of South Africa

Hennops River Revival	University of the Free State
Hilton College	University of the Western Cape
IIE MSA	University of Venda
Inkomati-Usuthu Catchment Management Agency	Upland River Conservation
Intaba Environmental Services	Varsity College
JG Afrika	Viva con Agua
Karoo Gariep Conservancy	Water for the Future
Klipriver Sustainability Forum	Water Research Commission
Kloof Conservancy	Waterberg Nature Conservancy
Kruger to Canyons Biosphere Region	WaterCAN
KZN Wildlife	Waterlab
KZN Wildlife Honorary Officers	WESSA
Lebone II College	Western Cape Government
Lesotho Highlands Development Authority	Westville Conservancy
Liberty NPO	WildED youth education
LIMCOM	Wildtrust
Lower Breede River Conservancy	WSP
WWF	