



A proposed method to implement a groundwater resource information project (GRIP) in rural communities, South Africa

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THESIS

**Submitted in fulfilment of the requirements for the degree of
Doctor of Philosophy in the Faculty of Natural Science and Agriculture
Department of Geohydrology
University of the Free State, Bloemfontein**

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July 2005

ACKNOWLEDGEMENTS

The Department of Water Affairs and Forestry, for providing me with the opportunity to further and complete my studies

Dr. Ingrid Dennis, for assistance, encouragement and guiding the study.

Prof. Van Tonder, for his continues assistance and enthusiastic comments.

Mr Weideman, Mr Pretorius, Mr Viviers, Mr Modisha and Mr Haupt and their teams, for implementing an unparalleled South African groundwater project.

Mr. Willem Du Toit, for believing in me and supporting me.

My wife, Christelle and son, Reinhardt, who supported and inspired me.

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LIST OF ACRONYMS AND ABBREVIATIONS

BWASA	- Borehole Water Association of Southern Africa
CCWR	- Computer Centre for Water Research
CGS	- Council for Geoscience
CMA	- Catchment Management Agency
CMC	- Commissioning Certificate
CMS	- Catchment Management Strategies
CSIR	- Council for Scientific and Commission for Scientific and Industrial Research
CWSS	- Community water supply and sanitation
D	- Thickness of the water-bearing zone
DA	- Drought Abstraction
DCASA	- Drilling Contractors Association of Southern Africa
DM	- District Municipality
DWAF	- Department of Water Affairs and Forestry
EC	- Electrical Conductivity
ECA	- Environmental Conservation Act
EF	- Exploitation Factor
EIA	- Environmental Impact Assessment
EP	- Exploitation Potential
EPE	- Estimated Position Error
EVX	- Environexcellence
FC	- Fracture Characteristic
GH	- Geohydrology, DWAF
GIS	- Geographical information System
GEOCON	- Geoconsultants
GPM	- Groundwater Projects Management
GPS	- Geographical Positioning System
GRIP	- Groundwater Resource Information Project
GUI	- Graphical User Interface
HP	- Harvest Potential
HO	- Head Office
IAH	- International Association of Hydrologists
ICM	- Integrated Catchment Management
ID	- Identification
IDP	- Integrated Development Plan
IGS	- Institute for Groundwater Studies
ISP	- Internal Strategic Perspective
IWRM/P	- Integrated water resource management and planning
IWQS	- Institute for Water Quality Studies
KGC	- Khulani Groundwater Consultants
LWUD	- Lead Water Use Directorate
MAR	- Mean Annual Recharge
MC	- Mothopong Consulting
MR	- Minimum Recharge
NGA	- National Groundwater Archive
NGDB	- National Groundwater Database
NGO	- Non-government Organisation
NWA	- National Water Act
NWRP	- National Water Resource Planning

NWRS	- National Water Resource Strategy
O&M	- Operation and Maintenance
PES	- Present Ecological Status
PMC	- Project Management Committee
PRO	- Primary Responsible Officer
R	- Recharge
REGIS	- Regional Geohydrological Information System
RF	- Radius of influence
RA	- Recharge Abstraction
RDP	- Reconstruction and Development Plan
RR	- Rainfall Reliability
RSA	- Republic of South Africa
SRS	- Source Reference Sheet
S	- Storage
s	- Storage coefficient
Sc	- Specific capacity
SFRA	- Stream Flow Reduction Activity
SRK	- Stephenson, Robertson and Kirsten
Sr	- Specific retention
SI	- Saturated Interstices
Sy	- Specific yield
SWCA	- Subterranean Water Control Areas
T	- Transmissivity
TDS	- Total dissolved salts
URV	- Unit reference value
VIP	- Ventilated Improved Pit-latrine
WARMS	- Water Authorisation and Management System
WMA	- Water Management Area
WMS	- Water Management System
WRC	- Water Research Commission
WRIS	- Water Resource Information System
WS	- Water Services
WSA	- Water Services Act
WSAM	- Water Situation Assessment Model
WSM	- Water System Management
WSDP	- Water Service development Plan
WSRA	- Water Services Areas

1 INTRODUCTION

Groundwater specialists in the 21st century find themselves in a peculiar environment known as Integrated Water Resource Management and Planning (IWRMP). IWRMP is international terminology used by a wide group of different water users, managers and planners and included are scientists and engineers. Part of the scientific group is a relatively small number of professional and technical individuals working as groundwater specialists. In South Africa the total number of groundwater specialists numbers more or less 250 people (DWA 2000c). Therefore, to identify and understand the role of groundwater as a resource and the groundwater scientist's role in the IWRMP domain, it is imperative that these concepts are discussed and explained. It will, however, be shown that knowledge or information concerning water resources form a vital part of management and planning of water resources. The study will also show how a properly developed and implemented groundwater information system, in rural South Africa, can bring groundwater resources closer to a bigger IWRMP domain.

1.1 INTEGRATED WATER RESOURCE MANAGEMENT

Water resource management has been part and parcel of civilizations for centuries and lack thereof or wrong choices sometimes led to the downfall of civilizations, for example in Peru and Mesopotamia (Lund, 2002). Over centuries nations recognised water as a strategic resource and with the Romans introducing water resource analysis and linking it to economic planning, the need for better water resources management became entrenched as part of modern human development (Lund, 2002). Water resources management developed as an engineering task, finding engineering solutions to ensure continuous water supply for economic and human development. However, in the 1960s with the rise of environmentalism in the United States of America, people started talking about a more comprehensive approach rather than linear engineering solutions (Grigg, 1996). Apart from environmental needs, population figures in the last century jumped from 1.65 to 6.1 billion and expected to be around 8 billion by the year 2025 (Al Baz *et al*, 2002). Population and industrial growth led to a growth in water requirements in 1950 from 1400 km³/a to an estimate of 5200 km³/a in 2000 (Clarke, 1993). Following the initial environmental criticism Al Baz *et al* (2002) mentioned three more waves of criticism concerning water resources management namely, effectiveness of solutions offered and economic waste of resources, the neglect of social aspects in water resources management and increasing awareness of the limits of the resources themselves. These waves of criticism led to a more comprehensive approach and by incorporating these and many other factors,

IWRM evolved over the last 50 years and gathered huge momentum. However, compared to the previous primary assurance approach, evolving over many years, IWRM is a new concept and understanding and implementation thereof relatively new and various groups have different opinions of IWRM.

“Integrated water resource management balances the views and goals of affected political groups, geographical regions, and purpose of water management; and protects water supplies for natural and ecological systems” (Grigg, 1996), thereby differentiating between 4 major groups in IWRM, namely political viewpoints, geographical boundaries, purpose and hydro-ecological needs. It also suggests that water resources managers require more skills than pure science or engineering, finding themselves in a multi-disciplinary field, requiring socio-economic and technical skills. In less complicated terms it may simply be viewed as the water adequacy for different water uses in a watershed for economic and social development and can be divided into three sub-systems namely the natural water resource system, human activity systems and water resource management systems, referring to the institutions and organizations managing water (Charania, 2005).

There are also different scenarios or realms of water resource management, including planning and coordination, organization or institutional, water operations and management, regulation, capital investments and facilities and policy development with each of these functions interchangeably linked (Grigg, 1996). Therefore integrated water resource planning (IWRP) forms part of a bigger IWRM process.

1.2 WATER RESOURCE PLANNING

Rational planning is a systematic procedure to resolve problems in the future and there are many theories on rational planning and how it needs to be done for water resource management purposes. Lund (2002) discusses the various aspects of rational planning in detail and distinguishes between six major approaches for water resource planning.

1.2.1 Requirements-based planning

Requirements-based planning is typically where future demands are forecast based on current use and the size of the reservoir is based on the future supply or what can be met with a repeat of historical stream flows, also called the firm-yield approach, where the supplies meet or exceed forecast use. Although requirements-based planning was used extensively in the past it often led to controversial

and over-expensive solutions and most recently lost some ground in water resource planning (Lund 2002).

1.2.2 Benefit -Cost-based planning

The benefit-cost-based planning approach is simple and attempts to consolidate multiple actions of different solutions into a monetary value to compare apples with apples. Net economic value is considered by many the strongest technical field in benefit-cost analysis and over the years have helped to eliminate unworthy projects. However, it may be difficult when calculating values for all actions, for example social aspects, selecting discount rates and representing risk preferences (Lund, 2002).

1.2.3 Multi-objective planning

Multi-objective planning can be seen as a more intuitive alternative to cost-benefit evaluations and visually display to decision-makers trade-offs between optimal and inferior solutions. However, it is limited to informal decision-making and difficult to visualise all actions of different solutions (Lund, 2002).

1.2.4 Conflict-resolution planning

Where political or ideological conflict exists water resource planning differs completely from previous approaches. Conflict of opinion needs to be discussed and considerable emphasis, effort and time is required to establish broad confidence and communication in both technical and decision-making processes. Typical conflict comes from environmental concerns and two sub-approaches can be identified, (i) adaptive management and shared vision and (ii) “watershed” planning. The first is an effort to acknowledge environmental issues in an existing system and manage these issues in the existing system or model the system where all stakeholders can agree on the modelling approach and introduce mitigating measures. The second approach differs from most previous approaches and requires all stakeholders in a watershed to be involved in discussions regarding management of the resources. If strong leadership is shown and all concerns are captured and addressed in the management plan, then this approach is very efficient in dealing with controversial water resource solutions. It, however, needs ample time and could be very costly (Lund, 2002).

1.2.5 Market-based planning

Market-based planning is simply where water use or the right to use water is negotiated with water managers and the water resources are developed based on the financial principles required by the market. It provides economic incentives that may help with development of reservoirs and adapt policies for economic growth, therefore tilt straightforward planning based on firm yield, economic - or conflict-based planning (Lund, 2002).

1.2.6 Practical “muddling-through” planning

This approach typically happens where political and economical circumstances do not allow for long-term planning and simply have a short-term incremental approach. This often helps with identifying recent mistakes but always have a long-term funding problem (Lund, 2002).

1.3 INTEGRATED WATER RESOURCE MANAGEMENT IN SOUTH AFRICA

In most African countries water resource management and planning approaches in the past were aimed to meet domestic and industrial needs and only recently have countries adopted a more integrated approach (Oyebande, 1975). In the Republic of South Africa (RSA) the National Water Act (NWA, 1998) and Water Services Act (WSA, 1997) govern water resources management and planning and the Minister of Water Affairs and Forestry is appointed by National Government as custodian of all water resources in the RSA. The Minister uses the department of Water Affairs and Forestry (DWAF) to fulfil this responsibility.

1.3.1 IWRM and the NWA

The aim of the NWA is to introduce IWRM to South Africa’s water resources managers and to see to it that water resources are protected, used, developed, conserved, managed and controlled through a process that meets basic human needs, equitable access, facilitates social and economic development, protects the aquatic and associated ecosystems, reduces and prevents pollution and degradation and meets international obligations. These are some but not all of the factors that need to be considered to introduce IWRM in South Africa (NWA, 1998). The NWA is implemented through the National Water Resource Strategy (NWRS), Catchment Management Strategies and a water use licensing process.

1.3.1.1 National Water Resource Strategy

The NWA introduces the NWRS to set a legal framework for implementation of IWRM principles on a national scale and also a framework within which water resources need to be managed at catchment level. The NWRS therefore gives a broad description of the available water resources and current management thereof, also introducing future water resource management strategies to serve as references for national water resource managers and decision makers (DWAF 2004a). It must be recognised that the NWRS cannot serve local needs, therefore in an effort to come to terms with manageable water regions, the country was divided into 19 Water Management Areas (WMAs) and the NWA also introduces Catchment Management Strategies.

1.3.1.2 Catchment Management Strategies

The aim of the CMSs is to introduce catchment specific strategies that are in harmony with the NWRS, taking into account protection, use, development, conservation and management of water resources, therefore to achieve IWRM in each specific WMA (NWA, 1998). Development of the CMSs requires accurate and relevant water resource information and includes availability, management, protection, conservation, monitoring etc. The NWA introduces Catchment Management Agencies (CMAs), implementing bodies to be established in each WMA, to develop and implement CMSs or they can be seen as institutions that need to introduce IWRM in each WMA (NWA, 1998). The NWA therefore deals with the natural resources and how to manage water resources in a sustainable manner.

1.3.1.3 Internal Strategic Perspectives

As part of capturing current water resource management practices and setting up guides for the future development of CMSs, DWAF developed Internal Strategic Perspectives (ISPs). The aim of the ISPs is to give a common approach and understanding of how DWAF views IWRM and therefore assist DWAF officials with the difficult task of being IWRM managers (DWAF, 2004c). The ISPs need to

The NWRS, CMSs and ISPs need verified groundwater information

promote groundwater development and use but can only do that if the information is available.

1.3.1.4 *Water Use Licences*

The NWA identifies 11 water uses, which take all possible water uses into consideration and according to the NWA (1998) all water uses must be registered except water use residing under general authorisation. All new water uses need licensing and applications must be made at the relevant responsible authority (DWAF). Therefore, if a water supply scheme for the abstraction or utilisation of ground- or surface water for bulk supply purpose is planned, the individual or group developing the scheme must submit a licence application to use the source in question. The following water uses, however, are of interest to or directly or indirectly related to groundwater:

- Section 21(a) Taking of water from a water resource (groundwater), for example equipping and pumping from a borehole.
- Section 21(c) Impeding or diverting the flow of water in a water resource, for example if a borehole is drilled in or near a stream and it changes the flow of water towards the borehole as a result of bank filtration.
- Section 21(d) Engaging in a stream flow reduction activity (SFRA) for example bank-filtration systems where boreholes are drilled close to rivers and thereby reduce flow.
- Section 21(e) Engaging in a controlled activity, where, as a result of the activity, the groundwater may be polluted.
- Section 21(g) Disposing of waste in a manner which may impact on a water resource, as above where the groundwater may be polluted.
- Section 21(j) 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, for example in mining activities where groundwater inflow needs to be controlled.
- Section 21(k) Using water for recreational activities, typically holiday resorts using warm deep circulating groundwater for healing spas.

The NWA also makes provision for the Reserve, which is a reflection of the Present Ecological Status (PES) of a resource. In terms of the NWA, no licence can be issued before the Reserve is determined. The Reserve is built into the NWA to determine the optimum water use, without degradation of the environmental status and not neglecting the people's needs. The Reserve determination can take place

at different levels, depending on the need, and ranges from desktop, rapid, intermediate and comprehensive. The Directorate Resource Directed Measures in the DWAF is responsible to coordinate the Reserve determinations, conducted by DWAF and other independent bodies.

1.3.2 IWRM and the Water Services Act (WSA)

The WSA aims are to provide for access to basic water supply, set national tariffs and norms for water services, enable water service authorities to develop water services development plans (WSDPs), a regulatory framework for water services institutions, gathering and monitoring of water services information (WSA, 1997). The WSA provides mechanisms and plans to implement IWRM at a services level and introduce water services authorities. The WSA describes in detail how water service authorities, providers, intermediaries, boards and committees are to be established and their functions, therefore describing the institutional arrangement of water services, being part of IWRM. The district municipalities (DMs) are regarded as water services authorities. The most critical requirement is the WSDPs, providing the technical detail to successfully provide water services in a sustainable manner and must include the physical attributes of the existing water infrastructure, size and distribution of the population, a time frame for the plan, existing water services, existing industrial use and disposal, number and location of people with no formal services and future water services requirements. Existing water services infrastructure includes all borehole information, including borehole information pump information and any other infrastructure associated with borehole abstraction and water supply from the borehole. After the WSDP is adopted it becomes part of the integrated development plan (IDP) contemplated in the Local Government: Municipal Systems (Act 32 of 2000). Imbedded in water resource management is a systematic approach of gathering data and conceptualising the system (Grigg, 1996) and from the discussion above it is quite apparent that the WSDPs require detailed water services infrastructure information. Typical profiles considered when developing a WSDP are social-economic issues, services levels, technical options, water resources, water conservation and demand management, water services infrastructure profiles, water balance, water services institutional arrangements, customer services, financial requirements and current and future projects (Bohlabela District Municipality, 2005).

WSDPs need detailed groundwater information associated with water services infrastructure

1.3.3 Interaction between NWA and WSA to achieve IWRM

Although it is quite clear that the NWA regulates the natural water resources systems and the WSA services delivery, they are bound through the NWRS and WSDPs respectively by Section 6 (1)(a)(ii) and 9 (f) in the NWA (NWA, 1998) and stipulates that when developing the NWRS and CMSs the national and regional plans developed as a result of the WSA need to be considered. Therefore whatever is captured in the NWRS and the CMSs needs to be captured in the WSDP.

Therefore taking into account the different approaches described in the WSA and NWA through the WSDPs and NWRS it is clear that in South Africa's case, when it comes, to IWRMP, almost all rational planning approaches were incorporated and it includes requirements-based, cost-benefit, multi-objective, conflict-resolution (which includes adaptive management and watershed), market-based and "muddling-through" planning.

1.4 IWRM AND GROUNDWATER

In most countries such as the USA, England, Poland, New Zealand, Japan and Nigeria groundwater management, planning and protection forms an essential part of IWRM and of IWRM strategy plans and water resource institutional arrangements (Mitchell, 1990). Viewing the concept of IWRM and the focus of IWRM through the WSA and NWA, it becomes clear that groundwater resources play an integral part of IWRM and groundwater point data and information form part of the foundation of IWRM (Figure 1). However, Grigg (1996) concurred that in the USA groundwater is often ignored in management and planning programmes and taken for granted. Therefore, although water management plans, among other water resources information, need also to incorporate a systematic gathering of groundwater information, this is sometimes not found in the bigger systematic IWRM approaches, but rather only emphasise the need for groundwater protection (Mitchell, 1990). If this occurs in developed countries such as the USA, Japan, and England where comprehensive IWRMP is continuously updated, then it can be argued that in developing countries such as South Africa, the neglect of groundwater in IWRMP may even be more frequent.

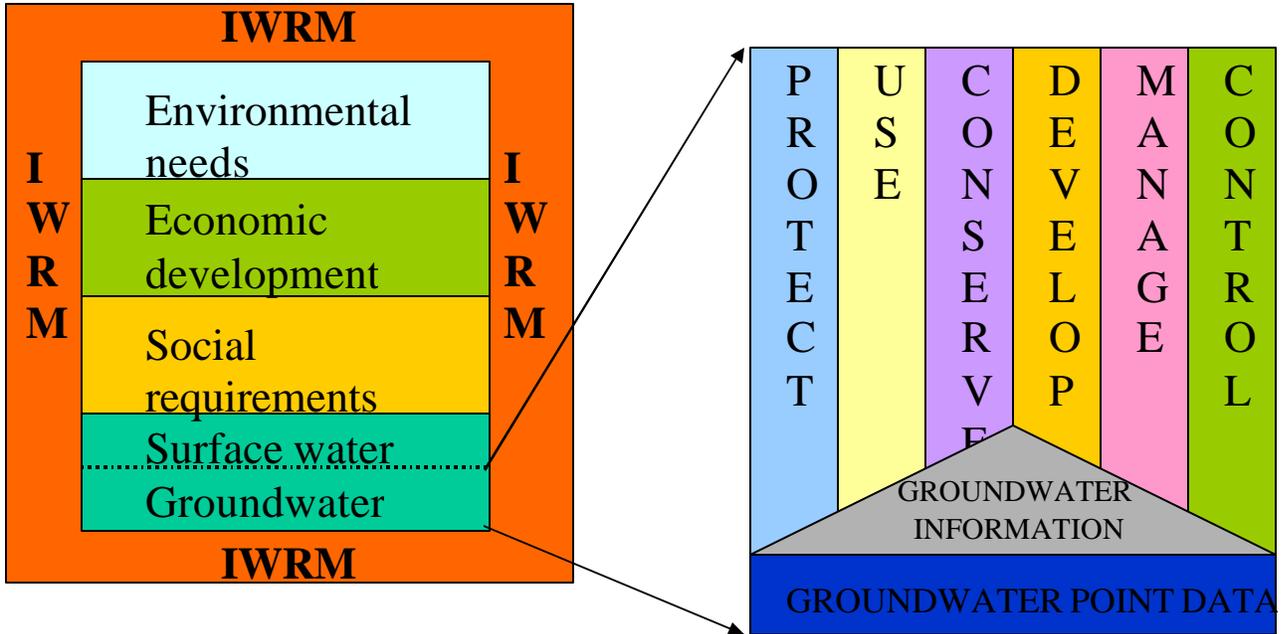
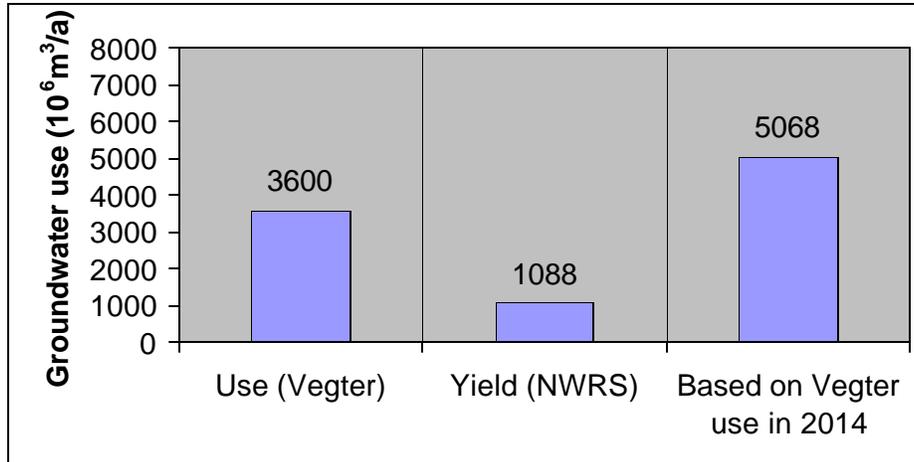


Figure 1 Simplistic visual presentation of the apparent role of groundwater in IWRM and the role of point data and information when implementing IWRM through the NWRS and WSDPs.

1.5 IWRM AND GROUNDWATER IN SOUTH AFRICA

In the NWRS groundwater is not introduced as an exciting nor strategic resource but rather sketched as an unsustainable resource only suitable for hand-pump installations, emergency water supply or rural use in small communities (DWAF 2004a). Due to this perception and groundwater's apparent marginal role as described in the NWRS, it is not regarded as a major role player in IWRM programmes. The perception is raised due to the perceived lack of reliability and availability of information. According to the NWRS (DWAF, 2004a), the total available yield from groundwater resources in South Africa is estimated at $1\ 088 \cdot 10^6 \text{ m}^3/\text{a}$. Vegter's (2001) estimation of current use due to the development of the modern drilling rigs $3\ 600 \cdot 10^6 \text{ m}^3$, corresponding well with the figure determined by Baron *et al* (1996) and suggests that the current use exceeds available yield threefold (Figure 2). The differing figures between use and yield create uncertainty with integrated water resource managers and therefore they rather use lower figures when considering groundwater as part of management solutions. During his exploitation potential assessment, Haupt (2001) also concluded that the available groundwater in South Africa can be as high as $19\ 000 \cdot 10^6 \text{ m}^3/\text{a}$.



Inconsistent groundwater data introduced a lack of groundwater “confidence” to IWRM managers in South Africa

Figure 2 Current and expected groundwater use in South Africa

The question is then: “Why do groundwater figures have such a huge variability?” This happens because capturing of borehole data is not a legal requirement in South Africa and information resulting from a large number of boreholes drilled every year are not captured. Therefore to ensure that groundwater does fulfil its rightful place in South Africa’s legislative water resource framework, the very foundation of it needs to be improved, that being reliable borehole information or point-source data.

The data needs to be captured in a manner that serves the needs of both the NWA and the WSA and useable and accessible to all relevant stakeholders. Therefore, when developing a WSDP for a district municipality where groundwater plays a strategic role, the information needs to be available to the water management authority in a format that is usable and accessible. For example the Bohlabela District Municipality (2005) WSDP lists and numbers different borehole installation types and clearly state that information on groundwater yield and information on spatial distribution is scarce, yield assurance in relation to surface water is unknown and in conclusion restricts the design yield from groundwater installations to 30% of the recommended yields. The list of the borehole data captured in the census in 2003 includes general information, operation functionality, ownership, construction dates and type and capacity (Bohlabela District Municipality, 2005). Data therefore needs to reflect water

services needs such as infrastructure information, accurate spatial distribution, sustainable yields and management requirements. Sustainable yield is not a fixed concept and may differ as monitoring and adaptive management changes, therefore better information improves management and changes our concept of sustainable yield (Maimone, 2004), emphasising the need for better monitoring and information management.

The data also needs to satisfy the needs of the NWRS and future CMSs, reflecting on recommended yields, strike depths, future development yields, of the available resources and future management thereof. In the current environment where borehole point data is limited and not verified in the field it makes it difficult to accurately estimate groundwater use and potential. The challenge for the groundwater group forming part of a bigger group of IWRM managers, is to introduce a systematic approach whereby groundwater point data is verified and so that it is usable for all integrated water resource managers and stakeholders. This will ensure that IWRM managers get a firm GRIP on groundwater as a water resource and as part of an integrated water resource. To achieve these goals the Groundwater Resource Information Project (GRIP) was proposed and implemented, providing the tool to capture and present borehole point data to be used by water service authorities or CMAs, national and local government, etc. If successfully implemented GRIP provides water service authorities and CMAs with verified borehole or point data information and enables IWRM institutions to protect, use, develop, conserve, manage and control groundwater resources through a process that meets basic human needs, allows equitable access, facilitates social and economic development, protects the aquatic and associated ecosystems, reduces and prevents pollution and degradation and meets international obligation.

GRIP provides the tool to capture groundwater data and thereby assists groundwater to play a bigger role in IWRM.

1.6 AIM OF THE THESIS

The aim of this study is to develop and implement a systematic approach to capture and verify relevant groundwater data in rural areas in the Limpopo Province, South Africa and to make the information available to all stakeholders involved in IWRM in Limpopo.

1.7 OBJECTIVES

The objectives of the project are to:

- Describe the role of groundwater in terms of IWRM and in South Africa
- Report on groundwater occurrence and presentation thereof in South Africa and Limpopo
- Propose a systematic approach to capture relevant groundwater data
- Implement the above-mentioned proposed approach
- Present comparative results of verified groundwater data with previous data
- Develop and implement a data and information distribution platform
- Promote GRIP as a tool to assist integrated water resources managers in South Africa
- Improve groundwater's role in IWRM in rural Limpopo.

1.8 AREA OF IMPLEMENTATION

The Limpopo Province is the most northern reaching province in South Africa and also one of the most poverty-stricken areas in the country, where basic water supply is a constant day-to-day struggle. The GRIP study area is illustrated in Figure 3.

During times of drought low yielding-hand pumps are implemented in the rural villages as emergency water supply projects (Figure 4). During the so-called emergency projects, borehole development and management are not prioritised and information concerning the groundwater resources and source development is not captured on the national groundwater database (NGDB) or the provincial database. The result is that almost all villages in Limpopo have a borehole available for use, but the resource information is not available to either the water resource planners or operation and maintenance crews. It was therefore envisaged that GRIP be implemented in Limpopo because it has a great probability of success. It will be illustrated that groundwater is widely used, however, due to the absence of a proper process of capturing and managing information, groundwater is invisible to IWRM managers and it is difficult for them to believe that groundwater is a sustainable resource.

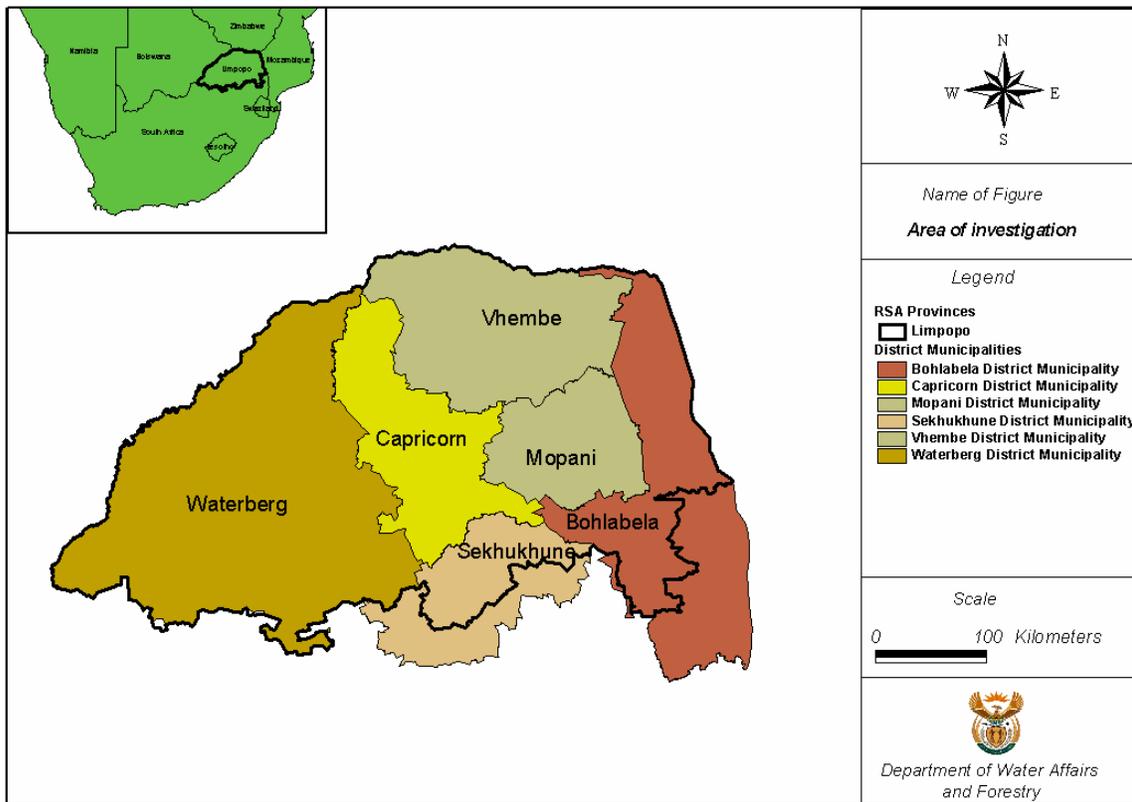


Figure 3 Limpopo, indicating district municipalities



Figure 4 Typical hand pump “emergency” drought-relief borehole developed for the Dinga community in Limpopo.

1.9 GROUNDWATER USE IN LIMPOPO

The complex geology leading to diverse geohydrological regions makes it almost impossible to generalise groundwater occurrences and/or us. This is quite evident in the middle and northern parts of Limpopo. If Vegter's (2001) groundwater use growth is accepted at 3.4%/a and if the Exploitation Potential is correct, then Limpopo is at the brink of groundwater over-abstraction. The reason for this is that there is approximately $725 \cdot 10^6 \text{m}^3/\text{a}$ exploitable groundwater in Limpopo, derived from the Harvest Potential value multiplied with an average Exploitation Factor of 50% and the use is at $550 \cdot 10^6 \text{m}^3/\text{a}$ (Haupt, 2000). Therefore if the groundwater-use growth rate of 3.4% (Vegter, 2001) is correct, the use will equal the availability in 2013/14. Du Toit (2002) conducted a short study and concluded that the use is more likely in the order of $460 \cdot 10^6 \text{m}^3/\text{a}$, a significance difference of approximately $100 \cdot 10^6 \text{m}^3/\text{a}$.

2 BACKGROUND

The background information discusses how groundwater as an industry developed in South Africa, groundwater data availability, different approaches to groundwater resource mapping and presentation of groundwater, groundwater use and legal requirements when it comes to groundwater management. The background information helps to place groundwater resources in context with IWRM by taking into account the historical development thereof and the current participation in the water sector.

2.1 GROUNDWATER DEVELOPMENT AND CURRENT STATUS

Vegter (2001) takes groundwater on an almost 100-year journey, giving insight in groundwater matters that are often not taken into account when dealing with groundwater as a historical water resource. Borehole drilling started in the late 1870's and was first used for government operations, e.g. railway stations, but gradually became more popular in the private sector and farming communities. In 1910 South Africa became a Union and during the following 74 years government-aided drilling operations delivered 327 400 boreholes. At the end of 1984 a large part of the DWAF drilling services were transferred to the Directorate Agriculture and Water Supply. During 1985 a total of 1876 boreholes were drilled, but the drilling records following the transfer are not clear. To date it is assumed that the government drills in the order of 600 boreholes per annum.

With the steel-rig percussion drill becoming more accessible to local contractors, the private sector entered the water-borehole business and overnight the whole industry boomed. Today there are approximately 450 active private drilling rigs in the country, each commissioning ± 22 boreholes per month, which means that $\pm 100\ 000$ water-bearing boreholes are drilled every year. Vegter (2001) estimated that by 1999 there were approximately 1.1 million water boreholes in existence, compared to only 225 000 captured on the NGDB. From drilling data and agricultural records Vegter (2001) calculated that the groundwater use in 1999 was about $3\ 360 \cdot 10^6 \text{ m}^3/\text{a}$ and increasing at 3.4%/a. The estimated use at the end of 2001 was in the order $3\ 850 \cdot 10^6 \text{ m}^3/\text{a}$.

Regarding the technical and scientific development of groundwater, Vegter (2001) also followed an interesting approach and divided groundwater investigations and research into five different eras or categories, starting with the pre-geophysical era (first drilling to 1935) when geology played a major role. This was followed by the geophysical borehole-siting era (1936 – 1955) and the era referred to by Vegter (2001) as the “Quest-for-quantification” era (1956 – 1976). This era was formed and

developed around the Water Act of 1956 and is also earmarked by Enslin's presidential address where he reiterated the need for proper groundwater development and management. Vegter (2001) also discusses mining and groundwater, environmental isotopes and the role of different organisations like the Council for Scientific and Industrial Research (CSIR), Water Research Commission (WRC) and the Institute for Groundwater Studies (IGS). Probably one of the most important aspects that Vegter (2001) touched on is the Commission of Enquiry into Water Matters of 1966. According to Vegter (2001) the Commission found there was a serious lack of groundwater management, control and understanding of groundwater resources. Before these issues were properly understood, groundwater moved into the next era – "Expanding activities" (1977 – 1997).

This era was kicked-off with the transfer of the Groundwater Division of the Geological Survey to DWAF and was merged with the newly established Directorate Geohydrology. Until then, groundwater being regarded as a "mineral" played a big role in the Geological Survey, which was engaged in scientific groundwater investigations. Under the Chief-Directorate: Scientific Services, Geohydrology together with the banking sector initiated hydrogeological mapping (Braune, 2002) and water quality investigations. The Reconstruction and Development Plan (RDP) also kicked off, making wide use of groundwater as a potable water resource. During this era organisations such as the Borehole Water Association of Southern Africa (BWASA) and the Drilling Contractors Association of Southern Africa (DCASA) emerged and started playing various roles in furthering groundwater development. Besides proclaimed subterranean water control areas (SWCAs), groundwater was still regarded as private water and groundwater use and management was uncontrolled. Usually SWCAs were proclaimed too late and by the time the groundwater came under management, the resource was largely degraded due to continuous over-abstraction (Du Toit, 2003).

The introduction of the NWA in October 1998 may also reflect the start of the next era for groundwater in South Africa, the so-called IWRM era and if not implemented correctly it may become the final era for groundwater (Vegter, 2001).

2.2 GROUNDWATER DATA AVAILABILITY

Entrenched in the GRIP hypothesis is the lack of available groundwater data and the need to understand current groundwater data spheres in South Africa and compare it with international practices.

2.2.1 National Groundwater Database (NGDB)

The NGDB data set is probably the most comprehensive borehole data set in South Africa (Figure 5) with an estimated 225 000 boreholes (<http://www.dwaf.gov.za/geohydrology/databases>)

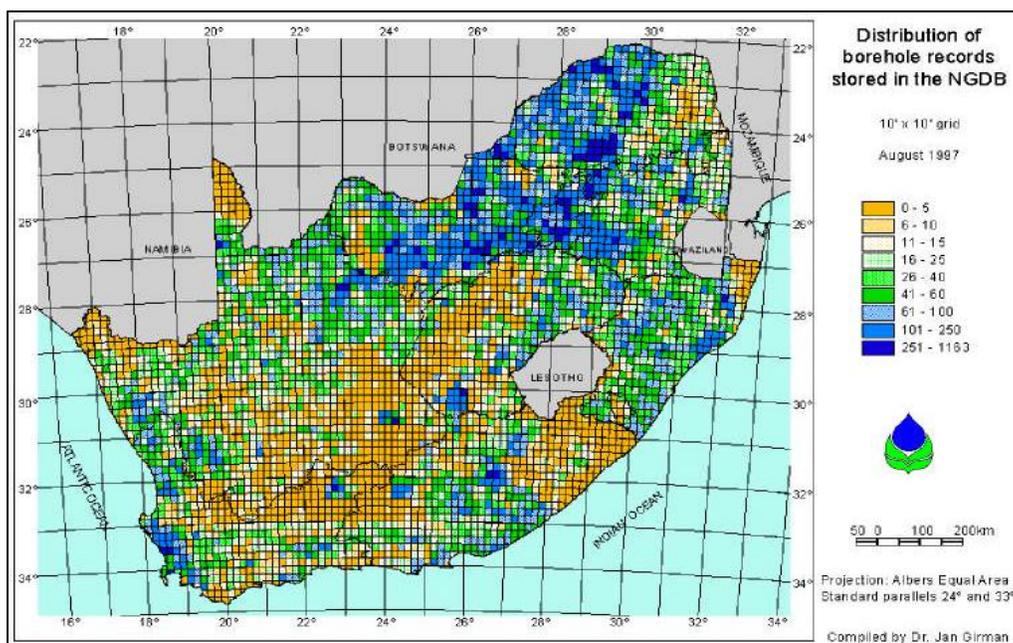


Figure 5 Distribution of borehole records stored in the NGDB (<http://www.dwaf.gov.za/geohydrology>)

The NGDB is driven by well-established institutional arrangements in DWAF and updating, day-to-day management and improvement thereof is the responsibility of the Chief Directorate: Information Management (CD:IM). The NGDB consists of different capturing menus and contains the following headings: main: user request, data retrievals, request, borehole composition, borehole construction, measurement and readings, miscellaneous, management system classification and system administration (DWAF, 2002). Borehole data is stored with an assigned site identification number known as a site-id and linked to a geographical position (Figure 6). The NGDB is not Internet-based and according to the NWRS the NGDB was to be replaced with a web-enabled National Groundwater Archive (NGA), which should have been operational by the end of 2004. The NGA is still in the a development phase (<http://www.dwaf.gov.za/geohydrology>).

The screenshot shows a software window titled "NATIONAL GROUND WATER DATABASE - NGDBDB". The menu bar includes "File", "Select", "Edit", "Macros", "Options", and "About". The main window is titled "BENTR: Basic Site Information" and "Report Management". The application is in "INQ" mode, with options for "ESC/BYE/NWS/HLP" and "ADD/CHG/DEL/INQ/BAC/NEX/FIR/LAS". The main heading is "- NATIONAL GROUND WATER APPLICATION - 150.MAINTAIN BASIC SITE INFORMATION (ENTRY)".

The form contains the following fields and controls:

- Site ID Code:** [Text field]
- Province:** [Dropdown menu]
- Map No.:** [Text field]
- District:** [Dropdown menu]
- No on Map:** [Text field, value: 0]
- Farm No.:** [Text field]
- Original Site Name:** [Text field]
- Site Name:** [Text field]
- Boring Branch No.:** [Text field]
- Region B/Hole No.:** [Text field]
- Topographic Setting:** [Radio buttons for Hartebeeshoek Datum and Cape Datum]
- Latitude:** [Text field, value: 0 00 00 00]
- Longitude:** [Text field, value: 0 00 00 00]
- Coord. Method:** [Text field]
- Drainage Region:** [Text field]
- Altitude (m):** [Text field, value: 0.00]
- Altitude Method:** [Dropdown menu]
- Map Scale:** [Text field, value: Not Applicable]
- Altitude Accuracy:** [Text field]
- Site Type:** [Text field]
- Site Selector:** [Text field]
- Nominal Diameter (mm):** [Text field, value: 0]
- Latest Depth:** [Text field, value: 0.00]
- Date Measured:** [Text field, value: 0]
- Depth Source:** [Text field]
- Site Status:** [Text field]
- Site Purpose:** [Text field]
- Water Use - Consumer:** [Text field]
- Water Use - Application:** [Text field]
- Reporting Institution:** [Text field]
- Equipment:** [Text field]
- Potability:** [Text field]
- Comment:** [Text field]
- Reliable:** [Text field, value: (Y/N)]
- Observation Hole:** [Text field, value: (Y)]
- Locked:** [Text field]
- Data Complete:** [Text field]
- Audited:** [Text field]
- Audited by:** [Text field, value: 0]
- Primary Arch.:** [Text field]
- Audited when:** [Text field, value: 0]
- Screen Updated:** [Text field, value: 0]
- Date Created:** [Text field]
- Date Updated:** [Text field, value: 000]

At the bottom of the window, the status bar shows "13:31:02", "INQUIRY REQUEST", and "Connected".

Figure 6 Basic site information electronic capture sheet

The NGDB borehole records are incomplete (Meyer, 1999) and most data points have little to no information on borehole infrastructure, at the very best it will only indicate that the borehole is equipped. Meyer (1999) concluded that the poor borehole data on the NGDB makes it difficult to conduct proper data analysis, as the data does not distinguish between dry and no-yield boreholes and therefore all dry boreholes are excluded in analyses. Little borehole pump-test or aquifer information is available and most unfortunate is that data quality auditing is done in the PC environment and boreholes are seldom if ever verified in the field (<http://www.dwaf.gov.za/geohydrology/databases/dataq.asp>). These current procedures as describe above are inadequate and may be the result of a lack of incentive-driven data capturing and the quality of data being voluntarily forwarded to the CD:IM. The result of this inadequacy is that it makes it immensely difficult for the end-user to confirm if the estimated 400 boreholes drilled daily is a true reflection of borehole drilling in South Africa and a huge amount of data is lost. The monetary value of the data lost is in the order of R600 million/a and borehole information lost is about 30 kilometres of borehole data per day (Botha, 2005). DWAF needs to consider developing an approach or procedure to capture data as it becomes available and set measures in place for continuous capturing of data in all sectors, including community water supply and sanitation (CWSS) projects and commercial use of groundwater for farming, industry and mining. The procedure therefore needs to set means and ways to capture real-time borehole data on the NGA.

The type and variability of data in the NGDB only allows limited use thereof, for example national groundwater mapping, however when developing the NWRS, CMSs or WSDPs it becomes questionable and introduce too many inconsistencies for IWRM managers to use.

2.2.1.1 Groundwater management tool- REGIS

The regional Geohydrological Information System (REGIS) is a hydrogeological information system, in which all relevant hydrogeological and related data are stored, managed, manipulated and queried in a uniform way. This can be used for geohydrological management and planning on national and regional scale. REGIS consists of *ArcView3.2 and Spatial Analyst* GIS and a relational linked *Oracle* database that contains all non-spatial data of the hydrogeological objects that are added to the system, for example administrative data, technical data, and measured and derived hydrogeological parameters. Various water boards and provinces in the Netherlands use REGIS (Figure 7). During 2000 and 2003 REGIS was adapted for REGIS Africa and DWAF started to use it (DWAF, 2005). To convince municipalities to buy into the groundwater system like REGIS will be immensely difficult, as (i) the system is very costly and (ii) the skill level to operate REGIS is high. REGIS therefore has its place in high-level planning in a national department like DWAF, but not in a rural environment, where we should be trying to promote groundwater through easy and cost-effective data availability.

2.2.2 Provincial groundwater H-regions

The database is based on the water services areas and historically there are six water services areas in Limpopo, representing the administrative level on which DWAF's Limpopo Regional Office implements water services. The water services areas are Bohlabela, Capricorn, Mopani, Sekhukhune, Vhembe and Waterberg with an estimated 2 200 rural villages or communities for the total area. The six areas are divided according to the H-numbering system adopted in the early 1990's and is a combination of geographical and political boundaries. There are in total 26 H-numbering regions in the study area that are clearly defined and are available as GIS polygon shape files (Figure 8).

2.2.3 Provincial database

Political change in South Africa also marked a change in the capturing and dissemination of water resources data. The old Directorate Macro Planning, DWAF, Head Office, know part of Water Services Information, required a comprehensive database on the available water resources that could be utilised during CWSS projects implemented in the old apartheid-based homelands. A database was developed using the H-numbering system with little input from the directorate Geohydrology, DWAF and funded mainly by the Directorate Macro Planning and the Regional Office, DWAF. During the data-acquisition period initiated by Macro Planning an independent consultant working with Macro Planning, developed a comprehensive groundwater database known as Aquabase (Weidemann, 2003). Aquabase is a user-friendly, Windows-based, groundwater database able to capture most groundwater data including geophysical, borehole-construction and borehole-testing data and also have some good mapping capabilities (Figure 9). Data was mainly gathered from the government-funded groundwater projects, capturing most boreholes drilled, as well as boreholes that could be found in the field. The Refurbishment Project implemented during the period from 1996 to 1998 resulted in population of the Aquabase database. Since the end of 1998 data was captured much less aggressively and the rate of data capturing dropped in magnitude (Du Plessis, 2002). The provincial database did not cater for the commercial farming communities, only for the old apartheid homelands. This renders a problem of *ad hoc* data capturing. The provincial database therefore has much the same problems of the NGDB, however due to boreholes been verified in the field, the accuracy concerning recommended borehole yields, borehole depth and borehole construction is much better in the provincial database. The results as mentioned above empowered the local groundwater users and gave them a sense of ownership. The provincial database also forced individual groundwater professionals to exchange and disseminate information (Weidemann, 2003). Due to internal political and personal beliefs in DWAF, Aquabase was never accepted nor considered as an official groundwater database for Head Office, DWAF, but became a popular commercial groundwater management tool and a provincial groundwater management tool.

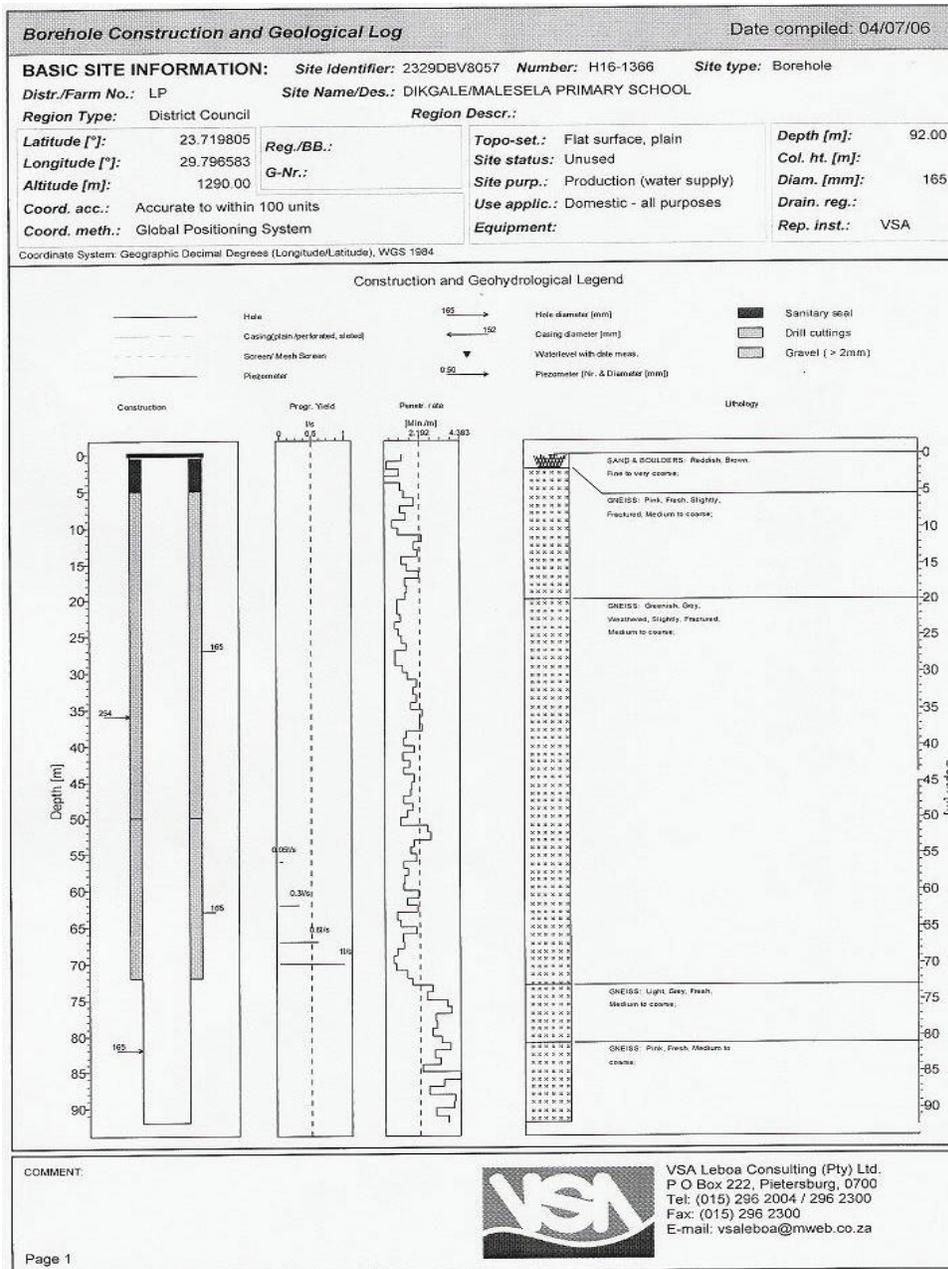


Figure 9 Typical borehole construction information captured and reported on Aquabase

2.2.4 Water quality database

The water quality database probably holds the most accurate point-source information and is available as a Water Management System (WMS). The WMS contains little borehole or aquifer information, but the quality data is excellent. The WMS database managers at the Institute for Water Quality Studies (IWQS) also worked together with the GRIP initiative to populate the WMS database (<http://www.dwaf.gov.za/iwqs/wms>).

DWAF requires a clear procedure to capture verified borehole data and make it accessible for all I&APs

2.3 GROUNDWATER DATABASES AND DISSEMINATION OF INFORMATION

Internationally there are a large number of groundwater databases available, with different applications and water use requirements. Most of the groundwater databases basic information sets are universal, however as a result of different groundwater management and use approaches supporting information sets can differ dramatically.

2.3.1 Canada, National Groundwater Database

The Geological Survey of Canada defined a National Groundwater Database project to collect data (<http://www.pes.rmcan.gc.ca>). Their project can be divided into three key activities: (i) the intent to implement collaboration and develop a mechanism to collect groundwater information, (ii) design and implement data management architecture and standards to store and exchange groundwater information through internal distribution channels and national initiatives and provide linkages with external and internal partners and (iii) deliver information in a usable form to governments, educators, practitioners and the general public, either as electronic or hard-copy information. Their objective can be summarised as to collate, assess and provide information about groundwater characteristics and to identify gaps thereof, to improve access and data interchange procedures, thereby raising the awareness through effective communication of groundwater information. The Canadian government capture their information and create collaboration with the help of a user-requirement questionnaire, divided into six sections, namely:

- Identification. Unique identification of individuals or groups.
- Role in the National Groundwater Database. The role of the individual or group, for example general public, water resource industry, consultation, educator, researcher, municipal, provincial or federal government.
- Type of data/information available. This section deals with the type and level of data available from the user. Typical information required is importance levels and data availability. It also deals with geology, borehole, borehole pump-test data, geochemistry, pollution sources, groundwater uses and sustainable yields and different kinds of maps generated.

- Data structure and format. Format of the data available, for example is the data hard copy based, GIS files, access files, Modflow files etc.
- Best practices and examples. If the user has good examples and are willing to share it he/she can send it to the Administrator.
- Participation in more formal user requirements. Would the user like to continue to be part of an ongoing project?

The Canadians have much the same database architecture as the NGDB but shifts their focus to monitoring and awareness of groundwater. They are also still in the beginning stages of the implementation thereof and it is still too soon see where they are leading to.

2.3.2 Australia, Victoria

The Victoria Groundwater Database in Australia (<http://www.nre.vic.gov.au/dnre/grndwtr>) also has similar information requirements as the NGDB but focuses on groundwater management and investigations. Four standard reports are created every six months concerning borehole location, aquifer information, borehole quality and a borehole composite report. The reports are generated for each 1:250 000 map sheet and published on the Internet. By using a “hotspot” composite image of the 1: 250 000 maps from Victoria it can visually be chosen and downloaded (Figure 10).

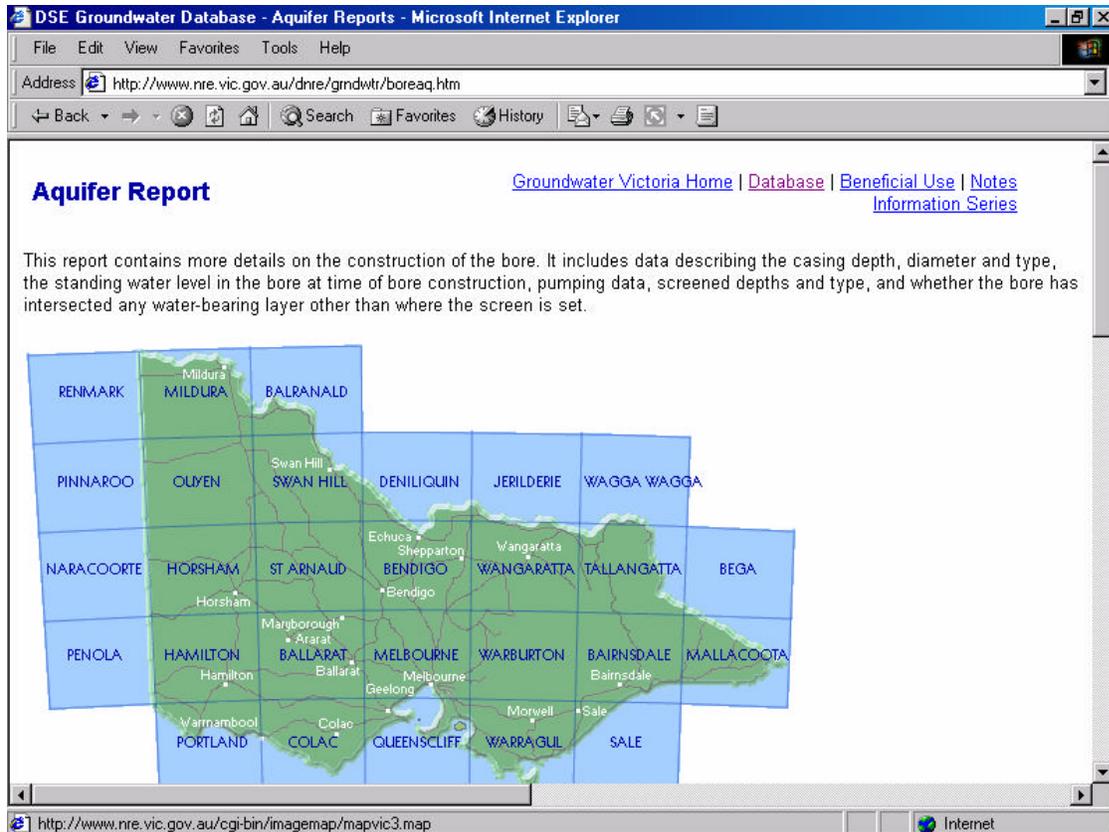


Figure 10 Aquifer report web-page from the Victoria groundwater database, showing the “hotspot” image to select a 1: 250 000 map sheet.

2.3.3 Texas, USA

The Texas Water Development Board in the USA has an interactive GIS system from where borehole and groundwater information can be downloaded and used with an interactive GIS viewer (<http://www.wiid.twdb.state.tx.us/>). Their goal is to effectively manage and distribute critical data and information, vital for drought-resistant water supplies. The Water Information Integration and Dissemination system has four major applications: (i) supply of groundwater data, (ii) submission of drillers reports, (iii) groundwater planning and (iv) survey reports. Surface water data as well as a mapping tool are included (Figure 11).

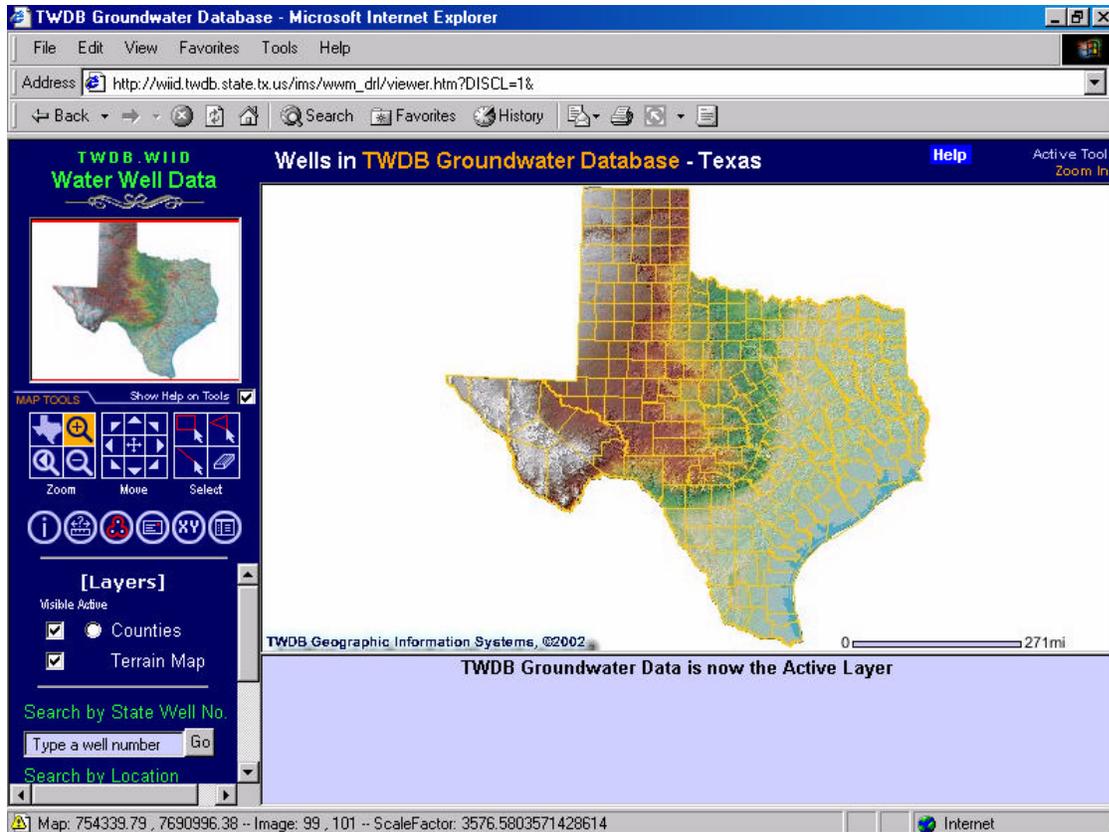


Figure 11 Texas, USA Groundwater Database uses a GIS viewer on their web-page to identify areas where data can be retrieved from.

2.3.4 Kentucky, USA

The Kentucky system, Water Resource Information Systems (<http://www.water.ky.gov/>), is similar to the Texas system, and leans to a fully integrated IWRM system. It is an interactive system and deals with drinking water, floods, groundwater, operations certificates, permitting and approvals, public involvement and assistance, status and regulation of surface water, waste water, water availability, water watch (news) and watersheds (managing and planning strategies). The groundwater is divided into awareness, digital database, geo-spatial database, image database, protection, technical assistance and monitoring and management. To retrieve groundwater information from the website is practical and easy. From the Water Resource Information Systems (WRIS) web-page select groundwater data and follow the instructions. Also on the WRIS web-page is an option to download already available groundwater reports (Figure 12).

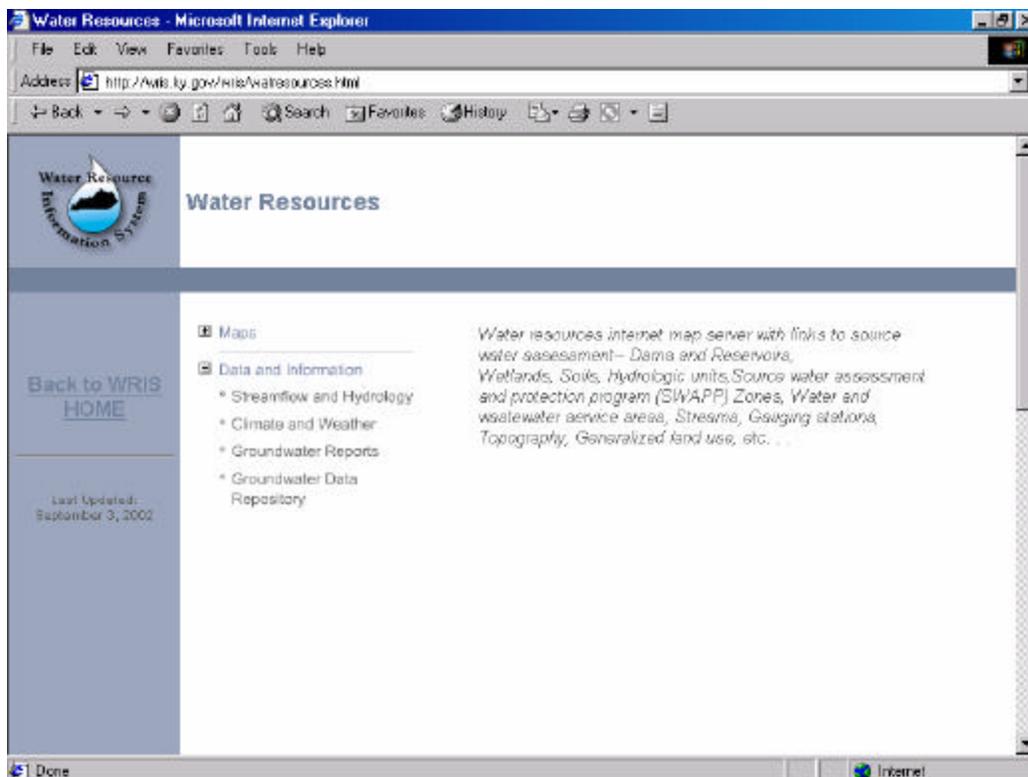


Figure 12 First-step to retrieve groundwater data from the Kentucky Water Resource Information Systems Web-page

The user is passed to the Kentucky Geological Survey website and then on to the watersearch web-page and can select from three options on how to search for groundwater data (Figure 13). If the user searches for a borehole, the user is passed on to the next web-page, given the options to search the database based on county or number or radius from a point, either in degrees decimal or latitude or longitude (Figure 14). If a county is selected the database is searched for all the boreholes available in the county and reported as a results web-page (Figure 15). The results web-page shows a summary of the data resulting from the search, including the number of boreholes, number of records per page and number of pages. The web-page also gives the options to (i) download a report as a spreadsheet, (ii) show the data on a map or (iii) download the borehole quality data. The user can choose to download the data in spreadsheet format. The data is then available in a format similar to an Excel spreadsheet format and can be used by any potential user (Figure 16).



Figure 13 Watersearch web-page on the Kentucky Geological Survey's website

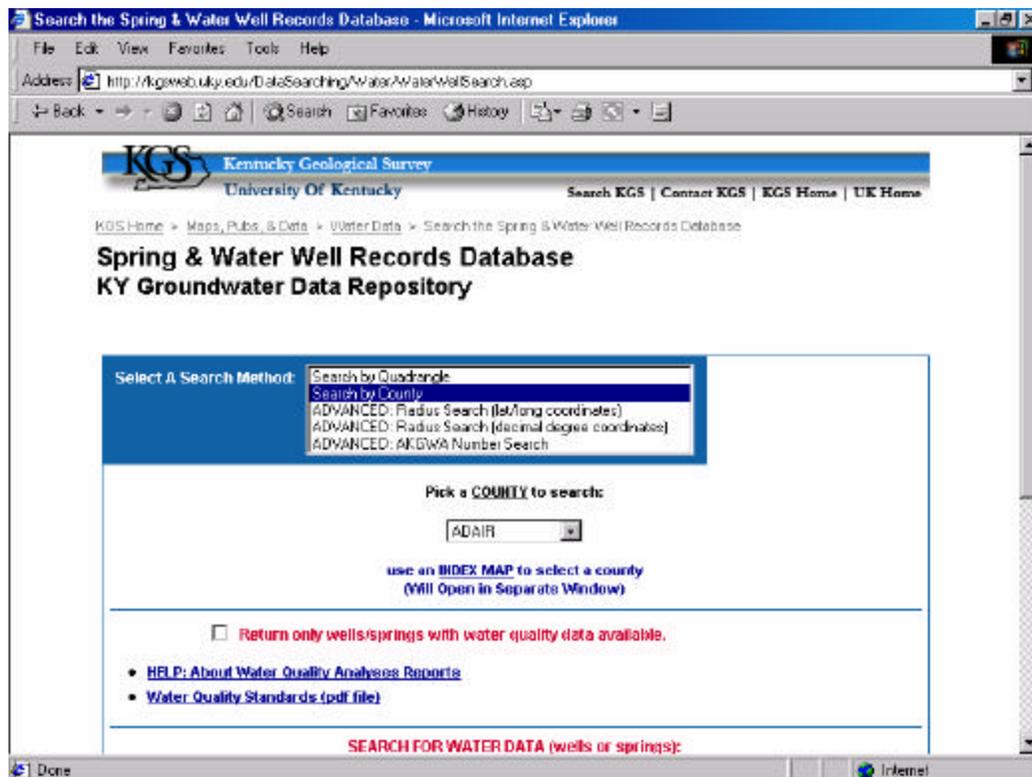


Figure 14 Groundwater data search options available on the Kentucky Groundwater Database watersearch web-page

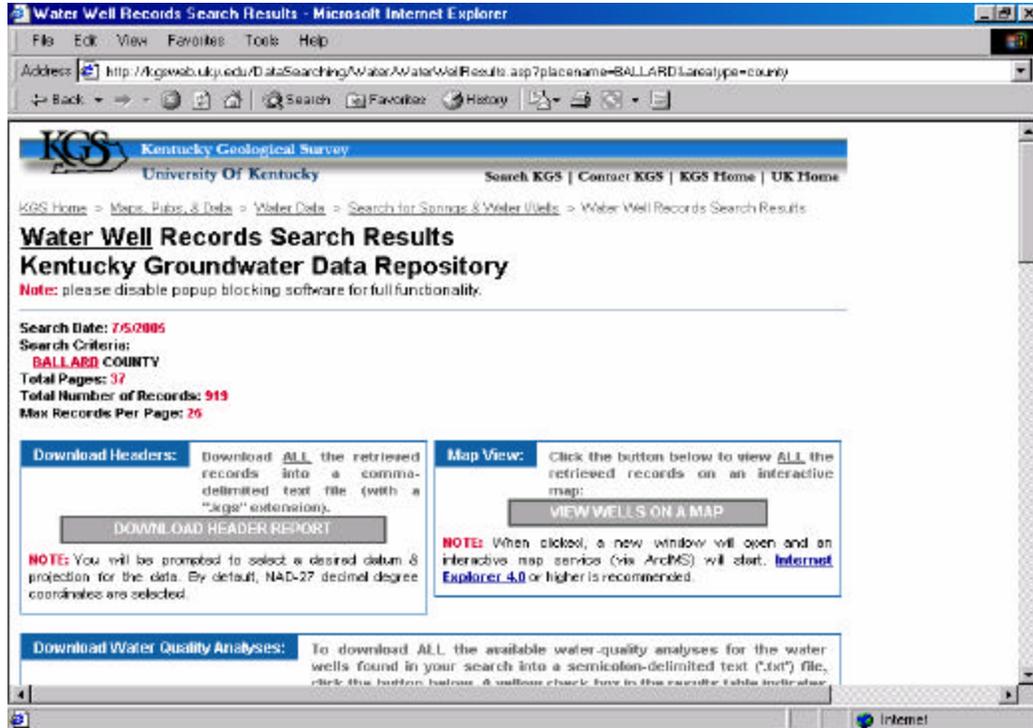


Figure 15 Results page showing results from a search completed on the Kentucky groundwater database

Print this page (for best results, use LANDSCAPE orientation)

Sort Results By: **KGS ID** Records Per Page: 25 RESUBMIT

First Page | 1 2 3 4 5 6 7 8 9 10 ----> | Last Page | GO BACK TO THE SEARCH PAGE | EMAIL FEEDBACK

AKGWA # KGS ID PUBLIC (if shown)	View Well On A Map (via ArcIMS)	Well Report (lithologic and casing data)	Quality Analyses?	Quadrangle	County	Construction Date	Primary Use	Depth to Bedrock	Total Depth	Static Water Level	Latitudinal (dec)
AKGWA #: 80035919 KGS ID: 113	MAP VIEW	WELL REPORT	--	La Center	Ballard	11/10/1998	MONITORING	-	30.4 ft	22.44 ft	37 (37)
AKGWA #: 80004684 KGS ID: 828	MAP VIEW	WELL REPORT	✓	Blandville	Ballard	1/1/1990	MONITORING	-	147 ft	97.84 ft	36 (36)
AKGWA #: 80004683 KGS ID: 829	MAP VIEW	WELL REPORT	✓	Blandville	Ballard	1/1/1990	MONITORING	-	92.6 ft	44.42 ft	36 (36)
AKGWA #: 80004682 KGS ID: 830	MAP VIEW	WELL REPORT	✓	Blandville	Ballard	1/1/1990	MONITORING	-	106.5 ft	59.24 ft	36 (36)
AKGWA #: 00000658 KGS ID: 1520	MAP VIEW	WELL REPORT	--	La Center	Ballard	5/20/1987	DOMESTIC	180 ft	180 ft	80 ft	37 (37)
AKGWA #: 00002191 KGS ID: 2662	MAP VIEW	WELL REPORT	--	Barlow	Ballard	5/7/1986	DOMESTIC	95 ft	95 ft	60 ft	37 (37)
AKGWA #: 00002194 KGS ID: 2665	MAP VIEW	WELL REPORT	--	La Center	Ballard	7/9/1986	DOMESTIC	94 ft	94 ft	45 ft	37 (37)
AKGWA #: 00002210 KGS ID: 2672	MAP VIEW	WELL REPORT	--	Lovellaceville	Ballard		DOMESTIC	88 ft	88 ft	4 ft	36 (36)
AKGWA #: 00002478 KGS ID: 2696	MAP VIEW	WELL REPORT	--	La Center	Ballard	7/27/1985	DOMESTIC	-	210 ft	100 ft	37 (37)
AKGWA #: 00002487	MAP VIEW	WELL REPORT	--								37 (37)

Figure 16 Borehole data downloaded in spreadsheet format from the Kentucky groundwater database

2.4 GROUNDWATER RESOURCE MAPPING

Various attempts were made in the past to develop groundwater resource maps with the aim to make groundwater more understandable to the layman. These maps play a major role in groundwater resource management and development.

2.4.1 Groundwater resources of the Republic of South Africa

The Groundwater Resources Map of the RSA basically identified lithostratigraphic units and with the aid of the available borehole data on the NGDB the Boreholes Prospects Map was also developed (Vegter, 1995a). By using different colours and shadings, the country was characterised in terms of “nature of water-bearing rock”, “probability of a successful borehole” and also “probability of a borehole yielding more than 2 l/s”. A borehole was regarded successful if it had a blow yield greater than 0.1 l/s. The concept of mean annual recharge (MAR) and storage was introduced and calculated on a national scale (Vegter, 1995b). The MAR is derived from rainfall values calculated by the Computer Centre for Water Research (CCWR) and selected groundwater monitoring points. The map series takes into account the requirements for base flow and vegetation growth. Sheet 2 is a composite map displaying the mean annual recharge (MAR), base flow, depth to groundwater, hydrochemical types, Total Dissolved Solids (TDS) and Saturated Interstices (SI). The SI map is significant and deals with the storage coefficient (order of magnitude) and the recommended drilling depth below groundwater level thereby reflecting the volume available in storage and calculated on a national scale. The SI map also reflects the storage medium type and indicates the success rate.

The rainfall reliability (RR) is a factor developed to classify an aquifer as being recharge- or storage dependent. The RR can be described as the 20th percentile rainfall divided by the median precipitation resulting in a percentage value. The inverse value (1/x) would reflect the length of an expected drought. For example, a 20th percentile value at 500 mm/a and a 50th percentile value at 650 mm/a would have a RR value of 77% and may indicate a drought period of 1.3 years. The MAR and RR were applied to develop the Minimum Recharge (MR), thereby calculating the least water entering a system over an area per time unit ($MR = MAR \cdot RR \cdot \text{area}$). A few other generic concepts were derived from this, including the Recharge Abstraction (RA), Drought Abstraction (DA) and Storage (S). The RA is basically equal to the MAR expressed per unit area.

The DA is a calculated value (m³) at which the water can be abstracted during a drought period:

$$(eq.1) DA = S*RR$$

Vegter (1995a) also mapped the groundwater storage, calculated as follows:

$$(eq.2) S = s*D$$

where: s – storage coefficient

D – thickness of the water-bearing zone

2.4.2 Hydrogeological Map Series (1: 500 000)

While Vegter was completing the Groundwater Resources Map, Haupt (1995), in collaboration with the WRC completed a pilot 1:500 000 scale hydrogeological map. The Pietersburg Hydrogeological Map serves as a base on which the envisaged 1:500 000 hydrogeological map series would be compiled (DWAF, 1998). The map uses different colours to differentiate between intergranular, weathered and fractured, fractured and karst water-bearing formations and four expected yield median borehole-yield categories superimposed using different shadings of the main colour. A schematic cross-section is included to give the user a conceptual illustration of groundwater occurrence. Haupt (1995) went further and set guidelines on how to site the boreholes, the expected success rates as well as the volume available for storage. The map also indicates the expected highest yielding borehole.

2.4.3 Groundwater Harvest Potential Map of the Republic of South Africa

The Groundwater Harvest Potential Map of the Republic of South Africa was developed to give groundwater users and water resource planners an idea of the sustainable available volume of groundwater per area (Baron *et al*, 1996). The same methodology was used as by Vegter (1995), but the approach was pitched slightly different. RA, DA, MR and S values were used with great success to determine a new term known as the harvest potential (HP). The methodology is easy to apply and by classifying aquifer recharge dependency, the HP can be calculated according to the interrelationships between the DA, RA, MR and S values. The HP value can therefore be expressed as:

$$(eq.3) HP = RA \text{ if } (DA > RA) \quad \text{or;}$$

$$(eq.4) HP = DA \text{ if } (MR = DA = RA) \quad \text{or;}$$

$$(eq.5) HP = S \text{ if } (DA < MR)$$

Although the HP map gives a good indication of the available groundwater, the author commented that the map does not cater for existing use or for environmental use. Furthermore, as a result of continuous uncontrolled groundwater development over a period of 20 to 30 years, little information is available on groundwater use. The development and current groundwater use will remain a stumbling block for water resource managers up and until groundwater development occurs in a controlled environment enforced by legislation.

If Vegter (1995a&b) is correct, the embedded calculations in the Groundwater Resources Map of RSA does take environmental sustainability into consideration, including base flow. Baron *et al* (1996) concluded that the HP gives a fair indication of what practically can be abstracted and in some areas the actual abstractability may be 10% less than the HP and is dependent on the transmissivity (T) or the aquifer's ability to transfer/release all the available water in storage to a boreholes. It is therefore function of the specific yield (Sy) and specific capacity (Sc) and specific retention (Sr).

$$(eq.6) \text{ Porosity} = Sy/Sc + Sr$$

Baron *et al* (1996) also suggested that a national evaluation of the transmissivity (T) be undertaken to assess the abstractability. However, little detailed national or regional information is available and a qualitative evaluation of aquifer T-values are still not possible.

2.4.4 Exploitation Potential Map

Haupt (2001) reasoned that there is a strong relationship between the borehole yield and aquifer T-values. He tried to quantify the so-called abstractability mentioned by Baron *et al* (1996) by developing an Exploitation Factor (EF) with which the average Harvest Potential (HP) in a quaternary catchment is multiplied, resulting in the Exploitation Potential (EP). The Exploitation Factor was calculated by using the average borehole blow yields obtained from the NGDB and the database from the directorate Macro Planning, DWAF. Depending on the average yield in a quaternary catchment, the EP was divided into five groups ranging from 70% to 30% of the HP. The final product is an EP value per quaternary catchment. The intention of the EP map was to incorporate it with the Water Situation Assessment Model (WSAM) of the Chief Directorate: Planning (DWAF). However, when the algorithm was implemented in the database application, the EF was interpreted incorrectly resulting in a groundwater exploitation much lower than anticipated (Haupt, 2003).

2.4.5 Groundwater Regions

Vegter (2001) later used lithostratigraphy and added physiography to divide South Africa into groundwater regions. As a first-order division he distinguished between regions consisting mainly of primary water-bearing formations and regions consisting of secondary water-bearing formations. The secondary water-bearing formations are subdivided into five types ranging from crystalline rocks to composite formations. In each region Vegter described the occurrence of groundwater as per water-bearing formation derived from data obtained from the NGDB and with great effect described the criteria for borehole siting with the aid of resistivity and magnetic anomalies.

2.4.6 Specific Capacity

Specific Capacity (Sc) can also be used to evaluate the borehole potential of an aquifer with indicative correlation between Sc and sustainable aquifer yield. Du Toit (1998) mapped the Kruger National Park in South Africa and used Sc to differentiate between the development potential of water-bearing formations. The Sc gives the aquifer yield per unit drawdown and is therefore also an indication of the T-value. The Sc is not only depended on the hydraulic parameters of the aquifer but may also be influenced by poor borehole construction. In the Limpopo Province, secondary aquifers are the most common and a secondary aquifer system may have fluctuating T-values, depending on the time pumped, the position of the observation boreholes, as well as the presence of boundaries. Du Toit (1998) mentioned that Sc captures the available storage and a borehole with a high yield does not necessarily have a high Sc .

Various aspects discussed above can be used to improve future mapping products:

- The maps are all derived from the NGDB and/or Aquabase and could easily be misinterpreted. The need exists to develop a framework where the available data on the various databases are verified with data in the field, that is developing a hydrocensus procedure.
- If it is considered that point data from the NGDB is mostly inadequate, then it can be argued that the quantification and presentation of the water resources captured in previous mapping attempts is also inadequate. However, the maps presented are far too regional and not site-specific enough and apart from improving the data set and verifying the data, one needs to create site-specific maps reflecting the groundwater planning potential at a more localised level.
- The maps are static polygons derived from point-data information but with little statistical

contouring. Therefore, as a project requirement borehole point data need to be in a format that can easily be manipulated with the aid of a statistical method in a GIS package, for example ArcView.

- The maps available do not cover the borehole yields (blw yields), nor do they cover recommended yields or sustainable yields, which will be a better planning tool.
- There is quite a difference of opinion on the natural groundwater occurrence in Limpopo as well as on a national level and by verifying the existing information a better understanding of the natural groundwater occurrence can be obtained.
- Data verification should be done on a provincial level to establish a baseline use and this will be done through the groundwater resource information project (GRIP).

Groundwater resource mapping is based on unverified and limited datasets

2.5 LEGAL REQUIREMENTS

Natural resource management needs to occur in the boundaries set by the effected acts and associated guidelines. The two vital environmental acts passed by government were the NWA and the ECA. Some other aspects, concerning the NWA in terms of information requirements, not discussed above, for example the water use authorisation process and management system needs to be considered when investigating the needs for groundwater resources information.

2.5.1 Information requirements captured in the NWA

Chapter 14 of the NWA (1998) requires monitoring and assessment of all water resources and provides for a national information system. The Minister needs to establish a information system that include, among others a groundwater information system. The act requires data and information for the protection, sustainable use and management of water resources, provide information for the NWRS, for research, planning, public safety, development, status of water resources, disaster management, environmental impact assessments, for the public and other water users. The NWA allows for the Minster to develop regulations for monitoring, assessment and the nature, type, time period and format of the data to be submitted to the national groundwater information system. The NGDB or the envisaged NGA may serve the purpose of a national groundwater system, but it is not fully functional.

In the Limpopo DWAF Region Office there are groundwater information needs, that cannot be met by the NGDB and to assist water resource managers, to plan and manage groundwater, an information system needs to be established. Once the regional data is available and verified, it can be uploaded to the national information system and therefore become part of a national groundwater system, as required by the NWA.

2.5.2 Water Use Authorisation Process

The Chief Directorate: Water Use and Conservation, DWAF compiled a guideline document for the authorisation process for individual applications of water use licences (DWAF, 2000a). The document refers to the legal framework of the licensing process and the parallel EIA regulations. In the document the proposed procedure is discussed and a detailed flow diagram is given, indicating the path of the licensing procedure. A primary responsible officer (PRO) will be allocated by the Regional Director and should be familiar with the particular water use. Therefore, when a licence application under Section 21(a) for groundwater use is submitted, the sub-directorate Geohydrology is required to identify a person to act as the PRO. The PRO will be managing the Water User Authorisation Process (WUAP) and will almost always be the point of entry and exit. Therefore where groundwater-related water-use licences play a leading role, the old Directorate Geohydrology will act as the leading water user directorate (LWUD) (DWAF, 2000a).

The Water User Authorisation Process (WUAP) consists of different stages:

- Stage 1 Legal validation and assessment
- Stage 2 Pre-assessment
- Stage 3 Extent of investigations
- Stage 4 Detailed investigations
- Stage 5 Final license application and recommendation
- Stage 6 Decision

During stage 2-6 different inputs and information will be required from the DWAF Directorate: Geohydrology in Head Office (HO) and also from the Geohydrology sub-directorate in the regions (DWAF, 2000a).

2.5.3 Water-Use Authorisation and Registration Management System (WARMS)

The WARMS is basically a water-use database application with a graphical user interface (GUI) that helps the DWAF with the registration process of the licence applications. It enables the DWAF or CMA to capture the licence process and to identify bottlenecks. After the evaluation of the licence application the DWAF or CMA officials will distribute the official documentation and a licence document is issued. The WARMS is able to generate reports and audits on the status of the authorisation process, therefore enabling the management of the resource used at a national level. It will also be used to implement water-use charges. It operates from distributed databases in the DWAF Regional Offices ensuring that real-time data is available. The WARMS, however, does not go into detail with the actual licence evaluation. With groundwater the WARMS understandably almost disregards geohydrological information and does not assist much with the decision making process (DWAF, 2000b).

2.5.4 The Water Services Act

In terms of the WSA (1997), DMs become water services authorities and are responsible for sustainable potable water supplies to the municipal districts.

In terms of the WSA the following responsibilities need to be looked at:

- Regional groundwater studies, for example harvest potential determination, groundwater map compilation, etc. should be conducted by the CMA.
- Development of groundwater sources intended for localized water supply projects within a district should be a WSA responsibility.
- Development of groundwater sources intended for regional water supply projects across Districts should be a DWAF responsibility.
- Development of groundwater sources for private use (farming, mining, etc.) should be the responsibility of the developer.

In all cases groundwater must be developed according to the CMS and licenses must and can only be obtained from the CMA.

2.5.5 The Environmental Conservation Act

In terms of the Environmental Conservation Act (ECA, 1989) Environmental Impact Assessment (EIA) regulations on bulk water supply have been promulgated and all bulk water supply schemes fall under these regulations. According to the regulations “bulk supply is water supplied in a significant volume to a local authority, who in turn reticulates it to individual consumers. It is also in some cases supplied in bulk to mines, industries, and agricultural schemes.”

It is clear that an EIA must be conducted for all bulk water supply schemes, including groundwater supply schemes, and a specialist should address the groundwater and/or the surface water issues. The hydrologist/geohydrologist should complete a hydrological/geohydrological report that should be included in the EIA and the water use licence application.

The acts envisage integrated water regulation ensuring IWRM, including groundwater. The EIA process should stipulate how groundwater should be managed and at what level groundwater investigations should be conducted to gather enough information to satisfy EIA regulations as well as

***To implement the NWA successfully South Africa needs to
have a reliable groundwater data set***

NWA licence conditions.

3 VISUAL ASSESSMENT OF GROUNDWATER IN LIMPOPO

A series of field visits in different H-regions in the study area forming part of the initial study were completed, thereby obtaining an intuitive measure of the groundwater occurrence, use and management. The results from the field visit were both positive and negative, indicating that groundwater is available and used but poorly managed.

3.1.1 Groundwater occurrence

During the field visit it became clear from the number of boreholes drilled in most of the rural villages visited that groundwater plays a major role in water supply and should therefore be readily available in the rural areas. Most of the boreholes were not equipped and it was difficult to deduce any kind of yield. However, during the field visit to the Nebo Plateau, an area 100 km south of Polokwane and notorious for its poor groundwater potential, the team came across a borehole being pump-tested at a yield of 20 l/s (Figure 17). If developed correctly, the borehole may have an operational yield of 5 l/s for a 24 hour pump cycle and be able to supply 18 000 people with potable water. Similar high-yielding boreholes were found in the Bochum area 70 km to the north-west of Polokwane (Figure 18) and in Dieprivier some 30 km east of Polokwane. Apparently these boreholes form part of CWSS projects and after contacting the project engineer it was not clear whether the boreholes were captured on the NGDB.

Current borehole data, however, indicate much lower borehole yields (Vegter, 1995a&b) in all these regions and it is suspected that boreholes are randomly drilled with little geohydrological input. These visual assessment results found during the field visit, confirm that if groundwater exploration is done according to sound scientific methodologies much higher yields can be obtained.



Figure 17 Borehole visited on the Nebo Plate au. After switching off the pumps this borehole had artesian flow of 3 l/s



Figure 18 Borehole tested by a field team near Bochum, Limpopo

3.1.2 Groundwater use and management

Prior to the field visit the NGDB was queried but none of the boreholes could be verified in the field. Many of the boreholes in the region have been equipped with hand pumps or mono pumps. The borehole pump installations were in very poor condition and a large number of the boreholes visited were out of use. Some of the mono-pump installations were vandalised to such a degree that the pump house and all the equipment was stolen, with only the pump and the concrete floor remaining (Figure 19). It became clear that communities did not understand the importance of caring for the groundwater installations and pump houses are neglected and bricks are taken to be used in private housing (Figure 20).



Figure 19 Borehole in the H15-region visited with almost all equipment stolen



Figure 20 Borehole installation in the H12-region where bricks were taken away

During the field visit it also became clear that groundwater development, the associated infrastructure and impacts it has on sanitation and soil conservation are not considered at all. The natural ecosystem around many of the equipped boreholes was completely destroyed. Pounding around the boreholes is common, making it difficult to believe that the ECA (1989), WSA (1997) and the NWA (1998) have any effect on management and use of borehole development and management in Limpopo (Figure 21). Pump operators interviewed do not understand the basic concepts of groundwater development and management and the issue of skills development and training also needs to be investigated.



Figure 21 Ponding and soil erosion as a result of poor borehole development and management

Although it is critical for the development of ISPs, CMSs and WSDPs, from the field visits it became apparent that the current status of the borehole infrastructure and condition thereof is not reflected in the NGDB, WMS or WARMS. Information concerning the current status, use and management thereof is essential for these documents supposedly introducing IWRM in South Africa.

4 OVERARCHING STRATEGIC AND IMPLEMENTATION PLANS

The introduction, background information and the visual field assessment as discussed above clearly illustrates why a more detailed and verified dataset is required before groundwater can fulfil the role it needs to play in IWRM. The previous discussions also highlight the need for a clear procedure to meet the requirements to successfully introduce groundwater in the IWRM realm. Therefore to meet the needs any propose procedure needs to consider the following components.

4.1 OVERARCHING STRATEGIC PLAN

A short and definite overarching strategic plan is required to illustrate how the GRIP procedures and results bring groundwater closer to the framework of IWRM in South Africa. The overarching strategic plan for the GRIP is to capture data, disseminated data, use data to develop different products and tools to include in the NWRS, CMSs, ISPs and WSDPs (Figure 22).

4.1.1 Hydrocensus (data collection)

It is clear the available data sets are not fully populated and not verified in the field and therefore there is the need for a comprehensive hydrocensus. The hydrocensus needs to consider the following actions:

- Establish clear aims and objectives for a hydrocensus
- Establish a hydrocensus team
- Establish a Project Management Team
- Gather and capture existing borehole information from the NGDB an other databases
- Develop a practical field form
- Capture and verify borehole infor mation in the field from newly identified and existing boreholes
- Synchronize field and existing database data.

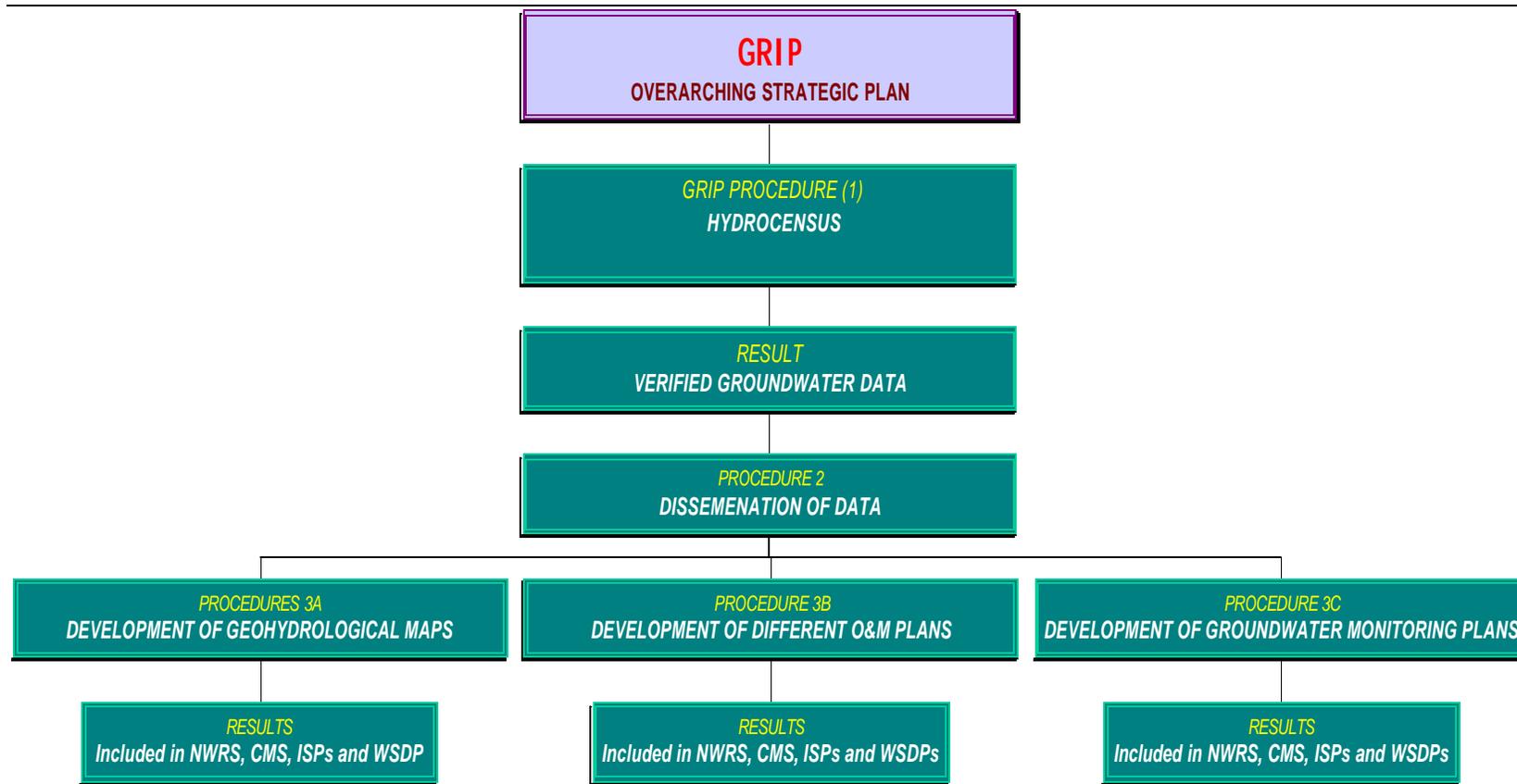


Figure 22 Overarching strategic plan attempting to illustrate how GRIP procedures and results fit into the IWRM implementation framework in South Africa

4.1.2 Dissemination of information to different interested and affected parties (I&APs)

- Integration into NWRS, CMSs and ISP documentation
- Integrate information into WSDPs
- Establish and promote an Internet information support service
- Integrate as part of the NGA
- Introduce to different levels of water resource management

4.1.3 Geohydrological mapping

- GRIP data to be used in new exiting mapping projects by DWAF
- Different scale maps as required by the end-user and various themes, including recommended borehole yields, borehole density etc.
- Client-defined maps: Developing maps with the aid of GIS as required by the Client.

4.1.4 Operation and maintenance plans

- Use borehole hydrocensus results to develop operation and maintenance plans
- Develop exploration plan
- Develop or introduce operational procedures
- Develop or introduce maintenance plans

4.1.5 Groundwater assessment plans

- Introduce groundwater assessment plans as part of and timeframes in accordance with the NWRS, CMSs and WSDPs.
- Develop or introduce existing procedures for groundwater assessment plans.

4.1.6 Groundwater monitoring plans

Continuous monitoring and updating of information on local and regional scale is required and monitoring plans need to be established.

4.2 IMPLEMENTATION PLAN

Based on the overarching strategic plan the “how to” needs to be unpacked. The GRIP is divided into 4 phases that can either be linked or implemented as stand-alone projects. It describes definite scopes, deliverables and beneficiaries for each phase.

- Phase 1 Data collection (Table 1)
- Phase 2 Assessment of data (Table 2)
- Phase 3 Target identification, siting, drilling and testing (Table 3)
- Phase 4 Final report and deliverables (Table 4)

The phases are not totally interdependent from each other, but the best results are obtained if all the phases are implemented in a chronological order as proposed. The workload, time and money is not reflected in the different phases, it only describes the actions required, therefore depending on the area covered, the number of boreholes, the complexity of the existing information and the available funding, the detail may change.

The essence of GRIP lies in phase 1. Phase 2, 3 and 4 are well used in previous mapping application by Haupt (1995), Meyer (1999) and Vegter (1995a&b) and can be regarded as manipulation and use of data. Although data collection also seems logical it does pose different challenges taking into account a rural water supply scale of 2159 rural villages, roughly 3.6 million people, variable types of borehole installations ranging from wind pumps to submersible pumps and an area covering almost half of Limpopo. Although all phases are mentioned and listed, only phase 1 is deemed necessary to develop in detail, implement and discuss for this study. The other phases as mentioned will follow, based on the result from the initial phase. If not implemented systematically, the lack of co-ordination will lead to either excessive costs or total failure of all phases.

Phase 1 is the essence of the GRIP

Table 1. PHASE 1: DATA COLLECTION

ACTIONS	DELIVERABLES	BENEFICIARIES
<ol style="list-style-type: none"> 1. Establishment of a hydrocensus team 2. Establishment of project management committee 3. Gathering of existing borehole information (existing reports) 4. Development of practical field forms 5. Establishment of an Internet information support service 6. Conduct field surveys 7. Capture data in hard copy 8. Capture and disseminate data electronically 9. Verify data 10. Supply data to provincial database and the NGDB/NGA 	<ul style="list-style-type: none"> • Hard copy data report of each rural village available in DWAF regional library • Web-enabled groundwater database populated with high quality verified data • Internet information support service • Interpretation of borehole reports • Planning and management reports • GRIP planning tool • Information available and used to improve WSDPs • Information available and used to improve ISPs • Information available and used to improve CMSs. • Information available to improve NWRS • Updated NGDB • Updated provincial database 	<ul style="list-style-type: none"> • IWRM managers • Various Directorates in DWAF Regional and National offices • District municipal councils • Local municipal councils • Water boards • Civil en geohydrological consulting groups implementing CCWS projects • Planning consultants • Provincial Departments including Environmental Affairs, Health and Welfare and Education • Various other stakeholders

Table 2. PHASE 2: ASSESSMENT OF DATA

ACTIONS	DELIVERABLES	BENEFICIARIES
<ol style="list-style-type: none"> 1. Consolidate new and existing borehole data 2. Analyse regional and structural geology using aerial photographs, remote sensing data, geological data, and regional and structural geology field data 3. Do a comprehensive borehole data assessment (borehole distribution, groundwater use, and water levels, flow directions, water quality, etc. using Arc View and Spatial Analysis as well as other appropriate technologies. 4. Capture and interpret available borehole pumping test-data and identify any further borehole pump test sites. 5. Conduct borehole pump-tests 6. Report per district municipality with the following outputs: water quality map, sanitation/protection zoning map; revised harvest/exploitation potential map, groundwater resources map, geological structures and borehole yield relationship, groundwater target map, etc. 7. Target identification for exploration/pilot drilling and monitoring zones, using outputs in step 1. 8. Populate and update the provincial database and NGDB 9. Identify and implement monitoring zones 	<ul style="list-style-type: none"> • Verified geohydrological information available on the Internet • Regional and structural analysis reports • Detailed electronic borehole pump-test data on Aquabase (regional database). • District municipal reports • Monitoring plans • Updated NDGB data • Updated provincial database 	<ul style="list-style-type: none"> • IWRM managers • Various Directorates in DWAF Regional and National offices • District municipal councils • Local municipal councils • Water boards • Civil engineering geohydrological consulting groups implementing CCWS projects • Planning consultants • Provincial Departments including Environmental Affairs, Health and Welfare and Education • Various other stakeholders

Table 3. PHASE 3: TARGET IDENTIFICATION, SITING, DRILLING AND TESTING

ACTIONS	DELIVERABLES	BENEFICIARIES
<ol style="list-style-type: none"> 1. Select representative targets for drilling and testing using the assessment results from phases 1 and 2. 2. Drill exploration/pilot holes to test and confirm potential of the selected targets. 3. Conduct pump testing on selected successful exploration boreholes and analyse results to establish aquifer characteristics and sustainable supply available from the various tested targets. 4. Identify suitable boreholes from the exploration/pilot boreholes that were drilled and tested that could be utilized for production purposes. 5. Consolidate results with Phase 1 and 2. 6. Populate and update the provincial database and the NGDB 	<ul style="list-style-type: none"> • Groundwater assessment reports and maps • Water-use status reports • Available groundwater resources • Groundwater resources verification for Water Services Planning • Improved groundwater development successes • More effective development and utilization of available groundwater resources • Updated NGDB • Updated provincial database 	<ul style="list-style-type: none"> • IWRM managers • Various Directorates in DWAF Regional and National offices • District municipal councils • Local municipal councils • Water boards • Civil en geohydrological consulting groups implementing CCWS projects • Planning consultants • Provincial Departments including Environmental Affairs, Health and Welfare and Education • Various other stakeholders

Table 4. PHASE 4: FINAL REPORT AND DELIVERABLES

ACTIONS	DELIVERABLES	BENEFICIARIES
<ol style="list-style-type: none"> 1. Produce a final report to Water Services Planning of the available groundwater resources for the area investigated. The final report should include the following decision-making information: <ul style="list-style-type: none"> • Quality of the groundwater (map). • Potential targets that will support a well-field development (concentration of boreholes supplying various villages) and targets that support single borehole development (local supply) with an overall indication of high potential and low potential groundwater areas (map). • Sustainable 24-hour abstraction rate per target plus number of boreholes required per target to (safely) maintain it (map). • Daily, monthly and annual available volumes of groundwater. • Existing infrastructure (reservoirs, pipelines, pumps, etc.) (map). • Sanitation status, recommended protection zoning of groundwater abstraction points, well fields and recharge areas as well as potential pollution threats (map). • Development cost per target. • A groundwater management plan. 2. Classification of the groundwater resources, quantification of the Reserve and resource quality objectives. 3. An operation and maintenance plan 4. Populate and update the provincial database and the NGDB/NGA. 5. Implementation of REGIS Africa in Limpopo. 6. Establishment of a groundwater service centre 7. Establishment of standard tender documents for: <ul style="list-style-type: none"> • Geohydrological component • Drilling • Testing • Equipping of boreholes • Implementation of CWSS <p>Development of groundwater protection maps for rural villages</p>	<ul style="list-style-type: none"> • Well-managed and protected groundwater resources • Reliable groundwater management information • Well-organised and thoroughly evaluated groundwater license applications • Operational groundwater quality, quantity and water level regional (levels 1 & 2) monitoring network • Operational level 3 network • Regular status reports • Well-maintained waste disposal, effluent disposal and potential pollution-threat sites with minimum pollution to ground water • Protection zoning of groundwater abstraction points and recharge areas • Early warning facility through effective monitoring network at waste disposal, effluent disposal and potential pollution-threat sites • Well-established and effective aquifer assessment and protection protocol for all new and existing waste disposal, effluent disposal and potential pollution-threat sites. • Motivated and well-trained staff • Well-informed and educated groundwater user • Well-informed and educated public 	<ul style="list-style-type: none"> • IWRM managers • Various Directorates in DWAF Regional and National offices • District municipal councils • Local municipal councils • Water boards • Civil en geohydrological consulting groups implementing CCWS projects • Planning consultants • Provincial Departments including Environmental Affairs, Health and Welfare and Education • Various other stakeholders

4.3 GRIP PROCEDURE PHASE 1: DATA COLLECTION

The first phase forms part of the verification process and is probably the most important part of any groundwater resource assessment programme. The development of GIS makes point-source information interpretation and management much more flexible. However, before data can be manipulated it needs to be verified in the field and at provincial level. It can be a labour-intensive and properly costly exercise and planning the data-collection phase became critical.

4.3.1 Aims

The aims are therefore to capture and verify field data in an efficient manner and also to capture groundwater resources information required in the context of requirements that meet South African IWRM needs.

4.3.2 Objectives

The objectives of Phase 1 are as follows:

- Establishment of a hydrocensus team
- Establishment of a project management committee
- Gathering of existing borehole information (existing reports)
- Development of practical field forms
- Establishment of an Internet information support service
- Conducting a field survey
- Capturing data in hard copy
- Capturing data electronically
- Verifying data
- Supplying data to the NGDB

4.3.3 Actions required to achieve objectives

4.3.3.1 Establishment of hydrocensus team

Implementation of GRIP on a provincial scale is a mammoth task and collection of and manipulation of multiple datasets are done as a team. The role of the consulting team is to roll out the GRIP out in the whole Limpopo. The GRIP Hydrocensus team consists of a simple structure (Figure 23). Khulani Groundwater Consultants (KGC), CWSS consultant appointed for a 2-year term (2002 –2004) served as the project co-ordinator. KGC appointed expert geohydrological consultants that conducted the field surveys in collaboration with them. The consulting team was responsible to report back to Groundwater Projects Management (GPM), who verified the field data and accepted the data as correct and captured it on the national database as a final verified dataset. The verified data is use by Geohydrology (DWAF Regional Office) responsible for the dissemination of information. The consulting teams were typically divided according to the District Municipalities (DM) and each consultant was responsible to implement the procedures in their area. It was imperative that local groundwater consultants were used not only to capture local expertise but also because they were familiar with the local geohydrological conditions and limited infrastructure.

4.3.3.2 Establishment of Project Management Committee (PMC)

The PMC manage the project to achieve the objectives set during the implementation of Phase 1. Project integration between different spheres are introduced. The PMC consists of representatives of all the different groups in the structure, with the chairman from the lead authority, DWAF. The PMC needs to investigate more effective management methodologies and the verification processes. It is also the PMC's responsibility to see to it that all the members are aware of the budgetary implications and progress. The PMC meets at a minimum once a month. An essential part of the PMC is providing proper minutes of progress and management decisions.

4.3.3.3 Gathering and capturing of existing boreholes information

The objective is to obtain existing borehole data from previous studies/investigations conducted by geohydrologists/engineers on behalf of various water supply developers. Water suppliers may include local and district municipalities, aid groups, DWAF (Water Services) and various other non-governmental organisations (NGOs). The existing data on the provincial database (Aquabase) and the NGDB need to be consolidated. The data is captured and stored both electronically and in a hard-copy

file is created and kept during the whole process, only after all possible data is gathered, can the project move to a practical field-implementation stage.

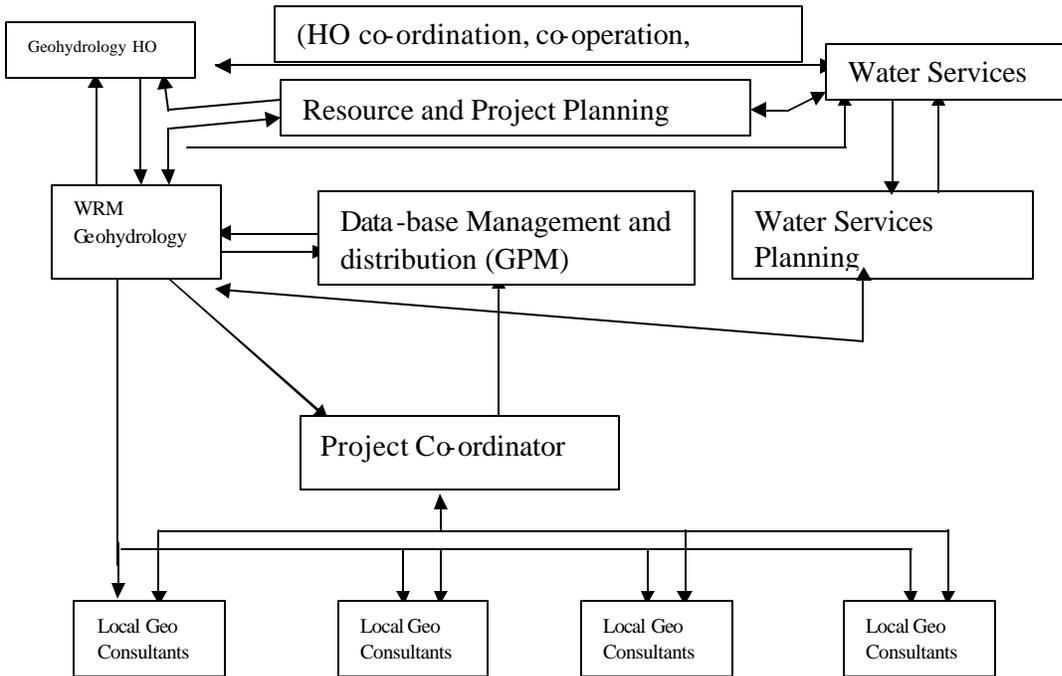


Figure 23 Project structure

4.3.3.4 Development of practical field forms

Correct capturing of existing data is essential, therefore the forms need to be practical and easy to understand by the user in the field, bearing in mind that some of field teams have much less exposure with regards to a hydrocensus than other more experienced consultants. The data sheets developed are simple and user-friendly and easy to capture electronically.

4.3.3.5 Establishment of an Internet information support service

The information era is well on its way and capturing and dissemination of borehole information needs to be available from the Internet. Based on the examples discussed in Chapter 2, an Internet-based dissemination systems needs to be developed.

4.3.3.6 Field survey

The field survey is a comprehensive exercise and involves co-ordination between different teams. It will involve a “traditional” geohydrological borehole survey and an audit of infrastructure associated with the boreholes. By capturing associated infrastructure information it is possible to deduct to

different water uses, for example individual, municipal, agricultural, housing, schools etc. It is important during this sub-phase to populate the water quality database (WMS) with close co-operation from the IWQS. During this sub-phase some geological background is captured, possible target areas identified and boreholes that could be pump-tested or re-drilled are also identified.

4.3.3.7 *Verify existing data with new data*

A second round of verification is deemed necessary to make sure that all the data is checked against existing data and to ensure that the data is correctly captured both in hard copy and electronic format. This sub-phase is the most crucial and forms the final verification process in the hydrocensus. During this sub-phase, the consulting teams, the quality control officer and the information-database manager check all the data already available.

4.3.3.8 *Cost of implementation*

The GRIP is the first of its kind in South Africa and due to the lack of any other reference data it is difficult to estimate the cost linked to the detailed data-collection process. The difficulty arises due to overlapping borehole development in most of the villages with some communities having more than 18 boreholes available. The positions and construction methods of these boreholes are mostly unknown. The cost-benefit to conduct a proper borehole census is therefore vastly under- or over-estimated. Preliminary cost per verified borehole is estimated to be far less with the increase in the number of boreholes in a village. The estimated cost per village may be in the order of R3 000 (Table 5) and includes the hydrocensus, consultation, project management, travelling, travel time, subsistence, equipment and borehole marking costs.

Table 5. Budget estimation for phase 1/ village (August 2002)

Description of action		Calculations based on:	Tariff per village
Census	Geohydrological field census: including data capturing and preparation per village	Team existing of 1 cat. D, 1 labourer	R 1,400
Consultation	Geohydrological data interpretation, reporting, data management and consultation	Cat. A-C depending on task definition	R 0
Project management	Project management including all project meetings, arrangements, documentation etc.	All: Budget based on 15% of costs.	R 200
		Fees total/village	R 1,600
Travelling	Travelling to and from village, from central point within area of appointment.	200 km average per Village at R2.91/km	R 582
Travel time	Total time spent on travelling to and from village	3 hours per village @ R100 per hour	R 300

Description of action				Calculations based on:	Tariff per village
Subsistence	All accommodation, meals and basic expenses			One day per village 30% of villages	R 57
Equipment	Equipment hire, including water quality measurement instrumentation (WQ), GPS and water level meter (WL)			WQ = R25, GPS = R30, WL = R30	R 85
Borehole Marking	Borehole marking - boreholes not marked, based on standard procedures			R180 per borehole, Average 2 boreholes / village	R 360
				Disbursement/village	R1,384
Boreholes/Village	4	6	8	TOTAL per village	R2,984
Cost/borehole	R746	R497	R373	TOTAL Villages	R2 417
				TOTAL	R 7,212,328

5 IMPLEMENTATION PROCEDURES FOR GRIP: PHASE 1

It is clear that groundwater information is required for successful implementation of IWRM and that a so-called GRIP approach can provide the required information. The question, however is can an idealistic programme like GRIP be implemented, especially on such a large scale? The only way to find the answer was to implement the GRIP plan.

5.1 IMPLEMENTATION PROCEDURE FOR PHASE 1

Various procedures and actions were developed prior to and during the implementation of GRIP. The further development of these and future use of these procedures are deemed necessary for successful implementation of similar projects in rural Southern Africa. During the GRIP implementation programme of Phase 1, which lasted 2 years starting from the beginning of 2002 to the beginning of 2004 much was learned. It gave an opportunity for DWAF and the groundwater consultants in the area to learn more of the practical side of a groundwater census and point-data capturing. The following results on the implementation procedures are available:

- The GRIP team and PMC
- Gathering and capturing of existing information
- Development of practical field forms and software support
- The establishment of an electronic information support service
- Field survey
- Captured data in hard copy
- Captured data electronically
- Verified data
- Data supplied to the national groundwater database

5.1.1 Establishment of GRIP hydrocensus teams

The hydrocensus part of the project was implemented via a two-year community water-supply tender (WF 7849A). The consultant Khulani Groundwater Consults (KGC) did not have vast experience in implementing a project of this magnitude and with the assistance of DWAF required assistance from five sub-consultants. The five sub-consultants represented all the major role players in groundwater in Limpopo over the last five years and included Water Systems Management (WSM), VSA Leboa (VSA), EnviroXcelence (EVX), Southern Africa Geoconsultants (GEOCON) and Mothopong Consulting (MC). Each of these sub-consultants as well as KGC was allocated a specific water services area and were therefore allocated a number of villages in the region to be surveyed for community supply boreholes and associated information. Geohydrological Project Management (GPM), a groundwater consulting firm appointed by DWAF Macro Planning, to supply them with groundwater information and update the provincial database (Aquabase), already had some data. This was due to GPM's custodianship of the data over the last 8 years. Therefore they were appointed to assist with the data dissemination and verification. The Council for Geosciences (CGS) was appointed to assist with the geological description of boreholes and quality control on reports done on behalf of the DWAF. Africon was also appointed as project specialists and assisted with the mapping. The DWAF Regional Office representation included Water Resource Management and Planning (WRMP) and from Head Office the Institute for Water Quality Studies (IWQS), National Water Resource Planning (NWRP), Option Analysis (OA) and Information Programmes (IP). The programme managers were Mr Fanie Botha, Principal Hydrologist and Mr Willem du Toit, Assistant Director - Geohydrology from DWAF's Limpopo Regional Office.

The PMC members were set up with representatives from all the sub-consultants and different DWAF sections. Mr Fanie Botha chaired the PMC with Mr Stephan Pretorius keeping and distributing all relevant documents. The PMC's role became more prominent as the project progressed with obstacles and difficulties to overcome. The scope of work in the tender contract was generic and the PMC needed to guide the project to achieve the above-mentioned objectives.

The diversity of the team together with local expertise ultimately steered phase 1 to achieve its objectives and with each PMC meeting integration of different water resource management approaches took place.

5.1.2 Gathering and capturing of existing information

The data from the NGDB and Aquabase was disseminated in electronic and hard-copy format and was used as baseline data to work from. The data were compared with new data obtained from various reports obtained from the engineering sector, government departments, local geohydrological consultants, DWAF Geohydrology Head Office and DWAF's Limpopo Regional Office.

Geohydrology DWAF Head Office and Regional Geohydrology were visited and Geohydrology (GH) reports obtained and incorporated into the data set.

Many of the government sectors in Limpopo deals with groundwater, but most of them are not aware of the value of the information gathered during the implementation of projects using groundwater as a water resource. The local civil engineering sector also has vast groundwater information gathered during water supply infrastructure projects in Limpopo. The teams had to visit each engineering consulting group working in Limpopo, gathering reports from CCWS projects conducted on behalf of national, provincial or local governments. The teams visited more than 80 engineering consulting firms and gathered in the order of 280 reports, which were scanned for groundwater information. Ultimately 90 of these reports were referenced in the GRIP electronic data and village files.

Local geohydrologists who are all part of the GRIP team also have a vast number of reports available; for example some dating back to 1978 when WSM staff were still employed by SRK (Pty) Ltd. The reports include borehole positions, drilling logs, pump-test results and recommendations.

An essential part of the GRIP was to attend the provincial and the area planning forums to network with the people involved with water supply at all local government organisations. Resulting from this is more information and transfer of geohydrological skills. For example, the Department of Health built more than 500 clinics in Limpopo, most of which are dependent on groundwater supplies. Initial water supply failed because boreholes were not drilled correctly nor were boreholes properly tested. However, with the involvement of the GRIP and the GRIP area consultant, the clinics project was intercepted, rectified and is an ongoing project in Limpopo.

5.1.3 Developing of practical field forms

After several site visits it became apparent that the visual assessments as described in Chapter 3 need to be captured in a format that can reflect the conditions in the field and also be stored in a database.

The field data sheets were developed to capture visually identifiable borehole data. Data field teams can identify critical issues by interviewing the relevant stakeholders and walking through the community. Field forms do not need to be too comprehensive, focusing on quality rather than quantity. Practical consideration on handling too many forms in the field also supports a minimalistic approach and by saving time the hydrocensus is more cost effective.

Two forms were developed, the first form to capture general community data and the second to capture detailed borehole and infrastructure data associated with each borehole. Although the forms were developed specifically for the GRIP, it can be used in any project, big or small, resulting in valuable information derived from on-site groundwater infrastructure.

5.1.3.1 Community data form

The objective is to describe general infrastructure identified through visual inspection, capturing the most relevant groundwater resources information and social economical issues that might have an influence on water supply (Figure 24). It serves several issues in IWRM, including available water infrastructure and low-cost housing information. Once the information is captured it is used to identify possible groundwater pollution sources and/or estimate water resource requirements. It comprises of the following information blocks:

- General information - community name, id, date, 1:50 000 map reference, latitude and longitude
- Demography and water supply - number of stands, people, water supply, cost recovery and access
- Sanitation and pollution - number of stands with ventilated improved pit latrines (VIPs), normal pit latrines, septic tanks or waterborne sewage, cemetery and waste disposal sites
- Low-cost housing – number of informal and formal structures
- General - private boreholes, basic sanitation risk and water supply options.

GRIP Electronic Community Field Data Sheet

PG 1

Version Number: 4

GENERAL				
Date of Visit	YYYY-MM-DD	Visited By	NAME	SURNAME
BASIC INFORMATION				
Reporting Institution		Community ID		
Community Name		Alternative Name 1		
Alternative Name 2		Alternative Name 3		
Community Center Longitude		Community Center Latitude		
1:50000 Map Ref		(Please attach a copy of the 1:50000 map portion indicating this community with it's		
DEMOGRAPHY and WATER SUPPLY				
Number of Stands		Number of People		
Primary Water source	G - Groundwater S - Surface Water N - None SG - Surface and Groundwater T - Tanker Z - Unknown P - Polluted source			
Number Of Stands with Water/Yard connections		Are these connections metered	YES	NO
Number Of standpipes		Is there cost recovery	YES	NO
How?	F - Flat Rate D - Diesel Only	Much? (Rand/Month)		
SANITATION and POLLUTION				
Number Of stands with VIP Latrines		Number Of stands with Septic Tanks/Waterborne		
Number Of stands with Normal Pit Latrines		Number Of stands with None		
Possible Pollution source: CEMETERY				
Longitude		Latitude		
Radius of influence		m		
Possible Pollution source: WASTE				
Longitude		Latitude		
Radius of influence		m		
Possible Pollution source: SEWAGE				
Longitude		Latitude		
Radius of influence		m		
LOW COST HOUSING				
Number Of Stands occupied		Number Of stands with informal housing		

Figure 24 Community information form as a download from the website gripdata.co.za (page 1)

GRIP Electronic Community Field Data Sheet

PG 2

OTHER	
Are there any private boreholes in use in and around the community	YES NO
Grade the possible influence of these private boreholes on the community water supply	
Will basic sanitation pose a possible pollution risk to the water sources of this community	YES NO
If YES, Please provide details	
Will further surveys be required at the community	YES NO
If YES, Please provide details with regards to type and priority	
What in your opinion should be done to completely satisfy the water needs of this community	
What in your opinion should be done to completely satisfy the sanitation needs of this community	

Figure 25 Community information form as a download from the website gripdata.co.za (page 2)

5.1.3.2 Borehole field data form

The aim of the field data form is to capture the minimum information to empower the water resource manager to evaluate the usability of each borehole in terms of WRM and WS (Figure 26, 27, 28, 29, 30 and 31). The information therefore does not only reflect all the minimum groundwater information as set by the DWAF 150 forms for the NGDB (DWAF, 2002), but also the infrastructure in and around the boreholes and the following information is captured in the borehole field forms:

- General information – site id, 1: 50 000 map reference, latitude/longitude, water use, consumer, topographical setting

- Pump details – type, manufacturer, serial number, condition, rpm
- Pump outlet – material, condition, diameter
- Engine details – model, type, serial number, condition
- Pump house details – type, material, condition, floor, block height, collar height
- Meter details – type, serial number, condition, manufacturer, units
- Borehole details – number, usage, date drilled, casing type, casing thickness, casing depth, blow yield and condition of the borehole
- Water level details
- Discharge details
- Pump test information
- Reservoir information
- Chemical data field and sample
- Other details – operator, monitoring details, electrical supply, pollution susceptibility
- Reference to existing reports
- Comments - other than above-mentioned. This information may be not applicable to a groundwater resource specialist but in the spirit of IWRM the data is required.

GRIP Electronic Borehole Field Data Sheet

PG 1

Version Number: 3		Reg. BH. Number	
GENERAL			
Date of Visit	YYYY-MM-DD	Visited By	NAME SURNAME
District		Municipality	
Reg. BH. Number	H	Area Name	
Reporting Institution			
BASIC INFORMATION			
Site ID Code		Community ID that this BH serves	
1:50000 Map Ref		Alt. BH. Number 1	
BH. Numbering	B - 20 x 40 bar P - Pipe I - Info plate	Alt. BH. Number 2	
New pole planted	YES NO	Date planted	YYYY-MM-DD
Farm Name		District Number	
Village Name	Electronic listed name	Province Number	
Latitude	- ,	Farm Number	
Longitude	,	Deg,Min,Sec	
Coordinate Method	T - Survey M - Interpolate G - GPS	EPE (if GPS selected)	
Coord. Ref. Point	C - Cape Datum H - Hartbeeshoek Datum	Coordinate Accuracy	0 - 1m 1 - 10m 2 - 100m 3 - 1000m 4 - 10000m
Coord. Time	HH:MM:SS		
Altitude	mamsl	Altitude Method	A - Altimeter L - Leveled M - Interpolate
Altitude Accuracy	0 - 1mm 1 - 1m 2 - 5m 3 - 10m 4 - 25m	NOTE: GPS Altitude method is NOT valid	
Site Type	B - Borehole D - Dug Well F - Fountain H - Sinkhole W - Well Point Z - Other	Site Purpose	E - Exploration M - Mine O - Observation P - Production R - Recharge S - Standby W - Waste Z - Other

Figure 26 Electronic field borehole data sheet (page 1)

GRIP Electronic Borehole Field Data Sheet

Version Number: 3		Reg. BH. Number	
BASIC INFORMATION cont...			
Site Status	D - Destroyed G - In Use U - Unused A - Abandoned	Consumer	N - Non-Urban UP - Urban # Planned streets UN - Urban # No planned streets UF - Urban # Farm environment US - Urban # Scattered houses
BH. usage (Hrs pump / day)		BH. usage (Hrs pump / week)	
Sec. Drainage Reg.	X nn X		
Water Application	AD - Agriculture/Domestic AI - Irrigation AS - Stock water only DA - Domestic DG - Garden only E - Nature Conservation P - Public TC - Commercial TI - Industrial TM - Mining TP - Power Generation	Topographic Setting	A - Alluvial Fan D - Dunes F - Flat Surface H - Sinkhole L - Dam or Lake M - Mountain P - Pan R - Along River S - Slope V - Valley T - Terrace
Borehole Installation Type	A - Airlift C - Centrifugal H - Handpump J - Jat M - Mono N - No Equipment P - Piston Q - Powerhead R - Recorder S - Submersible T - Turbine W - Windpump X - Windmill/Powerhead Z - Other	Basic Geology	
Comment			

Figure 27 Electronic field borehole data sheet (page 2)

GRIP Electronic Borehole Field Data Sheet

PG 3

Version Number: 3		Reg. BH. Number	
PUMP DETAILS			
Pump Condition	G - Good M - Moderate P - Poor	Pump RPM	rpm
Serial Number		Manufacturer	
Pulley Diameter	mm	Monitoring Facility	YES NO
Pumping main diameter	mm		
PUMP OUTLET			
Material		Condition	G - Good M - Moderate P - Poor
Diameter	mm	Type of feed	Gravity Pump Feed
Pressure Guage	YES NO	Guage Condition	G - Good M - Moderate P - Poor
Guage Working	YES NO		
POWER SUPPLY DETAILS			
Engine Type	D - Diesel E - Electric H - Hand W - Wind Z - Other	Engine Condition	G - Good M - Moderate P - Poor
Serial Number		Model	
Manufacturer		Power rating	kw
Engine RPM	rpm	Pulley Diameter	mm
Drive	Direct V-Belt		
PUMPHOUSE DETAILS			
Type	F - Fence G - Fence with gate L - Locked hut O - Open hut S - Shelter C - Cage	Material	C - Brick/Concrete F - Wire fence W - Wooden structure G - Galv Iron B - Brass D - Copper O - Plastic P - PVC S - Steel X - Stainless steel Z - Other
Condition	G - Good M - Moderate P - Poor		
Plinth Height above floor	mm	Floor Condition	G - Good M - Moderate P - Poor
Spacer Thickness	mm	Datum Level	

Figure 28 Electronic field borehole data sheet (page 3)

GRIP Electronic Borehole Field Data Sheet

PG 4

Version Number: 3		Reg. BH. Number	
METER DETAILS			
Manufacturer		Type	F - Flow (cubic meters) T - Time (hours)
Serial		Current Reading	
BOREHOLE DETAILS			
Date Drilled	YYYY-MM-DD	Concrete Height above ground	
Depth	m		
Casing perforated from	m	Casing Inside Diameter	m
Casing perforated to	m	Casing Wall Thickness	mm
Casing Depth	m	Casing height above ground	mm
Blow Yield	L/s	Condition	G - Good M - Moderate P - Poor
WATERLEVEL DETAILS			
Status	A - Affected by pumping D - Dry F - Flowing O - Obstructed P - Pumping R - Recovering S - Static	Method	A - Airline E - Electrical contact P - Pressure guage R - Recorder S - Steel tape U - Reported/Unknown X - Estimate
Date	YYYY-MM-DD	Can waterlevel be measured	YES NO
Level	mbmp	Collar Height (Floor thickness + plinth Height + Concrete Height + Casing Height + Space thickness)	magl computed
DISCHARGE DETAILS			
Type	F - Flow P - Pump	Method Measured	C - Current meter E - Estimate F - Flume M - Totaling meter N - Notch (V or U) S - Submerged orifice U - Venturi meter V - Volumetric W - Weir Z - Other
Date	YYYY-MM-DD	Current Flow	L/s

Figure 29 Electronic field borehole data sheet (page 4)

GRIP Electronic Borehole Field Data Sheet

PG 5

Version Number: 3		Reg. BH. Number	
TESTING DETAILS (all available)			
Recommended Yield 1	L/s	Duty Cycle	hrs
Recommended Yield 2	L/s	Duty Cycle	hrs
Date tested	YYYY-MM-DD	Test duration	hrs
Consultant/Contractor	NAME		SURNAME
RESERVOIR DETAILS			
Type C - Concrete E - Earth Dam N - No Reservoir P - Pond T - Steel tank V - PVC Tank Z - Zinc dam	Reservoir Size		m ³
	or height		circle
Pipe inlet Diameter	mm	Latitude	,
		Longitude	,
How long does it take to fill the reservoir when empty			hrs
Condition G - Good M - Moderate P - Poor	Comment		
CHEMICAL SAMPLING			
Sample Date	YYYY-MM-DD	Time	HH:MM:SS
Sample Number	For lab analysis	Sample Temp	degrees celcius
EC	mS/m	NO ₃	
pH		EH	
Method C - Colorometer S - Strips I - Instrument	Sampling Point T - Tap B - Borehole R - Reservoir P - Pipe		
OTHER DETAILS			
Is there a Pump operator	YES NO	Name & Surname	NAME SURNAME
Who employs the Operator		Is there telemetry installed	YES NO
Is the telemetry in working Condition	YES NO	Telemetry Condition	G - Good M - Moderate P - Poor

Figure 30 Electronic field borehole data sheet (page 5)

GRIP Electronic Borehole Field Data Sheet

PG 6

Version Number: 3		Reg. BH. Number	
OTHER DETAILS ... cont			
Does the Borehole feed directly into a main supply pipeline			YES NO
If YES, supply the IDs of the community IDs served by this pipeline			
ID of Community 1	ID of Community 2	ID of Community 3	ID of Community 4
Nearest Electrical Pole Number (within 2km)		Distance to nearest Electrical Pole (within 2km)	m
Distance to nearest Pollution source		Pollution source description	m
Borehole Owner	Activities near BH.		I - Industry F - Farming R - Residential
List other boreholes within 250m radius		Reg. Nr. Of BH. 1	Reg. Nr. Of BH. 2
Reg. Nr. Of BH. 3	Reg. Nr. Of BH. 4	Reg. Nr. Of BH. 5	Reg. Nr. Of BH. 6
Further Work	T - Testing L - Logging R - Refurbishment W - Waterlevel measurement P - Prep f. future monitoring		
REFERENCE			
Report Number	Author		NAME SURNAME
Title	Custodian		
Comments			

Figure 31 Electronic field borehole data sheet (page6)

5.1.3.3 *Commissioning certificate*

Apart from the data forms, a commissioning certificate was developed and used as a quality control tool. This enables a quality control officer, identified by the PMC, to do quality spot checks, leading to more accurate and effective capturing of field data. The commissioning certificate (CMC) was developed in later stages of the project, a necessity as an intervention to keep the field teams focused on the objective (Figure 32). Borehole data in the field forms are site-specific and the PMC needs to ensure that measures are taken to capture correct information in the field. The quality control officer, with the aid of the commissioning certificate, was tasked to objectively evaluate and certify the completion of all surveyed information. The commissioning certificate makes use of a simple check-list system with 14 points to be checked and includes:

- Date
- Village name
- Consultant information
- Was the sites visited?
- Was all the data visible on site, collected and noted on the GRIP field form?
- Was all the previously available data added to the field form (NGDB, reports etc.)?
- Where the co-ordinates checked after being plotted on a map?
- Is a pole planted at each liased site?
- Was all claimed poles planted during the GRIP?
- Every company needed to declare that they did indeed make a significant effort to visit all sites within the village.
- The summary table forwarded during the GRIP is correct and reflects completed work.
- We will rectify our survey when data is incorrect?
- The community form was completed on site, if possible discussed with the community.

- All pollution sites were listed as per field forms.

The CMC gives more management control to the PMC and makes it possible to send teams back if they do not comply with the 14-checkpoints as mentioned above

5.1.4 Electronic information support

To develop the required functionality as described below, comprehensive programming was done and Me Debbie Smith, Mr Willie Gouws and Mr Koos Viviers.

The available technology makes it easy to share data and ensure the availability of certain data series. Therefore, the PMC felt the need to develop information support services that comprise of an Internet site and a so-called interface tool, making it possible to download, capture or post data from various stakeholders and participants into the GRIP database. It has built with quality control rules and enables high profile users to capture borehole data and post it to the web-master or data manager. Verified data is captured on the Sequel Server database. Normal users can download data from the Internet in an Excel format. This can be any person with an interest in the available groundwater or borehole data in Limpopo. It specifically targets planners, geohydrologist, engineers and community leaders. The site www.gripdata.co.za is also a gateway to supply regional mapping data derived from the GRIP data and various other maps. The standard maps are useful tools that can assist planners during the development of water supply schemes. The interface tool was fully developed during the project and development thereof phased over a period determined by the available budget.

5.1.4.1 Phase 1 –Setting up of website

The development that was done during 2002/03 included the following:

- Registration of the www.gripdata.co.za domain and the development of the web site.
- Development of a digital field form on a smart-Excel spreadsheet that was based on the field form format, obtained from the GRIP technical team.
- The development of the GRIP borehole and community-demographic spreadsheet in Excel was finalised in July 2002.
- The GRIP database was developed on Sequel Server and served as the data storage facility, which

hosts the data on the Internet.

- The first batch of spreadsheet data covering 1300 boreholes was uploaded into the GRIP Data Interface in September 2002. This batch of data was, however, unverified and contained spelling and data type errors.
- Based on the data errors, the shortcut keys could not build data into Excel spreadsheets and it was decided to develop the GripGateway on Visual Basic.net.
- The GripGateway serves as:
 - a vehicle for the input of data into a digital format where the first level of data-quality checks are included
 - a tool where the data format is aligned and can be uploaded directly onto the Internet.
 - The Beta Version was released in December 2002, after which comments on enhancement were received from the PMC
- All data types have a date linked to it, therefore any borehole for example surveyed the old data will be stored in the database and the new data set will be tagged as active.
- Once data enters the GRIP database, it can be downloaded by GPM in spreadsheet format, verified and uploaded. It is tagged as “verified data” and set as “active” and the date of upload of the verified data is included in the database. The old data set is still included in the database should future queries arise. When a data query is received only the verified data will be retrieved from the database.
- The GRIP database includes functionality to enable customers to extract data for projects and requires them to supply any new data.

DEPT. OF WATER AFFAIRS & FORESTRY COMMISSIONING CERTIFICATE: GRIP PROJECT				
1.	CONSULTANT:	DATE:	DISTRICT:	Accuracy %
2.	VILLAGE NAME:	BOREHOLE NUMBER:	AREA:	15%
	COMMUNITY SITE ID:	ALTERNATIVE NUMBER:	QUATERNARY DRAINAGE REGION:	
3.	BOREHOLE EQUIPMENT & STATUS:	CONDITION:	TOPOGRAPHIC SETTING	20%
	CASING HEIGHT:	BLOCK HEIGHT:	MONITORING STATUS:	
4.	BOREHOLE EQUIPMENT DETAILS:	POWER : ELECTRICAL / DIESEL	PUMPHOUSE TYPE:	20%
	FLOOR STATUS:	MODEL / KW :	PUMPHOUSE STATUS:	
		POWER SUPPLY STATUS:		
		PUMP - Ref/min:		
5.	RESERVOIR TYPE::	PIPE INLET SIZE:		
	RESERVOIR SIZE (m3)	TYPE :	QUANTITY:	
6.	Co-ordinates:	Comments regarding plotting position:		40%
	LATITUDE:			
	LONGITUDE:	Distance from consultants plotting position:		
7.	SITE PURPOSE: EXISTING AND FUTURE			
8.	COMMENTS:			
	Work is done professionally			
	Work done is on a high standard			
	Only just acceptable!!! Need to improve standard.			%
	Consultant can be paid without delay.			
	Only just not acceptable!!! Need to improve standard.			
	Low standard - no accurate work			
	No standard set is met			
	Site was not visited			
	Field personnel has no experience and must be withdrawn from project.			
	No further payments without written instruction from the DWAF.			
9.	FAULT LIST:			
	Date when fault list must be rectified:			
10.	NUMBERING OF SITE			5%
	Type:	Quality:		
	COMMISSIONED BY:			
	INSTITUTION:	NAME:	SIGNATURE:	DATE:
				CONTACT NO:
	SUB-CONSULTANT :.....			
	TOTAL OF.....SITES DE-COMMISSIONED OUT OF.....			%
	THIS SITE IS DE-COMMISSIONED / IS NOT DE-COMMISSIONED			100%
	TOTAL % OBTAINED FOR THIS SITE			

Figure 32 Quality-control commissioning certificate

5.1.4.2 *Phase 2 - Upgrade of GRIP database*

Continuous changes to the system were made as the teams required it to enable data capturing and fieldwork to carry on continuously. These changes included:

- Change buttons on data sheet to follow in the same order as in the original Excel smart sheet so that the user has to follow the right sequence of data input.
- Include the ability to host geological logs, water levels with time, water quality data for macro- and microchemistry etc.
- Alter database to accommodate data levels (1-4) with colour codes. Level 1 = Blue, Level 2 = yellow, Level 3 = pink, Level 4 = purple, required parameters = red. For a site that has poor detail, verified data will represent level 4 data.
- Enhanced integrity checks: This step will involve more advanced data -integrity checks that will be done by the GRIP Gateway when data is archived.

5.1.4.3 *Phase 3 - Interfaces with AquaBase and the NGDB*

- Interface with AquaBase: Initial discussions with Mr Du Plessis from GPM indicated that it will be possible to export all the existing data in the Provincial database into the same .dbf format as the verified data provided to the GRIP database for upload into AquaBase. Handling duplicate data still exists and one way is to keep the “old” or less complete data sets in the database and set it as “inactive”, allowing the newer or more complete data to be set as “active”. This allows the newer or more complete data set to appear in the information reports with the ability to track older or less complete data sets via the GRIP database Administrator.
- NGDB interface: Include the data parameters that are required by the NGDB. The NGDB data codes are included in the GRIP database. The information reported in the NGDB 150 form (DWAF, 2002) is included in the output.

5.1.4.4 *Electronic data flow procedure*

The data flow process is followed from where field data is collected and uploaded on to the interface tool with the steps of verification. The process is described below:

- Print out GRIP field forms from GRIP Gateway (Paragraph 5.1.4.5) or the Internet.
- Field survey (Paragraph 5.1.5).
- Data entry into GRIP Gateway.
- Regional consultant gives hard copy files and electronic data to quality control officer.
- Quality control officer and his team check hard copy data and electronic data and supply data to GRIP database Administrator (GPM).
- GPM downloads data into Excel for third level of verification with Aquabase and NGDB.
- The batch of verified data is uploaded into the GRIP database and tagged as “verified” and set as “active” with the date.

5.1.4.5 GRIP Gateway

The GRIP Gateway is simply a visual basic generated capturing tool based on the community and borehole field forms to capture data in the format required by the GRIP database (Figure 33). It follows the same sequence and therefore allows the data capturing to take place quite easily.

Grip Gateway
File Data Sheets System Window HELP

Borehole Field Data Sheet -- NOT SAVED YET

HELP

TESTING RESERVOIR CHEMICAL SAMPLING OTHER REFERENCE

GENERAL BASIC PUMP PUMP OUTLET ENGINE PUMPHOUSE METER BOREHOLE WATERLEVEL DISCHARGE

General Information

Date Of Visit : ... Visited By : ...

District Municipality ... Local Municipality ...

Reg. BH. Number : Reporting Institution : ...

Verified By : ... Verified Date : ...

File Name : NOT SAVED YET
Assigned Queue : UN-ASSIGNED [Compatible with version 2_1 of printed BH Field data sheet](#)

Validate All Save to 'Ready To Upload' QUEUE Save to 'Busy' QUEUE Open EXCEL file CLOSE

Current Version: 7.7 User Logged In: Fanie User Role: Administrator System Project: Grip Project

Figure 33 New borehole capture sheet from GRIP Gateway Tool

5.1.5 Field survey procedure

From the results above it became clear that all the tools and measures were in place to start with the field survey, the teams were ready, the PMC set and all existing information available, with good electronic information support. Finally the teams needed field procedure guidelines to capture the best possible borehole and associated information in the shortest time possible. The CWSS guideline document (Hobbs & Marais, 1997) used for geohydrological develop, does have a sentence on data capturing but does not describe how the data must be captured and how the teams need to organise themselves. With the assistance of Mr Reinhardt Weideman a field procedure to improve quality without reducing the speed of the hydrocensus was compiled.

5.1.5.1 Pre-field documentation and requirements

All the relevant verified data from existing reports and old data available to the technician must be compiled into a summary table and added with the information that needs to be taken into the field. During compilation of the summary table the following needs to be considered:

- A numbering system that allows sequence numbering to be listed.
- A map with a summary of the villages in the area of investigation (GPM's electronic maps are plotted and used as basic reference maps).
- A map of each village with a summary table of the boreholes.
- Verify numbers already allocated in previous data sets.
- Check co-ordinates of the previous data against new measured co-ordinates.
- Use the maps to plot GPS co-ordinates (grid sheet) of those boreholes not already available on the maps supplied by GPM.
- Use plotted borehole positions to check again for already numbered boreholes, link the NGDB, or other data to the plotted point data, allocate new H-number to the borehole if it has no H-number and check the accuracy of existing data for that village.

5.1.5.2 *Arriving at the rural community*

When arriving in the rural village the field team needs to follow the set procedure:

- Visit the chief, headman, community leader, councilor etc. before starting the survey. In the event that one of the above persons is not available, the technician must make an effort to make an appointment or visit the Water Committee chairman or the second-in-charge of the community. This will ensure a positive attitude in the community towards the GRIP and associated activities.
- Check the correct settings on the GPS (on the Setup menu, chose Units, then check the map, date, position, EPE, etc.).
- Check co-ordinates at least 3 different co-ordinates on map and compare with GPS, and make sure errors creeping in due to the “Long Lat” and “Lat Long” issue on filed sheets are kept to a minimum.
- Do not list the co-ordinates unless the accuracy level is below 8 m. The normal accuracy level should be between 4 - 6 m, but is not reliable above 8 EPE (EPE on GPS).
- Interpolate the altitude from the map and list the GPS altitude.
- Take the co-ordinate of the Chief’s house, representative’s home and/or community center - it will serve as a future reference point.
- After leaving the reference point (Chief’s house) ensure that cemeteries, cattle dips, sewage works, waste disposal sites and any other possible pollution sources are listed and the GPS co-ordinates captured.
- All additional information listed on the GRIP community form needs to be completed during the borehole survey and the team should not leave village before it is completed.

5.1.5.3 *Capturing borehole data in the field*

The GRIP borehole data sheet is a visual assessment of what is on the ground concerning borehole and associated infrastructure. It is essential that all the information be captured correctly.

- Always try to save time in the field, fixed items e.g. community ID’s, map references, etc. can be completed at the office by the technician or the office personnel.

- Minimize the re-numbering of already numbered boreholes.
- Check old T-, G-, W-, B-borehole numbers with visible numbers on site at boreholes.
- If no information is available the field teams first need to contact their office through radios or cell phones to verify data, numbers or to require more information to link the correct number to an installation and only thereafter allocate a new number.
- With no pole installed, paint the number on the installation at a suitable place for the pole-plant team to see it.
- Ensure the numbering pole is painted (each pole is painted according to a colour assigned to each consultant).
- Each page and each item of the GRIP borehole field data sheet must be completed.
 - When entering the information make sure the reservoirs, boosters, sand points etc. are according to the number sequence in the field form sheet.
 - Check plotted co-ordinates for accuracy on site.
 - Pump details on Sheet 2 (Figure 27): The pump type must always be filled in and for unequipped boreholes and dry boreholes the field must also have an entry or comments.
 - Capture all possible information on the installation including the engine, pump and pump-house types.
 - If information is available borehole details are completed from the existing data. If the water level is measurable, capture the new borehole as well as the old water level, it can be compared with each other later.
 - The testing details on page 5 (Figure 30) cannot be completed during the field visit and will be an office task.
 - The chemical-sampling item, if not obtainable during the field visit, will also be completed at the office. (Dates of analyses are important and need to be captured later on the WMS).
 - Sheet 5 has a few items that require specific attention. The electrical pole number and distance is important information. This could influence the prioritising of boreholes to be

tested and with the electrical pole number listed the co-ordinates for that pole can also be obtained from Eskom as well as the voltage (380V, 220V etc.) or available power supply (kW) available.

- Measure the size of the concrete floor and describe the base or provide a drawing. This will also assist to allocate the previously allocated numbers to the same borehole when a numbering pole is missing.

If possible, note the following comments under the relevant areas on the borehole sheet:

- Only concrete floor – No pump house, no pump head, pipes or motor etc (diesel or electrical).
- Only pump house – No pump head, pipes or motor (diesel or electrical).
- Motorized– Pump house, pump head on borehole. In the case of no engine or electric motor fitted make sure pipes and pump is still fitted to the head. Also note if the engine is transported away from the installation for safe keeping. Note status of the equipment and if is in use or not and also provide reason.
- Hand pump – Is the hand pump lying next to the borehole with the borehole closed or not; still fitted on the borehole with pipes or not. Note the status of the concrete base of the installation. Note the make, current status and whether it is in use or not.
- Submersible pumps - Is a lockable manhole, electrical control box, electrical protection, visible cable and pipeline markers, flow meters and monitoring facilities installed. Note the status of equipment and if it is in use or not.
- Others -Windmills, play pumps etc. Ensure all the details visible are noted on the forms including the status and if it is in use or not.
- Unequipped boreholes - Indicate the status and its future role in groundwater.
- Rehabilitate - Possible production boreholes. Capture any information available about a blow yield, previous testing, construction details or community information.
- Monitoring - If the borehole casing is installed and capped and not filled with stones or any other material it can be used as a monitoring borehole. In some instances a weak borehole can also be rehabilitated when strategically positioned for monitoring purposes.

- Destroyed – This includes boreholes drilled dry with no casing installed or stone plugged. Boreholes known to be weak and filled with rocks will not be rehabilitated unless required for monitoring purposes.
- Take a picture for visual record (Figure 34).
- Before leaving a community make sure all boreholes within the community or serving the community are captured on separate GRIP field forms.



Figure 34 Some of the reference photos taken during GRIP. Note the numbering.

5.1.5.4 *New boreholes and borehole numbering*

All boreholes that are “new” boreholes or boreholes not captured during the desk study need to be captured as follows:

- All new borehole sites must be listed per village and new pole numbers captured on the poles-to-

be-planted sheet.

- Capture the boreholes on the borehole data sheet.
- Transfer data to the pole-planting team and make sure they plant it. Do not wait until five or more villages are listed (approximately 20 boreholes). This will confuse the pole -planting teams and they might struggle with too many outstanding numbers and poles.

5.1.5.5 *Back in the office*

The office verification is the last line of field verification for each team before the data is sent to the quality control officer. The following procedure needs to be followed at the office:

- Submit all field forms to the office team and ensure all data is submitted, including the photo's for editing – village list, borehole numbers and position of numbering poles etc.
- Check data on the summary table for correspondence with field information.
- If any data is available from a reliable source and not captured during the field visit add to the field form.
- Capture the data on the GRIP Gateway or on the spreadsheet format ready for upload on to the GRIP Gateway.
- Data should now be ready for the second verification process (Paragraph 5.1.6).

5.1.5.6 *Dynamics learned from field teams*

Apart from the above-mentioned procedure the teams learned a great deal in the field and the following suggestions are made to improve the effectiveness of the procedures:

- Each field team should consist of at least three sub-teams.
- There should at least be two survey teams (A1 & A2; B1 & B2) and one pole-planting team (C1 & C2).
- The field sub-teams should consist of at least two persons per team and therefore 4 people per team.

- The survey teams (A & B) can assist the pole planting teams (C1 & C2) and number the concrete blocks or borehole equipment and take photos to ensure that the correct number will be planted at a specific site. A black board can also assist for linking the photo to the number on the board.
- To eliminate boredom or fatigue and to familiarize the teams with the area and procedures swap the teams regularly, for example (A1 & C1; B1 & C2) and (B2 & A2) etc.
- Furthermore, during GRIP it was found that the most effective measure to take is to instruct the pole-planting teams to plant between 10 and 20 poles and then swap the team. This ensures regular rotation and effective communication between the teams and time to verify each other's actions.

5.1.6 Second Verification Procedure

As a final quality control measure before the data is captured as verified field and electronic data and as a hard copy, the data goes to the quality control officer for a final check. This is to ensure that the data is verified and ready for upload to the NGDB. The second verification procedure is divided into 3 phases.

5.1.6.1 Phase 1

- Collect all GRIP data already supplied to GPM - if any, because some teams will try to go around the quality control officer.
- Attach a quality-control certificate to the left inside -cover of the hard-copy file and also a summary of the sites included for that village and do the following:
 - Compile a list of all H-numbers allocated per area, starting from the very last number allocated by GPM. Also ensure that all the reservoirs, boosters, sand points etc. are listed and at its correct position on the sheet.
 - Ensure all data obtainable from all previous reports, data from the NGDB, data from Aquabase, and the GRIP survey are captured on the GRIP form. This will ensure that all possible data are available and checked by the responsible team.
 - Make sure all the maps needed for verification are received: (i) NGDB and (ii) Aquabase maps printed from electronic data available.
- If not available in a hard-copy file, insert copies of the hand-drawn field map, NGDB map, and

Aquabase H-number map.

- The area covered for the village (village cluster boundary).
- The electronic spreadsheet abstracted from GRIP Gateway compiled from the data surveyed.
- Split the data into separate files for each H-area.
- Sort the data per borehole number for each H-area.
- Insert a column in front of the table (column A).
- Use the “Fill” function to have the lines listed from 1 to the last allocated H-number.
- Insert the numbers not surveyed or not sorted to their correct position, this will mean data is sequential with gaps, reservoirs etc. where they belong. Make sure the A, B and C numbers previously used for re-drills etc. also receive an A, B or C after the number in “column A”.
- The table is now ready to be sorted in any way needed to successfully ensure no sites are lost or duplicated.
- Use the “auto filter” function to ensure all the village spellings are exactly the same, this will ensure that when the file is sorted per village the sites belonging to that village are following one another. Sort by village ascending and then by H-numbers, also ascending. For the purpose of the verification it is best to use the sorted-per-village GRIP Web sheet.
- Once the villages and numbers are sorted, use the field forms and make sure all data is captured in the spreadsheet.
- Abstract the completed village borehole data to the GIS system and print a map showing all liaised sites.
- Verify the plotting positions on the electronically printed final map against the field map, NGDB map and Aquabase map. If there are still differences, investigate and ensure the surveyed co-ordinates are correct.
- Check all the entries on the community field forms to ensure all are correctly listed and that all villages are entered on the community table as for the GRIP Gateway format.

5.1.6.2 Phase 2

If there are gaps in the data the quality control officer will send a hard copy and an electronic copy back to the team during Phase 2 and the following procedure needs to be followed:

- Open the electronic files received for the NGDB and Aquabase data. These files are forwarded separately for each map and also per area.
- Copy these files into three or four sheets within that Excel file of that map and sort them all separately (Village , H-numbers, NGDB-numbers, alternative numbers etc.).
- Take the village file (hard copy), open the NGDB data and Aquabase data according to the village - sorted sheet and ensure all the links listed are on the map, correctly listed against the number on the newly printed electronic map etc.
- Check all the NGDB numbers one by one on the map, also one by one on the sheet (sorted per NGDB sequence).
- Check all the H-numbers on the map, in the file, in listed data etc. against the table supplied to ensure the NGDB links are established or listed if already linked, on the attached certificate.
- List all numbers not on the new village map and not linkable from the NGDB and *vice versa*.
- Make sure the complete NGDB number is used and the correct map reference is inserted within the number. A wrong map reference will not be of any use when the linking is done.
- Enter the established link to the NGDB on the GRIP Gateway data sheet. The link with the correct H-number should be already entered on the NGDB. Also list the “OTHER” links between H-numbers and NGDB numbers on the GRIP Gateway data sheet.
- Make use of all alternative numbers listed through cross-referencing these numbers to all sites, files etc. available.
- Forward the corrected, verified GRIP Gateway data sheet to the quality control officer.
- Deliver the completed hard-copy village file to the quality control officer. The hard-copy file will eventually form part of the DWAF library and needs to be of a high standard.

5.1.6.3 *Phase 3*

Phase 3 is again the responsibility of the quality control officer and their office. The quality control officer's office accepts the file from the area consultant and scans it for completeness.

- The file is immediately discarded should the maps be incomplete.
- All sites are rechecked to be correctly labelled and on the village map. Sites not included as per GRIP field form will also not be included on the village map.
- All files are checked to identify all newly linked or linked sites with more than one number to be investigated and accepted, linked or removed.
- All sites not liased or most probably not searched for will be listed under the comment column of the certificate.
- Completed files are signed, listed on a table (per area consultant and village ID for future reference) and forwarded to GPM.
- Electronic GRIP Gateway data file per village or Excel sheet in the same format required by the GRIP database is e-mailed to GPM.

5.1.6.4 *Phase 4*

Phase 4 is the responsibility of the Data Administrator (GPM) and includes the following actions:

- Final linking and verification with the NGDB (one NGDB link is kept and therefore others will be removed after the verified data is linked).
- All comments on the certificate are listed and forwarded to the DWAF and each area consultant for comments and rectification.
- All hard-copy files are scanned for completeness and delivered to the DWAF library where it is filed according to the DWAF library system.
- All electronic data captured in the GRIP Gateway data-sheet files are checked and uploaded onto the GRIP database.

6 HYDROCENSUS RESULTS

In total 2159 villages were visited with the assistance of 12 teams, two per municipal district (Table 6). The field data sheet was completed and included both hydrological information as well as infrastructure information. The data was captured per village, in a hard-copy file format, and captured electronically before the hard-copy file was sent to the DWAF library. During the investigation it was found that in each of the villages investigated about 6 to 10 boreholes were visited with some having limited infrastructure ranging from hand pumps to electrical mono-pumps. The programme stopped between January 2003 and May 2003 and continued with the new financial year. Between May 2003 and August 2003 the second verification procedure was introduced. The system was refined and the hydrocensus was completed by the end of November 2003.

Table 6. GRIP SUMMARY FOR LIMPOPO (Verified data 2003/03/12)

DISTRICT	Villages listed	Villages surveyed	Sites captured	New sites marked (poles)	Ave. sites per village	Verification completed
BOHLABELA	164	164	987	280	6	141
CAPRICORN	519	442	3113	800	7	324
MOPANI	307	299	2659	870	9	240
SEKHUKHUNI	406	278	2018	143	7	189
VHEMBE	609	533	2977	1451	5	411
WATERBERG	154	154	1139	145	7	149
TOTAL :	2159	1870	12893	4189	7	1454
% VILLAGES COMPLETED						67

It was estimated that the full implementation of the GRIP phase 1 will probably take 3 years but with continuous hard work and dedication most of the results were available at the end of 2004. Some of the H-regions are already at a level to do proper reporting and the results look promising. The results are available at village level and reported at H-region level according to the district municipalities (<http://www.groundwaterdata.co.za/>).

6.1 DATA COVERAGE

The initial data indicate that there is a vast number of sites per village in all DMs (Figure 35) and it may be argued that on village level there is not enough data points but even at village level it seems as

if there is on average of at least 5 sites (Figure 36). Therefore at both village level and DM level there seems to be enough data available for IWRM managers to incorporate groundwater resources as part of IWRM.

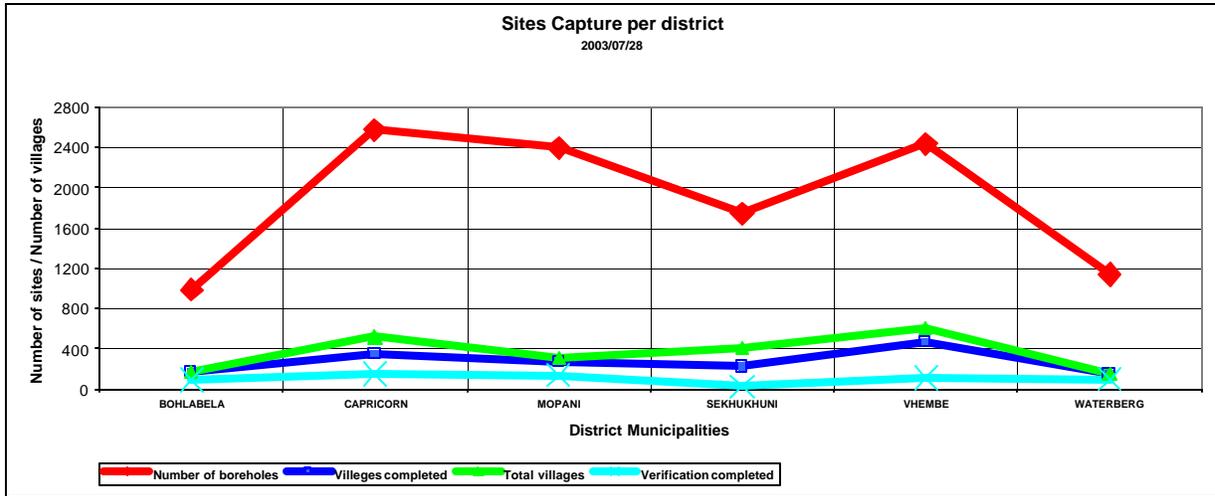


Figure 35 The relationship between the number of sites in the field and the number of villages and the progress up to date

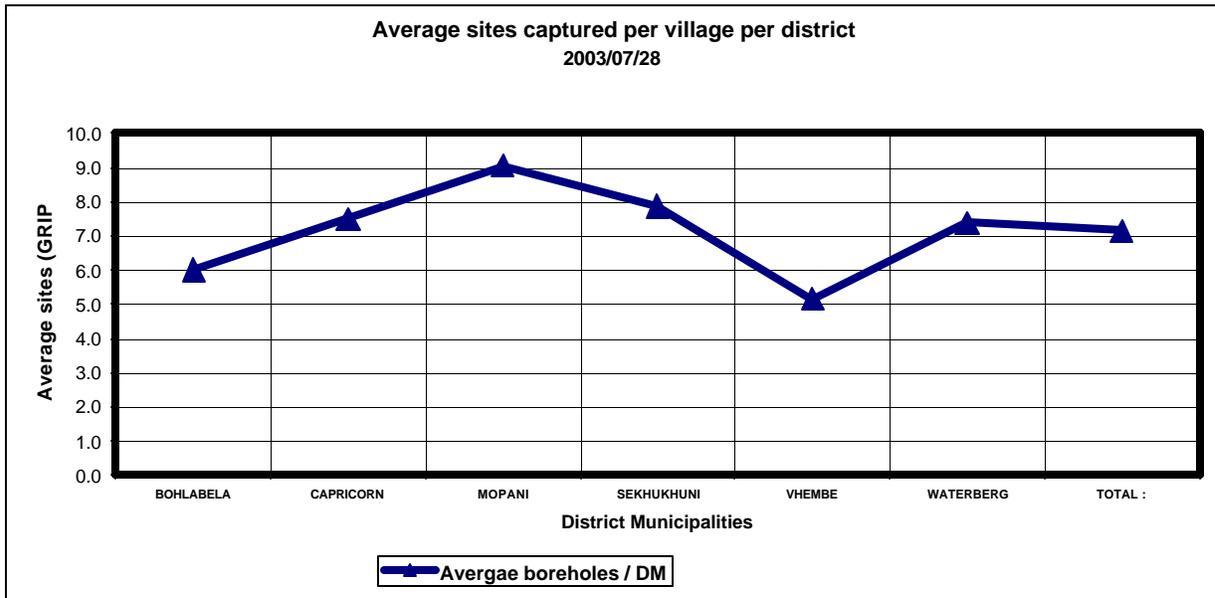


Figure 36 Average sites captured per district per village

6.1.1 Mopani District Municipality

To illustrate the availability and use of borehole data as a result of the hydrocensus, the H24 region in the Mopani District Municipality (DM) is used as an example. The Mopani District Municipality

consists of a total of 307 villages having 6 H-regions and an estimated 700 000 people depend on fresh water daily (Figure 37). The area consultant for the H14-region during the GRIP was VSA Leboa.

6.1.1.1 Database correlation

According to the NGDB there are 1113 sites and 590 on Aquabase (Table 7). During the GRIP hydrocensus 818 sites were verified in the field and 893 linked with the NGDB, 75 sites were linked to the same site-id and therefore 220 sites were not found in the field. Only 5 sites could not be found on the Aquabase database and 228 were added. There is a 73% correlation with the NGDB and a 61% correlation with Aquabase and with the aid of Arcview the different datasets are plotted, highlighting the inconsistencies (Figure 38).

Table 7. Summary of data set

Summary of groundwater data sets - H14-region								
AREA	*Sites available before verification			*Sites linked during GRIP				
	NGDB	Aquabase	GRIP	WARMS	Aquabase & NGDB	NGDB & GRIP	Aquabase & GRIP	GRIP & WARMS
GIYANI	1113	590	818		547	893	585	
% Correlation with GRIP		% Linked with GRIP						
NGDB	73%	NGDB	80%					
AQUABASE	99%	AQUABASE	99%					
WARMS		WARMS						
*Sites include purification plants, booster pumps, wells, sand points, reservoirs (See O&M for boreholes only)								

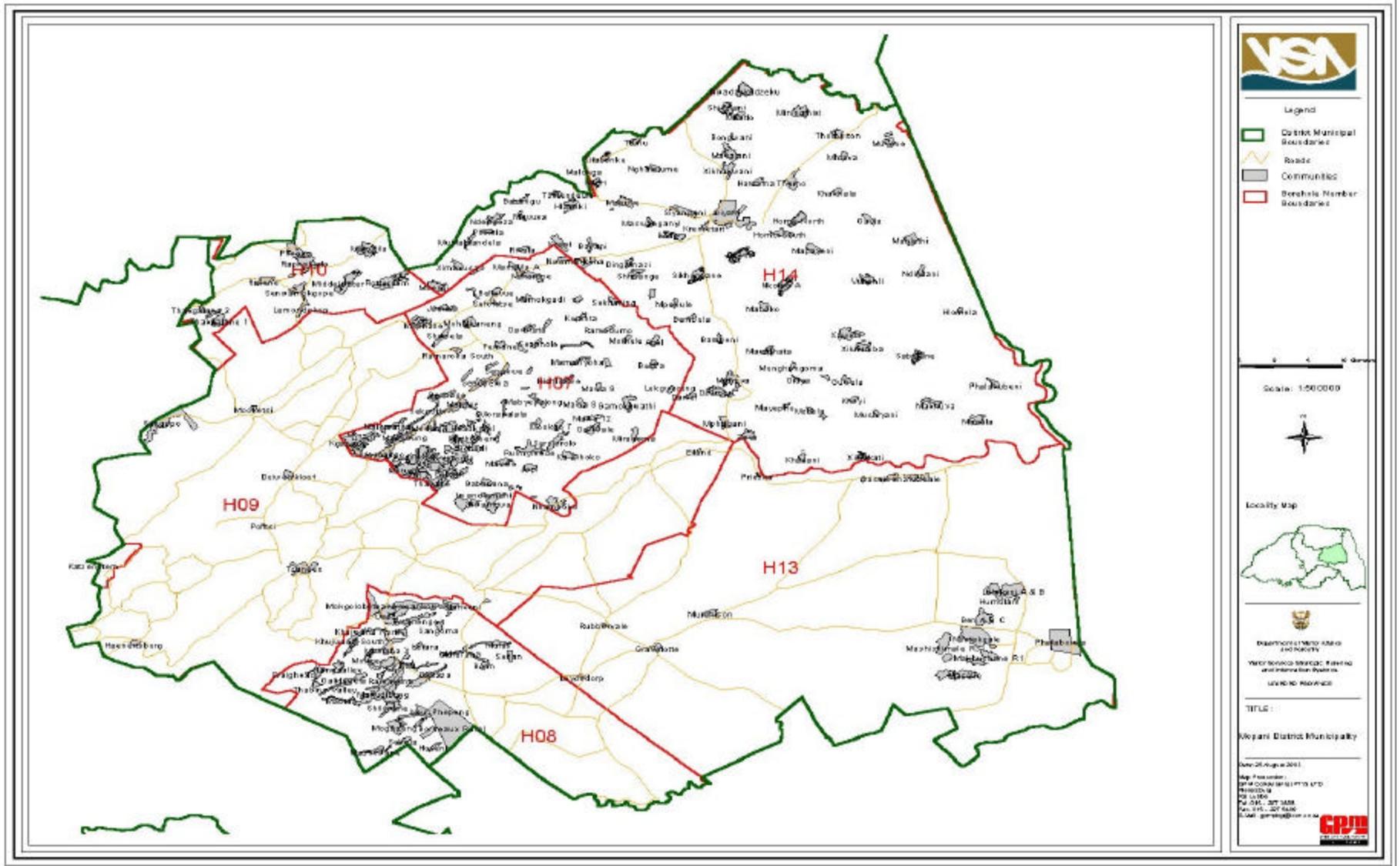


Figure 37 Reporting according to district municipality at H-regional level

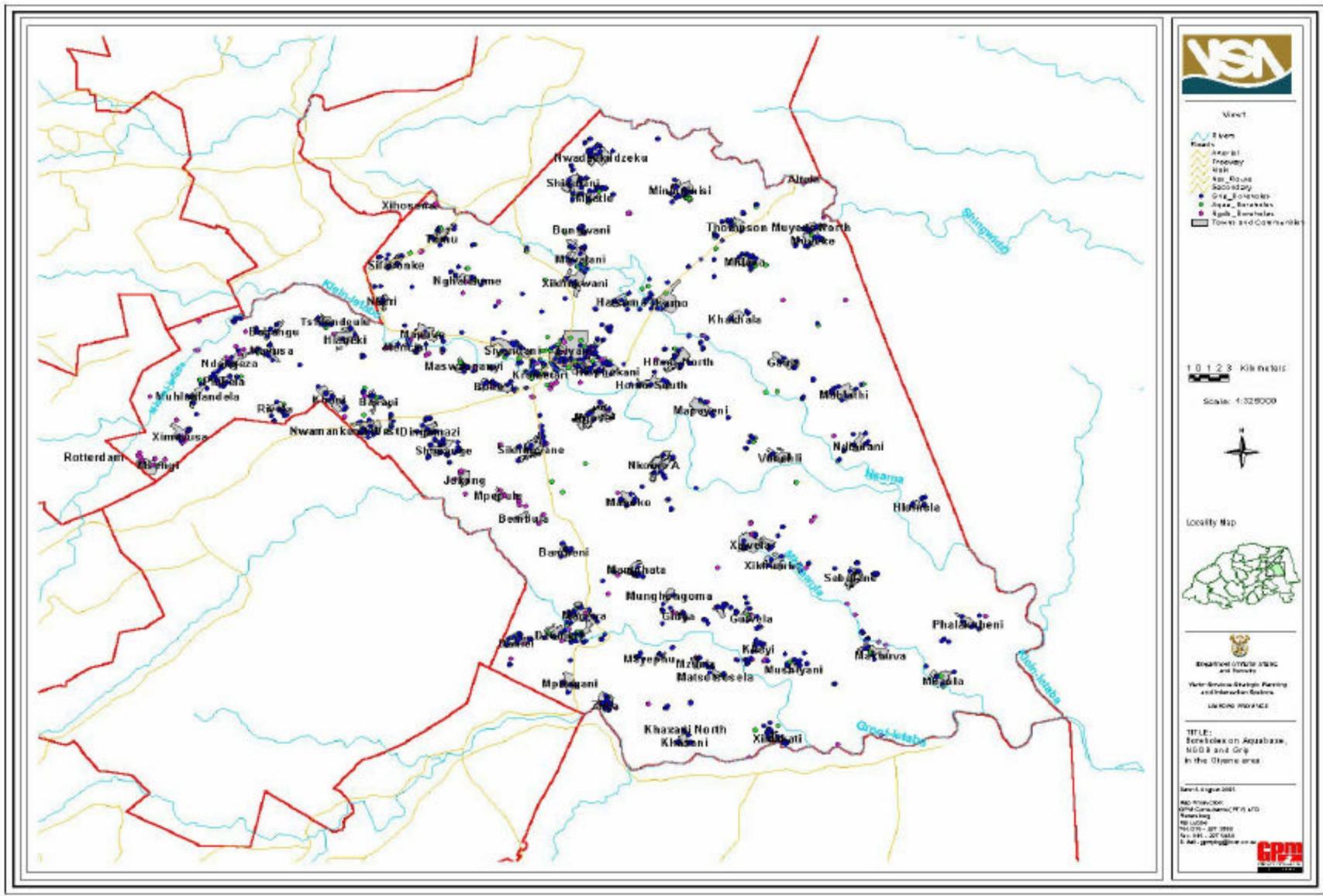


Figure 38 A combined view of the information available from the NGDB, Aquabase and GRIP information

6.1.1.2 Resource mapping correlation

If the data is compared with the low-end of the HP map (Figure 39) scenario, then it is quite evident that large volumes of the groundwater potential is already explored and that only 30% of the available resource has not been explored (Table 8). It also needs to be noted that some of the groundwater contributions like requirements for aquatic ecosystems and contributions to base flow are not captured as part of the HP values and these factors also need to be considered in a future water balance.

Table 8. Groundwater resource potential and development in the H-14 region

Summary of Water Resource Potential and Development					
Drainage Regions (H14)				Groundwater Potential	
Drainage areas within these boundaries are B82G, B81H, B82H, B81J, B82J, B90F				Litres/day	M³/day
				B82G, B81H & B82H are covering most of the area	
Low-end recharge scenario from Harvest Potential	33541096	33541			
Groundwater Recharge Calculations				Groundwater Balance	
Area (km²)	2950	Population	257500	Water from tested boreholes (l/p/d)	91.01
Low-end scenario of Harvest Potential	M³/Year	litres/sec	litres/day	Water calculated from recharge (l/p/d)]	130.26
Avg. recharge/km ²	4150.00	0.13	139	Water available from tested boreholes (l/s @ 24 hrs)	271.24
Total recharge	12243000	388	33541000	Water from calculated recharge (l/s @ 24 hrs)	388.21

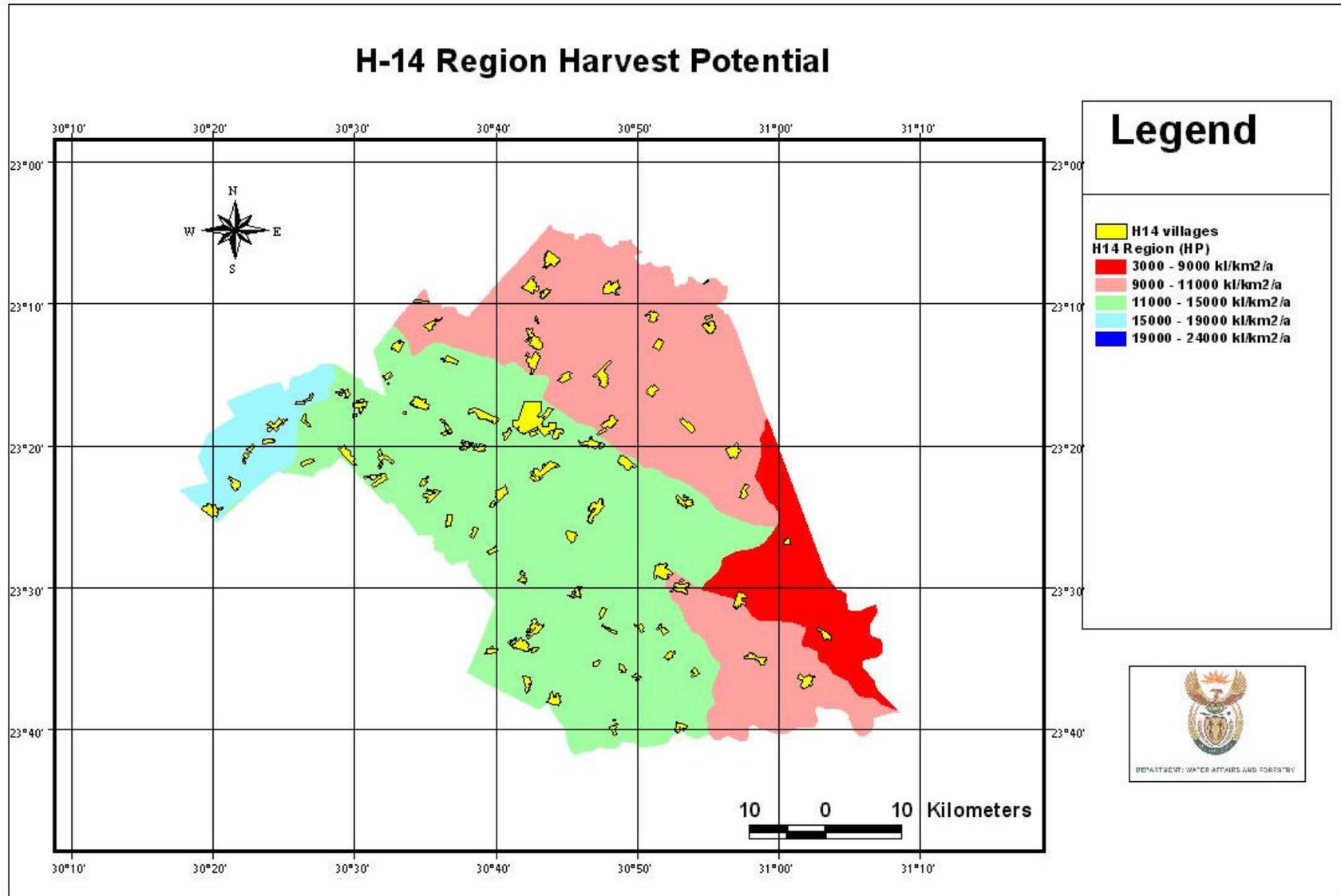


Figure 39 Harvest Potential map of the H14 region

6.1.1.3 Data density

To really have a visual assessment of the data coverage, the point data was buffered at 5 km distance with 1 km intervals and the data clearly indicate the whole of the H14-region is covered with borehole data (Figure 40). It indicates that the area has been explored in the past and groundwater characteristics for future planning is already available.

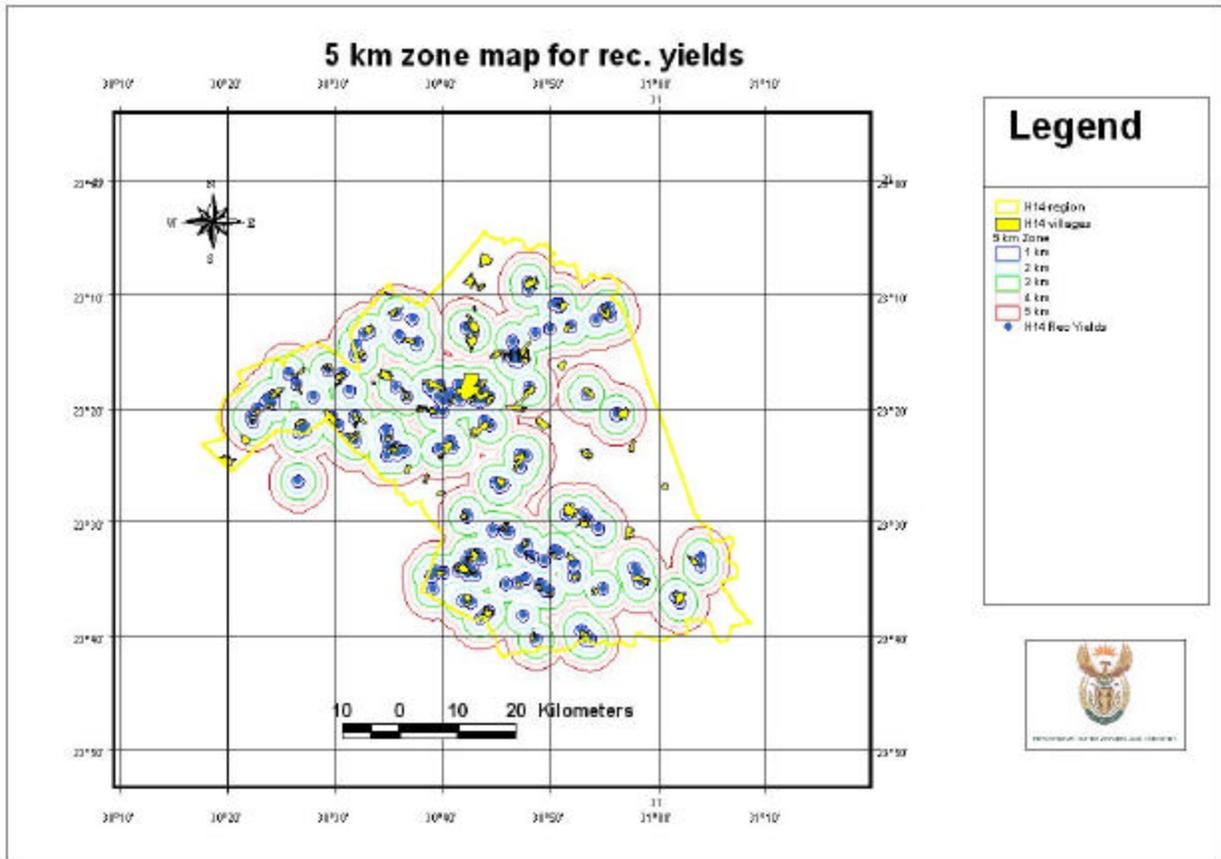


Figure 40 GRIP point data buffered to identify areas where no borehole recommendations are available in the H14-region (rec. – recommended).

6.1.1.4 Transmissivity map

From the 620 boreholes in the point-data set 273 were tested and assuming only the successful boreholes where tested then, it indicates on average that in the order of 38% of the boreholes verified were successful and have borehole pump-test information. According to Van Tonder (2004) there is a rough relation of 1:10 between the recommended yield (l/s) and the T-value (m^2/d) and one of the recommendations by Baron *et al* (1996) was to map the national T-values for South Africa. Therefore

by using boreholes having recommended yields, a first order transmissivity (T) value for all H-regions can be calculated and mapped (Figure 41).

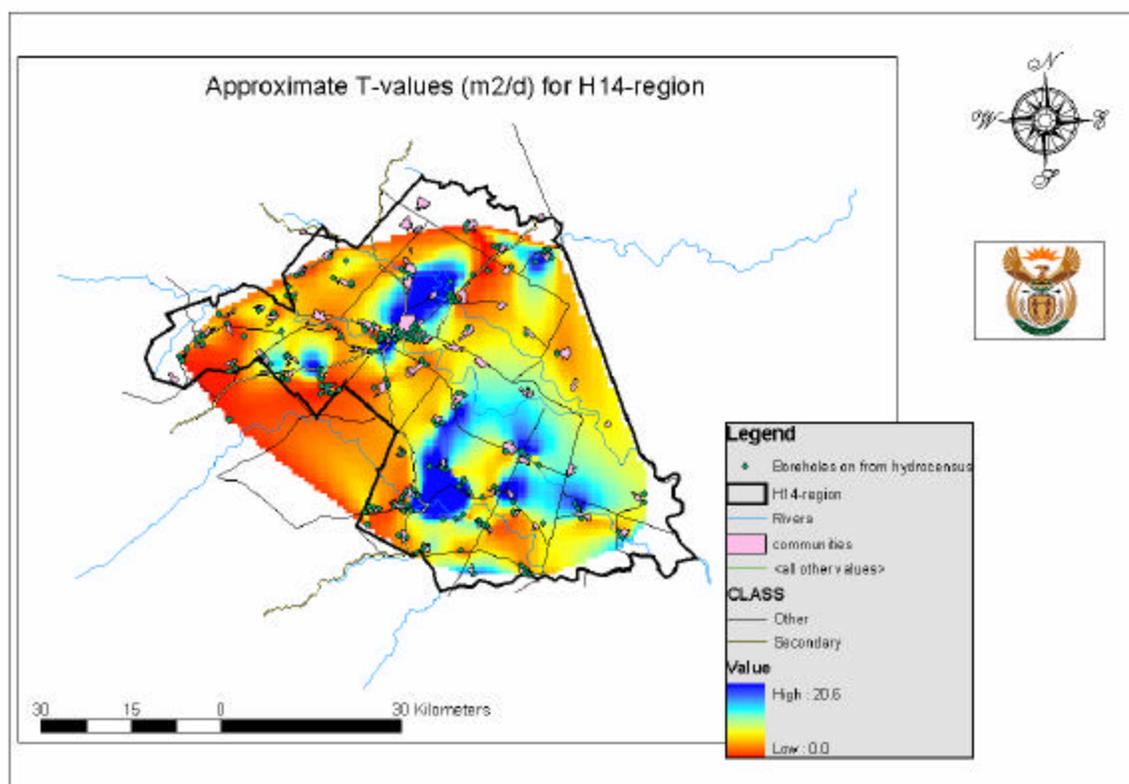


Figure 41 T-values derived for the H14-region derived from recommended yields

6.1.1.5 Sustainable yield

The recommend yield can be expressed as the recommended or sustainable borehole yield derived from historical data and will aid rational planning methodology (Figure 42). The estimated T-values are used together with the yield to calculate the radius of influence (RF). IWRM planners therefore can calculate sustainable yield for any area H-region and IWRM managers can calculate minimum distances for different production boreholes based on the expected T-value.

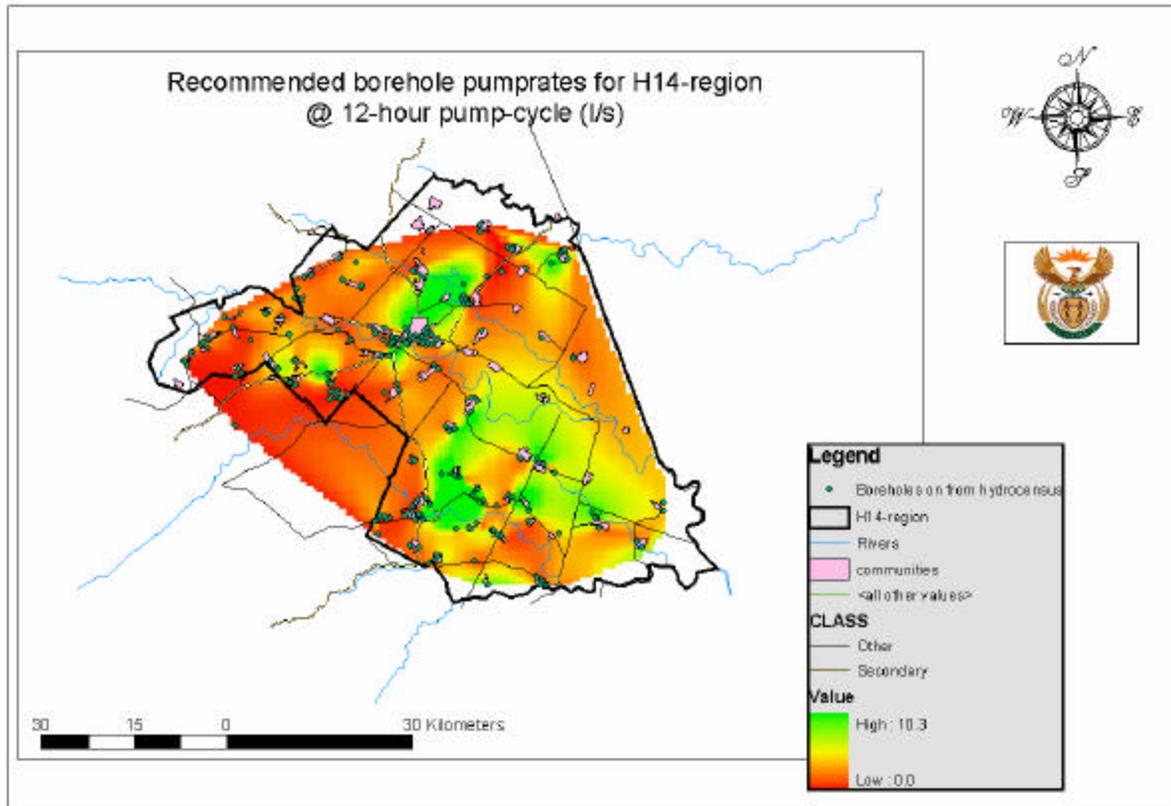


Figure 42 Recommended yields expressed as expected sustainable yields for planning purposes

6.2 BOREHOLE PUMP-TEST DATA

Prior to GRIP it was difficult for most IWRM managers or even geohydrological specialists to get any information concerning borehole pump-test data. By implementing the GRIP almost 4 000 borehole test-data sets have been identified. During the next two years all available borehole pump-test data sets will be captured on Aquabase and evaluated using the FC method. By applying the FC-method more realistic S and T-values can be calculated for regional mapping projects (Van Tonder *et al*, 2001).

6.2.1 FC method results

In the H14-region 20 boreholes (Table 9) were used as an example to illustrate the application of Aquabase and the FC method (Van Tonder *et al*, 2001). The results indicate that there are high yielding boreholes and also illustrates the remarkable difference for T-early and T-late values. It can be argued that T-late values are more representative of the aquifer and these values range from 1 to

130 m²/d. Although not done in this study the data can also be linked to the 1: 500 000 hydrological maps in terms of the lithological units.

A more practical application for example for water service providers and capturing in the WSDPs are the borehole abstraction rate and cycle length. For example take a community having a borehole as a water source, where the borehole is equipped with a diesel engine and a mono pump at a certain yield for a 12-hour pump cycle. When electricity becomes available in the particular community the pump is set at half the yield of the 12-hour cycle, however from the test results it appears the service provider or municipality can actually pump slightly more for a 24-hour pump cycle. The slight increase may be vital to the community and less capital expenditure will be needed, for example for developing another borehole or a pipeline from a surface resource.

Table 9. Summary of borehole pump-test results using the FC-method in H14-region.

No. on map	Borehole Depth (mbgl)	Static water level (mbgl)	Available drawdown (mbgl)	Constant yield (l/s)	Duration of test (min)	FC recommendation		Recommended pump set (mbgl)	Critical water level (mbgl)	Previous recommendation (l/s)	S-value	T-early (m ² /d)	T-late (m ² /d)
						for 12 hours	for 24 hours						
H14-0025	64.30	13.90	15.20	2.00	1200	1.20	0.83	42	30.0	1.5/8	1.1X10 ⁻³	6.00	90.00
H14-0067B	58.25	35.15	8.50	0.84	840	0.85	0.63	48	43.5	3.5/8	1.1X10 ⁻³	8.00	17.00
H14-0072	60.00	29.32	8.50	1.17	1440	0.57	0.40	48	37.0	0.8/12	2.2X10 ⁻³	11.00	11.00
H14-0100	53.00	39.80	1.50	6.05	1440	2.10	1.50	48	41.5	2.5/8	2.2X10 ⁻³	234.00	130.00
H14-0102	40.68	23.67	6.00	2.85	1440	1.40	1.00	36	28.0	no previous recom	2.2X10 ⁻³	275.00	40.00
H14-0108	46.87	12.85	11.50	1.20	1440	0.64	0.45	36	24.5	0.65/24(1.3/12)	1.1X10 ⁻³	11.00	10.00
H14-0129	98.00	6.00	8.40	15.00	1800	5.40	3.80	28	14.5	no previous recom	2.2X10 ⁻³	114.00	130.00
H14-0196	47.15	17.80	17.00	2.17	720	0.74	0.52	39	39.0	0.2/12	1.1X10 ⁻³	5.00	5.00
H14-0210	65.30	15.30	6.00	0.84	1440	0.21	0.15	28	21.3	0.4/12	2.2X10 ⁻³	12.00	6.00
H14-0218	51.90	12.25	11.50	0.32	480	0.10	0.07	25	25.0	0.11/24(0.22/12)	1.1X10 ⁻³	1.00	1.00
H14-0224	42.30	4.74	11.80	4.00	1440	1.80	1.30	28	16.0	1.5/24	2.2X10 ⁻³	25.00	30.00
H14-0225	100.00	1.80	9.00	0.75	1440	0.60	0.40	24	9.5	1/8	1.1X10 ⁻³	7.00	12.00
H14-0241	46.15	6.50	9.50	5.00	1440	2.80	2.00	24	15.0	no previous recom	1.1X10 ⁻³	69.00	50.00
H14-0242A	59.86	8.10	4.60	2.18	1440	1.00	0.70	36	13.0	no previous recom	2.2X10 ⁻³	70.00	40.00
H14-0243	47.70	6.28	20.80	15.00	2880	7.50	5.30	36	27.0	no previous recom	1.8X10 ⁻³	53.00	50.00
H14-0245	63.60	11.50	7.00	2.94	1440	1.75	1.24	36	18.0	no previous recom	2.2X10 ⁻³	39.00	40.00
H14-0250	29.50	6.47	12.70	14.70	3000	6.30	4.50	28	19.5	no previous recom	2.2X10 ⁻³	93.00	120.00
H14-0261	90.20	12.29	8.10	3.90	1440	1.56	1.10	36	20.5	no previous recom	2.2X10 ⁻³	32.00	20.00
H14-0271	35.20	17.11	7.00	3.20	1440	1.56	1.10	32	24.0	2.5/8	2.2X10 ⁻³	27.00	25.00
H14-0287	89.60	9.60	25.70	5.28	2880	2.30	1.60	48	35.5	1.67/24	1.1X10 ⁻³	24.00	15.00

6.3 GRIP CONTRIBUTION TO OPERATION AND MAINTENANCE

6.3.1 Immediate water supply benefits

From the 620 boreholes in the H14-region more than 55% are destroyed, only 33% work and more than 12% are damaged (Figure 43). The damaged boreholes are listed and supplied on maps to service providers and can be repaired immediately. The data suggests that in the H14-region alone 44 diesel pumps and 29 hand pumps are broken and by repairing the existing broken pumps it can be expected that hundreds of people could be served with much-needed water (Figure 44). Boreholes tested and recommended but not equipped are also listed and given to the water service provider.

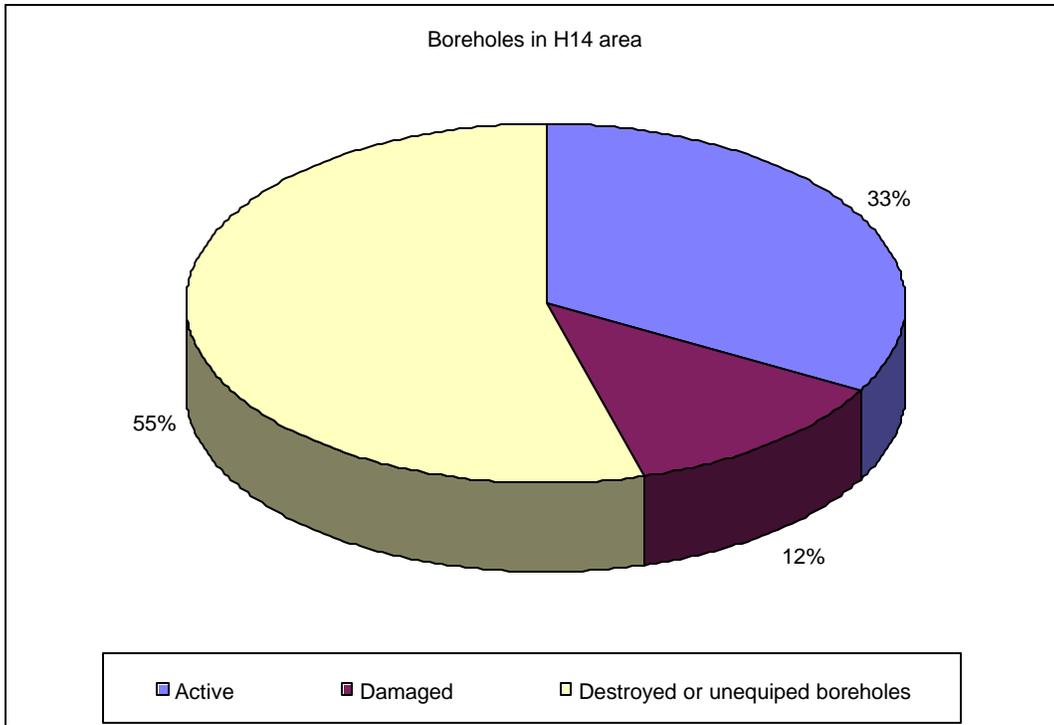


Figure 43 Many of the boreholes available in the area are not working or are destroyed

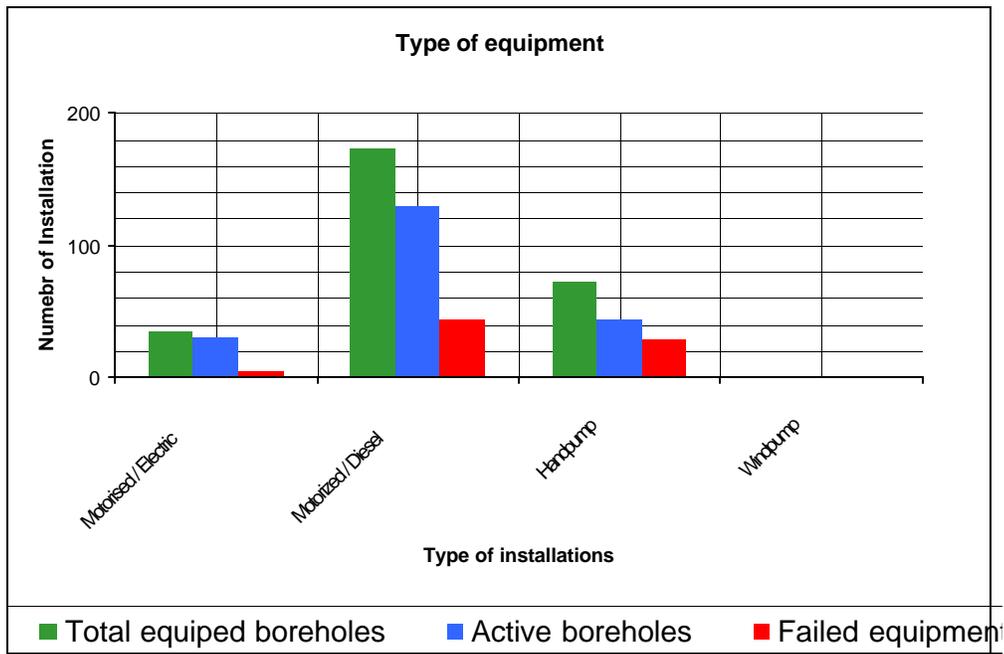


Figure 44 Electrical boreholes seem to be more effective/sustainable than the diesel or hand pumps.

7 DISSEMINATION OF INFORMATION

Based on the lessons learned from Texas, Victoria and Kentucky examples it is apparent that the Internet poses the most effective media to disseminate information, whereby datasets can be accessible to almost all interested and affected parties, making use and feedback simpler and faster. Therefore, as mentioned before, an information dissemination website was designed to make information accessible to all groundwater role players and publish available information (Figure 45). The web-site is bound for change as the full GRIP philosophy of integrated groundwater resource management as part of IWRM is introduced in the Limpopo Province.

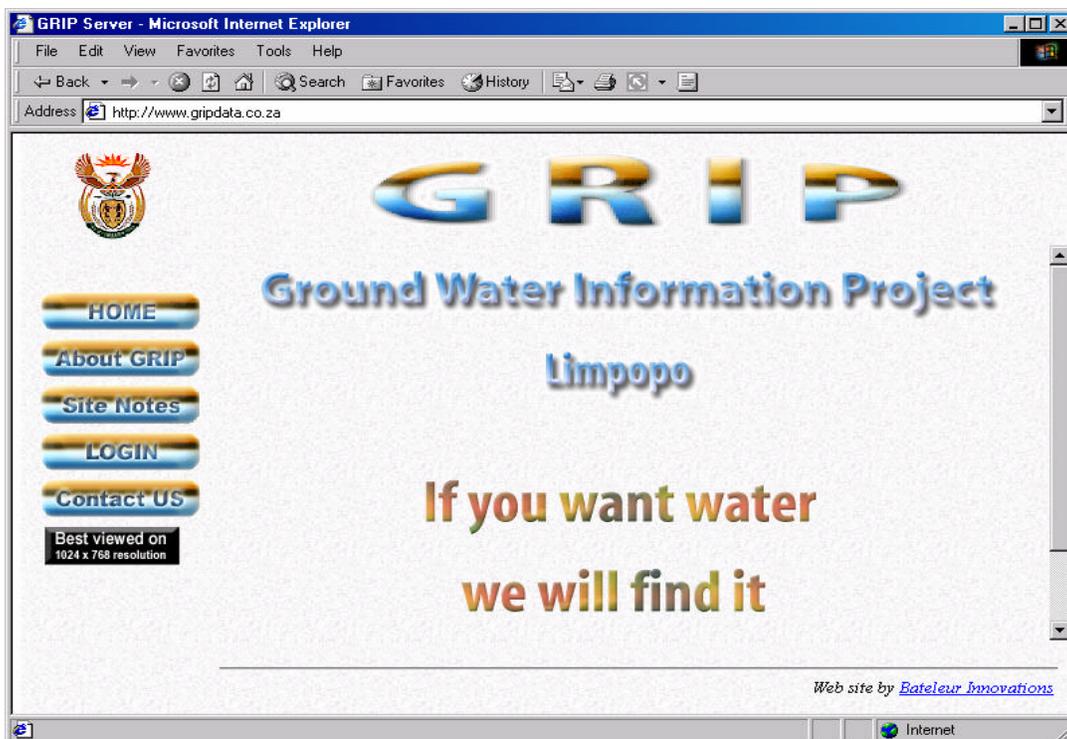


Figure 45 Introduction page to <http://www.gripdata.co.za> or <http://www.groundwaterdata.co.za>

7.1 HOME PAGE

Like any other the home page has an introduction paving the way forward with 5 basic options.

- Home
- About GRIP
- Site notes

- Login
- Contact us

7.2 ABOUT GRIP

About GRIP offers 4 menus to choose from:

- Home

Return the user to the home page

- Description

About GRIP gives a shortened introduction to the GRIP philosophy, with reference to ICM and the NWA. It captures the aims and the objectives and also alludes to the fiscal support from the DWAF.

- Scope

Scope introduces the user to a more detailed description of the implementation stages of GRIP, included are phase 1.1, describing the desk study up to phase 3.3 mentioning the possible long-term application of GRIP.

- Structure

Structure describes the core role-players involved with the implementation of GRIP. Discussing the role the groundwater consultants play to capture and report all the readily-available geohydrological information in Limpopo, how the Council of Geosciences will act as a regional support-service group during the project and how the Project Management Committee is structured.

7.3 SITE NOTES

The sites notes provide a rundown on the development of the Internet site and information management during the implementation period of GRIP. The information can be used as reference dates when enquiring on the time of implementation of the website.

7.4 LOGIN

The login button on the home page provides access to a login window, allowing the user to register basic information and includes the user's name, sur name, e-mail address and occupation (Figure 46). There is no official registration, but a user needs to enter the minimum information before he/she is

allowed to proceed. Many of the people involved in the groundwater industry in Limpopo have an engineering or planning background. The information required is therefore only for record purposes and to help develop a profile of the typical users of such a website. After completion of the compulsory information the user enters the GRIP –Server.

The screenshot shows a web browser window titled "GRIP Server - Microsoft Internet Explorer". The address bar contains "http://www.gripdels.co.za". The main content area displays the South African coat of arms on the left, the "GRIP" logo in large blue and yellow letters in the center, and a "Login" section below it. The login section includes the text "Please Supply Your Particulars Below - All Fields Are Compulsory" and a form with four input fields: "Name" (filled with "Fanie"), "Surname" (filled with "Botha"), "E-mail address" (filled with "rik@DWAF.gov.za"), and "Occupation" (filled with "hydrogeolists"). On the left side of the page, there is a vertical navigation menu with buttons for "HOME", "About GRIP", "Site Notes", "LOGIN", and "Contact US". At the bottom right of the page, it says "Web site by: Bluefleur Innovations". The browser's status bar at the bottom shows "Done" and "Internet".

Figure 46 Login page capturing user information

7.5 GRIP SERVER

The GRIP -server page gives the user 5 options to view or download information from the server and opens on the map option. This page is the heart of GRIP where data can be viewed and downloaded as required by the user (Figure 47) and contains:

- Maps
- Data
- GRIP Issues
- GRIP EC

- Log out



Figure 47 First page of GRIP – Server

Due to the already successful implementation of the GRIP Phase 1 in the Limpopo Province, the DWAF Regional Office in the Eastern Cape also started with a GRIP and their data are also published on the GRIP website.

7.5.1 MAPS

The maps menu is the first menu on the GRIP server and as mentioned is automatically available when logging on to the GRIP-Server. It shows basic background information and gives the user the opportunity to view several maps derived from data in Limpopo and in line with the NWRS distinguishes between the Limpopo WMA and the Levubu /Letaba WMA. This data is specifically targeted for non-geohydrological users, requiring some background information and have a need to include the information in their business plans and desktop studies. The maps are updated by the DWAF office with the aid of Arcview or any other GIS tool and published on the gripdata.co.za website in a .jpeg format. The shape-file data are not published on the website for the data may be

manipulated by the users. The current maps include locality, water levels, TDS values, nitrate, EC information, harvest potential and the exploitation potential map as developed by Haupt (2001).

7.5.1.1 *Water-level map*

The water-level map was derived from all the available information currently available on the provincial database or Aquabase as described in Chapter 2, with good data coverage in the densely populated areas and little data coverage in the commercial farming areas. The GRIP does not anticipate improving on the current state of data coverage, but with time and assistance from the NWA the situation may change. The water-level map therefore gives an indication of the water level in Limpopo in metres below ground level (mbgl). It therefore may in some instances, for example in the Dendron area, just north of Polokwane, show areas with very deep groundwater levels in the order of 70 mbgl. The map, if updated regularly will enable planners, farmers and other groundwater users to identify areas where possible groundwater abstraction takes place or where groundwater use may in the near future become an absolute. The data can be smoothed by applying statistical methods, but due to the many uncertainties the data is given to the user in its raw format.

7.5.1.2 *Harvest-potential Map*

As discussed previously the harvest-potential map for South Africa was developed by Baron *et al* (1996) with the aim to estimate the amount of groundwater that can be abstracted based on the surface area, thereby guiding the users on the sustainable use of groundwater. The GRIP website is therefore a porthole whereby potential users can access the harvest potential map and calculate their sustainable use according to the harvest potential. The harvest-potential boundaries are according to the quaternary catchment boundaries as required by the WSAM and not according to lithological units. The Directorate NWRP, Head Office, DWAF conducts regional and national planning using the WSAM and it makes business sense to align groundwater management with their thinking in order to achieve IWRM. Therefore, by using the quaternary catchment boundaries, it allows for some distortion of the harvest potential, however for the purpose of regional and national planning and conceptualisation, the quaternary boundaries are acceptable (Figure 48).

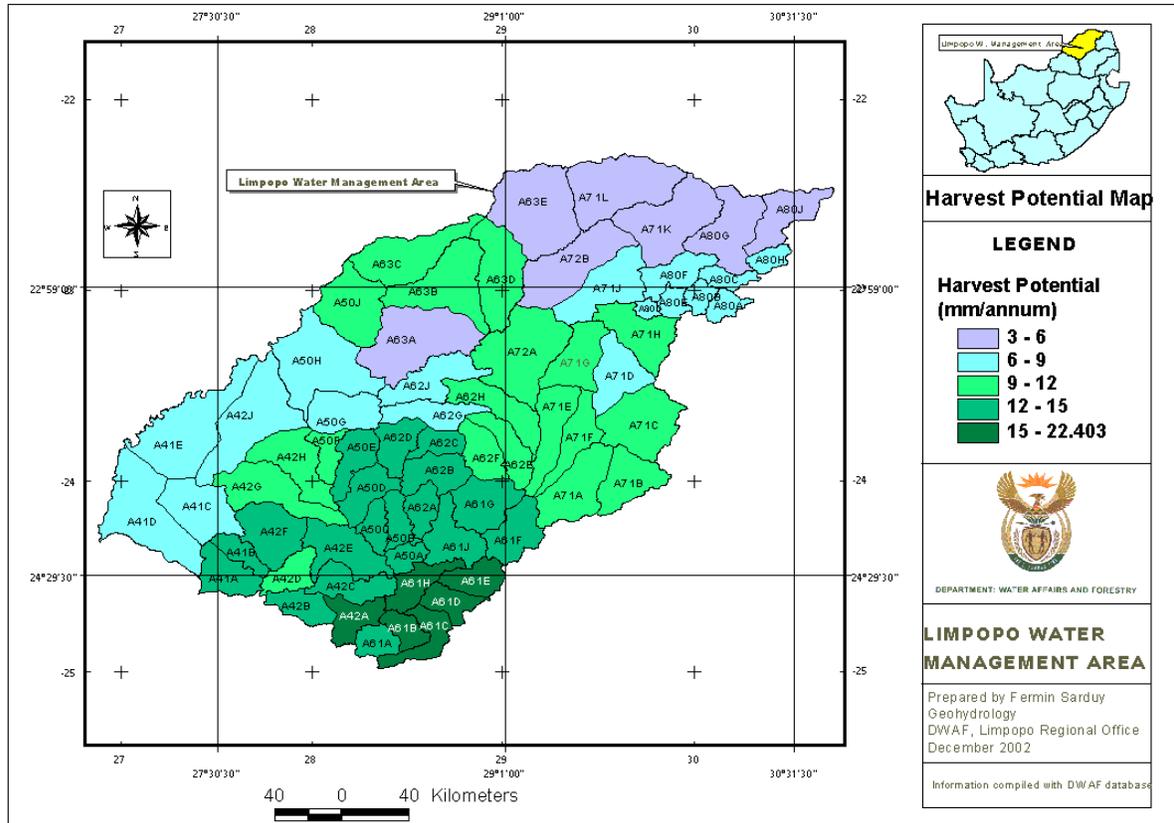


Figure 48 Harvest-potential map of the Limpopo WMA

7.5.1.3 Exploitation-potential map

The Exploitation-potential map as described in previous chapters is based on a reduction of the harvest potential. The map is therefore in the same format as the harvest-potential maps, but reduced as a result of current use, limited storage or difficulty of exploration (Figure 49).

7.5.1.4 Water-quality maps

Various water quality maps are available on the site and include the nitrate, TDS and the EC maps. The maps were also developed using the provincial database and are therefore quite distorted. Indicated are areas where possible pollution can occur or where groundwater use may not be suited for human consumption.

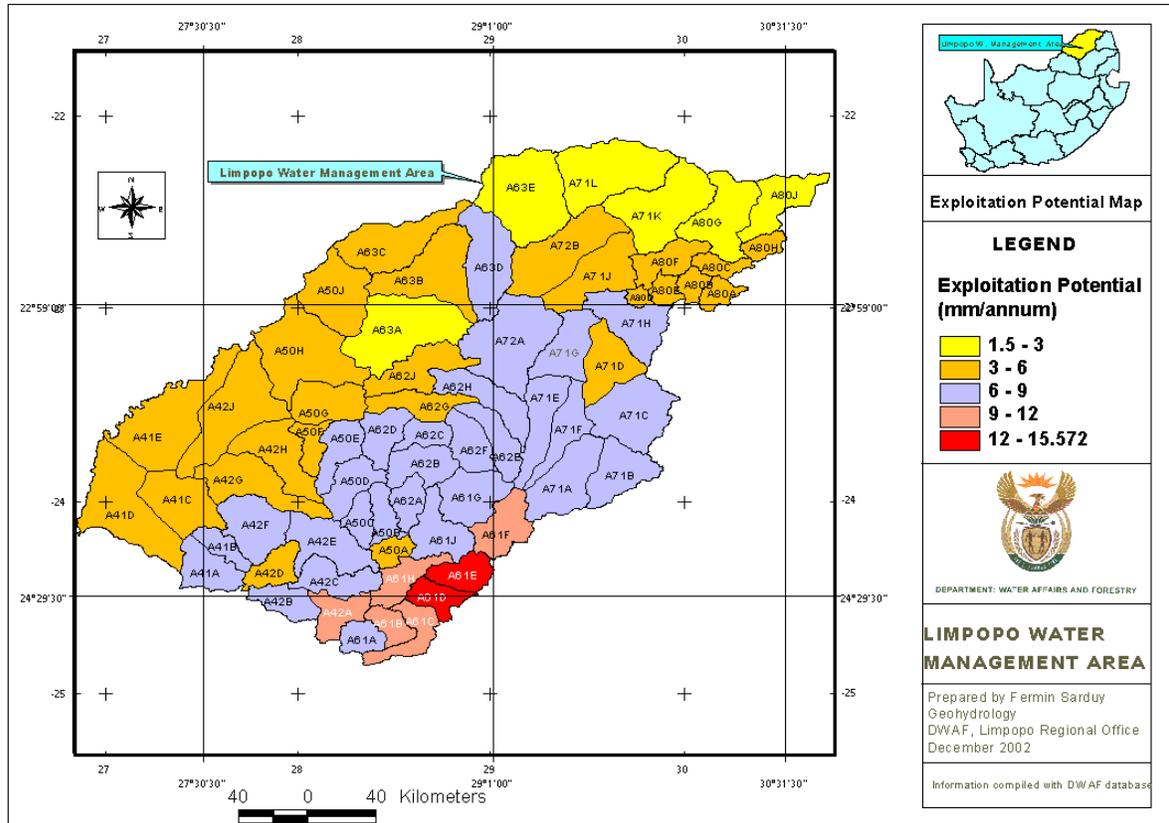


Figure 49 Exploitation potential of the Limpopo WMA

7.5.1.5 Summary of information

There is also a summary of the available groundwater use, mean annual recharge, exploitation potential and harvest potential, giving the user a visual comparison of the possible availability. The summary clearly indicates that the current use and the exploitation potential is currently similar and groundwater use may soon reach the maximum sustainable exploitation potential in Limpopo. This may be useful for planning purposes supplying a tool for determining possible groundwater overuse in Limpopo (Figure 50).

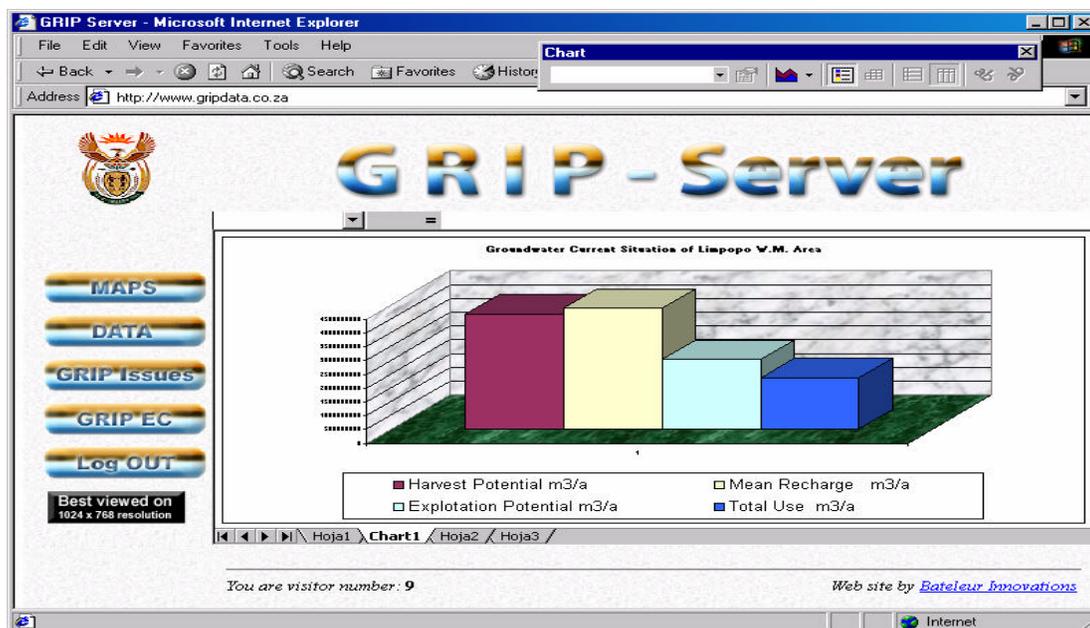


Figure 50 Summary of groundwater use in Limpopo

7.5.2 GRIP DATA

The data menu gives the user the opportunity not only to view data but also to download data from the GRIP server. Due to the versatility in the groundwater industry a vast number of role-players requires different sets and types of information. The borehole information can be filtered or queried according to various methods or search links. The GRIP data window also allows the user to either list the boreholes, give community detail or to view individual borehole information as captured in the field with the aid of the community on borehole field forms. The data can be downloaded and manipulated as required by the user. The filter requirements were therefore set to list the boreholes in a certain region or point, retrieve community detail or specific borehole detail.

7.5.2.1 List of boreholes

Listing of the boreholes and the associated information captured is obtained through several search links. Each of the links were designed to make it easier for different users to access data from the net and include consulting geohydrologists, planners, engineers, politicians, national and local government departments and the public.

* Borehole H-number (Appendix 2)

The borehole H-number search link provides the user with the opportunity to select, from a dropdown menu, a specific H-region and download all the borehole data from the selected area. This came as a

result of the H-number system in Limpopo whereby boreholes are marked in the field, as discussed in Chapter 2 (Figure 51).

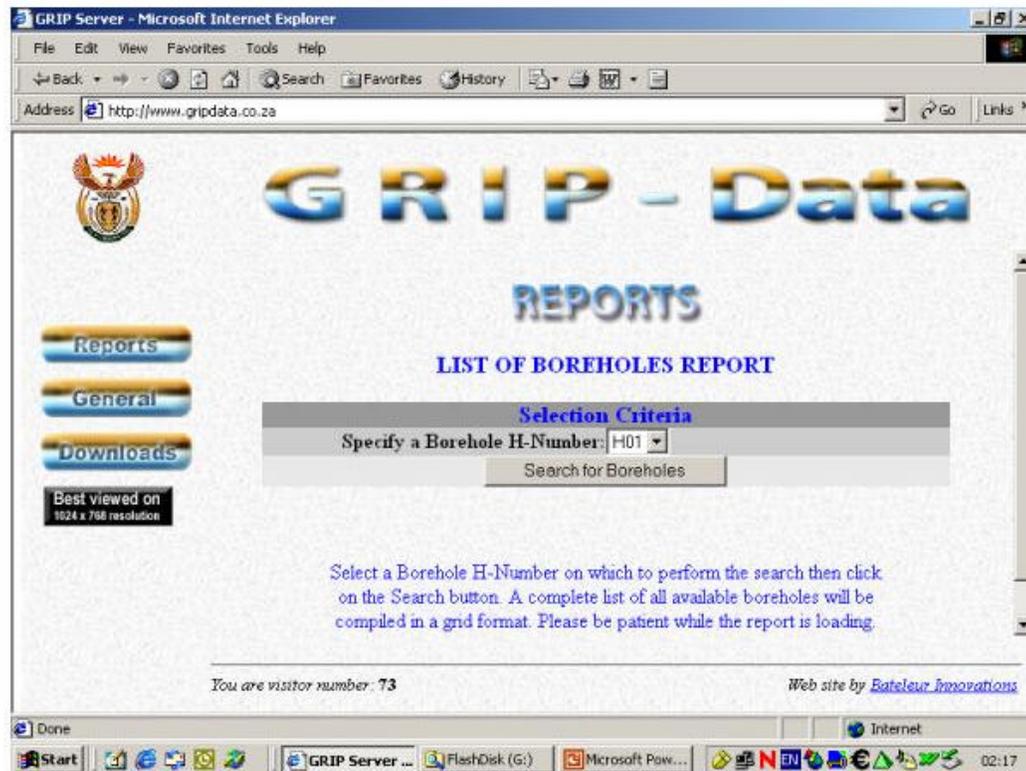


Figure 51 Selection Criteria for borehole H-numbers on website gripdata.co.za

After completing, the search a list of the borehole data available is displayed and gives the user the opportunity to download the data either in an Excel spreadsheet format or in a document format that has the same appearance as the NGDB form. The data displayed is the same information as on the field data sheet captured through the GRIP Gateway (Figure 52). The data captured in spreadsheet format can be manipulated and used with the aid of any statistical or surface plot programme, for example surfer or Arcview, depending on the user requirements (Figure 53).

Forward

LIST OF BOREHOLES REPORT

Export results to EXCEL

Display as NGDB form 150

Date Visited	Visited By	District	Municipality	BH Registration NR	Reporting Institution	Verified By	Verification Date	Site ID Code	Map Ref	Alt E Numb
7/18/2002	Steffan Kalbskopf	Capricorn (DC35)	Aganang	H04-1020	Geocon		1/1/1900	C9A62E024	2329 CC	NV
7/18/2002	Steffan Kalbskopf	Capricorn (DC35)	Aganang	H04-1571	Geocon		1/1/1900	C9A62E024	2329 CC	NV
7/19/2002	Steffan Kalbskopf	Capricorn (DC35)	Aganang	H04-0865	Geocon		1/1/1900	C9A62E024	2329 CC	NV
7/19/2002	Steffan Kalbskopf	Capricorn (DC35)	Aganang	H04-0866	Geocon		1/1/1900	C9A62E024	2329 CC	NV
7/19/2002	Steffan Kalbskopf	Capricorn (DC35)	Aganang	H04-0867	Geocon		1/1/1900	C9A62E024	2329 CC	NV
7/19/2002	Steffan Kalbskopf	Capricorn (DC35)	Aganang	H04-1440	Geocon		1/1/1900	C9A62E024	2329 CC	NV
7/19/2002	Steffan Kalbskopf	Capricorn (DC35)	Aganang	H04-1441	Geocon		1/1/1900	C9A62E024	2329 CC	NV
7/19/2002	Steffan Kalbskopf	Capricorn (DC35)	Aganang	H04-1570	Geocon		1/1/1900	C9A62E024	2329 CC	NV

Figure 52 List of boreholes and associated data available in H04 as filtered with the aid of the Borehole H-number link.

Microsoft Excel - H01-EXCEL.xls

File Edit View Insert Format Tools Data Sheet Window Help

G:\H01-EXCEL.xls

DATE OF VISIT	VISITED BY	DISTRICT	MUNICIPALITY	BH REGISTRATION NO.	REPORTING INSTITUTION	VER
2003/09/22	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-1267	MOTHOPONG	
2003/09/22	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-1268	MOTHOPONG	
2003/09/22	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-1269	MOTHOPONG	
2003/09/22	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-1290	MOTHOPONG	
2003/09/22	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-1291	MOTHOPONG	
2003/09/22	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-1292	MOTHOPONG	
2003/09/22	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-1401	MOTHOPONG	
2003/09/22	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-1402	MOTHOPONG	
2003/09/22	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-2370	MOTHOPONG	
2003/09/22	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01R2371	MOTHOPONG	
2003/09/22	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01R2372	MOTHOPONG	
2003/09/24	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-0373	MOTHOPONG	
2003/09/24	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-1138	MOTHOPONG	
2003/10/07	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-0370	MOTHOPONG	
2003/10/07	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-0371	MOTHOPONG	
2003/10/07	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-0372	MOTHOPONG	
2003/10/07	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-0375	MOTHOPONG	
2003/10/07	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-0376	MOTHOPONG	
2003/10/07	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-1137	MOTHOPONG	
2003/10/07	MOTHOPON	Capricorn (DC35)	Lepelle-Nkumpi	H01-1137A	MOTHOPONG	

Figure 53 Data downloaded and exported to an Excel spreadsheet ready for use.

DWAF’s Directorate IM, however still prefers to captured borehole data on the NGDB and it was thought that HO could capture the information via hard copies exported through the website as required by the data capturing team in HO. The reasoning being that the NGDB will be replaced by

the NGA in the next year and it will be a waste of valuable resources to develop an interface between the NGDB and the GRIP data. The NGDB option therefore came as a direct result of various meetings with the role-players involved with the NGDB capturing process. Both the GRIP team as well as the NGDB team decided that due to the introduction of the NGA, it will be both financially and technically wiser to wait for the NGA, before developing an interface between the GRIP data and the NGA. The NGDB hard-copy download option has a customisation export tool in the form of a tick-box option and enables the client to customise the NGDB form reflecting the level of detail required by the NGDB personnel. The tick boxes allow the user to choose from recommended data, sparsely populated and empty or immaterial options before exporting the data to the 150 form (Figure 54).

For more information see [Export Guidelines](#) below
Total Boreholes: 8

Choose Options
Display this number of BH's simultaneously
8 Recommended

Display these Forms

Legend
* Rating
R Recommended
S Sparsely populated
E Empty / Immaterial

i. NGDB-Format census Forms
Choose all: R S E

* No.	Form
<input checked="" type="checkbox"/> R 150	ENTRY
300 BOREHOLE CONSTRUCTION	
<input checked="" type="checkbox"/> R 330	CONSTRUCTION INFORMATION
<input checked="" type="checkbox"/> R 331	HOLE
<input checked="" type="checkbox"/> R 332	CASING
<input checked="" type="checkbox"/> S 333	OPENINGS

* No.	Form
600 MISCELLANEOUS	
<input checked="" type="checkbox"/> S 611	SITE SELECTION
<input checked="" type="checkbox"/> S 612	OWNER
<input checked="" type="checkbox"/> S 613	OTHER IDENTIFIER
<input checked="" type="checkbox"/> S 615	SITE VISITS
<input checked="" type="checkbox"/> S 617	REFERENCES

Figure 54 The tick option to select the detail of the information to be exported as the NGDB 150.

After selecting the level of input the user selects the export button and the data are exported to the NGDB 150 format and printed as hard copy-files (Figure 55). The export tool also provides an export guideline, which assists the user through the process of making the correct selection for their needs.

1 . H22-0587 **150 ENTRY**

Site ID Code	Map No.	Number on 1:50 000 map	Province, district and farm No.
1 NV	2 2230DA	3 -/-	4 PROV: LP DIST: MT Vhembe (DC34) FARM: 0000
Site Name			
5 FARM NAME: STATELAND FARM PORTION: MUYEXE (C9B90F002)			
Boring branch No.	Q-Number	Coor. method	Region Bhole Number
29	MUNICIPALITY: Mutale	30 -/-	- G - GPS
31 H22-0587			
Topographic setting	Latitude	Longitude	
6 V - Valley	7 -22.62666	8 30.5254	
Coordinates accuracy	Drainage Region	Altitude (m)	Method of measurement
9 1 - 10m	10 A80H	11 740	12 M - Interpolate
Site type	Site selector	Nominal Dia. (mm)	
13 Borehole	14 -/-	15 -/-	
Latest depth (m)	Date measured	Depth information source	Status of site
16 -/-	17 4 / 12 / 2002	18 REP. INST. [-/-]	19 U - Unused
Purpose of site	Water use: Consumer		Water use: Application

Figure 55 Borehole data exported into hard-copy format ready to print and/or captured on NGDB

* *District and local municipalities*

Many of the users are local and district municipalities and they would rather require data based on the district or local municipality borders. With the development of the search links in GRIP their needs were also met. Therefore a link to filter the data using the municipal borders was developed and the user can make a selection based on either the district municipality or local municipality borders, displaying the data in the same format as discussed above (Figure 56).

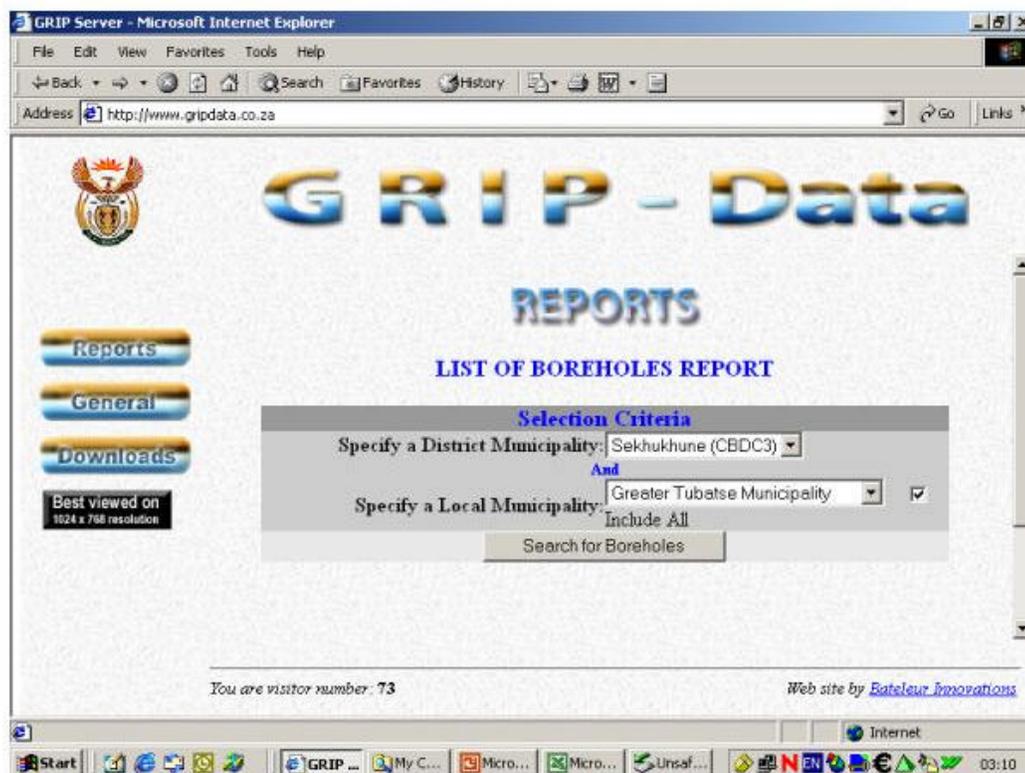


Figure 56 Selection criteria as displayed with the District or Local Municipality search link.

* *Radius from villages*

Resulting from numerous meetings and workshops with local developers and several engineering firms it became apparent that projects are often linked to villages, rather than regional supply and that there is a need to have borehole information available for a certain area around a village rather than relating the search to a specific village. The reason for this is that some boreholes are allocated to certain villages but are situated in an area owned by the neighboring village. This may create the situation where high-yielding boreholes, although allocated to a specific village, might yield enough potable water to sustain a regional supply for a number of villages. The filter option was therefore developed to make it possible to filter the database using a radius in meters from the village rather than only the village name.

* *Farm name*

All the villages reside on the original farms as allocated by the general survey. Without knowing the name of the village or villages as they can have several names the user can rather make a search using

the farm name. This is a useful tool for planners, engineers and geohydrologists constructing water supply schemes. Thereby making sure they are conducting the work on the correct farm name linked to a village in a specific district or local municipality.

* *Map Hotspots (Appendix 1; subsection 4 -6)*

It was required to make the data search more accessible for any person able to read a map, for example learners in rural areas requiring borehole data. For this reason a unique map hotspot search link was developed querying data based on an image file. It is a simple technique often used on the net but it is the first time it was developed in South Africa for retrieving borehole data. The hotspot option comprises a two-map series, the first map being that of Limpopo and the second local municipalities in the foreground and the H-numbering coverage in the background (Figure 57).

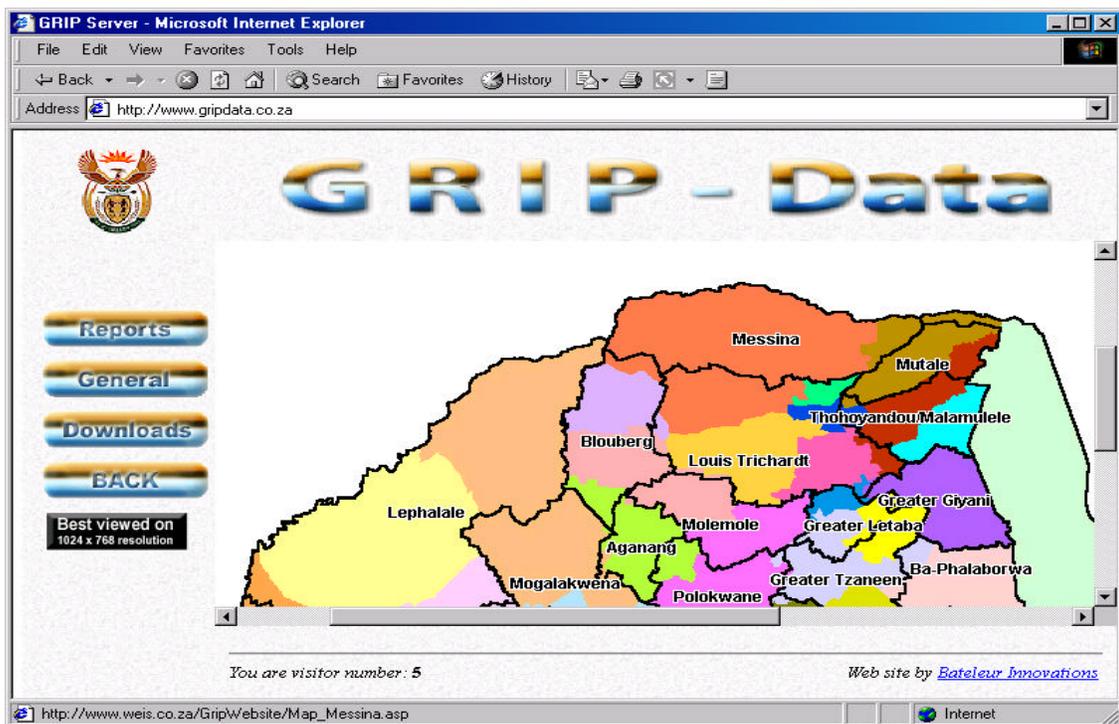


Figure 57 First map option when selecting the Map Hotspot link on the borehole -list option

The user is required to click on a local municipality, for example Aganang, the Aganang municipality area with the associated H-regions and villages are displayed. This enables the user to identify the H-regions of concern in a specific municipal boundary (Figure 58).

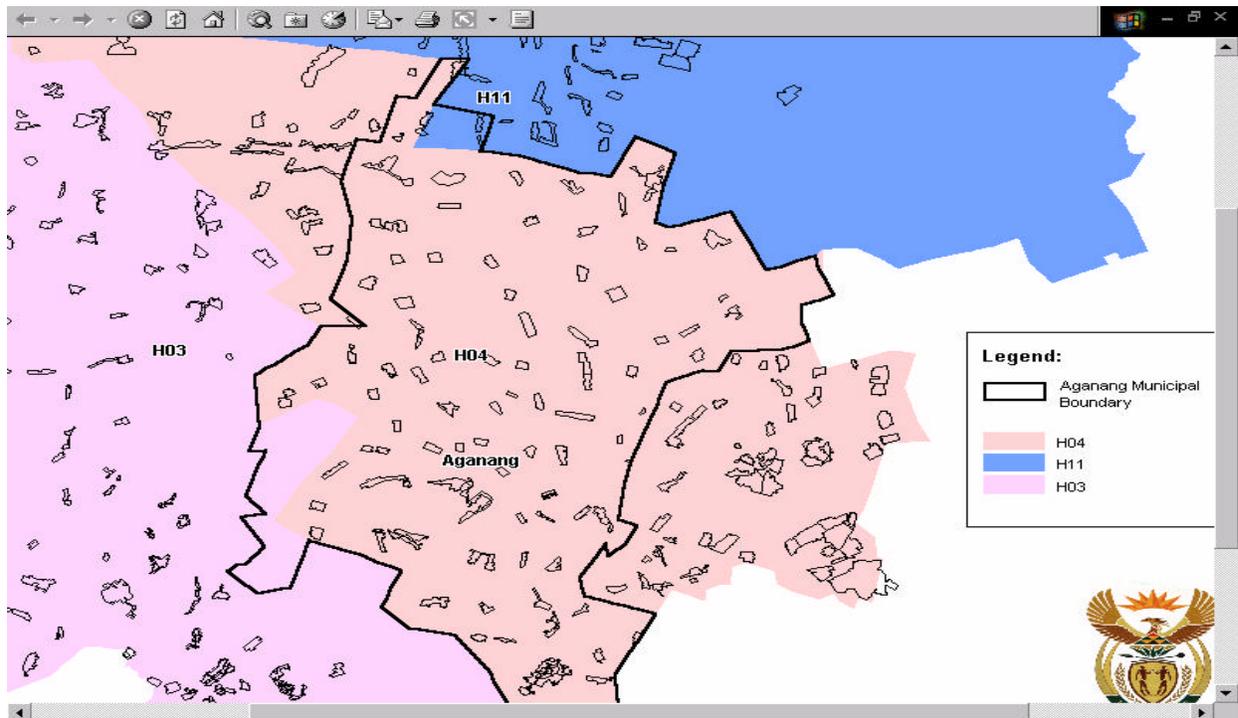


Figure 58 View of the Aganang Municipal boundary and the associated H-regions

The user can simply click on the H04-region and all the information captured during the GRIP is displayed in table format, downloaded as an Excel file in the format required by interface tool or exported into a NGDB 150 form and be printed. Using this procedure the data can only be viewed as per H-region, although some municipalities already indicated that they may require, in the near future, sorting done according to the municipal area. However, once the data are exported in an Excel format it can be viewed and sorted by most GIS packages using the polygon shape files.

* *Summary of H-regions*

Imbedded in the map hotspot search link, displayed as links on the web page below the second map (Figure 58), is a summary per H-region in the same format as described in Chapter 4 (Figure 59). The user can therefore have the pre-analyzed statistical information available in an Excel spreadsheet format, including graphs describing the current situation on groundwater including use, availability, current status and future potential in an H-region.

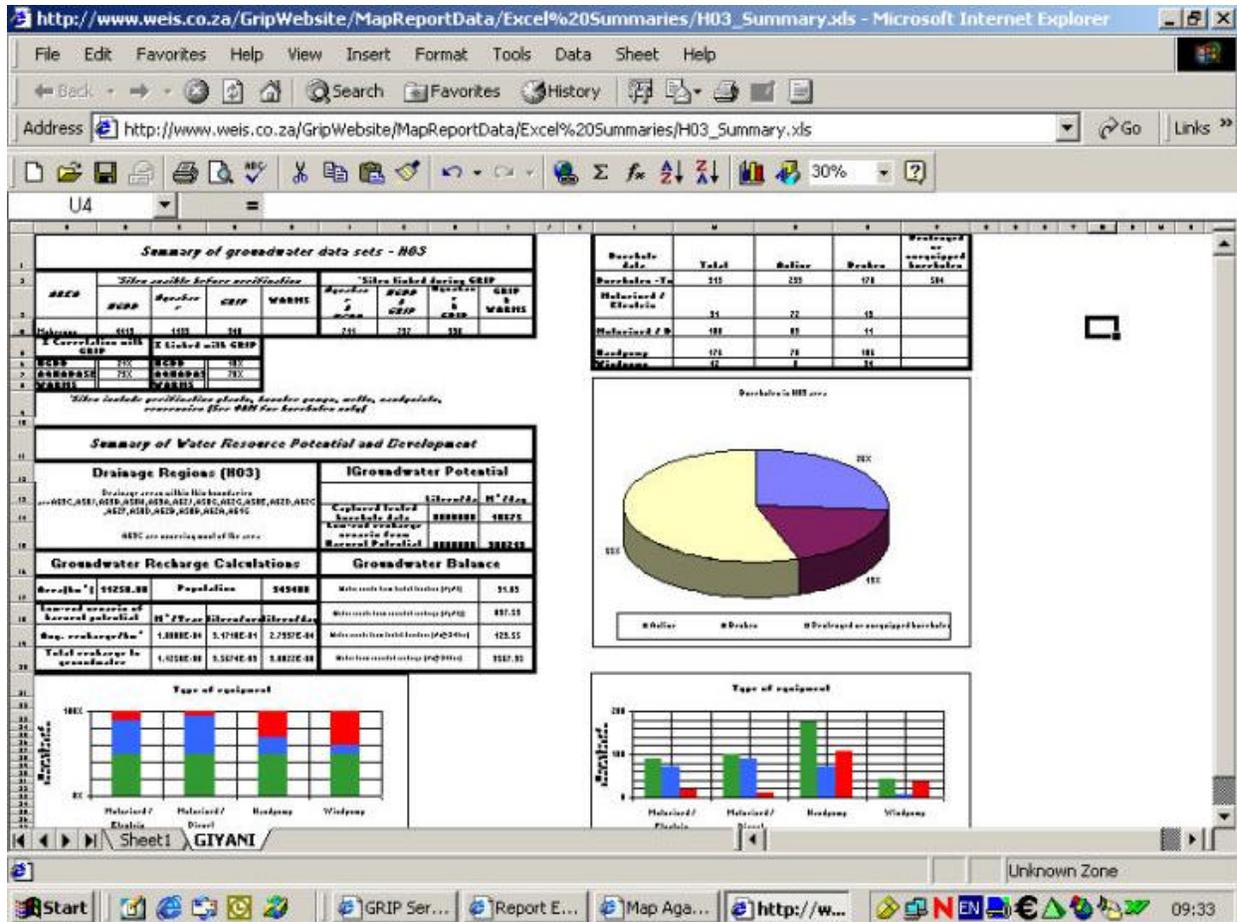


Figure 59 Summary per H-region as described in chapter 6 can be downloaded using the map hotspot filter link

7.5.3 GRIP ISSUES

The GRIP -ISSUES window is dedicated to create an opportunity for the user to give comments on the gripdata.co.za website regarding any of the aspects or functionalities of the site, including data and type errors as well as suggestions for improvement of the site.

7.5.4 GRIP EC

GRIP EC or GRIP Eastern Cape is the shortcut to some of the initial data captured during the first-phase information gathering in the GRIP Eastern Cape study. It also makes use of the so-called “hot-spot” technique whereby information available in a certain municipality can be retrieved simply by clicking on the screen (Figure 60). Therefore when you enter GRIP EC a map of the province appears, showing the different district municipality boundaries. If the user clicks on the district municipality area all the files available related to possible borehole information are retrieved from the database and

shown in a table format (Figure 61). The data includes over 50 reporting columns and includes a unique ID number, municipality, title, author, contact details, type, etc. The reports can also be sorted or searched according to the column name or a specific value and downloaded as a data file.

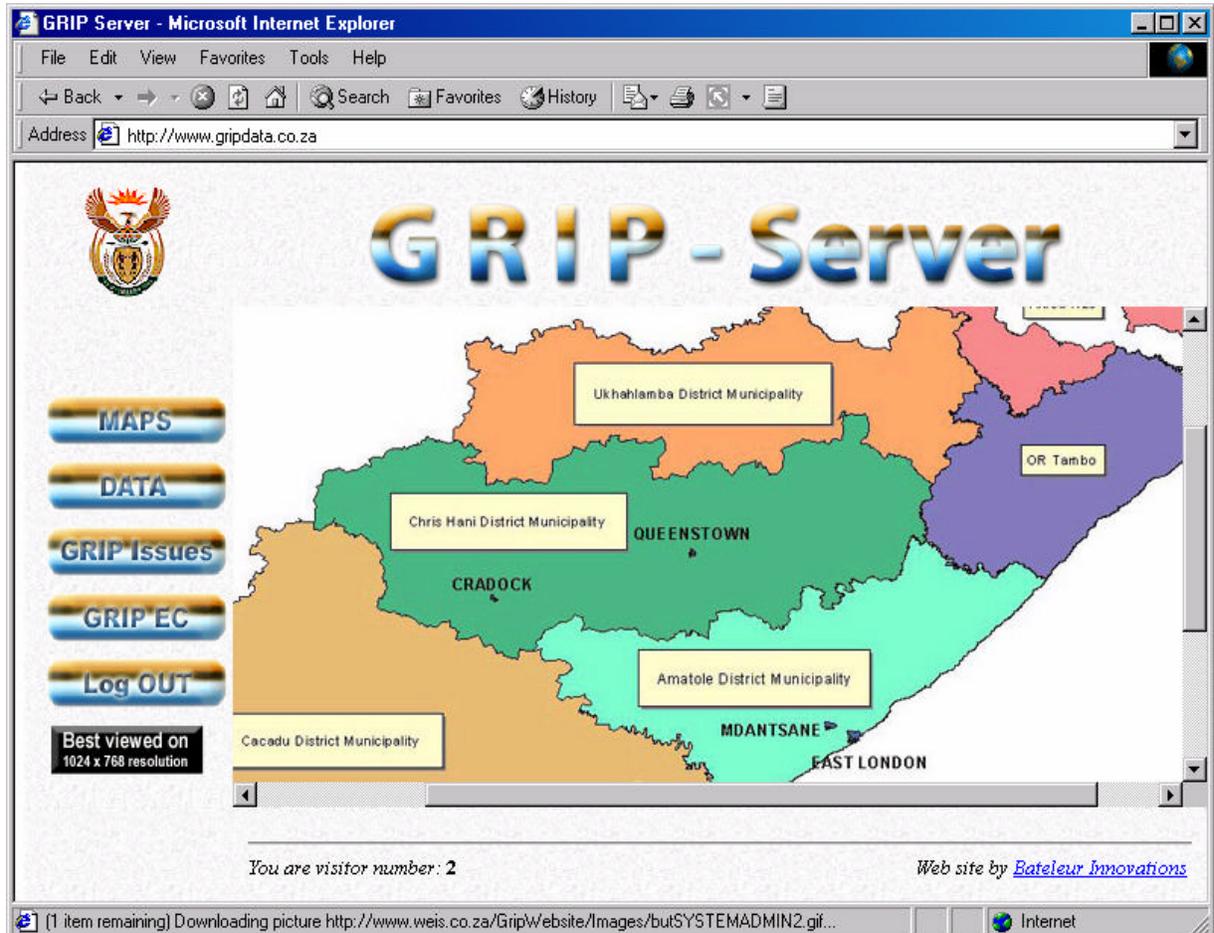
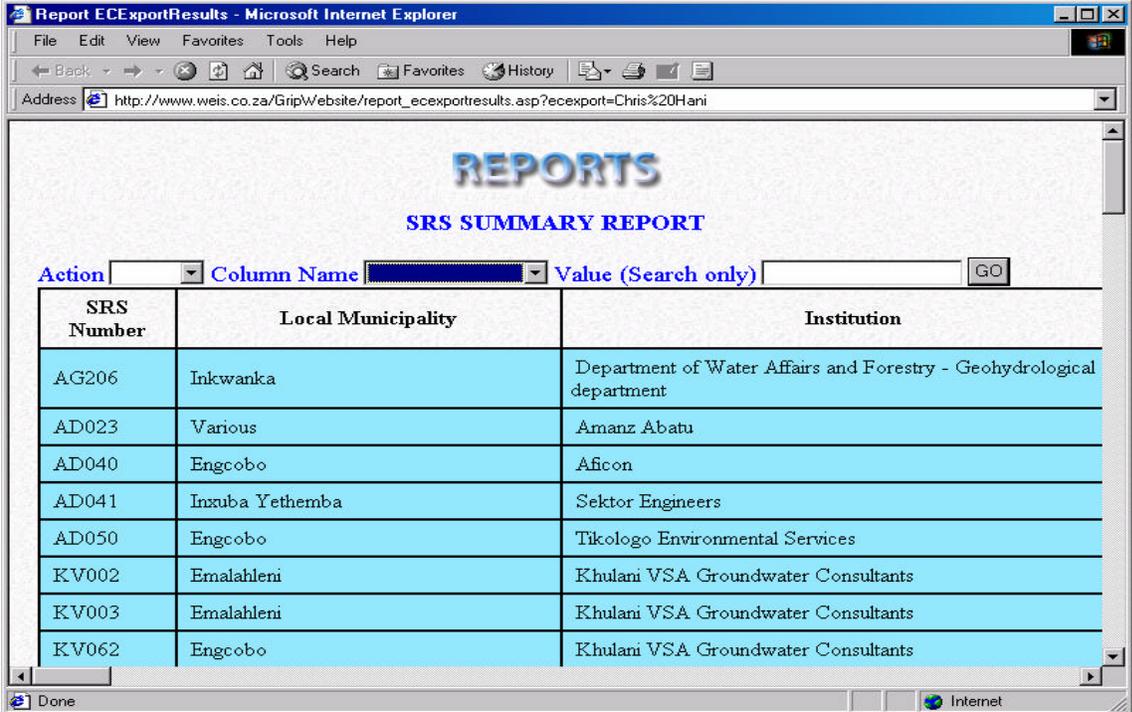


Figure 60 GRIP Eastern Cape map hotspot image to search for geohydrological reports available per District Municipality



Report ECEXportResults - Microsoft Internet Explorer

Address http://www.weis.co.za/GripWebsite/report_ecexportresults.asp?ecexport=Chris%20Hani

REPORTS

SRS SUMMARY REPORT

Action Column Name Value (Search only) GO

SRS Number	Local Municipality	Institution
AG206	Inkwanka	Department of Water Affairs and Forestry - Geohydrological department
AD023	Various	Amanz Abatu
AD040	Engcobo	Aficon
AD041	Inxuba Yethemba	Sektor Engineers
AD050	Engcobo	Tikologo Environmental Services
KV002	Emalahleni	Khulani VSA Groundwater Consultants
KV003	Emalahleni	Khulani VSA Groundwater Consultants
KV062	Engcobo	Khulani VSA Groundwater Consultants

Figure 61 Report on data available per district municipality

8 CASE STUDIES

The aim of the case studies are to apply the proposed methodologies, data and tools from the GRIP and test the practicality thereof. Therefore, in practical terms, how does the GRIP put groundwater management, planning in reach of town planners, water resource planners or planning engineers and thereby making groundwater a tangible part of IWRM? As mentioned, prior to the GRIP it was difficult for a water resource planners and managers to get a regional perspective on groundwater in a reasonable time, the GRIP approach allows information regarding (i) regional groundwater (ii) site specific groundwater and (iii) hard-copy files to be almost immediately available anywhere in the world. The data can be manipulated with a GIS programme, for example ArcView to compile a series of regional groundwater information sets or site specific information sets and to use the information sets to help promote groundwater as feasible option. The case study typically presents a regional data query and assessment using the current GRIP web-based data, Excel and ArcView 3.3. Most DM offices in Limpopo have access to Excel and the Internet and uses ArcView as a mapping tool. Therefore it is assumed that the DM offices have a fair understanding of the application of these tools.

8.1 REGIONAL PLANNING AND MANAGEMENT: CASE STUDY 1

8.1.1 Aim

The aim is to show how municipalities, for example the Mopani DM, typically need to update their groundwater situation assessments and development plans as part of their WSDPs. Previously it was difficult to get hold of groundwater information and most of the time groundwater information were guesstimated.

8.1.2 Methodology

Access to the database is obtained through the web as discussed above and the data obtained with the hotspot method. The area of interest as mentioned is the H14 area or the Giyani area and the data is downloaded for H14, exported as an Excel spreadsheet and saved as a dBase file. The municipal office also has access to basic infrastructure data including roads, rivers, villages and the H14 boundary and uses this as background information.

The data is sorted in Excel as the entries may vary from boreholes, booster pumps, purification works, weirs well points, to dams or reservoirs. Therefore by using the sort function all the boreholes are

identified and the rest are cut and pasted into a different worksheet, leaving some 540 boreholes available. The Excel spreadsheet is then exported as a dBase file.

The data set is added to ArcView as a table and through the legend editor several planning maps and data sets are developed for future planning. The basic data set has 548 entries in the H14 area, however the data is in a fairly robust format with many empty boxes or entries with validation errors for example the depth of boreholes. Using the legend editor, these entries were not included in the planning map sets.

8.1.3 Results

8.1.3.1 Borehole coverage and status

The first planning map is a basic borehole coverage map showing borehole coverage as well as the status of the boreholes in a specific area (Figure 62). It clearly shows that the H14 area was intensively explored in the past and at first it seems as if there is very little room left for the development of new boreholes. The data also shows that 27 of the boreholes are destroyed and that 338 are unused. A planner can now, before initiating further groundwater exploration projects, include in the WSDP a borehole yield analysis with the aim to test existing boreholes through a borehole testing programme. Furthermore, and possibly more significantly, it indicates that groundwater was and still is used in the area. Groundwater can be used as a future resource, thereby prompting the planner's interest in groundwater.

8.1.3.2 Type of equipment and condition

In order to obtain a better picture of the use and current abstraction it is required to know which of the boreholes are equipped and with what type of equipment the borehole is equipped. Using the same dataset and by applying a different field value the different types of equipment can be viewed. By double clicking on any specific borehole the detailed information concerning the pump house, floor pulley, serial numbers, sectorial use etc. can be obtained and viewed (Figure 63). The results of the coverages show that 239 boreholes are equipped, however only 175 are in use. Sixty four boreholes can be repaired.

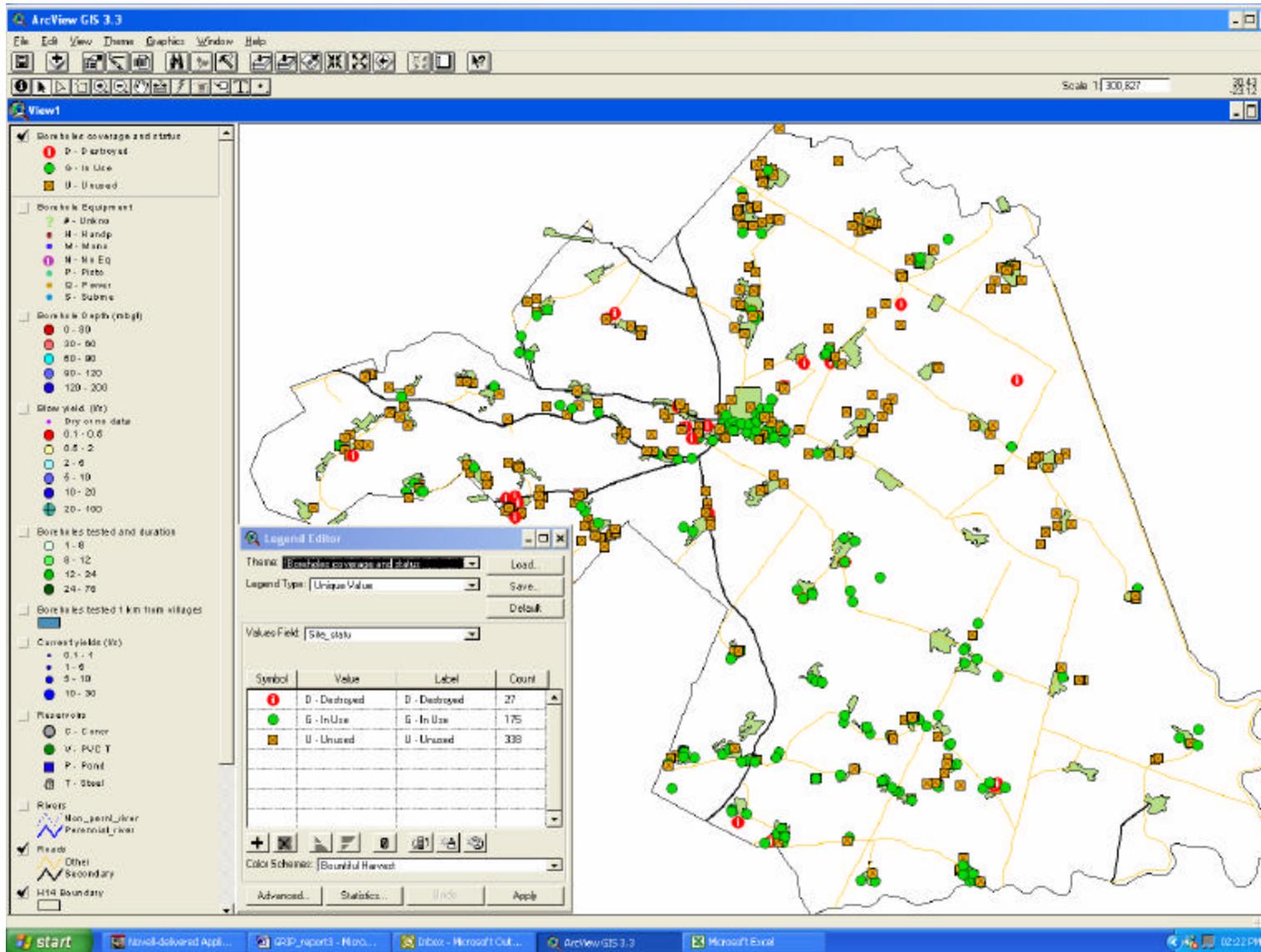


Figure 62 Borehole coverage in the H14 area with the status of the boreholes

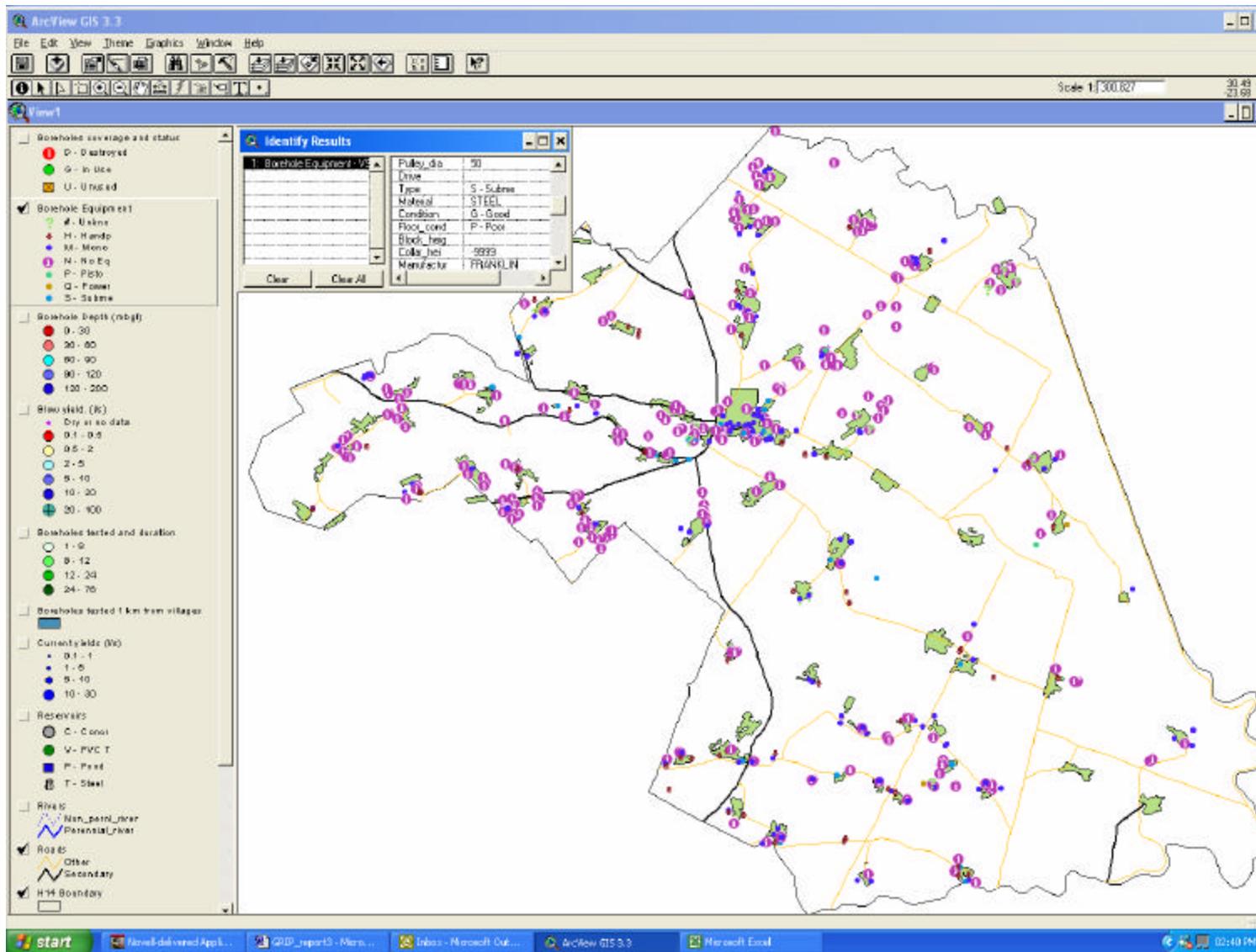


Figure 63 Type of equipment and the condition thereof

8.1.3.3 Borehole depths

From the data set 91 boreholes have no information concerning depth and 167 boreholes have a 0 entry, leaving 288 boreholes with known depths in the area. The majority of the boreholes were not drilled very deep with 24 (8.5%) boreholes between 0.1 m and 30 m, 150 (52%) boreholes between 30 m and 60 m and 82 (28%) between 60 m and 90 m. Therefore almost 90% have only been drilled to a depth of 90 m and little of the boreholes intended to explore the deeper aquifer system (Figure 64).

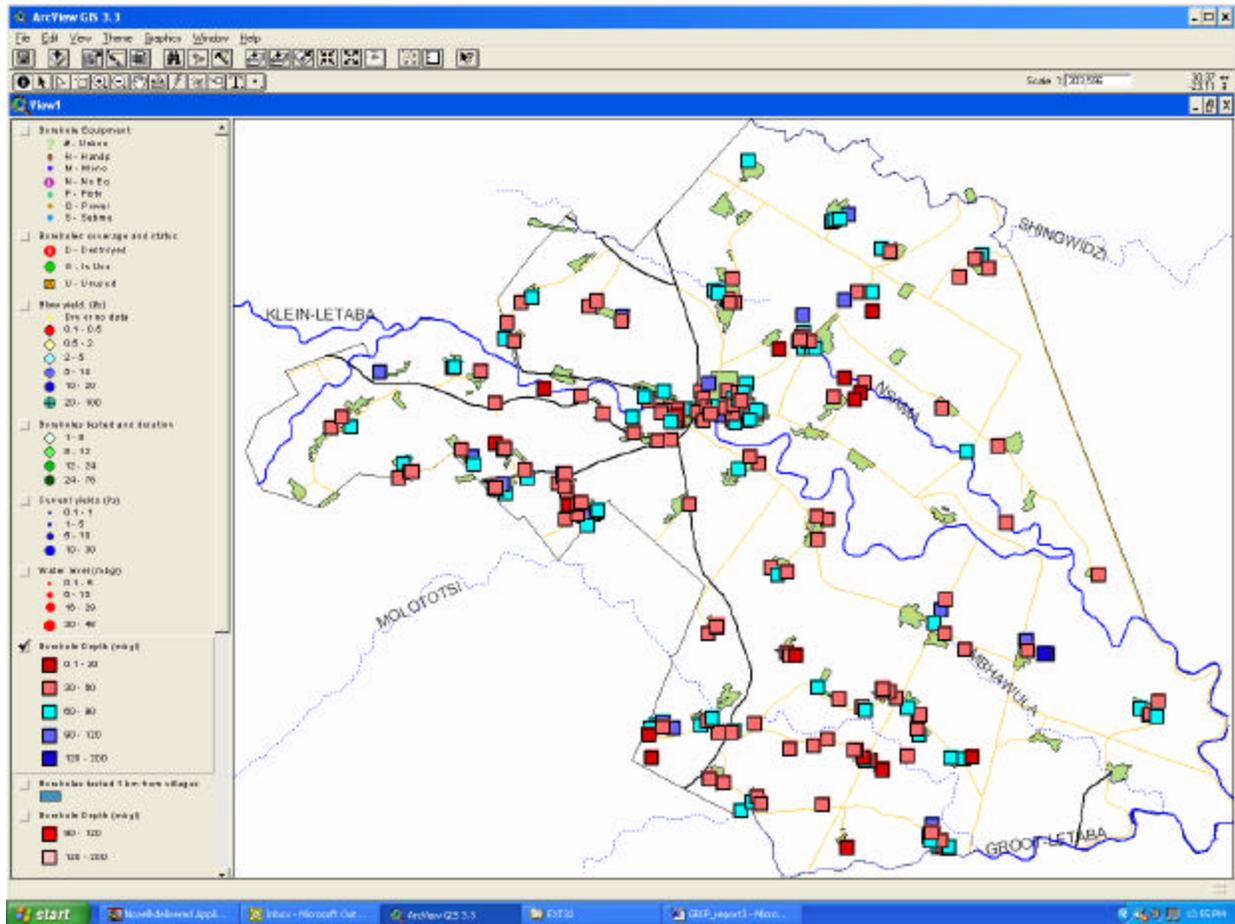


Figure 64 Borehole depths indicating that most boreholes are drilled between 30 and 60 metres deep.

8.1.3.4 Blow yields, actual yields and aquifer tests

Results from the blow -yield data are not promising and indicate that a large portion of the boreholes had a zero blow yield or no data at all. Therefore to guide a planner in identifying which of the boreholes have a yield worth including in a test analysis programme, a combination of sorting can be applied. First identify those boreholes already equipped (Figure 65) but not in use. If not included in

the first selection, include those boreholes which have been tested previously and lastly, if not selected through the previous rounds select boreholes with high blow yields. The reason for this selection approach is that in many cases borehole blow yields were lost and the boreholes were tested at a later period, therefore having a significant yield but a zero blow yield. In the event that only blow yields are the selection criteria for boreholes to be included in the borehole pump test programme, then many boreholes having high yields may not be selected for such a programme.

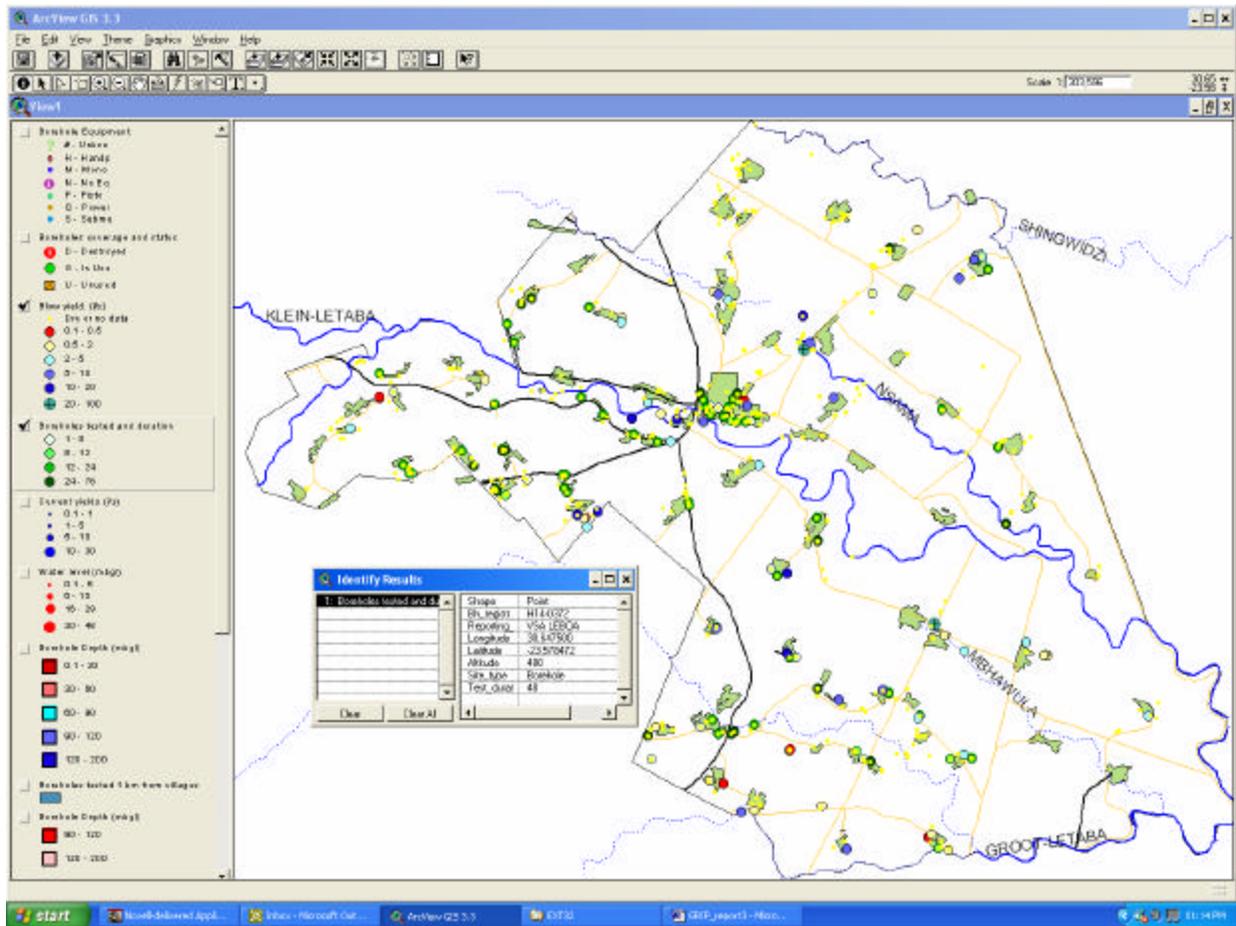


Figure 65 By combining both the blow yield and the borehole test data it becomes clear that although a zero blow yield was recorded the borehole may have a significant yield

As discussed above, various other maps and data sets, including sectorial use, information concerning the equipment and the condition of associated infrastructure are available. When it comes to detail design, this information will be required. However for a broad perspective and inclusion into the WSDP the maps developed give a good indication of future requirements for groundwater development, operation and management of the already available groundwater resource in the H14 area. By using a combination of these data sets effective planning can be done using the GRIP planning software.

8.1.3.5 Planning for future groundwater resources

For future groundwater exploration a planner needs to identify villages where groundwater exploration has not take place in the past. By applying the buffering technique (available in ArcView) with the borehole coverage, a planner can view all villages further than 1 to 5 km away from any known borehole. For example, by using the buffering technique one can list all the villages further away than 1 km in a table. In the case study 11 villages were identified and could be considered in a borehole exploration programme, prior to a borehole testing programme. The radius or distance chosen from a village is the prerogative of the planner, guided by the available budget or the political preferences. Using this technique different distances could be decided on, thereby prioritising villages to be explored. For example, at a distance of 5 km from existing boreholes only 2 villages in the H14 area have had no groundwater exploration (Figure 66).

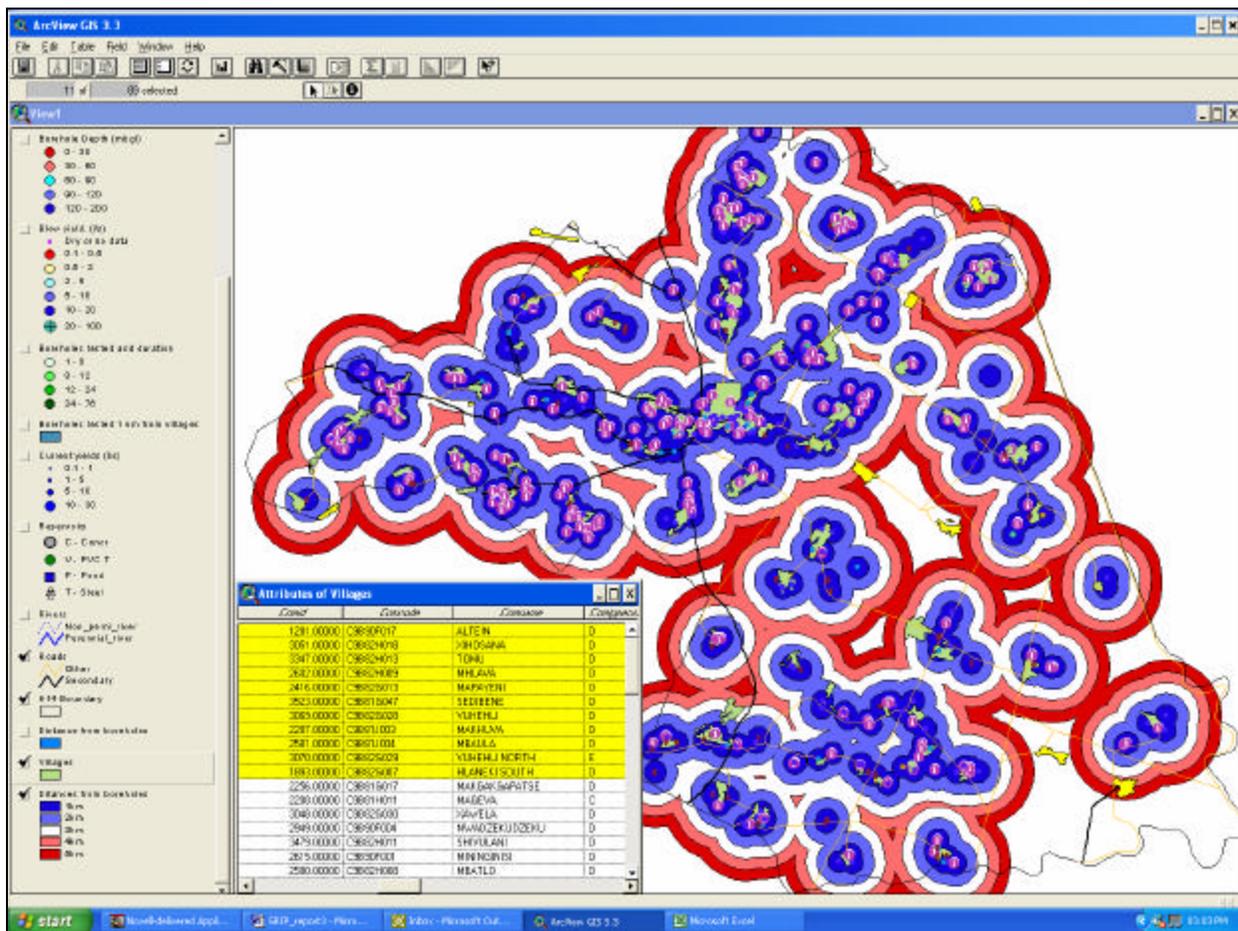


Figure 66 Buffering the current bore hole coverage to identify villages where groundwater exploration has occurred and listing those in excess of 1 km.

8.1.4 Conclusion

The water services planner responsible for a water services area, now has all the information available for the next financial year to provide a better estimation of the scope of work required. Therefore, in the spirit of IWRM, political, social economical and environmental factors can, for the first time, be used together with groundwater information derived from verified field data, to implement IWRMP in different water services areas or municipalities.

Due to a lack of reliable information, water services planners in district and local municipalities have negative preconceived ideas about groundwater. The first will be won if water service planners and managers realise they can make informed decisions concerning groundwater, using the presented groundwater information. Thereby giving groundwater an equal opportunity in the world of IWRMP.

The second battle will be won when water services planners or managers implementing groundwater supply schemes, (i) overcome the difficulty to access groundwater information and (ii) present groundwater as a favourable option to the municipal boards. The information sets discussed above allow water services planners and managers to showcase groundwater in its regional context, demonstrating there is information available for quantity, quality and infrastructure. There is enough information available to make an informed decision, thereby using the information sets to influence political, social and environmental beliefs in favour of groundwater. Thereby giving the municipal board the confidence to use groundwater as a sustainable water resource.

Previously boreholes were seen as point-source supplies and for every new need a new borehole was drilled. Water service planners and managers at municipal levels need to realise that it is not necessary to drill new boreholes each time. Existing boreholes might be refurbished and/or tested and can then be used as a sustainable supply. The number of boreholes not in use, broken or destroyed also highlights the importance of proper groundwater management plans. This again raises the issue of sustainable use in the context of maintenance and monitoring. The information therefore helps the operation and maintenance teams to focus their efforts on predefined infrastructure with known positions.

The information sets can also be used to train pump operators, drillers, the general public and local schools concerning groundwater use and management.

8.2 SITE-SPECIFIC PLANNING AND MANAGEMENT: CASE STUDY 2

Often site-specific queries as a result of political pressure require quick answers. Or following the broad development of a WSDP for the DM, the planning engineer need to develop a site-specific water-supply business plan for a certain community.

8.2.1 Problem

Typically in a municipal board meeting the village of Zala, in the H14-region, would be mentioned as a result of politically or personally motivated reasons. The town engineer needs to give a quick and simple answer to the mayor the following morning to discuss a plan of action. By using the same data set as downloaded from the GRIP website the town engineer can provide a quick assessment of the groundwater potential in and around Zala.

8.2.2 Methodology

A project is opened in ArcView and Zala is selected from the village theme and all the information for Zala is available immediately.

8.2.3 Results

The village has a population of just over 5 500 people and in total there are 8 boreholes in Zala, of which one is destroyed and two are not in use. The data indicates that four of the boreholes equipped with mono pumps used for agricultural purposes. There is one borehole equipped with a submersible pump for public use and one hand-pump for backup (one of the boreholes is not in use). Four of the boreholes' depths are available with an average depth of 60 m. The deepest borehole is 65 m deep and it can immediately be deduced that little is known on the deep groundwater development potential. Based on the blow yields an intuitive idea of the T-value can be deduced. One of the boreholes have a blow yield of 10 l/s, indicating if correctly sited boreholes may, have high T-values. The chemistry of the groundwater however maybe of concern, with two of the high yielding borehole having an EC value in excess of 70 mS/m. The information also indicates that there are two reservoirs at the village, one being concrete and one being PVC. It is not clear from the data, but from experience gained in Limpopo it can be speculated that the concrete reservoir is used for public purposes and the PVC for agriculture proposes. Most of the information can be plotted on a map using different symbols and graduated colours (Figure 67).

8.2.4 Conclusion

The town engineer or water services manager can report back to the mayor by using (i) the map and (ii) the associated borehole data sheet. It can be concluded that there is no need to drill new boreholes at Zala but there is an operation and management problem. The operation and management team is sent to investigate the cause of the breakdown in supply at the equipped borehole (submersible pump) and also to fix the broken hand-pump to be used in the meantime and as a future backup supply. The engineer can also report that he/she had an early-morning discussion with his/her counterpart at the Department of Agriculture, discussing the issue of also equipping one or more of the boreholes used for agricultural purposes, with the required infrastructure to enable the village use them for emergency domestic supply.

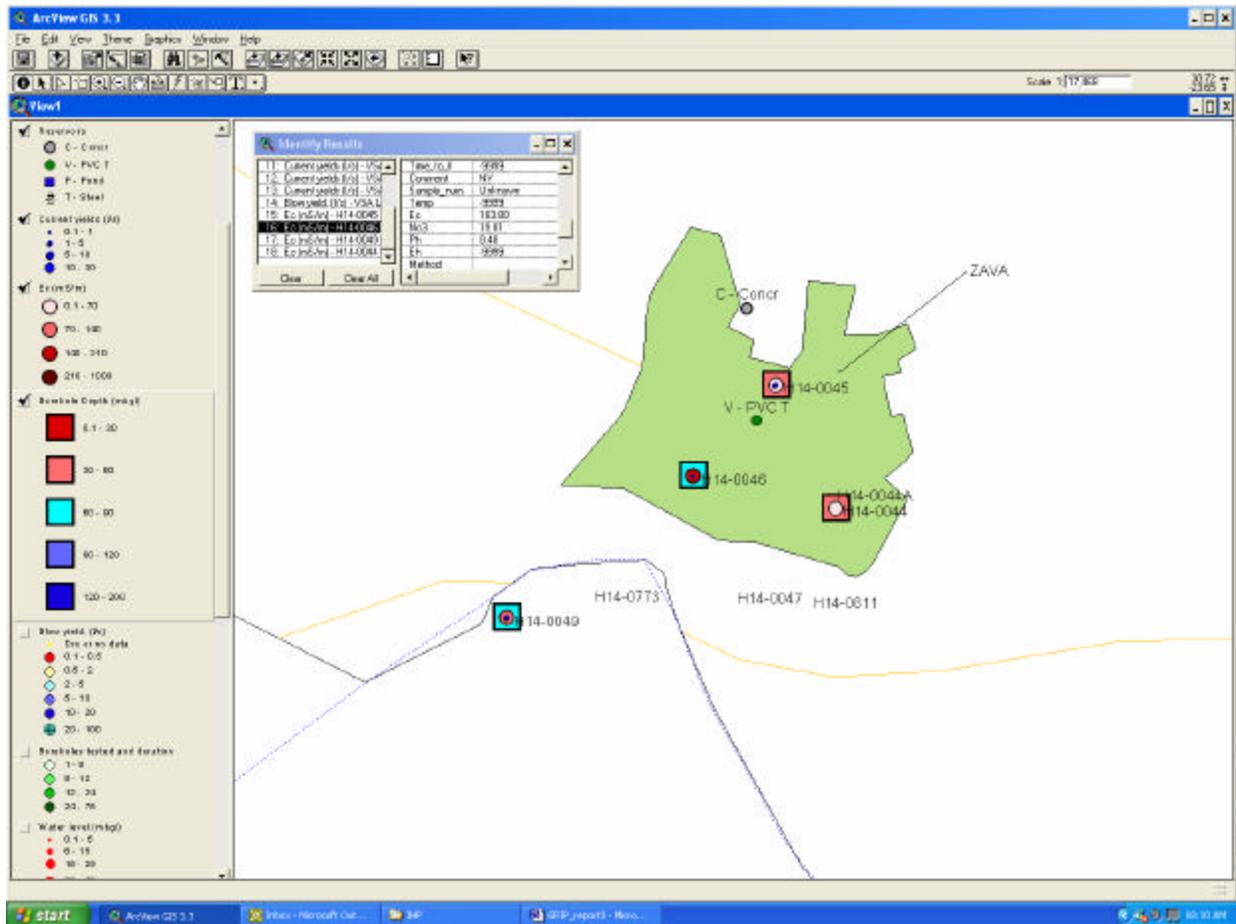


Figure 67 By using different symbols and graduated colours one can show yield, EC and borehole depth as well as the reservoirs at Zala.

In the emergency business plan the town engineer can also propose testing of all available boreholes at Zala. Based on the test results, the boreholes with high enough sustainable yields and good water

quality can be considered for refurbishment, pending of course on other economical, social and environmental factors.

8.3 NATIONAL WATER RESOURCE PLANNING: CASE STUDY 3

8.3.1 Aim

The aim is to show how the GRIP can ensure that groundwater, in the South African context, forms part of the bigger IWRMP. A more recent and real-time case study played off when the Directorate NWRP, Head Office needed some answers concerning a Ministerial inquiry concerning the towns of Pearston, Jansenville, Willowmore, Aberdeen and Graaff-Reinet. Mr Frans Stoffberg, Chief Engineer for the Sub-directorate Southern Region, in a very short period of 48 hours required information concerning the groundwater situation in the towns mentioned above.

8.3.2 Methodology

The GRIP Eastern Cape database was queried and 17 reports were identified, having specific information on groundwater concerning the five towns. During the first phase of GRIP all the available reports from DWAF and consultants were copied and stored in the Eastern Cape Regional Office in Port Elizabeth and Me Jane Baron, the local DWAF geohydrological specialist conducted the query and made copies of the relevant reports for Mr Stoffberg.

8.3.3 Results

At his arrival at Port Elizabeth Airport, on his way to a decisive meeting concerning the 5 towns, Mr Stoffberg received the reports. The already available reports on groundwater, previously not known to Mr Stoffberg, gave him the confidence to support groundwater as a development option.

8.3.4 Conclusion

Previously, it was difficult and time-consuming for the Directorate National Water Resource Planning to get access to reports compiled by specialists for municipalities or consulting engineers, but through the procedure introduced in GRIP, it places vital information at the fingertips of water resource planners, enabling them to stand up in high-level meetings with the Minister with hard evidence in hand to support future groundwater planning, development, and management and thereby ensuring that in South Africa, groundwater stays part of the bigger IWRMP.

9 GRIP PLANNING TOOL

The water service planners and managers at municipal level, with the help of the GRIP data, will now be able to determine how many boreholes were drilled in the past, yields, depths, borehole coverage and density of boreholes, which towns have access to boreholes, what is the purpose of the boreholes and what sector uses it and is there any existing infrastructure associated with the boreholes, for example reservoirs. All these questions can be answered by using data abstracted from the gripdata.co.za or groundwaterdata.co.za websites. It however takes time to manipulate the data and some municipalities may still not have access to expensive GIS packages and the necessary skills to use the data effectively.

9.1 AIM

A planning tool was therefore developed to help the GRIP user to do limited planning and to equip the user with a freeware GIS viewer, designed for the GRIP dataset. It is also available on the website and can be downloaded for use.

9.2 METHODOLOGY

Regional planning requires a more comprehensive overview of an area and in this case H14 in the Mopani DM was investigated. When planning water supply there are basically three important aspects that need to be taken into account namely sustainability of the borehole, costs involved in development and water quality issues. To assist planners the methodology discussed in the following sections has been developed into software and the three aspects mentioned are taken into account in the software. It is however important to note that this is a planning tool and field investigations will have to be done to validate findings.

9.2.1 Sustainability

Boreholes should be sited in such a manner that there is minimum interference, thereby allowing the maximum sustainable abstraction rate per borehole. The blow yield can be obtained from the GRIP database together with pumping test data. If transmissivity values are available they can be contoured for the area under investigation. To increase the size and distribution of the GRIP data set, the blow yield values can be used to obtain an estimate of transmissivity.

A common rule-of-thumb is that the blow yield can be used as a first estimate of the sustainable yield of a borehole. The GRIP database has both sustainable yield entries and blow -yield entries – although

the data sets are not complete by determining the relationship between the sustainable yields and blow yields in a given area, it allows the planner to use blow yields to determine sustainable yields. In the planning software this relationship is determined by means of a linear regression where $y = bx + c$. Both y and x represent a given set of points and in this case sustainable yields and blow yields. The other two parameters a and b are defined as:

$$(eq.7) \quad a = \bar{Y} - b\bar{X} \text{ and } b = \frac{n \sum xy - (\sum x)(\sum y)}{n \sum x^2 - (\sum x)^2}$$

where \bar{Y} is the average of all the y set of points, \bar{X} is the average of all the x data points and n is the number of data points in each set. The sustainable yield can be used to determine the transmissivity (T) of the aquifer using the following rule-of-thumb: $T \text{ (m}^2/\text{d)} = 10 \times \text{sustainable yield (l/s)}$. Once the transmissivity has been determined radius of influence (r_e) of existing boreholes can be determined using the following formula:

$$(eq 8) \quad r_e = 1.5 \sqrt{\frac{Tt}{S}}$$

where t = time for which the radius of influence is to be determined (usually a period of 1 year) and S is the storativity of the aquifer.

The transmissivity contour map and the radius of influence map for existing boreholes can now be plotted together. Highly transmissive areas not influenced by current abstraction boreholes, can be targeted for future development.

A method of testing the sustainability of these target areas is by determining a radius of influence for the potential borehole and ensuring that it does not intersect any existing borehole radii. In addition if a borehole is sited close to a river the planner must be aware of Reserve determinations (NWA, 1998). A flag will appear in the software to remind the planner of these considerations.

9.2.2 Costing of groundwater

In order to be able to compare the viability of groundwater compared to that of surface water, a costing tool is included. Aspects such as the development and testing of a borehole are included in this section. A calculator is then available to do the calculations associated with the costing. Aspects included in the costing tool are: borehole siting, drilling costs, casing, borehole testing etc.

9.2.3 Electrical conductivity

There is water quality available in the GRIP database. Most boreholes have an EC reading. These EC values are automatically plotted with the boreholes by means of a colour scale with the following ranges:

- Green < 70 mS/m
- Yellow 70 – 150 mS/m
- Red > 370 mS/m

The planner can therefore see what the quality of the groundwater is in the regions targeted in Section 9.2.3.

9.2.4 The influence of pit latrines

As GRIP focuses on the rural communities in Limpopo, the influence of pit latrines have to be taken into account as these are in most cases the only form of sanitation. There are 2 major water quality issues resulting from pit latrines when dealing with groundwater, namely nitrates and microbial contaminants. Nitrates cause cyanosis due to methaeglobinemia, which is toxic to infants. Nitrate can also reduce to nitrite, which combines with haemoglobin (oxygen-carrying red blood cell) to form methaemoglobin. Methaemoglobin is incapable of carrying oxygen. Bacteria and viruses can cause a number of illnesses such as typhoid fever, cholera, gastro-enteritis, hepatitis and meningitis.

Protection zones around planned boreholes are included to ensure that there will be no effect on the groundwater quality as a result of on-site sanitation.

The radius of a fracture as defined and calculated in the FC-method can be used to determine the protection zone. Various protection zones can then be delineated with associated risks (Van Tonder *et al*, 2001) as shown in Table 10.

Table 10. Risk associated with various protection zones

Risk	Protection zone
High or very high risk of microbial pollution	2 times fracture radius
Low risk for microbial pollution	1 times fracture radius
No risk for microbial pollution	0.5 times fracture radius
High risk for N for infants	2 times fracture radius
Low risk for N for infants	1 times fracture radius
No risk for N for infants	0.5 times radius

In order to calculate these protection zones on a planning level, where fracture information is not available, pump test data was analysed with the FC-method to determine transmissivity values and calculate the fracture radius (Figure 68). These two parameters were then plotted against each other to obtain a relationship between them. Transmissivity values can then be used to determine the fracture radii and protection zones.

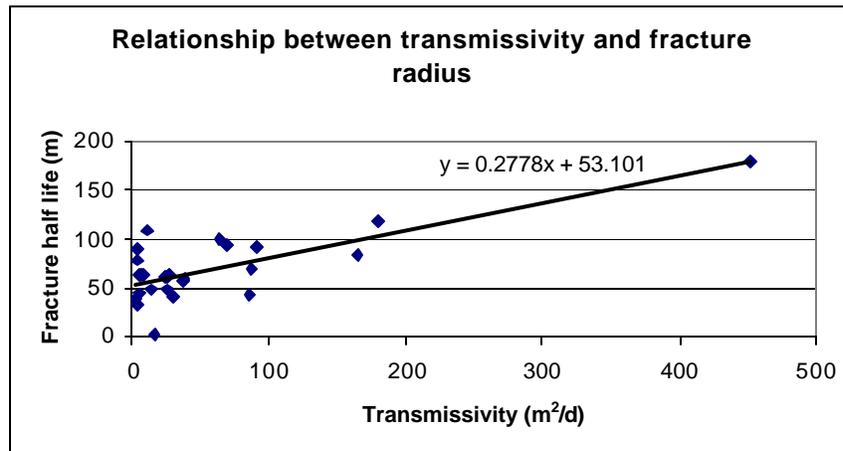


Figure 68 Relationship between fracture radius and transmissivity

The software (included as an attachment) is started up with the splash screen (Figure 69).



Figure 69 Splash screen for GRIP planning tool

9.3 RESULTS FROM THE DEVELOPMENT OF THE GRIP PLANNING TOOL

9.3.1 Planning views

Data exported from the GRIP database can be imported into the planning tool. The data columns used by the planning tool are borehole name, borehole depth, water level, blow yield, yield, EC, borehole co-ordinates and whether the borehole is in use or not. In addition to the data from the GRIP database, the planner can also pull in shape files. In this case the boundaries of the study area, the roads and river coverages have been included. These are displayed in a geographic environment (Figure 70). Boreholes not in use are displayed with crosses and boreholes in use are displayed with circles. If EC data is available the circles will be coloured in according to the scale defined in Section 6.1.3.

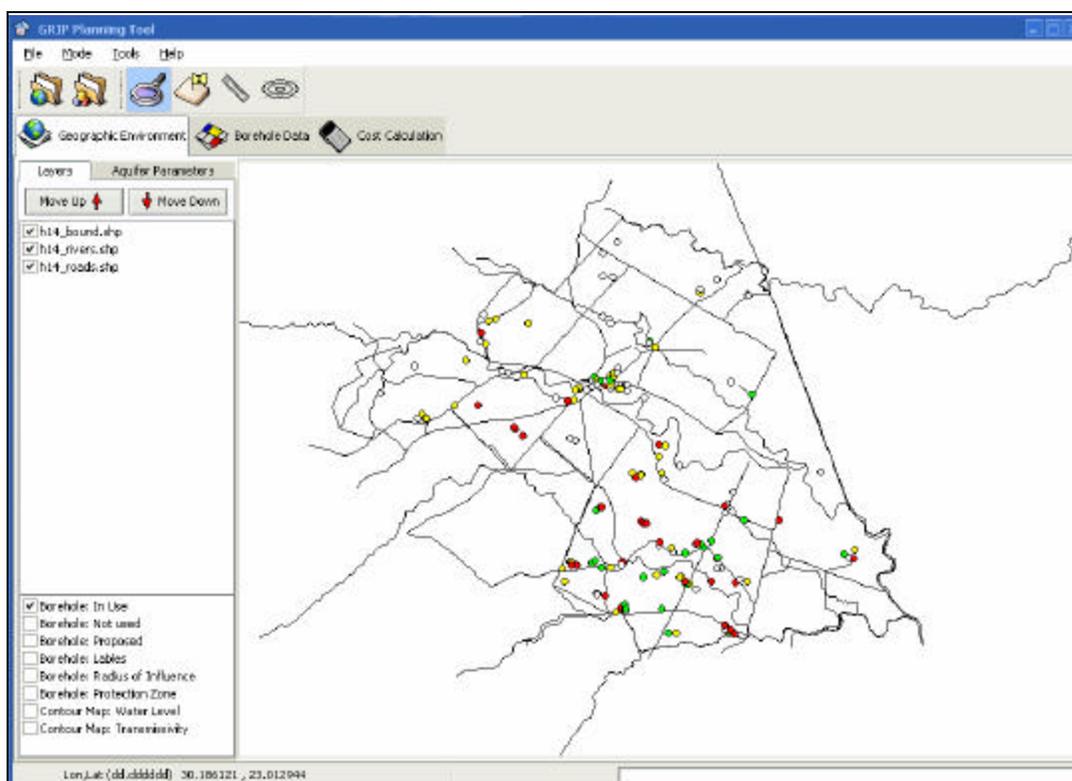


Figure 70 Available data displayed in GRIP planning tool

The software also determines the regression between yield and blow yield and plots a contour map of the transmissivity values as discussed in Section 6.1.1.4. The factor 10 is a default value used but the software allows the planner/user to vary the value. Once the transmissivity values are plotted (Figure 71) the radius of influence can be determined for the boreholes in use (Figure 72).

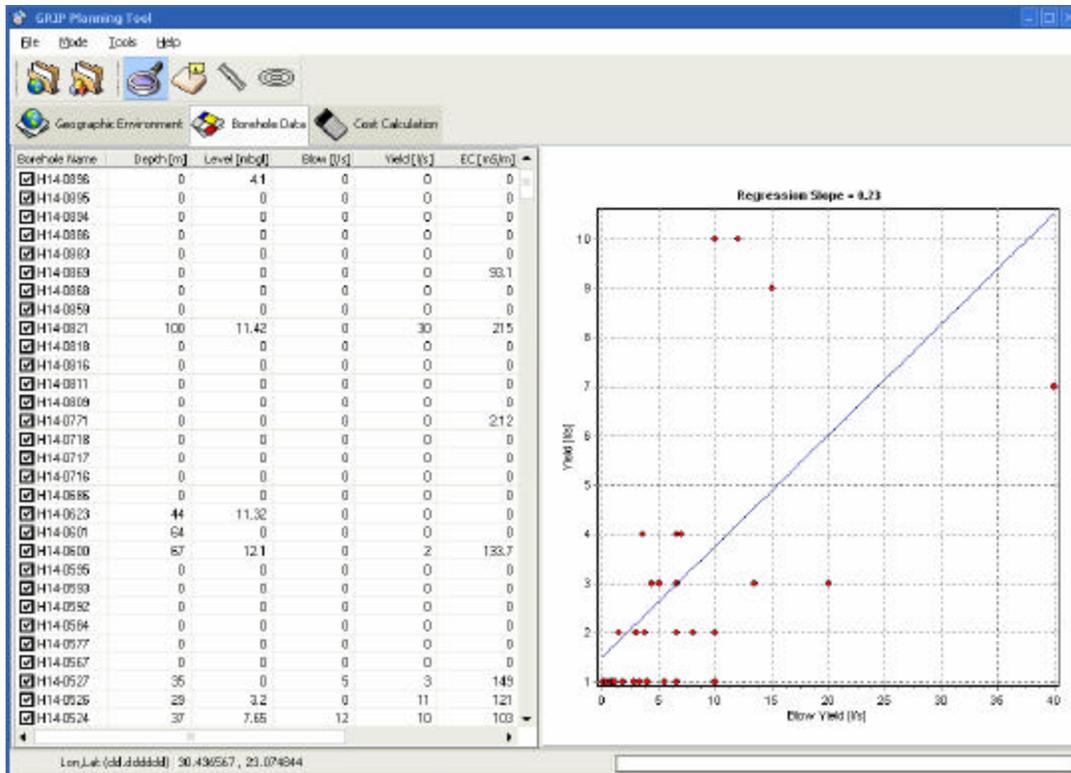


Figure 71 Regression values derived from available data

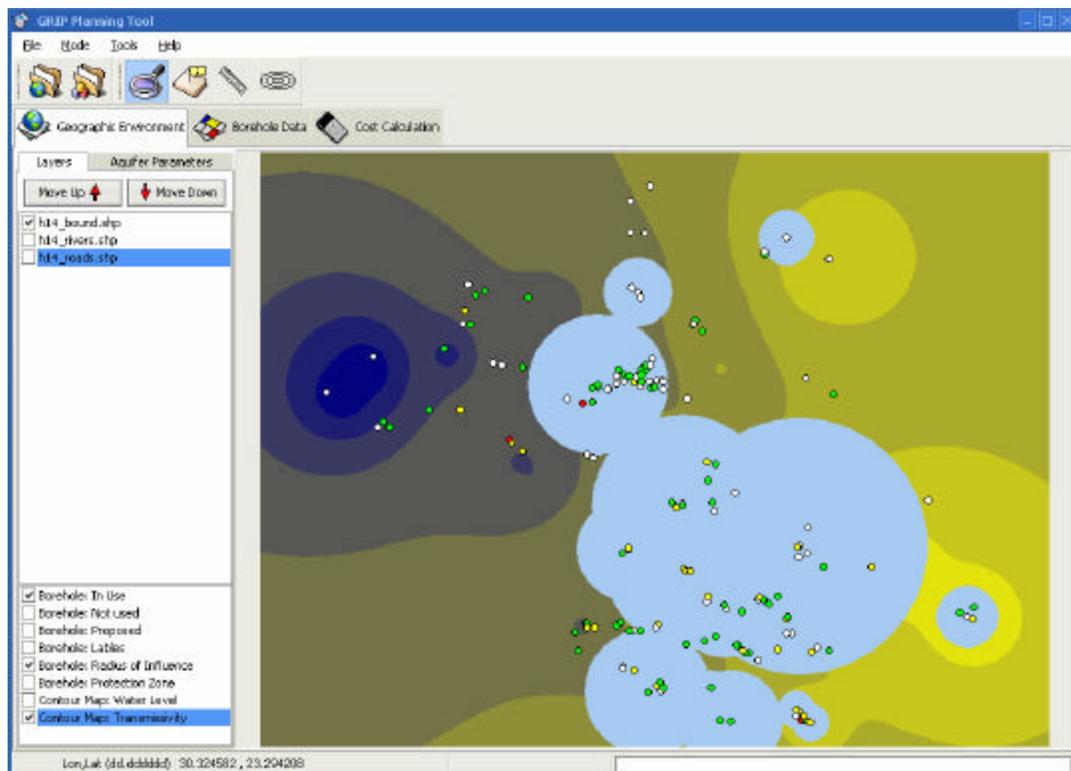


Figure 72 Contour map of transmissivity values and radii of influence

The planner can then view all the information available on the screen and place a borehole accordingly in areas where the transmissivity is high, electrical conductivity values are low and there are no overlapping radii of influence (Figure 73).

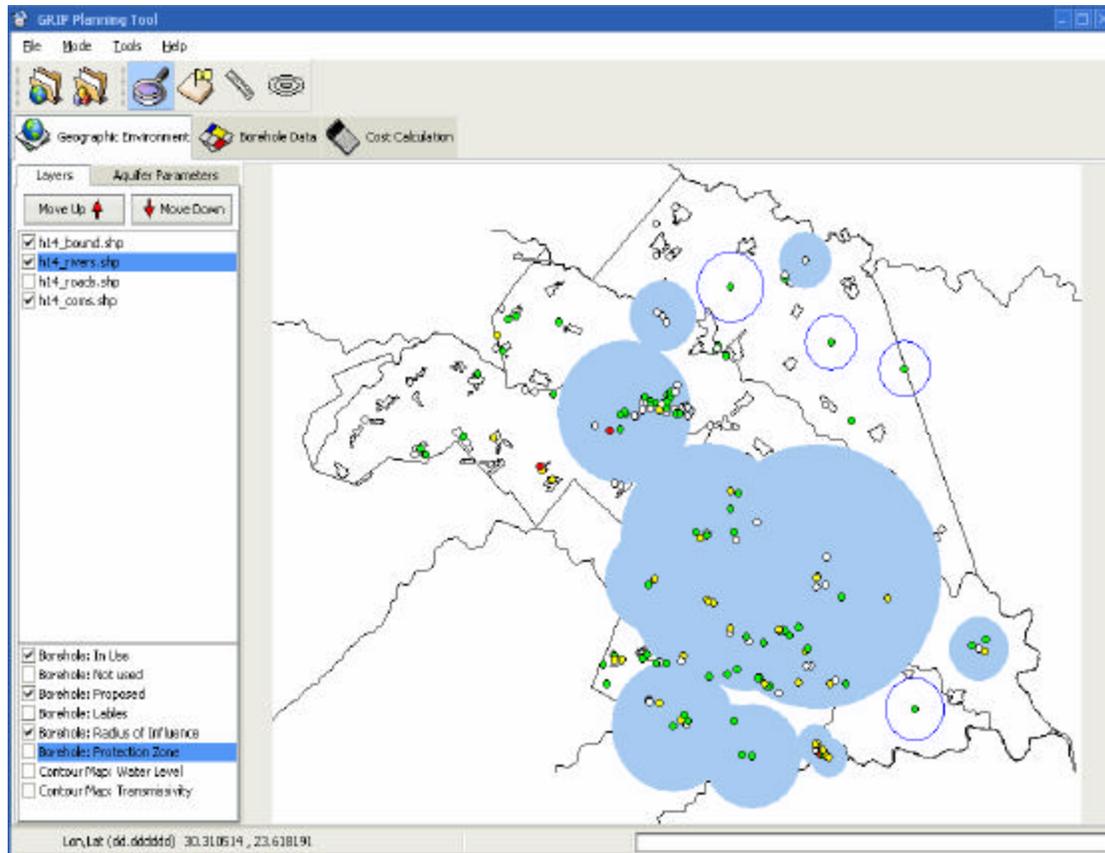


Figure 73 Placing of 4 potential boreholes

Once the borehole has been placed the software plots a protection zone as defined in Section 9.2.4. The protection zone and radius of influence for a new planned borehole is calculated from the information obtained from the closest boreholes and transmissivity contour map. If the radius of influence intersects another radius of influence the planner can slightly alter the placing of the borehole.

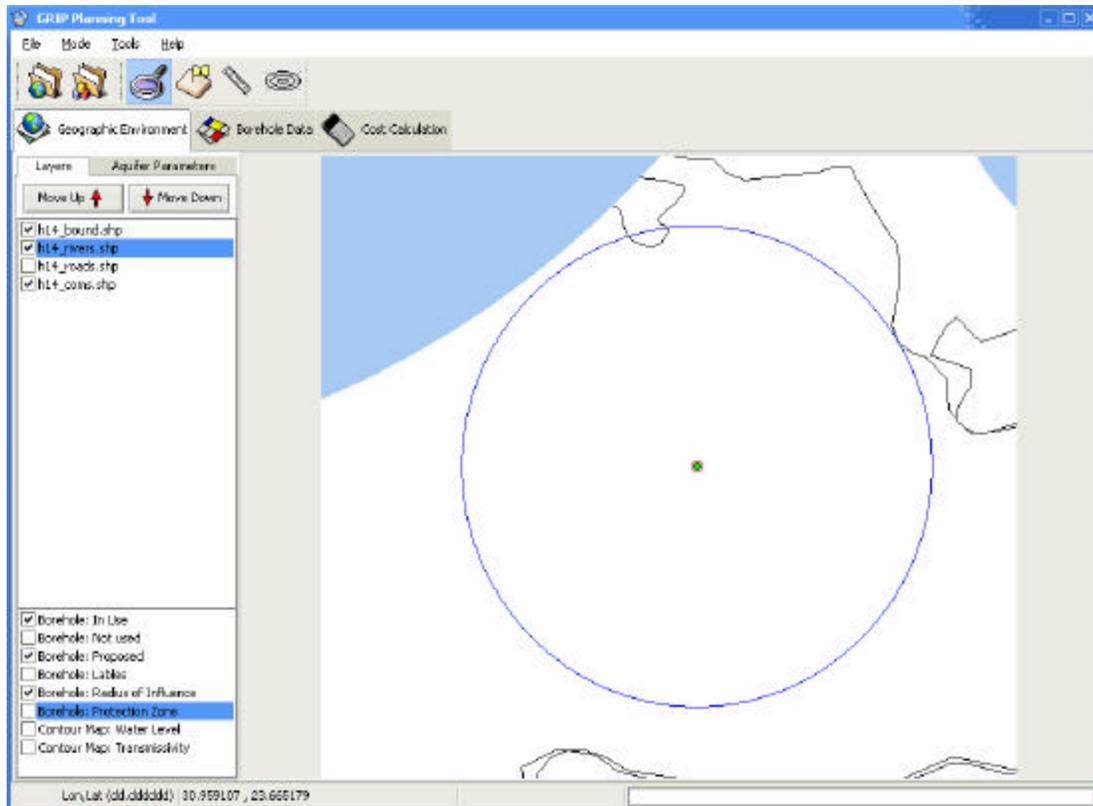


Figure 74 Zoom view to show radius of influence (blue) and protection zone (orange)

9.3.2 GRIP costing tool

The costing tool is selected for the borehole. Information from the closest existing boreholes already in the system will automatically be pulled through to the costing tool. The planner can then enter the costs related to the development of this particular borehole (Figure 75).

In addition the software will allow the user to enter the amount of groundwater needed in the area. The above process can be repeated until the target volumes are reached. A total cost will then appear for the target volume. The software then allows the planner to run various scenarios. In addition the software includes additional features such as allowing the planner to determine the distance between 2 points and to query the attributes attached to the imported shape files (Figure 76).

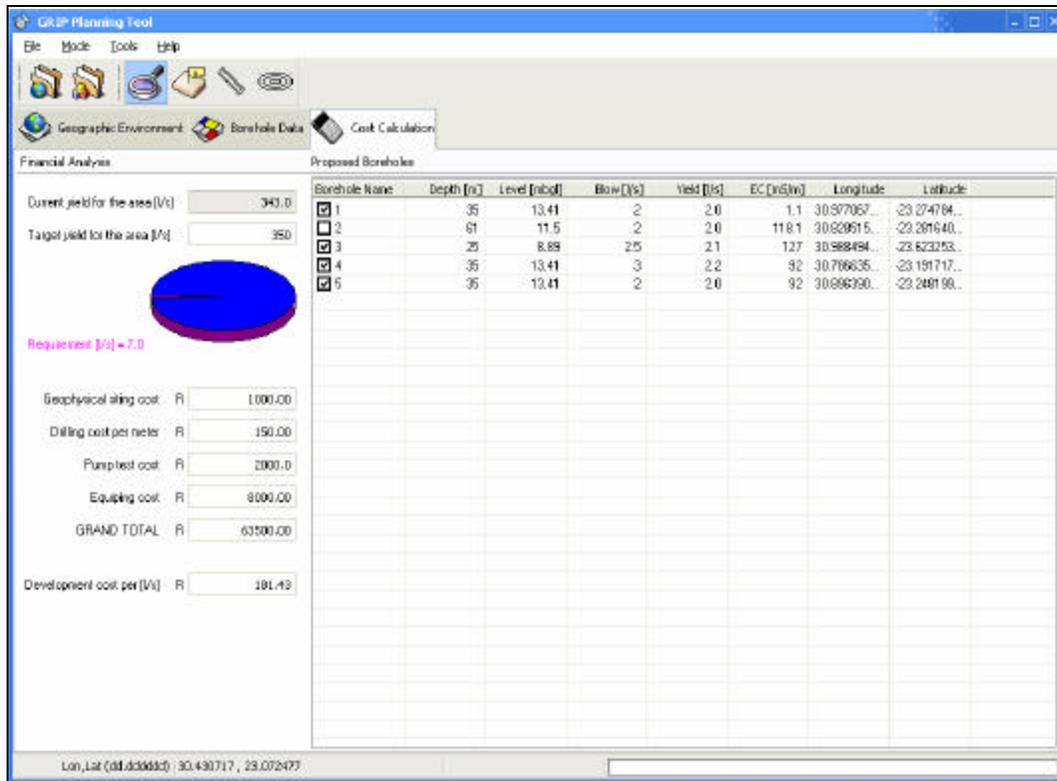


Figure 75 Costing tool as part of the GRIP planning tool

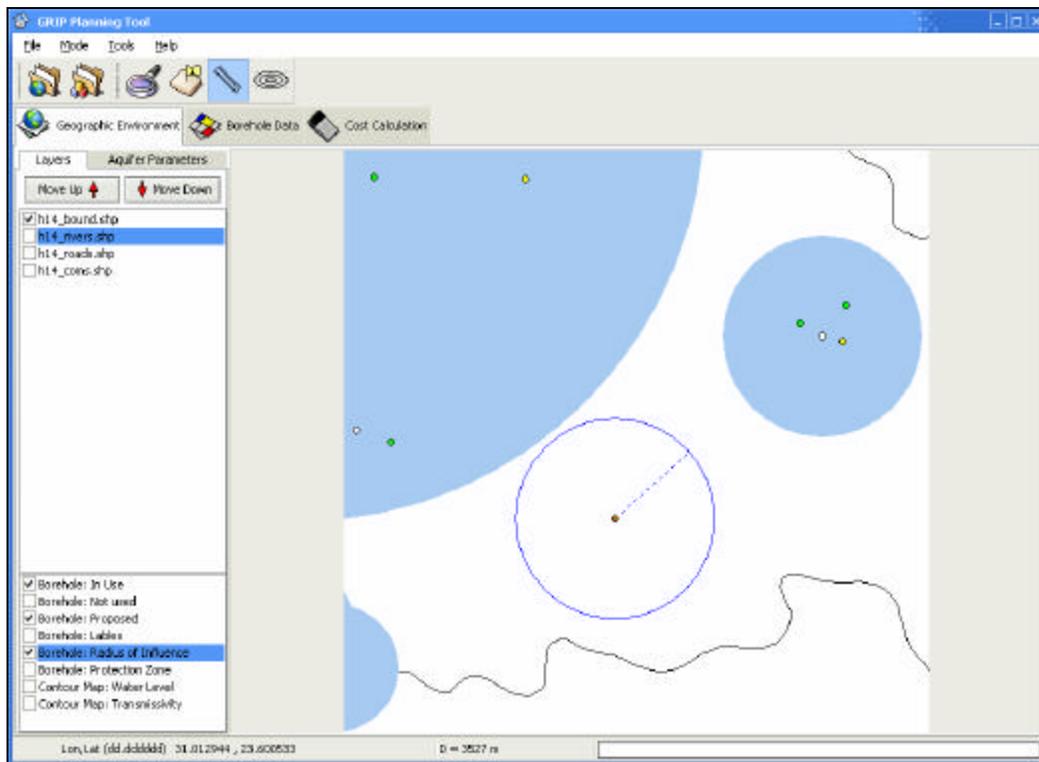


Figure 76 Additional features available (measuring radius of influence = 3527 m)

9.4 CONCLUSIONS

In the event that a planner or geohydrologist do not have access to a statistical GIS package, for example ArcView, then the GRIP planning tool can be downloaded from the Internet and used for developing information sets for in current management and future planning. The GRIP planning tool allows for similar results as in Case study 1, but limits the user to certain applications and because it has predetermined applications, it is easier to comprehend and apply.

The GRIP planning tool methodologies developed provide a broad perspective and a good indication on the current status of the boreholes in a region, potential target areas for groundwater development and highlight protection zones. The GRIP planning tool show the number, position, blow-, recommend and quality class of boreholes as a view and based on the recommended yields and the yield required, a water service planner can place “new” boreholes to meet the required yield. Based on the available borehole yields an estimated yield is calculated for each “new” borehole. This allows a better estimation of borehole requirements and how much money is to be spent on borehole development.

The GRIP tool is easy to download from the Internet and can be used by most potential users having access to the Internet.

10 FINDINGS

10.1 STRATEGIC ROLE GRIP PLAYS IN IWRM

The theme of IWRM carried through the study illustrates how integration of water resources through management and planning requires different water resource managers and planners to play their parts to ensure sustainable development and use of water resources. In South Africa, due to our lack of available water resources, this is more so and through the NWA and WSA, South Africa has made IWRM a tangible entity. At municipal level in rural areas, groundwater is still, and will be for a long time to come, not managed at a level that will ensure sustainable development thereof. The basic component to develop management and planning information sets, namely individual borehole data points are not verified and readily available in rural South Africa. The GRIP introduces a unique implementation methodology whereby various components, database requirements, dissemination of information and on-site experience, are combined to develop a methodology to capture, verify, manipulate and present individual borehole data thereby introducing groundwater as a feasible option as part of IWRM (Figure 77).

10.2 HYDROGEOLOGICAL VALUE OF GRIP

As a result of the implementation of the GRIP in the rural parts of the Limpopo Province, this area has the most comprehensive geohydrological dataset in South Africa, containing (i) verified borehole datasets and infrastructure information, (ii) predefined reports for each H-region and allocated according to district municipalities, (iii) the WMS database that was and continues to be populated through samples taken during GRIP and implementation of the next phases, (iv) after completion of GRIP more than 4000 borehole pump tests will be captured on Aquabase, (v) evaluations by using the FC-method and (vi) it is easily available on the Internet. The datasets are therefore available to anyone and can be used for future studies, bettering geohydrological concepts.

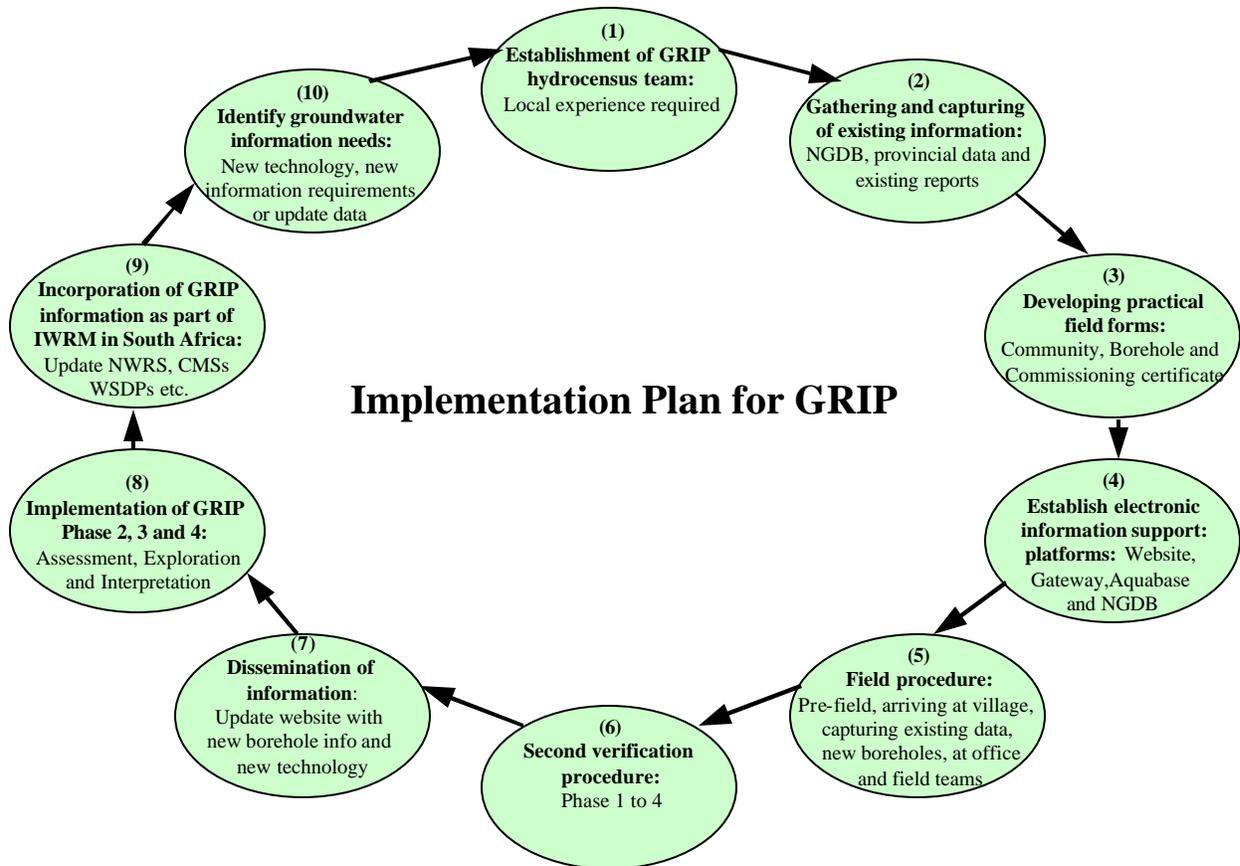


Figure 77 Schematic illustration of the implementation plan for the GRIP methodology.

10.3 HYDROCENSUS

The operational groundwater hydrocensus has been done in South Africa over the last 30 years. Depending on the requirements, the hydrocensuses were conducted only to meet the needs of specific projects. Groundwater hydrocensuses were conducted for various community supply projects and everybody assumed their method of conducting groundwater data collection was correct. Little has been said about the valuable contribution of a comprehensive, specifically-developed and well-executed groundwater hydrocensus in a rural environment and the positive effects it may have on IWRM. In South Africa, due to the lack of capital investment in source development during borehole-based water supply projects, hydrocensuses are almost always conducted at local level, with the exception of some DWAF Head Office projects. It is seen as an unnecessary financial obligation to projects and geohydrological information is rather captured through drilling of new boreholes than capturing information already available.

Therefore, the first hurdle to overcome was to secure capital and to continue to do so for a period to finish the initial groundwater hydrocensus assessment or phase 1. To do that the project management requested internal funding from DWAF with the motivation that the project will not only be technically and geohydrologically orientated, but water supply, operation, maintenance and planning will play an equal role during this first phase. The financial backing pushed the project development towards a more overarching community and borehole data-capturing study, thereby capturing the requirements of the sponsors, DWAF Regional Office, as well as geohydrological data. A natural outflow thereof is that the GRIP fits right into concepts captured in IWRM and in our water resources Acts, therefore not only investigating pure scientific issues around groundwater, but also contributing directly to community water supply programmes and future planning of water supply projects. In an environment where delivery outnumbers pure science, the GRIP is a unique approach and continues to enjoy financial support in both Limpopo and the Eastern Cape. The data captured through the GRIP procedures can be applied at various levels of water resource management and planning.

10.3.1 Cost associated with groundwater resource management in the Limpopo Province

The data collected gives a devastating picture of the boreholes captured during the Groundwater Resource Information Project (GRIP) conducted in the communal trust areas. Out of 12 254 boreholes, 5788 (47%) boreholes were unequipped or destroyed, 3165 (26%) were broken and only 3301 (27%) are active. Therefore more than 50% of the boreholes once equipped are not working. The cost to repair those boreholes broken will conservatively be around R15 million and the cost to re-drill the unequipped or destroyed boreholes R63 million. From the survey done some 4000 borehole-test data were found, with a current investment value of R45 million. For the remaining available ND working equipped boreholes, capital replacement cost is around R150 million. Therefore the water resource investment value is about R250 million. To put this into perspective - normally the capital available to develop boreholes as part of a community water supply project is about 10% of the total project cost. Using this percentage value and working back with the total number boreholes equipped (6466) the infrastructure replacement value may be in the order of R2 500 million.

10.3.2 Bore hole development

The borehole test data available indicate that each person in Limpopo could be supplied with 35 l/c/d. This clearly indicates that groundwater already plays a very significant role in water supply but that the operation and maintenance thereof is extremely poor. Furthermore, the mean average results indicate that there is more than 5 boreholes per village, although some villages may have no boreholes and

others in the order of 18 boreholes. It indicates that in many instances boreholes are drilled for the sake of drilling, without an effort to capture existing information available.

10.3.3 Planning and assessment

The GRIP data makes it possible for water resource planners and managers to use the borehole information and incorporate groundwater into their strategic plans. In DWAF the Directorate NWRP uses the GRIP data to conduct water situation assessments and future guideline documents such as the ISPs, forming the baseline documents for future development of CMSs. A more recent use of the GRIP data is the Regional Strategy and Infrastructure Plan for the Vhembe DM. The GRIP data indicated that there is definitely developed groundwater available and that existing sources can be expanded from 14% to 40%. This resulted in some of the surface water resources being diverted to regions less suitable for groundwater developments. Therefore the surface water can be used in another supply area or zone. The Directorate OA investigated development of new resources and recently used the GRIP data successfully to incorporate groundwater as a conjunctive resource in the Olifants River WRDP prepared for DWAF management, ultimately resulting in utilising groundwater in combination with surface water. The above-mentioned examples, demonstrates the use and advantages of having a verified groundwater database available when doing planning and assessment. It also illustrates that only by having well-verified groundwater information can and will it be incorporated into water management area planning.

10.3.4 Operation and management

Water service authorities can use the information to prepare proper O&M plans, but little evidence is as yet available to show that the data is used for these purposes.

10.3.5 Drought action plans

The verified information available on the databases, including Aquabase, NGDB and the GRIP website, generated via the GRIP can be used to great advantage in a time of drought to streamline emergency water-supply projects. It will enable the drought programme manager to immediately identify possible resources at different scenario levels. A first scenario can for example be to make a query to find out where boreholes with infrastructure are available but where they need minor repairs to function properly. From the GRIP database all villages where there are sufficient resources with equipment but where the boreholes do not work due to mechanical or electrical failure can then be

listed. In such a case GRIP therefore also lets the user know whether if the pump is diesel or electric. A second scenario will be to look at all the boreholes tested to find out where sustainable boreholes are in close proximity to the villages with drought-relief needs. By applying the above two scenarios the programme manager can already prioritise 75% of a drought-relief programme and start to send in maintenance and implementation crews where known resources are available and ready to be used.

10.4 GROUNDWATER AND REAL-TIME IWRM

The three case studies presented illustrate how the GRIP methodology, if implemented correctly, can produce groundwater information required for application at different levels of water resource planning and management. At a regional municipal level different information sets, for example more accurate groundwater resource maps for blow yields, recommended yields, quality water levels etc. and water services information, previously not available, can be produced to help with planning and management. The case studies also showed how the GRIP data set can be applied at community level for groundwater supply and management thereof. Most significantly, it showed how, at ministerial level confident support of groundwater development from senior water resource managers, as a direct result from implementing the GRIP methodology, can overcome huge political and social barriers for groundwater.

10.4.1 GRIP influence on NWRS, WSDPs, CMSs and ISPs

The NWRS will in the future use GRIP data to improve its reflection on groundwater's availability, use and protection and although not comprehensive enough, GRIP results are already included in several preliminary WSDPs and predefined results, similar to that on the GRIP website, are already presented in some WSDPs (Bohlabela District Municipality, 2005) and it is anticipated that future WSDPs will make more use of GRIP data. Several ISPs, for example the Olifants-, Limpopo and Letaba WMAs, included GRIP data to improve their presentation of groundwater use, development and future planning in the different WMAs. It is foreseen that CMAs will use the GRIP datasets when developing CMSs.

10.5 IMPLEMENTATION OF MONITORING PROGRAMMES

The GRIP dataset includes a vast number of boreholes in use and boreholes not in used. These were sorted and ranked according to monitoring the national groundwater monitoring requirements. Monitoring programmes were developed and implemented through GRIP. Therefore as a further

implementation of GRIP during 2004 and 2005 the national groundwater monitoring network was introduced in Limpopo Province, putting them 10 years ahead of any other region in South Africa (Van Wyk, 2005).

10.6 DISSEMINATION OF INFORMATION

The information disseminated from GRIP is done by following international examples, however, the GRIP website does not only serves as a groundwater or borehole database platform, but also serves the needs of the water service sector. Information is readily available and a unique GRIP planning tool places GIS, management and planning of groundwater in the hands of rural South African water services managers, often with limited monetary resources, limited GIS skills and little comprehension of groundwater's complexities, to start managing their groundwater resources in a more sustainable manner.

10.7 PROFESSIONAL INTEGRATION

Integration and transformation of different spheres in the professional environments, including geohydrologists, engineers, town planners, majors, municipal council members, surveyors, agriculturalists, water quality specialists, GIS specialists, academics, computer programmers and various other professionals, are all required to work together as a holistic and integrated team to implement a GRIP.

10.8 GROUNDWATER SPECIALISTS AND IWRM IN SOUTH AFRICA

Finally, from GRIP, it was learned that geohydrologists need to understand international and local concepts of IWRM and they need to speak as one, from one source, using verified information, creating an overarching trust in groundwater and thereby becoming part of a broader group of IWRM managers and planners.

11 RECOMMENDATIONS

This thesis starts to report on the lessons learned from implementing the GRIP, but in South Africa, even with full implementation of the GRIP, groundwater still have many known and unknown battles to fight before it will be fully assimilated into IWRM. The GRIP introduces a unique platform where from basic groundwater misconceptions, resulting from limited and incorrect data and information, can be challenged and hopefully rectified. Following out of GRIP are a few achievable recommendations:

- Complete all four phases of GRIP in the Limpopo Province
- Implement GRIP on a national scale
- Keep improving field forms
- When the NGA becomes available, import all GRIP data into the NGA
- Develop a legal system whereby data have to be reported to regional offices or CMAs
- Update the GRIP data through effective communication in and integration of different groundwater users and developers
- Update the GRIP dataset every five years through implementing a hydrocensus procedure
- Ensure that GRIP data is implemented in the NWRS, CMSs and WSDPs
- Improve the GRIP website as new technologies become available, for example capturing GRIP field data on the Internet using cellular phones (already achievable), real-time monitoring etc.
- Workshop GRIP with identified I&Ps every six months, ensuring continuous progress

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Summary

Groundwater forms an essential part of water supply in the Limpopo Province, South Africa. However, at planning level this message seems to be skewed and misinterpreted. Although a vast number of water supply schemes are developed using groundwater as a resource, these schemes are reported to fail and the resources are not considered sustainable. Therefore mistrust in groundwater has developed, planners effectively eliminate groundwater from integrated water resource planning and groundwater continues to be seen only as an *ad hoc* or emergency supply. The Groundwater Resource Information Project (GRIP) was introduced to compare available information with verified field information and it presents the information to planners and engineers in a format that is sensible and easy to incorporate, therefore presenting groundwater as an integrated sustainable and strategic resource. The work implemented during this project describes a hydrocensus - an information capturing and presentation protocol that can be introduced anywhere at any scale to give planners the opportunity to consider already developed groundwater infrastructure and incorporate it into the overarching planning. The methodology was developed to describe to the user how he/she should go about when conducting a hydrocensus to serve both the needs of water services and water resource managers

The development of groundwater in South Africa is discussed to provide a perspective on how groundwater was dealt with in the past and is looked upon now. Issues concerning groundwater resource mapping as attempted by the Department of Water Affairs and Forestry (DWAF) and the Water Research Commission (WRC) are discussed and commented on. Also discussed is the availability and format of groundwater data when creating maps and how the data are captured in the different databases. All the maps however are derived from questionable and unverified field data.

The legal perspective on groundwater in terms of the National Water Act (NWA), the Water Services Act (WSA) and the Environmental Conservation Act (ECA) is also briefly discussed. The different uses of water are mentioned where groundwater may have a significant contribution. Shortcomings in the Act are also discussed.

The proposed methodology spells out the so-called Groundwater Resource Information Project (GRIP) and with marketing in the 21st century becoming more important in science, the slogan “ Get a GRIP on groundwater” was adopted. The methodology highlights the importance of an integrated team with

various responsibilities and deliverables, the importance of field and office procedures and the involvement of the community. It describes various verification stages where a quality control officer checks field data through *ad hoc* site visits and where historically disadvantaged individuals previously not involved with a project of this nature, can learn from more experienced individuals.

Information gathered clearly illustrates that vast amounts of money are spent on groundwater development and that the majority of villages in Limpopo already have boreholes in close proximity. The raw data can be used for immediate planning, operation and management purposes. The core of GRIP is, however, dissemination of information and much time was spent to develop an interface where data is captured, validated and placed on a database accessible through the World Wide Web. The data can be downloaded through various methods available on the web page and exported as an Excel spreadsheet. The data can then be imported in a GIS tool and manipulated to develop a series of planning maps, develop site-specific water supply business plans or help planning engineers with day-to-day requests.

Prior to GRIP, it was difficult and time consuming for planners in Limpopo to get access to reports compiled by specialists for municipalities or consulting engineers, but through the means developed in GRIP, planning engineers are enabled to stand up in meetings and with hard evidence in hand support future groundwater development and planning, making it truly part of integrated water resource management (IWRM).

This study lasted from the beginning of 2002 up to the middle of 2004. Further implementation of GRIP continues in Limpopo and the Eastern Cape and there is a strong possibility that it might be implemented in Kwazulu/Natal and the Free State. The GRIP website, other technology and legislation may change with further implementation of GRIP

Opsomming

Grondwater is 'n essensiële deel van watervoorsiening in die Limpopo-provinsie van Suid-Afrika. Op beplanningsvlak kom hierdie boodskap egter nie altyd duidelik na vore nie. Hoewel groot getalle watervoorsieningskemas ontwikkel word met grondwater as 'n hulpbron, faal die meerderheid hiervan en word die hulpbron nie as volhoubaar beskou nie. As gevolg hiervan het 'n wantroue ontstaan in die gebruik van grondwater, beplanners het dit grootliks geëlimineer uit geïntegreerde waterhulpbronbeplanning en word die gebruik van grondwater steeds gesien as 'n *ad hoc* of noodmaatrêel. Die Grondwaterhulpbron-inligtingsprojek ("Groundwater Resource Information Project – GRIP") is ontwikkel met die doel om beskikbare grondwaterinligting te vergelyk met geverifieerde velddata. Hierdie inligting kan in 'n eenvoudige formaat beskikbaar gestel word aan beplanners en ingenieurs om te inkorporeer in hul strategiese beplanning. Dus kan grondwater voorgehou word as 'n geïntegreerde, volhoubare en strategiese hulpbron. Die projek is aangepak volgens die formaat van 'n hidrosensus – 'n protokol om inligting vas te lê en aan te bied op enige skaal sodat die beplanner reeds ontwikkelde grondwaterinfrastruktuur ook in ag neem en inkorporeer in die oorkoepelende beplanning. Die werkswyse is so ontwikkel dat dit baie duidelik aan die gebruiker beskryf hoe om 'n hidrosensus te doen.

As agtergrond word die ontwikkeling van grondwater in Suid-Afrika beskryf om die hantering van grondwater in die verlede in perspektief te stel, asook hoe dit tans beskou word. Grondwaterbronskartering soos geïmplementeer deur die Departement van Waterwese en Bosbou en die Waternavorsingskommissie word bespreek. Die beskikbaarheid en formaat van grondwaterdata vir die opstel van kaarte word bespreek, asook die vaslegging van data in verskillende databasisse. Al die kaarte is egter gebaseer op bevraagtekende en nie-geverifieerde data.

Die wetsaspekte rondom grondwater word bespreek in terme van die Nasionale Waterwet, die Waterdienstewet en Omgewingsbewaringswet. Die verskillende watergebruike waar grondwater 'n betekenisvolle bydrae kan lewer, word genoem. Tekortkominge in die Waterwet word aangespreek.

Die suksesvolle bemerking van wetenskap word toenemend meer belangrik, en daarom word hierdie projek bemark met die treflyn "Get a GRIP on groundwater", met verwysing na die volledige titel in Engels. Die metodologie beskryf en beklemtoon die belangrikheid van 'n geïntegreerde span met verskeie verantwoordelikhede en produkte, die belangrikheid van veld- en kantoorprosedures en die

samewerking van en met die gemeenskap. Dit beskryf verskillende fases waartydens data geverifieer word, o.a. deur *ad hoc* veldbesoeke van kwaliteitskontrole -beamptes. Histories-benadeelde individue wat nie voorheen by soortgelyke projekte betrokke was nie, kan in hierdie gevalle leer by meer ervare individue.

Tydens die ondersoek is bevind dat groot bedrae geld spandeer word op grondwaterontwikkeling en dat die meerderheid dorpie in landelike Limpopo reeds 'n boorgat in of naby die dorpie het. Die rou data kan dus gebruik word vir onmiddellike beplanning, operasionele en bestuursfunksies. Die kern van GRIP is egter disseminasie van inligting en daarom is baie tyd spandeer aan die ontwikkeling van 'n gebruikersvriendelike interfase waar data vasgelê en bevestig word en beskikbaar is in 'n databasis wat toeganklik is deur die Wêreldwye Web. Die data kan afgelaai word deur verskeie metodes beskikbaar op die webblad en uitgevoer word as 'n Excel-sigblad. Hiervandaan kan data ingevoer word na 'n GIS - program en gemanipuleer word vir die ontwikkeling van 'n reeks beplanningskaarte, terrein-spesifieke besigheidsplanne vir watervoorsienings of bloot om ingenieurs te help met dag-tot-dag versoeke vir inligting.

Voor die ontwikkeling van GRIP was dit moeilik vir beplanners in Limpopo om toegang te kry tot spesialisverslae wat saamgestel is vir munisipaliteite of raadgewende ingenieurs. Met die beskikbaarstelling van 'n stelsel soos GRIP word beplanners nou in staat gestel om met geldige data grondwaterbeplanning en ontwikkeling te ondersteun, sodat dit werklik deel kan word van geïntegreerde waterhulpbron-ontwikkeling.

Die studie het plaasgevind vanaf die begin 2002 tot middel 2004, maar die GRIP gaan steeds voort in Limpopo en Oos -Kaap en daar is sterk sprake vir implementering in Kwazulu/Natal en die Vrystaat. Die GRIP web blad, ander tegnologie en selfs wetgewing kan verander soos die GRIP in verdere fases inbeweeg.