CISMOL – Monitoring groundwater in the Hout catchment

by

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LIST OF ACRONYMS

CISMOL	Citizen Science Monitoring in the Limpopo
CS	Citizen Science
CSA	Citizen Science Alliance
DANIDA	Danish Aid
DDT	Dicholorodiphenyltrichloroethane
DWA	Department of Agriculture
DWS	Department of Water and Sanitation
EDC	Endocrine Disrupting Compound
ENoLL	European Network of Living Labs
ESGUSA	Enhanced Groundwater Monitoring Use in South Africa
GRIP	Groundwater Resource Information Project
ICTs	Information and Communication Technologies
IWRM	Integrated Water Resources Management
M and E	Monitoring and evaluation
MAR	Managed Aquifer Recharge
MER	Monitoring and Evaluation Report
NGOs	Non-Governmental Organisations
NWA	National Water Act
PAR	Participatory Action Research
PCB	Polychlorinated biphenyls
PRA	Participatory Rapid Appraisal
ROL	River of Life
RSA	Republic of South Africa
SAB	South African Breweries
SAWS	South African Weather Station
SDGs	Sustainable Development Goals
SONYC	Sounds of New York City
UNDP	United Nations Development Programme
UNSD	United National Statistics Division
UWC	University of the Western Cape
WRC	Water Research Commission
WRM	Water Resources Management

INTRODUCTION

This report brings together the key findings of deliverables three, four and five. As deliverable two is a training manual and a standalone report, it is not included in this final report. In Section one we begin by offering an overview of the conceptual framework for Citizen Science (CS). Section two presents the key findings for the Monitoring and Evaluation Report (MER) which was presented as deliverable four. This is followed, in section three, by an overview of Participatory Action Research (PAR), presented in this project as deliverable five. We then conclude the final report with a summary of key insights from the three sections.

The following project aims of the Citizen Science project entitled Citizen Science: Groundwater Monitoring in the Hout Catchment (CISMOL) are addressed in this report.

1. Train citizens on the use of appropriate technology to obtain relevant data on groundwater and rainfall
2. Improve the understanding of hydrogeological processes and groundwater-related socio-economic and agricultural issues in typical geological settings and farming communities in RSA, exemplified by the Hout/Sand River Catchment in the Limpopo Province
3. Define and promote sustainable groundwater management options in the Hout/Sand Catchment based on integrated hydrological modelling, resource indicator tools, and stakeholder engagement (citizen science)
4. Improve existing training material (completed as deliverable two)
5. Develop and implement a CS framework (completed as deliverable three)
6. Develop a verification and validation system to monitor and evaluate and report on the progress of CS

1. SECTION ONE: CITIZEN SCIENCE FRAMEWORK

Section one begins by offering the conceptual and geographical context for the citizen science project under the rubrique of CISMOL. It then addresses the challenges to which CS is being applied in the Hout Catchment. The third part of section one proposes a framework hypothesis and then a complete overview of citizen science. This is followed by a discussion on the living lab and the connection between the concept of a living lab and that of CS. As trust is an integral part of the work of CS the next part of section one covers the idea of trust and CS. We then conclude this section with a proposal for a CS frame.

1.1 Conceptual and geographical context

A conceptual framework is an analytical tool that is used to obtain a comprehensive understanding of a phenomenon. It can be used in different fields of work and is most commonly used to visually explain the key concepts or variables and the relationships between them that need to be studied.[1] It is not merely a collection of concepts but, rather, a construct in which each concept plays an integral role (Jabareen, 2009). The relevant concepts playing this integral role for the citizen science frame are (1) Citizen Science, (2) Sustainable Development Goals (SDGs), (3) Living Laboratory, and (4) Trust. In elaborating on each of these concepts it becomes clear that together they provide an innovative and critical framework for CS in general and in working in the confines of water resources management (WRM) – in this case groundwater monitoring.

1.2 Challenge to which CS is being applied: CISMOL

Groundwater is an increasingly important source of water supply to agriculture, households, and industry. Groundwater is generally well protected against pollution, can be exploited anywhere depending on the local conditions, and has a year-round availability. With population growth and increasing climate variability, groundwater also plays an increasingly important role in the Republic of South Africa (RSA) to enhance water and food security. Our present understanding of the threats to groundwater posed by climate change are far from clear, especially in light of the complex interactions between demographic and land use changes and the detailed unfolding of changes in key weather variables such as temperature and precipitation. That local water balances are already changing, and that such change is set to continue, is not controversial. However the precise shape of those changes locally, and the implications for groundwater's continuing ability to buffer seasonal and multi-year dry

[1] Wikipedia definition

periods are less well understood. Monitoring groundwater in the Hout becomes critical as it contributes to the body of knowledge on changes over time in groundwater levels, climate variabilities measured for instance by amount of rainfall or river flows (UPGRO, 2017).[2]

As one of the few countries in the world, South Africa is typically served by groundwater and is internationally recognized for its research expertise and research-based and sustainable practices within integrated groundwater management. More than 50% of communities in RSA depend on groundwater for their domestic and livelihood needs (DWS, 2016). However, groundwater resources are vulnerable to depletion and degradation if not protected and exploited in a sustainable manner. Mismanagement potentially leads to adverse impact effects on ecosystems, water access, human health, and agricultural production.

The proposed research has important strategic relevance for both the global north and global south. The research community and the water administration in RSA benefit from the Water Research Commission (WRC) capacity as well as the capacity of high-level Danish researchers who initiated the first phase of monitoring groundwater in the Hout through ESGUSA. In terms of developing capacity for integrated groundwater management in RSA, the project supports the South African Groundwater Strategy (DWS, 2016). The project also strengthens capacity and application experience in CS, and links to ongoing initiative with DWS, DEA[3], WRC[4], DST[5] and others to establish a Citizen Science Society of Southern Africa.[6] The framework will be relevant for projects that are not specifically to do with water but that are working across a humanities-natural science spectrum.

1.3 Framework hypothesis

The hypothesis for the framework is as follows: CS is a contributor to wiser and better management of water resources in the catchment and provides the pivot around which ideas of the living laboratory,[7] the sustainable development goals and trust are fixed. The application of CS mitigates for tension between social sciences, humanities and natural sciences, providing a lens where these

[2] In creating a CS framework it is necessary to first circumscribe the geographical and socio-economic landscape within which the living laboratory operates

[3] Dept. of Environmental Affairs, South Africa

[4] Water Research Commission, South Africa

[5] Department of Science and Technology, South Africa

[6] http://www.wrc.org.za/Lists/Events/DispForm.aspx?ID=399

[7] Henceforth living lab

disciplines benefit from science literacy and behavioural change across the spectrum of actors operating within the living lab.

1.4 Introduction to CS

Before continuing in the construction of a frame, we first present an overview of CS and lodge it within a conceptual frame. During the last decade, an exciting trend has been recorded worldwide, with thousands of lay people from, in, and across different countries becoming engaged in citizen science (CS) projects, through various modes and channels of collecting, commenting, transcribing and analysing data (Tauginienė et al., 2020). However, CS has been predominantly pursued within the realms of the natural sciences (Crain et al., 2014). Activities and projects following social sciences and humanities (SSH) topics and approaches are less easily discernible in CS practice, although they may be fuelled by some genuine and challenging questions (Heiss and Matthes, 2017). A survey of CS projects in Europe revealed that more than 80% of current CS practice is confined to life and natural sciences and only 11% to the social sciences and humanities (Hecker et al., 2018). The underrepresentation of SSH may be due to several reasons.[8] One of them is the stable and long-lasting bonds between CS and the natural sciences, with pioneer lay scientists mainly directing their interest towards the study of physical and natural phenomena by making use of positivistic methods of data collection and analysis (Tauginiene et al., 2020).

The field celebrated a milestone when "citizen science" appeared in the Oxford English Dictionary in 2014 with the following definition: "the collection and analysis of data relating to the natural world by members of the general public, typically as part of a collaborative project with professional scientists" (Bonney et al., 2016). There is a complexity involved in the collection and analysis of the data, the commitment of the 'public,' ideas behind what collaboration entails and what and how one defines a professional scientist. The lines drawn between the technical and less technical, between government and society, between different scales and institutional intersections are often quite

[8] We acknowledge also that there is an underrepresentation of projects from the global south. In a follow up WRC project, entitled Polycentricity, Pluralism and Citizen Science, we provide a more comprehensive literature review of citizen science within a developing country context. In particular we turn to authors such as Pollock et al. (2016) and their work in East Africa, Bhasker and Scott (2015) on the Theory of Education, Reason, Rowan and Bradbury (1981) on Human Inquiry, as well as the important work of Mark Graham and Jim Taylor (WRC Report No TT 763.18) on the development of citizen science tools for water resource monitoring. Although not explicitly citizen science, relevant too is the work in South East Asia, the South Asia Water Initiative (SAWI) on participatory groundwater management

entangled. A simpler understanding of CS is the interpretation – or/and collection of data by citizens in collaboration with government, research agents, academia, policy makers and planners. The central role of CS in many disciplines of academic research has been acknowledged by the Citizen Science Alliance (CSA)[9] which has almost 2 million volunteers. As the founder of the CSA, Lintott (2019) claims, we can no longer indulge in the twentieth-century habit of leaving science to the scientists, but in area after area we are finding that we must instead all pitch in.

CS has been widely discussed and explored amongst scientists, policy makers and planners, because it allows for genuine interactive and inclusive science engagement. In the water sector this is of particular relevance because of the integrated water resources management (IWRM) regime that dominated water resources discourse from the Dublin days in the 1990s right through to 2020. The main premise of IWRM was to achieve social equity, financial viability and environmental sustainability through managing the resource close to its point of use and, critically, by adopting participatory processes with ordinary citizens who depended on the resource when making any decision that might affect their lives.

CS provides a way to be interdisciplinary both within the University and across University Departments and within and across Departments in government. It permits the validation and classification of huge datasets that would otherwise be unmanageable. One tends to think of community science efforts as being isolated to small-scale tracking of local issues but this is not so as these grassroots efforts are now becoming networked to tackle widespread issues of social and environmental justice as well as questions about effective conservation practices. CS holds the potential for developing new ways to collectively solve big problems and to fundamentally change the relationship between science and society. Within the WRC and ESGUSA project we consider CS to be an approach whereby non-scientists are actively involved, to differing degrees, in the generation of new scientific knowledge, from which they also actively stand to benefit either intrinsically (e.g. increased scientific literacy) or extrinsically (e.g. increased social capital and improved well-being).

A reflection on the application of CS across disciplines is helpful. Some of the longest-running CS records in the world are from Japan. For example, the timing of cherry blossoms has been recorded in Kyoto for 1200 years, so long that they have been used in climate reconstructions (Aono and Kazui, 2008). Centuries-long phenology data also exist for other plant and animal species across Japan (Primack et al., 2009). The study of Ivan and Margary (1926) is also pertinent as it reports how many

[9] Almost two million volunteers www.zooniverse.org

centuries ago, in 1736, Robert Marsham started recording 27 phenological events, such as first flowering, leafing and the appearance of migratory birds, for more than 20 common plant and animal species in his family estates in Norfolk. An impactful example is the work of the Entomological Society Krefeld, where the work of citizen scientists over the course of nearly three decades allowed tracing a 75% decline in biomass (Hallmann et al., 2017). The Zooniverse gives people of all ages and backgrounds the chance to participate in real research with over 50 active online CS projects such as SONYC which is one such project, based at New York University who are developing a smart citizen sensor network with machine listening capabilities to identify and mitigate the sources of noise pollution in New York City. Another is Snapshot Serengeti which involves cameras tracking the movement of thousands upon thousands of animals migrating with and following the wildebeest.

SciStarter monitors active and non-complete projects and according to this source, there are currently more than 1500 CS projects globally that are registered and are active. From these 1500 projects about 200 are CS projects that are practiced in Africa.[10]

Barriers to successful CS projects can vary and may include asking volunteers to submit data too frequently, in inconvenient locations, or using protocols that are too complex (Kobori et al., 2016). Many techniques can help to overcome these barriers and attract appropriate audiences; techniques include implementing simple sampling methods, targeting audiences already interested in the activity, providing recognition for volunteers, and facilitating positive social interactions and the building of trust amongst participants in a 'living lab.' This allows democratising science and increasing its responsibility towards society. As CS projects focus on ecology and conservation and were started by natural scientists – e.g. ecologists and biologists – there has been, as discussed above, minimal involvement of social scientists (Romolini et al., 2012) and that means also minimal understanding of social science and humanity approaches that are so critical for the living lab to thrive and for the brokering of trust.

CS is becoming more formalized and more widely accepted among scientific, educational, and community-oriented domains, with additional factors – such as socio-political scenarios, economic conditions, and ethical considerations – influencing how the field is developing over time. This has to do both with the need to broaden the realms of CS in terms of what has been traditionally dealt by as

[10] There is no exact number of recorded CS projects in the Republic of South Africa (RSA) but many projects are being implemented through 1) CSIR - Council for Scientific and Industrial Research 2) SANSA - S.A National Space Agency 3) SANBI - S.A National Biodiversity Institute 4) CREW - Custodian of Rare and Endangered Wildflowers 5) iNaturalist 6) rePhotoSA 7) Cape Citizen Science

‘science’, and to a renewed interest in developing an enriched understanding of how to promote and sustain citizen involvement in scientific research over some socially relevant but still uncharted CS topics (Tanginiene et al., 2020). It has also to do with the need to instil an emancipatory role in the citizen’s contribution to research; inform policymakers with new science-based evidence (Purdam, 2014).

As Newman et al. (2012) argue, the future of CS will likely be inextricably linked to emerging technologies. By spanning multiple spatial, temporal, and social scales and by being designed to achieve a number of different outcomes, CS projects will need to adopt new technologies to allow participants and organizers to communicate and interact effectively (Newman et al., 2012, Kobori et al., 2016).

The **educational aspect** underpins the volunteer experience and literacy about groundwater is empowering and although encouraging citizen participation in data collection and analysis, it is primarily a means of meaningful education. Data obtained not just in one well but in many wells in a catchment, heightens awareness of the downstream/upstream movement of water but also enhances feelings of belonging and of being anchored in a watershed, embedded alongside others who also depend on the resource for their well-being.

Little is known about the precise mechanisms that motivate volunteers to contribute to data collection, though it is clear that a complex range of factors is involved. The factors predominately rely on the type of participants that are invited because different volunteers will be driven by different incentives. Volunteers from rural communities are most likely to accept any volunteer work based on the idea that they see it as an opportunity to network with NGOs and government officials in case of job opportunities, whereas with commercial farmers and small holder farmers they need to see how participating in research work will benefit them or their agricultural activities before buying-in to the process. Most if not all our volunteers who have joined needed some form of incentive, farmers wanted a guarantee that groundwater level data would be shared with them so that they can understand the aquifer better and the community volunteers wanted assistance with improving water supply systems within their various villages.

1.5 CS and the Sustainable Development Goals (SDGs)

The United Nations Secretary-General's synthesis report on the Post-2015 Development Agenda proposed one universal and transformative agenda for sustainable development, underpinned by rights and with people and the planet at the centre (UN, 2014). In September 2015, the United Nations 2030 Agenda for Sustainable Development, which consists of 17 Sustainable Development Goals (SDGs), was ratified. This Agenda provides a framework upon which governments can implement policies and actions towards achieving these goals by 2030. The SDGs cover many areas including, among others, poverty, food security, energy, health and well-being, inequality, gender, production and consumption, urbanization and numerous environmental issues affecting land and marine ecosystems as well as climate change (Fritz et al., 2019). The CS project relates to several of the SDGs, in particular, but as the following paragraph will show – not only – Goal 6 'Clean Water and Sanitation'. Strengthening global collaborations in implementation is the subject of goal 17. As with the Millennium Development Goals (MDGs), the UN's Post-2015 SDGs will only be achieved with the active engagement of volunteers. Volunteer contributions to sustainable development are distinctive. Volunteers' close engagement with communities in need, their skills and motivation to contribute to more inclusive, active and cohesive societies, and modelling/facilitation of the reciprocal exchange of knowledge and skills among stakeholders, make volunteers distinctive actors in support of the achievement of the SDGs (Haddock and Devereux, 2016). Volunteerism is at the core of CS and it implies that individuals give time without pay to activities performed either through an organization or directly for others outside their own household or related family members. We consider two categories of volunteers – the first refers to (informal) volunteering outside the context of an organisation. These volunteers that operate outside the context of an organisational setting, sometimes called "helping" or "neighbouring," are thought to be the major share of volunteer activity in many countries (Salamon et al. in Haddock and Devereux, 2016) and it is this "helping" or "neighbouring" aspect of volunteerism that guides and informs CS within the context of the ESGUSA Phase 1 project and this current WRC project.

The 17 SDGs endorsed by late September 2015 are intended to transform our world by addressing the social, economic and environmental challenges faced by the global community – with all countries and stakeholders acting in collaborative partnership. Most relevant within the context of CS and the role of volunteers in monitoring wells, rivers and rainfall are SDGs 5, 10, 16 and 17. Goal 16 promotes peaceful and inclusive societies, providing access to justice for all and building effective, accountable and inclusive institutions at all levels. Goal 17 aims to strengthen the means of implementation and revitalise the global partnership for sustainable development. These goals provide an opportunity to demonstrate the strong value-added that volunteerism brings as an integrating mechanism that helps people and institutions better connect in partnerships of mutual benefit, allowing synergies or complementarity towards common goals/targets and indicators. Additionally, SDG Goal 10, to reduce inequality, is particularly pertinent to many volunteer groups and might be considered a priority as they acquire knowledge and with it the power to make decisions and better understand their environment.

1.6 Living Labs and CS

A more recent approach to research on real-life challenges in collaboration with scientific and public actors is referred to as a Living Laboratory. A living lab is a research concept. It implies a user-centred, open-innovation ecosystem, operating in a territorial context (e.g. city, agglomeration, region) and integrating concurrent research and innovation processes between partners – be these from government, private sector, NGO or civic realms. Initial definitions included "a research methodology for sensing, prototyping, validating and refining complex solutions in multiple and evolving real-life contexts" (Eriksson et al., 2006) and an "experimentation environment in which technology is given shape in real-life contexts and in which (end) users are considered 'co-producers'" (Ballon et al., 2005). Thus, there are numerous definitions for the concept. The core idea of living labs goes back to the 1980s but gained more attention in the years after 2006 when the European Commission started funding the living labs movement (Dutilleul, Birrer, & Mensink, 2010).

Living labs enable a wide diversity of stakeholders, such as developers and researchers, to collaborate with users in innovation processes (Almiral and Wareham, 2008). Also shared among living labs is that their innovation processes are situated in real-life environments (Svensson & Ihlström Eriksson, 2012). Living labs foster innovation in an iterative process of gradually improving and refining a product in successive stages of research and design. The end-result of the process is not fixed at the beginning. In successive iterations, the design improves and becomes more concrete (Dekker et al., 2019). Furthermore, Dekker et al. (2019) state that a common element of living labs is that users are closely involved as 'co-creators' of the product or service. They are considered to have specialized knowledge from a user-perspective. They are involved from the early onset of the innovation process and their experiences and preferences become part of the product or service that is being designed.

The generation of ideas and the testing of concepts with consideration to the 'real world' is believed to create better insights into the practical suitability and application of innovations. In a study performed by CoreLabs (2007), five aspects have been identified that represent the shared mindset behind living labs: openness, continuity, empowerment of users and realism.

The European Network of Living Labs (ENoLL), an umbrella organization for living labs around the world, defines them as “user-centred open innovation ecosystems based on a systematic user co-creation approach, integrating research and innovation processes in real-life communities and settings” (Hossein et al., 2019). ENoLL has also defined the living lab as a “real-life test and experimentation environment where users and producers co-create innovation” and spontaneity (ENoLL 8th Wave Brochure, 2014, Humble, 2014). The advent of the European Network of Living Labs (ENoLL) in November 2006 as the international federation for living labs in Europe, as well as the larger world, has brought a large number of living labs under an umbrella association. Since 2006, the publication of scholarly articles about the subject has grown (Hossein et al., 2019).

Subsequently, these aspects were combined so that living labs were conceptualised as both a methodology and a milieu for organising user participation in innovation processes (Bergvall-Kåreborn et al., 2009). Living Labs come in different shapes and sizes. A different, more critical stream that is also related to the field of sustainability (transitions) research are Urban Living Labs. These are temporary, place-based interventions that facilitate experimentation in cities. An example is the Urban.Gro.Lab, an Urban Living Lab in the city of Groningen initiated by the Municipality and the University. Through the lab, research regarding spatial and societal issues is tested (von Wirth, Frantzeskaki and Loorbach, 2020).

Living labs have been a practice-driven phenomenon. Right up to this day, they represent a pragmatic approach to innovation (for instance of information and communication technologies [ICTs] and other artefacts), characterised by experimentation in real life and active involvement of users. Living lab practices are still under-researched, and a theoretical and methodological gap continues to exist in terms of the restricted amount and visibility of living lab literature vis-à-vis the rather large community of practice (Schuurman, 2015 in Ballon and Schuurman, 2015). The support that living labs receive from other intermediaries is also under-researched in the literature. The work within the context of the WRC project (and ESGUSA Phase One) contributes to the body of knowledge on the living lab and also takes a new direction by linking it to the SDGs, the work on citizen science and the ideas of trust.

In contrast to many other forms of innovation, living labs involve heterogeneous stakeholders such as academics, developers, industry representatives, citizens, and users, as well as various public and private organizations in living lab networks (Ballon and Schuurman, 2015). The previous literature largely takes the view that multiple different stakeholders participate in innovation activities (Hossein, Leminen and Westerlund, 2019). Leminen, Westerlund and Nystrom (2012) argue that living labs are not projects but rather a systematic method of innovation. Exploring how the role of the users changes over time in different projects and contexts is therefore crucial, as is a cross-country and longitudinal analysis of innovation in living labs. Understanding how living labs perform in multifaceted situations, as well as the power distribution in the networks and governance, is essential. For this reason the introduction of the concept of trust, presented below, is of prime value.

What makes these spaces interesting is that traditional role understandings are blurred. What is a researcher and what a practitioner? Which activities are they engaging in? What is expected from them? In addition, various kinds of knowledge are considered equal, while not the same, in addressing real-world problems, generating knowledge, formulating possible solutions, and directing actions (Wittmayer, 2018).

The concept is based on a systematic user co-creation approach integrating research and innovation processes. These are integrated through the exploration, experimentation and evaluation of innovative ideas, scenarios, concepts and related technological artefacts in an everyday context. Such cases involve user communities, not only as observed subjects but also as a source of creation. The current project uses the methodology for living labs for stakeholder-focused research approaches, operating in a selected small river catchment. Regular visits to the living lab assure good quality assessment of the ecological functionality, the needs of the local population (volunteers and those with whom they interact), validity of data transmitted and so forth. The feedback loop between the CS, research team, volunteers and government (in this case in the main, but not only DWS), is crucial to keep the laboratory 'living' and interactive. The mutual activities of researchers, development trainers, locals, government partners and practitioners is a common focus across all project activities.

The living lab is not simply a 'nice to have' but is essential in promoting better groundwater management through sharing concerns as well as data. Simultaneously, as practitioners from the region are trained in new methodologies using cost effective and appropriate technology adapted to the priorities in the catchments, the project sets up a community of practice where there is regular support to ensure that these methodologies are being applied. We see CS as integral to the living laboratory where we are enmeshing technology, materiality (such as the measuring instruments), natural resources, ideas and emotions and research integrity.

1.7 Trust and CS

One of the most critical ingredients for the implementation of a living lab and the application of citizen science is trust. This section deals with the idea of trust. We introduce here the concept and theoretical framework that informs discourses around trust, establishing whether and in what way trust is brokered and nurtured – or not as the case might be. We consider the way in which trust can be nurtured within different geographical settings – in this case between sections 1, 2 and 3 of the Hout Catchment. Trust has a social and political geography as well as a geography of place. We consider trust to be an essential ingredient for building networks and linkages (social capital),[11] both horizontally (between the volunteers themselves) and vertically – between volunteers, municipalities, tribal authorities, research team, government departments such as DWS. Trust is an outcome of a successful CS project and therefore critical to the CS frame. Like the idea of the living lab above, trust is not just 'nice to have' but is a 'must have' because it determines social action – engagement or disengagement as the case might be. It allows for the establishment of solidarities between water users, volunteers, research team members, private sector, donors and government.

It is pertinent to draw on the work of the well-known expert Ostrom (1990) who isolates three properties of social capital that are relevant for the CS component of this WRC project.

1. It does not wear out with use but rather with disuse
2. It is not easy to observe and measure
3. It is hard to construct through external interventions

Here are some possibilities that define trust as a component of social capital (1) trust is a set of behaviours, such as acting in ways that volunteers and others depend on one another, (2) trust is a belief in a probability that a person will behave in certain ways (predictability and reliance), (3) trust is an abstract mental attitude toward a proposition that someone is dependable 4) trust is a feeling of confidence and security that others with whom one is interacting, care.

Social capital is often constructed through external interventions. The concept refers to various social factors that contribute to well-being, although these factors are often elusive. We have seen in our own work how social capital can have both positive and negative attributes because it can inhibit collective action and stand in the way of a reform or a given research project. In other words – segments of society (such as the commercial farmers, or small-scale farmers) might 'stick together' and not open up their networks to build new social capital. In this sense, social capital might be negative. In our own project, we see positive aspects of social capital and the building of trust through

[11] Putnam (1993); Granovetter (1973, 1985); Seligman (1997), Goldin (2003, 2010, 2013)

our stakeholder workshops and the uptake of volunteers in section one and three as well as the eagerness of commercial farmers in section two to collaborate with us.

What is important within the context of the CS framework, is that there are two forms of social capital: the one relates to networks, associations, organizations and the rules that they follow, whilst the other is cognitive or attitudinal and as Krishna (2002) noted, this type of social capital is less tangible and unobservable as people carry it inside their hearts and heads. Trust is an attitudinal component of social capital. The two components of social capital often act together as the 'thinking' part (trust) predisposes people to mutually beneficial collective action and vice versa – mutually beneficial collective action can foster trust.

Citizens do not decide or behave outside a social context because they are embedded in concrete – although often fluid – ongoing systems of social relations which is why it was important for us to acknowledge local chiefs and counsellors (political leaders) in section one and three and the Agricultural Union in section two as well as government officials from the DWS and DWA as key stakeholders. We adhere to the 'rules of the game' as they are integral to our understanding of trust. For instance, when forging new links with volunteers in section one and three there were strict rules to adhere to – who to approach, how to 'open gates' and whose authority to listen to. The research team were aware that the building of trust would mean being privy to 'rules of the game' and game is certainly not to be taken lightly or in a pejorative manner. It is a deeply rooted set of rules that govern the commons at one level and the way in which social systems pivot around each other, protecting their own regimes whilst at the same time interlocking in an iterative way with other institutions on which they depend. These rules, in the case of section two of the catchment, were opaque and less easy to adhere to as the farmers form part of an 'old boys club' where, as members they have been negotiating trust amongst themselves for over thirty years – farming and working in the particular section of the catchment. This meant that opening gates took longer, was more sensitive, and required a careful step by step approach.[12] In all instances (section one, two and three of the catchment), these rules have most surely been established to reduce uncertainty by establishing a stable structure for human interaction. Trust is important for the practices and organizing principles that are established within and around these institutions.

[12] COVID-19 and the imposed lock down meant that visits to the field that were programmed for May and June 2020 did not take place and there is a delay in bringing commercial farmers on board although, two farm labourers, at the suggestion of a commercial farmer himself, have now been trained as citizen scientists

The way in which the ideas match the actual is not always neat. Institutions, committees and forums are expected to have both positive and negative effects on water users and although the paradigm of IWRM supposedly meant upstream-downstream social capital and trust, this is not in reality always the case. There needs to be adequate and accurate information for water users to make appropriate and efficient decisions. The project of monitoring groundwater in section one, two and three of the Hout is one step towards providing adequate and accurate information that can be shared between upstream-downstream users. In the ideal, it is a contributor to trust building within catchment areas and between different sections of the catchment.

We found in our own work, that there is an undersupply of social capital where it is most needed – in other words, social capital exists within different segments of the catchment, but not across segments. There is also an undersupply of social capital between government and farmers where it is most needed. The urgency for a supply of social capital is to equalize the balance of power between government and citizens and between citizens themselves so as to produce new networks and new bonds of trust. In the case of our project, being consistent, inclusive, consultative was a deliberate style to broker trust and it fits in well with the idea of a living laboratory presented in section two above.

For the progressive management of water systems – including – but not only groundwater – the CS framework emphasises the idea of process – CS being a long journey and not an end destination – in which differences and highly differentiated needs are acknowledged in their specificity. This means deliberately paying careful attention throughout the duration of any given project to a learning approach and attaining water literacy whilst ensuring no-one is left behind. As feminist thinkers, such as Nancy Fraser (2009) Iris Young (1990) or/and Bozalek et al. (2013), we too consider diversity and difference rather than universality. This attention to the specific rather than a very general audience or approach to stakeholders, brokers trust between strangers and creates a sense of belonging.

Participation, inclusion/exclusion, knowledge and power are determinants of how and in what ways trust is produced and maintained – in other words more participation is likely to mean more trust, more water literacy more trust and feelings of control or power of the individual are also likely to produce higher levels of trust. The living labs pivots around the brokering of trust. In research on sustainability transitions, they are transition arenas – protected spaces allowing for experimentation with radically different ideas, practices and roles (Loorbach, 2010), but dependant on trust as that ‘glue’ that binds.

This section has looked at the idea of trust and made it clear that it is tightly associated with the concept of CS. The themes of participation, inclusion, cooperation, reciprocity, agency and education are very much part of the CS/trust nexus. Future research would benefit from the construction of a 'trust' scale which measures trust between citizens themselves in a particular segment of the catchment, citizens across segments and trust between citizens and government. We believe that we have established relationships of mutual trust between the fifteen volunteers involved in the pilot project in the Hout as they can rely on us to attend to their grievances or concerns (such as broken dip meter, concerns about measurement accuracy) and there is a relationship of mutual trust and a building of social capital (new networks of allegiances) through the project activities.

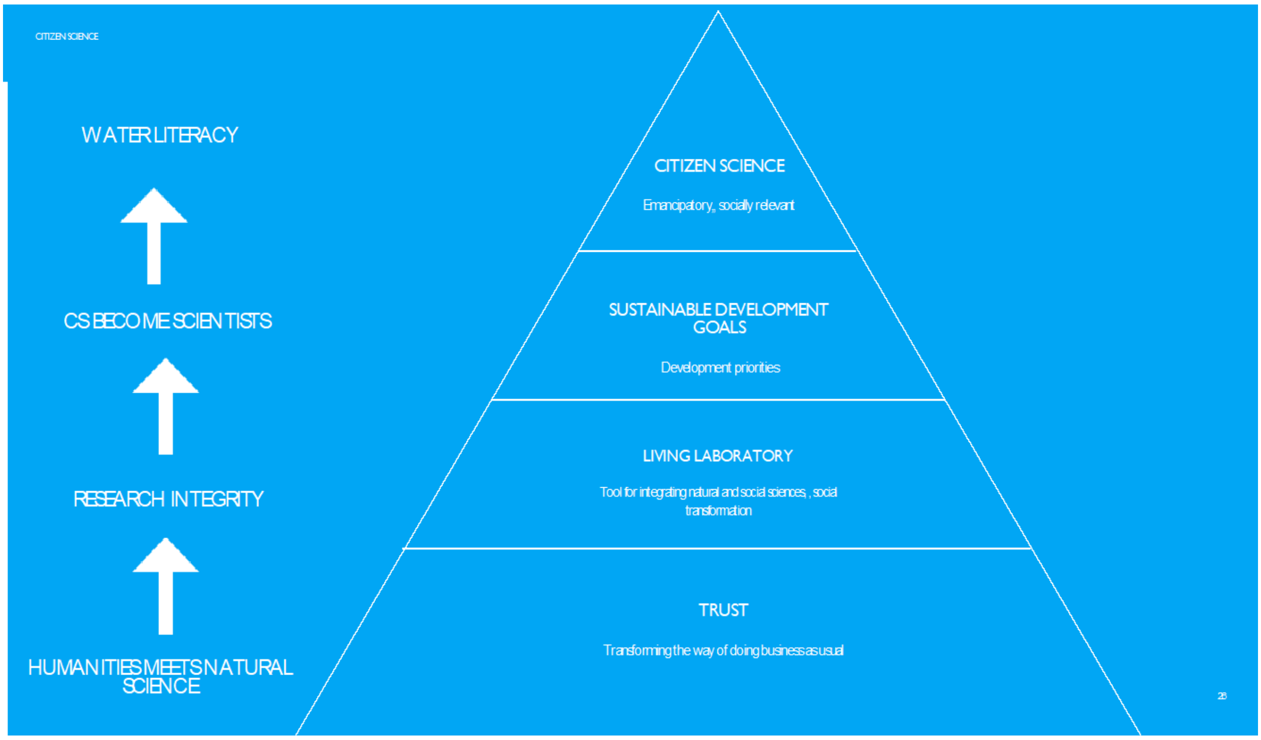
1.8 CS frame

The ideas of CS, SDGs, Living Lab and Trust presented in section one above, form the prongs and scaffold for the CS frame. First of all not to forget the context of the SDG which embeds the frame in a broader development paradigm. We are addressing inequality, poverty and concerns of climate change and unsustainability. The focus on the SDGs (6, 10, 16 and 17), especially but not only Goal 10, to reduce inequality, is particularly pertinent to our volunteer groups and might be considered a priority as they acquire knowledge and with it the power to make decisions and better understand their environment. Volunteer contributions to the SDGs are distinctive.

Secondly the concept of the Living Lab, and the reconstruction of the action space, emphasises the emancipatory aspect of CS but the 'living' implies dynamic co-creation of knowledge, the element of 'surprise' where the outcomes are not cast in stone but shift and re-form as the project progresses. In research on sustainability transitions, they are transition arenas – protected spaces allowing for experimentation with radically different ideas, practices and roles. The living labs pivot around the brokering of trust which is the third prong of the frame.

Thirdly the notion of trust, remembering that, in line with the principles behind the living lab it does not wear out with use but rather with disuse which implies regular face to face, or in the case of lockdown (COVID-19) WhatsApp, telephonic and other communication with our citizen scientist partners on the ground. Furthermore trust is not easy to construct from the outside through external intervention which, again, in line with the living lab emphasis, takes the view that the researcher is immersed in the research and is not 'dictating' terms of engagement top-down, for it is only in this way that sustainable trust can be (co)produced and the scaffold can hold together. Lastly, when considering trust, it is less easily visible as it is an invisible asset that people hold in their hearts and heads. Opportunities to tap into what is being carried requires smart participatory approaches (presented in section three below) which capture emotional well-being, such as pride, hope, dignity, etc. rather than shame, anxiety, fear or even anger. Core to the frame is the conscious integration of the natural sciences with its technical savvy and the social sciences and humanities where the focus is on the citizen component of science and processes in line with the living lab, SDGs and brokering trust. Research integrity is integral to the frame and includes properties such as honesty, accountability and transparency, professionalism and stewardship (also discussed in more detail in section three below). Citizen scientists becomes scientists with technical savvy and access to data as well as embeddedness in a wider catchment (upstream/downstream) and, importantly with the emancipatory component that comes with water literacy. Scientists become people savvy and participate in the spirit of the living lab.

Together these ideas bring the social sciences and humanities into the technical spaces of natural science – and vice versa, in this way integrating the social sciences with natural sciences. The application of feminist thinkers around diversity, social justice and particularity rather than universality remind us of research integrity and the creation of a more just social setting. Citizens become technically savvy and the distinction between the professional with their technical know-how and the citizen scientist becomes far more blurred. The result overall is emancipatory for citizen scientists as they gain water literacy and are better able to manage their water resources for sustainable future use. These ideas are captured in the diagram below.



Citizen Science Conceptual Frame

2. SECTION TWO: MONITORING AND EVALUATION REPORT (MER)

2.1 Introduction

We begin this section with an introduction and then we go on to defining monitoring and evaluation (M and E). In so doing we examine key elements implicit in M and E such as indicators and measurement processes. We ask how monitoring and evaluation are defined. We then look at the M and E geographical and social landscape, in other words the context of the M and E activities. The following discussion is on the data and flaws, strengths and validity. This is followed by a discussion on the technical aspects and monitoring objectives for the MER framework. Monitoring parameters and frequency for an MER framework follows. We then conclude the technical aspects of M and E and continue to discuss the social aspects of M and E. The final part of section two presents the MER framework.

We also aim to increase the research capacity within the Limpopo and beyond around integrated groundwater resource assessment and management. The M and E frame is one way in which to do so. Relevant to this Monitoring and Evaluation Report (MER) are most particularly objectives one, two and six – presented in our introduction to section one of this report – where we assess whether or not our technology is appropriate for obtaining the relevant data and linked to this is the relevance itself of the data (how accurate are the graphs, what has been measured and so forth). We cannot define and promote sustainable groundwater management options (objective three) without M and E and we cannot improve the understanding of hydrogeological and ground water related socio-economic issues without the M and E component. M and E enhances research capacity in the country as we learn what works and what does not work in integrated groundwater resource assessment and management in general and in particular locations and projects.

2.2 What is an indicator

An indicator is used to answer the question: how do we know whether or how much we have achieved our objective? It refers to a measure used to demonstrate change in a situation, or the progress in, or results of, an activity, project, or program. It is a sign showing where we are (current situation/actual results), the progress made so far (from baseline), and the remaining distance towards achieving our objective (expected results).

In other words, an indicator is a factor or variable that provides a simple and reliable means to reflect change. An indicator enables us to perceive the differences, improvements or developments relating to a desired change (output, objective, and goal). In M and E the term indicator is compatible with such terms as performance indicator, performance measure, indicator of success, and indicator of change (UNDP, 2009). An indicator (from the social perspective) could be the number of citizens who attended training and/or could cite behaviour change of the citizen during or after training. It could also be the number of training sessions organised in collaboration with the citizens since the start of the programme. Another indicator could be the number of citizens who are able to identify changes in the wells – or relationship between one well and another, by the end of the project.

Following the mantra 'You can't manage what you can't measure', indicators and their use have proliferated in recent decades at all scales – from project-level reporting to national environmental accounting to tracking progress at the global level.

A recent example is the adoption of the 17 Sustainable Development Goals (SDGs) under Agenda 2030 and the associated 169 targets and 232 indicators (Berthule et al., 2017). While these developments can be seen as positive, with an increased focus on science and data-informed decision making, they also pose the challenge of needing increased resources to collect 'softer' data, such as emotional well-being and how people feel. Although our project relates to a number if SDGs (for instance 5, 6, 10, 16 and 17) we will focus on SDG 10, reduced inequalities whilst examining both technological and 'hard' data monitoring (quantitative) alongside the 'soft' side of monitoring (qualitative), assessing what the results of the project in terms of reduced inequalities because of improved data and improved knowledge.

An indicator is thus a general term that can be applied in many different fields and contexts. To name a few, in conflict settings, in development settings, in economy, education, health, governance, environmental protection, etc. No matter what kinds of fields they are used in, all indicators have one thing in common; they consist of specific information that signals change in the field they measure and they can be used by project managers and directors as a basis for relevant decision-making, advising on what new or different steps need to be taken in the project to achieve our objectives and/or for policy change.

In the spirit of involving people in solutions to obtain sustainable practices, so too our gathering of information needs to be participatory and emancipatory for the volunteers and not only the research team. For this reason we follow an indicator development paradigm using CREAM, SPICED and SMART which we present in this section.

CREAM indicators are clear, relevant, economic, adequate and monitorable. This means they need to be precise (clear), appropriate to the subject and to the evaluation exercise (relevant), they should not be costly to collect (economic). The indicators should also have the ability to provide sufficient information on performance (adequate) and easily monitored and amenable to independent validation (monitorable). These are the CREAM principles and they are used to select good performance indicators (Schiavo-Campo, 1999). They are well suited to M and E systems that are results-based (see our section five below) and whose purpose is to monitor and evaluate the specific performance and outcomes of a project.

> If any of these five criteria are not met, formal performance indicators will suffer and be less useful. Performance indicators should be as clear, direct, and unambiguous as possible. Indicators may be qualitative or quantitative. In establishing results-based M and E systems, however, we advocate beginning with a simple and quantitatively measurable system rather than inserting qualitatively measured indicators upfront (Kusek & Rist, 2004).

In complex environments, like climate change adaptation, you won't always be able to find indicators that capture the whole reality and you will have to go for an indicator that is adequate, i.e. it's not the best, but acceptable or good enough given the circumstances. Monitorable means that the principles can equally apply to qualitative indicators and although performance indicators are generally quantitative in nature, the CREAM principles are formulated in a way that makes them equally applicable to qualitative indicators. The 'adequate' and the 'monitorable' instead of 'measurable' make sure that the CREAM criteria feel less like only goal setting or quantifiable indicators but encourage the use of qualitative indicators, pertinent to our study where we consider human well-being as a measurement of success.

The idea of SPICED goes hand in hand with CREAM but here we are more concerned with how the indicators are used rather than how they are developed. As we are concerned about social change in the CS project (once again a results-based M and E focus), the SPICED indicators make an impact and inform learning (Roche, 1999). The idea here is that the indicators are subjective, participatory, interpreted and communicable, cross-checked and compared and empowering as well as being diverse and disaggregated. Key informants (stakeholders) have a special position or experience that gives them unique insights – in other words what might seem to be anecdotal evidence becomes critical data because of the source’s value (subjective). Indicators should be developed together with those best placed to assess them – that is with the volunteers, local staff and other stakeholders (participatory).

Locally defined indicators may not mean much to others which implies that they need to be explained or interpreted to different stakeholders (interpreted and communicable). The validity of indicators needs to be cross-checked by comparing different indicators and progress – and by using different stakeholders (e.g. academics, government, volunteers) to ensure validity. The process of developing and assessing indicators should be enabling in itself and should allow stakeholders to reflect critically on their changing situation (empowering) and then finally there should be a deliberate effort to seek out different indicators from a range of groups and across gender. The data needs to be recorded in a way that these differences can be assessed over time (diverse and disaggregated).

SPICED criteria can easily be combined with other criteria, such as CREAM but also SMART, because they serve a different purpose. Briefly, SMART criteria were originally proposed as a management tool for project and program managers to set goals and objectives (Doran, 1981) but today SMART criteria have been well accepted in the field of M and E – rather than only project management. The acronym describes these indicators: specific (not vague), measurable (feasible to gather), agreed (accepted by volunteers and project partners), realistic (able to be gathered) and timeous (how long would it take to get the information. Together, the three elements constitute a progressive and inclusive indicator toolkit.

In the end we believe that we have found the right balance between quantitative and qualitative indicators that often provide context, in-depth explanation and sense-making towards what is quantitatively measured. The principles discussed are useful but should be seen as only one element that informs indicator development. In our report the qualitative indicators are reserved for assessing volunteer experience (section four of the report), such as behaviour, well-being and emotions and the quantitative are used for assessing the accuracy of the data (part three of this section).

Participatory, progressive, people-centred indicator development – ensures economic, social, political value of indicators for monitoring and evaluation so that ideals of social justice and emancipation are embedded in indicator development

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2.3 How do we define monitoring

Monitoring is a continuous or periodic function that uses systematic collection of qualitative and quantitative data to keep activities on track. It is a management instrument. Results-based project management focuses on performance and achievement of outputs, outcomes, and impacts. It supports monitoring by tracking where a project or program is at any given time with respect to project objectives, targets, and outcomes.

Knowledge management is the process by which a project is able to generate value and improve performance using intellectual and knowledge-based assets. M and E contributes to knowledge building and thus also to improved implementation of the project because it makes findings and recommendations accessible to target audiences (such as DWS, WRC, UWC) as well as the volunteers and participants in the project in a user-friendly way, We have twenty two core questions that we apply when guiding our monitoring activities. These are reflected in Table 1 below.

Table 1: Monitoring focus areas

Core focus	Expanded monitoring approach
What is the objective of the monitoring	Reinforce what is working in the system and modify what is not working
How often are we monitoring	What is our temporal frame: daily, weekly, monthly
Are we monitoring continuously	Do we monitor once – or twice – or is this an activity we are doing throughout the life cycle of the project (iterative)
What parameters are we measuring	Certain parameters are not giving us the product that we want and we might need to modify them
Who will be responsible for collecting data	Who is currently collecting data
Which tools will be most appropriate for data collection	What tools are we currently using
How best can we collect monitoring data for the CS component	What monitoring data are we currently collecting
Who is monitoring	Are we collaborating with DWS, with the farmers, the volunteers? Or is it only the research team that is monitoring
What are the known processes or activities we want to monitor	What is visible – on the CS app, 'well-being' of volunteers, buy-in into project, awareness of upstream/downstream as well as technical data
Are there unknown processes that might crop up	While monitoring – would we perhaps need to adjust our monitoring activities because new phenomena have been brought to the fore
What is the input	Are the ingredients (the training, the instruments, etc.) that are being used the correct ones (correct size dip-meters for instance, adequate training hours, etc.)
Who should be responsible for the collation and analysis	How is the data currently being analysed
How can we ensure the monitoring data guides the performance of the CS	How is data being used currently to guide CS performance
What is it we want to monitor from the technical side	Increased water levels, rainfall for instance and perhaps down the track water quality as well
What is it we want to monitor from the social side	What behaviour changes are we anticipating – what are people doing 'right' and what are their emotional responses as volunteers, what spin-offs does the monitoring have for individuals, households and communities

These indicators allows for performance measurement which is a key tool to assess how well a programme or policy achieves its objectives and to identify the appropriate indicators which are critical for this to be achieved effectively. Performance measurement has three main functions i) to make the most of limited resources, ii) to increase accountability and transparency (e.g. making government, civil society, research community and the general public aware of results), and iii) to improve decision-making by providing relevant information to inform internal management decisions for ensuring effectiveness of development aid (Holzapfel, 2014).

We monitor to improve program performance and management: providing information on how an activity, a project or a program works and how it might be improved. Indicators enable program staff to perceive differences, improvements or developments relating to the achievement of intended outputs, outcomes, objectives, and goals. As we have shown in the section on monitoring indicators above, indicators are at the bedrock of a M and E system. In project management and implementation, most of the monitoring activities are conducted around the development and measurement of the indicators. Meaningful indicators obtained from a system of data collection, analysis, findings and recommendations can lead to management information and thus play a key role in making management information systems operational – in other words assist the team to do 'the best' in implementing their project. Indicators enhance accountability: providing data that allows program staff, managers and directors to hold accountable to themselves, funders, beneficiaries and all other stakeholders.[13]

2.4 What is evaluation

There is a difference between monitoring and evaluation. Monitoring (discussed above) refers to an organized process of overseeing and checking the activities undertaken in a project, to ascertain whether it is capable of achieving the planned results or not. Conversely, evaluation is a scientific process that gauges the success of the project or program in meeting the objectives. Evaluation is a systematic and impartial assessment of an activity, project, program, strategy, policy, sector, focal area, or other topic aimed at determining the relevance, efficiency, effectiveness, impact and sustainability of the interventions and contributions of the involved partners (Global Environment Facility 2010).

The UNDP bureau for development policy proposes that evaluation is to promote accountability for the achievement of objectives and the contribution of the project to the broader groundwater and monitoring environment in general and water resources management in particular. Evaluation aims

[13] http://dmeforpeace.org/sites/default/files/3.9%20Indicators.pdf

to promote learning, tighten feedback loops so that one better understands the impacts of activities on the stakeholders and vice versa – the impact of the stakeholders on the plans and activities of the project. The purpose is to inform decision making, future projects and the wise spending of resources (human and financial capital).

2.5 M and E geographical and social landscape (context)

The Hout river is an ephemeral river that flows ensuing large and intense precipitation events and is situated in the Hout Catchment which has an area of 2478km^2 and is located northwest of Polokwane with an elevation range of 840-1739 m above sea level (Ebrahim et al., 2019). The Hout Catchment is a tributary to the Sand River which eventually drains into the Limpopo River as shown in Figure 1 below.

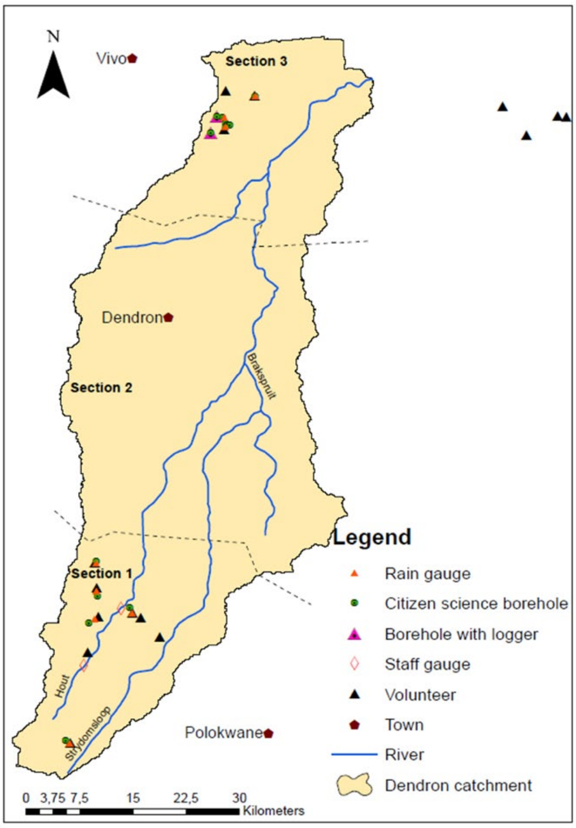


Figure 1: The distribution of monitoring points, depiction of sections and volunteer location

The Hout Catchment is predominantly known for its agricultural activities and for the substantial production of potatoes that are supplied by commercial farmers throughout the country. Most of the commercial farmers in the area grow potatoes, maize and accra vegetables. A handful of farmers supplement their crops by having game reserves in addition to their farming activities. All of the farmers in the area are dependent on groundwater for their irrigation and are thus heavy users of groundwater. Their irrigation methods are mainly the use of centre pivots, a method of crop irrigation in which equipment rotates around a pivot and crops are watered with sprinklers. The Catchment is mostly covered by sand soil and a dominant geology of crystalline complex of Hout River, Gneiss, with close to vertical dolerite dikes intruding into the subsurface.

The Hout River is the main river in the catchment. It is mostly dry throughout the year and only flows after heavy rainfall events. However, throughout the years, water is captured in the Hout Dam, but this prevents a large amount of water from the river flowing downstream. The catchment consists of a few types of water users namely; domestic users, small-scale farmers and commercial farmers and other industrial users such as Coca Cola, SAB, brickmaking industries, etc. For the purpose of the Enhanced Sustainable Use of Groundwater in South Africa (ESGUSA) project – and now for the Water Research Commission (WRC) follow through, the catchment has been divided into three sections. The division of the catchment into three different sections makes it easier to co-ordinate activities and have targeted interventions in terms of the CS activities. The sections correspond to political boundaries in the catchment. For instance, section one falls under the Polokwane District Municipality, section two is the Capricorn District Municipality (Molemole) whilst section three falls under the Vhembe District Municipality (Makhado). The dotted lines displayed on the map above are the boundary lines for the different municipalities. Some of the farms cross over municipal boundaries.

Figure 2: Pumping boreholes in Mamadila

2.6 Monitoring and evaluation of data – flaws, strengths and validity

There are two different monitoring and evaluation activities. First there is the monitoring of the boreholes in Kalkfontein and Mamadila that were drilled for the sole purpose of monitoring groundwater (see image one above). The MER framework for groundwater levels and quality is developed for the entire Hout-Sand Catchment – and we propose that it can be taken up in other catchments as well.

Groundwater monitoring networks are designed using statistical methods for optimising borehole placement and sampling frequencies, by using detailed hydrogeological information and local knowledge to place boreholes, or by a combination of both methods (Rosen, 2003). In order to design a pragmatic groundwater monitoring network a spatial density criteria-based approach is put forward. This approach allows the incorporation of best-practices; hydrogeological information and expert knowledge. The methodology comprises the following steps: define monitoring objectives for the area (1) develop optimal positioning criteria, and (2) decide on monitoring parameters and frequency.

2.7 Technical aspects and monitoring objectives for MER Framework

Defining monitoring objectives is critical to M and E. The Department of Water and Sanitation (DWS) with the assistance of stakeholders adopted the national monitoring objectives and priorities as shown in Table 2 below:

Table 2: Summary of national water resources monitoring objectives (AECOM, 2016)

Priority class	Objective	Description
1	Resource and infrastructure planning	To provide adequate monitoring data for determining the availability and quality of current and future water resources, aimed at the equitable and sustainable allocation of these resources to the population, environment and other economic sectors of society through planned infrastructure development and other interventions
2	Resource operations and management	To provide timeous monitoring data for the efficient operation and management of water resources to ensure the protection of resources and water users and to allocate water equitably and sustainably
3	Risk mitigation	To provide timeous water resources monitoring data for early-warning systems to mitigate negative impacts on humans, infrastructure, the economy and riverine and coastal ecosystems
4	Compliance and auditing	To provide water quality and quantity monitoring data to ensure compliance and auditing functions required for water use licensing, and other functions

In order to ensure that the full scope of monitoring requirements are taken into account a process of "unpacking" the generic monitoring objectives (AECOM, 2016) is required as is given in Table 3 below:

Table 3: Prioritised objectives for water resources monitoring (AECOM, 2016)

Main objective	Sub-objective
Resource and infrastructure planning	• Quantify available resource: this is one of the main reasons for water resources monitoring. The quantification of the resources is important to proper future allocation, planning and water resource development • Fitness for use: determining the usability and projected distribution of water quality determinants is key to plan the feasibility of schemes • Operating rules development: bulk surface water and primary-use wellfields require operating rules to ensure sustainability of use and the correct actions in times of stress on resources • Infrastructure design: the sizing and timing of infrastructure developments, as well as sedimentation and flood analysis, are supported by water resource monitoring elements
Resource operations and management	• Systems operation: giving effect to long-term water resources allocation planning through the implementation of operating rules, Reserve requirements and international obligations is key to the sustainable use of the water resources • System management: shorter-term allocation decisions are important to ensure that the curtailment of water supply and the blending of water for quality purposes are implemented when necessary
Risk mitigation	• Flood management: short-term events such as flood operating decisions for surface water and estuarine systems are important to avoid damages and the loss of life and property • Resource availability and fitness of use: For smaller system, the status, quality and availability of resources are important. • Critical levels: Critical levels that warn of impending environmental dangers are key for timeous corrective actions, such as the quality concerns relating to acid mine drainage and shale gas development.
Compliance and auditing	• Compliance checking: Legal requirements for water use licenses and the Waste Discharge Charge System require that compliance monitoring takes place. • Auditing: Auditing by DWS of the issues such as Reserve implementation compliance also need to be done on a non-frequent sample basis

These objectives inform the basis for setting the groundwater monitoring objectives around which the MER framework pivots. Based on the analysis of hydrogeological conditions, existing groundwater data and conditions, land-use activities and with input received from DWS officials, key objectives for future groundwater level and quality monitoring need to be monitored and evaluated and reported in a framework.

Baseline monitoring points reflect ambient conditions of the aquifer whilst the trend monitoring points are intended to show impacts from various land-use activities such as agriculture. For example, in the Hout-Sand Catchment, analysis is being conducted to identify monitoring points for baseline monitoring and monitoring points as trend monitoring stations. In both cases levels and quality of groundwater need to be monitored and evaluated and reported in a framework using the above parameters. In other words, a MER Framework is required for such information.

2.8 Monitoring parameters and frequency for MER framework

Sampling frequency is central to groundwater monitoring activities. Given the objective of sampling as monitoring the actual state of groundwater systems, criteria for the determination of the sampling frequency can be based on the trend detectability, the accuracy of estimation of periodic fluctuations and the accuracy of estimation of the mean values of the stationary component of the state variables, such as groundwater heads, temperature, and concentration of hydro chemical constituents (Zhou, 1996). For setting-up the MER framework for groundwater monitoring the focus is on, ambient conditions, trend detectability and impacts from on groundwater resources from various land-use activities in the catchment.

Figure 3: Preparing monitoring of well

Groundwater levels provide information on the amount of storage in a given aquifer. Comparisons of measured groundwater levels with long-term averages provide an indication of the state of groundwater resources within an aquifer (BGS, 2017). Observation over several years allows the prediction of aquifer response to current climatic and hydrological conditions (BGS, 2017). The control of groundwater hazards such as groundwater pollution requires the measurement of specific chemical constituents. Various statistical techniques (Zhou, 1996) are available to determine the frequency of monitoring for the Hout-Sand Catchment with a sub-optimal network and limited time series information which means that standard rules and practices need adherence as proposed in Table 4 below.

Table 4: Proposed groundwater monitoring frequencies for levels and constituents (AECOM, 2017)

Type of station	Proposed frequency Twice yearly (manual)	Monthly (manual)	Daily (manual)	Daily (automatic)	Sub-daily (automatic logger)	Near real-time
Baseline stations						
Water level		X			X	X
Rainfall		X		X	X	
Chloride (resource evaluation)		X				
General chemistry		X				
Trace inorganics		X				
Microbiology		X				
Priority pollutants		X				
Pesticides	X					
Chemicals of emerging concern		X				
Isotopes		X				
Trend station						
Water level		X			X	X
General chemistry		X				
Trace inorganics		X				
Priority pollutants	X					
Pesticides	X					
Chemicals of emerging concern	X					
Isotopes	X					

The rationale for the type of stations is explained below (modified from AECOM (2017).

- Water level: measurement of water levels provides seasonal and long-term trends in groundwater elevations. This makes available data to derive information about the changes in groundwater storage and evaluate potential areas of over-abstraction
- Rainfall: groundwater levels rise or decline is dependent on recharge from rainfall
- Chloride: the chloride mass balance method is commonly used to calculate recharge to aquifer systems
- General chemistry: constituents that determine the hazard of other variables and that may have hazard potential in own right
- Trace inorganics: inorganics that are seldom present above a few milligrams per litre but that entails a significant hazard
- Microbiology: micro biota that constitute a significant hazard to drinking water resources
- Priority pollutants: constituents considered to have a high hazard potential including those regulated under the Stockholm Convention [14]
- Pesticides: pesticides that are commonly used in South Africa and that entail a significant hazard and/or significant mobility
- Chemicals of emerging concern: chemicals where significant hazard has been demonstrated in laboratory work but the effect at user level is not fully understood (including EDCs)
- Isotopes: isotopes are useful tools to understand to understand groundwater movement, occurrence and age

2.9 Monitoring priorities for MER framework

In terms of national planning, the highest priority is given to resource and infrastructure planning (priority class one). The initial functions of the catchments include:

- Investigate and advise interested persons on the protection, use, development, conservation, management and control of the water resources
- Co-ordinate the related activities of water users and of the water management institutions within the water management area
- Promote the co-ordination of our implementation with the implementation of any applicable development plan established in terms of the Water Services Act, Number 108 of 1977

[14] Convention to protect human health and the environment from persistent organic pollutants such as PCBs and DDT

- Promote community participation in the protection, use, development, conservation, management and control of the water resources in our water management area.
- Power to manage, monitor, conserve and protect water resources and to implement catchment management strategies

In line with the above-mentioned functions, objectives for resource operations and management as well as risk mitigation and compliance auditing are proposed for the Hout-Sand Catchment (Table 5 below modified from Tables 2 and 3 above).

Table 5: Proposed groundwater monitoring priorities for Hout-Sand Catchment (modified from AECOM, 2016)

Main objective	Description	Sub-objectives
Resource operations and management	To provide timeous monitoring data for efficient operation and management of water resources to ensure protection of resources and water users and to allocate water equitably and sustainably	• Systems operation: giving effect to long-term water resources allocation planning through the implementation of operating rules and Reserve requirements • System management: shorter-term allocation decisions are key to ensure that the curtailment of water supply and the blending of water for quality purposes are implemented when necessary
Risk mitigation	To provide timeous water resources monitoring data for early-warning systems to mitigate negative impacts on humans, infrastructure, the economy and riverine and coastal ecosystems from floods, droughts, etc.	• Resource availability and fitness of use: for smaller system, the status, quality and availability of resources are important • Critical levels: critical levels that warn of impending environmental dangers are key for timeous corrective actions such as the quality concerns relating to shale gas development and droughts
Compliance and auditing	To provide water quality and quantity monitoring data to ensure compliance and auditing functions required for water use licensing and other functions.	• Compliance checking: legal requirements for water use licenses and the Waste Discharge Charge System require that compliance monitoring takes place

Main objective	Description	Sub-objectives
		• Auditing: auditing by DWS of the issues such as Reserve implementation compliance also need to be done on a non-frequent sample basis

2.10 Conclusion on groundwater monitoring (technical aspects)

The planning and management of groundwater in South Africa is weak due to inadequate groundwater monitoring systems. In addition, to date a MER framework to be monitoring, evaluating and reporting progress on groundwater resource is non-existent. We propose a MER framework to monitor, evaluate and report groundwater in the Hout-Sand Catchment. The framework will be populated with data from hydrogeological activities and field-based investigations and observations including those from citizen scientists. Monitoring objectives have been put forward that align with the national monitoring objectives and also functions of the generic catchments including the Hout-Sand Catchment. The objectives for resource operations and management; risk mitigation and compliance auditing are suggested for the Hout-Sand Catchment as shown in Table 5 above. The baseline and current trend monitoring stations as proposed by DWS form the backbone of the monitoring activities in the Hout-Sand Catchment where information will be generated for the designed Managed Aquifer Recharge (MAR) Framework. The monitoring points need to be optimised with the current regional groundwater monitoring network taking into account the positioning criteria. No widespread monitoring of groundwater levels and quality is currently happening resulting in consequent punitive non-action dealing with transgressors. Therefore, with the current infrastructure in place there is no opportunity for risk mitigation, compliance and auditing monitoring to ensure responsible groundwater use/abstraction. The monitoring parameters and frequency to measure at the baseline and trend stations has also been put forward in Table 5. The designing of the MER Framework is welcome despite being long overdue.

Management of water resources is possible only under conditions of availability of adequate qualitative and quantitative information about the state of the water body at any moment of time. Such information is necessary for taking decisions about allowable water usage and for substantiation of controlling actions and verification of their observation. Such time series information can be provided through water monitoring. Monitoring is the main source of feedback data in the system of water resources management. It allows us to determine quantitative and qualitative characteristics of water and to evaluate its suitability for certain kinds of usage. The CS component provides quality measurements comparable to formal observations. The project concentrates on monitoring time series of daily rainfall, river flow and groundwater levels in the Hout Catchment, this is done using the Mycitizenscience App – volunteers are able to upload daily data from the field through the app. The data can be validated by regular meetings from the professional team who check on an ad-hoc basis whether the CS measurements are correct.

Volunteers (Table 6) are trained on how to use dip meters and asked to capture data once a week and to send the data through to the Citizen App on their smartphones (see Figures 4 and 5 below).

In the future it is anticipated that volunteers will also capture data on groundwater quality. The data collected so far on groundwater levels and on rainfall has been validated as there are visits to the field every three months to test the data and verify the accuracy of the recordings of the volunteers.[15] As Lintott (2019) claims, there is no reason to believe that data collected by the volunteers is any less reliable than data collected by 'scientists.' The team anticipated resistance by volunteers in collecting data as they might be unsure as to what advantages they would have in capturing data but this was not case.

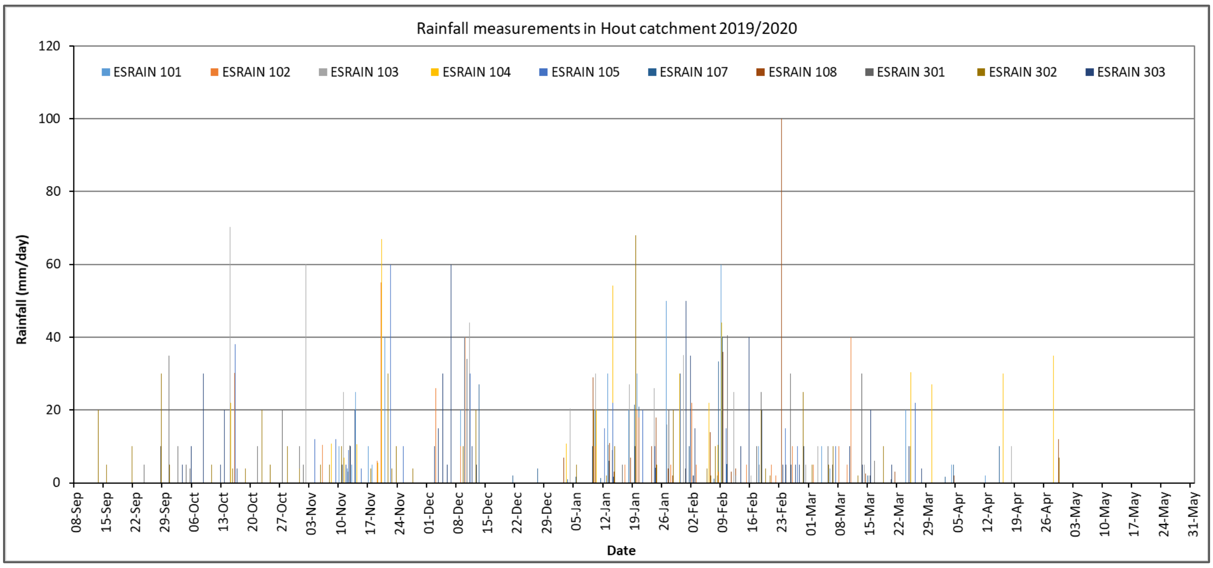


Figure 4: Rainfall readings recorded by volunteers (Sep 2019 to May 2020)

[15] During lock down due to COVID 19 (April 2020-July 2020) there were no visits to the field but communication through whatsapp was ongoing and any concerns that the volunteers had were expressed on whatsapp

Figure 4 above shows a typical rainfall reading recorded by CS volunteers in the Hout catchment from September 2019 to May 2020.

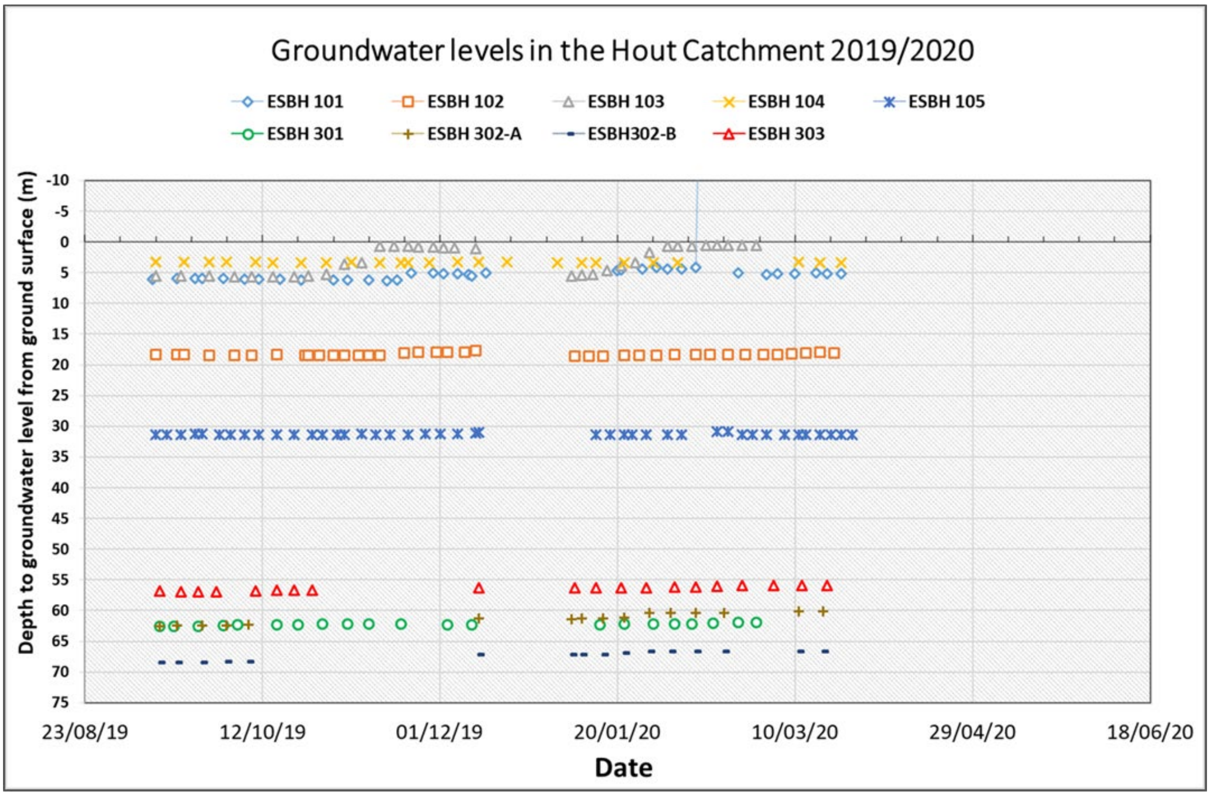


Figure 5: Groundwater level data collected by volunteers (Sept 2019 to April 2020)

Figure 5 above shows groundwater level data as collected by volunteers in the Hout also between the months of September 2019 to April 2020.

2.11 Social aspect to M and E

Figure 6 below show volunteers being trained with rain gauges and dip-meters

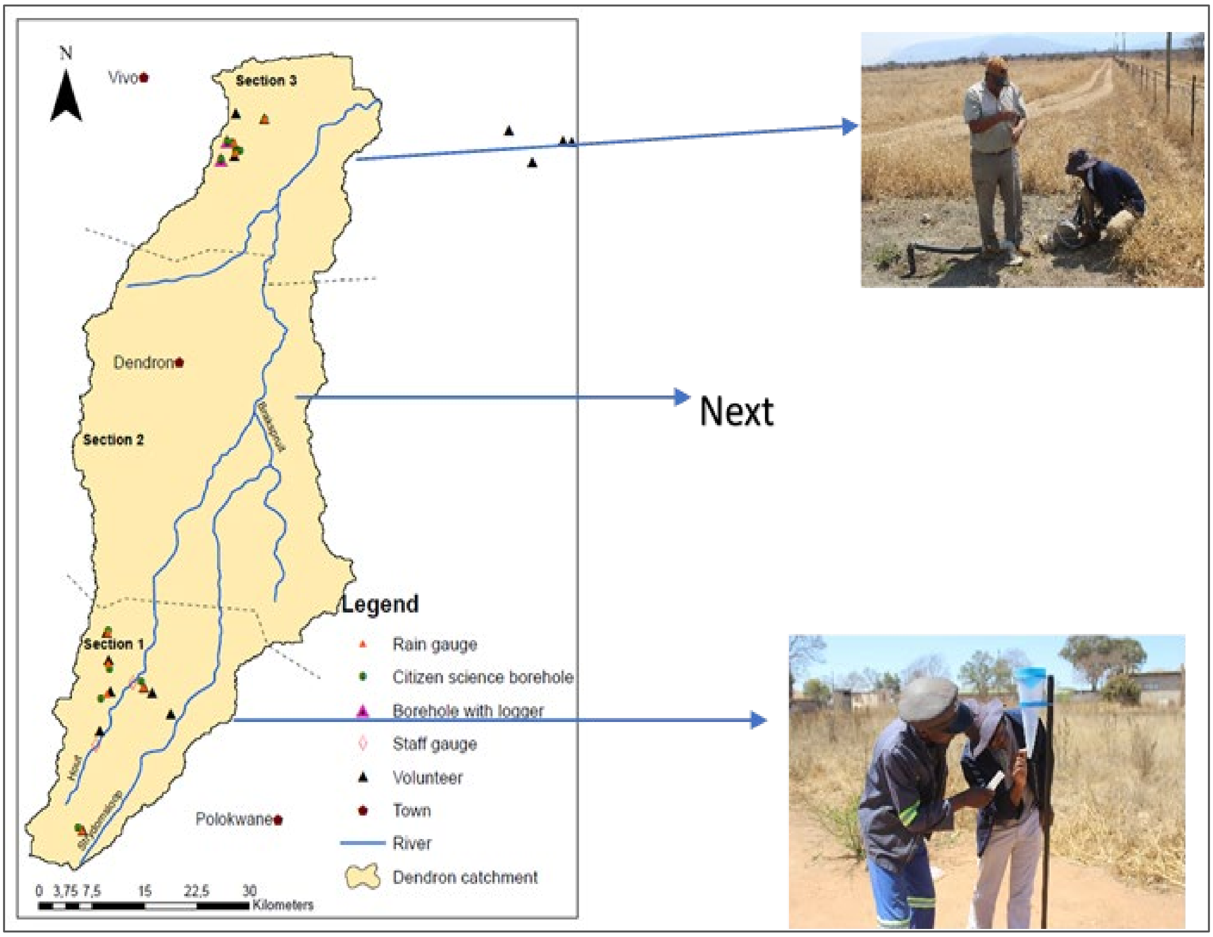


Figure 6: Training on using a dip-meter and rain gauge

Rain gauges were installed at the homes of the volunteers. Figure 6 above also reflects the demonstration from the trainer of how the volunteer should monitor rain water levels as part of the overall water resources monitoring in the catchment.

From the CS aspect which is the social angle of the project, we acknowledge that capacity development is a major concern for us and, unsurprisingly is also considered to be a priority for the international community, being declared a priority area of international development (UNDP, 2010). Capacity building implies both individual capacity as well as institutional capacity.[16] In our own MER we are concerned mainly – but not only – with individual capacity building. We monitor and evaluate capacities for engagement which are the capacities to generate, access, and use information and

[16] We acknowledge the relevance of the capacities for strategy, policy and legislation as well as capacities for management and implementation

knowledge and capacities to monitor and evaluate the processes applied. Monitoring at the individual capacity development level refers to the process of changing attitudes and behaviours, most frequently through imparting knowledge and developing skills through training. There is an emancipatory dimension to capacity building and in our instance capacity building is aimed at improved water literacy, although this is not the only positive outcome we expect. It also involves learning-by-doing, participation, ownership, and processes associated with increasing performance through changes in management, motivation, morale, and improving accountability and responsibility. In this regard we consider the following:

1. Engaging partners and building consensus
2. Assessing capacity assets and needs
3. Formulating capacity development strategies
4. Implementing capacity development strategies
5. Monitoring and evaluating capacity development efforts

As the WRC project builds on ESGUSA we 'adopt' eleven volunteers who are already monitoring groundwater in their wells and measuring rainfall in section one and three of the catchment (Table 6). These are the first generation of volunteers. The WRC has the opportunity to assess the work carried out in the first phase of ESGUSA where we were learning by dong in the spirit of what we have called in deliverable two of this project, the living lab. This is a space where knowledge is co-created and where we, the research team learn what the volunteers need in order for them to collect data, to ensure that there is no or minimum attrition and the continuation of the tasks that were agreed on in the contractual arrangement between the research and the volunteers. The next generation of volunteers have now been identified and two new volunteers have been trained in section one and four in section two.[17]

[17] Additional training was to take place in November 2020 but due to restrictions in movement because of COVID-19, the training was delayed and took place at the beginning of 2021

Table 6: First generation of volunteers

No	Section	Name	Community	BH NR	Latitude	Longitude
1	1	Jack Ledwaba	Manyepje	ESBH 101	-23 9049	29 1922
2	1	Loftus Ramazingya	Rambakgaphola	ESBH 102	-23 7562	29 2212
3	1	Florina Moeti	Ga-Moeti	ESBH 103	-23 7374	29 2733
4	1	Setsena Bartina	Diteng-teng	ESBH 104	-23 679	29 2325
5	1	David Manamela	Ga-Manamela	ESBH 105	-23 7226	-29 2325
6	3	Gershom Buys	Buysdorp	ESBH 301	-23 1157	29 3906
7	3	Aldrin Lawrence	Buysdorp	ESBH 302 A	-23 1234	29 394
			Buysdorp	ESBH 302 B	-23 1254	29 3958
8	3	Catherine Bassom	Buysdorp	ESBH 303	-23 089096	29 431679
9	1	Lucas Chokoe	Chokoe village	ESBH 106	-23 7773	29 2974
10	1	Mashela Dorah	Ga-Komape	ESBH 108		
11		Abrinah	Vaalkoop Village	ESBH 107		

The first step in monitoring is to capture details of the volunteers. These volunteers are in section one and three of the catchment (and now also – not reflected on above – in section two). The precise location is captured in longitude and latitude. We have also identified the boreholes that each volunteer is monitoring (ESBH). The name of the village where the volunteer is based is described in column four.

We proceeded to identify (co-create) with the volunteers certain criteria that would assist in monitoring the success – or lack thereof – of a volunteer to capture groundwater levels with the dip-meters provided and rainfall with the rain gauges provided. The three (smiley) tables below reflect on this data presented for the first generation of volunteers. As we proceed in the next phase of the project we will have a second generation of volunteers and will use these same indicators to assess them. However, we will also invite volunteers to develop further the monitoring sheet and help us understand what additional parameters need to be added to the (smiley) table/chart.

This chart is the main tool we used for assessing capacity assets and needs and monitoring and evaluating capacity development efforts. The indicator (co-created) list is not exhaustive as we are now, in the next phase of the project, developing this tool further and applying additional criteria. The criteria we have used to measure the success or lack thereof of volunteers to measure groundwater levels, rainfall and to be active on the CS App are as follows: learning of technology, errors in reading, ability to access CS app, interest in data on app, competence to train other volunteers, happy with process, technical problems, active on app (chatting, sharing experiences), has own borehole, public or private borehole, takes photo of the river, measures rainfall regularly and transmits data.

Table 7: Monitoring indicators – four first generation volunteers

Table 1: Section 1 Volunteers	Jack Ledwaba	Loftus Ramasinya	Vincent Moeti	Setsena Bartina 1/2
Borehole ID	ESBH 101	ESBH 102	ESBH 103	ESBH 104
Recruited	Hydrocensus Field Visit	Workshop (1st)	Workshop (1st)	Workshop (1st)
Learning of Technology	Resistant to technology uptake but through some training and regular uploads he has gotten better	Easily learnt technology	Resistance to technology but managed to learn quickly on how to operate the equipments	Easily learnt technology
Errors in Reading	Initially had difficulties in reading but after training he improved	He was able to do monitoring reading and understood it well	He was able to do monitoring reading and understood it well	Initially had difficulties in reading but after training he improved
Able to access CSApp	YES	NO - Lost his CS phone	NO - Lost his CS phone	YES- but shes having trouble with the phone shes using we may need to provide her with a cellphone
Interested in data in the App	YES - Interested in the final output of the project and how it can help in his community	YES - Interested in seeing the visuals of the monitoring he is doing	NO - Only does monitoring and does not enquire about the process. He is not good with technology so this might be the reason for not asking about the App	NO - She doesn't enquire about the data that she submits. Less interested in what the graphs represent but wants to understand how we will improve water supply conditions in the villages
Has competence to train other volunteers	YES but requires more training	YES. Has a good memory and understands quickly	YES- Will need lots of raining on the App, however he is good with taking measurements	NO - will need further training
Happy with process	YES	NO	YES	YES
Technical Problems	NO, Equipment is in good condition	NO - Equipment is in good condition	NO - Equipment is in good condition	NO - Equipment is in good condition
Is active on the app (chatting, sharing experiences)	Not active in the App. Only sends CS data	Not active because he lost his phone	Not active because he lost his phone	Not active she only sends monitoring data through the App
Has own borehole	Uses a public borehole	Uses a private borehole at a distance	Uses a public borehole	uses a private borehole at a distance
Takes photos of river	YES - but only when I have requested. Only sends images of borehole measurements.	only measures rainfall and GW	YES- but only when I have requested. Hasn't been very active seens he lost his phone	only measures rainfall and GW
Measures rainfall regularly And transmits data	measures daily and sends weekly	measures daily and sends weekly	measures daily and sends bi-weekly	measures daily and sends weekly
Public or private borehole	Public at a distance close to the Hout river	Private- at a distance household(old borehole)	Public- at a distance near Hout river channel	Private- at a local tavern (no operating anymore)

Table 8: Monitoring indicators – four first generation volunteers

Table I: Section 3 Volunteers	Gershom Buys	Aldrin Lawrence	Caterine Basson
Borehole ID Recruited	ESBH 301 Workshop (2nd)	ESBH 303-A&B Workshop (2nd)	ESBH 303 Workshop (2nd)
Learning of Technology	Easily learnt technology	Easily learnt technology	Easily learnt technology
Errors in Reading	He was able to do monitoring reading and understood it well	He was able to do monitoring reading and understood it well	She was able to do monitoring readings and understood it well
Able to access CS App	YES	YES	YES
Interested in data in the App	Yes, Interested in the data so that it can assist him with his farming activities	Yes, Interested in the data so that it can assist him with his farming activities	Yes, Interested in the data so that it can assist him with his farming activities
Has competence to train other volunteers	YES	YES	YES
Happy with process	YES	NO	YES
Technical Problems	No, Equipment is in good condition	Yes, Dipmeter is broken and cannot measure water level in his boreholes	Yes, Dip meter is stuck in her borehole and she cannot get it out of the borehole. I think this could due to the borehole being a household pumping borehole as well. The wiring can entangle.
Is active on the app (chatting, sharing experiences)	Not active, only focused on the data collection and farming	Not active, only focused on the data collection and farming	Not active, only focused on the data collection and farming
Has own borehole	Uses a private borehole in his farm	Uses a private borehole in his farm	Uses a private borehole in her yard
Takes photos of river	only measures rainfall and GW	only measures rainfall and GW	only measures rainfall and GW
Measures rainfall regularly And transmits data	measures daily and sends weekly	measures daily and sends weekly	measures daily and sends weekly
Public or private borehole	Private- in his farm	Private - in his farm	Private - in her yard

Table 9: Monitoring indicators – three first generation volunteers

Table I: Section I Volunteers	David Manamela	Lucas Choke	Masahela Dorah	Abrina Koena 2/2
Borehole ID Recruited	ESBH 105 Hydrocensus Field Visit	ESBH 106 Hydrocensus Field Visit	NA Workshop (1st)	NA Hydrocensus Field Visit
Learning of Technology	Easily learnt technology	Easily learnt technology	Resistance to technology but managed to learn quickly. She will need training on the App	Easily learnt technology
Errors in Reading	He was able to do monitoring reading and understood it well	He Initially had difficulties in reading but after training he improved	She Initially had difficulties in reading but after training he improved	She Initially had difficulties in reading but after training he improved
Able to access CS App	YES	NO - still requires training. He is a new volunteer and not much training was provided.	NO - she does not have a working phone, we still need to provide her with a smartphone	YES
Interested in data in the App	YES - Interested in the final output of the project and how it can help in his community	YES - Interested in the final output of the project and how it can help in his community	NO - She doesn't enquire about the data that he submits. This maybe due to the lack of understanding. We will need to create a workshop that can explain the puposes of monitoring and how it can help the volunteers	YES - Interested in the final output of the project and how it can help in his community
Has competence to train other volunteers	YES	NO	NO	YES
Happy with process	YES	NO	YES	YES
Technical Problems	NO - Equipment is in good condition	NO - Equipment is in good condition	NO - Equipment is in good condition	NO - Equipment is in good condition
Is active on the app (chatting, sharing experiences)	Not active she only sends monitoring data through the App	Still needs training with the App	Needs to receive a smartphone from the project	Not active. Only sub, its data when requested
Has own borehole	Uses a public borehole	Uses a public borehole	she has no borehole yet, still to be allocated a borehole	She has no borehole yet, still to be allocated a borehole
Takes photos of river	only measures rainfall and GW	only measures rainfall and GW	only measures rainfall and GW	YES - She takes photos of the river flow and dry bed
Measures rainfall regularly And transmits data	measures daily and sends weekly	measures daily and sends weekly	measures daily and sends weekly	measures daily and sends weekly
Public or private borehole	Public at a distance in the field	Public- at a distance in the field	NA	NA

As is reflected in the above charts most of the first generation of volunteers are 'happy with the process' of monitoring and with their role as volunteer. Some mastered the technology easily, others had more problems learning how to monitor their wells. Some measure rainfall regularly whilst others do not. We are aware that the group WhatsApp is not being used and very few volunteers are tapping into the web app.

Emotional well-being, happiness but also feelings of pride and dignity as identified by Goldin (2003) and Goldin (2013) are anticipated outcomes of the volunteer training and monitoring processes and we consider them to be prime variables to tap into. Most of the volunteers are interested in the data and they say that they would benefit from accessing the graphs and charts that are on the www.citizenscience site (Figure 7 below). Apart from validating the data during the December field trip, volunteers will also be taught how to interpret the data (see figures below) on the web through their smartphone app.

When we identify the next generation of volunteers, we will add indicators that are able to measure these attributes more precisely – and once again in the spirit of the living lab and CS, following the principles laid out in section one of this report which discusses CREAM, SPICED and SMART indicators, these variables will be co-created.

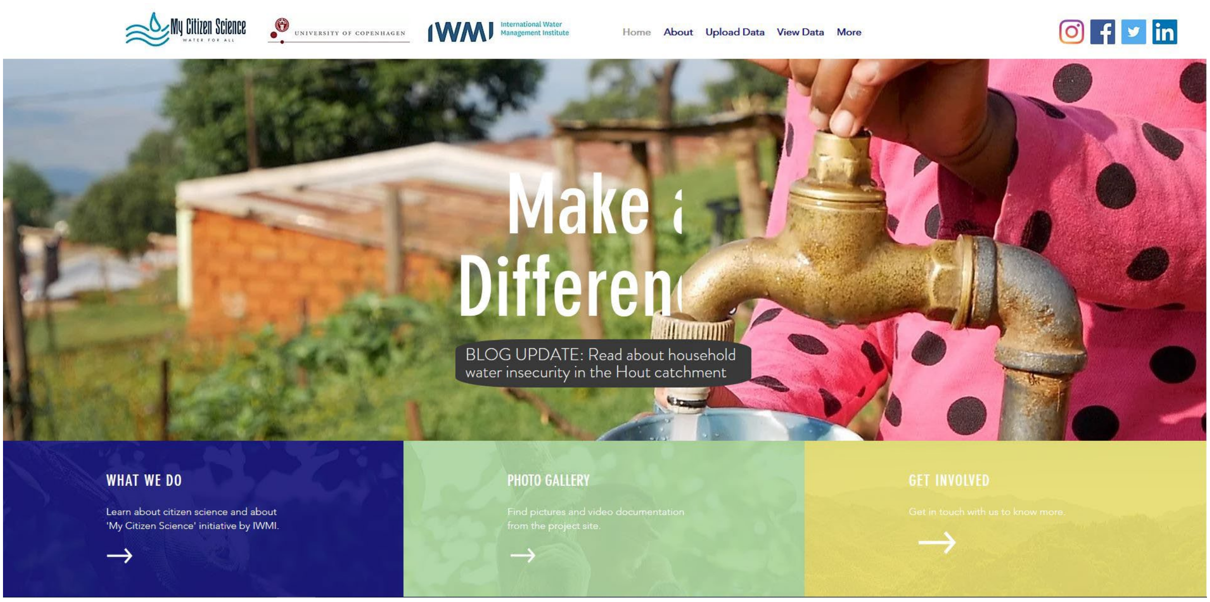


Figure 7: Mycitizenscience App used by volunteers to upload field data

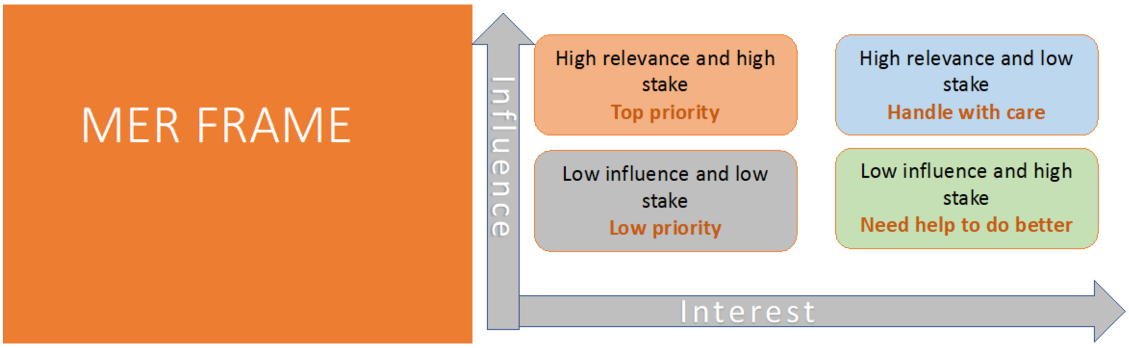
Further training (late December 2020 an January 2021) has focussed on training the second generation of volunteers but also on 'gaps' in the program – such as insufficient use of the WhatsApp on the smartphone but also to complete the vision for water literacy – where volunteers are able to access the data on the mycitizenscience app. Already, post training in October 2020, there is more activity on the phone app and volunteers are beginning to use it more readily. These are 'teething' problems that our team is experiencing with the first generation of volunteers. We did not emphasise sufficiently in the original training what the purpose of the app is and why there would be added value if the volunteers made use of it. Added value includes being aware of belonging to a group that stretches across the catchment, being able to share worries or concerns with measurement (or other) issues, reversing feelings of isolation and recapturing the 'togetherness' that volunteers experienced during the stakeholder workshops in 2019. This has particular significance given the COVID-19 ramifications and changes in the project cycle – such as postponing travel to the Limpopo. Another attribute of the CS App is that it conveys messages from the citizen scientists (volunteers) to the research team – for instance when a dip-meter is stuck or broken this can be recorded instantly on the app instead of waiting for the research team to 'find out' that the dip-meter is not working because a) no data is coming through onto the site and b) when in the field monitoring performance it becomes evident that the dip-meter is stuck or broken.

The quality control procedures are presented in the CS App forms where a step by step procedure ensures that correct practices of measurement have been taken when the volunteer fills out the measurement form. Special asterisks have been included to verify whether a reported data value is representative of what was intended to be measured. The form also requires that the volunteer includes an image of the observations. The rainfall data is also verified along with the data of the South African Weather Station (SAWS). As stated above, once every month a professional scientist takes field samples at the volunteers' respective boreholes – unannounced – to compare results obtained with that of the volunteers and to ensure proper use of the monitoring instruments.

We have argued in section 1.7 above that the notion of trust is a fundamental part of the CS framework. It is worth noting that trust itself is an indicator that the project is working. Or put differently, distrust is likely an indicator of discomfort and lack of buy-in from the volunteers. Unfamiliarity with CS can create vulnerability, the perception of risk, and the potential for a lack of trust not only between volunteers and the project team but lack of trust in the data. Our project provides an opportunity to gauge and nurture trust through frequent touch-base opportunities and we have experienced high levels of trust between volunteers and the research team. We will include an indicator of trust which we will tap into during the next stakeholder workshop – planned for February 2020, COVID permitting. Section two farmers were the most resistant to being part of the project – for many reasons but mainly because it was less obvious to farmers in this section what they had to gain from being part of the project. An indicator of trust is that the farmers did buy-in to the project and during the stakeholder engagement workshop held in November 2019, this segment of the population who were the target group for that workshop, manifested high levels of trust. This indicator of trust can be measured by the following: expression of interest in the project, request to train farm labourers on the farms in section two, willingness of farmers to share their data and so forth. We also tapped into the idea of trust in section one and three where once again at the stakeholder engagement workshops held during 2019 in these segments of the Hout, participants expressed high levels of trust again manifest through the following: willingness to collect data, willingness to share data, expression of support to the technical team (trainers), willingness to share findings with tribal chiefs, government, etc.

Certainly, an indicator of success for the project is ‘water literacy’ where volunteers who had no knowledge prior to the project learnt what works and what does not work in their wells: how much water there is: how much rainfall was gauged and so forth. The educational aspect underpins the volunteer experience and literacy about groundwater is empowering and also is a driver for a citizen to collect data and to be motivated to read and analyse the data – there is thus the emancipatory spinoff around water ‘facts.’

2.12 MER framework



- Which indicators are highly relevant and determine success or failure of project
- Which indicators are highly relevant but are not a deal-breaker for success of project
- Which indicators are not critical for success of project
- Which indicators are very important but are not showing maximum performance

The MER frame above is informed by three questions. What are we monitoring? What are we evaluating? How do we know we are on the right track? We access the indicators as per the four quadrants presented in the diagram above. There are indicators that are of interest and influence the project. From the corner left quadrant we see that there are indicators that have low influence and low stake in the success of failure of the project and these are low priority indicators. We then also have those that do not have much influence but are of significant value to the project – these need to be improved if they are not already showing improvement. We then have in the top right hand quadrant indicators that are very relevant but of low stake and these need to be handled with care because although they are not deal-breakers for the success of the project, they are relevant and could have impact one way or another (positive or negative). The most critical indicators are those in the left quadrant as they are highly relevant and can determine the success or failure of the project. The ones in the top right hand quadrant are also very important even though they are not showing maximum performance. If we apply these criteria to all our indicators we end up knowing for certain which ones are highly relevant and determine the success or failure of the project as a whole.

We present below a box taken from the work of Osborne and Gaebler (1992) who remind us of the power of measuring results.

- If you do not measure results, you cannot tell success from failure
- If you cannot see success, you cannot reward it
- If you cannot reward success, you are probably rewarding failure
- If you cannot see success, you cannot learn from it
- If you cannot recognize failure, you cannot correct it
- If you can demonstrate results, you can win public support

Box one: the power of measuring results: adapted from Osborne and Gaebler (1992)

Most experts look at the "what" questions – what are the goals? what are the indicators? – and not the "why" questions: why do we want to measure something? why is there a need in a particular country (or catchment) to think about these issues? why do we want to embark on building sustainable results-based M and E systems? To answer these "why" questions, there is a considerable amount of preparatory work to do before the actual construction of a results-based M and E system. That preparatory work takes the form of the readiness assessment (Kusek and Rist, 2004).

Kusek and Rist (2004) also make the link between results-based monitoring and evaluation and learning through new knowledge. New knowledge can be generated through the use of findings on a continuous basis. Knowledge management means capturing findings, institutionalizing learning, and organizing the wealth of information produced continually through the M and E system. Results-based monitoring and evaluation systems and units have a special capacity to add to the learning and knowledge process. When used effectively, M and E systems can be an institutionalized form of learning and knowledge. Learning must therefore be incorporated into the overall programming cycle through an effective feedback system. Information must be disseminated and available to potential users in order to become applied knowledge. This is in line with the arguments put forward in section one of this report, describing the advantage of adopting CREAM, SPICED and SMART indicators.

Learning (as we have seen in deliverable two) is emancipatory) – it not only improves water literacy but it enhances trust and reinforces at multiple levels of the project that we need to be accountable to one another and that learning is a process of empowerment.

Learning and Accountability

Programme monitoring and process of evaluation for sake of improving programmes (programme staff)

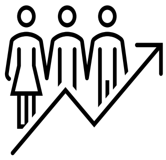
M and E studies for the sake of quality enhancement (regulatory agencies, government, communities)

•

Evaluation studies for sake of knowledge creation as part of contributing to scholarship
(scholars)

Evaluation informing decision making – continued funding, upscaling
(donors)

Monitoring and Evaluation



3. SECTION THREE: PARTICIPATORY ACTION RESEARCH (PAR)

3.1 Introduction

We begin this section on Participatory Action Research (PAR) by defining the concept, origins and meaning and examining the key elements implicit in PAR processes. We then examine PAR within the context of CS and provide typology of participation. We ask the question of why indeed PAR is needed. We then go on to present the application of two methods of PAR in our research – first participatory mapping and then the River of Life (ROL) exercise. The next part of section three presents research integrity including the principles of research integrity. We proceed with a discussion of PAR within the context of CS.

Although section two above has covered the topic of monitoring and evaluation, it is pertinent that we use PAR methods to develop a verification and validation system to monitor and evaluate and report on the progress of CS in a participatory manner. We also aim to increase the research capacity within the Limpopo and beyond around integrated groundwater resource assessment and management and illustrate the strength of PAR methods in doing so. We have already developed a CS framework as part of deliverable three, a Monitoring and Evaluation Report (MER) as deliverable four and we are now looking at the application of PAR amongst the citizens in the Hout. We believe that one cannot define and promote sustainable groundwater management options without PAR and we cannot improve the understanding of hydrogeological and ground water related socio-economic issues without the integration of a PAR component. PAR enhances research capacity in the country and beyond as we learn what works and what does not work in integrated groundwater resource assessment and management in general and in particular locations and projects.

3.2 Defining PAR: origins and meaning

Participatory action research (PAR) is considered a subset of action research, which is the "systematic collection and analysis of data for the purpose of taking action and making change" by generating **practical** knowledge (Gillis & Jackson, 2002, p.264). Action research discourse includes a myriad of terms, such as: participatory action research, participatory research, community-based participatory research, and other forms of participative inquiry, which may seem ambiguous for novice researchers intending to conduct action research (Greenwood & Levin, 1998; Gibson, Gibson & MacAulay, 2001). Participatory action research is variously termed as a dynamic educative process, an approach to social investigation, and an approach to take action to address a problem or to engage in socio-political action (Gillis & Jackson, 2002; Koch & Kralik, 2006). Participatory action research is considered a mode of systematic inquiry and an action research methodology that focuses on social change (Gillis & Jackson, 2002; Reason & Bradbury, 2006). PAR is a qualitative research methodology that fosters collaboration among participants and researchers. Thus, PAR is empowering as it promotes capacity development and capacity building amongst all who participate (McTaggart, 1991). PAR has been cited as an **educational** process, an approach to social investigation, and a way to take action to address problems and issues in communities and in groups of individuals (Hall, 1981).

The origins of PAR can be traced to the work of Kurt Lewin (1944), who is considered the founder of action research. Lewin, a Prussian psychologist and a Jewish refugee from Nazi Germany, embodied the philosophy “that people would be more motivated about their work if they were involved in the decision-making about how the workplace was run” (McNiff & Whitehead, 2006, p.36). Lewin also introduced the term ‘action research’ as a tactic to studying a social system while attempting to impart changes at the same time, and emphasizing the importance of client-orientated attempts at solving particular social problems (Gillis & Jackson, 2002). Lewin’s form of action research addressed problems of segregation, discrimination, and assimilation and assisted people in resolving issues and initiating change while studying the impact of those particular changes (Stringer and Genat, 2004).

The roots of PAR can also be traced to Paulo Freire, who believed that critical reflection was crucial for personal and social change. The participatory action research approach of Freire was concerned with empowering the poor and marginalized members of society about issues pertaining to literacy, land reform analysis, and the community (Freire, 1970). The widespread acceptance of a "participatory" approach is in part also due to the work of Robert Chambers in the 1990s which includes the techniques of participatory rural appraisal (PRA) and PAR which he developed himself or/and with others (see Chambers, 1997 and Chambers, 2007).

Participatory Action Research thus builds on a long and diverse history drawn from a range of disciplines, each of which has informed and developed its own understanding of what PAR is. Fundamental to PAR is a ‘shared recognition that science is more than adherence to specific epistemological or methodological criteria, but is rather a means for generating knowledge to improve people's lives' (International Collaboration for Participatory Health Research (ICPHR) 2013, 5).[18]

Following Kuhn's (1996) ideas on paradigms, PAR is a research paradigm – a widely accepted example of a system of assumptions, concepts and values that constitute a way of viewing reality. As such it serves the basis for defining what constitutes good research. PAR is considered democratic, equitable, liberating and is a life-enhancing qualitative inquiry that remains distinct from other qualitative methodologies (Koch et al., 2002). Ideally, the purpose of all action research is to impart social change, with a specific action (or actions) as the end point. PAR encompasses a "cyclical process of fact finding, action, reflection, leading to further inquiry and action for change" (Minker, 2000, p.191). PAR offers a radical alternative to knowledge development in its mandate to remain a collective, self-reflective inquiry for the purpose of improving a situation (MacDonald, 2012).

3.3 PAR and CS

Participatory research starts with a premise that knowledge has become the single most important root of power and control, and that ordinary people are rarely considered knowledgeable (Maguire, 1987). Today we know this is not true and in our engagement with citizen science we recognise the critical role that ordinary citizens have to play in gathering data and monitoring groundwater and rainfall in their backyards. Citizen Science provides a significant public engagement with science around concerns of ecological monitoring in general and groundwater monitoring in particular. In combining research with public education, citizen science also addresses broader societal impacts in a profound way by engaging members of the public in authentic research experiences at various stages of the scientific process (for instance as applied in our case study, by identifying boreholes and mapping water features) and using modern communication tools (such as the River of Life exercise or/and web applications from hand-held devices such as the smartphone) to recruit and retain participants (Dickinson et al., 2012). As Dickinson et al. (2012) also remind us, over the past few decades there have been new developments in information science in general and this is no different in the field of water resources management and groundwater monitoring.

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[18] The International Collaboration for Participatory Health Research (ICPHR) was created in 2009 as a place to bring together what we are learning internationally about the application of participatory research approaches to address health issues

PAR describes a growing family of approaches and methods that enable local people to share, enhance and analyse their knowledge of life. The behaviour and attitudes of outsider facilitators are crucial, requiring self-awareness and showing respect (see section on research integrity below). For participatory development practioners, a primary aim is to transform conventional development into a process of engagement with and by local people, rather than to use expert knowledge to dictate interventions (Cornwall and Jewkes, 1995). Despite interventions and research approaches that are manifest over the past few decades, there is still a naivety about power and power relations and a need, therefore, to build a more sophisticated and genuinely reflexive understanding of inequality, injustice and power with its manifestations and dynamics.

Due to the multiplicity of fields in which PAR has developed, it can have different meanings and at times be contradictory. “PAR was developed as a means for improving and informing social, economic, and cultural practice” which “in principle is a group of activities” whereby individuals with differing power, status, and influence, collaborate in relation to a thematic concern (McTaggart, 1991, p.169 in MacDonald, 2012). PAR recognizes and values that the people who we work with are not ‘objects’ of our research but are subjects and actively contribute to the research as social beings, within their own particular political, economic, and social contexts. PAR “is strongly value orientated, seeking to address issues of significance concerning the flourishing of human persons, their communities, and the wider ecology in which we participate” (Reason & Bradbury, 2006, p. xxii).

3.4 Typology of participation

Table 10: Typology of participation

Typology of participation (1)	Notification	People participate by being told what is going to happen. People's responses not listened to
	Providing information	People participate by answering questions posed by outsiders. No opportunity to influence research design. Findings not checked for accuracy
	Consultation	People participate by being consulted. External people listen to their views. External professionals define problems and solutions and may modify these in the light of responses by participants
Typology of participation (2)	Inducement	People participate providing labour or time in return for food or other incentives
	Project defined	People participate by forming groups to meet pre-determined objectives relating to a project which can involve the development of externally initiated objectives
	Interaction	People participate in identifying and framing issues, doing analysis and setting action plans together with outside facilitators. Greater control over decisions
Typology of participation (3)	Self-mobilisation	People participate by taking initiatives to change systems. They make contact with external institutions for resources and advice by retaining control over how resources are used. Self-mobilisation may or may not challenge inequitable distribution of wealth and power

As is clear from Table 10 above, there are typologies of participation that take one through steps of – or rather towards – emancipation – ranging from limited and reduced participation to emancipatory practice where those involved are empowered and in the case of this Water Research Commission (WRC) project on groundwater monitoring, become water literate and learn what works and what does not work when it comes to groundwater concerns. What is common within the range of typologies reflected in the table above, is that PAR is first and foremost an approach that is people centred – reflecting people centred perspectives. The focus is on power and control as we are concerned about the nature of society and the dynamics that are at play in the programmes and projects that are developed. Our concern is not simply about the technical or managerial aspects of the project however important these of course are. We see increased power for those that were disadvantaged in terms of access to data and knowledge. The seminal work of Schumacher (1973), 'Small is Beautiful' is a homage to the local – and an exposure of large or overpowering 'capital' that risks the depletion of natural resources. So too is the work of Ignacy Sachs (1978), 'The discovery of the third world' which promotes eco-development and here the 'discovery' is conceptual not geographical. The premise of these works, written over thirty decades ago, is that ordinary people are capable of critical reflection and analysis and their knowledge is not just relevant but necessary. Empowerment and transformation involve real social change and require research methods that are conducive to this transformation and change.

3.5 Why is participation needed

Why is participation needed? What ends does it serve? What are the relations of power at play in the local communities and in the larger social context and in the specific activities taking place? When answering the question 'why is participation needed' we address concerns of human rights, human flourishing and well-being and equity. We are concerned with access to knowledge – considering that knowledge is empowering and that it leads to changes in attitude and behaviour (and in our context with the goal of better water resources management). The end goals of participatory practices have intrinsic value (people feel empowered and being empowered makes one feel good about oneself – thus enhanced well-being and human flourishing) and extrinsic (people are able to make informed decisions that affect their every-day lives and change behaviour based on 'science' that they have been part of).

Both participatory action research and action research intend to produce practical knowledge that is useful to people in their daily lives. To accomplish this, these approaches involve practitioners, as subjects and co-researchers, learning to improve professional practices and local situations. Deeply rooted in participation, PAR expands traditional action research aspirations through strong

emancipatory intentions, which as we have shown above, are characteristically equated with empowerment. In its most ambitious expression, PAR participants co-create an enabling workplace environment, to 'get and give' information to make informed choices — which lasts beyond the life of a specific participatory action research initiative. This requires encouraging participation, acknowledging and sharing power, building relationships, establishing open communication, and negotiating change.[19]

We are aware in our application of PAR of cultural arrogance – which is where the researcher engaged in development practice, speaks of communities as though they are homogenous with a common set of interests rather than to consider diversity and pluralism – where each citizen scientists brings their own hopes, dreams, expectations, disappointments, experiences and so forth.

Timeframes are relevant when applying PAR as the acquisition of knowledge is a process and not an end point. The process needs careful plans and actions. In the case of our CS project, we have considered generations, or multi-layers of citizens scientists. The first generation – coming on board about eighteen months ago – have contributed to a better understanding of what is required to keep citizen scientists engaged, to provide the required technological support and to take the necessary steps to enhance, upscale and grow the project. We use the experiences gained to introduce a second generation of citizen scientists (over the past ten months or so) who build on lessons learnt from generation one scientists. We have embarked on a journey – and not an end point. The learning is part of the process. We take on the idea that 'pain is progress' or 'failing forward' as another way of looking at the journey – where there are hurdles, incongruences and 'mistakes' – but where we fail forward.[20] Rachel Slocum (1995) provides a brief overview of participatory approaches to development including issues such as power relationships within a community and between local institutions and outsiders. She explores the opportunities for using multi-media tools to strengthen the impact of other tools in conscious-raising, data-gathering, advocacy, and community decision-making and action. This is pertinent within the context of our own study – and in answering the question why participation? – as we have the tangible concerns of materiality (tools such as dip-meters, rain gauges, etc.) as well as the intangible or emotional aspects of community.

The term participatory does not only refer to the 'community' or citizen scientists but is used to include the researcher(s) who collected the data and other associated colleagues who have a vested

[19] Blog Mary Somerville – mentorSpace: the how of methods. www.methodspace. Accessed 2nd February 2021

[20] Here the work of John Maxwell (2000) – Failing Forward – is informative

interest in the research and who can be viewed as co-researchers who work collaboratively to take responsibility for engaging in a participatory process of collecting and constructing knowledge (Wimpenny and Savin-Badin, 2012). PAR seeks to understand and improve the world by changing it (Baum et al., 2006). PAR is an ongoing learning where the emphasis is on co-learning, participation and transformation (Greenwood et al., 1993). There is a humanistic aspect where socio-ecological problems are considered – and in the ideal solved – together rather than from the top down.

We recognise three main approaches to participation within the context of citizen science. First of all participation as facilitated by outside agencies for local people which meets efficiency objectives. Secondly there is the aspect of mutual learning which acknowledges participation as a partnership and thirdly there is the idea of enhancing self-determination where participation is driven by local people and the emphasis is on building agency and critical awareness. When approaching volunteers there are some basic questions that inform action. These are captured in the diagram below.

With these questions in mind, we are then able to set a number of tasks that are appropriate and feasible within the context of a particular locality for citizens scientists to adopt. In responding to the first question – what do we need to know about behaviour – we are able to realistically assess what citizens require from the research team and professionals in the project to remain committed and engaged. We understand that 'what people do' and 'who they do it with' informs their behaviour and that if we expect citizens to measure groundwater, we need to better understand what their daily obligations are, where they see themselves in their social setting and whether and in what ways they are willing to contribute to the project objectives. In applying methods (see section below) these concerns are addressed. As we respond to these question we keep in mind three key elements which are people, power and praxis (Finn, 1994). Thus, key in answering the why participation question is the concept of a collaborative process of research with the elements of education and action that are explicitly directed toward social transformation (McTaggart, 1997).

3.6 Applied PAR methods for CISMOL[21]

In line with the ideas put forward in deliverable two and the application of a citizen science framework, the focus is on the creation of spaces for genuine citizen participation. It is worth stressing again the ideals of pluralism and diversity where difference is recognised. Kelly (2005) in an article entitled, "Practical suggestions for community interventions using Participatory Action Research," described the background steps that researchers can employ when conceptualizing and initiating a research project with community partners using PAR. in the CISMOL instance, PAR was applied in various ways. In this section we describe two PAR exercises (1) participatory mapping, and the (2) River of Life.

3.6.1 Participatory mapping

The first step was to identify water features in a participatory exercise. Here a map was printed out and participants familiarised themselves with the boundaries of the Hout and their own villages. Participants (citizen scientists) welcomed an opportunity to interact and place stickers on the map. There was much back and forth discussion about where exactly a particular borehole was located. The interaction between both the citizens themselves (horizontal) and the citizens and the research team (vertical) lays the foundation for trust and a sense of not being alone but of belonging to a wider social group.

[21] There are multiple methods applied in participatory action research such as a Venn Diagram, matrices, actor network mapping, etc. We present only two methods here – participatory mapping and the River of Life Exercise – but it is noteworthy that the toolkit for PAR offers many other possibilities

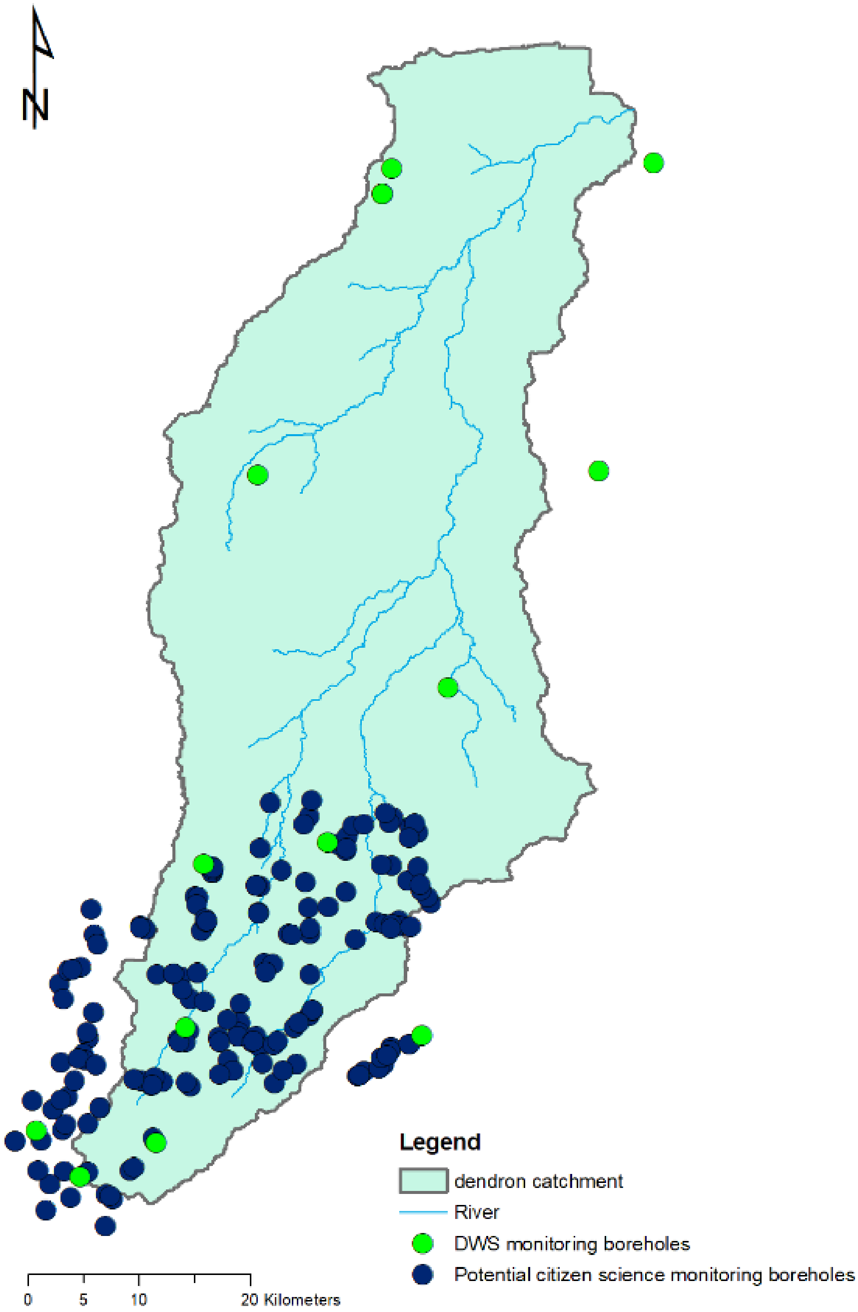

Figure 8: Borehole identification through participatory mapping

The mapping exercise was aimed at mapping the catchment and inviting participants to identify water features – such as dams, streams, pollution sources and boreholes. This mapping exercise was 'fun', participatory and informative. When checking on 'conservative' maps regarding water features in the Hout, the findings of the citizen scientists were quite precise (see Figures 9 and 10 below). The following map shows features of the catchment (wells, contamination points, rivers, ponds, etc.) that were identified by the citizens themselves – this allows for a sense of self-monitoring around what is going on in their catchment regarding water features. There is value in the emancipatory aspect of deliberating, identifying, discussing, dissenting – and finally agreeing on what needs to be put onto the map. One of the outcomes of the evaluation is that the map was plotted and the wells were identified but there was also a better sense of how the catchment was being divided (into three sections) and where each person 'belonged' on the map.

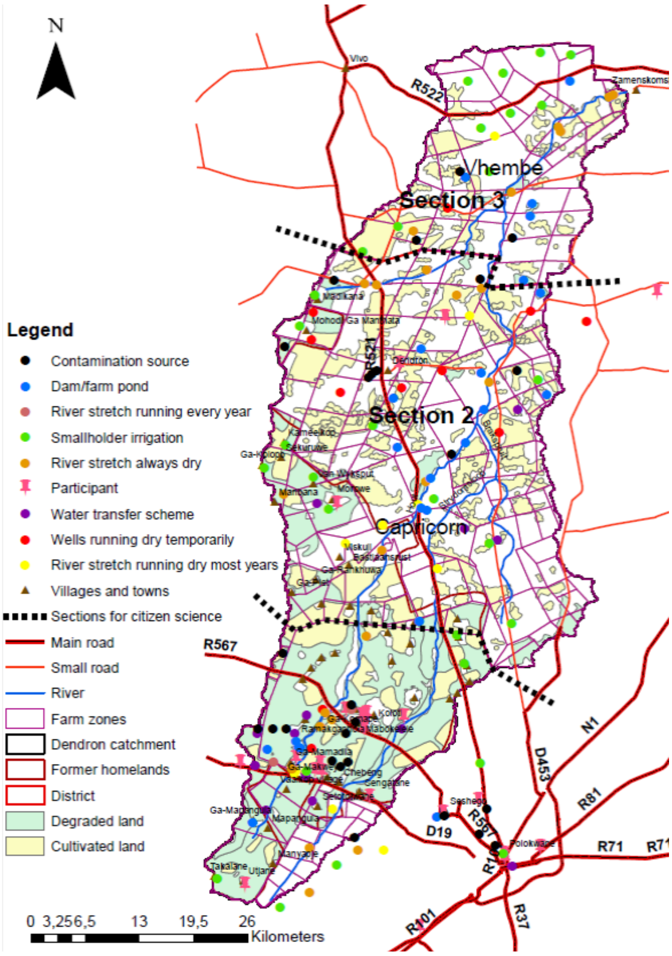

Figure 9: Map with stickers showing key features of catchment using PAR

Figure 10: Maps with additional features mapped using PAR

A second mapping exercise identified known boreholes (see Figure 10 above). There were a number of important points that were raised during the mapping exercise and the animated discussions that were part of it. Some of which are as follows: (1) municipal boundaries and catchment boundaries don’t always match: the area is divided into broad zones following land use patterns but not always matching water use, (2) in 2001 groundwater resources were examined and therefore there is some reference information available around the recharge and the different uses providing also data on population and estimated demand in 2045, (3) Polokwane Municipality have developed a Groundwater Master Plan and all existing boreholes have been identified. Our next step is to access this master plan, (4) from the 1950s the water table has dropped because of agricultural use around Dendron where there is heavy irrigation and commercial farmer activity, (5) existing borehole yields in this area are not yet known and the next phase of the project will address this hydrological void building on what has been learnt thus far about existing data, (6) water supply shows that there should be adequate water supply for communities but in fact communities suffer water shortages and the reason for this mismatch needs to be explored, (7) there has been extensive development for villages around Molete South at the top of the catchment but this needs to be assessed as people should not be encouraged to settle in recharge zones, (8) more boreholes have been developed than the resource can supply for and this is a supply-demand issue, (9) if a village has a borehole that does not work – do not drill another one. This means that borehole forensic evaluation is required using borehole camera logging plus other technology to visualise the subsurface and identify the cause for the malfunction of a particular borehole, (10) boreholes have been drilled in clusters in close proximity to one another and they cannot all be pumped. It is possible that they are not all tapping into the same aquifer system thus pumping tests are required before handing over a borehole to a user, (11) those that are not functioning need to be rehabilitated after forensic assessment.

Additional information emerging from the participatory mapping exercise is that a drilling operator is allowed to drill a borehole on a private farm and the National Water Act (NWA) stipulates that schedule one (individual use) does not require licensing whereas other users need authorisation and water use licenses. There is a licensing system which is not being applied. A license is necessary if an individual drills deeper than 80 meters. The borehole that is drilled belongs to the Department even if it has been drilled by a particular farmer. Furthermore, the placement of a particular borehole depends on the hydrogeological conditions and it needs to fit into the broader groundwater system as a whole.

Further information was forthcoming during the participatory mapping exercise. For instance, tests are not adequately scientific – however DWS does have guidelines on how to develop groundwater resources. The concern is a lack of data to evaluate the current state of the aquifers. Hydrologists are trained to conduct tests in a scientific manner to gather more data on boreholes. DWS stipulates that records must be kept but this is not being adhered to. Water regulations need to be reinforced and resources made available to enforce regulations including monitoring. The Groundwater Reliability Improvement Project (GRIP), in 2016, captured data that has been 'lost.' Once data is available it is not too challenging to produce simple graphs indicating what is happening to the water level and how much is being pumped – DWS is the custodian of our water resources and this data needs to be available for them. Data is helpful as a crisis can be avoided timeously. The next 'participatory' step for this project (and this was expressed by the volunteers) is to train volunteers in an interactive manner how to read the graphs that are being produced from the data that they have captured.

Participants were able to confirm that there are approximately 40 settlements in the catchment and that the Hout River Scheme is divided into two areas (Hout River Polokwane and Capricorn Municipality). Boreholes should not be tampered with as vandalism of boreholes is a concern for DWS – the CS approach is aimed at addressing the aspects of vandalism by having eyes and ears closer to the ground in specific (and remote) localities. Instrumentation for borehole monitoring is an asset of the Department and each instrument can cost as much as R 8 000 – therefore vandalism of equipment has dire financial consequences.

There was some discussion about villages that lie outside the Hout – for instance in the Sand Catchment. The Sand River Catchment River Agency exists to empower citizens and to serve as a liaison between DWS and water users. However, the Sand is just outside the borders of the Hout (as per the maps presented here). The Sand River often looks dry but beneath the surface there are water flows. When the Sand River does flow – parts of it are blocked by commercial farmers.

Water from the Hout Dam is currently pumped into two reservoirs. The treatment works are operational but not optimally so, because the plant supplied by ESKOM for the pumping has a lower capacity than it should have and this capacity needs to be increased. There are currently bilateral negotiations between DWS and ESKOM to resolve this problem. There is a general question to be asked about pumps and power supply – if twice the amount of power is being used then the lifespan of the pump would be shorter. Participants agreed that a cost-benefit analysis would be helpful in addressing this power issue.

Participants asked whether or not there was adequate information flowing between upstream and downstream farmers and it was agreed that this question needs to be answered with evidence-based data. Users were not sure who they should go to if there was a water concern in their village (for instance the water users association or irrigation board, water forum committee, community policing, local authorities or chiefs, municipal officers). Another question raised was the incentive for collecting data and the reason for why data should be collected in the first place. There was also a concern that data from the Department is not being shared with users in the Catchment and vice versa. Participants raised a critical concern about who is working in the catchment – particularly on this project – and urged that when 'new' faces appeared they should be properly introduced and participants should be aware of who – and why – someone is in the field and what role that person is playing in CISMOL.

3.6.2 River of Life (ROL)

Path maker, there is no path,
You make the path by walking.
By walking, you make the path[22]

[22] Antonio Machado, Border of a Dream: Selected Poems

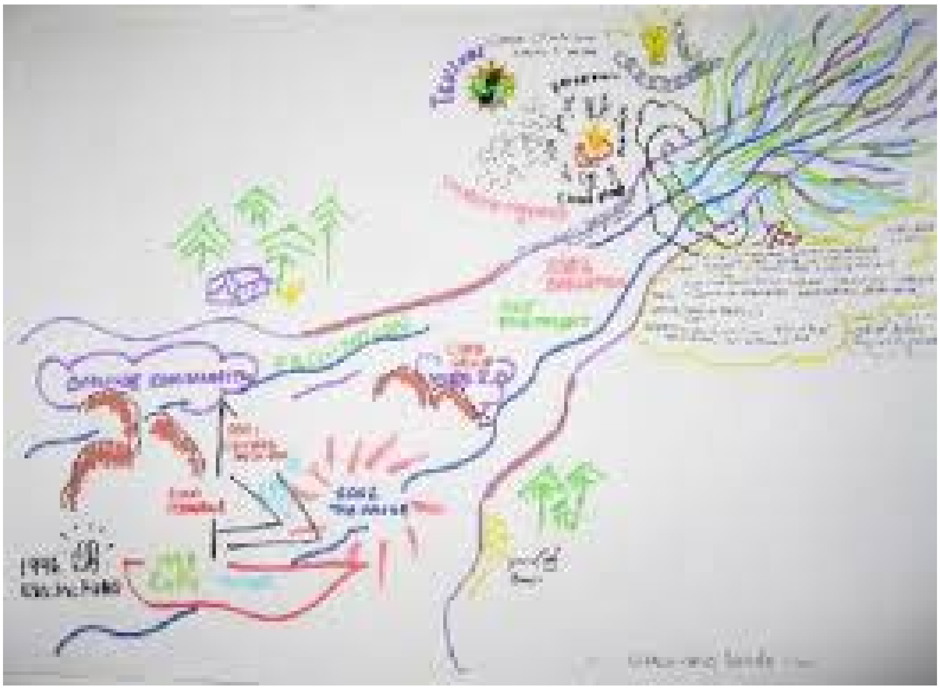

Figure 11: The ROL as a personal reflection tool

Machado's reminder (see poem above) is both simultaneously daunting and reassuring as it invites you to move towards the unknown (as a river takes its journey to the sea) as well as to reassure you that you will reach the sea as you embark on your journey. This is a call to step forward through unfamiliar terrain, knowing that there is not a single path – but many options – that determine one's own life journey. The questions that we put forward to the participants were as follows:

- If your life were a river, what shape would it take
- Where are the bends and turns when your situation or perspective changed
- Was the transition smooth or sudden
- Are there rocks or boulders — obstacles or life-altering moments — falling into your river
- Are there points at which it flows powerfully and purposefully or slows to a trickle
- Identify various key events in your life that shape your story — the boulders in the river or places where the river changes course
- If you were to divide your life journey into sections, where would the divisions occur and name or identify these 'divisions' or turns (tributaries)
- Think not only about your own tribulations – joys, pains, etc. – but also about what was going on in the world around you (or in your local village) – that might shape your river

Participants were given twenty minutes to draw their river and were encouraged to use the image of the river to the fullest and to think about their own life as a river, meandering up to the workshop event as well as different streams and tributaries that have helped (or hindered) the person get to where they are now. Participants were encouraged to think about the fast moving (easy) times in their lives and other more challenging times (indicated perhaps by rocks or stones in the river). Volunteers used this metaphor to its maximum – showing rapids, waterfalls, streams and ponds. Thinking about monitoring groundwater, participants were encouraged to consider what stumbling blocks might come along their way and during these times what emotions come to the fore. Would, for instance, they feel angry, fearful, hopeful or proud. How could their part in the project change the direction of a particular stream?

Participants were also invited to reflect on who might have brought them here as a volunteer in this project. Were these particular people (leaders, teachers or other) that the volunteer had met – or was it just a desire to move in a new direction (as a volunteer)? They were further invited to reflect on how they might feel about their life now and where they see themselves in ten years' time. As the image below shows, the next step is to share the ROL with others and to see where there are similarities or differences. The strength of this exercise is its potential to show difference and diversity. No one river has the same shape as another – each person has experienced individual events or moments that differentiate them from others whilst at the same time each individual experiences their lives in the form of a river – and all the rivers go to the sea. Thus, despite the differences (pluralism) there are similarities.

The table below presents the questions that guided the exercise.

Table 11: ROL Exercise

RIVER OF LIFE EXERCISE		
During the exercise (draw freely, use colours and smileys to depict your journey)	Thinking of the image of a river – where does your journey start	Name of your village, siblings, early childhood memories
	What are the tributaries or streams that have flowed out of the main river	Think of life events – images, where have there been turning points in your life – who was there at that time, what, where were they and how did this person – or event – influence you
	Thinking of the 'end of the journey' where the river goes to the sea – what would you like to see happen	Think of possible milestones, or achievements – either professional or personal (or of course both)

RIVER OF LIFE EXERCISE	
After the exercise (add smileys to your ROL)	What emotions come to the fore when you think back on your river
	How did you feel during the exercise
	What have your learnt from ROL stories presented by your fellow citizen scientists here today
	Would you be want to or be able to use the ROL exercise with others in your community as an icebreaker to learn more about a particular event or process

Figure 12: Participant sharing her ROL journey

3.7 Research integrity

The Singapore Statement (2010) on Research Integrity, was drafted at the Second World Conference on Research Integrity which took place in Singapore from the 21st to 24th July 2010. It is an important step toward promoting ethical conduct among scientists around the world and it is particularly pertinent when applying PAR. The statement encourages researchers to explore ways or efforts to promote global research integrity (Kleinert, 2010). Resnik (2009) states that challenges that prevent promoting global scientific integrity or that affect conducting research following ethical norms include social, political, cultural, and economic factors. These differ among nations and areas where research is carried out. However, researchers agree that there are some common standards for research ethics that transcend these differences. Research integrity aims at providing ethical guidance which research organizations, governments, and scientists can use to develop policies, regulations, and codes of conduct (World Conference on Research Integrity, 2010)[23]. Research integrity has a focus on four principles: (1) honesty, (2) accountability, (3) professionalism, and (4) stewardship. These four principles have twelve responsibilities pertaining to the ethical conduct of research. The responsibilities are around (1) data integrity, (2) data sharing, (3) record keeping, (4) authorship, (5) publication, (6) peer review, (7) conflict of interest, (8) reporting misconduct and irresponsible research, (9) communicating with the public, (10) complying with regulations, (11) education, and (12) social responsibilities (World Conference on Research Integrity, 2010). These principles and responsibilities are comprehensive, clear, and thoughtful and they play an important role in promoting global research integrity. We agree that ethical considerations are at the core of PAR.

Resnik (2009) claimed that since research activities often involve collaborations among investigators, laboratories, and institutions from different countries, it is crucial for the scientific community to establish and follow international integrity standards to avoid international incidents such as that of fraudulent papers published in journals. This is not relevant when considering PAR but what is relevant is the adherence to ethics and integrity. For instance, if using a mapping exercise, the context needs to be referenced and the process acknowledged. Resnik et al. (2006) give evidence of the need for global guidelines and these would apply also to PAR. The Singapore Statement plays an important role in informing national and local rules and guidelines for research integrity. The research integrity guides researchers on its implications for the conduct of research. The ethics of doing no harm is also pertinent in PAR exercises which might evoke uncomfortable or 'risky' emotions. These risk factors need to be assessed and care taken not to offend, nor to leave open 'wounds' that participants might have due to their past experiences but to aim for 'closure.' This is pertinent when conducting the ROL exercise.

3.7.1 Research principles

Honesty: The project workshops across the catchment reach out to all stakeholders in the Hout catchment and the participants are given an exact and accessible explanation of what can be expected from the project aims and objectives. All stakeholder concerns were adhered to before the project

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[23]World Conference on Research Integrity [last accessed December 21, 2010]; Singapore Statement. 2010. Available at http://www.singaporestatement.org/statement.html.

implementation and no false expectations were tolerated. Volunteers were told honestly what the expectations were for their participation and they also shared honestly their fears and hopes regarding their involvement in the project

Accountability and transparency: All stakeholders were encouraged to be honest on their water resource utilization so that the project team can have a better understanding of the catchment and to be transparent about their strengths and weaknesses that might affect the way they interact with their peers or with the research team. The DWS needed to address their own weakness in their law implementation across the catchment and the municipality was held accountable to the community around the challenges of water supply. The procurement process for dip-meters, rain gauges and smartphones was done transparently and guided by the UWC's procurement guidelines

Professionalism: The research team ensures that it acts to the best interest of stakeholders whom are affected in the catchment and allows all members who are interested in the research project to participate through the CS and to have their voices heard in the workshop contexts where stakeholders were brought together. The research team is well trained to carefully consider conflicting points of view and to give voice to those who might otherwise be muted. All participants are treated equally, with respect and with courtesy in workshops and field visits throughout the duration of the research project. All field investigations and data collection were carried out with utmost integrity, and data was collected using the standard operation procedures for different protocols. Data processing and quality assurance for field data was done throughout field procedures to ensure the integrity of the data and this was done in a participatory manner where volunteers engaged with the research team throughout the project bearing in mind principles of equity, diversity and pluralism.

Stewardship: The research data is made available to all researchers and stakeholders through the Citizen Science App as well as a project SharePoint for meta-data. Accessibility to the data means that the volunteers are provided with the necessary tools to assist in gauging borehole water levels, rain fall and river flows. This encourages stewardship of the resource as well as stewardship of the project instruments such as the dip-meter and rain gauges.

3.8 PAR discussion

The focus of a participatory process is on shared learning and action for social change within a local context (Cornwall and Jewkes, 1995). PAR does not follow a linear trajectory. One size fits all does not apply. PAR is also not a quick fix but an ongoing journey that is often unpredictable and comes with an element of surprise. PAR (within the context of our CS project) means applying different knowledges (experiential, practical, intuitive, analytic and emotional ways of knowing) that are all equally valued.

In the future it is anticipated that volunteers will also capture data on groundwater quality. The data is validated (in a participatory manner) and as Lintott (2019) claims, there is no reason to believe that data collected by the volunteers is any less reliable than data collected by 'scientists.' The team anticipated resistance by volunteers in collecting data as they might be unsure as to what advantages they would have in capturing data but this was not case.

As the project is about capturing 'hard' date, quality control measures are part of PAR. The steps followed for quality control are outlined in deliverable four, the Monitoring and Evaluation Report (MER). Suffice to say here is that through regular field visits and ongoing contact with volunteers on the volunteer app, we nurture trust and continue to listen to the needs, anxieties, hopes or/and fears of the citizen scientists. Both through the validation and transmission of the data and through stakeholder engagement workshops held in the Limpopo introducing the notion of CS, meeting with local chiefs and counsellors – there is obedience to trusted and agreed upon hierarchies. A sense of being part of a broader drilling and groundwater development project in the watershed is nurtured.

Figure 13: First generation volunteer becomes second generation 'champion'

PAR exercises, such as the three described above are mind changers – both attitude (let's co-operate), behaviour (being forthcoming with information, dialogue and debate) and commitment (belonging and having a vested interest in the same goals). Figure 13 above shows a first generation volunteer who collected groundwater level data (and rainfall) with a simple dip-meter. The volunteer now becomes a champion and a second generation citizen scientist as he is now ready to train other citizen scientists and will also monitor up to ten boreholes in and around his village. The figure shows the upgraded instrument that he was given for this purpose.

As the word cloud diagram above indicates the learning and uptake of knowledge is often disorderly, fragile, fleeting, fraught, cautionary and we can apply, what we have referred to in the CS framework (deliverable 2) agonistic learning which implies zigzagging through processes that form and re(form) often with jangling discord. This word cloud indicates the complex socio-economic and political environment in which PAR is embedded. There are surprises and unintended or unexpected outcomes. For instance, we had a bumpy ride in our endeavour to bring commercial farmers in section two of the catchment on board but finally we were able to do so and were surprised by the generosity of spirit and enthusiasm expressed by the commercial farmers. The PAR exercises applied contributed to their enthusiasm and as a result they were not only willing to participate in the project but were keen to share their data and asked that we train farm labourers as volunteers. We have now trained a second generation of volunteers on the commercial farms and will be training an additional ten volunteers during the course of February and March 2021.

Citizen scientists were fully committed to the project and although not obligatory most of them took daily fieldwork notes (see Figure 14 below).

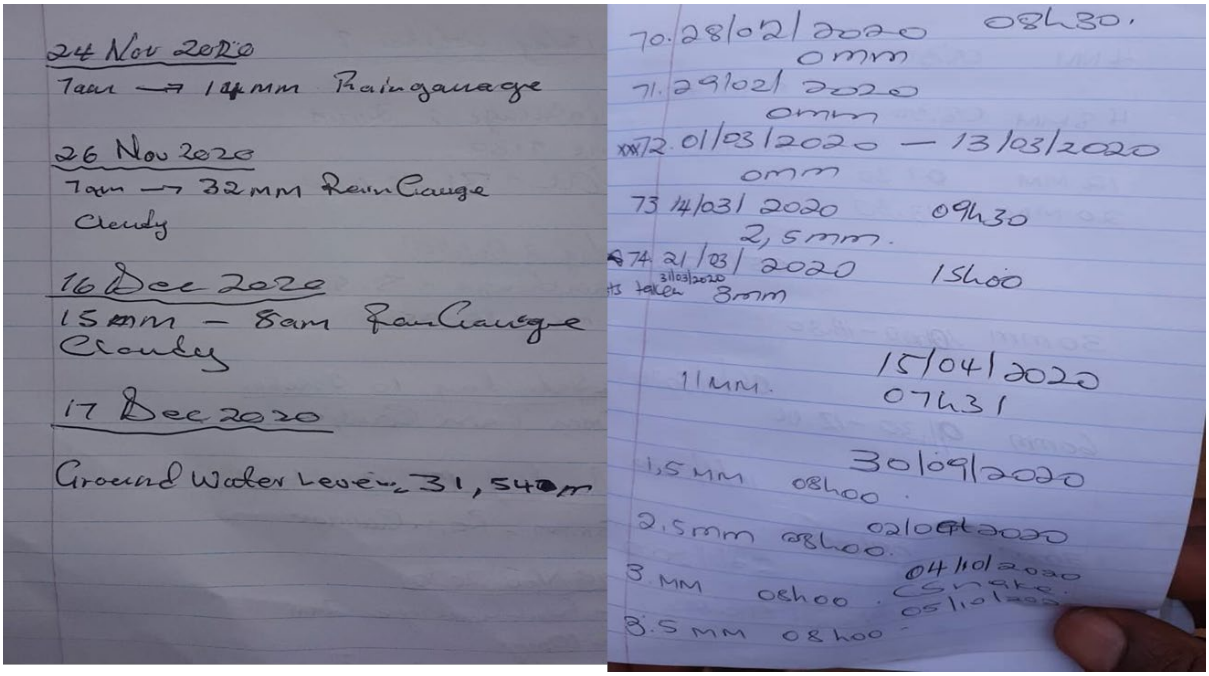

Figure 14: Fieldwork notes from volunteers

The success of the PAR training during the workshop reflects in the way volunteers go about their daily tasks. There is enthusiasm, joy and commitment in doing the work that is required. We attribute this to the 'process' where volunteers developed a sense of belonging and pride in being embedded in CISMOL. We see through the lens of participation, researchers and participants working together to examine a problematic situation or action to change it for the better (Wadsworth, 1998). And a louder murmur – and devious meandering – was due to COVID 19. The project hit the COVID repercussions with a loud bang as many of the project activities were interfered with. This required an agility on the part of the project team – and the citizen scientists themselves – where communication, verification, participation now takes place virtually through regular WhatsApp calls and messaging as well as face to face meetings which were one on one instead of in the planned (and preferred) workshop situation. This meant that citizen scientists were far more isolated on the one hand – but also connected on the other as COVID meant that our research team needed to take more – not less – interest and touch base with the citizens for much needed support – not only in collecting the data but also emotional support because of feelings of isolation and separation.

Figure 15: Groundwater monitoring under COVID regime

As COVID is a reality and affects the way that volunteers engage with one another and with the 'scientist' from the outside who pays regular visits to the field, an image (Figure 15 above) showing groundwater monitoring wearing an obligatory mask, is appropriate.

4. SECTION FOUR: CONCLUSION

What lines are we making in the sand? What parameters are we using to measure our successes and failures? Monitoring our progress and evaluating our project is an integral part of ensuring that the project objectives are met and that we are on track with our vision for CS. Our monitoring toolkit was populated using indicators based on principles of SPICED, SMART and CREAM. The project evaluation is ongoing. As we have the comparative advantage of being able to assess a project that has come to the end of its first cycle (ESGUSA) we are able to step back and with hindsight investigate the project principles, approaches, and results. The WRC project is allowing for an enabling environment where we piggy-back on ESGUSA and scrutinise the achievements we have made thus far. We have a first generation of volunteers who are now firmly embedded in the catchment. Some of these volunteers will take on the responsibility of training a second generation of volunteers. This in itself is an indicator of success (as shown in our 'smiley' chart in this report). As we monitor – and evaluate – the performance of the volunteers we are able to pinpoint behaviour changes and preferences that the volunteers might have. The team anticipated resistance by volunteers in collecting data as they might be unsure as to what advantages they would have in assisting in a data collection process – but this was not case.

Monitoring is twofold. First we monitor the data and the effects of gathering information on ground water levels (and rainfall). We consider whether this data is robust and can be used – and if it is being used, who is using it? Is the format that it is being presented user friendly? Are the volunteers themselves able to access the data? These are fundamental questions pertaining to CS and they go hand in hand with a set of questions that aim to elicit the 'softer' side which is to do with feelings and emotional well-being. How do the volunteers feel about the work that they are doing? Do they have a sense of pride? A sense of belonging to a broader catchment area? Do they have a sense of upstream/downstream flows and if not, what type of information is needed to ground them better in the catchment as a whole and boost water literacy. Furthermore, we also aim to increase the research capacity within the Limpopo and beyond our own project around integrated groundwater resource assessment and management through our outreach to the DWS, DOA, research community (capacity building and journal articles) and to our advisory committee (Reference Group).

We assert, as does Lintott (2019), that there is no reason to believe that data collected by the volunteers is any less reliable than data collected by 'scientists.' We will continue to develop the indicator toolkit and by the end of this second cycle of the project (March 2021) it is likely that there will be new indicators to add both for the technical assessment of the project as well as for the 'smiley' chart indicator set that we have proposed thus far.

Our discussion above has shown how participatory action research is considered a mode of systematic inquiry, an action research methodology that focuses on social change. It is a qualitative research methodology that fosters collaboration among participants and researchers. It is a life-enhancing qualitative inquiry that differs from other qualitative methodologies (such as semi-structured interviews, participant observation or/and focus groups). Its process is cyclical and we have shown through the participatory mapping exercise, for instance, how volunteers begin with fact finding, reflection and action which leads to further inquiry. In the ROL exercise we see participatory action research as self-inquiry where the participant embarks on a journey that is unknown, surprising but can lead to behavioural change. Participatory research builds on the premise that knowledge is the single most important root of power and control and CISMOL shows how ordinary citizens play a critical role in gathering data and monitoring groundwater and rainfall in their backyards. We see PAR as an educational process, an approach to social investigation, and a way to take action to address problems and issues in communities and in groups of individuals. It generates practical knowledge. As such it is emancipatory and not only enhances water literacy but also feelings of human well-being and human flourishing.

5. SECTION FIVE: REFERENCES

Almirall, E. and Wareham, J. (2008). "Living Labs and Open Innovation: Roles and Applicability" in *The Electronic Journal for Virtual Organizations and Networks* (10), pp.21-46

Aono, Y. and Kazui, K. **(**2008). **"**Phenological data series of cherry tree flowering in Kyoto, Japan, and its application to reconstruction of springtime temperatures since the 9th century" in *Royal Meteorological Society*

Ballon, P. and Schuurman, D. (2015). "Living labs: concepts, tools and cases" in Info 17 (4) https://doi.org/10.1108/info-04-2015-0024

Baum, F., MacDougall, C. and Smith, D. (2006). "Participatory action research" in *Journal of Epidemiological Community Health* 60 (10) pp. 854-857

Bergvall-Kåreborn, B., Ihlström Eriksson, C., Ståhlbröst, A. and Svensson, J. (2009). "A milieu for innovation: defining living labs" in *Proceedings of the 2nd ISPIM innovation symposium: Simulating recovery – the Role of innovation management* New York City, USA 6-9 December

Bertule, M., Bjørnsen, P.K., Costanzo, S.D., Escurra, J., Freeman, S., Gallagher, L., Kelsey, R.H. and Vollmer, D. (2017). Using indicators for improved water resources management – guide for basin managers and practitioners. 82 pp. ISBN 978-87-90634-05-6 (*21)* Available from: https://www.researchgate.net/publication/319765179_Using_indicators_for_improved_water_resources_management_-_guide_for_basin_managers_and_practitioners_82_pp [accessed Dec 09 2020)

Bonney, R., Cooper, C. and Ballard, H. (2016). "The theory and practice of citizen science: Launching a new journal" in *Citizen Science in Theory and Practice* (1) 1

Bozelek, V., Gachago, D., Alexander, L., Watters, K. and Wood, D. (2013). "The use of emerging technologies for authentic learning: A South African study in higher education in *British Journal of Educational Technology"* in *Special Issue: Emerging Technologies and Transformation Effect on Pedagogy* 4 (4): pp. 629-638

British Geological Survey (BGS) (2017). Groundwater level information. Online accessed 6 February 2017

Chambers, R. (1997). Whose reality counts: putting the first last. London Intermediate Technology Publications

Chambers, R. (2007). From PRA to PLA and pluralism: practice and theory *IDS Working Paper, no. 286*. Institute of Development Studies, Brighton

CoreLabs (2007). "Living Labs roadmap 2007-2010: recommendations on networked systems for open user-driven research, development and innovation" in *Open Document*, Luleå University of Technology, Centrum for Distance Spanning Technology, Luleå.

Cornwall, A. and Jewkes, R. (1995). “What is participatory research?” in *Social Science in Medicine* 41 (12) pp. 1667-1675

Crain, R., Cooper, C. and Dickinson, J.L. (2014). “Citizen science: a tool for integrating studies of human and natural system” in *Annual Review of Environment and Resources* 39 (1) pp. 641-665

Dedding, C., Nicole, S., Goedhart, J., Broerse, E. and Tineke A. Abma (2020). “Exploring the boundaries of ‘good’ participatory action research in times of increasing popularity: dealing with constraints in local policy for digital inclusion” in *Educational Action Research* DOI: 10.1080/09650792.2020.1743733

Dekker, R., Contreras, J.F. and Meijer, A, (2019). “The Living Lab as a Methodology for Public Administration Research: a Systematic Literature Review of its Applications in the Social Sciences” in *International Journal of Public Administration* DOI: 10.1080/01900692.2019.1668410

Dickinson, J., Shirk, J., Bonter, D., Bonney, R., Crain, R., Martin, J., Phillips, T. and Purcell, K. (2012). “The current state of citizen science as a tool for ecological research and public engagement” in *Frontiers of Ecology Environ* 10 (6) pp. 291-297

Doran, G.T. (1981). “There’s a S.M.A.R.T. way to write management’s goals and objectives” in Management Review 70.11 (35). Business Source Corporate

Dutilleul, B., Birrer, F. and Mensink, W. (2010). Unpacking European living labs: Analysing innovation’s social dimensions (SSRN Scholarly Paper No. ID 2533251). Rochester, NY: Social Science Research Network. Retrieved from http://papers.ssrn.com/abstract=2533251

Ebrahim, G., Villholth, K. and Bolous, M. (2019). “Integrated hydrogeological modelling of hard-rock semi-arid terrain: supporting sustainable agricultural groundwater use in Hout Catchment, Limpopo Province, South Africa” in *Hydrogeology Journal* doi:10/1007/s10040-019-01957-6

Eriksson, M,. Kulkki, S. and Hribernik, K. (2006). Living labs as a multi-contextual R and D methodology in the 12th International Conference Idots

European Network of Living Labs (2014). The 8th Wave [Brochure]. Retrieved from http://www.scribd.com/doc/209106191/ENoLL-8th-Wave-Brochure

Finn, J. (1994). “The promise of participatory research” in *Journal of Progressive Human Services* 5 (2) pp. 25-42

Fraser, N. (2009). Scales of Justice. Reimagining political space in a globalizing world. Columbia University Press

Freire, P. (1970). Pedagogy of the oppressed New York. Seabury Press

Fritz, S., See, L. and Carlson, T. (2019). "Citizen science and the United Nations Sustainable Development Goals" in *Nature Sustainability* 2 pp. 922-930 https://doi.org/10.1038/s41893-019-0390-3

GEF (2010). Monitoring and Evaluation. Evaluation Document no 4

Gibson, N., Gibson, G. and MacAulay, A. (2001). "Community-based research" in Morse, J, Swanson and Kuzel, A (eds). "The Nature of Qualitative Evidence" Thousands Oaks, CA. Sage.

Gillis, A. and Jackson, W. (2002). "Research methods for nurses: methods and interpretation" Philadelphia. FA Davis Company

Goldin, J. (2003). "Washing away the sins of the past. Transformation in the Water Sector" in *International Journal of Public Administration* 26 (6) pp. 711-731

Goldin, J. (2010). "Water Policy in South Africa: Trust and Knowledge as obstacles to reform" in *Review of Radical Political Economics Sage Publications 42 (2) pp.195-212*

Goldin, J. (2013). "Proposition for a sector toolkit: addressing the gap between policy and practice through the use of a multi-dimensional poverty framework" in *Water Policy* 15 pp. 309-324

Granovetter, M. (1973). "The strength of weak ties" in American Journal of Sociology 78 (6) pp. 1360-1377

Granovetter, M. (1985). "Economic action and social structure. The problem of embeddedness" in American Journal of Sociology 91 (3) pp. 481-510

Greenwood, D., Harkavy, I. and Whyte, W,F, (1993). "Participatory action research as a process and as a goal" in *Human Relations* 46 (2) pp. 17-192

Greenwood, D.J. and Levin, M. (1998). Introduction to action research: Social research for social change. Thousand Oaks, CA: Sage.

Habermas, J. (1968). Knowledge and human Interests. Boston. Beacon

Haddock, M. and Devereux, P. (2016). "Documenting the contribution of volunteering to the SDGs: the challenges and opportunities of universal SDGs for IVCOs and volunteer groups" in *Journal of Voluntary Services* 4 (1) pp. 68-100

Hall, B. (1981). "The democratisation of research in adult and non formal education" in Reason, P and Rowan, J (eds). *Human Inquiry: a source of new paradigm research* pp. 447-456. New York. Wiley and Sons

Hecker, S., Bonney, R., Haklay, M., Hölker, F., Hofer, H., Goebel, C., Gold, M., Makuch, Z., Ponti, M., Richter, A., Robinson, L., Iglesias, J.R., Owen, R., Peltola, T., Sforzi, A., Shirk, J., Vogel, J., Vohland, K., Witt, T. and Bonn, A. (2018). "Innovation in citizen science – perspectives on science-policy advances in Citizen Science" in *Theory and Practice* 3 pp. 1-14

Heiss, R. and Matthes, J. (2017). "Citizen Science in the Social Sciences: a call for more evidence in Ecological Perspectives" in *Science and Society* 26 (1) pp.22-36 DOI: 10.14512/gaia.26.1.7

Horwich, P. (1993) (ed). "Afterwords" in *World Changes. Thomas Kuhn and the Nature of Science*, edited by P. Horwich, Cambridge MA: MIT Press pp. 311-41

Holzapfel, S. (2014). The role of indicators in development cooperation: an overview study with a special focus on the use of key and standard indicators, Studies (81) ISBN 978-3-88985-588-6, Deutsches Institut für Entwicklungspolitik (DIE), Bonn

Hossein, M., Leminen, S. and Westerlund, M. (2019). "A systematic review of living lab literature" in *Journal of Cleaner Production* 213 pp. 976-988 DOI: 10.1016/j.jclepro.2018.12.257

Humble, D. (2014). The key principles of living labs. Masters thesis. Tilburg University

Ivan, D, and Margary, M. (1926). "The Marsham phenological record in Norfolk 1736-1925 and some others" in *Quarterly Journal of the Royal Meteorological Society* 52 (217) pp. 27-54

Jabareen, Y. (2009). "Building a conceptual framework: philosophy, definitions and procedure" in *International Journal of Qualitative Methods* 8 (4) pp. 49-62

Kelly, P, (2005). "Practical suggestions for community interventions using participatory action research" in *Public Health Nursing* 22 (1) pp. 65-73

Kleinert, S. (2010). "Singapore embraces international research integrity" in *The Lancet* (376) pp. 400-401

Kobori, H., Dickinson, J., Washitani, I., Sakurai, R., Amano, T., Komatsu, N. and Miller-Rushing, A. (2016). "Citizen science: a new approach to advance ecology, education, and conservation" in *Ecological Research*, *31 (1)* pp. 1-19

Koch, T. and Kralik, D. (2006). Participatory Action Research in Healthcare. Wiley and Blackwell

Koch, T., Selim, P. and Kralik, D. (2002). "Enhancing lives through the development of a community-based participatory action research programme" in *Journal of Clinical Nursing* 11 pp. 109-117

Kolb, D.A. (1984). Experiential learning. Englewood Cliffs

Krishna, A. (2002). Active social capital. Tracing the roots of development and democracy. Columbia University Press, New York, USA.

Kusek, J. and Rist, R. (2004). Ten Steps to a Results-Based Monitoring and Evaluation System. A Handbook for Development Practitioners. World Bank. Washington D.C.

Leminen, S., Westerlund, M. and Nystrom, A. (2012). "Living labs as open-innovation networks in Technology" in *Innovation Management Review* 2 (9) pp. 6-11
http://doi.org/10.22215/timereview/602

Lintott, C. (2019). The crowd and the cosmos. Adventures in the Zooniverse. Oxford University Press

MacDonald, C. (2012). "Understanding participatory action research: a qualitative research methodology option" in *Canadian Journal of Action Research* 13 (2) pp. 34-50

Marion Young, I. (1990). Justice and the politics of difference. Princeton University Press

Maxwell, J. (2000). Failing forward. Turning mistakes into stepping stones for success. Thomas Nelson Publisher

McNiff, J. and Whitehead, J. (2006). All you need to know about action research. Thousand Oaks. CA. Sage

McTaggart, R. (1991). "Principles for Participatory Action Research" in *Adult Education Quarterly* 41 (3) pp.168-187

McTaggart, R. (1997). Participatory Action Research: international contexts and consequences. University of New York Press

Minker, M. (2000). "Using participatory action research to build health communities in Public Health" in *Reports* 115 (2/3) pp. 191-197

Newman, G., Wiggins, A., Crall, A., Graham, E., Newman, S. and Crowston, K. (2012). "The future of citizen science: emerging technologies and shifting paradigms" in *Frontiers in Ecology and the Environment 10 (*6) pp. 298-304

Osborne, D. and Gaebler, T. (1992). Reinventing Government. Boston, Mass. Addison-Wesley Publishing

Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge, UK: Cambridge University Press

Paul, T. (2007). "On Trust. The moral psychology of conflicts of interest: insights from affective neuroscience" in *Journal of Applied Philosophy* 24 (4) pp. 367-380

Primack, R., Higuchi, H. and Miller-Rushing, A. (2009). "The impact of climate change on cherry trees and other species in Japan" in *Biol Conserv* 142 pp. 1943-1949

Purdam, K. (2014). “Citizen social science and citizen data? Methodological and ethical challenges for social research” in *Current Sociology* 62 (3) pp. 374-392

Putnam, R. (1993). Making democracy work: civic traditions in modern Italy. Princeton University Press, Princeton.

Reason, P, and Bradbury, H. (2006). A handbook of action research. Thousand Oaks CA. Sage

Resnik, D.B. (2009). “International standards for research integrity: an idea whose time has come?” in *Accountability in Research* (16) pp. 218-228.

Resnik, D.B., Shamoo, A.E. and Krimsky, S. (2006). “Fraudulent human embryonic stem cell research in South Korea: lessons learned” in *Accountability in Research* (13) pp. 101-109

Roche, C. (1999). Impact Assessment for Development Agencies: Learning to Value Change. Oxfam GB

Romolini, M., Brinkley, W. and Wolf, K, (2012). What is urban environmental stewardship? Constructing a practitioner-derived framework. USDA Forest Service, Pacific Northwest Research Station, Seattle (online publication)

Rosen, M. (2003). Groundwater monitoring networks in Silveira, L (ed) Encyclopedia of Life Support Systems, Oxford, UK

Sachs, I. (1978). The discovery of the third world

Salamon, L., Sokolowski, Wojciech, S., Megan, A. and Haddock. (2016). Closing the Gap? New Perspectives on Volunteering North and South. Chapter prepared for forthcoming *Perspectives on Volunteering: Voices from the South*, Jacqueline Butcher, ed. Springer Press

Schumacher, E. (1973). Small is beautiful. A study of economics as if people mattered. Blond and Briggs

Schiavo-Campo, S. (1999). “Performance in the public sector” in *Asian Journal of Political Science* 7(2)

Seligman, A. (1997). The problem of trust. Princeton University Press, Princeton, USA.

Slocum, R. (1995). “Power, process and participation: tools for change” in *Food and Agricultural Organisation* (FAO), United Nations

Stringer, E. and Genat, W. (2004). Action research in health. Columbus, Ohio.

Svensson, J. and Ihlstrom Eriksson, C. (2009). Open innovation in small enterprises: a living lab approach. Proceedings of the CC ISPIM Conference, Vienna

Tauginienė, L., Butkevičienė, E. and Vohland, K. *et al*. (2020). Citizen science in the social sciences and humanities: the power of interdisciplinarity. *Palgrave Communications* 6 (89)

UPGRO (2017). Groundwater's Contribution to Water Security in Africa: UPGRO Working Paper Unlocking the potential of groundwater for the poor (UPGRO)

United Nations (2014). Synthesis report of the secretary-general on the post 2015 Agenda

UNDP (2009). Handbook on planning, monitoring and evaluating for development results. New York http://www.undp.org/evaluation/handbook/documents/english/pme-handbook.pdf

UNDP (2010), *Measuring Capacity*. Capacity Development Group, Bureau for Development Policy

Von Wirth, T., Frantzeskaki, N. and Loorbach, D. (2020). Urban living labs as inter-boundary spaces for sustainability transitions? in *Handbook on Planning and Complexity*. Edward Elgar Publishing. https://doi.org/10.1057/s41599-020-0471-y

Wadsworth, Y. (1998). What is Participatory Action Research? *Action Research International*, Paper 2.

Westerlund, M. and Leminen, S. (2011). Managing the challenges of becoming an open innovation company: experiences from living labs. Technology Innovation Management Review 1 (1)

Wimpenny, K. and Savin-Baden, M. (2012). "Exploring and Implementing Participatory Action Synthesis" in *Qualitative Inquiry* 18 (8) pp. 689-698

Wittmayer, J (2018). Blurring the boundaries between science and society: spaces of interaction. Drift, Erasmus University

ANNEX ONE: Capacity Building, Proposal for Data Archiving and List of Publications

1. Capacity building

Post-doctorate scholar	Dr Innocent Muchingami
Masters Student	Resego Mokomela
Masters Student	Saunak
Masters Student	Wade Jeftha
Doctoral Student	Kasifa Kakai

2. Journal Articles

Goldin, J, Muchingami, I, Mokomela, R, Villholth, K, Kanyerere, T (2021). Diamonds on the soles of their feet. Water Policy (forthcoming)

Ray, SR, Goldin, J, Van Koppen, B, Villholth, K (2021). Factors determining household water and food insecurity: empirical evidences from rural and peri-urban communities of Hout Catchment, Limpopo, South Africa (forthcoming)

3. Data archiving: to be discussed during the meeting