EVALUATION OF A TRAINING MANUAL FOR GROUNDWATER RESOURCE MANAGEMENT AND GROUNDWATER GOVERNANCE FOR MUNICIPALITIES IN SOUTH AFRICA

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DECLARATION

I, **Johann de Lange**, declare that the master's degree dissertation that I herewith submit for the master's degree qualification *Master of Science majoring in Geohydrology* at the University of the Free State is my independent work and that I have not previously submitted it for a qualification at another institution of higher education.

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15 November 2021

DEDICATION

In memory of my parents Willem and Rita de Lange.

Always loved, never forgotten, and forever missed.

...Until we meet again

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ABSTRACT

Groundwater knowledge is crucial in water scarce countries like South Africa. The management of groundwater resources are often neglected, and there is a lack of proper knowledge in groundwater as a discipline. It is vital that countries such as South Africa enlighten the public and knowledgeable individuals about groundwater. Groundwater resource management and groundwater governance in municipalities is required to improve groundwater management and governance. The enhancement of knowledge and skills will improve groundwater governance and management and educate individuals on groundwater use, sustainability, and protection.

These problems can be resolved by developing and providing an easy-access platform. The platform provides individuals from various disciplines with sufficient information to gain general knowledge of groundwater.

The development of an easy-access platform (Thinkific) provided an easy gateway to narrow the bridge between groundwater and individuals and was used to determine the effectiveness of the "Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa". Within this dissertation, the effectiveness of the training manual was significantly proven on a sample of 55 young working adults (participants). The data collected from numerous participants provided a holistic perspective of the effectiveness of the dissertation. Different types of quantitative statistical techniques were used to collect, analyse, and display the data.

The main concept revolved around the Kirkpatrick's evaluation method. Only the first two levels of this evaluation model were utilised. Participants wrote pre- and post-tests and completed evaluation questionnaires. This was done to establish the enhanced level of knowledge within participants and to gather reactions regarding perception and satisfaction of the training manual. These tests indicate the effectiveness of the training manual. The data gathered from this training manual show that it is significant to use the training manual as a foundation for groundwater knowledge. The groundwater content in this training manual is sufficient to use for training.

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ABBREVIATIONS AND ACRONYMS

CUT	Central University of Technology, Free State
CMA	Catchment Management Agency
EC	Electrical Conductivity
IWRM	Integrated Water Resource Management
LMS	Learning Management System
MOOC	Massive Open Online Course
SAQ	Self-Administered Questionnaire
WRC	Water Research Commission

Chapter 1
Orientation to the study

1.1 Introduction and Background

South Africa is a water-scarce semi-arid country with an average annual precipitation approximately 500 mm, which is below 60% of the global norm (Mukheirbir and Sparks, 2005). South Africa is situated in a subtropical climate zone where the average potential evaporation rate surpasses the average precipitation rate thereby leading to a fluctuating groundwater recharge rate (Kelbe and Rawlins, 2004). Schulze (2005) explained that groundwater resources are vital under these conditions because of the global and local threats in climate changes. Turton et al. (2006) classified three primary threats of particular significance "[1]over-utilization, [2]pollution resulting from the mismanagement of aquifers, and [3]reduced recharge as a result of global climate change".

The growing demand for food, energy and other human consumptions and the constant change in climate in South Africa's rapidly growing population, resulted in an increasing dependence on groundwater (Megdal, 2018). Megdal (2018) also explained that water managers and policy makers must pay adequate attention to the quality and quantity of groundwater as the reliance on groundwater increases.

Münch and Conrad (2007), stated that groundwater allocation, management and groundwater governance had become an important topic of debate as groundwater represents an essential source of fresh water in various parts in South Africa and sustain numerous rural livelihoods. Groundwater governance and groundwater resource management in South Africa can be described as a transformative process of making decisions and implementing them (Jonker et al., 2010).

Groundwater management is formally described as the assessment of hydrologic and environmental aspects and involves the ability to get and implement results within a short time (Willis and Yeh, 1987). In addition to groundwater management, Moench et al. (2012) defined groundwater governance as: "The process through which groundwater related decisions are taken (whether on the basis of formal management decisions, action within markets, or through informal social relations) and power over groundwater is exercised".

Governance is usually carried out by an authority in power and takes into consideration the requirements of its subjects, though it may fail in many aspects.

Improved groundwater management and governance is required to better comprehend and manage groundwater use (Megdal, 2018). Luthuli et al. (2019) and Mankin (2009) described that local authorities should concentrate on training to ensure that public sector employees constantly enhance their skills, knowledge and performance.

Successful organisations recognise and accept that professional development and training remains vital in both public and private sectors for the gradual growth and evolution of business (Noe, 2010). Organisations are regularly challenged by the globalisation of rapid growth and change of science, technology, innovation, and competition between competent employees (Kimberly, 2004).

Organisations also understand that training is an essential human resource development function (Rajeev et al., 2009) and that training will permit organisations to revolutionise and fulfil goals (Salas et al., 2012). Training requires time, energy and money (Topno, 2012) within organisations and will aim to improve an employee's skill, knowledge and attitudes (Rosen et al., 2008). Organisations will thus invest in training (Kazbour et al., 2013).

Gerber et al. (1987) reasoned that organisations are responsible for training and development within departments to ensure that all employees are knowledgeable in their respective fields of work. Gerber et al. (1987) and Ntlebi (2003) indicated that South Africans, specifically human resource managers are confronted with a significant challenge in narrowing the gap between productive and unproductive employees and that training could be utilised to narrow the gap.

Various authors in previous literature indicated that training evaluation increased and emerged over time as an essential measure of organisational contribution due to the high demand for staff training (Goldstein et al., 2001; Kirkpatrick, 1998; Phillips, 2012).

1.2 Rationale of the Study

The rapid population growth and constant drought in South Africa led to the increased demand of groundwater resources fit for human consumption (Masindi and Duncker, 2016). As a developing country, South Africa remains in a process of constant change to enhance the operational, functional, and human resource components. The regular improvements implemented by organisations and the development of knowledge and skills of employees have become a crucial component in groundwater management (Luthuli et al., 2019). Riemann et al. (2012) stated that a vast majority of municipalities in arid regions are dependent on groundwater for drought management and utilise groundwater on a regular basis. There are numerous guidelines that have been developed in South Africa to ensure the correct management of groundwater resources. However, a lack of proper groundwater management in groundwater governance is still prominent. Professional training and development are critical for any organisation and should be made a priority (Luthuli et al., 2019). Luthuli et al. (2019), stated that an insignificant amount of training and development might lead to a decrease in employee motivation.

1.3 The Problem Statement

Public sector employees and professionals have shown insufficient knowledge and skills in groundwater management and governance during the looming water crisis and “day zero” phenomenon in South Africa. The lack of these elements resulted in excessive resource expenditures by local municipalities and governments.

To create a comprehensive groundwater resource management structure within municipalities, a training manual on groundwater resource management and groundwater governance for municipalities was developed by a project team of which I was part of for the Water Research Commission (WRC). The training manual was developed to capacitate municipal employees, technicians, managers, and decision-makers to increase groundwater knowledge and skills. Enhanced knowledge and skills will not just improve groundwater governance and management, but also educate individuals on groundwater use sustainability and protection.

The main purpose and research focus of this study was to assess the effectiveness of a training program known as “Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa” and to utilise Kirkpatrick's

(1998) framework for program evaluation to address the possible curriculum shortcomings as identified.

1.4 Research Aims and Objectives

The general aim of this research is to evaluate the effectiveness of a training program known as "Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa" by utilising Kirkpatrick's (1998) four-level framework for program evaluation.

This research aims to provide information on how the program was perceived as effective by focusing on the reactions of the trainees and their learning. The reactions of trainees relate to the opinions and attitudes of trainees regarding their level of program satisfaction (Kirkpatrick, 1998). Learning relates to the change in knowledge within participants before and after the program (Kirkpatrick, 1998).

1.4.1 Objectives

In realising this aim and purpose of the research, the following objectives will be pursued:

1. Identify the forces driving training evaluation and the barriers to effective training evaluation.
2. Evaluate different theoretical models used for training evaluation and design.
3. Investigate and measure Kirkpatrick's four-level hierarchy of training evaluation, focusing specifically on affective (participants reactions) and cognitive (learning) domains.
4. Formulate recommendations that can be proposed to effectively implement the training program to enhance service delivery related to groundwater resource management and groundwater governance.

1.5 Research Questions

Guided by the aims, objectives and problem statement of this study, the main research question was formulated below.

1.5.1 Main Research Question

How effective is the training program known as “Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa” in equipping municipal employees, technicians, managers, and decision-makers with the required knowledge and skills to enhance a better understanding of groundwater?

In terms of possible research approaches the main research question is broad, and the focus was narrowed by posing subsidiary research questions and hypotheses (null and alternative) for an effective research design (Mertens and Wilson, 2012).

1.5.2 Sub questions and Hypothesis

The following subsidiary questions and hypotheses were formulated:

1.5.2.1 Sub Question One: Program Satisfaction

How effective is the training program content with a specific focus on the affective reactions of participants?

Hypothesis 1:

- **Null hypothesis:** Affective reaction will not be significant towards the program.
- **Alternative hypothesis:** Affective reaction will be significant towards the program.

1.5.2.2 Sub Question Two: Learning

How effective is the training program content in facilitating the acquisition of new knowledge to participants?

Hypothesis 2:

- **Null hypothesis:** The program will not be effective in facilitating the acquisition of new knowledge to participants.

- **Alternative hypothesis:** The program will be effective in facilitating the acquisition of new knowledge to participants.

1.5.2.3 Sub Question Three: Recommendations

What recommendations can be proposed to effectively implement the training program to enhance service delivery?

1.6 Significance of the Study

Before the research commenced, it was discovered by the current researcher that insignificant research had been conducted in the groundwater scientific field pertaining to training evaluation in South Africa. This research provides information to potentially minimalise the gap of information in South Africa pertaining to training manuals designed to improve groundwater management and groundwater governance within municipalities.

Below is a summary of the areas where this study provides information to potentially minimalise the gap:

- Collect and analyse data which can be distributed to other stakeholders.
- Determine the level of groundwater knowledge in the public and private sector.
- Re-examine the effectiveness of "Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa".
- Formulate a standardised baseline for future training manuals.

1.7 Research Approach

This research will follow a quantitative research design approach and methodology to address the research objectives and questions. The quantitative research approach will aid in answering the subsidiary research questions and hypotheses by processing quantified data in a mathematical order and incorporate reliable survey instruments to measure effectiveness. This study approached a summative program evaluation by utilising Kirkpatrick four-level program evaluation framework.

Various data collection tools were created, analysed, and illustrated in a combination of descriptive statistics, graphs, and tables, given that this study aims to evaluate the effectiveness of a training program by utilising and measure Kirkpatrick's framework for program evaluation concentrating on different domains. Data collection instruments are described below and were self-developed.

1.7.1 Evaluation survey instrument: Level one

Various examples of Kirkpatrick (1998), measurement tools were collected and adapted to cover a range of three categories and thirty-eight questions. Each question was designed to gather reactions regarding the participant's satisfaction and perception within the training manual content, the evaluation platform, and the evaluation survey instrument.

The three categories in the survey questionnaire covered topics on the training content (twenty-two questions), training platform (eleven questions) and general program questions (five questions). IBM SPSS application for statistics was utilised to analyse the data in the form of descriptive statistics and graphs.

1.7.2 Multiple-choice pre-and post-test: Level two

Tests have been designed to include five different modules within the training manual. Below is a breakdown of the five different modules and the total of questions within the performance test:

1. Groundwater Management – Eighteen questions
2. Groundwater Monitoring – Nineteen questions
3. Groundwater Quality – Seventeen questions
4. Groundwater Quantity – Ten questions
5. Groundwater Regulations – Nineteen questions

Post-test questions were the same as the preliminary test questions but displayed in random order. This method eliminates the recollection of answers by respondents.

1.8 Structure and Organisation of the Dissertation

The current dissertation consists of 5 chapters as illustrated in Figure 1-1.

Chapter 1 provides an overview of the research introduction and background, rational of study, problem statement, research aims and objectives, research questions, significance of the study, research approach and the structure and organisation of the dissertation.

Chapter 2 covers the main literature review.

Chapter 3 provides the research design and methodology used in this study: research approach, data collection and analysis of information.

Chapter 4 contains the data collection and analysis process.

Chapter 5 provides a summary and conclusion of this study.

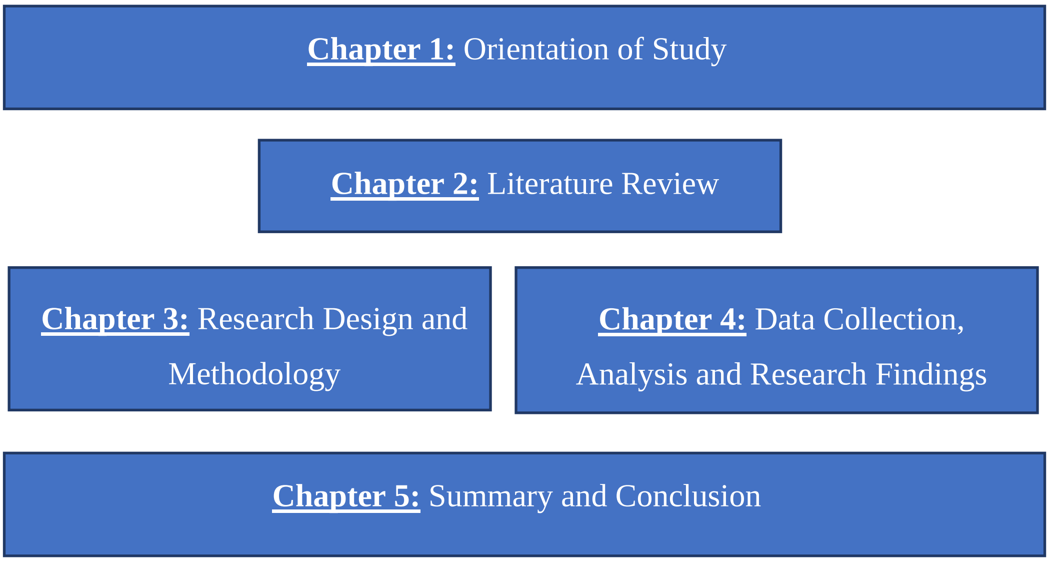

Figure 1-1: Organisation of the Dissertation.

Chapter 2
Literature Review

2.1 Introduction

The literature study provides a holistic approach to evaluation. This section focuses on the following objectives:

1. Identify the forces driving training evaluation and the barriers to effective training evaluation.

2. Evaluate different theoretical models and frameworks used for training evaluation and design.

3. Investigate and measure Kirkpatrick's four-level hierarchy of training evaluation, focusing specifically on affective (participants reactions) and cognitive (learning) domains.

4. Formulate recommendations that can be proposed to effectively implement the training program to enhance service delivery.

With respect to the above-mentioned objectives, a sufficient research contribution can be made. The literature commences with a comprehensive overview of evaluation by defining and describing evaluation in general, training evaluation, training effectiveness, formative, and summative evaluation. The chapter then proceeds to describe the strategic forces that drive training evaluation and the benefits thereof. After that, the chapter progresses through different evaluation models such as the description of Kirkpatrick's four-level evaluation that provides the core structure of this study.

2.2 Evaluation: A Comprehensive Approach

2.2.1 Evaluation Defined

A singular well-defined meaning for the word 'evaluation' can be controversial and challenging to find. Weiss (1972:1) described that "[e]valuation is an elastic word that stretches to cover judgments of many kinds". Evaluation has a diverse range of definitions in literature as the meaning thereof may often be interpreted differently by various people (Brinkerhoff et al., 2012).

Scriven (2001) and Mertens and Wilson (2012) elaborated further and see the term evaluation as a trans-discipline due to its extensive range of diverse meanings in different disciplines and cannot be described as an independent field. However, evaluation activities are not limited to one area of applied social science. It is also prevalent in other sciences such as biology, physics, geography, history, accounting, education, computer science, and business and management (Scriven, 2001).

Since evaluation is circumscribed in numerous ways and comes in many guises, Weiss (1998:4) broadly defines it as "the systematic assessment of the operation and/or the outcomes of a program or policy, compared to a set of explicit or implicit standards, as a means of contributing to the improvement of the program or policy".

This definition of Weiss (1998:4), sets out various key elements. Firstly, evaluation is seen as a systematic assessment or process implemented to determine the value, significance, or meaning of an activity (Scriven, 1991; Phillips, 2012). Stufflebeam, (2001), Beevers et al. (2019), acknowledge this and agrees that evaluation is a study designed to determine the value and to measure an object's merit and worth. Borate et al. (2014), concluded that evaluation is as a systematic process of valuation which ultimately delivers vital information that may be implemented for constant growth and improvement.

Secondly, there is underlying importance stressed on the terms program operation and outcomes. Evaluation is thus not just defined as a process to determine the values of something (Bramley, 2003) but also as the process used to determine the effectiveness, delivery and cost-effectiveness of training (Guyadeen and Seasons, 2018; Goldstein et al., 2001; Kirkpatrick, 1998). Finally, evaluation consequently determines the value or limitations of an objective to improve and refine processes efficiently and effectively (Brown et al., 2015).

Evaluations are in a broad sense the systematic collection and use of qualitative and quantitative data to aid users to develop knowledge and understand what a program does and how to manage a set of objectives (Scheirer, 2012).

2.2.2 Training Evaluation versus Training Effectiveness

Training effectiveness and training evaluation are frequently described in the literature as interchangeable terms but are, however, different concepts, and a clear distinction should be made between them (Alvarez et al., 2004).

Gopal (2008), indicated that most evaluations in the context of training will begin with the recognition of training needs and concludes with evaluation. Training needs were identified before the development of the "Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa".

The process of training evaluation is defined by Hamblin (1974), as, "any attempt to obtain information (feedback) on the effects of the training program and to assess the value of the training in the light of that information". In other words, training evaluation may be interpreted as a methodical anthology and assessment of judgmental and informative information needed to create and implement effective training decisions associated to the modification, selection and value of numerous academic activities (Werner and DeSimone, 2011; Goldstein, 1993). Lewis and Thornhill (1994) elaborated further and described training evaluation as a process that tries to evaluate training value, organisational outcomes, cost-effectiveness, and performance value of trainees.

Sims (1993) argues that training evaluation attempt to respond to the following question: "did training work, and if not, why not?" Newcomer et al. (2015), agrees with Sims (1993) and observed that training evaluation "… is the application of systematic methods to address questions about program operations and results".

Alvarez et al. (2004) defined training evaluation as a measuring technique used in a methodological approach to examine and determine learning outcomes. Alvarez et al. (2004) also described that training evaluation only offers a micro view on the results of training, since training evaluations only emphasise the outcome of training.

Goldstein et al. (2001), Noe (2010) and Schalock (2001) argue that evaluation is an orderly process implemented to collect and analyse data to determine the value and efficiency of training and if training has achieved its objectives.

In other words, training evaluation involves the procedure of assessing whether training is effective, achieved its objectives and assessing the impact that the training had on trainee's behaviour, performance, and results (King et al., 2001; Topno, 2012).

Vyas (2004) described that evaluation in training is an important measurement to determine the effectiveness of training. By evaluating training effectiveness, essential decisions on training improvements, structure, continuation, and resource allocation can be made (Rama Devi and Shaik, 2012). Evaluation of training effectiveness is defined by Schalock (2001) as the degree to which a program has achieved the set-out aims and objectives. Rama Devi and Shaik (2012) described that training would be more effective when the relationship between training outcomes and training objectives are closer together.

Training effectiveness is defined by Alvarez et al. (2004) as the analysis of individual training characteristics that will influence outcomes at various stages of the training process.

Al-Swidi and Al Yahya (2017), referred to training effectiveness as the level of improvement within an organisation to which an employee enhances his knowledge and skill because of training. In broad, training effectiveness refers to organisational benefits derived from training (Noe, 2010; Topno, 2012).

Alvarez et al. (2004) described that training effectiveness provides a macro view on training outcomes and defined training effectiveness as a theoretical approach to understand different learning outcomes. Alvarez et al. (2004) further elaborated and explained that effectiveness would benefit an organisation because it will determine the individual level of training outcomes and provide feedback to improve training.

In simple terms, training effectiveness acts as a measurement to determine how effective a training program is in achieving its goals by quantifying the knowledge of participants or students in the training program.

2.2.3 Formative and Summative Evaluation

A vast majority of training program evaluation design models, authors, and evaluators differentiate and classify types of evaluation into formative and summative evaluation to describe educational evaluations (Scriven, 1991; Dick, 1996).

Strunk, (2000), mentioned that “educational evaluations most often use a combination of summative and formative evaluation to render judgment about the value of the program being evaluated”.

Evaluation is considered by Scriven (1991) and Mathison (2005), as formative when it is performed throughout the development, delivery or when phases are implemented in a program or product with the goal to change and better the program. Goldstein (1993) states that to determine if a program has reached its operational and intentional objectives or to determine if any amendments are needed before program implementation, formative evolution is needed.

Hayes et al. (2016) acknowledged that formative evaluation could provide real-time feedback while, Brown and Gerhardt (2002) established that formative evaluations could assist in the improvement of training by means of identifying and elucidate gaps, trainee needs, and concerns about the training setting/environment within the training program.

Summative evaluation is defined by Kellaghan and Madaus (2002) as a process that is conducted after a program has been completion and that will benefit others. Summative evaluation deals directly with the outcomes of programs (Stufflebeam and Zhang, 2017). Summative evaluation can be beneficial to determine the usefulness of a program. Didicher (2016) mentioned to enhance the student participation a summative assessment is needed.

2.3 The Drive for Training Evaluation

2.3.1 Strategic Forces Driving Training Evaluation and the Purpose for Evaluation

Donovan et al. (2001) indicated that the concept for success transgressed towards intellectual assets in the contemporary climate of globalisation. Furthermore, including the development of information technology and the increase of competition. Donovan et al. (2001) also mentioned that the most critical aspect of this competition in firms and organisations is the ability to achieve goals, develop different skills and the implementation of these skills.

Haddock (2015) and Hashim (2001) observed that training evaluation is an essential term amongst different stakeholders, organisations and training consultants as an approach to justify training investments that might create a desire to monitor and evaluate a training course. Phillips (2012) however, indicated that when considering evaluation in training that “…there is still more talk than action.” In Addition to Phillips (2012), Hashim (2001) mentioned that evaluation in the field of training is often seen as a predicament, it substantially receives criticism and it is often ignored or unethically approached in many organisations. However, according to Hashim (2001) the view of evaluation is rapidly changing and contributing factors such as the cost of training, and the demand for accountability has increased the popularity of training evaluation amongst consultants and management.

Various authors in previous literature (Haddock, 2015; Topno, 2012) demonstrated that a need and purpose drive the increase of popularity within the practice of evaluation in training to:

- Recognise factors that either improve or constrain learning.
- Determine if the training objectives are achieved.
- Compare and determine the effectiveness of different training components and learning interventions.
- Identify the justification and cost within training programs.
- Evaluate the worth of training and identify gaps within the training program.
- Gain insights on the delivery, design, and development of training to improve future training programs.
- Review policies and document guidelines to establish whether the training program complies with the national guidelines and if it is aligned to the professional world.

The achievement of goals, development and implementation of skills mentioned by Donovan et al. (2001) can be seen as a purpose for training evaluation. Training evaluation might be conducted for several reasons.

Brown et al. (2015) provides the most prevalent training evaluation description to assign value or worth of training, to determine outcomes successfully and to improve the organisation performance. Topno (2012) describes that training evaluating can assist an organisation during the entire training lifetime to reach different goals and mentioned that training evaluation has two main aims: "…assessing training effectiveness and using it as a training aid".

Bramley and Newby (1984), identified that feedback, control, research, and intervention (the effect of the results on evaluation) as the four primary purposes of evaluation.

According to Van Dyk et al. (1997), training evaluation consist out of three purposes: decision-making, course improvement and system effectiveness, while Eleanor Chelimsky (cited in

Scheirer, 2012) described the three purposes of training evaluation as accountability, intervention, and program improvement.

2.3.2 Benefits of Training Evaluation

Phillips (2012) and Topno (2012) agree that the process of training evaluation can have several benefits for trainees and organisations by evaluating the effectiveness of training. The development of new skills lead to an increase of sales, a new work behavior and an increased number of satisfied customers Topno (2012). Prasad (2005) however, pointed out that the effectiveness measure of training is often a challenging task because of the long-term effect of training on the organisation and trainees.

Kraiger (2002) and Kaufman (1996) elaborated on the organisational benefits and mentioned that training evaluation could provide feedback to improve training, justify financial inputs, assist in the decision-making process about future training continuation, development and quality management purposes. Training evaluation can thus be seen as a marketing tool to aid training institutions to attract potential new costumers (Kraiger, 2002).

In addition to organisational benefits, Phillips and Phillips (2016), however indicated that training evaluation could also be beneficial to market future programs, identifying strength and weaknesses within training, interpret participants learning reactions and feedback, assist in quality management decision-making processes and determine if a program has reached its objectives.

Moreover, Mann (1996) indicated that useful evaluation information could be beneficial in terms of a validation measurement to evaluate, clarify and test training programs. Besides, training evaluation can contribute to decisions about training cost by demonstrating the usefulness of the training enterprise.

2.4 Existing Models for Training Evaluation and Training Effectiveness

Mertens and Wilson (2012) described evaluation models as a specific group of standards with specified boundaries, conditions, frameworks and rules that will describe what evaluators do and assist them to clarify and identify what an adequate evaluation is and prescribe them on how to conduct one. Smith (2010) explained that evaluation models are structured ideological concepts that provide consistent and adjustable guidelines to implement an evaluation.

A diverse range of models exist within the evaluation literature and are being utilised by organisations to evaluate training and training effectiveness. Candiotes (2014) elucidated that the rapid increase of diverse evaluation models and frameworks are due to the extensive outlooks, background, and personal viewpoints of the model creator. Candiotes (2014) and Stake (2004) further elaborated and mentioned that evaluation models or frameworks must merely be viewed as guidelines and must be given thoughtful consideration before implementation to suit your training aims and objectives.

Three models are described for training evaluation and training effectiveness. This dissertation focuses on only one model (Kirkpatrick's Evaluation Model).

2.4.1 The CIPP Evaluation Model

The Context, Input, Process, Product evaluation model or better known as the CIPP evaluation model is defined by its creator Daniel L. Stufflebeam (2003) as "a comprehensive framework for guiding evaluations of programs, projects, personnel, products, institutions, and evaluation systems". Anh (2018) described that the CIPP model emphasises on both formative and summative evaluations. Anh (2018) elaborated that the CIPP model is seen as formative in the implementation phases of a program for improvements and considered to be summative in the assessment phases of a project. Stufflebeam (2003) explained that evaluations summarised various important information and connotations and placed emphasis on accountability within the summative evaluation role.

CIPP is an acronym for the four core concepts of the CIPP model, as described by Stufflebeam (2003). It refers to each letter within the acronym as Context evaluation, Input evaluation, Process evaluation and Product evaluation. The CIPP model is constructed for use in self-evaluations and internal evaluations conducted by organisations, individuals, teams and external evaluators (Tiantong and Tongchin, 2013; Kellaghan et al., 2000).

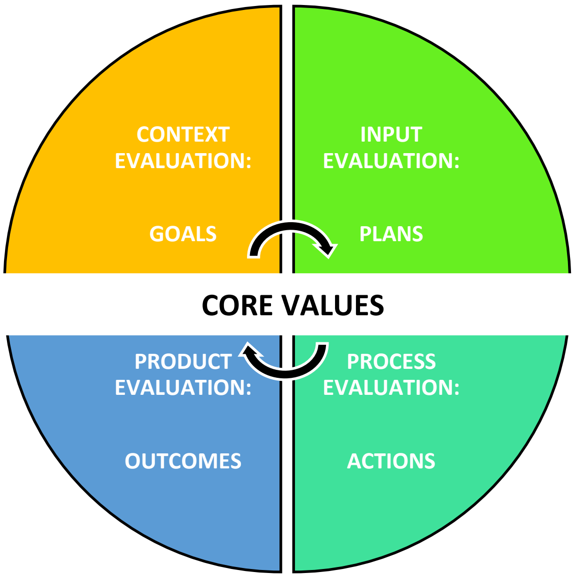

Figure 2-1: CIPP evaluation model. Modified from Stufflebeam (2003).

2.4.1.1 **Context Evaluation**

Context evaluation is described by Stufflebeam and Shinkfield (2007) as an evaluation area that formulates objectives and plans decisions by considering specific opportunities, development and training needs within a defined context (Figure 2-1). Topno (2012) described the concept of context evaluation as the process of measuring the correlation and extent between the actual needs of an organisation and the aims, goals, and objectives of a program. This will determine if the assessment needs are accurately identified.

Stufflebeam and Zhang (2017) described the main objectives of context evaluation as:

- To identify and define the needs of a population or group.
- The identification of problems and boundaries that can hinder assessed needs.
- Provide and identify funding opportunities focusing on needs.
- Identify a baseline for setting oriented goals in terms of improvements and assess the clarity thereof.
- Identify and solve problems vital to needs.
- Responsiveness of assessment needs.

2.4.1.2 **Input Evaluation**

The input evaluation part of the CIPP model allows for the development of structured decisions and the intended content used. The main considerations that need to be considered, include the available resources and other program strategies, also to determine which plans are best suited to address the needs for the design of program procedures (Candiotes, 2014). The purpose of this part of the CIPP model aims to identify and evaluate the system opportunities by analysing the resources, strategies, procedures, budget and the schedules (Worthen et al., 1997). This part of the CIPP model must include a monitored inventory of all the types of data and to plan accordingly (Figure 2-1).

2.4.1.3 **Process Evaluation**

The process evaluation part of the CIPP evaluation model involves the analysis of the data records (Prasad, 2005). This is an ongoing assessment regarding the implementation of the action plan constructed by the organisation (Figure 2-1). It also includes continues monitoring of the program. The process evaluation can be utilised to help implement the program strategies and activities (Topno, 2012).

2.4.1.4 **Product Evaluation**

The product evaluation part of the CIPP evaluation model includes the interpretation and analysis of the data obtained from the training and development aims. In other words, this refers to the interpretation of the organisations improvements to achieve their goals. It encompasses the positive and negative outcomes of the program (Figure 2-1) (Topno, 2012; Frye and Hemmer, 2012).

2.4.2 CIRO Approach

The abbreviation CIRO, refers to the four aspects of training: context, input, reaction, and outcome as shown in Figure 2-2. The CIRO model focuses on measurement that took place before and after training (Tennant et al., 2002).The CIRO model significantly focuses on the context and input aspect. Context assessment factors focus on the identification of training requirements and the creation of objectives that are in line with the organisations cultural and climate aspects. The input aspect refers to the design and implementation of the training activity. It analyses the effectiveness of the training courses (Tennant et al., 2002).

Reaction refers to the collection and using of information regarding the quality of training experience. The outcome aspect looks at the outcomes obtained from the activity or lesson (Tripathi and Bansal, 2017). The outcome is assessed on three levels: immediate, intermediate, and ultimate assessment. These refer to the change in knowledge, skills, attitude, performance and to evaluate the performance of the organisation after evaluation (Tennant et al., 2002; Tripathi and Bansal, 2017).

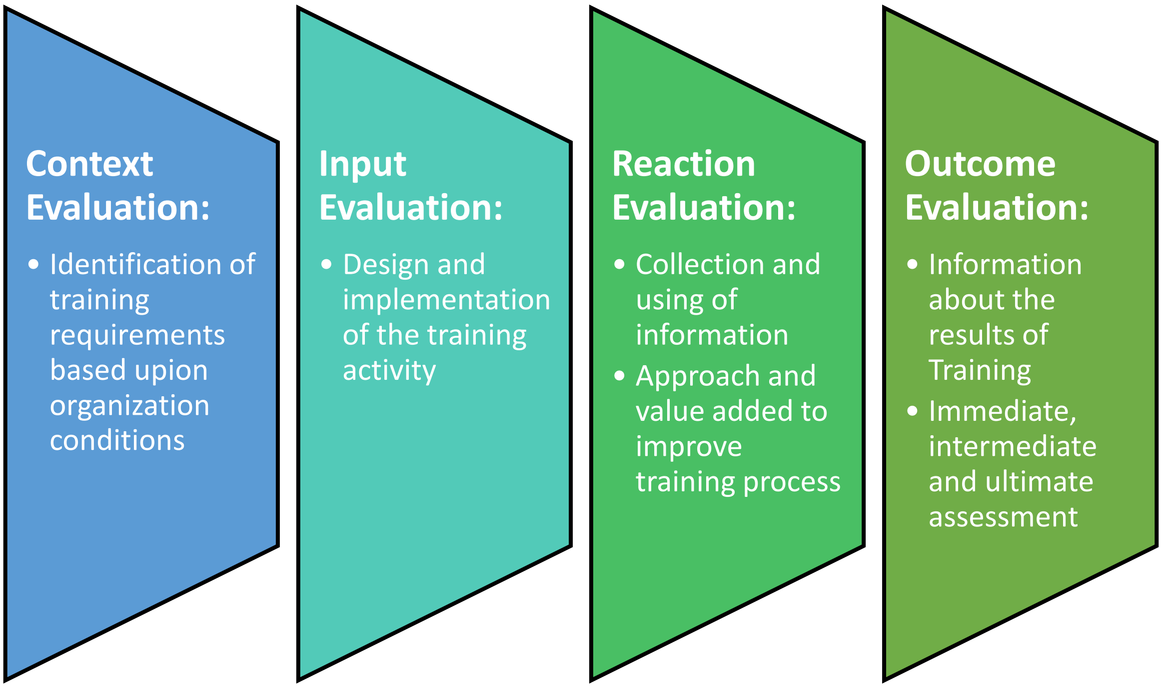

Figure 2-2: Summary of the CIRO evaluation model.

2.5 Kirkpatrick's Evaluation Framework

Below follows an in-depth description of the Kirkpatrick's Evaluation Framework model. This model is utilised in this study.

2.5.1 Definition and Background

Williams (1976), Scriven (1991) and Phillips (2012) capture the basic meaning of evaluation by defining it as a process with a systematic order to determine the value, worth, or meaning of a process or activity. Kirkpatrick (1998) however, see this process of evaluation as a four-level hierarchy or framework within training evaluation.

The Kirkpatrick four-level evaluation model was first developed and published in 1959 by Donald Kirkpatrick as the subject of his dissertation to evaluate his training programs

(Kirkpatrick, 1998; Kirkpatrick and Kirkpatrick, 2006). This model is widely known as one of the most dominated utilised frameworks (Bates, 2004) and popular approaches (Homklin, 2014; Topno, 2012) to program evaluation in organisations.

The Kirkpatrick framework measures the success of a program by utilising each level individually or collectively, to comprehend and focus on the trainee's affective (participants reactions) and cognitive (learning that took place) conceptualisation of the program (Candiotes, 2014; Kirkpatrick, 1998; Kirkpatrick and Kirkpatrick, 2006). The framework also determines the extent of behaviour changes within the workplace as well as to determine the organisational long-and short-term results yielded by the program (Kirkpatrick, 1998). Kirkpatrick's evaluation framework thus emphases on four different kinds of outcomes (Topno, 2012) and delineates the training outcomes as reaction, learning, behaviour, and results as seen in Figure 2-3 (Kirkpatrick, 1998).

Figure 2-3: Kirkpatrick's four-level evaluation framework (Kirkpatrick, 1998)

2.5.2 Level One: Reaction

Kirkpatrick (1998) described reaction as customer satisfaction. Kirkpatrick and Kirkpatrick (2016) defined level 1: reaction as "[t]he degree to which participants find the training favourable, engaging, and relevant to their jobs".

Kirkpatrick and Kirkpatrick (2016) also mentioned that the reaction level is familiar amongst learning professionals and that this level is one of the simplest to evaluate. This level assesses how well participants and learners react with the training program. Measuring reaction is vital for several reasons (Kirkpatrick and Kirkpatrick, 2006). Reactions typically provide feedback that is valuable to evaluate the program and improve future programs.

The opinions of trainees can also be used to improve the work performance, skill set and productivity of trainers. By measuring reactions, quantitative information is collected that can be used by trainers to establish standards and to inform managers about any concerns and the future of program (Kirkpatrick, 2009). Reactions, however, does not measure any changes in learning, beliefs, attitudes, or the organisational impact (Kirkpatrick and Kirkpatrick, 2006).

Kirkpatrick and Kirkpatrick (2016) recommends a set of guidelines described in Table 2-1, that should be followed when evaluating reactions to obtain the optimal benefits in level 1.

Table 2-1: Evaluation reaction guidelines (Kirkpatrick and Kirkpatrick, 2016)

Guideline Item	Guideline Description
Aim.	It is essential to determine how trainees will respond to certain aspects within the training program. The list should include the content of the program, the program schedule, the use of audio-visual aids, handouts, and cases studies. Reactions should also be collected on the knowledge, skill, and performance of the facilitator, as well as the learning facilities, meals (if applicable) and the worth that the contributors provide parts of the manual.
Design.	Ideally, the form should be designed to obtain maximum feedback and to complete the form in the least amount of time. Reaction forms are most effective in a multiple-choice format: Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree.
Encourage written comments.	Reaction sheets should include space for comments to offer suggestions or to explain answers to improve the program because tabulated ratings provide only a part of the participants' reactions.
Get honest and immediate responses.	Forms should have a strictly optional name field, but complete anonymity is essential for honest reaction responses. Participants often fear reprisal if their identity is known and may not provide honest and critical reactions. Immediate responses are crucial and by not issuing reaction sheets and collecting completed forms at after the program, could reduce the number of reaction sheets returned. This will have an impact on the completeness and value of the reaction results.
Develop acceptable standards.	Consider the following numerical tabulation: **Strongly Disagree - 1** **Disagree - 2** **Neutral - 3** **Agree - 4** **Strongly Agree - 5**
Standardisation.	When standards are established, the various aspects of the program can be evaluated, and the findings should then be compared to the standards. Several approaches are possible when standards are not met. The approaches that should be considered include a change in the delivery method, program content, learning facility and trainers. Qualitatively investigate why the standards are not met.

2.5.3 Level Two: Learning

Kirkpatrick and Kirkpatrick (2016) defined level 2: learning as “[t]he degree to which participants acquire the intended knowledge, skills, attitude, confidence, and commitment based on their participation in the training”. Topno (2012), describes Kirkpatrick’s definition of learning evaluation in simpler terms as the measurement of increased knowledge because of the learning experience. The increased of knowledge and skills within participants are easier to determine than how opinions, values, and beliefs are changed due to training (Topno, 2012).

Kirkpatrick (2009) indicated that the learning measurement is challenging as well as time consuming with regards to level 1. Learning measurement at this level is important because behaviour changes can only be accomplished when learning has occurred (Kirkpatrick, 1998). Table 2-2 provide a set of guidelines to evaluate learning, as described by (Kirkpatrick, 2009).

Table 2-2: Evaluating learning guidelines (Kirkpatrick and Kirkpatrick, 2016).

Guideline	Guideline Description
Make use of a reference group.	A reference group can be defined as a group of people within a sample that is excluded from training, whereas the experimental group are included. The control group is used as a baseline. Learning or change that took place will explain the differences between the experimental group and the control group. Data will not be considered valid and comparable when the two groups differ. Pre-and post-tests will be sufficient for a single group if it is not possible to have a reference group.
Convey a pre-and post-test.	Design a multiple-choice test to use within pre-and post-tests. This is done to evaluate and measure the skills, knowledge, and attitudes of learners. The questions of the pre- and post-test should be identical but can however differ in appearance.
Get a 100 percent response.	Incomplete responses (anything less than 100%) increase the difficulty of statistical analyses and decrease the accurateness. A higher response rate in performance data, increase the validity and accurateness of data statistically.
Act.	Effectiveness will be measured in learners and instructors. It is the responsibility of the trainer to use the indicators analysed to either improve his or her performance, to improve the individual learning activities or to be more effective in the future. The learning level forms the foundational phase to the behavioural realm.

2.5.4 Level Three: Behaviour

Level three include the evaluation of behaviour (Rice, 2011). Behaviour is defined by Kirkpatrick and Kirkpatrick (2016) as "[t]he degree to which participants apply what they learned during training when they are back on the job". Behaviour attempts to assess the level of knowledge, attitudes and skills transferred to the job by trainees (Homklin, 2014).

Mann (1996) defined the shift of training as the "degree to which trainees effectively apply the knowledge, skills and attitudes gained in a training context to the job. For the transfer to occur, learned behaviour must be generalised to the job context and maintained over a period on the job". Behaviour measurements and skill performance within the workplace is thus required to evaluate the transfer of training (Mann, 1996).

According to Kirkpatrick (1998) the behaviour level of evaluation within Kirkpatrick's framework become progressively more complicated and vital than the previous levels for various reasons. Trainees require opportunities to demonstrate their change. Secondly, the behaviour change is unpredictable. Thirdly, after the program trainees may apply the learning and additional skills in their current work environment and either adapt to new work behaviour, continue with their old behaviour or remain restraint by various factors preventing trainees from changing their behaviours.

Kirkpatrick (2009) proposes several guidelines that should be followed in evaluating behavioural changes within the training program. These guidelines are tabulated in Table 2-3.

Table 2-3: Evaluating behaviour guidelines (Kirkpatrick and Kirkpatrick, 2016).

Guideline Item	Guideline Description
Make use of a reference group.	The comparison in behaviour between the reference group and the sample group provide information regarding the changes that took place as a result of training.
Monitor behaviour changes.	Evaluation of the behaviour cannot be tested until the new knowledge and skills have been applied.
Evaluate the program before and after.	It is not always practical to implement a pre-evaluation and post-evaluation due to limitations such as time and budget. Alternatively, managers and supervisors could be interviewed after the program to identify and determine if there was any change in behaviour within participants.
Interview and survey supervisors and trainees – People who know the behaviour.	Information about behavioural changes should ideally be collected from people who train the trainees regularly and who are familiar with their previous behaviour. Decisions should be made on the reliability of data. Behavioural data collected might be distorted in validity and might be biased. More than one source of data should ideally be used. The data collected can then be statistically quantified and processed. Interviews are often significant in smaller groups and gather more detail regarding behavioural changes but are more time-consuming. A survey questionnaire is often more practical in larger groups and can provide the same data if it is appropriately designed.
Get a 100% response or sampling	The sample for behaviour change should be big enough to see a trend within behaviour data which include all participants.
Repeat the evaluation at appropriate times.	Observable behaviour changes of trainees might be altered when they return to work, within six months or never. Behaviour changes might occur or return after a while. Repeat the evaluation of behaviour changes at appropriate times. The time intervals to measure behaviour change will differ between each organisation and will include factors such as the type of behaviour and job climate.
Consider cost versus benefits.	It is essential to consider if the program will be repeated more than once. The time and cost spent to evaluate behaviour changes can be justified by a repeated program.

2.5.5 Level Four: Results

Level four is the most challenging level within Kirkpatrick's evaluation framework (Rice, 2011). This level determines the training impact on the organisation by measuring change. Kirkpatrick and Kirkpatrick (2016) defined this level as "[t]he degree to which targeted outcomes occur as a result of the training and the support and accountability package".

According to Kirkpatrick and Kirkpatrick (2006) the objectives of training programs in terms of organisational results include the improved quality and quantity of production, increased sales, higher profits, and decreased costs. Kirkpatrick and Kirkpatrick (2006) recommends a set of guidelines tabulated in Table 2-4 to determine what results were accomplished because of the training program.

Table 2-4: Evaluating results guidelines (Kirkpatrick and Kirkpatrick, 2016)

Guideline Item	Guideline Description
Reference group.	A reference group is used to form a baseline to demonstrate that changes took place. It is also used to eliminate external factors (excluding training) that could have caused a change to take place.
Allow time for results to be achieved.	Time must elapse before you can conduct the evaluation because there is no timeframe available on when changes should be measured. A trainer must consider all the various factors involved before evaluating training when deciding on the time-lapse.
Measure the program before and after.	This step simpler than to evaluate changes in behaviour. Records are usually available to determine the situation before the program. Figures are available to determine frequency, quality, production, and turnover.
Repeat.	It is an organisational decision to determine how often and when to evaluate. Results can change in a positive or negative direction at any time. Training professionals and evaluators need to determine the influence that training has on results.
Consider cost versus benefits.	The measurement of this level is more cost-effective than the behaviour level. More time and money should be spent on potential results with a higher value and a repeated program. The outcome from comparing actual results with program cost should provide information to determine if a program should continue or not.
Evaluate results	Communication is critical to protect success and can be described as the process of managing the tasks associated with the purpose, audience, timing, and reporting format of the training program.

2.6 Importance of Groundwater Training in Management and Governance

2.6.1 What is Groundwater?

Holmes (2000), mentioned that "groundwater means different things to different people". Groundwater, or subsurface water, is a term used to denote all the waters found beneath the ground's surface (Wijnen et al., 2012). However, hydrologists defined groundwater as water within the saturated zone, beneath the water table (Nel, 2006; Bear, 2012).

Heath (1983) described that water within the subsurface occurs in two different zones: the saturated and unsaturated zones. The unsaturated zone occurs directly below the land surface in most areas, containing both water and air (Lachassagne, 2021). The saturated zone is beneath the unsaturated zone, and all interconnected openings are filled with water (Lourens, 2013).

2.6.2 Background

Gaye and Tindimugaya (2019) stated that groundwater plays a significant role in supporting economic development and human well-being in urban and rural environments and is a fundamental component of the natural water cycle. As part of the water cycle, groundwater contributes to the flow in many streams and rivers and strongly affects river and wetland habitats for plants and animals (Todd and Mays, 2004).

Africa's groundwater resources are consistently challenged by the increasing threat of pollution, over-exploitation, water security and rapidly rising demand (Gaye and Tindimugaya, 2019). The increasing risk of water insecurity by organisations, municipalities and institutions in South Africa are due to the growing demand for food, energy and other human consumptions and the constant change in climate in South Africa's rapidly growing population (Seibert et al., 2013).

With limited water resources in South Africa and the increasing demand for available water resources (Otieno and Ochieng, 2004), groundwater conservation remains a priority (Van Der Vyver, 2016). It is, therefore, vital that we use groundwater resources efficiently (DWAF, 2004a). Riemann et al. (2012) stated that a vast majority of municipalities depend on groundwater for drought management and utilise groundwater regularly. Numerous guidelines have been developed in South Africa to ensure the proper management of groundwater resources. However, a lack of proper groundwater management in groundwater governance and a quantitative understanding of it is still prominent. Pallett et al. (1997) and Viljoen (2020) described that groundwater has always been inadequately managed, governed and utilised. Van Der Vyver (2016) mentioned that the inadequate management, governance, and utilisation of groundwater are exacerbated by the unawareness and lack of knowledge and training in groundwater. However, groundwater resources can still meet the demand, despite several groundwater management challenges, inadequate interest and under-development, if better managed and monitored (Braune and Xu, 2009). Thus, training strategies need to put in place on key aspect like groundwater sustainability, governance, and management, to ensure sustainable development and management of groundwater resources.

Pietersen et al. (2011) stated an increasing demand for competent and trained water professionals in the public sector. According to Smajgl et al. (2010), training through education and groundwater awareness campaigns will benefit managers, public individuals, and communities' collective skills and knowledge.

2.6.3 Groundwater training in South Africa

Groundwater has been an intricate part of civilisation since the dawn of time. People have relied on groundwater for drinking, irrigation and today, for industrial reasons. Groundwater is an essential source of water for arid and semi-arid areas such as South Africa (Marshak, 2011).

The Growing agricultural industry and semigration of people to densely populated areas in South Africa place tremendous strain on surface water and groundwater resources.

Previous studies have indicated that South Africa is a water-stressed country with an average annual precipitation of approximately 500 mm, which is below 60% of the global norm (Adom and Simatele, 2021). Perveen and James (2011) described water stress as an indicator "used to measure the degree of water resources vulnerability." Rogers and Hall (2003) indicated that the constraints associated with sustainable groundwater management are typically due to failures in governance structures.

Sustainability in water resource management is defined by Loucks (2000) as: "Water resource systems that are managed to satisfy the changing demands put on them, now and on into the future, without system degradation." Knueppe (2011) explained that the basic principles for adaptive and sustainable groundwater management are training and awareness-raising.

Due to the socio-economic disadvantages of South Africans, knowledge of groundwater resources and the management thereof is limited (Braune and Adams, 2013). However, public awareness of water shortages, environmental and hydrological concerns has increased over the past few years.

As a result of this awareness, the water sector, public sector, government, and universities have emerged with different groundwater educational programs, publications, and training manuals (Meyer, 2000; Rawlins, 1995). The extensive lack of information and data pertaining to groundwater is one of the fundamental causes of numerous problems associated with effective and sustainable management.

Gleeson et al. (2012) mentioned that hydrogeology is now being taught to students with diverse backgrounds at various departments and institutions. Gaye and Tindimugaya (2019)stated that various groundwater-related initiatives are ongoing to improve groundwater management. Gaye and Tindimugaya (2019) further elaborated and explained that the groundwater-related initiatives are typically categorised in terms of institutional coordination and stakeholder participation frameworks, information management programs and capacity building programs.

Groundwater training and awareness are available in South Africa but lack implementation. Knueppe (2011) mentioned that most management structures do not provide the necessary structural conditions to implement adaptive management approaches and that the South African groundwater governance does not have the capacity for adaptive management.

Van Der Vyver (2016) stated that even though groundwater awareness increased, a lot should be done to ensure the future supply of sustainable groundwater.

This study liberates South Africans to understand the importance of groundwater management and protection in South Africa.

2.7 Training Manual Development

The research done in this dissertation is confined to a continuous program named "Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa" (Kotzé, De Lange, et al., 2019). The training manual was proposed to the WRC and created and developed by a team of dedicated and skilled project leaders, researchers and geohydrologists. Part of the WRC project's deliverables included that the training manual on groundwater should be pilot tested and evaluated.

The application of the manual was to enhance knowledge and skills in groundwater resource management and groundwater governance. This enhancement would contribute to improved policies and decision-making and more sustainable groundwater resource management.

2.7.1 Training Manual Rational

The training manual rationale was motivated by explaining that the perceptions around groundwater use and the devastating effects on this resource are well known and needs serious attention. The proposal further explained that the overall perception around groundwater is that it is unsustainable and unreliable, and that surface water is seen as a more sustainable water source.

The training manual is further motivated by explaining that a mind shift is necessary for sustainable groundwater use. It is further motivated due to the lack of knowledge and skills within groundwater resource management and groundwater governance within South Africa. The development and implementation of a training course will empower and increase the knowledge and skills of stakeholders and communities.

2.7.2 Outcomes and Expected Impacts

Initially defined, the primary outcome was to develop a training manual for groundwater resource management and groundwater governance for municipalities. The expected outcomes stipulated in the proposal of the training manual predicted to be the following (Kotzé, van der Merwe, et al., 2019):

- The enhancement of knowledge and skills of municipal employees and communities in groundwater resource management and groundwater governance.
- More effective groundwater resource management within municipalities.
- Improved understanding of available groundwater.
- Increased sustainable use of groundwater resources in municipal areas reliant partially or solely on groundwater.
- Improved protection of groundwater resources.

- Improved planning and incorporation of poverty alleviation actions.
- Improved infrastructure.
- Improved policy and decision-making processes.

2.7.3 Aim

The aim of the training manual guided by the WRC, stipulated in the proposal of the project, was to establish the following:

- Training needs assessment for municipalities.
- Development of a draft training manual on groundwater resource management and groundwater governance for municipalities in South Africa.
- Pilot testing and evaluation of the draft training manual on groundwater resource management and groundwater governance for municipalities in South Africa.
- Develop a training manual on groundwater resource management and groundwater governance for municipalities in South Africa.

2.7.4 Methodology

The methodology of the development of the training manual was undertaken in four different work phases. The four work phases were proposed to address the aims (Kotzé, van der Merwe, et al., 2019).

- Work phase one: Development of research strategy and framework
    - Develop a research strategy and framework.
- Work phase two: Training needs assessment for municipalities
    - Identify different municipalities for groundwater-dependent towns in the Free State and Northern Cape Province to be used in the case studies.
    - Design questionnaires to understand the view and opinions of municipalities on groundwater management and governance aspects to be included in the training manual.

- Collect data using questionnaires at proposed workshops at the identified municipalities on the training needs on groundwater management and groundwater governance.

- Work phase three: Development of a draft training manual
  - Developing and draft a training manual that can be presented to municipalities for their feedback and evaluation.
  - Review and evaluate existing guidelines and ordinances for municipal groundwater management and groundwater governance.
  - Have consultations with existing groundwater professional institutions and organisations during the development of the draft Training Manual.
  - Incorporate the identified municipal needs and inputs established in work phase two.
- Work Phase 4: Pilot test presentation and evaluation of the draft training manual
  - Present the draft training manual to municipalities, managers and stakeholders in order to gather feedback.
  - Design questionnaires to collect information on the options and views of Municipalities on different aspects of the draft training manual regarding groundwater management and groundwater governance.
  - Evaluate the training manual by developing or choosing an evaluation criteria to incorporate the municipalities, managers and all other stakeholders' feedback.

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Chapter 3

Research Design and Methodology

3.1 Introduction

The following chapter provides a holistic overview of the quantitative approach utilised in this study. The Water Research Commission's (WRC) training manual was used (Kotzé, De Lange, et al., 2019). Two levels of the four-level framework (Kirkpatrick, 1998) provide the fundamental structure for this study. These include the reaction and learning level of the four-level framework. These two levels are critical and sufficient for this study. These levels are tested to address the curriculum limitations and restrictions. The choice of the selected population is also described. The sampling was structured and included participants from tertiary institutions with a background in groundwater as well as participants without groundwater knowledge. The method of data collection, measuring tools and the analysis thereof are explained, following the restrictions of this quantitative approach.

3.2 The Purpose of this Investigation

The main purpose and research focus of this study was to assess the effectiveness of a training program known as "Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa" and to utilise Kirkpatrick (1998) framework for program evaluation to address the possible curriculum shortcomings as identified.

The aim of the research was comprehended by pursuing the following objectives:

- Identify the forces driving training evaluation and the barriers to effective training evaluation.
- Evaluate different theoretical models and frameworks used for training evaluation and design.
- Investigate and measure Kirkpatrick (1998) four-level evaluation model, concentrating specifically on affective (participants reactions) and cognitive (learning) domains.

- Formulate recommendations that can be proposed to effectively implement the training program to enhance service delivery.

3.3 Research Questions and Hypotheses

Guided by the aims, objectives and problem statement, a research question was constructed.

How effective is the training program known as "Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa" in equipping municipal employees, technicians, managers, and decision-makers with the required knowledge and skills to enhance a better understanding of groundwater?

In terms of possible research approaches the main research question is broad, and the focus was narrowed by posing subsidiary research questions and hypotheses (null and alternative) for an effective research design (Mertens and Wilson, 2012) and to achieve the research questions identified.

The following subsidiary questions and hypotheses were formulated:

3.3.1 Sub Question One: Program Satisfaction

How effective is the training program content with a specific focus on the effective reactions of participants?

Hypothesis 1:

- **Null hypothesis:** Affective reaction will not be significant towards the program.
- **Alternative hypothesis:** Affective reaction will be significant towards the program.

3.3.2 Sub Question Two: Program Learning

How effective is the training program content in facilitating the acquisition of new knowledge to participants?

Hypothesis 2:

- **Null hypothesis:** The program will not be effective in facilitating the acquisition of new knowledge to participants.

- **Alternative hypothesis:** The program will be effective in facilitating the acquisition of new knowledge to participants.

3.4 Research Approach and Design

Saunders et al. (2007), defined research as "something that people undertake in order to find out things in a systematic way, thereby increasing their knowledge". Research approaches such as qualitative, quantitative research or a blended approach are frequently seen as different research methods used to conduct research (Pring, 2004; Ghauri et al., 2020). Nassazi (2013) mentioned that quantitative and qualitative research methods have remained dominated in educational research in the past years.

Pring (2004) however, argued that quantitative research is the primarily dominant factor within educational research. Qualitative research is described by Ghauri et al. (2020) as a method that place emphasis and focus on the understanding of respondents, following an interpretation and rational approach and are process orientated. Ghauri et al. (2020) also described that quantitative research differs from qualitative because the method place emphasis and focus on facts, follows a logical and critical approach and are result orientated. According to Ghauri et al. (2020) the main difference between quantitative and qualitative research is the different procedure of each. Ghauri et al. (2020) elaborated further that quantitative studies review results or findings by utilising measurements in a statistical strategy where a qualitative study does not.

To respond to the research question, the study will follow a quantitative research approach. The quantitative research approach will aid in answering the subsidiary research questions and hypotheses by processing quantified data in a mathematical order and incorporate reliable survey instruments to measure effectiveness. Candiotes (2014) explained that the quantitative research approach makes it possible for the researcher to contribute to the evaluation process objectively. Quantitative research collects numeric data that can evaluate variable relationships in statistical strategies to assess and evaluate findings (Creswell, 2002).

Saunders et al. (2019), described the research design as a comprehensive framework that describes the procedures, steps and plans necessary to fulfil the research questions and objectives posed within a study. De Vos (2002) indicated that the research design could add value to a study by assisting the researcher to systematically plan and arrange the process to achieve the main study objectives. Hofstee (2006) argue that the research design can be viewed as a holistic approach to obtain views, opinions, and perceptions on individual experiences.

Mertens and Wilson (2012) noted that quantitative research strategies or approaches are generally divided into three main types, namely experimental designs, quasi-experimental designs, and surveys. Mertens and Wilson (2012) elaborated and state that design categories such as quasi-experimental will largely determine the effectiveness of a program and design categories such as surveys will be more descriptive.

Survey data collection methods were developed for this study, given that this study aims to evaluate the effectiveness of a training program by utilising and measure Kirkpatrick’s framework for program evaluation concentrating on different domains.

This study approached a summative program evaluation. Survey data collection methods were developed for this study, given that this study aims to evaluate the effectiveness of a training program by utilising and measure Kirkpatrick’s framework for program evaluation concentrating on different domains.

3.5 Research framework

Kirkpatrick's (1998) four-level conceptual framework was utilised for this study. Refer to sections 2.5 in Chapter 2 for summative description of Kirkpatrick’s evaluation approach (Figure 2-3). The evaluation of the research and learning levels of Kirkpatrick’s four-level framework provided useful data to address the limitations and to adapt it accordingly.

The analysis and conclusion of this training manual must be measurable on the first two levels, which include the reaction and learning levels. Refer to section 3.3 in Chapter 3 for the questions asked for this research.

3.6 Population and sample

The original target population was municipal employees, technicians, managers, and decision-makers. Many officials were interested to participate, however indicated that due to the municipal election period and other commitments they could not. Tertiary groundwater students and non-professionals then became the main target population for the evaluation of this training manual. Most of the study population was students that are enrolled at Central University of Technology, Free State (CUT). The study population mainly resides in the Free State and various other towns and cities in South Africa. Most of these students are employed by municipalities as Environmental Health Practitioners with main responsibilities related to groundwater and surface water quality, water pollution and water management related aspects.

To ensure that the data is reliable, valid and adhere to standards the following principles were used:

- A consent form was constructed which was available before evaluation on the online learning platform (Figure 3-1).
- The sample population included students for CUT with knowledge in groundwater as well as non-professionals with no knowledge of groundwater. This provides a holistic overview of educated and non-educated individuals in groundwater. The sample consisted out of 55 individuals which was divided into five groups (refer to section 3.8.3)
- The evaluation was done over a period of two weeks. All participants were provided with the same time to complete the evaluation form and the same information was provided for all participants.
- Demographically, irrespective of race, gender, sexual orientation, and nationality all participants were provided with a fair, reliable, and valid questionnaire.
- All participants had the opportunity to contact the instructor.
- Participants with incomplete data were contacted.
- The questionnaire was conducted by the same instructor which conducted this research.
- All individuals had the same pre-test and post-test.

QUESTION 1 OF 1

Consent Statement

I volunteer to participate in a research project conducted by a Postgraduate student, *Johann de Lange* from the University of the Free State, Faculty of Natural and Agricultural Sciences doing his Master's degree in Geohydrology at the Institute for Groundwater Studies.
I understand that the study aims to evaluate the effectiveness of a training module content by utilising Kirkpatrick's four level framework for programme evaluation. I will be one of several people being that form part of this research.

ELECTRONIC CONSENT: Please select your choice below.
You may request a copy of this consent statement for your records.

Clicking on the "Agree" button indicates that you understand and agree to the following terms:

1. I give my consent to participate in this study.
2. I agree that I'm 18 years of age or older.
3. My participation in this project is completely voluntary. I understand that there will be no reimbursement or payment for my participation or time, from the researcher.
4. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences, unless stated otherwise.
5. I understand that the information provided by me in this online course will be used for research purposes. I understand that my responses will be kept strictly confidential. I understand that my name will not be linked with the research materials, and will not be identified or identifiable in the report or reports that result from the research. Any information shared to the wider public will be in statistical form and make no mention of my name ensuring your anonymity.
6. I agree that my anonymised data will be kept for future research purposes such as publications related to this study after the completion of the study.
7. I understand that all communications will be conducted in English.
8. I understand that my participation involves a pre-test, post- test and multiple surveys on my demographic profile, online learning proficiency and training programme evaluation.

Choose only ONE best answer.

A Agree

B Disagree

CONFIRM

Figure 3-1: Online participant consent form

3.7 The Training Manual Structure and Components

The program "Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa" (Kotzé, De Lange, et al., 2019) forms the central focus of this dissertation and was created and developed by various authors in a WRC project. Part of the deliverables of the WRC project included, that the training manual on groundwater should be pilot tested and evaluated. The application of the manual was to enhance knowledge and skills in groundwater resource management and groundwater governance. This enhancement would contribute to improved policies and decision-making and more sustainable groundwater resource management.

The program was presented and distributed on a web-based platform called Thinkific. This platform is discussed in section 3.8. The structure of the course, "Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa" (Kotzé, De Lange, et al., 2019), comprised of nine modules and only five modules was used on the web-based platform. The five modules established a standard and structure on which this evaluation was based. Every module included a few chapters with related content based on the objectives of the module. The objectives and grouping of main chapter headings of each module is described in Table 3-1.

Table 3-1: Training module objectives and main chapter headings grouping.

Module	Groundwater Management	Groundwater Monitoring	Groundwater Quality	Groundwater Quantity	Groundwater Regulations
Learning Objectives	To understand and describe the following: **-** Meaning of groundwater management **-** Flow-diagram illustrating the groundwater management process at Municipalities for bulk groundwater supply. - Understanding the functions of management.	To understand and describe the following: - Objectives and purpose of groundwater monitoring - Quality and quantity monitoring, their indicator parameters - Monitoring program design.	To understand and describe the following: - Indicators of groundwater quality and their measurements - National standards - Impacts of negative groundwater quality; and - Drivers/controls of groundwater quality.	To understand and describe the following: - Meaning of groundwater quantity and factors influencing groundwater quantity - Measures and indicators of groundwater quantity - To appreciate the importance of protecting groundwater quality - To understand the role of risk assessment and vulnerability mapping in managing groundwater quality -To examine the specific case of Urban Wastewater and Groundwater Quality	To understand and describe the following: - Groundwater licensing - Groundwater allocation - Groundwater protection - Groundwater Institutions
Grouping of Main Chapter headings	**Chapter 1:** Learning objectives and introduction **Chapter 2:** Groundwater management **Chapter 3:** The role of the groundwater coordinator **Chapter 4:** Summary	**Chapter 1:** Learning objectives and introduction **Chapter 2:** What is monitoring **Chapter 3:** Monitoring program design **Chapter 4:** Monitoring design **Chapter 5:** Summary	**Chapter 1:** Learning objectives and introduction **Chapter 2:** Water quality **Chapter 3:** Approaches to groundwater quality management **Chapter 4:** Why do groundwater supplies merit protection? **Chapter 5:** Risk assessment **Chapter 6:** Groundwater quality management **Chapter 7:** The National Water Act **Chapter 8:** Summary	**Chapter 1:** Learning objectives and introduction **Chapter 2:** Groundwater occurrence **Chapter 3:** Groundwater – environment linkages **Chapter 4:** Groundwater use **Chapter 5:** Quantification of groundwater resources **Chapter 6:** How much groundwater does South Africa have? **Chapter 7:** Groundwater and drought / climate change **Chapter 8:** Summary	**Chapter 1:** Learning objectives and introduction **Chapter 2:** Groundwater licensing and Groundwater allocation **Chapter 3:** Groundwater protection and Groundwater Institutions **Chapter 4:** Summary

3.8 Data Measurement Tools

Kirkpatrick (2009) explained that the Kirkpatrick’s four level evaluation model is generally applied to determine program evaluation by using quantitative methodologies. This dissertation measure two elements of the Kirkpatrick's evaluation model: [1]the reaction (affective domain) and the [2]level of learning (cognitive domain) of participants. Affective domains were measured by utilising an evaluation survey questionnaire and cognitive domains were measured by utilising a quasi-experiment method that consisted out of multiple-choice pre-tests and post-tests. In addition to measuring the affective and cognitive domains, this study also collected demographic information of participants as background information. The program and measurement tools were presented and distributed on a web-based platform called Thinkific.

3.8.1 Thinkific

A web-based platform Thinkific was used to obtain the data from the participants. Web-based platforms are one of the most commonly used methods to collect quantitative data (Bourque and Fielder, 1995). Thinkific is a massive open online course (MOOC) platform or web-based Learning Management System (LMS) that enables anyone to create and distribute courses. Simonson (2007) offered a sensible definition of LMS:

> Course management systems, also called learning management systems or virtual learning environments, are software systems designed to assist in the management of educational courses for students, especially by helping teachers and learners with course administration. The systems can often track the learners’ progress. While usually thought of as primarily tools for distance education, they are also used to support the face-to-face classroom (Simonson, 2007,p. vii).

The type of LMS selection was based on the following criteria stipulated in Table 3-2, to be aligned with the aims and objectives of this dissertation.

The comprehensive LMS platform Thinkific, closely met the criteria specified in table 3-2 and was selected as the measurement tool used. Thinkific enable teachers, businesses, and individuals to create online courses with existing or new material. Online courses, layouts, templates and content can be effortlessly organise and managed on the platform (Bedir et al., 2020).

Thinkific provides access to a wide range of multimedia forms, templates and lesson types to customise training programs and engage learner experience (Okide et al., 2019).

Table 3-2: Learning Management System selection criteria. Adapted from (Bates and Bates, 2005; Graf and List, 2005; Bedir et al., 2020; Fernández et al., 2011)

Criteria	Criteria Description
Ease of use	Teachers, participants, and administrators should find the platform user friendly, practical, and easy to use.
Interactivity, and Scalability	The LMS must provide sufficient ownership and control capabilities to ensure that teachers, participants, and administrators get benefited from the learning experience. The LMS should also be scalable to accommodate a wide range of participants and ongoing growth.
Security / Reliability / Performance	The LMS should include high security features, plugins, and certification and a high reliability and performance standard. This is to ensure data is safe and secure.
Support	Include online and offline support.
Flexibility and Integration	Should offer seamless integration and flexibility with existing tools and technologies.
Analytics and Exports	Provide analytics to teachers and administrators to evaluate student performance. Participants must be able to track individual progress. Teachers and administrators should be able to export all data collected on the LMS.
Accessibility	Should be accessible over a wide variety of digital devices and internet connections.
Cost	Include minimal fees to host and manage platform. Participants should be able to access and use program content at no cost.
Management and Design	Include adequate tools for teachers and administrators to manage content, resources, design, templates, platform selection, and hosting options.
Testing	Allow website testing functions.

3.8.2 Evaluation Survey Questionnaire (Affective Domain)

A self-administered questionnaire (SAQ) was utilised to collect data and measure the affective domains from participants. Lavrakas (2008) defined a self-administered questionnaire as: "… a questionnaire that has been designed specifically to be completed by a respondent without intervention of the researchers (e.g., an interviewer) collecting the data". Lavrakas (2008) described that SAQ's are typically independent but can also be used in a combination of other data collection methods. The SAQ are being widely used on online platforms and are one of the most commonly used methods to collect quantitative data (Bourque and Fielder, 1995).

A questionnaire can be described as survey instrument that consist out of a variety of questions to collect data from respondents. Questionnaire survey benefits include low costs, ease of use, anonymity and can provide adequate data for testing hypothesis (Gillham, 2008).

A SAQ was developed by utilising Kirkpatrick's first level of evaluation framework. The questions used in the evaluation questionnaire were adapted from various authors and questions can be seen in appendix A. The questionnaire survey covered four sections, [1]demographic, [2]training manual content (twenty-two questions), [3]the platform used (eleven questions) and [4]general (five questions) questions (Figure 3-2). Each question within the three sections was designed to gather reactions regarding the participant's perception and satisfaction.

The evaluation questionnaire consisted of both closed-ended questions and open-ended questions. Majority of the questions was close-ended questions with a few being open-ended to gather insights and feedback from the participants. Foddy and Foddy (1994) described that closed-ended questions limit the respondents' answers to a pre-existing set of answers being offered, while open-ended questions allow an expression of opinion. The close-ended questions answers were based on a five-point Likert scale. Preedy and Watson (2010) defined a Likert scale as "[a] type of psychometric response scale in which responders specify their level of agreement to a statement typically in five points: (1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree".
The Likert scale used to answer closed ended questions was [1]Very Dissatisfied, [2]Dissatisfied, [3]Neither, [4]Satisfied and [5]Very Satisfied.

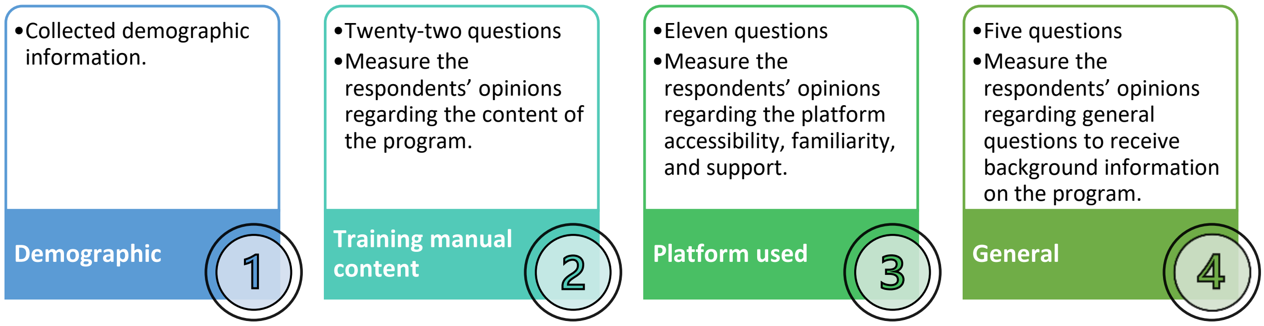

Figure 3-2: The four survey questionnaire sections

3.8.3 Level of Learning (Cognitive Domain)

Cognitive domains were measured by utilising a quasi-experiment method that consisted out of multiple-choice pre-and post-tests. Grant and Wall (2009) defined a quasi-experiment as: "… a study that takes place in a field setting and involves a change in a key independent variable of interest but relaxes one or both of the defining criteria of laboratory and field experiments…" Quasi-experiments includes changes that have been made by experiment-controlled and manager-controlled interventions and not manipulated (Grant and Wall, 2009).

The quasi-experiment method was utilised by Kirkpatrick's second level of evaluation framework by means of a pre-test and post-test. The tests are not divided into categories but are designed to suit five different modules within the training manual and were statistically analysed separately. Each performance test was designed with the focus to include the most important aspect of each module. Below is a breakdown of the five different modules, the total of questions and number of participants within the performance test:

1. Groundwater Management – Fifteen participants and eighteen questions
2. Groundwater Monitoring – Ten participants and nineteen questions
3. Groundwater Quality – Eight participants and seventeen questions
4. Groundwater Quantity – Seven participants and ten questions
5. Groundwater Regulations – Fifteen participants and eighteen questions

Post-test questions were identical to the pre-test questions but were displayed in a scramble order (Appendix B). This method eliminates the recollection of answers by respondents.

3.8.4 Significance of the Pre-and post-tests Questions

The pre-and post-tests questions asked in the evaluation of the training manual (Appendix B) have been used to assess and evaluate the effectiveness of the training manual. The questions within the five different modules were structured and asked to achieve the learning objectives within the training manual and get the most insight into what learners think and already know.

Questions were formulated objectively, requiring students to select the correct response from several alternatives to answer or complete the statement. Objective questions include multiple choice answers, true or false questions, matching questions, or the completion of sentences by selecting the correct answer. This way of constructing questions test and motivate participants to reinforce learning. The relevance of each question asked relate to groundwater in a way to better comprehend the concepts, ideas and terms within the different training manual modules.

3.8.4.1 Groundwater Management Pre-and post-tests

The significance of the eighteen questions (Appendix B) asked in the pre and post-test as part of the groundwater management module was to help students understand and better comprehend the term and concept of groundwater management. Questions were formulated to achieve the learning objectives specified in the training manual (Kotzé, De Lange, et al., 2019). The learning objectives of this module was to understand and describe the following:

- Meaning of groundwater management; and
- Flow-diagram illustrating the groundwater management process at Municipalities for bulk groundwater supply.
- Understanding the functions of management.

Barthel et al. (2017) explained that groundwater is a critical component and source of water worldwide for human survival. Nevertheless, groundwater is constantly faced with tremendous challenges in management, which will only grow as dependence on the resource increase. Groundwater management challenges in Africa include insufficient information about groundwater resources, groundwater pollution, climate change, and groundwater management (Gaye and Tindimugaya, 2019).

Groundwater management is generally described as assessing hydrologic and environmental aspects in terms of groundwater, the impacts associated with supply, quality, quantity, sustainability and demands among different consumers, and the optimisation of exploitation and use (White et al., 2019).

The management of groundwater resources involves the intervention in water matters and involves the planning, design, and operation of hydraulic works. A generally accepted principle is that “prevention is better than cure.” It is essential to better understand the quality, quantity, and impacts of groundwater use to manage groundwater resources effectively. White et al. (2019) mentioned that groundwater management links to groundwater-dependent sectors like agriculture, rural development, health, and environment are not well established in policy or practice.

It was, therefore, essential to ask the right questions to show that the concept of groundwater management is vital in the decision-making process.

3.8.4.2 **Groundwater Monitoring Pre-and post-tests**

The significance of the nineteen questions (Appendix B) asked in the pre and post-test as part of the groundwater monitoring module was to help students understand and better comprehend the term and concept of groundwater monitoring. Questions were formulated to achieve the learning objectives specified in the training manual (De Lange et al., 2019). The learning objectives of this module was to understand and describe the following:

- Objectives and purpose of groundwater monitoring
- Quality and quantity monitoring, their indicator parameters
- Monitoring program design.

Scarcity of water and the increasing concern of groundwater contamination have led to the implementation of monitoring networks and is a pre-requisite for effective management (Zhou Yangxiao, 1994). Zhou Yangxiao (1994) mentioned that previous literature indicated that groundwater resources need to be managed and monitored effectively to prevent the deterioration of groundwater quality and quantity.

Monitoring provides and includes data on groundwater quantity and quality of the resource itself and is an integral aspect of groundwater management (Sundaram et al., 2009).

Owen et al. (2010) stated that groundwater quality deterioration, groundwater abstraction and contamination occurs typically due to the absence of monitoring.

Monitoring groundwater is an essential component in groundwater management. In general terms, it is also described as the ongoing process of collecting data and organising and assessing data into information to improve decision-making and determine performance progress and trends (Jha et al., 2010).

The purpose and significance of the pre and post-test questions of groundwater monitoring provide data to assist management in groundwater resources and provide information for the implementation and development of groundwater policies (Kumar, 2011).

3.8.4.3 **Groundwater Quality Pre-and post-tests**

The significance of the seventeen questions (Appendix B) asked in the pre and post-test as part of the groundwater quality module was to help students understand and better comprehend the term and concept of groundwater quality. Questions were formulated to achieve the learning objectives specified in the training manual (Kotzé, De Lange, et al., 2019). The learning objectives of this module was to understand and describe the following:

- Indicators of groundwater quality and their measurements.
- National standards.
- Impacts of negative groundwater quality; and
- Drivers/controls of groundwater quality

Water quality is a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for an intended purpose (Owen et al., 2010). Groundwater is a vital component of water supply for residential, industrial, and agricultural purposes. However, many groundwater basins are being used unsustainably, and groundwater contamination is a growing water quality problem (Motlagh et al., 2020).

Asadi et al. (2020) described that identifying and managing groundwater qualities is essential for maintaining groundwater, which is essential for sustainable development. The purpose and significance of the pre- and post-test questions indicate if municipalities, managers and stockholders understand that the growing concern of groundwater's vulnerability to contamination mainly results from the rise of urbanisation and industrialisation (Nyika and Onyari, 2019)

3.8.4.4 Groundwater Quantity Pre-and post-tests

The significance of the ten questions (Appendix B) asked in the pre and post-test as part of the groundwater quantity module was to help students understand and better comprehend the term and concept of groundwater quantity. Questions were formulated to achieve the learning objectives specified in the training manual (Kotzé, De Lange, et al., 2019). The learning objectives of this module was to understand and describe the following:

- Meaning of groundwater quantity
- Factors influencing groundwater quantity
- Measures and indicators of groundwater quantity.
- To appreciate the importance of protecting groundwater quality
- To understand the role of risk assessment and vulnerability mapping in managing groundwater quality
- To examine the specific case of Urban Wastewater and Groundwater Quality

With the relative low seasonable rainfall and rapidly growing demand for groundwater, participants needed to understand and grasp the concepts of the questions associated with the learning objectives.

3.8.4.5 Groundwater Regulations Pre-and post-tests

The significance of the eighteen questions (Appendix B) asked in the pre- and post-test as part of the groundwater regulation module was to help students understand and better comprehend the term and concept of groundwater regulation. Questions were formulated to achieve the learning objectives specified in the training manual (Kotzé, De Lange, et al., 2019). The learning objectives of this module was to understand and describe the following:

- Groundwater licensing
- Groundwater allocation
- Groundwater protection

- Groundwater Institutions

The complex nature of groundwater and the diversity of uses and environmental interactions call for emerging groundwater problems to be addressed through integrated management and planning approaches (Quevauviller et al., 2016). Groundwater regulations form a fundamental role and are generally required to control and regulate groundwater development and activities that might compromise groundwater quality and availability, address increasing competition and conflict between groundwater users, and control the increasing threat of groundwater pollution (Vaessen and Brentführer, 2014).

Many governments have introduced legislation to regulate groundwater development and constrain activities that might compromise groundwater availability and quality. The importance of the pre- and post-test questions in relation to groundwater is that participants understand and grasp the concepts of how groundwater licensing, water allocation, regulation work in terms of the National Water Act, 1998 (Act 36 of 1998) and groundwater institutions.

3.9 Data collection

3.9.1 Development of Course (online)

3.9.1.1 Designing of site

The platform design includes numerous LMS elements. These include: a course home page, course name, course URL (Figure 3-3), custom completion page (Figure 3-4), site welcome (Figure 3-5) and weekly reminder (Figure 3-6). To gain access to the course participants was manually enrolled, or they could enrol themselves by signing up and enrolling on the following URL: *https://groundwatermanagement.thinkific.com/*. Refer to Appendix C for enrolment guidelines.

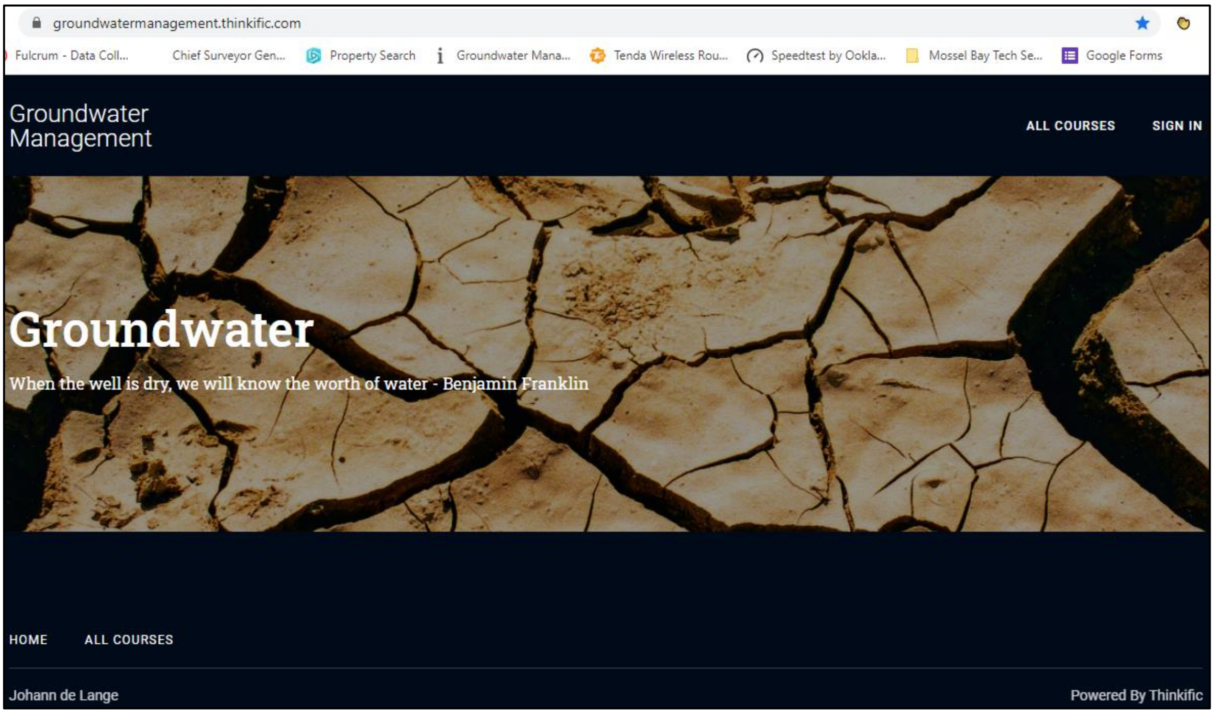

Figure 3-3: The image above depicts the course home page, course name and course URL.

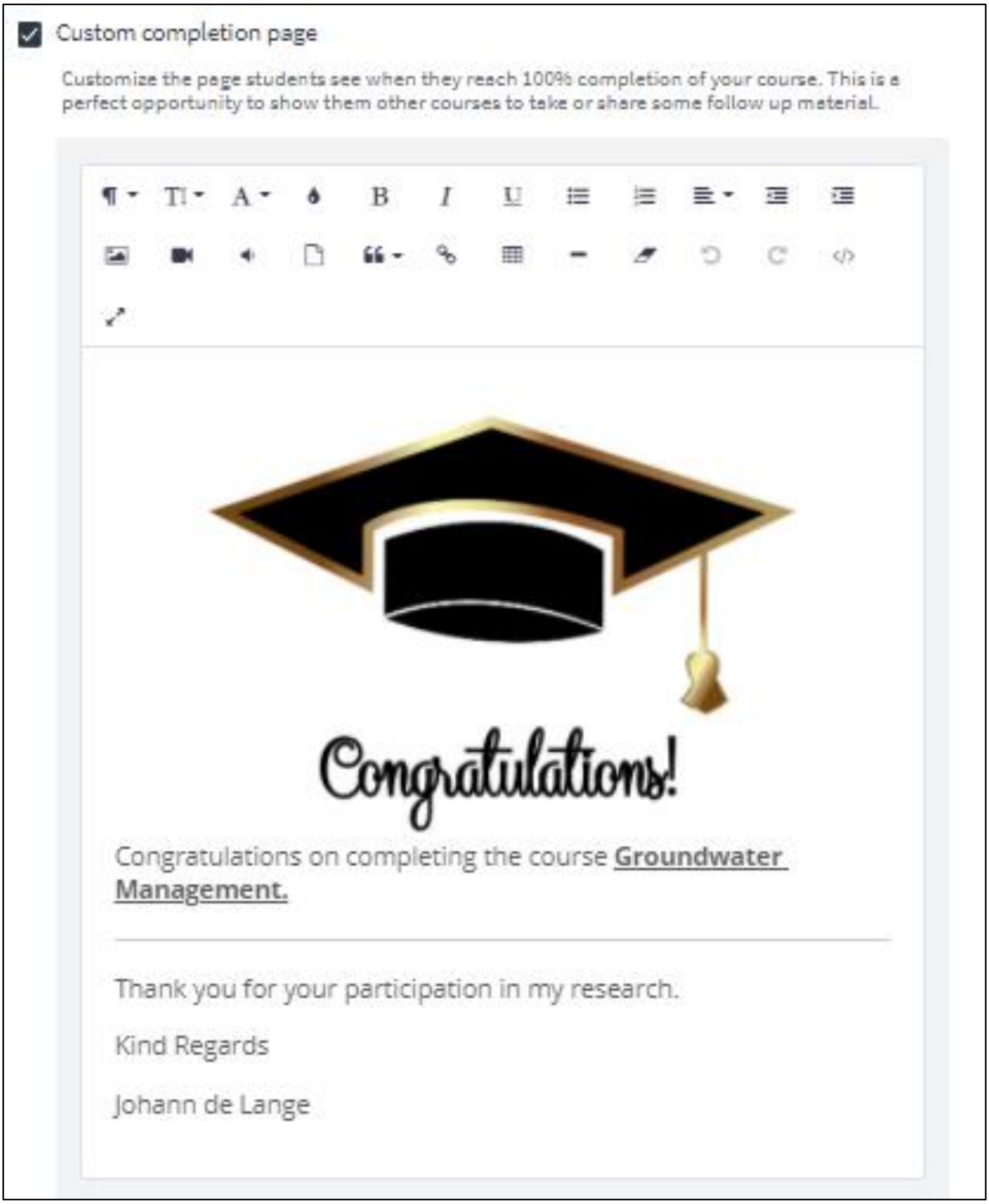

Figure 3-4: Custom completion page.

Dear Participant

My name is Johann de Lange. I am a Postgraduate student at the University of the Free State, Faculty of Natural and Agricultural Sciences doing my Master's degree in Geohydrology at the Institute for Groundwater Studies, under the supervision of Dr Yolandi Kotzé.

As part of my studies I am conducting research and wish to invite you to participate. My study is entitled "Evaluation of a Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa".

The study aims to evaluate the effectiveness of a training module content by utilising Kirkpatrick's four level framework for programme evaluation.

My research will aid to:

- Identify shortcomings in the training programme
- See the relationship of affective reactions in predicting training outcomes
- Develop improved training programmes for the future
- Adapt and proposed recommendations to effectively implement the training programme
- Identify shortcomings in the programme
- Improve general groundwater knowledge

If you are willing to partake in this research, please complete the attached consent form.

If you have any questions, please do not hesitate to contact me at *johanndelange14@gmail.com*.

Thank you for your time and participation.

COMPLETE & CONTINUE →

Figure 3-5: Site welcome.

GM Groundwater Management <noreply@notify.thinkific.com>

To Johann de Lange

Reply | Reply All | Forward | ...

Sun 10/6/2019 7:15 PM

Groundwater Management

Hi Johann de Lange!

This is a friendly reminder from Groundwater Management that you have active courses that are incomplete.

Here are the courses you are enrolled in:

- Groundwater Management is 21% complete. Resume this course.
-

Login to your account | Edit notification settings

Figure 3-6: Emailed weekly reminder.

3.9.1.2 **Main course content**

This section elaborates on the main course content. This section includes all the necessary content information to answer the pre and post-test questions. Below is an image depicting the start of the main course content (Figure 3-7).

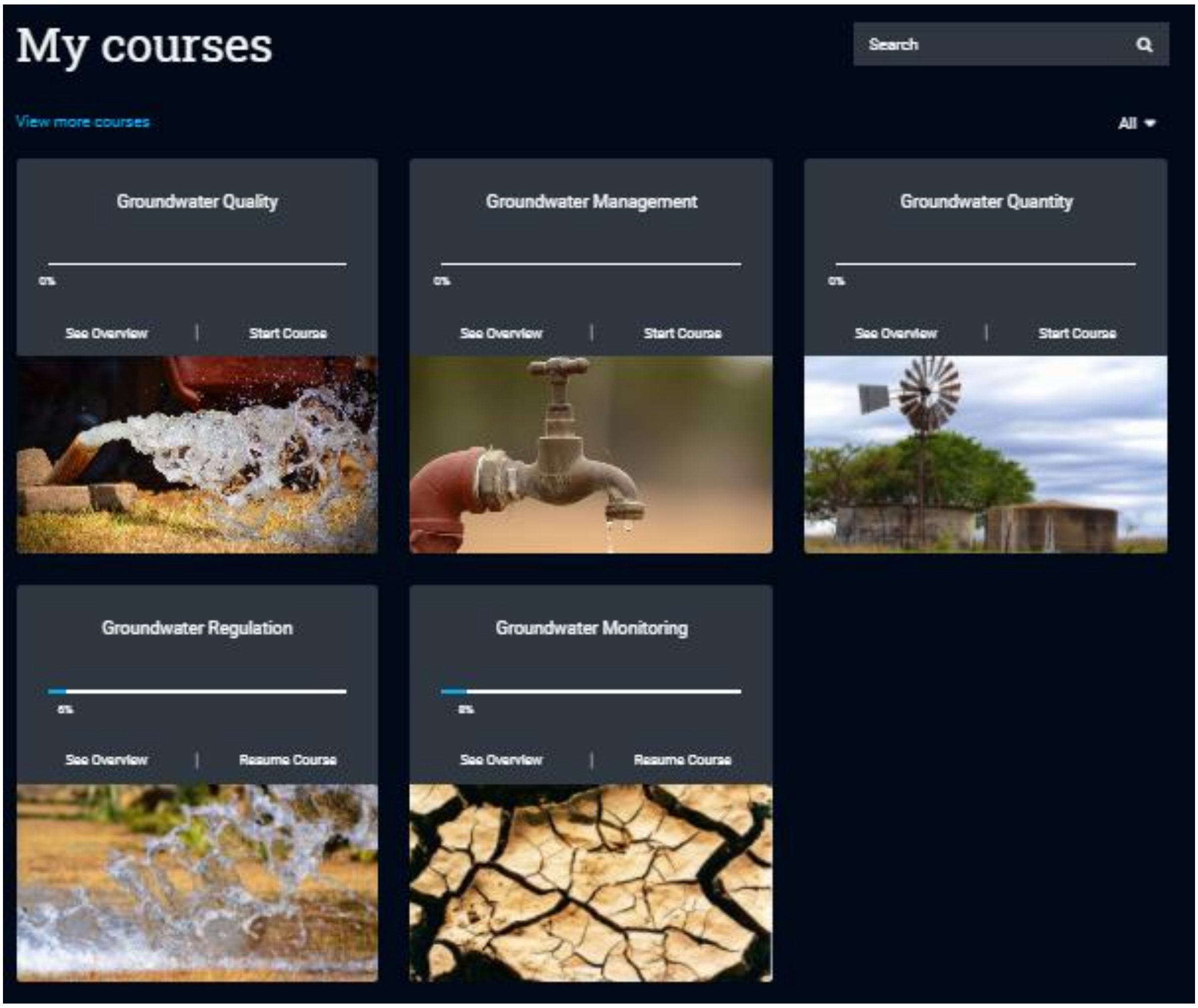

Figure 3-7: Main course content. There are various courses which needed to be completed. Groundwater Quality, Groundwater Management, Groundwater Quantity, Groundwater Regulation and Groundwater Monitoring.

Each module started by welcoming the participant to the course (Figure 3-8) and ended with "Next Step" (Figure 3-9).

- "Welcome to the course!" includes the following lessons (Figure 3-8):
    - "A message from the instructor",
    - "Consent statement",
    - "How to use this course",

- "Survey: Demographic profile", and
- "Let's test your knowledge on" Pre-test.

- 'Next Step" included the following:
  - "You're almost done" provided a summary of the timeline of the course by which deadlines should be completed.
  - "Final knowledge test' refers to the post-test.
  - "Before you go…" refers to the evaluation survey questionnaire.

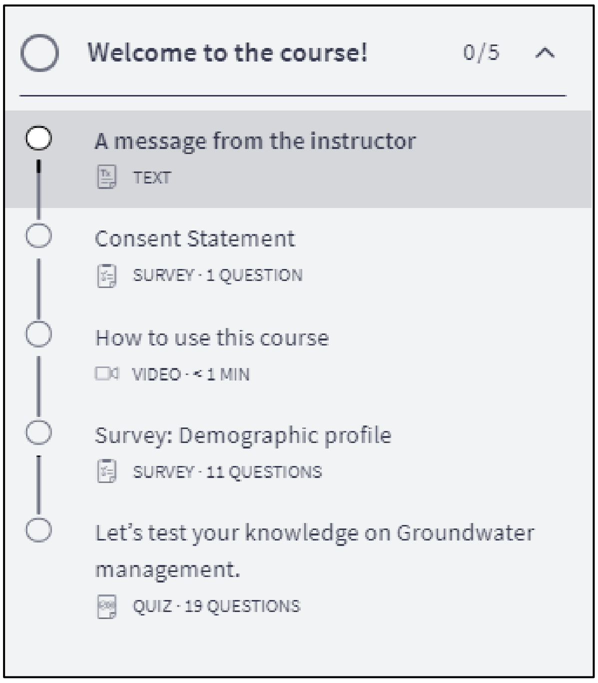

Figure 3-8: Welcome page to the course.

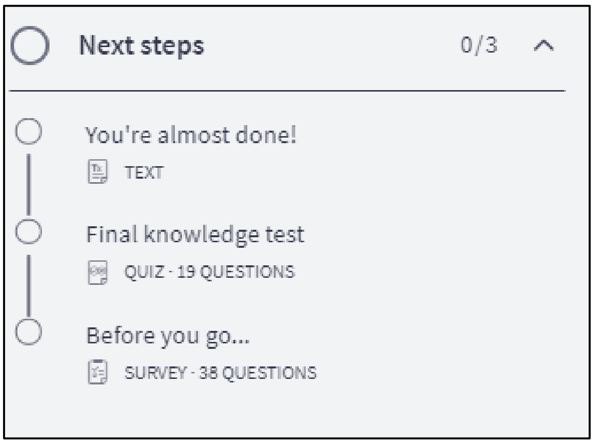

Figure 3-9: Next step title.

The theoretical course content derived from the WRC report "Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa" (Kotzé, De Lange, et al., 2019). The content was divided into different chapters (Figure 3-10). Each module included a chapter with information on how to complete the course and a chapter that contained the learning objectives of the specific module.

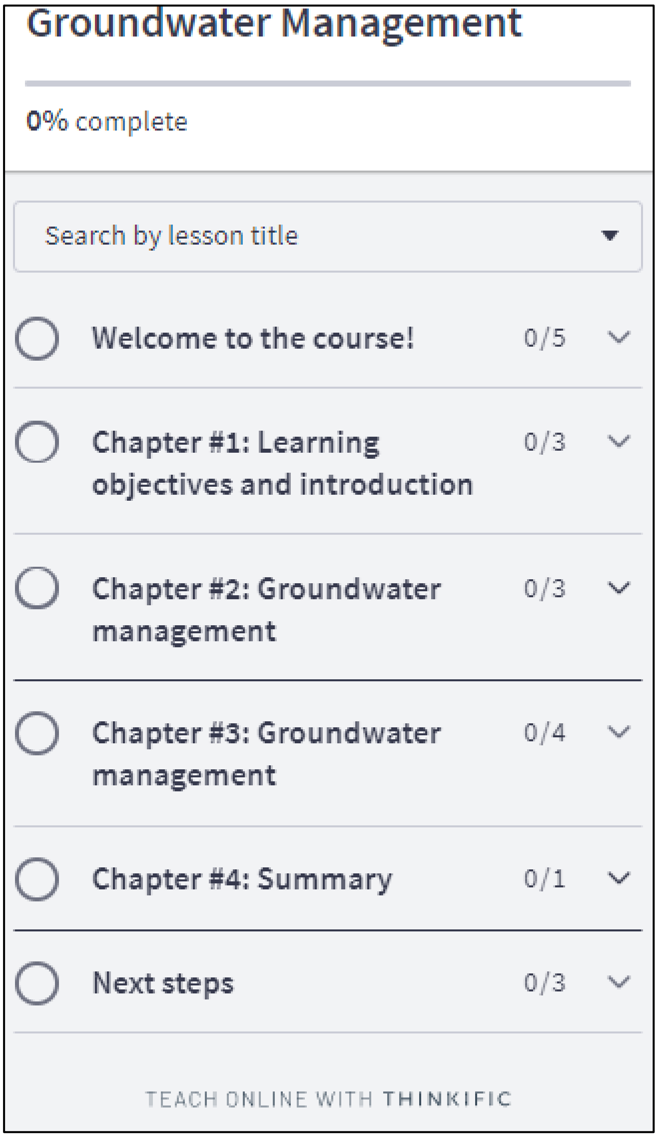

Figure 3-10: Chapters of the course content.

3.9.1.3 Course delivery

- Participants enrolled within the training course received two emails.
    - What module they have been enrolled in. This contains an individual link to the enrolled module.

    - Site welcome email. The emailed contained information to sign in and create a password.

- The course started with the collection of demographic information, which commenced to the pre-test. After the pre-test, the participants had the opportunity to study the course content to review and learn the assigned module content. After reviewing the content, the participants were granted the opportunity to complete the post-test. The participants had one week to review the course content before the post-test was available and had to be completed. After the post-test the participants had to review the training manual in an evaluation survey.
- A constant weekly reminder was emailed automatically from Thinkific to the participants to track their progress (Figure 3-6).
- It is critical that after each step the "Complete and Continue" button needed to be selected for the progress to be updated.
- If all the lessons are complete within a chapter a "POPUP" will appear that congratulate you on completing it.
- Students will ONLY complete the course if the progress shows 100% after the last test and survey.
- The participants had the will to contact the course administrator if they had any problems or technical difficulties.

3.9.2 Method of Data Collection

The Pre-test was used to obtain the general level of knowledge before the training modules comenced. 55 participants wrote the Pre-test. This was also used to set a benchmark to indicate the increase of knowledge gained during the online course. After the online training modules were completed, a Post-test was done and used to determine the differnece in the knowledge level (knowledge gained). The data collected, collectively, were used to compare the group statistics by means of descriptive statistics. The data collected from five groups were used to construct vaious graphs and tables. These tables present the information visually to indicate the gain in knowledge over the course of the training program. The data was collected on the online platform, Thinkfic. This data was then exported to Microsoft Excel, after which the data was then managed to prepare it for IBM SPSS.

3.10 Processing and analysis of information

The data collected on the comprehensive LMS platform Thinkific from the survey instruments and pre-tests and post-tests were recorded in the statistical package IBM SPSS and Microsoft Excel. This method was selected due to the small sample size and variety of build-in formulas that made the data analysing process easy. The charts, tables and graphs were created with the aid of IBM SPSS and Microsoft Excel and will be explained below.

3.10.1 Survey Instrument

The following survey instruments were used:

- Microsoft Excel was utilised to examine the data collected. The answers of the various participants were examined based on the questions of the survey. Additionally, Microsoft Words was also used to construct line graphs, histograms, and tables. This was used to provide a graphical representation of the data.
- IBM SPSS was used to calculate the descriptive statistics and frequency counts. Based on the data collected stack bar diagrams and histograms was constructed.

3.10.2 Pre-test and Post-test

The Pre-test was used to obtain the general level of knowledge before the training modules commenced. This was also used to set a benchmark to indicate the increase of knowledge gained during the online course. After the online training modules were completed, a Post-test was conducted and used to determine the difference in the participants' knowledge gained.

IMB SPSS have been utilised to conduct paired sample t-tests. Paired sample t-tests have been used to compare the mean scores from the same individual on pre-tests conducted in the start of the online course with the mean scores of the post-tests after the training (Xu et al., 2017). Paired sample t-tests are used to determine if the mean difference between two groups of observations is zero. Paired sample t-tests were also used to test the significance between pre- and post-tests. All t-tests were two-tailed.

3.11 Pre-and post-tests Questions Explained

The program “Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa” (Kotzé, De Lange, et al., 2019) formed the central focus of this dissertation and was created and developed by various authors in a WRC project. Part of the deliverables of the WRC project included that the training manual on groundwater should be pilot tested and evaluated. The application of the manual was to enhance knowledge and skills in groundwater resource management and groundwater governance. This enhancement would improve policies and decision-making and more sustainable groundwater resource management.

The pre-and post-test questions asked in the evaluation of the training manual (Appendix B) have been used to assess and evaluate the effectiveness of the training manual. The questions within the five different modules were structured and asked to achieve the learning objectives within the training manual and get the most insight into what learners think and already knew.

Questions were formulated objectively, requiring students to select the correct response from several alternatives to answer or complete the statement. Objective questions include multiple choice answers, true or false questions, matching questions, or the completion of sentences by selecting the correct answer. This way of constructing questions test and motivate participants to reinforce learning. The relevance of each question was to relate to groundwater to better comprehend the concepts, ideas, and terms within the different training manual modules.

Below is a breakdown of each question that includes the following:

- The importance of the question and why is there multiple-choice answers?
- The reasoning behind the correct answer (Correct answers are indicated with a red asterisk *)
- Question explained from a groundwater, groundwater management and geohydrological perspective
- The importance of the question for municipal employees and in a municipal environment

3.11.1 Groundwater Management

3.11.1.1 Question 1

Is the following statement True or False?

The term groundwater and groundwater management has been given inadequate attention and is not typically seen as an important and sustainable water resource for bulk supply that can be managed appropriately.

a. True*
b. False

3.11.1.1.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.1 (Appendix D) of the third module - Groundwater Management in the training manual. The question acts as an introductory question to the groundwater management module. It forms an integral part of assessing students understanding of course content and their level of competency in applying what they are learning.

The question can be divided into three sections:

- What is groundwater?
    - Do municipalities understand the terminology of “groundwater” and subsurface waters?
- Why does groundwater get inadequate attention is?
- Why is groundwater not typically seen as an important and sustainable water resource for bulk supply that can be managed appropriately?

The purpose of the question is to engage participants and help them understand the three divided sections of the question. Multiple-choice answers are used to assess participants' understanding and evaluate curriculum materials and teaching practices (Dufresne et al., 2002). By asking true or false questions, the learner’s retention of specific information from the course, reading comprehension, and general understanding of the material is tested.

3.11.1.1.1.2 The reasoning behind the correct answer

The correct answer is "True" because the introduction section (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

"In South Africa, the term groundwater and groundwater management has been given inadequate attention and is not typically seen as an important and sustainable water resource for bulk supply that can be managed appropriately."

3.11.1.1.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

To understand the question, we first need to understand and define the term groundwater. Holmes (2000) mentioned that "groundwater means different things to different people". Groundwater, or subsurface water, is a term used to denote all the waters found beneath the ground's surface (Wijnen et al., 2012).

To understand the term groundwater, we need to understand the terminology associated with subsurface waters. Fitts (2002) and Heath (1983) explained that water within the subsurface is divided into two main categories, namely the unsaturated (vadose zone) and saturated zones (Figure 3-11).

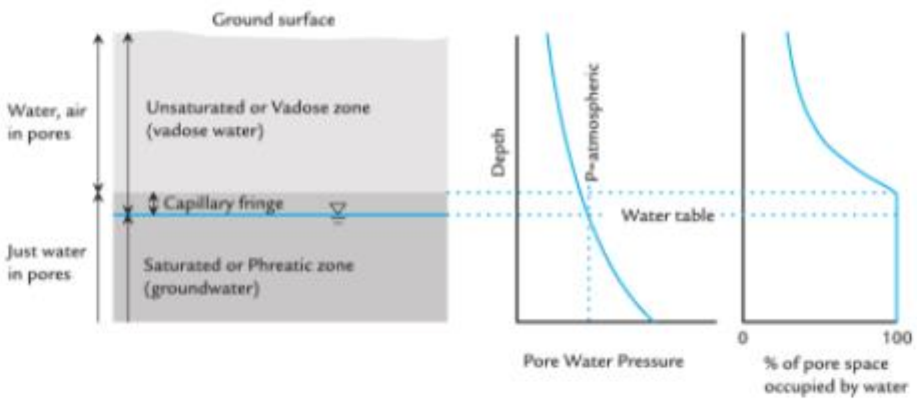

Figure 3-11: The categorisation of subsurface waters (Fitts,2002)

The unsaturated or vadose zone (Figure 3-11) occurs directly below the land surface in most areas (Lachassagne, 2021). It is defined as the zone that is located above the water table where the pore water pressure is lower than atmospheric pressure, thus containing both water and air. The term vadose water is used to describe all water situated in the unsaturated zone (Fitts, 2002). The saturated or phreatic zone (Figure 3-11) is located below the water table and is defined as the zone beneath the unsaturated zone where the water pressure is greater than atmospheric pressure (Lourens, 2013). This indicates that all the interconnected openings or pores are filled with water.

The capillary fringe is defined as a zone that is saturated with water but located above the water table, as depicted in Figure 3-11. The thickness of the capillary fringe typically varies depending on the pore sizes in the medium.

By understanding the terminology associated with subsurface water, hydrologists defined groundwater as water within the saturated zone beneath the water table (Nel, 2006; Bear, 2012).

The second part of the question mentioned that groundwater and groundwater management had been given inadequate attention. Foster and Chilton (2003) noted that groundwater as a resource is still generally under-valued, inefficiently exploited and inadequately protected. Adequate attention is rarely given to groundwater conservation, management, and protection while there is an urgent need for the rapid development of new water supplies. The inadequate constraint to groundwater as a water resource can be a severe constraint on sustainable development in the long term. The inadequate attention is often a result of a society that sees groundwater as an invisible water resource, unlike surface water, which can be seen and touched (Megdal, 2018).

The importance of groundwater from a geohydrological perspective is that it is seen as an essential and sustainable water resource serving as a reliable source of water for irrigation and domestic and industrial purposes in many countries (Hasanuzzaman et al., 2017). In addition, groundwater is a crucial resource to many countries, irrespective of their stage of economic development.

The acceleration of groundwater development has resulted in excellent social and economic advantages by providing low-cost, drought-reliable, high-quality water supplies for urban and rural populations (Kemper, 2004). Megdal (2018) explained that there is an increasing dependence on groundwater due to the growing demand for food, energy and other human consumptions and the constant change in climate in South Africa's rapidly growing population.

Whilst groundwater storage is vast, its rate of replenishment is limited. Therefore, water managers and decision-makers must pay adequate attention to the quality and quantity of groundwater as the reliance on groundwater increases (Megdal, 2018).

3.11.1.1.1.4 The importance of the question for municipal employees and in a municipal environment

It is essential that water users, water managers, decision-makers and municipal employees understand the term groundwater. They should understand that it could be used as a sustainable water resource for bulk supply if managed appropriately.

Municipal employees must know the difference between groundwater, surface and subsurface water. If water users, water managers and municipal employees do not understand the terminology associated with groundwater, they might not be in a position to protect, manage or benefit from it.

By asking this test question, municipal employees are engaged to understand the three sections of the question:

- What is groundwater?
- Why does groundwater get inadequate attention is?
- Why is groundwater not typically seen as an important and sustainable water resource for bulk supply that can be managed appropriately?

Municipal employees might not see groundwater as an invisible water resource anymore. Attention should be given to this resource, and better governance and management of groundwater are required to move toward sustainable groundwater use (Megdal, 2018).

Municipal employees must understand that groundwater is an important and sustainable water resource in a municipal environment.

3.11.1.2 Question 2

Is the following statement True or False?

To manage groundwater resources effectively, it is essential to better understand the quality, quantity and impacts of groundwater use.

a. True*
b. False

3.11.1.2.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.1 (Appendix D) of the third module - Groundwater Management in the training manual. This section acts as the introduction to the module to familiarise the reader with the term groundwater management.

The purpose and importance of the question are that the reader understands that it is difficult to manage a resource without understanding its termonoligy and its various aspects. The true and false option is provided as a test answer to encourage active learning and foster reflection within readers/learners.

3.11.1.2.1.2 The reasoning behind the correct answer

The correct answer is "True" because the introduction section (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

"A generally accepted principle is that "prevention is better than cure" and to manage groundwater resources effectively, it is essential to better understand the quality, quantity and impacts of groundwater use."

3.11.1.2.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

The question indicates that the management of groundwater resources will be easier when the concepts surrounding it are understood. The management of groundwater resources is described by Singh (2014) as a challenging task due to the growing water demand in industrial, agricultural, and domestic sectors. The declining or rising groundwater levels and associated resource contamination increased the complexity of groundwater management.

A wide variety of solutions could be considered to address the declining or rising groundwater levels and associated resource contamination problems. However, the solutions' effectiveness depends on the knowledge and terminology associated with the resource.

Conant Jr et al. (2019) explain that a basis for water resources management and environmental protection is formed by developing a multidisciplinary understanding of groundwater and surface water systems and the interaction to impact water quantity and water quality.

Why is this question important? Although knowledge and terminology associated with groundwater resources have improved, there is still a lack and limited guidance for conceptualizing groundwater terminology to municipalities. For this reason, the groundwater training manual (Appendix D) was created to provide a comprehensive and logical approach for groundwater management and groundwater governance.

3.11.1.2.1.4 The importance of the question for municipal employees and in a municipal environment

Nchoung (2015) describes that the successful management of groundwater begins with knowing the impacts of especially human activities on the quantity and quality of groundwater.

Why is the management of groundwater resources important for municipal employees in a municipal environment?

The management of groundwater resources is important because managers in a municipal environment have managerial power. The existence of linkages within the different institutional levels for groundwater management is to be established by managers. Carter et al. (2005) describe managerial power as the coordination between various levels of management that creates a good working relationship with other organisations. Therefore, municipal managers can be divided into two categories:

- Managers who recognize problems and effectively implement solutions
- Managers who are unwilling to recognize problems and effectively implement solutions

Nchoung (2015) indicates that authorities who distribute information and know the resource strengthen the management of their water resources.

3.11.1.3 **Question 3**

Management is defined as: “The attainment of organizational goals in an effective and efficient manner through _________________________ and controlling organizational resources.”

Choose one of the following:

a. planning, organizing, leading*
b. improvising, disorganize, following
c. development, determination, focusing
d. planning, determination, leading

3.11.1.3.1.1 **The importance of the question and why is there multiple-choice answers?**

The question is derived from section 3.2.1 (Appendix D) of the third module - Groundwater Management in the training manual. This section defines management and introduces the next section that describes the difference between management and governance within groundwater management. The question determines if the participants understand the term management.

The question defines the term management, where the participant must complete the definition by selecting the correct answer to complete the definition.

Multiple-choice answers are used to assess participants' understanding and evaluate if they understand management and the terms associated with it. The different answers test the knowledge skills of learners.

3.11.1.3.1.2 **Reasoning behind the correct answer**

The correct answer is “planning, organizing, leading” because the introduction section (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

“Daft and Marcic (2012) defined management as:

“The attainment of organizational goals in an effective and efficient manner through planning, organizing, leading, and controlling organizational resources.”

3.11.1.3.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

The term management is frequently misunderstood and misinterpreted. Geohydrologically it is important to understand that there is a difference between management and governance. In Barrett (2003; p.51), Mary Parker Follett defines management as "...the art of getting things done through people".

Riemann et al. (2012) explain that management in all business and human and organisation activities is the act of getting people together to accomplish desired goals and objectives.

From a geohydrological perspective, management is essential because it has the responsibility to:

- Communicate expectations
- Manage day-to-day operations and program implementation
- Report results

Management is thus a crucial component to comprehend and implement groundwater management.

3.11.1.3.1.4 The importance of the question for municipal employees and in a municipal environment

As organizations grow and expand in a municipal environment, it is important to differentiate and understand the difference between governance and management and who is responsible for each. The difference of who is responsible for each plays a vital role where accountability on groundwater management and sustainability is required. When the balance between the responsibilities management is established and functioning well, the organization/municipal will be able to better:

- Meet the expectations of clients, groundwater users, beneficiaries and other stakeholders;
- Deliver quality programs that are effective and efficient; and
- Comply with laws, regulations and other requirements

3.11.1.4 Question 4

Groundwater management is described as the assessment of ___________________aspects in terms of groundwater, and the impacts associated with supply, quality, quantity, sustainability and demands among different consumers and the optimization of exploitation and use.

Choose one of the following:

a. geological and social
b. hydrologic and geographical
c. hydrologic and environmental*
d. governmental guidelines and hydrologic

3.11.1.4.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.2.2 (Appendix D) of the third module - Groundwater Management in the training manual. This section explains the difference between management and governance within groundwater management. The question determines if the participants understand the difference between management, governance and groundwater management. It forms an integral part of assessing students understanding of course content and their level of competency in applying what they are learning.

The question defines the term groundwater management, where the participant must complete the definition by selecting the correct answer to complete the definition.

Multiple-choice answers are used to assess participants' understanding and evaluate curriculum materials and teaching practices. The multiple-choice format provides an efficient way to collect and analyze data from a large number of participants (Dufresne et al., 2002).

3.11.1.4.1.2 The reasoning behind the correct answer

The correct answer is “hydrologic and environmental” because section 3.2.2 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

“Groundwater management is formerly described as the assessment of hydrologic and environmental aspects in terms of groundwater, and the impacts associated with supply, quality, quantity, sustainability and demands among different consumers and the optimization of exploitation and use (Willis and Yeh, 1987).”

3.11.1.4.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

Jakeman et al. (2016) stated that water management is a challenging problem that has become one of the world's top priorities. Rittel and Webber (1973) explained that groundwater management is challenging. It involves multiple stakeholders and decision-makers with various goals and interests with various uncertainties caused by limited data, information, and knowledge.

Historically, groundwater has been seen as an invisible source that’s often hidden and more difficult to conceptualize thus undervalued. Jakeman et al. (2016) also explain that the timeframe of concern for groundwater system degradation is longer than many timeframes used in societal decision making. As a result, groundwater continues to be a minority in water resources management.

Groundwater management is vital because groundwater replenishment rates are exceedingly lower than groundwater depletion rates in many parts of the world (Jakeman et al., 2016). In addition, the decline of groundwater quality and quantity cannot sustain agricultural, industrial and urban demands in the developed world.

In addition, the decline of groundwater quality and quantity cannot sustain agricultural, industrial and urban demands in the developed world.

Willis and Yeh (1987) described groundwater management as the assessment of hydrologic and environmental aspects in terms of groundwater, and the impacts associated with supply, quality, quantity, sustainability and demands among different consumers and the optimization of exploitation and use.

Why is groundwater management important from a geohydrological perspective?

Groundwater management is important for the sustainability of the resource. Managing groundwater allows the resource water to extend its life cycle, including ecological service, over very long periods. One example of groundwater management principles includes that the abstraction from a groundwater reservoir should not be larger than the long-term average recharge in the long term (Kinzelbach et al., 2003).

Kinzelbach et al. (2003) mentioned a few other groundwater management strategies governing the sustainability of the resources, and this includes checks on over-pumping of an aquifer, consequences of groundwater table decline, seawater intrusion and upcoming of saltwater of boreholes near the coastline, degradation of groundwater quality, quantity and soil salination.

3.11.1.4.1.4 The importance of the question for municipal employees and in a municipal environment

Why is groundwater management important in a municipal environment?

Various municipalities depend on groundwater as it forms the primary source of drinking water. However, groundwater is generally not adequately managed to ensure long-term sustainability (Tom Gleeson et al., 2012). Groundwater management could also benefit municipalities in drought-prone areas, where groundwater is typically the only perennial water supply source (Carlow et al., 1997).

If employees in a municipal environment understand groundwater management, they would be able to (DWAF, 2004b):

- Fulfil legal obligations (i.e. ensuring use and protection of groundwater according to national and international laws).
- Monitor and analyse data (e.g. groundwater levels and abstraction).
- Optimise groundwater usage.
- Protect groundwater from contamination.
- Create awareness and educate people about sustainable groundwater use.

3.11.1.5 Question 5

Moench et al. (2012) defined groundwater governance as:

a. “A simple act to coordinate and gather people to achieve a set of objectives and goals”.
b. “The process through which groundwater related decisions are taken and power over groundwater is exercised.”*
c. “The art of getting things done through people”.
d. “The ability to get and implement results within a short time”.

3.11.1.5.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.2.2 (Appendix D) of the third module - Groundwater Management in the training manual. This section explains the difference between management and governance within groundwater management. The question determines if the participants understand the difference between management and governance.

The question defines the term groundwater governance, where the participant must complete the definition by selecting the correct definition to complete the answer.

Multiple-choice answers are used to assess participants' understanding and evaluate if they understand and know the definition of groundwater governance. The different answers test the knowledge skills of learners.

3.11.1.5.1.2 The reasoning behind the correct answer

The correct answer is:

"The process through which groundwater related decisions are taken and power over groundwater is exercised."

Because section 3.2.2 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates:

"In addition to groundwater management, Moench et al. (2012) defined groundwater governance as:

"The process through which groundwater related decisions are taken (whether on the basis of formal management decisions, action within markets, or through informal social relations) and power over groundwater is exercised."

3.11.1.5.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

Fourie (2020) explained that groundwater governance is a relatively new concept that emerged in the late 2000s. Previously, integrated water resource management and sustainable water management approaches have been used to describe how we manage our groundwater resources. The water community has increasingly emphasized that the global water crisis is centrally a crisis of governance (Braune & Adams, 2013).

Foster et al. (2010) initially define groundwater governance as:

“the exercise of appropriate authority and promotion of responsible collective action to ensure sustainable and efficient utilisation of groundwater resources for the benefit of humankind and dependent ecosystems”.

Foster and Garduño (2013) later updated his definition to be more consistent with other authors and defined groundwater governance as:

“the enabling framework and guiding principles for responsible collective action to ensure control, protection and socially - sustainable utilisation of groundwater resources for the benefit of humankind and dependent ecosystems.”

Fourie (2020) explained that effective water governance is needed:

- To ease the increasing pressure of the groundwater demand
- To increase the access to clean water
- To be more accountable and transparent due to corruption
- To decentralise the management of the water sector and thus to reform the sector to have decision making at lower levels
- To minimise the insecurity of water rights and the unequal distribution of water rights

Why groundwater governance?

Rogers and Hall (2003) explain that the concept of governance in the water sector arose to ensure more rational water resource management, ensure that the poorest people have access to water and generally contribute to changing the attitude and views within the sector. By the governance of groundwater resources, threats to groundwater resources are prevented.

3.11.1.5.1.4 The importance of the question for municipal employees and in a municipal environment

Groundwater governance is crucial for municipalities because it could assist in developing and modifying frameworks to protect groundwater resources. Groundwater governance is critical to preventing groundwater resources risks.

3.11.1.6 Question 6

The process of making decisions is described as ________________, while the process of implementing them is described as water management.

Choose one of the following:

a. Water policies
b. Water management
c. Water Strategies
d. Water governance*

3.11.1.6.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.2.2 (Appendix D) of the third module - Groundwater Management in the training manual. This section explains the difference between management and governance within groundwater management. The question determines if the participants understand the difference between management and governance.

The question can be divided into two statements that describe water governance and management:

- Water governance is described as the process of making decisions.
- Water management is described as the process of implementing decisions made in water governance.

The question test if the reader understands the difference between water government and management by allowing the participant to complete the definition by selecting the correct answer to complete the definition.

Multiple-choice answers are provided with similar incorrect answers to assess participants' understanding of the two terms.

3.11.1.6.1.2 **The reasoning behind the correct answer**

The correct answer is “Water governance” because section 3.2.2 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

“Therefore we can agree with Jonker et al. (2010) that the process of making decisions is described as water governance, while the process of implementing them is described as water management.”

3.11.1.6.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

As explained in the previous question, governance is the act, process or power of governing. It is described as the decision making process in the administration of an organisation.

Pietersen et al. (2011) explained that groundwater is recognised as a significant and strategic resource to meet the needs of rural communities, urban water supply, overall water security, food security, and the environment and therefore need to be governed at a national level.

3.11.1.6.1.4 **The importance of the question for municipal employees and in a municipal environment**

The National Water Act, 1998 (Act 36 of 1998) provides the necessary framework within which to protect, use, develop, conserve, manage and control our water resources (Bredenhann & Braune, 2000). It is vital that the Act needs to be underpinned by implementation-level policy and a structured management strategy. Integrated management of groundwater and surface water is generally required in order to provide for adequate protection of the resource. This is why water governance and management is important in a municipal environment.

3.11.1.7 **Question 7**

What is regarded as the “building blocks” or the four basic functions of management?

a. Planning, organising, leading and controlling*
b. Development, categorizing, managing and governing
c. Planning, development, determination and focus.
d. Organising, determination, controlling and governing

3.11.1.7.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.2.3 (Appendix D) of the third module - Groundwater Management in the training manual. This section explains the functions and building blocks associated with management. By understanding the four basic management functions or building blocks, a framework for groundwater management could be developed.

Multiple-choice answers are provided with similar incorrect answers to assess participants' understanding of the two terms.

3.11.1.7.1.2 The reasoning behind the correct answer

The correct answer is “Planning, organising, leading and controlling” because section 3.2.3 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

“Management is normally divided and distinguished in four basic management functions and is regarded as the building blocks for management. These “building blocks” is categorized as planning, organising, leading and controlling...”

3.11.1.7.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

Management operates through various functions (Riemann et al., 2012).

Why Is Management Important?

All organizations rely upon group efforts to achieve goals, and whenever multiple people are required to work together, management is necessary. Implementing management allows goals to be accomplished, people to be more efficient and make better decisions.

Riemann et al. (2012) explain that business schools typically distinguish four basic management functions (Figure 3-12): planning, organising, leading, and controlling.

- **Planning:** Deciding what needs to happen in the future and generating plans for action
- **Organising:** Making optimum use of the resources required to enable plans to be carried out successfully
- **Leading:** Determining what needs to be done in a situation and getting people to do it

- **Controlling/monitoring:** Checking progress against plans, which may need modification based on feedback

These four management functions are the building blocks for various types of management. Understanding the four management functions would be easier to implement and understand geohydrological management types such as groundwater management.

Figure 3-12: The four basic management fuctons (Kotzé, Merwe, et al., 2019)

3.11.1.7.1.4 The importance of the question for municipal employees and in a municipal environment

Why is management important for municipal employees?

A manager's primary challenge is to solve problems creatively. The four major functions of management: planning, organizing, leading, and controlling help managers respond to creative problem-solving.

As mentioned before, the four management functions form the building blocks for various types of management. Understanding the four management functions would be easier to implement and understand geohydrological management types such as groundwater management.

3.11.1.8 Question 8

Is the following statement True or False?

The four basic management functions provide insignificant steps in the process to achieve organizational goals, and are not related to each other.

a. True
b. False*

3.11.1.8.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.2.3 (Appendix D) of the third module - Groundwater Management in the training manual. This question is a follow-up question on the four basic functions of management. This section explains the functions and building blocks associated with management. The question test if the reader understands that the four functions of management are valuable steps to achieve organizational goals. By understanding the four basic management functions, a framework for groundwater management could be developed.

The true and false question is asked to test reading comprehension.

3.11.1.8.1.2 The reasoning behind the correct answer

The correct answer is "False" because section 3.2.3 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

"These functions or so called "building blocks" provide valuable steps in the process to achieve organizational goals, and are related and interrelated to each other."

3.11.1.8.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

Why Is Management Important?

As mentioned in question 8 of the groundwater management module, all organizations rely upon group efforts to achieve goals, and management is necessary whenever multiple people are required to work together. Implementing management allows goals to be accomplished, people to be more efficient and make better decisions. The four basic functions of management are important in geohydrology to effectively protect, manage and govern groundwater resources, and we need to understand basic management principles.

3.11.1.8.1.4 The importance of the question for municipal employees and in a municipal environment

Why is management important for municipal employees?

A manager's primary challenge is to solve problems creatively. The four major functions of management: planning, organizing, leading, and controlling help managers respond to creative problem-solving. The functions assist employees in planning, organising, taking the lead, and controlling resources effectively.

3.11.1.9 Question 9

The first foundation phase and the most important component of the four basic management functions is:

a. Organising
b. Controlling
c. Planning*
d. Leading

3.11.1.9.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.2.3.1 (Appendix D) of the third module - Groundwater Management in the training manual. This section is the subsection that explains the four basic management functions. The question determines if the participants understand the difference between the four basic management functions or building blocks.

The question test if the reader understands the difference between the four functions by providing all four functions. The question asks the participant to pick the correct answer by selecting the correct building block that acts as the most important component.

3.11.1.9.1.2 The reasoning behind the correct answer

The correct answer is "Planning" because section 3.2.3.1 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

“Planning is the first foundation phase and the most important component of the four building blocks. It involves the process of selecting certain objectives and determines a sequence of steps and actions that need to be followed to achieve those objectives.”

3.11.1.9.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

The foundation face of the four basic management functions is described as planning (Kotzé, Merwe, et al., 2019).

Carpenter et al. (2012) described planning as the function of management that involves setting objectives and determining a course of action for achieving those objectives. Planning requires managers to be conscious of environmental conditions facing their organization and forecast future conditions. Planning also demands that the managers be excellent decision-makers. Planning is described as a process that consists of various steps (Carpenter et al., 2012):

- Evaluating environmental forces and organisational resources: Planners must be aware of their environmental surroundings and critical contingencies facing their organization regarding economic conditions, competitors, and customers.
- Establishment of organisational goals. This is where planners forecast future conditions.
- Develop strategies and plans to achieve goals: Planners must establish objectives of what needs to be achieved and when.
- Formulate decision making: Planners must decide the best courses of action for achieving objectives.
- Implementation: The planner must formulate necessary steps and ensure the effective implementation of plans.

3.11.1.9.1.4 The importance of the question for municipal employees and in a municipal environment

Planing in a municipal environment is crucial to evaluate, establish, develop, formulate and implement plans. By doing this, groundwater governance and management will be an easier task to complete.

3.11.1.10 Question 10

For the development of a functional flow-diagram for groundwater management. The following components should be included:

Select the incorrect component as your answer:

a. Data collection
b. Awareness
c. Previous Groundwater knowledge*
d. Legal Framework

3.11.1.10.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.2.4 (Appendix D) of the third module - Groundwater Management in the training manual. This section explains and defines groundwater management. The section indicates that a functional flow diagram for groundwater management could be developed by understanding the four basic management functions.

The question determines if the participants understand the different components incorporated within a groundwater management flow diagram or framework by providing different multiple choice answers.

3.11.1.10.1.2 The reasoning behind the correct answer

The correct answer is "Previous Groundwater knowledge" because section 3.2.4 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

"Through adapting and understanding the four functions of management mentioned earlier as planning, organising, leading and controlling we can develop a functional flow-diagram for groundwater management. The flow diagram should include the following components:

- Data collection, capturing and monitoring
- Planning
- Data analysis
- Protect
- Awareness
- Legal Framework ".

3.11.1.10.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

Section 3.2.4 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stated that a flow diagram should include various components like data collection, capturing and monitoring, planning, data analysis, protection and awareness and legal framework.

Why is a framework important from a geohydrological perspective.

It is impossible to develop an acceptable groundwater management strategy for a particular region without good understanding and knowledge about the resource. Applying groundwater management without successfully collecting, capturing, and monitoring groundwater-related data would be impractical.

Hydrologists should understand that a certain number of basic information is required to manage groundwater effectively, and the more intensive groundwater abstraction becomes, the more data are required for the management thereof.

3.11.1.10.1.4 The importance of the question for municipal employees and in a municipal environment

The question is important in a municipal environment because a groundwater management framework provides a guideline for optimal incorporation and integration of the management functions in the municipal structure. A framework is generally designed to be applicable at a local level to achieve sustainable groundwater management.

3.11.1.11 Question 11

A hydrocensus is an:

a. excellent example of groundwater data collection*
b. excellent example of groundwater monitoring
c. excellent example of groundwater governance
d. excellent example of groundwater policies

3.11.1.11.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.2.4.1 (Appendix D) of the third module - Groundwater Management in the training manual. The question explains that it is impossible to develop an acceptable groundwater management strategy for a specific region without good knowledge about the resource. The question is test whether learners/participants understand the importance of a hydrocensus and its terminology.

The purpose of the question is to engage participants and help them understand what a hydrocencus is and the importance of data collection, capturing and monitoring. Multiple-choice answers are used to assess participants' understanding on the definition of a hydrocensus.

3.11.1.11.1.2 **The reasoning behind the correct answer**

The correct answer is “excellent example of groundwater data collection” because section 3.2.4.1 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

“A hydrocensus is an excellent example of groundwater data collection and is a task that consists of collecting information on water features, water supply sources and sources of potential. In addition to this, rainfall data are also very valuable.”

3.11.1.11.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

Evenson et al. (2018) explained that the availability of water could be divided into four components:
“(1) the need for a certain volume of water to meet the intended purpose, (2) the timing characteristics with which water is delivered, (3) the adequate quality of the water for the intended purpose, and (4) the need for water to meet both human and environmental/ecological uses.” A water-availability analysis of any given area or site should typically consider the quantity of water, the timing of water delivery, and water quality.

A water census or groundwater hydrocensus needs to be conducted to determine water availability effectively. What is a groundwater hydrocensus? A groundwater hydrocensus (water census) is an activity that involves the gathering of information on water features, water supply sources and sources of potential water pollution in a particular site or area (DWAF, 2004b).

A hydrocensus is explained by Evenson et al. (2018) to be complex and must generally incorporate and report information at various spatial scales. Hydrocensus data should include information from small watersheds to national compilations. Hydrocensus information should be reported in a practical manner in order for it to be beneficial to local water managers, decision-makers, municipal employees and stakeholders.

A Hydrocencus summarises and simplifies information on available water sources and potential polluting activities. The focus of a hydrocensus must be on the scientific aspects of water availability

DWAF (2004b) stipulated that a hydrocensus aims to:

- Identify details of water-related features (e.g. stormwater channels, erosion gullies, weirs, diversion embankments) and disused or abandoned boreholes and wells.
- Identify features where water could collect in rainy periods (quarries, borrow pits, seasonal puddles, etc.).
- Identify potential sources of contamination (latrines, waste disposal sites, animal kraals, defecation sites, animal watering points, soak-away pits and drains, etc.).
- Identify visible features and symptoms (e.g. borehole casing rusted away at the surface, presence of algal blooms in stagnant water) that indicate the potential for water contamination.
- Identify water sources and, where possible, indicate the flow rate and the quality of each water source.

Why do a hydrocensus?

Water is a scarce and strategic resource, and the recent drought and water crisis experienced in South Africa added pressure on our groundwater resources. Groundwater resources can be polluted by various factors that could influence the quality and quantity of the resource. In other words, it is essential to assess the possible impact of any development initiative concerning water resources before approving the initiative. Moreover, to manage our groundwater resources, we need to understand their functioning, and this is done through hydrocensus.

3.11.1.11.1.4 The importance of the question for municipal employees and in a municipal environment

For a municipality to know and manage their groundwater resources effectively, they need to know and understand who uses the water, its quality, what resources are used, how much water is used, and why. To determine this, a hydrocensus needs to be completed. A hydrocensus is an excellent example of groundwater data collection and is a task that consists of collecting information on water features, water supply sources and sources of potential pollution.

A hydrocensus needs to be implemented on a municipal level to determine the water availability within the municipal jurisdiction. In monitoring data, an estimation of the amount of water we use and the quality thereof is established.

Municipalities could use the information to implement a management procedure during a water crisis or drought. By understanding how much groundwater/water is available, municipalities could better manage and govern the resource for water demand, conservation and sustainability. A hydrocencus will also assist municipalities on a district and local scale during times of need.

3.11.1.12 Question 12

Is the following statement True or False?

Monitoring is done by testing groundwater quality, recording the amount of groundwater used (abstraction rates) and the levels of groundwater.

a. True*
b. False

3.11.1.12.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.2.4.1 (Appendix D) of the third module - Groundwater Management in the training manual. This section explains the data collection, capturing and monitoring of groundwater management. This section indicates that it is impossible to develop an acceptable groundwater management strategy for a specific region without a good knowledge of the resource. The section also explains that an estimation of the amount of water and quality we use is established by monitoring.

The question test if participants understand the process of monitoring by asking a true or false type question.

3.11.1.12.1.2 The reasoning behind the correct answer

The correct answer is "True" because section 3.2.4.1 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

"Monitoring is done by testing groundwater quality, recording the amount of groundwater used (abstraction rates) and the levels of groundwater."

3.11.1.12.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

In monitoring data, an estimation of the amount of water we use and the quality thereof is established. Monitoring is done by testing groundwater quality and recording the amount used (abstraction rates) and groundwater levels. Monitoring is an essential element of integrating groundwater science with water-management decisions and is an ongoing process.

Why is groundwater monitoring important?

Nchoung (2015) explain that groundwater is managed following the results obtained from monitoring. Monitoring groundwater provides information on the quality and quantity of groundwater resources. Monitoring results will indicate whether groundwater quality is declining over the years or not. Monitoring results also indicate changes to groundwater quantity.

3.11.1.12.1.4 The importance of the question for municipal employees and in a municipal environment

Why is monitoring important in a municipal environment?

Scarcity of water and the increasing concern of groundwater contamination have led to the implementation of monitoring networks and is a pre-requisite for effective management (Zhou Yangxiao, 1994). Zhou Yangxiao (1994) mentioned that previous literature indicated that groundwater resources need to be managed and monitored effectively to prevent the deterioration of groundwater quality and quantity.

Monitoring in a municipal environment is important as it could help trace contaminant sources of pollutants. Monitoring also provides and includes data on groundwater quantity and quality of the resource itself and is an integral aspect of groundwater management (Sundaram et al., 2009). Owen et al. (2010) stated that groundwater quality deterioration, groundwater abstraction and contamination occurs typically due to the absence of monitoring.

Monitoring groundwater is an essential component in groundwater management. In general terms, it is also described as the ongoing process of collecting data and organising and assessing data into information to improve decision-making and determine performance progress and trends (Jha et al., 2010).

3.11.1.13 Question 13

Municipal By-laws are described as a _____________ that addresses public interest, enforce standards of conduct and are just like any other laws in the country.

a. dynamic government-implementation tool
b. dynamic management-implementation tool
c. dynamic monitoring-implementation tool
d. dynamic policy-implementation tool*

3.11.1.13.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.2.4.2 (Appendix D) of the third module - Groundwater Management in the training manual. This section explains that effective ways of creating groundwater management are to establish and implement municipal laws. The question determines if the participants understand what a municipal by-law is.

The question defines the term municipal by-laws, where the participant must complete the definition by selecting the correct answer to complete the definition.

Multiple-choice answers are provided to assess participants' understanding and evaluate curriculum materials and teaching practices.

3.11.1.13.1.2 **The reasoning behind the correct answer**

The correct answer is "dynamic policy-implementation tool" because section 3.2.4.2 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

"By-laws are described as a dynamic policy-implementation tool that addresses public interest, enforce standards of conduct and are just like any other laws in the country."

3.11.1.13.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

By-laws are laws passed by the council of a municipality to regulate the affairs and the services the municipality provides in its area of jurisdiction. A municipality derives the power to pass a bylaw from the Republic of South Africa Constitution, 1996, which gives specified powers and competencies to local government as set out in Part B of Schedule 4 and Part B of Schedule 5.

From a geohydrological perspective, the primary function of by-laws is to protect groundwater and ensure it is used sustainably. By-laws are described as a dynamic policy-implementation tool that addresses public interest, enforces standards of conduct, and is just like any other laws in the country (Kotzé, Merwe, et al., 2019).

By developing by-laws, we can manage groundwater resources effectively and emphasise the protection of sustainability, conservation, and environment protection.

Targeted focus points for by-laws in groundwater management include:

- Polluted sites in regards to Groundwater
- Borehole Construction and Abandonment
- Groundwater Quality and Quantity
- Groundwater Monitoring and Maintenance
- Groundwater Allocation and Access

It is important to remember that by-laws serve no purpose if not implemented and enforced.

3.11.1.13.1.4 **The importance of the question for municipal employees and in a municipal environment**

It is important for municipal employees to know groundwater by-laws to protect groundwater and that by-laws can be implemented within a municipal environment.

The Municipal Systems Act regulates the process of assigning powers and functions to local government. This is important to ensure that municipalities receive adequate funding to fulfil assigned powers and functions. It also helps ensure that the three spheres of government work in a coordinated way.

Municipalities can exercise their executive and legislative authority in several ways:

- The development and adopting policies, plans, strategies and programmes
- The establishment and maintaining an administration
- Promoting and undertaking development
- Setting targets for delivery
- Providing municipal services or regulating the provision of municipal services and implementing national and provincial legislation and its by-laws.

However, municipalities must know that passing by-laws without enforcing them serve no purpose. Failure by a municipality to enforce its by-laws amounts to a failure to affect the obligations imposed upon a municipality by section 152 of the Constitution.

3.11.1.14 **Question 14**

Is the following statement True or False?

Someone who does not act in accordance with the by-law can be charged with a criminal offence, receive a penalty, or be challenged in court.

a. True*
b. False

3.11.1.14.1.1 **The importance of the question and why is there multiple-choice answers?**

The question is derived from section 3.2.4.2 (Appendix D) of the third module - Groundwater Management in the training manual. This section explains that effective ways of creating groundwater management are to establish and implement municipal laws. The question determines if the participants understand what a municipal by-law is.

The question defines the term municipal by-laws, where the participant must determine if the statement is true or false by selecting the correct answer.

Multiple-choice answers are provided to assess participants' understanding and evaluate curriculum materials and teaching practices.

3.11.1.14.1.2 **The reasoning behind the correct answer**

The correct answer is "True" because section 3.2.4.2 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

"Someone who does not act in accordance with the by-law can be charged with a criminal offence, receive a penalty or be challenged in court.."

3.11.1.14.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

By-laws are laws passed by the council of a municipality to regulate the affairs and the services the municipality provides in its area of jurisdiction. A municipality derives the power to pass a bylaw from the Republic of South Africa Constitution, 1996, which gives specified powers and competencies to local government as set out in Part B of Schedule 4 and Part B of Schedule 5.

From a geohydrological perspective, the primary function of by-laws is to protect groundwater and ensure it is used sustainably. By-laws are described as a dynamic policy-implementation tool that addresses public interest, enforces standards of conduct, and is just like any other laws in the country (Kotzé, Merwe, et al., 2019).

3.11.1.14.1.4 **The importance of the question for municipal employees and in a municipal environment**

The Municipal Systems Act regulates the process of assigning powers and functions to local government. This is important to ensure that municipalities receive adequate funding to fulfil assigned powers and functions. It also helps to ensure that the three spheres of government work in a coordinated way.

Municipalities can exercise their executive and legislative authority in several ways:

- The development and adopting policies, plans, strategies and programmes
- The establishment and maintaining an administration
- Promoting and undertaking development
- Setting targets for delivery
- Providing municipal services or regulating the provision of municipal services and implementing national and provincial legislation and its by-laws.

However, municipalities must know that passing by-laws without enforcing them serve no purpose. Failure by a municipality to enforce its by-laws amounts to a failure to affect the obligations imposed upon a municipality by section 152 of the Constitution.

3.11.1.15 **Question 15**

Choose the most accurate answer:

By developing Municipal by-laws we can manage groundwater resources effectively and place emphasis on

a. the protection of policies, and management.
b. the protection of legislation, and borehole construction.
c. The protection of sustainability, conservation and the protection of the environment.*
d. the protection of polluted sites, and groundwater allocation

3.11.1.15.1.1 **The importance of the question and why is there multiple-choice answers?**

The question is derived from section 3.2.4.2.1 (Appendix D) of the third module - Groundwater Management in the training manual. This section explains the need for municipal laws. The question determines if the participants understand the need for municipal by-laws.

The question is formulated to choose the correct answer to complete the sentence with the options provided. Similar answers are provided to test the assess participants' understanding and knowledge.

3.11.1.15.1.2 **The reasoning behind the correct answer**

The correct answer is “The protection of sustainability, conservation and the protection of the environment” because section 3.2.4.2.1 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

“By developing by-laws we can manage groundwater resources effectively and place emphasis on the protection of sustainability, conservation and the protection of the environment.”

3.11.1.15.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

By-laws are laws passed by the council of a municipality to regulate the affairs and the services the municipality provides in its area of jurisdiction. A municipality derives the power to pass a bylaw from the Republic of South Africa Constitution, 1996, which gives specified powers and competencies to local government as set out in Part B of Schedule 4 and Part B of Schedule 5.

From a geohydrological perspective, the primary function of by-laws is to protect groundwater and ensure it is used sustainably. By-laws are described as a dynamic policy-implementation tool that addresses public interest, enforces standards of conduct, and is just like any other laws in the country (Kotzé, Merwe, et al., 2019).

By developing by-laws, we can manage groundwater resources effectively and emphasise the protection of sustainability, conservation, and environment protection.

Targeted focus points for by-laws in groundwater management include:

- Polluted sites in regards to Groundwater
- Borehole Construction and Abandonment
- Groundwater Quality and Quantity
- Groundwater Monitoring and Maintenance
- Groundwater Allocation and Access

It is important to remember that by-laws serve no purpose if not implemented and enforced.

3.11.1.15.1.4 The importance of the question for municipal employees and in a municipal environment

It is important for municipal employees to know groundwater by-laws to protect groundwater and that by-laws can be implemented within a municipal environment. By developing and implementing by-laws, we can manage groundwater resources effectively and emphasise the protection of sustainability, conservation, and environmental protection

3.11.1.16 Question 16

Which of the following statements is false?

In order to implement the effective protection of groundwater resources, the groundwater coordinator within a management area will need to have a broad understanding of:

a. Aquifer importance
b. The average rainfall*
c. The role of groundwater in the broader environment
d. Potentially polluting activities.

3.11.1.16.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.2.5 (Appendix D) of the third module - Groundwater Management in the training manual. This section explains the role of the groundwater coordinator. The question determines if the participants understand the role of the groundwater coordinator.

The question asks what statement is false from the answers provided.

3.11.1.16.1.2 The reasoning behind the correct answer

The correct answer is "The average rainfall" because section 3.2.5 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

"In order to realise the effective protection of groundwater resources, the groundwater coordinator within a management area will need to have a broad understanding of:

• Aquifer importance

• Aquifer vulnerability

• The role of groundwater in the broader environment

• Potentially polluting activities.

• Aquifer protection.”

3.11.1.16.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

The question derived from the manual explained that a groundwater coordinator within a management area would need to have a broad understanding of specific groundwater-related terms that includes knowledge of aquifers.To understand the multiple-choice answers provided as options, we first need to understand an aquifer.

An aquifer is described as the saturated area beneath the water table. The saturated or phreatic zone (Figure 3-11) is located below the water table. It is defined as the zone beneath the unsaturated zone where the water pressure is greater than atmospheric pressure (Lourens, 2013). This indicates that all the interconnected openings or pores are filled with water. An aquifer is a body of saturated rock through which water can easily move. The movement of water within an aquifer is highly dependent on the permeability of the aquifer material.

Geohydrologically, the question is important to understand the term aquifers and their associated risk, vulnerability and protection.

3.11.1.16.1.4 The importance of the question for municipal employees and in a municipal environment

By understanding what a groundwater coordinator can or cannot do, municipalities are better positioned to protect and manage groundwater. By understanding the term aquifers, municipalities are more aware of where groundwater comes from, and the resource is less likely seen as an invisible source.

Municipalities should also be aware that groundwater coordinators will form a critical link in local groundwater management planning and implementation processes. It is important to note that good leadership is required to facilitate communication between stakeholders, sectors and governmental agencies and to support information exchange between stakeholders and national governments. In other words, the groundwater coordinator gives a voice to everyone.

3.11.1.17 **Question 17**

Risk assessment and impact assessment provides important tools for prioritising actions where

a. human and financial resources are unlimited.
b. human and financial resources are limited.*
c. pollution and groundwater resources are limited.
d. pollution and groundwater resources are unlimited.

3.11.1.17.1.1 **The importance of the question and why is there multiple-choice answers?**

The question is derived from section 3.2.5 (Appendix D) of the third module - Groundwater Management in the training manual. This section explains the role of the groundwater coordinator. The question determines if the participants understand the role of the groundwater coordinator.

The question test if participants understand that risk assessment and impact assessment provide essential tools for prioritising actions where human and financial resources are limited.

The multiple-choice answers are provided to test the understanding of participants.

3.11.1.17.1.2 **The reasoning behind the correct answer**

The correct answer is “human and financial resources are limited” because section 3.2.5 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

“Risk assessment and impact assessment provide important tools for prioritising actions where human and financial resources are limited. The effectiveness of these measures in protecting groundwater resources must be measured by appropriate monitoring and assessment, which is used to refine protection programmes.”

3.11.1.17.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

Kotzé, Merwe, et al. (2019) explain in the groundwater management module that risk assessment and impact assessment provides important tools for prioritising actions where human and financial resources are limited. Aven and Renn (2009) describe risk as "…an uncertain consequence of an event or an activity with respect to something that humans value." In other words, risks are independent of our knowledge and perceptions and are defined as an event where the outcome is uncertain (Aven and Renn, 2009). The analytical definition of risk is explained by Yohe (2009) as the probability outcomes multiplied by the severity of its consequences. Groundwater is generally seen as a risk that needs to be assessed and is import in geohydrology.

3.11.1.17.1.4 The importance of the question for municipal employees and in a municipal environment

By understanding risk and impact assessments, municipalities are better positioned to manage, protect and govern groundwater resources. Before groundwater can be managed, basic terms should be understood to aid the management process.

3.11.1.18 Question 18

Is the following statement True or False?

A Groundwater Resource Governance Section, will ensure support to water services institutions in the operation, maintenance and management of groundwater supply schemes.

a. True*
b. False

3.11.1.18.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 3.3 (Appendix D) of the third module - Groundwater Management in the training manual. This section summarises the groundwater management module. The question determines if the participants understand the actions necessary for sustainable groundwater management.

True and false multiple choice answers are provided to test the knowledge on groundwater management with relation to the groundwater governance section.

3.11.1.18.1.2 The reasoning behind the correct answer

The correct answer is "True" because section 3.3 (Appendix D) of the third module - Groundwater Management (Kotzé, Merwe, et al., 2019) stipulates that:

“Establish a Groundwater Resource Governance Section, which will ensure support to water services institutions in the operation, maintenance and management of groundwater supply schemes.”

3.11.1.18.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

The groundwater management module summarised that a groundwater resource governance section is required for sustainable groundwater management. The section will need to support water services institutions during groundwater supply schemes' operation, maintenance, and management. The functions of the section must include the evaluation of artificial recharge potential and conjunctive use schemes.

3.11.1.18.1.4 The importance of the question for municipal employees and in a municipal environment

A groundwater resource governance section will assist municipalities in sustainable management, protection and governance of groundwater. Therefore, municipalities need to know and understand a groundwater resource governance section.

3.11.2 Groundwater Monitoring

3.11.3 Groundwater Quality

3.11.3.1 Question 1

Is the following statement True or False?

Water quality is a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for an intended purpose.

a. True*
b. False

3.11.3.1.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 5.2.1 (Appendix D) of the fifth module - Groundwater Quality in the training manual. This section describes what is meant by water quality. The question test if the participants understand the term water quality.

True and false multiple choice answers are provided to test the knowledge on groundwater quality.

3.11.3.1.1.2 **The reasoning behind the correct answer**

The correct answer is "True" because section 5.2.1 (Appendix D) of the fifth module - Groundwater Quality (Kotzé, Merwe, et al., 2019) stipulates that:

"Water quality is a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for an intended purpose."

3.11.3.1.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

Water quality is a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for an intended purpose (Owen et al., 2010). Groundwater is a vital component of water supply for residential, industrial, and agricultural purposes. However, many groundwater basins are being used unsustainably, and groundwater contamination is a growing water quality problem (Motlagh et al., 2020).

Asadi et al. (2020) described that identifying and managing groundwater qualities is essential for maintaining groundwater, which is essential for sustainable development.

3.11.3.1.1.4 **The importance of the question for municipal employees and in a municipal environment**

A manager in a municipal environment needs to understand that when we speak of water quality, we usually want to know if the water is good enough for its intended use. The intended use could be for domestic, farming, mining or industrial purposes, or its suitability to maintain a healthy ecosystem. A manager in a municipal environment needs to understand that the growing concern of groundwater's vulnerability to contamination, mainly results from the rise of urbanisation and industrialisation (Nyika and Onyari, 2019).

3.11.3.2 **Question 2**

Is the following statement True or False?

Water quality management, involves the maintenance of the fitness for use of water resources on a sustained basis, by achieving a balance between socio-economic development and environmental protection.

a. True*
b. False

3.11.3.2.1.1 **The importance of the question and why is there multiple-choice answers?**

The question is derived from section 5.2.2 (Appendix D) of the fifth module - Groundwater Quality in the training manual. This section describes what water quality management means. The question test if the participants understand the principle behind managing water quality by providing true and false, multiple choice answers.

3.11.3.2.1.2 **The reasoning behind the correct answer**

The correct answer is “True” because section 5.2.2 (Appendix D) of the fifth module - Groundwater Quality (Kotzé, Merwe, et al., 2019) stipulates that:

“Water quality management, therefore involves the maintenance of the fitness for use of water resources on a sustained basis, by achieving a balance between socio-economic development and environmental protection.”

3.11.3.2.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

Krenkel (2012) describes that water quality management deals with all aspects of water quality problems related to the beneficial uses of water, while water pollution control usually connotates adequate treatment and disposal of wastewater. Water quality management involves the maintenance of the fitness for the use of water resources on a sustained basis by achieving a balance between socio-economic development and environmental protection.

3.11.3.2.1.4 **The importance of the question for municipal employees and in a municipal environment**

Water quality is defined as measuring water's physical, chemical, biological, and microbiological characteristics. It is important to understand water quality to decide if it can be used for domestic, agricultural or industrial purposes. Water quality results are used to pinpoint any changes or trends that appear in water bodies over a period of time. The importance of regularly monitoring water quality is essential to identify any existing problems or issues that could emerge in the future.

Governments and communities must meet a range of water quality goals, and monitoring data and information is used to determine whether or not these goals are met.

3.11.3.3 Question 3

Is the following statement True or False?

Deteriorating water quality leads to decreased treatment costs of potable and industrial process water, and increased agricultural yields due to increased salinity of irrigation water.

a. True
b. False*

3.11.3.3.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 5.2.3 (Appendix D) of the fifth module - Groundwater Quality in the training manual. This section describes the need to manage water quality. The question test if the participants understand the term water quality management.

True and false multiple choice answers are provided to test the knowledge on groundwater quality management.

3.11.3.3.1.2 The reasoning behind the correct answer

The correct answer is “False” because section 5.2.3 (Appendix D) of the fifth module - Groundwater Quality (Kotzé, Merwe, et al., 2019) stipulates that:

“Deteriorating water quality leads to increased treatment costs of potable and industrial process water, and decreased agricultural yields due to increased salinity of irrigation water.”

3.11.3.3.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

A manager in a municipal environment needs to understand that when we speak of water quality, we usually want to know if the water is good enough for its intended use. The effects of polluted water on human health, the aquatic ecosystem, and various sectors of the economy, including agriculture, industry, and recreation, can be disastrous. Deteriorating water quality leads to increased treatment costs of potable and industrial process water and decreased agricultural yields due to the increased salinity of irrigation water.

3.11.3.3.1.4 The importance of the question for municipal employees and in a municipal environment

Municipalities should understand that the deteriorating of water quality could affect treatment costs. Not managing groundwater will result in quality deterioration and unnecessary expenditure from municipalities to fix mistakes that could have been avoided.

3.11.3.4 Question 4

Common water quality problems include:

a. Sanitation, geology and rainfall
b. Plastic bags and elevation
c. Salination, eutrophication, micro-pollutants, microbiological pollutants, erosion and sedimentation*
d. Animals

3.11.3.4.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 5.2.3 (Appendix D) of the fifth module - Groundwater Quality in the training manual. This section describes the need to manage water quality. The question tests whether the participants understand water quality management and water quality problems.

3.11.3.4.1.2 The reasoning behind the correct answer

The correct answer is “Salination, eutrophication, micro-pollutants, microbiological pollutants, erosion and sedimentation”. Section 5.2.3 (Appendix D) of the fifth module - Groundwater Quality (Kotzé, Merwe, et al., 2019) stipulates and explains common water quality problems such as salination and eutrophication micro-pollutants, microbiological pollutants, erosion and sedimentation.

3.11.3.4.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

It is described that most water quality-related problems are inherent in the geological characteristics of the source area. However, other common water problems occur due to poor water quality management applications in a municipal environment. Common water quality problems include salination, eutrophication, micro-pollutants, microbiological pollutants, erosion and sedimentation. The common water problems is explained in section 5.2.3 (Appendix D) of the fifth module - Groundwater Quality (Kotzé, Merwe, et al., 2019)

3.11.3.4.1.4 The importance of the question for municipal employees and in a municipal environment

The question is important in a municipal environment to understand common water quality problems. By understanding the general water quality problems, managers can prevent it in the future.

3.11.3.5 Question 5

Which of the following prominent principles DOES NOT form the basis of water quality management policies and practices in South Africa?

a. The management of water quality must be carried out in an integrated and holistic manner, acknowledging that all elements of the environment are interrelated.
b. Implementation of a National Pricing Strategy*
c. The precautionary approach to water quality management applies, in which active measures are taken to avert or minimise potential risk of undesirable impacts on the environment.
d. Participative management in the management of water quality must be advocated, ensuring that all interested and affected parties, and previously disadvantaged persons have an equal opportunity to participate.

3.11.3.5.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 5.2.5 (Appendix D) of the fifth module - Groundwater Quality in the training manual. This section describes the underlying principles of groundwater quality management. It indicates that sustainability, equity and efficiency are the central guiding principles in the protection, use, development, conservation, management and control of water resources.

The question tests whether the participants understand the main principles that form the basis of water quality management policies and practices in South Africa.

3.11.3.5.1.2 The reasoning behind the correct answer

The correct answer is "Implementation of a National Pricing Strategy" because section 5.2.5 (Appendix D) of the fifth module - Groundwater Quality (Kotzé, Merwe, et al., 2019) stipulates that:

"The following prominent principles form the basis of water quality management policies and practices in South Africa.

- The management of water quality must be carried out in an integrated and holistic manner, acknowledging that all elements of the environment are interrelated.
- Decision-making must ensure that the best practicable environmental option is adopted by taking account of all aspects of the environment including all the people in the environment.
- The precautionary approach to water quality management applies, in which active measures are taken to avert or minimise potential risk of undesirable impacts on the environment.
- In general the principle of Polluter Pays, applies. In accordance with this principle, the cost of remedying pollution, degradation of resource quality and consequent adverse health effects, and of preventing, minimising or controlling pollution is the responsibility of the polluter.
- Participative management in the management of water quality must be advocated, ensuring that all interested and affected parties, and previously disadvantaged persons have an equal opportunity to participate.
- Transparency and openness must underlie all decision-making processes, and all information must be made accessible in accordance with the law."

3.11.3.5.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

Krenkel (2012) describes that water quality management deals with all aspects of water quality problems related to the beneficial uses of water, while water pollution control usually connotates adequate treatment and disposal of wastewater. Water quality management involves the maintenance of the fitness for the use of water resources on a sustained basis by achieving a balance between socio-economic development and environmental protection.

3.11.3.5.1.4 The importance of the question for municipal employees and in a municipal environment

Water quality is defined as measuring water's physical, chemical, biological, and microbiological characteristics. It is important to understand water quality to decide if it can be used for domestic, agricultural or industrial purposes. Water quality results are used to pinpoint any changes or trends that appear in water bodies over a period of time. The importance of regularly monitoring water quality is essential to identify any existing problems or issues that could emerge in the future.

Managers in a municipal environment should understand the underlying principles of groundwater quality management. It indicates that sustainability, equity and efficiency are the central guiding principles in the protection, use, development, conservation, management and control of water resources.

3.11.3.6 Question 6

Hierarchy of water quality management decision-taking includes the following principles:

a. Pollution prevention, waste minimization, precautionary and differentiation principle*
b. Water policies, social media and monitoring principles
c. Water law, contamination and pollution prevention principles
d. Instagram and Twitter

3.11.3.6.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 5.2.6.2 (Appendix D) of the fifth module - Groundwater Quality in the training manual. This section describes the hierarchy of water quality management and decision-taking.

The question tests whether the participants understand the hierarchy of water quality management and decision-taking.

3.11.3.6.1.2 **The reasoning behind the correct answer**

The correct answer is “Pollution prevention, waste minimization, precautionary and differentiation principle”. Section 5.2.6.2 (Appendix D) of the fifth module - Groundwater Quality (Kotzé, Merwe, et al., 2019) indicates that the hierarchy of decision-taking is pollution prevention, waste minimization, precautionary and differentiation principle.

3.11.3.6.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

Krenkel (2012) describes that water quality management deals with all aspects of water quality problems related to the beneficial uses of water, while water pollution control usually connotates adequate treatment and disposal of wastewater. Water quality management involves the maintenance of the fitness for the use of water resources on a sustained basis by achieving a balance between socio-economic development and environmental protection.

3.11.3.6.1.4 **The importance of the question for municipal employees and in a municipal environment**

Managers within a municipal environment should understand that decisions in regard to water quality management are made in terms of a hierarchy of principles, which is specifically aimed at marrying the protection, use and development of water resources. The hierarchy includes pollution prevention, waste minimization, precautionary and the differentiation principle.

3.11.3.7 **Question 7**

The National Water Act makes use of two different approaches to water quality management, they are:

a. Municipal by-laws and water policies
b. Resource directed water quality management and source directed water quality management*
c. Pollution directed measures and groundwater quality
d. Facebook and Twitter

3.11.3.7.1.1 **The importance of the question and why is there multiple-choice answers?**

The question is derived from section 5.3 (Appendix D) of the fifth module - Groundwater Quality in the training manual. This section describes why do groundwater supplies merit protection.

The question tests whether the participants understand the main difference between resource directed water quality management and source directed water quality management.

3.11.3.7.1.2 **The reasoning behind the correct answer**

The correct answer is “Resource directed water quality management and source directed water quality management” because section 5.3 (Appendix D) of the fifth module - Groundwater Quality (Kotzé, Merwe, et al., 2019) stipulates that:

“Aquifers worldwide are experiencing an increasing threat of pollution from urbanization, industrial development, agricultural activities and mining enterprises. It may take many years or decades before the impact of a pollution episode by a persistent contaminant becomes fully apparent Resource directed water quality management and source directed water quality management in groundwater supplies abstracted from deeper wells and take even longer to clean up.”

3.11.3.7.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

The question tests whether the participants understand the main difference between resource directed water quality management and source directed water quality management.

Resource-directed strategies aim to understand the inherent characteristics and current and potential future use of the water resource itself. These are then used to determine the required level of protection. The measures implemented under this strategy are directed at managing such impacts as do inevitably occur in such a manner as to protect the reserve and ensure suitability for the beneficial uses of the resource.

Source-directed strategies aim to minimise or prevent the impact of developments or activities on groundwater quality at the source. In the past, source-directed controls have been principally targeted at point sources of pollution to surface waters.

3.11.3.7.1.4 The importance of the question for municipal employees and in a municipal environment

The protection of water quality in South Africa is to be achieved by the combination of three core strategies:

- Resource-directed strategies
- Source-directed strategies
- Remediation strategies

Municipalities should understand the differences because these strategies are under the umbrella of a groundwater quality strategy.

3.11.3.8 Question 8

Is the following statement True or False?

Groundwater is usually unsafe to drink without treatment, unlike surface water.

a. True
b. False*

3.11.3.8.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 5.3.1 (Appendix D) of the fifth module - Groundwater Quality in the training manual. This section describes natural groundwater quality.

The question tests whether the participants understand factors associated with natural groundwater quality by providing a selection of true and false multiple choice answers.

3.11.3.8.1.2 The reasoning behind the correct answer

The correct answer is "False" because section 5.3.1 (Appendix D) of the fifth module - Groundwater Quality (Kotzé, Merwe, et al., 2019) stipulates that:

"Groundwater is usually safe to drink without treatment, unlike surface water. This is because harmful microbiological pathogens such as bacteria and viruses usually cannot survive for long in aquifers. However, it is normal for chlorination to be carried out as a precaution for most public groundwater supplies."

3.11.3.8.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

It is generally stated that groundwater from non-polluted areas is safe for domestic purposes. It is described that the chemical composition of natural groundwater is determined by the host rock in which it is found. The various salts, metals and organic chemicals found in groundwater are essential for human wellness. However, high concentrations of salts and metals change the quality of water.

3.11.3.8.1.4 The importance of the question for municipal employees and in a municipal environment

The question is essential for municipalities to understand that a location of a borehole affects its quality. Selecting a borehole in a non-polluted area will benefit cost-effectiveness within a municipality.

3.11.3.9 Question 9

Aquifers may be polluted by

a. point source discharges or from diffuse pollutants*
b. Geology elevation
c. Plastic bags
d. Cows

3.11.3.9.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 5.4.1 (Appendix D) of the fifth module - Groundwater Quality in the training manual. This section describes how do aquifers become polluted.

The question tests whether the participants understand how aquifers become polluted by providing a selection of multiple choice answers.

3.11.3.9.1.2 The reasoning behind the correct answer

The correct answer is “point source discharges or from diffuse pollutants” because section 5.4.1 (Appendix D) of the fifth module - Groundwater Quality (Kotzé, Merwe, et al., 2019) stipulates that:

“Aquifers may be polluted by point source discharges or from diffuse pollutants.”

3.11.3.9.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

Riemann et al. (2012) describe that aquifers may become polluted by specific point sources, such as waste ponds or effluent discharge from factories and mines, or they become polluted from diffuse pollution such as the application of agricultural fertilizers and pesticides. Groundwater may also become polluted through well head contamination from poorly constructed or designed boreholes.

Groundwater systems like aquifers can also be polluted by subsurface contamination. In the vadose (unsaturated) zone, natural subsoil profiles actively and effectively attenuate many water pollutants especially human excreta and domestic wastewater by biochemical degradation and chemical reaction.

Concern about groundwater pollution relates primarily to the phreatic (water table) aquifers, especially where the unsaturated zone is thin and the water-table is shallow. Deeper and confined aquifers are afforded much greater natural protection by the overlying ground.

3.11.3.9.1.4 **The importance of the question for municipal employees and in a municipal environment**

Municipalities should be able to understand that aquifers can also get polluted. There is often a misconception in the municipal environment that aquifers or groundwater cant get polluted. This misconception plays a role in the mismanagement of groundwater in general.

3.11.3.10 **Question 10**

The protection of water quality in South Africa is to be achieved by the combination of few core strategies.

Pick the INCORRECT strategy

a. Resource-directed strategies
b. Source-directed strategies
c. Remediation strategies
d. Protection-directed strategies*

3.11.3.10.1.1 **The importance of the question and why is there multiple-choice answers?**

The question is derived from section 5.4.9 (Appendix D) of the fifth module - Groundwater Quality in the training manual. This section describes groundwater quality management. It indicates that historically emphasis was placed on protecting the quality of South Africa's surface and marine water resources, while policies and strategies to deal with groundwater pollution were scarce.

The question tests whether the participants understand the three core strategies of protecting water qualities in South Africa by providing a selection of multiple choice answers.

3.11.3.10.1.2 **The reasoning behind the correct answer**

The correct answer is "Protection-directed strategies" because section 5.4.9 (Appendix D) of the fifth module - Groundwater Quality (Kotzé, Merwe, et al., 2019) stipulates that:

"The protection of water quality in South Africa is to be achieved by the combination of three core strategies:

• Resource-directed strategies (chapter 3 of NWA)

• Source-directed strategies (mainly chapter 4 of NWA)

• Remediation strategies (chapter 3 of NWA)."

3.11.3.10.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

The question tests whether the participants understand the main difference between resource directed water quality management, source directed water quality management and remediation strategies.

Resource-directed strategies aim to understand the inherent characteristics and current and potential future use of the water resource itself. These are then used to determine the required level of protection. The measures implemented under this strategy are directed at managing such impacts as do inevitably occur in such a manner as to protect the reserve and ensure suitability for the beneficial uses of the resource.

Source-directed strategies aim to minimise or prevent the impact of developments or activities on groundwater quality at the source. In the past, source-directed controls have been principally targeted at point sources of pollution to surface waters.

Remediation strategies aim to remediate historical groundwater pollution, where practicable, to protect the reserve and ensure at least fitness for the purpose served by the remediation.

3.11.3.10.1.4 The importance of the question for municipal employees and in a municipal environment

The protection of water quality in South Africa is to be achieved by the combination of three core strategies:

- Resource-directed strategies
- Source-directed strategies
- Remediation strategies

Municipalities should understand the differences because these strategies are under the umbrella of a groundwater quality strategy.

3.11.3.11 Question 11

Pick TWO answers:

Examples of resource-directed measures include:

a. Resource classification*
b. Determination of resource management classes*
c. Licenses
d. General authorisations

3.11.3.11.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 5.4.9.1 (Appendix D) of the fifth module - Groundwater Quality in the training manual. This section describes resource-directed strategies. It indicates that resource-directed strategies aim to understand the inherent characteristics and current and potential future use of the water resource itself.

The question tests whether the participants understand the examples of resource-directed measures by providing a selection of multiple choice answers.

3.11.3.11.1.2 **The reasoning behind the correct answer**

The correct answer is “Resource classification” and “Determination of resource management classes” because section 5.4.9.1 (Appendix D) of the fifth module - Groundwater Quality (Kotzé, Merwe, et al., 2019) stipulates that:

“Resource-directed strategies are aimed at understanding the inherent characteristics and current and potential future use of the water resource itself.

These are then used to determine the required level of protection. The measures implemented under this strategy are directed at managing such impacts as do inevitably occur in such a manner as to protect the reserve and ensure suitability for the beneficial uses of the resource. Examples of resource-directed measures include:

• Resource classification.

• Determination of resource management classes.

• Reserve determination.

• Setting of resource quality objectives.”

3.11.3.11.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

The question tests whether the participants understand resource directed water quality strategies.

Resource-directed strategies aim to understand the inherent characteristics and current and potential future use of the water resource itself. These are then used to determine the required level of protection. The measures implemented under this strategy are directed at managing such impacts as do inevitably occur in such a manner as to protect the reserve and ensure suitability for the beneficial uses of the resource.

3.11.3.11.1.4 **The importance of the question for municipal employees and in a municipal environment**

Resource-directed strategies are a core strategy used in protecting water quality in South Africa. Managers in a municipal environment should understand that resource-directed measures include:

- Resource classification.
- Determination of resource management classes.
- Reserve determination.
- Setting of resource quality objectives

3.11.3.12 **Question 12**

CMA is an acronym for:

a. Catch Many Apples
b. Catchment Management Agency*
c. Condition Monitor Accreditation
d. City Management Agency

3.11.3.12.1.1 **The importance of the question and why is there multiple-choice answers?**

The question is derived from section 5.4.9.3 (Appendix D) of the fifth module - Groundwater Quality in the training manual. This section describes remediation strategies. It indicates that remediation strategies aim to remediate historical groundwater pollution, where practicable, to protect the reserve and ensure at least fitness for the purpose served by the remediation.

The question tests whether the participants understand the acronym for catchment management agencies by providing a selection of multiple choice answers.

3.11.3.12.1.2 **The reasoning behind the correct answer**

The correct answer is "Catchment Management Agency" because section 5.4.9.3 (Appendix D) of the fifth module - Groundwater Quality (Kotzé, Merwe, et al., 2019) stipulates that:

"Remediation strategies are aimed at remediating historical groundwater pollution, where practicable, to protect the reserve and ensure at least fitness for the purpose served by the remediation. Under Chapter 4 of NWA, the clean up of contaminated groundwater is the responsibility of the polluter, who must also bear the costs of remediation. In the case where the responsible person(s) cannot be identified or has failed to comply with the law, remedial action may be undertaken directly by the Catchment Management Agency (CMA)."

3.11.3.12.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

A statutory body established in terms of the National Water Act is referred to as a catchment management agency (CMA). CMAs will be governed by a board appointed by the minister and will begin operating as soon as the governing board has been appointed. The governing board must reflect and represent the interests of all relevant sectors and stakeholders, as well as their interests in the water management area.

The establishment of the 19 water management areas in South Africa from the Catchment management agencies (CMAs) is stipulated by the National Water Act (36 of 1998).

3.11.3.12.1.4 The importance of the question for municipal employees and in a municipal environment

Catchment forums involve stakeholders in the decision-making process about water resources management and are being used significantly by the department of water affairs. Catchment forums contribute to the representation and assistance of stakeholders in the establishment of CMA. The purpose of a CMA is to delegate water resource management to the regional or catchment level and primarily involve local communities in the process.

3.11.4 Groundwater Regulations

3.11.4.1 Question 1

Is the following statement True or False?

A licensing system for groundwater is aimed to introduce regulating interdependencies among water users and has wider benefits.

a. True*
b. False

3.11.4.1.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 4.2.1 (Appendix D) of the fourth module - Groundwater Regulations in the training manual. This section describes the need for a groundwater licensing system.

The question tests whether the participants understand the importance of a groundwater licensing system.

3.11.4.1.1.2 The reasoning behind the correct answer

The correct answer is "True" because section 4.2.1 (Appendix D) of the fourth module - Groundwater Regulations (Kotzé, Merwe, et al., 2019) stipulates that:

"A licensing system for groundwater is aimed to introduce regulating interdependencies among water users and has wider benefits."

3.11.4.1.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

Water resources have traditionally been allocated based on social criteria, ensuring that water for human consumption, sanitation, and food production is given priority. The increasing population growth made water scarcity a significant problem in many countries. With pollution and degrading water quality, our fresh water resources are limited. Hence, the competition between water for drinking, irrigation and the industrial sector.

Applying a licencing system for groundwater, a right to use (but not ownership of) the water itself can be implemented. A licencing system will reduce interference between abstraction wells, avoid counterproductive conflicts that may arise and resolve emerging disputes between neighbouring abstractors.

3.11.4.1.1.4 The importance of the question for municipal employees and in a municipal environment

By implementing and adopting a groundwater monitoring licence system, municipal managers will be able to protect and regulate groundwater resources.

3.11.4.2 Question 2

Choose three correct answers:

The main objectives of a groundwater license system are established to

a. Reduce the interference between abstraction wells*
b. Avoid pollution
c. Resolve geological and geographical queries
d. Improving economic efficiency*
e. Implementing demand management programs to reduce groundwater abstraction*
f. Improve social and economic benefits

3.11.4.2.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 4.2.1 (Appendix D) of the fourth module - Groundwater Regulations in the training manual. This section describes the need for a groundwater licensing system.

The question tests whether the participants understand the importance of a groundwater licensing system.

3.11.4.2.1.2 The reasoning behind the correct answer

The correct answer is "Improving economic efficiency" because section 4.2.1 (Appendix D) of the fourth module - Groundwater Regulations (Kotzé, Merwe, et al., 2019) stipulates that:

"The main objectives of a groundwater license system are established to (Dinar, Rosegrant and Meinzen-dick, 1997):

- Reduce the interference between abstraction wells,
- Avoid counterproductive conflicts that may arise,
- Resolve emerging disputes between neighbouring abstractors.
- Fostering the participation of water users in groundwater management;
- Improving economic efficiency;
- Implementing demand management programs to reduce groundwater abstraction;
- Systematic collection of abstraction charges to raise revenue for resource management;
- Possible subsequent trading of abstraction rights to promote more efficient water use;

- Developing conjunctive use of surface water and groundwater resources.”

3.11.4.2.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

Applying a licencing system for groundwater, a right to use (but not ownership of) the water itself can be implemented. A licencing system will reduce interference between abstraction wells, avoid counterproductive conflicts that may arise and resolve emerging disputes between neighbouring abstractors.

3.11.4.2.1.4 **The importance of the question for municipal employees and in a municipal environment**

The question tests whether the participants understand the importance of a groundwater licensing system.

3.11.4.3 **Question 3**

Groundwater allocation is the process of determining how water ……………………..

Choose one of the following:

a. will be shared among the demand of different users and uses.*
b. will be collected and protected.
c. will be monitored and manage.
d. will be governed.

3.11.4.3.1.1 **The importance of the question and why is there multiple-choice answers?**

The question is derived from section 4.3.1 (Appendix D) of the fourth module - Groundwater Regulations in the training manual. This section describes groundwater allocation.

The question tests whether the participants understand what is meant with groundwater allocation.

3.11.4.3.1.2 **The reasoning behind the correct answer**

The correct answer is “will be shared among the demand of different users and uses” because section 4.3.1 (Appendix D) of the fourth module - Groundwater Regulations (Kotzé, Merwe, et al., 2019) stipulates that:

“Groundwater allocation is the process of determining how water will be shared among the demand of different users and uses.”

3.11.4.3.1.3 **Question explained from a groundwater, groundwater management and geohydrological perspective**

Groundwater allocation is the process of determining how water will be shared among the demand of different users. The need for water allocation is developed due to the increasing scarcity of water resources in terms of desirable quality and quantity that needs to satisfy the demands of different users. Water allocation form thus a significant universal function of water management with the primary objective to maximise the societal benefits derived from water. These benefits can be classified as economic, social and environmental. Non-renewable resources such as groundwater need to implement a groundwater abstraction rights system. This must be consistent with variable factors such as fluctuating groundwater levels, decreasing well yields, and groundwater quality deterioration (Owen et al., 2010).

3.11.4.3.1.4 **The importance of the question for municipal employees and in a municipal environment**

Municipal managers should understand that groundwater allocation is the process of determining how water will be shared among the demand of different users. Sharing information amongst different users is essential during the regulation, governance and management of water.

3.11.4.4 Question 4

The need for water allocation developed due to the fact of ……………………………… that need to satisfy all the demands of the different users.

Choose one of the following:

a. increasing scarcity of the water resource *
b. hydrological and environmental impacts
c. governmental guidelines
d. an abundance water resource

3.11.4.4.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 4.3.1 (Appendix D) of the fourth module - Groundwater Regulations in the training manual. This section describes groundwater allocation.

The question tests whether the participants understand what is meant with groundwater allocation.

3.11.4.4.1.2 The reasoning behind the correct answer

The correct answer is "increasing scarcity of the water resource" because section 4.3.1 (Appendix D) of the fourth module - Groundwater Regulations (Kotzé, Merwe, et al., 2019) stipulates that:

"The need for water allocation developed due to the fact of increasing scarcity of the water resource in terms of desirable quality and quantity that need to satisfy all the demands of the different users (Tandi, no date)."

3.11.4.4.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

Groundwater allocation is the process of determining how water will be shared among the demand of different users. The need for water allocation is developed due to the increasing scarcity of water resources in terms of desirable quality and quantity that needs to satisfy the demands of different users. Water allocation form thus a significant universal function of water management with the primary objective to maximise the societal benefits derived from water. These benefits can be classified as economic, social and environmental. Non-renewable resources such as groundwater need to implement a groundwater abstraction rights system. This must be consistent with variable factors such as fluctuating groundwater levels, decreasing well yields, and groundwater quality deterioration (Owen et al., 2010).

3.11.4.4.1.4 The importance of the question for municipal employees and in a municipal environment

Municipal managers should understand that groundwater allocation is the process of determining how water will be shared among the demand of different users. Sharing information amongst different users is essential during the regulation, governance and management of water.

3.11.4.5 Question 5

Is the following statement True or False?

Water allocation form a significant universal function of water management with the main objective to maximise the societal benefits derived from water.

a. True*
b. False

3.11.4.5.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 4.3.1 (Appendix D) of the fourth module - Groundwater Regulations in the training manual. This section describes groundwater allocation.

The question tests whether the participants understand what is meant with groundwater allocation.

3.11.4.5.1.2 The reasoning behind the correct answer

The correct answer is “True” because section 4.3.1 (Appendix D) of the fourth module - Groundwater Regulations (Kotzé, Merwe, et al., 2019) stipulates that:

“Water allocation form thus a significant universal function of water management with the main objective to maximise the societal benefits derived from water.”

3.11.4.5.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

Groundwater allocation is the process of determining how water will be shared among the demand of different users. The need for water allocation is developed due to the increasing scarcity of water resources in terms of desirable quality and quantity that needs to satisfy the demands of different users. Water allocation form thus a significant universal function of water management with the primary objective to maximise the societal benefits derived from water. These benefits can be classified as economic, social and environmental. Non-renewable resources such as groundwater need to implement a groundwater abstraction rights system. This must be consistent with variable factors such as fluctuating groundwater levels, decreasing well yields, and groundwater quality deterioration (Owen et al., 2010).

3.11.4.5.1.4 The importance of the question for municipal employees and in a municipal environment

Municipal managers should understand that groundwater allocation is the process of determining how water will be shared among the demand of different users. Sharing information amongst different users is essential during the regulation, governance and management of water.

3.11.4.6 Question 6

A suitable measure of groundwater resource allocation is necessary to achieve optimal allocation of the resource. Several criteria's are used in water allocation.

Choose the one incorrect statement/criteria:

a. Flexibility in the allocation of water
b. Political and public acceptability
c. Protection of Municipal by-laws*
d. Administrative feasibility and sustainability

3.11.4.6.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 4.3.1 (Appendix D) of the fourth module - Groundwater Regulations in the training manual. This section describes the criteria for groundwater allocation.

The question tests whether the participants understand what is meant with groundwater allocation.

3.11.4.6.1.2 The reasoning behind the correct answer

The correct answer is “Protection of Municipal by-laws” because section 4.3.2 (Appendix D) of the fourth module - Groundwater Regulations (Kotzé, Merwe, et al., 2019) stipulates that:

“Howe, Schurmeier and Shaw (1986), described several criteria’s used in water allocation (Owen et al., 2010)(Dinar, Rosegrant and Meinzen-dick, 1997):

- Flexibility in the allocation of water, so that the resource can be reallocated from use to use, place to place, for more social benefits, economic and ecological uses through periodic review, and avoiding perpetuity in allocation;
- Security of tenure for established users, so that they will take necessary measures to use the resource efficiently; security does not conflict with flexibility as long as there is a reserve of the resource available to meet unexpected demands.
- Predictability of the outcome of the allocation process, so that the best allocation can be materialized and uncertainty (especially for transaction costs) is minimized. Equity of the allocation process should be perceived by the prospective users, providing equal opportunity gains from utilizing the resource to every potential user.
- Political and public acceptability, so that the allocation serves values and objectives, and is therefore, accepted by various segments in society.
- Efficacy, so that the form of allocation changes existing undesirable situations such as depletion of groundwater, and water pollution, and moves towards achieving desired policy goals.
- Administrative feasibility and sustainability, to be able to implement the allocation mechanism, and to allow a continuing and growing effect of the policy.”

3.11.4.6.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

Water allocation systems determine how water will be shared among the demand of different users. Water allocation systems will protect existing water users and govern the sharing of limited water during a drought. This is done to facilitate efficient water use.

Effective water allocation becomes particularly important as demands exceed reliable supplies. As water demands increase with population and economic growth, water allocation systems must be expanded and refined.

Economic, social and environmental factors form the basis for water resource allocations and objectives. They should be well-defined to ensure that groundwater is available for human consumption, sanitation, and food production.

3.11.4.6.1.4 The importance of the question for municipal employees and in a municipal environment

Municipal managers should understand that groundwater allocation is the process of determining how water will be shared among the demand of different users. Sharing information amongst different users is essential during the regulation, governance and management of water.

3.11.4.7 Question 7

For better water allocation the management of monitoring water resources and uses is important. Implementation tools that assist in this process include:

Choose one Answer:

a. Monitoring, governance and water security
b. Water laws
c. Planning instruments, managerial guidelines, information systems and public education*
d. A groundwater hydrocensus

3.11.4.7.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 4.3.3 (Appendix D) of the fourth module - Groundwater Regulations in the training manual. This section describes groundwater allocation.

The question tests whether the participants understand what is meant with groundwater allocation.

3.11.4.7.1.2 The reasoning behind the correct answer

The correct answer is “Planning instruments, managerial guidelines, information systems and public education” because section 4.3.3 (Appendix D) of the fourth module - Groundwater Regulations (Kotzé, Merwe, et al., 2019) stipulates that:

“For better water allocation the management of monitoring water resources and uses is important. Implementation tools that assist in this process include planning instruments (monitor aquifer quantity/quality, water users and population), managerial guidelines (steps to monitor and evaluate applications), information systems (software to manage applications) and public education (political and public awareness).”

3.11.4.7.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

Groundwater needs to be allocated in a manner that will allow activities reliant on water to have access to a sufficient and reasonably reliable supply. Restrictions and limits on the amount of water allocated must be set for sustainability and resource protection. Therefore all water users should be identified, registered and monitored for an allocation system to work.

Water allocation is important to meet demand with the significant involvement of governments. The allocation by governments, typically described as public allocation, has been used to manage groundwater effectively by laws, policies and registrations.

3.11.4.7.1.4 The importance of the question for municipal employees and in a municipal environment

Monitoring water resources and uses is important in a municipal environment for better water allocation. Municipal managers should be aware that implementation tools can monitor water resources. Implementation tools include planning instruments (monitor aquifer quantity/quality, water users and population), managerial guidelines (steps to monitor and evaluate applications), information systems (software to manage applications) and public education (political and public awareness.

3.11.4.8 **Question 8**

The National Water Act makes use of two different kinds of processes, for effective resource protection.

a. Municipal by-laws and water policies
b. Resource directed measures and source directed controls*
c. Source directed measures and resource directed controls
d. Facebook and Twitter

3.11.4.8.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 4.4 (Appendix D) of the fourth module - Groundwater Regulations in the training manual. This section describes groundwater Protection.

The question tests whether the participants understand what is meant with groundwater protection.

3.11.4.8.1.2 The reasoning behind the correct answer

The correct answer is "Resource directed measures and source directed controls" because section 4.4 (Appendix D) of the fourth module - Groundwater Regulations (Kotzé, Merwe, et al., 2019) stipulates that:

"The National Water Act makes use of two different kinds of processes, for effective resource protection. Resource directed measures (RDM) are the first process that set a number of objectives that will determine the desired level of protection for each resource. The second process is source directed controls."

3.11.4.8.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

The question tests whether the participants understand the main difference between resource directed water quality management, source directed water quality management and remediation strategies.

Resource-directed strategies aim to understand the inherent characteristics and current and potential future use of the water resource itself. These are then used to determine the required level of protection. The measures implemented under this strategy are directed at managing such impacts as do inevitably occur in such a manner as to protect the reserve and ensure suitability for the beneficial uses of the resource.

Source-directed strategies aim to minimise or prevent the impact of developments or activities on groundwater quality at the source. In the past, source-directed controls have been principally targeted at point sources of pollution to surface waters.

3.11.4.8.1.4 The importance of the question for municipal employees and in a municipal environment

The purpose of source directed controls is to control and manage the impacts in relation to water resources so that the resource protection objectives are achieved.This is important for municipalities to understand and regulate groundwater resources.

3.11.4.9 Question 9

A balance between water resource protection and the use of a water resource is described as IWRM.

IWRM is an acronym for?

a. intelligent water resource managers
b. integrated water resource monitoring
c. is water really manageable
d. integrated water resource management*

3.11.4.9.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 4.4 (Appendix D) of the fourth module - Groundwater Regulations in the training manual. This section describes groundwater protection.

The question tests whether the participants understand the importance of a groundwater protection.

3.11.4.9.1.2 The reasoning behind the correct answer

The correct answer is "integrated water resource management" because section 4.4 (Appendix D) of the fourth module - Groundwater Regulations (Kotzé, Merwe, et al., 2019) stipulates that:

"A balance between water resource protection and the use of a water resource is described as integrated water resource management (IWRM)."

3.11.4.9.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

Integrated Water Resources Management (IWRM) is described as a process that promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare equitably without compromising the sustainability of vital ecosystems. Operationally, IWRM approaches involve applying knowledge from various disciplines and the insights from diverse stakeholders to devise and implement efficient, equitable and sustainable solutions to water and development problems.

3.11.4.9.1.4 The importance of the question for municipal employees and in a municipal environment

IWRM is a process that could assist managers in a municipal environment with the protection, governance and management of groundwater resources in South Africa.

3.11.4.10 Question 10

CMA's is an acronym for:

a. Catch Multiple Apples
b. Catchment Monitoring Agencies
c. Countable Municipal Act
d. Catchment Management Agencies*

3.11.4.10.1.1 The importance of the question and why is there multiple-choice answers?

The question is derived from section 4.5.1 (Appendix D) of the fourth module - Groundwater Regulations in the training manual. This section describes Catchment Management Agencies.

The question tests whether the participants understand the importance Catchment Management Agencies.

3.11.4.10.1.2 The reasoning behind the correct answer

The correct answer is "Catchment Management Agencies" because section 4.5.1 (Appendix D) of the fourth module - Groundwater Regulations (Kotzé, Merwe, et al., 2019) stipulates that:

"A statutory body established in terms of the National Water Act is referred to as a catchment management agency (CMA)."

3.11.4.10.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

A statutory body established in terms of the National Water Act is referred to as a catchment management agency (CMA). CMAs will be governed by a board appointed by the minister and will begin operating as soon as the governing board has been appointed. The governing board must reflect and represent the interests of all relevant sectors and stakeholders, as well as their interests in the water management area.

The establishment of the 19 water management areas in South Africa from the Catchment management agencies (CMAs) is stipulated by the National Water Act (36 of 1998).

3.11.4.10.1.4 The importance of the question for municipal employees and in a municipal environment

A statutory body established in terms of the National Water Act is referred to as a catchment management agency (CMA). CMAs will be governed by a board appointed by the minister and will begin operating as soon as the governing board has been appointed. The governing board must reflect and represent the interests of all relevant sectors and stakeholders, as well as their interests in the water management area.

The establishment of the 19 water management areas in South Africa from the Catchment management agencies (CMAs) is stipulated by the National Water Act (36 of 1998).

3.11.4.11 Question 11

What is the purpose of Catchment Management Agencies?

a. To delegate monitoring results to municipalities and primarily involve the public in the process.
b. To delegate water resource management to the regional or catchment level and primarily involve local communities in the process*
c. To serves its members that is govern by a management committee
d. To catch fish

3.11.4.11.1.1 The importance of the question and why is there multiple-choice answers?

The correct answer is “Catchment Management Agencies” because section 4.5.1.1 (Appendix D) of the fourth module - Groundwater Regulations (Kotzé, Merwe, et al., 2019) stipulates that:

“A statutory body established in terms of the National Water Act is referred to as a catchment management agency (CMA).”

3.11.4.11.1.2 The reasoning behind the correct answer

The correct answer is “To delegate water resource management to the regional or catchment level and primarily involve local communities in the process” because section 4.5.1.1 (Appendix D) of the fourth module - Groundwater Regulations (Kotzé, Merwe, et al., 2019) stipulates that:

“The purpose of a CMA is to delegate water resource management to the regional or catchment level and primarily involve local communities in the process. CMAs form therefore the fundamental course of action for managing water resources at catchment management level (DWAF, 2000).”

3.11.4.11.1.3 Question explained from a groundwater, groundwater management and geohydrological perspective

A statutory body established in terms of the National Water Act is referred to as a catchment management agency (CMA). CMAs will be governed by a board appointed by the minister and will begin operating as soon as the governing board has been appointed. The governing board must reflect and represent the interests of all relevant sectors and stakeholders, as well as their interests in the water management area.

The establishment of the 19 water management areas in South Africa from the Catchment management agencies (CMAs) is stipulated by the National Water Act (36 of 1998).

3.11.4.11.1.4 The importance of the question for municipal employees and in a municipal environment

A statutory body established in terms of the National Water Act is referred to as a catchment management agency (CMA). CMAs will be governed by a board appointed by the minister and will begin operating as soon as the governing board has been appointed. The governing board must reflect and represent the interests of all relevant sectors and stakeholders, as well as their interests in the water management area.

The establishment of the 19 water management areas in South Africa from the Catchment management agencies (CMAs) is stipulated by the National Water Act (36 of 1998

Chapter 4
Data Analysis and research findings

4.1 Overview of this chapter

The following chapter describes the analysis and findings for this dissertation. The information collected was then managed and presented in tables and graphs. The chapter starts with the demographic data of the participants which include the gender and age, employment and qualification and degree of groundwater knowledge of the participants. The chapter commenced with the evaluation of the survey questionnaire which includes the reaction of the questions asked. Chapter 4 also includes the level of learning, and the chapter ends with a conclusion.

4.2 Demographic

Demographic questions seek basic information about respondents that allows the researcher to understand where each person fits in the general population. Questions such as age, gender, employment, and qualifications play an essential role in the questionnaire. Gender plays a significant role in identifying the target population because women are always the central part of water provision, management, and safeguarding (Ray, 2007). The training manual was developed to be suitable for a wide variety of groups with different backgrounds and skills. By asking their level of qualification, the researcher could establish each participant's level of knowledge. Demographic questions enable the researcher to establish a perfect target population for the training manual and resonate with the desired audience.

4.2.1 Gender and Age

The data in Table 4-1 and Figure 4-1 present the gender distribution of the sample and Table 4-2 and Figure 4-2 present the diversification of age groups within the survey participants.

Table 4-1: Participants gender frequency count.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Female**	34	61.8	61.8	61.8
	Male	21	38.2	38.2	100
	Total	**55**	**100**	**100**	

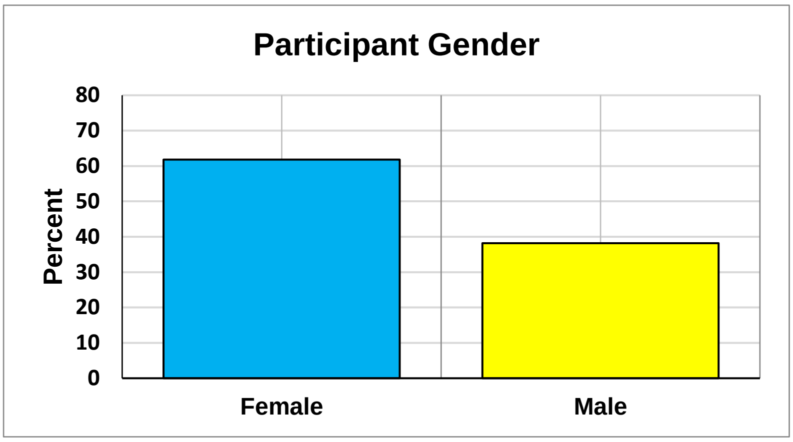

Figure 4-1: Participants gender frequency distribution.

Table 4-1 and Figure 4-1 illustrate that most participants (61.8%) in this sample group are predominantly women (thirty-four respondents). Only 38.2% of the survey participants are males (twenty-one participants). The data in Table 4-2 and Figure 4-2 illustrate that 89.1% of the respondents are younger than 35 years old. Just 6 participants of the sample group (10.9%) are between 35-44 years old.

Table 4-2: Participants age group frequency count.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**18-24 years old**	20	36.4	36.4	36.4
	25-34 years old	29	52.7	52.7	89.1
	35-44 years old	6	10.9	10.9	100
	Total	**55**	**100**	**100**	

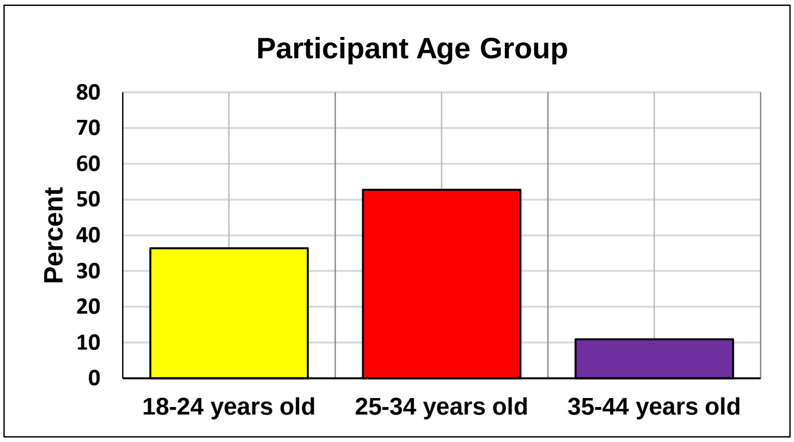

Figure 4-2: Participants age group frequency distribution.

4.2.2 Employment and qualifications

The employment status (Table 4-3 and Figure 4.3) and participants' qualifications (Table 4-4 and Figure 4-4) are presented below. This researcher wanted to establish the number of respondents currently employed and the extent of participants with an undergraduate or postgraduate degree. The data in Table 4-3 and Figure 4.3 indicate that more than half of the participants are full-time employed (54.5%). Twenty participants (36.4%) are still students, while 7.3% (four respondents) are unemployed and 1.8% (1 respondent) part-time employed.

Table 4-3: Participants employment status frequency count.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Student**	20	36.4	36.4	36.4
	Full-time employment	30	54.5	54.5	90.9
	Unemployed and currently looking for work	4	7.3	7.3	98.2
	Part-time employment	1	1.8	1.8	100
	Total	**55**	**100**	**100**	

Figure 4-3: Participants employment status frequency.

From the frequency count and percentage in Table 4-4 and Figure 4-4 it can be observed that only one respondent (1.8%) of the sample has a qualification less than a high school degree. Seven participants (12.7%) out of fifty-five participants have a high school or equivalent degree. More than half of the sample (49.1%) of the respondents obtained an undergraduate degree. 14.5% (eight participants) obtained a postgraduate degree, whilst 21.8% (12 respondents) of the sample group have some college but no degree.

Table 4-4: Participants highest qualification obtained frequency count.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Some college but no degree**	12	21.8	21.8	21.8
	Bachelor's degree	27	49.1	49.1	70.9
	Honours degree	5	9.1	9.1	80
	Master's degree	2	3.6	3.6	83.6
	High school degree or equivalent	7	12.7	12.7	96.4
	Doctorate	1	1.8	1.8	98.2
	Less than high school degree	1	1.8	1.8	100
	Total	**55**	**100**	**100**	

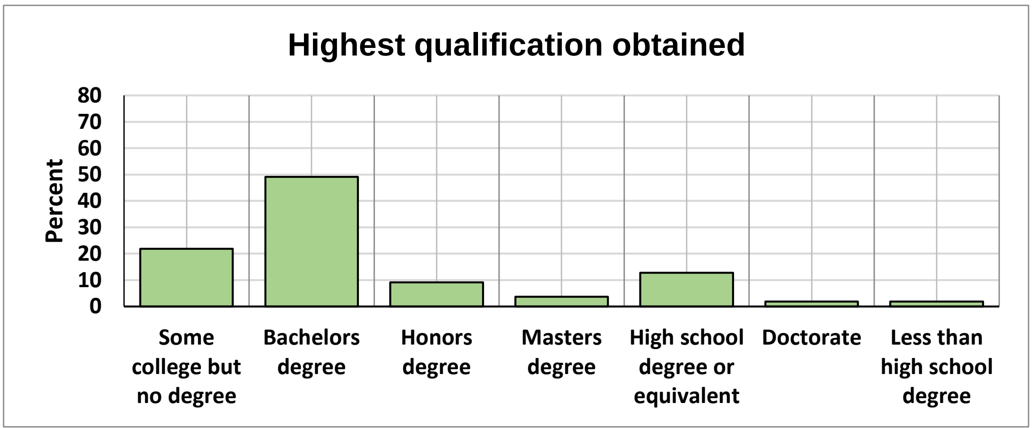

Figure 4-4: Participants highest qualification obtained frequency distribution.

4.2.3 Degree of groundwater knowledge

The data in Table 4-5 and Figure 4-5 indicate and inform the level of groundwater knowledge of participants in the sample before attending the program.

Table 4-5: Participants degree of groundwater knowledge frequency count.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Intermediate**	16	29.1	29.1	29.1
	Basic	31	56.4	56.4	85.5
	Intermediate High	3	5.5	5.5	90.9
	Advanced	5	9.1	9.1	100
	Total	**55**	**100**	**100**	

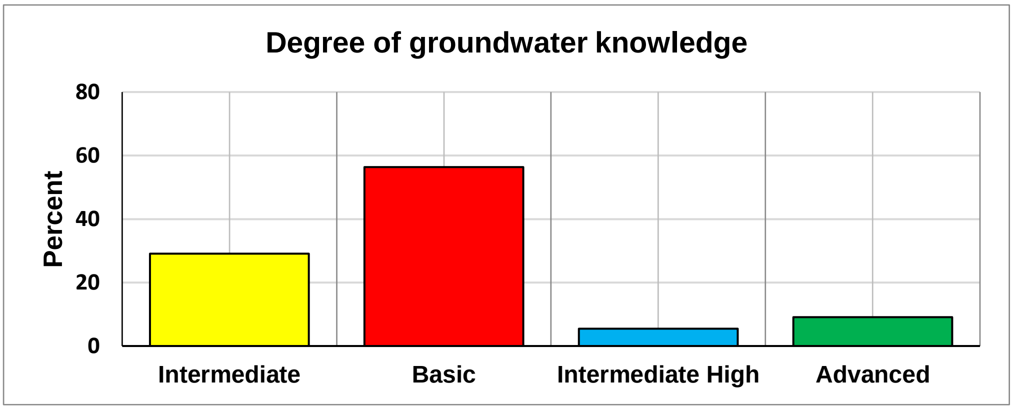

Figure 4-5: Participants degree of groundwater knowledge frequency distribution.

Derived from the frequency count (Table 4-5 and Figure 4-5) it is apparent that 56.4% of the respondents had basic knowledge on groundwater. Sixteen (29.1%) out of the fifty-five respondents have intermediate knowledge of groundwater. A low 14.6% of participants in the sample indicated that they have intermediate high or advanced knowledge of groundwater.

4.3 Evaluation Survey Questionnaire (Affective Domain)

This section elaborates, answer and investigate the first research question by utilising Kirkpatrick's first level of evaluation framework. The evaluation survey covered three sections, [1]training manual content (twenty-two questions), [2]the platform used (eleven questions) and [3]general (five questions) questions (Figure 3-1). Each question within the three sections was designed to gather reactions regarding the participant's perception and satisfaction. The first research question and hypothesis derived from the objectives are:

How effective is the training program content with a specific focus on the affective reactions of participants?

Hypothesis 1:

- **Null hypothesis:** Affective reaction will not be significant towards the program.
- **Alternative hypothesis:** Affective reaction will be significant towards the program.

Participants had to respond to every question on a five-point Likert scale by selecting between [1]Very Dissatisfied, [2]Dissatisfied, [3]Neither, [4]Satisfied and [5]Very Satisfied. Section 4.3.1 begins to discuss the first set of questions within the satisfaction survey questionnaire and focus on the program content category.

4.3.1 Reactions to questions regarding program content

This section of the evaluation questionnaire contained twenty-two items intended to measure the participants' opinion regarding the content of the program. Twenty of the twenty-two questions in this category were structured on a five-point Likert scale by choosing one of the following score items: [1]Very Dissatisfied, [2]Dissatisfied, [3]Neither, [4]Satisfied and [5]Very Satisfied. The last two questions in this category were designed to be open-ended questions to gather insights and feedback from the participants. Frequency tables and bar charts for survey questions one to ten (Figure 4-6 and Table 4-6) and question eleven to twenty (Figure 4-7 and Table 4-6) follow below with an individual discussion of each item.

Table 4-6: Frequency count on questions regarding the program content.

	Very Dissatisfied		Dissatisfied		Neither		Satisfied		Very Satisfied		Positive Responses
	N	%	N	%	N	%	N	%	N	%	%
Content Q1	0	0.0%	1	1.8%	8	14.5%	20	36.4%	26	47.3%	83.6%
Content Q2	0	0.0%	1	1.8%	9	16.4%	22	40.0%	23	41.8%	81.8%
Content Q3	0	0.0%	0	0.0%	9	16.4%	24	43.6%	22	40.0%	83.6%
Content Q4	0	0.0%	1	1.8%	9	16.4%	28	50.9%	17	30.9%	81.8%
Content Q5	0	0.0%	1	1.8%	6	10.9%	22	40.0%	26	47.3%	87.3%
Content Q6	0	0.0%	0	0.0%	4	7.3%	20	36.4%	31	56.4%	92.7%
Content Q7	1	1.8%	1	1.8%	13	23.6%	25	45.5%	15	27.3%	72.7%
Content Q8	0	0.0%	1	1.8%	8	14.5%	19	34.5%	27	49.1%	83.6%
Content Q9	0	0.0%	2	3.6%	6	10.9%	23	41.8%	24	43.6%	85.5%
Content Q10	1	1.8%	1	1.8%	7	12.7%	23	41.8%	23	41.8%	83.6%
Content Q11	1	1.8%	5	9.1%	7	12.7%	24	43.6%	18	32.7%	76.4%
Content Q12	0	0.0%	1	1.8%	6	10.9%	18	32.7%	30	54.5%	87.3%
Content Q13	0	0.0%	0	0.0%	7	12.7%	18	32.7%	30	54.5%	87.3%
Content Q14	2	3.6%	0	0.0%	7	12.7%	21	38.2%	25	45.5%	83.6%
Content Q15	2	3.6%	9	16.4%	19	34.5%	17	30.9%	8	14.5%	45.5%
Content Q16	0	0.0%	0	0.0%	3	5.5%	13	23.6%	39	70.9%	94.5%
Content Q17	2	3.6%	9	16.4%	11	20.0%	17	30.9%	16	29.1%	60.0%
Content Q18	0	0.0%	1	1.8%	6	10.9%	26	47.3%	22	40.0%	87.3%
Content Q19	1	1.8%	1	1.8%	4	7.3%	18	32.7%	31	56.4%	89.1%
Content Q20	0	0.0%	1	1.8%	7	12.7%	21	38.2%	26	47.3%	85.5%

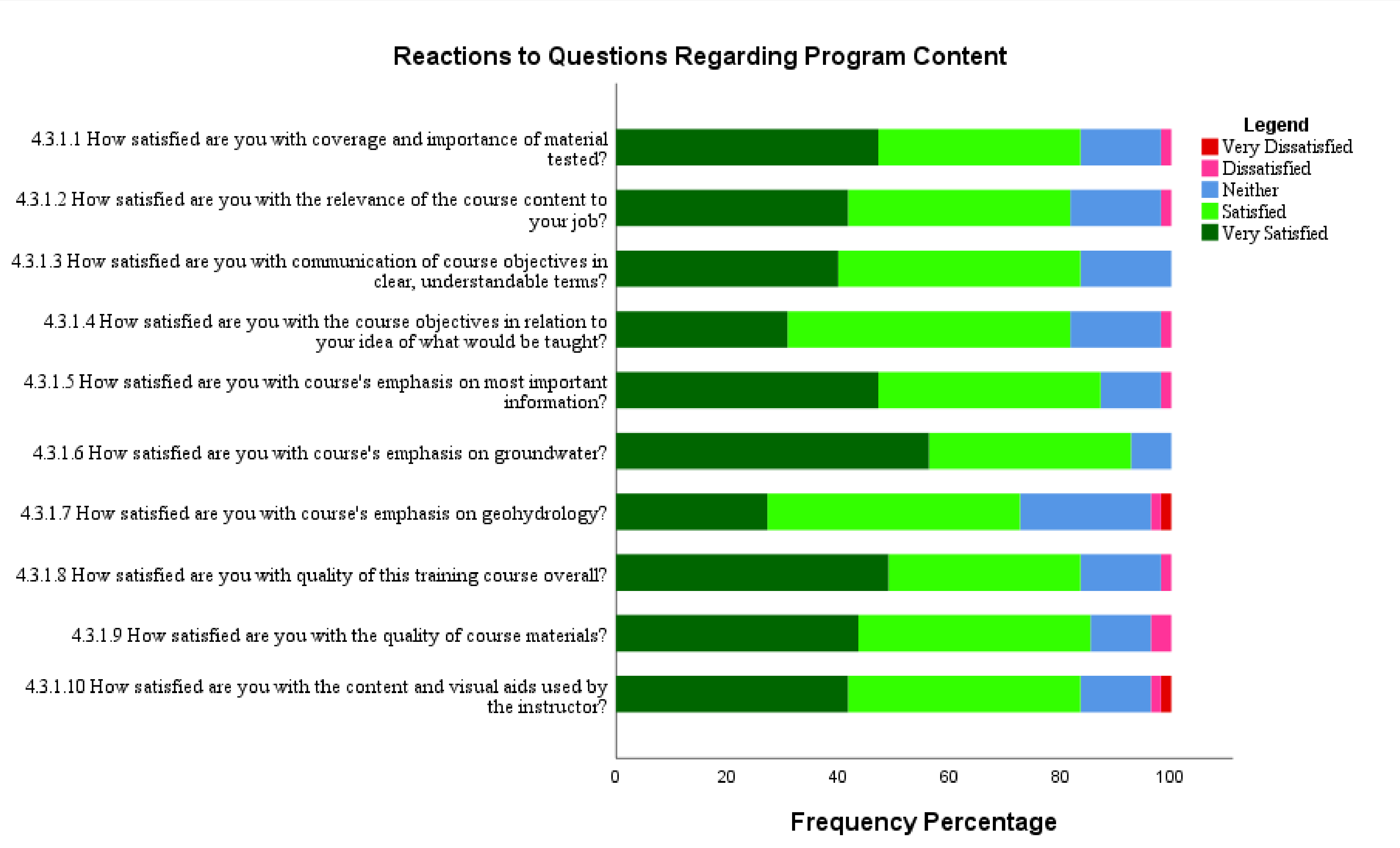

Figure 4-6: Frequency distribution on the questions 1- 10 regarding the program content.

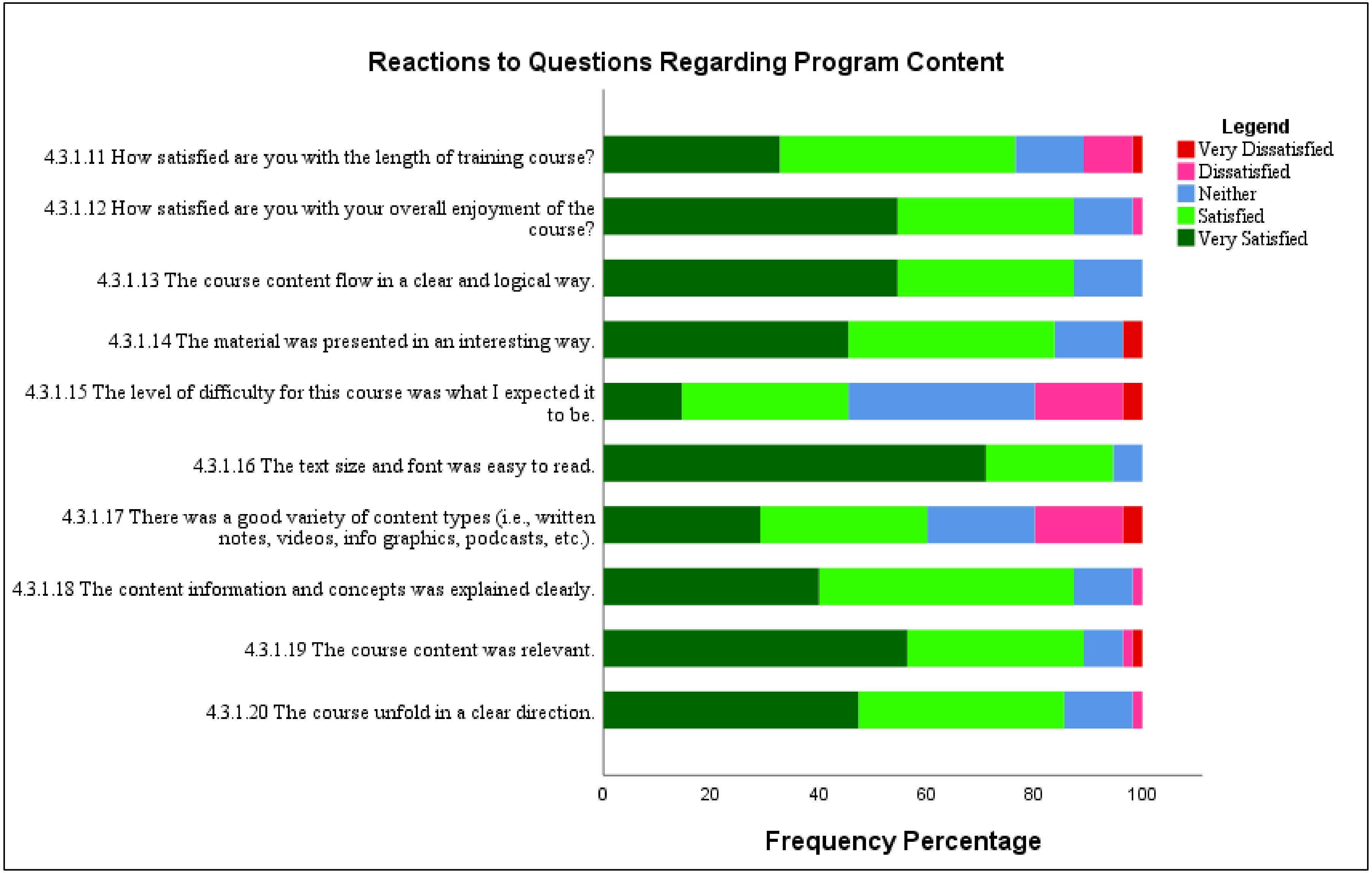

Figure 4-7: Frequency distribution on the questions 11- 20 regarding the program content.

4.3.1.1 **Question 1: How satisfied are you with the coverage and importance of material tested?**

The statistics in Table 4-6 and Figure 4-6 show that 47.3% (twenty-six respondents) of the participants are very satisfied with the coverage of material tested, whilst another 36.4% (twenty respondents) are satisfied, 14.5% (eight respondents) were unbiased. Only 1.8% (one respondent) of the respondents is dissatisfied with the range of material tested. None of the participants indicated that they were very dissatisfied with the range of material tested.

4.3.1.2 **Question 2: How satisfied are you with the relevance of the course content to your job?**

The data in Table 4-6 and Figure 4-6 indicate that 41.8% (twenty-three respondents) of the respondents are very satisfied with the relevance of the course content to their job environment, whilst another 40.0% (twenty-two respondents) are satisfied, 16.4% (nine respondents) where neutral and only 1.8% (one respondent) of the respondents are dissatisfied with the applicability of the course content to their job environment. None of the participants indicated that they were very dissatisfied with the relevance of the course content to their job environment.

4.3.1.3 **Question 3: How satisfied are you with communication of course objectives in clear, understandable terms?**

The statistics in Table 4-6 and Figure 4-6 indicate that 40.0% (twenty-two respondents) of the participants strongly accepted that the course objectives were delivered in clear and understandable terms while 43.6% (twenty-four respondents) are satisfied, and 16.4% (nine respondents) were neutral in their decision. The margin just below the majority of the sample participants agree that course objectives were communicated in clear and understandable terms.

4.3.1.4 **Question 4: How satisfied are you with the course objectives in relation to your idea of what would be taught?**

The data in Table 4-6 and Figure 4-6 indicate that 30.9% (seventeen respondents) of the respondents are very satisfied with the course objectives, whilst 50.9% (twenty-eight respondents) are satisfied, 16.4% (nine respondents) where neutral and only 1.8% (one respondent) of the respondents are dissatisfied with the program content.

4.3.1.5 Question 5: How satisfied are you with course's emphasis on most important information?

The statistics in Table 4-6 and Figure 4-6 illustrate that 47.3% (twenty-six respondents) of the participants believed strongly that the course content place important emphasis on information whilst 40.0% (twenty-two respondents) are satisfied, 10.9 % (six respondents) where unbiased in responses and only 1.8% (one respondent) of the respondents dissatisfied.

4.3.1.6 Question 6: How satisfied are you with course's emphasis on groundwater?

The statistics in Table 4-6 and Figure 4-6 illustrate that 56.4% (thirty-one respondents) of the respondents are very satisfied with the training manual emphasis on groundwater, whilst another 36.4% (twenty respondents) are satisfied and 7.3% (four respondents) were neutral. None of the participants were dissatisfied or very dissatisfied with the course's emphasis on groundwater. This is an important question regarding to the content and indicate that most participants are very satisfied with the emphasis on groundwater in the program.

4.3.1.7 Question 7: How satisfied are you with course's emphasis on geohydrology?

This question followed on the question regarding the emphasis on groundwater. Participants are however happy with the emphasis on groundwater but believes that more emphasis should be placed on geohydrology within the course content. Table 4-6 and Figure 4-6 indicate that merely 27.3% (fifteen respondents) of the respondents are very satisfied with the course's emphasis on geohydrology, whilst another 45.5% (twenty-five respondents) are satisfied, 23.6% (thirteen respondents) where unbiased in their decision and only 1.8% (one respondent) of the respondents are dissatisfied and very dissatisfied with the training manual emphasis on geohydrology.

4.3.1.8 Question 8: How satisfied are you with quality of this training course overall?

Table 4-6 and Figure 4-6 indicate that 49.1% (twenty-seven respondents) of the respondents are very satisfied with the general quality of the training manual whilst another 34.5% (nineteen respondents) are satisfied, 14.5% (eight respondents) where unbiased and only 1.8% (one respondent) of the respondents are dissatisfied with the general quality of the training manual. None of the participants were very dissatisfied.

4.3.1.9 Question 9: How satisfied are you with the quality of course materials?

The statistics in Table 4-6 and Figure 4-6 illustrate that 43.6% (twenty-four respondents) of the participants are very satisfied with the quality of the training manual content and material, whilst another 41.8% (twenty-three respondents) are satisfied, 10.9% (six respondents) where unbiased and 3.6% (two respondents) of the respondents are dissatisfied with the quality of the training manual content and material. None of the participants were very dissatisfied.

4.3.1.10 Question 10: How satisfied are you with the content and visual aids used by the instructor?

Table 4-6 and Figure 4-6 show that 41.8% (twenty-three respondents) of the respondents are very satisfied with the content and visual aids used, whilst another 41.8% (twenty-three respondents) are satisfied, 12.7% (seven respondents) where unbiased in their decision and only 1.8% (one respondent) of the respondents are dissatisfied and very dissatisfied with the course’s content and visual aids. Improvement regarding visual aids is necessary to increase participants’ satisfaction level.

4.3.1.11 Question 11: How satisfied are you with the length of training course?

Table 4-6 and Figure 4-7 illustrate that 32.7% (eighteen respondents) of the participants are very satisfied with the length of the training course, whilst another 43.6% (twenty-four respondents) are satisfied, 12.7% (seven respondents) where unbiased in their decision, 9.1% (five respondents) of the respondents are dissatisfied and only 1.8% (one respondent) are very dissatisfied with the length of the training course. The increase in adverse reactions indicates that participants are unhappy with the length of modules in the training program.

4.3.1.12 **Question 12: How satisfied are you with your overall enjoyment of the course?**

The statistics in Table 4-6 and Figure 4-7 show that 54.5% (thirty respondents) of the respondents are very satisfied with the general enjoyment of the training manual, whilst another 32.7% (eighteen respondents) are satisfied, 10.9% (six respondents) were neutral in their decision and 1.8% (one respondent) of the respondents are dissatisfied. None of the participants were very dissatisfied with the overall enjoyment of the training program.

4.3.1.13 **Question 13: The course content flows in a clear and logical way.**

The data in Table 4-6 and Figure 4-7 indicate that 54.5% (thirty respondents) of the respondents strongly believed that the training course content flow in a clear and logical way, whilst another 32.7% (eighteen respondents) are satisfied and 12.7% (seven respondents) were neutral in their decision. None of the participants were dissatisfied or very dissatisfied with the course content flow.

4.3.1.14 **Question 14: The material was presented in an interesting way.**

Table 4-6 and Figure 4-7 illustrate that 45.5% (twenty-five respondents) of the participants strongly believed that the training course was presented in an interesting way, whilst 38.2% (twenty-one respondents) are satisfied, 12.7% (seven respondents) where unbiased in their decision and 3.6% (two respondents) of the respondents are very dissatisfied with the presentation of the course.

4.3.1.15 **Question 15: The level of difficulty for this course was what I expected it to be.**

The statistics in Table 4-6 and Figure 4-7 indicate that 14.5% (eight respondents) of the respondents are very satisfied with the level of difficulty of the course that they expected, whilst another 30.9% (seventeen respondents) are satisfied, 34.5% (nineteen respondents) where unbiased in their decision, 16.4% (nine respondents) of the respondents are dissatisfied and 3.6% (two respondents) are very dissatisfied with the level of difficulty of the course that they expected. Participants generally expected the course to be more difficult. The course was, however, compiled to be suitable to a wide variety of groups with different educational backgrounds. The majority of participants that completed the pilot test had high educational backgrounds and therefore expected the course to be more difficult.

4.3.1.16 Question 16: The text size and font were easy to read.

Table 4-6 and Figure 4-7 indicate that the majority 70.9% (thirty-nine respondents) of the participants strongly believed that the training course content text size and font were easy to read, whilst 23.6% (thirteen respondents) are satisfied, and 5.5% (three respondents) were unbiased in their decision. None of the participants were dissatisfied or very dissatisfied with the training course content text size and font and believed that it was easy to read.

4.3.1.17 Question 17: There was a good variety of content types (i.e., written notes, videos, infographics, podcasts, etc.).

The statistics in Table 4-6 and Figure 4-7 are almost relatively evenly distributed among the Likert scale. The data, however, indicate that 29.1% (sixteen respondents) of the respondents strongly believed that the course had a good variety of content type while another 30.9% (seventeen respondents) are satisfied, 20% (eleven respondents) were neutral in their decision, 16.4% (nine respondents) of the respondents are dissatisfied, and 3.6% (two respondents) are very dissatisfied with the variety of content types. A lack of a good variety of content types increased the dissatisfaction level and decreased satisfaction reactions of participants.

4.3.1.18 Question 18: The content information and concepts were explained clearly.

The statistics in Table 4-6 and Figure 4-7 indicate that 40% (twenty-two respondents) of the participants strongly agree that the course content information and concepts were clearly explained, while another 47.3% (twenty-six respondents) are satisfied, 10.9% (six respondents) were neutral in their decision and only 1.8% (one respondent) of the participants are dissatisfied and believed that the course content information and concepts were not clearly explained. None of the participants were very dissatisfied with the question raised.

4.3.1.19 Question 19: The course content was relevant.

Table 4-6 and Figure 4-7 illustrate that 56.4% (thirty-one respondents) of the participants agree that the course content was relevant while 32.7% (eighteen respondents) are satisfied, 7.3% (four respondents) were neutral in their decision and 1.8% (one respondent) of the participants are dissatisfied, and 1.8% (one respondent) are very dissatisfied and believed that the course content was not relevant.

4.3.1.20 Question 20: The course unfolds in a clear direction.

Table 4-6 and Figure 4-7 show that 47.3% (twenty-six respondents) of the participants are very satisfied on how the course unfolds in a clear direction, whilst 38.2% (twenty-one respondents) are satisfied, 12.7% (seven respondents) were unbiased in their decision and 1.8% (one respondent) of the respondents are dissatisfied on how the course unfolds. None of the participants are very dissatisfied with the way the course.

4.3.1.21 Question 21: What additional learning content should be included in the course?

This question was the first open-ended question, designed to gather insights and feedback from the participants on any additional learning content that should be included in the course. The question was optional to answer. Thirty-three participants provided feedback. A total of twelve participants proposed that a more comprehensive approach should be followed to include a better variety of content types. This is parallel with the data received form question 17 (see section 4.3.1.17) and could be one of the reasons why the response percentage is relatively low for that question.

Additional learning content that was proposed include the following:

- Geographic information systems (GIS) and how it relates or indicates locations for underground water.
- Basic Geology and the impact of Geology on Geohydrology.
- Drilling techniques.
- Define terms and definitions.
- Groundwater contaminants and its effects on the environment, if not treated.
- The negative impacts when water allocation processes and management is not followed.
- Technology that can be used to improve groundwater quality.
- How certain soil types affect groundwater generally.
- The impact on groundwater with regards to fracking, climate and increasing population.

- Described the difference between groundwater and surface water in terms of treatment sampling of groundwater in more depth.
- Describe the problems that occur when creating or implementing policies for groundwater.
- Include a chapter about the overall state of the Republic of South Africa (RSA) in relation to groundwater and how more to preserve this resource.

4.3.1.22 **Question 22: Any recommendations?**

This question was the second open-ended question. This question was designed to gather more insights and feedback from the participants to establish if there is any feedback regarding the training content that can increase the positive response rate by participants. The feedback received was generally the same as the previous question. However, there were a few additional ideas proposed:

- Participants wanted to take part in additional training courses regarding groundwater. Some participants asked to have similar courses on a more regular basis to improve their knowledge.
- Participants proposed that course content should have case studies and a practical aspect.
- Some participants argued that the tests should be more challenging and include fewer questions. One participant also proposed that the questions within the pre-test and post-test should differ. Kirkpatrick, however, recommends that the same questions should be asked to establish a change in learning.

4.3.2 Reactions to questions regarding program platform

This section within the evaluation questionnaire examines the respondent's views regarding the platform used as described in the methodology. It consists of eleven questions. The questions are based around three themes, namely the accessibility, familiarity, and support of the platform. Ten out of the eleven questions were structured on a Likert scale. The last question in this category was designed to gather feedback from the participant and is thus an open-ended question. Individual discussion, frequency tables and bar charts for survey questions on the program platform (Figure 4-8 and Table 4.7) will be explained below.

Table 4-7: Frequency count on questions regarding the program platform.

	Very Dissatisfied		Dissatisfied		Neither		Satisfied		Very Satisfied		Positive Responses
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**%**
Platform Q1	0	0.0%	4	7.3%	7	12.7%	16	29.1%	28	50.9%	80.0%
Platform Q2	1	1.8%	1	1.8%	13	23.6%	14	25.5%	26	47.3%	72.7%
Platform Q3	0	0.0%	1	1.8%	6	10.9%	19	34.5%	29	52.7%	87.3%
Platform Q4	0	0.0%	2	3.6%	6	10.9%	23	41.8%	24	43.6%	85.5%
Platform Q5	1	1.8%	2	3.6%	11	20.0%	25	45.5%	16	29.1%	74.5%
Platform Q6	0	0.0%	0	0.0%	6	10.9%	18	32.7%	31	56.4%	89.1%
Platform Q7	1	1.8%	0	0.0%	7	12.7%	20	36.4%	27	49.1%	85.5%
Platform Q8	0	0.0%	2	3.6%	10	18.2%	23	41.8%	20	36.4%	78.2%
Platform Q9	0	0.0%	1	1.8%	7	12.7%	20	36.4%	27	49.1%	85.5%
Platform Q10	0	0.0%	0	0.0%	7	12.7%	20	36.4%	28	50.9%	87.3%

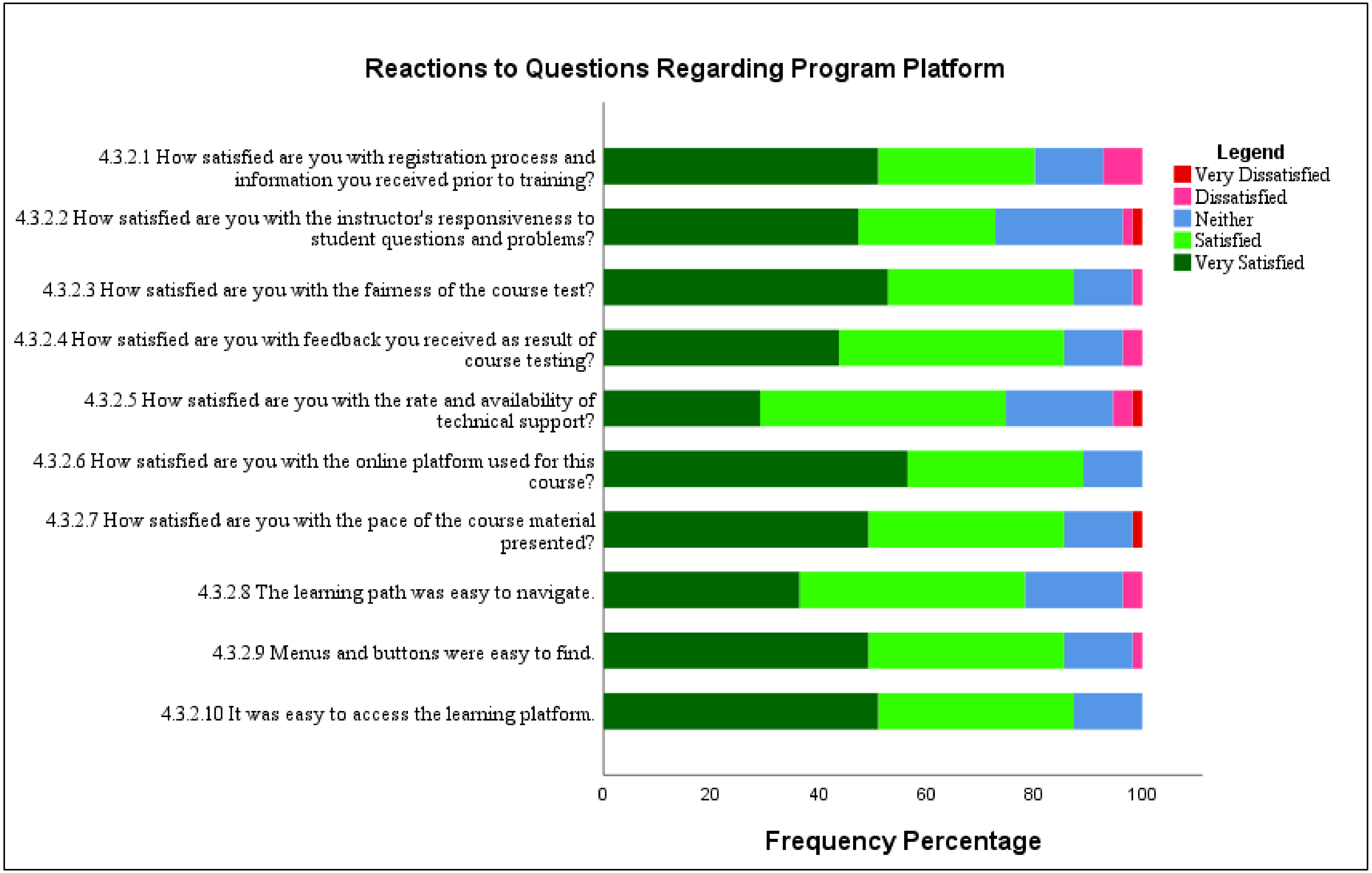

Figure 4-8: Frequency distribution on questions regarding the program platform.

4.3.2.1 Question 1: How satisfied are you with registration process and information you received prior to training?

The statistics in Table 4-7 and Figure 4-8 indicate that 50.9% (twenty-eight respondents) of the participants are very satisfied with the registration process. 29.1% (sixteen respondents) are satisfied, 12.7% (seven respondents) where unbiased and 7.3% (four respondent) of the respondents are dissatisfied with the registration process and information received before training. None of the participants were very dissatisfied with the registration process and information received before training.

4.3.2.2 Question 2: How satisfied are you with the instructor's responsiveness to student questions and problems?

The statistics in Table 4-7 and Figure 4-8 indicate that 47.3% (twenty-six respondents) of the participants are very satisfied with the responsiveness to problems and questions, whilst another 25.5% (fourteen respondents) are satisfied, 23.6% (thirteen respondents) where unbiased, 1.8% (one respondent) of the participants are dissatisfied and 1.8% (one respondent) of the respondents are very dissatisfied with the responsiveness.

4.3.2.3 Question 3: How satisfied are you with the fairness of the course test?

The statistics in Table 4-7 and Figure 4-8 show that 52.7% (twenty-nine respondents) of the participants are very satisfied with the fairness of the course testing, whilst 34.5% (nineteen respondents) are satisfied, 10.9% (six respondents) where neutral and only 1.8% (one respondent) of the respondents are dissatisfied with the fairness of the course testing. None of the respondents were very dissatisfied.

4.3.2.4 Question 4: How satisfied are you with feedback you received as result of course testing?

The statistics in Table 4-7 and Figure 4-8 indicate that 43.6% (twenty-four respondents) of the respondents are very satisfied with feedback received, whilst 41.8% (twenty-three respondents) are satisfied, 10.9% (six respondents) where unbiased and 3.6% (two respondents) of the respondents are dissatisfied with the feedback received.

4.3.2.5 Question 5: How satisfied are you with the rate and availability of technical support?

The statistics in Table 4-7 and Figure 4-8 illustrate that 29.1% (sixteen respondents) of the respondents are very satisfied with the rate of technical support received, whilst another 45.5% (twenty-five respondents) are satisfied, 20% (eleven respondents) were neutral with their decision, 3.6% (two respondents) of the respondents are dissatisfied, and 1.8% (one participant) are very dissatisfied with the rate of technical support received.

4.3.2.6 Question 6: How satisfied are you with the online platform used for this course?

The statistics in Table 4-7 and Figure 4-8 illustrate that 56.4% (thirty-one respondents) of the respondents are very satisfied with the online platform used, whilst 32.7% (eighteen respondents) are satisfied and 10.9% (six respondents) were neutral in their decision None of the participants were dissatisfied or very dissatisfied with the platform used for this course.

4.3.2.7 Question 7: How satisfied are you with the pace of the course material presented?

The statistics in Table 4-7 and Figure 4-8 show that 49.1% (twenty-seven respondents) of the participants agree that the pace of the course material presented was accepted, whilst 36.4% (twenty respondents) are satisfied, 12.7% (seven respondents) where unbiased and only 1.8% (one respondent) of the respondents are very dissatisfied.

4.3.2.8 Question 8: The learning path was easy to navigate.

The statistics in Table 4-7 and Figure 4-8 indicate 36.4% (twenty respondents) of the participants strongly agree that the learning path was easy to navigate, whilst 41.8% (twenty-three respondents) are satisfied, 18.2% (ten respondents) where unbiased and 3.6% (two respondents) of the respondents are dissatisfied and agree that the learning path was difficult to navigate. Changes to the navigation path are necessary to increase positive response rates.

4.3.2.9 Question 9: Menus and buttons were easy to find.

The statistics in Table 4-7 and Figure 4-8 illustrate that 49.1% (twenty-seven respondents) of the respondents are very satisfied with the familiarity of menus and buttons on the platform, whilst 36.4% (twenty respondents) are satisfied, 12.7% (seven respondents) were neutral in their decision and only 1.8% (one respondent) of the respondents are dissatisfied with the familiarity of menus and buttons on the platform.

4.3.2.10 Question 10: Was it easy to access the learning platform?

The statistics in Table 4-7 and Figure 4-8 indicate that 50.9% (twenty-eight respondents) of the participants agree that it was easy to access the learning platform, whilst 36.4% (twenty respondents) are satisfied, and 12.7% (seven respondents) were neutral in their decision and believe that it was easy to access the learning platform.

4.3.2.11 Question 11: What was the most frustrating technical problem you faced with the learning platform?

This question was the first and only open-ended question in this section, designed to gather insights and feedback from the participants on the most frustrating technical problems that occurred while using the platform. The question was optional to answer. Sixteen participants provided reliable feedback. The majority of responses received indicated that the most frustrating technical problem was to have a constant internet connection. Other frustrating problems identified included sign in and familiarity with the platform interface. Accessibility was also identified as a frustrating factor because the platform was only accessible on a desktop platform and not on a mobile device.

4.3.3 Reactions to general questions

The third and final section of the evaluation survey measures the reactions of participants of the training manual in a few general questions. This section consists of five questions that were structured on a Likert scale. These questions will provide background views of the participant about training and the training program. Frequency tables and bar charts for survey questions on the general questions (Figure 4-9 and Table 4-8) follow below with individual discussion.

Table 4-8: Frequency count on questions regarding the general questions.

	Very Dissatisfied		Dissatisfied		Neither		Satisfied		Very Satisfied		Positive Responses
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**%**
General Q1	3	5.5%	5	9.1%	12	21.8%	20	36.4%	15	27.3%	63.6%
General Q2	0	0.0%	1	1.8%	13	23.6%	24	43.6%	17	30.9%	74.6%
General Q3	20	36.4%	14	25.5%	13	23.6%	5	9.1%	3	5.5%	14.5%
General Q4	0	0.0%	1	1.8%	6	10.9%	18	32.7%	30	54.5%	87.3%
General Q5	0	0.0%	2	3.6%	12	21.8%	22	40.0%	19	34.5%	74.6%

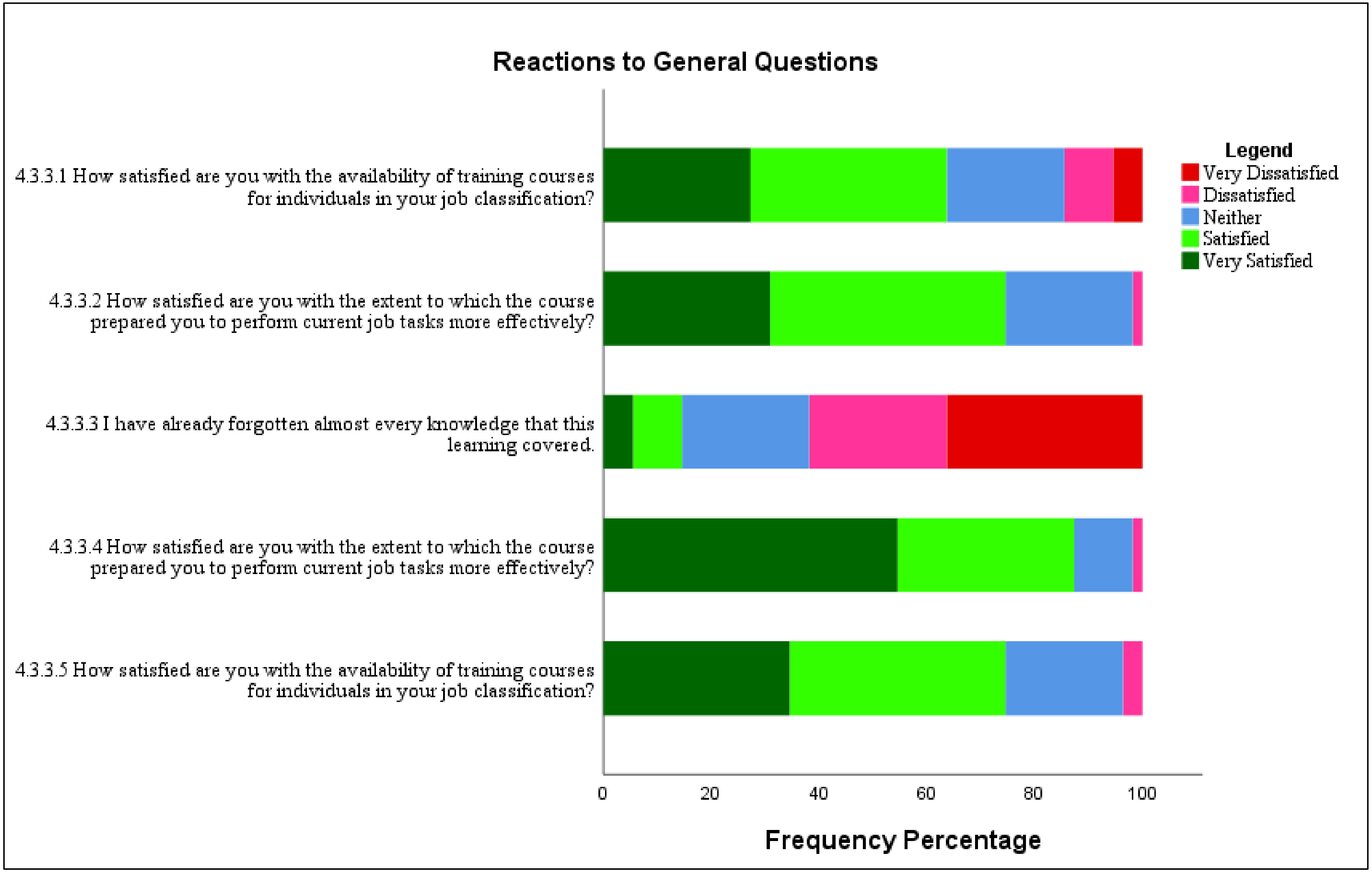

Figure 4-9: Frequency distribution on questions regarding the general questions.

4.3.3.1 Question 1: How satisfied are you with the availability of training courses for individuals in your job classification?

The statistics in Table 4-8 and Figure 4-9 illustrate 27.3% (fifteen respondents) of the respondents are very satisfied with the availability of training courses for individuals in their job, whilst 36.4% (twenty respondents) are satisfied, 21.8% (twelve respondents) where unbiased, 9.1% (five respondents) of the participants are dissatisfied, and 5.5% (three respondents) of the respondents are very dissatisfied. The data gathered thus indicate that there is an opportunity to provide training courses for individuals within their job environment.

4.3.3.2 Question 2: How satisfied are you with the extent to which the course prepared you to perform current job tasks more effectively?

The statistics in Table 4-8 and Figure 4-9 illustrate 30.9% (seventeen respondents) of the respondents strongly believed that the course prepared them to perform current job tasks more effectively, whilst 43.6% (twenty-four respondents) are satisfied, 23.6% (thirteen respondents) were neutral in their answer and 1.8% (one respondent) of the respondents are dissatisfied and believed that the course did not prepare them to perform current job tasks more effectively. These results should be taken lightly, as no behavioural changes were tested within this research study. It will be good if future studies include the third level of Kirkpatrick to determine a change in behaviour.

4.3.3.3 Question 3: I have already forgotten almost every knowledge that this learning covered.

The statistics in Table 4-8 and Figure 4-9 illustrate an extremely low 5.5% (three respondents) of the participants that firmly believed that they had forgotten almost every knowledge that this learning covered, whilst 9.1% (five respondents) are satisfied, 23.6% (thirteen respondents) where unbiased, 25.5% (fourteen respondents) of the respondents are dissatisfied, and 36.4% (twenty respondents) of the respondents are very dissatisfied. Low positive reactions in this question point out that participants gain knowledge. This, however, still need to be tested with Kirkpatrick level 2 evaluation framework.

4.3.3.4 Question 4: I feel that I had enough time to complete the course to the best of your abilities.

The statistics in Table 4-8 and Figure 4-9 illustrate that 54.5% (thirty respondents) of the participants that believed that they had enough time to complete the course, whilst 32.7% (eighteen respondents) are satisfied, 10.9% (six respondents) where unbiased and 1.8% (one respondent) of the participants are dissatisfied and agree that they did not have enough time to complete the course.

4.3.3.5 Question 5: I learned everything that I was expected to learn.

The statistics in Table 4-8 and Figure 4-9 illustrate that 34.5% (nineteen respondents) of the participants agree that they learned everything that they expect to learn, whilst 40% (twenty-two respondents) are satisfied, 21.8% (twelve respondents) where unbiased and 3.6% (two respondents) of the respondents are dissatisfied and believed that they did not learn everything that they expect to learn. The downward trend in positive reactions indicated that participants expected to learn more. At first glance, one should think that the objectives are not clearly defined. However, section 4.3.1.3 described that the majority of the sample participants agree that course objectives were communicated in clear and understandable terms.

4.3.4 Evaluation Survey Questionnaire Discussions

4.3.4.1 Discussions of frequency count for satisfaction survey

Table 4-6, 4-7 and 4-8 show an additional column named positive percentage. This column indicates the frequency percentage of positive choices made by respondents for each question. These values have been calculated by adding the frequency percentages of “Satisfied” and “Very Satisfied” to determine the impact of negative responses related to “Dissatisfied” and “Very Dissatisfied”. In the process of applying this method, outliers within the responses could be identified. The line graphs illustrated in Figures 4-10, 4-11 and 4-12 below show what questions or items of the three sections within the satisfaction survey received the highest percentage of negative ratings.

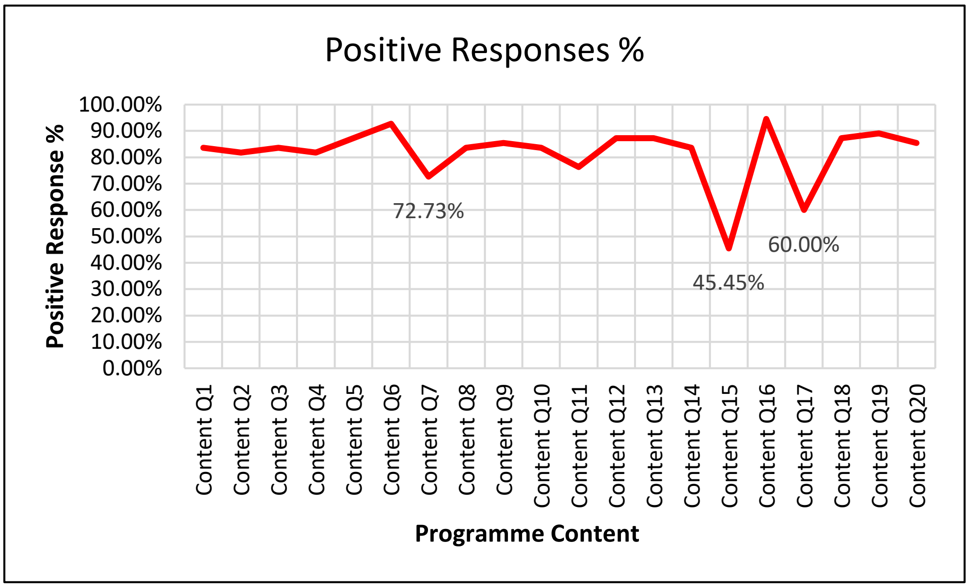

Figure 4-10: Positive Response Percentage of the Programme Content.

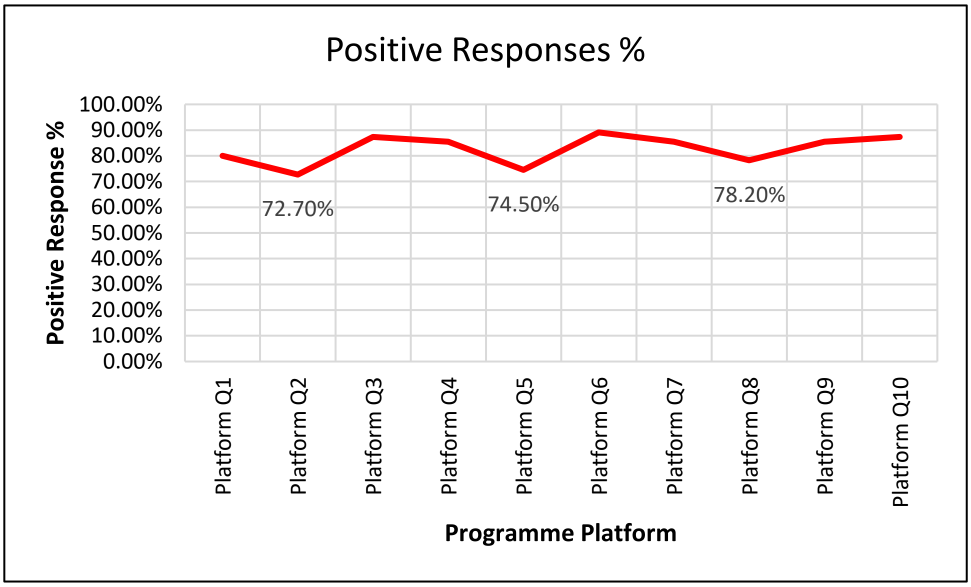

Figure 4-11: Positive Response Percentage of the Programme Platform.

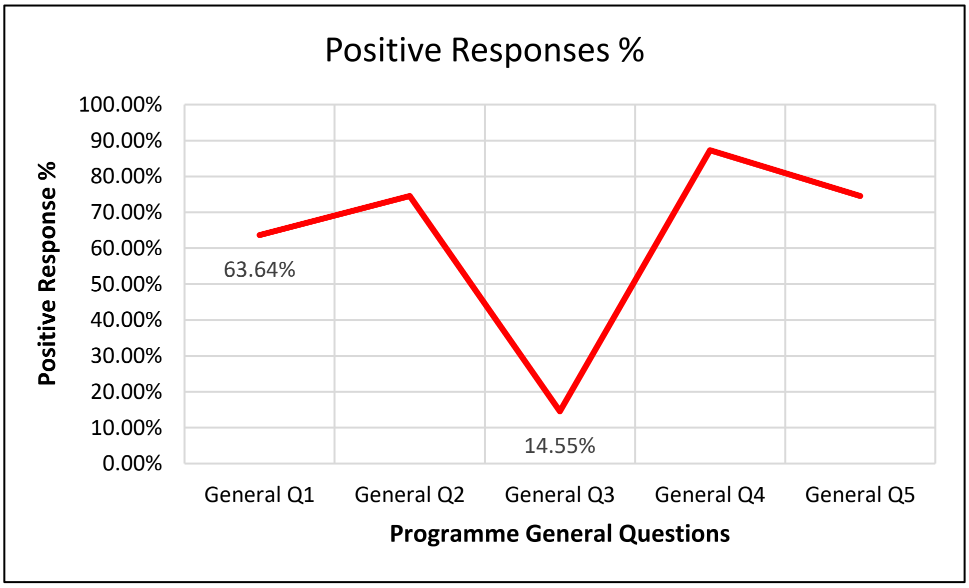

Figure 4-12: Positive Response Percentage of Programme General Question.

Clear outliers are identified as survey question fifteen (Content Q15) and seventeen (Content Q17) in the program content category and question three (General Q3) in the program general question category.

The statistics in Table 4-6 and Figures 4-7 and 4-10 illustrate that question fifteen had the lowest positive response (45.5%) from respondents in the program content category. In other words, 54.6% of participants expected the course to be more difficult. Note that the training manual was developed to be suitable for a wide variety of groups with different backgrounds and skills. The second question within the same category also identified as an outlier, is question seventeen with a positive response percentage of 60%. This response rate is relatively low in regard to the other positive response percentages displayed in Figure 4-10. In other words, 40% of participants agree that there are not a good variety of content types (i.e., written notes, videos, infographics, case studies, etc.) within the course. This relatively low percentage correlates with the feedback received from the open-end questions in section 4.3.1.21 and 4.3.1.22. The feedback gathered proposed that a more comprehensive approach should be followed to include a better variety of content type such as infographics, illustrations, and case studies.

The other eighteen questions within the program content category all received relatively high response percentages by the respondents, which highlights that the program content difficulty and a small variety of content types are a disadvantage the effectiveness of the training manual.

With respect to the general question category, question three (general Q3) is identified as an outlier within the positive percentage range, as illustrated in Table 4-8 and Figure 4-9 and 4-12. The graph (Figure 4-12) depicts a tremendously low positive percentage of 14.55%. This low percentage is an advantage and indicates that participants gain knowledge. This should only be seen as a guideline until the results analysed from Kirkpatrick level 2 evaluation framework confirms it.

4.3.4.2 Conclusion for the satisfaction survey questionnaire

The overall view and positive responses from the respondent's survey in terms of course content and content presentation point to an effective program. However, as previously mentioned, there are a few focus areas. Two of the biggest concerns include that more than half (54.6%) of the participants expected the course to be more difficult and secondly, 40% of participants believe that the program lack in content variety. These two apprehensions have the potential to impact the overall effectiveness and quality of the program regarding the affective and cognitive domains of participants. Change in learning of respondents could be affected by the two concerns. Firstly, no change in learning or lower post-test scores may be explained by the fact that participants perceive the training content as monotonous because the training course does not cover a respectable variety of training content types, i.e., notes, illustrations, infographics, podcasts, etc. Secondly, a significant change in learning or higher post-test scores could potentially be clarified by the fact that participants expected the course to be more difficult.

The quantitative approach and use of data of this study were unable to investigate prohibitive factors such as gender, marital status and age that need to be addressed to improve the program. A qualitative follow up study is recommended to better comprehend research findings and to improve and re-design course content for future use. A qualitative study will capture the changing attitudes from participants within a sample and will provide an opportunity to participants to express and elaborate on specific responses provided. By revisiting the research question, sub questions and hypothesis in section 1.5.2 and the data analysis and research findings in this chapter, it was concluded that the alternative hypothesis was accepted for the affective reactions of participants.

4.4 Level of Learning (Cognitive Domain)

This section elaborates, answer and investigate Kirkpatrick's second level of evaluation framework by utilising a pre-test and post-test. The tests are not divided into categories but are designed to suit five different modules within the training manual and were statistically analysed separately. Each performance test was designed with the focus to include the most important aspect of each module. Below is a breakdown of the five different modules, the total of questions and number of participants within the performance test:

1. Groundwater Management – Fifteen participants and eighteen questions
2. Groundwater Monitoring – Ten participants and nineteen questions
3. Groundwater Quality – Eight participants and seventeen questions
4. Groundwater Quantity – Seven participants and ten questions
5. Groundwater Regulations – Fifteen participants and eighteen questions

Identical pre-test and post-test questions were used, however the order of the pre-test questions varied from the post-test questions.

This method eliminates the recollection of answers by respondents. The second research question and hypothesis derived from the aims and objectives of the study are:

How effective is the training program content in facilitating the acquisition of new knowledge to participants?

Hypothesis 2:

- **Null hypothesis:** The program will not be effective in facilitating the acquisition of new knowledge to participants.
- **Alternative hypothesis:** The program will be effective in facilitating the acquisition of new knowledge to participants.

4.4.1 Descriptive statistics for pre-test and post-test

This chapter introduces the descriptive statistics, histograms, and frequency distributions for the various training modules pre-tests and post-tests.

Table 4-9: Descriptive statistics for pre-test and post-test.

	Course Name									
	Groundwater Management		Groundwater Monitoring		Groundwater Quality		Groundwater Quantity		Groundwater Regulation	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Count	15	15	10	10	8	8	7	7	15	15
Mean	76	86	70	83	79	91	64	74	61	81
Standard Error of Mean	2	3	3	4	3	3	10	11	3	4
Median	74	89	73	88	78	94	55	91	58	84
Mode	68[a]	95	60	90	78	94	55	100	58	74[a]
Standard Deviation	9	11	11	14	9	9	26	30	12	15
Variance	88	122	111	190	75	88	666	907	146	212
Minimum	63	63	55	50	67	72	27	36	37	42
Maximum	95	100	85	95	94	100	100	100	79	100
Sum	1141	1290	700	825	634	726	446	517	912	1210
a. Multiple modes exist. The smallest value is shown										

4.4.1.1 Groundwater Management

The descriptive statistics in Table 4-9 and Table 4-10 for the Groundwater Management module indicated that the minimum scores (63%) were identical for both the pre-test and post-test. The maximum score for this module increased with 5% as the pre-test maximum was 95% and 100% for the post-test. The mean of the pre-test and post-test descriptive statistics indicates an improvement of 9.9% as the pre-test mean was 76.1% and post-test mean score 86%. Table 4-9 shows that the standard deviation of the pre-test was 9.4% and 11.1% for the post-test. The standard deviation indicates the typical pre-test percentage that participants tend to fall from the mean test score.

Table 4-10: Descriptive statistics for Groundwater Management pre-test and post-test.

Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Pre-Test	15	63	95	76.07	9.362
Post-Test	15	63	100	86.00	11.026
Valid N (listwise)	15				

Table 4-11 and Table 4-12 represents the pre-test and post-test scores frequency distribution for the module: Groundwater Management is graphically illustrated in Figures 4-13 and Figure 4-14. The statistics for the pre-test in Table 4-11 and Figure 4-13 illustrate a histogram with the distribution of data which falls on the boundaries of an approximately normal curve distribution. A normal curve represents a perfectly symmetrical distribution of data (Dudley-Marling and Gurn, 2010). The normal curve is slightly skewed with a higher percentage of participants with a test score below the mean. Majority of pre-test scores are clustered around the mean. The post-test statistics in Table 4-12 and Figure 4-14 indicates an increased in test scores, where eleven participants scored less than 80% in the pre-test, to only five participants that scored less than 80% in the post-test. Figure 4-14 illustrated an almost symmetrical distribution of data. The number of participants with post- test scores higher than the mean is slightly higher than those below the mean. Twelve out of the fifteen participants in this module had a post-test score between 74% and 95%, whereas ten participants in the pre-test scored within the same range.

Table 4-11: Frequency distribution for Groundwater Management pre-test average.

Pre-Test					
		Frequency	Percent	Valid Percent	Cumulative Percent
Test results (%)	63	2	13.3	13.3	13.3
	68	3	20.0	20.0	33.3
	74	3	20.0	20.0	53.3
	79	3	20.0	20.0	73.3
	84	2	13.3	13.3	86.7
	89	1	6.7	6.7	93.3
	95	1	6.7	6.7	100.0
	Total	**15**	**100.0**	**100.0**	

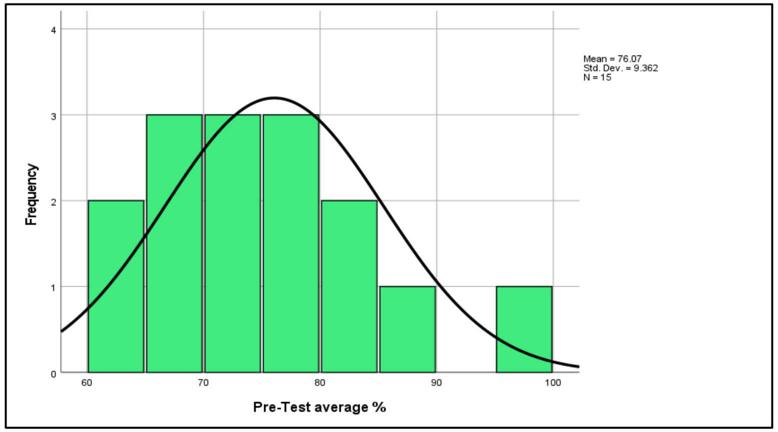

Figure 4-13: Histogram for Groundwater Management pre-test average. %

Table 4-12: Frequency distribution for Groundwater Management post-test average.

Post-Test					
		Frequency	Percent	Valid Percent	Cumulative Percent
Test results (%)	63	1	6.7	6.7	6.7
	74	2	13.3	13.3	20.0
	79	3	20.0	20.0	40.0
	84	1	6.7	6.7	46.7
	89	2	13.3	13.3	60.0
	95	4	26.7	26.7	86.7
	100	2	13.3	13.3	100.0
	Total	**15**	**100.0**	**100.0**	

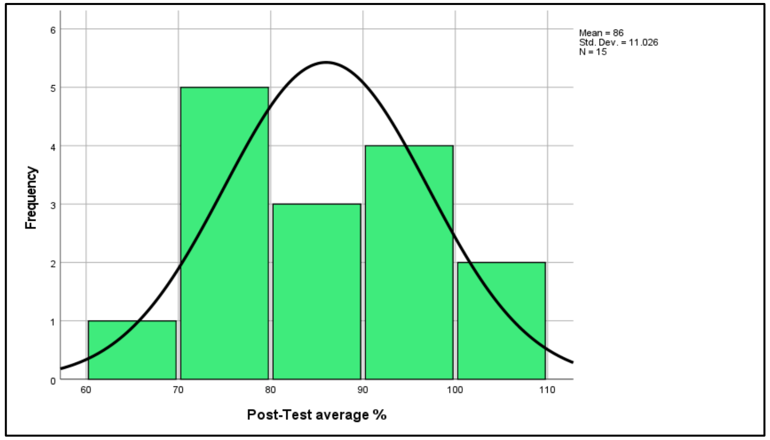

Figure 4-14: Histogram for Groundwater Management post-test average %

4.4.1.2 **Groundwater Monitoring**

The descriptive statistics in Table 4-9 and Table 4-13 for the Groundwater Monitoring module indicated that the minimum scores differed with 5% within the pre-test and post-test data. Minimum test scores for the pre-test were 55% and 50% for the post-test. The maximum score for this module increased with 10% as the pre-test maximum was 85% and 95% for the post-test. The mean of the pre-test and post-test descriptive statistics indicates an improvement of 12.5% as the pre-test mean was 70% and post-test mean score 82.5%. Table 4-9 and Table 4-13 indicate a standard deviation of 10.5% for the pre-test and 13.8% for the post-test. The sample size of this module was ten participants.

Table 4-13: Descriptive statistics for Groundwater Monitoring pre-post-test.

Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Pre-Test	10	55	85	70.00	10.541
Post-Test	10	50	95	82.50	13.794
Valid N (listwise)	10				

Table 4-14 and Table 4-15 represents the pre-test and post-test scores frequency distribution for the module Groundwater Monitoring and are graphically illustrated in Figures 4-15 and Figure 4-16. The statistics for the pre-test in Table 4-14 and Figure 4-15 illustrate a histogram with an approximately normal curve distribution. 50% (five participants) had test scores less than the mean and 50% (five participants) greater than the mean. The distribution of data indicates that 95% of test scores fall between +/- 2 standard deviations around the mean.

The post-test statistics in Table 4-15 and Figure 4-16 indicates an increased in test scores, where nine participants scored less than 85% in the pre-test, to only four participants that scored less than 85% in the post-test. The mean of 82.5% indicates the central tendency of the distribution. Figure 4-16 illustrated a slightly negative skew distribution of data. The negatively skewed distribution show that most test scores are plotted on the right side of the graph and the mean of 82.5% is lower than the median (88%) and mode (90%).

Table 4-14: Frequency distribution for Groundwater Monitoring pre-test average.

Pre-Test					
		Frequency	Percent	Valid Percent	Cumulative Percent
Test results (%)	**55**	1	10.0	10.0	10.0
	60	3	30.0	30.0	40.0
	70	1	10.0	10.0	50.0
	75	2	20.0	20.0	70.0
	80	2	20.0	20.0	90.0
	85	1	10.0	10.0	100.0
	Total	**10**	**100.0**	**100.0**	

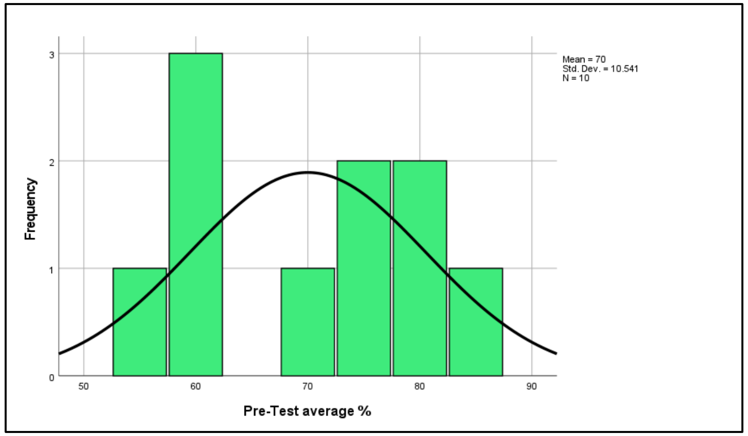

Figure 4-15: Histogram for Groundwater Monitoring pre-test average %

Table 4-15: Frequency distribution for Groundwater Monitoring post-test average.

Post-Test					
		Frequency	Percent	Valid Percent	Cumulative Percent
Test results (%)	**50**	1	10.0	10.0	10.0
	70	1	10.0	10.0	20.0
	80	2	20.0	20.0	40.0
	85	1	10.0	10.0	50.0
	90	3	30.0	30.0	80.0
	95	2	20.0	20.0	100.0
	Total	**10**	**100.0**	**100.0**	

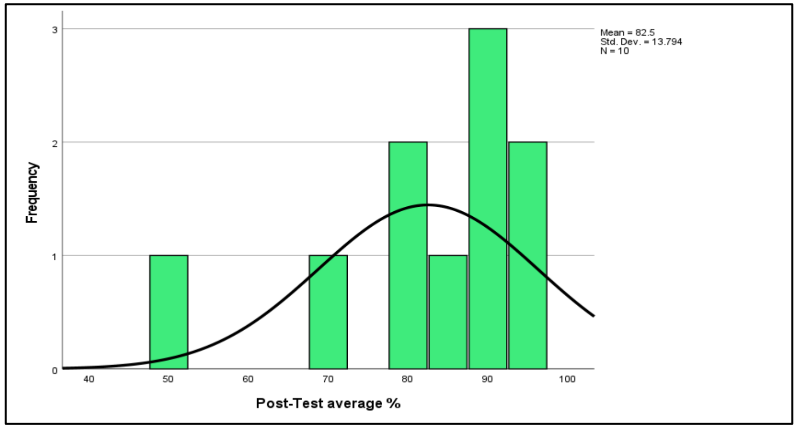

Figure 4-16: Histogram for Groundwater Monitoring post-test average. %

4.4.1.3 Groundwater Quality

The descriptive statistics in Table 4-9 and Table 4-16 for the Groundwater Quality module indicated that the minimum scores differed with 5% within the pre-test and post-test data. Minimum test scores for the pre-test were 67% and 72% for the post-test. The maximum score for this module increased with 6% as the pre-test maximum was 94% and 100% for the post-test. The mean of the pre-test and post-test descriptive statistics indicates an improvement of 11.5% as the pre-test mean was 79.3% and post-test mean score 90.75%. Table 4-9 and Table 4-16 indicate a standard deviation of 8.631% for the pre-test and 9.4% for the post-test. The sample size of this module was eight participants.

Table 4-16: Descriptive statistics for Groundwater Quality pre-test and post test.

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Pre-Test	8	67	94	79.25	8.631
Post-Test	8	72	100	90.75	9.392
Valid N (listwise)	8				

Table 4-17 and Table 4-18 represents the pre-test and post-test scores frequency distribution for the module Groundwater Quality and are graphically illustrated in Figures 4-17 and Figure 4-18. The statistics for the pre-test in Table 4-17 and Figure 4-17 illustrate a histogram with the distribution of data which falls on the boundaries of an approximately normal curve distribution. The mean (79.3%), median (78%), and mode (78%) are nearly identical. Two participants had pre-test scores below 78%, four participants had 78% and two participants had scores higher than 78%.

The post-test statistics in Table 4-18 and Figure 4-18 indicates an increased in test scores, where seven participants scored less or equal than 89% in the pre-test, to only three participants that scored less or equal than 89% in the post-test. The mean of 90.8% indicates the central tendency of the distribution. Figure 4-17 illustrated a symmetrical normal curve distribution, where the mean (90.8%), median (94%), and mode (94%) are nearly identical. Five out of the eight participants had scores between 90% and 100% and is an increased from the pre-test.

Table 4-17: Frequency distribution for Groundwater Quality pre-test average.

Pre-Test					
		Frequency	Percent	Valid Percent	Cumulative Percent
Test results (%)	**67**	1	12.5	12.5	12.5
	72	1	12.5	12.5	25.0
	78	4	50.0	50.0	75.0
	89	1	12.5	12.5	87.5
	94	1	12.5	12.5	100.0
	Total	**8**	**100.0**	**100.0**	

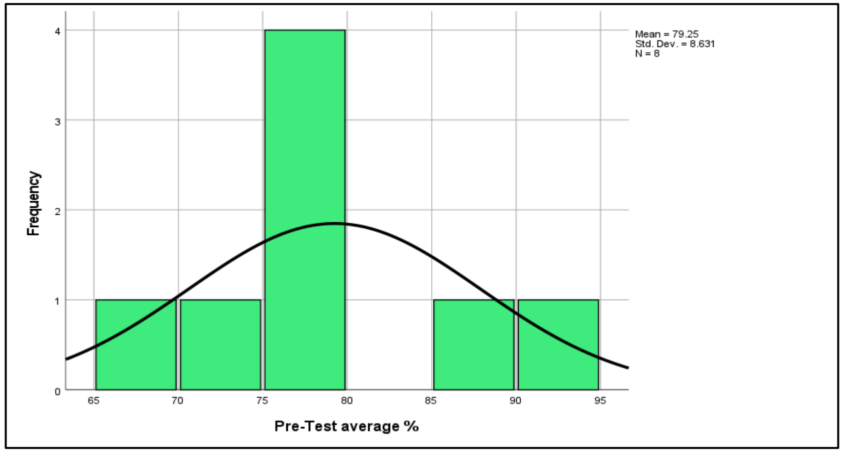

Figure 4-17: Histogram for Groundwater Quality pre-test average %.

Table 4-18*: Frequency distribution for Groundwater Quality post-test average.*

Post-Test					
		Frequency	Percent	Valid Percent	Cumulative Percent
Test results (%)	**72**	1	12.5	12.5	12.5
	83	1	12.5	12.5	25.0
	89	1	12.5	12.5	37.5
	94	3	37.5	37.5	75.0
	100	2	25.0	25.0	100.0
	Total	**8**	**100.0**	**100.0**	

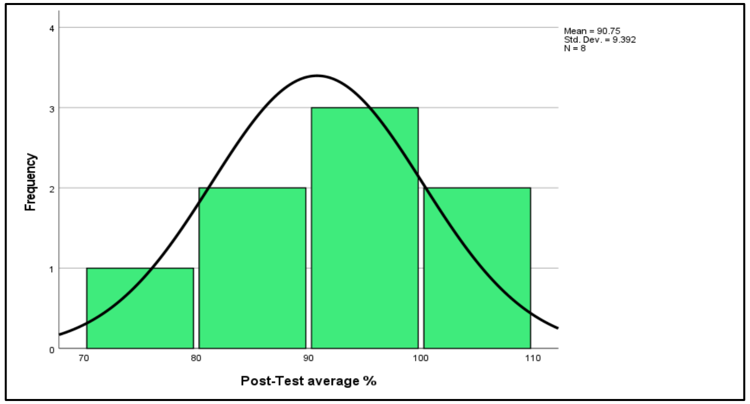

Figure 4-18*: Histogram for Groundwater Quality post-test average. %*

4.4.1.4 Groundwater Quantity

The descriptive statistics in Table 4-9 and Table 4-19 for the Groundwater Quantity module indicated that the minimum scores differed with 9% within the pre-test and post-test data. Minimum test scores were relatively low for the pre-test 27% and 36% for the post-test. The maximum score (100%) was identical for both the pre-test and post-test. Data in the pre-test and post-test indicate a high average increased between minimum and maximum test scores. The mean of the pre-test and post-test descriptive statistics indicates an improvement of 10.14% as the pre-test mean was 63.7% and post-test mean score 73.9%. Table 4-9 and Table 4-19 indicate a standard deviation of 25.8% for the pre-test and 30.1% for the post-test. The sample size of this module was seven participants.

Table 4-19: Descriptive statistics for Groundwater Quantity pre-test and post-test.

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Pre-Test	7	27	100	63.71	25.812
Post-Test	7	36	100	73.86	30.119
Valid N (listwise)	7				

Table 4-20 and Table 4-21 represents the pre-test and post-test scores frequency distribution for the module Groundwater Quantity and are graphically illustrated in Figures 4-19 and Figure 4-20. The statistics for the pre-test in Table 4-20 and Figure 4-19 illustrate a histogram with an almost normal curve distribution. The mean of 64% is slightly higher than the median (55%), and mode (55%). Four participants had pre-test scores identical or below 55%, and three participants had scores higher or equal than 73%.

The post-test statistics in Table 4-21 and Figure 4-20 indicates an increased in test scores, where four participants scored less or equal than 55% in the pre-test, to only three participants that scored less or equal than 45% in the post-test. Figure 4-20 illustrated a distribution, where four participants post-test scores average between 91% - 100% and three participants post-test scores were between 36% - 45%. The post-test standard deviation of 30.1% defines the width of the normal distribution that resulted in a flatter widespread distribution curve.

Table 4-20: Frequency distribution for Groundwater Quantity pre-test average.

Pre-Test					
		Frequency	Percent	Valid Percent	Cumulative Percent
Test results (%)	27	1	14.3	14.3	14.3
	45	1	14.3	14.3	28.6
	55	2	28.6	28.6	57.1
	73	1	14.3	14.3	71.4
	91	1	14.3	14.3	85.7
	100	1	14.3	14.3	100.0
	Total	**7**	**100.0**	**100.0**	

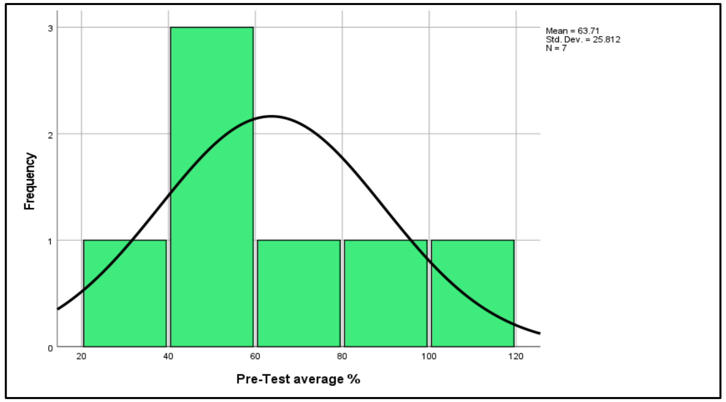

Figure 4-19: Histogram for Groundwater Quantity pre-test average %.

Table 4-21: Frequency distribution for Groundwater Quantity post-test average.

Post-Test					
		Frequency	Percent	Valid Percent	Cumulative Percent
Test results (%)	36	1	14.3	14.3	14.3
	45	2	28.6	28.6	42.9
	91	1	14.3	14.3	57.1
	100	3	42.9	42.9	100.0
	Total	**7**	**100.0**	**100.0**	

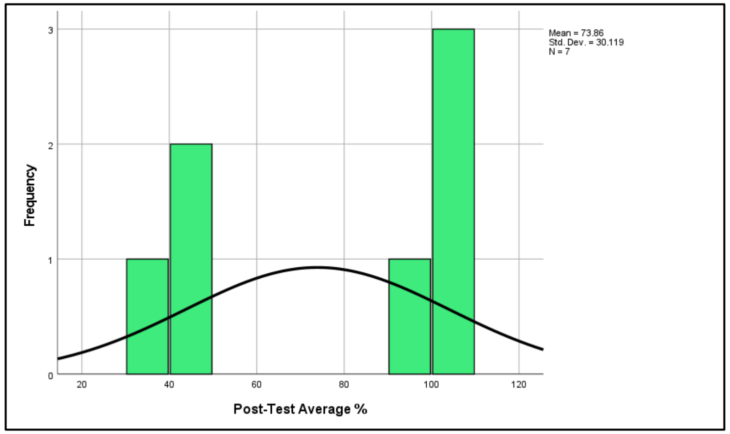

Figure 4-20: Histogram for Groundwater Quantity pre-test average. %

4.4.1.5 Groundwater Regulation

The descriptive statistics in Table 4-9 and Table 4-22 for the Groundwater Regulation module indicated that the minimum scores differed with 5% within the pre-test and post-test data. Minimum test scores for the pre-test were 37% and 42% for the post-test. The maximum score for this module increased with 21% as the pre-test maximum was 79% and 100% for the post-test. The mean of the pre-test and post-test descriptive statistics indicates an improvement of 19.9% as the pre-test mean was 60.80% and post-test mean score 80.7%. Table 4-9 and Table 4-22 indicate a standard deviation of 12.1% for the pre-test and 14.5% for the post-test. The sample size of this module was fifteen participants.

Table 4-22: Descriptive statistics for Groundwater Regulation pre-test and post-test.

Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Pre-Test	15	37	79	60.80	12.066
Post-Test	15	42	100	80.67	14.544
Valid N (listwise)	15				

Table 4-23 and Table 4-24 represents the pre-test and post-test scores frequency distribution for the module Groundwater Regulation and are graphically illustrated in Figures 4-21 and Figure 4-22. The mean of 60.8% indicates the central tendency of the distribution. The statistics for the pre-test in Table 4-23 and Figure 4-21 illustrate a histogram with a slightly skew in distribution of data. The skewed distribution indicates a mean of 60.8%, a median of 58% and mode of 58%. Nine participants had pre-test scores below or equal than 58%, and six participants had scores higher than 58%.

The post-test statistics in Table 4-24 and Figure 4-22 indicate an increased in test scores, where fourteen participants (93.3% of participants) scored less or equal than 74% in the pre-test, to only four participants (33.3% of participants) that scored less or equal than 74% in the post-test. The mean of 80.675% indicates the central tendency of the distribution. Figure 4-22 illustrated a slight skew distribution, where the mean is 80.7%, the median 84% and mode 74%. Eighty percent of the participants that attended this module had a post-test score that range between 74% - 95%.

Table 4-23: Frequency distribution for Groundwater Regulation pre-test average.

Pre-Test					
		Frequency	Percent	Valid Percent	Cumulative Percent
Test results (%)	**37**	1	6.7	6.7	6.7
	42	1	6.7	6.7	13.3
	53	2	13.3	13.3	26.7
	58	5	33.3	33.3	60.0
	68	2	13.3	13.3	73.3
	74	3	20.0	20.0	93.3
	79	1	6.7	6.7	100.0
	Total	**15**	**100.0**	**100.0**	

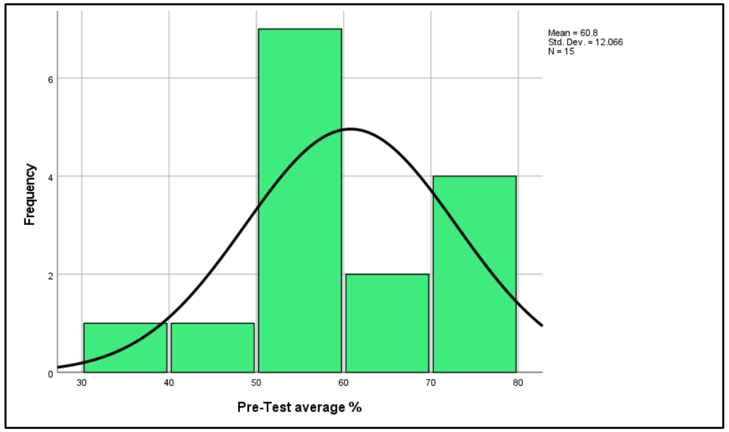

Figure 4-21: Histogram for Groundwater Regulation pre-test average %

Table 4-24: Frequency distribution for Groundwater Regulation post-test average.

Post-Test					
		Frequency	Percent	Valid Percent	Cumulative Percent
Test results (%)	**42**	1	6.7	6.7	6.7
	63	1	6.7	6.7	13.3
	74	3	20.0	20.0	33.3
	79	2	13.3	13.3	46.7
	84	2	13.3	13.3	60.0
	89	3	20.0	20.0	80.0
	95	2	13.3	13.3	93.3
	100	1	6.7	6.7	100.0
	Total	**15**	**100.0**	**100.0**	

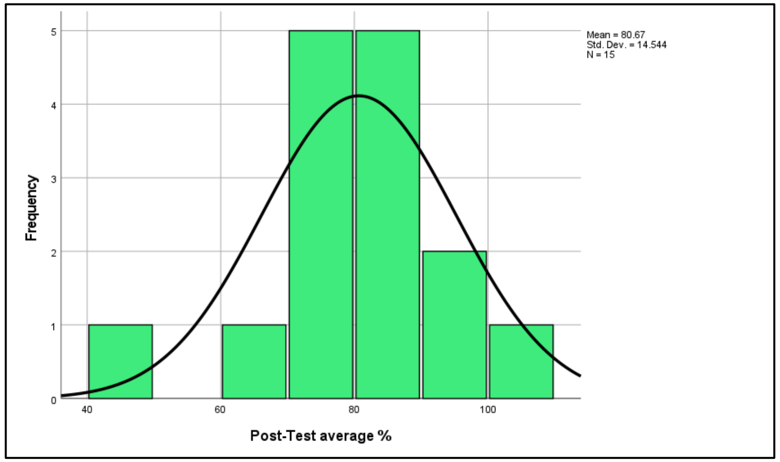

Figure 4-22: Histogram for Groundwater Regulation post-test average.

4.4.2 Test of significance

A paired sample t-test was conducted to compare pre-test and post-test scores by participants.

4.4.2.1 **Groundwater Management**

A paired-samples t-test was conducted to compare pre-test and post-test scores by participants by providing training on the Groundwater Management module. Table 4-25 show a significant difference in participants tests scores achieved between pre-test (mean= 76.07, SD= 9.362) and post-test (mean= 86.00, SD=11.026). A paired sample t-test for pre-test and post-tests found this difference to be significant, t (14) = -4.083, $p < 0.05$, r = 0.583.

These results suggest that the training provided on Groundwater Management to participants did influence the test scores between the pre-test and post-test. Because the p-value is less than 0.05, we accept the alternative hypothesis and reject the null hypothesis.

Table 4-25: Groundwater Management paired sample t-test for pre-tests and post-tests.

Paired Samples Statistics									
		Mean	N	Std. Deviation	Std. Error Mean				
Pair 1	Pre-Test	76.07	15	9.362	2.417				
	Post-Test	86.00	15	11.026	2.847				
Paired Samples Correlations									
		N	Correlation	Sig.					
Pair 1	Pre-Test and Post-Test	15	0.583	0.022					
Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Pre-Test - Post-Test	-9.933	9.422	2.433	-15.151	-4.715	-4.083	14	0.0011186

4.4.2.2 **Groundwater Monitoring**

Pre-test and post-test scores by participants were analysed by a paired-samples t-test. Table 4-26 shows a significant difference in participants tests scores achieved between pre-test (mean= 70.00, SD= 10.541) and post-test (mean= 82.50, SD=13.794). A paired sample t-test for pre-tests and post-tests found this difference to be significant, t (9) = -4.197, $p < 0.05$, r = 0.573.

These results suggest that the training provided on Groundwater Monitoring to participants did influence the test scores between the pre-test and post-test. Because the p-value is less than 0.05, we accept the alternative hypothesis and reject the null hypothesis.

Table 4-26: Groundwater Monitoring paired sample t-test for pre-tests and post-tests.

Paired Samples Statistics									
		Mean	N	Std. Deviation	Std. Error Mean				
Pair 1	Pre-Test	70.00	10	10.541	3.333				
	Post-Test	82.50	10	13.794	4.362				
Paired Samples Correlations									
		N	Correlation	Sig.					
Pair 1	Pre-Test and Post-Test	10	0.573	0.083					
Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-Test - Post-Test	-12.500	11.607	3.670	-20.803	-4.197	-3.406	9	0.0078041

4.4.2.3 **Groundwater Quality**

Table 4-27 shows a significant difference in participants tests scores achieved between pre-test (mean= 79.25, SD= 8.631) and post-test (mean= 90.75, SD= 9.392). A paired sample t-test for pre-tests and post-tests found this difference to be significant, t (7) = -5.277, $p < 0.05$, r = 0.769.

These results suggest that the training provided on Groundwater Quality to participants did influence the test scores between the pre-test and post-test. Because the p-value is less than 0.05, we accept the alternative hypothesis and reject the null hypothesis.

Table 4-27: Groundwater Quality paired sample t-test for pre-tests and post-tests.

Paired Samples Statistics									
		Mean	N	Std. Deviation	Std. Error Mean				
Pair 1	Pre-Test	79.25	8	8.631	3.052				
	Post-Test	90.75	8	9.392	3.321				
Paired Samples Correlations									
		N	Correlation	Sig.					
Pair 1	Pre-Test and Post-Test	8	0.769	0.026					
Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-Test – Post-Test	-11.500	6.164	2.179	-16.654	-6.346	-5.277	7	0.0011524

4.4.2.4 Groundwater Quantity

Table 4-28 shows no significant difference in participants' tests scores achieved between pre-test (mean= 63.71, SD= 25.812) and post-test (mean= 30.119, SD= 30.119). A paired sample t-test for pre-tests and post-tests found this difference not to be significant, t (6) = -1.397, p > 0.05, r = 0.775.

These results suggest that the training provided on Groundwater Quantity to participants did not actually influence the test scores between the pre-test and post-test. Because the p-value is higher than 0.05, we accept the null hypothesis and reject the alternative hypothesis.

Table 4-28: Groundwater Quantity paired sample t-test for pre-tests and post tests.

Paired Samples Statistics									
		Mean	N	Std. Deviation	Std. Error Mean				
Pair 1	Pre-Test	63.71	7	25.812	9.756				
	Post-Test	73.86	7	30.119	11.384				
Paired Samples Correlations									
		N	Correlation	Sig.					
Pair 1	Pre-Test and Post-Test	7	0.775	0.041					
Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-Test – Post-Test	-10.143	19.213	7.262	-27.912	7.626	-1.397	6	0.2119743

4.4.2.5 Groundwater Regulation

Table 4-29 indicate a significant difference in participants tests scores achieved between pre-test (mean= 60.80, SD= 12.066) and post-test (mean= 80.67, SD= 14.544). A paired sample t-test for pre-tests and post-tests found this difference to be significant, $t\ (14) = -4.827$, $p < 0.05$, $r = 0.293$.

These results suggest that the training provided on Groundwater Regulation to participants did influence the test scores between the pre-test and post-test. Because the p-value is less than 0.05, we accept the alternative hypothesis and reject the null hypothesis.

Table 4-29: Groundwater Regulation paired sample t-test for pre-tests and post-tests.

Paired Samples Statistics									
		Mean	N	Std. Deviation	Std. Error Mean				
Pair 1	Pre-Test	60.80	15	12.066	3.116				
	Post-Test	80.67	15	14.544	3.755				
Paired Samples Correlations									
		N	Correlation	Sig.					
Pair 1	Pre-Test and Post-Test	15	0.293	0.288					
Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-Test – Post-Test	-19.867	15.941	4.116	-28.695	-11.039	-4.827	14	0.0002688

4.4.3 Level of Learning Between Pre-test and Post-test Discussions

4.4.3.1 **Discussions of pre-tests and post-tests**

The majority of the modules results from the pre-tests and post-tests indicated a substantial increase of groundwater knowledge within participants. There is however a single module which does not indicated a statistically significant difference (Groundwater Quantity). This module did show an increase of knowledge within participants but is not considered to be significant as indicated with the paired sample t-test. There are however, in some cases, a difference between the outcomes of the pre-test and post-test.

These outcomes identified, indicated areas and level of poor knowledge within individuals and could be used to improve specific modules within the training manual. The modules identified include Groundwater Monitoring, Groundwater Quantity and Groundwater Regulation with pre-test minimum scores that range between 27% and 55%. These modules should form a focus area of the training program and be modified to enhance the level of knowledge of individuals. Overall, all modules indicated to be significant and clearly indicate an increase in the level of knowledge within participants. By revisiting the research question, sub questions and hypothesis in section 1.5.2 and the data analysis and research findings in this chapter, it was concluded that the alternative hypothesis was accepted for the acquisition of new knowledge within participants.

4.5 Conclusion

By utilising the first two levels of the Kirkpatrick hierarchy, various points of concern and interest was identified. Two of the biggest concerns within the evaluation survey questionnaire include that [1]more than half (54%) of the participants expected the course to be more difficult and secondly, 40% of participants believe that the program lack in content variety (i.e., written notes, videos, infographics, case studies, etc.).

Firstly, no change in learning or lower post-test scores in the Groundwater Quantity module could be explained by the fact that participants perceive the training content for this module as monotonous. Reason for this is that the training course does not cover a respectable variety of training content types, i.e., notes, illustrations, infographics, podcasts, etc. Secondly, a significant change in learning or higher post-test scores could potentially be clarified by the fact that participants expected the course to be more difficult.

The pre-tests and post-tests scores indicated a substantial increase of groundwater knowledge within participants. Outcomes from the pre-test and post-test and evaluation survey, identified modules that should be improved within the training manual. The modules identified include Groundwater Monitoring, Groundwater Quantity and Groundwater Regulation. These modules should form a focus area of the training program and be modified to enhance the level of knowledge of individuals.

Chapter 5

Summary and Conclusion

5.1 Overview of this Chapter

The following section reflects on the research question.

> How effective is the training program known as "Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa" in equipping municipal employees, technicians, managers, and decision-makers with the required knowledge and skills to enhance a better understanding of groundwater?

This section also provides a brief review to the research questions and hypothesis. Limitations and recommendations are also provided for designers, trainers, educators, and organisations.

5.2 Limitations of this study

- All four levels of Kirkpatrick's (1998) four level model could not be applied in this study. The third and fourth level of data collection required a longer period to analyse (a period of years). Only level one and level two of Kirkpatrick's (1998) four level model was utilised. Refer to chapter 2 under section 2.5.
- The sample size also restricts the reliability of the data collected. Only 55 participants participated in the study. This data will thus not provide a significant population distribution.
- Participants only had access to the LMS platform on certain devises such as laptop/computer.
- Practical examples were not included in the training manual. This restricted the participants to only gain theoretical knowledge. There was also a lack of case studies which would provide more practical examples.
- The complexity of the online questionnaire and content was also a challenge for the participants to navigate the website.

- Not all participants were provided with the same course content. Participants were divided within five groups to evaluate each module.
- The quantitative approach and use of data of this study were unable to investigate prohibitive factors such as gender, marital status and age that need to be addressed to improve the program.

5.3 Recommendations

The recommendations formulated below are proposed to effectively implement the training program to enhance service delivery.

- Determine any significant influence of a language barrier. There are various participants whose first language is not English.
- The use of more understandable vocabulary should be taken into consideration. This can be done by using English at a level which all participants can understand. A list of defined words should be added to the training manual to better comprehend certain terms.
- Written test can also be used to determine the effectiveness of the online course. This study restricted the participants to use the internet thus a more reliable result can be obtained regarding the significance of the content.
- The amount of content provided should also be considered. An excessive amount of content could overwhelm the participants and their ability to finish the course.
- A more comprehensive approach should be followed to include a better variety of content types (i.e., written notes, videos, infographics, case studies, etc.).
- A more diverse group of participants should also be considered for future studies. The diverse group should include managers, municipal members, public sector employees and professionals.
- Ensure that all participants own/have a smart device and access to a stable internet connection to access the LMS and participate in the study.
- Ensure that the online website is user friendly and easy to navigate.
- Include case studies which provide more practical examples.

- To ensure validity and consistency all participants should be provided with the same training modules and content.
- Exclude groundwater quality aspects from the groundwater quantity module.
- A qualitative follow up study is recommended to better comprehend research findings and to improve and re-design course content for future use. A qualitative study will capture the changing attitudes from participants within a sample and will provide an opportunity to participants to express and elaborate on specific responses provided.

5.4 Conclusion

The research was conducted as a deliverable for the WRC. The general aim of this research was to evaluate the effectiveness of a training program known as "Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa". The training manual was developed to educate municipal employees, technicians, managers, and decision-makers to increase their knowledge and skills regarding groundwater resource management and ground water governance. Five out of the nine modules from the training modules were used, as these modules demonstrated to be an area of concern within municipalities.

To respond to the aim of this dissertation, the Kirkpatrick's (1998) four-level framework for program evaluation was utilised. To evaluate the effectiveness of the training manual participants wrote pre-tests and post-tests and completed evaluation questionnaires. This was done to establish the enhanced level of knowledge within participants and to gather reactions regarding perception and satisfaction of the training manual. A self-administered questionnaire (SAQ) and instruments was utilised to collect data and measure the affective and cognitive domains from participants. The data collected were recorded, processed, and analysed in the statistical package IBM SPSS and Microsoft Excel.

The results, findings and conclusions contained in this dissertation indicate that the training manual received positive responses from participants and identified the manual to be beneficial and effective. All statistical data collected from the pre-tests and post-tests indicated that the level of knowledge increased within participants on all five modules. The level of knowledge in the module Groundwater Regulation improved the most with a mean difference of 20%.

By revisiting the research question, sub questions and hypothesis one and two in section 1.5.2 and the data analysis and research findings in Chapter 4, it was concluded that the alternative hypothesis was accepted for both the affective reactions and the acquisition of new knowledge of participants.

Hypothesis 1:

- Null hypothesis: Affective reaction will not be significant towards the program.
- Alternative hypothesis: Affective reaction will be significant towards the program.

Hypothesis 2:

- Null hypothesis: The program will not be effective in facilitating the acquisition of new knowledge to participants.
- Alternative hypothesis: The program will be effective in facilitating the acquisition of new knowledge to participants.

Despite the fact that the dissertation identified certain shortcomings and limitations of the training manual, the adequate level of reactions and increased of knowledge within participants are still seen as positive and significant. Prospective studies and research should incorporate the recommendations and limitations within this dissertation to enhance similar and future training manuals.

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Appendix A:
Evaluation Survey Questionnaire

Focus	Type	Question
Content	Likert Scale	How satisfied are you with coverage and importance of material tested?
Content	Likert Scale	How satisfied are you with the relevance of the course content to your job?
Content	Likert Scale	How satisfied are you with communication of course objectives in clear, understandable terms?
Content	Likert Scale	How satisfied are you with match of course objectives with your idea of what would be taught?
Content	Likert Scale	How satisfied are you with course's emphasis on most important information?
Content	Likert Scale	How satisfied are you with course's emphasis on groundwater?
Content	Likert Scale	How satisfied are you with course's emphasis on geohydrology?
Content	Likert Scale	How satisfied are you with quality of this trainingcourse overall?
Content	Likert Scale	How satisfied are you with the quality of course materials?
Content	Likert Scale	How satisfied are you with the content and visual aids used by the instructor?
Content	Likert Scale	How satisfied are you with the length of training course?
Content	Open	What additional learning content should be included in the course?
Content	Likert Scale	How satisfied are you with your overall enjoyment of the course?
Content	Likert Scale	The course content flow in a clear and logical way.
Content	Likert Scale	The material was presented in an interesting way.
Content	Likert Scale	The level of difficulty for this course was what I expected it to be.
Content	Likert Scale	The text size and font was easy to read.
Content	Likert Scale	There was a good variety of content types (i.e., written notes, videos, info graphics, podcasts, etc.).
Content	Likert Scale	The content information and concepts was explained clearly.
Content	Likert Scale	The course content was relevant.
Content	Likert Scale	The course unfold in a clear direction.
Content	Open	Any recommodations?

Focus	Question Type	Question
Platform	Likert Scale	How satisfied are you with registration process and information you received prior to training?
Platform	Likert Scale	How satisfied are you with the instructor's responsiveness to student questions and problems?
Platform	Likert Scale	How satisfied are you with the fairness of the course test?
Platform	Likert Scale	How satisfied are you with feedback you received as result of course testing?
Platform	Likert Scale	How satisfied are you with the rate and availability of technical support?
Platform	Likert Scale	How satisfied are you with the online platform used for this course?
Platform	Likert Scale	How satisfied are you with the pace of the course material presented?
Platform	Likert Scale	The learning path was easy to navigate.
Platform	Likert Scale	Menus and buttons was easy to find.
Platform	Open	What was the most frustrating technical problem you faced with the learning platform?
Platform	Likert Scale	It was easy to access the learning platform.

Focus	Question Type	Question
General	Likert Scale	How satisfied are you with the availability of training courses for individuals in your job classification?
General	Likert Scale	How satisfied are you with the extent to which the course prepared you to perform current job tasks more effectively?
General	Likert Scale	I have already forgotten almost every knowledge that this learning covered.
General	Likert Scale	I feel that I had enough time to complete the course to the best of your abilities.
General	Likert Scale	I learned everything that I was expected to learn.

Appendix B:
Pre-Test and Post-Test Questions

Groundwater Management Module				
Question	**Choice1**	**Choice2**	**Choice3**	**Choice4**
Is the following statement True or False? The term groundwater and groundwater management has been given inadequate attention and is not typically seen as an important and sustainable water resource for bulk supply that can be managed appropriately.	True	False		
Is the following statement True or False? To manage groundwater resources effectively, it is essential to better understand the quality, quantity and impacts of groundwater use.	True	False		
Management is defined as: "The attainment of organizational goals in an effective and efficient manner through .... and controlling organizational resources." Choose one of the following:	planning, organizing, leading	improvising, disorganize, following	development, determination, focusing	planning, determination, leading
Groundwater management is described as the assessment of .... aspects in terms of groundwater, and the impacts associated with supply, quality, quantity, sustainability and demands among different consumers and the optimization of exploitation and use. Choose one of the following:	geological and social	hydrologic and geographical	hydrologic and environmental	governmental guidelines and hydrologic
Moench et al. (2012) defined groundwater governance as: Choose one of the following:	"A simple act to coordinate and gather people to achieve a set of objectives and goals".	The process through which groundwater related decisions are taken and power over groundwater is exercised."	"The art of getting things done through people".	"The ability to get and implement results within a short time".
The process of making decisions is described as .... , while the process of implementing them is described as water management. Choose one of the following:	Water policies	Water management	Water Strategies	Water governance
What is regarded as the "building blocks" or the four basic functions of management? Choose one of the following:	Planning, organising, leading and controlling	Development, categorizing, managing and governing	Planning, development, determination and focus.	Organising, determination, controlling and governing.
Is the following statement True or False? The four basic management functions provide insignificant steps in the process to achieve organizational goals, and are not related to each other.	True	False		

Groundwater Management Module				
Question	**Choice1**	**Choice2**	**Choice3**	**Choice4**
The first foundation phase and the most important component of the four basic management functions is:	Organising	Controlling	Planning	Leading
For the development of a functional flow-diagram for groundwater management. The following components should be included: Select the incorrect component as your answer:	Data collection	Awareness	Previous Groundwater knowledge	Legal Framework
A hydrocensus is an:	excellent example of groundwater data collection	excellent example of groundwater monitoring	excellent example of groundwater governance	excellent example of groundwater policies
Is the following statement True or False? Monitoring is done by testing groundwater quality, recording the amount of groundwater used (abstraction rates) and the levels of groundwater.	True	False		
Municipal By-laws are described as a ………… that addresses public interest, enforce standards of conduct and are just like any other laws in the country.	dynamic government-implementation tool	dynamic management-implementation tool	dynamic monitoring-implementation tool	dynamic policy-implementation tool
Is the following statement True or False? Someone who does not act in accordance with the by-law can be charged with a criminal offence, receive a penalty or be challenged in court.	True	False		
Choose the most accurate answer: By developing Municipal by-laws we can manage groundwater resources effectively and place emphasis on……….	the protection of policies, and management.	the protection of legislation, and borehole construction.	the protection of sustainability, conservation and the protection of the environment.	the protection of polluted sites, and groundwater allocation.
Which of the following statements is false? In order to implement the effective protection of groundwater resources, the groundwater coordinator within a management area will need to have a broad understanding of:	Aquifer importance	The average rainfall	The role of groundwater in the broader environment	Potentially polluting activities.
Risk assessment and impact assessment provide important tools for prioritising actions where	human and financial resources are unlimited.	human and financial resources are limited.	pollution and groundwater resources are limited.	pollution and groundwater resources are unlimited.
Is the following statement True or False? A Groundwater Resource Governance Section, will ensure support to water services institutions in the operation, maintenance and management of groundwater supply schemes.	True	False		

Groundwater Monitoring Module					
Question	**Choice1**	**Choice2**	**Choice3**	**Choice4**	**Choice5**
Is the following statement True or False? Monitoring can be defined as the process of collecting data in a systematic manner that is used for a specific purpose.	True	False			
Is the following statement True or False? The absence of accurate and reliable groundwater data can compromise the accurate assessment and status of groundwater supply of the resource.	True	False			
Management decisions must be based on information, not on data. A lack of data and skills results in inadequate information for decision support and poor management of the resource. Choose the correct answer for the following statement. The hierarchy of monitoring information includes:	Decision, Knowledge, Understanding, Information and Data	Water laws, Water Policies and Water monitoring	Identify, Collect, Solve and Query	Data, Knowledge, and Reporting	
You can't manage, what you can't measure. Groundwater management can't be implemented without appropriate monitoring. Below is a list of typical objectives in relation to monitoring for groundwater management. Please pick two objectives that will form part of monitoring for groundwater objectives.	Development of water quality guidelines and/or standards	The impact of social media	The average rainfall in a catchment	Provide access to the groundwater system for collection of water samples	Raise awareness of the importance of investing in the collection and management of high-quality water-related information for supporting water resource management.
The purpose of monitoring is to:	Verify contaminated areas for effective water management.	Supply information and data and verify that groundwater levels and groundwater quality is suitable for intended users and uses.	Supply information on polluted boreholes.	Supply information on groundwater aquifers and verify the yield of boreholes.	
A monitoring cycle is a systematic planning process to develop acceptance or performance criteria for the collection, evaluation, or use of environmental data. The monitoring cycle generally describe the steps and processes for effective water management. Pick the correct answer to name these steps in the cycle:	Create a Facebook page, take pictures of boreholes, create social and public awareness.	Monitor location, frequency and data management.	Water management, define information needs, design monitoring programme, data collection, data storage, distribution and interpretation.	Water management, define water policies and design pollution action plan.	

Groundwater Monitoring Module					
Question	**Choice1**	**Choice2**	**Choice3**	**Choice4**	**Choice5**
Is the following statement True or False? Monitoring programmes are usually developed to support and assist various management actions with different objectives. Monitoring programs assist in the following: Monitoring locations, monitoring frequency, data and information management, record keeping and reporting.	True	False			
A number of factors play a role in determining the location of monitoring points. Please pick three factors that play a role in determining the location of monitor points.	Accessibility to groundwater	Depth of borehole	Pollution sources	Geology and geographical setting	Depth of groundwater table
Monitoring frequency is dependent on:	The purpose of sampling, type of sampling and depth of aquifer formations.				
Is the following statement True or False? In the monitoring design process, the following parameters should not be monitored; Groundwater level measurements, water flow/quantity monitoring systems, rainfall, field parameters, water quality and borehole development and yield testing.	True	False			
The depth to the water level in a borehole is also called the static water level or the rest water level. This is the groundwater level in a borehole not influenced by artificial recharge or by abstraction. These values are used to determine hydraulic gradient and the direction of groundwater flow. As what can the hydraulic gradient be described?	The rest water level	The abstraction rate	The slope of the water table	The water table	
Information can be provided for temporal trends in groundwater levels and flow direction due to the effects of groundwater abstraction, rainfall and drought by doing what kind of measurements?	Groundwater level monitoring measurements	Average rainfall measurements	Groundwater contamination measurements	Groundwater yield tests	
A dip meter is used to…	Determine the groundwater flow	Determine the groundwater quality	Determine the groundwater quantity	Determine the groundwater level	
A few steps are used in measuring the groundwater level. Pick one	Use safety glasses	Put sunscreen on	Use a reference point marked at each well.	Lower the dip meters probe recklessly into the piezometer/borehole until the audio signal, light indicator stops - this will be the position of groundwater level.	

Groundwater Monitoring Module				
Question	**Choice1**	**Choice2**	**Choice3**	**Choice4**
What is the most effective way to measure water flow?	Flow meter	Dip meter	TLC	Magnetometer
By testing field parameters on site, the assessment and analysis of various physical, chemical and microbiological features and variables in groundwater can be determined. Field testing methods include:	Water levels, yield, water flow and abstraction rate	Temperature, pH, EC, Eh, DO and alkalinity	Wind speed, soil sampling and elevation	pH, rainfall, soil density and acidity
pH is described as…	the measurement of the concentration of helium ions in a solution.	the measurement of the concentration of hard ions in a solution.	the measurement of ions in a solution.	the measurement of the concentration of hydrogen ions in a solution.
EC is an acronym for…	Electrical Conductivity	Ethernet Cable	Electrical Current	Eastern Cape
Is the following statement True or False? The principle behind purging a well prior to sampling is to remove stagnant water from the well bore to assure that the sample is representative of the groundwater in the geologic formation being sampled.	True	False		

Groundwater Quality				
Question	**Choice1**	**Choice2**	**Choice3**	**Choice4**
Is the following statement True or False? Water quality is a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for an intended purpose.	True	False		
Is the following statement True or False? Water quality management, involves the maintenance of the fitness for use of water resources on a sustained basis, by achieving a balance between socio-economic development and environmental protection.	True	False		
Is the following statement True or False? Deteriorating water quality leads to decreased treatment costs of potable and industrial process water, and increased agricultural yields due to increased salinity of irrigation water.	True	False		
Common water quality problems include:	Sanitation, geology and rainfall	Plastic bags and elevation	Salination, eutrophication, micro-pollutants, microbiological pollutants, erosion and sedimentation	Animals
Which of the following prominent principles DOES NOT form the basis of water quality management policies and practices in South Africa?	The management of water quality must be carried out in an integrated and holistic manner, acknowledging that all elements of the environment are interrelated.	Implementation of a National Pricing Strategy	The precautionary approach to water quality management applies, in which active measures are taken to avert or minimise potential risk of undesirable impacts on the environment.	Participative management in the management of water quality must be advocated, ensuring that all interested and affected parties, and previously disadvantaged persons have an equal opportunity to participate.
Hierarchy of water quality management decision-taking includes the following principles:	Pollution prevention, waste minimization, precautionary and differentiation principle	Water policies, social media and monitoring principles	Water law, contamination and pollution prevention principles	Instagram and Twitter
The National Water Act makes use of two different approaches to water quality management, they are:	Municipal by-laws and water policies	Resource directed water quality management and source directed water quality management	Pollution directed measures and groundwater quality	Facebook and Twitter

Groundwater Quality				
Question	**Choice1**	**Choice2**	**Choice3**	**Choice4**
Is the following statement True or False? Groundwater supplies merit protection because they are a vital resource for the supply of potable water in both rural and urban environments.	True	False		
Is the following statement True or False? Groundwater is usually unsafe to drink without treatment, unlike surface water.	True	False		
Aquifers may be polluted by	point source discharges or from diffuse pollutants	Geology elevation	Plastic bags	Cows
Is the following statement True or False? Groundwater quality management requires the assessment of pollution hazard and risk to groundwater, delineation of groundwater vulnerability zones, control of effluent discharges, as well as the construction of containment structures in order to avoid or reduce groundwater pollution.	True	False		
Groundwater quality may be measured by	Monitor Boreholes	Using a dip meter	Sampling and analysing the groundwater from selected wells	Measure the water flow rate
Groundwater quality management should be pro-active and attempt to prevent the contamination of groundwater resources, and thus avoid the lengthy, expensive and often ineffective remediation of contaminated aquifers. Groundwater protection initially involves two key aspects. They are:	Assessment of aquifer pollution vulnerability and mapping of groundwater pollution hazards	Borehole casings and electric fences	Monitoring and water policies	Abstraction rate and water flow
The protection of water quality in South Africa is to be achieved by the combination of few core strategies. Pick the INCORRECT strategy	Resource-directed strategies	Source-directed strategies	Remediation strategies	Protection-directed strategies
Pick TWO answers: Examples of resource-directed measures include:	Resource classification	Determination of resource management classes	Licenses	General authorisations
CMA is an acronym for:	Catch Many Apples	Catchment Management Agency	Condition Monitor Accreditation	City Management Agency
According to the National Water Act, how many uses of water specified by the National Water Act (Section 2) are there?	1	11	19	10

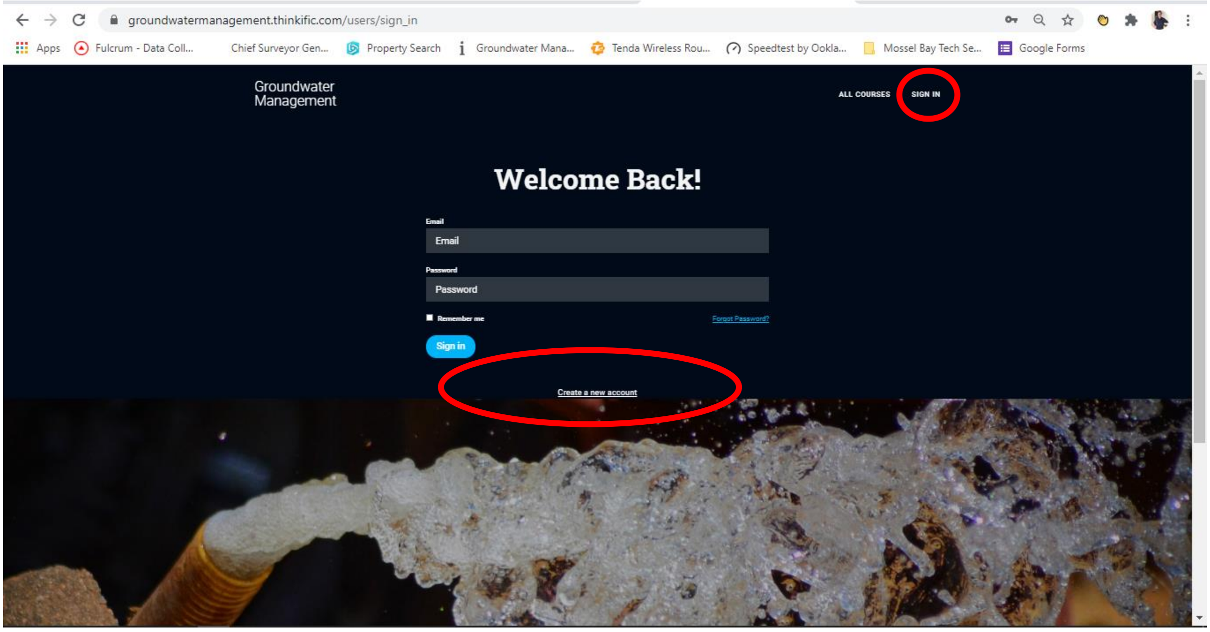
Groundwater Quantity				
Question	**Choice1**	**Choice2**	**Choice3**	**Choice4**
Is the following statement True or False? The country has limited water resources and is ranked globally amongst the twenty most water-scarce countries.	True	False		
South Africa's aquifer systems have received their water-bearing properties, in particular the permeability, through the region's historical geological and hydrological development and as a result of the physical and chemical composition of the different rock types. Permeability can either be termed primary or secondary. When is permeability termed primary?	If it is formed as the rock is formed (intergranular)	If it is formed in the rock formation itself	If it is formed after the rock formation has formed	If it is a rock
More than…………of South Africa is underlain by hard-rock, or secondary, aquifers controlled by secondary faulting and jointing.	20%	90%	70%	35%
Groundwater flow in an aquifer is governed by the aquifer's intrinsic characteristics (shape, size, permeability etc.) but also by its…	Abstraction	Elevation	Location	Recharge
Examples of known South African Aquifer-Dependent Ecosystems include: Pick the INCORRECT answer:	In-aquifer ecosystems in the dolomites (North West Province)	Springs and seeps in the TMG sandstone (Western Cape)	Table Mountain group	Lakes and punctuated estuaries on the shallow sand aquifers of the east and south coast
Groundwater contributes ………… % of all the water resources been used in South Africa	5%	10%	15 %	20%
GIS layers were developed for various levels within a conceptual aquifer system Level 1 - base of the aquifer Level 2 - base of the natural dynamic groundwater elevation Level 3 - current groundwater elevation Level 4 - average groundwater elevation What does level 5 represent?	Water level restriction	Top of the aquifer	Static storage zone	Dynamic storage zone
A basic water-balance approach, is where…	the change in storage in a system is unequal to all inputs to, plus all outputs from the system.	the change in storage in a system is equal to all inputs to, less all outputs from the system.	a system is equal to all inputs	the change in storage in a system
GRP is defined as the maximum volume (m3) of groundwater that can be abstracted per unit area per annum without causing any long-term 'mining' of the aquifer system. GRP is an acronym for?	Groundwater Recharge Potential	Groundwater Resource Potential	Great River People	Groundwater Radiation Potential
Is the following statement True or False? The Potable Groundwater Exploitation Potential (PGEP) of aquifers in South Africa is estimated at 14,802 Mm3/a, which declines to 12,626 Mm3/a during a drought.	True	False		

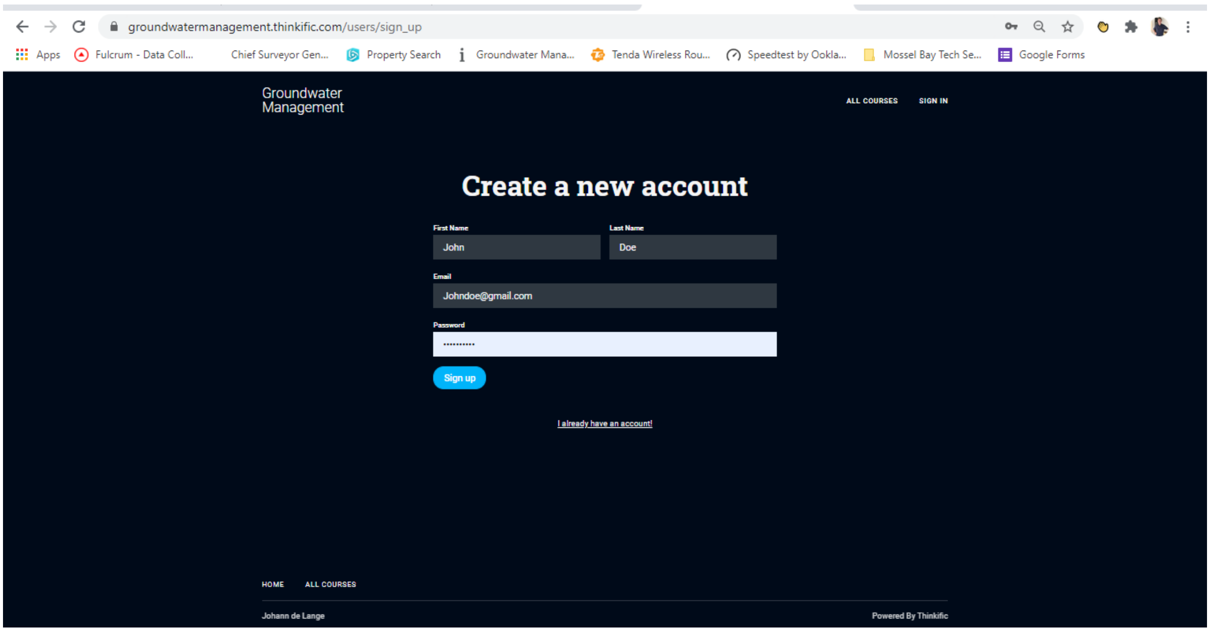
Groundwater Regulation				
Question	**Choice1**	**Choice2**	**Choice3**	**Choice4**
Is the following statement True or False? A licensing system for groundwater is aimed to introduce regulating interdependencies among water users and has wider benefits.	True	False	Improving economic efficiency	Implementing demand management programs to reduce groundwater abstraction
Choose three correct answers: The main objectives of a groundwater license system are established to:	Reduce the interference between abstraction wells	Resolve geological and geographical queries	Improving economic efficiency	Implementing demand management programs to reduce groundwater abstraction
Groundwater allocation is the process of determining how water ……………… Choose one of the following:	will be shared among the demand of different users and uses.	will be collected and protected.	will be monitored and manage.	will be governed.
The need for water allocation developed due to the fact of …………………………… that need to satisfy all the demands of the different users. Choose one of the following:	increasing scarcity of the water resource	hydrological and environmental impacts	governmental guidelines	an abundance water resource
Is the following statement True or False? Water allocation form a significant universal function of water management with the main objective to maximise the societal benefits derived from water.	True	False		
A suitable measure of groundwater resource allocation is necessary to achieve optimal allocation of the resource. Several criteria's are used in water allocation. Choose the one incorrect statement/criteria:	Flexibility in the allocation of water	Political and public acceptability	Protection of Municipal by-laws	Administrative feasibility and sustainability
For better water allocation the management of monitoring water resources and uses is important. Implementation tools that assist in this process include: Choose one Answer:	Monitoring, governance and water security	Water laws	Planning instruments, managerial guidelines, information systems and public education	A groundwater hydrocensus
The National Water Act makes use of two different kinds of processes, for effective resource protection.	Municipal by-laws and water policies	Resource directed measures and source directed controls	Source directed measures and resource directed controls	Facebook and Twitter
A balance between water resource protection and the use of a water resource is described as IWRM. IWRM is an acronym for?	intelligent water resource managers	integrated water resource monitoring	is water really manageable	integrated water resource management
Is the following statement True or False? The National Water Act states that the National Water Resource Strategy must: Contain and set a number of objectives for the establishment of institutions to undertake water resource management.	True	False		

Groundwater Regulation				
Question	**Choice1**	**Choice2**	**Choice3**	**Choice4**
Water resource management according to the National Water Act is divide into three distinctive institutions. Is it	Catchment management agencies, water user associations and international water management bodies.	Agricultural Research Council, Mhlathuze Water and the Department of Water affairs.	Transnet, Eskom and South Africa Airways	Rand Water, Water service Providers and Catchment management agencies.
CMA's is an acronym for:	Catch Multiple Apples	Catchment Monitoring Agencies	Countable Municipal Act	Catchment Management Agencies
How many Water Management Areas (WMAs) was establish in South Africa from the Catchment management agencies that is stipulated by the National Water Act (36 of 1998)?	18	19	9	16
What is the purpose of Catchment Management Agencies?	To delegate monitoring results to municipalities and primarily involve the public in the process.	To delegate water resource management to the regional or catchment level and primarily involve local communities in the process	To serves its members that is govern by a management committee	To catch fish
Is the following statement True or False? A Water User Association is an institution that serves its members and is govern by a municipal committee.	True	False		
WUAs allow people to be more active within a community and to combine their resources and expertise to effectively manage and carry out water-related activities. Some core functions of water user associations include the following: Please identify one incorrect core function:	Act as interface between consumers and management	Ensure and regulate optimum usage of groundwater and distribution	Encourage the unlawful use of groundwater	Prevent groundwater from being waste
The primary role and function for an international water management body is to	Implement groundwater regulations	Implement international agreements in terms of management and development of water resources shared with and between neighbouring countries	Implement groundwater policies	Involve stakeholders in the decision-making process
Is the following statement True or False? For an effective monitoring program at municipalities an operational groundwater licensing system and water allocation program need to be developed.	True	False		

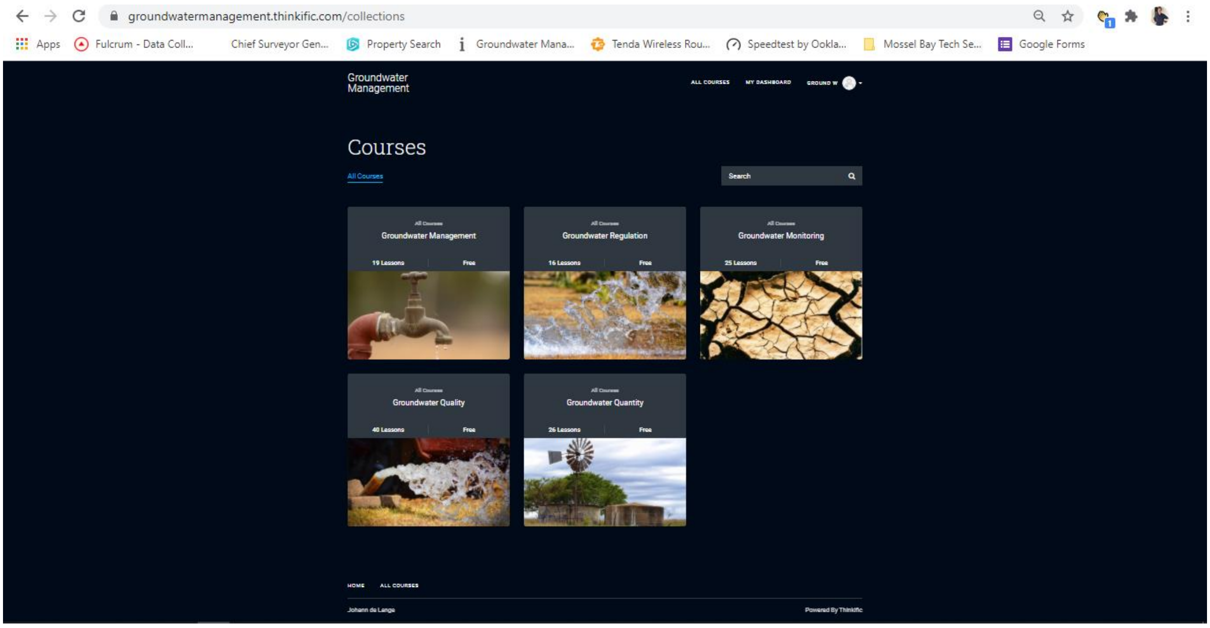
Appendix C:
Enrolment Guidelines

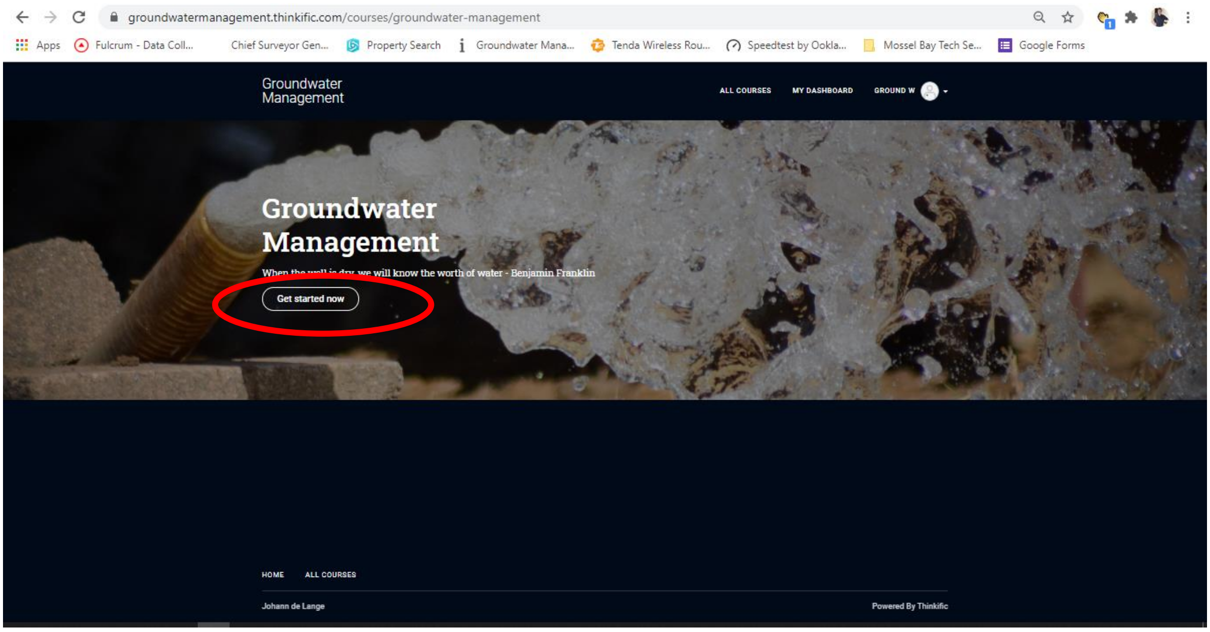
Step 1: Create a new account by clicking the "sign in" in button and then select the "create a new account" option. Complete the account creation process by filling out details such as first name, last name, email address and password.





Step 2: Select the preassigned course and select the option "Get started now". Participants would also receive a welcome email with sign in details.





Appendix D:
Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa

Training Manual for Groundwater Resource Management and Groundwater Governance for Municipalities in South Africa

Report to the

Water Research Commission

by

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Module 1: Hydrological Cycle

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1. Learning objectives

To understand and describe the following:

- Processes and components of the hydrological cycle and their purpose;
- Linkages between the hydrological cycle processes;
- Water balance equation; and
- Factors influencing the processes of the hydrological cycle and their interdependence.

1.1 Introduction

It is important to recognize and comprehend the basic concepts of water. The basic concepts can influence the quality and chemical characteristics of water, the amount available and prevent contamination. Water occurs in three phases: solid, liquid, and gas. It forms a distinguished feature of the Earth.

Depending on the environment in which water occurs, water can rapidly change its phase this plays an important role in the climate system. The concept of the hydrological cycle underlines the fact that water is both renewable and limited. With the absence of water there would be no global ecological system otherwise known as the biosphere and Earth would be a lifeless planet (Paisley, 2013).

1.2 Hydrological cycle

The term hydrologic cycle, also known as the water cycle, forms a conceptual model and a fundamental concept in hydrology and refers to the continuous movement and storage of water between the biosphere, atmosphere, lithosphere and hydrosphere (Heath, 1983).

The concept of the hydrologic cycle is critical in understanding the occurrence of water and the development and management of water supplies.

The cycle has no beginning or end and water is typically present in all three phases. This cycle forms one of the greatest natural processes and is vital for sustaining life on earth by providing water to plants, animals and humans. A graphic illustration of the hydrological cycle is given in Figure 1.1.

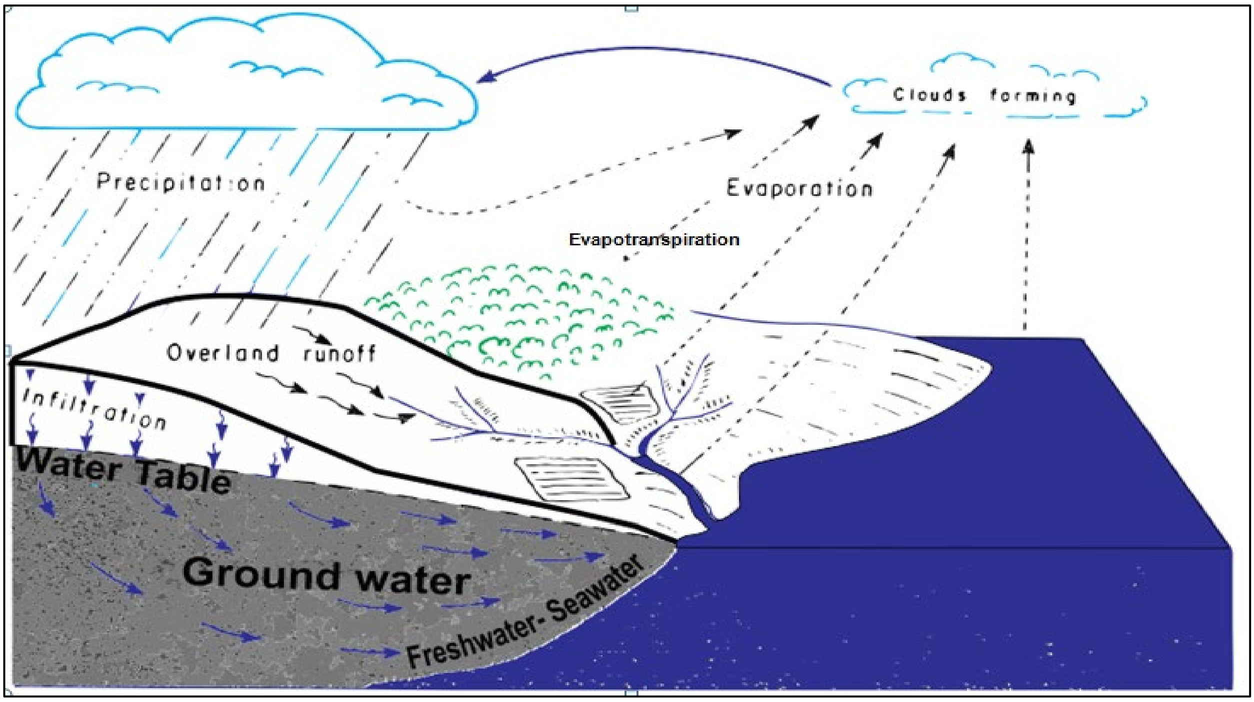

Figure 1.1: The Hydrological Cycle adapted from (Heath, 1983).

1.3 The process of the hydrological cycle

Water in the hydrological cycle is continuously exchanged and moved between the atmosphere and earth as illustrated in Figure 1.1. The driving forces associated with the hydrological cycle include the radiation from the sun. The result of heating of the ocean water by the sun is the key process that keeps the hydrologic cycle in motion. After and in the duration of a precipitation event, water will be typically divided into different portions and stages in the hydrological cycle. A portion of the water normally evaporates and returns directly to the atmosphere, a part of the remaining water will form runoff by water flow over the earth's surface and a percentage infiltrates into the soil (Johnstone *et al.*, 2010).

Once the water percolates into the soil, it may either be taken up by plant roots and some water may return to the atmosphere by transpiration. A certain amount of water also becomes part of our drinking water supply, or seep into lakes, streams, or oceans. Water and moisture in the atmosphere accumulates, and ultimately forms clouds, which return the land surface or oceans in the form of precipitation. Overland flow otherwise known as runoff occurs if the rate of precipitation exceeds the rate of infiltration. The first part of infiltration replaces soil moisture, and thereafter, the excess percolates slowly across the intermediate zone to the zone of saturation (Heath, 1983).

Water in this zone moves downward and laterally and results in ground-water discharge such as springs or seeps in the bottom of streams and lakes or beneath the ocean. The cycle of water by means of precipitation and evaporation or evapotranspiration is called the hydrologic cycle (Jensen, 1999).

1.4 Components of the hydrological cycle

1.4.1 Evaporation

Evaporation is defined as a slow transition of a liquid substance into the gaseous state. As water is heated by the sun, it creates energy that causes surface molecules to become energized and break free from the force binding them together. This normally leads to the transition between liquid substance and gas, where the water evaporates and rise into the atmosphere (Environment and Climate Change Canada, 2013). The majority of evaporation occurs from the oceans, and wind increases the rate of evaporation.

1.4.2 Transpiration

This is the process where plants released water vapour from their leaves and stems by a process called transpiration. Plants only use about 1% of water for growing purposes while the rest is released back to the atmosphere (Csaba & Juhász, 2011).

1.4.3 Condensation

Condensation is the terminology for the transition from water vapour (gaseous form of water) into liquid water. This process occurs in the atmosphere when warm air rises with its water vapour content, cools and loses its capacity to hold water vapour. Water vapour ultimately condenses. When it condenses it becomes a liquid again or turns directly into a solid (ice, hail or snow). The condensing water droplets form the clouds (Environment and Climate Change Canada, 2013).

1.4.4 Precipitation

Precipitation refers to the various forms of atmospheric water falling onto, or condensing on, the Earth's surface for instance rain, snow and hail. In principle, precipitation is caused by condensation of water vapour once the air is cooled to its dew-point. The cooling is generally caused by adiabatic expansion of the uplifted air, due to the decrease in atmospheric pressure with height. Precipitation is a major element of the hydrologic cycle, and is responsible for the fresh water on the planet (International Atomic Energy Agency, 2000).

1.4.5 Runoff

Runoff also known as overland flow or surface runoff is the flow of water that occurs when excess water flows over the Earth's surface. This process occurs because the underlying soil is saturated and reached it full capacity, or because rain precipitates more quickly than soil can absorb it, or because of manmade areas such as roofs, streets and pavements. Runoff is also seen as visible flow of water in rivers, creeks and lakes as the water stored in the basin drains out.

1.4.6 Percolation

Some of the precipitation and snow percolates and infiltrates through cracks, joints and pores in soil and rocks until it reaches the water table where it becomes groundwater.

1.4.7 Groundwater

Groundwater is water that exists in the pore spaces and fractures in rock and sediment beneath the earth’s surface. It is naturally replenished by surface water from precipitation or snow and then moves through the soil into the groundwater system where it recharges the water table. Depending on the geology, the groundwater can support the flow of streams.

1.4.8 Water table

The water table is the upper surface of the saturated zone of an unconfined aquifer at which pore pressure is equal to that of the atmosphere. This is the interface between the unsaturated zone and groundwater and may rise and fall seasonally.

1.5 Factors influencing the processes of the cycle

1.5.1 Runoff

The absence of vegetation or the disturbance on the land surface by factors and activities such as construction, agriculture, logging, or mining often reduce infiltration rates and increase runoff. The result of excessive runoff can typically create erosion and carry sediments or other pollutants into lakes, streams, and wetlands (Johnstone *et al.*, 2010).

1.5.2 Evapotranspiration

The rate of evapotranspiration at any location on the Earth's surface is controlled by several factors (Csaba & Juhász, 2011):

- Energy availability: The more energy available, the greater the rate of evapotranspiration.
- The humidity gradient
- The wind speed
- Water availability: Evapotranspiration cannot occur if water is not available.
- Physical attributes of the vegetation.
- Soil characteristics

1.5.3 Infiltration

Factors that influence and affect infiltration include (U.S. Geological Survey, 2016);

- Precipitation
- Base flow
- Soil characteristics:
- Soil saturation
- Land cover
- Slope of the land
- Evapotranspiration

1.6 Water Balance

A combination of field experiments and water balance modelling can provide us with a better understanding of the components of the hydrological cycle from which to develop appropriate management options.

The term water balance is based on the law of conservation of mass. This law according to Zhang, Walker and Dawes (2002), states that any change in the water content of a specified soil volume during a identified period must be equal to the difference between the amount of water added to the soil volume and the amount of water withdrawn from it.

A water balance can thus be established for any given area of the earth's surface by calculating the total precipitation input and the total of various outputs. The purpose and aim of the water balance is to describe the various ways in which the water supply is expended. The water balance is a method by which we can account for the hydrologic cycle of a specific area, with emphasis on plants and soil moisture.

The water balance is defined by the typical hydrologic equation and can be assessed for any area and for any period of time.

Inflow = Outflow + Change in Storage

The water balance is basically a statement of the law of conservation of mass as applied to the hydrologic cycle.

1.7 Summary

The hydrological cycle is usually described as a recurring effect with a variety of forms of movement of water and changes of its physical state on a given area of the Earth. The main processes of the hydrological cycle consist of: precipitation, infiltration of water into soil, evapotranspiration, recharge of groundwater and ground flow, runoff and movement of water in river channel systems.

1.8 Exercises and tasks

1. Describe the Physical processes which make up the hydrological cycle.
2. Illustrate the water cycle with all of its components.
3. Name and explain two factors that influence the hydrological cycle.
4. Define the water balance and explain the water balance equation.

1.9 Report from student for evaluation and assessment

1.9 Reference

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Module 2: Water Law

Contents

2. Learning objectives

To understand and describe the following:

- To appreciate the need for legislation of Water
- To understand the key components of water legislation and the Water Act
- Applicable laws and by-laws.

2.1 Introduction

Water Legislation aims to regulate the relationship between persons and between the people and the state administration on water resources. It includes all legal provisions on development, use, protection and management of groundwater resources, which may be either scattered in various enactments or integrated into a comprehensive water law. South Africa is significant in terms of its water law and policy and is the most advanced.

The National Water Act and the Water Services Act should be used within each other side to side in regard to the water management regime in the Republic. The Water Services Act provides the tools and laws to ensure that all South Africans have access to a basic water supply and sanitation.

2.2 Why water legislation

Water legislation is required to regulate water development, limit activities that can compromise water availability, sustainability and quality, concentrate on the increasing competition and associated conflict between water users, and address the threat to water pollution (Eduvie, no date).

According to University of California, 2014 Groundwater Legislation is responsible to:

- Adopts a state definition of “sustainable groundwater management”
- Empowers local agencies to achieve sustainability
- Establishes a uniform framework for local groundwater management planning
- Respects regional differences and provides local agencies flexibility to tailor plans that meet their needs
- Provides state technical assistance
- Improves coordination between land use and groundwater planning

- Provides for state review of groundwater plans and limited state intervention authority when local action has been insufficient
- Protects water rights

Numerous government municipalities have introduced legislation to regulate water and groundwater development and to limit activities that might compromise groundwater availability and quality (Nanni *et al.*, no date).

2.3 Basic Legal Concepts

It is of great magnitude to know and note the difference between the concepts of ‘legislation’ from that of ‘law’.

Legislation is defined as a written law, enacted by a body or person authorised to do so by the Constitution or other legislation. While the term law referred to the complete system of rules that everyone in a country or society must obey. According to the terms stipulated in section 2 of the Interpretation Act 33 of 1975, ‘law’ refers to “…any law, proclamation, ordinance, Act of parliament or other enactment having the force of the law.”

2.4 Components of legislation

Contemporary legislation of groundwater must, be flexible, enforceable and enabling. As a result must basic legislation be limited to fundamental powers and concepts, and the detail associated with regulations and implementation plans.

Some of the specific provisions and components of legislation are discussed below according to (Owen *et al.*, 2010).

2.4.1 Water Abstraction and Use Rights

Water rights along with other factors provide the foundation for abstraction and the right to abstract or divert water. The right to abstract or divert water including groundwater can be granted to individuals, public entities, or private corporations, under certain terms or conditions. Such rights are commonly issued by the water resources authority or by the law courts directly.

2.4.2 Wastewater Discharge Licensing

The licensing of wastewater discharges is designed to protect water against pollution. The ‘polluter-pays principle’ is normally embodied within this area of legislation.

Other components of legislation include:

- Catchment or Aquifer Level Resource Planning
- Conjunctive Use of Groundwater and Surface Water
- Land Surface Zoning for Groundwater Conservation and Protection
- Facilitating Water-User and Stakeholder Participation
- Provisions for Groundwater Monitoring

2.5 Institutional arrangements

Water legislation should ensure the enabling environment is established for effective management of water resources, including groundwater.

2.5.1 Water Boards

Government-owned Water Boards play a key role in South African water sector and resource management. They operate dams, bulk water supply infrastructure, some retail infrastructure and some wastewater systems.

The water boards typically report to the Department of Water Affairs. There are 15 different Water Boards in South Africa.

Any municipality responsible for ensuring access to water service in the Act is defined as the Water Service Authority. This authority may perform the functions of a Water Service Provider, and may also form a joint venture with another water services institution to provide water services.

2.6 Implementation of (ground) water legislation

Successful implementation of (ground)water legislation depends on a number of factors according to Owen *et al.* (2010) and include:

- The administrative set-up and the level of training of water administrators
- A clear understanding of the institutional roles and functions at all relevant levels

- An adequate level of public awareness and acceptance of legal provisions
- Political willingness to promote and attain sustainable groundwater management.

2.7 The National Water Act

2.7.1 Purpose of the Act

According to the National Water Act 36 of 1998, the purpose of the Act is to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways which take into account, and include the following factors:

a) meeting the basic human needs of' present and future generations;
b) promoting equitable access to water;
c) redressing the results of past racial and gender discrimination;
d) promoting the efficient, sustainable and beneficial use of water in the public interest;
e) facilitating social and economic development;
f) providing for growing demand for water use;
g) protecting aquatic and associated ecosystems and their biological diversity;
h) reducing and preventing pollution and degradation of water resources;
i) meeting international obligations;
j) promoting darn safely;
k) managing floods and droughts.

The Act provides that national government is the public trustee of the nation's water resources and requires it 'to ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons and in accordance with its constitutional mandate'.

The Ministry of Water Affairs and Forestry is responsible to 'ensure that water is allocated equitably and used beneficially in the public interest, while promoting environmental values'. Catchment management agencies and the water resource classification system act as practises that help to meet the above mentioned objectives.

2.7.2 Water Use

Pending a final determination of the Reserve, the Act provides for a preliminary determination, which is a necessary prerequisite for the authorisation of a water use. The term “Water Use” is widely defined by the Act to not only include the ‘use’ of water but also activities that could have an adverse impact on water resources.

Water uses identified in terms of section 21 of the National Water Act (Act 36 of 1998) as:

- 21a) taking water from a water resource;
- 21b) storing water;
- 21c) impeding or diverting the flow of water in a watercourse;
- 21d) engaging in a streamflow reduction activity contemplated in Section 36 of the Act;
- 21e) engaging in a controlled activity identified as such in section 37(1) or declared under section 38(1);
- 21f) discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit;
- 21g) disposing of waste in a manner which may detrimentally impact on a water resource;
- 21h) disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process;
- 21i) altering the bed, banks, course or characteristics of a watercourse;
- 21j) removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people;
- 21k) using water for recreational purposes.

The Act provides that a person wishing to use water must be licenced to do so, except in three situations -

1. Uses of water that are likely to have sufficiently insignificant impacts on water resources.
2. Applies if the water use is a continuation of an existing lawful use.
3. Water use permissible in terms of a general authorisation.

2.8 Summary

The National Water Act (No. 36 of 1998) is an Act to provide for fundamental reform of the law relating to water resources. The purpose of this Act is to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled.

The National Government is responsible for the allocation and use of water resources to ensure the sustainable use through the protection of the quality of water resources for the benefit of all water users.

2.9 Exercises and tasks

1. Explain the need for water legislation
2. Define the term Law and Legislation
3. Describe the concept Water boards
4. Name and explain two components of Legislation
5. What is the Purpose for the Water Act and describe the term ‘water use’ in detail

2.10 Report from student for evaluation and assessment.

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Module 3: Groundwater Management

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3. Learning objectives

To understand and describe the following:

- Meaning of groundwater management, and
- Flow-diagram illustrating the groundwater management process at Municipalities for bulk groundwater supply,
- Understanding the functions of management.

3.1 Introduction

Water is our present, past and future and essential to life and may be the most reusable and recyclable commodity on earth (Azad, 1976). The Bill of Rights of The Constitution of South Africa Act (1996) section 27(1)(b), stated that; "Everyone has the right to have access to sufficient food and water..." and section 24(a) stated that; "Everyone has the right to an environment that is not harmful to their health or well-being...". It's therefore important to manage and monitor the state of water, in particular groundwater resources and environmental trends, so that it is possible to deal with problems related to sustainability, water scarcity and efficiency.

In South Africa, the term groundwater and groundwater management has been given inadequate attention and is not typically seen as an important and sustainable water resource for bulk supply that can be managed appropriately. Regardless of this, many municipalities is reliant on groundwater resources and manage it successfully.

A generally accepted principle is that "prevention is better that cure" and to manage groundwater resources effectively, it is essential to better understand the quality, quantity and impacts of groundwater use.

3.1.1 Importance of Groundwater for Management

Groundwater is a vital concept worldwide and many nations and various people and many industrial premises depend on it for their water supply. Accelerated development over the past few decades has resulted in great social and economic benefits, by providing low-cost, drought-reliable and (mainly) high-quality water supplies for both the urban and rural population and for irrigation of (potentially high value) crops.

In South Africa's most water supplies in small towns originate from groundwater sources. These are geographically widespread and almost two-thirds of South Africa's population depend on them for their domestic water needs, states the Department of

Water Affairs (DWA). Therefore awareness and understanding will assist with the proactive management of groundwater in South Africa (Knüppe, 2010).

3.2 GROUNDWATER MANAGEMENT

3.2.1 Defining Groundwater management

In order to evaluate and better comprehend groundwater management, general terms and concepts need to be discussed, to obtain a broader understanding and perspective of what groundwater management entails.

Daft and Marcic (2012) defined management as:

"The attainment of organizational goals in an effective and efficient manner through planning, organizing, leading, and controlling organizational resources."

Or as Mary Parker Follett (1868-1933) (Barrett, 2003) defined it as:

"Management is the art of getting things done through people"

Management can thus be described as a simple act to coordinate and gather people to achieve a set of objectives and goals.

3.2.2 Management vs governance

Groundwater resources management and groundwater governance are closely related but are two different processes. These two processes normally comes into effect when societies realise that actual conditions urge that human efforts related to groundwater should go beyond plain exploitation.

Governance and management are different processes but not different scales of action. Both processes can take place together at local, regional, national or global scales (Seward and YXU, 2015).

Groundwater management is formerly described as the assessment of hydrologic and environmental aspects in terms of groundwater, and the impacts associated with supply, quality, quantity, sustainability and demands among different consumers and the optimization of exploitation and use (Willis and Yeh, 1987). Groundwater management involves the ability to get and implement results within a short time.

In addition to groundwater management, Moench *et al*. (2012) defined groundwater governance as:

"The process through which groundwater related decisions are taken (whether on the basis of formal management decisions, action within markets, or through informal social relations) and power over groundwater is exercised."

Governance is usually carried out by an authority in power & takes into consideration the requirements of its subjects, though it may fail in many aspects.

Therefore we can agree with Jonker *et al*. (2010) that the process of making decisions is described as water governance, while the process of implementing them is described as water management.

3.2.3 Functions of Management

Management is normally divided and distinguish in four basic management functions and is regarded as the building blocks for management. These "building blocks" is categorized as planning, organising, leading and controlling Figure 1. We can't develop a framework for groundwater management without first discussing and understanding these building blocks. These functions or so called "building blocks" provide valuable steps in the process to achieve organizational goals, and are related and interrelated to each other.

Figure 1: The four basic management functions

3.2.3.1 Planning

Planning is the first foundation phase and the most important component of the four building blocks. It involves the process of selecting certain objectives and determines a sequence of steps and actions that need to be followed to achieve those objectives. Planning requires the process of being conscious about the challenges and encounters facing a business or organisation and to predict future economic and business encounters. Formulation of objectives and steps on how to reach deadlines can then be implemented. After the assessment of various alternatives as conditions change, decisions can be made on the best steps of help allocate resources. Good management consist of good planning and it is always an ongoing process.

3.2.3.2 Organising

Organising is the process of management and can be described as the steps to develop an organising structure and assigning available resources to ensure that all objectives will be accomplished successfully and efficiently. To be able to organise effectively all activities to be accomplished must be identified, classified, assigned to individuals and delegated. Without the organising step, organisations and businesses will have no structure and is likely to fail.

3.2.3.3 Leading

Leading can also be described as guiding or directing and is the process of motivate, influence, communicate and forming effective groups to achieve the business goals and objectives. The most important aspect of leading is good communication skills. This can be accomplished by assessing one another, good and effective problem solving skills and building positive relationships. This building block helps to move the organisation and company towards better goal achievement.

3.2.3.4 Controlling

The last building block of management involves ensuring and measuring achievements in contrast to the previous selected goals and objectives. It can thus be described as process to establish if plans are still being followed and implemented, and track the progress being made. Controlling also requires managers to act fast and be able to identify sources of deviation from successful achievement of goals, and to provide an alternative course of action.

3.2.4 Groundwater management

In evaluating management according to its definitions and functions, a better picture developed about the process of groundwater management.

Groundwater management is generally described as the assessment of hydrologic and environmental aspects in terms of groundwater, and the impacts associated with supply, quality, quantity, sustainability and demands among different consumers and the optimization of exploitation and use (Willis and Yeh, 1987).The management of groundwater resources for beneficial use means the intervention in matters concerning water that could include planning, design and operation of hydraulic works. It assumes that an authority exist that will be influential enough to impose decisions upon individuals or influence people’s behaviour.

Through adapting and understanding the four functions of management mentioned earlier as planning, organising, leading and controlling we can develop a functional flow-diagram for groundwater management. The flow diagram should include the following components:

- Data collection, capturing and monitoring
- Planning
- Data analysis
- Protect
- Awareness
- Legal Framework

3.2.4.1 Data collection, capturing and monitoring

It is impossible to develop an acceptable groundwater management strategy for a certain region without a good knowledge about the resource. Applying groundwater management without successfully collecting, capturing and monitoring groundwater related date would be impractical. A number of basic information is required to be able to manage groundwater effectively, and the more intensive groundwater abstraction become the more data are required for the management thereof.

Data collections must occur over long consistent periods to create a time series to identify variation and trends in data and correlate any change in the groundwater environment. Existing reports may be obtained and used for some data collection, but in most cases additional field work is required. Collection of data includes topographic and geologic data as well as an accurate hydrological survey. Hydrologic survey data includes the groundwater pump and rest levels, borehole locations, water abstraction rates, quantity and quality. A hydrocensus is an excellent example of groundwater data collection and is a task that consists of collecting information on water features, water supply sources and sources of potential. In addition to this, rainfall data are also very valuable.

In the process of monitoring data, an estimation of the amount of water we use and the quality thereof is established. Monitoring is done by testing groundwater quality, recording the amount of groundwater used (abstraction rates) and the levels of groundwater. Monitoring is an essential element of any effort to integrate groundwater science with water-management decisions and is an ongoing process (Holliday, Marin and Vaux, 2007).

3.2.4.2 Legal framework

Effective ways of creating groundwater management is to establish and implement municipal by laws. Municipal By-laws is a kind of law, better described as a form of delegated legislation created by local government and must be distinguished from common law. These by-laws must be approved and authorised by a Municipal Council to regulate the affairs and the services that a municipality provides within its area of jurisdiction. The Constitution of the Republic of South Africa (1996) section B of Schedule 4 and 5, gives specified authority and capabilities to local government, that enable a Municipality to create a by-law. A by-law is thus developed with a purpose and vision to control a situation in an attempt to govern all possibilities.

By-laws are described as a dynamic policy-implementation tool that addresses public interest, enforce standards of conduct and are just like any other laws in the country. Someone who does not act in accordance with the by-law can be charged with a criminal offence, receive a penalty or be challenged in court. Legislation like by-laws allows communities to be more involved in local government affairs, and encourage municipalities to engage more in communities.

3.2.4.2.1 Need for by-laws

By developing by-laws we can manage groundwater resources effectively and place emphasis on the protection of sustainability, conservation and the protection of the environment. By focusing on the need for by-laws one often overlooks other targeted focus points for by-laws in groundwater management such as:

- Polluted sites in regards to Groundwater
- Borehole Construction and Abandonment
- Groundwater Quality and Quantity
- Groundwater Monitoring and Maintenance
- Groundwater Allocation and Access

It is important to remember that by-laws serve no purpose if it is not implemented and enforced.

3.2.5 THE ROLE OF THE GROUNDWATER COORDINATOR

In order to realise the effective protection of groundwater resources, the groundwater coordinator within a management area will need to have a broad understanding of:

• Aquifer importance

• Aquifer vulnerability

• The role of groundwater in the broader environment

• Potentially polluting activities.

• Aquifer protection

A differentiated approach will be needed to make best use of available resources and ensure that least risk is posed to the most important aquifers. The groundwater coordinator will need to understand where groundwater resources are most vulnerable in the catchment, and liaise with land-use planners to ensure that contamination threats are minimised.

Risk assessment and impact assessment provide important tools for prioritising actions where human and financial resources are limited. The effectiveness of these measures in protecting groundwater resources must be measured by appropriate monitoring and assessment, which is used to refine protection programmes.

Effective communication with groundwater users, industry, farmers and other catchment managers will be the key to protecting aquifers. Punitive measures alone will not bring about the desired levels of protection. It will be necessary that a range of important stakeholders in the catchment have an appreciation of groundwater value and vulnerability.

3.3 SUMMARY

For sustainable Groundwater Management, the following actions are necessary:

- Ensure the implementation of existing strategies, regulations and guidelines on groundwater management such as the Artificial Recharge strategy and others.
- Establish a Groundwater Resource Governance Section, which will ensure support to water services institutions in the operation, maintenance and management of groundwater supply schemes. Functions must include the evaluation of artificial recharge potential and conjunctive use schemes.

A key finding has been that groundwater management links to groundwater-dependent sectors like agriculture, rural development, health and environment are not well established in policy or in practice. Internationally, there is a recognition that such a situation, although quite common, can only be addressed through a long-term process through which viable national, regional and local systems can evolve, within a strategic framework in which these intended relationships between diverse sets of interventions or management approaches and the development goals are brought out. Key issues are clarity on the roles and responsibilities of different institutions and the creation of effective co-ordination mechanisms between different agencies.

3.4 Exercises and tasks

1. What is your municipality already doing to manage their groundwater efficiently?
2. What does your Municipality see as the most important Groundwater management issues to take up next?
3. How do politics and socio-economic factors affect the process of managing groundwater in your municipality?
4. In your opinion, please explain the sustainable Groundwater development in terms of the four basic management functions.
5. What is the main difference between groundwater management and governance?
6. Does your municipality have any bylaws which are already implemented? If yes, then please name them, if not please indicate what bylaws you would want at your municipality for effective management.

3.5 Further Reading

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Module 4: Groundwater Regulation

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4. Learning objectives

To understand and describe the following:

- Groundwater licensing;
- Groundwater allocation;
- Groundwater protection; and
- Groundwater Institutions.

4.1 Introduction

Groundwater regulation form a fundamental role and is normally required in order to control and regulate groundwater development and activities that might compromise groundwater quality and availability, to address increasing competition and conflict between groundwater users, and to control the increasing threat of groundwater pollution.

Water regulation forms an important groundwater management strategy that is implemented through implementation and development of a licensing and water allocation system.

4.2 Groundwater licensing

4.2.1 Need for a groundwater licensing system

A licensing system for groundwater is aimed to introduce regulating interdependencies among water users and has wider benefits. The main objectives of a groundwater license system are established to (Dinar, Rosegrant and Meinzen-dick, 1997):

- Reduce the interference between abstraction wells,
- Avoid counterproductive conflicts that may arise,
- Resolve emerging disputes between neighbouring abstractors,
- Fostering the participation of water users in groundwater management,
- Improving economic efficiency,
- Implementing demand management programs to reduce groundwater abstraction,
- Systematic collection of abstraction charges to raise revenue for resource management,

- Possible subsequent trading of abstraction rights to promote more efficient water use,
- Developing conjunctive use of surface water and groundwater resources.

4.3 Groundwater allocation

4.3.1 Groundwater allocation defined

Groundwater allocation is the process of determining how water will be shared among the demand of different users and uses. The need for water allocation developed due to the fact of increasing scarcity of the water resource in terms of desirable quality and quantity that need to satisfy all the demands of the different users (Tandi, no date). Water allocation form thus a significant universal function of water management with the main objective to maximise the societal benefits derived from water. These benefits can be classified as economic, social and environmental, each with a corresponding principle such as efficiency, equity and suitability (DINAR *et al*., 1997) .Non-renewable resources such as groundwater need the implementation of a groundwater abstraction rights system. This must be consistent with variable factors such as fluctuating groundwater levels, decreasing well yields and the deterioration of groundwater quality (Owen *et al.*, 2010).

4.3.2 Criteria for allocation

A suitable measure of groundwater resource allocation is necessary to achieve optimal allocation of the resource. Economic, social and environmental factors form the basis for water resource allocations and objectives and should be well-defined to ensure that groundwater is available for human consumption, sanitation, and for food production (Dinar, Rosegrant and Meinzen-dick, 1997).

Howe, Schurmeier and Shaw (1986), described several criteria's used in water allocation (Owen *et al.*, 2010) (Dinar, Rosegrant and Meinzen-dick, 1997):

- Flexibility in the allocation of water, so that the resource can be reallocated from use to use, place to place, for more social benefits, economic and ecological uses through periodic review, and avoiding perpetuity in allocation;
- Security of tenure for established users, so that they will take necessary measures to use the resource efficiently; security does not conflict with flexibility

as long as there is a reserve of the resource available to meet unexpected demands;

- Predictability of the outcome of the allocation process, so that the best allocation can be materialized and uncertainty (especially for transaction costs) is minimized. Equity of the allocation process should be perceived by the prospective users, providing equal opportunity gains from utilizing the resource to every potential user.
- Political and public acceptability, so that the allocation serves values and objectives, and is therefore, accepted by various segments in society.
- Efficacy, so that the form of allocation changes existing undesirable situations such as depletion of groundwater, and water pollution, and moves towards achieving desired policy goals.
- Administrative feasibility and sustainability, to be able to implement the allocation mechanism, and to allow a continuing and growing effect of the policy.

4.3.3 Groundwater allocation

Groundwater needs to be allocated in a manner that will allow activities reliant on water to have access to a sufficient and reasonably reliable supply. Restrictions and limits on the amount of water allocated must be set for sustainability and protection of the resource. Therefore all water users should be identified, registered and monitored for an allocation system to work (Tandi, no date).

Water allocation has usually been provided to meet demand with significant involvement of governments. The allocation by governments, typically described as public allocation, has been used to manage groundwater effectively by laws, policies and registrations (Dinar, Rosegrant and Meinzen-dick, 1997).

According to White Paper on a national water policy for South Africa (1997), under the allocation licensing policy (Section 6.2.2), all existing and new water users will have to apply for registration of their water use within a certain period. The basis of registering and granting a licence to water users will be of beneficial interest to the public and assist in the process of managing the resource.

Applications for licensing procedures and registrations will be evaluated and assessed systematically according to priority areas (Department of Water Affairs and Forestry, 1997). Areas that will be considered first normally include water stress areas, environmental damage areas and competition between users. An assessment of groundwater resources must be conducted before any allocation. Allocations is typically specified in terms of the location of water use, the volume of water to be used, the time at which it is to be abstracted, its quality and reliability areas (Department of Water Affairs and Forestry, 1997).

The allocation system should "promote use which is optimal for the achievement of equitable and sustainable economic and social development" (Levy and Xu, 2011).

For better water allocation the management of monitoring water resources and uses is important. Implementation tools that assist in this process include planning instruments (monitor aquifer quantity/quality, water users and population), managerial guidelines (steps to monitor and evaluate applications), information systems (software to manage applications) and public education (political and public awareness).

4.4 Groundwater protection

Protection of our water resources is critical at this point. South Africa is currently facing a serious drought and the threat of water shortages in major centres. Water resources natural functionality should be preserve if we are to ease the effects of water scarcity. In 1998, the National Water Act was promulgated and places emphasis on the purpose to ensure the optimal and sustainable use and protection of limited water resources.

The National Water Act makes use of two different kinds of processes, for effective resource protection. Resource directed measures (RDM) are the first process that set a number of objectives that will determine the desired level of protection for each resource. The second process is source directed controls. The purpose of source directed controls is to control and manage the impacts in relation to water resources so that the resource protection objectives are achieved.

The National Resource Strategy 2 (2013), developed in South Africa, indicates strategic actions and objections for water resource protection (Corrigan, 2015): Manage for sustainability by using Resource Directed Measures (RDM) to set and approve a management class, and associated reserve and resource quality objectives, for every significant water resource in the country.

- Invest in strategic water resource areas by increasing their protection status.
- Maintain National Freshwater Ecosystem Priority Areas (NFEPAs) in good condition and include them in protected area network expansion plans, where appropriate.
- Invest in the strategic rehabilitation of key catchments to improve water quality and water quantity through Natural Resource Management Programmes (NRM).
- Minimise pollution from wastewater treatment works into surface and groundwater resources.

A balance between water resource protection and the use of a water resource is described as integrated water resource management (IWRM). The protection and management of water resources is important because the lack thereof can be inefficient and expensive.

4.5 Groundwater Institutions

Institutional arrangements on municipal levels are needed such as institutions to have an effective regulatory environment where rules and goals (objectives) can be correctly executed. There is a variety of institutions involved in groundwater management to manage development, regulate changes, conserve, restore and protect groundwater resources.

The National Water Act states that the National Water Resource Strategy must:

- Contain and set a number of objectives for the establishment of institutions to undertake water resource management; and
- Determine the inter-relationship between institutions involved in water resource management.

It is important to note that all water resources management institutions must function in accordance with the National Water Resource Strategy. Therefore it is stipulated that water resource management according to the National Water Act (NWA) is divide into three distinctive institutions (figure 1) specifically catchment management agencies (CMAs), water user associations (WUAs) or international water management bodies (IWMBs).

At the national level, the minister of water affairs is overall responsible for effective water management and the Department of Water Affairs (DWA) role is to provide a "national policy and regulatory framework" for regional and local institutions to conduct the management of water resources (Department of Water Affairs and Forestry, no date).

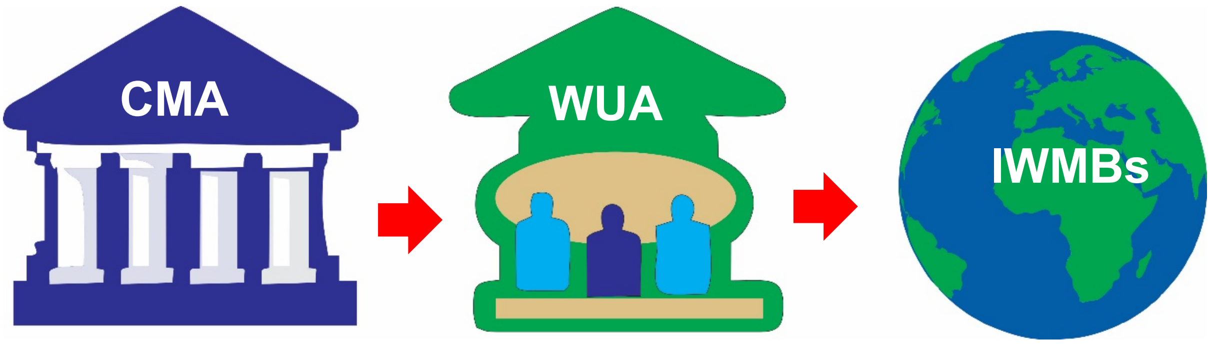

Figure 1: The three distinctive institutions

4.5.1 Catchment Management Agencies (CMAs)

A statutory body established in terms of the National Water Act is referred to as a catchment management agency (CMA). CMAs will be governed by a board, which is appointed by the minister and will begin operating as soon as the governing board has been appointed (DWAF, 2000). The governing board must reflect and represent the interests of all relevant sectors and stakeholders, as well as their interests in the water management area.

The establishment of the 19 water management areas in South Africa from the Catchment management agencies (CMAs) is stipulated by the National Water Act (36 of 1998).

4.5.1.1 Purpose of CMAs

The purpose of a CMA is to delegate water resource management to the regional or catchment level and primarily involve local communities in the process. CMAs form therefore the fundamental course of action for managing water resources at catchment management level (DWAF, 2000). CMAs are also required to seek co-operation between various stakeholders and interested persons on water related matters (Department of Water Affairs and Forestry, no date).

Other important purposes of CMA involved the management of water resources and the development and implementation of a catchment management strategy (CMS) within their water management area. CMA must contribute towards social and economic factors. Note that the National Water Resource Strategy and the catchment management strategy must be in harmony relative to each other (Department of Water Affairs and Forestry, no date).

4.5.1.2 Catchment Management Forums

Catchment forums involve stakeholders in the decision making process about water resources management and are being used significantly by the department of water affairs (DWAF, 2001).

The role of catchment management forums is to assist in facilitating stakeholder consultations. Catchment forums contribute to the representation and assistance of stakeholders in the establishment of CMA and the development of CMS. Catchment forums must promote the integrated planning and cooperative resource management between CMAs and support the water resource management operations of the CMA (DWAF, 2001).

4.5.2 Water User Associations (WUAs)

Water User Associations (WUAs) is a co-operative association of individual water users who wish to undertake water-related activities for their mutual benefit. This association is established by the minister under the National Water Act. Section 92 of the National Water Act, Act no. 36 of 1998 state that the minister may in some cases establish a water user association but it should be ensured that it meets the objectives of the people where national requirements may override local entitlements.

A water user association is an institution that serves its members and is govern by a management committee (Department of Water Affairs and Forestry, no date). It can also provide a method through which the catchment management strategy can be implemented at local level (Department of Water Affairs and Forestry, no date).

4.5.2.1 Purpose of WUAs

WUAs allow people to be more active within a community and to combine their resources and expertise to effectively manage and carry out water-related activities. Some core functions of water user associations include the following (Department of Water Affairs, 2010):

- Act as interface between consumers and management
- Ensure and regulate optimum usage of groundwater and distribution
- Prevent any unlawful act that can reduce the quality
- Prevent groundwater from being waste
- Prevent unlawful use
- Promoting sustainable use
- Protect area of operation
- Provide assistance in the data collection, capture and monitoring process
- Provide general management
- Resolve disagreements between members
- The protection of the environment and ecological balance

4.5.3 International Water Management Bodies (IWMBs)

The term international water management body is described as a corporate body with all the relevant powers and capacity of a regular person. IWMBs are generally established by the Minister during consultation with the cabinet, and will be published as a notice in the Government Gazette. The primary role and function for IWMB is to implement international agreements in terms of management and development of water resources shared with and between neighbouring countries. It also include regional co-operation over water resources.

Other functions in which the IWMBs can assist in include management, training, financial and support services (Department of Water Affairs and Forestry, no date).

4.6 Summary

Groundwater regulation forms an important role in the process to control and regulate groundwater development and activities that might compromise groundwater quality and availability. For an effective monitoring program at municipalities an operational groundwater licensing system and water allocation program need to be developed.

Institutional arrangements on municipal levels play a significant role to have an effective regulatory environment, raise awareness and identify opportunities to collaborate with other agencies.

4.7 Exercises and tasks

1. Why is there a need for groundwater licensing?
2. Define the term allocation and provide the criteria thereof.
3. Describe and name the different groundwater institutions and their purpose.

4.8 Further reading

Foster, S., Kemper, K. (2002-2006) *Sustainable Groundwater Management: Concepts and Tools Sustainable Groundwater Management. Concepts & Tools, Series Overview.*

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4.9 Report from student for evaluation and assessment

4.10 Reference

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Module 5: Groundwater Quality

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5.1 Learning Objectives

To understand and describe the following:

- Indicators of groundwater quality and their measurements;
- National standards;
- Impacts of negative groundwater quality; and
- Drivers/controls of groundwater quality.

5.2 Introduction

Groundwater quality is a hidden issue inside a hidden resource, and as a result far too little attention is given to it. Most groundwater comes out of the earth as good quality potable water that needs almost no treatment before distribution and use (Figure 1). This good quality is a result of the protection that the ground affords the water by filtering out bacteria and protecting the water from pollutants generated at the land surface (Barrett, 2003). In a piped supply system, precautionary disinfection and liming to reduce corrosion in the piping network may be the only treatments required. As a result groundwater is a highly valuable resource for water resources managers. On the negative side, once groundwater has become polluted, it is usually a very long, complex and expensive task to restore the water quality, and in many cases the groundwater resource may be effectively destroyed as a potable water supply it is for these reasons that the monitoring, prevention and remediation of groundwater pollution is a vital management issue. The specific objectives of this module are to:

- Provide guidance on the identification and assessment of threats to groundwater quality
- Introduce management tools and strategies that may be used to either avoid or ameliorate such threats.

According to Groundwater division of GSSA one of the most important natural changes in groundwater chemistry occurs in the soil. Soils contain high concentrations of carbon dioxide which dissolves in the groundwater, creating a weak acid capable of dissolving many silicate minerals. In its passage from recharge to discharge area, groundwater may dissolve substances it encounters or it may deposit some of its constituents along the way. The eventual quality of the groundwater depends on temperature and pressure conditions, on the kinds of rock and soil formations through which the groundwater flows, and possibly on the residence time (www.iwrm.co.za).

Figure 1: Measuring wellhead chemistry/ Groundwater Quality (Adopted from www.infrastructurene.ws)

As a result the groundwater chemistry from various places in South Africa will differ depending on the aquifer in which it is found and may make the water unsuitable for certain uses. For example, water from the Malmesbury shales is unsuitable for most uses due to high total dissolved salts. Groundwater in granites (e.g. in Limpopo) naturally contains fluoride in high concentrations.

It is essential to have the quality of the water from a borehole intended for domestic use tested before consumption. Even natural groundwater may contain substances which can make it unfit for consumption (gwd.org.za).

5.2.1 What is meant by water quality?

Water quality is a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for an intended purpose. These characteristics are controlled of influenced by substances, which are either dissolved or suspended in water (Owen *et al.*, 2010).

Although scientific measurements are used to define the quality of water, it's not a simple thing to say that “this water is good," or “this water is bad ". The quality of water that is required to wash a car is not the same quality that is required for drinking water. Therefore, when we speak of water quality, we usually want to know if the water is good enough for its intended use, be it for domestic, farming, mining or industrial purposes, or its suitability to maintain a healthy ecosystem.

5.2.2 What is meant by water quality management?

Guidelines for groundwater resources management in water management areas, South Africa: volume 2. 2004 states that water quality is changed and affected by both natural processes and human activities. Generally natural water quality varies from place to place, depending on seasonal changes, climatic changes and with the types of soils, rocks and surfaces through which it moves. A variety of human activities, e.g. agricultural activities, urban and industrial development, mining and recreation, potentially significantly alter the quality of natural waters, and changes the water use potential. The key to sustainable water resources is, therefore to ensure that the quality of water resources are suitable for their intended uses, while at the same allowing them to be used and developed to a certain extent.

Effective management is the tool through which this is achieved. Water quality management, therefore involves the maintenance of the fitness for use of water resources on a sustained basis, by achieving a balance between socio-economic development and environmental protection. From a regulatory point of view the "business" of water quality management entails the ongoing process of planning, development, implementation and administration of water quality management policy, the authorisation of water uses that may have, or may potentially have, an impact on water quality, as well as the monitoring and auditing of the aforementioned (Owen *et al.*, 2010).

5.2.3 Why the need to manage water quality?

The effects of polluted water on human health, on the aquatic ecosystem (aquatic biota, and in-stream and riparian habitats) and on various sectors of the economy, including agriculture, industry and recreation, can be disastrous. Deteriorating water quality leads to increased treatment costs of potable and industrial process water, and decreased agricultural yields due to increased salinity of irrigation water. On the other hand not all health, productivity and ecological problems associated with deteriorating water quality are ascribed to man's activities. Many water quality related problems are inherent in the geological characteristics of the source area. The occurrence, transport and fate in the aquatic environment of numerous persistent and toxic metals and organic compounds (e.g. pesticides) have given cause for serious concern. Contamination of groundwater resources, or of sediments deposited in riverbeds, impoundment's and estuaries by toxic and persistent compounds can cause irreversible pollution, sometimes long after the original release to the environment has ceased (Guidelines for groundwater resources management in water management areas, South Africa: volume 2, 2004).

5.2.3.1 Salinisation

A persistent water quality problem is salinisation, which has two major causes, natural and anthropogenic. The origin of natural salinisation of river water is geological. Man-made causes are multiple. A wide variety of man's activities are associated with increased releases of salts, some in the short and others in the long term. Immediate increases in salt concentrations result from point sources of pollution, such as the discharging of water containing waste by industries. Diffuse pollution, resulting inter alia from poorly managed urban settlements, waste disposal on land and mine residue deposits pose even a bigger problem, as it impacts over a larger area on the water resource. The effect of diffuse pollution on groundwater is also often problematic in terms of remediation (Barrett, 2003).

5.2.3.2 Eutrophication

Another major water quality problem is eutrophication which is the enrichment of water with the plant nutrients nitrate and phosphate. This encourages the growth of microscopic green plants termed algae. As nutrients are present in sewage effluent, the problem is accentuated wherever there is a concentration of humans or animals. The algae cause problems in water purification, e.g. undesirable tastes and odours, and the possible production of trihalomethanes or other potentially carcinogenic products in water that is treated with chlorine for potable purposes.

5.2.3.3 Micro-pollutants

A water quality issue which is receiving increasing attention among industrialised nations is pollution by metals and man-made organic compounds, such as pesticides.

Serious incidents of health impacts to man and animals have occurred at places throughout the world through uncontrolled exposure to these micro-pollutants. Pollution of this type tends to be highly localised and associated with specific industries or activities. Mining activities often expose pyrite containing rock formations to air and water to produce acid rock drainage. Due to the low pH of acid rock drainage heavy metals are mobilised. The Department of Water Affairs and Forestry has recently established a water pollution control works in the Brugspruit catchment, at huge cost, to treat acid rock drainage emanating from abandoned coal mines.

5.2.3.4 Microbiological pollutants

Water contamination by faecal matter is the medium for the spread of diseases such as dysentery, cholera and typhoid.

5.2.3.5 Erosion and sedimentation

Average sediment yields for South African catchments range from less than 10 to more than 1 000 tonnes/km^2/annum. In some parts of the country erosion has increased by as much as tenfold as a result of human impacts. Apart from the loss of fertile agricultural soil, off-site damage like loss of valuable reservoir storage, sediment damage during floods and increased water treatment costs, have been largely ignored even though these are estimated to be in excess of R 100 million per year.

5.2.4 Who is water quality being managed for?

Being the public trustee of the Nation's water resources, the Minister of Water Affairs and Forestry and his Department, the Department of Water Affairs and Forestry, has to manage South Africa's water resources to ensure continued adequate water supplies of acceptable quality to all recognised users. From a water quality management point of view these recognised users consist of, five water user sectors; these being the domestic, agricultural, industrial and recreational water user sectors , as well as the aquatic ecosystem, also constituting the water resource base (Owen *et al.*, 2010).

5.2.5 The underlying principles of groundwater quality management

According to Meyer (2002) and Riemann *et al*. (2011) sustainability, equity and efficiency are recognised as the central guiding principles in the protection, use, development, conservation, management and control of water resources. These guiding principles are inherent to the management of water quality. Water resources must therefore be judiciously managed and equitably shared by all water users in the most optional manner. In water quality management, sustainability means that the protection of water resources must be balanced with its development and use. This "balance" is attained through a process of resource classification, the determination of an associated Reserve and the determination of Resource Quality Objectives. Resource Quality Objectives, inter alia, stipulate in-stream water quality objectives aimed at meeting the water quality requirements of the five water user sectors, and are aimed at ensuring fitness for use of South Africa's surface water, groundwater and coastal estuaries. The concepts of Resource Quality Objectives and Resource Quality that were introduced by the National Water Act, 1998 (Act No. 36 of 1998), necessitate that water quality management, now, also takes responsibility for the management of the aquatic ecosystem quality (in-stream and riparian habitat, and aquatic biota quality).

The following prominent principles form the basis of water quality management policies and practices in South Africa.

- The management of water quality must be carried out in an integrated and holistic manner, acknowledging that all elements of the environment are interrelated.
- Decision-making must ensure that the best practicable environmental option is adopted by taking account of all aspects of the environment including all the people in the environment.
- The precautionary approach to water quality management applies, in which active measures are taken to avert or minimise potential risk of undesirable impacts on the environment.
- In general the principle of Polluter Pays, applies. In accordance with this principle, the cost of remedying pollution, degradation of resource quality and consequent adverse health effects, and of preventing, minimising or controlling pollution is the responsibility of the polluter.
- Participative management in the management of water quality must be advocated, ensuring that all interested and affected parties, and previously disadvantaged persons have an equal opportunity to participate.

- Transparency and openness must underlie all decision-making processes, and all information must be made accessible in accordance with the law.

5.2.6 Approaches to groundwater quality management

According to Riemann *et al*. (2011) water quality management, in South Africa, has evolved from a pollution control approach, which essentially concentrated on source directed management measures, to the current approach where water quality management consists of an integrated source, remediation and resource directed management approach which recognises the receiving water users', as well as the aquatic ecosystem's water quality requirements. This water quality management approach is actualised through a combination of measures and arrangements provided for in the National Water Act, 1998 (Act No. 36 of 1998); these provisions including:

- The protection of water resources;
- the establishment of Water Management Strategies and Water Management Institutions;
- the licensing of water use. (Which includes the licensing of discharges through coastal marine out-fall pipelines to the marine environment);
- the implementation of a National Pricing Strategy containing a system of Waste Discharge Charges; and
- the establishment of a National monitoring system and a National information system.

5.2.6.1 Resource directed water quality management

Meyer (2002) further opines that in order to counter the continuing deterioration of water quality and to meet the challenges of the future, the Department of Water Affairs and Forestry has adopted a Receiving Water Quality Objectives approach, consisting of a Receiving Water Quality Objectives approach for non-hazardous substances and a Pollution Minimisation and Prevention approach for hazardous substances (Figure 2).

The Receiving Water Quality Objectives approach for non-hazardous substances accepts that the receiving water environment has a certain, usually quantifiable, capacity to assimilate waste without serious detriment to the quality requirements of its recognised users. However, if applied without the necessary precaution, the Receiving Water Quality Objectives approach for non-hazardous substances will inevitably lead to the deterioration of water resources to the point where they will be less fit for use by the recognised water user sectors. To counter the limitations of this approach, a precautionary approach was accepted to avert danger and minimise uncertainty and potential risk of undesirable impacts on the environment (Guidelines for groundwater resources management in water management areas, South Africa: volume 2. 2004).

Figure 2: Resource directed water quality management (adopted from gwd.org.za).

For those wastes that are hazardous and a threat to the environment due of their toxicity, persistence and extent of bio-accumulation, a precautionary approach aimed at minimising or preventing their entry into the water environment, was adopted.

5.2.6.2 Hierarchy of water quality management decision-taking

Decisions in regard to water quality management are made in terms of a hierarchy of principles, which is specifically aimed at marrying the protection, and use and development of water resources. The hierarchy of decision-taking is as observed from Figure 3 below:

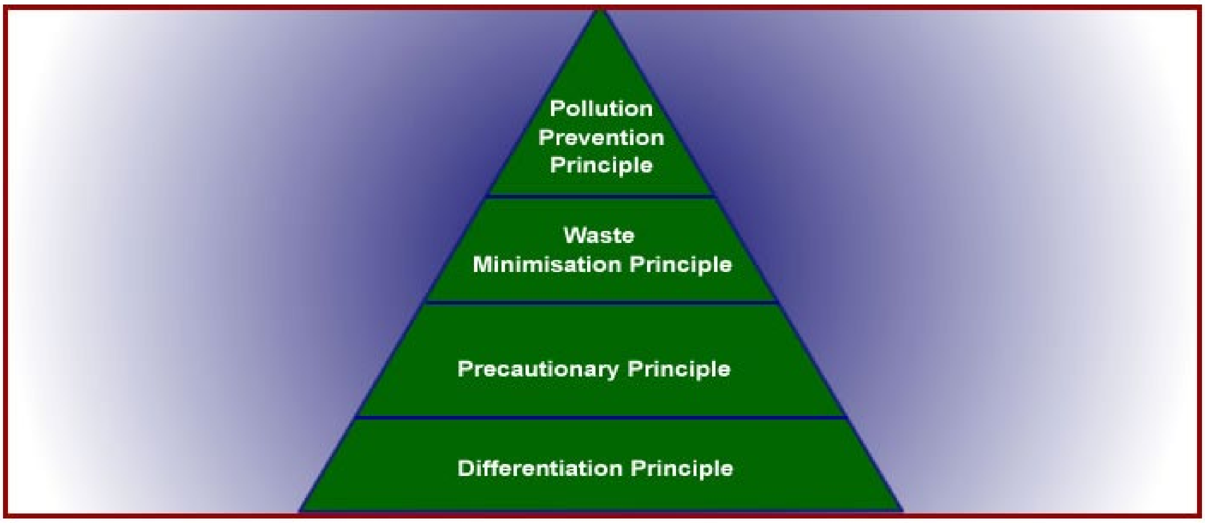

Figure 3: Hierarchy of water quality management decision-taking (adopted from www.dwa.gov.za)

5.2.6.3 Source directed water quality management

Without efficient and effective source directed controls, the water quality objectives set through resource directed water quality management will, in most cases, not be met. Prior to authorising a license application for a water use that may potentially impact on water quality, the applicant must conduct an impact assessment. Such an impact assessment has to demonstrate that the source directed controls proposed (Figure 4), are sufficient to ensure that the water resource remain fit for use by the recognised water user sectors, in accordance with the Receiving Water Quality Objectives approach. Impact assessments must also consider the cumulative effects of actions that in itself may not be significant, but may be significant when added to the impact of other similar actions (Riemann *et al*., 2011).

Figure 4: Source directed water quality management (adopted from gwd.org.za).

5.3 Why do groundwater supplies merit protection?

www.dwa.gov.za opines that groundwater is a vital natural resource for the reliable and economic provision of potable water supply in both the urban and rural environment. For municipal water supply, high and stable raw-water quality is a prerequisite, and one best met by protected groundwater sources. Too often those exploiting groundwater for the provision of potable water supply have taken no action to protect water quality. Aquifers worldwide are experiencing an increasing threat of pollution from urbanization, industrial development, agricultural activities and mining enterprises. It may take many years or decades before the impact of a pollution episode by a persistent contaminant becomes fully apparent in groundwater supplies abstracted from deeper wells and take even longer to clean up.

- Groundwater supplies merit protection because they are a vital resource for the supply of potable water in both rural and urban environments.
- Water managers need to initiate proactive campaigns and practical actions to protect the natural quality of groundwater.

5.3.1 Natural groundwater quality

Groundwater is usually safe to drink without treatment, unlike surface water. This is because harmful microbiological pathogens such as bacteria and viruses usually cannot survive for long in aquifers. However, it is normal for chlorination to be carried out as a precaution for most public groundwater supplies.

Monitoring of the microbiological quality of a groundwater source gives important information about the groundwater system, and early warning of problems. Groundwater contains dissolved “minerals” such as chloride, sodium, iron and others, in the same way as surface water. The natural dissolved mineral content of groundwater depends on a number of factors, including the aquifer material and the groundwater residence time. Figure 5 indicates natural groundwater electrical conductivity (mS/m) in RSA. In some cases, high levels of dissolved minerals cause groundwater to be brackish or even saline. In some (relatively rare) cases, naturally high levels of dissolved constituents like fluoride, arsenic or nitrate render groundwater unfit to drink, even though it may taste perfectly fresh (Riemann *et al*., 2011).

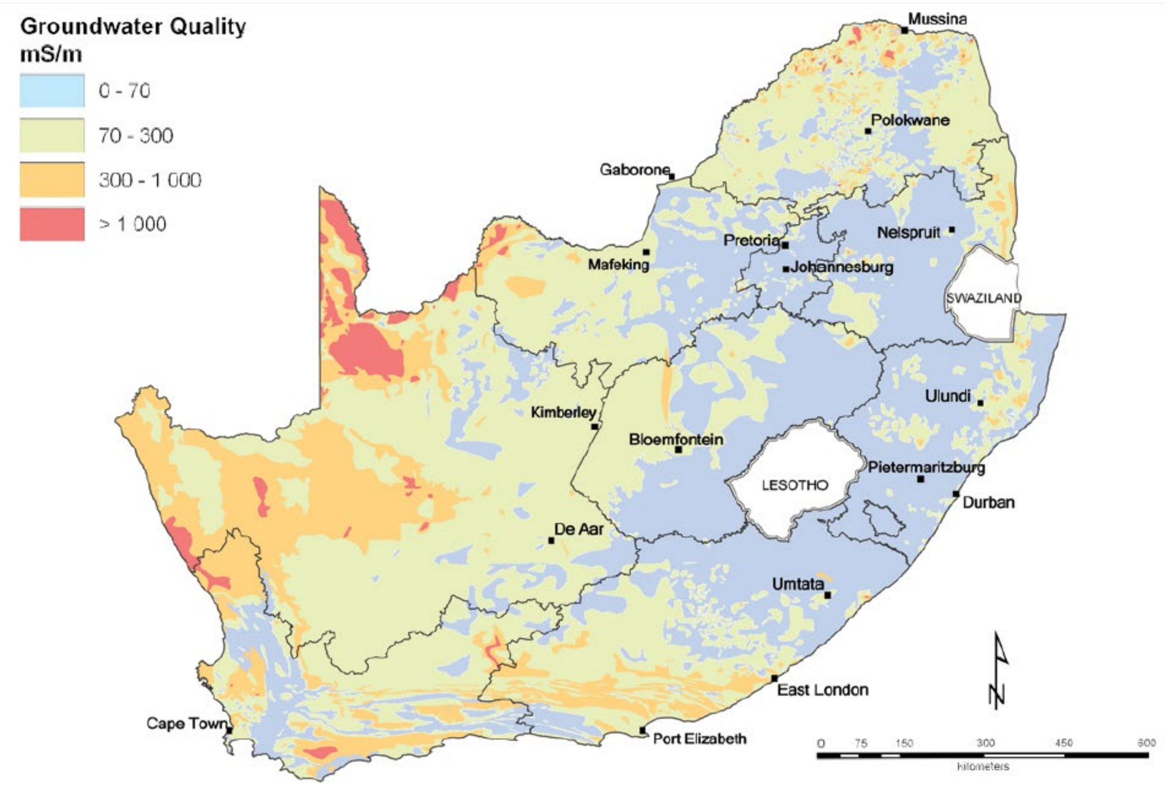

Figure 5: Electrical conductivity map of groundwater in RSA. (Adopted from www.dwa.gov.za).

The map in Figure 6 shows nitrate concentrations in groundwater across South Africa, based on available data. In areas where nitrate is higher than allowable limits, groundwater will need to be treated or blended.

Monitoring is the key to understanding natural groundwater quality variations. Groundwater is normally less susceptible to pollution compared to surface water, since an overlying unsaturated zone generally protects it. However, once polluted, groundwater is difficult and expensive to clean up. Groundwater pollution can come from a variety of sources, and in the worst cases can make groundwater unsafe to drink and uneconomical to treat (www.iwrm.co.za).

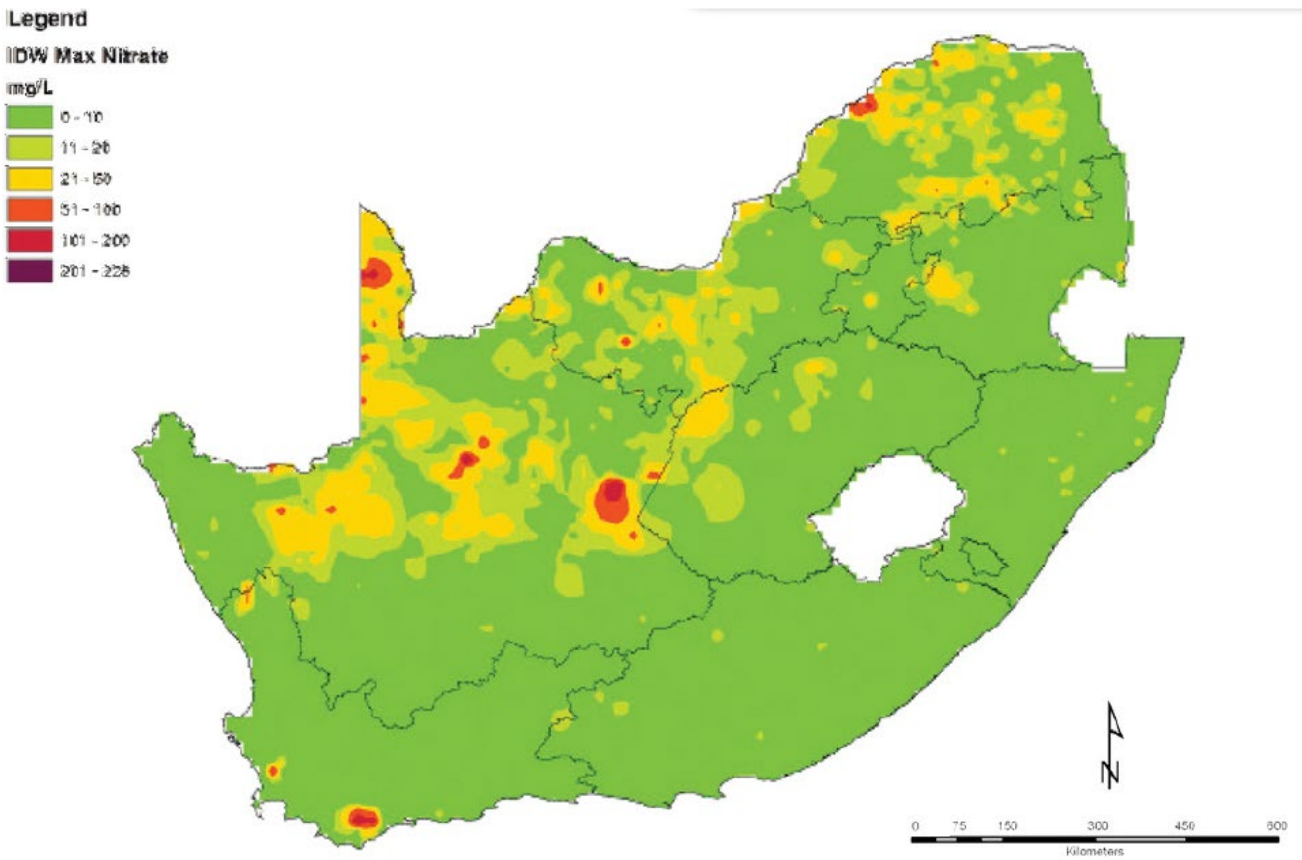

Figure 6: Map of nitrate levels in groundwater in South Africa. (Adopted from www.dwa.gov.za).

5.3.2 Protection zone policy in South Africa

A common method that is used world-wide to help protect groundwater quality is to establish areas or “protection zones” around groundwater abstraction points (and sometimes well fields and even whole aquifers) within which activities that may pollute groundwater are controlled. It is also obviously not enough merely to define a protection zone – of equal importance are the restrictions or rules that are made for activities within the protection zone, and the enforcement of these.

Riemann *et al*. (2011) states that groundwater source protection zones are commonly used in many European countries and in the United States (where they are known as wellhead protection zones) to protect major or vulnerable groundwater sources (See Figure 7) for the groundwater levels of RSA).

There are various documents that cover groundwater protection in South Africa, including protecting single groundwater sources from point-source pollution. The specific legal requirement that will adequately protect groundwater, through protection zoning, is through the recently assented classification of water resources. However, it is usually much easier, quicker and cheaper to protect groundwater from pollution or the effect of over-abstraction than it is to try to reverse the damage at a later date. Groundwater protection is therefore an economic as well as an environmental imperative, and groundwater protection measures and policy will save money in the long term. The cost of dealing with polluted or contaminated groundwater can also involve considerable hardship to people and the environment.

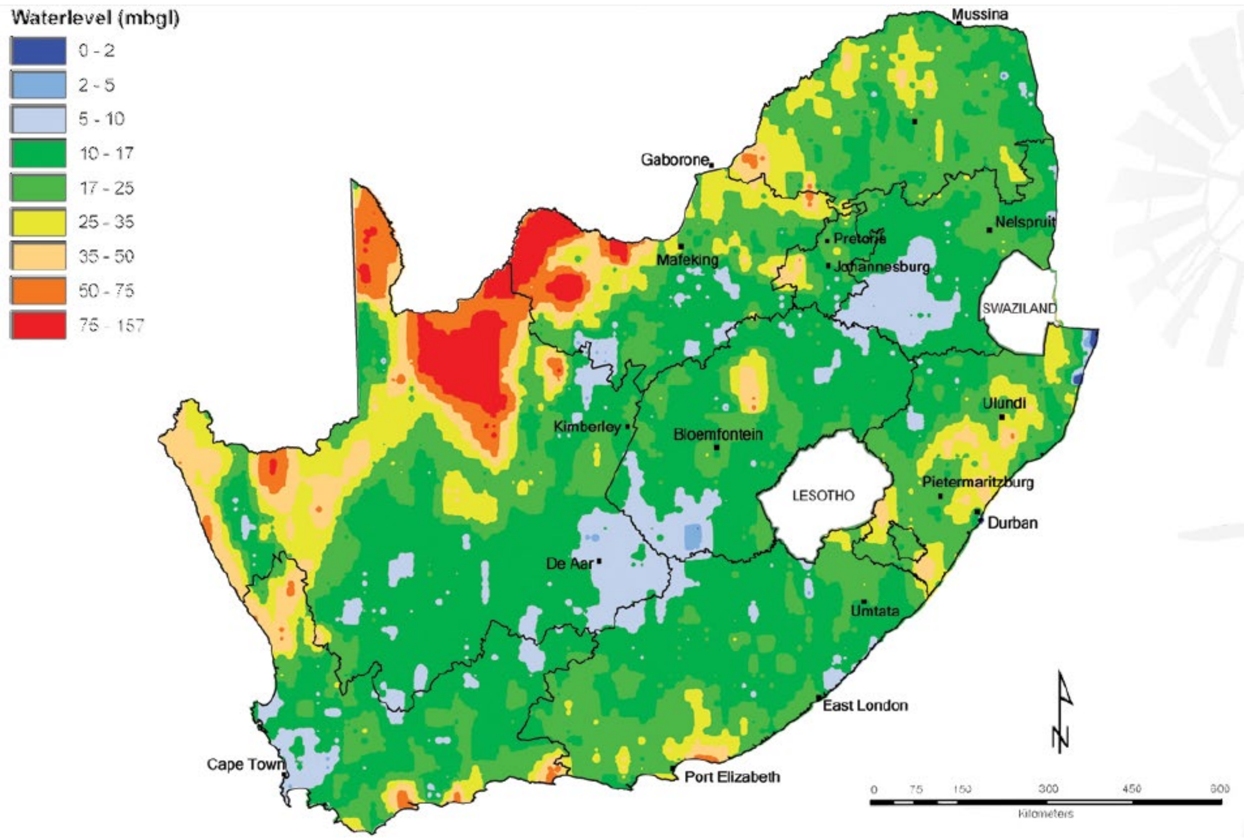

Figure 7: Groundwater levels map of RSA. (Adopted from www.dwa.gov.za).

5.4 Risk assessment

5.4.1 How do aquifers become polluted?

According to Riemann *et al*. (2011) aquifers may become polluted by specific point sources, such as waste ponds or effluent discharge from factories and mines, or they become polluted from diffuse pollution such as the application of agricultural fertilizers and pesticides. Groundwater may also become polluted through well head contamination from poorly constructed/designed boreholes.

According to www.dwa.gov.za when subsurface contamination is inadequately controlled, and exceeds the natural attenuation capacity of the underlying soils and strata, then the groundwater system becomes contaminated by this waste. In the vadose (unsaturated) zone, natural subsoil profiles actively and effectively attenuate many water pollutants especially human excreta and domestic wastewater by biochemical degradation and chemical reaction. Concern about groundwater pollution relates primarily to the phreatic (water table) aquifers, especially where the unsaturated zone is thin and the water-table is shallow. Deeper and confined aquifers are afforded much greater natural protection by the overlying ground. The threats to groundwater arise from a variety of different sources (Fig 8.1) and many of these are quite different from sources that typically pollute surface water bodies, due to differences in the mobility and persistence of contaminants in the subsurface as compared to surface water bodies. What is clear is that if the source, nature and pathways of the pollutant(s) are properly understood, then sharply-focused pollution control measures can produce major benefits for relatively modest cost if correctly targeted at key point sources.

In summary:

- Aquifers may be polluted by point source discharges or from diffuse pollutants.
- Typically aquifers become polluted when pollution is inadequately controlled and exceeds the natural attenuation capacity of the ground.
- Groundwater quality management requires the assessment of pollution hazard and risk to groundwater, delineation of groundwater vulnerability zones, control of effluent discharges (e.g. by a system of permits), as well as the construction of containment structures (e.g. lined waste ponds) in order to avoid or reduce groundwater pollution.

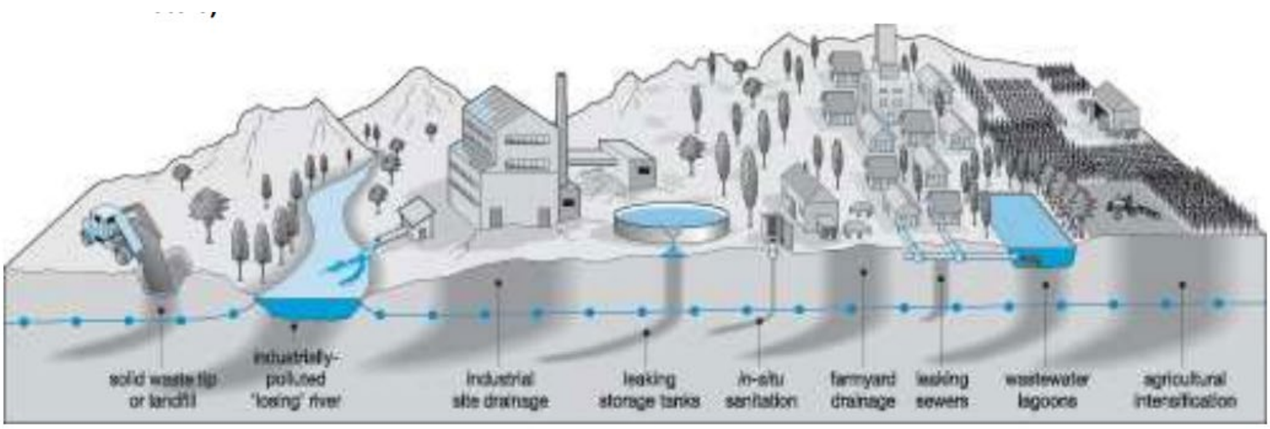

Figure 8: Land use activities commonly generating a groundwater pollution threat. (Adopted from www.agw-net.org)

5.4.2 Groundwater pollution

Just because water is underground does not mean that it cannot be polluted. Groundwater can be contaminated in many ways (See Figure 9). Groundwater associated with coal deposits often contains dissolved minerals poisonous to plants and animals. Pollutants dumped in the ground, in landfills and at sites of animal husbandry or pollutants introduced below ground such as in unlined latrines and burial sites, may leak into the soil and work their way down into aquifers.

Pollutants include substances that occur as liquids like petroleum products, dissolved in water like nitrates or are small enough to pass through the pores in soil like bacteria. Movement of water within the aquifer is then likely to spread these pollutants over a wide area, making the groundwater unusable and spreading disease.

Figure 9: Sources of Groundwater Pollution. (Adopted from gwd.org.za.)

5.4.3 How is groundwater quality measured and monitored

A key aspect for management of groundwater quality is the application of water quality monitoring at selected boreholes, especially in areas considered to be at risk. Groundwater quality may be measured by sampling and analysing the groundwater from selected wells. Monitoring (Figure 10) may be pro-active with monitoring wells installed prior to a planned activity that may generate pollution (Figure 6), so that changes to the groundwater condition can be measured as they occur. Alternatively monitoring may be reactive with monitoring wells installed to monitor possible pollution from an already existing facility/activity. This subject is dealt with more fully in the Module (7) on Groundwater Monitoring.

Meyer (2002) believes that there are several issues involved in groundwater quality monitoring that need to be considered, adding considerable complexity to the task. The cost of chemical analyses may be very high, depending on the parameters analysed. In many instances, especially for organic agro-chemicals and industrial reagents, local laboratories may not be equipped to carry out the required analyses. Where possible, cheap indicator parameters should be identified and measured as an alternative to a full chemical analysis. Sampling wells, if not in regular daily use, need to be thoroughly flushed before sampling. Sampling points need to be carefully selected, which requires a clear understanding of the groundwater flow patterns and knowledge of the location of the sources of pollution. Sampling frequency needs to also be considered and will be based on the sensitivity of the pollution problem, and the frequency of flow inducing or flushing events such as groundwater recharge.

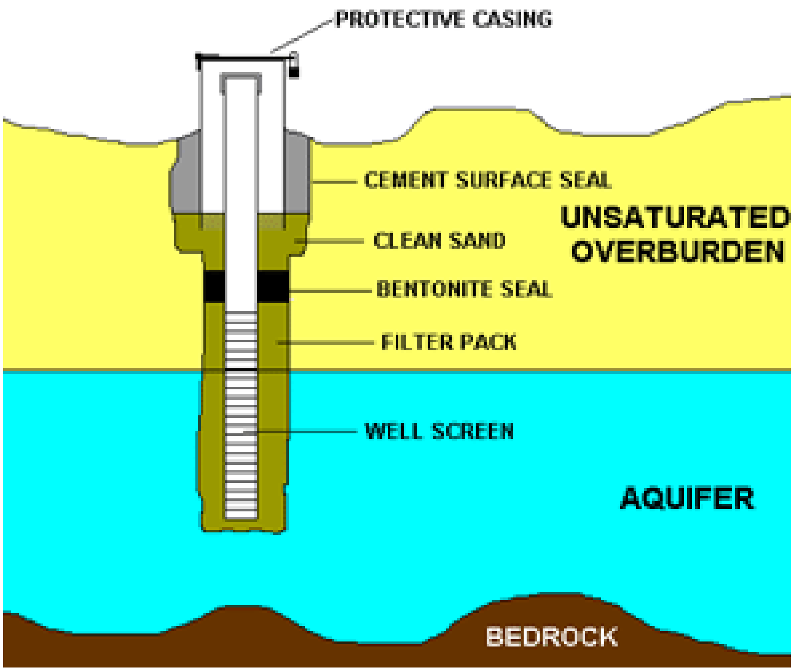

Figure 10: Monitoring Well. (Adopted from www.geologicresources.com).

5.4.4 Protecting groundwater from pollution

Management of groundwater quality requires both the protection of aquifers and groundwater from ingress of pollutants and also the remediation/treatment of polluted resources. It should be noted that treatment of polluted groundwater is complex, expensive, often only partially successful and it may take many years of treatment before groundwater quality can be restored. Groundwater quality can range from high quality potable water to something that is entirely toxic, with a full range of water qualities in between. In addition to protection and remediation, groundwater quality management may include the matching of different water qualities to different uses and blending of different water qualities to provide a larger groundwater resource of intermediate but still acceptable quality for a particular use requirement (Guidelines for groundwater resources management in water management areas, South Africa: volume 2. 2004).

Groundwater quality management should be pro-active and attempt to prevent the contamination of groundwater resources, and thus avoid the lengthy, expensive and often ineffective remediation of contaminated aquifers. Groundwater protection initially involves two key aspects.

These are:

1. assessment of aquifer pollution vulnerability and
2. mapping of groundwater pollution hazards.

Together these two factors may be then used to generate a groundwater pollution risk map. Such maps may be used to guide the location of proposed new developments such that the risk of groundwater contamination is reduced in sensitive area and they can be used in already developed areas to assess probable zones already at risk or polluted from ongoing activities. Once the risk has been identified and assessed, then certain groundwater quality management practices may be introduced. These may include:

- groundwater quality monitoring to assess actual groundwater quality status and changes to quality over time
- prohibition of certain activities in sensitive or vulnerable areas
- prohibiting the disposal of certain levels of waste except in sealed facilities
- management of both the quality and quantity of effluent and waste disposal by a series of permits
- monitoring of compliance with regulations/perm.

5.4.5 What does groundwater pollution protection involve?

As we have seen, to protect aquifers against pollution it is essential to constrain land-use, effluent discharge and waste disposal practices.

One widely used strategy has been the establishment of groundwater protection zones (Figure 11). Simple and robust zones may be established with indications of which activities are permissible/possible. Such zones need to be incorporated into the town/city planning maps and legislation and used to guide various developments. Such zones have a key role in setting priorities for groundwater quality monitoring, environmental auditing, etc. and can help to reduce the costs involved in producing groundwater quality maps.

There is need for sensible balances between protecting aquifers and boreholes, but aquifer oriented strategies are more acceptable. It may not be cost-effective to protect all parts of an aquifer equally. This will depend on the groundwater use, the contaminant loads, flow paths, etc. (Riemann *et al*., 2011).

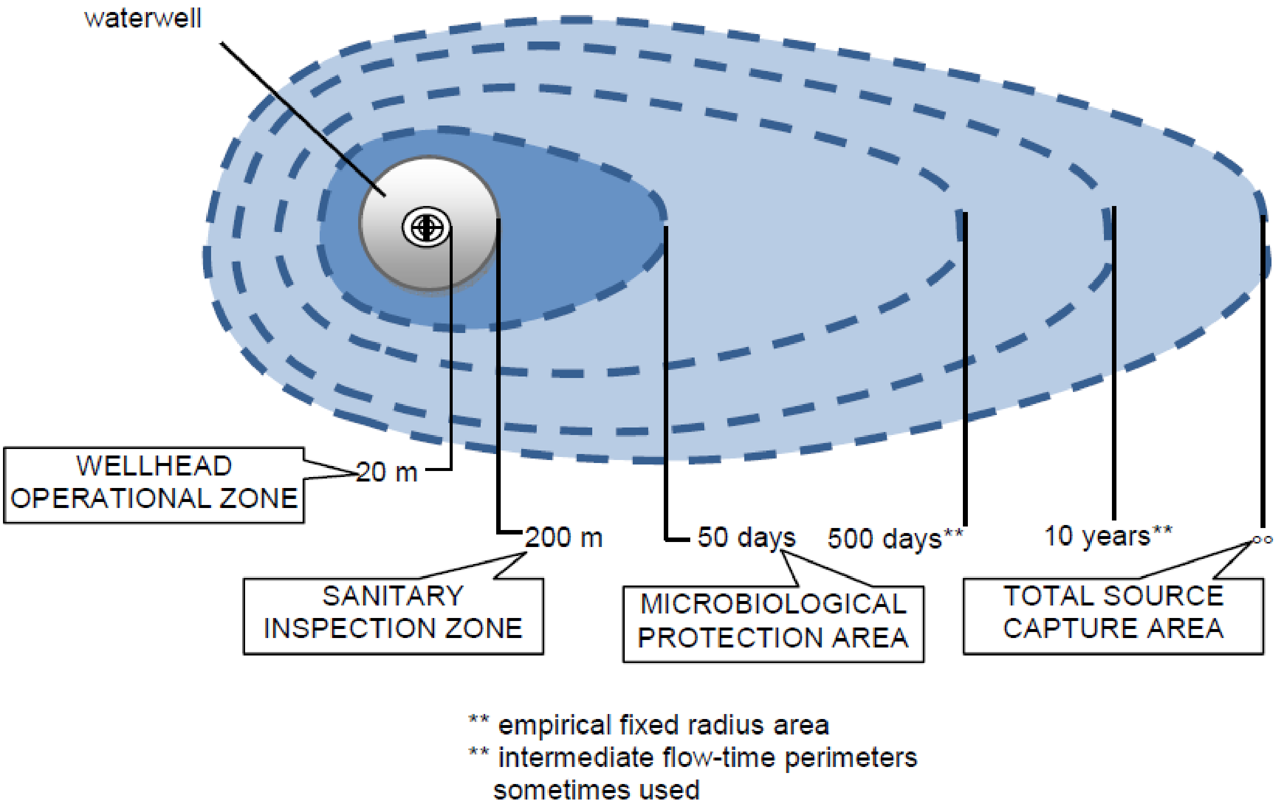

Figure 11: Groundwater protection zones are a simple but powerful tool for protecting important groundwater sources. Restrictions on various activities are imposed, depending on the zone, typically based on the flow time to the abstraction point (www.dwa.gov.za).

In summary:

Land-use, effluent discharge and waste disposal practices must all be managed in order to protect aquifers against pollution. Simple and robust zones need to be established with indications of which activities are permissible/possible.

5.4.6 Who should promote groundwater pollution protection?

The principle that the “polluter pays” should be applied in cases of groundwater pollution. However the source of pollution may be difficult to definitively ascertain in cases of diffuse pollution and in urban/industrial environments where there are multiple point sources causing pollution. The ultimate responsibility or groundwater pollution protection must lie with the relevant agency of national or local government. Nevertheless, an obligation also exists on water-service companies to be proactive in undertaking pollution hazard assessments for their groundwater sources.

5.4.7 Urban wastewater and groundwater quality

Urban wastewater may be considered as a special case for groundwater quality management. This is because urban wastewater generation is unavoidable, ubiquitous and growing in volume all the time as cities grow. In addition, there are very real benefits that can be realized from urban wastewater such as groundwater recharge and the provision of irrigation water for certain crops. Alongside such benefits, urban wastewater also contains real hazards in terms of bacterial pathogens and industrial wastes with a wide range of organic and inorganic substances.

5.4.8 How does urban wastewater relate to groundwater?

There is steadily-increasing wastewater generation by most growing cites and the management of this wastewater is a significant problem for cities, especially in developing countries. Unfortunately many sewerage systems discharge directly to surface watercourses with minimal treatment and little dilution in the dry season. The rather rudimentary and common wastewater handling and reuse practices in developing nations tend to generate high rates of infiltration to underlying aquifers especially in the more arid climates. Infiltration through the ground improves the wastewater quality and stores it for future use, but can also pollute groundwater.

5.4.9 Groundwater quality management

Historically emphasis was placed on the protection of the quality of South Africa's surface and marine water resources, while policies and strategies to deal with groundwater pollution were scarce. Under the National Water Act, the status of groundwater has now been changed from private water to public water and new efforts are being made to afford groundwater the same protection enjoyed by surface water resources. Policies and strategies for groundwater quality management in South Africa are now being developed by DWAF with the stated mission:

"To manage groundwater quality in an integrated and sustainable manner within the context of the National Water Resource Strategy1and thereby to provide an adequate level of protection to groundwater resources and secure the supply of water of acceptable quality."

The protection of water quality in South Africa is to be achieved by the combination of three core strategies:

• Resource-directed strategies (chapter 3 of NWA)

• Source-directed strategies (mainly chapter 4 of NWA)

• Remediation strategies (chapter 3 of NWA)

The relationship between these strategies is illustrated in Figure 12.

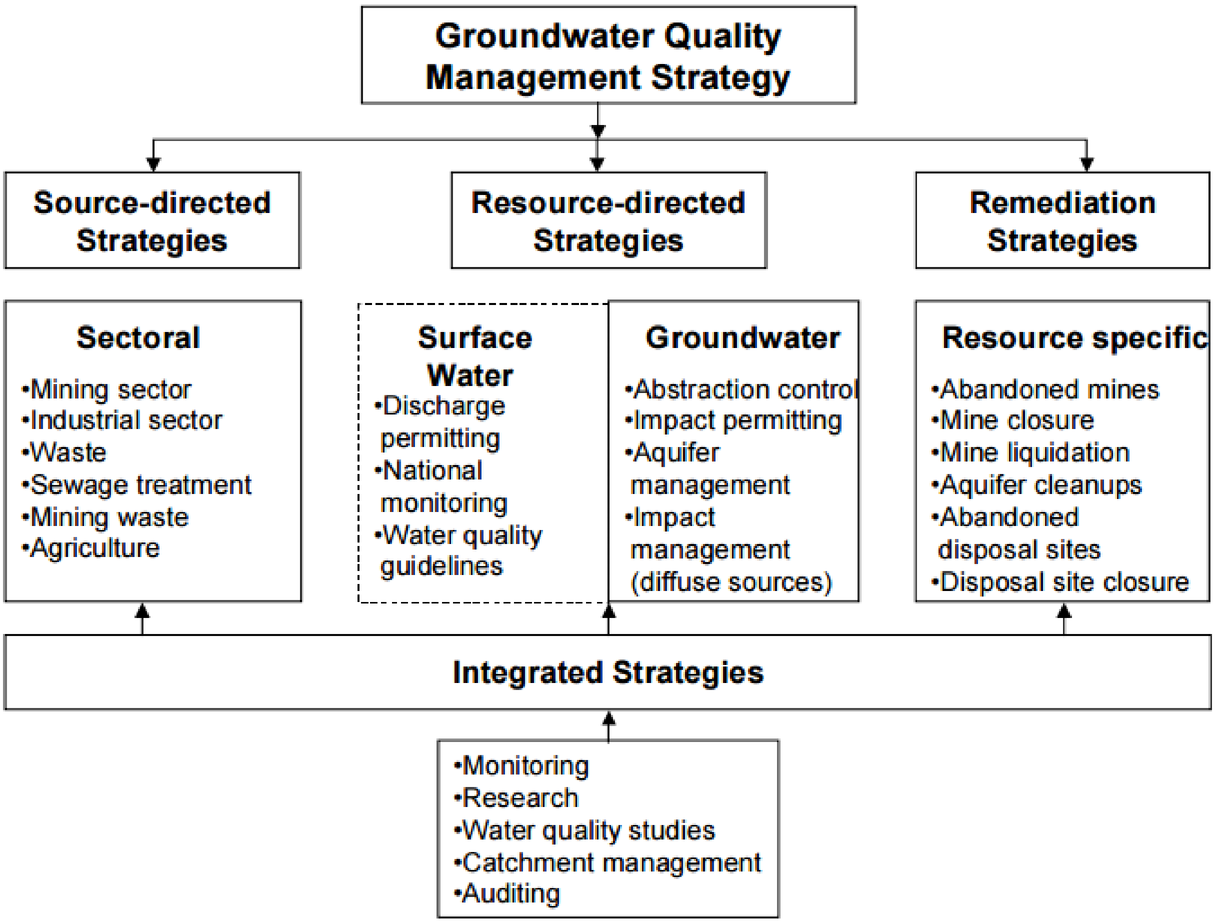

Figure 12: Integrated strategies to manage groundwater quality in South Africa (adopted from DWA, 2000).

5.4.9.1 Resource-directed strategies

Resource-directed strategies are aimed at understanding the inherent characteristics and current and potential future use of the water resource itself.

These are then used to determine the required level of protection. The measures implemented under this strategy are directed at managing such impacts as do inevitably occur in such a manner as to protect the reserve and ensure suitability for the beneficial uses of the resource. Examples of resource-directed measures include:

• Resource classification.

• Determination of resource management classes.

• Reserve determination.

• Setting of resource quality objectives.

5.4.9.2 Source-directed strategies

Source-directed strategies are aimed at minimising, or preventing at source possible, the impact of developments or activities on groundwater quality. Source directed controls have, in the past, been principally targeted at point sources of pollution to surface waters and coastal marine waters. Examples of source directed controls include:

• Licences and general authorisations.

• Standards to regulate the quality of waste discharges.

• Minimum requirements for on-site management practices.

• Requirements for minimising water use impacts.

• Requirements for remediation of polluted water resources.

5.4.9.3 Remediation strategies

Remediation strategies are aimed at remediating historical groundwater pollution, where practicable, to protect the reserve and ensure at least fitness for the purpose served by the remediation. Under Chapter 4 of NWA, the clean-up of contaminated groundwater is the responsibility of the polluter, who must also bear the costs of remediation. In the case where the responsible person(s) cannot be identified or has failed to comply with the law, remedial action may be undertaken directly by the Catchment Management Agency (CMA). Remedial measures for which the CMA is accountable include:

• Setting and evaluating priorities for remedial action

• Clean-up of abandoned sites

• Emergency action plans or procedures for accidental spills.

Recognising that groundwater management will have limited resources; actions taken by the groundwater coordinator to implement groundwater protection need to be prioritised according to:

• The value of the groundwater resource

• The vulnerability of the resource and

• The risk of adverse impacts on human health and ecosystems.

5.5 The National Water Act (1998)

According to www.dwa.gov.za the National Water Act provides the framework within which the Department can manage the protection, use, development, conservation and control of South Africa's water resources.

The eleven uses of water specified by the National Water Act (Section 2) are:

- taking water from a water resource
- storing of water
- impeding or diverting the flow of water in a watercourse
- engaging in a stream flow reduction activity
- engaging in a controlled activity identified as such in section 37(1) or declared under section 38(1)
- discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit
- disposing of waste in a manner which may detrimentally impact on a water resource
- disposing in any manner of water which contains
- waste from, or which has been heated in, an industrial or power generation process
- altering the bed, banks, course or characteristics of a watercourse removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people, and
- using of water for recreational purposes.

The eleven uses are not rights and may generally take place only in terms of an authorisation or licence.

In implementation of the Act the Department must take into account the following (section 2 of the Act):

a) basic human needs of present and future generations

b) the need for equitable access to water

c) redressing the results of past racial and gender discrimination

d) promoting the efficient, sustainable and beneficial use of water in the public interest

e) facilitating social and economic development

f) providing for growing demand for water use

g) protecting aquatic and associated ecosystems and their biological diversity

h) reducing and preventing pollution and degradation of water resources

i) meeting international obligation

j) promoting dam safety

k) managing exposure to, and effects of, floods and droughts.

National government is empowered through the Act to establish suitable institutions and to ensure that they have appropriate community, racial and gender representation.

The Act will enable the Department to effectively implement its new policies regarding groundwater quality management. The following will be important:

- groundwater no longer enjoys the status of private water and is now subject to the same control measures as surface water;
- powers to monitor, assess, plan and audit performance of all water users have been provided for in the Act;
- the Department can within its available resources provide extension and support services and play a role in building capacity at community level; and
- the Department will be able to influence land-use planning decisions, to regulate or prohibit land-based activities, to develop and implement Best Practice standards and to implement source controls where necessary. Implementation of Best Practice standards as conditions of authorisation managed by other organs of state will be particularly important (www.dwa.gov.za).

5.6 Summary

Groundwater occurs as part of the natural water cycle. Groundwater is formed by precipitation, such as rain water, that infiltrates down into the soil layer, but is not utilised by plants, and then percolates deeper underground. Groundwater is thus water that is found in the spaces between sand and soil particles or within the cracks in hard rock underground. Access to groundwater is done by means of drilling boreholes or utilising springs. In South Africa users of groundwater include municipal, rural, agricultural and mining. A large number of the population in rural areas depend on boreholes for the provision of drinking water. Agriculture also utilises a large percentage of groundwater for crop irrigation practices (Meyer, 2002).

According to Barrett (2003) the quality of groundwater is normally safe to drink, but could be affected by its underground environment in that it may dissolve some of the minerals in the rock with which it comes in contact. The monitoring of groundwater quality and quantity is thus important to ensure that it is utilised sustainably. Groundwater quality monitoring is done through taking water samples from monitoring boreholes and analysing the water quality at a SANAS accredited laboratory (www.aquatico.co.za). Groundwater is a merchandise which is proposed to be utilized wisely whilst ensuring its serenity and sacredness as far as quality and amount. Universal usage in segments, for example, streamlined, metropolitan, commercial, agricultural and private makes groundwater polluted and changing over it as a powerless element.

Groundwater pollution and over-abstraction are serious problems in certain parts of South Africa. Poor and deteriorating groundwater quality is widespread and can be attributed to diverse sources in various sectors such as mining, industrial activities, effluent from municipal wastewater treatment works, storm water runoff from urban and especially informal settlements (where adequate sanitation facilities are often lacking), return flows from irrigated areas, effluent discharge from industries, etc.

The mining footprints undoubtedly impact on water sources whether it is surface or groundwater. Poor and deteriorating groundwater quality is widespread and can be attributed to diverse sources in various sectors such as mining. The discharge or decant of contaminated water and highly saline effluents from mining activities and/or abandoned mines (commonly referred to as acid mine drainage) is a serious environmental threat and social concern (www.aquatico.co.za).

5.7 Exercises and tasks

1. Are you aware of any significant groundwater quality issues in your region in either the urban or rural?

2. Give examples of groundwater pollution in your municipality. How can it be avoided in future environment?

3. What controls over groundwater pollution do you have? Are they effective?

4. Who manages/ maintains groundwater protection zones in your region? Are there any reforms that you would recommend?

5. What happens to waste water from your city?

6. Identify a common groundwater quality problem in one of your countries.

7. What would you change to improve the management of the problem?

8. Please share your experience of groundwater quality problems in your municipality.

9. According to the National Water Act, how many uses of water specified by the National Water Act (Section 2) are there? Name these uses.

10. What do you think of natural groundwater quality? Do you think it should/not be treated before consumption? Please state your reasons.

5.8 Report from student for evaluation and assessment.

5.9 References

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Module 6: Groundwater Quantity

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6. Learning objectives

To understand and describe the following:

- Meaning of groundwater quantity;
- Factors influencing groundwater quantity; and
- Measures and indicators of groundwater quantity;
- To appreciate the importance of protecting groundwater quality;
- To understand the role of risk assessment and vulnerability mapping in managing groundwater quality;
- To examine the specific case of Urban Wastewater and Groundwater Quality.

6.1 Introduction

South Africa is a relatively dry and drought prone country. The rainfall is generally low and erratic with a mean annual precipitation in the order of 500 mm compared to the world average of 860 mm. Some 21% of South Africa receives less than 200 mm/a. The country has limited water resources and is ranked globally amongst the twenty most water-scarce countries. The distribution of these resources has, to a large degree, dictated the establishment of settlements, routes of migration and man's mode of living. The historic importance of the water resources can be gauged by the hundreds of town and farm names relating to water, i.e. Bloemfontein, De Aar.

In terms of South Africa's overall water consumption, groundwater contributes only some 15% of the total volume consumed (DWAF, 2002). This percentage belies the fact that over 300 towns and 65% of the population are entirely dependent upon this resource for their water supply. Lack of reliable hydrogeological information has been identified as one of the reasons why groundwater has generally not been developed to its full potential. It is estimated that some 12 million people are still without an adequate supply of water to meet their basic needs. Over 80% of South Africa is underlain by relatively low yielding, shallow, weathered and/or fractured-rock aquifer systems. By contrast, appreciable quantities of groundwater can be abstracted at relatively high-rates from dolomitic and quartzitic aquifer systems located in the northern and southern parts of the country, respectively, as well as from a number of primary aquifers situated along the coastline (Figure 1).

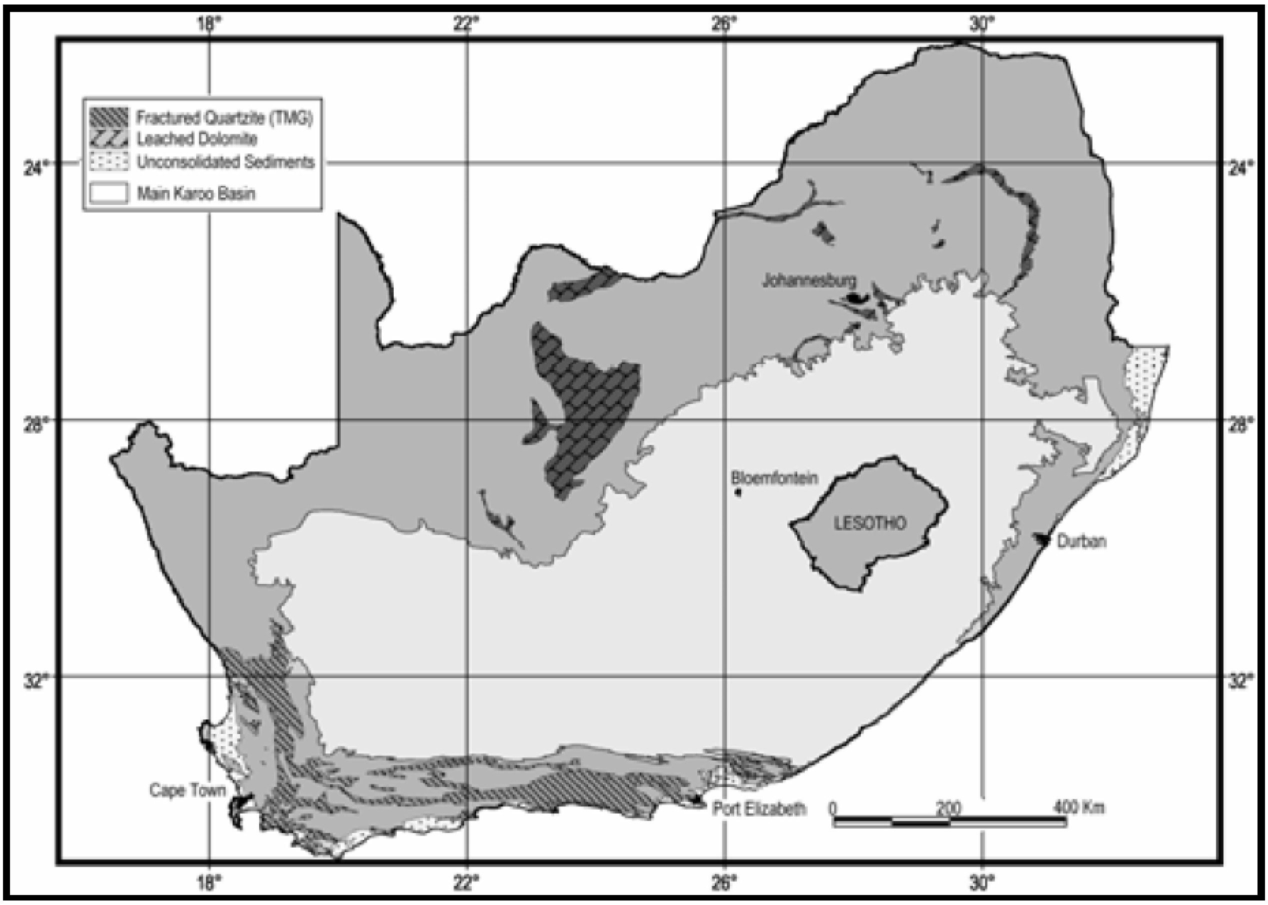

Figure 1: Distribution of significant secondary and primary aquifer systems in South Africa (Groundwater strategy, 2016).

This module highlights and summarizes the results of the Department of Water and Sanitation's Groundwater Resources Assessment Phase 2 (GRA2) project which aimed at quantifying the recharge, storage and sustainable yield of the aquifer systems in South Africa.

In late 2003, the Department of Water and Sanitation (DWS) initiated the Groundwater Phase 2 Project, which is aimed at the quantification of the groundwater resources of South Africa on a national scale. The project has been carried out by key DWS personnel and other consultants, i.e. SRK consulting, and was completed in June 2005. Algorithms have been developed for the estimation of aquifer storage, recharge, baseflow and the groundwater reserve. The quantities derived for the key aspects of recharge, aquifer storage and extractable groundwater are 30,520, 235,500 and 19,000 Mm^3/a, respectively.

6.2 Previous work

The question as to the total amount of groundwater available for development in South Africa could not, until recently, be answered by hydrogeologists, much to the frustration of water resource engineers and planners, not to mention the hydrogeologists themselves. Whilst the 'Surface Water Resources of South Africa' publication is in its third edition, no similar such body of work is available for groundwater. Early attempts at quantifying the groundwater resources of South Africa, e.g. Enslin (1970), Vegter (1995), were largely educated guesses. Estimates of the sustainable groundwater yield as derived by these pioneers of hydrogeology in the country were 2,500 and 5,400 Mm^3/a, respectively. Concern about the lack of systematic country-wide groundwater data collection and interpretation led the Directorate of Geohydrology in Department of Water and Sanitation (DWS) to launch in mid-1990 a programme to compile a series of 21 hydrogeological maps of South Africa at a scale of 1:500 000, each of which has an accompanying explanatory booklet. This was basically an aquifer classification project and was completed in 2005 (Figure 2).

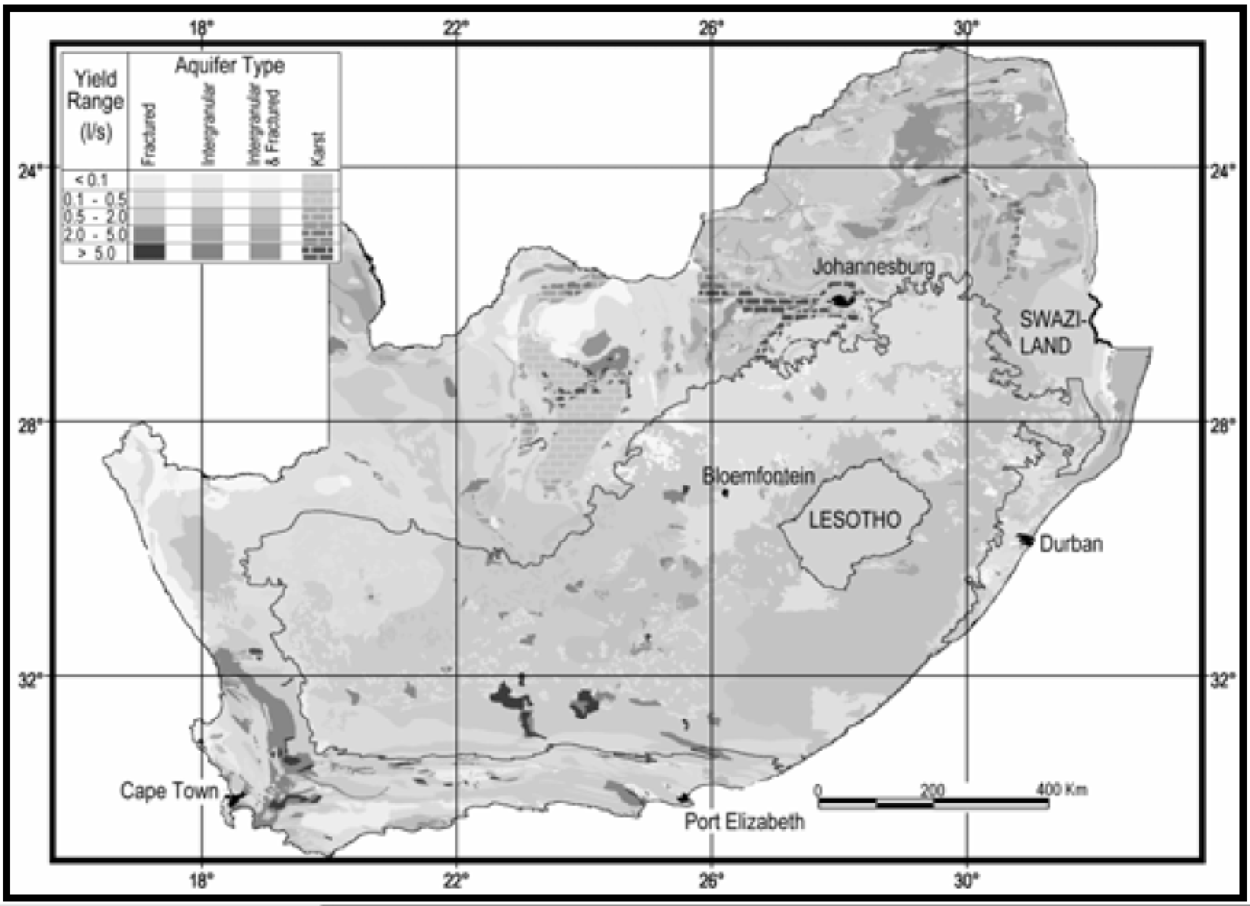

Figure 2: Composite of DWAF's 21 1/500,000 scale aquifer yield maps of South Africa (Groundwater strategy, 2016).

In 1995, Vegter however produced the first synoptic and visual representation of the groundwater resources of South Africa. The work was published in a set of seven maps and an explanation booklet. It provided a valuable indication of availability of groundwater on a regional scale. The series of maps depict borehole yield probabilities, depth to groundwater-level, groundwater quality / hydrochemical type, mean annual recharge and groundwater contributions to baseflow on a national scale. The main maps basically represent a statistical analysis of information stored in DWS's National Groundwater Data Base.

This work was built-on by Baron, Seward and Seymour (1998) with production of the so-called 'Groundwater Harvest Potential' map of South Africa. Regional estimates of aquifer storage and recharge were used to provide a sustainable groundwater yield in $m^3/km^2/a$, which the authors defined as 'the maximum volume of groundwater that could be abstracted per annum without depleting the particular aquifer'. Their estimate was 19 000 Mm^3/a. Haupt (2001) further refined the Harvest Potential map by recognizing that in many cases aquifer permeability would be the main factor limiting the utilisation of the so-called harvest potential. He applied a factor to the harvest potential based on country-wide borehole yield analyses and came up with an estimate of groundwater availability of 10 000 Mm^3/a.

6.3 Groundwater occurrence

Water not only covers three quarters of the Earth's surface: it is also present almost everywhere below ground surface, down to considerable depth and in continuous motion. It represents an invisible component of the hydrosphere and of the water cycle. This groundwater represents by far the biggest portion of all liquid (not frozen) freshwater on earth – about 96% (see figure below). In comparison, the global volume of freshwater in lakes is less than 1% of the total fresh groundwater volume (see Figure 3).

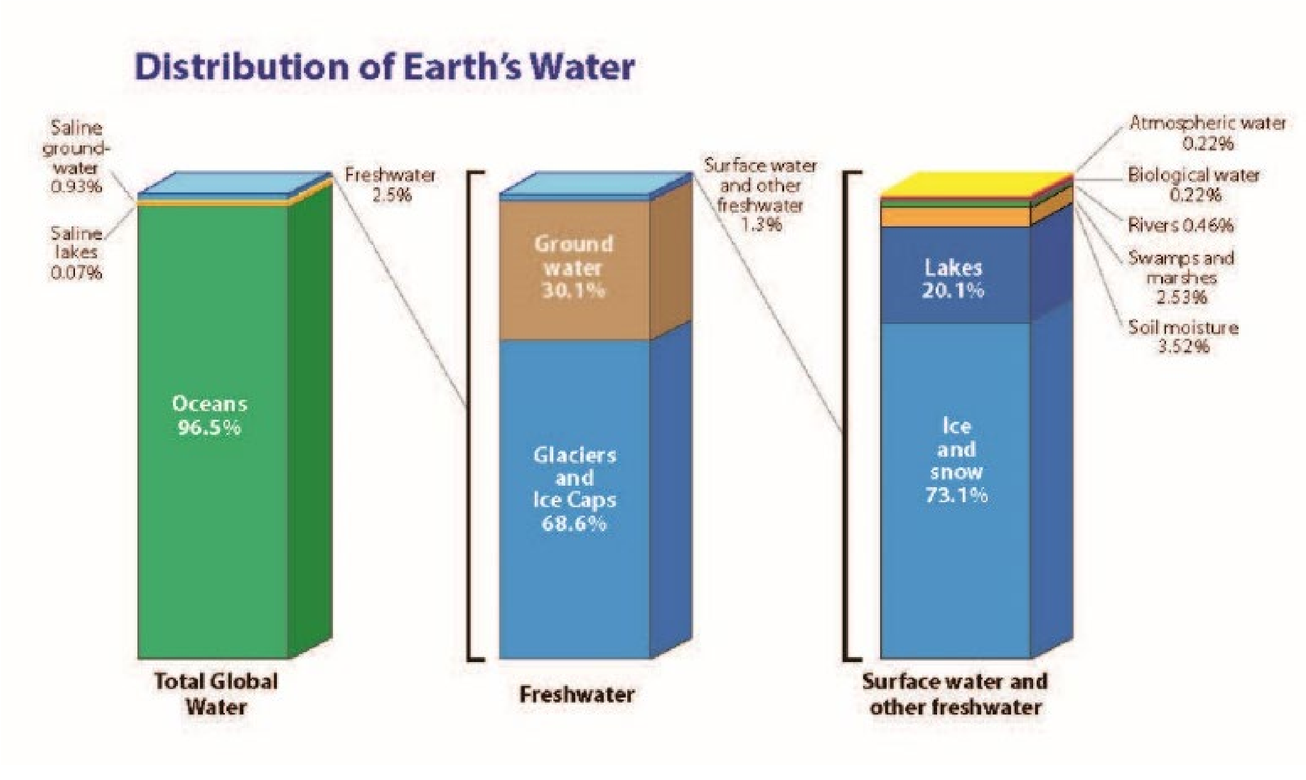

Figure 3: The groundwater portion of the earth's freshwater (Murray *et al.*, 2010).

6.4 Groundwater occurrence in South Africa

South Africa's aquifer systems have received their water-bearing properties, in particular the permeability, through the region's historical geological and hydrological development and as a result of the physical and chemical composition of the different rock types. Figure 4 illustrates the main types of permeability found in different rock types. Permeability is termed primary if it is formed as the rock is formed (intergranular) and secondary if it is formed in the rock formation itself (fissures and caverns, fractures, joints and faults).

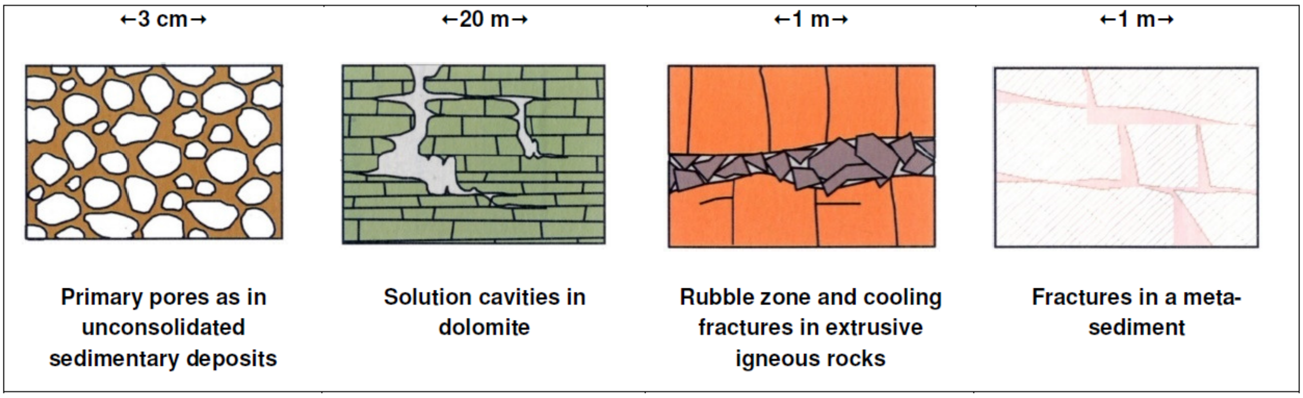

Figure 4: Different aquifer permeability types (Murray *et al*., 2010).

The simplified geology map in Figure 5 enables a national-scale view of the main aquifer types in South Africa based on the aquifer properties of the main lithology (rock type) of the different rock strata.

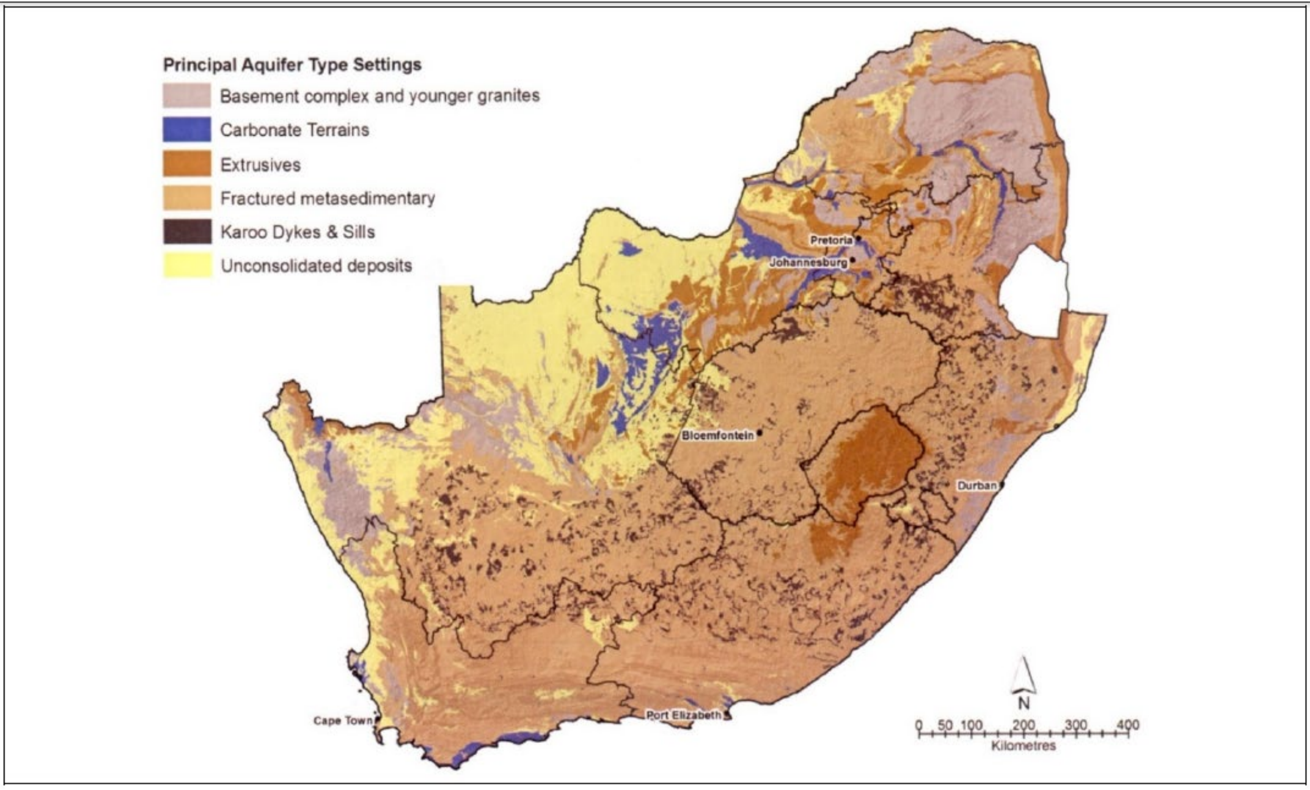

Figure 5: Main aquifer types in South Africa (Colvin *et al*., 2007).

More than 90% of South Africa is underlain by hard-rock, or secondary, aquifers controlled by secondary faulting and jointing. Primary (sandy) aquifers generally are restricted to the coast, alluvial valley deposits and the Kalahari.

A very pragmatic aquifer classification was already developed in 1995 to support the regulatory system developed by the then Department of Water and Sanitation – see (Parsons, 1995).

Table 1.1: Aquifer Systems in South Africa (after Parsons, 1995)

AQUIFER SYSTEM CLASSIFICATION	**COVERAGE OF COUNTRY (%)**	**GENERAL LOCATION**
MAJOR AQUIFERS	18	Primary aquifer systems along the coast; Dolomitic systems in parts of Gauteng, Mpumalanga, the Northern Cape and North West Province; Rocks of the Table Mountain Group bordering the Cape coast; Parts of the Karoo Supergroup; Cities and towns receiving water from major aquifer systems are Pretoria, Mmabatho, Atlantis, St. Francis Bay and Beaufort West.
MINOR AQUIFERS	67	Minor aquifers occur widely across South Africa with variable borehole yield and water quality. They supply many smaller settlements, e.g. Nylstroom, Williston, Carnarvon and Richmond.
POOR AQUIFERS	15	Poor aquifers occur mainly in the dry northern and western parts of the country. The generally low borehole yields of poorer quality are, however, still of critical importance to small rural communities.

A map showing the spatial distribution of major, minor and poor aquifers is shown in Figure 6.The map also shows locations where groundwater sources are used, either as sole source or in combination with surface water sources.

A critical characteristic in terms of groundwater's exploitation is the depth that has to be drilled to encounter groundwater. This is expressed as the depth to the first water strike and the country-wide situation is shown in the map, Figure 7. This depth ranges between 30-60 m for large parts of the country, to over 120 m, in particular under the deep sand cover in the Kalahari.

The thickness of the water-saturated formation determines the storage of an aquifer. This is particularly important in times of drought. However, the sustainable utilization of an aquifer is dependent on its natural replenishment or recharge, just as in the case of river flow. The management task is to ensure that utilisation stays within the limits imposed by rainfall and recharge. Groundwater differs from rivers in that the response to rainfall is not "flashy", but reflects over a period of months or even years. The response to droughts is also much slower, with groundwater therefore a far more buffered resource than surface water. Surface characteristics and geology can result in 'preferential recharge areas' and it is important to know and understand these. A project supported by the WRC is presently underway to map these areas, so that they can be better protected (Nel *et al*., 2013; Nel *et al*., 2015).

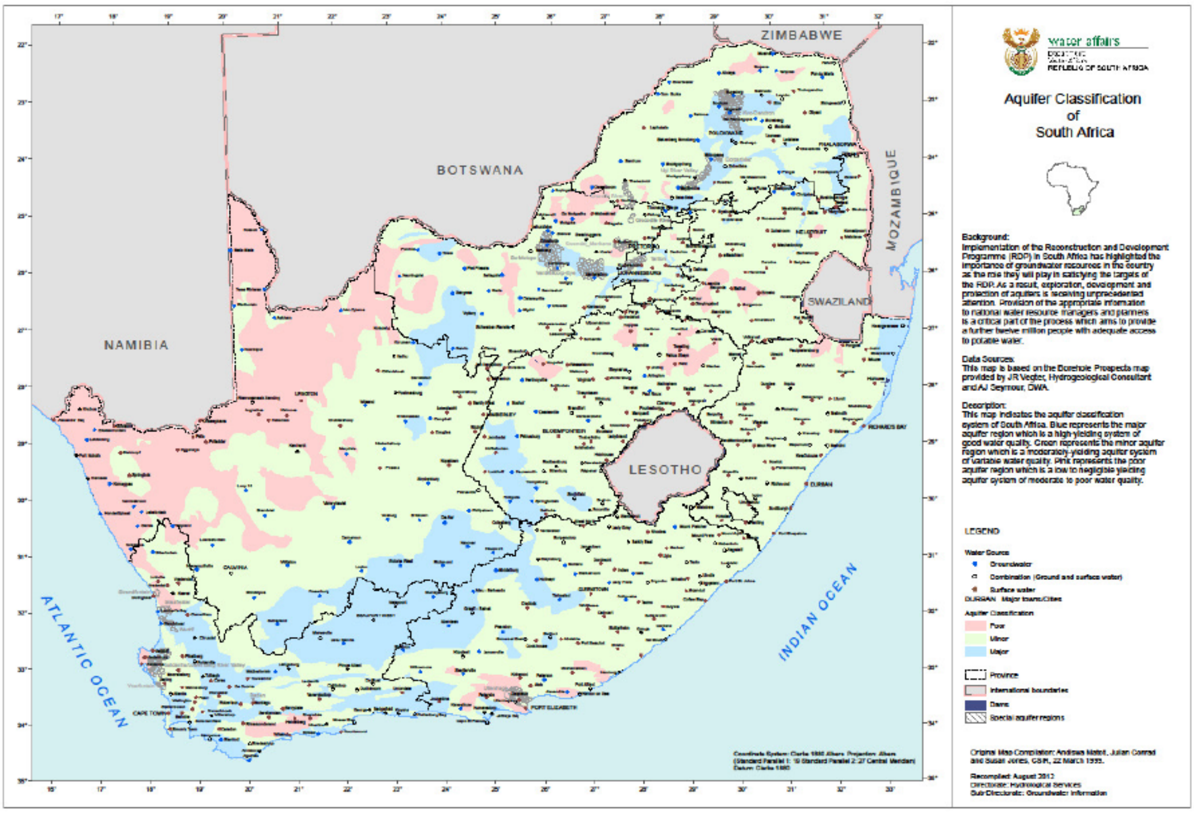

Figure 6: Aquifer classification in South Africa (Groundwater strategy, 2016).

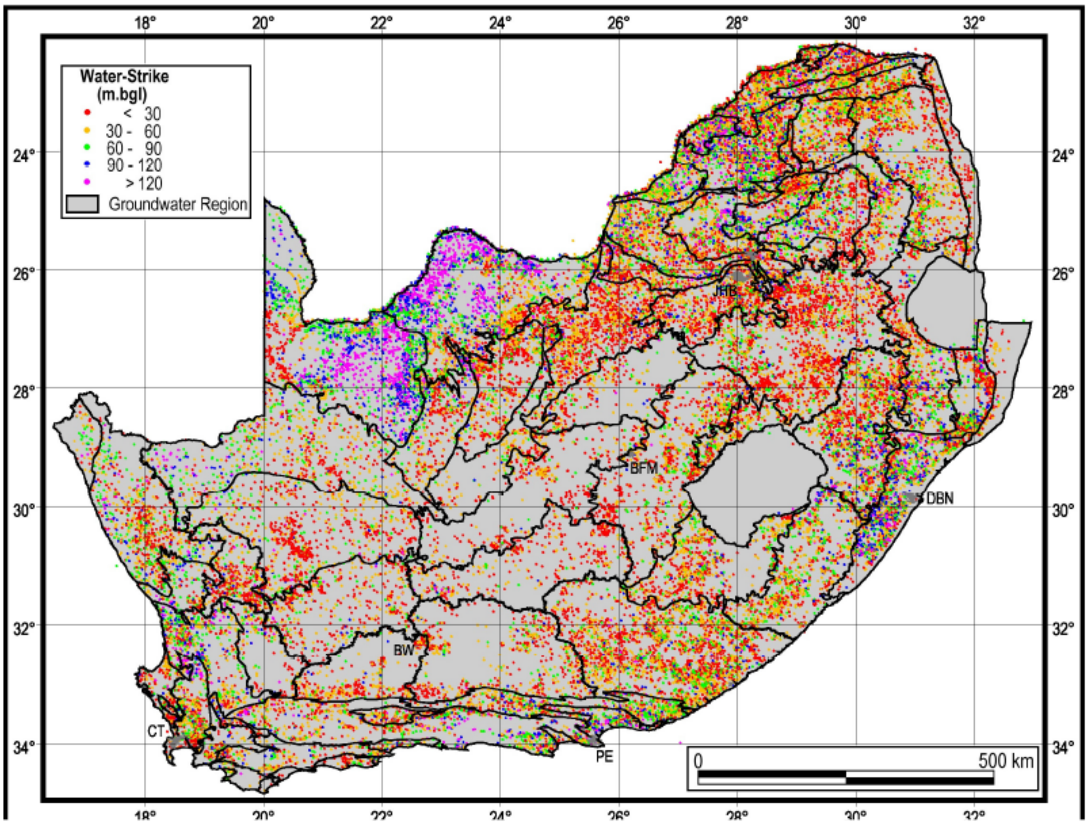

Figure 7: Depth to Water Strike in South Africa (Groundwater strategy, 2016).

6.5 Groundwater – environment linkages

An aquifer – literally a 'water carrier' – is both a reservoir and a transport channel. Groundwater flow in an aquifer is governed by the aquifer's intrinsic characteristics (shape, size, permeability, etc.) but also by its recharge, largely produced by infiltration of precipitation. Most of the groundwater flow eventually ends up in springs and streams. In coastal areas there may be a significant outflow into the sea. Groundwater recharge and groundwater discharge are thus the links between groundwater and the other components of the water cycle. This is illustrated in the water cycle diagram (Figure 8) below (Colvin *et al*., 2007).

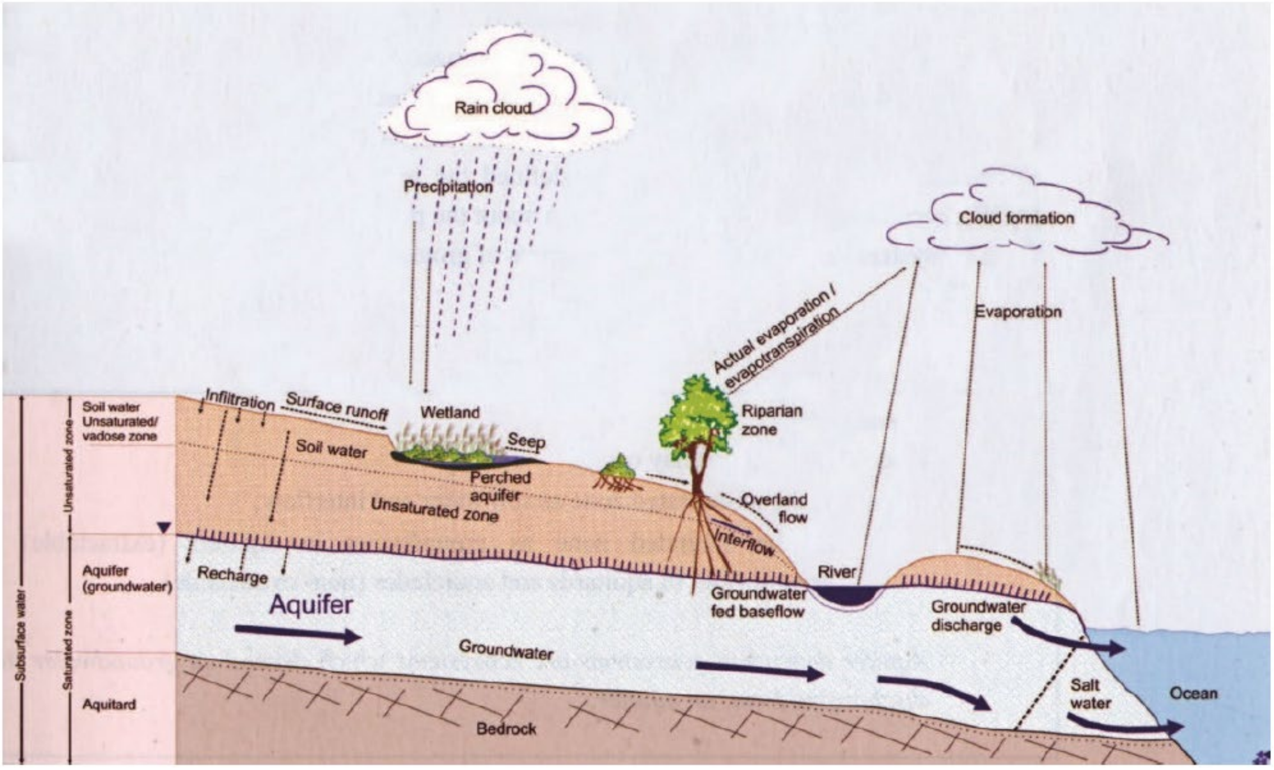

Figure 8: Subsurface and surface flows of water in the environment (Colvin *et al*., 2007).

Wherever groundwater flows or discharges to the surface, Aquifer-Dependent Ecosystems (ADEs) can occur. Their identification is often difficult, but a type-setting and identification study has been undertaken to guide groundwater management and allocation (Colvin *et al*., 2007). Examples of known South African Aquifer-Dependent Ecosystems include:

- in-aquifer ecosystems in the dolomites (North West Province);
- springs and seeps in the TMG sandstone (Western Cape);

- terrestrial keystone species such as Acacia erioloba in the Kalahari;
- lakes and punctuated estuaries on the shallow sand aquifers of the east and south coast;
- riparian zones in the seasonal alluvial systems of the Limpopo;
- seeps on the Karoo dolerite sills.

6.6 Groundwater use

To put the quantification of groundwater resources into perspective, a brief discussion on its use in South Africa is given. Groundwater contributes 15% of all the water resources been used in South Africa. Figure 9 below provides a breakdown of groundwater use for different economic sectors and Figure 10 indicates how this is further broken down into different Water Management Areas. Large volumes of groundwater are used for irrigation in the drier, more sparsely populated west of the country. Such a volumetric aggregate is however not always a good reflection of the importance of groundwater for a specific sector.

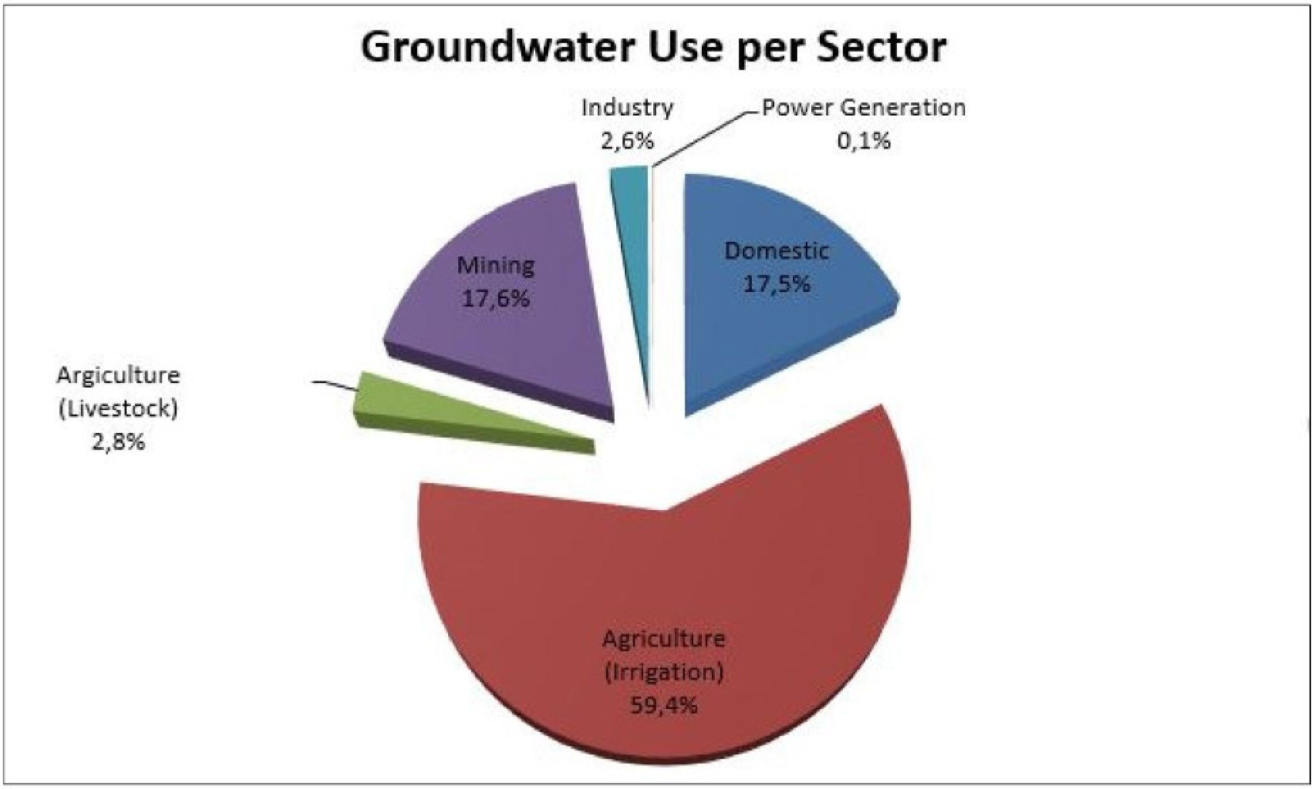

Figure 9: Breakdown of groundwater use for different economic sectors (Colvin *et al*., 2007).

Groundwater is widely but variably used across the whole of the country. A more detailed breakdown of the sectoral use of groundwater in the major surface water catchments is provided by Colvin *et al*. (2007) and is in Figure 10. This study the most up to date estimate of total groundwater use in South Africa, deriving a figure of 1,770 Mm^3/a. Sixty four percent of all groundwater abstracted is used for irrigation.

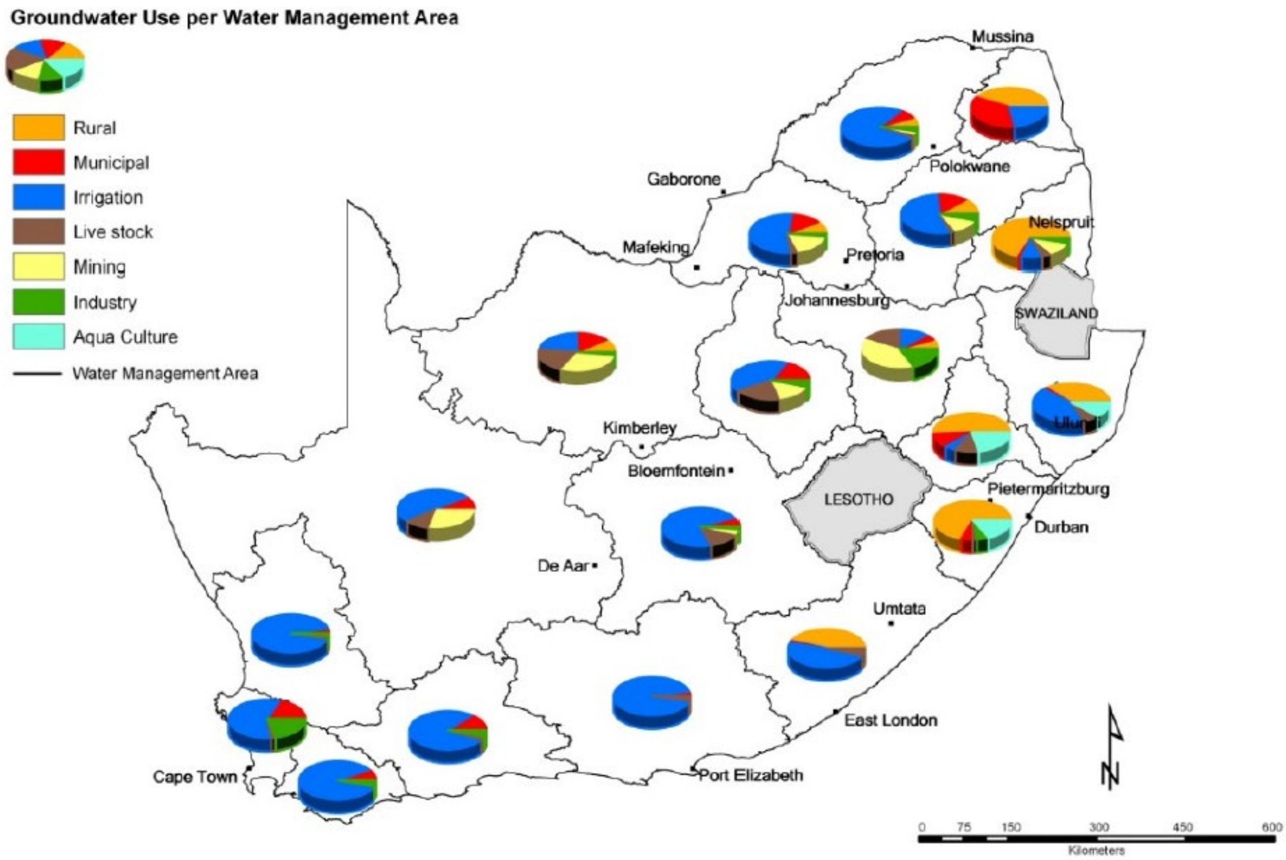

Figure 10: Groundwater use per Water Management Area (Groundwater strategy, 2016).

The Reconstruction and Development Programme (RDP) and subsequent plans and strategies have enabled major progress in supplying our citizens with an improved water supply since 1994. According to the 2010 Millennium Development Goal (MDG) Report (UNDP, 2010) in 1996 only 61% of the national population was using an improved drinking water source. In 2013 that figure stands at 95% (DWA, 2013), meaning that South African has easily achieved its MDG obligation in relation to water. This achievement would not have been possible without groundwater becoming an important source. In 5 of the 9 provinces more than 50% of settlements now have a groundwater supply, Limpopo leading with 84% followed by North West and Northern Cape Provinces, both with more than 65% of communities supplied from groundwater.

In terms of volumes, it represents a very small portion of the overall water supplied, but in terms of the national objective of development and the elimination of poverty and inequality, it represents major progress.

Groundwater is becoming increasingly important for urban water supply. 22% of towns use groundwater as sole source and another 34% in combination with surface water. Water sources of domestic water supply (urban & rural) are shown in Figure 11.

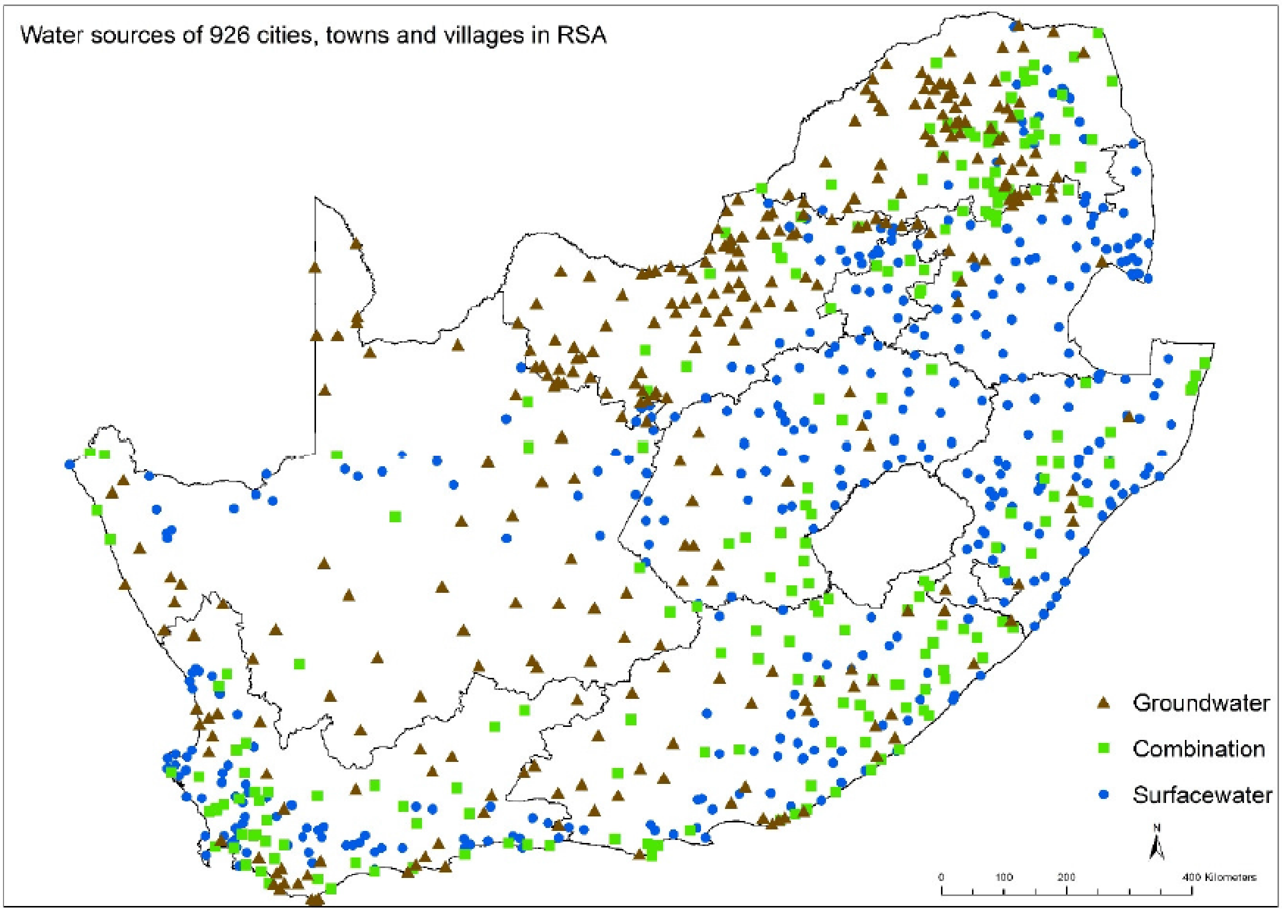

Figure 11: Water sources of domestic water supply (urban & rural) (Groundwater strategy, 2016).

6.7 Quantification of groundwater resources

Whilst the 'Surface Water Resources of South Africa' publication is currently undergoing its fourth revision, no similar such body of work is available for groundwater. In late 2003, the Department of Water and Sanitation initiated the so-called Phase 2 Groundwater Resources Assessment (GRA2) project, the main aim of which is to quantify South Africa's groundwater resources. The project also required that GIS-based algorithms be developed that would enable DWS to easily update the groundwater resource potential estimates in the years ahead as new and more detailed geohydrological information became available. A raster or grid based GIS model was developed and all and outputs were produced at a cell size of 1x1km. The following key outputs from the project will be discussed (1) aquifer storage, (2) recharge and (3) yield.

6.7.1 Aquifer storativity

GIS layers were developed for various levels within a conceptual aquifer system (Figure 12). These aquifer levels are grouped into two broad zones; namely (i) ‘static’ storage zone, which is the volume of groundwater available in the permeable portion of the aquifer below the zone of natural water level fluctuation (level 2), and (ii) ‘dynamic’ storage zone, which is the volume of groundwater available in the zone of natural water level fluctuation. The levels are listed below:

Level 1 – base of the aquifer

Static

Level 2 – base of the natural dynamic groundwater elevation

Level 3 – current groundwater elevation

Level 4 – average groundwater elevation

Dynamic storage

Level 5 – top of the aquifer

A sixth level, a management water level restriction, was introduced to take into account any possible environmental, legal or other constraints placed on the volumes of water that may safely be abstracted from an aquifer system, e.g. restrictions to ensure that DWAF’s ‘Reserve’ requirements are met, restrictions on maximum water level drawdown in dolomitic aquifers due to the hazard of sinkhole formation or avoiding intrusion of saline water.

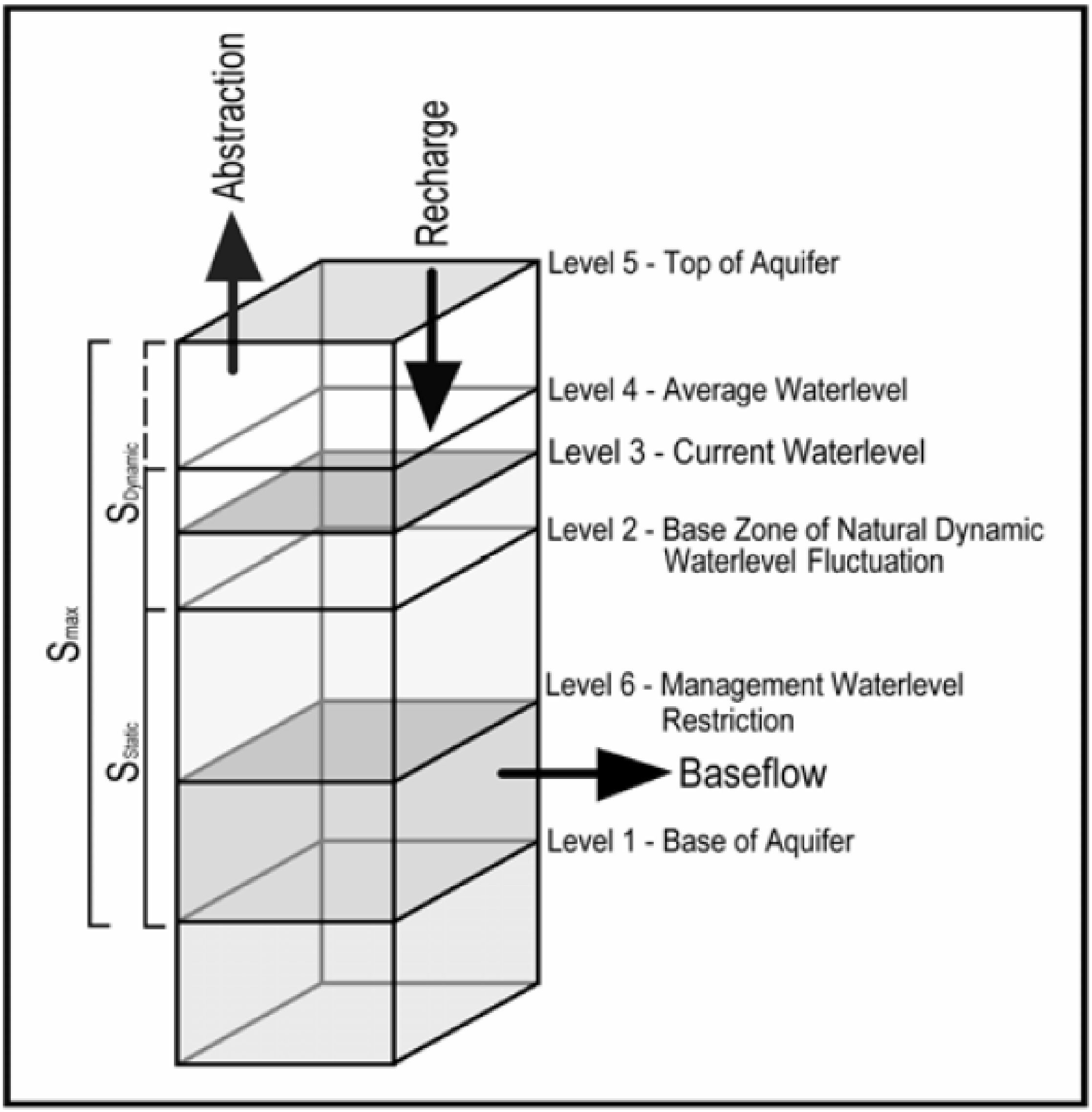

Figure 12: Six Levels in Aquifer System used to assess volumes of Groundwater held in storage (Colvin *et al.*, 2007).

The volume of water stored between any two aquifer levels or zones is estimated as the volume of aquifer material reduced by an appropriate storage-coefficient or specific yield. The GIS model makes use of a number of these potential storage volumes (levels) together with parameters such as rainfall recharge and base-flow to determine the annual volumes of groundwater available for use on a sustainable basis.

The approach involved defining the thickness and storativity of two aquifer zones, (i) the upper 'weathered-jointed' or WZ and (ii) the underlying 'fractured' zone or FZ. It is estimated that 79% of this water is stored in the WZ which is on average only 33 m thick, as opposed to an average FZ thickness of 121 m – providing a mean aquifer thickness of 154 m. The mean storativity of the WZ and FZ is estimated at 2.62×10^{-3} and 1.52×10^{-4}, respectively. The distribution of storage is shown in Figure 13 which indicates that some 235,500 Mm^3 of groundwater may be stored in aquifer systems in South Africa.

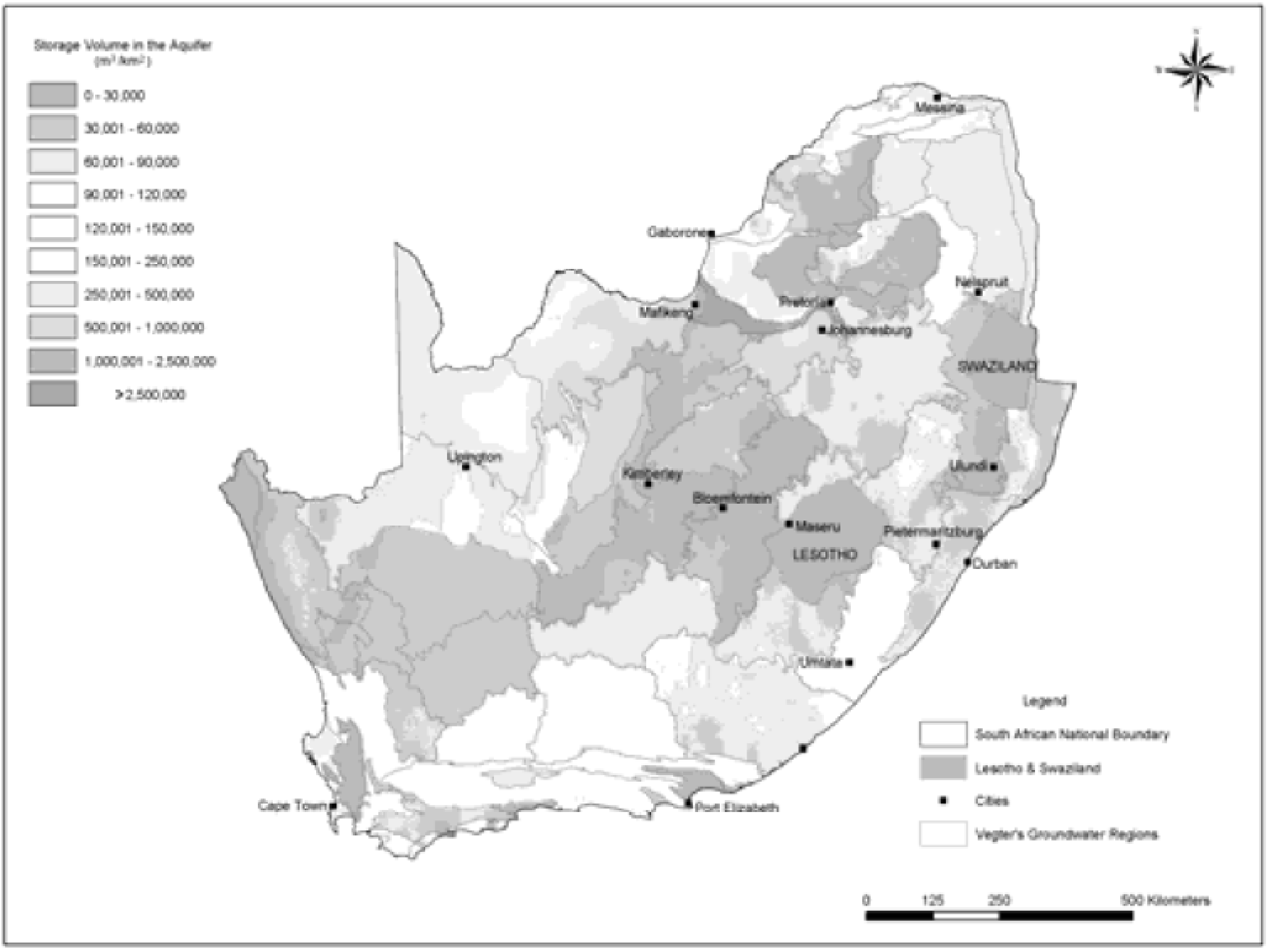

Figure 13: Estimated total volume (m^3/km^2) of groundwater stored in South African Aquifers (Groundwater strategy, 2016).

6.7.2 Aquifer recharge

The annual groundwater recharge from rainfall was estimated using the chloride-mass-balance and a GIS based modelling approach using various empirical rainfall versus recharge relationships. This was followed by cross calibration of results with field measurements and detailed catchment studies. A mean annual recharge volume of 30,520 Mm^3 was thus calculated.

6.7.3 Groundwater resource yield estimates

The methodology developed to estimate the sustainable yield of the groundwater resources during the GRA2 project employs a basic water-balance approach, where the change in storage in a system is equal to all inputs to, less all outputs from the system.

Over long periods of time and where the groundwater system is in its natural state (i.e. without any abstraction), the natural inputs will be in balance with the natural outputs, such that the change in storage will be zero. This means that the groundwater component of the hydrological system is in a quasi steady-state, which implies that the averaged values of the variables have not changed over the time period over which the averaging took place. However, if groundwater is abstracted from the system, this balance is disturbed and the system is no longer in steady-state and water levels will decline in response to withdrawals from groundwater storage.

A new steady-state will be established, in theory, if abstraction does not exceed recharge. If abstraction exceeds recharge the system will remain in a dynamic (transient) or unsteady-state. Groundwater is now removed mainly from storage, as well as a proportion from river systems.

A GIS based raster-modelling approach was used to apply these basic water-balance equations to each cell in the study domain for both steady and unsteady-state conditions. The steady-state algorithms are applied to produce information relating the 'average' groundwater conditions using 'averaged' input datasets (i.e. mean annual recharge, average water level, etc.). These averaged outputs will only require updating should more accurate input datasets be acquired or if the algorithm is enhanced. The transient-state algorithms need to be applied at regular time intervals, in this case yearly, to produce outputs about the current status of the groundwater resource, and will be required as input information generated during the previous time step (i.e. antecedent conditions such as aquifer storage and water levels). The algorithms are developed in a hierarchical system whereby the output from one lower-order algorithm is required as input into the next higher-level algorithm, where an additional refinement or management restriction is applied and so on.

6.7.3.1 Groundwater resource potential

The Groundwater Resource Potential (GRP) is defined as the maximum volume (m^3) of groundwater that can be abstracted per unit area per annum without causing any long-term 'mining' of the aquifer system (i.e. without continued long-term declining water levels). The GRP is based purely on physical inputs / outputs and aquifer storage. It is therefore not equivalent to the 'sustainable' or 'optimal' yield of the system, which normally takes into account factors such as intrusion of poor quality water, variable aquifer permeability, practical and cost issues relating to extracting the water, etc.

Two basic algorithms have been developed to determine the GRP based on the (i) average or steady-state (AGRP) and (ii) dynamic or transient-state aquifer conditions. The steady-state Groundwater Resource Potential dataset is similar to DWAF's Harvest Potential map in that they both provide estimates of the maximum volumes of groundwater that are potentially available for abstraction on a sustainable basis, and only take into consideration the volumes of water held in aquifer storage and the recharge from rainfall. The feasibility of abstracting this water is limited by many factors due mainly to the physical attributes of a particular aquifer system, economic and/or environmental considerations. One of the most important of these is the inability to establish a network of suitably spaced production boreholes to 'capture' all the available water in an aquifer system or on a more regional scale (Water Systems Management, 2001). The factors limiting the ability to develop such a network of production boreholes, include, inter alia, the low permeability or transmissivity of certain aquifer units, accessibility of terrain to drilling rigs, unknown aquifer boundary conditions.

The Average Groundwater Resource Potential or AGRP of aquifers in South Africa (Figure 14 and 15) is estimated under normal rainfall conditions at 49,249 Mm^3/a, which decreases to 41,553 Mm^3/a during a drought. These estimates are regarded as the maximum volumes that could be abstracted on a sustainable basis, if and only if, an adequate and even distribution of production boreholes could be developed over the entire catchment or aquifer system – which is impractical both physically an economically.

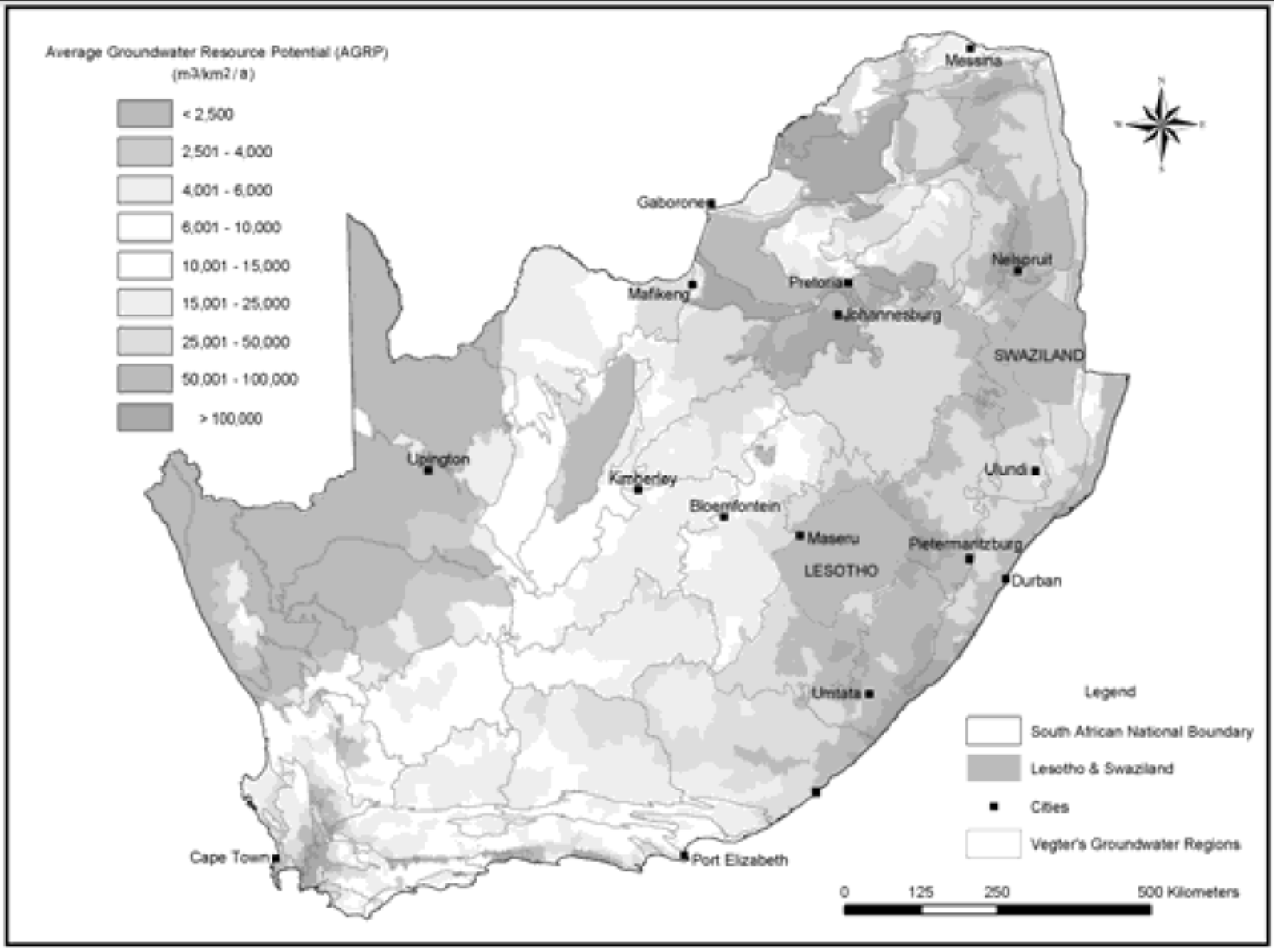

Figure 14: Average Groundwater Resource Potential for South Africa (Groundwater strategy, 2016).

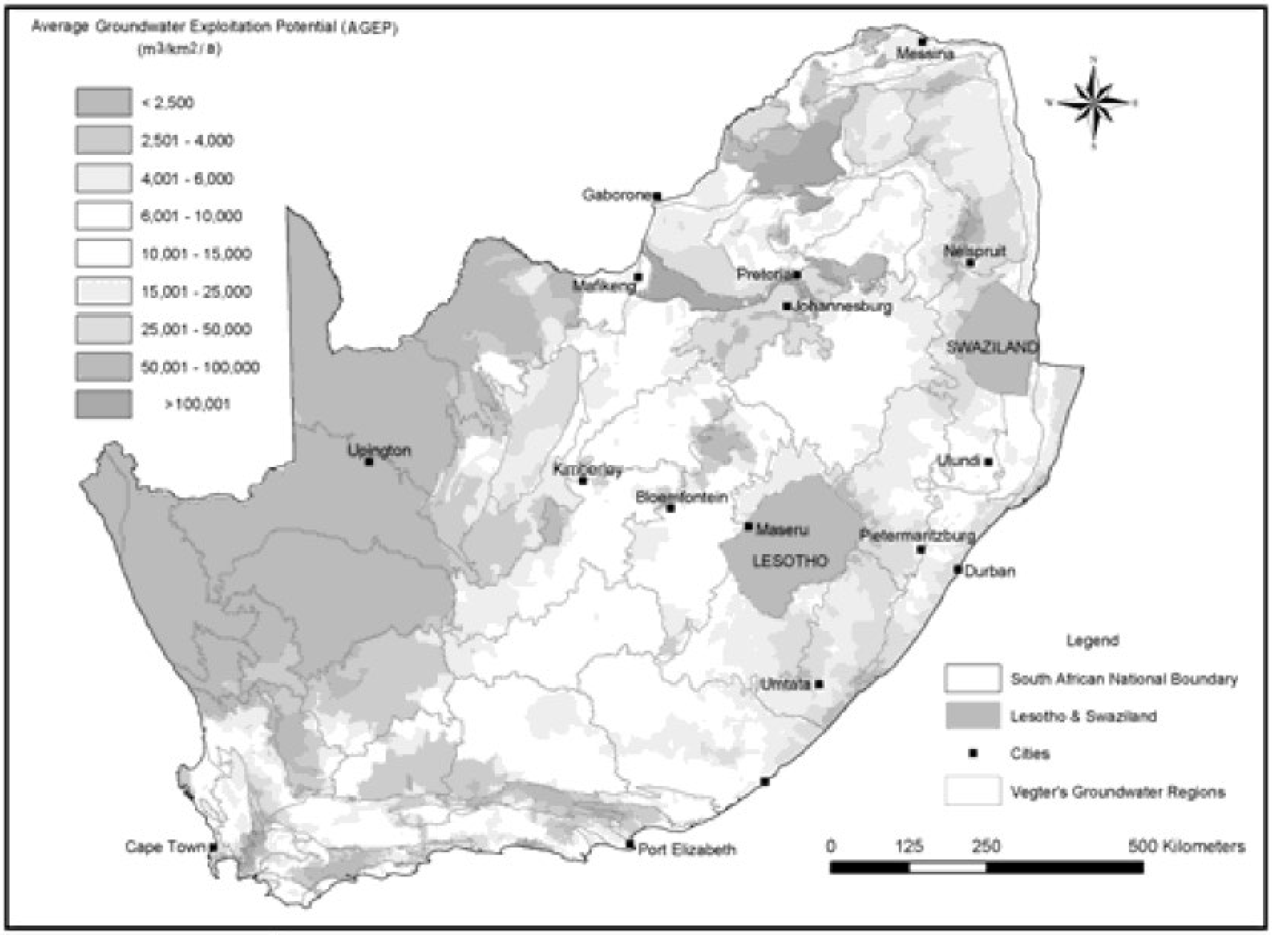

Figure 15: Average Groundwater Resource Potential for South Africa (Groundwater strategy, 2016).

6.7.3.2 Groundwater exploitation potential

In order to account for the pumping limitations discussed above, the GRA2 project made use of Haupt's (2001) concept of an 'Exploitability Factor' or EF and Vegter's (1995) national 'Borehole Prospects' coverage to generate a 1x1km EF grid for the country. Vegter stated that the prospects of obtaining a groundwater supply from a particular lithological unit may be judged by analysis of the yield distribution of an adequate number of randomly spaced boreholes drilled into this unit. He classified the lithostratigraphic units of the country into 16 water-bearing categories and analysed the yield information from 120,000 boreholes obtained from DWAF's NGDB. The Borehole Prospects coverage is therefore an indication of the extent to which various lithological units are able to act as aquifers.

The EF factor was applied to the AGRP grid to produce the so-called 'Average Groundwater Exploitation Potential' or AGEP coverage. The total AGEP of aquifers in South Africa is estimated at 19,073 Mm^3/a, which declines to 16,253 Mm^3/a during a drought. It is likely that, with an adequate and even distribution of production boreholes in accessible portions of most catchments or aquifer systems, these volumes of groundwater may be annually abstracted on a sustainable basis.

Groundwater quality is one of the main factors restricting the development of available groundwater resources. Although there are numerous problems associated with groundwater quality, some of which are relatively easily remediated, high concentration of total dissolved solids, nitrates and fluoride are considered to be the most common and serious problems associated with water quality on a regional scale.

6.7.3.3 Potable groundwater exploitation potential

The Potable Groundwater Exploitation Potential (PGEP) of aquifers in South Africa (Figure 16) is estimated at 14,802 Mm^3/a, which declines to 12,626 Mm^3/a during a drought. Nationally, this represents almost a 30% reduction in the annual volumes of available groundwater for domestic supply due to water quality constraints.

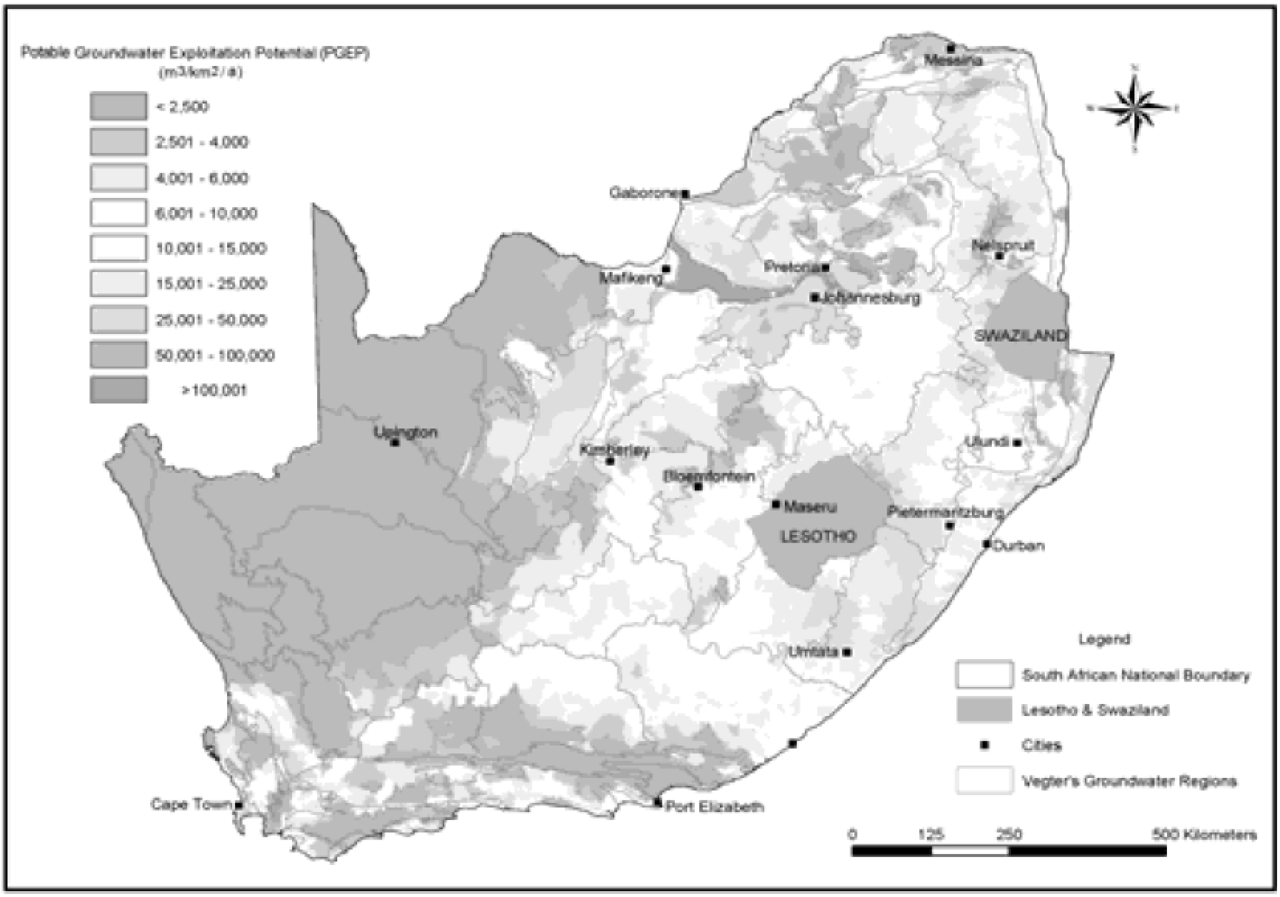

Figure 16: Potable Groundwater Exploitation Potential of South Africa (Groundwater strategy, 2016).

6.7.3.4 Utilisable groundwater exploitation potential

The volume of water that may be abstracted from a groundwater resource may ultimately be limited by anthropogenic, ecological and/or legislative considerations, which ultimately is a management decision that will reduce the total volume of groundwater available for development – referred in the GRA2 project as the Utilisable Groundwater Exploitation Potential (UGEP). This includes the important legislative restriction imposed on the volumes of groundwater available for utilisation by the requirements of the 'Groundwater Component' of the Reserve as stipulated in the South African National Water Act of 1998. Other aspects such as protection against the hazards of saline intrusion or sinkhole formation, conserving important groundwater dependant ecosystems, maintaining baseflow to rivers, etc. can all be factored in using this approach.

The Utilisable Groundwater Exploitation Potential (UGEP) under normal rainfall conditions and under drought conditions is estimated at 10,353 and 7,536 Mm^3/a, respectively (Figure 17). The UGEP represents a management restriction on the volumes that may be abstracted based on the defined 'maximum allowable water level drawdown' and therefore it is always less than or equal the AGEP. It is likely that, with an adequate and even distribution of production boreholes in accessible portions of most catchments or aquifer systems, these volumes of groundwater may be annually abstracted on a sustainable basis.

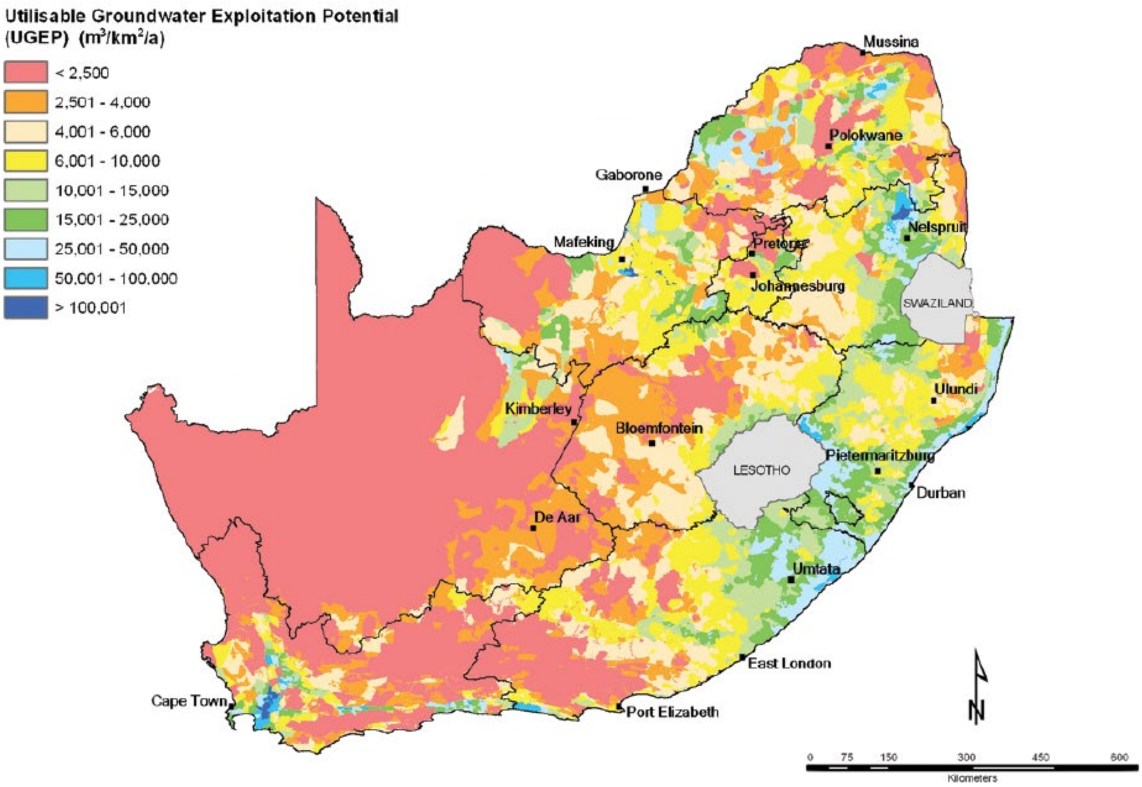

Figure 17: Utilisable Groundwater Exploitation Potential for South Africa (Groundwater strategy, 2016).

6.8 How much groundwater does South Africa have?

One of the most important questions that is frequently asked is "how much groundwater do we have in South Africa?" This question is more complex than it might first seem, because using groundwater in a sustainable way for water supplies, without harming the environment, depends on sufficient data and on factors including recharge (i.e. what proportion of rainfall percolates into the ground to become groundwater), the quality of the groundwater, and the properties of the aquifer (i.e. an aquifer that supports only very low yielding bore holes may contain a lot of groundwater, but still not be very useful for water supply). The most recent scientific estimates place groundwater in South Africa in the same league, volumetrically, as our storedsurface water resources: The total volume of available, renewable groundwater in South Africa (the Utilisable Groundwater Exploitation Potential, or UGEP) is 10 343 million m³/a (or 7 500 million m³/a under drought conditions. (See Table 6.1 below for a breakdown of groundwater availability per Water Management Area)

Table 1.2: Groundwater Availability per Water Management Area (WMA) modified after Colvin *et al*. (2007).

Number	**Water Management Area**	**UGEP (Million m^3/a)**
1	Limpopo	644.3
2	Luvuvhu and Letaba	308.9
3	Crocodile West and Marico	447.8
4	Olifants	619.2
5	Inkomati	667.8
6	Usutu to Mhlatuze (including Swaziland)	862.0
7	Thukela	512.6
8	Upper Vaal	564.0
9	Middle Vaal	398.1
10	Lower Vaal	645.1
11	Mvoti to Umzimkulu	704.9
12	Mzimvubu to Keiskamma	1 385.9
13	Upper Orange(including Lesotho)	673.0
14	Lower Orange	318.0
15	Fish to Tsitsikamma	542.4
16	Gouritz	279.9
17	Olifants/Doring	157.5
18	Breede	362.9
19	Berge	249.0
Total		10 343.4

We currently use between 2 000 and 4 000 million m³/a of this groundwater. Therefore there is the potential to considerably increase groundwater supplies in South Africa. In contrast, the assured yield of South Africa's surface water resources is approximately 12 000 million m³/a, but more than 80% of this is already allocated. Although most (but not all) large-volume water users rely on surface water, the majority of small water supplies, which are critical to livelihoods and health, depend on groundwater (See figure 10 for the groundwater use per sector in WMA).

6.9 Groundwater and drought / climate change

Groundwater's resilience to drought is well known – often one of the first responses in times of serious drought is to drill boreholes. The southern African region is already prone to droughts, and climate change scientists predict that this may get worse – climate change forecasts for southern Africa anticipate hotter, drier weather, particularly in the west. Rainfall events may be more intense, but less frequent. With surface water resources already stretched in South Africa, groundwater should form a very important part of our climate change adaptation strategy in terms of assuring continuity of water supplies. Much work still needs to be done regarding the effects of climate change on technical issues such as groundwater recharge.

However, the seriousness of the issue is not in doubt – as a recent UNEP publication on climate change in southern Africa puts it: "…climate change may bring about a new set of weather patterns and extremes that are well beyond what the local communities in southern Africa are capable of dealing with.

The advantages of groundwater (much lower evaporation/evapotranspiration and slower declines in drought years, because the volumes stored underground are so much higher compared with surface water) mean that it should form a key part of our strategy to adapt to climate change. Groundwater will be less directly and more slowly impacted by climate change, as compared to, e.g. rivers (surface water). This is because rivers get replenished more quickly, and droughts and floods are quickly reflected in river water levels. Only after prolonged droughts will groundwater levels show declining trends. Groundwater is also closely linked to the issue of food security through irrigation of crops and maintenance of environmental flows.

The replenishment of groundwater is controlled by long-term climatic conditions. Since rainfall is the main source of recharge to aquifers, climate change may have a considerable impact on groundwater resources. Under predicted climate change conditions, groundwater has to be used and managed in a sustainable way in order to maintain its buffering and contingency supply capabilities, as well as maintain adequate water quality for human consumption.

Land-use planning has to consider groundwater resources as a precious and finite resource, and take all necessary measures to protect groundwater resources and their recharge mechanisms in the long run. Other impacts of climate change on groundwater include possible salinisation of coastal aquifers as sea levels rise, higher annual temperatures increasing rates of evapotranspiration (and therefore reducing recharge), and more intense storm events which can destroy small alluvial aquifers associated with river channels.

Our understanding of the impact of climate changes on groundwater in South Africa is limited and further research need to be conducted on various aspects of groundwater (quality and quantity) to quantify the impact on groundwater and on the communities that are dependent on groundwater.

Recommendations made elsewhere in this document on topics such as artificial recharge, groundwater data collection and groundwater research all form part of our strategy for meeting climate change.

6.10 Summary

Estimates of the available groundwater resource potential of South Africa range from a maximum of 47,727 Mm^3/a to as low as 7,536 Mm^3/a. For general water resource planning purposes, it is recommended that the so-called 'Average Groundwater Exploitation Potential' or AGEP be adopted where the total volume of groundwater available for abstraction under normal rainfall conditions is estimated at 19,073 Mm^3/a and which declines to 16,253 Mm^3/a during a drought. It is likely that, with an adequate and even distribution of production boreholes in accessible portions of most catchments or aquifer systems, these volumes of groundwater may be annually abstracted on a sustainable basis. Only approximately 6% by volume of the AGEP is currently being abstracted on an annual basis.

6.11 Exercises and tasks

1. Explain and illustrate with diagrams how Groundwater occurs in South Africa.

2. How much Groundwater does South Africa have? Support your answer with the use of Groundwater use per sector.

3. Based on the content of this module and your observations, how does the use of groundwater have an effect on the following?

- Drought in South Africa
- Overall Hydrological Cycle

4. Summarize the Groundwater Quantity "Concept" based on your opinion and/or experience

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6.12 Report from student for evaluation and assessment.

6.13 References

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Module 7: Groundwater monitoring

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7. Learning Objectives

To understand and describe the following:

- Objectives and purpose of groundwater monitoring;
- Quality and quantity monitoring, their indicator parameters;
- Monitoring programme design.

7.1 Introduction

Scarcity of water and the increasing concern of groundwater contamination have led to the implementation of monitoring networks and is a pre-requisite for effective management (Zhou, 1994).

Research and knowledge about groundwater resources and the increasing development in population, industrial and agricultural water demand, has indicated that groundwater resources need to be managed and monitored effectively to prevent the deterioration of groundwater quality and quantity (Zhou, 1994).

According to Makeig (1991), the need for the regulation and management of activities that indicates a threat to groundwater quality has become more important over the years.

A balance between supply and demand can be seen in groundwater resources and as a result there is a narrow link between the quantity of useable groundwater and the quality of that water. The effective management and protection of groundwater resources depends on the knowledge and understanding of basic principles, as well as the availability of information on factors affecting the quantity and quality (Zhou, 1994).

Monitoring provides and includes data on groundwater quantity and quality of the resource itself and is an integral aspect of groundwater management (Sundaram *et al.*, 2009). In the absence of monitoring, groundwater quality deterioration, groundwater abstraction and contamination takes place without any safeguard for this resource (Owen *et al.*, 2010).

A groundwater monitoring system operation, programme and design needs careful planning in which significant and useful information can be achieved in a sustainable, cost effective manner (Owen *et al.*, 2010).

7.2 What is monitoring

7.2.1 Monitoring Defined

Groundwater monitoring is impractical without a clear and distinct definition.
Bosman (2014) defined monitoring as the process of collecting data in a systematic manner that is used for a specific purpose. In other words it is data that is collected at a certain suitable frequency, location and on specific features of the water resource, to ensure that date recorded in regard to the resource status is complete, accurate and cost effectively.

The organisation of such data into information which is to be used in improving the decision-making process,

- Directly as a management tool for the company and
- Indirectly to inform government the public and other parties.

Monitoring of groundwater is an important component in groundwater management and is also described in general terms as the ongoing process of collecting data and the organising and assessment of data into information to improve decision making and determine performance progress and trends (*Basic Information*, 2016 and Jha, 2010).

7.2.2 Monitoring Information

Appreciation of the importance of reliable data (values collected by measurement) and information (data which had been evaluated and interpreted to indicate the state of conditions) is lacking regardless that monitoring is a vital and integral component of all hydrogeological studies. In groundwater management the collection of data and the interpretation of information on groundwater resources play an important role and form the foundation for management.

The absence of accurate and reliable groundwater data can compromise the accurate assessment and status of groundwater supply of the resource (Department of Water Affairs, 2013).

“A reliable dataset can only be achieved through approved, standardized, capturing procedures of quality approved data” (Department of Water Affairs, 2010).
Monitoring is thus necessary for precise and sufficient data collection to inform decision making, and reduce and manage risks. The ultimate objective is to provide information that can be used for planning, decision making and operational water management (Department of Water Affairs, 2013).

According to Bosman (2014), management decisions must be based on information, not on data. A lack of data and skills results in inadequate information for decision support and poor management of the resource. The hierarchy of monitoring information can be seen in figure 1.

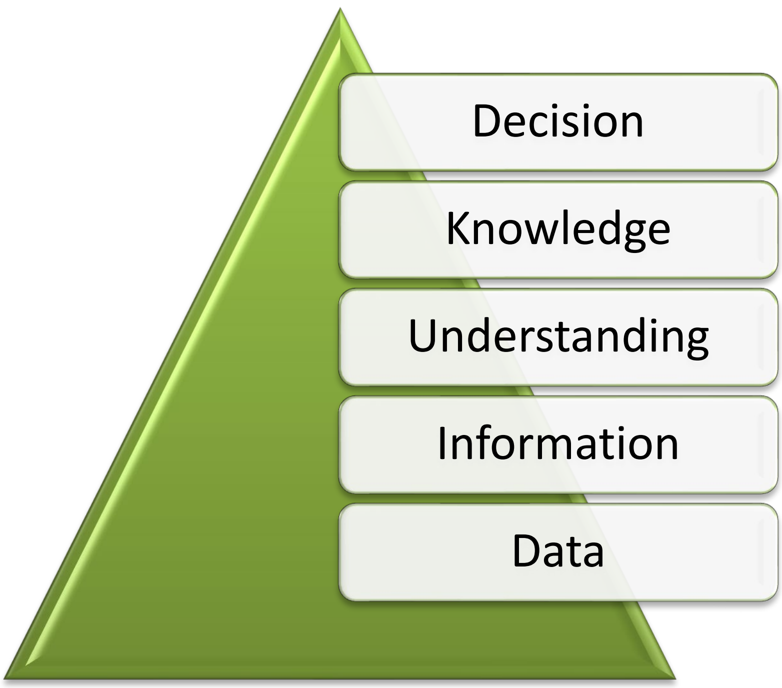

Figure 1: Hierarchy for monitoring information (Bosman, 2014).

7.2.3 Objectives of monitoring

It is said that you can’t manage, what you can’t measure. Groundwater management can’t be implemented without appropriate monitoring. Objectives are described as a specific action on how goals and purposes of monitoring can be achieved (PNAMP, 2010).

It is important that objectives of groundwater monitoring are established, specified and recorded. By recording objectives misunderstandings can be avoided on a later stage, it can act as an effective communication method with sponsors and assure that a monitoring programme is a systematically planned exercise. They are also important to see if objectives are being met or not when evaluating the program.

To assist with the developing of groundwater objectives, the following questions might be considered: (Bartram and Ballance, 1996; PNAMP, 2010).

- Constraints that can play a role on monitoring programme
- Management requirements in regard to funding entities, managers, etc.
- Monitoring design characteristics
- What frequency should be used?
- What information is required on water quality?
- Which variables should be measured?
- Who is going to use the monitoring data and why?
- Why is monitoring going to be conducted? Is it for basic information, planning and policy information, management and operational information, regulation and compliance, resource assessment, or other purposes?

Below is a list of typical objectives in relation to monitoring for groundwater management. This list provides some examples and may be used to form a basis for establishing objectives (Bartram & Ballance, 1996; Department of Water Affairs and Forestry, 2006; Fretwell, Short & Sutton, 2003; Department of Environmental Protection, 2001; Water Research Commission, 2000; World Meteorological Organization, 2013; Bartram and Ballance, 1996; Bosman, 2014).

- Aquifer materials or their hydrologic properties characterize
- Detection of contaminated areas
- Develop and implement a national monitoring and information management plan to record and maintain easily accessible and accurate data to support decision making, reduce and manage risks and deal with emerging climate change impacts.
- Development of regulations covering the quantity and quality of waste discharges
- Development of water quality guidelines and/or standards.
- Ensure uninterrupted continuation of existing monitoring programmes
- Evaluation of the effectiveness of a water quality management.
- Groundwater resource characterized
- Identification of sources of pollution and extent of pollution
- Improve governance of monitoring and information management in the water sector.
- Measure the hydraulic head at a specific location in the groundwater flow system
- Provide access for conducting tests or collecting information necessary to
- Provide access to the groundwater system for collection of water samples
- Raise awareness of the importance of investing in the collection and management of high-quality water-related information for supporting water resource management.
- To obtain information on local groundwater quantity and detection of signs influencing water quality.
- Water pollution control programme development

7.2.4 Purpose of monitoring

"Why do we monitor?" This is the question we should start with in any attempt to assess groundwater monitoring. Being able to describe the purpose of monitoring create and assist a background for direct monitoring activities. The purpose is generally set by regulatory actions and laws (action plans, water standards, regulations, laws, directives) and aims to detect trends and evaluate the environmental and groundwater resource state (Kristensen & Bøgestrand, 1996).

A monitoring programme should start by discussing the real need for information and data. The purpose of monitoring is to supply information and data and verify that groundwater levels and groundwater quality is suitable for intended users and uses. Monitoring should reflect the data needs of the various water users involved. Many monitoring programmes serve several purposes such as defining, develop, and set objectives of management needs. A purpose of monitoring also determines if management objectives are being achieved, assessing trends, provide early warning systems programme evaluation and policy development (Bosman, 2014).

The need and purpose of monitoring depends on the type of facility that requires monitoring, the location of monitoring and the complexity of conditions (Department of Environmental Protection, 2001).

The purpose of monitoring groundwater provides data to assist management in groundwater resources (the availability, sustainability, protection, conservation, determining impacts on quality and quantity) and provides information for implementation and development of groundwater policies and their effectiveness (efficiency of policy, controls, treatments and use of restrictions.

7.3 Monitoring programme design

7.3.1 The Monitoring cycle

The monitoring cycle is a systematic planning process to develop acceptance or performance criteria for the collection, evaluation, or use of environmental data.
A well-developed monitoring design plays a critical role in ensuring that data are sufficient to draw relevant conclusions (U.S Environmental Protection Agency, 2002).

The monitoring cycle generally describe the steps and processes for effective water management. A monitoring cycle (figure 2) entails the process of defining the objectives and purposes of information needs, the design of a monitoring programme, the process of data collection types and processes and the process of data storage, analysis, interpretation and distribution (Bosman, 2014).

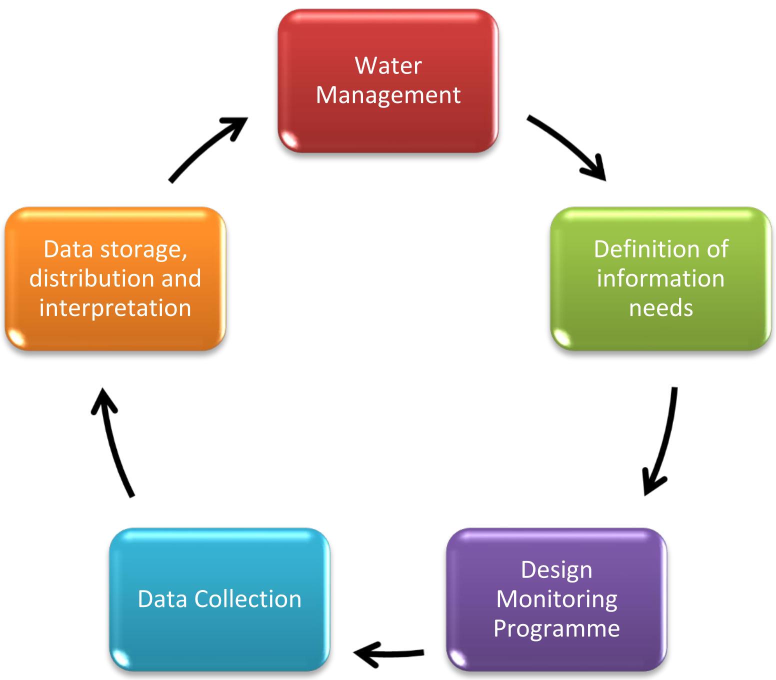

Figure 2: The monitoring cycle (Bosman, 2014).

7.3.2 Monitoring Programme

Monitoring programmes are usually developed to support and assist various management actions with different objectives. Monitoring programs assist in the following;

- Monitoring Locations
- Monitoring Frequency
- Data and information management and record keeping (discussed in Module 8)
- Reporting

7.3.2.1 Monitoring Locations

The main requirement and first task in groundwater design for a successful monitoring system is to determine the location of monitoring points (Department of Environmental Protection, 2001). Monitoring points can't be placed at random, but should be placed at the most suitable location to collect the required information and data accurately. A monitoring position that is not placed at the correct location might indicate incorrect groundwater information and data, which will lead to inaccurate evaluations, assessments and wrong decisions.

Before any monitoring location is selected, existing data should be assessed. This will assist in selecting the appropriate location and reduce cost of implementing a monitoring program. Existing data and information may be obtained from previous studies, site visits, aerial photographs, publications, geophysical and hydrological surveys as well as aquifer tests to name a few (Department of Environmental Protection, 2001).

A number of factors play a role in determining the location of monitoring points. (World Meteorological Organization, 2013; Department of Water Affairs and Forestry, 2006; Bosman, 2014; Fretwell, Short and Sutton, 2003):

- Accessibility to groundwater
- Activities nearby
- Physical constrains visible on site
- Pollution sources
- The purpose of monitoring programmes (objective and purpose).
- Variation in groundwater health and safety implications of the location low conditions and directions
- Depth of groundwater table
- Health and safety implications.

All the mentioned factors contribute towards defining the location of monitoring points and thus are a qualified person required to choose the appropriate location of groundwater monitoring points. These points should be clearly indicated, mapped and described in accessible format with coordinates (Department of Water Affairs and Forestry, 2006).

7.3.2.2 Monitoring Frequency

The monitoring frequency need to be defined once the location for monitoring points and the parameters to be measured is established. Monitoring frequency is dependent on the purpose of sampling, the type of sampling and the depth of the aquifer formations (Harter, 2003). Monitoring frequency in a monitoring program is among the most important components (Taylor and Alley, 2001).

Monitoring and sample frequency is depended and influenced by the characteristics of the water source and the amount of people allocated with water. Groundwater quality is generally described as more constant than other waters and less groundwater samples should be sufficient depended on the use for data (Water Research Commission, 2000). The minimum and recommended number of samples and sampling frequencies for different points in the water supply system is discussed in detail in the report: Quality of Domestic Water Supplies, Volume 2: Sampling Guide by The Department of Water Affairs and Forestry.

7.3.2.3 Reporting

Reporting vary greatly depending on the intended use and have to focus on the amalgamation of the data collected, rather than on the individual numbers that make up the data. In the reporting process it is important to remember that for effective understanding of reports that the resource and environmental situation must be clearly described and defined.

Keep in mind that not everyone is a specialist and that monitoring reports should be written in simple ways and should contain clear explanations (Bartram and Ballance, 1996). Monitoring results should be reported for a diverse audience in understandable terms that include the effects of processes, events and mechanisms on water.

7.4 Monitoring design

In the monitoring design process a few important parameters should be monitored;

- Groundwater level measurements
- Water Flow/Quantity monitoring systems
- Rainfall
- Field parameters
- Water quality
- Borehole development and yield testing.

7.4.1 Groundwater level measurements

The depth to the water level in the borehole is also called the static water level or the rest water level. This is the groundwater level in a borehole not influenced by artificial recharge or by abstraction. These values are used to determine hydraulic gradient and the direction of groundwater flow. The hydraulic gradient is described as the slope of the water table. This is therefore the change in hydraulic head (the elevation to which water will rise in a borehole connected to a specific point under pressure in an aquifer) over a certain distance (Department of Water Affairs, 2015).

By monitoring groundwater level measurements, information can be provided on the water levels within the boreholes and the hydraulic gradients within individual aquifers and between aquifers in layered aquifer systems. Groundwater level monitoring measurements over a long period is important and therefore provides information on the temporal trends in groundwater levels and flow direction due to the effects of groundwater abstraction, rainfall and drought (Sundaram *et al.*, 2009). Changes in water levels may perhaps directly be linked to groundwater quality changes.

Note that one can't monitor production boreholes with permanently installed pumping equipment without a piezometer tube to provide access to the borehole casing. The piezometer tube is a small diameter pipe alongside the main borehole casing. It is essential to have an established reference point when monitoring the depth to groundwater level. The reference point must be identified with a permanent marker or paint spot to provide a constant starting point for monitoring on the well casing (California Department of Water Resources, 2016).

7.4.1.1 Groundwater level measurements using a dip meter

The water level meter or dip meter uses a probe attached to a permanently marked polyethylene tape, fitted on a reel. The probe detects the presence of a conductive liquid between its two electrodes and is powered by a standard 9 volt battery. Once contact with water is made, the circuit is closed, sending a signal back to the reel. This will result in an activation of a buzzer and a light. The groundwater level is then determined by taking a reading directly from the tape, at the reference point marked on top of the borehole casing.

7.4.1.2 Steps in measuring the groundwater level

(Sundaram *et al.*, 2009 and California Department of Water Resources, 2016)

1. Wash your hands or wear disposable gloves- remember your working with drinking water.
2. Ensure that the dip meter is clean.
3. Before starting record the sampler's name, the date and time of measurement as well as the elevation (relative to sea level) and coordinates of borehole in a logbook or monitoring form that has been determined by utilizing local benchmarks and survey instruments.
4. Water levels will be measured from reference point marked at each well. The measuring point is located on the top of the steel protective casing (surface casing).
5. Switch the dip meter on when having an on/off switch.
6. Remove or open the end cap on top of piezometer tube.
7. Lower the dip meters probe slowly into the piezometer until an audio signal, light indicator, or meter deflection is noted – this will be the position of groundwater level.
8. Double check the position on cable by lowering and lifting the probe a little while checking the audio signal, light indicator, or meter deflection.
9. Keep the correct position with fingers or by temporally marking or pinching the cable.
10. Read and record the measurements seen on cable on your logbook.
11. Subtract the height of the casing above the ground level from the measurement. To record the water level relative to the ground surface, the measured distance between the measuring reference point (e.g. top of casing) and the ground surface is subtracted.
12. Check and insure that the measurements are recorded correctly, i.e.15 metres and 8 centimetres is recorded as 15.08 m and not 15.8 m. 15.8 m is thus 15 metres and 80 centimetres.
13. Clean the probe and cable and dry it probably to prevent contamination on next borehole.
14. Close or put back the end cap on top of piezometer tube.

7.4.2 Water Flow/Quantity monitoring systems

The best way to successfully monitor groundwater flow/quantity is by installing flow meters.

Although the installation of water flow meters not a common practice is among the majority of water supply boreholes, it will provide an effective monitoring system to record the volume of water pumped on a daily basis (Meyer, 2002). The ability of any flow meter is to accurately measure a wide range of flow rates.

Groundwater flow monitoring is very site specific and is dependent on the local geohydrology. Thus is a suitable qualified person necessary to evaluate and assist in the technical procedure of a groundwater flow monitoring program (Department of Water Affairs and Forestry, 2006).

7.4.3 Rainfall

Meyer (2002) described that rainfall an important role play in the recharge of aquifers. Therefore is the monitoring of rainfall a vital component in groundwater management and the data of monitored rainfall can be used to estimate groundwater recharge. The installation of low cost rain gauges can be used to monitor rainfall on a daily basis but the manually recorded data is often unreliable. Thus should a cumulative rainfall sampler be used that will allow rainfall measurements to be recorded an extended period without the loss or manipulated data.

7.4.4 Field parameters

The assessment and analysis of various physical, chemical and microbiological features and variables in groundwater can be determined by testing field parameters on site (Bartram and Ballance, 1996). A number of reasons contribute to the fact why "location based" field analysis is a significant advantage and include the following; (Weaver, Cavé and Talma, 2007), (Bartram and Ballance, 1996)

- Samples are not yet contaminated or changed in terms of characteristics due to storage in a container
- The efficiency of purging can be monitored and check
- The procedure or sampling sequence may be determined in relation to the result of certain values

- Obtain reliable values of groundwater field parameters that might change during the transport of sampling bottles
- Some variables must be measured after the sample collection due to aeration, oxidation and degassing
- Field analysis may be the only feasible way to obtain water quality information, when there are no laboratories within a reasonable distance of the sampling stations.

Field testing procedures and steps can be accessed in (Weaver, Cavé and Talma, 2007) and field testing methods include;

- Temperature
- pH
- Electrical conductivity (EC)
- Redox potential (Eh)
- Dissolved oxygen (DO)
- Alkalinity

7.4.4.1 Temperature

Temperature has an important influence on the physicality and chemistry characteristics of the water and is often the easiest field parameter to measure (Sundaram *et al.*, 2009). The temperature of groundwater is a significant parameter in water quality because it regulates the concentration dissolved oxygen of the water and influences the tempo of biological and chemical reactions (Frankenberger and Esman, 2012). The rate of chemical and metabolic reactions generally increases at higher water temperatures, and higher temperatures also increase the solubility of salts in water but decrease the solubility of gasses in water.

It is important that the groundwater temperature is measured in situ, since the fact that a water sample will reach the same temperature gradually as the surrounding air (Bartram and Ballance, 1996).The fluctuation in groundwater temperatures that is relative constant throughout the year is determined by geological factors, such as the groundwater formation, heat transferability of rocks, anthropogenic factors and the distance between the surface and groundwater (Sundaram *et al.*, 2009). Groundwater is typically measured in situ with a thermometer or TLC device and indicted in degrees Celsius or Fahrenheit.

7.4.4.2 pH

The amount and chemical form of several substances (organic and inorganic) dissolved in groundwater along with the alkalinity and acidity of groundwater is generally described by the pH of groundwater (Sundaram *et al.*, 2009). pH is described as the measurement of the concentration of hydrogen ions in a solution. The results fluctuate on a scale 0 to 14 (<7 is acidic, 7=neutral, >7 is basic) (Frankenberger and Esman, 2012). Values above 14 and below 0 are achievable in concentrated solutions, but not found in groundwater.

The suitability of groundwater for rural, domestic and commercial uses, the effect of toxicity of other substances and the ability of groundwater to transport harmful chemicals are important properties controlled by the pH of Groundwater (Sundaram *et al.*, 2009).

Groundwater pH may be affected by affected by numerous factors like the bedrock within the aquifer, nearby pollution sites and acid mine drainage. Field measurements of the pH is essential, otherwise the analysis should be completed in a laboratory within a 24 hour period (Frankenberger and Esman, 2012).

7.4.4.3 Electrical conductivity (EC)

Conductivity is described according to Weaver, Cavé and Talma (2007) as the ability of an aqueous solution to conduct an electric current. In simple terms described as the ability of water to pass an electrical current. Conductivity in groundwater is affected and depended by the presence of inorganic dissolved solids chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge) (Frankenberger and Esman, 2012). This is used as an indicator of how salt-free, ion free, or impurity free a sample of water is. EC profiling is also used to determine the depths of fractures which intersect the borehole. The lower the EC of the water is, the purer the water. The higher the EC value of the water, the higher the conductivity of the water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity (Sundaram *et al.*, 2009).

Note that all measurements is reported in millisiemen per metre (mS/m) and that the EC is measured in the field due to the fact that conductivity changes with storage time and is temperature-dependent (Bartram and Ballance, 1996).

7.4.4.4 Redox potential (Eh)

A measure of the oxidising/reducing conditions of the groundwater system is determined by redox potential (Eh) (Sundaram *et al.*, 2009). Redox is measured in units of millivolts (mV) and is usually reported as relative to the standard hydrogen electrode (SHE). Redox potential data is useful in interpreting metal species in solutions.

7.4.4.5 Dissolved oxygen (DO)

The dissolved oxygen concentrations remain a good indication of water quality and typically depend on the physical, chemical and biochemical activities in the water body (Bartram and Ballance, 1996). Dissolved oxygen (DO) concentration represents the amount of oxygen that is dissolved in a waterbody and is proportional to the local atmospheric pressure and inversely related to water temperature and salinity (Frankenberger and Esman, 2012). Dissolved oxygen can be influenced by the rapid decomposition of organic materials, high ammonia concentrations, high temperatures and low flow.

7.4.4.6 Alkalinity

Alkalinity values change rapidly when groundwater samples have been withdrawn from boreholes. To ensure accurate measurements, these variables should be monitored and measured in the field (DWAF, 1998). The alkalinity of water is its capacity to neutralise acid. The alkalinity of some waters is due only to the bicarbonates of calcium and magnesium (Bartram and Ballance, 1996). Alkalinity is described as the acid neutralising capacity of water.

7.4.5 Water Quality

The quality of water or water quality in the monitoring process can be described as the suitability of water for various uses in terms of its concentration and state in relation to the physical characteristics, organic and inorganic material present in the water (Bartram and Ballance, 1996). The analysis of groundwater quality monitoring, consist of a number of parameters and include chemical, physical and bacteriological tests (Meyer, 2002).

The physical, chemical or biological characteristics present in groundwater are usually determined by in situ measurements and by the analysis of groundwater samples. The four key components in groundwater quality monitoring are on site/field measurements, the analysis and collection of groundwater samples, the assessment of the analytical results and the reporting of the findings (Bartram and Ballance, 1996). Groundwater quality depends on a number of factors and includes human activities, composition of recharge water and rainfall, relationship between groundwater and soil, and physical, geochemical, and biochemical processes within aquifers (Bartram and Ballance, 1996).

Groundwater quality testing must be a compulsory action for municipalities providing bulk groundwater supply to communities.

7.4.5.1 Sampling

Appropriate sampling procedures are necessary for the effective monitoring of groundwater quality. The monitoring of groundwater quality samples is dependent on different sampling techniques. Chemical and microbiological monitoring samples require distinct sampling techniques to ensure that contamination of samples does not occur. The process of sampling groundwater in boreholes may require purging or stratified techniques depending on the purpose for the water quality sampling (Weaver, Cavé and Talma, 2007).

The principle behind purging a well prior to sampling is to remove stagnant water from the well bore to assure that the sample is representative of the groundwater in the geologic formation being sampled. Stagnant water in the well bore results from the water's contact with the casing and atmosphere between sampling events and removal of stagnant water is important because it modifies the chemistry of groundwater (Department of Environmental Protection, 2001).

Purging of the borehole involves the removal of sufficient water until the field chemistry parameters (pH, EC, DO, Eh, temperature, and turbidity) remain stable. For most cases, this involves the removal three times the volume of water contained in the borehole and should be removed in high yielding boreholes to remove the dead volume (Weaver, Cavé and Talma, 2007).

Stratified sampling is done by the process of sampling a relative small amount of water from specific depths within a borehole, but the water column should not be disturbed excessively while sampling. This process will identify horizons where pollution enters the borehole. It is desirable to conduct an electrical conductivity profile to indicate inorganic pollution that can determine the need for stratified sampling.

Sampling processes, collection and steps is described in Quality of Domestic Water Supplies Volume 2: Sampling Guide (Water Research Commission, 2000).

7.4.6 Borehole development and yield testing

Note that the process of monitoring already starts at the drilling process. When developing a new borehole it is important to record all relevant information from the specific borehole or get the information from the driller. Information includes:

- BH diameter
- Drilling record, i.e. depth, geology, water strikes, blow yield, rate of penetration, date of completion, casing collar height, coordinates
- Water samples
- Selection, type and diameter of casings and screens
- Type of Sanitary seal
- Type of drilling method
- Borehole drilling Chips

Yield testing methods to be monitored include slug, step/drawdown and constant rate tests. All of these yield testing methods should be monitored to determine the best safe yield for a specific borehole. The safe yield is defined as the maximum rate of withdrawal that can be sustained by an aquifer without causing an unacceptable decline in the hydraulic head or deterioration in water quality in the aquifer (Department of Water Affairs, 2015).

7.5 Summary

The term monitoring provide and include data on groundwater quantity and quality of the resource itself and is an integral aspect of groundwater management.

The design of a systematic significant monitoring program for groundwater management requires the proper definition of objectives from which quantitative criteria can be derived. The objective of a primary monitoring network can be defined as monitoring the actual condition of groundwater systems.

Monitoring of groundwater is an important component in groundwater management and is also described in general terms as the ongoing process of collecting data and the organising and assessment of data into information to improve decision making and determine performance progress and trends.

It is important to remember that you can’t manage what you can’t measure.

7.6 Exercises and tasks

1. Define monitoring
2. What are the main objectives for monitoring?
3. Describe and illustrate the monitoring cycle.
4. Name, describe and develop a monitoring program for your municipality with guidance to this module.

7.7 Further reading

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7.8 Report from student for evaluation and assessment

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Module 8: Data and information Recording and Management

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8. Learning objectives:

- Data and information recording and management
- Basic tools/devices for data recording and management
- Relevant Legislation

8.1 Introduction

"Information management deals with the value, quality, ownership, use and security of information in the context of organizational performance (Wilson, no date)."

Information management is described as the management of information assets and the principles of turning data into information, knowledge, action and value. The comprehensive process on the allocation of groundwater is dependent on quality, accurate and timely information. Thus is there a need to identify main issues, effective implementation and the need for information management functions in regard to groundwater management within a defined practical management unit (Owen *et al.*, 2010).

8.2 Information and Data Management

8.2.1 Information and Data Management Process

The general information management process steps that can be used to manage and derive any desired information for decision-making and informing stakeholders is given in Figure 1. These management steps are required before data and information can be effectively used.

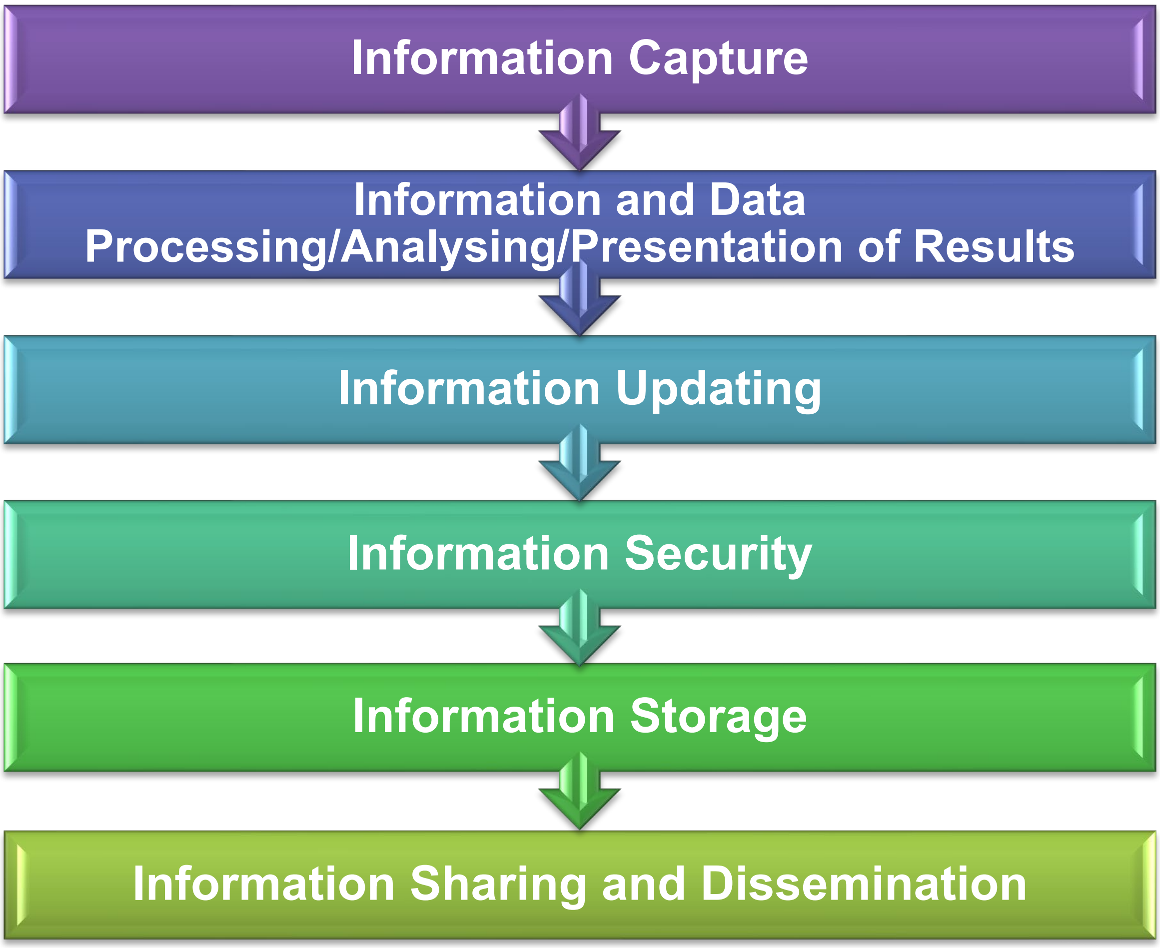

Figure 1: Information Management Process steps adapted from (Owen *et al.*, 2010)

8.2.1.1 Information Capture

This process entails the collection of raw data such as quality and quantity parameters, groundwater users, groundwater uses, groundwater levels and flow directions to name a few. The monitoring chapter (Chapter 7) in this guideline provide more examples and information for capturing raw data. The initial step in information capturing typically starts with information capture objectives, purposes, methods and steps for accessing desired information (Owen *et al.*, 2010).

8.2.1.2 Information and Data Processing/Analysing/Presentation of Results

Data processing is the method by which raw data is transformed into spatial information, time series, quality diagrams and statistics (Jousma, 2006). There is hence, a need to determine and decide the level of quality control programme necessary to produce the desired information and to define the processing mechanisms to be used.

Note that this task of data processing is usually reserved for or managed by the hydrologist or hydrogeologist. The processing of data should allow for interpretation of the groundwater resource.

Different types of data processing are often used and the presentation of results is discussed individually for the following three parameters:

- Groundwater Levels
- Statistical Analysis of data
- Groundwater Chemistry

8.2.1.2.1 Groundwater levels

Groundwater level data and information can be presented spatially as groundwater level contour maps or as a time series in the form of hydrographs.

Groundwater level contour maps

These maps represent the elevation of water level in respect to a reference level (sea level). Water level data need to be converted from the form of depth below surface to the form of water table elevation to construct contour maps.

Contour maps might indicate average values over a period or just indicate a single date. Note that for effective interpretation of a water table contour map one need to consider topography, drainage patterns, recharge, discharge and subsurface geology. The data and time period should also be presented on the map. Groundwater level contour maps acts as visual inspection on which groundwater level data can be checked and monitored (Jousma, 2006).

Groundwater level hydrographs

Groundwater level hydrographs show the variation of groundwater levels for a particular location in time (Jousma, 2006). It is indicated that water levels fluctuate when the water table increase or decrease as a result of storage and therefore it can be plotted on a hydrograph (figure 2).

Hydrographs are a fundamental component of the assessment of hydrological factors and they indicate a way to relate and evaluate impacts on the groundwater resource by natural and human influences.

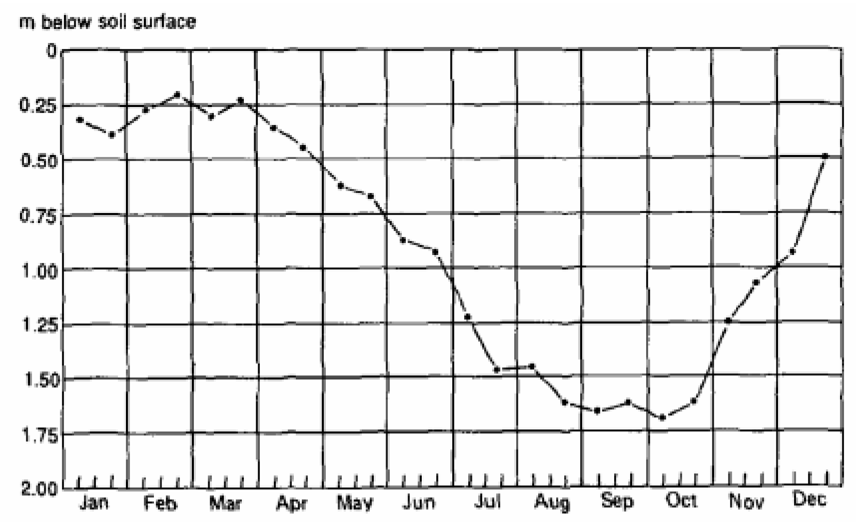

Figure 2: Hydrograph of a Water Table Observation Well (Kumar, 2014)

8.2.1.2.2 Statistical Analysis of data

Statistical analysis of data or statistical approaches includes graphical and mathematical methods to analyse monitoring groundwater data (Commonwealth of Pennsylvania, 2001). The graphical procedures summarize, interpret and visualize data which is used for the assessment of statistical features and includes box and whisker plots (figure 3) and time series plots. Mathematical methods include the calculation of the mean, median, average, data distribution and indicate trend analysis.

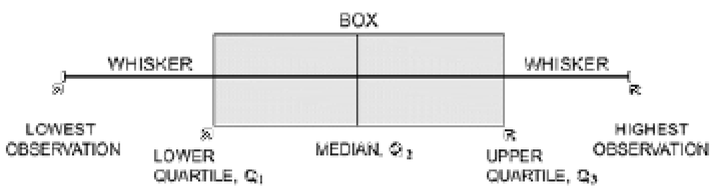

Figure 3: Box and whisker plot (PDF statistics)

8.2.1.2.3 Groundwater Chemistry

Water quality diagrams help to assess and evaluate the water type. This classification and evaluation of water types form a fundamental component in understanding the hydrogeology and hydrological factors (Jousma, 2006). These factors are determined by chemical analyses, where the data from which may be grouped and statistically evaluated (Zaporozec, 1972).

There are a significant number of methods and techniques that may be used depending on the physical and chemical properties of groundwater. These methods help to classify, compare and summarize large volumes of data (Zaporozec, 1972).

Plots such as Piper, Durov or Stiff diagrams help to evaluate and characterize groundwater resources and illustrate any changes in the hydrochemical facies (Jousma, 2006).

Piper diagrams

Piper diagrams are used for the comparison of many waters. These diagrams indicate inorganic compounds/concentrations with the cations and anions shown by separate plots (Bosman, 2014).

Piper diagram is used as an effective graphical representation of chemistry in water samples in hydrogeological studies and groundwater management.

Piper diagrams thus indicate the interpretation of major ionic species in [% meq/L] as seen in figure 4.

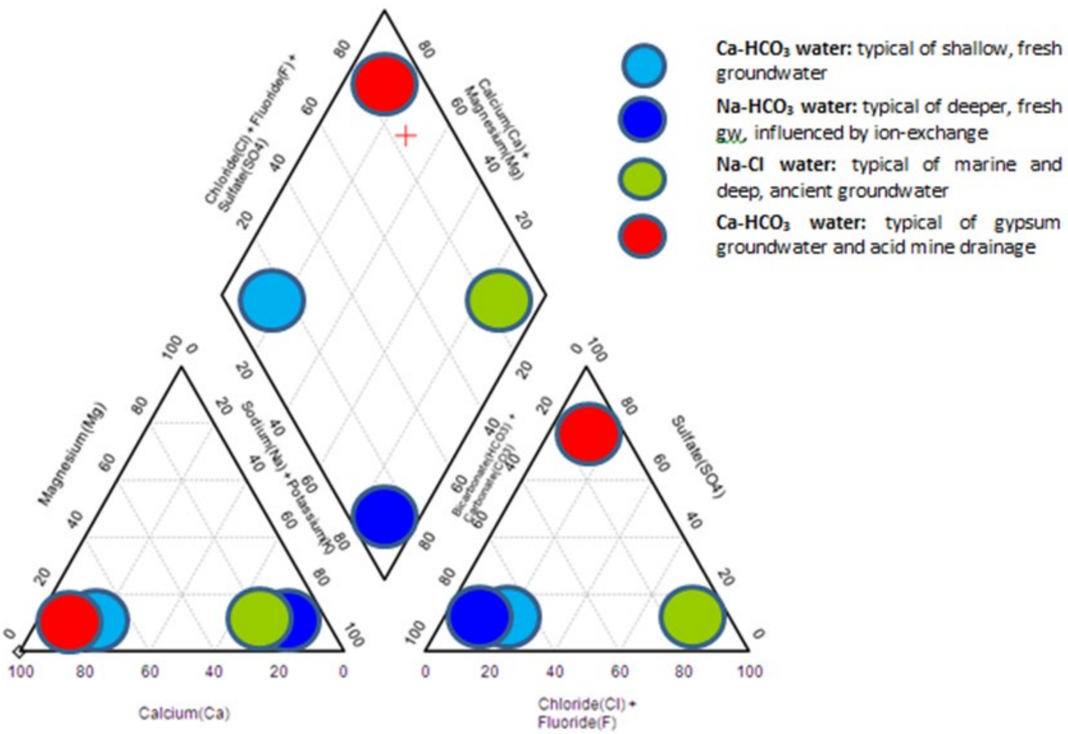

Figure 4: Interpretation of a Piper Diagram (Bosman, 2014)

Durov diagrams

The Durov diagram assists with the analysis of chemical compositions and total dissolved solids. The Durov diagram is provides more information on the hydrochemical facies by assisting in the process to identify water types and displays geochemical processes that could assist in understanding and evaluating the quality of groundwater.

The diagram (figure 5) is a combined plot consisting of 2 ternary diagrams (cations plotted against anions).

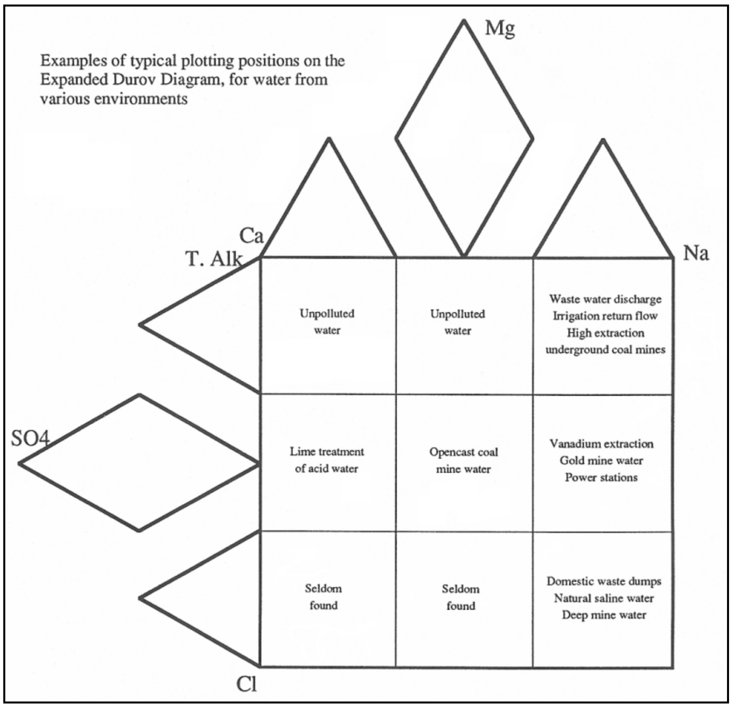

Figure 5: Durov Diagram (Bosman, 2014)

Stiff diagrams

The Stiff diagram (Figure 6) is a distinctive method that graphically represents different water ions. This diagram indicates the differences or similarities in water and changes associated with depth in water composition. The major ionic species is indicated as milli-equivalents per litre [meq/L].

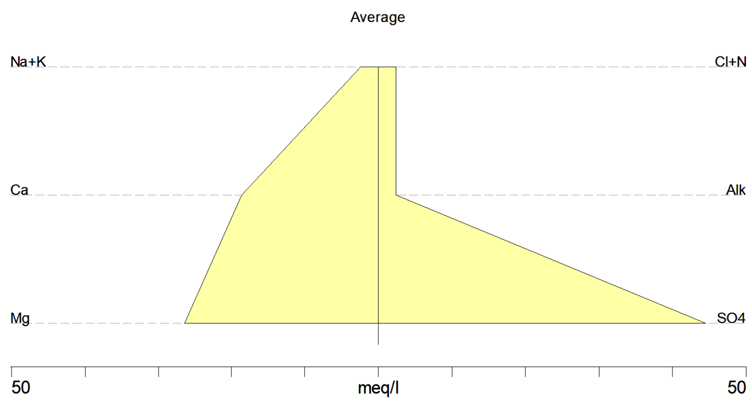

Figure 6: Stiff Diagram (Bosman, 2014)

8.2.2 Information Management Tools

Information management is described as discussed earlier in this module as the management of information assets and the principles of turning data into information, knowledge, action and value. Information management also include the distribution of that information.

To facilitate the organisation and classification of information a variety of tools are available and consist of:

- Geographical Information Systems (GIS)
- “Google Earth” Program
- Manual Systems

8.2.2.1 Geographical Information Systems (GIS)

Geographical information systems also known as GIS is a computer based software used to display and analyse spatial data that are linked to databases. Spatial data is described as data with a geographical component connected to some place on the earth. GIS is thus a tool used to capture, store, process, analyse and visualize spatial information.

As soon as a specific database is updated, the associated map will be updated as well. Basically by continually updating data captured from monitoring, updated maps are available for stakeholders to view (Owen *et al.*, 2010). The disadvantages of GIS are that the required software is often expensive like Esri ArcGis but freeware like QGIS is available and user friendly. Another disadvantage is that special training is required to use the software programme. Geographic Information Systems (GIS) can perform complex data manipulations, analyse and display a combination of information graphically (Department of Water Affairs and Forestry, 2006).

8.2.2.2 “Google Earth” Program

The “Google Earth” programme or freeware is a combines the power of the Google Search engine with other factors such as satellite imagery, maps, terrain and 3D buildings. A bird’s eye view of the world's geographic information for any area is thus available. Google earth can be used to assist in identifying geological boundaries using surface features to infer tectonic structures. Google Earth is also valuable for mapping out boundaries and identifying borehole locations (Owen *et al.*, 2010).

8.2.2.3 Manual Systems

Manual systems refers to a system where all relevant data, information, documents, maps, field notes and drawings are stored in hard copy format. This method involves minimal capital cost and no computer software or training is required. Disadvantages of a manual system is that physical storage is often not enough, data can be manipulated and the update of information is time consuming (Department of Water Affairs and Forestry, 2006).

8.3 Data and Information Recording Tools

8.3.1 Field Notebook/Logbook

A field logbook or field notebook should be completed and maintained for all sampling and monitored events. The purpose of a logbook is to keep accurate written records of the field personal daily activities in a bound logbook that will be sufficient to recreate the project field activities without reliance on memory. This book would be used to describe monitoring procedures (U.S. Environmental Protection Agency, 2010).

In logbooks/notebooks field personal should record sufficient information so that someone can reconstruct the field activity without depending on field sampler memory. It is important to note that all entries must be written in black waterproof ink or in pencil. The book must contain accurate documentation of field activities, field data observations, deviations from project plans, problems encountered, and actions taken to solve the problem. In addition to the investigation data and documenting field activities, field logbooks should include, but are not limited to the following: (U.S. Environmental Protection Agency, 2010):

- Arrival on site and departure from site date and times
- Project personnel and subcontractor personnel on site
- Date and time of activities
- Site location and coordinates

- Purpose of site visit
- Site and weather conditions
- Regulatory agencies and their representatives (including phone numbers, site arrival and departure times),
- Level of health and safety protection
- Identification of well
- Well depth
- Static water level depth
- Well yield – high or low.
- Purging device, purge volume and pumping rate
- Time well purged.
- Measured field parameters
- Sampling methodology and information
- Sample Locations (sketches are very helpful)
- Equipment calibration records
- Equipment present and equipment used
- Sample Source, identifications, container used and labelling names
- Specific considerations associated with sample acquisition
- A chronological description of the field observations and events
- Sample conditions that could potentially affect the sample results
- If deviating from plan, clearly state the reason(s) for deviation
- Persons contacted and topics discussed
- Daily Summary

8.3.2 Field Investigation Data Forms

Groundwater sampling information to be recorded on the Groundwater Sampling Field Data Sheet includes:

- Instrument calibration data
- Water levels
- Purge volumes and analysis data
- Field measurements
- Sampling information
- Shipping information.

8.3.3 Chain of Custody

A chain-of-custody record should be established to provide the documentation necessary to trace sample possession from time of collection to final laboratory analysis. Components of sample custody procedures include the use of field logbooks, sample labels, custody seals, and Chain of Custody (COC) forms. Each person involved with sample form will accompany the samples during shipment from the field to the laboratory (U.S. Environmental Protection Agency, 2010).

The record should account for each sample and provide the following information (Kasich, Taylor and Nally, 2012):

- Sample identification number.
- Printed name and signature of collector.
- Date and time of collection
- Specific location of sample collection
- Description of samples
- Sample type (i.e. groundwater).
- Identification of well
- Number and types of containers.
- Parameters requested for analyses.
- Preservatives used.
- Carrier used.
- Printed name and signature of person(s) involved in the chain of possession18.
- Date/time samples were relinquished by sampler and received by the laboratory
- Internal temperature of shipping container upon opening at laboratory, if applicable.
- Presence/absence of ice.
- Special handling instructions (if any).

More complex diagrams that can be used for the interpretation of chemistry are the Piper and Durov diagrams. These diagrams are discussed in detail in the *Minimum Requirements for Monitoring at Waste Management Facilities* (DWAF, 2005).

8.4 Summary

The term information management is a new way to reflect the role of information in organizational performance and it has a substantial impact on the thinking of professionals and management personal working in a variety of fields. Without an effective data recording and management program, management in groundwater would not succeed.

8.5 Exercises and tasks

1. Define information management
2. What are the six steps in the information and data management process?
3. Name different ways to represent groundwater chemistry data?
4. Information management tools are describe as the process of turning data into information. Name two useful tools that can be implemented at your municipality.

8.6 Report from student for evaluation and assessment.

8.7 References

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Module 9: Operational and maintenance related to bulk groundwater supply schemes

Contents

9. Learning objectives

To understand and describe the following:

- Operation and maintenance
- Effective operation strategy

9.1 Introduction

The objective of a successful operation and maintenance programme related to bulk groundwater supply schemes is to provide safe drinking water.

It has been observed that lack of attention to the important aspect of Operation & Maintenance of water supply schemes in several towns often leads to deterioration of the useful life of the systems necessitating premature replacement of many system components.

Some of the key issues contributing to the poor Operation & Maintenance have been Identified as follows according to Azad (2005):

- Lack of finance, equipment, material, and inadequate data on Operation &Maintenance
- Inappropriate system design; and inadequate Workmanship
- Multiplicity of agencies, overlapping responsibilities.
- Inadequate operating staff
- Illegal tapping of water
- Inadequate training of personnel.
- Lesser attraction of maintenance jobs in carrier planning.
- Lack of performance evaluation and regular monitoring.
- Inadequate emphasis on preventive maintenance
- Lack of O & M manual.
- Lack of real time field information, etc.

Therefore, there is a need for an effective operation strategy and legal framework for groundwater supply schemes.

9.2 What is operation and maintenance

9.2.1 Operation

Operation related to bulk groundwater supply schemes refers to timely and daily operations otherwise known as routine work. These operations include a series of actions completed by operators on different components of a system such as equipment, plant and machinery (Ministry of water and energy, 2013).

Other activities include the proper major operations to deliver safe drinking water, the correct handling of equipment, machineries and facilities and enforcing policies and procedures (Davis and Brikké, 1995).

9.2.2 Maintenance

The term maintenance is defined as a series of activities aimed at keeping the plant, equipment, structures and other related facilities in optimum serviceable condition and working order (Jain, 2013).

Maintenance can be divided into preventive, corrective and reactive maintenance adapted from (Davis and Brikké, 1995; Ministry of water and energy, 2013; Brikké, 2000 and Castro, Msuya and Makoye, 2009):

9.2.2.1 Preventive maintenance

This is the actions performed on a regular and timely basis to ensure that equipment and infrastructure are operating effectively and are in good condition to preserve assets and minimize unforeseen failures. These actions consist of regular inspections, servicing, minor repairs and replacement.

9.2.2.2 Corrective maintenance

Actions performed to repair or either restores malfunctioning equipment and infrastructure to sustain reliable facilities and ensure effective operating conditions. Actions may result from problems that were discovered during the preventive maintenance process or as a result of failures during operation.

9.2.2.3 Reactive maintenance

Reactive maintenance also referred to as crisis maintenance, is the response reaction to public complaints, emergency breakdowns and a crisis to restore a failed supply.

By only implementing and relying on crisis maintenance it may lead to a complete system failure because of frequent breakdowns, poor service level, high operation and maintenance costs and user dissatisfaction.

9.3 Objectives of operation and maintenance

The main objectives of an efficient operation and maintenance program related to bulk groundwater supply schemes is to operate water facilities efficiently to provide a reliable supply of safe drinking water, in adequate quantities at a suitable pressure and to maintain and operate the functions of the bulk groundwater supply scheme in working condition (Jain, 2013).

Objectives of operation and maintenance are not possible unless it includes the actions that will reduce the impact on quantity and quality of water sources of the environment. The objectives are achieved through appropriate planning, design and construction in the operation and maintenance plan of bulk water supply schemes (Ministry of water and energy, 2013).

9.4 An Effective Operation and Maintenance Strategy

An effective operation and maintenance strategy is required because the lack of interest and enthusiasm to the important aspects of operation & maintenance of bulk groundwater supply schemes, typically leads to the deterioration and dysfunction of systems and contribute to poor operation and maintenance.

The minimum requirements for an effective operation and maintenance strategy according to Azad, 2005 are:

- Preparation of a plan for operation and maintenance.
- Providing required personnel to operate and maintain.
- Availability of spares and tools for ensuring maintenance.
- Preparation of GIS based maps of the system
- Preparation of a water audit and leakage control plan
- Maintaining records on the system including history of equipment, cost, life, etc.

9.4.1 Preparation of a plan

It is essential to prepare a plan/program for operation and maintenance of each and every major unit and for the entire operation and maintenance scheme.

The general operation and maintenance plan should be constructed scheme wise for their various individual units. This plan/program needs to contain procedures and actions, checks and inspection at routine intervals.

Development of individual plans for operation and maintenance must be prepared for all relative units, systems and pieces of equipment. It is essential according to Jain (2013), that each individual unit or system have a plan to fix responsibility, timing of action, ways and means of achieving the completion of action and contain what objectives are meant to be achieved by this action.

The plan/program should be followed by trained staff and will form the basis for supervision, evaluation and inspection of the status of an effective operation and maintenance plan/program.

9.4.2 Providing required personnel to operate and maintain

Personal, management and staff responsible for the operation and maintenance plan must be experienced, efficient, motivated and well qualified. Operating staff is required to run the system plan while supervisory staff, like management is needed to monitor the operations and provide professional support.

The management at municipalities have to become more service orientated and be enthusiastic and equipped to run an effective operation and maintenance plan.

Personal, management and staff should be carefully chosen for the job description and trained to carry out important and necessary actions.

Training of these above mentioned individuals entail that a clear and define job description shall be prepared for each operator. This will contain detailed instructions on how to carry out actions required in the operation and maintenance plan. Training will normally include personnel management, job training, performance tasks and problematic case studies. This training is vital to prevent experimentation by operating personnel to interfere with equipment and systems.

9.4.3 Availability of spares, supplies and tools for ensuring maintenance

It is vital that municipalities have all the essential spare parts and tools available at all times for operational and maintenance work. This will reduce the down time of a supply scheme and increase maintenance (Ancheta, 2012).

To assure that spares, supplies and tools do not get replenished, it is best to manage and maintain an inventory register and keep tools locked in a safe location with minimal access (Castro, Msuya and Makoye, 2009). The inventory list of spare parts that have to be readily available can be drafted on the basis of manufacturer's recommendations or the consumption of material in previous years. It will also be important to arrange quality checks for all tools before storage and that routine maintenance of tools and plants is necessary for ensuring that they are in a fit state to be used when repairs and replacements are taken up (Azad, 2005).

9.4.4 Maintenance of records

The requirement for good maintenance records is often overlooked. The maintenance plan programme contains as to what should be done and when. A record and report system shall be compulsory to list all basic data of equipment and the history of the equipment. A reporting system will assist the operator to notify the supervisor/ manager of the problems of each system and piece of equipment that require repair and replacement attention (Azad, 2005).

A typical record list includes the following:

1. Name of equipment and location of equipment
2. Number available or installed
3. Serial number
4. Type and class
5. Date of procurement/installation
6. Cost of procurement and installation
7. Name of manufacturer with address and telephone No.

8. Name of distributor/dealer if purchased through them with address and telephone number.
9. Name of servicing firm with address and telephone number.
10. Service manuals
11. Descriptive technical pamphlets
12. Major overhauls: Details of date, nature of cost
13. When next overhaul is due.
14. Date, type and cost of repairs and replacement
15. Cost of spares and cost of labour for repairs.

9.5 Summary

The main difference between operation and maintenance is that operation involves activities necessary to deliver the service, while maintenance involves activities that keep the system in good operating condition.

The performance and management process can only be effective implemented and achieved if recording of the events is done and evaluated using properly set standards and if the process is done by trained staff regularly.

9.6 Exercises and tasks

1. Name and describe a few key issues that can contribute to poor operation and maintenance.
2. Define the operation and maintenance process.
3. Develop an operation and maintenance program for bulk water supply schemes for your municipality with guidance to this manual.

9.7 Further reading

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