Creating Citizen-Science for Groundwater Monitoring prior to potential Shale Gas Development in Cradock (South-Eastern Karoo, South Africa)

By

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DECLARATION:

In accordance with Rule G5.6.3, I hereby declare that the above-mentioned treatise/ dissertation/ thesis is my own work and that it has not previously been submitted for assessment to another University or for another qualification.

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To God be the Glory!

PREFACE

This study was conducted under the auspices of the Africa Earth Observatory Network (AEON) Karoo Shale Gas Baseline Study (KSGBS) Transdisciplinary Group based at the Nelson Mandela University (NMU), South Africa. The journey of developing a Citizen Science (CS) Framework for Community Engagement and Capacity Building in Groundwater Monitoring for South Africa's Shale Gas Development (SGD) precincts has been an insightful and exciting one. The CS study was motivated by the AEON Baseline Study which was commissioned by National Government to undertake research into the baseline conditions of the South-Eastern Karoo Region, prior to potential SGD. The baseline study commenced in 2014, encompassing interactive project themes which included, Groundwater Monitoring and Analysis, Gas Flow Detection, Surface and Critical Zone Changes as well as the monitoring of Seismic Events. Legal and rural engagement issues, socio-economic and health risk analyses, also came to the fore. More information about the AEON Transdisciplinary Baseline Study is found on the AEON website (www.aeon.org.za). It is against this backdrop, that an in-depth exploration of how Citizen Science (CS) can be utilized to establish critical areas of inquiry within the community of Cradock (Pilot Study Area) was initiated, as well as an exploration of community concerns regarding SGD and the proceeding remedial actions utilizing CS.

The need to understand the community's main concern regarding the potential effects of SGD on their groundwater resources, and how to address these, led to 4 Community Roundtable Meetings being held together with background reviews on Cradock, which enabled the researcher to design a relevant CS strategy. Key Informant Interviews and Reflective Journals also formed part of the Collaborative Action Research Approach that was adopted. Utilizing this approach, was instrumental in the development of a trusting relationship between AEON and the Cradock Community. During the four phases of the CS study, it became apparent to the researcher, that scientists across the world are increasingly becoming aware of the need to actively engage with local communities in the Eastern Karoo. This engagement contributes towards improved communal knowledge and understanding of the science surrounding SGD and its associated impact on the environment (ground and surface water, economy and overall social well-being). The importance of engaging local leaders and existing community structures was evident from the onset of the CS process. Community leaders provided valuable advice which guided the CS process, which ultimately contributed to the success of the study.

The Inxuba yeThemba Municipality (IYM) officials were helpful gatekeepers, who at the start of the stakeholder identification process, assisted the research process by identifying key stakeholders within the Cradock community. The individuals identified, were later recruited into the study. Stakeholders included farmers (emerging and commercial), the youth, women and community leaders (Ward Councilors and Chiefs). During information sharing sessions that were structured in the form of Roundtable Meetings, comprising of community leaders, AEON scientists, farmers and ordinary citizens, the value placed on water resources in Cradock by the community, particularly by community members from Lingelihle and Michausdal townships was highlighted.

The community expressed how they needed skills training on Groundwater Monitoring prior to any SGD taking place. Participatory Rural Appraisal tools were used to encourage collaborative engagements between the researcher and the participants. One of the challenges experienced prior to the commencement of the CS training process included the non-responsiveness of the community to the first and second CRM invites, based on their incorrect assumption, that AEON was in support of SGD. This initial perception had a negative effect on trust-building and the community's initial engagement in the CS processes and the KSGBS. Following the third CRM with community stakeholders, the significance of the KSGBS and CS application with regards to Groundwater Monitoring, was clarified and therefore recognized by community members as an opportunity to enhance their skills and knowledge relating to SGD and Groundwater Monitoring.

The formation of a liaison group, namely the Cradock Working Group (CWG), was instrumental in liaising between the community and the researcher. The CWG role included organising meetings and interviews where necessary, with the assistance of expert advice from the AEON Hydrogeologist who conducted the Groundwater Monitoring Training. The CWG assisted in the recruitment of trainees, by advising the researcher on the criterion and method of recruitment (advertising in the local noticeboard for 15 working days) which ensured that community members were afforded equal opportunity to apply. A total of 8 youth (5 females and 3 males) successfully completed the Groundwater Monitoring Training, which covered Hydrocensus and Groundwater Sampling aspects. Hydrocensus and Groundwater Sampling data was captured manually, but trainees were also equipped with the skill of capturing and sharing field data using a customised application (Xoras App) which was developed by the AEON Unit. The development of the Citizen Science strategy in Cradock was an essential tool which facilitated community empowerment and engagement in the KSGBS, with particular emphasis on Groundwater Monitoring Training. It is important to highlight how the CS process enabled the involvement of the 8 unemployed youths to develop Groundwater Monitoring skills which could potentially propel them towards small-scale entrepreneurship efforts. At the end of the training, trainees received Completion Certificates at a Certification Ceremony on the 21st of November 2017 held at AEON in Port Elizabeth. The ceremony was also attended by IYM representatives.

ABSTRACT

Citizen Science is an integral tool for community engagement in scientific project design, implementation, data interpretation and reporting, in the quest to promote local capacity development as well as scientific knowledge. Based on the relevance of public engagement in aspects of the natural environment and associated scientific issues associated with the risks and opportunities of potential Shale Gas Development (SGD), a Citizen-Science (CS) study was designed in the Eastern Karoo region of South Africa linked to a Shale Gas Baseline Study initiated by the Africa Earth Observatory Network (AEON). As the pilot area of the baseline study, the town of Cradock was chosen to be the study area for this research; and CS was used to facilitate the identification of the Cradock community's abilities to monitor the effects of potential SGD in this region. The development of new knowledge, skills and support, as well as a deeper understanding of the community's role in Citizen Science studies, was also facilitated by this process.

This study demonstrates the feasibility of integrating Citizen Science into existing community structures in Africa, thereby encouraging community engagement in the developmental programmes through participatory methods. Using a collaborative Action-Research Approach, consistent community roundtable meetings and key informant interviews served as invaluable platforms for the establishment of a 7-member community working group, that played the liaison role between the researcher and the Cradock community in the CS implementation process. Coupled with this was the recruitment and the training of eight young citizens in conducting a hydro-census and groundwater sampling for six boreholes within the identified Cradock commonage farms, as well as two boreholes on the farm of an identified emergent farmer. The engagements between the researcher, AEON scientists, the community working group and the community at large, enabled the successful implementation of CS training in two groundwater monitoring aspects and the testing of eleven water quality parameters. The training process was combined with the design and the development of a customised 'Xoras' Online Application, which was used to capture and share the hydro-census data recorded. Experiential learning in hydro-census and groundwater sampling resulted subsequently in an increased understanding and awareness of these aspects (Figure A). Even if SGD does not materialise in the South-Eastern Karoo, CS training will enable communities in the Shale-Gas Development precincts to participate in local decision-making forums on ground water, health, or on any related regional development projects. It is anticipated that the adoption of CS will

promote future community engagements, especially about water across this water-scarce region, allowing for greater community-voice representation in resource-policy decisions related to potential Shale-Gas and related natural resource industries in the Karoo.

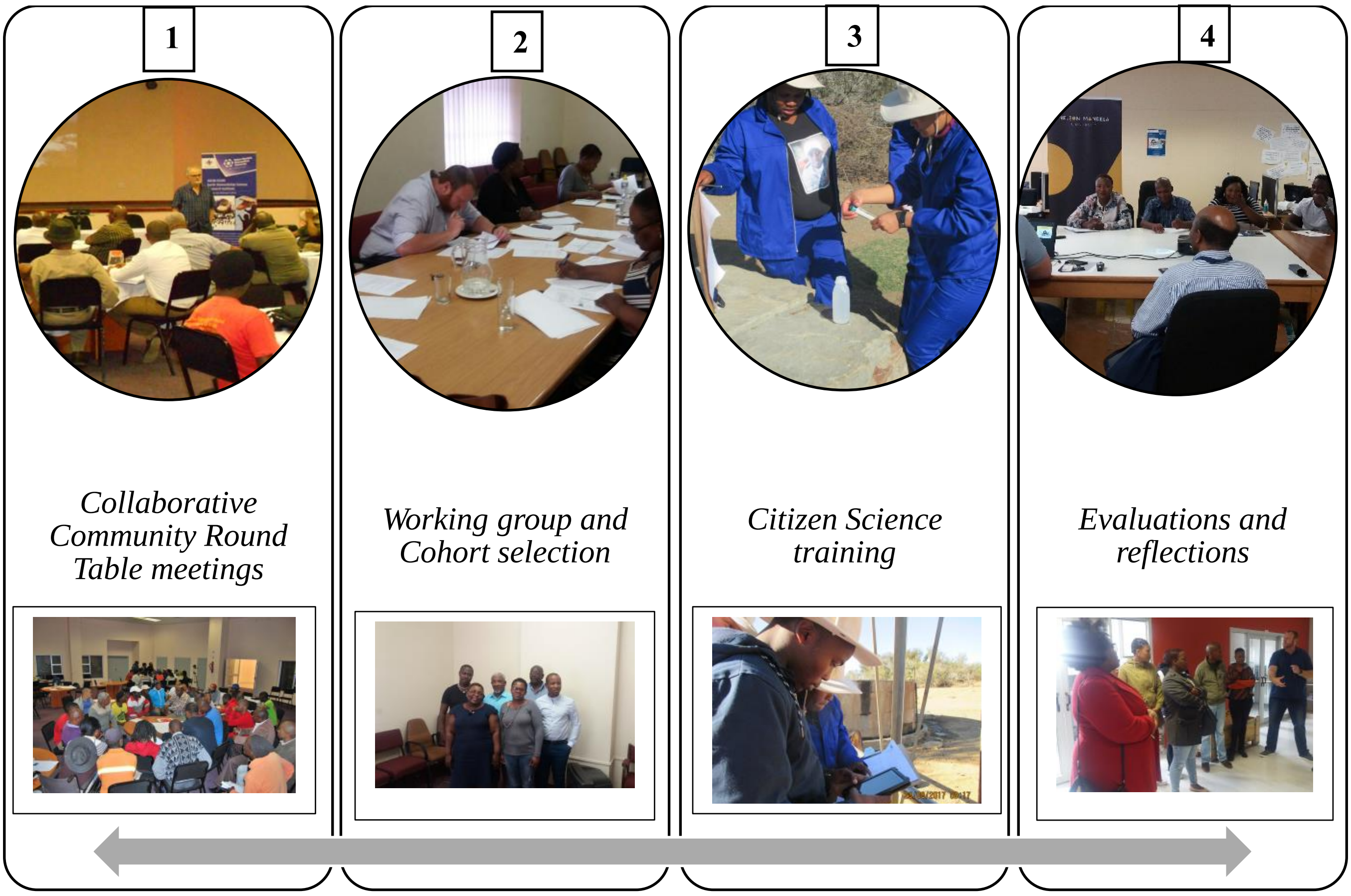

Figure A: Summary of the Cradock Citizen Science process at various stages in Groundwater Monitoring over a period of 3 years (2015 – 2018)

Key words: Citizen Science, Community, Action Research, Participatory Rural Appraisal, Shale Gas Development, Groundwater monitoring, Hydro-census, Groundwater sampling

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LIST OF ACRONYMS

AEON	-	Africa Earth Observatory Network
AR	-	Action Research
CBNRM	-	Community-Based Natural Resources Management
CDB	-	Cradock Borehole
CRM	-	Community Roundtable Meeting
CS	-	Citizen Science
CSP	-	Citizen Science Process
CWG	-	Community Working Group
DETR	-	Department of Environment, Transport and the Regions
DWAF	-	Department of Water Affairs and Forestry
ECSA	-	European Citizen Science Association
ESSRI	-	Earth Stewardship Science Research Institute
FAO	-	Food and Agricultural Organisation
GPS	-	Global Positioning System
IPCC	-	Intergovernmental Panel on Climate Change
IYM	-	Inxuba yeThemba Municipality
KRPs	-	Key Result Points
KSGBS	-	Karoo-Shale Gas Baseline Study
LRAD	-	Land Redistribution for Agricultural Development
NMU	-	Nelson Mandela University

OPAL	-	OpenAir Laboratories
PLAS	-	Proactive Land Acquisition Strategy
PPSR	-	Public Participation in Scientific Research
PRA	-	Participatory Rural Appraisal
SEPA	-	Scottish Environmental Protection Agency
SGD	-	Shale Gas Development
SLAG	-	Settlement Land Acquisition Grant
UK	-	United Kingdom
UNEP	-	United Nations Environment Programme
WUA	-	Water Users Association

CHAPTER 1: INTRODUCTION

1.1 CITIZEN SCIENCE IN CRADOCK: BACKGROUND TO THE STUDY

Citizen Science is an approach that aims to instil active public participation in scientific project activities at any implementation phase. Project phases can include problem identification, project planning, data collection, interpretation, evaluation or reporting (Irwin, 1995; Bonney, 2009; Cavalier and Kennedy, 2016). Despite Citizen Science (CS) being an old practice, introduced prior to the 20^{th} century, there has since been a rising need for fundamental data, technological development, scientific data processing and reporting that creates new opportunities for public participation (Silvertown, 2009; Haklay, 2015). The participation of the public in a CS project, has generally been referred to as the involvement of people belonging to a community, in the various aspects of a project, in order to solve their local challenges (Buytaert, et al. 2014; Shah and Martinez, 2016; Hinckson, et al. 2017; Liu, et al. 2017; Haklay, et al. 2018 in Mathieu and Aubrecht, 2018).

Historically, Citizen Science[1](CS) has contributed to the advancement of environmental and scientific awareness among the general public (MacKenzie et al., 2014; Zhang et al., 2013; Bonney et al., 2009). In South Africa, the national government has been emphasising the importance of public participation in development activities through a few Acts and Regulations, since its independence in 1994. The Constitution of the Republic of South Africa (1996) highlighted how community participation in all phases of development is actually the responsibility of all local municipalities. Community participation thus seen for instance, in municipal Integrated Development Plans (IDPs), as one of the strategies South Africa uses to engage and address the specific needs of the citizens in respective local areas.

Bearing this in mind and considering the basis of the CS concept, this study has explored the South Eastern Karoo regions' - Inxuba yeThemba Municipality's (IYM) current concerns in relation to the anticipated Shale Gas Development (SGD) in this area. The focus is on the community of Cradock town, which is one of the SGD precincts, and the pilot study area for the Nelson Mandela University – Africa Earth Observatory Network (NMU-AEON) Karoo Shale Gas Baseline Study (KSGBS). In response to the SGD related community concerns, the focus of this research was specifically on the active engagement of Cradock residents in

[1] "Public engagement in the design, collection, analysis and reporting of scientific research"

addressing these concerns. Through collaborative engagement sessions with the concerned citizens, one of the highest-ranking concerns raised was their lack and need of skills and capacity to monitor the potential impacts of SGD on the towns groundwater resource. This led to the careful, systematic selection of young men and women from Cradock to be trained mainly in groundwater monitoring (hydro-census and groundwater sampling).

For the purposes of clarity in this research, it is important to attempt to define "community". Charles and Crow (2012) assert that the concept has been "ill-defined", possibly due to a lack of a consensus on a definition. The general understanding of community is that the term has evolved from referring to a location and boundaries, to a more advanced meaning, in which interest, values and visions are evident. Macqueen et al. (2001, p. 1929) explains that community refers to "a group of people with diverse characteristics, who are linked by social ties, share common perspectives, and who engage in joint action in geographical locations, or settings".

Miller (2011) also records Aristotle's description of a community as "a compound of parts having functions and interests in common". This may mean that it is a system with living beings who share a commonly defined location or space. For this study, the term community will be referring to the Cradock residents, who share common resources and concerns about the possible SGD in Cradock and the Karoo region.

1.1.1 Why Citizen Science?

Until relatively recent, public participants in science were mostly 'subjects' (people from whom data are collected for a research experiment), as opposed to being participants (people who contribute to, and are active in, the research experiment) (Reason, 1998). Past-to-recent CS related publications highlight that the role played by public participation in citizen science projects has been mainly as data collectors, particularly in biological studies (Tulloch et al., 2013; Theobald et al., 2015; Yang et al., 2019).

In this context, Citizen Science (CS) has been described as a move towards increasingly democratizing science (Bonney et al., 2015). This is whereby attention is given to the impacts of scientific research on the concerned local communities, incorporating principles of accessibility to research results, as well as transparency and accountability between all stakeholders involved. This may have been drawn from Irwin's (1995) description of CS as involving the public more deeply in dialogue and decision-making about their environment and associated science and technological issues, often with a focus on evaluating the risks and opportunities. Historical examples of early CS projects include the North American Lighthouse Keepers, who collected the data on bird strikes around 1880; the National Weather Service Co-operative Observer programme of the United States that started in 1890; and in 1900, the annual Christmas Bird Count launch by the American based National Audubon Society (Droege, 2007; Bonney et al., 2009; Ceccaroni and Piera, 2016).

Practitioners in scientific fields have also shown that people who participate in CS project activities tend to more likely learn a specific science-related topic in detail. Bird biology is one example, whereby the local public are exposed to nature first-hand through bird-watching activities ranging from the anatomy to the conservation of species (Brossard et al., 2005). Brossard has described how participants in the Bird Biology project are likely to develop an appreciation of bird biology, to grow protective instincts for related ecosystems and for the natural environment, for the benefit of all concerned.

In marine science, for instance, engaged local citizens and concerned stakeholders, such as fishermen, become familiar with the research results, once they become involved in the scientific processes (Goffredo et al., 2010). This may lead to a better evaluation of scientific information to which the local citizens may well have contributed (Starr, 2010). Furthermore, CS can contribute to a much more reliable system for the effective management of marine organisms and habitats. This is of the utmost importance, with the ever-increasing use of the marine environment for shipping, energy generation, and construction, as well as recreation purposes (Thiel et al., 2014).

The concept (CS) generally has since developed from and across many disciplines, fostering collective reflection on project activities (Wechsler et al., 2014). However, not all CS projects can have the same objectives – due to the variable type of projects, which can be collaborative, co-creative, or contributory, thereby determining the level of public participation (the details are expanded in Chapter 2). Given these differences, CS projects might not necessarily need to be held as standards for the democratisation of science, for which it was never intended.

In South Africa, public participation is a understood as a process whereby representatives from communities express their views and highlight their concerns, needs or viewpoints, thereby influencing decisions that are made, which may directly affect them (Department of Provincial and Local Government Republic of South Africa, 2007(c)). In principle, public participation refers to the ability of affected communities (in this case Cradock) to clearly communicate their concerns and issues with the local government and development agencies, in this case with respect to the anticipated SGD. Therefore, CS can generally be defined for this study, as an approach that facilitates active engagement of the local public through skill development strategies, which in this study will meet the desired need for groundwater monitoring skills built prior to the anticipated SGD. The knowledge and understanding of CS processes require a holistic perspective, encompassing the different levels of public involvement in the various scientific projects. In this study the collaborative and contributory CS approaches were adopted and facilitated in engaging the Cradock community in all the phases of the study.

As summarised in Table 1.1, the most prominent citizen science projects in South Africa include the Invasive Species South Africa project of the South African National Biodiversity Institute (SANBI), and the Southern African Bird Atlas Project (SABAP2), which was launched in 2007 as a joint venture between the Animal Demographic Unit at University of Cape Town, Birdlife South Africa and the South African National Biodiversity Institute (SANBI) (Harrison et al., 2008 ; Wilson et al., 2013). There is also the Cape Citizen Science project, whose main purpose is to survey plant disease in the Fynbos Biome, yielding results linked to the positive conservation of the biodiversity in the Fynbos Biome (Hulbert, J. 2016).

Table 1.1 Examples of three well-documented Citizen Science projects in South Africa

Project Name	**Invasive Species Project**	**Southern African Bird Atlas Project (SABAP2)**	**Cape Citizen Science project**
Project focus	Mapping alien species of the Cape Peninsula	Mapping distribution and abundance of birds in South Africa, Lesotho and Swaziland	Survey on Plant disease in the Fynbos Biome
Project commencement year	January 2016	2007	2016
Host organisation	South African National Biodiversity Institute (SANBI) and Natural Resources Management Programme (NRMP) in Cape Town	University of Cape Town, South African National Biodiversity Institute (SANBI) and Birdlife South Africa	University of Pretoria and Stellenbosch University

Given the difference in the nature of the project and the goals, it is important to evaluate the role and position of the general public in the different scientific projects with different goals (including projects in Table 1.1). As such, the scope of public participation can be seen to encompass a range of scientific fields, as well as different funding organisations and institutions. Evaluating CS projects on aspects, such as knowledge gain in the scientific activities, and the associated opportunities and challenges, is therefore necessary.

To date, various organised citizen science projects, especially those with an environmental focus, are flourishing – as a result of scientists requiring increasing amounts of data, and many citizens being willing to contribute to the understanding and conservation of the natural and human environments (Strauss et al., 2015). Thus, to counteract the use of citizens as subjects of research, this study explores the recorded potential of citizen science applications as a capacity building tool in a development context, by answering questions such as:

- How does citizen science empower participants to carry out scientific investigations on their own?
- Why adopt Citizen Science in groundwater monitoring?

Here, I explore CS within the Cradock community, focusing on the involvement of the local community members in the CS collaborative process and facilitating the development of skills for groundwater monitoring. This has value for the community, because Cradock is recognised as a potential precinct for Shale Gas Development (SGD). Central to this analysis, is the recognition that the local community values the water resource; and they are eager to know whether SGD will, or might, contaminate their water systems. The robustness of CS application in Cradock is informed by the acknowledgement of the community's value of their water resource and the building of their capacity to influence, and benefit from, development in their area.

The validation of current understanding about CS, particularly at the local community level, where there is no scientific exposure, is also explored. A definition of the problem driving this study is discussed below. This is then followed by a research motivation that informs the formulation of context specific citizen science approaches, and it then concludes with describing the research objectives in each of the chapters.

1.2 WHY CITIZEN SCIENCE IN GROUNDWATER MONITORING?

Citizen science is a well-developed concept, aimed at increasing the scientific understanding amongst the local public (Bonney et al., 2009). As the pilot area for the AEON Karoo Shale Gas Baseline Study Programme (KSGBS), Cradock is also one of the potential Shale Gas Development (SGD) precincts. The Africa Earth Observatory Unit (AEON), together with support from the Eastern Cape government of South Africa has provided the resources for the implementation of this baseline study. Rising concerns and challenges prior to possible development (SGD) in the area included the lack of capacity to monitor the potential impacts of SGD on the local environment, particularly on groundwater resources.

Therefore, Cradock residents participated in the KSGBS community-engagement processes, contributing valuable information to the citizen science focus of this research and gaining much-needed knowledge about SGD.

According to the London Department of Environment, Tourism and the Regions (DETR, 2001), healthy voluntary and community sectors are essential for the effective functioning of society. The rationale for community participation is thus based on local citizens being well placed to identify their own needs, particularly in rural areas where there is a strong sense of community, coupled with significant diversity between local areas (Wilson et al., 2005). This has been put into practice across the world by developmental partners (or non-profit organisations), academics and government departments, working at the local level in development projects that focus on community engagement and "bottom-up" initiatives. Bottom-up approaches refers to the involvement of communities at various levels of the development project, from the definition phase, implementation, evaluation and monitoring of project activities through the defined community structures (Cohen and Uphoff, 1977).

The participation of local communities through consultation – by involving them in development partnerships, making them to see projects as their own, has also been advocated for by various practitioners, including Chambers (1993). Mubita, et al. (2017:243) further describes that "participation can lead to empowerment of the weak and disadvantaged; as it enables local people to be in command of investigations thus creating a sense of ownership of the development process and strongly places local people in positions to identify, determine and control their priorities for action". There is an indication of acknowledgement that, in designing CS projects, it is important to align these projects with the community priorities (Pandya, 2012).

The Legislative Sector Support of South Africa (SALS, 2013) advocates best practice in public participation, that should include innovative modes of public education and media campaigns, public consultation, national dialogue, as well as other creative means. It is therefore important in an ever-expanding era of human destruction of natural environments, that a better understanding is required of how decisions can be implemented to meet the needs of the public, and further how the concerned public can be engaged in the decision-making and implementation processes. In South Africa, the Bench Marks Foundation aims to embed itself in the community and produce evidence-based research challenging the sustainability paradigm, particularly in mining (Bench Marks Foundation *Annual Report*, 2016). The Bench Marks Foundation *Annual Report* (2016) records how the foundation runs a Community Monitors Programme which seeks to strengthen community-based organisations, engaging mining communities and their organisations with corporations and civil society formations. Meaningful engagements and sustained community capacity building programmes are some of the resulting changes that are seen to have taken place as a result of this Bench Marks programme.

In this regard, collaboration between scientists and the local public has the potential to broaden the scope of research and to enhance the abilities of scientists to collect appropriate scientific data. These collaborations emerged between the young people of Cradock, such as school children, unemployed youth and occasionally retired elderly citizens, among many interested population groups in the study area during the first phase of the study (see Figure 1.2). Citizen science is becoming an active process of community present-day scientific discoveries drawing on a wider population that is beyond professional science.

The use of the social media, for instance Facebook blogs, is being used as a platform for community learning and interaction with both the researchers and other participants, about scientific project data. The Instagram platform is another active platform, where for example, geo-tagged pictures show monarch butterfly habitats and migrations in more than 500,000 posts; and this information is analysed in comparison with ecological monitoring programmes (Yang et al., 2019). However, there is no explicit mention of how the participants benefitted from such CS projects, besides the satisfaction of being contributors of the data, whereby they collected the data and posted it on the stipulated platforms.

Although several research studies have confirmed the link between CS and community participation (Bonney et al., 2009; Zhang et al., 2013), minimal literature focuses on how CS influences public participation and knowledge development. Few studies have acknowledged the role of CS in promoting public participation and knowledge development; the emphasis has been placed more on the project outputs, challenges and related quality-control solutions (Dickinson et al., 2010; Clarke, 2012; Cooper et al., 2012; Tulloch et al., 2013).

It is against this background that citizen science emerged as a relevant topic for study in both academic and policy development discourse. Although local citizens' contribution to science may be valuable at the regional to the global scale (for example the SABAP2 project in Table 1.1), this could be a result of how CS has a history of a volunteerism base (Dickinson et al., 2012; Kragh, 2016), where people give their time and skills to a project without expecting any benefit in return. It is apparent that science education and environmental education have become increasingly distant in terms of incorporating values and behavioural change (Wals et al., 2014). The impacts of any CS process on the individual's capacity to contribute to science, need to be explored and better understood. I was therefore encouraged to explore these aspects of citizen science that have contributed effectively to public-capacity building with a particular focus on groundwater monitoring.

1.3 AIM AND OBJECTIVES OF THE STUDY

The main aim of this study is to propose possible capacity building and community-participation strategies for the Cradock community via CS processes. This is aimed at enabling skills development in groundwater monitoring, prior to shale-gas exploration and possible future exploitation in this community. The emphasis is on designing a CS framework that can be adopted for similar capacity-building purposes in the potential SGD precincts across the greater Karoo regions, such as Graaff-Reinet, Jansenville and Pearston (see highlighted location points in topography map, Figure 1.1 below).

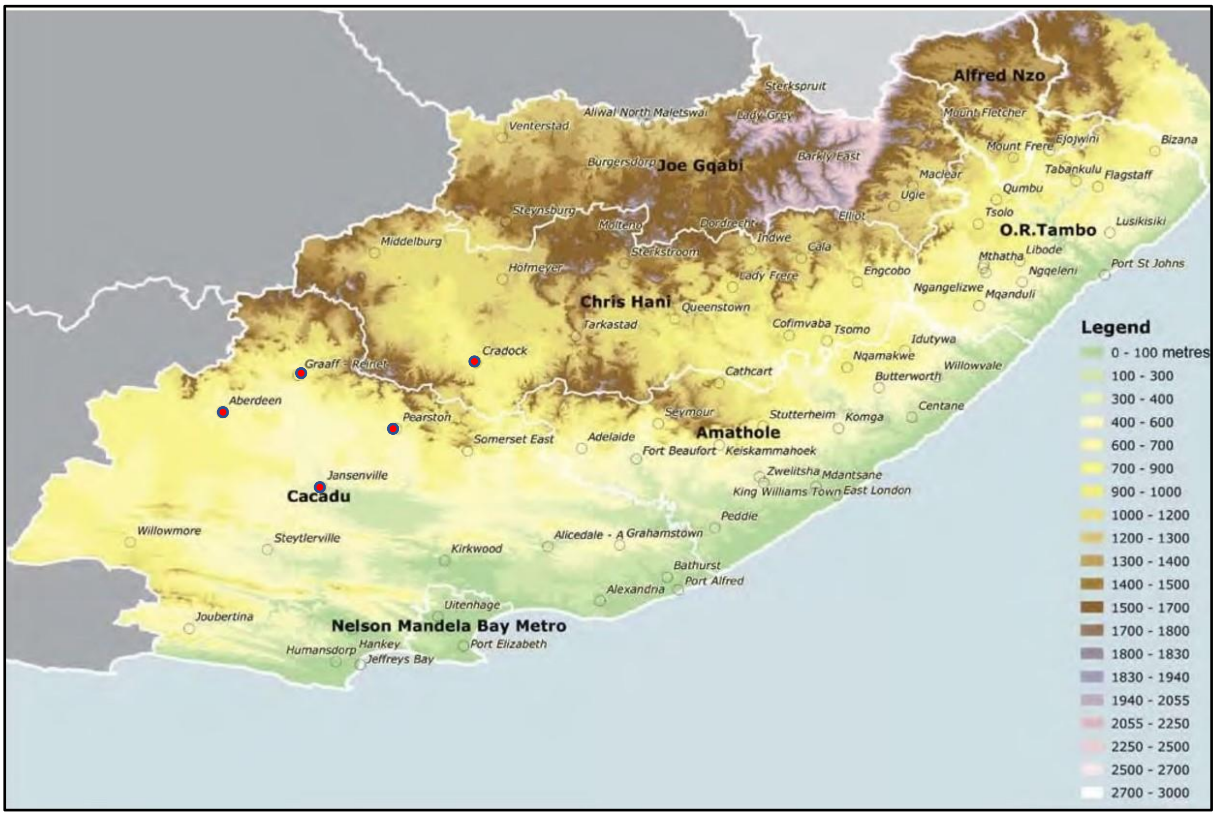


Figure 1.1: Eastern Cape Topography Map: SGD precincts (Cradock, Jansenville, Aberdeen and Pearston) also shown - (1995 – Contours/Height above sea level). (Source: Eastern Cape Socio-economic Atlas, 2012:22)

This framework will be proposed as a planning and implementation tool that can be used to identify community-capacity needs, to develop and implement strategies, and to evaluate and draw lessons ahead of potential SGD.

The following objectives, therefore, guided the research: -

- To explore the concept and principles of CS as a means for capacity building of local communities;
- To identify and assess the concerns of the Cradock community in view of the potential shale-gas development;
- To apply CS as an approach to address the main priority concern of the Cradock community – the lack of capacity to conduct groundwater monitoring in the event of potential SGD and
- To explore policy options that could best enhance the adoption and up-scaling of the CS approach, in the potential Shale-Gas Development precincts of South Africa.

1.4 PROBLEM STATEMENT

Public participation, as earlier alluded to, remains a fundamental element of community transformation, integrated development planning at local government level, and local governance capacitation (Aulich, 2009; Kakumba and Nsingo, 2008). The engagement and active participation of communities in any activity have been two central features of adequate development and governance for over a century worldwide. Despite the emphasis on participation in national or international development planning, many development processes take place without adequate consultation and accountability to local communities.

Consequently, the need for local communities to have some control over the development and the use of their resources, is one of the key problems driving this research in one of the SGD precincts in South Eastern Karoo. The factors that contribute to these problems are given, but are not limited to, the lack of substantive community-engagement practices and the non-existence of a robust link between community priorities and project objectives (FEMA, 2011). There is thus a clear need for further research on these factors.

In the case of South Africa, over the past twenty years or more of constitutional democracy, the country has not had transparent and participatory mechanisms for democratically deciding on implementing new technologies or development projects (Fig, 2012 in Quartey, 2015). This has resulted in developments being implemented, without having any tangible impact on the lives and livelihoods of the poor and marginalised. Protests or litigation against development projects are frequently a result of this impact, because the marginalised have been left out of debates that are usually confined to governmental and business circles.

However, within the scientific community, there is a growing acknowledgement that local communities or “laypersons” are capable of acquiring knowledge and developing a clearer understanding of the importance of their participation in science-affiliated initiatives. It is in this context that CS becomes a relevant topic for study in both academic and policy-development discourse. Concepts, such as community-based natural resources management (CBNRM); community science; community engagement, and ultimately citizen science, have subsequently emerged.

CS implies that an engagement process between scientists and local communities (non-scientists) in a scientific activity, contributes to the advancement of scientific knowledge, and ultimately to the achievement of a specific scientific goal (Krasny and Bonney, 2005).

Additionally, the formation of partnerships between local communities and scientists aimed at answering global challenges should be encouraged. These partnerships may range from community involvement in the identification of a problem deemed scientific by professionals, to the collection and analysis of the scientific data from within their local geographical areas.

However, the commitment of the community members and the availability of funding may mean the limitation of such partnerships (Danielsen et al., 2005). A recent example from South Africa is the *Abalobi* initiative, an application that helps small-scale fishermen in Cape Town to link their own knowledge on fishing to building resilient communities in the face of climate change. These fishermen have significant knowledge of fishing, although they may not be the link to how communities can benefit beyond merely fishing.

Adopting citizen-science in this research points to the vital importance of engaging local community members of Cradock in the national SGD debate, which forms part of the AEON Karoo Shale Gas Baseline Study (KSGBS). This involves providing a forum for discussion with the local communities concerning the scientific nature of the KSGBS, Shale Gas Development (SGD) and its potential effects including their related concerns.

Inadequate consultation by companies (such as Bundu Gas and Oil Exploration (Pty) Ltd, Falcon Oil and Gas Ltd and the Shell Exploration Company) applying for shale gas exploration licences across the Southern Karoo, and the absence of genuine consultation with the poorer Karoo communities, was a major deficiency in the permit-granting process (de Wit, 2011; CER, 2011, AEON, 2018). The AEON Karoo Shale Gas Baseline Study was therefore endorsed by the Eastern Cape government, as part of the response to this deficiency, through community consultation, particularly the historically disadvantaged living in the township centres and the townships of the Karoo region (Morkel and de Wit, 2018, AEON, 2018).

1.4.1 Background to the KSGBS

The KSGBS started in early 2014, aiming at reviewing and improving an understanding of, the deep geology, health, natural ecosystems (biology, zoology), hydrogeology (ground water), seismicity and natural gas-leakages of the Karoo. This will assist in establishing a forensic baseline of groundwater quality and water levels across the Karoo, including the identification of any micro-seismic events and methane gas leakages related to the hydraulic fracturing and the harvesting of shale gas. Thus, enabling the quantification and ultimately management of any potential risks and opportunity costs associated with SGD in these communities.

Having awareness of other major basins in the world being drilled for oil or gas by various oil companies and facing subsequent degradation of their natural environment, the Karoo was identified by the South African government, as an area where a baseline study needed to be completed before any SGD could take place. In the states of New York, Pennsylvania, Ohio, Maryland and West Virginia, since 2011, there has been an increase in natural gas development (the Marcellus and Utica Shale) (US Energy Information Administration, 2011). However, following natural gas drilling in the Marcellus shale region in Pennsylvania state, high concentrations of methane contamination in surrounding drinking water wells was identified, causing a high health risk to general public (Abualfaraj et al., 2018). A volunteer-friendly protocol (Alliance for Aquatic Resource Monitoring) was also developed in an effort to generate sound and useful scientific outcomes to help assess impact from gas extraction activities (Wilderman and Monismith, 2016).

The risk of possible salinization of shallow groundwater through leaking of the natural gas wells and subsurface flow can be projected and the over extraction of water for the high-volume hydraulic fracturing may induce water shortages or potential conflicts with other water users (Vengosh et al., 2019). For instance, water consumption for SGD from the Marcellus, Barnett, Haynesville, Eagle Ford, Woodford Shale and Horn River in British Columbia varies from 8000 to 100 000 cubic metres (2-13 million gallons) per unconventional well (Lutz, et al. (2013). In drier regions however such as the Karoo Basin in South Africa; Texas and Colorado in the United States, a higher aquifer use and groundwater exploitation for hydraulic fracturing may lead to local water shortages. In wet regions as well extraction of water for hydraulic fracturing can induce water shortages (Mitchell (2013). In view of possible water shortages in the event of SGD, alternative water resources such as brackish to saline groundwater, treated domestic wastewater (Kondash, et al. 2014) could be considered as potential alternatives for drilling and hydraulic fracturing in water scarce areas (Rivard et al., 2013). In view of the United States of America (USA) based SGD related cases, among others, the South African government, as a proactive strategy, recognised the need for baseline studies to be conducted before the proposed Shale Gas Development commences.

The KSGBS argues that the lack of adequate information and knowledge about SGD and its potential impacts, places Karoo communities at risk of the severe impacts of Shale Gas Development, and not being able to mitigate these effectively (Morkel and de Wit, 2018). Exacerbating the problem, is the increasing evidence of the SGD debates that have been between the companies applying for licences to conduct shale gas exploration, the elites and governing structures, without the inclusion of the local South African residents of the areas likely to be affected by SGD. The involvement of the elite population usually results in decisions being made for citizens without any regard for their consent or impute. No representativity is evident (where the elite are involved), as compared to a technocratic environment, and there is a concentration of power, not in the hands of citizens but in the hands of a parliament and elected representatives who in some cases become vulnerable to corruption (Carson and Martin, 1999). A quote from the National Framework for Sustainable Development in South Africa of 2008, Havemann et al. (2011, p. 44) states that "it is the poor who often experience the economic costs of ecosystem degradation most directly; because the majority of poor households depend on natural resources and ecosystem services". It is for this reason that there has been reported lack of inclusion on the part of the local communities in the SGD precincts, in the SGD debates and decision-making forums.

As observed by Morkel and de Wit (2018), government agencies have not taken sufficient action to disseminate SGD information to the local Karoo communities, or to solicit their views and concerns. This is one of the reasons that led the South African government to place a moratorium on shale-gas exploration in the country in 2011, allowing the government time to further investigate the potential benefits and risks that shale-gas extraction may hold for the country and the environment (Shabangu, 2012; ASSAf, 2016).

Figure 1.2 below gives a brief summary of the SGD process in South Africa (2010 – 2019).

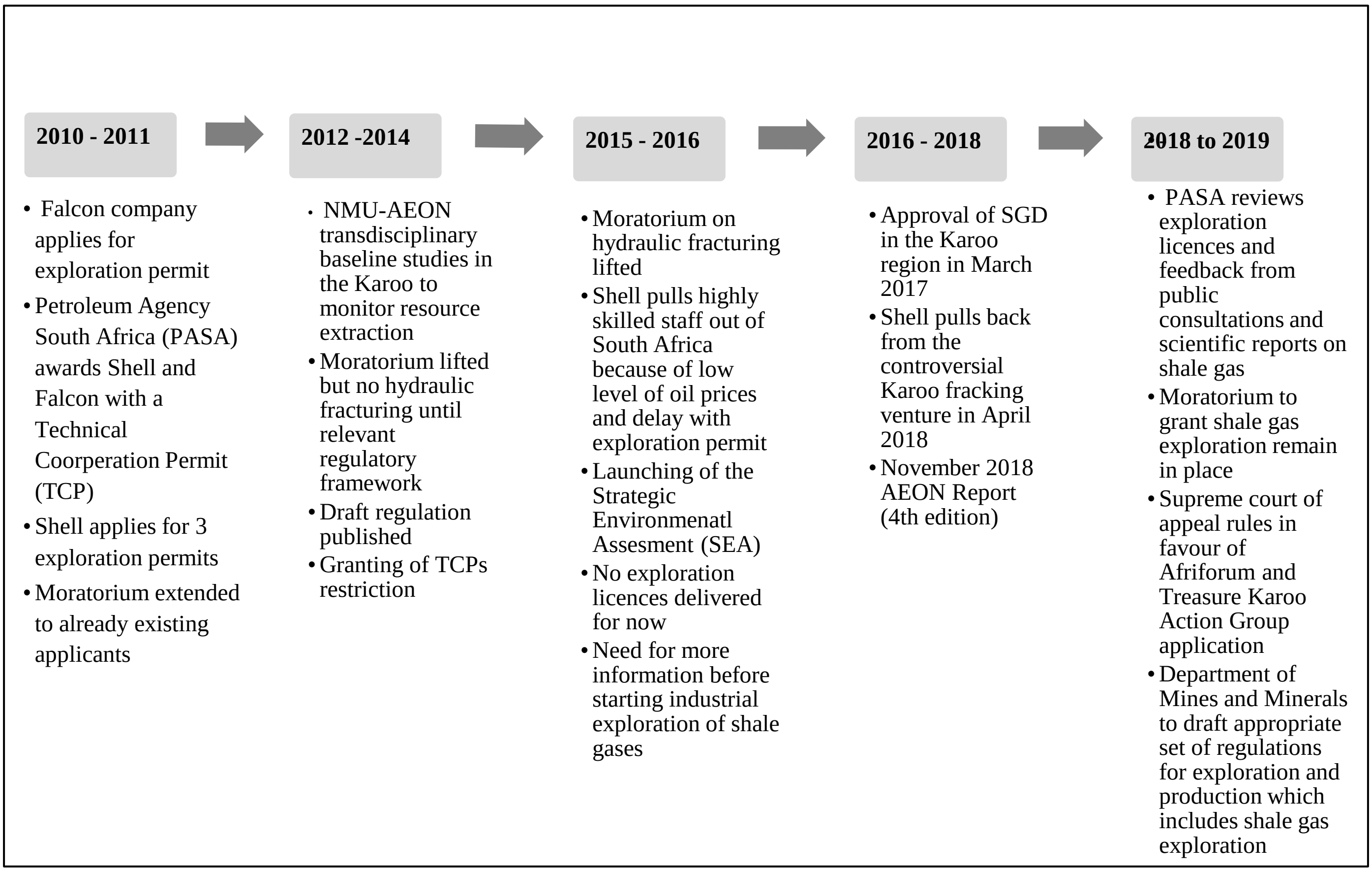


Figure 1.2: Summary of the South African Shale Gas Development Timeline (2010 - 2019)

In this regard, the motivation for using CS provides an important bottom-up approach in addressing the development initiatives promoting community-engagement processes with the communities concerned. South Africa's Technical Readiness to Support the Shale Gas Industry Report (ASSAf, 2017), is potentially useful in highlighting research gaps and areas requiring the refinement of mainstream science, thereby contributing to the Karoo Shale Gas Baseline Study (KSGBS) focus, also referred to as the AEON Baseline Study.

The CS focus of the AEON Baseline study in the Karoo hopes to benefit the South African government and local stakeholders (representatives from Cradock youth organisation, women's co-operatives, business fraternities, the farming community, municipal officials, academics, and scientists) in particular, as it facilitates adaptive capacity building through the active participation of the Cradock community. Community members can be capacitated through training in groundwater monitoring, water analysis, data sharing, reporting and decision-making. Additional expected benefits to the Karoo community would be a greater understanding of the resilience of Karoo hydro- and eco-systems.

Therefore, the researcher was given more clarity and guidance towards the main aim of this study – to identify and develop citizen scientists (young women and men in particular) through local community participation in a specified training process. Meaning, engaging in a training process centred on a response to one of the Cradock community's highest priority concerns – the need for knowledge and skills to conduct groundwater monitoring prior to potential SGD effects.

A total of seven community priority areas were raised during the first community roundtable meeting (CRM), held in the first phase of the study. The CRM participants included stakeholders who are resident in Cradock, the AEON-NMU officials, and the researcher. Following a ranking exercise on the main resources in Cradock in order of importance, participants raised a concern related to the potential impacts of SGD on Cradock's water resources (both surface and ground water). This concern ranked the highest and the community's need for capacity and skills to conduct groundwater monitoring was also mentioned as key. Thus, the study was structured, bearing in mind this main concern and adopting citizen science (CS) as a tool to build community skills and capacity for groundwater monitoring. Eight young women and men, selected from within Cradock, constituted the trainees in groundwater sampling (the collection of samples from groundwater wells) and hydro-census (this refers to the gathering of information on water-resource features, the potential sources of water pollution, and the under-ground source of water supply) at selected borehole sites.

The end result is to empower these selected Cradock youths and to motivate them to establish small, sustainable, self-reliant entrepreneurships linked to groundwater monitoring, among other possible ventures. The CS training aims to equip the trainees to assess whether ground water is fit for human and livestock consumption. This is important, because if community members are empowered to conduct this assessment, it would reassure them whether their water is safe; and it would enable them to have some control over monitoring the impacts of fracking on their water sources.

The AEON baseline study reiterates that a critical success factor for such a science and technology project is directly linked to community-engagement practices. Citizens residing in an area with anticipated development activities (in this research it is the town of Cradock, Figure 1.3 (a) below), would need to acquire knowledge, skills, and support, as well as a deeper understanding of the importance of their participation in the scientific activity.

In essence, as Chapin et al. (2011) reiterates, there is a need for local citizens to develop a passion for science and development, as well as the patience and resilience needed in the development of the stewardship of their natural environment.

The science of earth stewardship can be described as one that entails trans-disciplinary collaboration among many disciplines, such as the natural and social sciences, environmental sciences, political sciences, as well as sociology and anthropology. Various authors including Chapin et al. (2011), state that the success of science stewardship exists by engaging broad segments of society, in order to develop a new ethic of environmental citizenship. This resonates with this study's aim of developing local capacities and linking citizen stewardship to the Karoo hydro-ecosystem.

Local community groups may range across business communities, learners, religious communities, community-based organisational representatives, and other active groups in the Cradock locality. It is thus important to document the different views regarding citizen science-related projects (see Chapter 2).

This study also will expand on the need to use social media platforms for the sharing of scientific discoveries during the collaborative project. It is imperative to discuss scientific facts with the local communities and to encourage their participation in the scientific research programmes as active CS participants: for example, in collecting and testing water samples and educating them about water and the natural water systems. It is also about improving their understanding of the science and politics of water resources, and for communicating with the professional scientists through, for example, the online sharing of recorded groundwater monitoring data, including high-resolution images.

As such, one of the researcher's preliminary actions in the study was to explore the current groundwater monitoring capacities of the Cradock communities, in order to design an aligned capacity building and engagement strategy.

As earlier alluded to, due to the lack of knowledge and clarity of the potential risks and benefits of the anticipated SGD in the Karoo, public consultations and engagements with companies and/or government, usually result in unhelpful emotional debates around environmental issues and human ethics (AEON Report (4), 2018). Therefore, this study seeks to explore both the theory and the practice of community engagement in scientific research; and to target the local communities that are expected to learn about the consequences of an absence of baseline studies, and how to conduct groundwater monitoring prior to potential resource abstraction (SGD).

Throughout this process, communities participate in the baseline-science studies as fellow researchers, not as research subjects.

1.5 STUDY AREA: PROFILE OF CRADOCK

Cradock is one of the oldest towns located in the semi-arid region of the Karoo (Eastern Cape Province), about 300 kilometres north of Port Elizabeth (Myburgh, 1978). The town, which was established around 1814, is now located in the Inxuba yeThemba Local Municipality (IYM) (translated as "Beacon of Hope") under the Chris Hani District of the Eastern Cape Province (Figure 1.3 (a)).

The majority of Cradock residents live in the townships of Lingelihle and Michausdal, the residential areas designated for the black people under the apartheid regime. Although the original inhabitants of this region were Khoi herders and hunter gatherers, and then Xhosa farmers, the town was established by and largely populated by white farmers during the colonial era. The town was named after Sir John Cradock, the governor of the Cape Colony at that time.

Prior to the establishment of Cradock town, fierce conflict had existed between the early European settlers and the Xhosa people, around the 17th and 18th centuries, due to competition for land and livestock raiding (McKenna, 2011). With the Great Fish River flowing from the West to the East, Cradock remained an ideal place to develop commercial agriculture. As history relates, the then colonial government established irrigation schemes to grow lucerne, which was crucial in Angora goat and ostrich farming.

Cradock then became one of the principal economic centres of the Cape Midlands (Tetelman, 1997:16-21). The growth of the economic environment through the expansion of commercial agriculture had a ripple effect on the socio-economic conditions of Cradock, and especially on the black people living in the town. The Karoo-Midlands region was known for agriculture, where, for over 200 years, the Dutch settlers produced agricultural products (mainly sheep, wool and mohair). With the Great Fish River running through this town, these products turned the town into an epicentre of the agrarian economy in South Africa by the late 1820s (Tetelman, 1997 p. 21; Butler, 1985 in Mkhize, 2012).

Figures 1.3(a) and (b) below show the location of the study area. They also show the borehole-sampling sites surrounding Cradock.

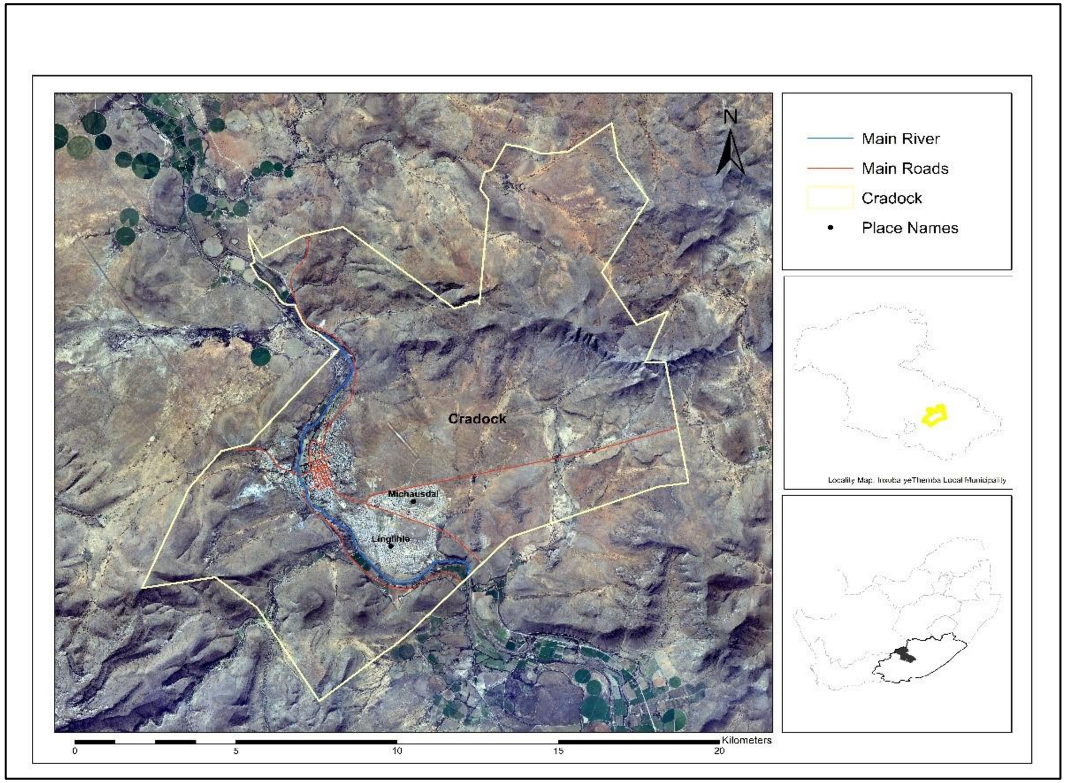


Figure 1.3 (a): Map of Study area around the town of Cradock, Eastern Karoo, South Africa

Figure 1.3 (b): Borehole sites within Cradock Commonage farms, Eastern Karoo, South Africa

The history of Cradock town records that it was once surrounded by one of the richest agricultural regions of South Africa, covering approximately 594 000 hectares across which grazing capacity ranged between four to five hectares for small stock units, and between ten and twenty hectares for large stock units (Signeu, 2007). As the years passed the Dutch settlers could not survive the conflict that the British in the region created in order to acquire greater control of the local economy. As the Dutch farmers sold their land to the British farmers, the agrarian economy improved.

Many residents of the town supplemented their wages by keeping livestock that grazed on the commonage, provided by the municipality (Marsden, 1986). Unfortunately, according to the enactment of the 1913 Land Act, black South Africans were deprived of the right to own land (Modise and Mtshiselwa, 2013). Colonial rule contributed to increasingly harsh economic conditions for the black population. The (white owned) commercial agricultural economy became responsible for the employment of much of the black population (as either domestic servants or farm workers).

The African (black) residents of Cradock stayed together in what was called the "Tams" area during the 1940s. Under the subsequent Apartheid law, separation of these communities occurred, as a result of the Group Areas Act of 1950, when the coloured residential area was designated as Michausdal (Figure 1.3b). As the black community grew, in accordance with the Governance Notice 2771, the township of Lingelihle was established (Figure 1.3b; Signeu, 2007). The demand for labour in Cradock increased with the construction of a railway line that transformed the transportation system to the cities of Port Elizabeth and Cape Town.

In the midst of the growth of the agrarian economy of Cradock town (1928 - 1938), more white farmers were constructing houses for themselves; while more black people were employed as farm servants and sought to be allowed to herd their livestock on the commonages (Marsden, (1986) in Zungu, 2017). There was noticeably little effort to increase the land size to be available to them, so that they might cope with their poverty; and the infrastructure in their locations became dilapidated (Tetelman, 1997:20).

Land issues in South Africa remain inevitable and appropriate to address even in the 21st century. Around the 1930s, both African (black) and European (white) farm workers experienced the devastating effects of the Great Depression; and the Cradock town suffered low economic returns from the primary farm produce (Zungu, 2017). From 1948 onwards the apartheid regime herded millions of black South Africans into overcrowded 'homelands', destroying remaining independent farming communities in the ‘white areas’ and undermining the ability of the ‘homelands’ to provide local communities with an agricultural su bsistence base in the process.

The termed ‘destructive’ legislations of the 20th Century, which include the 1936 Natives Trust and Land Act and the Group Areas Act of 1950, were introduced and meant for rural and urban land rights (CDE, 2005). The opening of the Orange-Fish river tunnel in 1975 allowed farming in the arid Karoo to remain profitable. However, through the 1980s, rural poverty led to secondary urbanisation and high levels of unemployment and poverty in rural towns like Cradock and poor social and economic conditions led to a highly mobilised township population resisting apartheid in the 1980s.

Post - 1994, the manifesto of the African National Congress (ANC) generally presented that as part of the comprehensive rural development policy, a supply of residential and productive land needed to be given to the poorest section of the rural population and aspirant farmers. In order to improve livelihoods and quality of life for the poor and marginalised black communities, redistribution of land needed to be considered to acquire commercial farmland. (CDE, 2005). The redistribution of land was from white to black South Africans, for purposes of restoring land rights to people dispossessed of land since the Natives Land Act of 1913. The redistribution of an approximated 30% of the total hectares of farmland was the mission to reach, to achieve for historically disadvantaged black communities by 2014. (South Africa, 1977; Mtombeni, et al., 2019)

It was between 2008 and 2011, when a diversified agricultural economy developed (commercial), through irrigation farming – although many of the farms were characterised by extensive livestock agriculture (mainly sheep farms) in Cradock (Mkhize, 2012). The Chris Hani District Spatial Development Framework Review of 2015 records how the district and its local municipalities, including the IYM, each became responsible for the provision of services and infrastructure within their municipal boundaries. These services are explained in this review document to be facilitated through the development and the implementation of Integrated Development Plans (IDPs), Spatial Development Frameworks (SDFs) and the Local Economic Development (LED) Plans. This means that much attention is needed, especially towards the communities in designated municipalities, to support them, by including the opportunity to participate in these forums, among others.

The Inxuba yeThemba Municipality which houses Cradock and Middleburg towns, has an estimated population of 60 296, whose density is one of the lowest in the Province with a total of 6.03 people per square kilometre (CHDM draft IDP Review, 2019-2020). The Draft IDP reports how the municipality has a total of 20 400 households and when classified by type of water access, 596 households (2%) do not have formal piped water. Other water supply sources include drilled boreholes, springs dams and the Fish River abstraction (direct removal of water from rivers and aquifers). For purposes of this study, focus will be on Cradock town because it constitutes the pilot area for the AEON Baseline study and will constitute the study community for this research.

According to the 2011 Census of South Africa, Cradock constitutes a small to medium-sized urban centre in the Chris Hani District that experiences high levels of poverty. (Figures 1.3 (a) and (b)).

1.5.2 Emerging farmers

The period between 2007 and 2017, addressing poverty alleviation (including curbing the problems of roaming livestock, assisting with farm infrastructure) was one of Inxuba yeThemba Municipality mandates. One initiative of the IYM to fulfil this mandate was where they bought a farm (commonage) in Cradock for black farmers (referred to as emerging farmers) who are beneficiaries of the government's land reform programmes (Moloi, 2008). Emerging farmers, who are by definition previously disadvantaged (that is black), have been described negatively as, 'backward', 'non-productive', or who 'practise subsistence agriculture' (Kirsten and Van Zyl, 1998); however, they are willing to produce and participate in the business market.

According to the IYM Integrated Development Plan (IDP) (2017 - 2022), emerging farmers mostly farm in groups and in the case of Cradock, they farm on 1 200 hectares of commonage rented from the municipality. They are not beneficiaries of land redistribution programme and to date access to land and water for agriculture remain a challenge in South Africa for these farmers as they do not have title deeds.

Between 1994-1999, the Settlement Land Acquisition Grant (SLAG) was useful to the implementation of land redistribution (FAO, 2010). However, a moratorium was placed on

SLAG in 1999 and it was discontinued in 2000 following criticism for the slow rate with which the transfer process was being completed and for the reported low quality of the land being transferred (South Africa, 2003; FAO, 2010). In 2001 the Land Redistribution for Agricultural Development (LRAD) replaced the SLAG, aiming at providing grant support to emerging farmers (Antwi and Nxumalo, 2014 in Sebola, 2018). The success of LRAD was not evident as the Proactive Land Acquisition Strategy (PLAS) was later adopted in 2006, which is the policy currently available for land distribution to promote emerging black farmers (Sebola, 2018). One of the conditions in this policy is that beneficiaries are provided with land in a lease agreement for a period of 3 – 5 years after which they can purchase the land for permanent ownership (Cousins, 2013). Emerging farmers, however, continue to face challenges that include a lack of appropriate skills, little support from government, and limited access to agricultural finance (IDP, 2017 - 2022).

Based on the brief background history regarding the terms used to define emerging farmers in South Africa and the context of this study, emerging farmers refer to two categories of people. Firstly, those who are the beneficiaries of land reform programmes, described by Matungul et al. (2001) as those whose educational levels are generally low and who do not qualify for financial credit because they cannot use the land as collateral. Secondly, the new individuals (who could either be white or black South Africans) in agriculture who are not benefitting from any government programme, whose farming is for both subsistence, and attempting to participate in commercial markets, intending to produce and sell more of their produce (Matungul et al. 2001).

It should be noted, that emerging farming in South Africa has been associated with black subsistence farming (Machete, et al. 2004), and the majority of these emerging farmers are blacks. According to the FAO (2010) review of experiences of establishing emerging farmers in South Africa, the Proactive Land Acquisition Strategy (PLAS) implemented by the Department of Land Affairs, allows emerging farmers to access land as they need and have the advantage of not being dependent on people to access grants and land. The FAO review also states some of the opportunities the emerging farmers have access to, an agrarian reform coordinator. This coordinator is situated at district or municipality level, would be knowledgeable of the farming opportunities, the land reform and processes involved and share these with the emerging farmers

1.5.3 Study sites for Groundwater monitoring training

During the first phase of this study, it was evident that these two types of emerging farmers were actively participating in the CS process (community roundtable meetings and cohort selection). Thus, the boreholes used as groundwater monitoring training sites were within the commonage farms where the second type of emerging farmers were found. During the final (test) week of CS training, the CS participants sampled the ground water on the farm of one emerging farmer, who benefitted from land distribution and was using the land for subsistence and commercial value. More detail about the sample sites is provided in Chapter 4 and 5of this research.

The groundwater monitoring training was introduced to test the effectiveness of citizen science in this part of the Eastern Karoo region. The CS concept itself is context-specific; and it is adequately understood in a collaborative approach (to be discussed in Chapter 3). A community representative group (Community Working Group – CWG) collectively with the researcher, identified the IYM commonage farms as ideal to conduct the CS training.

The responses from the study interviews reflect that these boreholes had previously been monitored eight years prior to this study, and consequently, the CWG selected these sites to be used for the CS training. Commonage farms, particularly in terms of groundwater monitoring, have also been paid limited scholarly attention. Additionally, the boreholes were located within a maximum of a 5-kilometre radius from Cradock town, to allow prospective trainees to access them easily during the training. The commonage boreholes were largely located in [Elandsberg, Egg Rock, Taaiboschleegte, Sondaghoek and Pechelsdam farms. In total, eight functioning boreholes from these farms were sampled (see Figure 1.3b).

CHAPTER 2: CITIZEN SCIENCE AND ITS APPLICATION IN GROUND-WATER MONITORING

2.1 INTRODUCTION

This chapter seeks to explore the concept of citizen science, giving a background history of how it emerged, including the global definitions surrounding it, as put forward by different authors. These definitions will help in clarifying the working definition for this study. This is followed by a detailed presentation on citizen science application in groundwater monitoring, together with a discussion on globally recognised CS based methodologies. Emphasis is further placed on CS principles of application, which informed the author on the relevant methodologies to adopt in this study. These methodologies have the context of groundwater monitoring within Cradock community, prior to potential Shale Gas Development (SGD).

2.2 CITIZEN SCIENCE – A CONCEPT OR A REALITY?

Citizen Science (CS) processes create platforms for local communities (across the world) to connect with science and scientific research. It is a multi-faceted concept to define; and has been broadly described by different researchers (for example, Cooper et al., (2007); Cohn (2008); Bonney et al., (2009); Silvertown (2009) and Xue (2014)). To understand this concept, one needs to try and define "science". In general, "science" denotes a body of knowledge obtained from experiments or observations about the natural world.

The challenges to formulate a concrete definition of CS have been in the complexity of the context of its application (McKinley et al., 2015). This has prompted many authors to pursue varied approaches to define and explain the concept of Citizen Science. Since the aim of this study is on community capacity building to conduct groundwater monitoring and how citizen science can contribute to this process, it is paramount that attention be focussed first on defining CS at this stage.

2.3 WHAT IS CITIZEN SCIENCE?

Simply defined, citizen science is a practice of engaging the public in scientific activity (Bonney et al., 2014, Shirk et al., 2012 and Silvertown, 2009). A scientific activity usually involves, but is not limited to, model design, experiments and analysis. In this understanding, the definition for CS is often contextual; since it can be more broadly understood as referring to citizens observing natural phenomena and environmental characteristics, to a genuine revolution in ‘science’ that recognises the role of social learning of the surrounding environment (see Table 2.1).

Table 2.1: Various definitions of Citizen Science

Author and Year	**Citizen Science Definitions (paraphrased)**
Oxford English Dictionary (2014) http://www.oxforddictionaries.com/definition/american_english/citizenscience	Scientific work undertaken by members of the general public, often in collaboration with, or under the direction of professional scientists and scientific institutions.
Irwin (1995)	Developing concepts of scientific citizenship which foreground the necessity of opening up science and science-policy processes to the public.
Bonney (2009)	Projects in which non-scientists, such as amateur bird-watchers, voluntarily contributed to scientific data.
McKinley et al. (2015)	Participation by the public in a scientific project.
Kruger and Shannon (2000)	The process whereby citizens are involved in science as researchers.
Bonney et al. (2014)	Scientific research and monitoring projects for which members of the public collect, categorize, transcribe or analyse scientific data.
UNEP Yearbook (2014)	A process in which people, who are not professional scientists, take part in one or more aspects of science – systematic collection and analysis of data, development of technology, testing of natural phenomena and dissemination of the results of activities. Such participation is mainly on a voluntary basis.
Bhattachanjee, (2005)	A research technique that enlists the public in gathering scientific information.
Gommerman and Monroe (2012)	A form of participatory research used to attain and increase scientific and environmental awareness amongst the local public.
Silvertown, (2009)	Volunteers who collect and or process data as part of a scientific enquiry.
Green Paper on Citizen Science (2013)	The general public engagement in scientific research activities, when citizens actively contribute to science either with their intellectual effort, or surrounding knowledge or with their tools and resources.

The citizen science activities are further described by McKinley et al. (2015) as producing information that is open to the same system of peer review, as that applied to conventional science (a professionally based approach to science led by and carried out by scientists, technicians and students). This view further contributes to the understanding that ‘context’ plays a role in the interpretation of what CS is, and how it can be applicable. Thus, for this study, CS is defined as an approach that facilitates the active engagement of the local public as contributors to scientific research activities (from the first to the last step).

To note, Bonney et al. (2009) refined the CS concept, as one which falls under the umbrella term of Public Participation in Scientific Research (PPSR); and this is well known to produce variable results, depending on the context of the application, when analysed. Furthermore, as in Table 2.1 above, Bonney et al. (2014) depict in a more detailed definition of CS as one that promotes public engagement and active involvement in almost every stage of the scientific project or activity (collect, categorise, transcribe or analyse scientific data). The degree of public participation in a CS project, therefore, was expressed by this author as one that ultimately varies across the different project categories. These are either contributory, collaborative or co-created (see Chapter 2 - Section 2.3.1).

It is therefore notable from Table 2.1 above that definitions of the citizen-science concept differ and overlap in terms of their applicability or the context. These differences set the stage from which one can understand or interpret CS, without bypassing its main objective of actively engaging non-professional communities in scientific project activities. All the authors in Table 2.1 tend to agree that CS has to do with people participating in at least one scientific activity. This could be systematic, future-oriented, relative, comprehensive, or trans-disciplinary. Stemming from the UNEP Yearbook (2014) definition of CS in the table above, and for the purposes of this study, citizen science is to be used as an approach, instead of as a research technique. In the context of this study it is understood to mean a process of active participation (particularly in groundwater monitoring) of the community that is facing the likelihood of SGD in its vicinity.

2.3.1 Critical Analysis of the Citizen-Science Concept

The theoretical context surrounding the Citizen-Science often links it with common terms, such as ‘community science’, ‘participatory science’, ‘crowd-sourcing’, ’crowd-science’ and ‘civic science’, in the definitions of the concept of CS. Authors, including Bonney (2009), Silvertown (2009), and Gommerman and Monroe (2012) and McKinley et al. (2015), suggest a variety of interpretations and application scenarios for CS. Although expressed heterogeneously, a scholarly review of the definitions reveals similarity in the meaning of the concept, particularly the reference to public participation. One challenge for this study is therefore to design a more precise definition and terminologies.

To further assess the existing roles played by CS, a New York based non-profit organisation, Cornell Lab of Ornithology (CLO) [2], defines citizen science as "a range of ideas – from a philosophy of public engagement in scientific discourse to the work of scientists driven by a social conscience". It is important to note that the CLO specialises in understanding birds and other wildlife, involving the public in scientific discoveries, and the use of available knowledge for the better conservation of the earth and its resources. As such, a proposed working definition of CS activities from the CLO, became "projects in which volunteer's partner with scientists to answer real-world questions" (LaKind et al., 2016, p. 534).

In environmental science, the UK Environmental Observation Framework (UK-EOF, 2011) defines citizen science as "the volunteer collection of biodiversity and environmental information that can contribute to expanding human knowledge about nature and its ecosystems." The process of the public participating in environmental observations shows how CS can be crucial, in combining scientific research with education, in providing a public platform to contribute to science. This is in line with the EU Biodiversity Plan, which asserts that CS should be "an active involvement of civil society, which needs to be encouraged at all levels" (SEPA et al., May 2014, p. 1).

Citizen Science can be understood to be a valuable means of gathering quality scientific data, while encouraging citizens to get involved in biodiversity conservation activities, mostly through providing observations. In some projects, the involvement of citizens may be aimed at resource-exploitation projects, or other practices that are not sustainable. In as much as citizen involvement contributes positively to science, CS may not be considered necessarily a sustainable approach, particularly in those contexts where CS does not have an educational or capacity building spin-off.

[2] Cornell University. Defining Citizen Science. Available online at: http://www.birds.cornell.edu

In terms of the extent of public involvement in a CS project, the concept has been further described by Bonney et al. (2009) as encompassing these three categories, - contributory, collaborative or co-created (Table 2.2):

Table 2.2: Categories of Citizen Science (adapted from Bonney et al., 2009)

Category	**Description**
1. Contributory	Usually scientist designed; and the public is mainly involved in data collection.
2. Collaborative	Projects that are structured by the scientists; but the citizens are given opportunities to provide some input on project design, and in data collection.
3. Co-created	Projects that are more democratic partnerships between scientists and the public, whereby the public is actively engaged in all the steps of the scientific project (from beginning to end).

The three categories in Table 2.2 above, describe the relationship between scientists and citizens at different CS project phases, understanding their capabilities, both physically and intellectually, in contributing to, and impacting on science. The descriptions of these CS categories could be a contributing factor in the lack of a precise definition for citizen science which has been earlier alluded to.

However, since the aspect of engagement is deployed more frequently in the preceding citizen-science literature, this study prefers to define CS as a process, whereby non-professional scientists voluntarily participate actively in one or more aspects of a scientific activity. This is centred on the specific scientific activity of groundwater monitoring in Cradock, South-Eastern Karoo. The definition falls into the collaborative and contributory citizen science categories, as an active part of the Karoo Shale-Gas Research Programme (AEON, 2018).

Citizen science in this study is further unpacked as an intricate process of creating a level of capacity for selected individuals from the Cradock community, to collaborate with an AEON hydrogeologist during groundwater monitoring training. Active participation is also the key to allowing the local public to be part of science – not as subjects, but as fellow researchers. For this research, active participation provides a means for the study community to gain new knowledge, to conduct the relevant scientific work, and to create local opportunities in water-related industries.

It is evident that understanding citizen science processes may vary between different contexts. This tends to have implications for the development of clear-cut citizen-science application guidelines. To accommodate the nuances of diverse CS activities, it is appropriate to explore the application frameworks for citizen science, and the approaches surrounding it, in order to achieve the main aim of developing a generic CS framework for this study.

2.4 CITIZEN SCIENCE: GUIDELINES AND APPROACHES

Earlier in this chapter, CS was described as a concept that can be adapted and applied within diverse contexts and disciplines by using the appropriate and relevant methods. The European Citizen Science Association (ECSA) in 2015 drew up the holistic citizen-science principles and approaches that can be adapted in any project context. The ECSA is an organisation composed of a network of researchers across over twenty-seven countries across the European Union and beyond, created to encourage the growth and development of CS initiatives in Europe. The sub-sections below elaborate the CS principles in detail, in order to better understand the different CS applications.

2.4.1 Citizen-Science Principles and best practices

This study seeks to embrace appropriate citizen-science principles that clarify what underlies the good practice of CS. In a layperson’s language, a principle is a rule of conduct; and CS -related research echoes the fact that community involvement in science is more than giving instruments to individuals. It allows participants to collect field data, so that they have a greater sense of participation and can contribute to scientific outcomes, and possibly policy decisions.

It is therefore imperative, as defined by the ECSA (2015), to have a principled approach, in which the critical standards and behaviours of science are supported through competent, methodological, ethical and intellectual actions in bringing non-scientists and science professionals to work together in a scientific process. In support of this realisation of citizen-science principles, benchmarks for conducting a citizen-science project have been summarised in Table 2.3 below.

Table 2.3: Summary Principles of Citizen Science (adapted from ECSA; 2015)

<u>Summary Principles of Citizen Science (adapted from ECSA; 2015)</u>
• Actively involve citizens in scientific endeavour that generates new knowledge or understanding. • Citizen science projects need to have a genuine science outcome. • Both the professional scientists and the citizen scientists must benefit from taking part in the process. • Citizen scientists may, if they wish, participate in multiple stages of the scientific process. • Citizen scientist should receive feedback from the project: how the data is being used, and what research, policy or societal outcomes are. • Consider citizen science as a research approach like any other, with limitations and biases that need to be considered and controlled for. • Publish results in an open access format, where possible – citizen science project data and meta-data are to be made publicly available. • Citizen scientists are acknowledged in project results and publications. • Citizen science programmes are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact.

The above principles list provides some clarity on how important it is for the co-ordinators of citizen science projects to consider the legal and ethical issues surrounding copyright, intellectual property, data-sharing agreements, confidentiality, attribution and the environmental impact of any activities beforehand, and throughout the project. This mainly stems from the realisation that both the professional scientist and the non-professional citizen expect to benefit from a CS project, without the latter being a subject of research, but also a fellow contributor to science, thus being acknowledged in the publication of the research results.

Adding to the listed CS principles, McKinley et al. (2015: 7 – 12) describe how there is no universal standard for CS, however investing in a CS project could produce intrinsic outcomes throughout the CS project stages which, in summary, includes:-

i. *It often operates at greater geographic scales and over longer periods of time than conventional science, and sometimes at greater resolutions.*
ii. *It can speed up and improve field detections.*
iii. *It can lead to increased data and image analysis.*
iv. *It can help refine the research questions.*
v. *It could help researchers to better identify and study connections between humans and their environments.*
vi. *It engages people in decision-making processes.*
vii. *It promotes collaboration between people and organisations, thereby creating synergies and improving the project or the programme outcomes.*
viii. *It brings new perspectives into the decision-making process.*
ix. *It fosters environmental stewardship, whereby volunteers are often prompted to care for the environment and to develop a sense of place.*
x. *It assists in providing knowledge and answers to local community questions of concern.*
xi. *It incorporates local and traditional knowledge into science and management.*
xii. *It builds an awareness of an organisation's mission.*
xiii. *It improves scientific literacy; and it builds expertise.*
xiv. *It encourages the participation of volunteers, thereby making it possible to address questions that would be unanswerable in any other way.*
xv. *It provides real-time monitoring (an early-alert system).*
xvi. *It facilitates stakeholder engagement in identifying problems and solutions; programme development, implementation and evaluation; public support for and involvement in management's decisions.*
xvii. *It provides information on species abundance, distribution, phenology, and behaviour; and it provides:*
xviii. *Resources' valuation; and the mapping of ecosystem services.*

From this background and the examples of CS application outcomes, CS is an evolving process. There is however, seemingly limited literature on the citizens participating before, during and after a CS project. This is compounded by the paucity of research articles attempting to synthesise the impacts, especially the social impacts on the communities involved.

In view of potential outcomes in CS projects, such as undertaken by McKinley et al. (2015), proponents of CS are often met with the argument that it produces poor quality data, as a result of not having an evaluative tool on the citizen-produced data (Outcome (iii). It should be deemed crucial to be able to quantify the added value of the CS process, not only for the specific scientific impact, but also in terms of the social, economic and environmental impact, and for having common indicators that can be applied across a wide spectrum of CS projects.

Of additional importance to realising the value of CS, is the establishment and maintenance of trust between the non-scientist citizens and the professional scientist researchers, which McKinley et al. (2015) mentioned. It is stipulated that CS processes should encourage the participation of volunteers (Outcome *xiv*); and these processes should facilitate stakeholder engagement (Outcome *xvi*). However, the local community's distrust towards the scientific researchers and their activities may have a negative impact on the project's success. Therefore, non-engagement or less open dialogue between the local public involved and the scientists – to build trust before the CS project commences – may have a negative impact on those researchers who are bound by a time limit to complete a project. For example, the Chicago Area Pollinator Study (CAPS), which relied on citizen scientists to gather urban bee diversity information, failed to capture the educational impact of the project on the citizen scientists (Druschke and Seltzer, 2012). This ultimately contributed to less participant-learning outcomes.

Despite a number of unsuccessful CS case studies, well-supported citizen-science projects and participants can produce more scientific data with greater gains than in conventional research. Aside from gaining capacity and skills about the local environment at all scales, local citizens can display improved confidence during scientific projects. Furthermore, new local networks can be built, thereby contributing to guided decision-making, and an understanding of the change and variability within ecosystems (Poona, 2008). Thus, scientists need to seek an understanding of the change and the variability in the ecosystems, thereby discovering the potential value of citizen science, which deserves attention and support, in order to yield substantiated results. With this mind, it is pertinent to recognize the guidelines for some global citizen science projects.

2.4.2 Citizen-Science Principles versus Citizen-Science Guidelines

The definitions of citizen science (Table 2.1) suggest, *inter alia*, varied citizen science approaches for different scientific projects. Hence, the approaches employed for CS become diverse, depending on the project context, the CS category (contributory, co-created or collaborative), and consequently the procedures in question (Bonney et al., 2009). This also contributes to how CS as a concept and methodologies, evidently evolves. In essence, good practice CS has even been described as a process of learning, by doing an activity, which is usually facilitated by advanced technology (Cohn, 2008). For instance, the use of mobile-application technology to record scientific readings, facilitates the real-time recordings of scientific observations by citizen scientists.

As mentioned in section 2.2, in some citizen-science project categories, the participants are involved in a single step of the research process; whereas in other projects, the participants are involved in multiple steps and in different ways (Danielsen et al., 2009; Dickinson et al., 2012; Miller-Rushing et al., 2012). These scenarios suggest that the design of CS approaches depends very much on the purpose of the research project. Most existing methodologies satisfy the principles for structuring CS, as noted in the European White Paper on Citizen Science (Sanz et al., 2014), despite not having a universally accepted methodological framework for citizen science.

To produce a sustainable citizen-science activity or project, therefore, one can refer to Bonney et al, (2009), who identified and proposed the appropriate methodological process steps for a citizen-science project. The steps were developed through learning from unsuccessful projects; and these include:

1) *Choose a scientific question;*
2) *Form an evaluation team;*
3) *Develop, test and refine protocols, data forms and educational support materials;*
4) *Recruit participants;*
5) *Train participants;*
6) *Accept, edit, and display the data;*
7) *Analyse and interpret the data;*
8) *Disseminate the results;*
9) *Measure the outcomes (*and lastly one can add to Bonney et al.'s steps a tenth one) ,

10) *Acknowledge the work of the non-scientists.*

The above steps are a sequence that comprises a CS methodological process and they are consistent with the findings of Shirk et al. (2012) and Tweddle et al. (2012), who contend that a CS process should include identifying the research question; establishing a research team; defining research aims and target participants; testing and modifying the protocols; data analysis and feedback reporting, as well as evaluation. Scholars such as Shah and Martinez (2016) affirm that CS application requires a strategy or plan, which needs to be adapted to the specific needs of the community in question. In this study, the successful adoption of a CS methodological process means responsiveness to the socio-cultural and economic environment of the Cradock community and the expected outputs of the study.

The emphasis needs to be made that citizen-science methodologies are evolving; but despite this, specific steps do need to be followed within a CS project (2013 Green Paper). The Green Paper (2013) already stipulated that the European government has since adopted these as the guidelines for CS professionals.

It is therefore important to highlight the detailed descriptions for each of these CS steps listed above, which shape and guide CS approaches, as recommended by Bonney et al. (2009) and Robertson (2015) – see Table 2.4 below.

Table 2.4: Typical Citizen Science project steps (Source: Bonney et al., 2009; Robertson, 2015)

Citizen Science Step	Description and Explanation of Stage
1) Choosing a scientific question;	Project co-ordinators need to consider that most participants will be first-time "amateur" observers. Therefore, significant training of the participants is advised, especially for projects demanding high skill levels.
2) Forming an evaluation team;	Develop a team comprising multiple disciplines. Researcher needs to ensure scientific integrity of the project, and to develop protocols that would contribute to the data validity. These procedures need to be done both during and after the project implementation. Project teams, which have limited access to all disciplines, partner with other organisations at local or regional level.
3) Develop, test and refine protocols, data forms and educational support materials;	Project leader(s) need(s) to provide clear data-collection protocols, simple and logical data forms; support for participants to understand how to follow the protocols and submitting their information. Protocols specify when, where, and how the data should be collected. Quality data forms which are easy to understand and to complete, are helpful to prepare the data for analysis. Such support and more will determine that the public collects and submits accurate, quality data. Caution needs to be taken of bias, for instance, incidences of over-reporting, or of under-reporting.
4) Recruiting participants;	Depending on the goal of the project, the recruiting process may range from the use of press releases, advertisements, presentations and more, including public announcements and posters in search of potential participants. It is advised to collaborate with other organisations given that the project is of a trans-disciplinary nature; or it is targeting a specific audience, such as youth groups.
5) Train participants;	Training the participants to digest project materials and to gain confidence in data-collection skills.
6) Accept, edit, and display data;	One of the educational features of CS is that all the data collected need to be accepted, edited and analysed by both professionals and the public.
7) Analyse and interpret data	Large datasets, need to develop criteria for identifying the data that may contain (systematic) errors.
8) Disseminate results	The results are published in journals, or as technical reports to disseminate to target audiences. It is important to publish the results in literature, such as the local newspapers, or magazines, to show the public how fellow citizens are contributing to science, coupled with the hope of motivating new individuals to participate in similar projects.
9) Measure outcomes	This step is vital to ensure that both the scientific and educational objectives have been met.

Given the CS steps and descriptions in Table 2.4 above, one could indicate that they enabled this researcher to develop a methodological framework, in order to achieve the aim of this study.

2.5 CITIZEN SCIENCE IN HYDROLOGY

The provision of water resources is one of the most fundamental ecosystem services for humanity, whether it is ground water or surface water. In the United States of America, community-based water monitoring projects have been recorded ever since the early 1900s (see Table 2.2), as a common practice (Overdevest et al., 2004; Conrad and Hilchey, 2011). It is important to note how hydrological science underpins most decision-making on water resources; and how it serves as a basis for assessing risks related to water, such as floods, droughts and pollution.

Buytaert et al. (2014) also noted how there has been a heterogeneity and difficulty with regard to the engagement of the local public in actual water management and governing processes. In view of this complexity, the role of citizen science, particularly in groundwater resource monitoring is fitting for exploration in the South-Eastern Karoo, where SGD could take place and as a contribution to the AEON Baseline Study. The section below aims to provide a review of the available literature on citizen science in the context of hydrology, groundwater monitoring, and to review the existing examples that are contextually relevant to this study.

2.5.1 Citizen-Science Application in Groundwater Monitoring

The contribution of water resources to human development and the threats emerging from environmental change, groundwater contamination and other stressors reveal the dire need for novel approaches to generate new knowledge about the hydrological cycle, as well as how this knowledge could be used in groundwater resource management (Milly et al., 2008; Hipsey and Arheimer, 2014; IPCC, 2014). In the context of citizen science, the development of more robust, cheaper and lower maintenance equipment creates new opportunities for accurate data collection (Buytaert et al., 2014). In addition, these authors are of the view that in monitoring aspects of the hydrological cycle, there is a need for the use of advanced technology; and that hydrology has not been an evident scientific discipline for the application of citizen science.

Challenged by this notion, the water science research community has managed to advance ample evidence of the utility of CS in various forms. Literature on CS application in hydrology, reveals that the knowledge gained contributes to decision-making processes, improves understanding, and the management of catchment areas (MacKay et al., 2015). In support of this view, Buytaert et al., (2014), points out the strong dependence of CS application in hydrology on the existence of trust and a legitimate foundation among the involved parties. The engagement of local citizens in water-management projects tends to contribute vitally to hydrological resilience at the community level.

Notable examples of CS in water-management projects includes the Waterton Lakes National Park in Canada, as well as smallholder farmers' engagement in monitoring the water levels of the Sondu river catchment in Kenya (Sutherland et al., 2015). One of the growing recorded characteristics within these CS projects is the enthusiasm of volunteer participants. Clearly, from the available data sources in comparison to the data in Table 2.5 below, one can approximate the existence of a possible gap in terms of documenting CS applications in groundwater monitoring. The gap is also largely acknowledged in the South African context, which forms part of this study's motivation.

A summary review of citizen science projects in hydrology, Table 2.5, specifically water-quality monitoring, as adapted from Buytaert et al. (2014), is based mostly on United States' experiences (Volunteer Water Quality Monitoring, 2014). According to the European and American case studies, the level of community engagement is seemingly limited to data collection only, whilst the professional scientists mostly design CS projects, analyse and disseminate the data collected.

In the South African context, water quality projects where CS has been adopted, allow the involvement of citizens who are interested in water management activities and improving their understanding of related issues and problems leading to a form of empowerment to respond to such challenges. Reference is made to the WRC-funded CS project coordinated by a KwaZulu Natal (KZN) province-based organization called GroundTruth and the Wildlife and Environment Society of South Africa (WESSA). The project involves the development of citizen science tools such as miniSASS (South African Scoring System) and the Spring tool.

The miniSASS tool was designed for use by aquatic scientists and environmental practitioners to assess river health and identifying over 10 groups of macroinvertebrates (such as worms, crabs, snails and beetles) (Vallabh, et al., 2016). The tool has evolved with its main emphasis centered on civic action and social learning for schools and social groups among others. The spring tool on the other hand, is one that concentrates on background information on springs, which are not only important for rural water supply in many areas, but can have cultural, religious or tourism significance. A health index on the tool leads the citizen scientists through steps of determining the location and type of spring and investigating the surrounding land use and geomorphology of the area. The citizen scientists would then rate the intensity of 10 different kinds of impact on the spring, including livestock grazing, pollution, vegetation removal, soil erosion and groundwater withdrawal. A datasheet is finally completed that allows the citizen scientists to calculate the Ecological Condition of the spring as the percentage of change that has occurred compared to its natural (original) condition. An example of the application of the spring tool is the project for the Women's Leadership and Training Programme (WLTP), facilitated by GroundTruth in 2017 within two communities of KwaZulu Natal province of South Africa. The Spring tool assisted in determining the ecological condition of the 8 springs in the areas and revealed that the water clarity of the springs was greater than that of the local rivers. According to Graham and Taylor (2018), when the spring water emerges from the ground it normally reflects a limited exposure to soil erosion, pollution or trampling. The application of the Spring Tool seemingly has potential to be extremely useful in rural communities where springs are vital water sources.

In other developing countries, for example, Ethiopia, India, South Africa, the role of the public in groundwater management projects is also recognised; and it is considered to be easier in problem identification and the assembling of working teams, more than in the co-creation and implementation of the knowledge relating to water-management processes. In western India, capacity building of communities in scientific mapping, monitoring, and management of aquifers was evident through the Managed Aquifer Recharge through Village Intervention (MARVI) project, resulting in an improved self-sustenance of the villagers (Jadeja et. al. 2015). Consequently, there is a need to explore the potential of CS in project stages from problem identification, data collection, and analysis to reporting, among other process steps, and providing room for trans-disciplinary practice.

Table 2.5: Examples of Citizen-Science Applications in Hydrological Science (modified from Buytaert et al., 2014)

Study	Study site	Programme objectives	Data collected	Level of engagement by citizen scientists	Role of professional scientists
MacKnickle and Enders, 2012	Mountain region in the Nicaraguan-Honduran border	A prototyping approach for conflict management	Water quality parameters	Collaborative or participatory science	Problem definition; training; data analysis and interpretation
World Water Monitoring Challenge, 2014	Global	Water Quality monitoring, education and outreach	Water quality parameters	Distributed intelligence	Design of monitoring programme; training; data dissemination
CoCoRaHS - Community Collaborative Rain, Snow and Hail Network, 2014	United States of America	Precipitation measurement	Rain, Snow, Hail	Distributed intelligence	Design of monitoring programme, training, data dissemination
Water Action volunteers (Overdevest et al., 2004)	9 catchments in Wisconsin, USA	Water quality monitoring	Water quality and flow, biological health	Distributed intelligence	Design of monitoring programme, training, data analysis
Citizens water quality testing programme (New York City Water Trail Association, 2014)	New York – New Jersey Harbour and Estuary	Water quality monitoring	Pathogens (coliforms)	Distributed intelligence	Design of monitoring programme, training, data analysis, and dissemination
Waterwatch (Nicholson et al., 2002)	10 catchments in Victoria, Australia	Water Quality monitoring	Turbidity, electrical conductivity, pH and total phosphorus	Distributed intelligence	Design of monitoring programme, data collection, data analysis
Water Reporter (2014)	Chesapeake Bay, Maryland and Virginia, USA	Pollution monitoring	Observation of pollution occurrence	Crowdsourcing and Distributed intelligence	Design of data exchange mechanism

The preceding review (Table 2.5) clearly reveals that many of the hydrogeology related CS collaborations have taken place in the European regions. Citizen science-based strategies linked to groundwater monitoring in Africa, particularly South Africa, have not been adequately documented in the scientific literature. In East Africa for instance, there is a pilot study in Kenya, where smallholder farmers are helping to monitor water levels in the Sondu river catchment as an initiative to develop a monitoring system that can improve flood and drought warnings (Sutherland et al., 2015 and Del Bello, L, 2016). It is vital to examine how CS projects have been implemented in the South African context, in order to bridge the existing knowledge gaps. The benefits of this CS research in the Karroo can be found in it being a pilot study, setting building blocks for the future long-term wider implementation and informing future grassroots-based citizen-science interventions in groundwater monitoring in this same region of Africa as a whole.

Buytaert et al. (2014) claim that citizen science in water-resource management has been in an infancy stage, particularly in terms of the formulation of a stand-alone application framework. Water resources, providing fundamental ecosystem services, are significant for sustainable development and poverty alleviation. However, during the implementation of some projects, such as those listed in Table 2.5, research has brought to light associated challenges and opportunities posed by CS application in the hydrological field (see Table 2.6 below).

Table 2.6: Commonly measured hydrological variables, challenges and opportunities emerging from Citizen-Science applications (modified from Buytaert et al., 2014)

Variable	Opportunities	Challenges
Water quality	Cheap analytical toolkits; automatic measurement of proxies; macro/invertebrate observation and identification	Parameters (such as temperature (ºC), Ph (measure of a solutions acidity); Electrical Conductivity, Heavy metals, Nutrients, Dissolved oxygen) being costly and difficult to analyse; need for adequate documentation of observation context; sampling strategy
Vegetation dynamics	Very accessible technology (e.g. GPS, photography); remote identification	Systemization; data processing; remotely sensed data
Water use	Availability of electronic sensors; convenient data communication via internet in built environments.	Interpretation and extrapolation of generated data; potential human interference
Streamflow	Cheap yet robust water level measurements; collection of calibration data; emerging image analysis techniques for stage and flow measurements	Proper installation and maintenance; quality control; technical support

Table 2.6 above reflects how citizens' engagement in water science has been dominated particularly by **Opportunities** in the data-collection phases in comparison to the data-analysis process (see under **Challenges** column). This could be attributed *inter alia* to the non-availability of efficient, low-cost equipment used during the data-collection phases. Challenges arise during data analysis and the reporting phases, whereby expensive and highly automated equipment is used to create rich and interactive hydrological data-based models by the professional scientists (Buytaert et al., 2014).

To leverage citizen science for water-resource management, major challenges have been identified through the literature research. One scientific concern, for instance, is the validity of data produced through citizen-science; and how this affects the reputation of professional researchers thereby potentially discouraging any possible innovation (Buytaert et al., 2014). To minimise project failure to deliver, it is therefore important to set realistic goals that the implementers are able to accept as reliable (Riesch and Potter, 2014).

Within this scope, therefore, a need arises for an adaptation of the existing frameworks, and to develop new ones to move from a singular technocratic expert view on decision-making support towards a more collaborative CS framework. The framework should allow knowledge and skills-creation exchange. Drawing from this understating, the researcher in this study, set as one of the objectives – the need to explore on the application of citizen science in groundwater monitoring (see Chapter 3).

Buytaert et al. (2014), further added a challenging factor of transparency, which normally rises during the problem identification phase in a water resource-related citizen-science project. Scholars in the water resource management field, therefore, recommend for these projects to define resource management concerns or problems before commencement, in a transparent and deliberative process with the communities concerned. This will promote the inclusion of traditionally marginalised, and resource-poor project actors. Maintaining transparency from beginning to end of this research is a matter of major importance; and this will be explained further in Chapter 3 as part of the methodological approach.

Contextually expressed, the expected outcome of this research will be to contribute towards improving the Karoo Shale-Gas Baseline knowledge as well as improving the current state of local capacities in Cradock and designing a capacity-building framework that could nurture local communities in the science of groundwater monitoring. This framework will be proposed as a channel to contribute to the AEON Karoo Shale-Gas Baseline study. Included in the impact of this study would be the capacity-building policies, national and institutional frameworks and value systems, which will be adopted for this goal to be achieved.

Approaches to achieve the main study aim, involved intensive collaborative meetings between the researcher and selected interested stakeholders from Cradock. A systematic citizen-science framework was designed, which can be adopted in a project focussing on citizen participation in scientific research of this nature (groundwater monitoring).

2.6 SUMMARY

The conceptualisation of citizen science in hydrology (mainly groundwater monitoring) in this chapter, offers useful insights to the collaboration and contribution of this concept between scientific and the non-scientific communities. The concept not only considers and captures knowledge of the non-scientist; but it is also necessary in the sustainable development discourse. The discussion here is also clear testimony that researchers are increasingly recognising the need of citizen science to contribute in general and specifically to the water science and water-management field in South Africa.

The following chapter focuses on the methodology applied during the water-science process that endeavours to answer the key research objectives of this study.

CHAPTER 3: THE CITIZEN SCIENCE RESEARCH APPROACH

3.1 INTRODUCTION

This chapter reviews the categories of citizen science adopted for this study (contributory and collaborative). In addition, the chapter also expands on the principles and the aspects of citizen science in the formulation of place-specific methodologies for application to the case study of Cradock, and for the engagement of its local citizens in the science of groundwater monitoring. This study adopts a qualitative research design (c.f. Denzin and Lincoln, 2000), the details of which are provided in the sections below, including a description of the data-generating techniques, sampling procedures and a summary of the plan of action.

3.2 THE RESEARCH DESIGN

A multi-disciplinary approach was used, which required diverse expertise and information sources. A multi-disciplinary approach is a technique that combines tools from multiple disciplines (social, economic and biophysical sciences) to conduct research. Being applicable to current issues, this approach has been described to be action oriented (Molteberg and Bergstrom, 2000); and consequently, guided the aim of this study, including the CS process. An Action-Research (AR) approach was therefore adopted in leading the citizen-science process and the formulation of the methods for data collection. AR is a form of social inquiry, which aims to improve a practice and generate knowledge (Koshy et al., 2011). AR is therefore appropriate; because it is not aimed at merely acquiring knowledge, or new data; but it also involves the research participants directly in the process of the data collection analysis and reporting.

This research is a qualitative study utilizing AR methods to develop a case study on the South-eastern Karoo community of Cradock in collaborative CS activities. Creswell (2007) states "case study research is a qualitative approach in which the investigator explores a bounded system (a case) over time, through detailed data collection involving multiple sources". In this case study, I sought a holistic understanding of concerns of Cradock community regarding the potential SGD in the area and how CS could be used to address one of the concerns. As Yin (2003) denotes, case study design allows for an intensive examination of contextual conditions because the context is highly pertinent to the phenomenon of the study. This study was of one case or community and did not use a comparison group and it was of limited scope given that it was a pilot in the AEON Baseline Study.

Greenwood and Levin (2007) suggest that AR also aims to build collaborative partnerships between the researcher and a group or community involved in the research process. In this study, the research process proceeded as a cycle, involving joint planning, action, observation, reflection and evaluation. The reflection phase is followed by further cycles including planning, acting, observing, reflecting and evaluation in an action-research cycle of learning (Figure 3.1 modified, after Kemmis and McTaggart, 1988).

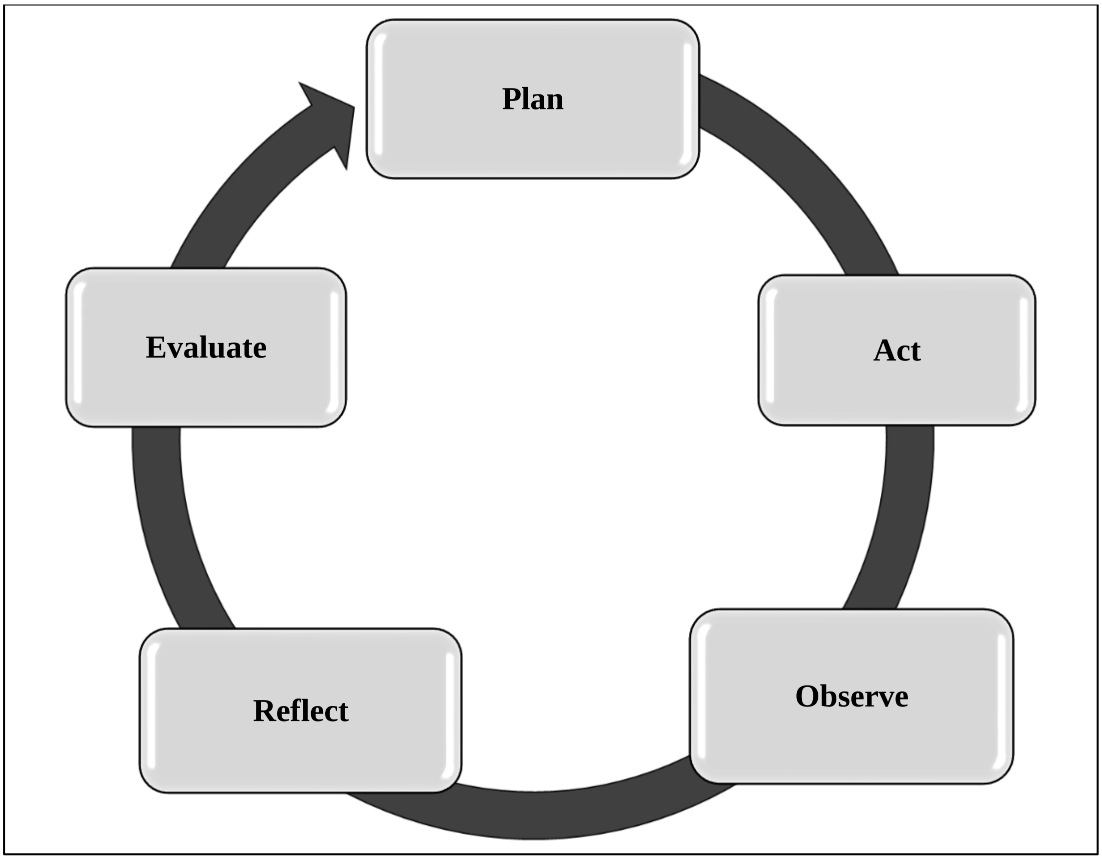


Figure 3.1: Action Research (AR) Process – Cycle of learning

This study recognises how qualitative research can be formulated as a scientific enquiry (Maxwell, 2004a; Locke, 1989), which in this context appreciates the complexity of citizen-science categories (Section 2.3). AR was thus instrumental in aligning to the purpose of this study.

The AR cycle of learning combined CS theory and practice by working *with* people, rather than *on* people, in a 'collaborative and systematic process' (Lewin, 1946:34-36). This practice cultivated community participation, which facilitated the empowerment and transformation of the Cradock community through primary and secondary data-collection methods, such as Key-Informant Interviews, Focus-Group Discussions (FGD), and non-Participant Observations (see Appendix A).

The primary data-collection methods tested the secondary data that were sourced from published resources, such as the *Step-by-Step guide on Implementing a Rural Groundwater Management System for South Africa* (DWAF, 2004), the *Shale Gas Strategic Environmental Assessment (SEA) Process Document* (Scholes and Lochner, 2015*)* and the literature, including journal articles on the background of Cradock community, the Citizen-Science concept and its application in groundwater monitoring. Action Research can thus be viewed as an approach that facilitates the researcher to address issues by producing guidelines for best practice (Denscombe, 2010).

The choice for this qualitative research approach (AR) was informed by how representative the generated data would be – for both the study community and the AEON Baseline study. In effect, the AR approach was designed to give the participants room to openly and freely express themselves at every research phase: for instance, through FGDs and reflective journaling. In addition, behavioural indicators of change in the knowledge development, experiential learning, where possible, change could be observed and documented as evidence. These were also identified and documented.

3.3 THE DATA-GENERATION PROCESS

To capacitate the Cradock community with skills and knowledge about groundwater monitoring (hydro-census and groundwater sampling), the researcher adopted a collaborative citizen-science category. In this category, the researcher designs the CS process; and the participants are involved in more than one stage of the process, thereby contributing to the way in which issues or concerns are defined and addressed, or research results are communicated. To commence this process, the researcher conducted a desktop study based on published reports (including Municipal records, such as the Integrated Development Plan reports) and online data to establish the issues of concern arising from within the study community of Cradock.

As described in Chapter 1, this study follows the prospective announcement to have shale gas exploration in the Eastern Karoo region of South Africa. The desktop study was undertaken in parallel with the first Roundtable Cradock stakeholder meeting, coupled with key informant interviews (unstructured), Focus-Group Discussions, participant scoring and the ranking of priorities, in addition to key probes using reflective logging and participatory observations. The use of Participatory Rural Appraisal (PRA) methods during stakeholder community meetings and CS training, encouraged community participation at all levels; and it assisted the data mining required to carry out a focussed action-research processes.

The AR Approach for this study was divided into four phases, which are summarised in Table 3.1 below.

Table 3.1: Summary of the Data-collection phases (Source: Researcher, Nyaradzo Dhliwayo (ND), August 2017)

PHASE	Activity	Actor (s)	Period/Time frame
1)	-Problem identification process through Prioritisation of issues of community's concerns; -establishment of community boundaries -Cradock community mobilization and - Collaborative planning or research process -Formulation of a community-representative team ('working group'), - Cohort selection for citizen science training in groundwater monitoring and - Designing of a groundwater monitoring training guide	- Cradock Community – Cradock stakeholders (representatives from the Cradock Youths, women co-operatives, business fraternities, farmers' associations) - Researcher (ND) and AEON	2015 - 2017
2)	- Recruitment of CS cohort from Cradock; - Selection and Mapping of groundwater monitoring sites and - Resource procurement for groundwater monitoring training	- Cradock community including its stakeholders - AEON hydrogeologists - Researcher (ND)	January 2017 – July 2017
3)	- CS cohort Training (theory and practical) - Focus-group meetings with the cohort trainees, - Reflective meetings with the working group in conjunction with the groundwater monitoring experts; - Reflective journaling sessions with the trainees - Pre and Post-groundwater monitoring training	- Researcher (ND) - AEON-NMU Hydrogeologist (trainer) - CS trainees	August 2017 – November 2017
4)	- Reflection and Evaluation	- Researcher (ND) in collaboration with CS cohort, Cradock working group and a team of AEON scientists	2018

The following sections describe in detail the above tabulated four phases (AR cycles) of this study and the methodologies adopted in each of them.

3.3.1 Phase 1: Sampling Procedure and Researcher – Community Collaborative Engagement

3.3.1.1 Study Population and Sampling Procedures

The implementation of the collaborative AR approach in this study can be clarified by specifying the sampling methods, the design of the interview schedules, a design of training schedules and the procedures used to identify the study participants. As a result of Cradock being the pilot study area for the AEON Karoo Shale Gas Baseline Study (KSGBS), this town became the study focus of this research and respondents came from the two main residential areas, namely Lingelihle and Michausdal (see Figure 1.3b). Cradock residents who responded to the researchers call to participate in the study, included small businessmen, local farmers (emerging and commercial), the local youth and local government officials. These participants were identified by using the snowballing technique, which is defined in the next section.

3.3.1.2 Sampling procedure: Stakeholder identification

The first step in the fieldwork of the study, was to approach the AEON Baseline Study co-ordinators parallel to the collaborative meetings with the Inxuba yeThemba Municipality (IYM) officials where Cradock is situated. Through these meetings, the researcher was guided on to design the sampling procedure, in order to select a representative sample of the study participants. As Creswell (2013) generally denotes, the sampling of participants requires access to the individuals for determining the number of participants needed for a study. The techniques used to identify the participants for this research were a combination of purposive sampling and snowball sampling.

Purposive sampling involves the inquirer or researcher selecting a study population, or location to inform a specific research aim. In snowballing, once a participant has been identified, s/he would identify other potential participants (in this study referred to as stakeholders) in the community in the practice of chain referrals (for example, Noy, 2008). The identified participant would also lead the researcher to other knowledgeable key potential active stakeholders or participants in the community.

The actual number of participants accrued by using this technique is not definite; as it is defined to involve respondents chosen until a level of saturation, when no new issues emerged. Through the support of the IYM officials, a list of IYM stakeholders adapted from the generic Local Economic Development (LED) forum invitee list (Appendix B) was provided. It should be noted that the municipality consists of two towns Cradock and Middleburg, and since the study was only focussing on Cradock town the researcher concentrated on inviting stakeholders from this area. Each of these stakeholders was individually invited to the first community roundtable meeting (CRM1), as part of the first phase of the study.

The stakeholders (resident and active in Cradock) who were able to respond to the researcher came mainly from the local IYM, the local farmers (commercial and emerging), Water Users Association (WUA), businesses, women's cooperatives and the unemployed young men and women population. The researcher was able to work with these respondents with the intention of facilitating future community roundtable meetings, FGDs, key informant interviews, which eventually became a platform for the selection of the citizen-science trainees (see Section 3.3.2.2).

Subsequent consultations with Cradock residents through the first and second roundtable meetings (Figure 3.3), were catalysts to the identification of more stakeholders within the community; who were then invited to participate in the third CRM. Eight of these stakeholders were later elected by the community members attending CRM3, constituting the community representative committee, referred to in this study as the 'community working group' (CWG).

During the third roundtable meeting held at the Vusubuntu Cultural Village in Cradock, the IYM Municipal manager facilitated the selection process of the working group. This process was a response to the community's need to have a representative committee, which would be a liaison team between the researcher and the general community for the duration of this research (see Chapter 4 – Figure 4.4).

The selection of a working group was a natural, transparent process that took place during CRM3. The participants attending CRM3 collectively suggested and reached a consensus of forming a representative group that who would be a liaising between the researcher and the community during the CS study. Stake (2005:457) states that if most important criterium is "opportunity to learn" then variety may be more important than representativeness in the selection of cases. The election of the CWG was an opportunity hear the voice from the Cradock community, in terms of how to take the next step in the collaborative CS process. The

CWG was not primarily representative of a particular group in Cradock but it was a case of community interest to establish this group in order to facilitate future CS process steps.

The CWG consisted of eight (8) members - one male emerging farmer's representative; one businessman; 2 women representatives (one owned a catering business and one was a commercial farmer); 1 male youth representative (member of the ANC Youth league); 1 local South African National Congress Organisation (SANCO) representative and 2 IYM officials.

This group was collaboratively selected by the stakeholder participants present during the third CRM3 to serve as the advisory group to the researcher, and as a bridge between the researcher and the community at any phase of the study. For example, in the second phase of the study, where the cohort-selection process for groundwater monitoring training had to be developed. The selection of the cohort was done through collaboration between the working group, the researcher and the AEON groundwater specialist scientists, who were going to conduct the groundwater monitoring training. The three parties agreed on a procedure to be followed, to give an equal opportunity for the Cradock community to go through an application and shortlisting process, to be considered for admission into CS training.

3.3.1.3 Procedure for selecting the key informants

The Key informants were drawn from the community stakeholders and representatives, who participated in the CRMs. The local IYM development officers, the Department of Water Affairs officials, academia (KSGD project co-ordinators from Nelson Mandela University) and emerging farmers (defined in Chapter 1, Section 1.5), formed part of the key informants. Some of the key informant interviewees were also members of the CWG. The researcher identified the CWG members as key informants, because of them being representatives of the community stakeholders, together with the deep knowledge they had concerning their respective affiliations (see Chapter 5, (Table 5.2).

After the initial meeting (CRM1) with IYM officials, telephonically the researcher contacted these respective stakeholders to set up appointments for the interviews.

This research process took place during the first phase of the study, in the last quarter of 2015. However, due to the fact that key informants were pursuing their day-to-day activities within their community affiliations, such as Farmers' Association meetings, and year-end farming activities, including crop harvesting, their availability for interviews, including roundtable meetings was restricted. Thus, the timing to meet with the stakeholders could only take place with the help of the local municipality officials (IYM). When the stakeholders could only be available at certain times, due to work, or other commitments, the researcher needed to be conscious of the timing or season (in terms of dates, weeks or months), until the participants became accommodating or available.

The use of official ethical clearance letters from the Nelson Mandela University, supported by the researchers' supervisor became necessary, as proof that the research was approved by the learning institution (see Appendix A).

For the researcher, it was important to be aware of matters limited by power play – and awareness of working with university researchers, and that may have been overwhelming for the Cradock stakeholders. Additionally, being aware of the possible SGD within Cradock created, an overwhelming sense of uncertainty in relation to its impacts on the community's biophysical and socio-economic environment. The researcher was mindful of these factors throughout the research period and kept constant communication with the working group and the IYM concurrently. To address such challenges, the researcher stated at the onset of the study, her willingness to learn and be informed by the study community of their experiences and concerns related to the potential shale-gas development plans, including the CS process. In this way, the research encouraged the participants to openly and freely express themselves during the research process, whenever they felt it necessary to do so. These expressions were observed by the researcher during the CRMs (see Table 4.1 (a and b); and Table 5.1).

3.3.1.4 Unstructured interviews for Data Acquisition

During the first phase of the study (2015 – 2016), the researcher utilised the qualitative method of the unstructured exploratory interviews with selected stakeholders from Cradock and the AEON's project co-ordinators of the Shale Gas Baseline Study. The subsequent stages of the elicitation interviewing techniques were intended to adequately capture the study's community knowledge and concerns about the proposed (SGD) in the study area. Each interview took between 15 minutes to 20 minutes long. The project co-ordinators of the KSGBS from AEON were interviewed, in order to understand the nature of the Baseline Study and the shale-gas exploration process, its potential impacts, both negative and positive on groundwater resources. In addition, unstructured interviews were conducted with the officials from the Inxuba yeThemba Municipality and the Department of Water Affairs (Cradock office), as well as the selected citizen-science cohort (at the end of the training).

The questions asked during the interview processes were open-ended, allowing the researcher and interviewees to discuss the questions and relevant topics in detail (Appendix A). Where necessary, probing questions were explored– in a bid to seek clarity and to elicit more information about the background of the proposed SGD and the community's response. Key informant interviews with the community leaders were interactive; and they proved to be essential in generating data, as the researcher gained rapport and trust with the respondents. The process of developing rapport between the IYM officials and the community at large with the researcher took place parallel to the first, second and third phases of the data-collection process (Table 3.1).

The researcher was able to observe the respondents' non-verbal gestures during the interviews, which proved helpful and important in assessing the validity of the response and the intensity of the perspectives on controversial issues, such as their inclusion in ongoing SGD discussions in the community, the pros and cons of SGD, the roles of women and youth in view of potential SGD, and the possibilities of employment opportunities in view of both SGD and CS training. In situations where the respondents did not understand the questions, follow-up questions were explored.

The challenge of using unstructured key informant interviews was that the stakeholders in the study area were initially reluctant to make themselves available themselves to the researcher and AEON researchers, who at first were treated with suspicion as outsiders. The suspicion was amplified by the fact that international exploration companies, such as Bundu Gas and Oil Exploration (Pty) Ltd.; Falcon Oil and Gas Ltd and the Shell Exploration Company, had obtained exploration permits from the Department of Mineral Resources and the associated news about the prospects of job creation and other SGD-related benefits. The researcher was occasionally suspected by the study community to be linked to these companies and advocating for SGD. As earlier mentioned in Section 3.3.1.3, trust-building with the local community was essential.

3.3.1.5 Community Roundtable Meetings (CRMs)

The exploratory community roundtable meetings (CRMs) were used to establish and document the local community's knowledge and understanding of the proposed SGD in Cradock, including their concerns at the time of this study. The CRMs contributed to the consensus and trust-building between the researcher and the community (Community Places, 2014); and they encouraged multi-stakeholder involvement (from government, private agents, community leaders) during the research process. In the same vein, the roundtable meetings brought people (men, women, youth, all ages) together as a community, despite their differences, to collaboratively define or identify community concerns relating to potential SGD in an open discussion.

Figure 3.2: First Community Roundtable Meeting (CRM1) with Cradock community stakeholders with the Director: AEON introducing the Karoo Shale Gas Baseline Study and Citizen Science research (25 October 2017)

Figure 3.2 above is a picture showing the Director of AEON introducing the Karoo Shale Gas Baseline Study to the Cradock residents and the representative stakeholders at the first CRM.

The study used three of these roundtable meetings, in order to give the community members equal opportunities to participate and be involved in the baseline study process including the

CS study. The researcher assumed the role of a student by positioning towards learning from the informants to avoid the impression that the researcher knows everything about the topic. This step served the purpose of building trust with the community leaders, who then approved the research to be conducted in the area. Additionally, it acquainted the researcher with the community's existing way of life and the political and social structures that formed a basis to frame the research process, consequently leading to the identification of the main concerns, in view of the proposed SGP. The researcher introduced the CS research focus during at this stage in this CRM – in addressing the main concern of community's' lack of capacity in groundwater monitoring (CS training). The sampling of the citizen science trainees followed however at a later stage in Phase three.

CRMs are an effective data-collecting method that embraces both the bottom-up and the top-down approaches in data acquisition; and this allows one to identify the respective participants during discussions and to observe them interacting with each other (Community Places, 2014; Arwal, et al., 2017). During CRMs, the researcher observed, and audio-recorded as well as video-recorded, the participants' responses and comments. The recordings were transcribed and coded into specific themes that are subsequently analysed and discussed in the Chapters 4 and 5 of this research.

For instance, the initial meeting (CRM1), used in-depth conversations with key informant community stakeholders and experts, helping the researcher to introduce the key issues of concern surrounding the potential shale-gas development in the area. Therefore, a good knowledge about the study area's socio-economic wellbeing, natural environment and cultured diversity was recorded, captured and established.

Three (3) five-hour (5 hour) roundtable meetings were conducted within the first data collection phase, assisting the study community and the selected citizen-science trainees to share their thoughts and concerns about the prospective SGD programme. These concerns were mainly linked to the likely impacts of shale-gas exploitation on Cradock's social wellbeing. The information shared guided the researcher in building on the objectives for this study.

Subsequent community roundtable meetings proceeded from the established acquaintance with the community's culture. This contextual understanding enabled the development of probing questions to understand how the community view their natural environment in the light of the proposed potential shale-gas exploration. The engagement of additional key community stakeholders in these roundtable meetings enabled the elicitation of collaboratively constructed views about how shale-gas development has been understood. Reference was made to the possible, albeit unknown, effects of SGD on one of Cradock's resources – water (a scarce resource in the study area), that raised the most considerable concerns from the CRM participants. Participants at these meetings were divided into smaller groups of 12 - 20 people and were guided throughout the FGDs by the researcher; so that the information they provided remained within the scope of the topics under investigation. An element of flexibility was permitted by the researcher, bearing in mind the collaborative nature of the Action-Research process, thereby allowing the study participants to contribute to the process (Figure 3.3).

	
CRM 2: Participation of Cradock Stakeholder participants (Women) at the Vusubuntu Cultural Village, Cradock	CRM 2: Participation of Cradock Stakeholder participants (Men) at the Vusubuntu Cultural Village, Cradock

Figure 3.3: Stakeholder group participation (men and women) during CRM2 (*discussing concerns related to potential SGD in Cradock*)

A list of matters arising for further discussion in the roundtable meetings, were extracted from the key informant-interview sessions; and these included:

1. *The community's existing knowledge and understanding of the citizen science concept (public participation in scientific research);*
2. *Knowledge and understanding of the proposed shale-gas exploration project in the study area and its potential effects;*
3. *The main sources of information and channels of communication in the community;*
4. *Concerns arising at individual, organisational or community level in view of the proposed shale-gas exploration;*

5. *Strategies to curb or meet their listed concerns;*
6. *Views about their current knowledge surrounding the exploration of shale gas in the community;*
7. *Criteria and the procedure for CS cohort selection.*

Appendix 2 provides the precise questions used by the researcher during the roundtable meetings, in exploring the community's concerns at the time of the study (as given in Chapter 4, Table 4.1(b)).

Below is Figure 3.4, outlining the guiding steps taken by the researcher during each of the roundtable meetings, from which the matters were generated and addressed.

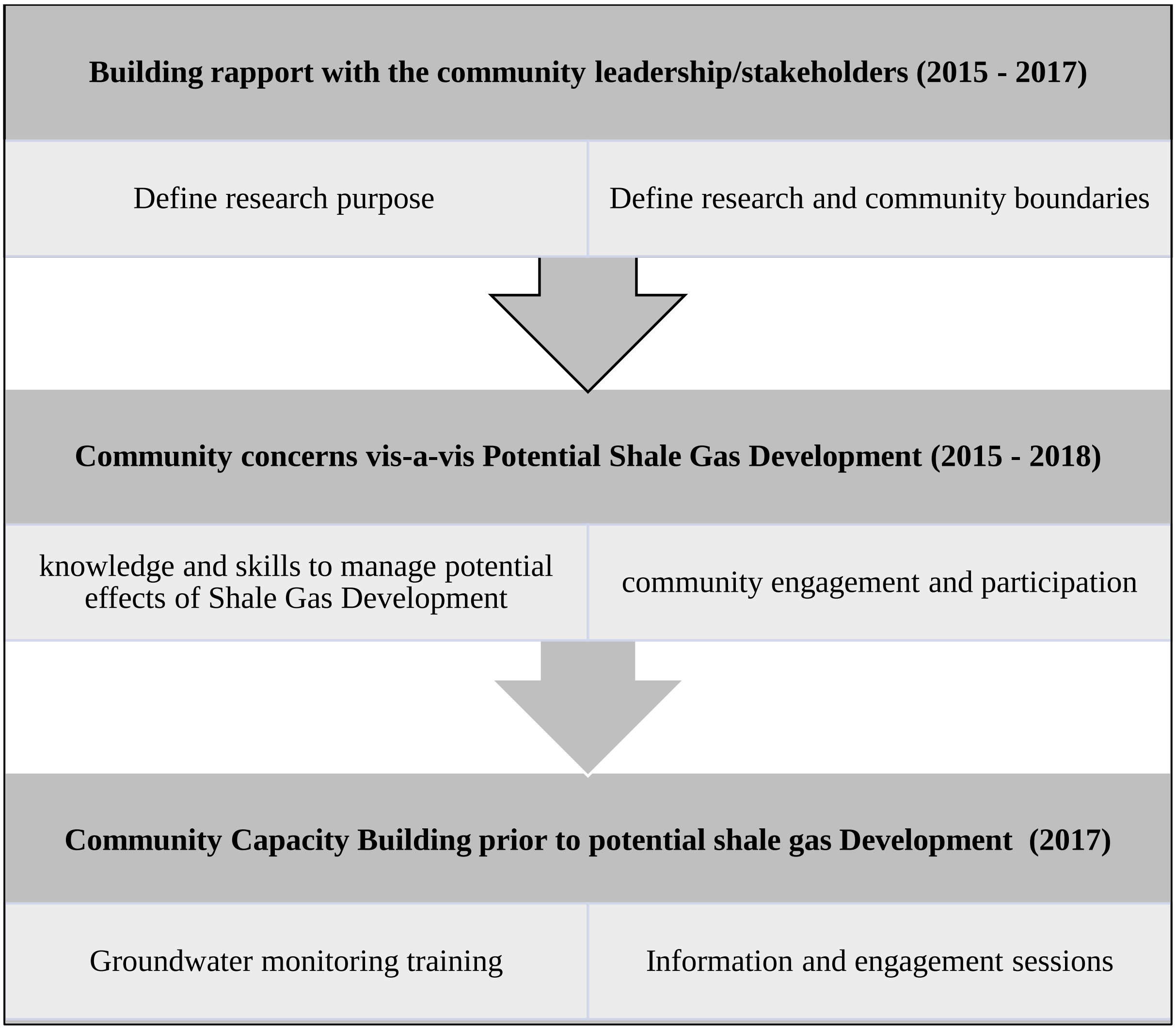


Figure 3.4: Guiding Steps developed by the researcher during each Community Roundtable meeting (5 hours per session for three Community Roundtable Meetings between 2015 - 2018)

Participants in the roundtable meetings were given opportunities to express their understanding of the concept of citizen science as well; the current state of their environment and the socio-economic history, in addition to how the news of the potential shale-gas development has been shaping the spheres of their lives. At this stage, it was necessary to emphasise that the description of their experiences and concerns should be traced back to a period in 2011 when they first learned about the prospects of potential Shale-Gas Development in the Karoo.

3.3.1.6 Focus Group Discussions (FGDs)

Focus Group Discussions were conducted with the stakeholders attending the CRMs including the CWG and the selected CS trainees. The FGDs with the stakeholders attending the CRMs were held with groups of 12 – 20 participants at a time for the purpose of getting in depth understanding on their perceptions about the proposed SGD and concerns towards its potential impacts. The method engaged Cradock residents attending (who included farmers (emerging and private farmers, youth, women in business and ordinary citizens) and the main resources they have which they considered to be potentially threatened if SGD is to take place. FGDs with the CWG and the CS cohort were held parallel to each other upon set dates and times as the data collection process continued. The following tools were used during the FGDs:

- **Ranking and Scoring**

Ranking and scoring are recorded to be useful Participatory Rural Appraisal (PRA) activities which enhance learning from local people about their criteria, choices and priorities that help in effecting change. This PRA tool provided information on Cradock residents' resources of importance and justification for the choices. The CRM participants shared with the researcher resources that exist in their area and are of concern for possible pollution or impact from SGD. Listing of these resources during the FGDs and ranking them in order of group preferences was part of the PRA exercise that led to the prioritisation of one resource focus for the CS training (see Section 5.2.2.2: Insert 1)

3.3.2 Phase 2: Preparation for Groundwater Monitoring Training

3.3.2.1 Groundwater monitoring training site selection

The selection of the training sites was mainly based on their location within or closeness to Cradock town where trainees could access. Eight borehole sites were selected for training on how to conduct groundwater monitoring (see location map in Figure 1.3b). Coupled with this decision, was the active involvement of the CWG, insisting on selecting boreholes located within the commonage farms (IYM owned and leased to emerging farmers). Not having been monitored for over eight years (at the time of this study), boreholes from the commonage farms were selected in an attempt to explore their groundwater quality status. During interviews, the emerging farmers who use the farm, expressed concern on the borehole water quality based on their different uses for both domestic and livestock use.

Following further collaborative engagements with the CWG and the AEON-based hydrogeologist (CS trainer), it was established that the commonage farm borehole sites were convenient and accessible to the trainees, being within a 5-kilometre distance from their agreed central meeting point, the Vusubuntu Cultural Village. The Cradock commonage farm boreholes were unique training sites, given the effect that the training is anticipated to have on building groundwater monitoring capacity and the knowledge development among the trainees, farmers, and ultimately, the municipality.

Access to the commonage farms was mainly facilitated by the IYM Agricultural Officer, and a male intern attached at the IYM at the time of the study, who conducted field duties in these commonages. To facilitate easy access to the farms and boreholes, the assistance of the intern, who had an informed relationship with the emerging farmers, was helpful because some of the farmers may have been uncomfortable to allow access to their farms, including background information of the farmland to the unfamiliar members of AEON’s research team. A male field assistant, fluent in the local language of isiXhosa, was included, after clearly specifying the attributes of the study focus – groundwater monitoring training, and the necessary resources required for the success of the training. Having an isiXhosa-speaking assistant was necessary; because farmers in the commonage farms were mainly Xhosa-speaking.

The assistance offered by the intern also included contacting the working group to arrange planning and reflective meetings throughout the data collection phases; and whenever there was need to meet, to assist during the fieldwork activities. The researcher requested and was issued a Borehole Monitoring Clearance letter by the IYM Agricultural Officer (see Appendix C), which was presented to each farmer upon a site visit.

3.3.2.2 Cohort Selection

Initially, the researcher planned to use a systematic sampling technique, of selecting the participants from the Cradock youth database available at the IYM offices. However, following a reflective meeting with the CWG, the IYM and the expert AEON hydrogeologist (bearing in mind the focus of this research), a new selection process was considered. The working group agreed to develop selection criteria, and to advertise the CS training programme to the Cradock population at large through the local IYM official noticeboard, for a period of fifteen (15) working days. Constant community roundtable meetings were held with the "selection criteria of the trainees" on the meeting agendas, including related concerns from the community leadership, as represented by the working group (see Appendix B with the contents of the roundtable meeting agenda and the concerns raised by the community, and Appendix D for the selection criteria and related processes).

The selection criteria were developed, and channelled first through an advertisement at community level, calling for interested persons to be part of the study, as groundwater monitoring trainees (see advertisement in Figure 3.5).

Earth Stewardship Science

AEON

Nelson Mandela Metropolitan University

for tomorrow

INXUBA YETHEMBA

AEON/NMMU CRADOCK SHALE GAS BASELINE STUDY

CITIZEN SCIENCE TRAINING PROGRAMME

The Nelson Mandela Metropolitan Univerity (NMMU) with support from the Eastern Cape Government is currently coordinating the Karoo Shale Gas Baseline Study Research within selected Karoo areas. Thus NMMU in partnership with the IPED Department, have identified the need for community engagement and empowerment which will involve developing a Citizen Science Program - one of the NMMU graduate student's research focus (Ms Nyaradzo Dhliwayo,) under the supervision of Professor Maarten De Wit (Chair in Earth Stewardship Science, NMMU).

The citizen science programme will focus on the theoretical and practical aspects of Groundwater Monitoring and Analysis (Hydro-census and Groundwater sampling) and run for approximately 6 weeks where +/- 12 youths will be trained and evaluated. As a result, the trainees who become involved in this training will:

1. Learn to identify groundwater monitoring aspects and properties which make water fit or unfit for consumption
2. Work with professional hydrologists from the government and the private institutions to report on aspects of Cradock's groundwater quality
3. Educate and engage other local citizens on groundwater monitoring processes
4. Be empowered for entrepreneurship (groundwater monitoring and analysis)

APPLICATION CRITERIA

- Unemployed out of school youths
- Must have completed Grade 12
- Ages 18 – 35
- ***Women are encouraged to apply***

DOCUMENTS REQUIRED

- A detailed CV (indicating the Ward of residence)
- A motivation (expression of interest) letter

If you are interested in this training programme, please submit your CV's and motivation letters at the local Registry offices to Ms Zelda by **14th October 2016.**

For more information about this training programme, please contact **Mr Sonwabo Luzipo; Mr Siyabulela Nxele** on **048 801 5095** or **Ms Nyaradzo Dhliwayo** on Nyaradzo.dhliwayo@nmmu.ac.za

PLEASE NOTE: This opportunity is not open to individuals who are currently participating in other learnerships or similar programmes. The selection of applicants will follow the equal opportunity rules of the NMMU institution.

1

Figure 3.5: Screenshot of the Citizen-Science Training Programme Advertisement (Dhliwayo, N: October 2016)

The process of advertising allowed an equal opportunity to the residents of Cradock, and not having a selected few who could be already benefitting from other empowerment programmes in the town. Notably so, the key informant interviewees revealed that a considerable number of youth empowerment programmes were ongoing at the time of this study in the town. These programmes included construction work and administrative issues. Thus, the word-of-mouth route of recruiting the citizen-science trainees was not going to be comprehensive as this would have been a disadvantage – possibly attracting people who were already part of an already ongoing training progamme (Ockenden, 2007).

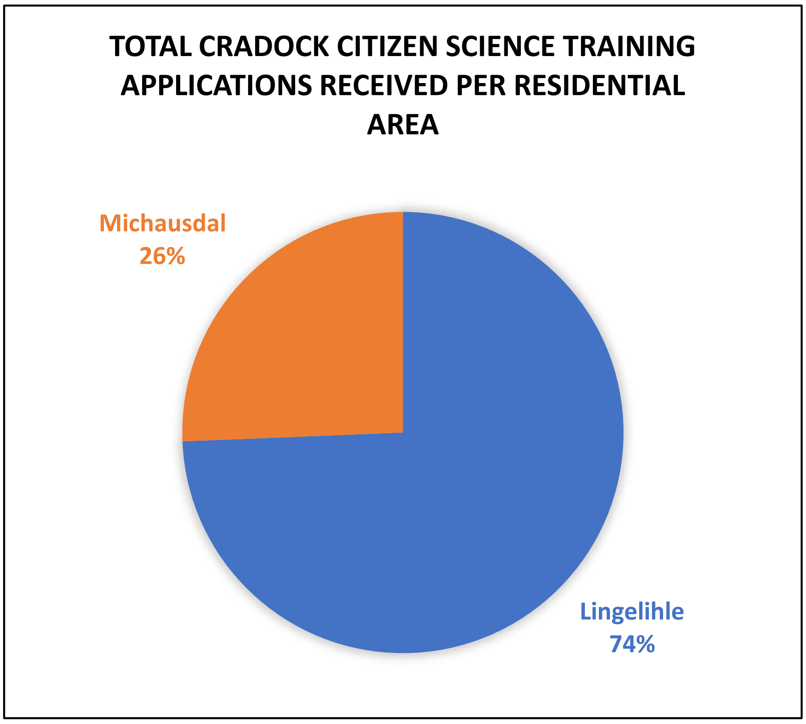
The researcher therefore liaised with the Working Group and the AEON hydrologist (who was going to train the CS), on the training programme structure and contents of the advertisement, considering the associated ethical issues. To become trainees in a citizen-science project or possessing a qualification did not necessarily contribute much during recruitment; however, as earlier stated in the literature (Chapter 2 - Section 2.3.1), one's willingness to engage in changing the world as a volunteer in science makes a difference. Hence, the aforementioned reason of the researcher to want a systematic sampling plan, had to be withdrawn to suit the context of the Cradock community, as guided by the working group.

The researcher eventually adopted a purposive-sampling technique (advertisement), which allowed the recruitment of diverse participants, who were not affiliated to any ongoing community programme or work, in a transparent manner. It is important to highlight the fact that the selection criteria process was guided by the following questions arising from the three CRM reflective meetings, key informant interviews and ad hoc conversations held with the working group:

1) *What will the people be doing?*
2) *For how long is the training going to be?*
3) *Where will the training take place?*
4) *Is there going to be any remuneration?*
5) *Who can apply?*
6) *What are the benefits of applying and getting into the CS programme?*

The CS programme advertisement therefore was strategically designed to answer the above questions, without undermining the citizen-science principles and guidelines. This process took a period of seven months (March 2016 – October 2016). Shortlisting and interviews by the researcher and the working group were conducted in November 2016 through reflective CWG meetings in a way that enhanced the accessibility of the prospective participants in a transparent form. Figure 3.6 below shows the total CS applications received per residential area.

As depicted by the Figure 3.6 below, 10 out of 39 applicants (26%) were from Michausdal (1 Male and 9 Females) whilst 29 out of 39 applications (74%) were from Lingelihle township (9 Males and 20 Females). Reference is made to the background of the study area (Chapter 1) where Lingelihle is a predominantly black community whilst Michausdal is predominantly coloured community.



Cradock Residential area	Total Applications received
Lingelihle	29
Michausdal	10
	39

Figure 3.6: Total Cradock Citizen Science Training Programme applications received per residential area.

Regarding the interviewing of the shortlisted candidates, the *curriculum vitae* (C.V.s) of each applicant, helped the researcher to contact and invite them. With the help of the IYM-appointed assistant, the shortlisted candidates were contacted telephonically. A date for their interview was set by the working group in collaboration with the groundwater monitoring expert (the trainer), who was part of the interview panel. Besides the candidates meeting the required criteria, the limited resources available to undertake the study were an important factor to be considered. Following a shortlisting meeting, and interviews of the prospective cohort, under the facilitation of the researcher, the AEON hydrogeologist, in collaboration with the CWG, 38% (15 out of 39) of the applicants were successful.

It is important to note that a period of six months elapsed between the time of the final selection of the successful candidates (February 2017) to the time the training commenced (August 2017).

During these six months, the researcher embarked on fieldwork preparation in liaison with the AEON department and the IYM officials. These activities included a Focus-Group Discussion with the CS successful candidates to introduce them to the training process and to establish their current capacity and knowledge about groundwater monitoring before the training started. Additionally, logistical arrangements were conducted by the researcher in collaboration with the IYM officials, commonage farmers where the borehole sites were identified and the acquisition of a clearance letter from the IYM Agricultural officer (see Monitoring Site Clearance in Appendix A).

The purchasing of groundwater training equipment (electrical-conductivity meter, water sampling bottles), the procurement of protective material for the trainees, comprising overalls, hats and boots (see Appendix D) was planned and executed during the six months period, to allow a seamless start to the CS training. However, due to arising employment opportunities and family responsibility reasons, five of the chosen trainees had to leave the CS programme and only eight candidates successfully completed the training.

3.3.2.3 Smartphone technology

Technology, including mobile phones in the form of software applications, as well as information technology infrastructures and platforms, can benefit citizen-science approaches (Hecker et al. 2018). The potential for smartphone technology, for instance, is seen in their assistance in quality control and the acceptance of data for a more general impact. The accessibility of the citizen to the scientist; the ease within which a citizen can connect with the biophysical environment, in order to collect and share the data, are some of the positive impacts following the use of technology in CS projects. Monitoring with smartphones by citizens is referred to as mobile-crowd sensing (MCS) by Rutten et al. (2017). The main reasons for the use of smartphones as monitoring devices in this study include:

- Much of the Cradock youth population own a smartphone.
- The increasing technological developments which result in high-quality sensors in smartphones that can be used to collect and record the data.

- An increasing availability of plug-in devices for smartphones which offers a lot of opportunities.

To facilitate the mobile data capturing during CS training, a customised software application (app.) termed '*Xoras*' was developed by the AEON unit. The app name is in the Khoi language and it means, the waterhole - dug in the ground. The application was used to capture and share field data collected during groundwater monitoring training.

The eight CS trainees were introduced to this app and trained using the mobile device (Samsung Android version 6.0 Tablet) with the inbuilt app, to record hydro-census information per borehole site that they sampled. Hydro-census information captured included the farm name, a description of the farm location (including pictures), the water temperature, the electrical conductivity of the water, as well as the global positioning co-ordinates of the location (elevation, latitude and longitude). Pictures, together with the hydro-census information recorded in the app format are then uploaded to the database for viewing by the scientists based at AEON in Port Elizabeth.

The app has a section to save the already captured data for a revisit called "*View/Add Entry*" and a section for sending a direct message to the scientist under the same entry as *"Send us a message*", in case of additional comments the user may need to add for a particular site (see Figure 3.7 below). During the groundwater monitoring training in this study, the data collected by the trainees was captured both on the physical (hard copy) hydro-census sheet (see Appendix C) and in the 'Xoras' app, which also served as an enabling data capturing tool.

<table>
<tr>
<td>


Step 1 – Switch on Tablet and identify the ‘Xoras” Application Icon on the screen
</td>
<td>


Step 2 – Xoras Open Application
</td>
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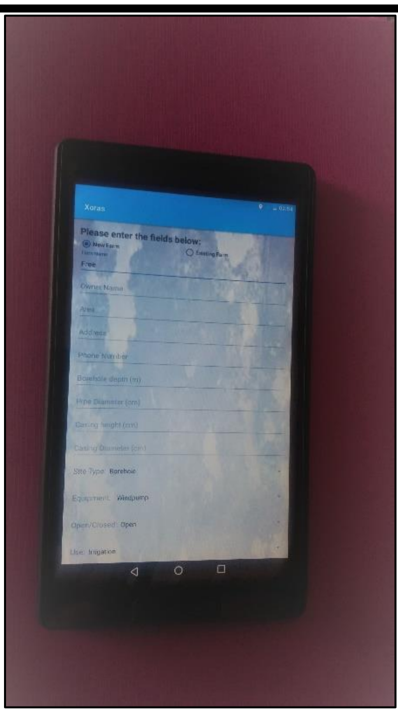
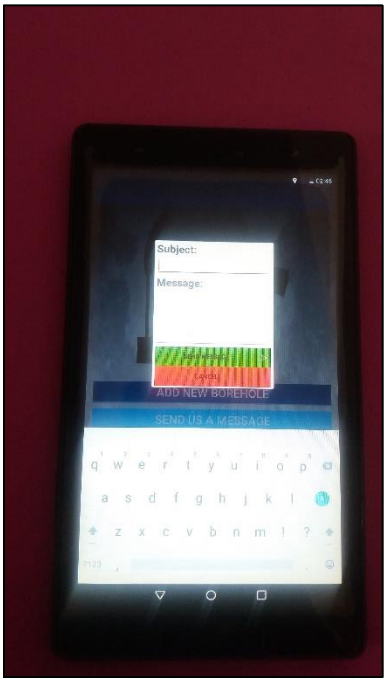
<tr>
<td>


Step 3 – Enter Hydro-census Data
</td>
<td>


Step 4 – Send Message (if needed) and Save File
</td>
</tr>
</table>

Figure 3.7: Selected images of the “Xoras” Software Application for Hydro-census data Capturing

Meanwhile, mobile crowd-sensing is associated with strengths and weaknesses which should be kept in mind when designing any CS project. Notable strengths of using the Xoras mobile app. included, highly mobile and scalable; low-cost; automatic time stamp, inbuilt GPS; and the user could save, edit and continue when necessary. The disadvantage however includes how the devices' hardware (Tablet) were not specifically developed for the task (data collection monitoring) to ensure data trustworthiness. Unless if they have been designed specifically for that one purpose, similar to the case of the Tablets used in this study by the CS trainees. The CS trainees did not have to use the Tablets for any other purpose except for purposes of capturing hydrocensus data with the Xoras app. and after a days' training, hand-in the Tablet to the researcher.

An additional cause of concern that may need attention, is the accuracy of data capture when a group of citizens are using one mobile device to collect data. Due to the lack of co-operation with fellow group members, Participant 5 of the CS cohort forgot the step of taking pictures of one of the borehole sites during the final week of practical hydro-census and groundwater sampling. The participant followed an option for sending a separate message using the same Xoras App, ("*inbox message facility*"), specifying the details of the borehole site and the reasons for sending pictures separately from the online form.

The latter two weaknesses in the use of smartphones in CS research, are mostly a challenge to overcome, because of an increase in data trustworthiness, which often leads to a decrease in privacy protection and the other way around – particularly if the device is being used by more than one individual within a project. Another option would be to employ the use of a mobile device strictly for monitoring purposes, and storing the devices within the organisation, or the local municipality offices' safe room. This will avoid the possibility of personal use and the invasion of personal privacy on the part of the "user," or the individual using the application.

3.3.2.4 Non-participant Observations

This study utilised non-participant observation during the fieldwork, where the researcher observed the events, activities and community interactions within the study area. The researcher physically entered the Cradock community and spent significant time organising community roundtable meetings, key informant interviews with selected stakeholders in the Eastern Karoo town, and the groundwater monitoring training programme. The researcher collected both audio- and video-recordings, including follow-up reflective questions and seeking clarity for observations made during the four data-generation phases. The non-participant observation technique enabled the researcher to observe and capture the community engagement and the capacity-building processes as they unfolded over the period of the study.

The secondary data sources (document review), further assisted the researcher in defining the citizen science and the groundwater monitoring aspects on which the study focused (hydro-census and groundwater sampling). In conjunction with other data-generating phases (Figure 3.4), document reviews were used to verify the key informant knowledge and for guarding against bias in other data sources.

3.3.3 Phase 4: Evaluations and Reflections

3.3.3.1 Reflective journaling

This technique was an ongoing exercise from the onset of the data-generation process, practised by the researcher and by the cohort during the groundwater monitoring training process. A research notebook was used to record the thoughts and observations related to any part of one's task. Given the collaborative and participatory nature of the study, the journaling exercises were done by the researcher and the researched, to describe the experiences in each step of the cyclical action-research process. Reflections facilitate a level of engagement with material and concepts, for example in achieving deep learning that depends on students organising their knowledge and constructing a set of connections between the different concepts (Ramsden, 2003).

A wide range of qualitative data was obtained through avenues, such as observations, participants' comments, reflective thoughts and impressions around the context of the CS study (see Appendix C).

Based on the philosophy of Schon (1983), this approach ("reflection-in-action"), has the potential to identify knowledge and to build new knowledge, based on an individual's practice. As a result, the researcher kept a journal and recorded her observations and experiences, as well as notes on the implementation of the research process. This is in recognition of Silverman (2007), who described the qualitative research process as one of noting and understanding phenomena, advocating an approach with observation at its core.

A non-participant observation tool was therefore used (Section 3.3.6); and through the use of reflective logs, as an instrument to complement the observations, the researcher built some complexities into the analysis (Baker, 2006).

The use of reflective logs is described by Strauss et al. (2015) in partnership with the Cornell University Lab of Ornithology. The author maintains that recording one's observations and discoveries forms part of being a scientist's duty. The CS trainees of the groundwater monitoring activity were thus each given reflective logs, which they completed daily after every hydro-census and groundwater sampling activity. The logs comprise mainly reflective thoughts of experiences and observations (what they noticed, learnt and tried) during the groundwater monitoring/training process (see Appendix C).

This process served as a learning space, and an avenue for the participants to voice their opinions, thereby calling for further deep thinking.

Figure 3.8 presents the citizen-science framework of the processes adopted during the field-data collection phases of this study. The framework developed by Bonney et al. (2009) was used by the researcher as a standard strategy. However, the process was modified, due to the context of this study; and additional steps were added, thereby enabling the creation of a working-group team, reflective meetings and journals for students, as well as the selection criteria (see shaded boxes in Figure 3.8 below). A context-specific framework is one with outputs of the study; and Chapter 4 and Chapter 5 highlight more on these variations.

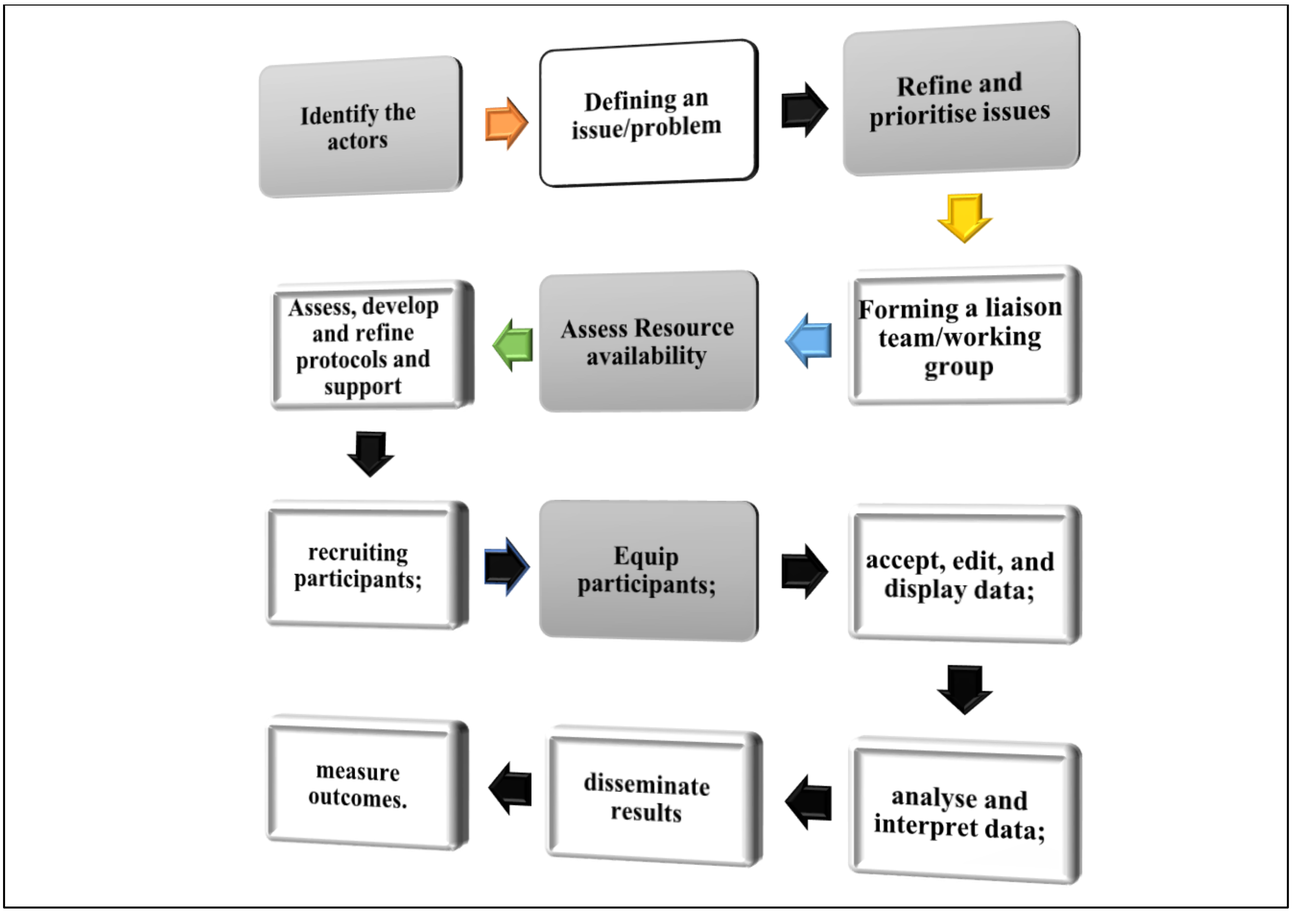


Figure 3.8: Typical Citizen-Science framework of processes (adapted from Bonney et al., 2009, and modified for this study.)

In adopting the CS steps for a citizen-science project by Bonney et al. (2009), the engagement processes require the community concerned to either be voluntarily involved, or be recruited, following agreed-upon criteria by the concerned parties, thereby meeting the project's purposes (Worthington, et al., 2012; Philippoff and Baumgartner, 2016). Various reviews indicate that in both contexts, the participants were expected to be committed to the requirements of the data collection and the scientific processes (Wright, 2011; Minkman et al., 2017). Participants' knowledge about the community's culture, or administrative structures, is also important. This would apply to the research assistants as well, who are expected to be well-dignified, mature people, known and respected in the study area.

This is because, in some citizen-science projects, and as a qualitative inquiry, assistants form part of the research team, whose quality and attributes help facilitate the entire research process, including the research design (collaborative typology), navigating through the researched area, and observing the necessary protocols in the data analysis.

In this qualitative study, the process is through active participation. It embraces both top-down and bottom-up approaches, in terms of input from the researcher, the professional scientists and the assistants. The researcher introduced the topic of study; however, the information on how and where to start may also come from the study community, following their appreciation of the study. Since participants should be actively involved in the design of the study, within a collaborative citizen science project, it becomes vital to highlight the necessity of assigning the specific roles that the research assistant is expected to perform; although flexibility (for instance availability) in these tasks may need to be considered.

Below is a summary table of all meetings held during the study, particular focus on the CRMs that led to the cohort selection process.

Table 3.2: Summary of specific meeting dates during the CS study (*CRM = Community Roundtable Meeting)

Date of meeting	Purpose of meeting
21 October 2015	**CRM1** First KSGBS and CS information session
28 April 2016	**CRM2** Second information session - follow-up meeting from CRM1.
18 May 2016	**CRM3** Third information session - Follow-up meeting from CRM1 and CRM2. Hydraulic fracturing model presentation by AEON scientists and Selection of 8-member working group
1 June 2017	**CRM4** Update meeting on the CS process and introduction of the successful cohort to the Cradock community.
7 August – 8 September 2017	**CS Training sessions** CS hydrocensus and groundwater sampling training on selected Cradock's commonage farms.
6 - 7 November 2017	**CS Cohort evaluation** Evaluation and certification workshop of CS cohort held in Port Elizabeth at AEON offices (see Appendix C)

In summary, the community-engagement processes for this study, supported by the Cradock Working Groups' involvement, was intended to serve the following purposes, among others:

1) Building trust between the researcher and the study community;

2) Promoting freedom, comfort and enthusiasm on the part of the participants to openly express themselves;
3) Timeously resolving challenges or conflicts, which might arise during the research process (for example, assurance that the researcher was not a supporter of SGD, camouflaged to assess the environment pre-shale gas exploration);
4) Seeking assistance from individuals from the community, who have a wealth of information, to facilitate field logistics and navigability in the community, such as the emerging farmers, or IYM officials;
5) The interpretation of local language, circumstances or atmospheres, which the researcher could not easily understand; and
6) Allowing room for the researcher to conveniently and comfortably conduct the fieldwork under the guidance of people known in the community (ethics).
7) Acknowledging the role of the selected cohort in conducting groundwater sampling and hydrocensus through the skills training and evaluation process.

3.4 DOCUMENT REVIEW

The scope of data collection for this study extended to the review of the secondary data sources, particularly the background of the study community and the study sites: the Karoo Shale-Gas Baseline Study (KSGBS); its potential impacts on groundwater; and the application of citizen science in groundwater monitoring. A document review provided a comprehensive summary of the key role played by citizen science in the field of groundwater monitoring, the various citizen-science related case studies in South Africa, and to compare the findings with those existing in the literature, which is a strategy to enhance the strengths and the comparability of such research results.

Information on SGD, Citizen Science and on related impacts of these processes on groundwater monitoring, (hydro-census and groundwater sampling, to be specific) was accessed from the relevant textbooks, government and non-governmental publications, internet websites and print media. At the level of understanding the existing knowledge about citizen science, this study reviewed citizen science in South African published documents and conference proceedings. The reviews were useful in understanding the probable impacts of citizen participation in water science, and on other scientific-development projects, similar (groundwater monitoring) to this study’s focus.

The procedure to conduct groundwater sampling and hydrocensus for this study, in reference to the *Toolkit for Water Services* by Potter et al. (2004), was designed by the researcher, and in the context of this study (see Field Guide in Appendix D).

3.5 RECORDING AND STORING THE DATA

The unstructured key informant interviews, open-ended conversations with the Cradock community participants were video- and audio-taped, and then transcribed by the researcher. The transcriptions were supplemented by interviews, and non-participant observation notes, including journal reflections, in case audio- or video-recordings gave problems.

Given that the study area's main local languages, are Afrikaans and isiXhosa, they were used for communication during the field interviews, including capturing and recording interview statements with the help of an interpreter, who translated these languages to the researcher in English. However, in the beginning of each of the interviews and roundtable meetings, including the groundwater monitoring training sessions, it was agreed amongst the participants to use English as the main language of communication (not forsaking the use of their vernacular or mother tongue, when needed).

To manage the difficulty of simultaneously asking questions and writing responses, a research assistant was assigned to operate the audio-recording instrument, which the researcher could transcribe at a later stage. Writing notes was intended to make sure that all the statements were accurately captured; and at the same time, to facilitate the interview processes and the training sessions. In addition, there could have been some aspects of the interview process, such as non-verbal expressions and post-interview comments, which may not have been audio-recorded. As such, the video recordings would be of help and note-writing and journaling played a vital role in capturing such non-verbal expressions. Photographs were taken to complement the observation notes, thereby illustrating important features and activities.

At the end of each field-data collection session with the Cradock stakeholders, the working group or the cohort participants, notes taken by the researcher were read out to those present, to verify whether all the statements had been accurately captured. As part of the cyclic nature of AR, the reflective sessions and confirmations of information discussed and captured at every meeting, ensured that more insights could be given (where necessary); as the study participants reviewed and analysed what they had stated.

In this study, the filing system of the researcher's DELL laptop (64-bit operating system) with 4GB memory and Maxx-Audio Pro by Waves studio quality sound-recording system included also, a Samsung HD-CMOS Sensor video camera with a 4GB memory card. Each recorded audio and video transcript are saved as a unique file in a specific folder; and it is identifiable by a file number and a recording date. Handwritten interview notes and transcription notes, including the observation notes, were later transcribed, typed and stored as separate files in the researcher's DELL laptop. Each transcription would then be merged with the respective field notes and recording for the purpose of syncing during analysis.

3.6 DATA ANALYSIS AND INTERPRETATION

In this study, the data analysis involved working with unstructured texts from CRMs, interviews and reflective journals which were analysed using thematic analysis, needing careful interpretation, in order to provide valid conclusions to scientific audiences, while remaining faithful to the generators of the knowledge. According to Creswell (2007), conducting data analysis involves a spiral process of moving in an analytical cycle, rather than a linear way. The researcher embarked on a spiral journey with the collected data texts, images, video recordings, during observations, reflective journaling and key informant interview notes, which best describe the situation under study. In the context of this study, the researcher has attempted to answer the "why" and the "how" questions mentioned in Chapter 1 (Section 1.1) by clear, concise and well-thought out techniques for the data analysis.

Several aspects of the data collection, transcription, classification, interpretation, visualisation, and management were tackled, as part of the analytical process, before the data presentation. These capabilities include reliable data storage and organisation, the ability to generate queries, flexibility in coding and generating themes, and the measurement of relationships among sections, hierarchical analysis, and the generation of templates within various methodologies. The quantitative data from the groundwater sampling results was straightforward and did not need comprehensive statistical analysis. In terms of further sharing of this study's results and the wider AEON Baseline Study and the processes involved, the permission to distribute the results will be based on the terms of AEON's position as a research institute.

Thematic analysis of the qualitative data was based on the Action Research approach in which main themes emerged from the transcribed and coded text collected. Interviews were transcribed in Windows Microsoft Word (version 2016). Pre and post tests and reflective logs were transcribed in Windows Microsoft Excel (version 2016) which was used to analyse the data. A thematic analysis of the group-interview responses, key informant interviews and the researcher's non-participant observations, was conducted. During CRMs, the researcher observed, and audio-recorded as well as video-recorded, the participants' responses and comments. The recordings were transcribed and coded into specific themes using Microsoft Excel.

3.7 ETHICAL CONSIDERATIONS

For this research, significant ethical principles were applied. I was committed to uphold the ethics of research by obtaining ethical clearance from the official Ethics Committee (REC-H) of Nelson Mandela Metropolitan University. The study upheld the principle of informed consent, which indicates that all possible or adequate information regarding the goal of the study, as well as possible advantages and disadvantages of participating, are made available to the research participants as accurately and as completely as possible (Strydom, 1998). The participants consequently are able to make a voluntary and thoroughly reasoned decision about their possible participation (ibid).

The study was carried out in an area where the Nelson Mandela University AEON Karoo Shale Gas Baseline study was being carried out. Consent was initially sought out with the local Inxuba yeThemba Municipality, who were the gatekeepers to this study. It was explained to these authorities, the study aims and objectives and the related field activities including possible outcomes. The participants were assured of constant communication from the researcher during the research process. The participants' informed consent was obtained after they had been briefed on the aim, procedures, possible risks, and benefits of the research. This took place at every first meeting of with the IYM officials, the CRM participants and the CS trainees.

The research participants were informed of their right to withdraw at any stage whenever they felt the need to do so. Seven of the fifteen recruited citizen science trainees withdrew from this study for reasons explained in Section 3.3.2.2. Only eight of the recruited candidates, completed the CS training.

To uphold the principle of privacy in this study the participants were assured that their actual names would not be used during the data analysis and discussion of the findings. The participants were made aware that a final copy of the thesis would be made available in the university library, and that a report back of the thesis findings will be made after the completion of the study.

3.8 CONCLUSION

An Action Research approach was adopted in this study to address the application of citizen-science in groundwater monitoring within Cradock community, where potential shale-gas development is expected. This paradigm allowed the use of an action research approach to be adopted for purposes of gathering the community input in a collaborative sense, in order to get a richer description of the context in which the Cradock community responds to the prospective shale-gas development plans, their concerns, and how they were willing to be engaged. The qualitative nature of the study, especially the cyclic process of action research, allowed for the capturing of salient and new ideas, useful for appropriate interventions relating to the capacity-building of the selected community participants in groundwater monitoring. To capture these open-ended questions, reflective journaling was used, which facilitated the generation of participants' views and perspectives.

The use of qualitative research methods, such as reflective journaling, was intended to capacitate the Cradock population in devising sustainable interventions through capturing their concerns (should shale-gas exploration take place in their community or not) and embarking on a citizen-science training intervention. Key informant interviewing was undertaken to understand better the context in which shale-gas development prospects are shaped; and how the study population view and respond to the development project and the variability in the local environment – mainly in the groundwater aspect. The approach was also intended to complement mainstream qualitative research through enriching explanations in theories and models of citizen science and groundwater monitoring aspects.

Participants (from Phase 1 – 4), were allowed to withdraw from the study at any time, as CS is voluntary based. Seven of the fifteen trainees withdrew from this study for reasons based on new job offers and family responsibility to which they could not commit to the CS study. Only eight of the successful candidates, completed the CS training.

Exploring citizen science concept would arguably require a greater geographic coverage in terms of data collection, to map activities such as groundwater monitoring across South Africa. However, Cradock being the pilot study for the KSGBS, is a necessary case to explore on the existing community's' knowledge and capacities in groundwater monitoring. The engagement of key informants external to the study setting and existing community structures managed to draw independent insights on the current concerns and possible processes to follow in order to create CS in this community.

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CHAPTER 4: CRADOCK CITIZEN-SCIENCE TRAINING IN GROUND-WATER MONITORING: PROCESSES AND FINDINGS

4.1 INTRODUCTION

This chapter presents the findings gathered during the study, using the Action-Research Approach and key informant interview tool, focusing on establishing the community's capacity to monitor ground water prior to potential Shale-Gas Development (SGD).

4.2 PHASE ONE – STAKEHOLDER IDENTIFICATION, COMMUNITY CONSULTATION AND PROBLEM FORMULATION

To establish the community's knowledge regarding the prospects of shale-gas development (SGD) in Cradock, and the community's capacity to monitor the potential effects of this development, the researcher engaged in unstructured key informant interviews and community roundtable meetings (CRMs). The capacity-building strategies that would benefit the community, in the event of SGD in their locality, were identified in the process. Two AEON project co-ordinators were interviewed; one, who oversaw the social cohesion processes in the KSGBS; and the second who was responsible for the hydro-geological aspects of the baseline study.

The two co-ordinators were interviewed before, during and after the baseline study commenced – to explore and understand the purpose of the AEON Karoo Shale-Gas Baseline Study. Thereafter, two IYM managers were interviewed in Cradock; and four members of the working group, which was a liaison between AEON officials, the researcher and the Cradock community. The interviews were audio-taped, transcribed and coded in English.

4.2.1 Cradock Community Consultation and Problem formulation

As part of the Action-Research process, after key informant interviews with the AEON coordinators and IYM managers, the researcher embarked on the reflection and evaluation steps, which resulted in the planning of community roundtable meetings. This led to the first Community Roundtable Meeting (CRM1), being held at the Vusubuntu Cultural Village on the 25th of October 2015 in Cradock. This CRM was conducted with an attendance of fifty (50) Cradock stakeholders, in collaboration with ten (10) graduate students from the AEON. The aim of this meeting was to conduct an in-depth exploration of the community's knowledge and understanding of the proposed shale-gas development programme in the town, including their related concerns (Figure 4.1).

Figure 4.1: First Community Roundtable Meeting showing a representative of one stakeholder group summarising the outcomes of discussion, with the researcher (Far Left: Ms Nyaradzo Dhliwayo). Venue: Vusubuntu Cultural Village, 2015

Given the overall objective of this study – creating citizen science in Cradock– it was necessary to engage the AEON graduate students in this first CRM. The presentations by the graduate students offered an information-exchange platform between the Cradock community and the AEON scientists, with particular reference to the trans-disciplinary nature of the KSGBS. The meeting was planned and conducted with the consent of the Cradock community leaders, which included the local councillors and the civil society representatives in the community at the time of the study.

In the first CRM, the researcher:

a) Using the Focused-Group Discussions (FGDs), introduced the aim of this research to the Cradock community (see Appendix A), who were present; and defined the CS concept, giving the contextual meaning in relation to the KSGBS – the active participation of the local Cradock community (non-scientists) in the scientific activities based on the baseline study. The participants in the FGDs comprised of CRM participants, who collaboratively divided themselves into four groups.

b) To explore the Cradock community's concerns over the proposed SGD, the researcher engaged the participants in a focussed group discussion, addressing questions listed in (Box 4.1) using the ranking tool (see Section 3.3.1.6). The use of one of the community's local languages, IsiXhosa, was also adopted (with the help of an interpreter), in order to bring a clearer understanding of the definition of CS and the related SGD concepts.

Box 4.1: First Community Roundtable Meeting (FGD Questions) (Held on 25 October 2015, Vusubuntu Cultural Village, Cradock)

1) What are your concerns about shale gas, as the community?
2) How best do you want to be engaged in this process to build awareness and community participation?
3) How best can information be communicated amongst the community?
4) Which other stakeholders need to be included in this process?
5) Which resources within the community should be considered as critical in this process?
6) What do you not like about the ongoing shale-gas debate, and how information is communicated to you?
7) What did you not like about today's session? What can be improved?

As such, it is important to mention the isiXhosa translation of the CS concept which is *Umthathi nxaxheba or Ulungiso (Burgerwetenskap in*Afrikaans). The capacity-building focus that was intended for in citizen-science development in the community was also highlighted and explained – with the necessary translations for the participants' benefit.

c) Invited the community's support (local leaders; the youth; local farmers; local municipality (IYM); women in business) in the research process;

d) Established the community's current knowledge and skills capacity. Guiding questions (Box 4.1) were used by the researcher during the FGDs, where the CRM participants volunteered to split into four groups, to discuss each of these questions in detail.

In order to explore and respond to the concerns of the participating community members in CRM1, it was important for the participants to interact and engage with the subject of the research in a participative, free, open and non-threatening environment. The researcher divided the participants into four (4) groups, consisting of randomly elected participants, an identified group facilitator, a transcriber and a rapporteur, to present the respective responses to the questions posed in Box 4.1 above.

At the end of a group discussion, the researcher convened the groups to have one meeting during which there was a combined discussion of the responses given by each group. The community stakeholder representatives, municipal councillors and the civic society representatives present also engaged in the discussions. The responses to the questions are tabulated (Table 4.1(a) and Appendix B).

e) Cultivated a trust relationship between the researcher and the Cradock community;
f) Developed a strategy for community participation in the next phase of the study.

The rationale behind the collaborative action in a CRM was to identify the capacity needs and motivation of the broader community, in order to address their public concerns – such as the community's emerging need of skills to manage the effects of the potential shale-gas development in the area. A thematic analysis of the group-discussion responses (Table 4.1(a), page 203 of this thesis) – Appendix B), key informant interview notes and the researcher's non-participant observation notes, was conducted. Evolving themes included, knowledge of SGD in the Karoo region; concerns about groundwater; response to energy companies and citizen rights. A detailed discussion of these findings is in Chapter 5.

4.3 PHASE TWO – CONTINUED STAKEHOLDER ENGAGEMENT AND COHORT SELECTION

Following the completion of the first phase of the data collection, the researcher further engaged in reflective and planning meetings with the IYM and AEON representatives, to serve as the collaborative Planning and Reflective steps of the AR approach process. Thus, a second round of key informant identification and consultation took place, resulting in the arrangement of two (2) Cradock stakeholder meetings, which ran consecutively (in April and in May 2016). These were meant to reflect on, and address any concerns raised in the first CRM, and to build trust between the researcher and the community.

The stakeholder's attendance, however, in the second CRM was considerably low in comparison with the attendance at the first meeting (CRM1).

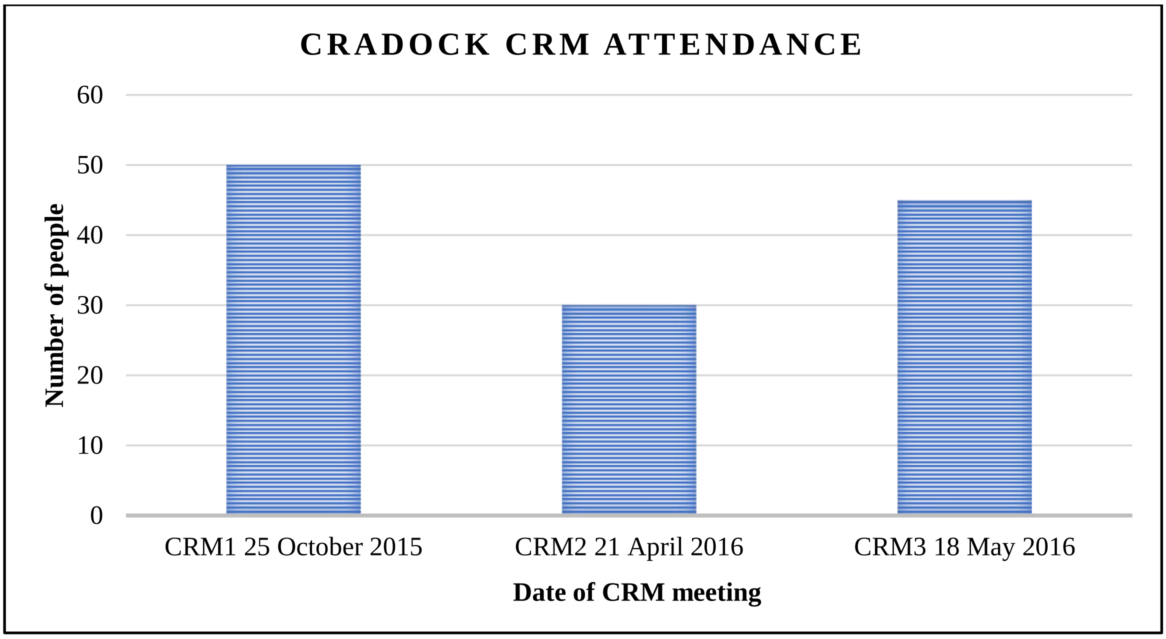

Figure 4.2: Cradock CRM attendance: CRM 1, 2 and 3

Similar to CRM1, I took the lead as the facilitator of meetings, and engaged the stakeholders present on the purpose of the research. I then used the Participatory Rural Appraisal (PRA) tool, FGDs explore on their concerns as a community. Participating stakeholders in each of the CRMs (CRM2 and CRM3) consisted of local emerging and private farmers, business owners, the youth and IYM officers. The table below (Table 4.1 (a)) contains the concerns and suggestions which they raised.

Table 4.1 (a): Concerns and Suggestions raised at the CRM 2 and CRM 3 in Cradock

CRM 2 (held on 28 April 2016)	**CRM 3 (held on 18 May 2016)**
Concerns raised by 30 participants: • We need a working committee representing the community • We need clarity on fracking licences issued to date • The ideal selection criteria of the citizen scientists or cohort that will be trained in groundwater monitoring • Next roundtable discussion date set on 18th May 2016	Concerns raised by 45 participants: • We need a simplified fracking model presentation for all community members to understand • Selection criteria for the cohort to be specified • Importance of Groundwater monitoring • Election of a working group/committee • Clarity on fracking licences issued to date

Following the listing of concerns, about the SGD debate process and the CS study process, a ranking exercise was conducted with the same CRM participants, in four separate FGDs. These involved the ranking of critical resources (Section 3.3.1.6) in their area which the Cradock participants were concerned about, which could be potentially affected by SGD (see Section 5.2.2.2, Insert 1). Water as a critical resource in Cradock was mentioned constantly in all four FGDs and when the groups' responses were shared during CRM1, the participants continued to mention water at the top of the critical resource list, particularly groundwater in comparison to other listed resources (land, human resources, and skill empowerment). This response shaped the focus of the CS training – groundwater training.

Despite the 40% decrease in attendance at CRM2 (Figure 4.2) in comparison to CRM1, it was the response of the residents in Cradock that was important and essential to the understanding of the KSGBS and their role in the process.

As Figure 4.3 below reflects, in the second CRM the stakeholders present were different from the ones that attended CRM1. Emerging farmers and representatives from the farmer associations, or committees, were the notable different stakeholders attending CRM2. Farmer representativeness increased from two (2) in CRM1 to twenty (20) in CRM2, bringing 50% change of overall stakeholders in attendance between the first and second CRMs.

A challenge was experienced, where the attendance of first-time participants in CRM2 were different from the ones who attended CRM1, resulting in the researcher organising CRM3, which had an increased number of attendees (45) compared to the thirty participants in CRM2. From the table above (Table 4.1) it can be noticeable that concerns and suggestions raised in CRM2 were the same as in CRM3. Therefore, the next CS process phase had to be strategized, given the recurring issues being raised by the CRM participants.

<table>
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<tr>
<td>CRM 2: Attendance of Cradock Stakeholder representatives at the Vusubuntu Cultural Village, Cradock</td>
<td>Mr Barry Morkel (PhD student and AEON Baseline Study Co-ordinator) giving a presentation on the potential role of the Cradock community in the KSGBS during the CRM2</td>
</tr>
</table>

Figure 4.3: CRM 2 imagery reflecting stakeholder attendance (26 April 2016, Vusubuntu Cultural Village, Cradock)

At each of these roundtable meetings and FGDs, the researcher elaborated and explained fully the concept of citizen science and the role of the local community in the AEON Baseline study *(Cradock Stakeholders' Representative Forum Agenda, April 2016 – Appendix B).*

4.3.1 Cradock Working Group and Cohort selection

As the community representative group was formed, its purpose or role in the CS process (Box 4.2) had to be defined clearly and presented to the local IYM manager - to be a link between the researcher and the community in relation to the citizen science in the groundwater monitoring study process. The liaison group collectively among its members gave itself a name - the Cradock Shale-Gas Baseline Study Working Group (CWG) (Figure 4.4).

Figure 4.4: Picture of the Cradock Shale-Gas Baseline Study Working Group (CWG) (*Picture taken at the first Working Group meeting, at the Inxuba Yethemba Municipality (IYM) Boardroom, Cradock)*

The working group (CWG) was formed during the third CRM, under the facilitation of the IYM officials with the researcher. The full mandate of the working group is summarized in Box 4.2, as agreed upon by the respective elected members and community stakeholders present at the CRM3.

Box 4.2: Purpose of the Cradock Shale Gas Working Group (discussed and defined during CRM2)

- *Purpose of the committee:*
  - To be the voice of the people
  - To provide guidance and advice to NMU and the community
  - To act as liaison between NMU and the Cradock community
- *Structure of the committee and requirements*
  - Include stakeholder representatives from the commercial farmers; minister’s fraternal; tourism; community services; water users’ association; women’s co-operatives and emerging farmers
- *Suggest a Name for the committee* – for example Working Group
  - IYM includes Middleburg and Cradock; thus we need to include them; political issues; tension between Cradock and Middleburg
  - The AEON baseline study focuses on Cradock only as a pilot study; thus let’s be careful not to stall the process. Middleburg will be excluded from the AEON baseline study and CS research process
- *Elect a Chairperson and a Deputy Chairperson*.
  - The Secretariat will be from the local municipality (IYM)

In response to the concerns raised by the community on the potential impact of shale gas development on Cradock’s groundwater resource, and the lack of skills to detect the groundwater consumption status, (during the first and second CRMs), the researcher invited the stakeholders’ consent and the CWG to identify candidates from the community for skills training (citizen science). The meeting agreed to present the elected candidates in the next roundtable setting (CRM4), whose date was agreed upon under IYM official leadership.

Emphasis was made by the CWG on the importance of ensuring that the selection criteria for the citizen science trainees, is formulated, giving an equal opportunity to the community members to be part of the study (considering the community concerns raised on making available a stipend and the high unemployment rate in the town). The criteria were formulated by the researcher, in collaboration with the CWG and the AEON hydrogeologist – the CS trainer in groundwater monitoring.

Figure 4.5: Cradock Community Working Group and AEON Hydrogeologist during the CS shortlisting process – Far left is the chairman of the working group

An integral part of the Action-Research process was the CWG's engagement in the selection process of the trainees (cohort) (Figure 4.5). For full details on the cohort-selection process, see Chapter 3 (Section 3.3.2.2).

4.4 PHASE THREE: CITIZEN-SCIENCE COHORT TRAINING

Following the recruitment of the citizen-science cohort of eight youths (aged between 21 to 37 years old), a fourth CRM was organised, to introduce the cohort to the Cradock community, highlighting their role in the research and planning the next phase of the CS study, which involved the groundwater monitoring training. A separate Focus-Group Discussion (FGD) was held with only the cohort before the commencement of the groundwater monitoring training. The purpose of this FGD was to establish the baseline knowledge and the capacity of each of the selected trainees, before the commencement of the training. Table 4.2 below reflects the responses from eleven CS trainees, who attended this focus-group discussion, to four guiding questions.

It should be noted that at the commencement of the CS training, the number of successful trainees was thirteen, however on the first Focus Group Discussion (FGD) only 11 attended because one of the trainees had a family emergency and one trainee did not respond to the invitation. The sample size (n=11) which at the end of the training reduced to (n=8). Qualitative data collected through interviews, reflective logs, Pre and Post-tests supported and expanded on the study findings. Table 4.2 only shows responses from the 11 trainees during their first FGD before the commencement of the groundwater monitoring training.

Table 4.2: Responses from the CS trainees during the first Focus-Group Discussion – held on 17 February 2017 in the IYM Boardroom, Cradock											
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**
1. What do you want to learn in the Citizen Science Programme?	How to establish business	Would like to learn more about groundwater sampling and Hydrocensus. - I would like to learn also more about the EC Meter and more about the boreholes. - I also like to know more about shale gas and learn more about how the borehole should work	Want to learn how does one detect if water is fit for consumption	Water sampling	I want to know more about the theory and practical of how to take the samples and to do hydrocensus	Want to learn more about the programme; more details about Hydrocensus and Water Sampling; Possible opportunities and benefits of the programme	I want to learn about what water analysis and hydrocensus is and what type of equipment they use for it	Would love to hear more about the training, what water sampling and hydrocensus is	To learn about water sampling; What are the benefits and opportunities of this ground water programme; To learn how to keep water safe or how to take care of water and how to measure water and why water is so important to us; To learn about hydrocensus	I would love to learn what groundwater sampling is and hydrocensus because I don't know any of it. Practically and theory I want to learn how to take a groundwater sampling and how to do so	More about shale gas and be deeper in this project
2. What do I know about Groundwater Sampling?	Don't know anything	None	I don't know anything	Don't know nothing about it, willing to learn	None	Don't know	No idea; no experience; Willing to learn	Familiar with sampling with sampling processes; Cleanliness of Sampling Equipment e.g. PH meter, jars	Don't have any knowledge about it	none	none
3. What do I know about Hydrocensus?	Stats receiving from sampling;	No knowledge about it	nothing, no skills; no experience	I don't know anything about it	no idea what this is; no experience	don't know anything about it	None	Don't know nothing about it;	none	don't know	none

	Recording of data				in it; willing to learn			willing to learn			
4. What have you learnt today?	I have learnt more about the differences between people and their different way of seeing the future	working together with communities; working in a team; introduction about the programme	exact aim of baseline study; - career opportunities	learnt the introduction about the learnership; the importance of knowing each other	I learnt more about the training programme, for example the reason behind it and where it is leading	I learnt what is shale gas and how they can help and the community and know about each other and bond	today I got to know my colleagues that I am going to do the programme with and what we are going to do for the next 3 weeks	introduction about the learnership programme; working as team; working with the community	-More information and clarity on the programme; -Got to know my colleagues	I learnt more about teamwork and introduce ourselves and know each other. There was also a briefing about hydrocensus and groundwater sampling and about what we were doing in the next 6 weeks. It was a good session, and everyone was friendly	

The results from the FGD with the cohort informed the researcher in the design of an effective citizen-science process involving the design and implementation of a groundwater monitoring (hydro-census and groundwater sampling) field guide and capacity-building strategy. Additionally, it assisted the AEON hydrogeologist (trainee) to plan in collaboration with the researcher, the training programme, according to the capacity needs and concerns raised by the trainees. Figure 4.6 below shows the researcher in the first FGD with the cohort trainees, presenting their expectations and current capacity needs regarding the groundwater monitoring and training.

Figure 4.6: First FGD with the selected cohort (held at Inxuba yeThemba Municipality Boardroom (17 February 2017)

At the end of the FGD, the cohort completed a Pre-test before the CS groundwater monitoring training commenced. This served the purpose of mainly establishing the current knowledge and the skill of the trainees relating to hydro-census and groundwater sampling. Pre-test results provided guidance for the actual training activities, as well as a basis of comparison with the Post-test results (after training). The Pre and Post-tests were designed as a method for establishing the role played by the citizen- science training programme in capacity building to the Cradock community (Chapter 3).

- **Hydro-census and Groundwater Sampling Field-Guide Design**

Defining the groundwater monitoring components and the related aspects was important for the Cradock community, CWG and the selected 13 trainees, to understand the basis of the citizen-science study and their role in it. The researcher, under the guidance of the AEON hydrogeologist and the literature on groundwater monitoring (for example, the *Toolkit for Water Services,* DWAF, 2004), developed a Hydro-census and Groundwater Sampling Field Guide (Appendix D), that assisted the cohort during training. Further reference was made to the Department of Water Affairs – *Groundwater Strategy* of 2010.

The structure of the field guide was informed by the guidelines and the *Step-by-Step guide on implementing a Rural Groundwater Management System for South Africa* (DWAF, 2004). The hydro-census and the groundwater sampling guide were therefore contextualised to match the highest-ranked community's capacity needs raised in CRM1 (see Appendix D).

- **Groundwater Monitoring: Safety Precautions**

The researcher assessed the capacity, the preparedness and the safety needs of the cohort to conduct a hydrocensus and groundwater sampling within the selected commonage farms of Cradock. The assessment included (a) establishing the protective clothing needed for the trainees and their individual sizes (shoe, overalls and sun hats); (b) establish special health and dietary requirements per trainee, which may contribute to the success or the failure of their participation, such as allergies (See Appendix D) (c) established the readiness and motivation of the trainees to embark on the CS training (See Figure 4.2).

The Safety, Health and Environmental (SHE) Department, stationed at the Nelson Mandela University, was consulted and advised the researcher on the vital health and safety field precautions to take during the CS training programme. These precautions were based on the SHE's current knowledge and experiences in the natural environment and involvement within different communities (see Appendix D).

- **Hydro-census and Groundwater Sampling – Actual Cohort Training**

Parallel to the safety and health preparedness, was the procurement of the hydrocensus and groundwater sampling equipment. These include, the Electrical Conductivity (EC) meter; groundwater sampling bottles and a cooler box; hand-held Global Positioning System (GPS); field tape measure; hydrocensus sheet and the accompanying stationery. The cohort were trained on the purpose of, and how to use, each piece of equipment. Electrical Conductivity means the ability of a material, such as water, or a metal for an electric current to pass through. It can be measured in the field by using a portable conductivity probe and meter (Moore et al., 2008); and Figure 4.7 below, shows equipment the Cradock CS trainees were taught how to use for purposes of hydrocensus and groundwater sampling.

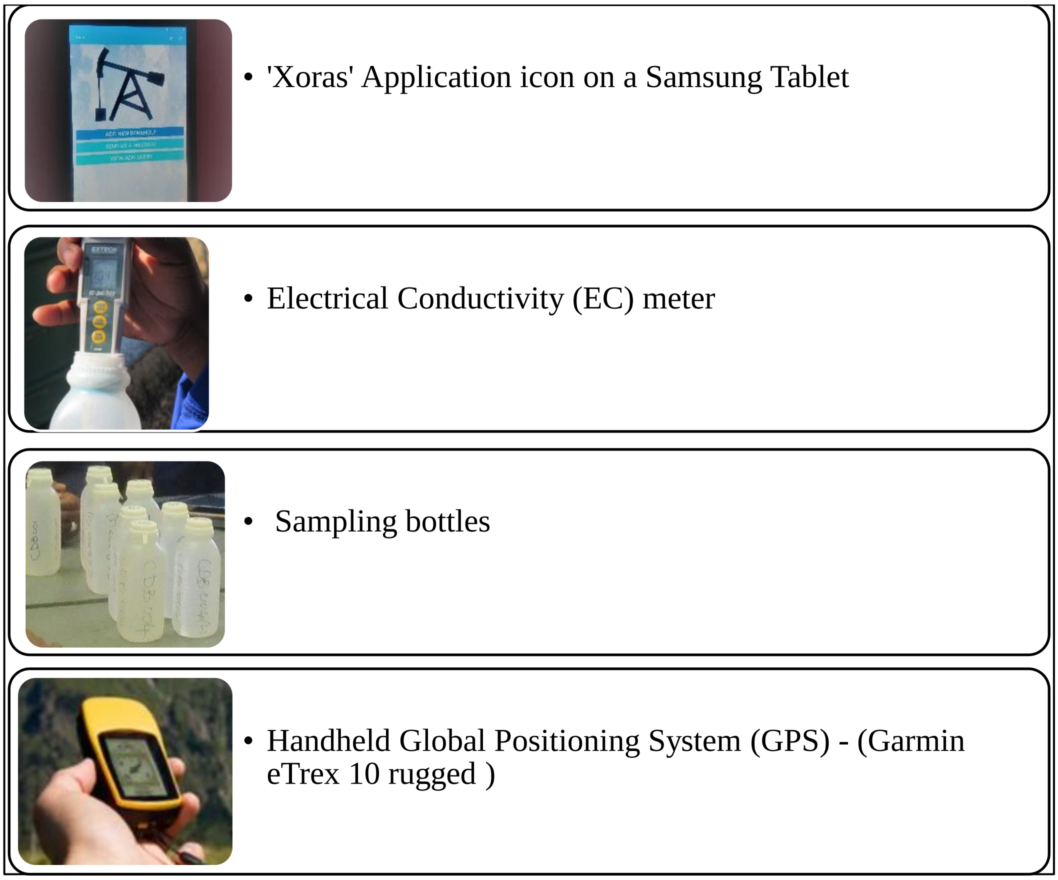

Figure 4.7: Tools learnt and used by the CS cohort during Hydrocensus and Groundwater Sampling training

During the data-generation process, the research used the term “activity” to distinguish the different activities that the participants were engaged in, such as: hydro-census training, groundwater sampling, observations, non-participant observation and reflective journaling. They were all characterised within a similar AR cyclic process (Plan > Act > Observe > Reflect). During this process, the researcher kept a journal, in which her reflections, observations, experiences, as well as notes on the implementation of the whole research process, were recorded.

It is worth noting, how all the CS trainees remarked that the groundwater monitoring training would be significant for them in terms of skill development and inspiring their career paths (Figure 4.2). This primarily occurred during their first introductory Focussed Group Discussion (on 17 February 2017), the Pre and Post-tests, and reflective journaling sessions during the four (4) weeklong groundwater monitoring training.

Table 4.3 provides an extract of responses of each candidate for Questions 6 and 8 of the Pre-test; and Question 8 and 10 of the Post-test. Figure 4.8 (a) below is a bar chart representing the main responses for *Question 8: "What do you hope to take away or learn from this training programme".*

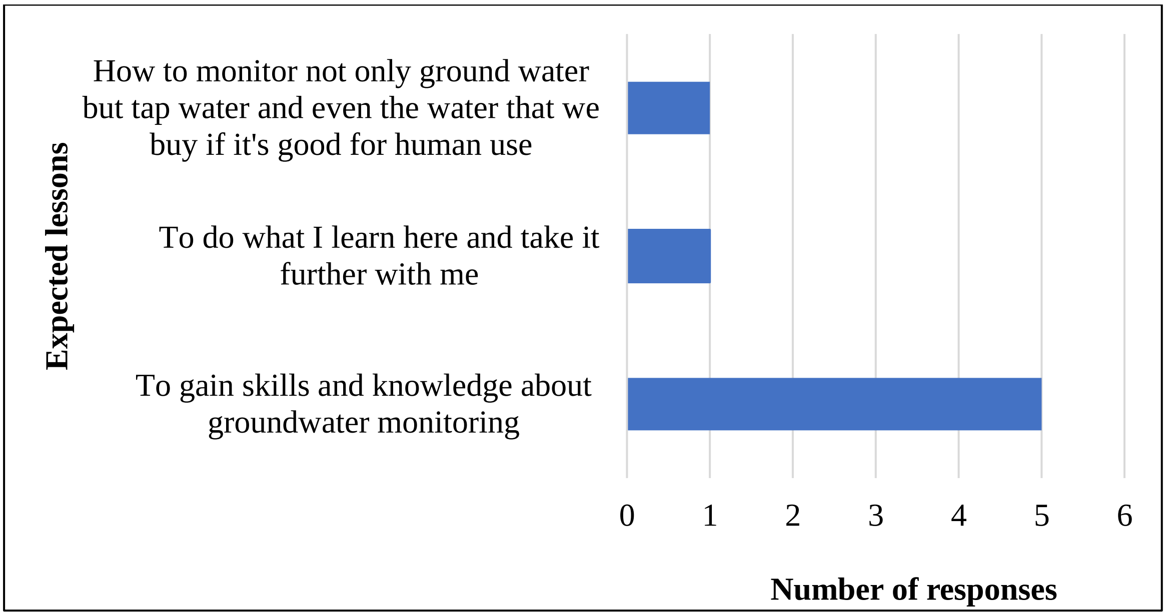

Figure 4.8 (a): Cohort's expected lessons to gain from the Citizen Science programme

Out of the 8 remaining trainees, 5 of them indicated how they are expecting to gain skills and knowledge about groundwater monitoring, with one of them expecting to take the lessons further in their lives. It will not be surprising that this is one of the candidates (P6) who indicated their future career in training others after the CS programme. (See Table 4.3, Question 6)

> *"Since Cradock is a Karoo, I want to be train how to test water and be sure is safe for our health" (P6)*

Due to the withdrawal of five of the selected trainees during the training, the Pre and Post-tests presented are only for those who were consistent from the commencement to the end of the training. A complete summary table of the Pre and Post-test results is provided in Tables 4.3 and 4.4 (Appendix C).

Table 4.3: Extracts from Cohorts' Pre-test results and emerging themes – (Examples Questions 6 and 8)

Combined Cohort Pre-test Results and Emerging Themes									
Question (s)	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**EMERGING THEMES**
6.What are your possible career interests in line with the citizen science groundwater monitoring training programmes	Access skills in the field be able to help out in the farming sector as it lacks water monitors	To study more in citizen science groundwater monitoring when I complete my training, I'm going to Middleburg because there is a place of boreholes so I wanted to go and gain more		Ground water technician	Science and ground water monitoring	Since Cradock is a Karoo, I want to be train how to test water and be sure is safe for our health	To become a ground water technician	Absent	- employment in the farming sector; - study; - groundwater technician; - to train others on how to test water
8. What do you hope to take away or learn from this training programme?	Skills and knowledge	To do what I learn here and take it further with me		Checking not only ground water but tap water and even the water that we buy if it's good for human use	Knowledge and skills	I want to learn more about the groundwater importance of it	Able to test and deal with hydrological issues	Absent	- skills and knowledge; - learn about groundwater and its importance; - learn how to know if ground/tap water is good for consumption

Table 4.4: Extracts from Cohorts' Post-test results and emerging themes – (Examples Questions 8 and 10)

Combined Cohort Post-test Results and Emerging Themes								
Question (s)	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**EMERGING THEMES**
8.What are your possible career interests in line with the citizen science groundwater monitoring training programmes	being able to monitor the water in the communities and farms and maybe open a monitoring company	I wanted to go and study further if NMU will be available short courses but for now I'm going to look for a job that I can test some water and sampling the water	Geologist	Ground water monitor specialist	engineering or geologist	To start up my our business and also do groundwater monitoring around my area and teach my community about it	to become the inspect of the groundwater or to become farm owner and sample my own water or groundwater specialist	- Water monitor in the community; - Open a specialist monitoring company; - short courses; - geologist; - engineering; - teach the community about protecting groundwater; - Farm owner
10. Can you list what you have taken away or learnt from this training programme?	How to engage with a farmer, take samples, complete the hydrocensus sheet manually and electronically	I can sample water, can take the water EC and Temperature, can write a hydrocensus and tablet how to fill it in. I learned a lot, it's easy to do it physically but not practically	How to do the hydrocensus sheet. How to take samples from the borehole	That most of us are just drinking or using water without being cautious of the water is good enough for human consumption	I learned how to test ground water. How to communicate with farmers	To take the samples manually and electronically and send them to the lab	how to take samples of the water and how to measure the diameters, what question should I ask the farm owner	- how to engage with farmer; - taking water samples; - hydrocensus process and sheet; - human ignorance towards water quality, consumption and use

Following the completion of the CS training, a Post-test was conducted and Figure 4.8 (b) below reflects the responses of Question 10 *“Can you list what you have taken away or learnt from this training programme?”*.

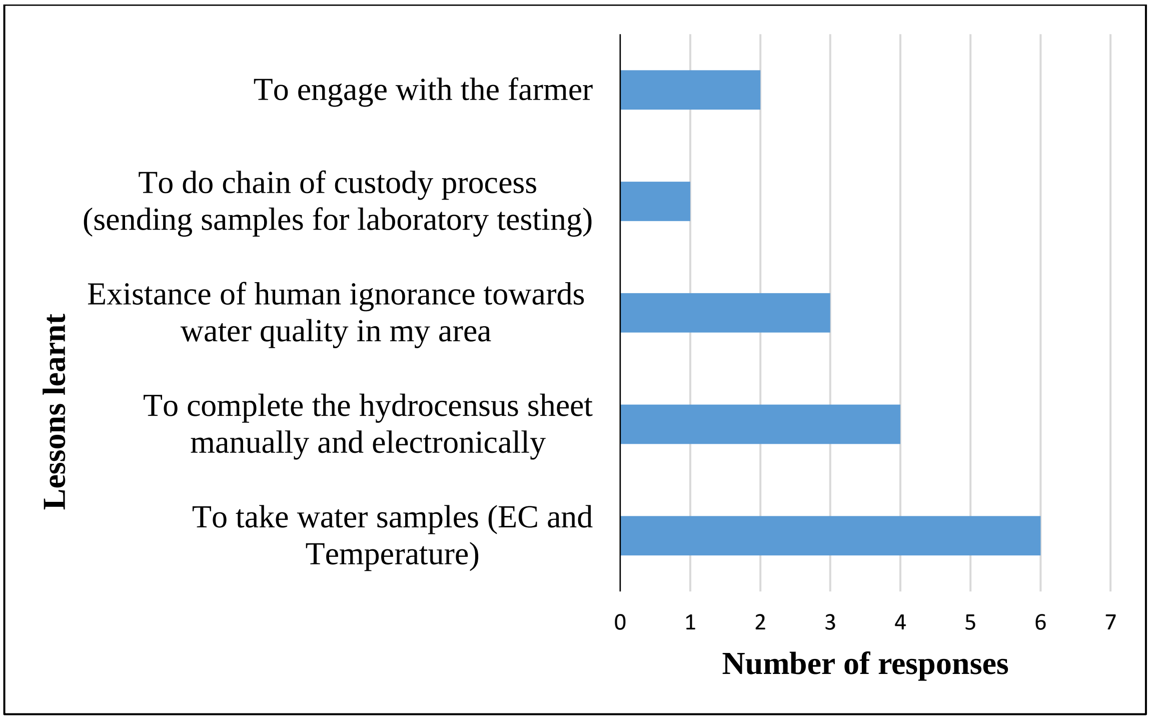

Figure 4.8(b): Lessons learnt by the cohort participants from the CS programme

Six out of 8 trainees indicated their knowledge gain in conducting water sampling, with more learning how to record the hydrocensus information among other skills. The rationale for exploring the before (Pre) and after (Post) training status of the cohort, was essential to gauge the capacity and motivation of the trainees to participate in the groundwater monitoring process, such as taking water samples in preparation for laboratory analysis. All eight (8) participants were interviewed, and their responses were transcribed and coded in English. The names and personal details of all the trainees were changed, in order to protect their anonymity; and in the following discussion, each participant will be identified as either Participant One (P1) or Participant Eight (P8).

The first two weeks of training covered the theoretical background of groundwater monitoring and practical field exercises under the professional facilitation of the AEON hydrogeologist. Figure 4.9 below, shows the cohort’s first day of the Hydro-census theoretical training under the leadership of the AEON hydrologist.

Figure 4.9: First day of Hydrocensus training by the AEON hydrogeologist (seated far right)

As indicated in Section 4.3, the training commenced with hydro-census followed by groundwater sampling. The number of identified boreholes to sample were eight; and the trainees were divided into three groups (two groups of 3 people and one group of 2). The number in the group of 2 trainees was a result of one trainee leaving the programme during the 2nd week of training.

Each group was assigned three boreholes to sample; and each of the groups rotated on the eight boreholes, going through the three weeks of practical training. Following these two weeks of practical training, the cohorts were given an additional two weeks to go through the practical exercises on their own, without supervision; and thereafter to give feedback on their experiences. The individual trainee experiences were recorded in the Reflective logs. In the fifth and final week of training, the hydrogeologist assigned the cohort to two new boreholes (different from the sampled commonage farm boreholes) from one emerging farmers' boreholes (labelled KEI001 and KEI002). The emerging farmer had his own private farm where he operates for commercial and subsistence purposes. These new boreholes were suggested and randomly selected by the CWG in collaboration with the hydrogeologist. The boreholes being new (different from the ones the cohort had practical training on) were chosen for purposes of evaluating the cohort, post groundwater training. A third borehole (CDB003) was added to the assessment task by the hydrogeologist because the borehole was the only one using generator to pump compared to the rest of the 7 boreholes which were wind pumps. On the three boreholes (CDB003; KEI001 and KEI002), the cohort were assessed on their adoption of skill to conduct groundwater sampling and hydro-census. Included in the assessment was the submission of the Chain of Custody, to send the water samples to the NMU-Innovation laboratory, without supervision.

The detailed programme of the training and how the cohort was divided into groups is summarised in Table 4.5.

Table 4.5: Citizen-Science Training Programme held in Cradock Commonage Farms

WEEK 1	ACTION	DATE	VENUE
	Orientation and Introduction to the CS training programme – Hydrocensus and Groundwater sampling	**Day 1** **(10 – 13h00)** **(2pm – 4pm)**	Vusubuntu Cultural Village
	Theory and practical		Vusubuntu Cultural Village / Farm site
	Farm site practical (Groups split)	**Day 2** **Group 1 (8am – 11am)** **Group 2 (14h00 – 17h00)**	Identified Farm sites
		Day 3 **Group 3 (8am – 11am)** **12noon – Reflective session**	Identified Farm sites
WEEK 2	Repeat last week's practical sessions - Farm site practical (Groups rotate)	**Day 4** **Group 3 (8am – 11am)** **Group 2 (14h00 – 17h00)**	Identified Farm sites
	-Introduce use of the 'Xoras' Application	**Day 5** **Group 1 (8am – 11am)** **14h00-16h00 - – Reflective session**	Identified Farm sites Vusubuntu Cultural Village
WEEK 3 **(Determined evaluation)**	Groups rotate and deployed without trainer. Nyaradzo will be an outsider (participant observer) -Repeat previous work done on hard copy sheets and tablets	**Day 6 – Group 2 & 1** **Day 7 – Group 3** **Day 8 – Reflective session**	Identified farm sites Transport from community
Week 4	Repeat of week 3	**Day 9, 10 and 11**	Identified farm sites Transport from community
Week 5	Evaluation week	**Day 12, 13, 14**	New farm sites
End of Training			

4.5 GROUNDWATER SAMPLE LABORATORY RESULTS

Water is a basic human need, mainly for domestic purposes, (drinking, cooking, personal hygiene and laundry). As such, it is critical to determine the water quality status, how the water quality may affect the domestic and livestock uses. For illustrative purposes in this pilot study, in terms of the CS training conducted in Cradock, this section presents only the hydro-census and groundwater sample results.

The Hydrocensus and the groundwater sampling data for all ten borehole samples (including the two unfamiliar test sites on a private farm), recorded by the eight trainees, were organised by the researcher in Windows Microsoft Excel (version 2016); and they are in Appendix C. The captured information includes the physical parameters of the borehole sites and the chemical properties of the sampled groundwater at each site. The owners of the boreholes have not been informed of their individual borehole results; as such, the farmers' identities is not included in this discussion – for confidentiality purposes.

All sampling bottles were labelled with a special borehole ID (for example CDB001), which helped distinguish each sample for laboratory analysis and for the purposes of discussion in this study. The date and time of the recordings and the sampler (person collecting the sample) were recorded on the hydro-census sheet for each completed sample (see Appendix C). The collected samples were immediately stored in an iced cooler box provided by AEON, which was strictly used for collected water samples, until delivery for analysis at the NMU-InnoVenton laboratory – Institute for Chemical Technology and Downstream Chemicals Technology Station - in Port Elizabeth (see Figure 4.10 below). The InnoVenton laboratory not only offers analytical services and technology support for internal (NMU staff and students) and external customers but houses the Department of Science and Technology (DST) funded Microalgae to Energy project.

Figure 4.10: Cohort representative completing the Chain of Custody: Water samples ready for despatch to Port Elizabeth (NMU InnoVenton Laboratory)

Following the end of each hydrocensus and groundwater sampling week, a chain of custody was completed by the all 8 trainees. This exercise is used to track the collected water samples from the sample points in Cradock to the laboratory for analysis, certifying that each sample is a representative of the sampled borehole water (see Chain-of-Custody form in Appendix D).

The following result sections will review the groundwater sample data for all boreholes, used for the practical training of the cohort.

4.5.1 Hydro-census data interpretation for Three Test sites

At the time of the study, the commonage borehole information was recorded by the citizen-science trainees, with the sampling timeframe spread out between August – September 2017. This information is expected to help compare and assess the changes in any hydro-census related variables that may occur and future related studies, or groundwater management plans for the same area.

For experiential learning purposes, the hydro-census information recorded during the final week (Week 5) of the training, was part of the CS trainee's assessment, where they did not have supervision by the hydrogeologist, are shown in Table 4.6 (a) and Table 4.6 (b). The AEON hydrogeologist identified one familiar borehole to the trainees (CDB003) and two new (unfamiliar to the cohort) borehole sites, (KEI001 and KEI002), for groundwater sampling knowledge and the skills-assessment.

As mentioned in Chapter 3, the eight trainees were divided into three groups; and each of the group members took turns to record on the Hydro-census sheet and in the Tablet using the Xoras App.

Table 4.6 (a): Hydro-census Information for Three Borehole Test Sites - Final Assessment Week of CS training (without Hydrologist supervision)

WEEK 4										
GROUP 1										
	Longitude (ºE)	**Latitude (ºS)**	**Elevation (metres)**	**Time**	**Site Description**	**Site Type**	**Borehole depth (metres)**	**Casing Height (cm)**	**Casing Diameter (cm)**	**Pipe diameter (cm)**
CDB001	25.66313	32.22073	864	12:11:00 PM	1km from gate; house around…..	electric pump	48	8.5	15.5	0.2
KEI001	25.58711	32.09312	918	3:03:00 PM	next to the farmhouse	….	±13	21	12.5	4.5
KEI002	25.60875	32.11208	896	4:12:00 PM	On the road to Hofmeyer next to the farm; cemented dams	Borehole	±12	15	14	4
CDB003	25.67239	32.16897	919	1:19:00 PM	1km from the gate. There is a kraal around cemented dam	Borehole	…	0	5	3.5
GROUP 2										
KEI001	25.58709	32.09319	918	10:00:00 AM	we collected water from the tank ±200m from borehole and the pipe is underground	Borehole	30-40	27	18	5
KEI002	25.60875	32.11209	895	11:00:00 AM	Borehole is next to the pig sty, near the trees	Borehole	…	29	16	4
CDB003	25.67237	32.169	929	12:05:00 PM	± 300m from entrance gate behind the cattle kraal under the shed	Borehole	…	36	14	5
GROUP 3										
KEI farmBM001	25.60875	32.11208	894	3:10:00 PM	On the Hofmeyer road first cross on your left-hand side there is white houses and a kraal	Borehole	16cm	21.5cm	5	39 (13 pipes x3)
KEI farmBM002	25.67239	32.16897	919	1:25:00 PM	on the Tarkastad road next to Ruskamp; there is a gate on the right-hand side 5km in from the gate to the borehole site	Borehole	15.5	0	5	…
CDB003	25.5886	32.09221	931	4:00:00 PM	5km away from Kei first farm, turn left hand side there is a big dam on the left-hand side and two big houses	Borehole	…	12	26	5

Due to the length of the full hydro-census sheet in Appendix C, for this section, the researcher did not include the following columns: Borehole number, Area Photo number, Address and Telephone number. The full hydro-census sheet is in Appendix C. The EC Profile, Water Level and Slug test were not recorded; as the **hydro-census** training did not include these **parameters.**

Table 4.6 (b): Hydro-census information for Three Borehole Test Sites - Final Assessment Week of CS training (without Hydrologist supervision)

WEEK 4 (…. continued)										
GROUP 1	**Equipment**	**O, Open/ C, Closed**	**Use**	**Status (P-in use, U-not in used**	**EC, uS/cm**	**T (°C)**	**Sampled (Yes-Y/No-N)**	**Comments (On-site notes from observations and farmer conversations with trainees)**	**Area**	**Farm Owner**
KEI001	Borehole	closed	Domestic	P	3.32ms	23.1	Y	There are 2 dams; the one is filling water to the other dam; the water is salty and used for washing and laundry. There is irrigation around and cattle dung and skins	CDK	IYM
KEI002	electric pump	closed	Domestic and livestock	P	1021	24.4	Y	Borehole is situated in a clean surrounding area. There are onions around planted	CDK	IYM
CDB003	Borehole	closed	D&L	P	985	23.4	Y	There are cows around and the kraal for cows is near. There are shacks around. Tested the electric pump ; it runs about 4.8 seconds per litre; They use it 3 times a week for 12hours	CDK	IYM
GROUP 2										
KEI001	electric pump	closed	Domestic not for consumption	P	3.65ms	19.9	Y	Pipe passing under shed and there is a lot of cow-dung. Borehole is 30-40 m deep. The water is collected from second linked tank ; the water is for domestic use only not for consumption	CDK	IYM
KEI002	electric pump	closed	Agricultural and domestic	P	1056	22.1	Y	Next to the pig sty not from house and onions planted around it	CDK	IYM
CDB003	electric pump	closed	Domestic and livestock	P	1033	21.5	Y	Behind the cattle kraal; 1.80,1.53, 1.64, 1.59 therefore average of 1.59 per 500ml with four test runs	CDK	IYM

GROUP 3										
KEI farmBM001	submersible	closed	domestic, livestock and agricultural	P	1033	23.3	Y	Next to a kraal and there is a garden ; there are ducks next to the kraal; the water is running 3hours a day every week	CDK	IYM
KEI farmBM002	submersible	closed	Domestic and livestock	P	1084	21.4	Y	There is a kraal next to the borehole site and cows. To measure the strength it takes 0.7 seconds with 500ml bottle ; pumps once a day per week 7 up to 12 hours the water is running	CDK	IYM
CDB003	submersible	closed	Domestic	P	3.70ms	21.4	Y	1 hour a day every week; there were old hard boards and tyres next to the water. The owner of the farmer is not sure how deep is the hole ; They use the water only to wash clothes not for drinking because the water is too salty and the longitude and latitude are going to change because the water and borehole are not on the same site	CDK	IYM

4.5.2 Analytical Results for Three Borehole Test Sites

The data presented in Table 4.7 show the laboratory results of the chemical components of the three selected test sites taken during the final assessment week of groundwater sampling (5th – 6th September 2017).

Table 4.7: Results of Groundwater Sample data (Test sites) collected during the final Week of CS training (InnoVenton Laboratory, produced in December 2018)

AEON Sample ID	**InnoVenton Sample ID**	**pH**	**Conductivity (µS/cm)**	**TDS (mg/l calculated)**	**CO3 Alkalinity (calculated)**	**HCO3 Alkalinity (calculated)**	**P- Alk as mg CaCO3/l**	**T-Alk as mg CaCO3/l**	**F mg/l**	**Cl mg/l**	**NO2 mg/l**	**NO3 mg/l**	**PO4 mg/l**	**SO4 mg/l**
CDB003	2017-1934	7,42	959	582	40,76	413,30	20,38	454,05	0,69	47,37	ND	9,04	ND	34,11
KEI 001	2017-2098	7,42	3590	1968	133,06	483,60	66,53	616,66	1,49	693,81	5,01	27,07	ND	410,13
KEI 002	2017-2099	7,46	1117	588	131,31	354,68	65,66	486,00	0,75	65,23	3,47	14,72	ND	51,12

Groundwater sample bottles delivered to NMU-InnoVenton Lab, were checked for proper labelling, including the date and time sampled (as per Chain of custody and Equipment and Methods sheet in Appendix D). The groundwater samples in Table 4.7 above were interpreted, according to the South Africa Water Quality Guidelines for Domestic Use, (DWAF, 1998). Table 4.8 below provides the explanation of the classification scheme.

Table 4.8: Classification system used to evaluate selected Water Quality Standards based on Electrical Conductivity (Department of Water Affairs and Forestry, 1998)

Quality of Domestic Water Supplies, DWA & F, Second Edition, 1998	
Class 0	- Ideal water quality - Suitable for lifetime use.
Class 1	- Good water quality - Suitable for use, rare instances of negative effects.
Class 2	- Marginal water quality - Conditionally acceptable. Negative effects may occur in some sensitive groups
Class 3	- Poor water quality - Unsuitable for use without treatment. Chronic effects may occur.
Class 4	- Dangerous water quality - Totally unsuitable for use. Acute effects may occur.

Table 4.9: Groundwater quality within 3 selected borehole sites in Cradock (of selected major anions and parameters based on the Electrical Conductivity)

Nr	pH		EC mS/m	Cl mg/l	SO4 mg/l	F mg/l	NO2-N mg/l	NO3-N mg/l	PO4 mg/l
Class 0 Limits	5,0	9,5	70,0	100	200	0,70	6,00	6,00	
Class 1 Limits	4,5	10,0	150,0	200	400	1,00	10,00	10,00	
Class 2 Limits	4,0	10,5	370,0	600	600	1,50	20,00	20,00	
Class 3 Limits	3,0	11,0	520,0	1200	1000	3,50	40,00	40,00	
Class 4 Limits	3,0	11,0	>520	>1200	>1000	>3.5	>40	>40	
(upper limits)									

No.	Date	pH	EC	Cl	SO_4	F	NO_2N	NO_3N	PO_4
			mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CDB003		7,42	95,90	47,37	34,11	0,69	0,00	9,04	**0,00**
KEI 001		7,42	359,00	693,81	410,13	1,49	5,01	27,07	**0,00**
KEI 002		7,46	111,70	65,23	51,12	0,75	3,47	14,72	**0,00**

According to the Department of Water Affairs & Forestry (DWAF), and Department of Water and Sanitation (DWS), ground water needs to be sampled twice yearly; as ground water is generally stable in pristine areas, such as the Karoo (Department of Water Affairs and Forestry, 2000).

It is important to highlight the fact that in this study, the groundwater sampling, which took place was done for CS training purposes, to capacitate the young Cradock residents on how to conduct a hydro-census and groundwater sampling. The study did not incorporate a comprehensive set of chemical parameters to conclusively characterise the groundwater chemistry needed for robust baseline analyses. However, the training exposed the cohort to the South African hydro-census and groundwater sampling process, equipping them for possible application within their community in the future. It is important to note that the availability of domestic water quality classifications, contributes to the decision-making processes on the safety of the water supplied, or its viability for domestic supply within an area or community.

The Laboratory data provided by NMU-InnoVenton in December 2018 (Table 4.7) was imported into a calibrated Microsoft Excel Worksheet (DWS – Domestic Water Quality Standards). According to the Water Quality Assessment Guide of 1998, water quality is defined in terms of its microbiological, physical and chemical characteristics (DWAF, 1998). The water-quality guidelines classify a specific water sample based on the worst element, or parameter, including the colour-coded classification system (Table 4.8).

Based on the electrical conductivity (of 3 test sites – Table 4.9 above), the groundwater status for sites CDB003 and KEI002 is predominantly in the category of Class 1 (Good Water Quality – Insignificant risk, suitable for use, with rare instances of negative effects). However, site KEI001 water quality is Class 2 (Low risk, conditionally acceptable. Negative effects may occur in some sensitive groups).

4.6 CONCLUSION

The findings in this Chapter present a reflection on the Action-Research (AR) process and how this process built the knowledge and skills capacity of the Cradock community. This involved the adoption of Citizen-Science principles in the AR process, contributing to the skill development of eight youths, who engaged in groundwater monitoring training over a period of four weeks within the IYM-owned commonage farms. Citizen Science is first seen to facilitate the integration of the Cradock community and the AEON institutional structures in a collaborative way through the community roundtable meetings. These engagements formed building blocks upon which mental processes that contribute to the construction of capacity development emerged. Based on the Action-Research process outlined in this chapter, as well as on the observation and reflective journal notes made during the process, the researcher extracted themes, which are discussed in the next chapter, highlighting in detail examples from the 4-week groundwater monitoring-training processes.

CHAPTER 5: ANALYSIS AND DISCUSSION OF THE FINDINGS

5.1 INTRODUCTION

In this chapter, different themes and categories that emerged during the data-analysis phase of this study are discussed. The main aim of the study to establish how Citizen Science can be used as a tool for the Cradock community's capacity building, focussed on two aspects of groundwater monitoring: hydro-census and groundwater sampling. Below an attempt is made to provide answers to the key objectives of study, by elaborating on the identified themes and categories.

A summary of the themes and categories is presented in Table 5.1. Each theme is supported and validated against the literature and methodologies of this study, in order to explore similarities, contradictions and discrepancies. The narrations from the participants during the research activities are cited verbatim, as evidence of my understanding of the relevant themes. Certain "exact" words of the participants may be cited more than once, in order to illustrate different aspects of the discussion by the use of the ellipsis (….), and to indicate that some elements of a conversation have been left out for ethical reasons.

Furthermore, some words have been added to set the verbatim quotations within the original context that the actual conversation was made, and these are indicated with an enclosed square bracket […], in place of certain verbatim quotations, pseudonyms are used for ethical reasons.

The findings are presented in explorative format, supported by quotations of verbatim conversations of the participants from the transcribed interviews, reflective journals, community roundtable meetings (CRMs) and Pre and Post-tests. A short conclusion of the discussion will be provided at the end of the chapter.

5.2 CONTRIBUTION OF CITIZEN SCIENCE IN COMMUNITY-CAPACITY BUILDING

The interpretation of the study transcripts, such as reflective logs, relied significantly on the understanding of the participants' sense of place in the context of their engagement in environmental stewardship – groundwater monitoring in this instance. Knowledge of the supporting literature reviewed for this study also assisted in the analysis of the role played by citizen science (CS) in building community capacity during the Cradock youth groundwater monitoring training. The responses from this study's participants during the data-generation process, signify what McKinley et al. (2015) established as one of the core citizen-science outcomes - “facilitating stakeholder engagement in identifying problems and solutions, programme development, implementation and evaluation and public support for involvement in management decisions’’.

In this case, McKinley et al. (2015) assert that stakeholder engagement in citizen-science projects improves information exchange between the public and the scientist, thereby enhancing understanding of environmental issues and community responsiveness to the issues. It is my contention, therefore, that the articulations by the study community regarding their participation during the community roundtable meetings, interviews and the cohort’s groundwater monitoring training, contributed to the outcome of this study.

The intention of this chapter is to find a “golden thread” that seeks to explain how citizen science contributes to the capacity building of Cradock residents. At a glance, emerging sub-categories were identified during the data coding of the participants’ responses and thematic analysis. Sub-categories also emerged during engagement with the data and these fit into six themes. A summary of the themes and categories are provided in Table 5.1. The sub-category column contains examples of phrases, as expressed by the participants during the reflective journaling exercises (Chapter 3 of this thesis), as well as the phrases used by the participants in the telling of their stories and experiences during the study period.

The use of narratives and stories provided a different type of research material, which is oriented particularly to how humans relate to things (past, present), including associated actions and resultant consequences (Dahlstrom, 2014 and Moezzi et al., 2017)). The analysis of the data collected for this study revealed that citizen science significantly influences the process of scientific knowledge and skill-capacity building among the young and the aged. The six broad themes and ten categories that emerged from the analysis of the study data are presented below.

Table 5.1: A Summary of Themes, Categories, and Sub-categories

Themes	Categories	Sub-categories / Reflective statements
1.Limited Knowledge and Information on Shale Gas Development in Cradock	1.1 Limited knowledge and information on Shale Gas Development in Cradock, fosters debate on community roles.	"Nothing about us, without us" "Ward committees, SGB's, clinic committees, CDW's, sport council, political parties, faith-based organisations" "With the different approval levels of SGD, does the community have a say (Yes or No) regarding fracking?" "the community is not well informed"
	1.2 Limited information on Shale Gas Development (SGD) in Cradock affects community cohesion.	"Nothing about us, without us" "Untrustworthy" "Exclusion from previous discussions" "We need clarity on the truth regarding job opportunities. How many jobs and what skill levels are considered? Will people (Cradock) meet the criteria? What are the direct employment opportunities around fracking?" "A bit of knowledge about shale gas" "What is going to happen to the next generation" – section 2.3 "Immigration to the shale gas site – what guarantee is there that local people will be given preference?"

		"The different kind of information from companies because it is not empowering our communities." "The emphasis on profitmaking, rather than community."
2.Citizen Science stimulates stakeholder engagement	2.1 How Citizen science fosters stakeholder input and engagement	"We need to establish a structured forum" "Establish a study group – needs to assist in the information transfer" "We need more community meetings" "Nothing about us without us" "AEON must have an open line, so that we can put our concerns across through the structure we are going to set up here." "Use social media to best communicate with us – e.g. WhatsApp, Facebook, emails." "Involve other stakeholders in this process, such as Water Users Association, SANCO, Women's Organisations, Municipality, Department of Agriculture, and Department of Environment and Energy." The application criteria for the citizen science cohort not to disadvantage other community member groups. Identification and access to CS training sites (farms)

		In identifying community's issues of concern prior to potential SGD Aids empowerment for decision-making
	2.2 Citizen science facilitates the definition or classification of critical resources (prior to potential SGD)	"Water" – water pollution, "Human Resources" – "skills empowerment" "Land (security, access for drilling and facility, soil erosion) "Land security" "Bursaries" "Need for workshops and the technical information on protection of natural resources, such as water"
	2.3 Citizen science creates synergies between community and scientist, thereby contributing to improved project outcomes	"Need of simplified presentations" "Does AEON/NMU need information on current private businesses who could at least give the selection criteria information advice" (in preparation for citizen-science training) "We need a sifting mechanism to select the citizen science trainees, to avoid a huge turn-out, such as the 2015 SETA construction programme which had 200 people showing interest." "We do not want to exclude people; because some people are drop-outs even though they might have Maths and Science."

		"Stakeholders could identify within their existing local structures, how and who to elect as potential citizen-science trainees."
3. Citizen-Science training stimulates cognitive abilities.	3.1 Citizen Science stimulates the participants to envisage future success and to act to realise their ambitions. - Citizen science motivates potential community contribution to science	<u>Pre-test</u> "hardworking, I want to learn more about the groundwater and study further" "Better chances of employment" "Access to skills and be able to help out in the farming sector; as it lacks water monitors." <u>Post-test</u> "I want to be a Groundwater technician" "I am going to Middleburg because there is a place with boreholes, so I want to gain more in the training" "Engineering or geologist" "Study further at NMU" "To start-up my own business and also do groundwater monitoring around my area and teach my community about it." "Need to address human ignorance and lack of knowledge towards water quality and use." How can I get access to the equipment and the Xoras App?

		How will I be supported after the programme? "We have got a challenge, if filtering systems that are not working. Are you going to provide filtering system for us as a community, or what?"
4. Citizen Science promotes / builds scientific literacy	4.1 Citizen science promotes knowledge and skills capacity gain Experiential learning – reflective journal entries Theory discussion on Ground water in South Africa	What is Ground water and Hydro-census? Importance of Groundwater, Where is ground water stored? And how do we get ground water out of aquifers? "How to engage with the farmer during groundwater monitoring" "How to collect groundwater samples from the borehole; How to use the EC meter" "Recording using hydrocensus sheet and electronically (tablet) and sending samples to the laboratories for further scientific testing." - "what is meant by saturated zone? *(Participant Four, P4 – Day 1 of training)*

5.2.1 THEME 1: Knowledge and Information on Shale-Gas Development in Cradock

The problem statement for this study describes how concerns about non-inclusive community consultation and the non-availability of simple and specific information on Shale-Gas development impacts on resources and associated opportunities contributed to the suspension on hydraulic fracturing in the Karoo by the South African government (see Chapter 1). Similarly, participant responses during the 3 CRMs, with an attendance of between 50 people (CRM1), 30 people (CRM2) and 45 people (CRM3), reflected a limited to lack of information and understanding on SGD in this community. Thus, fostering debates about Cradock's community roles and responsibilities in the SGD dialogue, and potentially affecting this community's interest in development of any kind. An understanding of the background to the SGD prospects in the Karoo region of South Africa was thus required, in order to develop an appropriate approach that would address these and other concerns. The sections below further elaborate on this theme.

5.2.1.1: Category 1.1 - Limited information on Shale-Gas Development in Cradock, fosters debate on community roles

From the review done (Chapter 1) about the background of this study, it is apparent that there was an existing lack of knowledge and clarity about risks and opportunities of the proposed SGD in the Karoo region. Despite public consultations and engagements with companies that applied for permits to undertake shale gas exploration in this region, there still existed a lack of knowledge about the interested groups within the Karoo communities who are already involved in the SGD dialogue at national level. This formed part of the motivation to commence the AEON Karoo Baseline Study, with citizen science being one of the paramount components.

Recorded reports state that some South African government agencies lack knowledge about the shale-gas industry; and they do not have the technical and administrative capacity to address the social and environmental challenges of shale development (for example, ASSAF, 2017; Morkel and de Wit, 2018). The data generated by using the Action-Research approach, proved that the Cradock community does not have substantial SGD knowledge; and it needs to understand – as well as to identify – their roles in the SGD debate.

During the first community roundtable meeting (CRM1), held on 25 October 2015, at the Cradock Vusubuntu Cultural Village, one of the participants asked a question:

> *[…] with the different approval levels of Shale-Gas Development, does the community have a say (Yes or No) regarding fracking?* (Unidentified community member during the first CRM held at Vusubuntu Cultural Village, Cradock, Appendix A)

Similarly, the participant expressed that the lack of knowledge on the shale-gas development process in South Africa causes them (Cradock community) to be unsure of their role in the decision-making process (for or against shale-gas development), let alone the whole community, particularly the poor and marginalised. The CRM1 constituted the start of the community buy-in step of Phase One data-generation process; and, this seemingly promoted dialogue on SGD information and knowledge-sharing between the researcher, the Cradock community and the AEON scientists.

It is important to highlight that community engagement generally facilitates the identification or prioritisation of citizen concerns for purposes of project planning, thereby helping during decision-making and the evaluation of a community plan (Community Planning Toolkit – Community Engagement, Community Places (2014). This was evident in the CRM participants' responses during the buy-in phases of the study (Phase 1 to 3), where it became apparent that the engagement process provided a space in which the general Cradock community members, and representatives from different organisations active in the town, could openly criticise a process.

Following the non-attendance of notable stakeholders from Cradock, the participating community members in either of the CRMs could also cross-examine and express to the researcher the need and importance of engaging more Cradock stakeholders during the CS process.

For instance, during CRM1, the participants observed and highlighted during the meeting the absence of representatives from the Ward committees, School-Governing Body (SGB), Clinic Committees, Community-Development Workers (CDW), Sport Council, Political parties and Faith-based Organisations. A request by the CRM1 participants was made, to the researcher, to invite and engage these non-represented stakeholders in the next community-buy-in phase (Report on the 1st Cradock Shale Gas Community Roundtable, 18 May 2016).

Sisk et al (2001) describes how participatory approaches fall short when participants or communities believe that they are being used to formalise already made decisions or that their efforts will not matter in the future. Additionally, Manor (2004) notes that when ordinary people realise that what appears to be an opportunity for greater influence in practice is rather a cosmetic exercise, they feel conned and betrayed. As much as this study had a clear transparent goal, stemming from a transparent KSGBS which was supported by the Department of Environmental Affairs, the delivery of this message during CRM1 may not have been clear to the Cradock residents participating. Simply inviting Cradock residents, stakeholder representatives to the first CRM, creating a collaborative space and recording community voices seemingly was not enough to empower citizens and promote community engagement during the KSGBS. Understandably so, CRM2 (held May 2016) was then organised, and the omitted stakeholders from CRM1 were invited. Invitations for CRM2 were sent to the mentioned missing stakeholders in CRM1, by the researcher in collaboration with the CWG, although the attendance was low compared to CRM1 by 40%. In order to engage more stakeholders in the CS process, a third CRM was therefore organised, where a 50% increase in stakeholder attendance was recognised (Figure 4.2).

To further understand the Cradock stakeholder participation, particularly in the CRMs, the researcher conducted 8 semi-structured one on one interviews and 3 focus group discussions with the CWG members. These sessions were opportunities to explore among many, the reasons why the Cradock residents and stakeholders would not attend CRMs including why they participated in the CRMs. Assumptions were raised about power relations within the community, especially between the leaders, the municipality officials and normal residents - where community leaders may have been using their positions in power, to influence decision-making in community engagement meetings. This may have been the case given how Gaventa and Valderrama (1999) describe how the participation of the community in any development process is about power and how it is exercised by different social actors in the spaces created for interactions between community members and development practitioners.

Recurring statements such as *"Nothing about us without us",* (see in Table 5.1) were seemingly indicative of how the community valued consent and engagement in any ongoing or potential development programme within their town of residence. Community members were found asking the researcher questions such as *"what are the intentions of the institution or organisation when they become in contact with the concerned communities?".* This question was undeniably asked by Cradock residents during every CRM, interview session and focus group discussions. Recurring questions posed to the researcher included,

> *"What are the benefits of the proposed SGD to the community?"* and
>
> *"Is the CS programme an employment opportunity for us*?"

The questions reflected a lack of understanding on the purpose of AEON and the Baseline Study, which was being viewed by the Cradock community members and stakeholders as a potential employment opportunity and not as a benchmarking activity for NMU to embark on before any SGD can be considered in the Karoo region as a whole. These reflections also highlighted that although discussions may have started (with the community leaders or the IYM officials), the poor and marginalised communities still needed to be engaged and to participate in their numbers in the SGD debate processes including the CS programme. In order to build the trust between the researcher, AEON and the resident community, existing community structures (Section 5.5.2) were used in collaboration with the IYM, leading to the organising of CRM2 and CRM3.

Community participation in Cradock was observed to be an expected form of social responsibility which retained honour for other members of the community and to the institution or agencies organising any engagement meetings. As such the understanding of the existing community dynamics including the power relations within, were acknowledged as they in turn challenged the researcher's and institution' (NMU) belief on the whole community. CRM participants expressed how the power issues seemingly existing in their community, needed to be brought forward and addressed collaboratively to avoid undermining of the participatory processes and regain the community cohesion and trust (Section 5.2.1.2).

On the other hand, one could wonder if the privileged population of Cradock (white community residents and farmers, the black landowners and business owners), or government officials influenced any decision-making related to development programmes which may or may not benefit the whole community. As earlier highlighted during CRM1, elite residents were the ones who had privileges including access to knowledge and information about the anticipated SGD in the Karoo region and were engaged more in related debates in the municipality or the region. Sources of SGD information stipulated ranged from online websites and being invited to SGD debate forums (Section 5.2.1.2).

5.2.1.2 : Category 1.2 - Lack of information on SGD in Cradock affects the community's' cohesion

The lack of information on SGD expressed by the participants (Lingelihle and Michausdal residents) in this study resonates with their community-cohesion status. The Local government Association (2002) describes community cohesion as how well (or not) communities are knitted together as a whole, in terms of their existence of shared social values, which enable communities to work together to pursue common goals and create a sense of belonging and citizenship. During Phase One of the study (see Chapter 3), the Cradock residents participating in CRM1 (from Lingelihle and Michausdal), indicated how they felt excluded from the SGD engagement process. It became apparent during this research phase, that information about the potential SGD in Cradock was unclear and unknown within this community. This status was affecting the Cradock residents' trust in development companies and external bodies engaging with the community about SGD at the time of this study.

The spontaneous queries of the CRM participants during the research process provides evidence of the lack of knowledge and clarity on SGD prospects in the area. Statements, such as "*the community is not well informed*" (Table 5.1; Theme 1) came from participating Cradock stakeholders in the CRMs. This was despite the initial introduction of the CS study by the researcher, as a student from the Nelson Mandela University. Comments, such as *"untrustworthy"* were spoken by the community roundtable participants (representing the poor and marginalised); as they reflected on seemingly rich and privileged Cradock stakeholders, who were involved in the national SGD dialogue at the time of the study and had an advantage (information access) over the marginalised community members.

While these expressions (more in Table 5.1) could have been attributed to the inter-personal qualities facilitated by the citizen-science process (Community Roundtable Meetings, see Chapter 3), it was also deduced that the participation of Cradock residents during the CRMs was affected by their lack of sufficient information on the anticipated SGD. Lack of internet access and efficient channels of communication to provide SGD related information, were the major information barriers expressed by the Cradock community members attending the CRMs. The main reason for alluding to this was, information about SGD being available to the elite (described in the CRMs as the privileged community members, white commercial farmers and community leaders holding influential positions in the community), in comparison to the poor, under-privileged Cradock community members.

The word “us” was repeatedly mentioned in the CRMs, as the participants referred to themselves (as the poor, black or coloured residents) as well as other under-privileged fellow residents (who did not have access to SGD-related information).

> *“Nothing about us, without us” (CRM 1 participants)*

This may be indicating a deep awareness of the reality within a larger community group within a marginalised society. Similarly, in the same CRM1, the participants revealed that they needed more information on SGD. The following questions were raised by the participating residents:

> *“We need clarity on the truth regarding job opportunities. How many jobs and what skill levels are considered? Will people (Cradock) meet the criteria? What are the direct employment opportunities around fracking?”*

Similar questions were raised in CRM2 and CRM3, as well as in a series of *ad hoc* planning and review meetings, that were held between the researcher and the CWG, to bring clarity and understanding. Using the reflective process of the AR approach, each meeting addressed these concerns, respectively, through the collaboration between the CWG by means of the local IDP and LED forum meetings, as platforms to respond to these questions. It was only during the third CRM that diverse stakeholder groups from the study area were represented; and detailed presentations were made in CRM2 and CRM3 to address these concerns and questions.

The detailed presentations given included one during the third CRM where a simplified model of hydraulic fracturing was presented by the AEON scientists. The Cradock community participants gained a visual understanding of what takes place during hydraulic fracturing and its potential impacts to the surface and underground environment, particularly on the community’s groundwater resources (Figure 5.1).

Figure 5.1: Simplified hydraulic fracturing model presentation by AEON scientists during CRM3 at Vusubuntu Cultural Village, Cradock (18 May 2016)

Further questions were posed by the participants during the second community roundtable (CRM2), including;

"How sustainable is fracking?"

"Will we run out of water?"

"What happens after 10 years if fracking is to happen?"

*(*Questions during CRM2)

These questions were indicative of a high sense of urgency among the Cradock poor communities to know more about the proposed SGD in the region and their role as residents in the potential SGD site area of Cradock. According to the UKLGA (2004), common vision and sense of belonging forms part of community cohesion; and it is the basis on which an individual's trust with others can thrive.

Meanwhile, study participants in the CRM1, expressed the opposite, as they referenced the above-mentioned statements,

"Exclusion from previous discussions"

and

"Nothing without us about us"

These statements indicate how the ordinary, underprivileged Cradock community members were not informed or involved in the SGD discussions (at local level), in as they were expecting to be.

Cradock is likely to continue asking more questions to find clarity on SGD and related concerns to community cohesion (between the elite and the poor), if the related information is not presented clearly. Freely expressive statements, such as the above, are also central to the CS process stages, of providing knowledge and answers to local community concerns (Chapter 2; Section 2.3.1).

As such, a potential role that CS plays is in empowering the community to make informed decisions and to act in their interests.

5.2.2 THEME 2: Citizen Science facilitates stakeholder engagement

In Chapter 2 of this study, I discussed citizen science principles, guidelines and best practices, which confirm that the facilitation of stakeholder engagement in identifying problems and solutions, is one of the notable CS process outcomes. Within this theoretical understanding, CS influence on the engagement opportunities opened for study participants, can be interpreted as a way whereby CS stimulates communities to voice their inputs. This is especially experienced if the set-up is interwoven within existing official structures; and if the connection to local societal benefits exists (Danielsen et al., 2005).

In other words, communities are able to express their understanding of the current status of affairs, highlighting concerns related to critical resources and possible solutions to these issues.

5.2.2.1: Category 2.1 – Citizen Science fosters stakeholder input and engagement

The findings of this research suggest that applying CS principles and guidelines, provides participants with a pathway of what can be regarded as the "right" way to engage local stakeholders. Cradock stakeholder participants voiced their thoughts on the "right" strategy, as that which is the "right way to engage" them as a community; and one which would be effective in sharing information and knowledge about SGD and their response to the CS focus of the study (see Table 5.1: Theme 2). In addition, engagement with those Cradock residents who wished to establish relations with external organisations (for example AEON), was also facilitated though CS the process.

The articulation of the "right" engagement of communities was voiced, following the notion of "*exclusion from discussions*". This was raised by the Cradock stakeholders participating in the initial community-engagement phases (CRM1 and CRM2). As such, their (stakeholders') thoughts and ideas about right strategy included how knowledgeable residents or officials were about SGD. Officials in this context, referred to members of the community within the local Municipality, community leaders, the researcher, AEON scientists and other SGD interested stakeholders and companies. The statement "*Nothing about us without us*", dominated the conversation as stakeholders expressed the need for inclusive community engagement.

Therefore, CS provided a platform for dialogue between the scientists (the researcher and AEON scientists) and non-scientists (Cradock community and leadership). The stakeholders further mentioned that no activity in their area would be done without their knowledge and contribution - *"nothing about us without us"* - as the residents of the land, who would be affected by SGD. The CRM1 and CRM2 undoubtedly revealed the Cradock community's expressions on the expected or "right" strategy to engage them as a whole community, without excluding any residents, during the study. Statements, such as the following, were captured: -

> […] "*We need to establish a structured forum*" *(*views from Focus-Group Discussion, CRM 1)
>
> and
>
> "*Establish a study group – needed to assist in the information transfer*" […] (views from Focus-Group Discussion, CRM 2*)*

The statements show that the Cradock residents felt let down by the way most of the community was being left out, and not represented, or included in any of the SGD-related dialogues taking place in the community. A statement from one of the community stakeholders suggested the need for "*more community roundtable meetings*". However, they acknowledged the CRMs held by NMU-AEON and the researcher as independent research, adhering to institutional rules of engagement, which do not allow them to be constantly held in the communities. For example, the stakeholders who were participating in the CRM1 highlighted that the "right" way to engage the Cradock community in the KSGBS was: -

"AEON must have an open line, so that we can put our concerns across through the structure we are going to set up here";

and

"Use social media to best communicate with us – e.g. WhatsApp, Facebook or emails"

and

"Involve other stakeholders in this process, such as the Water Users' Association, SANCO, Women Organisations, Municipality, Department of Agriculture, and Department of Environment and Energy"

Given that this is a collaborative study, the researcher's response to the above-mentioned CRM stakeholder contributions was to employ the AR Approach cyclic steps of Reflecting – Evaluating – Planning - Acting on further data-generation steps, in order to meet this study's objectives. The notion raised of improving community engagement, establishing "*a structured forum"* came out strongly from the 50 CRM1 participants. In this context, the structured forum was therefore formed under the facilitation of the Inxuba yeThemba Municipality (IYM) officials. The membership of this forum was determined by the stakeholders present at the CRM 2 held at Vusubuntu Cultural Village and the respective members named the forum "the Cradock Shale-Gas Working Group" (CWG).

Below is Table 5.2, showing the roles or positions held by each elected member of the Cradock Working Group.

Table 5.2: Composition of the Cradock Working Group (CWG)

	Affiliation within Cradock	Gender	Role played in the CWG
1.	Emerging farmer	Male	Chairperson
2.	IYM Manager	Male	Secretariat
3.	IYM Manager	Male	Overseeing the Secretariat
4.	Businesswoman and farmer	Female	Women in Agriculture representative
5.	SANCO	Male	SANCO representative
6.	ANCYL	Male	Cradock Youth representative
7.	Businessman	Male	Men in business representative
8.	Businesswoman	Female	Women in cooperatives or business representative

It is important to note that the members of the CWG each were representatives of at least one stakeholder group within Cradock (for example, the Chairperson, who was a representative from the emerging farmers). Through collaborative engagements between the researcher, IYM officials (who were the gatekeepers to this study) and the AEON, the roles of CWG were defined, as listed in Box 4.2 of Chapter 4.

The basis of establishing a representative group (CWG), reflected Bonney et al. (2009) conventional CS process level of “forming an evaluation team”, which was alluded to in Chapter 2. This step requires the community concerned to voluntarily be involved, following agreed-upon criteria by the concerned stakeholders. The working group was representative of the active stakeholders, who were participating in the CRM dialogues; and they were selected to represent Cradock community’s concerns about the CS process to the researcher; and they contributed to the process collectively (Figure 5.2). See also Appendix B with the concerns and issues raised during CRM1.

Figure 5.2: Reflective Discussions during CRM1 (Chairperson of the Cradock Working Group, at the time of study), giving a groups' report back. Venue: Vusubuntu Cultural Village, Cradock (25 October 2015)

It is also worth noting that the CWG developed an engagement bond, what can be termed 'trust', with fellow community residents, as well as empowering them to participate and represent the community in the selection of CS trainees for groundwater monitoring and training. Examples of comments and contributions made during CRMs by the stakeholders are discussed in Section 5.2.2.3 (Category 2.3). Statements given, such as:

"We do not want to exclude people because some people are dropouts; even though they might have Maths and Science",

and

"We need a sifting mechanism to select the citizen-science trainees, to avoid a huge turnout, such as the 2015 SETA construction programme, which had 200 people showing interest."

These were repeatedly reinforced by the CWG during *ad hoc* planning and reflective meetings ahead of the cohort-selection process, designing of the CS recruitment advertisement (Appendix D), as well as the shortlisting and interviewing process of the selected CS trainees.

In reference to the objective of this section – how CS fosters stakeholder engagement, the Community Roundtable Meetings illustrated the importance of involving or reaching out to all members of the community in any research programme from the beginning. What could be surprising and interesting in this case (as earlier mentioned) is that basic lessons had to be learnt by the responsible persons for the KSGBS and the CS study (AEON and the researcher), the local municipality (IYM), the CWG and the community members, who were aware of the CRMs. Although in the first CRM, community members and stakeholders attended; yet, according to the participants' responses, there was no true representation of all the concerned Cradock residents – leading to CRM2 and CRM3 being convened. As such, the CS process could not progress until there was a consensus to move forward between both the KSGBS and the CS study; since the two processes shared a similar study area (Cradock being the pilot study area of the KSGBS).

In addition, late advertising, or notifications by the local municipality of any CRM being held, was mentioned in the CRMs, and as one of the contributing factors towards the low attendance of the participants in these CRMs (particularly CRM2). This may have been attributed to the inability of the local municipality to effectively communicate with the local community members on the planned CRMs; the inability or priorities of the local community members in response to the call to attend the roundtable meetings. Notably so, through all four CRMs, one came to an awareness that bottom-up processes are crucial in allowing the articulation of community concerns, and for addressing them in a collective manner.

5.2.2.2: Category 2.2 – Citizen Science enables collective classification of community-critical resources (prior to potential SGD)

Emanating from the three community roundtable meetings held during Phase 1 and Phase 2 of this study and given the study participants' expressed limited understanding of SGD, the PRA tools used afforded them the opportunity to define and classify critical resources within Cradock and in the surrounding farming areas. From the participants' responses, it became clear that the possibilities of SGD in Cradock, brought uncertainties in this community. Uncertainties raised, for instance, focussed on the potential SGD impact on land and water resources – in terms of possible land displacement and possible water pollution, respectively.

During CRM1, the 50 participants were divided into four groups; and they embarked on a ranking exercise, where water was listed as the greatest critical resource, for which the community were concerned about - if SGD should take place in Cradock (see Insert 1 below taken from Table 4.1(a), Appendix B).

Insert 1: Ranking of the highest critical resources by stakeholder participants during CRM1, Cradock (Extract from Table 4.1 (b), Question (e), Appendix B)

	GROUP 1 (8 participants = 16%)	**GROUP 2 (10 participants = 20%)**	**GROUP 3 (15 participants = 30%)**	**GROUP 4 (17 participants = 34%)**
e) Which are the critical resources within the community which need to be considered in the SGD process?	• Water • Human resources • Land (Access for • Drilling and factory or facility)	• water pollution • Land security - guard against soil erosion, etc minerals	• water • skills empowerment • bursaries • gas • land • oil	• the technical information on protection of natural resources (e.g. water) • Workshops

Participants in CRM1 further asked:

> "*What is the effect of the gas if it seeps through the cracks into the soil and the underground water resources?*"

Contributing to the discussion about the concerns over water-resource pollution, and how water is a scarce resource in Cradock (and Karoo as a region), the participants had further questions including:

> *"How sustainable is fracking? Will we run out of water? What happens after 10 years if fracking is to happen?"*

It became evident that, for the CRM1 participants, their understanding of the critical resources of concern was inspired by the support they needed at the time of the study. These included, human resources and bursaries concerns, as listed in Table 4.1 (b) (Appendix B). The collaborative process of CS is seen to have awakened in Cradock residents the desire for a secure future in terms of land security, sponsored education ("bursaries") and skill development prior to potential SGD, which could be attributed to the 2016 unemployment rate for the municipality (Inxuba yeThemba Municipality) of 16.8% at the time of this study (ECSECC, 2017).

In this regard, the participants acknowledged the importance of seeking clarity with regard to the prospects of SGD, in order to ascertain their envisaged future.

From the above-mentioned CRM participant responses, attending to the ranked critical resources, demands an enabling process to equip the community with the necessary skills and the capacity to manage the resources prior to potential SGD, as well as considering the future generations (sustainability). This inspired the focus of this study, in which the researcher's approach became geared to capacitate the Cradock community through a selected cohort, by training them to conduct groundwater monitoring and to achieve an empowered community in this regard (see Chapter 3, Section 3.6).

5.2.2.3: Category 2.3 - Citizen Science creates synergies between the community and the scientists

In related community-engagement views, the Cradock residents participating in the CRMs (stakeholders and general community members) expressed their willingness to collaborate with the researcher in this study; as, for example, reflected in statements, such as:

> "*Does AEON need information on current private businesses who could at least give the selection criteria information advice?"*

This indicated a voluntary expression to collectively engage with the researcher in meeting some of their listed needs in Table 4.1(a). Given that this had to be a collaborative CS study, the researcher paid attention to the ideas and statements mentioned by the participants, which also contributed to the collective development of a selection of criteria for the CS cohort.

Ideas that came from the CRM participants, Cradock community leaders, the CWG and the AEON scientists, included the following:

"Stakeholders could identify within their existing local structures, how and who to elect as potential citizen-science trainees."

CS, therefore, at this stage of the research contributed to the creation of synergies with the study community, thereby illuminating new perspectives into decision making, CS training programme development and improved outcomes. It should be noted that contributions from the stakeholders who were resident in Cradock, the CWG and the researcher and the scientist (trainee) assisted in the design of a cohort of criteria and the selection process. The selection criteria (see also in Section 3.3.3.2) for the CS trainees were endorsed by the IYM, the CWG and the AEON scientist, who trained the trainees; and these criteria was included in the advertisement of the programme at the local council's noticeboard (Figure 3.5).

5.2.3 THEME 3: Citizen-Science training stimulates cognitive abilities

The Citizen-Science training in the groundwater monitoring aspects of the hydro-census and the groundwater sampling, highly resonated with the community's highest ranked critical resource of water (Section 5.2.2.2). As stated in Chapter 3, water is a scarce resource in the study area; and the possibility of SGD in Cradock raised considerable concerns from the community – and particularly its impact on ground water. The uses of groundwater in Cradock range from farming (livestock and crop production) to household use. Within the selected borehole sites (in commonage farms), the farmers mainly use ground water, which runs the risk of running dry, as a result of the scarcity of rain in the Karoo region. Whether the water is suitable for human consumption or not (including livestock use) at local level (even if SGD does not take place) was one of the purposes for the CS training.

5.2.3.1: Category 3.1 – Citizen Science stimulates participants to envisage future success and act to realise their ambitions

The impact of CS on human well-being can also be interpreted as a channel, through which the cognitive abilities are stimulated, whether male or female. The cognitive engagements and abilities facilitated by the CS cohort training of eight (8) Cradock youths, reveals how the young people were able to think and express views about their own self-development. They were able to perceive their capabilities in the present, whilst visualising their future, as skilled citizens, to conduct groundwater monitoring.

Emanating from the first Focus-Group Discussion (FGD1) with the CS cohort, the researcher needed to explore their groundwater monitoring capacity and skills status, including their motivation in being part of the training (See Table 4.2 in Chapter 4.). The cohort, composed of five (5) females and three (3) males, who are classified through the letter P (participant), each linked to a numerical number (P1 – P8). Since the training was planned to be centred on the two aspects of groundwater monitoring (hydro-census and groundwater sampling), all eight trainees expressed their desire to learn about these.

The cohort also stated their expectations for the training programme, which included:

- To learn about the opportunities and the benefits of the training;
- To learn more about SGD details; and
- To learn how to determine whether water (surface or ground) is fit or unfit for consumption.

Stemming from the cohort's responses, the introduction of CS was an opportunity for each of them to contribute to the science of groundwater monitoring at the community level; and to inspire them to start their own income-generating projects that related to the skills gained during the CS training. The trainees seemed to realise that their potential success in the groundwater monitoring training programme, might open up future opportunities.

This was also mirrored by the Pre and Post test results (Appendix C); as each of them responded to these career-related questions, for example: -

Pre-test questions

- *Question 3 (Q3) - What motivated you to join the citizen science programme?*
- *Question 6 (Q6) - What are your career interests in line with the citizen-science groundwater monitoring training programme?*

Post-test questions

- *Question 3 (Q3) – How has the citizen-science programme experience impacted your initial motivation to join?*
- *Question 8 (Q8) – What are your career interests, following the completion of the citizen-science groundwater monitoring training programme?*

The above Pre and Post training questions (captured in greater context in Appendix A), yielded responses that the trainees already envisage possible employment opportunities to emanate from the skills gained from the training. For example, responses, such as one from P4 for Pre-test Question 6, "*What are your possible career interests in line with the citizen-science groundwater monitoring-training programmes?*" (see Table 5.3 (a)) These included:

“To become a groundwater technician”

In addition to the ambition of being employed as a groundwater technician, joined the training programme; as they envisaged themselves making a difference in the South African farming sector; once they had gained groundwater monitoring skills. P1 further stated:

> *“Access to groundwater monitoring skills in the field; and being able to help out in the farming sector; as it lacks water monitors.”*

P2 also stated that they needed to study further, learn more about groundwater monitoring; and envisaged making an impact in the town of Middleburg, known to for having many boreholes that needed to be monitored.

In terms of P2’s career interest, they stated:

> *“I want to study more in citizen science and ground water. When I complete my training, I am going to Middleburg; because there is a place with boreholes.”*
> *[…]*

From the above two ambition-related statements, it is evident that cognitive abilities within the participants were not ending or stopping at the training phase; but they also wanted to be part of the training; since this gave them hope towards a designated identity. This begins with improving on opportunities, for them to achieve the identity of a successful citizen, for instance in the farming or water management sector. For example, as illustrated in Table 5.3(a) below, the responses from P1 and P2, including a third participant, P4, to Question 6 of the Pre-test question discussed above.

Table 5.3 (a): Question 6 of the Pre-test results for selected trainees (P1, P2 and P4)

Participant (P)	P1	P2	P4
6.What are your possible career interests in line with the citizen science groundwater monitoring training programmes	Access skills in the field be able to help out in the farming sector as it lacks water monitors	To study more in citizen science groundwater monitoring when I complete my training, I’m going to Middleburg because there is a place of boreholes, so I wanted to go and gain more	Ground water technician

On the other hand, in the Post-test, the same participants (P1, P2 and P4), reflected on their career interests which did not change from the period before to after the 4-week groundwater monitoring training (see Table 5.3 (b) example below from the Pre and Post-test in Appendix C).

Table 5.3 (b): Question 8 of the Combined Post-test result for selected trainees (P1, P2 and P4

Participant (P):	**P1**	**P2**	**P4**
8.What are your possible career interests in line with the citizen science groundwater monitoring training programmes	being able to monitor the water in the communities and farms and maybe open a monitoring company	I wanted to go and study further if NMU will be available short courses but for now I'm going to look for a job that I can test some water and sampling the water	Ground water monitor specialist

Citizen science in Cradock therefore seemed to contribute to career aspirations of the cohort, through providing potential roles, skills and resources which each of them identified with and aspire towards.

Table 5.3 (c): Combined Post Test results for Question 8

	P1	P2	P3	P4	P5	P6	P7	P8	P9	Major Theme
8.What are your possible career interests in line with the citizen science groundwater monitoring training programmes	Being able to monitor the water in the communities and farms and maybe open a monitoring company	I wanted to go and study further if NMU will be available short courses but for now I'm going to look for a job that I can test some water and sampling the water	Geologist	Ground water monitor specialist	Engineering or geologist	-	-	To start up my own business and also do groundwater monitoring around my area and teach my community about it	to become the inspect of the groundwater or to become farm owner and sample my own water or groundwater specialist	- Water monitor in the community; - Open a specialist monitoring company; - to study short courses - geologist; - engineering; - get a job and teach the community about protecting groundwater; - Farm owner

Acquiring knowledge about the features and status of the water-monitoring sites during the training, motivated the cohort (for instance P4), to develop an urgency to contribute to positive change in the community soon after the training.

The CS training did not only result in development of identity and aspiration in terms of career interests and interests in further learning, but notable cognitive development that took place. For example, on aspects including critical thinking and application skills; understanding of concepts such as hydrocensus and groundwater and the parameters linked to these processes. Before engaging into hydrocensus and groundwater training, the cohort were exposed to theoretical and practical training of these aspects. It is through the expressions given in the cohorts' reflective logs that cognitive ability development is identified. One can refer to the responses of the cohort to the Pre and Post test questions on the definition of hydrocensus (Question 4 (c, i) and groundwater monitoring (Question 4 (a, i) (Appendix C). An improved understanding of these concepts reflected significantly the knowledge and thinking capacity development of the trainees after the CS training.

Another example reflecting a growth in the understanding of new concepts is from, Group 2 trainees (P4 and P6), during Week One of training (Appendix C, Reflective Logs). P4 indicated that they *"learnt about electro connectivity. More aware on how to monitor water in general"*. Meanwhile, P6 had an in-depth explanation of what they learnt in the same first week of training.

> *"I learned a lot of things. How to use GPS how to fill in hydrocensus sheet. The important part when you take water sampling. You must use fresh water. Use 3 bottle and you must rinse it first mark all slides as well as top of the lid. Be sure your bottles are tightly close and place it in the cooler box"*

During Week Two of training, P8 indicated the following,

> *"I learnt that the submersible works with electricity or the generator and you have to switch on the submersible before taking the samples and you have to let the water up to 5-10 minutes to learn how to fill in the hydro census on the tablets. I learn how to get in the app and what I must fill in the app"*

The above expression reflected significant knowledge and skills development in the use of technology (Xoras App) and in collecting water samples from a submersible borehole.

The engagement of the cohort amongst themselves and with the researcher from the onset of the training to its completion, portrays to what is considered as a positive affective cognitive feeling that is observable in people's perseverance in pursuing an activity that requires time, effort and or concentration (Lehmann et al. 2012; Schaufeli, 2014; Simpson, 2009). The hydrocensus data entries by the trainees, reflective journaling (Appendix C) and following groundwater monitoring protocols throughout the training, enhanced the trainees' critical thinking, differentiation, and application of skills.

5.2.4 THEME 4: Citizen Science promotes scientific experiential learning

Responses from the cohort continued to reveal that citizen science informs intellectual processes that underlie complex individual behaviour, linked to stimulating scientific and experiential learning. This confirms the theory of experiential learning, which specifies that it begins with a concrete experience, but is followed by learner reflection, and then application of the knowledge or skills gained (Kolb, 1984). The scientific-experiential learning during CS training, involved engaging the eight trainees in the theoretical and practical experiences of groundwater sampling and hydro-census. This also encompassed the reflective journaling process (see Appendix C). In doing so, using reflective logs, the trainees were exposed to a different way of learning and understanding the groundwater monitoring processes; as they applied individual observation skills and reflecting in a journal format by following these three themes: -

a) Knowledge generation or experience *("I Noticed")*
b) Reflecting on the experience or knowledge gained *("I Learned")*
c) Applying the knowledge gained, or the lessons learnt *("I Tried")*

a) Knowledge generation or Experience ("I Noticed")

The Cornell lab of Ornithology in Australia, states that part of being a citizen scientist includes recording observations and discoveries. The eight (8) CS trainees were given reflective logs at the beginning of their groundwater training, to journal or record their reflections for every day of the training until the last day (see Appendix C). As recorded in Chapter 3, the trainees were divided into groups of three, according to the available resources (equipment, including the trainer); and it should be noted that for each borehole site, the group members took turns (per site) to practise hydro-census and groundwater sampling procedures (Figure 5.3 and Figure 5.4).

The composition of each group was determined systematically, whereby each trainee was given an opportunity to pick a numbered piece of paper (numbered 1, 2, or 3); and everyone who picked a piece of paper numbered "1" would form part of a group. Consequently, the cohort then formed into three groups, with the following composition of participants: -

Table 5.4: Composition of the 3 Cohort training groups

Group Number	Participant Identity (P)	Gender (Male -M or Female – F)
Group 1	P 9	M
	P 7	M
	P5	F
Group 2	P 1	M
	P 6	F
	P 4	F
Group 3	P 2	F
	P 3	F
	P 8	F

When the training commenced, each group member would return home each day and record their observations and reflections, according to the log template provided (see Appendix C.). This part of the citizen-science process allowed the trainees to exercise their observation skills during each training session and borehole site visit. This could also be interpreted as the "right" way to engage the local public in development plans, as discussed earlier in Section 5.2.2.1.

In this regard, in the third week of training (dated 29 August 2017), P3 said,:

> *"I have noticed that farmers are not monitoring their dams and boreholes; because on the 15/08/17 we went to Taaiboschleegte farm to take water samples there; and there was a dead cow next to the dam and a dead monkey inside the dam today." (Figure 5.3; P3 on 29 August 2018)*

Being attentive to the details of the surrounding environment of Borehole Site CDB004 (See Hydro census Sheet – Appendix C) on the first visit (15 August 2017) and on the second visit (29 August 2017), indicated the observation by P3, on the importance of not only noticing, but reporting the non-existent groundwater monitoring of the site in the commonage farms, by the respective authorities, Inxuba yeThemba Municipal agricultural officers and the owner of the farm. The lack of regular groundwater monitoring of site CDB004 was a response given by the farmer using the borehole and dam for watering his livestock (mainly cattle). As such the participants on this day recorded their observation and comments from the resident farmer. Below is Figure 5.3, a picture taken of Group 2 trainees, discussing the site observations during the hydrocensus - Borehole site CDB004.

Figure 5.3: Group 2 conducting a Hydrocensus at Borehole and dam site CDB004. Note: Standing by the vehicle are the researcher and the driver of the hired transport used by the cohort during the CS training (Photo taken by P1, using the Tablet and uploaded on Xoras App)

Both participants, P6 and P3 of Group 2, alluded to what they observed at site CDB004, to the irregular monitoring of the borehole, reservoir and its surrounding environment. P6 stated,

> *"Today we re-visited the farm; there is still that dead monkey and the cow skin; and the bones were still there." (Participant 6)*

The hydro-census sheet was the first recording instrument the participants used before learning how to record their observations on the "Xoras" app in the Tablet Samsung Android version 6.0 provided. P6 is seen to have noted an additional discrepancy at another borehole site (CDB005), following a conversation with the farm owner. On the site, as indicated in the Hydrocensus sheet, P6 stated that,

> *"There was also a windmill that has not been working since last year; so there is no water for livestock in that farm."*

Additionally, P2 of Group 3, upon their borehole monitoring visit, proved to be an active learner; who, through engaging in discussion during experiential learning:,

> *"I also notice on the one farm the wind stops and the pump did not blow water out […] I realised what I read in the field guide on waiting for up to 5-10 minutes after the wind blows before collecting a sample" […]*

This realisation by P2 reveals how the groundwater trainee was a keen learner, actively engaging with the field guide (see Appendix D); and gaining knowledge of the preliminary steps one needs to take before the start of groundwater sampling.

b) Knowledge gained from the experience ("I Learned")

The methodology Chapter of this study described how reflective journaling can be used to encourage reflection on the participants' learning or practice. It became clear during the CS groundwater monitoring training and log entries, that the cohort's attitudes towards the training was a result of their willingness to learn and to gain groundwater monitoring skills. The Pre-test results, to the Question 3 *"What motivated you to join the citizen science programme?"* attests to the similar portrayed attitudes.

Besides what the trainees noticed (I noticed) during the four-week on-site training, they also expressed what they "learnt" each day of their training experiences from working in their groups, including statements such as, *"the fewer members of the group, the more attention,"* by P4. Each trainee expressed the knowledge and the information gained during the training period. P2 gave a detailed explanation and the learning points to note when conducting a hydro-census and groundwater sampling.

P2 explained as follows: -

> *"I learned that when we go to a site, we must go prepared and have all the equipment that we need. It is very important; and to complete the Hydro-census sheet; we must have 3 bottles: the 1st is the primary, the 2nd bottle is the secondary, and the 3rd bottle must be tested on the site.*
>
> *The primary and secondary bottles must be written on all 4 sides of the bottle, and also on the lids; and they must be rinsed before we pour the water into the bottles. It is very important that we must seal the bottle correctly. The primary and secondary bottles must be put away in the cooler box. It is very important that we must look carefully around us on what could be harmful to affect the water". (P2 from Group 3, Day 1, Week 1 of the theoretical training)*

The understanding of groundwater sampling procedures when one is getting ready for a site visit, as recorded in detail by P2 above, has embedded within it the notion of knowledge-generation. It also suggests that the youth are understanding groundwater sampling procedures, including the manual and electronic data capturing of the hydro-census information. Figure 5.4 (a) reflects the AEON Hydrogeologist (CS trainer), observing and specifying the sampling steps, which P2, P3 and P8 were able to recall in the first and second week of the CS training.

A. Group 3 ready with 3 water sampling bottles. P3 collecting water sample.

B. Mr Divan Stroebel (Hydrogeologist trainer, illustrating how to seal tight the primary and secondary sampling bottles

C. P3, P2 and P8 attentively observing Mr Stroebel sealing sample water bottle

D. Mr Divan Stroebel continues to specify the importance of sealing the sampling water bottles tight before storing in cooler box

Figure 5.4 (a): A pictorial presentation of P2, P3 and P8 on site CDB002. Experiential learning on Hydro-census and Groundwater Sampling steps under the supervision of the trainer (AEON Hydrogeologist)

As explained in Chapter 3 (Methodology), the second week of training comprised an introduction to the use of an electronic device with a custom application named “Xoras”. The digital application designed by AEON and the Department of Information and Technology (Faculty of Engineering, Built Environment and Technology, at Nelson Mandela University), allowed the hydro-census data to be recorded electronically, similar to the hard copy hydro-census sheet.

P2 indicated how she learnt to work on the Samsung Tablet, using the Xoras Application: -

> *"[….] I learnt to work on a tablet, but it was very easy to first do the hard copy and then before you put the data on the tablet, make sure on the hardcopy that it is correct every day […]; and if you feel happy about it, then you can put the data on the tablet. It is very important to look for the mistakes on the hydro-census sheet, and make the wrong right, before you put the information on the tablet […]".* (P2 during Week 2 of training)

Figure 5.4 (b): P2 recording Hydrocensus information of site CDB002 using the Xoras Application on Samsung Tablet during Week 2 of CS training. P3 and P8 look on and confirm the information from the completed hard copy Hydrocensus sheet.

P6 on the other hand, learnt and wrote how she understood the use of a GPS and the importance of collecting fresh water from a pump during water sampling, by stating: -

> *"I learned a lot of things. How to use GPS and how to fill in the hydro-census sheet. The important part when you take water sampling, you must use fresh water. Use 3 bottles and you must rinse them; but first mark all the sides, as well as on the top of the lid. Be sure your bottles are tightly closed and place them in the cooler box"* P6 during Week 2 of training).

Particular reference is also made to the lessons learnt by the trainees in the third and fourth week of training. GPS stands for Global-Positioning System, which was developed by the United States Department of Defence (Mohinder et al, 2001) as a space-based satellite navigation system that determines the exact location on earth's surface at any time (Hoque, 2016). The CS trainees used a handheld GPS (Garmin eTrex 10 rugged) during the four-week training (Figure 5.4 (c), to record the coordinates of the borehole sites that were sampled, as part of the hydro-census process.

Figure 5.4 (c): P6 giving the GPS reading to P4 and P1, to record on the hydrocensus sheet.

P2 from Group 3 expressed how one can learn from another trainee through the vehicle of communication. P2 explained that,

> *[…] "I learn that communication with the group is a good thing, we taught each other and helped each other a lot today [….] I learnt that [….] and the dam has got its own East & South reading on the GPS" […] (Participant 2 during Week 3)*

From these findings, during the "I Learnt" phase of experiential learning, and observations drawn, the development of teamwork within the three groups helped the trainees to better understand groundwater sampling and hydro-census processes. During the final assessment week of training, the three (3) groups were deployed to two different borehole sites (KEI001 and KEI002), and one known submersible borehole (CDB003). The trainees, during this final week, indicated how they had gained new knowledge and skills, as they worked independently without supervision from the AEON hydrogeologist. In this regard, P8 from Group 3 learnt to:

> *[…] I learn that when we take the EC, we must know that when it shows the number and with mS/cm (milli siemens per centimetre) the water is not bad; but when it's high,* ((µS/*cm – micro siemens per centimetre) that means the water is very salty […] (P8, during Week 4).*

Figure 5.5: Group 3 (P8, P3 and P2) measuring the EC of water sampled from borehole site CDB004

Meanwhile, in the fourth week of training, P9 shared as follows,

"I learnt how to update the information I entered on the tablet"

From the "I Learnt" responses, the experiential learning exposed to the trainees, implies that citizens interested in scientific activities are able to participate and engage in the practical scientific activities and to contribute to scientific knowledge. Citizen Science therefore can be seen to contribute by providing opportunities for scientific and experiential learning outcomes, with which the trainees have identified and aspire towards (see Reflective logs in Appendix C).

c) Applying Knowledge gained, or lessons learnt ("I Tried")

The notion of experiential learning is one process that helps people to link what they have learnt, with prior knowledge, and applying the lesson learnt from this linking. This scenario emerged strongly from the trainees' notes in their individual reflective logs submitted. The majority of the participants acknowledged that the CS training in hydro-census and groundwater sampling is entrenched with stimulated activities that have real-world learning value. These activities were summarised as "*interesting and hands-on*" within the first week of the training by P4:

> *"The programme got more interesting, as we got hands on and started doing work on our own."*

Figure 5.6 provides an example of Group 3 (P2, P3 and P8), during Week 1 learning the hands-on groundwater sampling and hydro-census practical exercise on site CDB007**.** Thus, the trainees had an opportunity to explore by themselves the hydro-census processes, putting into practice what they had learnt theoretically about groundwater monitoring and sampling in the first week of training.

Figure 5.6: Group 3 of the cohort (P6, P4 and P1) practising hands-on Hydro-census process (taking the Electrical Conductivity (EC) reading) with the trainer looking on (Far left: AEON Hydrogeologist)

The practical training activities were further conceived of as yielding self-confidence for the trainees, for example P4 stated;

> *"The video was very helpful; it was at a level that anyone can understand; from watching the video, I was more confident to engage in underground water monitoring."*

This statement by P4 confirms the value of Kolbe's third phase of experiential learning, which involves application of new knowledge and skills ("I Tried") to any problem or scenario. During week four (4) of the training, P1practised what he had learnt during the introductory theory lesson about the importance of communicating with the farmer before, during and after sampling groundwater at any site.

As such, P1 explained how on borehole site – KEI001 – where he tried,

> […] "*Putting my training into actual practice, by independently communicating with an actual farmer* […]" (P1 on Borehole Site KEI001, Week 4).

P9 also indicated, during the fourth week of training, his awareness of the importance of having water fit for human consumption, when he explained that,

> *"I have tried to communicate with the owner [KEI farm owner] to keep his water in a good state."*

Meanwhile, P8 indicated her confidence in the groundwater sampling steps that she followed during the third week of training without the trainer's supervision, as:-

> *"I tried to take the samples of water inside the dam; but the one that was coming to pump – not the one in the dam. I tried to close the bottle tightly; so that the water would not leak out."*

Figure 5.7 below shows P8 collecting a water sample at site CDB007**.**

Figure 5.7: P8 collecting a water sample from Borehole site CDB007 (Elandsberg) during Week 4 of training

While there are different ways to engage the participants in scientific research, the reflective log was seen in this study as a tool that built the trainees' own complex understanding of related groundwater monitoring aspects. And because it can start with what the participant has done ("I Learnt") and what they have seen ("I Noticed"), reflective logging can be introduced as a practical and understandable research instrument. This is illustrated by what P8 experienced in Week 4 as indicated in the Insert 2 below, extracted from the Combined Reflective Log (Appendix C).

Insert 2: Citizen-Science Reflective Log for Participant 8 (P8)

	I Noticed	**I Learnt**	**I Tried**
P8	I noticed that every time when you are on site, you must look around for the description; because it is very important to describe the nature of the farm and the site. I noticed that the borehole and the dam can be separated on the site. They are not always on the same site. I noticed that I must always look for comments around the site.	I learn that I must write the diameters on the GPS at the time I'm standing under the borehole; because every time I moved, the GPS sensing, the latitude and the longitude changes. I lean that the water that I sample must be the water that comes out from the pump, not the water in the dam. I learnt that both the borehole and the dam can be at a separate site, not at the same site; although the borehole is spinning; but not the water we are getting in the dam. I learnt that I must put the water samples in the cooler box immediately; so that the water cannot become heated; and I learnt that when I take the temperature and the EC, I must wait for the results to be steady.	I tried to take the samples of water inside the dam; but the one that was coming to pump not the one in the dam. I tried to close the bottle tightly so that the water cannot leak out.

The link between the three reflective notes by P8, (Insert 2), indicates how interaction between hydro-census and the groundwater monitoring theory and practical application, created knowledge and understanding for self-empowerment for the trainee. In addition, the participants felt intrigued, and acknowledged how fast the hydro-census data could be conveyed when they learned to use the Xoras Application (installed on the Samsung Android Tablet).

Figure 5.8: P3, P2 and P8 felt intrigued by how fast the Xoras application is when conducting hydrocensus at site CDB003.

P2 expressed:

> *"…I tried to work on a tablet, so it was really interesting and a faster way."*

Citizen science in Cradock, therefore, was realized to have contributed to the participants' sense of knowledge about "what is Shale-Gas Development?"; "what is hydrocensus?"; "what is groundwater sampling?" and "what is the importance of monitoring ground water?" It did so by presenting them with theoretical and practical information, and resources from which they could learn.

The CS training presented the selected eight young males and females with a space through which they could critique the established structures, such as municipal Borehole-maintenance systems and common generalisations, such as "non-scientists cannot contribute to science." This notion was presented in the individual reflective logs and recordings on the hydro-census sheet (hard copy and electronic "Xoras"). The results portray how Citizen Science offers behaviour and team-work attitudes in instances where fellow citizens fall short. For example, P1 from Group 3, indicated how it took time to teach members from another group (Group 2) on how to measure the strength of water from site CDB003 (a submersible pump; Appendix C)).

Figure 5.9: Illustration by the AEON Hydrogeologist on how to measure the strength of a pump from site CDB003. Looking on is the Group 3 members

The contribution of significant people such as family and community leaders to the cohort's skill development, was expressed in the Pre and Post-test analysis. An example is when P4 indicated how she did not engage with their family about water issues prior to the CS training (See Appendix C, Pre–test results). But she expressed after the training (Post-test), how her conversations increased from *"never"* to *"every day, there is always a lecture that I give to my siblings about saving water, closing taps tight and any form of saving."*

Not only did P4 start engaging with family and friends about water issues in her home after the CS training programme; but it helped her to see a way into the status of the water resource in the commonage farms and possibly across the Cradock town, stating, *"That most of us are just drinking, or using water without being cautious of whether the water is good enough for human consumption".* Across the training programme sessions, whether prior to the commencement of the training or during the CS groundwater training and reflective sessions, the cohort described how being accountable to their families and community, drove them to learn the content and skills about SGD and groundwater monitoring. Table 5.5 below shows how taking on the groundwater monitoring expertise, empowered the cohort with knowledge and skills to take action in groundwater monitoring, in order to improve their own lives, for their community, or for the water environment.

Table 5.5: Expectations from the CS cohort – Pre and Post training

	Pre CS training	**Post CS training**
Career interests in line with the CS training programme?	- employment in the farming sector; - study; - groundwater technician; - to train others on how to test water	- Water monitor in the community; - Open a specialist monitoring company; - to study short courses; - geologist; - engineering; - teach the community about protecting ground water;
Expectations and lessons learnt from the CS training programme?	- skills and knowledge; - learn about groundwater and its importance; - learn how to know if ground/tap water is good for consumption	- how to engage with farmer; - taking water samples; - hydro-census process and sheet; - human ignorance towards water quality, consumption and use

5.3 REFLECTIONS OF THE RESEARCHER

The results of the Pre and Post-training tests, indicate that CS contributed to the way the cohort (trainees) relate to and think about groundwater resources, coupled with the skills to conduct hydro-census and groundwater sampling. Qualitative data from the reflective journals and key informant interview responses, substantiated the Pre and Post-test results; and the data demonstrated that the groundwater monitoring training not only provided the cohort with enhanced knowledge of the current groundwater status in the commonage farms; but hydrocensus as a useful way of capturing the environmental features surrounding a water-resource site; whilst learning about the vulnerability of groundwater resources to shale-gas development activities. Overall knowledge and skills gained throughout the 4-week groundwater monitoring training, also stimulated the participants to envisage future success; and to act to realise their ambitions in groundwater monitoring-related careers; thus, showing the potential for this type of CS training programme to inspire cognitive abilities amongst involved participants. Figure 5.9 below shows two bar charts of the Pre-training expected lessons to be gained and the Post-training lessons learnt by the cohort.

Research in citizen science has been primarily focused on understanding its benefits to scientific analysis, such as reducing research costs, and the ability to collect data over vast areas of space and time. It is only in recent years that researchers have become interested in the collaborative aspect of citizen science; and how it may impact the participants and respective communities themselves; for instance, determining whether the participants are gaining more knowledge about the scientific issues in the context.

Another aspect of CS that has had very little attention in prior research is its impact on participants' attitudes. For example, Brossard et al. (2005) state that citizen scientists do not significantly change their attitudes towards the environment when they are involved in any project. However, in reference to this study, the trained cohort expressed that they had developed positive attitudes towards groundwater resource monitoring. It is also worth noting that this study in Cradock, as was the case with Brossard et al. (2005), was based on a small sample size, limiting the researcher's ability to test the statistical significance for minor changes that may have occurred.

Future qualitative research evaluating or using citizen science as a tool in groundwater monitoring initiatives on participants' attitudes, would benefit from having an extensive population sample, and thus allowing for a reliable quantitative analysis.

Consistent with this desired outcome, the results of the Pre and Post-test analyses revealed that AEON facilitated the adoption of behaviors, such as active reporting of the existence of faulty boreholes or unclean ground water. The highlighted non-existence of borehole monitoring in Cradock's commonage farms for eight years (at the time of the study), was noted from the key informant interview responses with the farm owners; and it was recorded by the trainees (Section 5.2.4). This reflects the need for municipal authorities to understand the importance of frequent groundwater monitoring in this landscape, especially with regard to the potential SGD effects on this scarce resource. Drawing from the Post-test results (Appendix D), the CS programme built the trainees' confidence and a sense of responsibility to communicate with others about the groundwater-related aspects/issues, thereby helping to strengthen the community's capacity to address future development plans.

5.4 SUMMARY

The study results suggest how a citizen-science programme can offer an innovative alternative, or how they can complement traditional forms of capacity building for groundwater monitoring activities. For instance, how the Cradock CS training can serve as a model to assist in related capacity-building programmes, focusing on groundwater monitoring, in the surrounding areas. Given that such programmes, like the CS training in groundwater monitoring are to be considered useful capacity-building tools for non-scientific citizens, or the youth unemployed in the future, scientific evidence must show quantitatively how participants are making a difference on the ground and contributing to a more efficient and consistent rural groundwater-monitoring programmes.

Additional research is, however, needed on the opportunity and effectiveness of CS, - potential job creations, business ventures and other scientific educational initiatives that can play a role in addressing the capacity needs and concerns raised by the Cradock residents (and by inference other Karoo towns), in view of potential SGD. As an example, one way to increase the level of engagement and to retain citizen-science volunteers long-term, is to provide feedback in the form of press releases, newsletters and even incentives and challenges (Dickinson et al., 2012).

Even though this research was a limited project, it should be considered a successful pilot that should be extended across the Karroo region proposed for Shale Gas Development. As AEON is not currently providing these methods of follow-up, the researcher recommends that follow-up research be conducted in Cradock, in order to create a stronger sense of community engagement in any development programmes concerned.

CHAPTER 6: PURPOSE AND POTENTIAL OF CITIZEN SCIENCE - POLICY DIRECTIONS AND SYNTHESIS

6.1 SUMMARY OF CITIZEN SCIENCE IN SOUTH-EASTERN KAROO REGION (CRADOCK)

This study explored the concept of Citizen Science (CS) and its influence in groundwater monitoring, using an Action Research approach prior to the onset of possible hydraulic fracturing in the Cradock area. The results depict that designing and implementing a CS framework is an inductive process - based on the interpretation of the researcher in collaboration with the study community. The realisation by Cradock community of the potential development of Shale Gas in this part of the Karoo gave rise to community concerns over the potential impacts of this industry on the socio-economic and biophysical environment.

The major findings from the four phases of this study, beginning with an overview of the study outcomes from the design and application of Citizen Science (CS) in relation to groundwater monitoring in Cradock, to reflections from the study participants, are highlighted below. A summary of major insights in the methodological approach used and modified steps taken during CS application in groundwater monitoring training, is also given. These insights are used to identify possible topics of future research in the field of CS, mainly its integration in the field of groundwater monitoring, providing possible policy directions to frame groundwater monitoring processes across the proposed SGD precincts.

6.1.1 Study Outcomes

A cohort of 8 young people (aged between 21 and 37 years) from Cradock, who were unemployed at the time of the study, gained notable skills and knowledge on how to conduct groundwater monitoring. Specific focus was on skills development on hydrocensus and groundwater sampling aspects, with the aim of producing domestic groundwater quality data, according to the South Africa Water Quality Guidelines for Domestic Use (DWAF, 1998). As Briggs et al. (2009) states; “Without a group goal, collaboration does not exist”, CS training was a response to the highest ranked concern raised by the Cradock community - lack of skills to monitor the potential impact of the proposed Shale Gas Development on Cradock’s scarce groundwater resource. This concern became the major goal for the CS training, which took place, using boreholes sites from in the Inxuba yeThemba Municipality (IYM) owned commonage farms. The theoretical and practical training in groundwater monitoring was conducted by the AEON hydrogeologist, while the researcher facilitated the process.

Although problem definition can be described as a starting point in a CS process, in order to link all of the process steps, an appropriate approach such as the Action Research (AR) approach, with cyclical actions (Plan – Act – Reflect – Evaluate), was required. The AR approach placed CS at a low risk of being dismissed as an unreliable tool to produce scientific data (Cavalier, 2016), and gave it an opportunity to produce essential knowledge and data on the groundwater monitoring aspects of hydrocensus and groundwater sampling, at grassroots level. In such a development – Shale Gas Development (SGD) – the study drew upon the local citizens (non-scientists) for their meaningful contribution to the related scientific inquiry and policy discourse through the adoption of a collaborative CS typology. Therefore, from CS literature and the study's practical research process, the CS principles used for the Cradock community can be summarised as: -

- Actively engaging the local citizens in scientific endeavours to generate new knowledge and understanding.
- Both professional scientists and the non-scientists benefit from taking part in the CS process.
- Citizen scientists receiving feedback from the researcher and professional scientists involved – on how the hydrocensus and groundwater sampling data is used, and the research, policy or societal outcomes achieved
- Considering Citizen Science as a research approach.
- Engaging local community structures within municipalities, to assist in understanding the essence of the CS process and implementing of project activities.

In recognizing the above five principles, the researcher collaboratively engaged with the existing community leadership structures in Cradock. With the support of AEON scientists, selection of an 8-member working group (6 males and 2 females) and design of a CS training programme, including the facilitation of 4 Community Roundtable Meetings (CRMs) and a 4-week groundwater monitoring training and evaluation, were undertaken. These processes were designed to meet the highest ranked need for knowledge and skill development amongst the Cradock community – on how to monitor effects of potential SGD on their groundwater resource. Sampling groundwater from Cradock's' commonage farm boreholes was a way of establishing the current groundwater quality status in this farming area in terms of its microbiological, physical and chemical characteristics. The main groundwater sample data results were for 3 borehole test-sites where the parameters were based on Electrical Conductivity (EC). This information is expected to contribute to groundwater management strategies within Cradock's were municipality and at national policy level before and after SGD, or any form of development that might take place in this part of the Eastern Karoo region.

Prior to CS training, community roundtable meetings, key informant interviews and observations were conducted by the researcher in collaboration with Cradock stakeholders and community leaders as a means of engagement and building trust, leading to the design and implementation of a CS training programme. Participants in these forums included representatives from the local Inxuba yeThemba Municipality, Water Users Association, Emerging farmers association, members of the Business fraternal, Women cooperatives and Women in business, political parties, the Youth council representatives and general community residents.

The eight youth trainees took part in practical exercises based on the theoretical knowledge and skills gained during the 4-week theoretical and practical training. The training created an experiential learning environment for the cohort, exposing them to hydrocensus and groundwater sampling equipment (the Global Positioning System (GPS), EC meter, 'Xoras' App) and scientific value of groundwater sampling in determining whether it is fit for domestic use or not. Essentially the cohort shared their experiences during the CS programme through reflective journaling, Pre and Post-tests, enriching the learning experience and set to inspire others when the CS programme expands to the rest of the Karoo SGD precincts.

In establishing the impact of the Cradock CS training, an evaluation workshop was conducted at the Nelson Mandela University in collaboration with selected AEON graduate students. This involved a Post-test, which was used to assess the cohorts' skills and knowledge gained during the training programme (Appendix 6). The 8 trainees were able to express how to apply their newly acquired skills and knowledge of monitoring groundwater in their community and individual homes.

However, the trainees also highlighted how important resource availability is (including equipment, funding, and manpower) necessary for future success in a similar project. Furthermore, 6 out of 8 trainees expressed their desire to enrol into school to attain qualifications in line with groundwater monitoring so that they can contribute to the groundwater management in their community (Post-training test – Appendix C).

However, through-out the study, shortcomings associated with citizen science as an approach were also observed. For instance, the need to keep all 8 trainees motivated to participate in groundwater monitoring training, which was a challenge since all eight trainees stated how they were unfamiliar with the hydrocensus and groundwater monitoring processes and the equipment involved. Conducting the Pre-training and Post-training tests revealed improved knowledge and skill on groundwater monitoring among the cohort and reflective indicators on how to further grow the CS programme (Section 6.3). Below is a summary of the outcomes of the CS training programme.

Table 6.1: Summary of outcomes of Citizen Science application in Cradock

Citizen Science application in Cradock;-

- Modelled a framework, which provided the local citizens of Cradock (non-scientists) an opportunity to actively engage and interactively learn experiences in the AEON Karoo Shale Gas Baseline Study and Groundwater Monitoring training.
- Afforded an estimated 120 Cradock residents (from the CRM attendances) a chance to actively engage and voice their concerns related to potential SGD and witnessing the result of their efforts (the CS training programme).
- Resulted in AEON scientists being exposed to the important role played by the community structures (within IYM), to facilitate the participation of the local citizens in the KSGBS and the implementation of CS.
- Resulted in 8 youths gaining experiential learning from the reflective CS training process. The youths demonstrated that they can be trusted for the data collected.
- Created relationships amongst 8 young citizens, contributing to youth aspirations to be future professional scientists (hydrologists and geologists).
- Created an economical way to collect scientific data, given that citizen involvement is mainly based on voluntary basis.
- Facilitated the collection of hydrocensus information from a total of 8 borehole sites within the IYM commonage farms. This improved the understanding of the groundwater quality status in these selected areas, suggesting possible interventions.
- Validated information collected before scientific development or related decisions are made.

Notable challenges experienced during CS training were mainly the lack of clear information about the Karoo Shale Gas Baseline Study (KSGBS) and the prospects of SGD in this part of the Karoo. Initially the community would not respond to CRM invites, under the wrong assumption that NMU was one of the supporting institutions enforcing hydraulic fracturing. This false assumption, led to the community's initial lack of trust towards the NMU institution, which threatened the community's engagement in the CS processes and the KSGBS. A series of consistent buy-in meetings with community stakeholders, led to a growing recognition of the significance of the KSGBS and CS application in the groundwater monitoring, which subsequently became an opportunity to enhance the understanding of the importance of groundwater resource management.

Despite the study being contextualised – specific to Cradock's highest-ranking community concern over potential SGD impacts on groundwater – this CS study did not address other concerns raised by the community. It is important to emphasize that resource availability and being a pilot study (involving graduate students not always available to address CS related activities), may have been contributing factors to this result. However, addressing all the community concerns or issues could have resulted in an extensive, multi-facetted way resulting in a holistic and dynamic understanding of CS impact in relation to these issues. Section 6.3 summarises on the proposed recommendations for future CS related developments.

6.1.2 Modification of the Eight-Step Citizen-Science Process (CSP)

In this study, four research steps were developed and integrated into the then eight-step citizen-science framework by (Bonney et al., 2009) (Figure 6.1).

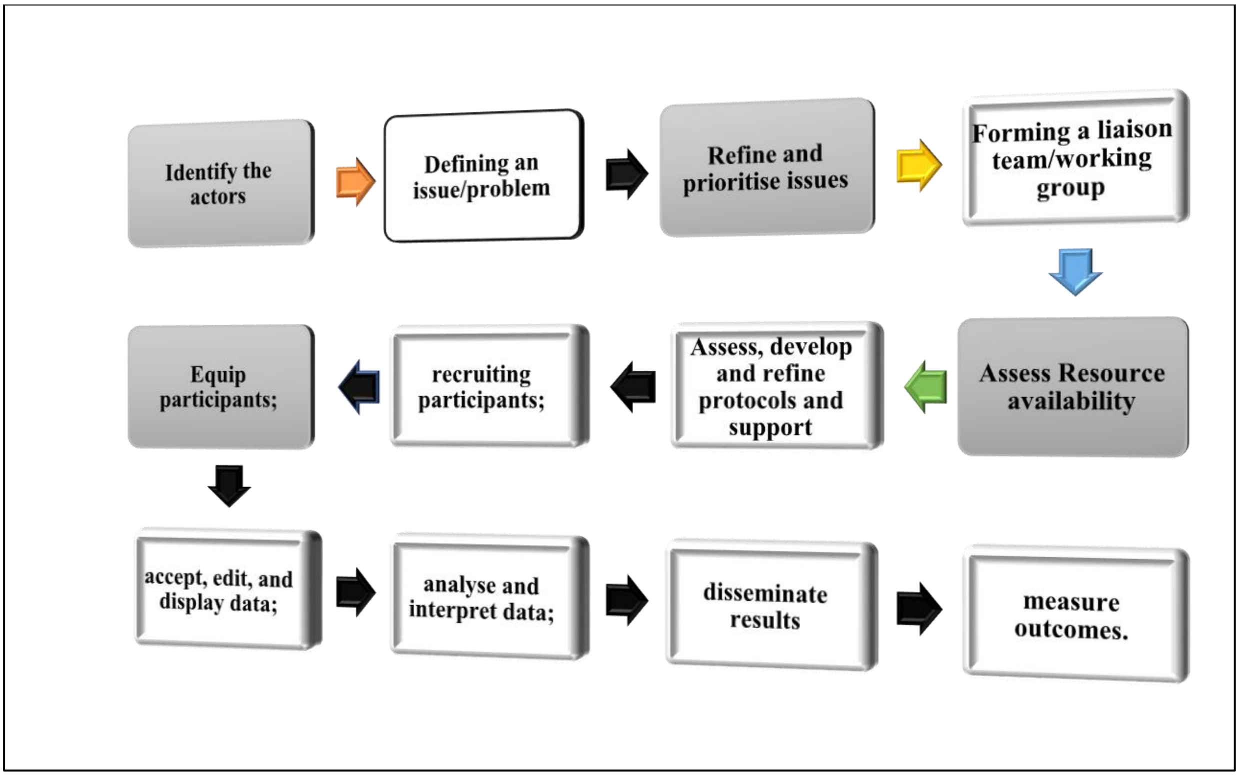

Figure 6.1: Modified Cradock Citizen-Science Process Framework: Shaded steps were developed for and applied in this study (modified from Bonney et al., 2009)

The four newly formulated steps in Figure 6.1 above (namely **Identify actors; Define and prioritise issues; Equip participants and Assess Resource availability**), contributed to the formation and implementation of a contextual CS strategy for this study. Figure 6.2 below outlines this practical strategy which can be adopted in the Karoo SGD precincts. The definition of issues to be addressed in this CS study, was inspired by the knowledge and understanding of the principles governing the CS concept and the typology that links to the study context (collaborative and contributory).

It is in this **concept analysis** phase that the methodological approaches and tools of application are developed and enabling processes are engaged. This included, designing a CS training guide; identifying the training sites and developing the Xoras software application, among others (see Figure 6.2).

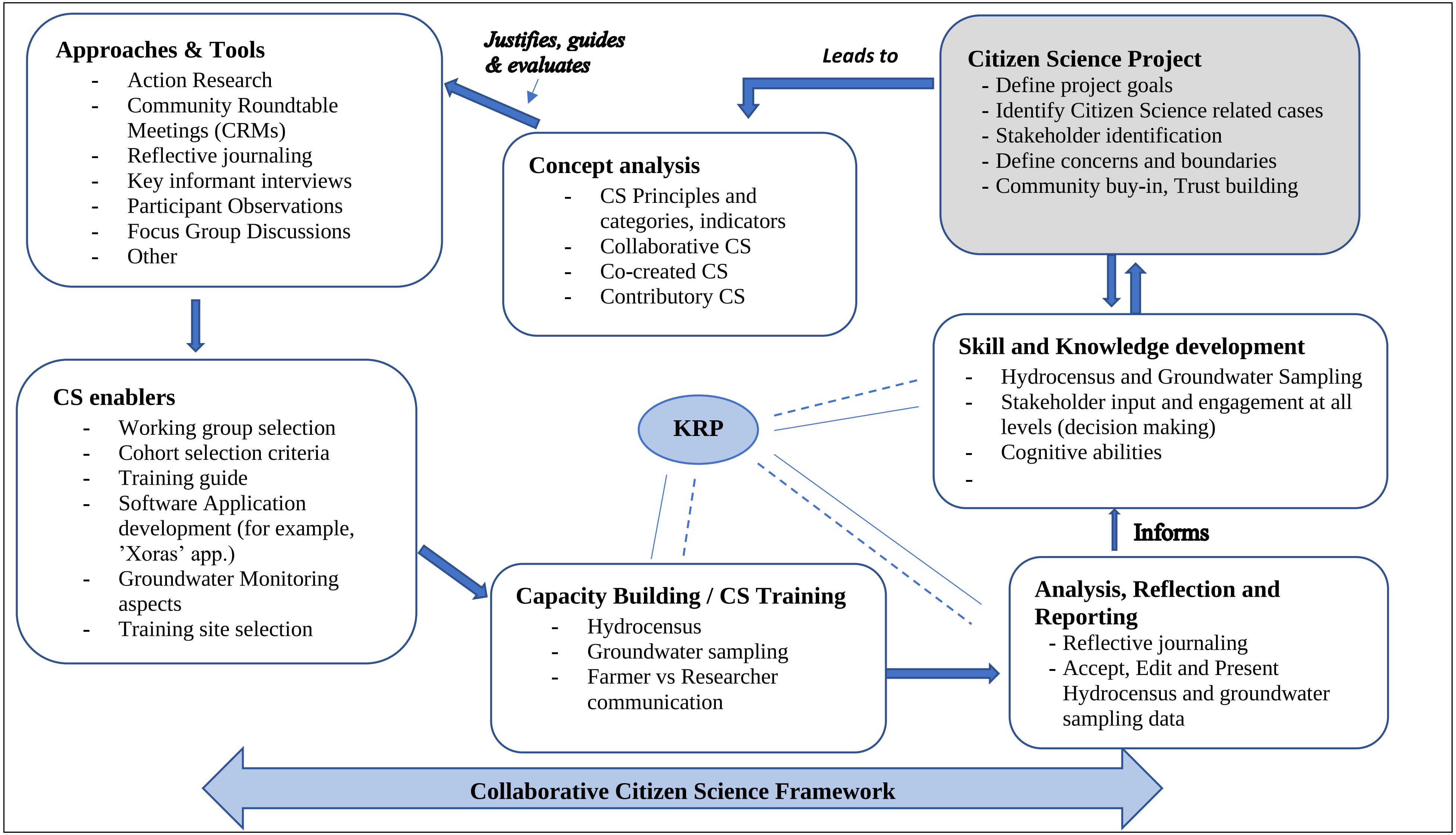

Figure 6.2: Simplified overview of a Collaborative Citizen Science Framework in Groundwater Monitoring. The dashed lines (- - -) are highlights from Cradock CS study's findings (KRP- Key Result Pointers).

To summarise Figure 6.2, introducing the four new CS steps in this study, resulted in (a) trust-building between the researcher, AEON and buy-in by concerned Cradock residents; b) The understanding of CS application in groundwater monitoring at a global level **(Concept analysis)**; and c) The **Key Result Pointers** (KRPs), stemming from the CS application (cohort recruitment and training process). Depending on the CS context, **Capacity Building Training**; **Skill and Knowledge development**; and ability to reflect and report (**Analysis, Reflection and Reporting)** are the key results that can be attainable in a CS development project. The **Analysis, Reflection and Reporting** step, refers mainly to concluding protocols that need to be followed in any CS project. The protocols for data collection and validation are important; but these protocols should also include; how and when feedback is provided? And how and when evaluation will take place?

To contribute to the body of knowledge is one of the main motivations to start or join a citizen-science project. Different goals put different restrictions on the required quality of the data. For example, a project that aims at raising awareness, focuses on the trends and thus allows larger error margins than a project where gaining insight of daily temperature distribution is important. However, even if the data are not going to be used to formulate policy; or if it does not provide new knowledge, the data can always be used for planning purposes, such as a project or engagement intervention responding to the data produced. The CS process has proven that the participants value the provision of feedback on the results; impact of the individual contribution and impact of the collective (community) contribution. As such, CS should also occupy space in mitigation studies and adaptation analysis related projects.

One of the crucial areas that this study covered and that is potentially useful for enhancing community-scientific knowledge in groundwater monitoring, is an extensive methodological deployment of multi-stakeholder science dialogue intended to share the experiences and the knowledge between the AEON scientists and the Cradock non-scientists. This was reflected during the CRMs, especially CRM3 where a simulated hydraulic fracturing model was designed by the AEON students. A methodology for future studies on CS in groundwater-monitoring applications would need to proceed from this, in order to adequately complement the two sciences, and to operationalise the thesis outcomes.

This study did not view CS as a superior capacity-building tool in groundwater-monitoring science; neither did it regard CS as occupying the peripheries of groundwater-monitoring knowledge. Thus, it would be naïve to disregard its usefulness, or to consider it as a replacement to the already existing groundwater monitoring knowledge and skills. In Cradock, the study's short-term CS programme on groundwater monitoring aimed to produce results; and to use them to improve the local municipality's' groundwater management knowledge and skills. However, building such a scheme took a period of time; and the researcher could only present updates on the hydro-census and the groundwater sampled data, that were collected by the 8 trained young people.

6.2 POLICY DIRECTIONS

A fundamental element of Citizen Science that emanates from this study, is that there is an increased potential of local citizen engagement in science contributing to the development of evidence-based policies at local, national and international development scales. Growing concerns of Shale-Gas Development in the Karoo region of South Africa, its potential risks and the existing incapacities to adequately tackle its potential impacts, are emerging challenges – not only in South Africa – but also globally. Citizen Science is found to be a practical concept that allows professional scientists to effectively engage the public, to jointly design, implement and monitor scientific-developmental projects. The concept is especially needed in Africa where schooling and training by government is not always effective as elsewhere in developed nations (for example in the Europe and United States of America).

In societies with CS experience, it is important to note that collaborative engagements with local citizens, are potential avenues to accelerate data needed for effective decision-making purposes. The issues of local community rights, knowledge, concerns, and their active engagement to make decisions about any development interventions that may affect them, including SGD, are paramount in Karoo precincts. It is therefore important to advance the global agenda for groundwater resource management, by meaningfully engaging and building the capacities of local citizens, where local groundwater management can first be realised. This means that in such communities as Cradock, the application of CS was highly influenced by collaborative engagement.

Additionally, the neglect of local citizens and their lack of capacity or scientific skills, should be reconsidered, especially in the current dispensation, where sustainable and collaborative groundwater-resource management is increasingly occupying local, regional and international policy space. Given that SGD has not commenced yet in Cradock and AEON having completed the baseline study (AEON, 2018), the CS programme could not continue further. There is a need for AEON, the South African government and responsible authorities, to intervene and extend the CS study, carrying forward the skills and capacity building of more communities in the SGD precincts. CS can be used to aid decision-making and for exploring development alternatives during the early stages of the policy-making process, whereby the responsible authorities can formulate concerns and issues, together with the citizens in questioning and developing alternative scenarios. For example, during phase one of these studies, there was a step of defining the community SGD related concerns, issues and boundaries and establishing community buy-in.

Citizen Science can also be used to explore the views of local citizens, bringing their concerns to the forefront and giving real, hard information to the ordinary people whom they can use to decide on development plans and contribute to, or critique the policies. Reference is made to the Cradock community during the consecutive community roundtable meetings, where the stakeholder participants opened up about their concerns on the potential impact of SGD; and how they needed to understand better the nature of, as well as the potential risks and benefits of SGD. The knowledge deficit expressed by the Cradock community, prompted the AEON researchers, for example, to prepare and present a simulated hydraulic-fracturing model (Chapter 5, Figure 5.1).

When there is a desired alternative, citizen science can be used to persuade public opinion to accept this preferred alternative. This, however, depends on the power relations involved, who the stakeholders are; and what influence they have. Communities may collaboratively change their opinion on a proposed policy, with increasing insight in the groundwater management system's status quo. The purpose is to build resilient communities who should continuously get groundwater management capacity-building opportunities; as they move towards resource sustainability. In the final stage of the decision process, when a preliminary decision has been made, the CS can be used to validate this decision.

6.3 LESSONS FOR (FUTURE) CITIZEN-SCIENCE PROJECTS

The thesis thus recommends future research in the following areas: -

- Providing recognition for the work done or contributions by communities involved in CS projects. In reference to the Cradock community, recognition can be through providing feedback on the hydro-census and groundwater sampling results collected by the eight youths during the training. Reflecting on the meaning of the results collaboratively with all the research participants, will have potential to raise awareness on the groundwater quality status of the sampled sites and increase the community's motivation to be involved in any future CS related projects. This can form part of an extension to the 2017 Cradock CS training in groundwater monitoring and contribute to the collaborative trust building relationship between the Cradock community and the NMU-AEON scientists, which should be an ongoing process (Action Research).

- Conduct an inventory on the current groundwater-monitoring frequency of the commonage boreholes which were sampled during this study. It would be an opportunity to suggest and generate benchmarks and monitoring mechanisms with the responsible municipality authorities, given that the boreholes had last been monitored eight years at the time of CS groundwater monitoring training.

- In collaboration with the established Cradock Working Group, explore the current employment status of the trained CS cohort –since the completion of the training. Evaluate their views on the CS groundwater monitoring training in comparison to the Post-training test. Seek consent and find out how they can be involved in the training of other community members in Cradock or from neighboring SGD precincts. This form of inquiry may enable a start of a conversation on the opportunities and challenges the CS training exhibited, in order to design a tentative roadmap for streamlining groundwater monitoring in future CS activities.

- The community gate keepers and professional scientists to consider developing a CS strategy, before CS projects commence - based on the defined issue or concern – which can either be related to SGD or not. Having set out a strategy, open to amendment depending on context of application, can assist in providing the participants with unique opportunities to contribute to science and policy development at local, regional or international level.

- Extend the CS study in Cradock and adopt the Cradock Citizen-Science Process Framework and implement before the commencement of SGD within the Karoo precincts of South Africa. This comes with adequate resource support from all enabling stakeholders to the implementation of this process. Engaging in a train-the-trainer process whereby the trained cohort from Cradock are involved and they train other community members from these precincts, drawing from their CS training experience afforded to them by NMU-AEON.

- Develop Citizen Science Information or Training Hub for the community members in the Karoo Shale Gas precincts. The Hub can host CS related projects, addressing pressing concerns raised by the communities in view of the anticipated SGD. Project activities may include the use of the Xoras App to classify photos images from the community and surrounding environment; sampling of surface or groundwater in defined areas at a specified timeframe. Along the way citizen scientists and professional scientists may directly make new discoveries of the Karoo's state of the biophysical environment. This will be a multi-disciplinary way of engaging the Karoo community in research and encourage resources stewardship, upon being recognized in scientific publications.

- Engage and strengthen new development practitioners for future CS projects, to increase the resource support and infrastructure to enhance innovation and scientific knowledge development among participants. In Cradock's' CS in groundwater monitoring project, collaborations between the stakeholders including the AEON scientists, local Water User's Association, Department of Water Affairs, AEON graduate scientists, the Water Research Council and the Department of Lands and Agriculture and existing active community structures, facilitated the engagement and skill development processes, including community buy-in prior to the CS study.

- There is need to avoid or manage any potential local community conflicts (politically, economically, traditionally or culturally inclined), in order to develop a relevant, contextualised CS project which will produce data that not only benefits the expert scientists but the respective communities. This can be achieved by inviting and engaging the relevant stakeholders who did not participate in this study, to map the CS extension project in Cradock and beyond.

- Develop ways to have open access to scientific data collected by the CS participants and expertise – non-scientists and professional scientist network - determining which information is freely available to the public, where comments and contributions can be freely given and accepted.

- To help citizen science students to set-up new strategies for themselves such as new business opportunities relating to groundwater monitoring cooperatives.

The CS training built the trainees' confidence and a sense of responsibility to communicate with others about the groundwater monitoring related aspects/issues, thereby helping to strengthen the community's capacity to address future development plans. Future research could benefit from an evaluation and monitoring assessment of the Cradock groundwater training, including the participants' feedback on their involvement, and the extent to which they represent the broader population of Cradock as a whole. This latter recommendation could help improve future CS project implementation processes and outcomes at local and regional scale.

6.4 CONCLUSION

It can be concluded that young people can be trained to monitor their groundwater resources when they are engaged through CS, despite the use of minimal range of groundwater monitoring parameters and limited resources. The monitoring capabilities are recorded as qualitative descriptions and explanations of daily experiences and observations during the training period. The complementary role of the local community's structures and concerns cannot be disputed, given the demonstrated range of methodological processes for identifying several CS cases studies, as well as the guiding principles leading to the design of a collaborative CS approach.

It cannot be ignored that the process of defining the goal of a CS project and prioritising community concerns, may be lengthy and could stand as potential barrier to timeous CS application as a tool for capacity building. This may be true for CS projects with planned start and end date, whereby unexpected delays or vis-à-vis take place due to unpredicted community aspects. On the contrary, in this study, community participants in collaboration with the community stakeholders, AEON and the researcher, gave much thought to the priority concern of the community in view of potential SGD effects, in order to design an appropriate CS strategy. Building and maintaining trust, coupled with consistent communication between the Cradock community, the researcher and the AEON scientists, were considered necessary to the successful CS implementation focussing on a specific community need. As such, it is necessary that researchers or scientists pay attention to the citizen science trainees and study communities in CS projects and not only the project outcome. This counts as being accountable to the citizen science trainees or the community involved, responding promptly to the ongoing scientific study and inspiring the community to get involved in the CS activities.

What remains is to implement CS as an on-going capacity-building and community-engagement process and help the participants see that there is opportunity to move forward, expanding into the Karoo SGD precincts. The key issue that should be addressed by the scientific community now, is to integrate communities from the SGD precincts into the proposed CS framework (Figure 6.1), for the purposes of both enhancing scientific knowledge and skill capacity in groundwater monitoring. As this study only focussed on only one priority community concern (of groundwater monitoring in Cradock), addressing other ranked concerns such as potential impacts of SGD on the community's health status, economic status, surface water, land and agriculture and using CS as an application tool, should be considered.

This research has contributed to our knowledge of Citizen Science in water monitoring through this unique pilot study, as well as yielding capacity building results specifically related to aspiration development for career and further learning opportunities related to groundwater monitoring among the cohort trainees. The study further developed practical procedure and protocol (see Appendix D) for supporting CS in the SGD context, and a practical tool and protocol for this process which has potential for further expansive development especially via more extensive training and support to a larger group of CS monitors in the Karroo areas that are affected by SGD. The study has tried out this practical procedure and the protocol via a participatory methodology. It is here where the specific contribution of the study lies, and it is also here where the claim to new knowledge can be made.

Towards the end of the study, there has been a sense of the need to quantify citizen science impact, which goes a long way in further determining CS impact – particularly when correlated with the qualitative, descriptive data. A robust, quantitative design and implementation of future related CS studies is likely to draw different perspective on the impact of citizen science. As a planning and implementation tool, CS can be used to develop the necessary scientific capacities, evaluate and draw lessons. As such, the Cradock CS framework can be used as an important point of reference for sustainable citizen engagement and empowerment.

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APPENDICES

Nelson Mandela Metropolitan University

for tomorrow

Faculty RTI Committee (Faculty of Science)
Tel: +27 (0) 41 5042268
E-mail: lynette.roodt@nmmu.ac.za

Ref: H16-SCI-GEO-005

Contact person: Mrs L Roodt

Date: 16 November 2016

Dear Prof M De Wit/ N. Dhliwayo

TITLE OF PROJECT: CITIZEN SCIENCE IN THE EASTERN KAROO PROVINCE: DEVELOPING LOCAL CAPACITIES WITHIN RURAL COMMUNITIES TO MONITOR EFFECTS OF POTENTIAL SHALE GAS EXPLORATION

Your above-entitled application was considered and approved by the Sub-Committee for Ethics in the Faculty of Science on 30 October 2016.

The Ethics clearance reference number is **H16-SCI-GEO-005** and is valid for three years. Please inform the Committee, via your faculty officer, if any changes (particularly in the methodology) occur during this time.

An annual affirmation to the effect that the protocols in use are still those, for which approval was granted, will be required from you. You will be reminded timeously of this responsibility, and will receive the necessary documentation well in advance of any deadline.

We wish you well with the project. Please inform your co-investigators of the outcome, and convey our best wishes.

Yours sincerely

Lynette Roodt
Manager: Faculty Administrator
Faculty of Science

Appendix A: Interview Schedules & Consent Letters

NELSON MANDELA UNIVERSITY

Faculty of Science

Earth Stewardship Unit

Nelson Mandela University

Tel: +27 (0)41 504-2778

• PO Box 77000 • Nelson Mandela Metropolitan University

• Port Elizabeth • 6031 • South Africa • www.nmmu.ac.za

September 2017

Structured face-to-face interactive interview schedule with the <u>Commonage Farmers</u>:

REQUEST FOR CO-OPERATION

Good-day. My name is Nyaradzo Dhliwayo. I am a Doctoral student in Environmental Geography with the Nelson Mandela Metropolitan University (Port Elizabeth). I wish to request your participation in answering this structured face-to-face interview in November 2016 when I visit your area. The interview is aimed at helping me gather information necessary for the completion of my Doctoral thesis on, *<u>"Citizen Science in the Eastern Karoo: Developing local capacities within rural communities to monitor effects of potential shale gas exploration"</u>*. My research is being conducted under the Nelson Mandela Metropolitan University (NMMU) Karoo Shale Gas Baseline Programme.

Your participation in the interview is voluntary and you are assured that the information you provide will be kept confidential and used only for educational purposes. I would appreciate it very much if you would sincerely answer all questions. This informed consent statement has been prepared in compliance with current statutory guidelines.

GROUND-WATER MONITORING IN CRADOCK: COMMONAGE FARMER'S

1. How long have you been a resident on your Cradock farm; and what has been or are your sources of water?
2. Can you describe your main uses of water please?
3. On whom and what do you rely on for information regarding ground-water issues?
4. How often is your ground-water monitored? In addition, are you satisfied or not? Please explain.
5. Cradock has been identified as one of the hot spot areas for shale-gas exploration. Could you share your knowledge about shale-gas exploration and its potential effects on the ground water.
6. Can you describe your involvement in ground-water monitoring within your area.
7. Given your response above, how would you describe your current capacity to monitor your ground-water resources on the farm? Please explain your answer.
8. What are your concerns over the potential shale-gas exploration effects on your ground-water resources?
    a. What measures do you think need to be put in place to meet your concerns?
9. Do you have any suggestions about the engagement of farmers in the monitoring of ground-water resources in your community?

Thank You.

Faculty of Science
Earth Stewardship Unit
Nelson Mandela University
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• Port Elizabeth • 6031 • South Africa • www.nmmu.ac.za

25 October 2015

Focus Group Discussion schedule with the Local Community:

REQUEST FOR CO-OPERATION

Good-day. My name is Nyaradzo Dhliwayo. I am a Doctoral student in Environmental Geography with the Nelson Mandela Metropolitan University (Port Elizabeth). I wish to request your participation in answering this structured face-to-face interview in August 2017 when I visit your area. The interview is aimed at helping me gather information necessary for the completion of my Doctoral thesis on, *"Citizen Science in the Eastern Karoo: Developing local capacities within rural communities to monitor the effects of potential shale-gas exploration"*. My research is being conducted under the Nelson Mandela Metropolitan University (NMMU) Karoo Shale-Gas Baseline Programme.

Your participation in the interview is voluntary and you are assured that the information you provide will be kept confidential and used only for educational purposes. I would appreciate it very much if you would sincerely answer all the questions. This informed consent statement has been prepared in compliance with current statutory guidelines.

Focus Group Discussion Guiding Questions

(To establish rapport and the current Cradock community capacity building needs)

1. What is your understanding of shale gas exploration?
2. May you describe the first thing that comes to your mind when you hear the statement shale gas?
3. Who have been the main information sources on shale gas exploration issue?
4. It has been mentioned that Cradock has been left out of the local community engagement process with regards to the possible shale gas exploration in the area. What do you think are the reasons for this situation?
5. What have been the community engagement processes ongoing in the community prior to potential shale gas exploration? Any engagement processes in line with groundwater monitoring?. Please explain further as by who have been facilitating these.
6. How has been the local Cradock community's response to the prospective occurrence of the exploration activity especially in line with groundwater? May you please explain?
7. Have there been any concerns being raised by the community with regards to possible shale gas exploration in the area? Please explain.
8. What are your concerns about possible shale gas exploration in the area? Please explain.
9. What do you think is the best way to engage Cradock community in view of the possible shale gas exploration plans the future holds?
10. Do you have any suggestions to the government and other organisations, which can help to improve the engagement of Cradock community?

CRADOCK GROUND-WATER MANAGERS – IYM MANAGERs

1. How long have you been working in the field of Hydrology?
2. Will you please describe your experiences in working with the Karoo, particularly the Cradock community?
3. Cradock has been identified as one of the hot spot areas for shale-gas exploration. The community has raised some concerns about the effects of shale-gas exploration on their ground water. Could you share your knowledge about shale-gas exploration and its potential effects on ground water?
4. Are you aware of the international or national guidelines, which govern the monitoring of ground-water resources?

   If yes, may you please shed more light on what the government is doing, according to such guidelines? How would you describe the local Cradock community's expertise in ground-water monitoring?
5. How has the government engaged communities like Cradock in the processes of ground-water monitoring?
6. What are the challenges that have been, or will be, associated with the engagement of Cradock community in ground-water monitoring practices?
7. In what way does the Cradock community as a whole contribute to the development of the economy?
8. How would you describe the ground-water status of the local Cradock area in relation to potential shale-gas exploration. Would you please explain.
9. How would you describe the importance of ground-water monitoring?
10. In view of the potential shale-gas exploration in the Eastern Karoo, how important is it for local communities to be knowledgeable about ground-water monitoring?

Thank You

NELSON MANDELA UNIVERSITY

Faculty of Science
AEON/Earth Stewardship Unit
Nelson Mandela University
Tel: +27 (0)41 504-2788

15 August 2017

<u>NELSON MANDELA UNIVERSITY KAROO SHALE-GAS BASELINE STUDY</u>
<u>Citizen Science Study Consent Letter: Transport / Driver</u>

My name is Nyaradzo Dhliwayo (Ms); and I am a Doctoral student in Environmental Geography undertaking research at the Nelson Mandela University in Port Elizabeth. The research involves building capacities of local citizens within the Eastern Karoo, enabling them to become skilled in groundwater monitoring effects of potential shale gas exploration. This forms part of the citizen science programme being initiated under the on-going Karoo Shale Gas Baseline study. My research will be conducted under the supervision of Professor Maarten De Wit (NMU, South Africa).

I am hereby seeking your consent in the use of your vehicle and your services as driver to assist during the whole groundwater citizen science training period for participants of my study. Below is a list of specifications expected in line with the NMU Safety and Health procedures:

a. *Vehicles used are in a roadworthy condition (Valid roadworthy certificate)*
b. *Drivers of vehicles should be in possession of a valid South African drivers licence for the code of vehicle driven*
c. *Drivers are medically fit to operate vehicles (Valid medical certificate of fitness)*
d. *Drivers transporting passengers have a valid PDP (Professional Driving Permit) for transporting of passengers*

In the event that you decide to withdraw from the study, you are advised to inform the researcher using the contact details given below. I am also accompanied by a Hydrogeologist from NMU, who will be leading the training sessions. Furthermore, it is important that you are aware of the fact that the NMU Research Ethics committee has approved the ethical integrity of the study. The mandate of this committee is to protect the rights and dignity and wellbeing of the research participants that participate in student or staff-research projects.

While every precaution will be taken for your safety and welfare during the study, the researcher, and/or NMMU/AEON or any other party associated with the citizen-science training will not be held responsible, should any prejudice, loss, damage, illness or injury occur during the study. This includes a non-indemnity against the recovery of costs, resulting from damage, loss and/or medical conditions or hospitalisation, unless such loss is caused by the researcher's negligence, wilfulness, or is a deliberate act.

For the purposes of Field training preparations, please indicate and explain (briefly) if you have any medical condition, of which you need the researcher to be aware: ………….…………….. Although your identity will at all times remain confidential, the results of the research study may be presented at scientific conferences or in specialist publications.

Thank you for your time and consideration in this matter.

Yours sincerely
Nyaradzo Dhliwayo (Ms.)
Email: Nyaradzo.dhliwayo@mandela.ac.za
Tel: +27 73653 0025

……………………………………
Signature of Transport provider/Driver

NELSON MANDELA UNIVERSITY

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August 2017

CITIZEN SCIENCE TRAINEES

Pre-test training guide

1. Name:

   ………………………………………………………………………………………………..

2. What is the highest level of education you have completed?

   ………………………………………………………………………………………………

3. What motivated you to join the citizen science programme?

   ………………………………………………………………………………………………

4. **Can you explain what you understand by the following terms:**

   a) <u>Groundwater:</u>

   i. What is groundwater?

   ………………………………………………………………………………………

   ii. How is groundwater stored?

   ………………………………………………………………………………………

   iii. How does one access groundwater?

   ………………………………………………………………………………………

   iv. Why is groundwater important?

   ………………………………………………………………………………………

   v. What are the uses of groundwater?

   ………………………………………………………………………………………

b) Groundwater monitoring

i. What is groundwater monitoring?

…………………………………………………………………………………

ii. Why is groundwater monitoring important?

…………………………………………………………………………………

c) Hydrocensus

i. What is Hydrocensus?

…………………………………………………………………………………

ii. Have you been involved in any hydrocensus related activity before?..........

iii. If Yes, please state where? ....

5. In South Africa, which legislation, law, or policy governs the use of groundwater?

………………………………………………………………………………….........................

6. What are your possible career interests in line with the citizen science groundwater monitoring training programme?

………………………………………………………………………………………………

7. Have you engaged in any talk or conversations with your family or friends about water conservation? If Yes, please explain how often (e.g. once a week, once a month, everyday)

………………………………………………………………………………………………

8. What do you hope to take away or learn from this training programme?

………………………………………………………………………………………………

9. If you have, any questions or comments please feel free to add them in the spaces below.

………………………………………………………………………………………………

Thank You

Faculty of Science

Earth Stewardship Unit

Nelson Mandela University

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• Port Elizabeth • 6031 • South Africa • www.mandela.ac.za

September 2017

CITIZEN SCIENCE TRAINEES

Post-test training guide

1. Name:

   ……………………………………………………………………………………………..

2. What is the highest level of education you have completed?

   ……………………………………………………………………………………………

3. How has your motivation to join the citizen science programme been impacted by the citizen science programme?

   ……………………………………………………………………………………………

4. Following the citizen science programme, can you explain what you now understand by the following terms:

   Groundwater:

   i. What is ground water?

      …………………………………………………………………………………......

   ii. How is ground water stored?

      ………………………………………………………………………………….....

   iii. How does one access ground water?

      …………………………………………………………………………………

   iv. Why is ground water important?

      …………………………………………………………………………………

v. What are the uses of ground water?

………………………………………………………………………………………

Groundwater monitoring

What is groundwater monitoring?

………………………………………………………………………………………

Why is groundwater monitoring important?

………………………………………………………………………………………

Hydro-census

What is a Hydro-census?

………………………………………………………………………………………

5. Have you been involved in any hydro-census- related activity before?..........
6. If Yes, please state where? ....
7. In South Africa, which legislation, law, or policy governs the use of ground water?

   ………………………………………………………………………….........................

8. What are your possible career interests in line with the citizen-science groundwater monitoring training programme?

   ………………………………………………………………………………………

9. Have you engaged in any talk or conversations with your family or friends about water conservation since the start of the citizen-science programme? If Yes, please explain how often (e.g. once a week, once a month, everyday).

   ………………………………………………………………………………………

10. Can you list what you have taken away or learnt from this training programme?

    ………………………………………………………………………………………

11. If you have, any questions or comments please feel free to add them in the spaces below.

    ………………………………………………………………………………………

Thank you

Cohort Reflective Session Guiding Questions

1. What did you enjoy most about today?

2. What did you learn during today's sessions that you anticipate using in your work?

3. Was there anything you did not understand during today's sessions?
   Please provide specific explanation.

4. What is the most valuable thing you learned today (knowledge or skills)?

IYM Borehole Monitoring Site Clearance

INTERNAL MEMORANDUM

TO : SMME DEVELOPMENT OFFICER

CC : NMMU SHALE-GAS PROJECT

FROM : AGRICULTURAL DEVELOPMENT OFFICER

SUBJECT : COMMONAGE BOREHOLE

DATE : 08 MAY 2017

……………………………………………………………………………………………

This communication serves as an explanation to provide information on the issue of Commonage boreholes. Currently, Inxuba Yethemba Municipality is having 6 commonages in the unit of Cradock that are being utilised by emerging farmers for the purpose of changing their livelihood through livestock and crop production.

The following are the names of the commonages where boreholes are situated:

1. Elandsberg – it's 7km away from town on your way to Queenstown road and have 5 boreholes in deferent camps, two boreholes are not working.
2. Egg Rock – Its 6km on your way to Queenstown road and have no boreholes including Airstrip.
3. Taaiboschleegte – Almost 5km on your way to Queenstown road and have 4 boreholes, two are not working.
4. Peschelsdam – Almost 5km on your way to Somerset east via R337 road and have 2 boreholes; one is not working.
5. Sondaghoek – Almost 5km to Somerset east via R337 road and has 1 borehole.

Yours in service delivery

…………………………

Mr S. SALMAN

Agricultural Development Officer

Appendix B

IYM Stakeholder list

Cradock Members of LED Forum: List of stakeholders invited to Community Roundtable Meeting held on 21 October 2015 (list provided by IYM officials)

Fairtown Carwash Co-op

Ikamvalethu Recycling Co-op

Ilisolomzi Bakery and Agricultural Development Co-op

Iphupha Lomama Dry Cleaning Co-op

Klaradyntjie Catering Co-op

Maliphuhle Ilinge Lamakhosikazi

Masakhe Youth Project

Michael Bunu Agricultural Development Co-op

Nonqubela Agricultural Co-op

Oyisa Agricultural Development Co-op

S14 Printing Co-op

Sivukile Agricultural Co-op

Siwa Sivuka Youth Development

Siyavuya Fodder Production

Umsobomvu Wool and Mohair Development

Waste Management Project

Wings of Hope Co-op

Worriors Panelbeaters Co-op

Other invitees

Commonages

Business forum

Sugar beet farmers

Labour

Farmers association

Thubalethu

Phambili

Government departments

Cdw

Cradock business forum

Commercial farmers

Afri forum

<u>Member based organizations</u>

South African Youth Council (SAYC)

Sanco IYM

Cosatu –Notwala

Sadtu – Mbotya

Samwu

Nettawu – Hermans

Political parties

Taxi association

Imatu

Caters association

IYLBF

Consortium

Cradock Rate payers association

<u>Middleburg Members of LED Forum:</u>

LED Officer

Informal Traders

Youth in Business

Sub-Contractors

Taxi Federation

Co-Ops(Induba (Farmers Association)

<u>Councillors</u>

Zizi (Chair person)

Goniwe (Deputy Chair person)

All Councillors

Table 4.1 (b) Themes from First Community Roundtable Meeting Group responses (CRM1)

Themes/Questions	GROUP 1	GROUP 2	GROUP 3	GROUP 4
a) What are your concerns about shale gas, as the community?	• There is a need for more information *(on shale gas)* • More simplified technical presentations (with models and demonstrations, needing to be more interactive) • Impact on the environment from contamination (precautionary measures) • Lack of measuring tool	• What will happen in the future concerning the next generation? • Eruption – tsunami • (earthquakes) Who is going to gain?	• Job controlled opportunities Boost or growth of economy • Gas and oil price decrease or affordable • Poverty reduction • Possibility of earthquakes • Air and water pollution • Health risk • Danger to ecosystem	• The community is not well informed • Who will benefit from shale gas?
b) How best to engage the process and build community awareness and participation?	• Establish a study group (diversity). The group needs to assist in the information transfer	• Nothing about us without us	• Community meeting • Establish a structured forum Mass media	• AEON must have an open line so that we can put our concern across

				through the structure we are going to set up here
c) How best to communicate information amongst the community?	• Community meetings • Direct contact with stakeholders and community groups	• Some workshops – us and them • Sharing of information using media	• Social media (WhatsApp, emails, Facebook) • Public consultation and participation	• We need to set-up a structure from the stakeholders (currently here)
d) Other stakeholders which need to be included in the SGD dialogue processes.	• Department of Agriculture and Department of Environment and Energy • Water uses associations	• Community involvement Municipality • Different organisations (SANCO, Women's Organisations; etc)	• Ward committees SGB's, clinic committees, CDW's Sport council, political parties, Faith based organisations	• The structure must communicate with other stakeholders that are not here

e) Which are the critical resources within the community which need to be considered in the SGD process?	• Water • Human resources • Land (Access for drilling and factory or facility)	• Land security - guard against soil erosion, etc minerals • - water pollution	• skills empowerment • bursaries • gas • land • water • oil	• Workshops and the technical information on protection of natural resources (e.g. water)
f) What do you not like about the ongoing shale gas debate and how information is communicated, overall?	• Exclusion from previous discussions	• Untrustworthy	• Emphasise on profit making rather than the welfare of community • Poor community involvement • Implementation moves at small pace	• The different kind of information (companies) because it is not empowering our communities

f.1) What did you not like about today's session, or what could be improved upon?	• First part of presentation, too technical	• Language (complicated and scientific) • Advantages and disadvantages (explain to us) • Propose: To be educated in a simple language and more practical than theoretical	• Too complex, technical and scientific • Practical functioning of IT	
g) What have you gained today?	• Was informative (we understand where we fit in, or our role)	• A bit of knowledge about shale gas • The difference between shale gas and moss gas	• Simplified and complex presentations Marginal knowledge about shale gas	• We as the communities have the right to be informed

Community Roundtable Meetings: Invitation letters

NELSON MANDELA UNIVERSITY

Earth Stewardship Science

Research Institute

Maarten de Wit, Science Director of AEON
Chair of Earth Stewardship Science
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15 October 2015

Cradock, Eastern Cape

NMMU KAROO SHALE GAS BASELINE STUDY IN COLLABORATION WITH CRADOCK COMMUNITY STAKEHOLDERS: INFORMATION SHARING WORKSHOP

Dear Stakeholder

I am the coordinator of the Karoo Shale Gas baseline research studies at the Nelson Mandela Metropolitan University (NMMU) in Port Elizabeth. There are a number of graduate students participating in this NMMU study that would like to conduct an information session with you as an important stakeholder relating to this on-going Shale Gas Baseline Study. Part of this study includes developing a Citizen Science Programme that we would like to initiate in Cradock. We would like to develop our research work further through interactive presentations on the importance of community engagement and empowerment in line with scientific components of the NMMU Shale Gas Baseline Study. For this we would like to organize a workshop in Cradock focusing on further discussions with you and other community stakeholders from Cradock municipality in order to develop transparent relationships between us and the communities.

In line with many of our previous meetings, we are hereby seeking your consent and confirmation to attend this workshop to be held on **Wednesday 21 October 2015** from **0900hrs – 1300hrs at Vusubuntu Cultural Village, Cradock.** Attached for your information please find a copy of the **Workshop Agenda** (subject to minor changes).

If you require any further information, please do not hesitate to contact me or the following on: Barry Morkel - barry.morkel@nmmu.ac.za and Nyaradzo Dhliwayo - nyaradzo.dhliwayo@nmmu.ac.za.

Thank you for your time and consideration in this matter.

Yours sincerely

Professor Maarten de Wit

STAKEHOLDERS REPRESENTATIVE FORUM

VUSUBUNTU CONFERENCE CENTRE @ 10H00 – 21ST APRIL 2016

AGENDA

1. Opening & Welcoming
2. Credentials
3. Apologies
4. Purpose of the meeting

   4.1 Cradock Shale Gas Community Stakeholders briefing and Roundtable Preparatory session

   4.2 LED Forum (Terms of Reference)

   4.3 Contractors (IPED as point of entry)
5. Discussions
6. Resolutions / Way Forward
7. Closure

INXUBA YETHEMBA

UMASIPALA WASEKHAYA / PLAASLIKE MUNISIPALITEIT / LOCAL MUNICIPALITY

INTEGATED PLANNING AND ECONOMIC DEVELOPMENT

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"A coherent developmental municipality putting people first and providing a better life for all its citizens"

11 May 2016

RE: NMMU-KAROO SHALE GAS BASELINE STUDY IN COLLABORATION WITH CRADOCK STAKEHOLDERS AND LOCAL COMMUNITY - 2nd ROUNDTABLE DISCUSSION

Dear Stakeholder/Community Member,

As part of the ongoing NMMU-Karoo Shale gas baseline study, this office in collaboration with the Earth Stewardship Science Research Institute (AEON) from Nelson Mandela Metropolitan University invites you to the **NMMU-Karoo Shale Gas Baseline Study 2nd Roundtable discussion workshop** to be held on the **18th May 2016**. This is a follow-up to the previous stakeholder meetings held within our Cradock community. The main purpose of this meeting is to focus on one component of the study which includes developing a Citizen Science Programme that needs to be initiated in Cradock. We are also looking forward to being introduced to your structured forum as highlighted in the 1st roundtable discussion held on **21st October 2016**.

Attached for your information please find a copy of the **Workshop Agenda** (subject to minor changes).

If you require any further information, please do not hesitate to contact the following on:

Mr. Jojiyasi - ljojiyasi@gmail.com

Mr. Sonwabo - Sonwabo@iym.gov.za or Son2025@yahoo.com

Barry Morkel - barry.morkel@nmmu.ac.za

Nyaradzo Dhliwayo - nyaradzo.dhliwayo@nmmu.ac.za.

Thank you for your time and consideration in this matter

Your attendance and contribution to this meeting will be highly valued.

Yours Faithfully

Mr L Jojiyasi

LED Manager

Earth Stewardship Science

NELSON MANDELA UNIVERSITY

NMMU-KAROO SHALE-GAS BASELINE STUDY IN COLLABORATION WITH CRADOCK STAKEHOLDERS AND THE LOCAL COMMUNITY

2nd ROUNDTABLE DISCUSSION

VUSUBUNTU CONFERENCE CENTRE @ 10H00 – 18th MAY 2016

<u>AGENDA</u>

1. Opening & Welcoming
2. Purpose of the meeting

2.1 Recap of 1st Cradock Stakeholders Roundtable Workshop

2.2 Shale Gas exploration Model – A simple way to frack (Maarten)

2.3 Discussion

BREAK

2.4 Community Rights and Consultation

2.5 NMMU-Karoo Shale gas Baseline study + Citizen Science

2.6 Discussion

LUNCH

2.7 Groundwater Monitoring and Analysis and Citizen Science Training

2.8 Question and Answer Discussion

2.9 Citizen Science cohort selection

3. Towards a Shale Gas Development Roadmap
4. Way Forward
5. Closure

Earth Stewardship Science

Research Institute

NELSON MANDELA
UNIVERSITY

NMMU-KAROO SHALE GAS BASELINE STUDY IN COLLABORATION WITH CRADOCK STAKEHOLDERS AND LOCAL COMMUNITY

3rd ROUNDTABLE DISCUSSION

VUSUBUTHU CONFERENCE CENTER @ 09H00 – 1st June 2017

AGENDA

09h00	Welcome & Introductions (LED Councillor Lena Davids)
09h10	Purpose of the meeting (Working group Representative Ms. S.B. Vayeke)
09H15	Recap of 2nd Cradock Stakeholders Roundtable Workshop (Ms. Nyaradzo Dhliwayo)
09H20	Background of the NMMU-Karoo Shale gas Baseline study (Prof. Maarten de Wit)
09h30	Citizen Science Research Programme (Ms. Nyaradzo Dhliwayo & Mr. Divan Stroebel)
10h30	**BREAK**
11h00	AEON/NMMU Karoo Shale gas Baseline study Theme Presentations (5min sessions) (Ms. Nadia van der Walt; Ms. Verouschka Sonn; Ms. Chwayita Kani; Mr. Barry Morkel; Ms. Shanene Oliviera)
11h30	Discussion (Facilitator: Mr. Kei Pieterse / Working group Chairperson)
12h00	Break-away sessions per NMMU Baseline Study Theme
13h00	**LUNCH**
13h45	Towards a Shale Gas Development Roadmap (Prof. Maarten de Wit)
14h15	Workshop Evaluation
14h30	Closure

Appendix C:

Completed Pre and Post-tests and Completed Reflective Logs

COMBINED PRE TEST										
1.Name:	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**		**MAJOR THEMES**
2.What is the highest level of education you have completed?	matric	matric	matric	Mechatronics NQF Level 3	matric	Grade 12	Bachelor degree in social sciences	ABSENT		- Matric; - NQF Level3 ; - BA; - Absent
3.What motivated you to join the citizen science programme?	to expand the knowledge that I have regarding ground water	I wanted to learn more about the groundwater and also wanted to take this far like go and study further about the ground water	I always wanted to go into the agriculture field so I think that the citizen science program will help me	Since there was possibility of a shake gas program coming up and the fact that it possed an effect to the water. Better chances of employment	I found interest because of water and it is important to me to learn about this	It is an opportunity for me to	The fact that it has something to do with ground water issues			- Knowledge gain in groundwater issues; - Employment chances; Study further
4.Can you explain what you understand by the following terms:										
a) GROUNDWATER										
i)What is groundwater?	The water which runs below the surface of the earth	It is water that is under the ground and stored in boreholes	Groundwater is water be need the surface of the earth	Water that is down from the ground using windmills	It is water that is found underground	Ground water is the water that found underground between cracks and stone /sand	It is water that is found underground on soil			- Water found underground; - Water that runs below the groundsurface
ii)How is groundwater stored?	Below the surface	In boreholes we normally find it on farms		In boreholes	On plastic bottles	Underground	It is stored on reservoirs or dams			
iii)How does one access groundwater?	using boreholes propelled by windmills	if you trained for it and most farmers do access they bore holes		We use windmills to get the water on ground surface then use	By drilling underground	I don't know	When it is generated underground where it is located			
iv)Why is groundwater important	It would be a never ending source	It is important on farmers because the farmers use more water everyday so they stored their water in boreholes and or fire for example, the fire brigade normally make they tank full in the town where the is underground hole		Its clean water that does not have chemicals. it nature given	Because they are clean water	Because is natural we don't need treatment and there is no water vapour	Because when there is scarcity on surface water people resort to ground water			- Perennial; - Fire extinguishing; - Farming; - It is clean, naturally occuring, nonexpensive; -There is no water vapour
v)What are the uses of groundwater?	For human consumption as well as livestock	Example for fire brigade and when the town/rivers are empty		Used for drinking, for washing, for stock drinking, cooking and watering the plants	To drink, to bath and to plant	Watering plants for drinking and cleaning	Domestic, agricultural, mining and otherwise			- Human consumption; - Livestock; - Fire extinguisher; - Crop production; - Mining
b) GROUNDWATER MONITORING										

i)What is groundwater monitoring?	it is when the water is checked so that its status is known			To check if the water is good for human use and not contaminated	It moniters people wo do not have access to water	Is to make sure that everything surround our environment is clean and our boreholes are seal safe everytime	It is daily or weekly checking of groundwater as to its fit			- checking the status of water (safe); - checking if water is fit for human consumption; - monitors population with or without water - making sure there is a clean environment
ii)Why is groundwater monitoring important?	To know where it goes, if its not being contaminated and if its consumable	Because we drink the water and it must be tasked		Contaminated water might be fatal or cause diseases	To keep the water clean	To make sure that is clean and safe from hazardous things	It is important in that, by monitoring you identify whether it is suitable for drinking and agricultural use for so no harm can occur			- for record keeping purposes; - to check if it is fit for consumption; - to check for sanitation
c) HYDROCENSUS										
i)What is hydrocensus		Hyrdocensus is monitoring in the ground water		Don't know	I don't know	I don't know	Statistical purposes on water related issues			
ii) Have you been involved in any hydrocensus related activity before?	no	N/A								
iii) If yes, please state where?				no						
5.In South Africa, which legislation, law, or policy governs the use of groundwater				Don't know	The right to have clean water	I don't know	Water Act, Groundwater Act, Water Use Act			- Water Act, Groundwater Act, Water Use Act; - I don't know; - the right to have clean water; - blank
6.What are your possible career interests in line with the citizen science groundwater monitoring training programmes	Access skills in the field be able to help out in the farming sector as it lacks water monitors	To study more in citizen science groundwater monitoring when I complete my training, im going to Middleburg because there is a place of boreholes so I wanted to go and gain more		Ground water technician	Science and ground water monitoring	Since Cradock is a Karoo, I want to be train how to test water and be sure is safe for our health	To become a ground water technician			- employment in the farming sector; - study; - groundwater technician; - to train others on how to test water

7.Have you engaged in any talk or conversation with your family or friends about water conservation? If yes, please explain how often (once a week, once a month, everyday)	Yes, about every week	Yes, because I told them every day that when I complete my study I going to take my CV to Middleburg		never	Every day because water we use everyday	No	Yes, once a month			- Yes, every week; - Yes, once a month; - Yes, everyday; - No; - Blank
8.What do you hope to take away or learn from this training programme?	Skills and knowledge	To go what I learned here and take it further with me		Checking not only ground water but tap water and even the water that we buy if it's good for human use	Knowledge and skills	I want to learn more about the groundwater importance of it	Able to test and deal with hydrological issues			- skills and knowledge; - learn about groundwater and its importance; - learn how to know if ground/tap water is good for consumption
9.If you have, any questions or comments please feel free to add them in the spaces below.		I wanted you to help me to get my cv in Middleburg at the borehole place.		None at the moment	At the end of this course will we be receiving any certificates?		None			- the end of this course will we be receiving any certificates? ; - Need help in posting my C.V.?; - None

COMBINED POST TEST											
1.Name:	P1	P2		P3	P4	P5	P9	P8		**MAJOR THEMES**	
2.What is the highest level of education you have completed?	matric	Grade 12		matric	Mechatronics NQF Level 3	Grade 12	matric	Grade 12		- Matric; - NQF Level 3; - Grade 12	
3.How has your motivation to join the citizen science programme been impacted by the citizen science programme?	Has given me a wider sense on all the groundwater and how it is stored and for its importance	When I apply and get in I did some research and I find the project very interesting		As for me my dream was always to go and study Agriculture. So this programme have just given me more experience on farming	More knowledge and more qualifications for better chances of employment	I wanted to learn more about the programme	It has helped me to know or have better knowledge of how to keep water monitored and the status of it	citizen science has motivated me a lot because I learn the thing that I did not know more experience the skills		- wider sense of groundwater ; - how groundwater is stored; - groundwater importance; - more experience on farming; - better employment chances; - monitoring skills	
4. Following the citizen science programme, can you explain what you now understand by the following terms:											
a) GROUNDWATER											
i)What is groundwater?	it's the water that would be accessed underground by means of boreholes or springs	it is water that is under the ground between the rocks and soil		Groundwater is water beneath the surface of the earth	Water that is gathered underground in between rocks and soil	is the water that comes from the ground when it rains	It is the water that is underground and used for domestic livestock	groundwater is the water that are coming from pipe in the borehole that come from underground		- Water accessed underground	
ii)How is groundwater stored?	in aquifers below the surface	it is stored in a borehole and in pipes that runs		It is stored in rocks under the ground in aquifers	Underground like in wheels, boreholes	when it rains the water stays between the rocks underground	Aquifer or is stored on the ground and also in stones	it is started on 15 August 2017 at Vusubuntu and Municipality farms		- in aquifers; - in boreholes; - between rocks	
iii)How does one access groundwater?	drilling a borehole ; spring	it can be access faster if it's a wind pump or a submersible pump where the generator must be switch on to get the water		To make a hole in the ground where there are aquifers and put in pipes to pump the water up words	Windmills and electrical water pumps	by using windpump or electrical pump to pump water from the ground	By sing borehole or windmill	You access the groundwater by knowing the pipes under the groundwater		- drilling borehole; - pipes underground	

iv)Why is groundwater important	its an endless supply of water and is much more cleaner than surface water and would be absorbed by the sun	it is important for farm owners to help them save water and use less water		Because many farmers are using groundwater on their farms and for their households	Groundwater is natural clean water that is not tempered with	because its clean and cool we can use them for household	It's a clean surface water and is not scarce	It is important because now we know which water is fine for drinking and we know why must the water be tested		- endless supply; - cleaner than surface water; - domestic and livestock; -	
v)What are the uses of groundwater?	for domestic, livestock and irrigation	in the farm owners case they are use it for domestic, agriculture and livestock most of the time		It can be for livestock, domestic, and agriculture	Irrigation, human consumption, for agriculture -livestock	irrigation, domestic, livestock	It provides water for domestic, livestock, vegitation	Because the groundwater are different from the tap water the groundwater is coming from		- domestic; - livestock; - irrigation; - agriculture	
b) GROUNDWATER MONITORING											
i)What is groundwater monitoring?	testing and monitoring water	it iswater that gets out of a pipe and continue running by windpump and it must be monitoring by sample it and take the EC reading		Groundwater monitoring iswhen you are completing a hydrocensus sheet over every three months	To monitor or check the electro connectivity of ground water and check if it is fit for human use	is to check or test the groundwater every now and then	Is to check whether the water is clean and be able to be used for	it is water we collect from the ground and we monitor it		- testing if water is fit for consumption; - checking the electro connectivity of groundwater; - it is completing the hydrocensus sheet over every three months	
ii)Why is groundwater monitoring important?	To be able to keep record on your water to know when there is a change in it	so that you can see how salty or fresh your water is and it is important to test / sample your water every 3/6 months for farm owners		so you can keep record of the groundwater and that if the water is safe for humans to use	So that you can see when your water is contaminated and maybe when you can trace when you can see what was the cause	to check how clean the water and are there any chemicals in the water	So that to keep record of the status of water that is being used	it help the people and the farm to know that the water is fine to be used		- keep record of any changes	
c) HYDROCENSUS											
i)What is hydrocensus	taking samples of your water that would be sent to the lab and that would be prepared every 3 months	it is the water sampling and testing of the borehole and you must complete a hydrocensus sheet as well		is where you fill in a sheet after you have taken measurements of the borehole site of the equipment and water sample	Gathering information even if its on a piece of paper or talet about the place where you will monitor water	is to test the groundwater on the farms or certain areas the paper that you keep all the information	Is the taking of sample of water and be tested to assure that the water is clean to be used	hydrocensus is the measurement that we take from the borehole all the work we do we call hydrocensus		- gathering information about horehole site ; - sampling water and sending it to the labs	
5.Have you been involved in any hydrocensus related activity before?	no	yes		yes	yes	yes	no	yes		- Yes (x5); - No (x2)	

6. If yes, please state where?		cradock CS training programme		cradock citizen science	NMMU citizen science programme	cradock citizen science programme	n/a	cradock		- Yes (x5) - Citizen Science Programme by Nelson Mandela University; - No (x2) - N/A	
7.In South Africa, which legislation, law, or policy governs the use of groundwater	environmental and water affairs	water act		water act	Water conservation, Water Act	water act - the right to have clean water	Environmental and Water Affairs DPT of the Republic	water act		- Water Act (x5); - Environmental and Water Affairs (x2)	
8.What are your possible career interests in line with the citizen science groundwater monitoring training programmes	being able to monitor the water in the communities and farms and maybe open a monitoring company	I wanted to go and study further if NMMU will be available short courses but for now I'm going to look for a job that I can test some water and sampling the water		geologist	Ground water monitor specialist	engeneering or geologist	To start up my our business and also do groundwater monitoring around my area and teach my community about it	to become the inspect of the groundwater or to become farm owner and sample my own water or groundwater speacialist		- Water monitor in the community; - Open a specialist monitoring company; - short courses; - geologist; - engineering; - teach the community abouth protecting groundwater; - Farm owner	
9.Have you engaged in any talk or conversation with your family or friends about water conservation? If yes, please explain how often (once a week, once a month, everyday)	Yes, at least once a week	yes, everyday because maybe it can make doors open for me I wanted to be working with sampling water		yes - once a week	Yes, every day. There is always a lecture that I give to my siblings about saving water, closing taps tight and any form of saving	yes, once a week	Yes, everyday	yes - everyday when come back from the programme		- Yes (x7); - Yes, Once a week (3); - Yes , Everyday (x4)	
10.Can you list what you have taken away or learnt from this training programme?	How to engage with a farmer, take samples, complete the hydrocensus sheet manually and electronically	I can sample water , can take the water EC and Temperature , can write a hydrocensus and tablet how to fill it in . I learned a lot , its easy to do it physically but not practically		how to do the hydrocensus sheet. How to take samples from the borehole	That most of us are just drinking or using water without being cautious of the water is good enough for human consumption	I learned how to test ground water. How to communicate with farmers	To take the samples manually and electronical and send them to the lab	how to take samples of the water and how to measure the diameters, what question should I ask the farmowner		- how to engage with farmer; - taking water samples; - hydrocensus process and sheet; - human ignorance towards water quality, consuption and use	

11.If you have, any questions or comments please feel free to add them in the spaces below.	how can I get access to the equipment and the application to capture the information	N/A			Since all of us learners were taken from unemployed community members is the any equipment that we can be sponsored with since all of them cost too much. Thank you for the opportunity	I would like to thank the committee of this programme for giving me such an opportunity to learn about the groundwater.	How will I be supported after the programme	the programme was so impressed , we learn many things we did not know		- access to equipment used for hydrocensus and sampling (manual and electronically); - how can we be supported after the training program; - Thank you the organising team of this training ; - Other/Not applicable	

Completed Reflective Logs

COMBINED CITIZEN SCIENTIST'S REFLECTIVE LOG

Part of being a scientist is recording your observations and discoveries. Use these pages to document what you notice, learn, and try in your citizen science project

DATE	I NOTICED	I LEARNED	I TRIED
Week 1 **14th – 16th August 2017**			
GROUP 1 **BOREHOLE SITES: CDB005; CDB004; CDB003**			
P5	I noticed that the famers are not monitoring, the ground water. The BH is built next to the outlet where animals drink	Water from mountains is cleaner than the water that are near the B.H	We tried to learn how to complete the spreadsheet and how to use the GPS and E.C., we tried asking important questions like, how we take measures of water?

P9	I have noticed that farmers do not monitor their water and BH is being built next to the outlet were cows drink water and they mess around	Water from mountain is cleaner than the one that are being pump from the low level	I tried to learn how to complete the spreadsheet and how to use GPS and EC. I also ask a question about we have to take water directly from the BH
RESEARCHERS' OBSERVATIONS/COMMENTS – CDB005 not working, broken pump - readiness of IYM with resources to start training - farm access keys, -diesel for pump - trainees could have entered more information			
GROUP 2 **BOREHOLE SITES: CDB006; CDB007**			
P1	The different BH position and evaluation on the farm and the different purpose of use	How to notate on the spreadsheet and to use the different electronic devices	Completing the hydocensus sheet and physically collecting the samples from the different site
P4	Video was played showing us of the work that we are expected to do	More clarity on underground water first. learnt about electro connectivity.	Asking questions on things that were not clear for clear

		More aware on how to monitor water in general	information if what is expected from me.
P6	I have noticed that the water sampled are totally different from the one that we found in boreholes, tape water(municipality) and the one that sold from the rental shops or wholesales	I learned a lot of things. How to use GPS how to fill in hydrocensus sheet. The important part when you take water sampling. You must use fresh water. Use 3 bottle and you must rinse it first mark all slides as well as top of the lid. Be sure your bottles are tightly close and place it in the cooler box	In the second site I tried to do the whole procedure. Do hydrocensus sheet, take water sampling and test it. I Also tried to use GPS
RESEARCHERS' OBSERVATIONS/COMMENTS:			
GROUP 3 **BOREHOLE SITES: CDB009; CDB002**			
P2	I have noticed to take notes because it is very important and take everything serious the training	I learned that when we got to a side we must go prepared and have all the equipment that we needed. It is very important and to complete the	

	I also notice on the one farm the wind stops and the pump did not blow water out so I realized what I read that we must wait up to 5-10 minutes after the wind blow before we can take samples of water	Hydrocensus sheet and that we must have 3 bottles 1st is the primary, the 2nd bottle is the secondary and the 3rd bottle must be tasted on the side. The primary and secondary bottles must be written on all 4 slides of the bottle and also on the lids and must the rinsed before we throw the water in the bottles. It is very important that we must seal the bottle correctly. The primary and secondary bottles must put away in the cooler box. It is very important that we must look carefully around us what could be harmful to affect the water.	
P8 **16/8/17**	I noticed that I must know what is going to work and must have all the equipment I'm going to use and I must know the place of the farm. I noticed that I ask the	I learn what I must do with the supplies of water. I learnt how the GPS work. I learn how to keep the water supplies	I tried to switch on/off the GPS. I tried to measure the metres. I tried to find out the latitudes and longitudes of the borehole. I

	farm owner about the pipes that are in the borehole. I must pack all the equipment	safe. Li learnt the difference between the hydro-census and water supplies	tried to teak photos on the cameras. I tried to take the EC and temperature of water
P3 **15/8/17** **16/8/17**	In the video + theory I noticed the three different aquifers. That water goes faster through cracking rocks and slower mud Always before you leave a sampling site ensure that all the equipment is collected and safely stored for the next sample site	What Groundwater Monitoring is and where it comes from Hydrocensus, aquifers porosity How to complete a Hydrocensus sheet and how to work with the GPS, how to sample water on the EC meter	I tried at home to do research about the Hydrocensus and groundwater monitoring How to take water samples from the (BH) pipe and now to sample it with the EC meter

RESEARCHERS' OBSERVATIONS/COMMENTS:

CDB008 – sealed, not working. No sample taken

Any other comment/ questions/ suggestions

P5 (16/8/17)

How do we get hold of the farm workers?

Do we do appointments before visiting the farm?

P1 (16/8/18)

How would the strength of the pump measured?

P9 (16/8/17)

How do we communicate with farm owners to make appointments for visiting certain farm?

P4 (15/8/17)

The video was very helpful it was at a level that anyone can understand from watching the video I was more confident to engage about underground water monitoring.

P2 (16/8/17)

Today's session was very interesting and I enjoy it a lot and also learned more about the water.

P8 (16/8/17)

I suggest we must also try to work with other things like dams or rivers not only boreholes so that we can be able to work with other things.

P3

none

DATE	I NOTICED	I LEARNED	I TRIED
Week 2 **21st – 23rd August 2017**			
GROUP 2 **BOREHOLE SITES: CDB001; CDB009**			
P6	I have noticed that most of the farmers are using their ground water for livestock and domestic work only.	I learned how to use on captured with IPED on the field. And is very important to monitor your ground water to check if its clean and healthy for human being	I tried to capture all the information that I received from the farmer on the Ipod
P4	Split into groups of 3 Our group, group 2 had a chance to go to farm site and few equipment was introduced to us. EC meter, sampling bottles Hydrocensus sheet GPS etc	The fewer members of group the more attention I learnt to identify water source location, how to clean sample bottle, taking sample water closing and securing bottle and how to fill in Hydrocensus sheet.	Tried using GPS took water samples but cleaned bottles first, did electro connectivity on one bottle put the lids securely on bottle

			samples and put them in cooler, filled the Hydro-census sheet
RESEARCHERS' OBSERVATIONS/COMMENTS			
GROUP 3 **BOREHOLE SITES: CBD001; MB002; CDB003**			
P 2	I noticed on the last side (Taaiboschleegte) that we visit it was; and it was working with a generator and that was not a solar panel. So, we thought it was a solar panel pump I also notice on a farm maybe the pump is broken and didn't work that we must ask the farmer for how long does the pump not working if it is +/- 1 of 2 years than it is not working progress and it is important to write it in the common box on the hardcopy and tablet	I learned something new about a person that is working with a generator; and I was shocked because it is different from the other because we only were doing wind pump. It was really interesting how fast it is and how strong it came there. It is very interesting and you must do it 5 times on a stopwatch. I learnt how to work on a tablet but it was very easy, to first do the hard copy and that before you put the data on the tablet	I tried to work on a tablet; and it was really interesting and a faster way.

		make sure on the hardcopy is correct everyday Thing is filled in correct and if you feel happy about it than you can put it on the tablet. It is very important to look for the mistakes and make the wrong write before you put it in the tablet	
P8 **22/8/17**	I noticed that the submersible does not work like a wind pump and it doesn't have pipe inside it. I noticed that the submersible only works when you switched on the generator, it doesn't work when the electricity or generator is off. I noticed that the diameters and the heightened of pipes are not at the submersible and are next to the generator	I learnt that the submersible works with electricity or the generator and you have to switch on the submersible before taking the samples and you have to let the water up to 5-10 minutes to learn how to fill in the hydro census on the tablets. I learn how to get in the app and what I must fill in the app	I tried to switch on the tablet fill on the hydro census on the tablet and how to submit my work or my samples when I finish to fill in. I tried to fill in the hyrdocensus by myself so that I can understand how to do the hydro census.

P3 **22/8/17**	Always to make sure before you sent samples to the defined dispatch site that you have completed the chain of custody sheet and the right amount of samples that are in the cooler box is also written down on the sample sheet. That there is a difference between wind pump and an electrical pump. At an electrical pump, first have to ask the farmer how long the water is running and how fast it comes out of the pipe. Rinse both bottles and lids with water to be samples. If the pump is not running you should ask the farmer to switch on the pipe and wait for 5-10 minutes before you take a sample	That after every three months is you are sampled water it then becomes groundwater monitoring. That if you have sampled your water and your EC meter is above one thousand you will have to write it down in (MS). To as possible put the samples that you have taken in the cooler box after you have sampled it with the EC meter. How to capture the Hydrocensus on the tablet. That if the water isn’t coming out of the BH pipe it doesn’t mean he farmer is not using the BH unless if it was broken we could have said that he isn’t using the BH. The lids must always have that white thing on and it must be tightly closed around the bottles. And to never take samples from reservoir or dam water. Always ensure to take fresh sample water.	How to complete the Hydrocensus sheet on the tablet. How to take the diameter height and also to take a photo on the table of the sampling bottles clearly and on top of the lid and on all sides of the bottle and to put a (s) at between brackets to say secondary for the second bottle sampled.

29/08/2017	I have noticed that farmers are not monitoring their dams and boreholes because on the 15/08/2017 we went to Taaibos farm to take water samples there was a dead cow next to the dam and a dead monkey inside the dam. today		
RESEARCHERS' OBSERVATIONS/COMMENTS			

GROUP 1 BOREHOLE SITES: CDK001; CDK002			
P9	ABSENT		
P5	I noticed that when we use a tablet, things are much faster and working as a group helps a lot because we learn a lot as a group	I learned a lot about the tablet we are using. I learned that things are much easier when you are using a technology and it is faster	Learning as much as I can about how the ground water works and how they should be tested
RESEARCHERS' OBSERVATIONS/COMMENTS			
Any other comment/ questions/ suggestions **P1 (/8/18) -** How would the strength of the pump measured? **P4(25/8/18) -** The programme got more interesting as we got hands on and started doing work on our way			

DATE	I NOTICED	I LEARNED	I TRIED
Week 3 **28th – 30th August 2017**			
GROUP 1 **BOREHOLE SITES: CDK003; CDB007**			
P5	I noticed that working as a team is very. important this week I worked alone and the mistakes that I did with measurements but I noticed many things this time around I think I am ready to work alone	I learned many things like using a tablet on this programme and I learned more about groundwater. I finally tasted the water they were fresh and cool. And I learned a lot in terms of what I need to bring when I am going to the site	Even though I worked alone this week , I tried learning as possible as I can and I tried to work accordingly even though I had no team my experience was different this time around
P9	ABSENT		

GROUP 2 **BOREHOLE SITE: CDB005; CDB004; CDB003**			
P4 **29/8/17** **30/8/17**	Absent due to hospitalization Groups were deployed without the trainer to the farm sites	Groups were introduced to tablets Learnt to use a tablet which was the same as Hydrocensus sheet	Tried doing the Hydrocensus sheet and working with tablet as my group was showing me
P6	Today we re-visit the farm there still that dead monkey and the cow skin and bones were still there. There was also a windmill that has not been working since last year so there is no water for livestock in that farm	How to use GPS and iPad	I tried to capture the information I received from the farmer on the iPad

GROUP 3 CDB003; CDB007			
P8	I noticed that every time when you on site you must look around for the description because it is very important to describe the nature of the farm and he site. I noticed that the borehole and there dam can be separated on the site. They are not always on the same site. I noticed that I must always look for comments around the site.	I learn that I must write the diameters on the GPS at the time I'm standing under the borehole because every time I moved, the GPS sensing, the latitude and the longitude changes. I lean that the water that I sample must be the water that comes out from the pump not the water in the dam. I learn that both borehole and the dam they can be at a separate site not at the same site although the borehole is spinning but the water we are getting in the dam. I learn that I must put the water samples in the cooler box immediately so that the water cannot get the heat	I tried to take the samples of water inside the dam but the one that was coming to pump not the one in the dam. I tried to close the bottle tightly so that the water cannot leak

		and I learnt that when I take the temperature and the EC I must wait for the results to be steady	
P2	I noticed that we were visit the new site and that the new site and that the borehole and dam was a bit away from the borehole	, I learn that communication with the group is a good thing we taught each other and help each other a lot today, I learn also about how to do the borehole on a tablet and the E&S of a GPS and the dam got his own E&S reading on @ GPS	I tried to copy and paste on the tablet and I got it right
P3	There could be three different BH sites one on farm and on the tablet you don't new farm site you just exiting and continue on the same page	That there will always be a difference between the longitude and latitude when the BH (wind pump) and sampling dam are not on the same site	
RESEARCHER'S COMMENTS/OBSERVATIONS			
Any other comment/ questions/ suggestions? **P6 -** Since we are a group of 3 we got a chance to do everything on our own **P4 -** Since we were a small group of 3 and we visited 3 site we all had chances to do each work required from underground water monitor			

DATE	I NOTICED	I LEARNED	I TRIED
Week 4 **4th – 6th September 2017**			
GROUP 1 **CDB003; KEI001; KEI002**			
P9 **5/9/17**	I have notice the farm and BH is not well run cause there are dug around it	I have learned how to use the material myself	I have tried to communicate with the owner to keep his water in a good state
6/9/18	I have noticed the farm is well kept and also that the BH are built in a clean place from livestock Most of the farmers are using electric BH and they are clean than the other ones using windmill. Also	How to update the information to the tablet	To test the water which is sour

	built not close to the livestock		
P5	I noticed that when you working on the farm you can't just go and work I must introduce myself and explain to owners what am I doing and answer any questions they ask me, it's part of networking	I learned how to use the machines that test temperatures and EC of ground water at first it was difficult for me to understand but I learned a lot from it	Working accurately with my team and discuss what was difficult. I tried taking advise from the Tebatso when we testing water he gave us a good advice like cleaning the machine with clean water before testing other water.

GROUP 2 KEI001; KEI002; CDB003			
P6 **06-09-2017**	I have notice that the water we have tested from MR KEES' farm surprise farm is very dirty to compare with other farms and other farmers are not sure about their borehole depth	How to collaborate water strength	I tried to
P1	That the farmer doesn't know much on his borehole as for the depth and that the water has very different uses		Putting my training into actual practice by independently communicating with an actual farmer
P4 **8/9/17**	Most farmers are not sure of borehole depth	How to calculate water strength	Calculating water strength

GROUP 3 CDB003; KEI001; KEI002			
P2 **6/9/17**	I noticed on one farm that the belt and the sampling is not on one side and I write on my comment that the longitude and latitude will be change	I learnt how strong the stream of the water was but before I can do that I ask the farmer so he told me so it was not necessary for me to measure the stream at the water	I tried to show the other group how to measure the stream of the water and they tried it on their own
P 8	I noticed that the cell number of the farm owner is very important and the address. I noticed that it is very important to ask the farm owner how long does the owner let the water	I learn that the electric pump is having many pipes outside the borehole. I learn that when we take the EC we	I tried to measure the steam of the water. I tried to take the EC water the water was very salty so the EC number changed to 3,70

	running for how long and how many times per week	must know that when it shows the number and with us the water are not bad but when its Ms that means the water are very salty	
P3	That the equipment of the submersible there is no causing height it is levelled as the Groundwater level on one of the farms	That there is a difference between the US and the MS on the EC meter	
RESEARCHERS' COMMENTS/OBSERVATIONS			
Any other comment/ questions/ suggestions			

Completed Hydrocensus Sheet by Cohort trainees

Borehole ID	Borehole no. (KB)	Area	Longitude (°E)	Latitude (°S)	Elevation (m)	Date	Time	Site Description	Site Type	Borehole Depth (m)	Casing Height (cm)	Casing Diameter (cm)	Pipe Diameter (cm)	Equipment	O, Open/C, Closed	Use	StatUs (P in Use, U UnUsed)	Water Level (m)	EC (uS/cm)	T (°C)	EC profiled	Slug	pH	Photo number	Sampled (Y/N)	Comments	Area	Farm Name	Farm owner	Address	Telephone no.
TRAINER'S RECORDINGS WEEK 1																															
CDB005	5	Cradock	025.7334 9	32.16064	1036	16/08/17	8:50:00 AM	About 2km from gate; Cemented reservoir	Borehole (BH)	48 (pump depth - 16 pipes)	44	17.0	0.35	Wind pump	Closed	Livestock	P	N/A	N/A	N/A	N/A	N/A	N/A	1;2;3	N	Broken pump	Cradock	Taaibosch laagte	IYM	IYM	IYM
CDB004	4	Cradock	025.6986 6	32.16426	956	16/08/17	9:50:00 AM	1km from gate; cemented outlet to the dam	Borehole (BH)	54 (pump depth - 18 pipes)	24	11.5	4.5	Wind pump	Closed	Livestock	P	N/A	1081	16.2	N/A	N/A	N/A	4;5;6;7 ;8	Y	Dead cow skeletotns near reservoir; Dead monkey inside the reservoir waters; animal waste close to revervoir,	Cradock	Taaibosch	IYM	IYM	IYM
CDB003	3	Cradock	025.6723 0	32.16902	92.4	16/08/17	10:31:00 AM	1km from gate; cattle kraal next to reservoir	Borehole (BH)	Unkown	0 (ground level)	14.5	3.0	Submersible pump	Closed	Livestock & Domestic	P	N/A	Unknown	Unknown	N/A	N/A	N/A	9;10	N	Kraal next to borehole; Diesel leakage but there is cement around pump; Farmer pumps six days a week for 12 hours each	Cradock	Taaibosch	IYM	IYM	IYM
CDB006	6	Cradock	025.7208 4	32.15159	1022	16/08/17	11:42:00 AM	2km from entrance gate; 3-4m from ditch; 3.5 metres from	Borehole	unknown	29	15	4.0	Wind pump	closed	Livestock	P	N/A	980	15.3	N/A	N/A	N/A	1,2,3	Y	Animal waste around dam	Elandsb erg	Elandsberg	IYM	IYM	IYM
CDB007	7	Cradock				16/08/17		3,5km from dam wall	Borehole	42 (14 pipes)	20	unknown	5.5	Wind pump	Closed	Livestock; Domestic;D rinking	P	N/A	902	14.7	N/A	N/A	N/A	4,5,6	Y	Dam a meter away; water pumped 150m from reservoir; strong fresh flowing water into reservoir		Elandsberg	IYM	IYM	IYM
																													IYM	IYM	IYM
CDB009	9			32.14845	966	16/08/17	3:12:00 PM	5km from gate; House settlement next to kraal	Borehole	unknown	45	unknown	5.0	Wind pump	Closed	Domestic and livestock	P	N/A	N/A	N/A	N/A	N/A	N/A	1,2,3	N	Empty dam close to borehole - Discard	Eggrock	Eggrock	IYM	IYM	IYM
CDB002	2			34.21964 4	897	16/08/17	4:12:00 PM	3km from sewage treatment plant - 1st gate on the right hand side; 50m from the road	Borehole	21 (7 pipes)	16	15	5.0	Wind pump	Closed	Livestock	P	N/A	1231	17.7	NA	N/A	N/A	4,5,6	Y	Cattle puddle 20metres next to borehole	Cradock	Sondagshoe k	IYM	IYM	IYM
GROUP 1 - WEEK 1																													IYM	IYM	IYM
CDK005	5	Cradock	025.7334 9	32.16064	1036	16/08/17	8:50:00 AM	2km from gate; cemented reservoir surrounded with zinc	Borehole	48 (pump depth)	44	17	3.5	Wind pump	closed	Livestock	P	N/A	N/A	N/A	N/A	N/A	N/A	1,2,3	N	Broken pump - the tail/wooden ...broken	CDK	Taaibos-laagte	IYM	IYM	IYM
CDK006	6	Cradock	025.6986 6	32.16426	956	16/08/17	9:50:00 AM	1km from gate; cemented dam & outlet for livestock to drink	Borehole	54 (pump depth)	24	11.5	4.5	Wind pump	closed	Livestock	P	N/A	1081	16.2	N/A	N/A	N/A	4,5,6,7, 8,9	Y	Dead cow on the ground and dead monkey inside the dam. Cows are peeing around borehole and dam. Sampled dam water	CDK	Taaibos-laagte	IYM	IYM	IYM
CDK007	7	Cradock	025.6723 0	32.16902	924	16/08/17	10:31:00 AM	1km from the gate & cemented dam & next to kraal	Borehole	Unknown	0	14.5	3	Submersible	closed	Domestic & Livestock	P	N/A	N/A	N/A	N/A	N/A	N/A	10,11,1 2,13	N	Kraal next to the borehole; petrol pump in cemented house; farmer uses pump 6 days a week for 12 hours; Did not sample because of no diesel	CDK	Taaibos-laagte	IYM	IYM	IYM
GROUP 2																															
CDB006	6	Cradock	025.6946 5	32.15158	1022	16/08/17	11:42:00 AM	2Kkm from entrance gate, about 4metres from ditch	Borehole	....	29	15	4	Wind pump	closed	Livestock	P	N/A	980	15.3	N/A	N/A	N/A	1,2,3	Y	Cows' frield 2cm from the wind pump	CDK	Elandsberg	IYM	IYM	IYM
CDB007	7	Cradock	025.6946 5	32.14753	1000	16/08/17	1:10:00 PM	3,5m from dam wall and from farm house	Borehole	42 (14 pipes x3m)	20	0	5.5	Wind pump	closed	Livestock and Domestic	P	N/A	902	14.7	N/A	N/A	N/A	4,5,6	Y	Water pumped at 150m from reservoir; sampled from reservoir;strong fresh flowing water	CDK	Elandsberg	IYM	IYM	IYM
GROUP 3																															
CDB009	9	Cradock	025.6642 5	32.14845	966	16/08/17	3:12:00 PM	5km at the egg rock near the houses and kraal	Borehole	....	45	...	5	Wind pump	closed	Domestic & livestock	P	N/A	N/A	N/A	N/A	N/A	N/A	1,2,3	N	Empty dam close by	CDK	Egg Rock	IYM	IYM	IYM
CDB002	2	Cradock	025.6072 7	32.19644	897	16/08/17	4:12:00 PM	3km from the Shurings U-turn right the first gate and 50m in	Borehole	21 (7 pipes)	16	15	5	Wind pump	closed	Livestock	P	N/A	1231	17.7	N/A	N/A	N/A	4,5,6	Y	20km from the hole there is cattle that pee	CDK	Sondagshoe k	IYM	IYM	IYM
																													IYM	IYM	IYM

GROUP 3 - WEEK 2																													IYM	IYM	IYM
MB001	1	Cradock	25.73349	32.16065	1040	22/08/17	12:07:00 PM	Tarkastad road on your right hand side there is a big gate and 5km on in the farm	Borehole	42 (14 pipes)	44	18.5	6	Wind pump	closed	Livestock	P	N/A	N/A	N/A	N/A	N/A	N/A	1,2,3	N	No sample - pump not working. Borehole depth is 14x3	CDK	Taaiboss-laatge	IYM	IYM	IYM
MB002	2	Cradock	25.69868	32.16425	953	22/08/17	12:45:00 PM	Tarkastad road on the right hand side there is a gate and three kilometres in from the gate	Borehole	39 (13 pipes)	22.5	14.1	5	Wind pump	closed	Livestock	P	N/A	1097	18.9	N/A	N/A	N/A	4,5,6,7,8,9	Y	Dead cow close to the borehole and lots of cow movements near the hole	CDK	Taaiboss-laatge	IYM	IYM	IYM
CDB003	3	Cradock	25.67235	32.16902	927	22/08/17	1:22:00 PM	Tarkastad road . There is the resting place on the right hand side next to rest place there is a gate and 2km in from the farm	Borehole	unknown	0	17	4	Submersible	closed	Domestic and agriculture	P	N/A	1096	18.4	N/A	N/A	N/A	10,11,12	Y	Yes sampled; 0.8 seconds fast for 500ml to be full; 12hours in 6 days per week; there is big kraal next to the borehole	CDK	Taaiboss-laatge	IYM	IYM	IYM
GROUP 1																															
CDK001	1	Cradock	025.62059	32.21101	937	22/08/17	2:55:00 PM	Close to housing area in a farm; Cemented dam	Borehole	21 (pump depth)	30	15	6	Wind pump	closed	D & L	P	N/A	1070	19.7	N/A	N/A	N/A	……	Y	Next to kraal, dead cow, schack that is nearby and dumped refuse & toilet next to the dam. Dam is overflowing	CDK	Potschesdam	IYM	IYM	IYM
CDK002	2	Cradock	025.6025	32.19643	902	22/08/17	3:40:00 PM	45m from gate, cemented dam	Borehole	27 (pump depth)	21	12	4.5	Wind pump	closed	Livestock	P	N/A	1227	18.3	N/A	N/A	N/A	……	Y	Leaking of water from dam. Cattle comes with numbers to drink	CDK	Sondagshoek	IYM	IYM	IYM
																													IYM	IYM	IYM
GROUP 2																													IYM	IYM	IYM
CDB008	8	Cradock	025.62051	32.21101	939	23/08/17	9:07:00 AM	Next to Jojo tank and a big goat kraal	Borehole	27 (pipe depth of 9 pipes)	28	0	5	Wind pump	Closed	Livestock and domestic	P	N/A	1060	18.5	N/A	N/A	N/A	1,2,3	Y	Big goat kraal is very close to the dam; Dead cow skin near to the dam; there is ash around the dam	CDK	Potchesdam	IYM	IYM	IYM
CDB009	9	Cradock	025.60725	32.19645	901	23/08/17	9:57:00 AM	100m from main gate surrounded by thorn trees	Borehole	21 (Pipe depth of 7)	23	23	4.5	Wind pump	closed	Livestock	P	N/A	1189	20.1	N/A	N/A	N/A	N/A	J/VA	….	CDK		IYM	IYM	IYM

GROUP 2 - WEEK 3																													**IYM**	**IYM**	**IYM**
CDB005	5	Cradock	025.67232	32.16899	925	29/08/17	11:53:00 AM	300m from main gate; back of cattle kraal ; under small shed	Borehole	…	…	17.5	5	electric pump	closed	Domestic and livestock	P	N/A	1042	21	N/A	N/A	N/A	1,2,3,4	Y	Near a kraal and there is a dead goat in the kraal	CDK	Taaibos	IYM	IYM	IYM
CDB004	4	Cradock	025.69868	32.16425	954	29/08/17	12:29:00 PM	150m from entrance gate between thorn trees	Borehole	48m (16 pipes)	24	15	4	Wind pump	closed	Livestock	P	N/A	1094	23.1	N/A	N/A	N/A	5,6,7,8	Y	Dead cow next to pump and a dead monkey in the dam and surrounded by a lot of cow dung	CDK	Taaibos	IYM	IYM	IYM
CDB003	3	Cradock	025.7350	32.16064	1039	29/08/17	1:11:00 PM	1km from entrance gate within a mountain ridge	Borehole	42 (14 pipes)	44	16	5.5	Wind pump	closed	Livestock	U	N/A	N/A	N/A	N/A	N/A	N/A	9,10,11,12,13	N	Since 2016 in November the pum has not been repaired	CDK	Taaibos	IYM	IYM	IYM
GROUP 3																													**IYM**	**IYM**	**IYM**
CDB003	3	Cradock	25.68857	32.13733	1029	29/08/17	3:00:00 PM	On Tarkastad road on the left hand side there is a big date. Drive in 2km from the gate and then there is a second gate and drive 5km from the second gate and drive 5 km from the second gate and walk 1km away from the gate	Borehole	unknown	28	15.5	5	Wind pump	closed	Livestock	P	N/A	1126	22	N/A	N/A	N/A	1,2,3,4,5	Y	The water is pumping and is running into the bush. The trap with standing water. The farmer doesn't know the borehole depth so we do not know how many pipes or how deep is the borehole . There is lots of bees on borehole	CDK	Elandsberg	IYM	IYM	IYM
CDB007	7	Cradock	025.694966	32.14752	1002	29/08/17	3:55:00 PM	On the same farm 5km from second gate. There is a dam, house and a big kraal	Borehole	51 (17 pipes)	20.5	25	5	Wind pump	closed	Livestock and domestic	P	N/A	890	21	N/A	N/A	N/A	6,7,8,9	Y	There is an old wind pump next to the borehole; Longitude (025.694966) and Latitude (32.14752) are going to change because the borehole and the dam are not on the same site. There is also a dam next to the borehole ; Next to the sampling dam there is a pig's shack and a kraal ; the dam is overspilling	CDK	Elandsberg	IYM	IYM	IYM

GROUP 1																													IYM	IYM	IYM
CDK003	3	Cradock	025.68854	32.13734	1032	30/08/17	9:17:00 AM	1km from gate and cemented dam	Borehole	unknown	29	15.5	6	Wind pump	closed	Livestock	P	N/A	1211	16.3	N/A	N/A	N/A	....	N	The dam is ...; There is dirty water around it; The water in the dam is green; There is a creep near the dam; It is not working and the water are dirty and green; its very dirty around the dam	CDK	Elandsberg	IYM	IYM	IYM
		Cradock	025.69465	32.14755	999	30/08/17	10:31:00 AM	1km from gate ; Houses around borehole is a kilometre from the dam	Borehole	unknown	20	17	6	Wind pump	closed	Livestock and domestic	P	...	...	...	...	...	...	...	...	There is a dry dam here; There are houses near and there is an old borehole pipes lying here near the wind pump. No sample ; There are animals around the dam and a pig house and ducks near the dam and goat kraal	CDK	Elandsberg	IYM	IYM	IYM
																													IYM	IYM	IYM
GROUP 1 - WEEK 4																													**IYM**	**IYM**	**IYM**
CDB001	1	Cradock	025.66313	32.22073	864	05/09/17	12:11:00 PM	1km from gate ; house around.....	electric pump	48	8.5	15.5	0.2	electric pump	closed	Domestic and livestock	U	N/A	1319	23	N/A	N/A	N/A	...	Y	Collected water from the pipe because there is no electricity; there is salt in the ground; the dam is not working	CDK	Bhlowana	Mr Bholowana	Stembok Transport	27736530025
CDB002	2	Cradock	025.58711	32.09312	918	05/09/17	3:03:00 PM	next to the farm house	....	±13	21	12.5	4.5	Borehole	closed	Domestic	P	N/A	3.32ms	23.1	N/A	N/A	N/A	....	Y	There are 2 dams ; the other one is filling water to the other dam; water is salty and used for washing and laundry. There is irrigation around and cattle dung and skin	CDK	Surprise	Mr Kei	Hofmeyer road	764096581
CDB003	3	Cradock	025.60875	32.11208	896	05/09/17	4:12:00 PM	On the road to Hofmeyer next to the farm; cemented dams	Borehole	±12	15	14	4	electric pump	closed	Domestic and livestock	P	N/A	1021	24.4	N/A	N/A	N/A	.....	Y	Borehole is situated in a clean surrounding area. There are onions around planted	CDK	Peldin	Mr Kei	Hofmeyer road	764096581
	4	Cradock	025.67239	32.16897	919	06/09/17	1:19:00 PM	1km from the gate . There is a kraal around cemented dam	Borehole	...	0	5	3.5	Borehole	closed	D&L	P	N/A	985	23.4	N/A	N/A	N/A	...	Y	There are cows around and the kraal for cows is near. There are shacks around. Tested the electric pump ; it runs about 4.8 seconds per litre; They use it 3 times a week for 12hours	CDK	Taaibos-Laatge	IYM	IYM	IYM
GROUP 2																													IYM	IYM	IYM
KEI001	1	Cradock	025.58709	32.09319	918	06/09/17	10:00:00 AM	we collected water from the tank ±200m from borehole and the pipe is underground	Borehole	30-40	27	18	5	electric pump	closed	Domestic not for consumption	P	N/A	3.65ms	19.9	N/A	N/A	N/A	1,2,3	Y	Pipe passing under shed and there is a lot of cow-dung. Borehole is 30-40 m deep. The water is collected from second linked tank ; the water is for domestic only not for consumption	CDK	Surprise	Mr Kei	Hofmeyer road	764096581
KEI003	2	Cradock	025.60875	32.11209	895	06/09/17	11:00:00 AM	Borehole is next to the pig sty, near the trees	Borehole	...	29	16	4	electric pump	closed	Agricultural and domestic	P	N/A	1056	22.1	N/A	N/A	N/A	4,5,6	Y	Next to the pig sty not ffrom house and onion planted around it	CDK	Peldin	Mr Kei	Hofmeyer road	764096581
CDB003	3	Cradock	025.67237	32.16900	929	06/09/17	12:05:00 PM	± 300m from entrance gate behind the cattle kraal under the shed	Borehole	...	36	14	5	electric pump	closed	Domestic and livestock	P	N/A	1033	21.5	N/A	N/A	N/A	7,8,9,10	Y	Behind the cattle kraal; 1.80,1.53, 1.64, 1.59 terefore average of 1.59 per 500ml within four test runs	CDK	Taaibos	IYM	IYM	IYM
GROUP 3																													IYM	IYM	IYM
CDB003	1	Cradock	025.67239	32.16897	919	06/09/17	1:25:00 PM	on the Tarkastad road next to Ruskamp; there is a gate on the right hand side 5km in from the gate to the borehole site	Borehole	15.5	0	5	...	submersible	closed	Domestic and livestock	P	N/A	1084	21.4	N/A	N/A	N/A	1,2,3,4,5	Y	There is a kraal next to the borehole site and cows . To measure the strength it takes 0.7 seconds with 500ml bottle ; pumps once a day per week 7 up to 12 hours the water is running	CDK	Taaibos-Laatge	IYM	IYM	IYM
KEI farmBM001	2	Cradock	025.60875	32.11208	894	06/09/17	3:10:00 PM	On the Hofmeyer road first cross on your left hand side there is white houses and a kraal	Borehole	16cm	21.5cm	5	39 (13 pipes x3)	submersible	closed	domestic, livestock and agricultural	P	N/A	1033	23.3	N/A	N/A	N/A	6,7,8,9,10,11	Y	Next to a kraal and there is a garden ; there is ducks next to the kraal; the water is running 3hours a day every week	CDK	Buldine	Mr Kei	PO Box 326	834748482
KEI farmBM002	3	Cradock	025.58860	32.09221	931	06/09/17	4:00:00 PM	5km away from Kei first farm , turn left hand side there is a big dam on the left hand side and two big houses	Borehole	...	12	26	5	submersible	closed	Domestic	P	N/A	3.70ms	21.4	N/A	N/A	N/A	12 to 17	Y	1 hour a day every week; there was old hard boards and tyres next to the water. The owner of the farme is not sure how deep is the hole ; They use the water only to wash clothes not for drinking because the water is too salty and the longitude and latitude are going to change because the water and borehole are not on the same site	CDK	Surprise	Mr Kei	PO Box 326	834748482
																													IYM	IYM	IYM
																													IYM	IYM	IYM
																													IYM	IYM	IYM
																													IYM	IYM	IYM

Appendix D

Earth Stewardship Science Research Institute

NELSON MANDELA UNIVERSITY

AEON/NMMU CRADOCK SHALE-GAS BASELINE STUDY

Citizen Science Training Programme Advert

The Nelson Mandela Metropolitan University (NMMU) with support from the Eastern Cape Government is currently coordinating the Karoo Shale Gas Baseline Study Research within selected Karoo areas. In partnership with the IPED Department, NMMU identified the need for community engagement and empowerment which will involve developing a Citizen Science Programme - one of the NMMU graduate student's research focus (Ms Nyaradzo Dhliwayo,) under the supervision of Professor Maarten De Wit (Chair in Earth Stewardship Science, NMMU).

The citizen science programme will focus on the theoretical and practical aspects of Groundwater Monitoring and Analysis (Hydro-census and Groundwater sampling); run for approximately 6 weeks where +/- 12 youths will be trained and evaluated. As a result, the trainees who become involved in this training will be able to:

1. Identify groundwater monitoring aspects and properties which make water fit or unfit for consumption
2. Work with professional hydrologists from the government and the private institutions to report on aspects of Cradock's groundwater quality
3. Educate and engage other local citizens on groundwater monitoring processes prior to potential shale gas exploration
4. Be empowered for entrepreneurship (groundwater monitoring and analysis)

APPLICATION CRITERIA

Unemployed out of school youths

- Must have completed Grade 12
- Ages 18 – 35
- ***Women are encouraged to apply***

DOCUMENTS REQUIRED

- A detailed CV (indicating the Ward of residence)
- A motivation (expression of interest) letter

If you are interested in this training programme, please submit your CV's and motivation letters at the local Registry offices to Ms Zelda by **14th October 2016.** For more information about this training programme, please contact **Mr Sonwabo Luzipo**; **Mr Siyabulela Nxele** on **048 801 5095** or **Ms Nyaradzo Dhliwayo** on Nyaradzo.dhliwayo@nmmu.ac.za

PLEASE NOTE: *This opportunity is not open to individuals who are currently participating in other learnerships or similar programmes. The selection of applicants will be guided by the recruitment procedures of the Nelson Mandela Metropolitan University (NMMU).*

Earth Stewardship Science

Research Institute

NELSON MANDELA UNIVERSITY

Citizen Science - Hydro-census and Groundwater Sampling Field Guide

(contextually designed and implemented by the researcher, Ms Nyaradzo Dhliwayo, 2017**)**

Main Purpose:

- To identify preliminary infield water quality;
- To conduct water sampling,
- To analyse and determine whether sampled water is fit for human consumption or agricultural purposes

The following equipment / resources are required:

- EC meter x1

- 1 Field GPS

- Sampling bottles

- Stationery (clipboard, notebook, pencil, eraser, field tape measures, cooler box)

- farm area to conduct groundwater monitoring

- transport to and from the training and sampling sites

- Hydro-census Sheet

- Water Sampling sheet

SAFETY NOTE:

Before entering any site, ensure that the site is safe to work on and identify any potential hazards.

A: ***Hydro-Census Procedure***

Please take note of the following:

1. Make sure you have all your equipment ready
2. Ensure appointment has been scheduled with farm or property owner
3. Acquaint yourself with the farm or property owner
4. Identify the various sources of water on the farm (farm/property owner)
5. Discuss the uses of water on the farm (farm/property owner)
6. Visit the water sites and record the readings as outlined in the Hydrocensus sheet
    a. Allocate a name to every water source site you visit and take the GPS reading
    b. Ensure that the water tested is "fresh" water (refer to "water sampling procedure" below)
    c. Record the state of immediate surroundings in "comments" (wind, livestock tracks, trees, other)
    d. Record the form of land use where the water source is situated
    e. Proceed to record all readings as per Hydrocensus sheet

B: ***Water-Sampling Procedure***

<u>NOTE</u>: Ensure the Hydrocensus sheet has been completed before any sampling

<u>SURFACE WATER SAMPLING</u>

1. Commence recordings on the sampling sheet
2. Ensure the name of the sampling site and coordinates corresponds with the logging sheets (both Hydrocensus sheet and sampling sheet)
3. Take 2 sampling bottles and mark (permanent marker) them **<u>clearly</u>** on **<u>top</u>** of the bottle lid and on **<u>all</u>** sides of the bottle as follows:
    a. Bottle 1 (Primary)
    b. Bottle 2 (Secondary)
4. Rinse both bottles and lids with the water to be sampled
5. Fill-up the bottles to the top (if possible) and tightly close with the lid
6. Place the water bottles in the cooler box
7. Complete the sampling sheet and ensure all fields are recorded

<u>GROUND-WATER SAMPLING - WIND PUMP</u>

1. Commence recordings on the sampling sheet
2. Ensure that the name of Sampling site and Coordinates are corresponding with the logging sheets (both Hydro-census sheet and sampling sheet)
3. Ensure the wind pump is working and pumping ("turning")
4. Take 2 sampling bottles and mark (permanent marker) them **<u>clearly</u>** on **<u>top</u>** of the lid and on **<u>all</u>** sides of the bottle as follows:
    a. Bottle 1 (Primary)
    b. Bottle 2 (Secondary)
5. Identify pipe outlet directly from pump i.e. before water enters the reservoir/dam
    a. Sample to be taken from this outlet
6. Before taking a sample, wait 5 minutes (Wind pump should be turning and the wind must be blowing consistently)
    a. This is to ensure that "fresh" water is sampled and not stagnant water in the pipes
7. Rinse both bottles and lids with the water to be sampled

8. Collect the sample water directly from the identified pump outlet and not reservoir water (always ensure to collect fresh water).
9. Fill-up the bottles to the top (if possible) and tightly close with the lid
10. Place the water bottles in the cooler box
11. Complete the sampling sheet and ensure all fields are recorded

GROUND-WATER SAMPLING - ELECTRICAL PUMP

1. Commence recordings on the sampling sheet
2. Ensure that the name of sampling site and coordinates are corresponding with the logging sheets (both Hydrocensus sheet and sampling sheet)
3. Take 2 sampling bottles and mark them **clearly** on **top** of the lid and on **all** sides of the bottle as follows:
    a. Bottle 1 (Primary)
    b. Bottle 2 (Secondary)
4. Identify pipe outlet directly from pump i.e. before water enters the reservoir/dam
    a. Sample to be taken from this outlet
5. Ensure the pump has been running for more than 10 minutes before collecting the water sample.
    a. If pump is **not running,** request the farm owner to switch on the pipe and wait for 5 - 10 minutes before you take the sample
    b. This is to ensure that "fresh" water is sampled and not stagnant water in the pipes
6. Rinse both bottles and lids with the water to be sampled
7. **IMMEDIATELY** collect sample from the identified pump outlet and not reservoir/dam water (always ensure to take fresh sample water).
8. Fill-up the bottles to the top (if possible) and tightly close with the lid
9. Place the water bottles in the cooler box
10. Complete the sampling sheet and ensure all fields are recorded

IMPORTANT NOTE:

Before you leave a Sampling site ensure the following: -

a. All sections of the Hydro-census sheet and the sampling sheet have been completed
b. All sample bottles are **clearly** labelled and are **correctly** stored in the cooler boxes
c. All equipment is collected and safely stored for the next sample site
d. Ensure site is left in the original state

C: SAMPLE DESPATCH

1. List and record the number of samples you have taken
2. Complete the chain of custody sheet
3. Deliver the samples and equipment to the defined despatch site
4. Contact Baseline study co-ordinator and responsible researcher

D: AEON – *Groundwater Analysis Equipment and methods utilized*

pH

Equipment:

Hanna pH Meter (HI 9126 pH/ORP Meter)

Combination pH Electrode - Can be refillable or non-refillable (HI1230; 0-12 pH 5 to 70°C)

Procedure:

Instrument and probe are calibrated using a two point calibration (pH 4 and 7)

The quality of pH calibration is checked by measuring the pH value and potential difference (mV) of pH7 and 4 (QC) buffers, are measured.

Measure samples(s) and record the pH values and temperature of solution

Samples and calibration and QC buffers are all measured at 25°C ±0.5

Electrical Conductivity

Equipment:

WTW LF330 Conductivity Meter and WTW 325 probe

Procedure:

Calibration in control standard solution

Measure control standard solution of 0.01 mol/L KCl.

The meter automatically considers the temperature dependence of the control standard solution and stores the determined cell constant.

Measurement: Selecting measuring mode

The meter will give the temperature of the sample and the conductivity value with units shown

Quality control procedure:

A 1431 µS/cm and 3000 µS/cm at 25°C conductivity standard is measured.

TDS

As for conductivity, meter is switched to TDS (TDS is calculated from the conductivity of the sample)

Alkalinity

Equipment:

250cm^3 Erlenmeyer flasks

50.00cm^3 Burette

10.00cm^3 Pipette (depending on the sample volume chosen)

Method:

Phenolphthalein Alkalinity and Total Alkalinity

- Pipette 10 ml of sample into a conical flask. (filter if necessary)
- Add 3 drops. If the colour is pink continue with the titration.
- Titrate with 0.02 M H_2SO_4, until a colourless end point. Record this TF and use in the calculation**.**
- Now, using the colourless solution from the analysis above, continue with the following:
- Add 5 drops of mixed indicator.
- If there is colour titrate against 0.02 M H_2SO_4 to a red colour

Anions

Equipment:

Metrohm IC 761 Compact

The IC system is equipped with a Metrosep A Supp 5 150/4.0 anion-separation column for analyses with chemical suppression. The standard eluent used is 1.0 mmol/L $NaHCO_3$ and 3.2 mmol/L Na2CO_3.

The Metrohm IC is equipped with a suppressor module, which uses (H2SO4)100mM solution for regeneration and distilled and degassed water for rinsing. The system needs ~ 1mL of sample to aspirate and the sample loop (amount injected onto the column) is 20 µL. A minimum sample size of 5 ml is needed to carry out IC analysis.

Method:

External calibration using anion standards

5 point calibration curves

- Fl^- (0.05, 0.5, 1, 5 & 10ppm)

- Cl^- (1, 10,50, 100 & 200ppm)
- NO_2 (0.05, 0.5, 1, 5 & 10ppm)
- NO_3 (1, 5, 10, 50 & 100ppm)
- PO_4 (10, 20, 50, 100 & 200ppm)
- SO_4 (10.20,50, 100 & 200ppm)

QC – F (~5 ppm), Cl (50 ppm), NO2 (5 ppm), NO3 (50 ppm), SO4 (50 pm) and PO4 (50 ppm).

Samples were filtered with 0.45µm syringe filters, run as-is and then diluted accordingly to fit into the validated linear range.

Chain of Custody

Project: Karoo Shale Gas Research Programme	**Name of Sampler:** Cradock NMMU CS Trainees
Project Contact: Divan Stroebel **Mobile:** 082 099 2366 **Project Contact Details:** Geoscience Department, Nelson Mandela University	**Requested Analysis**

	Physical Parameters	Macro and Traces (only anticipated elements listed)						Hydrocarbons	Noble Gasses
Number of Samples: 20	EC pH Alkalinity TDS REDOX	Br Ca Cl F K Mg Na	CO3 HCO3 NH4 NO2 NO3 PO4 SO4	Al As B Ba Cd Co Cr Cu F	Fe Hg Li Mn Mo Ni Pb Ra Rb	Sb Se Si Sr U V Zn		Ethanol Benzene TAME Toluene Ethylbenzene o-Xylene m+p-Xylene Naphtalene	He Ne Ar Kr Xe Rn
Sample List: See Attached									

Relinquished By:	Date:	Time:	Received By:	Date:	Time:
Name: Bernedine Sign: Buchels	06/09 2017	17:10	Name: N. Dhluwayo Sign: [illegible]	6/9/17	17:14
Relinquished By:	**Date:**	**Time:**	**Received By:**	**Date:**	**Time:**
Name: Sign:			Name: Sign:		
Relinquished By:	**Date:**	**Time:**	**Received By:**	**Date:**	**Time:**
Name: Sign:			Name: Sign:		

Sample ID's							
CDB 005	CDB 003 (S)						
CDB 003	CDB 003 (S)						
CDB 003	CDB 003 (S)						
KEI 001	KEI 001 (S)						
KEI 002	KEI 002 (S)						
* KEI FARM	KEI FARM						
BM 001	BM 001 (S)						
* KEI FARM	KEI FARM						
BM 002	BM 002 (S)						
CDB 001	CDB 001 (S)						
CDB 002	CDB 002 (S)						
CDB 003	CDB 003 (S)						

Number of Samples: 20

Chain of Custody

Project: Karoo Shale Gas Research Programme	Name of Sampler: TRAINING GROUP
Project Contact: Divan Stroebel Mobile: 082 099 2366 Project Contact Details: Geoscience Department, Nelson Mandela University	**Requested Analysis**

	Physical Parameters	Macro and Traces (only anticipated elements listed)					Hydrocarbons	Noble Gasses
Number of Samples: 8	EC pH Alkalinity TDS REDOX	Br Ca Cl F K Mg Na	CO3 HCO3 NH4 NO2 NO3 PO4 SO4	Al As B Ba Cd Co Cr Cu F	Fe Hg Li Mn Mo Ni Pb Ra Rb	Sb Se Si Sr U V Zn	Ethanol Benzene TAME Toluene Ethylbenzene o-Xylene m+p-Xylene Naphtalene	He Ne Ar Kr Xe Rn
Sample List: See Attached								

Relinquished By:	Date:	Time:	Received By:	Date:	Time:
Name: KHAYALETHU Sign: K. Jamani	23/08/17	11:01	Name: N. Dhliwayo Sign: NDuyo	23/8/17	11:03
Relinquished By:	**Date:**	**Time:**	**Received By:**	**Date:**	**Time:**
Name: Sign:			Name: Sign:		
Relinquished By:	**Date:**	**Time:**	**Received By:**	**Date:**	**Time:**
Name: Sign:			Name: Sign:		

Sample ID's							
CDB001	CDB001(S)						
CDB002	CDB002(S)						
CDB003	CDB003(S)						
CDB004	CDB004(S)						

Number of Samples: 8