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Data Management and Reporting for Drinking Water Quality Monitoring in Community- Managed Supplies



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Thesis submitted in fulfillment of the requirements for the degree Master of Science in Engineering

Plagiarism Declaration

I know the meaning of plagiarism and declare that all the work in the document, save for that which is properly acknowledged, is my own.

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Executive Summary

Despite progress in service delivery since 1994, 19% of South Africans still do not have access to an improved water source for domestic use. Even where an improved source is available, drinking water quality monitoring systems may be inadequate, preventing consumers and authorities from accurately assessing the safety of the water supplied. For both service delivery and drinking water quality monitoring, the greatest challenge lies in rural areas. Community involvement in the management of supplies is a sustainable, effective strategy for water service provision in rural areas, and has been used successfully in South Africa. However, small rural supplies are most prone to water quality problems, and are also hardest to monitor.

Water quality is highly variable in space and time, so for communities to know the actual safety of their source, they must be involved in monitoring it rather than relying on irregular visits from an external authority. Using field test kits and sanitary inspection techniques, it is feasible for communities to perform basic drinking water quality monitoring themselves. However, community-based Water Services Providers may not have access to the skills and materials needed to react to problems they identify through monitoring. Community-based Water Services Providers therefore need ongoing support from the responsible Water Service Authority.

Water Service Authorities, which may be district municipalities with hundreds of community-managed supplies under their jurisdiction, are legally responsible for ensuring the quality of water supplied to all consumers. Without the assistance of communities, this requirement, which would involve regular testing in many remote and inaccessible supplies, is extremely difficult to fulfil. Water Service Authorities also struggle to respond timeously to problems in remote supplies, as they are often unaware of the problem for some days. Two-way communication between the Water Service Authority and the Community-based Water Services Provider is therefore essential to an effective monitoring programme.

Information and communication technologies, particularly mobile phones on the cellular network, offer potential solution to the challenge of supporting community-managed supplies. Following an investigation into the information needs of various stakeholders in community management, a prototype

drinking water quality information system for community-managed supplies was developed. The prototype system incorporates

- A mobile phone-based data collection and reporting component (for use at the community-managed supply)
- Data transmission over the cellular network
- A central spatial database
- A browser-based data management and reporting application (for use by the responsible Water Services Authority)
- A raw data access interface for spatial and non-spatial data

The feasibility of such system was then evaluated according to the Bridges.org Real Access / Real Impact criteria. As part of the evaluation, user interviews were conducted with five Water Service Authorities in the Eastern Cape.

The findings show that a community drinking water quality information system is feasible, and could be a useful tool for community-based Water Services providers and the organisations that support them. A mobile device-based system in particular was shown to be appropriate to the operational context of community supply management. A set of high-level functional and non-functional requirements was developed for such a system, and sustainability factors, such as development of a supportive local ICT services sector, were also considered. Based on an evaluation of the prototype development process, recommendations were made for a full pilot system as the next iteration of development.

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List of Abbreviations

3NF	Third Normal Form
ASCII	American Standard Code for Information Interchange
BoTT	Build, Operate, Train, Transfer
CBO WSP	Community-Based Organisation Water Services Provider
CD	Compact Disc
CMA	Catchment Management Agency
CRUD	Create, Read, Update, Delete
CSS	Cascading Style Sheets
DWAF	Department of Water Affairs (of South Africa)
EAV	Entity-Attribute-Value
eWQMS	Emanti Water Quality Management System
GIS	Geographic Information Systems
GML	Geographic Markup Language
GPRS	Global Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HIV/AIDS	Human Immuno-Deficiency Virus/ Acquired Immune Deficiency Syndrome
HTTP	Hypertext Transfer Protocol
ICT	Information Communication Technology
ICT4D	Information Communication Technology for Development
IT	Information Technology
J2ME	Java 2 Micro Edition
JTWI	Java Technology for the Wireless Industry
MDG	Millennium Development Goal
MMS	Multimedia Messaging Service
NACI	National Advisory Council on Innovation
ODBC	Open Database Connectivity
OGC	Open Geospatial Consortium
OSS	Open Source Software
PC	Personal Computer
PDA	Personal Digital Assistant
RUP	Rational Unified Process
SANS	South African National Standard
SMS	Short Message Service
SSA	Support Services Agent
TB	Tuberculosis

TCO	Total Cost of Ownership
TCP/IP	Transmission Control Protocol/Internet Protocol
UDig	User-Friendly Desktop GIS
UN	United Nations
UNICEF	United Nations International Children's Fund
USSD	Unstructured Supplementary Service Data
WAP	Wireless Access Protocol
WFS	Web Feature Service
WHO	World Health Organisation
WIG	Wireless Internet Gateway
WML	Wireless Markup Language
WMS	Web Map Service
WSA	Water Service Authority
WSDP	Water Services Development Plan
WSP	Water Services Provider
WUA	Water User Association
XML	Extensible Markup Language
XP	Extreme Programming

University of Cape Town

1 Introduction

1.1 Topic

Data Management and Reporting for Drinking Water Quality Monitoring in Community-Managed Supplies.

1.2 Statement of the Problem

Target 10 of Millennium Development Goal 7 is “Reduce by half the proportion of people without sustainable access to safe drinking water”. The WHO/UNICEF Joint Monitoring Programme for Water and Sanitation (JMP), set up to track progress towards this goal, describes access to safe drinking water and hygienic sanitation as “a precondition for health, and for success in the fight against poverty, hunger, child deaths and gender inequality” (WHO/UNICEF 2006). Inadequate water, sanitation and hygiene services are responsible for 5.7% of the total burden of disease worldwide (Pruss et al, 2003), and account for 1.6 million preventable child deaths each year (UNICEF, 2005). The preventable nature of water and sanitation related disease and death makes this a public health priority. Water and sanitation improvement is also an economic goal - investment in water and sanitation services in poor countries is associated with an average annual GDP growth of 3.7%, compared to 0.1% for countries without improved water and sanitation services (WHO/SIWI, 2005).

Significant progress in water services provision has been made, both in South Africa and in the rest of the developing world. The Department of Water Affairs reports that 13.4 million South Africans were supplied with a basic improved source between 1994 and 2004 (DWAF, 2004), and the WHO/UNICEF Joint Monitoring Programme's mid-term assessment states that the world is on track to meet MDG drinking water target (WHO/UNICEF JMP, 2004). However, once an improved water source has been installed, it must be monitored throughout its useful life to ensure that adequate maintenance has been carried out, and that the water supplied remains safe to drink. As the number of people served by improved supplies increases, regular monitoring of water quality in an unprecedented number of water supplies must be undertaken. This requires effective systems for the collection, management and dissemination of water quality data. Community management of supplies, particularly in rural areas of

the developing world, is recognised as an effective service delivery model (Vermeulen, 2001)(Lockwood, 2001). However, the remote location of these supplies and the often limited resources available in the community make monitoring of community-managed supplies particularly challenging (WHO, 1997).

Just as new technologies for water testing have emerged in recent years, so too have new information and communication technologies. ICT has the potential to improve the management of water quality monitoring activities, enhance communication, transparency and accountability within and between the agencies involved, and make service delivery and resource allocation more efficient. Developed world water service providers have been able to take advantage of new ICT systems for data management and reporting. However, the evolution of these systems is market-driven, and they may be unsuitable to meet the specific infrastructural and capacity challenges present in the developing world.

Particularly in relation to Millennium Development Goal (MDG) 7, the United Nations Information and Communication Technologies Task Force recognises opportunities for community-level resource management, with ICT and Geographic Information Systems (GIS) as an “enabler” (United Nations ICT Task Force, 2005). In the context of routine water quality monitoring in the developing world, it may be possible to streamline data collection, storage and reporting through the use of an ICT-based management system. The rapid adoption of mobile phone technology in the developing world offers a particularly promising opportunity for low-cost, user-friendly data management and reporting to support community-managed supplies.

1.3 Aims of Research

- Investigate and describe the operational context for routine water quality monitoring in community supplies in South Africa.
- Identify role players, data flows and uses for monitoring data, and derive from this a set of high-level user requirements for an ICT-based management system.
- Develop a prototype data collection and reporting system to demonstrate the system proposed for the case study context. This prototype will then be used to obtain feedback from stakeholders on the role of ICT in water quality monitoring.

- Evaluate the suitability of the proposed ICT-based management system for the operational context.

1.4 Initial Hypothesis

- An ICT-based management system could help to meet the information needs of stakeholders in community supply management in South Africa. These information needs can be defined through a process of participatory design.
- Using a prototyping approach, it is possible to define a set of functional and non-functional requirements for such a system, against which a working pilot system could be developed.
- A technology strategy based on “appropriate” technologies such as mobile devices (and particularly data transmission over cellular networks), web-based reporting and open source software can provide the foundation for a system that will meet the specific challenges of monitoring community-managed supplies

1.5 Areas to be Investigated

- Operational context for drinking water quality monitoring in community-managed supplies in South Africa.
- Modelling of information needs. This would include the development of a data model, and also a set of high-level use-cases describing actors in water quality monitoring in community-managed supplies in South Africa.
- Identification of appropriate technologies for a monitoring and reporting system for community-managed supplies in South Africa.
- Suitability of the proposed system to the operational context, including sustainability considerations.

1.6 Research Outline

In investigating the possible usage contexts and operational requirements of a mobile device-based

drinking water quality reporting system for community-managed supplies in the developing world, the following approaches were used:

- Exploration of the operational context through a literature review and through the examination of South African and international guidelines and best practises.
- Development of a working demonstration system. The system uses a basic mobile phone to collect and transmit field test and sanitary inspection results, and displays the results on a web-based interactive map.
- Assessment of the system concept through demonstrations to, and interviews with, local authorities responsible for drinking water quality monitoring. The design of the interviews, as well as the system assessment was guided by the Bridges.org Real Access / Real Impact criteria, described in Chapter 2.

1.7 Scope and Limitations

- This research forms part of the EU-funded AQUATEST project. The project full title is “Low-cost water test for developing countries – a preparatory study”. Because the proposed low-cost test is likely to be most useful in the management of small community water supplies, these supplies will be the main focus of the research.
- This thesis is concerned with demonstrating the feasibility of an ICT-based management system, and identifying possible constraints and sustainability factors. As such, development will not proceed beyond a working prototype.

2 Planning and Assessing ICT-enabled Development

Rather than being a driver of development for its own sake, information and communication technologies (ICTs) act as an “enabler” or “facilitator” in development projects, monitoring and facilitating progress towards development goals (Marker et al, 2002) (G8 Digital Opportunities Task Force, 2001) (UN ICT Task Force, 2005). In respect of the role of ICTs in the achievement of the Millennium Development Goals, the UN ICT Task Force states:

If strategically deployed, and integrated into the design of development interventions, ICT can enable development resources to go that much further by facilitating the development of cost-effective and scalable solutions. Networking technology can enable developing countries to benefit from new economic opportunities resulting from the re-organisation of production and services taking place in the global networked economy. It is believed that ICT will increasingly become one of the main enablers in the pursuit of poverty alleviation and wealth creation in developed and developing countries alike.

(United Nations Information and Communication Technologies Task Force , 2005)

There are numerous examples of successful ICT-enabled initiatives in the developing world. In South Africa, Cell-Life is using mobile phones to improve home-based carers' ability to support HIV-positive people undergoing antiretroviral treatment (Donald et al, 2007) (Anand, 2005). A land rights registration project in India uses the locally-designed Simputer, a portable Linux-based computer designed to overcome the challenges of language localisation and illiteracy (Thakur et al, 2004). Where the technology and the implementation plan match the local context, ICTs can deliver significant benefits by supporting local communities.

This chapter considers the process of planning an ICT-enabled development project, from the initial strategic overview down to the development of a working prototype. First, the relationship between development strategy, information strategy and technology strategy is discussed. Two frameworks for consideration of the operational context in project planning – the Real Access Criteria (Bridges.org, 2005) and the Onion Ring Model (Heeks, 2005) - are then presented. A discussion of an appropriate

software engineering methodology for ICT-enabled development - Socially Aware Software Engineering (Blake & Tucker, 2006) - concludes the chapter.

2.1 Development Strategy, Information Strategy and Technology Strategy

Based on the Information Systems Strategy Triangle (Figure 1) (Pearlson & Saunders, 2005), Grimshaw and Talyarkhan (2005) describe the ICT4D Triangle, a framework for incorporating ICTs into development projects. In place of a business strategy, ICT-enabled development projects have a development strategy, such as providing the poor with better health care by strengthening capacity in the public health sector, or ensuring access to clean water by improving water quality monitoring.

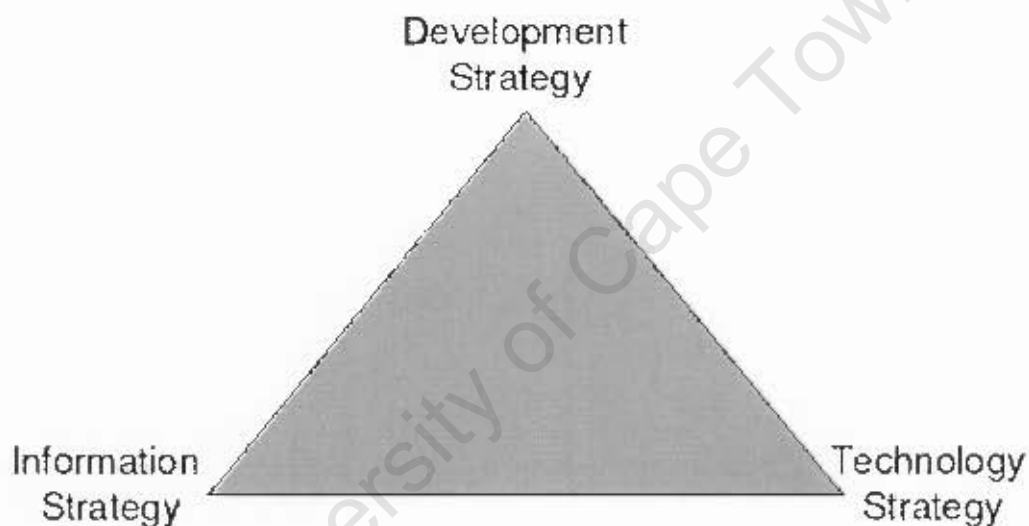


Figure 1: The Information Systems Strategy Triangle

The development strategy is placed at the apex of the triangle because it drives the information strategy and the technology strategy. The information strategy and the technology strategy serve but do not determine the direction of the project.

Harris (2001) incorporates the development strategy, information strategy and technology strategy components into a process flow, which may be repeated over several iterations (Figure 2). Clarification of the development strategy should be the starting point of each iteration. The development strategy is supported by the information strategy, and delivered by the technology strategy.

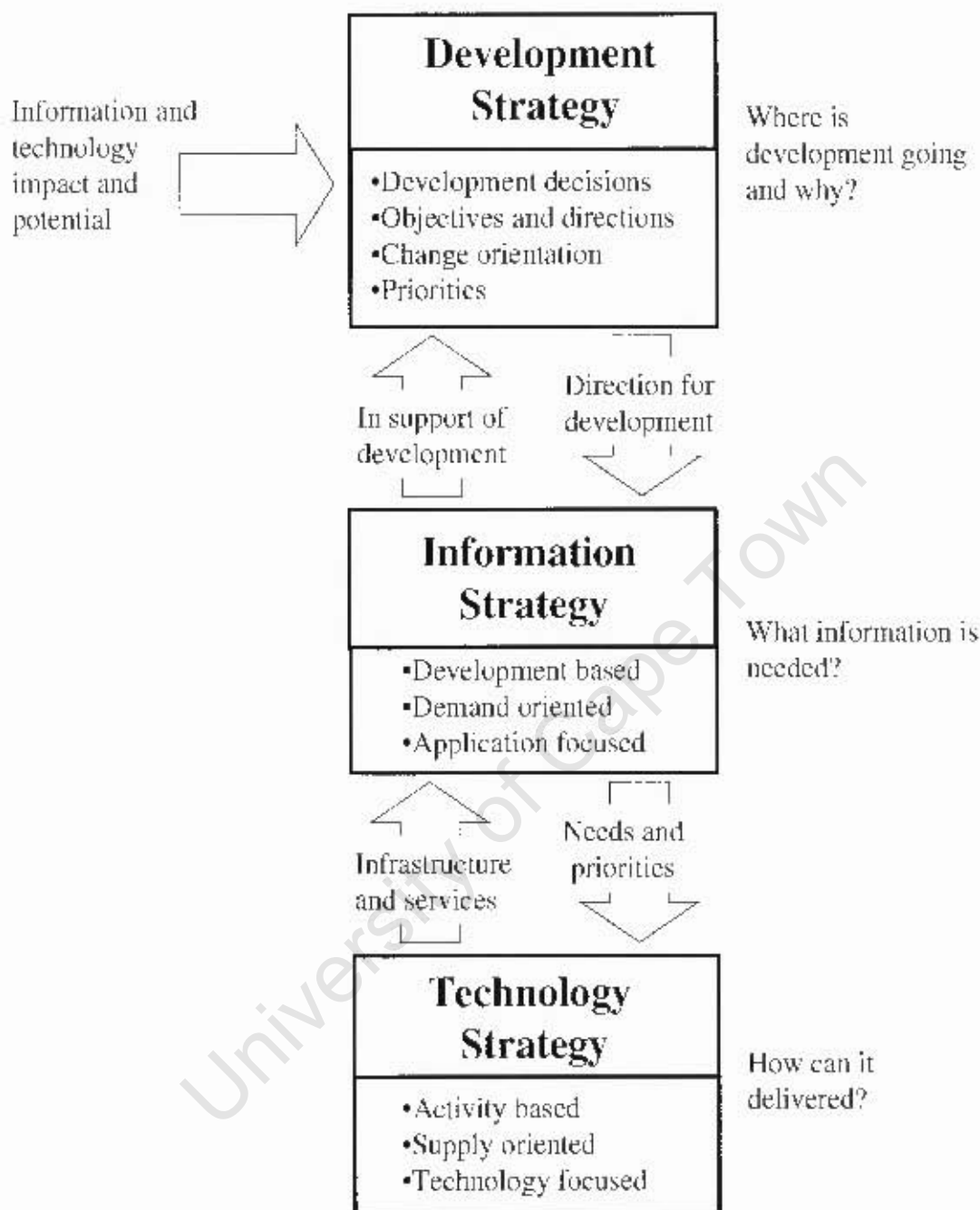


Figure 2: Relationship between ICTs and Development (Harris, 2001)

The core development strategy of this project is to ensure safe drinking water in small community-managed supplies by supporting routine monitoring and reporting. The development strategy is supported by an information strategy of improving two-way communication between community members carrying out monitoring, operations and maintenance at the supply, the community they serve, and the

organisations responsible for assisting them. This information strategy, based on the South African operational context described in Chapter 3, is discussed in detail in Chapter 4. The technology strategy focuses on low-cost, low-infrastructure technologies such as mobile phones and open source software, and is discussed in detail in Chapter 6.

2.2 Operational Context Considerations for System Design

The success of any IT system depends as much on appropriate technology as on social, institutional and infrastructural factors. Heeks (2005) illustrates these in the Onion-Ring Model, shown in Figure 3.

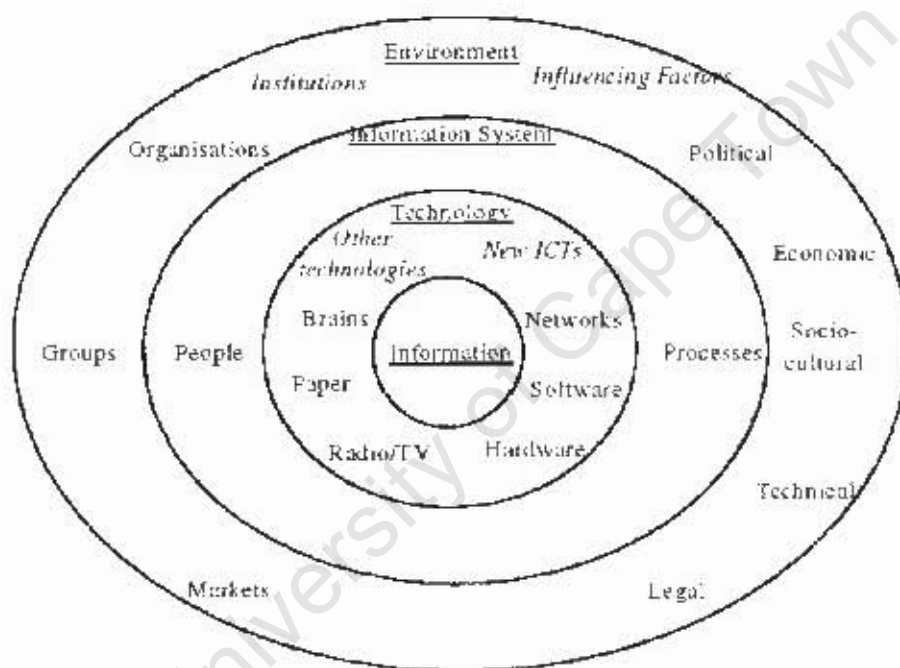


Figure 3: The Onion-Ring Model (Heeks, 2005)

ICT-enabled development projects need to be planned with careful consideration as the design-reality gap is often most pronounced in the developing world (Heeks and Bhatnagar, 1999). Bridges.org's Real Access / Real Impact framework addresses the fit between ICT-enabled development projects and their operational context. Described as a "holistic approach" to planning, monitoring and evaluating ICT-enabled development (Bridges.org, 2005), the framework consists of the following 12 criteria:

- Physical access to technology

- Appropriateness of technology
- Affordability of technology and technology use
- Human capacity and training
- Locally relevant content, applications, and services
- Integration into daily routines
- Socio-cultural factors
- Trust in technology
- Local economic environment
- Macro-economic environment
- Legal and regulatory framework
- Political will and public support

To evaluate the feasibility of a mobile phone -based data collection and reporting system for community-managed supplies, a subset of the Real Access / Real Impact criteria were chosen to serve as a framework.

The criteria identified were :

- Physical access to technology
- Appropriateness of technology
- Affordability of technology and technology use
- Human capacity and training
- Locally relevant content, applications, and services,
- Political will and public support.

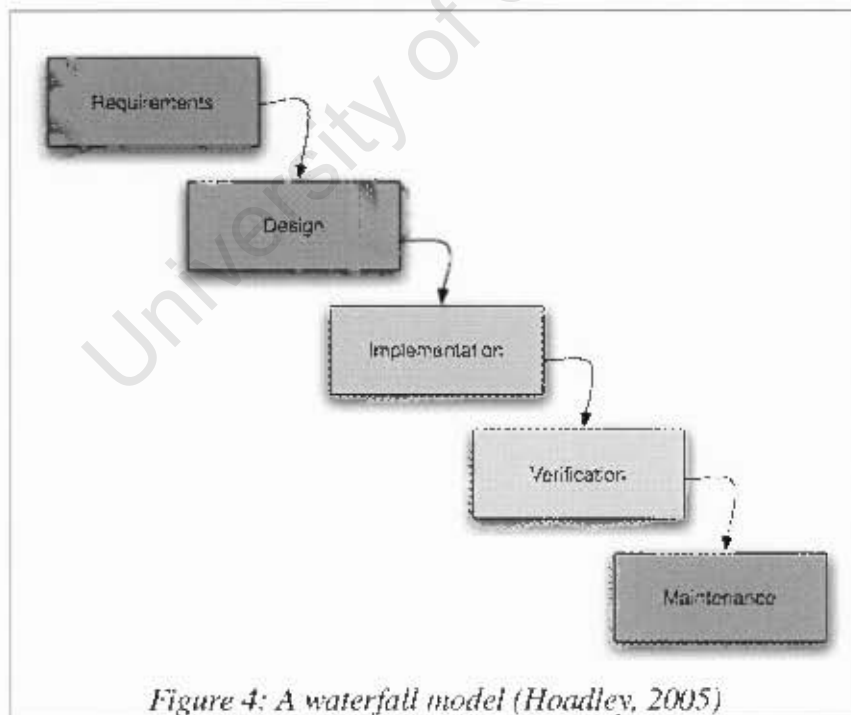
These criteria formed the basis for a questionnaire intended to be used in initial interviews with municipal officers involved in drinking water quality monitoring. While it became clear during the interview sessions that an informal discussion format was more useful than a structured questionnaire, application

of the Real Access / Real Impact criteria to the proposed system still provides the framework for the analysis of the findings that appears in Chapter 7.

2.3 Software Engineering Methodologies and Socially Aware Software Engineering

Software Engineering, which attempts to plan and manage the entire life cycle of software projects using engineering principles, emerged in response to the “software crisis” of unplanned “build now, fix later” projects (Gain, 2003). Software Engineering methodologies specify defined ways in which tools, methods and processes can be systematically applied to the design, planning, implementation and maintenance of software projects. Some widely used methodologies are:

- **Waterfall Models**, in which a series of stages that are executed sequentially. The input of each stage being required by the next. This model is inflexible as it cannot accommodate changes to requirements after the requirements definition phase, early on in the project.



- The **Spiral Model** (Boehm, 1998), which emphasises iterative software development. Each iteration (one revolution of the spiral) incorporates a small amount of each activity (planning of objectives, identification of risks, design, and development), and is concluded by a review, the outcome of which informs the next iteration.

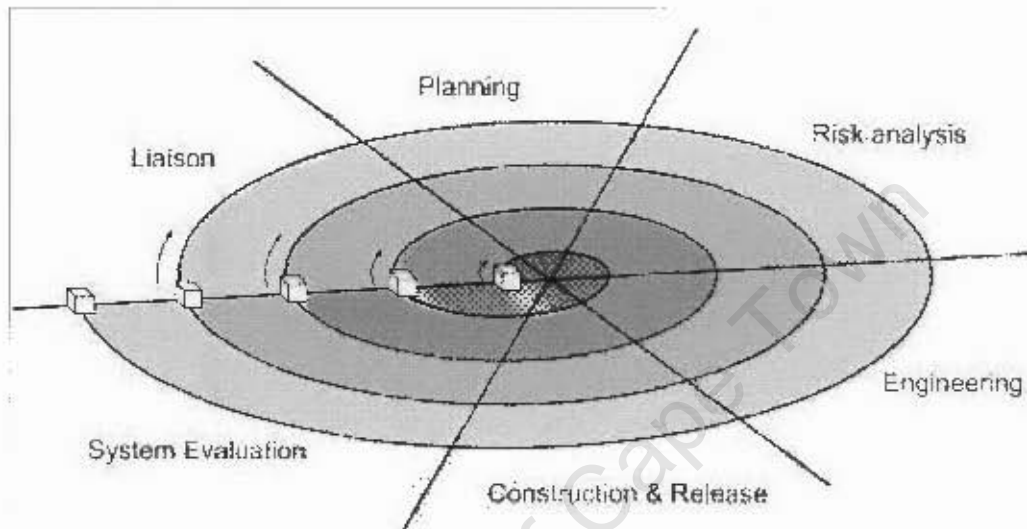


Figure 5: A Spiral Model (adapted from BOADICEA, 2007)

- The **Rational Unified Process (RUP)**, which is a comprehensive model for medium to large projects. The RUP defines four stages, namely Inception, Elaboration, Construction and Transition. Activities such as user requirements definition, prototype construction and architecture design take place in each phase, playing a larger or smaller role as appropriate. The RUP is an iterative, incremental development process. It also emphasises continuous investigation and management of user requirements using Use Cases.

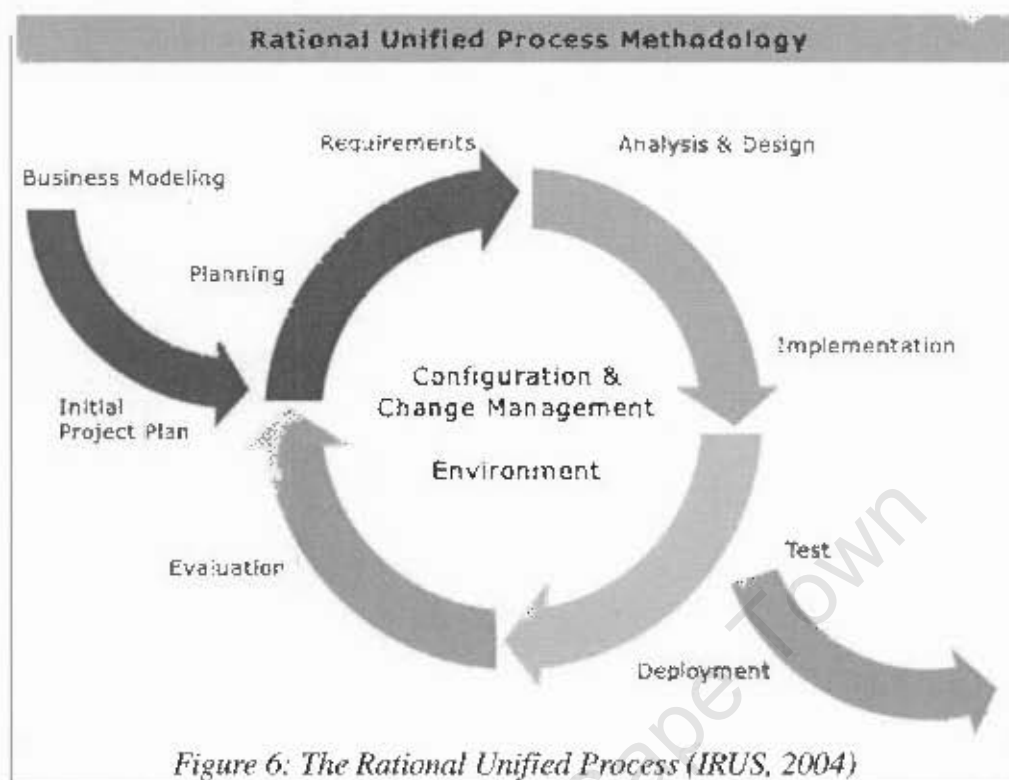


Figure 6: The Rational Unified Process (IRUS, 2004)

- **Extreme Programming (XP)** (Beck, 1999), a lightweight methodology suitable for smaller projects. XP projects are planned and built in short iterations of a few weeks, with a just-in-time design approach. Developer productivity is a particular focus of XP, and it advocates stand-up meetings, pair programming and limitations on overtime to achieve this.

Iterative and incremental software engineering, in which learning from previous development and implementation phases informs the next phase, is a common thread through modern software engineering methodologies. Iteration over several cycles of development makes it easier to define and redefine requirements, which users are often initially not able to articulate in a way that software engineers will understand (Brooks, 1986). Unlike waterfall models, iterative and incremental models are able to accommodate changes to requirements once design and development have already started.

Blake and Tucker (2006) have developed the concept of Socially Aware Software Engineering, drawing on iterative and incremental development, Action Research and Participatory Design methods. While Participatory Design involves users in the definition of system requirements, cultural and linguistic barriers, as well as the users' sometimes limited experience with and understanding of the technologies

involved, may limit the extent and usefulness of this involvement. The Socially Aware Software Engineering approach recognises that true participation requires learning on both sides, and that an iterative and incremental approach can accommodate this. Iterative and incremental planning, development, implementation and evaluation of a software project also fits well into the framework of Action research.

Rapid and evolutionary prototyping approaches are a key component of Socially Aware Software Engineering (Blake, 2006). Prototyping, where a rough, scaled down demonstration system is developed prior to the development of the full system, helps:

- End-users to visualise the way they will interact with the final system, and how it will fit into their context. Potential problems are easier to identify, and can be corrected sooner.
- Developers to experiment with potential user interfaces and technology choices, and to identify which are suitable.

Prototypes may be simplistic and non-functional (such as a series of user interface screens drawn on a whiteboard), or they may quite closely approximate the final system. Evolutionary prototyping, where a working prototype is put into production early on and developed incrementally while in use, is particularly useful where user requirements are not defined or easily definable at the start of the project (Carr & Verner, 1997). Users, designers and developers working with the system in real situations are able to discover and refine the system requirements over the life of the project. Evolutionary prototyping has been used successfully in resource-constrained settings (Brown et al, 2007), particularly where the system fills an urgent information need, and the initial implementation timeframe is very short.

The software development component of this project is the first stage of an iterative, incremental prototyping approach. This includes:

- Initial identification of user requirements (functional and non-functional) – Chapter 7
- Identification, evaluation and selection of technical components to meet these requirements – Chapter 8
- Development of the prototype system – Chapter 8

- Evaluation of the prototype from functional and technical perspectives – Section 8.6
- Recommendations for the next stage of development – Chapter 10

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3 Operational Context: Water Services Provision in South Africa

South Africa's water policy was extensively overhauled following the transition to democracy in 1994. Prior to this, the responsibility for water services provision lay with autonomous provincial or homeland government departments, with varied effectiveness and capacity (Muller, 2002). Water policy did not directly address access to basic water, being confined to water resource management. The Water Act, too, largely addressed issues around irrigation rights and industrial use of water (Abrams, 1996). As a result, while access to water in metropolitan (and “white”) areas was comparable to other industrialised countries, rural areas and homelands had extremely poor service levels (Muller, 2002) (Thompson et al, 2004).

In contrast, the new policy framework is based around the human right to basic water and sanitation (Folifac, 2006). At the highest level, South Africa's new water policy is informed by principles such as:

- Development should be demand-driven and community based.
- Basic services are a human right.
- “Some for all” rather than “All for some”

The legislative backbone of this policy originates in the Bill of Rights, which protects the right to sufficient water. The National Water Act (Act 36 of 1998) places overall responsibility for the water resource with national government, acting through the Department of Water Affairs and Forestry (DWAF). This responsibility includes the equitable provision of safe water for basic domestic use to all South Africans, while ensuring sustainability through integrated resource management.

The definition of basic supply is provided by the Compulsory National Standards and Measures to Conserve Water, which are part of the regulations that support the Water Services Act (Act 108 of 1997).

According to the regulations, a basic supply is:

- (a) the provision of appropriate education in respect of effective water use; and
- (b) a minimum quantity of potable water of 25 litres per person per day or 6 kilolitres per household per month -

- (i) at a minimum flow rate of not less than 10 litres per minute;
- (ii) within 200 metres of a household; and
- (iii) with an effectiveness such that no consumer is without a supply for more than seven full days in any year.

Compulsory National Standards and Measures to Conserve Water, 2001

This level of access is the first rung on what the Water Supply And Sanitation White Paper (1994) refers to as the Water Ladder. The Water Ladder concept describes the Government's strategy of ensuring first that the basic level of service is supplied, and then planning for a process of improvement of service levels. The higher "rungs" on the water ladder could include access to piped water in the yard of each household, followed by running water inside each house (Kasrils, 2003). However, equitable access to a basic water supply – the first rung on the ladder - is a prerequisite for progressive service improvement.

3.1 Progress in Service Delivery

At the start of democracy, South Africa faced a very severe service delivery backlog. In 1994, an estimated 40% of South Africans did not have access to safe drinking water (Mackintosh, 2004). Significant progress has been made in the sector, and twelve years later, the proportion of people who remain unserved has dropped to an estimated 19% (DWAF, 2006). However, rural areas are still problematic: 23% of rural dwellers do not have access to an improved source (United Nations, 2007), and in 2003, Statistics South Africa estimated that 76% did not have access to potable water on site (Statistics South Africa, 2003, in Ueckermann, 2006). This disparity in access levels between rural and urban areas is also present elsewhere in sub-Saharan Africa: Mozambique, Angola, Uganda and Congo have urban / rural access rates of (72% / 26%), (75% / 40%), (87% / 56%) and (84% / 27%) respectively (United Nations, 2007).

3.1.1 Large Projects Since 1994

When the first democratic government came into power in 1994, meeting unmet basic needs was immediately prioritised as part of the ruling ANC's promise of "a better life for all". This happened in the form of the Reconstruction and Development Programme (RDP). DWAF was heavily involved in the

provision of water and sanitation services under the RDP, initially through twelve Presidential Lead Projects (endorsed by President Nelson Mandela), which were later expanded to the capital works programme (DWAF, 2004). The projects focussed mostly on delivering basic services to rural dwellers, particularly those in former homeland areas, and were implemented in partnership with a range of organisations including municipalities (those with sufficient capacity), NGOs (the Mvula Trust in particular), water boards and private sector organisations (Muller, 2002).

In 1997, the need to scale up service delivery at a greater rate than DWAF could manage at its existing capacity became apparent. Through the Build, Operate, Train and Transfer (BoTT) scheme, DWAF began to contract the private sector to plan and implement new supplies in several provinces. These supplies were then transferred to suitably trained local government structures, which were formally established after the local government elections in 2000.

Some of the BoTT projects, as well as other early projects undertaken by DWAF (and as some undertaken by the Mvula Trust) have been criticised for being unsustainable (Wellman, 1999). This is partly due to technology choices, which were not always matched to the level of service for which the community was able to pay (Jones & Williamson, 2005), but also to a lack of constructive community involvement (Netshiswinzhe, 2000) and even vandalism by communities in some cases (Wellman, 1999).

Funding for the development of new schemes in previously unserved areas was initially provided by government, with communities responsible for covering operations and maintenance costs. However, the realisation that the poorest people would still be forced to use unsafe sources rather than pay for water (Kasrils, 2000) resulted in South Africa's Free Basic Water policy being implemented during 2000 - 2002. Under the policy, the first 6000l per household per month are provided free of charge, with any additional usage being charged at an escalating block tariff rate (Folifac, 2006). De Le Harpe (2003) presents conflicting viewpoints regarding the application of the Free Basic Water policy in community-managed schemes. On one hand, the Mvula Trust argues that by transferring the funding for operations and maintenance from the community to the municipality, the policy also transfers the responsibility for carrying out these functions, and community "ownership" of the scheme may be compromised. On the other hand, a municipal official feels that as municipalities are responsible for ensuring access to water, it is correct to directly provide them with funding to carry out this responsibility. Despite these concerns, it

is acknowledged that in implementing the free basic water policy, the government has demonstrated its full commitment to carrying out the service delivery obligation placed upon it by the Bill of Rights (Mvula Trust, 2006).

As DWAF's role in direct service provision is devolved to local level, its involvement in large-scale infrastructure projects is changing. The Masibambane programme, which aims to support the local government structures responsible for water services delivery, is in keeping with this changed role. Described as “a multi-annual, multifaceted Water Services Sector Support Programme (WS-SSP) of the Government of South Africa in the water services sector, whose overall objective is to provide basic water supply and sanitation services to selected poor rural communities through institutional support to assist various levels of public sector institutions” (DWAF, 2005c), Masibambane began in 2001 and will run until 2012.

3.1.2 Service Delivery in the Former Homelands

South Africa's former homeland areas remain disproportionately affected by service delivery backlogs. The homelands (or bantustans) were areas set aside for black South Africans under the apartheid government's policy of separate development. Each had its own government structures, although these were plagued by political infighting, lack of capacity, and lack of support from their assigned constituents. Turton and Meissner (2002) describe the homelands as “a manifestation of the ecological marginalisation that was a consequence of the long-term and systematic resource capture strategies that the minority government had institutionalised during the apartheid era.” Supporting this view, Abrams, (1996) notes that under the separate development policy, approximately 75% of all South Africans subsisted on 13% of the land, much of it of poor quality .

This legacy persists today, and former homeland areas remain a challenging environment for sustainable service provision (Malzbender et al, 2005). Many people living in these areas are still very poor, and the pattern of migrant labour that the homelands were designed to encourage has allowed HIV/AIDS to spread with devastating effect. Under the previous regime, service provision was highly centralised, and infrastructure development was used to win the favour of the people. Improved services were usually supplied free of charge, with little consideration given to sustainability, and maintenance was seldom

carried out. This has resulted in raised expectations, coupled with a culture of non-payment for services (Vermeulen, 2002).

3.2 Institutional Water Services Structures

The South African government is constitutionally separated into local, provincial and national spheres. This structure is not directly hierarchical, with the three spheres described in the Constitution as “distinctive, interdependent and interrelated”. Each sphere of government has a defined set of responsibilities, and contains the bodies necessary to carry out these responsibilities. In the context of water services provision, the role of national government encompasses the overall management of the water resource. This responsibility is carried out through DWAF, the public trustee of the nation's water resources. Local government, however, is responsible for service delivery, and the Water Services Authority role responsible for water services delivery is therefore located within local government. Provincial government is involved indirectly, being tasked with ensuring strong and accountable local government structures.

The various institutions involved in water services provision are shown in Figure 7.

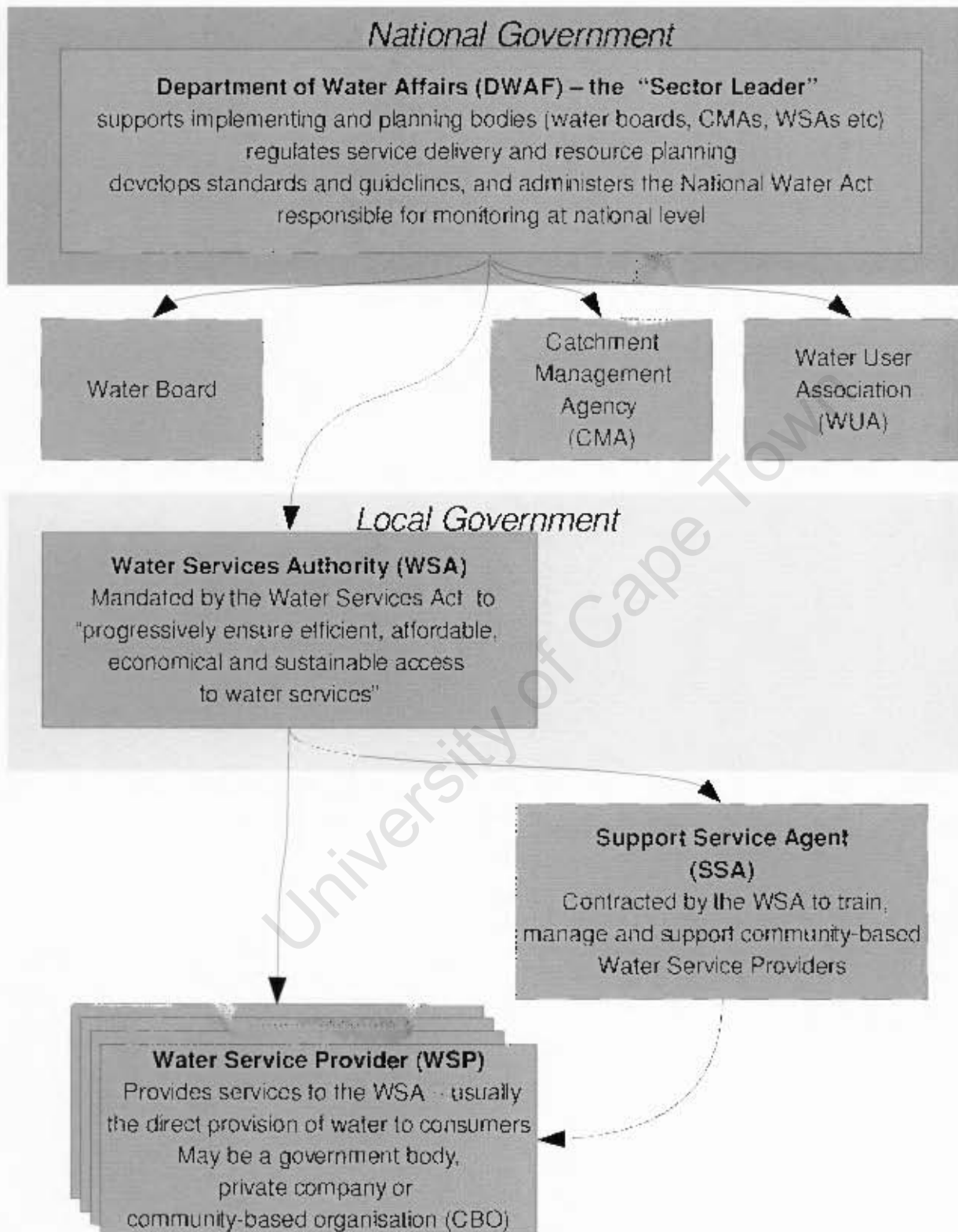


Figure 7: Organisations Involved in Water Services Provision

3.2.1 The Department of Water Affairs and Forestry (DWAF)

In many rural areas, local government structures were not in place immediately after the transition to democracy. Those that did exist had widely varying capacity, and the funding mechanisms to address capacity issues at local government level were also not yet operational. (Muller, 2002). During this DWAF was an active provider of water services, particularly in formerly unserved areas.

Today, DWAF is in transition towards a role as the 'sector leader' or 'custodian' (Jones and Williamson, 2005). While it is still responsible for ensuring basic water supply, provision of services is handled by local government in the form of a local, district or metropolitan municipality, which fulfils the Water Services Authority role. As sector leader, DWAF aims to support, monitor and build capacity in the various Water Services Authorities. This role includes establishing standards (such as SANS 241 for drinking water) and best practices, performing surveillance and providing support. As such, DWAF is the regulator of service provision by local government, with the power to intervene where such services are inadequate (DWAF, 2003).

DWAF has a further role in information management at national level. Tools such as the recently implemented Water Quality Management System, eWQMS, fulfil not only the obligation to provide support to local government, but also provide the information needed for DWAF's support and regulatory functions.

DWAF is also responsible for operationalising and updating policy and legislation around water services and water resource management. Folifac (2006) highlights DWAF's "policy responsiveness" as a key strength in effectively delivering services, citing the Free Basic Water policy as an example.

3.2.2 Catchment Management Agencies, Water User Associations and Water Boards

While they are not directly involved in water services provision, Catchment Management Agencies (CMAs), Water User Associations (WUAs) and Water Boards may all be involved as information producers or consumers in a drinking water quality information system. CMAs, for example, are responsible for resource quality management, and may need to be alerted if water quality problems are identified at community level.

The National Water Act defines the functions of the Catchment Management Agency, which is responsible for water resource management in its catchment area. This function includes licensing and monitoring water use, abstraction and discharge, as well as overseeing land use and environmental integrity related to the water resource. Of the nineteen CMAs that will eventually serve all the catchment areas of South Africa, four were in place by 2006, with the remaining fifteen expected to be operational by 2010 (DWAF, 2006). Until a CMA is fully operational in a Catchment area, DWAF will carry out the functions of the CMA in that area.

In rural areas where people may rely on untreated water for domestic use, it is particularly important that the CMA carries out its mandate effectively (DWAF, 2005b). Schreiner et al (2002) also stress the CMA's obligation to carry out communication and public participation activities related to the water resource in its area of operation, which they envisage being used to promote gender-sensitive and pro-poor water policy.

Water User Associations (WUA) are an extension of the concept of an irrigation board present under the previous regime. Any group of users may, with approval from the Minister of Water Affairs and Forestry, form a WUA, which exists as a localised, co-operative group of water users involved in water-related activities for mutual benefit (Thompson et al, 2001). In practice, this structure will largely be used for former irrigation boards, smallholder irrigation schemes in the former homelands, and groups of large-scale non-agricultural users such as mines (Faysse, 2004).

Unlike CMAs and WUAs, Water Boards are not a user-controlled structure. A Water Board is a bulk supplier of water to large scale (industrial and agricultural) users, and may also sell bulk treated water to other Water Service Providers.

3.2.3 Water Services Authorities

The responsibility for water services provision (as well as refuse, electricity, primary healthcare and other services) lies with the local government sphere, and is performed by a local, district or metropolitan municipality. Where an area is part of a metropolitan municipality (a densely populated urban area, of which there are currently six), the Water Services Authority (WSA) role is assumed by the metropolitan municipality. In all non-metropolitan areas, the district municipality is the WSA for the district. The

Municipal Structures Amendment Act (Act 33 of 2000), which assigns municipal responsibilities, also makes provision for local municipalities (small areas of three to six towns, or which there may be several within a district municipality) to be authorised to act as the WSA (Mackintosh, 2004).

The Water Services Act (Act 108 of 1997) defines the WSA role as a duty to “progressively ensure efficient, affordable economical and sustainable access to water services” for all constituents. This does not mean that the WSA is a direct provider of services, which is the role of the Water Service Provider (WSP), described in the next section. However, as an organ of state, the WSA is responsible for initiating and maintaining appropriate contractual arrangements with WSPs, monitoring their performance and their ability to meet the needs of the area served, and providing information and education to consumers. Muller (2002) describes the WSA role as a “governance” role, while the WSP role is a “provision” role.

The WSA is also responsible for planning current and future service provision and improvement. The Water Services Development Plan (WSDP), which must be informed by considerations of equity, environmental sustainability, cost reduction and economy of scale, both within the WSA's area of responsibility and within the wider region, is the formal documentation of this planning process. The WSDP must be based on

- Information about the relevant physical and socio-economic characteristics of the municipal area
- An inventory of existing water and sanitation services
- Information about existing water users, particularly unserved groups

The WSDP should draw on this information to outline how the municipality intends to deliver and improve services over the next 5 years, including contracting relevant Water Services Providers. Planning for operations and maintenance as well as infrastructure upgrading for current and future supplies is also part of the WSDP, as is the provision of cost estimates and timeliness for the work proposed in the plan. The process of draft WSDP submission and evaluation is expected to be complete by March 2007 (DWAF, 2006).

3.2.4 Water Service Providers

The Water Service Provider (WSP) role, also described in the Water Services Act, refers to the responsibility for actual provision of the service. This role may be assumed by the municipality, a private company, a non-profit company or a community-based organisation. The separation of functions between the WSA and the WSP must exist even when they are fulfilled by the same entity, and accounting and management structures are required to be separate under the Act (Mackintosh, 2004). Where the WSA chooses not to use a municipal entity, water board or organ of state as a WSP, the WSP must be selected by a competitive tendering process (De La Harpe, 2003). However, DWAF (2003) reports that efforts are under way to remove this requirement where the desired WSP is a community-based organisation.

WSPs also have an obligation to communicate directly with the consumer, in a way that can be easily understood. This includes the development and communication of a consumer charter as well as an obligation to make mechanisms available to receive suggestions, queries and fault reports from consumers. WSPs must also provide consumer-friendly billing. (DWAF, 2003)

3.3 Community-Managed Supplies

Community management of water services provision can be an efficient, sustainable and cost-effective option for rural supplies, provided sufficient resources are allocated to supporting and building the capacity of the community (Vermeulen, 2001) (Brikke, 2000). The importance of “bottom-up” or “demand-responsive” development of community-managed schemes is also widely acknowledged. In South Africa, the Mvula Trust has been extensively involved in developing and supporting community-managed schemes, and has developed the “Mvula Model” for the establishment of such schemes (De La Harpe & Vermeulen, 2001). In this model, communities:

- access the necessary resources themselves
- take responsibility for implementation of their water services scheme
- receive support from external agents and local government where required

(De La Harpe, 2003)

In the South African context, a community-based organisation acting as a water services provider (CBO WSP) is defined as:

- An organisation with a defined set of rules. The governance function implied by this arrangement leads Vermeulen (2001) to suggest a two-tier structure for CBO WSPs, separating the governing body from the staff involved in the day-to-day running of the organisation
- A not-for-profit organisation – any surplus income is retained and may only be used to further the objectives of the organisations
- Serving a defined community, with a mandate from that community (either as elected representatives, or under an agreement with the community)
- Acts in the interests of the community, and is accountable to it.

(after De La Harpe & Vermeulen, 2001)

Community-managed schemes are useful in the first instance because they are able to operate in areas that would be difficult for other WSPs to access sustainably (De La Harpe & Vermeulen, 2001). The other major advantage of community management is improved sustainability and recovery through enhancing buy-in. To achieve this, however, participatory approaches must be effectively utilised right from the scheme's conception. Netshiswinzhe (2000) defines effective participatory approaches as “those which fully enable project beneficiaries and other role players to explore, together, options, constraints, trade-offs and competing ideas and strategies before reaching a final decision”, contrasting this kind of approach with top-down scheme planning and management, which is all too common. Community management can also support economic development at local level (De La Harpe & Vermeulen, 2001), but Negussie (2001), drawing on experiences from Uganda, cautions that for this to happen, there must be a strong commitment to decentralising resources parallel to the decentralisation of responsibilities.

While correctly implemented community management programmes can deliver significant benefits, the challenges that CBO WSPs face are great. Among others, these include building and retaining human capacity, accessing technical support and spare parts when operational problems arise, maintaining the trust of the community, and remaining sustainable through cost recovery (De La Harpe & Vermeulen,

2001) (Brikke, 2000). Netshiswinzhe (2000) also highlights an almost complete lack of monitoring and evaluation around community-managed schemes, which is “crippling” the sector.

In response to these challenges, the Support Services Agent (SSA) role was defined by DWAF (De La Harpe, 2003). An SSA is a provider of defined services to CBO WSPs on behalf of the responsible WSA, and as such is contracted to the WSA. Services provided may include involvement in the establishment of CBO WSPs, provision of training, assistance in technology selection and bulk purchasing on behalf of a number of CBO WSPs (utilising economies of scale not otherwise available) (De La Harpe, 2003).

Monitoring and evaluation of schemes is also likely to form part of the work of the SSA, and work is being done to assist CBO WSPs in reporting the information required for this process (Potter et al, 2006).

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4 Drinking Water Quality Monitoring for Small Community Supplies

Drinking water quality monitoring entails an assessment of the probable 'safety' of the source, including chemical and microbiological quality as well as risk assessment and risk management information (WHO, 2004). This information is used in the daily operations of the water supplier, informing fault resolution, supply improvement and resource allocation. Monitoring information also contributes to maintaining transparency and accountability between the water supplier and its consumers. On a regional level, collated summary information from monitoring programmes should be used to highlight under-served areas, and to facilitate equitable and efficient resource distribution to address imbalances in access to safe water. (Redhouse et al, 2005). Surveillance, defined by the World Health Organisation (WHO, 2004) as “an investigative activity undertaken to identify and evaluate potential health risks associated with drinking-water”, is a complimentary activity to drinking water quality monitoring. Surveillance ensures that the design of the monitoring programme is providing accurate information on the safety of drinking water, and also provides insight into the overall effectiveness of the system from a health perspective (Howard, 2002).

WHO (2004) confirms that throughout the world, it is often community-managed supplies that are most prone to water quality problems. Volume 3 of the Guidelines for Drinking Water Quality deals specifically with surveillance and monitoring in these supplies, and lays out general principles including:

- The central role of microbiological monitoring
- The importance of ensuring that monitoring and surveillance activities lead to engineering improvements and remedial action.
- The need to consider not only water quality but also all other health-related aspects of drinking water

(WHO, 1997)

Remedial action, maintenance, resource allocation and supply improvement operations rely on monitoring information, but collecting this information in often under-resourced community-managed supplies can

be very difficult (Robertson et al, 2003). This type of supply is among the hardest to monitor because of a lack of capacity in the community, as well as large distances between supply points (WHO, 2004). Effective information management and dissemination is a further challenge (not only in community-managed supplies but in monitoring programmes throughout the world). MacDonald (2004) is concerned that

“All too often, monitoring projects are initiated with a minimum of forethought, and result in a collection of poorly documented data which are never analysed, provide little or any feedback to resource managers, and contribute little or nothing to our understanding of the systems being monitored”

(MacDonald, 1994)

Monitoring community-managed supplies may be particularly expensive, as supplies are numerous and often remote and inaccessible. In the developing world, the collection, processing and dissemination of data collected by monitoring programmes is further constrained by the need to develop inexpensive solutions that do not hamper cost recovery and sustainability. It is therefore essential that the monitoring programme is able to meet the management need, and to provide useful, timeous feedback (Bartram, 1999, in Robertson et al, 2003).

Even where monitoring and evaluation of community-managed supplies does take place, Potter et al (2000) recognise that monitoring programmes often fulfil only a one-way reporting function. While communities may be involved in the collection of monitoring data, they are seldom able to effectively make use of the information that is generated. This is consistent with the view of Ward et al (1986) that water quality monitoring throughout the world suffers from the “data-rich but information poor syndrome”, where large amounts of data are never collated and interpreted to provide useful information.

The solution to the “data-rich but information poor syndrome” has two dimensions:

- The information that is collected must be defined by the management needs it will fulfil (which may change over the course of the monitoring programme).
- This information must provide useful feedback to the organisation responsible for operations and maintenance at the scheme, quickly enough to initiate a timeous remedial action, and in a format

that can be readily understood.

This is represented by Timmerman et al (2000) as a feedback loop, as shown in Figure 8.

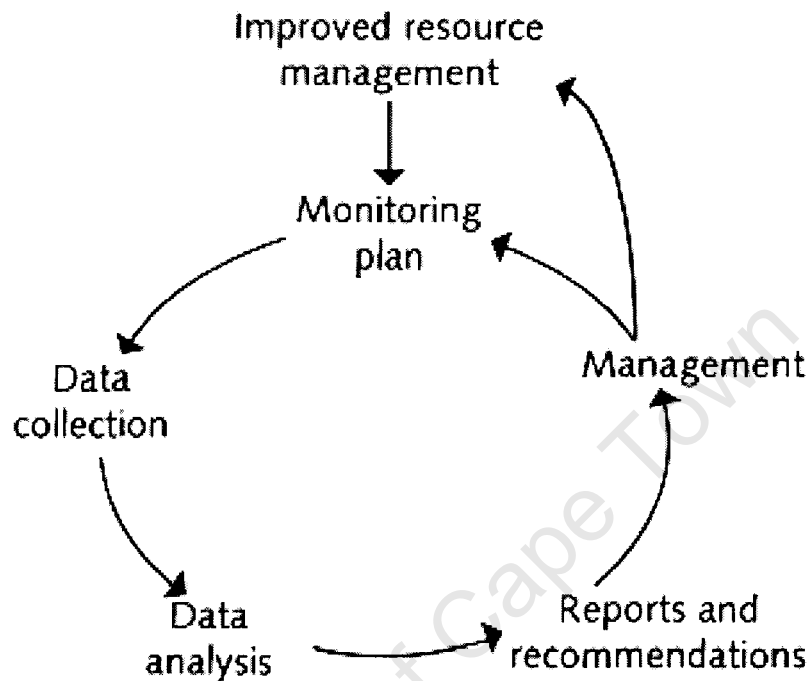


Figure 8: Water Quality Monitoring Feedback Loop (Timmerman et al, 2000, after MacDonald, 1994)

Community involvement in decision making, management, operations and maintenance of water supply projects is supported by the collection and effective use of monitoring information (Potter et al, 2000). To realise this, it is necessary to close the feedback loop and provide two-way communication of monitoring information at community level. In the sections that follow, the information needs of each stakeholder in drinking water quality monitoring in South Africa's community-managed supplies are explored, with a view to proposing an information system that can assist in achieving two-way communication.

4.1 South African Context

4.1.1 Roles and Responsibilities

At national level, DWAF is mandated by the National Water Act to carry out monitoring and surveillance of all aspects relating to water resource management and water service delivery. The information required to fulfil this function will not usually be collected by DWAF itself, but rather by CMAs (which will monitor water usage and the quality of the water resource) and WSAs (which will monitor service delivery and the quality of the water supplied to consumers). DWAF will operate as the surveillance agency, and will also provide technical and organisational support to the organisations responsible for carrying out monitoring (Hodgson & Manus, 2006). The Department of Health also plays a supportive role by collecting information about water-borne disease, and being the lead agency in drinking water quality emergencies (DWAF, 2005).

WSAs bear the primary responsibility for ensuring that safe drinking water is supplied to all consumers in their area of operation. This includes carrying out operational and compliance monitoring of all Water Services Providers. According to the Water Services Act, WSAs are required to

- monitor drinking water quality on a monthly basis
- compare the quality of drinking water supplied to the relevant national standard
- communicate relevant information regarding water quality to consumers

(Hodgson & Manus, 2006)

The monitoring obligation of WSAs includes operational monitoring (continuous monitoring of control parameters likely to affect the quality of the water supplied) as well as compliance monitoring (verification of the integrity of the barriers put in place to ensure that drinking water is safe, and of the ability of operational monitoring to provide early risk detection) (DWAF, 2005). While non-compliance is not criminalised, it is an offence under the act to refuse to provide information about water quality to consumers or the regulator, or to provide misleading information (Mackintosh, 2004).

In the case of community-managed schemes, the WSA remains responsible for ensuring the quality of the water supplied. This is acknowledged as a challenge given the remoteness of many CBO WSPs, and the

capacity constraints evident in WSAs (Nel, 2007, personal communication). At community level, Potter et al (2000) also raise concerns around the ability of CBO WSPs to collect and effectively make use of monitoring information in the daily running of the scheme. Reasons for this include capacity challenges, difficulty communicating with the WSA when assistance is required, and a mismatch between the information collected (which mainly records infrastructure development indicators) and the information needed by the CBO WSP.

4.1.2 Current Situation

In a survey of drinking water quality monitoring by WSAs, DWAF (2004, cited in Mackintosh et al, 2004) found that more than 50% of South African WSAs do not have monitoring programmes that conform to the relevant national guidelines. The 2005 Drinking Water Quality Framework for South Africa, which was developed in response to this finding, cites the main factors for the inadequacy of monitoring programmes at WSA level. These factors, which are consistent with findings from Papua New Guinea (Kingston, 2004) and India (Rajiv Gandhi National Drinking Water Mission, 2006) include:

- WSAs are not aware of the necessary requirements to set up an effective Drinking Water Quality Management programme;
- Management and monitoring of drinking water services are often inadequate;
- Infrastructure is poorly maintained;
- WSAs may be hindered by institutional capacity problems such as insufficient or untrained staff, and budgetary constraints, and
- Appropriate interventions are not in place to address poor quality drinking water.

(DWAF, 2005)

Mackintosh et al (2004) confirm the impact of widespread non-compliance with drinking water quality monitoring legislation. In a study of drinking water supplied by different types of Water Services Providers in the Western Cape, average failure rates of 42% and 19% were reported for total coliforms and faecal coliforms respectively. Failure rates were lowest in major towns (7% and 0%), and highest in village/community samples (71% and 32%).

The Drinking Water Quality Framework details the functions that DWAF, as sector leader, will fulfil to support municipalities in improving drinking water quality monitoring. These include facilitating information sharing and capacity development, ensuring that monitoring is included in water service development plans, and providing technical and best practice guidelines to WSAs. The development of appropriate tools, including the Drinking Water Quality Framework as well as a water quality management information system, is also part of this role.

4.1.3 Rollout of the Water Quality Management System (eWQMS)

Emanti Management's Water Quality Management System (eWQMS) was developed in partnership with DWAF and the Institute of Municipal Engineering of South Africa (IMESA), responding to the drinking water quality monitoring needs of WSAs. The geo-referenced, web-based system provides information from three perspectives, namely:

- Technical Perspective: Technical staff responsible for effective water services functions.
- Management Perspective: Municipal top management and councillors, who will determine the priority of technical projects.
- Community Perspective: Civil Society, who provide inputs to their society representatives as to priorities regarding service delivery.

(Mackintosh et al, 2005)

eWQMS also allows WSAs with existing drinking water quality or laboratory information systems to feed in data from these system. The advantage of a web-based system is that DWAF, the Department of Health and other stakeholders can access relevant information immediately (Mackintosh et al, 2005). However, ways to effectively communicate this information to consumers are still being explored (Karshagen, 2007, personal communication).

Delport (2007) and De Souza et al (2006) report that the system has allowed municipalities to work “smarter” by improving the efficiency of monitoring programmes at WSA level, and has also raised awareness of drinking water quality management issues. After an initial pilot phase, full rollout of the system should have been completed in March 2007 (DWAF, 2005c). While eWQMS is developed using

open source components such as PHP and MySQL, the system itself is not open source, and will therefore presumably be supported and hosted by Emanti Management or DWAF in the short term.

4.2 Information Needs For Community-Managed Supplies

Drinking water quality monitoring in community supplies in the developing world is particularly difficult, and often not carried out. However, it is these areas that are most in need of water services improvement, and drinking water quality monitoring systems need to be strengthened to support this. Community involvement in decision making, management, operations and maintenance of water supply projects is supported by the collection and effective use of monitoring information (Potter et al, 2000). Monitoring information is used both internally in the daily operations and maintenance of the schemes, and externally by organisations that regulate, support and evaluate the supply. Figure 9 below shows the different information users and producers in a community management setting. This is followed by a discussion of the role played by each, and the associated information needs.

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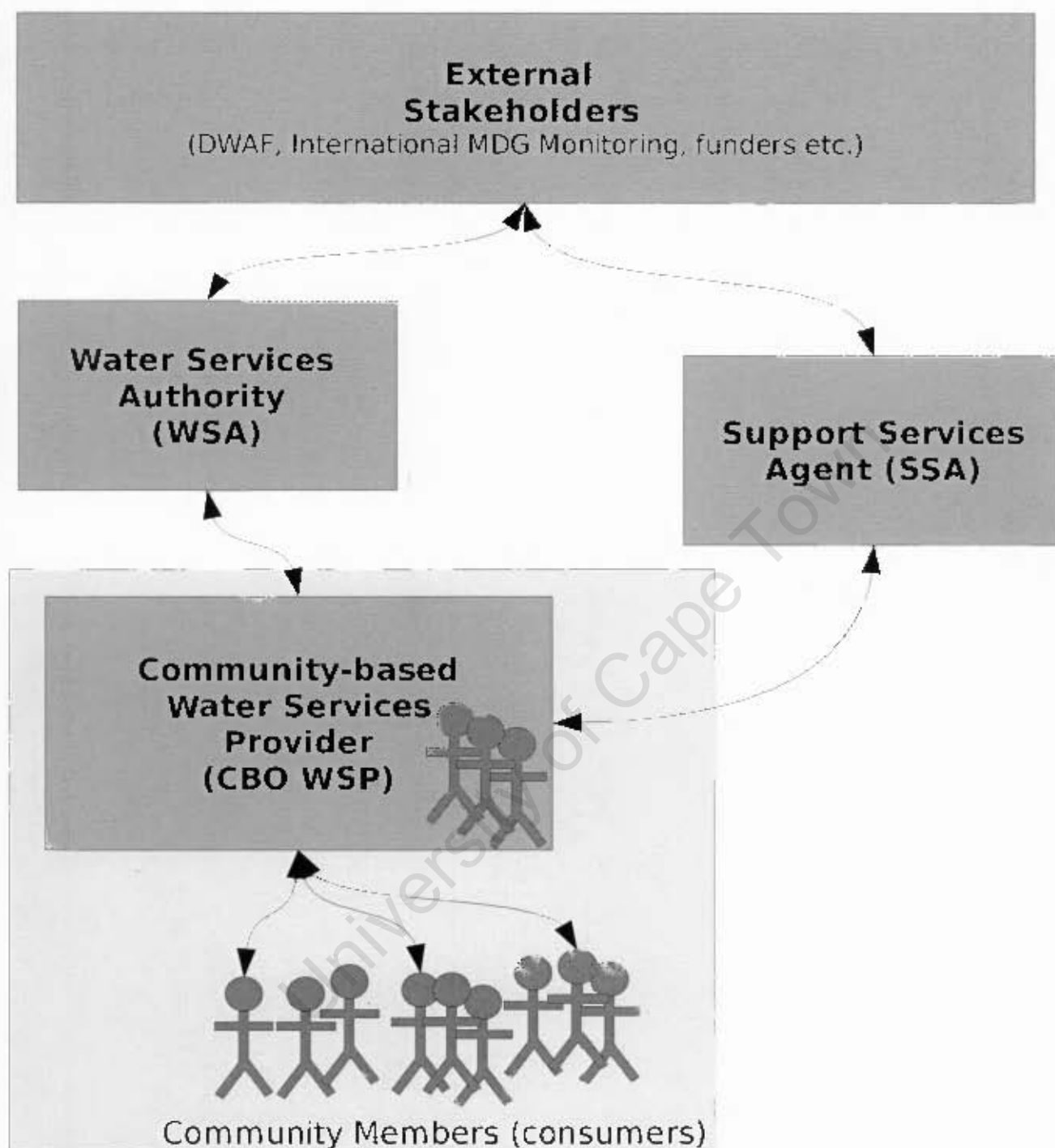


Figure 9: Information Users and Producers For Community-Managed Supplies

4.2.1 Operational Monitoring and Water Safety Plans

Bringing together concerns about water safety, particularly in small supplies, WHO (Davison et al, 2004) advocates improving management of drinking water quality through a Water Safety Plan approach. A

Water Safety Plan is “a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer” (WHO, 2004). The Water Safety Plan identifies the following characteristics of the water supply:

- The hazards that the water supply is exposed to and the level of risk associated with each
- How each hazard will be controlled
- How the means of control will be monitored
- How the operator can tell if control has been lost
- What actions are required to restore control
- How the effectiveness of the whole system can be verified

Godfrey and Howard (2004)

While remaining consistent with existing best practice in drinking water quality management, a Water Safety Plan approach places particular emphasis on identifying and monitoring control measures, and on timely corrective action when necessary. This imposes stringent data collection, reporting and communication requirements.

Operational monitoring is a key component of the Water Safety Plan. Water Safety Plans consider operational monitoring as a “screening” mechanism to identify sources that may potentially become unsafe. As such, measuring a few relevant parameters as often as possible is considered more important than accurately measuring a comprehensive, but largely irrelevant, set of parameters. (Godfrey and Howard, 2004). *E.coli* (or thermotolerant coliforms as a substitute) and chlorine residual (if chlorination is practised) are considered critical parameters, supplemented where appropriate by turbidity (where any treatment is effected) and pH (if chlorination is practised) (WHO, 1997).

This minimal monitoring approach should always be supplemented by a sanitary inspection. A sanitary inspection is a risk assessment exercise, in which the measures taken to protect the source from contamination are checked, and any potential hazards identified (Howard, 2002). The sanitary inspection

is done in conjunction with microbiological testing, as the latter may not always identify sources at risk of contamination, and does not provide any information about the source of contamination. Taken together with microbiological test results, the information generated from a sanitary inspection can be used to make recommendations for remedial action.

A protected spring, such as the example shown in Figure 9 below, might be monitored using the checklist in Figure 10.



Figure 10: Protected Spring in Alfred Nzo District Municipality (De La Harpe 2003)

I Type of facility: PROTECTED SPRING SOURCE	
1. General information: Health centre	
Village	
2. Code no.—Address	
3. Water authority/community representative signature	
4. Date of visit	
5. Water sample taken?..... Sample no..... Thermotolerant coliform grade.....	
II	Specific diagnostic information for assessment Risk
1.	Is the spring source unprotected by masonry or concrete wall or spring box and therefore open to surface contamination? Y/N
2.	Is the masonry protecting the spring source faulty? Y/N
3.	If there is a spring box, is there an unsanitary inspection cover in the masonry? Y/N
4.	Does the spring box contain contaminating silt or animals? Y/N
5.	If there is an air vent in the masonry, is it unsanitary? Y/N
6.	If there is an overflow pipe, is it unsanitary? Y/N
7.	Is the area around the spring unenclosed? Y/N
8.	Can animals have access to within 10m. of the spring source? Y/N
9.	Does the spring lack a surface water diversion ditch above it, or (if present) is it nonfunctional? Y/N
10.	Are there any latrines uphill of the spring? Y/N
Total score of risks /10	
Contamination risk score: 9-10 = very high; 6-8 = high; 3-5 = intermediate; 0-2 = low	
III	Results and recommendations
The following important points of risk were noted:..... (list nos 1-10)	

Figure 11: Sample Sanitary Inspection Form for a Protected Spring (WHO, 1997).

4.2.2 Organisations Supporting Community-Managed Supplies

In community-managed supplies, the responsibility for producing recommendations and performing remedial actions may not lie with the person performing monitoring activities (sanitary inspection, field test etc.). In the South African context, both the Support Services Agent (if this model is used) and the Water Services Authority (WSA) will at times assume these responsibilities. Therefore, two-way

communication between responsible parties is necessary to realise the full benefit of the monitoring programme.

The scaling up of Community-Based Organisations as Water Service Providers means greater management challenges for the responsible WSA. While the WSA is responsible for compliance monitoring, it is also responsible for ensuring that water supply within its area of jurisdiction is safe (Water Services Act, 1997). Where the Water Services Provider (WSP) function is performed by a CBO that may not have the capacity to solve all water supply-related problems itself, this role may include a taking more hands-on approach to operational monitoring and scheme maintenance. For example, in the case of a mechanical failure at a remote community-managed scheme, it may be that the CBO WSP does not have the technical skills or the tools required to repair the problem (Illing & Gibson, 2004). Unless the fault can be reported immediately to the WSA (or to an SSA contracted to fulfil the support function), the community may be forced to drink from potentially unsafe sources. There is therefore a need for better fault reporting and fault resolution mechanisms between the CBO WSP and the supporting WSA or SSA, avoiding what one WSA manager termed the “community abandonment model” of community-managed water supply (De La Harpe, 2003).

Trust between the CBO WSP and the WSA is also facilitated by a good information flow between the two. The CBO WSP can prove its accountability by reporting regularly on an agreed set of indicators (Illing & Gibson, 2004). The WSA can improve community perception of its services by responding timeously to issues raised in these reports, particularly where the quality of the water supplied, or the effective functioning of the CBO WSP, may be impaired. As the role of the CBO WSP is formalised, agreed indicators and milestones can become part of the contractual arrangement between the WSA and the WSP (Illing & Gibson, 2004).

At an overview level, WSAs tasked with supporting several hundred community-managed schemes need regular reports from each scheme if they are to prioritise interventions and distribute resources effectively. At this scale, paper-based reporting and data capture is a time-consuming and expensive overhead, and may prevent overview data from being available timeously to decision-makers. It may also become difficult to flag and track the response to problems that have been reported. A further use for data reported by community schemes is in fulfilment of the WSA's own reporting obligations to higher levels

of government. Even in an area with 600 remote rural schemes, each scheme must be monitored on a monthly basis in accordance with the Water Services Act. The only feasible way to fulfil this reporting requirement is by requiring CBO WSPs to carry out the required monitoring themselves, and to automate the collection and collation of the reports produced.

4.2.3 Reporting to the Community

Customer relations between the Water Services Authority and the community it serves are likely to be improved through the use of community Water Service Providers (Illing & Gibson, 2004). However, for this to happen, the community must be confident that the quality of their water supply is good, and that the Water Service Provider is adhering to good management practises. This in turn requires good communication between the WSP and the community it serves, realised through regular reporting. If the service provided is above the basic service level (which by law is free), the duties of the CBO WSP will also include usage monitoring and revenue collection, which can only operate effectively if transparency is maintained.

As consumers, communities have a right to information about the quality of their drinking water, and particularly about any potential health impacts. However, providing the results of analysis or sanitary inspection in raw form may not be useful to non-specialists. The organisation responsible for dissemination is obliged to provide information about drinking water quality in a form that will be as widely understood as possible (WHO, 1997). This information may also be linked to hygiene education, or information about household water treatment and safe storage.

Community awareness of drinking water quality also allows informed lobbying to take place. In a study of drinking water quality and surveillance in the rural Peddie district in the Eastern Cape, Monyai (2004) found that although 94% of communities in the area had some form of water committee, most lacked the managerial capabilities, technical skills and funds to function effectively. Some communities showed the researchers windmills that had been broken for two or three years. Communities were very grateful to be presented with the results of analyses performed on their water sources, and some requested that they be given copies of the research, which they would use to lobby government for improvement. This is consistent with the strategy of the Strategic Framework for Water Services (DWAF, 2003), which states

that “the most important and effective monitoring strategy for the sector is strengthening the voice of the consumer”

While DWAF has rolled out a system (eWQMS) that will make drinking water quality readings available to the public via the Internet (de Souza et al, 2006), this will only serve a very small percentage of consumers, virtually none of whom are supplied by high-risk small and community-managed supplies. Such electronic systems need to be supplemented by “information” systems that use more accessible traditional technologies, such well-placed public notices and community meetings (WHO, 1997) (Godfrey & Howard, 2002), or new technologies such as mobile phones.

4.2.4 Reporting to External Stakeholders

The primary communication need for systems of community-managed supplies is between the community-based water service provider and the responsible water services authority. However, external stakeholders at national level (health authorities, authorities responsible for resource allocation and planning) and international level (aid agencies, organisations monitoring progress towards international development goals) may also need information about drinking water quality in community-managed supplies.

National planning and prioritisation of water services provision relies on the availability of detailed information about which areas are served with safe drinking water, and which are not. Good data on access to safe water, which should include information about the geographic location of each water supply, allows equitable distribution of resources to be effected (Redhouse et al, 2005). This is necessary to allow authorities to justify why certain areas are prioritised for interventions in a transparent way, and to empower civil society to monitor resource distribution.

At international level, it is clear that aid resources are not distributed equitably: Redhouse et al (2005) estimate that countries home to 90% of the people without safe water receive less than 40% of international aid for water.

While the world may be on track to meet target 10 of MDG 7, developing new sources will fall short of delivering sustainable access to safe water unless all existing sources are adequately maintained

(WHO/UNICEF 2006). Drinking water quality monitoring is an integral part of effective maintenance, and therefore of delivery on target 10. As service coverage increases in the developing world, the operations and maintenance structures that support established supplies must also begin serving an unprecedented number of consumers. Monitoring and surveillance activities need to be scaled up accordingly.

Drinking water quality monitoring also enables more accurate monitoring of access to safe water as part of all development goals (Gundry et al 2006). Rather than assuming an equivalence between the presence of an improved source and access to safe water, information about actual water quality can be used to measure real access levels, prioritise interventions and allocate resources accordingly.

University of Cape Town

5 Profiles of Areas Visited

This section expands on the operational context for drinking water quality monitoring in South Africa, by briefly describing the socio-economic conditions and water service provision arrangements in each area visited during the assessment phase of the project.

Interviews and System demonstrations were conducted at five Water Service Authorities in the Eastern Cape. Of these, three were District Municipalities (Alfred Nzo District Municipality, Chris Hani District Municipality, O.R. Tambo District Municipality) and two were Local Municipalities (Makana Municipality and Buffalo City Municipality). One representative from Amatola Water, a Water Board contracted to provide bulk water to several local municipalities in the greater East London area, was also interviewed.

The legacy of the Apartheid government's homeland policy is still very evident in the areas visited. While previously white areas such as Makana Municipality comprise commercial farms and well-resourced small towns, former homeland areas such as O.R. Tambo District Municipality, Alfred Nzo District Municipality and Chris Hani District Municipality have a large rural population, high unemployment and poverty figures and a severe service delivery backlog. This in turn influences water service priorities, and while the former homeland areas focus on sustainable community management in remote rural areas, community management is non-existent in previously white areas. A mobile phone-based system and associated field testing is therefore largely applicable to the three district municipalities in the former Transkei.

The areas visited during interviews are shown in Figure 12.

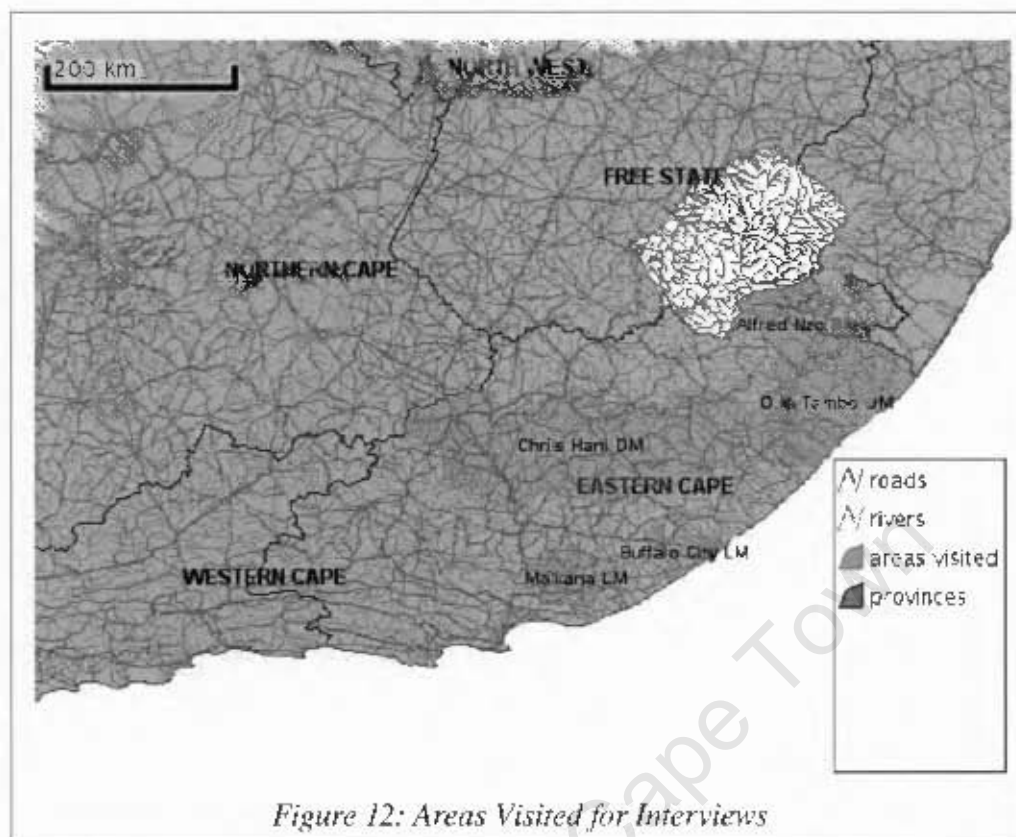


Figure 12: Areas Visited for Interviews

5.1 Makana Municipality

Makana Municipality is a local municipality within the Cacadu District Municipality. The municipality has its headquarters in Grahamstown, and there are four other significant towns in the region (Seven Fountains, Alicedale, Fort Beaufort and Riebeeck East). The remaining rural portion of the area consists largely of commercial farms. Rural households, mostly farmers and farmworkers, make up approximately 18% of the total households in the municipality (Cacadu District Municipality, 2006).

Water services provision is mainly through small piped systems in each town, with associated water treatment works and operational monitoring. These small systems are operated by the municipality, acting as both Water Services Authority and Water Services Provider. Farmers and farmworkers who do not have access to a municipal water supply use private boreholes. The water services backlog is small – in 2001, over 95% of households in municipal area had access to at least the minimum acceptable level of potable water supply.

5.2 Buffalo City Municipality

Buffalo City Municipality is a local municipality incorporating the City of East London as well as several larger towns. Despite this, 21% of households in the municipality were classified as rural in the 2001 census (Amathole District Municipality, 2006). Buffalo City Municipality is authorised to perform the Water Services Authority function by the Amathole District Municipality, to which it belongs. Amatola Water, a water board, provides bulk water to industrial users and to Buffalo City Municipality.

At the time of the 2001 census, the water services backlog in Buffalo City Municipality was estimated at 6.27%. It is likely that this backlog has been partly addressed since then, although in the large townships of Mdantsane and Zwelitsha this may mean only the minimum service level of a communal standpipe within 200m of every household. Drinking water quality monitoring is focussed on operational monitoring at service reservoir and treatment plants. Some smaller community supplies exist, and these are monitored when capacity is available. The difficulty of getting to some of the more remote supplies, including the financial implications of the rising petrol price and time spent travelling to sites, also constrains the monitoring programme (Karshegen, D. 2005, Personal Communication).

5.3 Chris Hani District Municipality

Chris Hani District Municipality is a largely rural district on the northern border of the Eastern Cape province, with a total area of around 38 000 km². Much of the district is part of the former Transkei homeland area. Rural or semi-rural households account for 95% of the population (Health Systems Trust, 2007), and 43% live below the poverty line (Statistics SA, 2001). The District Municipality is the Water Services Authority, and is tasked with addressing a water services backlog of approximately 39% (Chris Hani District Municipality, 2006).

While water supply in the larger towns is treated and subject to operational and compliance monitoring, there are many small and remote rural communities whose supplies are seldom monitored. In total, there are about 600 separate water supplies schemes in the district (Nel, F. 2007, Personal Communication), some of which are community-managed (Mvula Trust, n. d.).

5.4 O.R. Tambo District Municipality

O.R. Tambo District Municipality has its headquarters in Mthata, the capital of the former Transkei homeland. According to the municipality's Water Services development plan, 70% of households live below the poverty line, and 78% do not have access to the basic level of water supply (O. R. Tambo Water Services Development Plan, 2003). Rural households make up 95% of the district (PIMSS, 2000, in O. R. Tambo District Municipality, 2006), spread over an area of 12 857 km².

Where water supply infrastructure exists in urban areas, lack of maintenance has meant that this is often in a state of disrepair. While O.R. Tambo District Municipality is currently the Water Services Authority, the Water Services Development Plan includes a recommendation to investigate devolving this function to local municipality level where capacity exists. In several larger towns, including Mthata and Port St. Johns, the local municipality acts as the Water Services Provider. At both local municipality and district level, skills shortages are a challenge, and the extreme poverty prevalent in the area means that virtually all funding for water services provision comes from grants (O. R. District Municipality, 2003).

5.5 Alfred Nzo District Municipality

Alfred Nzo District Municipality has an area of 7 952km², bordering KwaZulu-Natal to the East and Lesotho to the North. Like O.R. Tambo DM, high levels of poverty and unemployment plague the district's mostly rural population, and 98% of households qualify for free basic water (De La Harpe, 2003). The water services backlog is estimated at at least 55% (Alfred Nzo District Municipality, 2006), based on data from the 2001 national census.

The District Municipality acts as the Water Services Authority for the entire area. As over 99% of the population lives in rural areas (De La Harpe, 2003), there is a strong focus on the use of community-based organisations (CBOs) as water services providers. A Support Services Agent (SSA) is contracted to train and support newly-established CBO Water Services Providers while the scheme is being implemented and capacity building is taking place. This approach, the first large-scale use of CBO WSPs in South Africa, has met with success (Mvula Trust, n. d.)(De La Harpe, 2003)(Illing & Gibson, 2004), and continues to expand into new areas.

6 Appropriate Technologies for the Development Context

Primo Braga, Daly and Sareen (2003) identify “stepping-stone” technologies that could contribute to ICT-enabled development. These include low-cost devices, wireless networks and Free and Open Source software. Depending on the operational context, some or all of these may be appropriate for water quality monitoring data collection, data management and reporting. This chapter looks specifically at two “stepping-stone” technologies: mobile devices and Open Source software.

At the end of the chapter, a short case study OpenMRS, an Open Source medical records system for the developing world, is presented. OpenMRS system is designed and managed in a way that actively encourages customisation and collaboration, providing a sustainable implementation model that could inform the design of a community drinking water quality management information system.

6.1 Remote Data Collection and Reporting using Mobile Devices

The ever-increasing penetration of mobile devices makes them ideal for systems requiring remote data collection and reporting. Mobile devices on the cellular network also allow feedback on a report to be immediately sent to the person sending the information. In the context of water quality monitoring, this could include advice on how to react to a test result, or a concerning sanitary inspection observation. This two-way information flow could support community management of water resources, while simultaneously improving monitoring capabilities of the water supply authority.

Cellular network coverage is expanding rapidly, with the GSM Association projecting that 90% of the world's population will have coverage by 2010 (GSM Association, 2006). African cellular phone subscribers numbered 76 million at the end of 2004, a penetration rate more than three times that of fixed lines (Gray, 2006). African cellular network coverage figures are also high – for example, 96% of South Africans live in areas covered by the cellular network (Vodacom, 2007). The GSM Association estimates that Coverage statistics by population for several other African countries are shown in Figure 13, while Figure 14 shows coverage by geographical area for South Africa, Rwanda and Zimbabwe

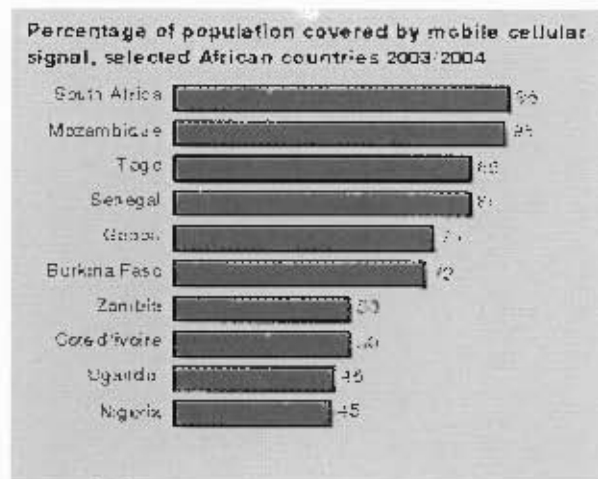


Figure 13: Cellular Network Coverage by Population for Selected African Countries (ITU, 2006)

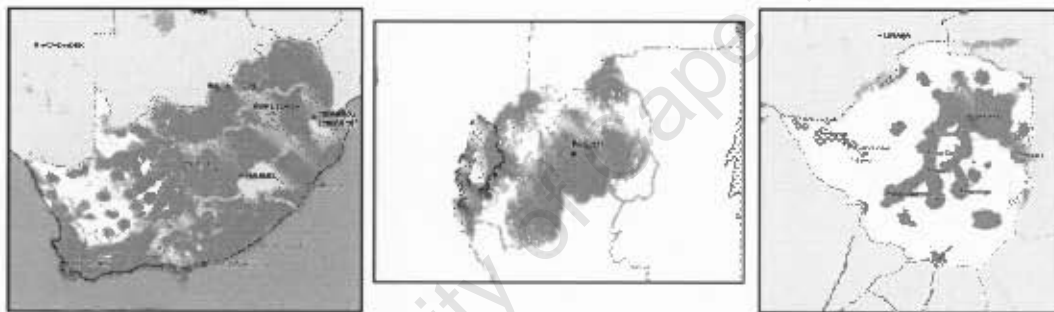


Figure 14: Cellular Network Coverage Maps for South Africa, Rwanda and Zimbabwe (GSM World, 2006)

6.1.1 Data Transmission over the Cellular Network

As well as extensive coverage, cellular network also offers relatively inexpensive and fast ways to transmit small amounts of data. An analysis of the records of an Indian cellular operator (Zerfos et al, 2004) revealed that over 70% of SMS text messages reach their destination in under 10 seconds. This is consistent with Cell-Life's experience in South Africa (Anand, 2005). An SMS can store up to 160 characters, and can cost as little as ZAR 0.32. Data services such as GPRS are increasingly available, and these can offer significant cost savings in data transmission (Fynn et al, 2006).

It is recognised that, while cellular operators may advertise coverage over a particular area, cellular signal strength can vary over short distances. Where coverage is variable, it may still be possible to connect the

device to a signal booster, thereby providing communication to areas with marginal coverage.

Alternatively, a store and forward data transmission system, where information is stored on the device for transmission when signal becomes available, is useful. SMS or text messaging is one such store-and-forward service. SMS-based, store-and-forward data transmission has been successfully implemented in India, where a pilot project using phones to record microlending information allows data to be stored on the device and transmitted when the travelling loan officer is in an area with network coverage (Parikh and Lazowska, 2006). Data transmission from remote community-managed water supplies is likely to require similar store-and-forward functionality, as network coverage is acknowledged to be problematic (Nel, 2007, Personal Communication) (De La Harpe, 2003).

Other GSM network services, such as USSD (Unstructured Supplementary Service Data) and GPRS (Global Packet Radio Service), allow real-time communication in an "always-on" session. GPRS in particular can offer significant cost savings over SMS. GPRS is packet-switched, meaning that data is broken up into small chunks ("packets"), transmitted as efficiently as possible, and reassembled at the receiving end. GPRS traffic is charged according to the quantity of data transmitted. It is primarily intended for email and web browsing. GPRS data costs in South Africa have recently dropped from R30 per megabyte to ZAR 2.00 per megabyte, and over 1 000 000 characters can be stored in one megabyte. An SMS can store 160 characters, and costs around ZAR 0.30 when bought as part of a bundle.

6.1.2 Menu-Based Data Collection

Mobile devices are increasingly seen as a rapid, accurate, secure replacement for paper-based data collection methods (Satellife, 2005). Mobile phones in particular are rugged, able to operate on battery power for long periods of time, and usable even by people who are illiterate or semi-literate (Chipchase, 2005). This makes them ideal for use in the developing world. Mobile adoption, and subsequent economic growth, have been impressive; The Economist reports that 10 extra phones per 100 people can increase economic growth by 0.6 percentage points (The Economist, 2005).

Different devices, from a low-end mobile phone to a smartphone or personal digital assistant (PDA) have different data collection capabilities. Mobile device user interfaces for data collection are often based on the paper forms that preceded them. The user must navigate through a set of questions on the device, just

as they would fill in responses to those questions on a paper form. The Satelife PDA project in Uganda (Satelife, 2005), where health workers collect various types of data on specially-programmed PDAs, is one example of this. Another is Cell-Life's Aftercare project in Gugulethu township near Cape Town, where home-based carers collect information on the patients they visit on a low-end mobile phone, and then transmit the information to a central database using SMS (Anand, 2005). It is easy to see how a sanitary inspection form, like the one shown below for a protected spring, could be delivered as a customised menu on a mobile device.

I. Type of facility: PROTECTED SPRING SOURCE	
1. General information:	Health centre:
	Village:
2. Code no.—Address:	
3. Water authority (community representative signature):	
4. Date of visit:	
5. Water sample taken?	Sample no.:
The monitoring officer's grade:	
II. Specific diagnostic information for assessment	
	Risk
1. Is the spring source unpowered by masonry or concrete wall or spring box and therefore open to surface contamination?	Y/N
2. Is the masonry protecting the spring source faulty?	Y/N
3. If there is a spring box, is there an unventilated inspection door in the masonry?	Y/N
4. Does the spring box contain contaminating dirt or animals?	Y/N
5. If there is an air vent in the masonry, is it unventilated?	Y/N
6. If there is an overflow pipe, is it unsanitary?	Y/N
7. Is the area around the spring unimproved?	Y/N
8. Can animals have access to within 30m of the spring source?	Y/N
9. Does the spring lack a surface water diversion ditch close to, or (if present) is it non-functional?	Y/N
10. Are there any latrines up hill of the spring?	Y/N
Total score of risks:	
(10 = very high, 6-8 = high, 3-5 = intermediate, 0-2 = low)	
III. Results and recommendations	
The following are the main points of risk:	
List any other:	

Figure 15: Paper-based sanitary inspection form



Figure 16: Mobile device equivalent

Mobile devices have extensive capabilities beyond acting as a paper form replacement, and these capabilities are already used by innovative mobile applications in the developing world. Among others, they include:

- **Data storage.** In the Satelife PDA project, searchable medical reference works are pre-loaded onto the device, giving health workers access to information that can help them make difficult diagnoses.

- **Fast Transmission of Urgent Data.** Cell-Life's Aftercare project incorporates a system of alerts, so that if a carer sees that a patient is in urgent need of care, they can alert the patient's doctor via the Aftercare system
- **Location Awareness.** CyberTracker, a PDA-based system for animal trackers in the Kalahari, incorporates a GPS chip to record the location of an observation (Blake, 2002). Various high-end mobile phones now also incorporate a GPS, or can be attached to a compact GPS module.
- **Image and Voice Capture.** The CAM system for microfinance in India (Parikh and Lazowska, 2006) used Nokia N-60 series camera phones to operate an innovative microfinance system in India. The system is accessed and navigated by capturing cameraphone-scannable barcodes off specially designed forms. Illiterate loan applicants can record their reason for requesting a loan as a voice message, eliminating misunderstanding.

6.2 Open Source Software

DWAF (2005) recommends the use of Open Source Software for drinking water quality data management. This recommendation is primarily for cost and interoperability reasons, and is consistent with the South African government's policy to use Open Source Software where it is seen to be the best option, offering equal advantages to the proprietary solution (NACI, 2004).

Open Source Software (OSS) refers to software for which the source code is made publicly available at no cost. By having access to a program's source code, the user is free to

- adapt the program to their needs
- learn from the code
- release improvements to the public
- redistribute copies for any purpose.

OSS is attractive to developing countries, where proprietary alternatives are prohibitively expensive on limited budgets, especially considering unfavourable exchange rates. In a development context, money

saved on software can be spent on training and infrastructure upgrading, enhancing the sustainability of the project and improving its ability to address the core development goal.

Several developing country governments have recognised the economic advantages offered by Open Source software, as well as its potential benefits to the local IT industry. The South African government has come out in support of Open Source software, undertaking to implement an open source solution where analysis shows it to be the best option, and to prefer it where it offers equal advantages to the proprietary solution. The implementation of Open Standards (see 6.2.3) is also seen as a priority (NACI, 2004). Bruggink (2003) praises a decision that he believes "acknowledges the need to create knowledge, understanding and capacity in order to realize the full potential of open source to deliver savings in the public sector as well as downstream social and economic benefits for the country". Brazil, China and India have also adopted policies supporting Open Source software.

6.2.1 Reasons for Using Open Source Software

The argument for Open Source software is most frequently made in terms of cost. Users are not required to pay licensing fees, as with proprietary software, and Total Cost Of Ownership (TCO) for open source software may (subject to environmental factors) be far lower as a result (Glance et al, 2004) (Wheeler, 2005) (MERIT, 2006). Bruggink (2003) likens open source software to generic drugs, which have been largely responsible for bringing first-world healthcare within reach of the developing world. The cost advantage is particularly relevant for projects where scalability is important, as proprietary software licensing costs generally increase as the number of users increases. There may also be savings in other components of TCO, as supplementary services such as training and support may be provided by anyone and not exclusively those chosen by the creators of the software.

The development of proprietary software is market-driven. As a result, groups of users who are not seen as profitable are less likely to find software that fits their needs. Language localisation is one example of this. While Microsoft Office 2003 supports 34 languages (Becker, 2004), the open source OpenOffice.org project lists 90 language localisation projects at various stages of completion (OpenOffice.org, 2007). customisation for specific applications, or to fit specific local conditions, is also possible with Open Source software as the program source code is freely available.

Open Source software often has a security advantage over proprietary software, and popular open source operating systems in particular are far less vulnerable to viruses than proprietary alternatives (NACI, 2004). Viruses and spyware can make systems run so slowly that they become almost unusable. More seriously, this type of malicious software can also allow an intruder to gain access to sensitive data. This problem is exacerbated by the wide availability of pirated software in the developing world, in some cases sold as a legal copy. Pirated software may not be eligible for security updates (Microsoft Windows XP has implemented this strategy), or undesirable programs may be hidden on the installation media. Open Source software offers a legal and secure alternative (Samoladas & Stamelos, 2003).

Particularly in emerging markets such as South Africa and Brazil, policies that support Open Source software are also seen as a way to expand the local IT sector. Open Source software represents a vast resource freely available to local software developers and providers of associated services. Participation in the Open Source community also offers an informal apprenticeship for world software developers, at no cost (MERIT, 2006). Policies supportive of OSS are acknowledged to support the development of the sector (MERIT, 2006) (NACI, 2004), and a strong local IT sector will greatly improve the long-term sustainability of ICTs in development projects.

6.2.2 Limitations of Open Source Software

Despite its advantages, Open Source software remains subject to all usual ICT evaluation criteria, and there are situations where it may not be appropriate. While Open Source software may be attractive in terms of licensing cost, factors such as usability, performance, reliability and scalability are equally important when choosing software components. Lack of documentation is regarded as a weakness of some Open Source projects, and concerns around usability have also been raised (Nichols & Twidale, 2002). ICT-enabled development projects in areas where the local IT industry is not yet well-developed may choose proprietary software because better support is available locally. Availability and pricing of supplementary services (localisation, training, support) should also be investigated before deciding on Open Source software (Wheeler, 2005).

6.2.3 Open Standards

A standard is a set of rules governing how a system component can interact with other system components. For a communication component (such as a modem), a standard could specify the interface that the component must present to other components wanting to send or receive data from it. For data, a standard could take the form of a prescribed storage format (such as ASCII text) or a prescribed exchange format (such as the extensible mark-up language, XML). Standards can be *de jure* (formally stipulated by an authoritative body) or *de facto* (informal, arising out of extensive use). An example of a *de jure* standard is the Open Geospatial Consortium's Geographic Markup Language (GML). TCP/IP, which governs the way computers communicate over the Internet, is a set of *de facto* standards.

An open standard is a standard whose development is undertaken collaboratively by, or in consultation with, all interested parties. The standard is then made freely available. This is in contrast to a proprietary standard, which is developed by a particular manufacturer and not released in order to prevent other manufacturer's products from working with its system components or data. As a result, open standards encourage interoperability (the ability of components from different manufacturers to integrate seamlessly and interchangeably into a system).

DWAF (2004) notes the importance of software interoperability in water quality monitoring, between systems used by different agencies as well as with legacy systems. NACI (2004) also recommends that governments and the public sector prefer systems that comply to open standards. In so doing, they stimulate of the local software industry to provide support, training and alternative software components, and increase the available options for both current and future system components.

6.3 Case Study: OpenMRS, A Open Source Medical Records System Framework for the Developing World

OpenMRS is an Open Source, collaborative framework designed to meet the challenges of medical records management for the HIV and TB epidemics that are devastating the developing world. There are OpenMRS implementations in Kenya, South Africa, Uganda and Rwanda, and over 25 000 HIV-positive people have patient records managed through an OpenMRS implementation (Mamlin & Biondich, 2006). Apart from the core medical records system, there are also developers working on innovative mobile

device interfaces to OpenMRS, an integrated reporting module and a “shrink-wrap” desktop version of the system (Seebregts et al, 2007).

As with most successful Open Source projects, OpenMRS leverages a strong developer community. In addition, the organisations that lead the OpenMRS project focus on building a strong implementer community (Seebregts et al, 2007). The system is designed to be highly configurable with no programming knowledge, allowing each implementer to tailor the implementation to the particular local context. Should additional customisation be required, the Open Source nature of OpenMRS allows implementers to contract any capable software developer to perform this. The implementer community provides a support network for new implementers, using tools such as forums, a mailing list, a wiki (a type of collaborative, editable web page) and face-to-face implementers meetings (Seebregts et al, 2007).

The combination of Open Source software usage and a collaborative approach allows OpenMRS to be highly customisable to local needs, low-cost and supportive of innovation. Combined with the support available from a strong implementer community, OpenMRS is a sustainable electronic medical records system that developing countries can implement and maintain themselves.

7 Requirements Definition

In this section, functional and non-functional system requirements are derived based on the operational context and information needs described in Chapters 3 and 4. An overview of the functional requirements is presented in the form of Use-Case diagrams and Use-Case narratives (after Jacobson, 1987). These, as well as non-functional requirements derived for the operational context, are then developed into a high-level requirements specification.

7.1 Use-Cases and Use-Case Narratives

Use-cases describe how various system actors (usually, but not always, human users) interact with a system. High-level or casual use-cases are appropriate for initial system definition, as they can be developed and modified easily, and are readable by non-specialists (Cockburn, 2001).

Following from the discussion of community drinking water quality information needs in Chapter 4, this section presents high-level use cases describing how stakeholders might interact with a community drinking water quality information system to fulfil their information needs.

7.1.1 Community Water Committee Use Case

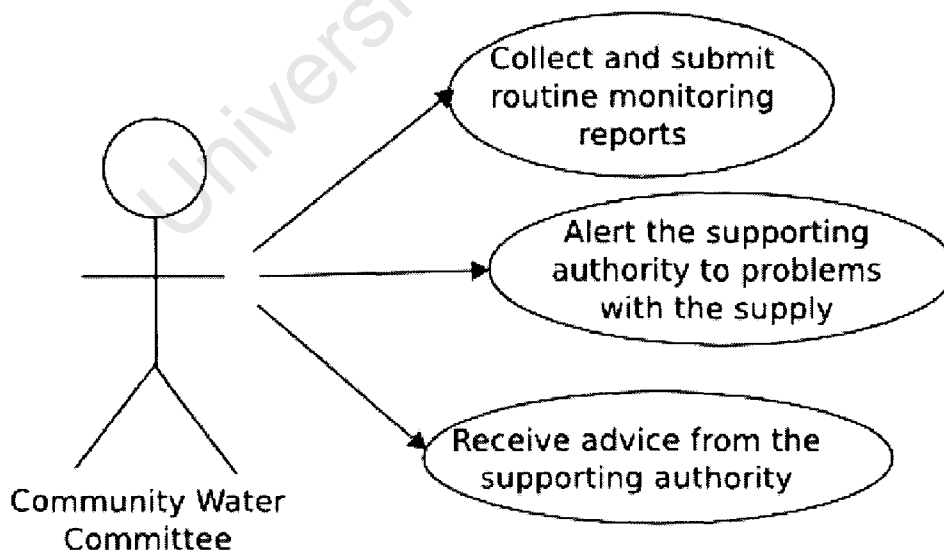


Figure 17: Community Water Committee Use Case

The Community-Based Organisation acting as the Water Service Provider (CBO WSP) needs to:

- Collect and report on an agreed set of indicators (which may include qualitative factors such as community satisfaction, and quantitative factors such as a field test result or sanitary inspection score)
- Submit these routine monitoring reports to the Supporting Authority (WSA and/or SSA), and receive confirmation that they have been received.
 - If routine monitoring reports were not received, get an error report with advice on how to proceed.
- Alert the Supporting Authority when there is a problem at the supply that they cannot solve, or when they require advice.
 - The alert should be able to include as much information as possible about the exact nature of the problem.
 - When the alert has been sent, confirmation of its receipt should be returned.
- Receive advice or warnings from the Supporting Authority.

7.1.2 Community Member Use-Case

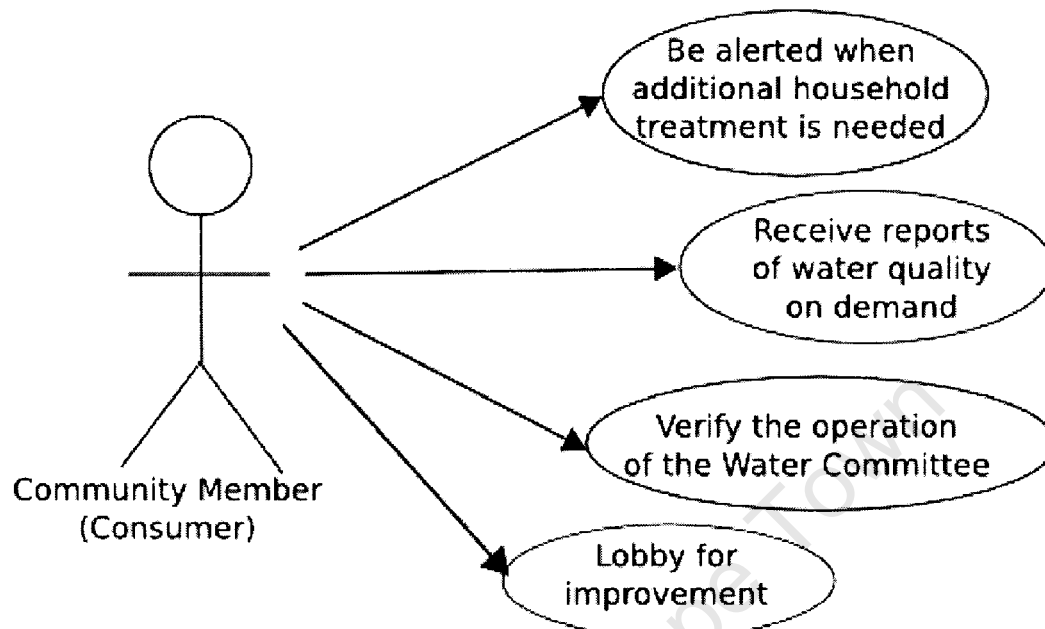


Figure 18: Community Member Use Case

The Community Member (consumer) needs to:

- Have access to information about the quality of their water
- Be timeously alerted to water quality problems, and informed about the action they should take
- Verify that the CBO WSP is carrying out its function correctly, and that safe drinking water is being supplied
- Use the water quality monitoring data to lobby local government for improvement (e.g. source protection measures)

7.1.3 Supporting Authority Use-Case

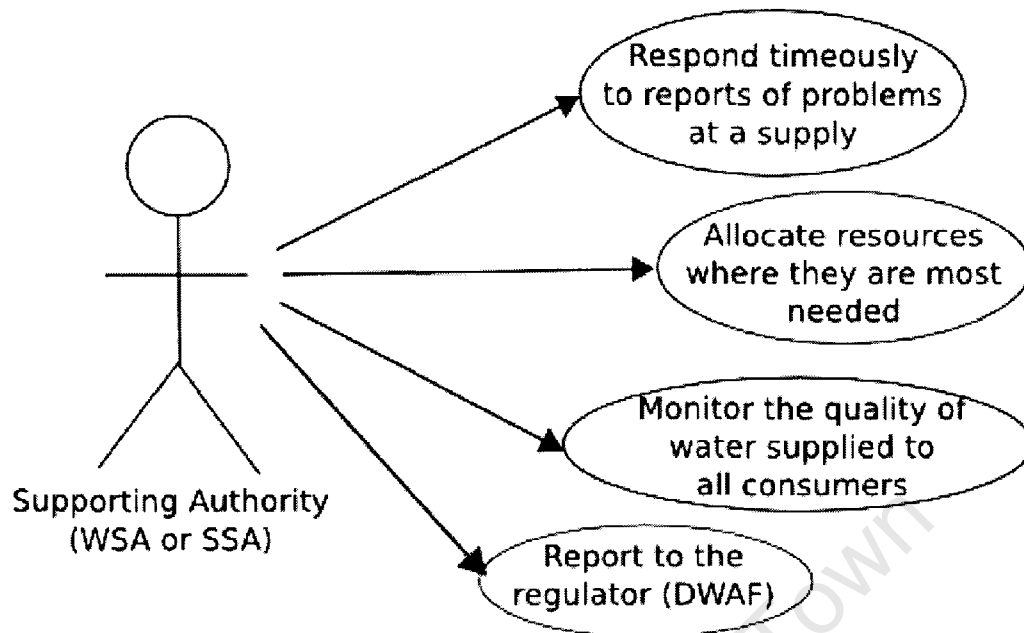


Figure 19: Supporting Authority Use Case

The Water Service Authority (WSA), and/or a Support Services Agent to whom some of the responsibility for supporting community supplies is contractually delegated, may need to:

- Monitor the quality of the water supplies to consumers on a monthly basis (a legislative requirement in terms of the Water Services Act), and report to the regulator (DWAf)
- Support community-managed supplies by providing advice or technical assistance in the event of problems at the supply
- Allocate resources where they are most needed

7.1.4 External Organisation Use-Case

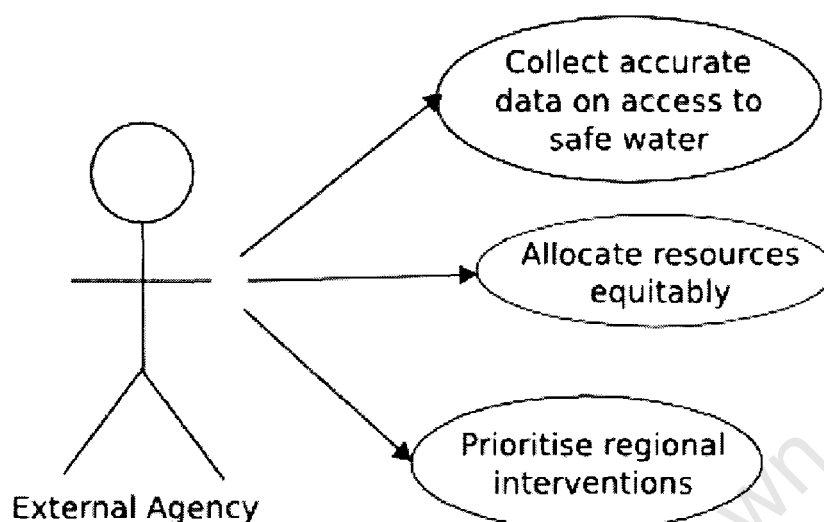


Figure 20: External Organisation Use-Case

External organisations may be interested in raw data from community-managed supplies, which they can incorporate into analysis. These organisations may need to:

- Monitor progress towards development goals around safe water based on the quality of water supplied, not the type of source (improved or unimproved)
- Prioritise regional interventions
- Allocate resources transparently and equitably

7.2 Infrastructure Assumptions

In designing a system to deliver the functionality described in the use-cases, infrastructure constraints imposed by the operating environment must be taken into account. This is necessary to satisfy Real Access Criteria 1 (Physical Access to Technology) and 2 (Appropriateness of Technology).

For the community drinking water quality management system, the following infrastructure constraints were assumed. These were derived based on the operational context for community-managed supplies described in Chapter 3, and were confirmed during the user interview stage of the project.

- At the site of the community-managed supply, there may not be electricity. Cellular signal reception is likely to be available at the site or nearby (for example, at the top of a nearby hill, or in a small town that community members may visit periodically for supplies). However, signal reception may be variable in time and space.
- At the site of the Water Service Authority or Support Services Agent, the electricity supply is reasonably reliable. There is also likely to be an internet connection, as the roll-out of eWQMS, a web-based system, necessitated the installation of internet connections at all district municipalities. However, the internet connection may not always be available, as WSAs are not always located in major centres with technical support nearby, and connectivity problems may take some time to rectify.
- Users from external organisations wanting to access raw data from the system (for research or further manipulation) have a reliable internet connection.

7.3 System Components

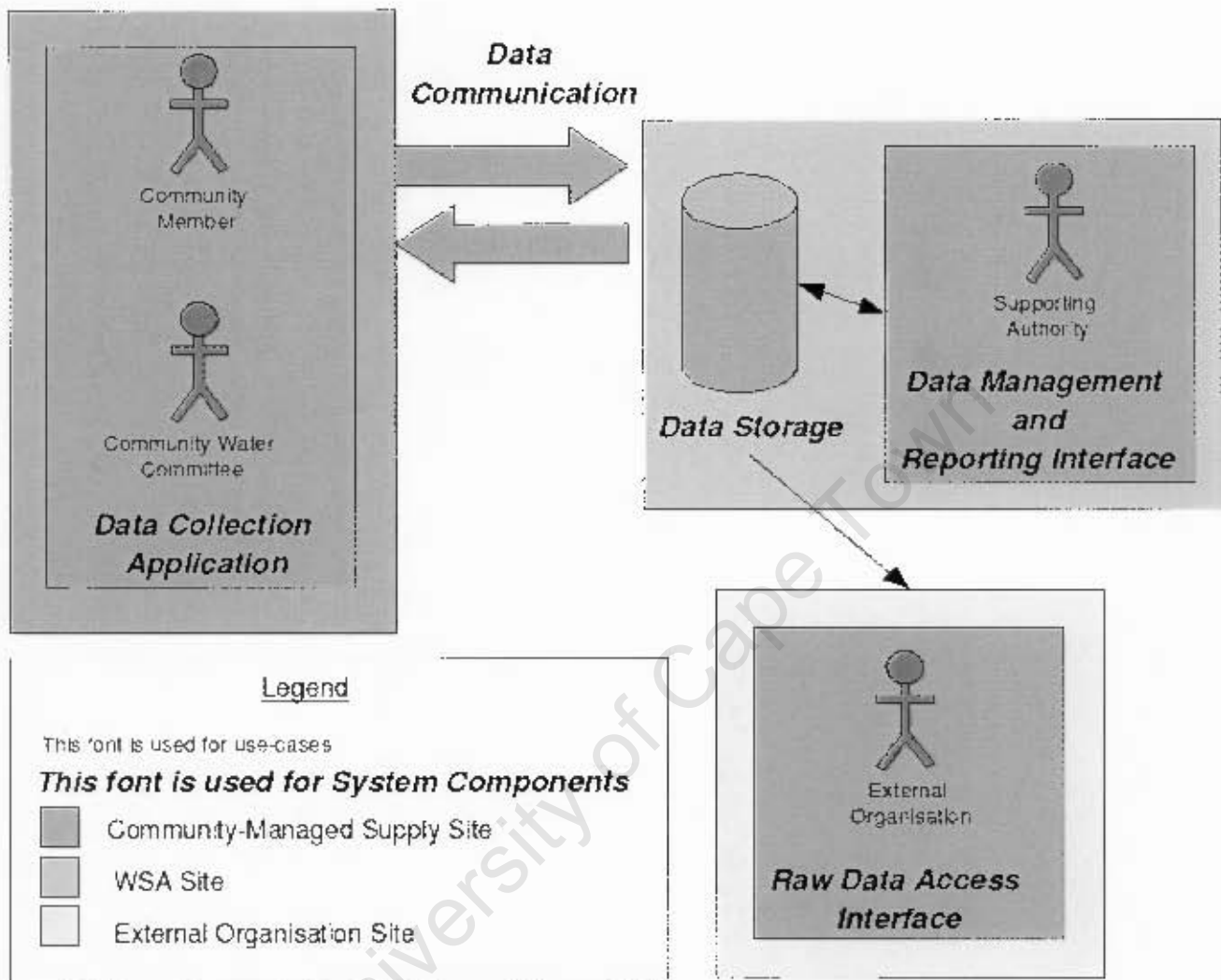


Figure 21: System Components arranged by Use-Case and Operating Environment

Different users of a community water management system operate under different environmental constraints, as well as requiring different system functionality, content and presentation. In order to match system design choices closely to user needs, the system was divided into components. In the next section, high-level functional and non-functional requirements will be developed for each component.

7.4 High-Level System Requirements

The table below presents the high-level system requirements, divided into functional and non-functional requirements. Functional requirements, which define the services a system needs to provide to users, have been derived from the use-cases in the previous section. Non-functional requirements, which define the constraints under which the system should operate, are derived from the infrastructure assumptions in 6.2, and the operational context for community-managed supplies in South Africa in Chapter 3.

<i>System</i>	<i>Functional Requirements</i>	<i>Non-Functional Requirements</i>
<i>Component</i>		
1. Data Collection Application	<ul style="list-style-type: none"> (a) Allow guided data collection for a set of indicators defined by the responsible WSA (b) Allow collection of free text alert messages (c) Receive confirmation of message receipt (d) Receive information and warning messages 	<ul style="list-style-type: none"> i. Easily translated into local languages ii. Usable by semi-literate users iii. Require very little user training iv. Not require electricity to operate

<i>System</i>	<i>Functional Requirements</i>	<i>Non-Functional Requirements</i>
<i>Component</i>		
2. Data Communication	<p>(a) Transmit reports, alerts, recommendations and warning messages between the CBO WSP and the supporting authority.</p> <p>(b) Store-and-forward data when no cellular signal is available</p>	<p>i. Available on relatively inexpensive, rugged phones</p> <p>ii. Reliable – will deliver a message even if not immediately</p>
3. Data Storage	<p>(a) customisable – should be able to store results from any user-defined test</p> <p>(b) Geo-referenced – sites should have a location in co-ordinates</p>	<p>i. Reliable – should allow automated backups of the database</p> <p>ii. Standards compliant</p>

<i>System</i>	<i>Functional Requirements</i>	<i>Non-Functional Requirements</i>
<i>Component</i>		
4. Data Management and Reporting Interface	<p>(a) Allows user to access all readings from a site</p> <p>(b) Provide a graphical warning when a reading exceeds a prescribed limit</p> <p>(c) Produce graphs showing readings over time for a parameter</p> <p>(d) Allow user to interact with the system via a simple, clickable map interface</p> <p>(e) Provide quick access to incoming alerts</p> <p>(f) Provide a way to mark alerts as received and acted upon</p> <p>(g) Provide an interface to send messages to all sites, or to a selection of sites</p> <p>(h) Submit data to other systems, particularly the existing eWQMS system</p>	<p>i. May need to be available off-line in certain areas</p> <p>ii. Usable by non-technical people</p> <p>iii. Easy to support and maintain</p> <p>iv. Available on most hardware currently in use – should not require significant processing power, memory or storage capacity</p>

<i>System</i>	<i>Functional Requirements</i>	<i>Non-Functional Requirements</i>
<i>Component</i>		
5. Raw Data Access Interface	(a) Allow read-only access to all non-sensitive data. (b) Allow users to download the data set (c) Allow users to access the dataset as a web service	v. Standards Compliant vi. Well documented vii. Secure – should not allow unauthorised modification of data

University of Cape Town

8 Prototype Development

The prototype system was developed primarily as a working demonstration that could be shown to potential users. During interviews, users interacted with the working prototype system, and could then help to refine the user requirements. Prototyping was also used to validate the chosen technologies and system architecture, and identify any design changes or potential problems before the start of the next development iteration.

The prototype system implements a subset of the required functionality of each component. To define this subset, the system presented above was divided into:

- A **routine monitoring subsystem**, for regular reporting on an agreed set of indicators
- An **alerts subsystem**, for *ad-hoc* communication between the WSA and the community

The routine monitoring subsystem was chosen for development as the prototype system. Only the parts of the data model and data collection component relevant to the monitoring subsystem are therefore discussed in the sections that follow. However, the alerts subsystem remains extremely important, as verified by users during interviews. All the technology and design choices here apply to both subsystems, and the addition of alerts functionality would require extending the current prototype, but would not require changes to the system design or to the implementation of the monitoring subsystem.

While only the prototype design process is described in this chapter, the development and configuration of each component was also a significant part of this project. There is a need to document the development and configuration work that was done, as this will allow further work on this or similar systems to build on what has already been done. Rather than exhaustively documenting the configuration and development portion in text, Appendix A contains a fully functional live CD, which contains a bootable, customised operating system. All the components described here are installed and configured on the live CD, which will run without affecting existing operating systems on any suitably configured computer. Because all components used and developed are Open Source, the live CD also includes all the relevant source code and configuration information. The inclusion of the live CD enables anyone with the

necessary programming, database administration and system configuration skills to fully reproduce all the development and configuration work done for this project.

8.1 System Architecture

A client-server architecture is the obvious choice for a system where many distributed users need to access the data in different ways (Feinstein, 2000). Figure 22 shows a client-server architecture, differentiating the functions of the client and server components.

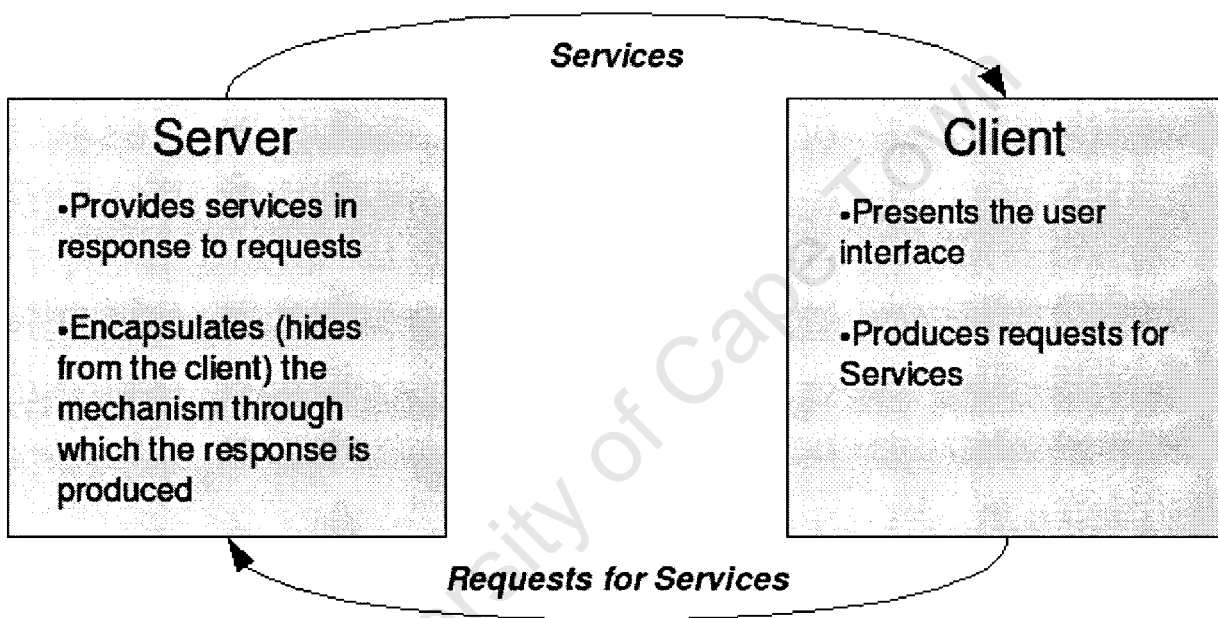


Figure 22: A client-server architecture. After Feinstein (2000) and Sinha (1992)

In most web-based systems, the server is further divided into application server and database server components. The application server receives a request from the client, requests data from the database server where necessary, and processes the request into a response to be sent to the client. This is a three-tiered client-server architecture – the client is the first tier, the application server the second tier, and the database server the third tier. Conversely, a two-tiered client-server architecture, which is more common in desktop applications, usually consists of the client and the database server only. In this case, the functions of the application server are performed on the client side.

In a three-tiered architecture, very little processing is typically done by the client, which is only responsible for producing requests and presenting results from the application server. This kind of client is called a “thin” client, and does very little or no data processing. The hardware requirements on the client side of a thin client system are therefore low. Two-tiered applications, which usually incorporate the application server's the data processing operations into the client, make use of a “thick” or “fat” client. Depending on the type of data and the processing being done (for example, large files or multimedia visualisations), the hardware requirements on the client side can be higher when a thick client architecture is chosen.

A browser-based, three-tiered, thin client architecture was chosen for the prototype system. The main factor influencing this choice was maintainability, as a browser-based system can be very easily updated by making changes on the server only. This means that technical support staff do not need to travel to distant client sites. This architecture also imposes lower hardware requirements on the client side, which is important when processing geo-referenced data.

Potential problems arising from poor network connectivity were considered when choosing the client-server model. These could be mitigated by:

- Using low-end PCs as clients, but putting the money saved in this way into good network infrastructure and security
- Stimulating the local IT industry to provide support services to networks on the client side
- If necessary, considering hosting the database on a local server on site, so that it does not need to be accessed over the Internet. As discussed in Section 8.4, if this option is chosen, SMS is a more feasible data transmission method. Regular replication of the database to an external server would also need to be in place to allow external access to the data, and to ensure that data is securely backed up.

Figure 23 shows the architecture chosen for the prototype system.

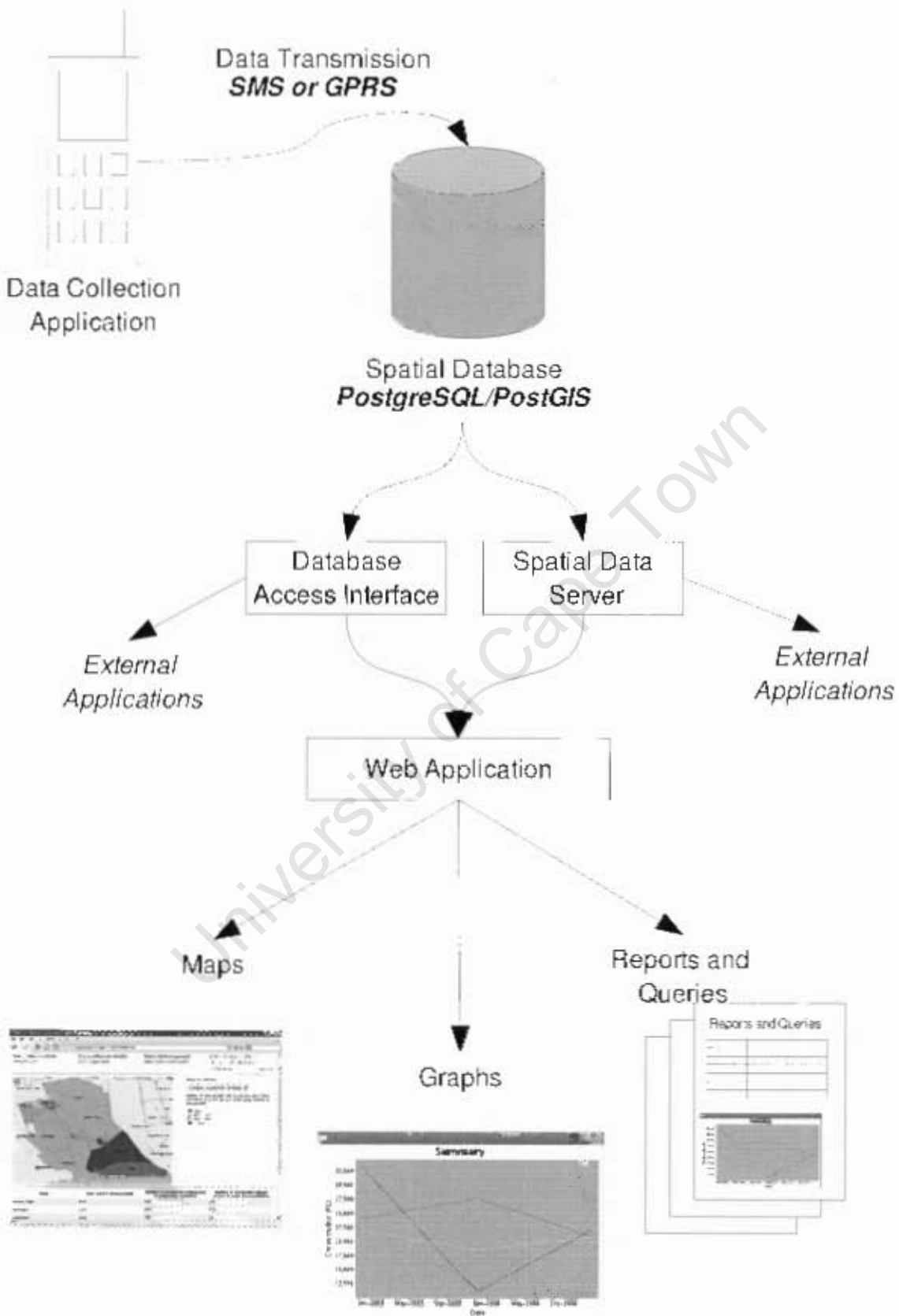


Figure 23: Prototype System Architecture

8.2 Data Collection and Data Transmission

At the start of this project, mobile devices (specifically, mobile phones on the GSM network) were identified as potentially suitable for data collection and reporting by community-managed supplies. Mobile phones currently available in South Africa offer widely varying functionality, from basic voice calls and text messages only on the cheapest phones, to high-speed internet access and scaled-down versions of common PC applications (office suite, email client, organiser) on high-end phones.

While the extensive capabilities of high-end phones may prove very useful in community supply management, considerations of cost, simplicity, power usage and theft prevention mean that lower-end phones were chosen as the target platform for the prototype. Only technologies that are available on phones in the ZAR 300.00 to ZAR 800.00 range were therefore considered. For data collection, possible technologies therefore include WIG (Wireless Internet Gateway) and J2ME (Java 2 Micro Edition). For data transmission, SMS (Short Message Service), GPRS (General Packet Radio Service), MMS (Multimedia Messaging Service), WAP and USSD (Unstructured Supplementary Service Data) are available on phones in the specified price range. As both WAP and USSD require a two-way exchange of data over the cellular network (Anand, 2005), they are not very useful where network coverage is poor or variable, and were excluded.

8.2.1 Data Collection

For the menu-based data collection component, WIG (Wireless Internet Gateway) and J2ME (Java Micro Edition) applications were considered.

WIG applications were initially designed to browse external websites written in Wireless Markup Language (WML), using WAP (Wireless Access Protocol). However, all 32K SIM cards now incorporate a WML browser, allowing WIG menus to be stored as static files on the SIM card and accessed on the built-in WML browser (Anand, 2005). WIG menus are available on almost all currently available phones, but have the following disadvantages:

- The size of the menu is limited to 1 kilobyte

- Special arrangements must be made with the network operator (Vodacom, MTN or Cell-C in South Africa) to “push” the WIG menu onto each SIM card. This can only be done by the network operator.
- Translation into other languages must be done manually, with a new WIG menu being created for each language

Anand (2005) and Anand and Rivett (2006) describe a successful menu-based WIG system in use in several home-based care organisations around South Africa. The choice of WIG for this system was based on the high cost of J2ME-capable phones at the time it was initially developed (2003 – 2005). Since then, this cost has come down significantly (Fynn et al, 2005). This makes J2ME an attractive option, as its advantages include:

- Users can download (“pull”) J2ME applications onto any capable phone. The network operator does not need to be involved
- The maximum size of J2ME applications varies from phone to phone, but all phones conforming to the Java Technology for the Wireless Industry (JTWI) specification must have a maximum application size limit of 64 kilobytes or larger
- A range of user interface widgets (check boxes, dropdown lists etc.) is available, helping to improve the user experience
- Like all Java applications, J2ME applications can be easily translated by storing all text strings in a separate language-specific file

For the prototype system, ease of development within a limited timeframe was also a consideration.

While WIG menus require specialised development tools (Anand 2005), J2ME is by far the most widely used mobile application platform, and as a result is supported by standard, full-featured Java development environments such as NetBeans and Eclipse. Combined with the advantages listed above, this made J2ME the preferred platform for the data collection application. A screenshot of the completed application running in the NetBeans simulator is shown in Figure 24.

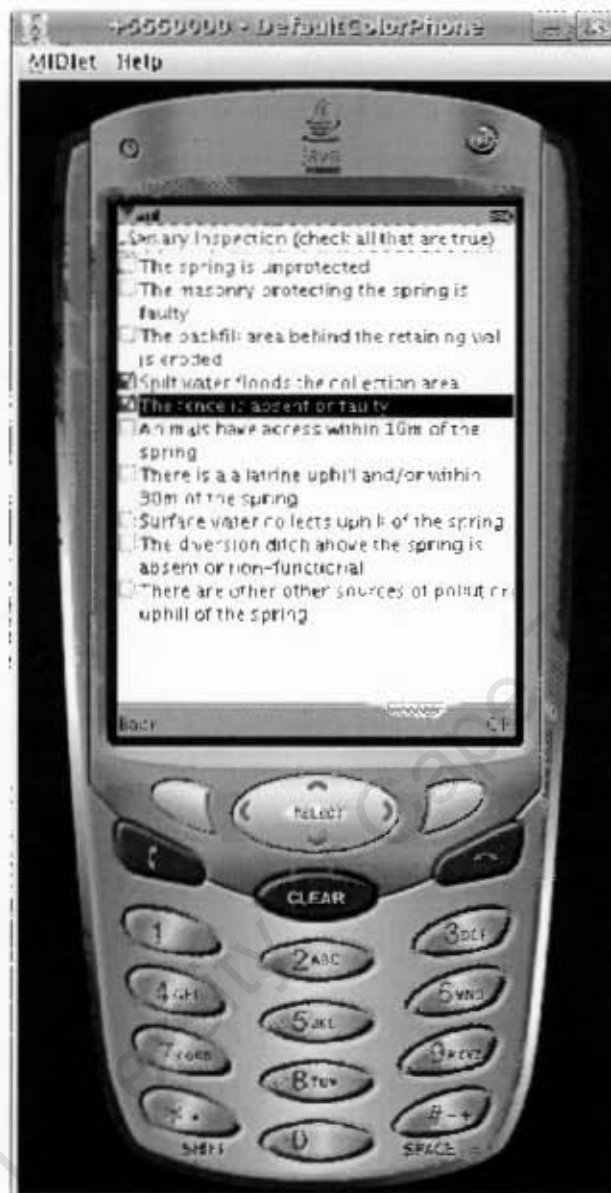


Figure 24: Prototype J2ME Data Collection Application

8.2.2 Data Transmission

SMS has been part of the GSM standard since its inception, and is available on nearly all mobile phones currently in circulation. SMS is useful as a data transmission method because it is relatively inexpensive – around 30c for a message if a bulk package is bought from a service provider. However, there is a size limit of 160 characters on one SMS message, so depending on the quantity of data collected, one report

may comprise more than one message. A particular advantage of SMS is reverse billing. Using this service, the user (or company) at the receiving end of the message can pay the message cost, and messages can be sent even from phones with no airtime. SMS-capable phones also implement a store-and-forward sending strategy, which means that reports that can not be sent because of reception problems are queued until reception is available, and sent automatically.

When sending regular, small amounts of data (such as water quality readings) over GPRS, significant cost savings over SMS are possible. Although GPRS is not available on the most basic phones, it is currently possible to buy a GPRS-enabled phone around ZAR 700.00. The cost saving is particularly evident as the number of transactions increases, as shown in Figure 25 below.

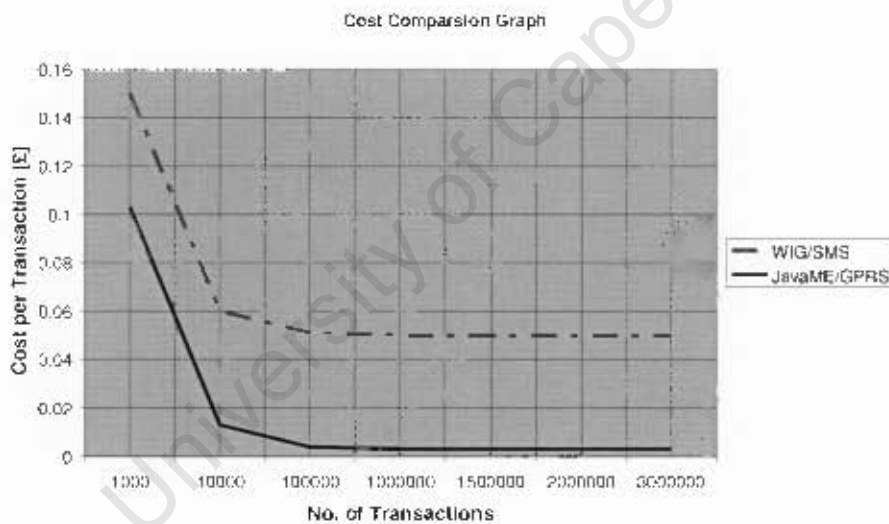


Figure 25: Cost per transaction vs. number of transactions: GPRS and SMS (Fynn et al, 2006)

A disadvantage of GPRS is that it does not natively implement store-and-forward (Varghese & Siddharth, no date). This would have to be written as part of the J2ME application.

Using SMS, a GSM modem, with a SIM card, is required on the receiving side to accept the message and transmit it to a software component called an SMS Gateway. The SMS gateway receives the SMS, and

runs a service (which may call a script on a web server or on the local machine) to insert the data into the database. Because data is received and sent only through the GSM modem, the database server does not have to have a permanent Internet connection when SMS is chosen as the data transmission mechanism.

Using GPRS, it is possible to send an HTTP GET or POST request (containing the data to be transmitted) directly to the database server for insertion into the database, and the need for specialised hardware on the server side is eliminated. However, to do this, the database server must be externally accessible (always connected to the internet). GPRS is therefore less suitable for situations where Internet connectivity is limited or slow, and the database server is hosted on site.

For the prototype system, both SMS and GPRS-based data transmission were implemented. This was done to evaluate the ease of developing systems for both methods. Only GPRS data transmission is available on the live CD, as the hardware required to receive SMSs, namely a GSM modem, would not be present.

As the choice of data transmission method is dictated partly by cost and service availability, and partly by the choice of local or offsite database hosting, a future system could easily implement both methods and maintain flexibility in this regard.

8.3 Storage Component

A relational database is the standard storage mechanism for dynamic data used by web applications. Database management systems for relational databases, such as MySQL, PostgreSQL, Oracle and Microsoft SQL Server, provide a powerful mechanism for storing and retrieving data that is frequently changed or updated. Both MySQL and PostgreSQL are Open Source, stable and widely used. For geo-referenced data, PostgreSQL provides the PostGIS extensions, which comply with the Simple Features for SQL standard. This is by far the most widely used open source geo-database system, and is therefore well supported by other open source GIS tools (Ramsey, 2006). For this reason, a PostgreSQL database (with PostGIS extensions) was chosen as the data storage mechanism. The only datasets not stored in the database are the roads, rivers and districts layers used as a backdrop to the sampling points layer shown in the map viewer (described in the next section). These datasets change very rarely, and are therefore stored

in a flat shapefile format, which offers better performance than a geo-referenced database table for large datasets.

8.3.1 Data Model

Once the decision to use a relational database had been taken, the following requirements dictated the design of the data model for the prototype system

- The data model should be normalised to at least the third normal form (3NF) (Codd, 1990), to impose design principles that improve maintainability and extensibility. The requirements for this are:
 - Duplicate columns are eliminated, and each record has a primary key (first normal form)
 - In the case of composite primary keys, each column depend on the whole key (second normal form)
 - Each column depends on the primary key for the table (third normal form)

(After Coulson, 2006)

- The data model should allow results to be recorded for any tested parameter, as the parameters to be measured may need to be defined by the user to respond to a particular operational context.

This last requirement is difficult to model in a normal static database structure, as for each new type of test from which results should be stored in the database, a new column would have to be added to the results table. This situation is analogous to that of medical test results, where a patient is only ever tested for a tiny subset of the possible parameters that could be measured. The Entity-Attribute-Value (EAV) model, also used in OpenMRS, is typically applied to this kind of data.

The skeleton tables below compare a representation of test results in a conventional relational model, with one in the EAV model.

Conventional Relational Data Model	EAV Model
<i>Site</i> (<u>id</u> ,name,location)	<i>Site</i> (<u>id</u> ,name,location)
<i>Sample</i> (<u>id</u> , <u>site_id</u> , ecoli,total_coliforms,turbidity)	<i>TestType</i> (<u>id</u> ,name,units)
	<i>Sample</i> (<u>id</u> , <u>site_id</u>)

MeasuredValue(id, sample_id, test_type, value)

In the EAV model, a concept table stores a continuously growing list of possible parameters that can be measured. Measured values for each parameter then store the concept to which the measurement refers (as a foreign key) and the actual value measured (Nadkarni, 2001). In the table above, TestType is a concept that represents any type of test that could be performed as part of a drinking water quality monitoring programme.

The EAV model makes extracting information from the database more complicated. In the EAV model example above, you would need to look at all four tables to find the site name, test name and test results for all samples taken at a site, while in the conventional model, this information could be obtained from only the two tables shown. However, its flexibility is a great advantage, as it can accommodate any set of test types without requiring a schema change. A water safety plan approach entails monitoring control points that are chosen according to local environmental conditions, and may be different for different supplies, making flexibility an essential aspect of the data model.

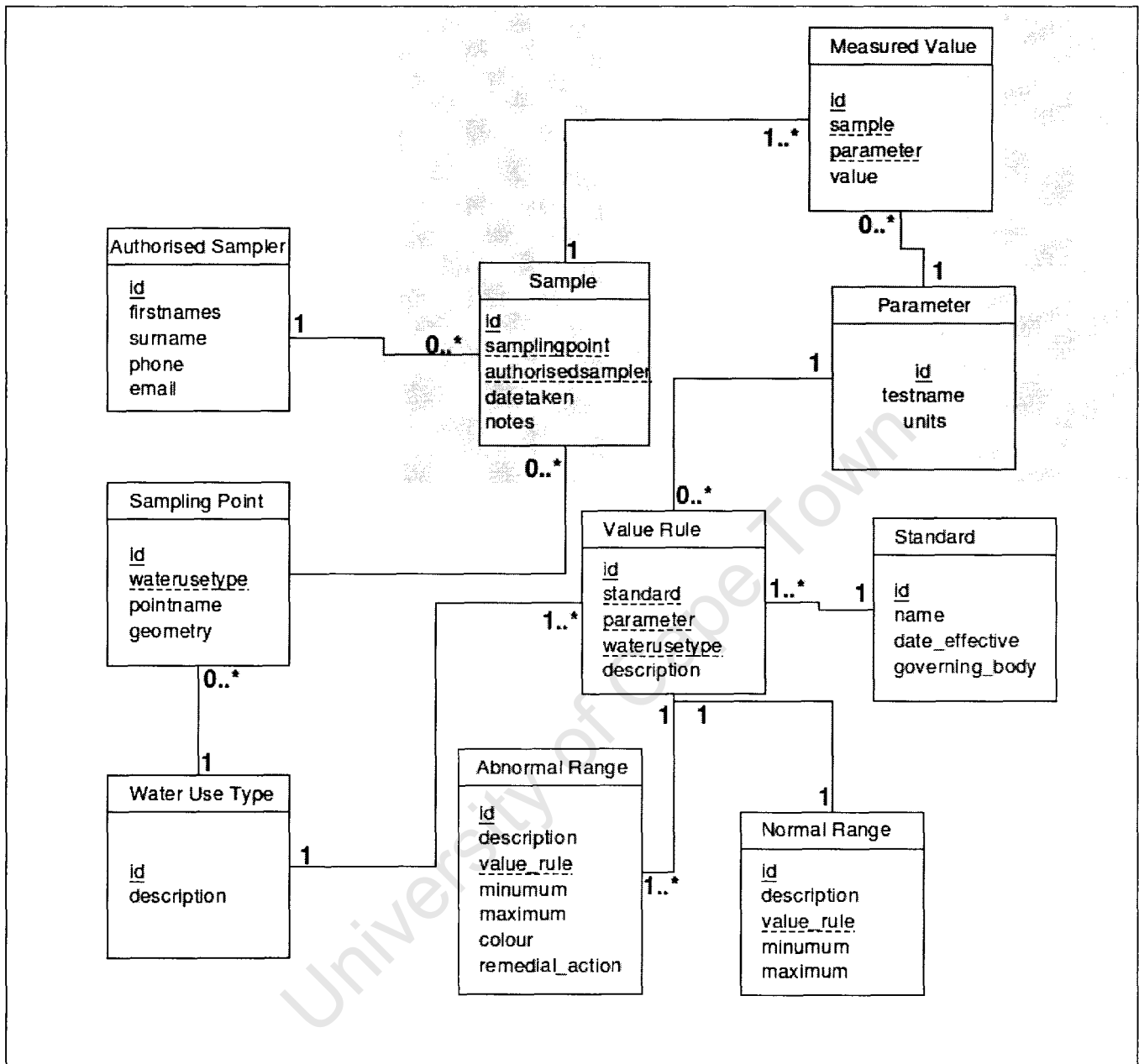


Figure 26: Data Model Diagram. The EAV model is used for test results (relations Sample, MeasuredValue and Parameter)

To achieve flexibility, the test results portion of the community drinking water quality data model uses the EAV model. The rest of the database uses a less complex conventional relational model. Figure 26. shows the data model for the routine monitoring subsystem.

8.4 Data Management and Reporting Component

The choice of a thin client architecture means that the functionality of the data management and reporting component is split over the web application server and the client, with the client responsible only for the presentation of the data. In a browser-based thin client, the work of the client consists mostly of graphically displaying results computed on the application server. The desired presentation of the results is specified by the server using HTML (hypertext markup language, which defines content and semantics) and CSS (cascading style sheets, which define the style and formatting of the HTML content).

The work of the application server includes:

- Retrieving non-spatial data from the database in response to user requests
- Providing the clickable, navigable map interface and responding to spatial requests (What features are within this bounding box? What are the attributes of the feature located at a point clicked on the map?)

Although not implemented in the prototype system, the application server should also handle creating, deleting and updating tests, authorised users, sites and standards (Create, Read, Update and Delete, or CRUD functions) in the database, in response to user requests.

The data management and reporting component is designed so that the primary user interaction takes place through an interactive map of sites. Other data access methods, such as searching for a site selected from a list of all available sites, were also implemented, and although a query builder interface was not included in the prototype system, this would be an essential component in the complete system. The decision to implement the map interface as the major component of the prototype system was taken because it offered an interesting user interaction paradigm for system demonstrations and user interviews. It was also the most technically challenging part of the system, and the prototyping process was used to verify that it was possible to fulfil this requirement as designed, within the limits of the operational context.

Ramsey (2006) lists a large collection of Open Source spatial data server and client components. Of these, UMN Mapserver is the most widely used. It is a spatial data server written in C, using Open Source libraries including GEOS (for spatial queries), gdal (for raster and vector data handling) and proj4 (for

projections), and support more formats and is faster than comparable proprietary packages (Ramsey, 2006). While UMN Mapserver is a good choice on the server side, it does not implement a client.

Rather than extending a separate mapserver client, Cartoweb, a client-server framework built on top of UMN Mapserver was chosen for the map display part of the prototype. Cartoweb is written in PHP, a scripting language that is widely used for interactive websites. The entire system is designed as a plugin framework, and well documented to allow developers to extend and customise it easily. It is also highly configurable. While the many different configuration files make it difficult to set up initially, it is ideal as a framework for building customised applications.

The screenshots below show the data management and reporting application.

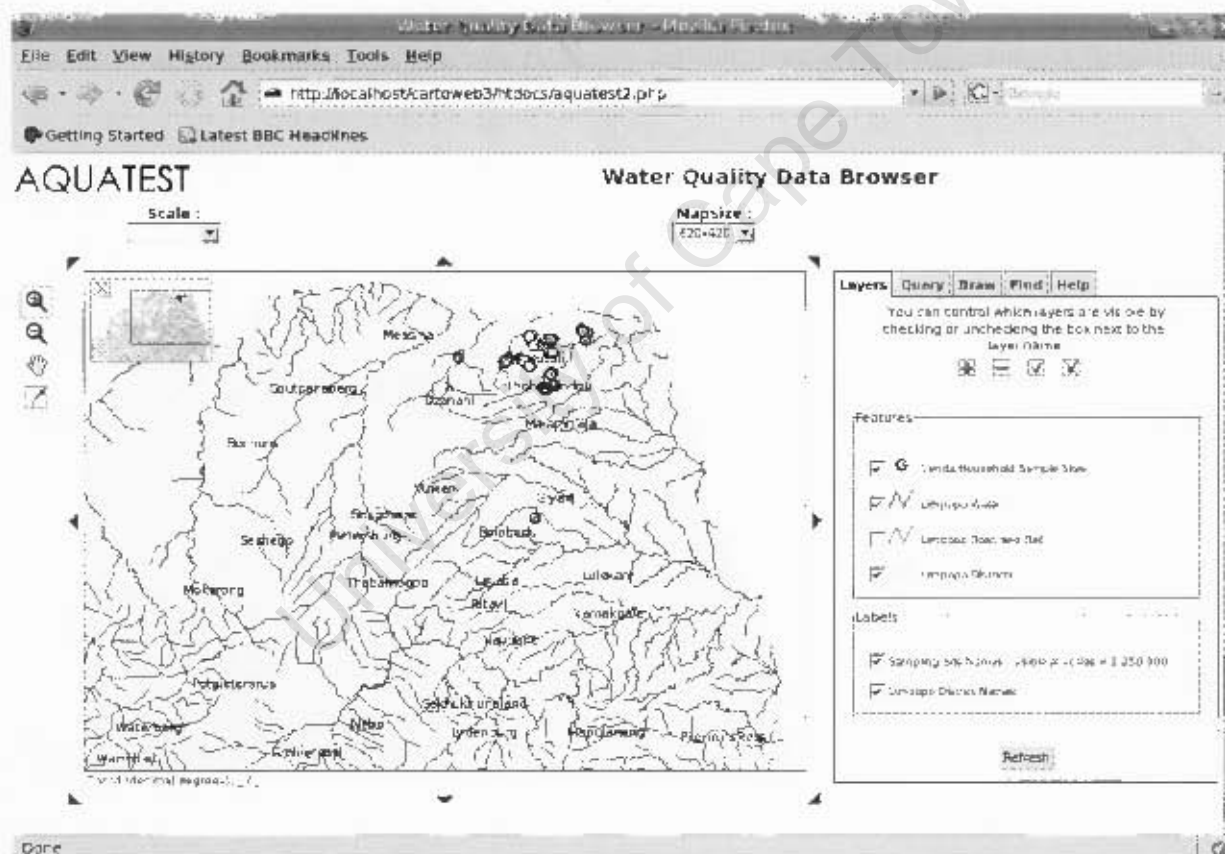


Figure 27: Data Management and Reporting Interface - main screen

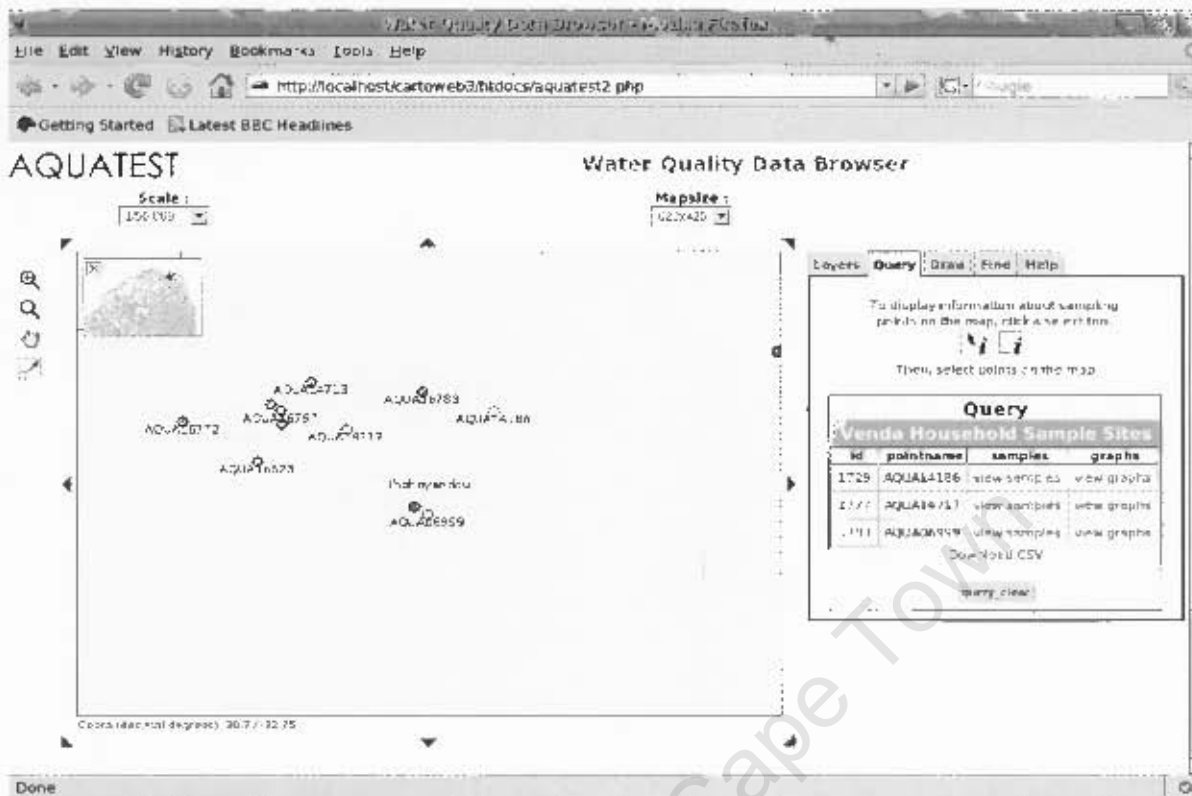


Figure 28: Data Management and Reporting Interface - A query based on points selected on the map

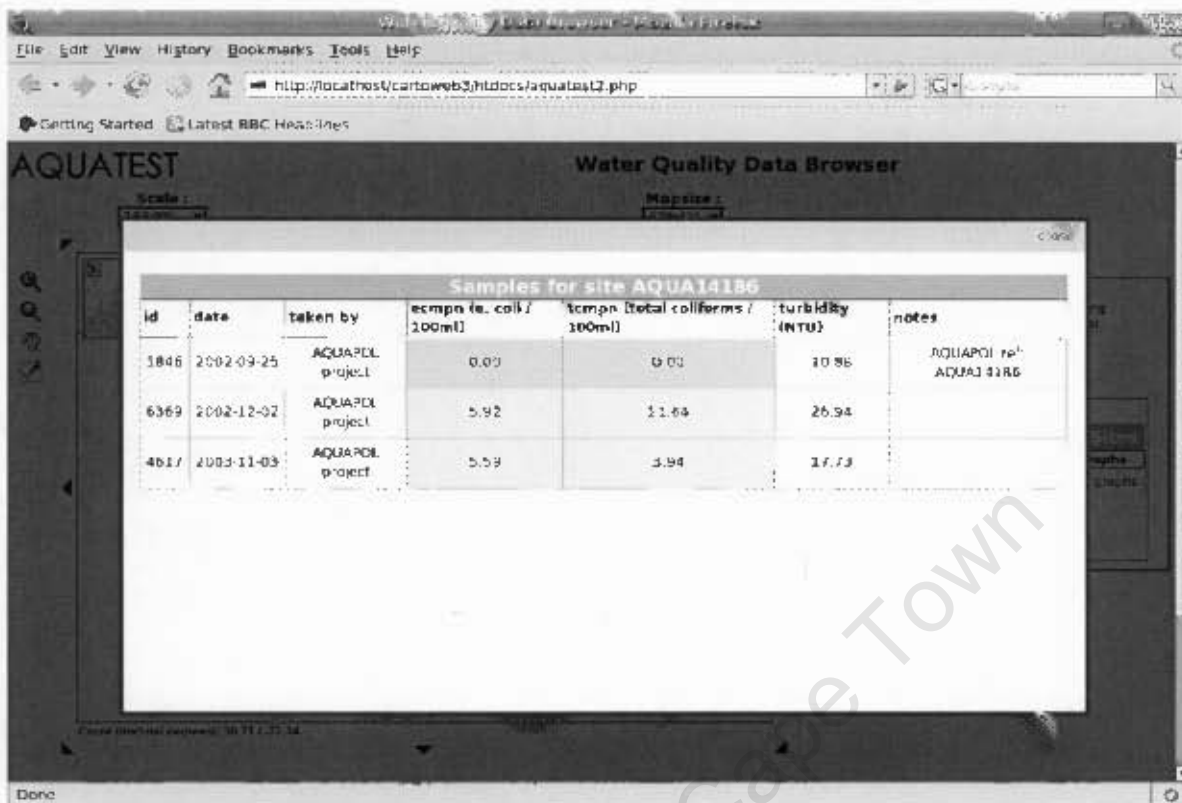


Figure 29: Data Monitoring and Reporting Interface - Table of monitoring results for a site, coloured to indicate value relative to the relevant standard

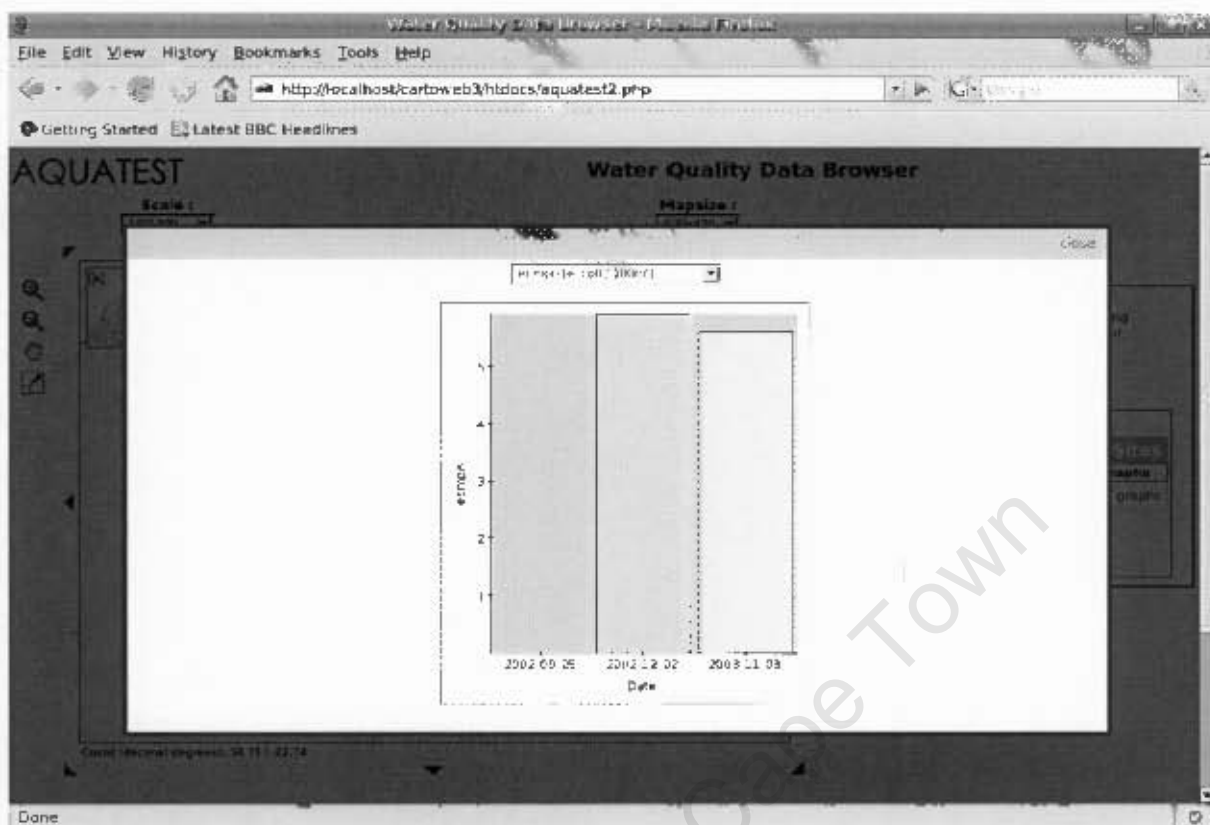


Figure 30: Data Management and Reporting Interface - Graph of monitoring results for a site, coloured to indicate value relative to the relevant standard

8.5 Raw Data Access Interface

The raw data access interface should allow external users to view, download and further manipulate the data stored in the community drinking water quality information system. Standards compliance is essential in the design of this interface, as users may wish to interact with the data using external applications (such as a spreadsheet program, or a spatial data viewer). Open standards, which place no restrictions on who can implement the standard, are preferred, as they do not limit the user's choice of external application.

Where the database server is not hosted on an internet-accessible server (as would be the case for sites without a reliable internet connection), raw data access over the Internet relies on replicating the database to an Internet-accessible server. As real-time data access is not the goal of this interface, replication could take place at scheduled intervals (for example, once a day). It is possible to replicate the database over an

Internet connection that is not appropriate for database access, such as a connection over the GSM network (Brown et al, 2007).

8.5.1 Access to Non-Spatial Data

External access to PostgreSQL databases is already implemented by the database server, as long as database is located on a server that can be accessed over the internet. PostgreSQL fully implements the SQL 92/99 standards for data storage and retrieval, and also has application programming interfaces available for Java (through JDBC), ODBC, Perl, Python, Ruby, C, C++ and PHP, among others (PostgreSQL, 2007). The only configuration necessary is the creation of appropriate user roles for external users who are likely only to have read access to data. However, this interface does not provide specific functionality for spatial data (such as indexing and caching), and is therefore more suitable for access to the non-spatial data in the community drinking water quality management system.

8.5.2 Access to Spatial Data

Spatial data access over the Internet is governed by the Open Geospatial Consortium (OGC)'s Web Map Service (WMS), Web Feature Service (WFS) and other standards. These standards have been widely adopted, and as well as being implemented by most Open Source GIS components, major proprietary systems such as ESRI's ArcMap can work with WFS and WMS datasets.

GeoServer is a mature, open source spatial data server that also serves as the reference implementation for the OGC standards. While MapServer is more widely used, it is only fully compliant with the WMS standard, and not with WFS. As a result, Geoserver was the chosen spatial data server for the community drinking water quality information system.

Although Geoserver itself works immediately on extracting the downloaded archive, there is some configuration required to specify the data that should be available from the server. The configuration files used for the raw data access interface are available on the live CD. Udig (User-friendly Desktop GIS), an Open Source data viewer that uses some of the same components as GeoServer, is one of many applications that can be used to explore spatial data from WFS and WMS servers. Udig was used to test the spatial data server configuration, and is also installed on the live CD.

8.6 Findings from Prototype Development

The prototype development process was undertaken to achieve the following two goals:

- Provision of a working demonstration system that could be used as a common reference point for users and system designers during design discussions
- Selection of an appropriate technology strategy for each component.

The working demonstration system was developed within the time constraints of the project, and was installed on a laptop for the system demonstrations conducted in the Eastern Cape, satisfying the first goal.

The evaluation of the technology strategy in the context of a full pilot system was informed by the user interviews conducted in the Eastern Cape. The findings from this evaluation, based on the Real Access criteria of Physical access to technology, Appropriateness of technology, Affordability of technology and technology use, Human capacity and training, Locally relevant content, applications, and services, and Political will and public support, are presented in Chapter 9. However, a brief evaluation of the main components of the technology strategy in the context of the prototype development process is presented in the sections that follow.

8.6.1 Open Source Components

The use of open source components for prototyping allowed the demonstration system to be delivered without incurring any software licensing costs. The time cost of demonstration system development was approximately 120 hours, or one month of full-time work. While a comparison of TCO for system development using proprietary or Open Source software is beyond the scope of this project, in this case the use of Open Source software components provided a no-cost prototype solution in an acceptable time.

8.6.2 Low-cost mobile devices on the GSM network

From a development viewpoint, mobile devices implementing the J2ME MIDP (Mobile Device Information Profile) standard are very easy to work with using established tools such as the Sun Wireless Toolkit. That almost all currently available Java phones implement this standard is an indication of its

success. J2ME application development also benefits from the wider Java development ecosystem, and development can be done in established, stable Java development environments such as NetBeans and Eclipse. J2ME also makes it easy to provide a consistent, intuitive user interface by providing standard widgets. However, it is sometimes difficult to standardise the behaviour of these widgets across different devices, so it may be worth limiting the range of supported devices to a few common mobile phones. Additionally, the low-range phone chosen for the prototype system, (the Motorola L6, which costs around R700.00), is recommended for the pilot system based on its value for money, and adequate feature set.

8.6.3 A combined relational and Entity-Attribute-Value (EAV) data model

The EAV model makes it possible to develop a flexible, extensible database schema. However, the complexity of queries is increased, as is data presentation. Bugs in the queries used to extract and classify samples for each site comprised a significant portion of the development work. The EAV model may not have been necessary for a prototype system, as its advantages are not immediately visible. However, the combined EAV and relational approach seems suitable for the full system, where flexibility is important.

8.6.4 A three-tiered client-server model for the browser-based data management and reporting component

The choice of a client-server architecture is a good one where network connectivity is useful and should be used where possible, but may not always be available. This was the case with the demonstration system, which had to be contained on a laptop for demonstrations. Archiving a working system on a live CD without making any significant configuration changes was also possible because of the client-server model.

From a development point of view, the three-tiered model with a browser-based client means that the application can be developed against a consistent platform, and can be run on any system that can run an Apache web server and a standards-compliant web browser such as Mozilla Firefox.

For user demonstrations, a browser-based client is useful because it presents a familiar user interface. This allows users to concentrate on functionality of the system rather than on trying to understand how they would access this functionality, as they might in an application with an unfamiliar user interface.

8.6.5 Open Standards compliant components

The use of Open Standards-compliant components, particularly PostgreSQL and PostGIS, made the provision of a raw data access interface very simple.

For non-spatial data, PostgreSQL offers a comprehensive interface for direct access by users or for access by external application. However, non-expert users wanting to further manipulate or query the data may be limited by the lack of simple query-by-example tools for SQL databases. It may be necessary to consider also providing a subset of the data in spreadsheet format for such users.

For spatial data, GeoServer is fully standards compliant. As common open source as well as commercial GIS packages (such as ArcMap and MapInfo) implement the OGC standards, users are able to access spatial data through a software package with which they are familiar.

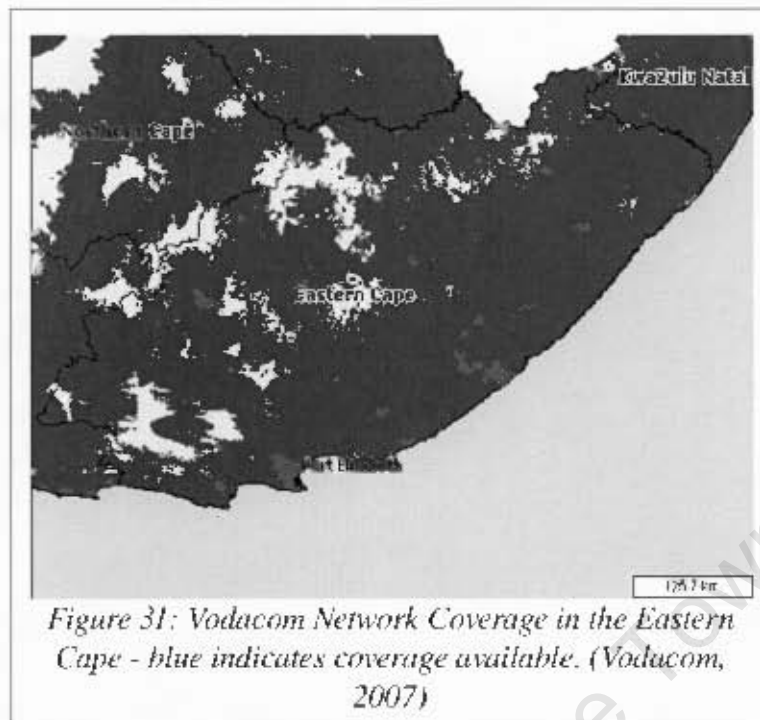
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9 Findings from Practitioner Interviews and System Assessments

9.1 Physical access to technology

This criteria was assessed through observation rather than through interviews. As the Water Services Authority function is the responsibility of the District Municipality, and is only devolved to the local municipality where capacity exists at the local municipality, it can be assumed that Water Services Authorities have access to personal computers. In all the areas studied, the municipal officials we interviewed, used a personal computer in their work. Internet access was also available in all WSAs visited, at the level of a shared broadband connection. DWAF has been responsible for upgrading IT infrastructure in some WSAs in preparation for the rollout of a new Water Quality Management System, eWQMS. In addition to this system, commercial Geographic Information Systems (GIS) were in use at least two of the WSAs visited, and Amatola Water uses a commercial Laboratory Information System, LIMS (Gulwa, 2007, Personal Communication).

Access to technology at the level of a community-managed WSP is likely to be much more limited. In Alfred Nzo District Municipality, for example, 78.47% of households do not have access to electricity (Alfred Nzo District Municipality Report, 2006/07), and only 360km of the 547km road network is paved (De La Harpe, 2003). Even in the larger towns of East London, Grahamstown, Mthata and Queenstown, power failures occurred or were reported around the time we visited the area. Despite this, community WSPs are known to generally have access to mobile phones, and also sometimes to report faults by SMS (Gcali, 2007, Personal Communication). Cellular network coverage in the Eastern Cape is good, as shown in Figure 31.



This map shows coverage for one network operator (Vodacom) only – South Africa's other operator, MTN, claims to cover a similar but slightly larger area (MTN, 2007).

Because a system using mobile devices on the cellular network for data collection does not need Internet connectivity for data entry, it allows the responsibility for data entry to be devolved to someone on site. Mobile devices and data transmission over the cellular network therefore offer much wider physical access to technology than the existing Internet-based DWAF system, as identified by one participant in the interviews:

“I would say where your system has a lot of relevance or a lot of benefit would be in your rural areas, because they will not have a computer system or internet access. The DWAF system is internet based, so if you don't have access to the internet you cannot enter the data, so I can see it would have relevance there. Possibly you could even link onto that, as a service to DWAF even, or as well as to the municipality”

(Karshagen, 23 May 2007, Personal Communication)

9.2 Appropriateness of technology

Nel (2007, Personal Communication) confirms that most staff involved in water quality monitoring at WSA level have at least a tertiary degree, and some level of computer literacy. Although they often require additional training at the beginning of their employment. Staff use a desktop PC to perform their daily work. None of the participants raised concerns about the use of a web-based system at WSA level, possibly as the DWAF eWQMS system has already been introduced. The usefulness of this system was mentioned several times, and its success is likely to improve user support for future ICT-based systems at WSA level.

Economic opportunities in the rural areas of the Eastern Cape are few, and migration of employable people to urban areas is endemic. This translates into local community WSPs having to rely sometimes on illiterate or semi-literate employees to perform monitoring (De La Harpe, 2003). All municipal engineers who participated in the study also agreed that for a mobile phone-based system to be useful, it would need to be made available to CBO WSPs in the local language (predominantly Xhosa in the Eastern Cape). However, the response to the idea of a mobile phone-based system was generally positive, and it was felt that because communities already do use mobile phones, it was likely to be well received.

The need for a low-cost microbiological water test was also universally agreed, and it was felt that the availability of the test was likely to be a prerequisite for the success of a system where communities are expected to monitor their own supplies (Gcali, 22 May 2007, Personal Communication) (Mzayiya, 25 May 2007, Personal Communication). In Alfred Nzo District Municipality, the H₂S test is used, but this does not satisfy the monitoring requirements imposed by SANS 241 as it is a presence-absence test. A field test would therefore be most useful if it was accepted by the regulator (DWAF) as an acceptable monitoring method for faecal coliform contamination (Malgas, 24 May 2007, Personal Communication).

9.3 Affordability of Technology and Technology Use

Budget constraints are often cited as an obstacle to water quality monitoring, particularly in areas where a large percentage of the population lives below the poverty line and does not pay for basic services. Mackintosh et al (2004) state that drinking water quality management is not prioritised in municipal budgets. Concerns around the cost of a mobile device-based system were therefore expected. While some

interviewees did ask about royalties and SMS costs, there was a general consensus that the benefit of a system that would allow remote sites to be monitored without physically travelling to the site was likely to outweigh the costs involved. It was also the view of several people that, should such a system prove successful, DWAF as “sector leader” could be asked to assist in providing it to WSAs and CBO WSPs, as has been done with eWQMS.

9.4 Human capacity and training

Training of CBO WSPs regarding water quality monitoring is currently addressed either by the WSA, or by a Service Support Agency such as the Mvula Trust (Mvula Trust, date unknown). At community level, this kind of training could incorporate training in a mobile phone-based reporting system, providing the system is kept simple. In the rural Eastern Cape, the impact of HIV/AIDS and rural-urban migration means that frequent turnover of operators is a challenge. This means that any ICT system needs to be very simple to learn, minimising training time.

Several participants suggested that a mobile phone-based system could facilitate involving school children in water quality monitoring. This was seen as a good way to educate children about water quality and hygiene practices, and also as a way to pilot and refine system usability. All the municipalities interviewed said that they were already involved in programmes at school level.

The availability of technical support and training service providers is likely to be challenging, as in general only large towns offer these services. Remote support models or other support system need to be considered. eWQMS is designed as a web-based solution, accessed over the internet, in an attempt to minimise the need for on-site support.

9.5 Locally relevant content, applications, and services

Different monitoring requirements exist for different water source types. This includes the selection of parameters to be monitored (which may also be dictated by the availability of field tests) as well as the design of sanitary inspection checklists. WHO (1997) also acknowledges that cultural differences between communities will affect the monitoring of acceptability criteria such as water colour, odour and quantity supplied. The data collected by a reporting system should therefore be configurable, preferably by non-

technical users at Water Supply Authority level (Gcali, 25 May 2007, Personal Communication). One participant also stressed that in addition to certain prescribed aspects that need to be reported on, someone reporting from a community should also be able to voice their concerns in plain text, as this would increase the perception that the WSA was receptive to the concerns and problems of the CBO WSPs.

Participants considered interoperability with other systems to be of great importance, particularly with other drinking water quality monitoring systems such as eWQMS but also with systems used to monitor related municipal activities. For example, the institutional arrangements within Alfred Nzo District Municipality see routine monitoring undertaken by the water services department, while ad-hoc samples are also taken by environmental health officers. Communication between departments can present a challenge, as water services may treat (for example, chlorinate) a source that is found to be contaminated without addressing the cause of contamination, which is seen as the responsibility of the environmental health officers (Nel, 24 May 2007, Personal Communication). This problem is exacerbated by incompatible IT systems in use at the respective departments.

9.6 Political will and public support

Participants stressed that the provision of safe drinking water is “a political issue” (Gulwa, 25 May 2007, Personal Communication), and that district municipalities are often criticised for not responding quickly enough when problems occur. One participant attributed this directly to problems of information flow, stating that:

“We are battling with reporting. People are complaining we don't attend timeously to problems, they are for days without water. But in fact we only now hear that there was a problem. But if someone had your system they could pick it up instantly. Sounds very very useful.”

(Gcali, 25 May 2007, Personal Communication)

While the system was seen as a way to reinforce accountability of the WSA to the CBO WSPs and the community, it could also help WSAs to trust the CBOs. De La Harpe (2003) records the view of one municipal official that “monitoring the CBOs is more expensive than controlling them”. The shift of

accountability to CBO WSPs contributes greatly to their success, and this could be facilitated by better two-way communication.

From a management perspective, the need for information to inform programme planning and resource allocation, particularly at local government level, was also identified. One participant stated that

“the more information you have available to make the work easier for the guys, the better for me but also, for us at management, that information is very important. I think that lacks in local government alot [...] if you go to site and test milk, for example, what will you do about the results? Whether they comply or don't comply, what are you doing about the results? If you have a guy in your area who does not comply, you write him a letter. If, however, you have 50 negative results, you have a big issue and you must plan and budget accordingly. These type of systems can help you to keep up-to-date and it's very very nice.”

(Nel, 24 May 2007, Personal Communication)

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10 Conclusions and Recommendations

This research project intended to support the following hypotheses (section 1.4):

- An ICT-based management system could help to meet the information needs of stakeholders in community supply management in South Africa. These information needs can be defined through a process of participatory design.
- Using a prototyping approach, it is possible to define a set of functional and non-functional requirements for such a system, against which a working pilot system could be developed.
- A technology strategy based on “appropriate” technologies such as mobile devices (and particularly data transmission over cellular networks), web-based reporting and open source software can provide the foundation for a system that will meet the specific challenges of monitoring community-managed supplies.

The concluding sections that follow contain a discussion of these points, based on the findings in the previous chapter. Recommendations for the next phase of the project (a full pilot system) are also developed.

10.1 Assessment of the Information Need

Small and community-managed supplies are among the most prone to water quality problems, and are also the hardest to monitor. Reasons for this include:

- Remote location of supply points
- Lack of resources (including trained personnel and laboratory facilities)
- Lack of communication between organisations carrying out operational monitoring, verification and surveillance activities.

In South Africa, Water Services Authorities (WSAs) at local government level may have many rural community schemes under their jurisdiction, and are struggling to fulfil their legal obligation to monitor the schemes. As a result, CBO WSPs sometimes find it difficult to access support for problems they cannot solve themselves, and communities may be forced drink unsafe water as a result. WSAs in turn

have difficulty trusting CBO WSPs, and cannot devolve to them the responsibility for operational monitoring and reporting.

Capacity issues exist within WSAs, and this may mean that operational monitoring of rural schemes is compromised, particularly when schemes are very remote. Drinking Water Quality Management Systems have been shown to help WSAs work “smarter” with existing resources (De Souza et al,2006), responding to the challenge of limited capacity.

As well as supporting the daily operations of community-managed schemes, information about water quality at community supply level allows institutions responsible for resource allocation to prioritise areas most at risk for water quality problems. The information on which such decisions are based should be made publicly available, as this enforces transparency and equitable distribution of resources.

Through participatory design utilising a working prototype, it was possible to refine the system requirements based on user input. The creation of the working prototype system for user demonstrations meant that users were able to visualise the system being used in their context, and give targeted, relevant feedback. The insistence of most participants that alert functionality be included in the system from the start is an example of user feedback, obtained through participatory design, that might otherwise have been lost.

10.2 Major Functional Requirements

During user interviews, the prototype system was demonstrated to users to refine the requirements derived in Chapter 7. The interviews confirmed the following functional requirements for a community water quality information system:

- **Data Collection Component:** Two types of information need to be collected and stored in a community water quality information system:
- Routine reports on an agreed set of indicators and control points (including water quality test results)
- Ad-hoc alerts, such as be requests from the CBO WSP for assistance from the WSA or warnings about possible drinking water quality problems from the WSA.

To record this information, a reporting tool for use by communities should allow input both in the form of a structured menu (for agreed indicators and control points) and in free text (for alerts).

- **Data Transmission Component:** Store-and forward data transmission is essential as network coverage may be variable. Once a report has been sent, it should be possible to receive it immediately at the WSA site, even if internet connectivity is not available.
- **Data Storage Component:** The design of an operational monitoring programme, including selection of control points and microbiological and chemical test parameters, reporting frequency and languages used, will vary from place to place. A data storage system should be able to accommodate these variations by incorporating a high degree of flexibility. The data storage system should also be capable of storing integrated spatial and non-spatial data.
- **Data Management and Reporting Interface:** The WSA should be able to access the stored data through an interface that allows
 - Alert notification, management and transmission
 - Viewing and manipulation of routine reporting information, both per site and aggregated.This functionality should be accessible in a user-friendly way. Spatial data should be displayed on a navigable map interface as part of the Data Management and Reporting Interface.
- **Raw Data Access Interface:** An Open Standards-compliant interface is needed for external users and external applications to access the spatial and non-spatial data stored in the system.

10.3 Major Non-Functional Requirements

10.3.1 Physical Infrastructure Constraints

The operational context for community drinking water quality monitoring is partly defined by its physical infrastructure constraints. This imposes the following non-functional requirements:

- At the community site, the data collection and reporting component used by the community water committee should not require an electricity supply, or Internet accessible

- At the site of the WSA, internet access is likely to be available but may not be reliable, so the system should not rely on always-on, high-speed internet access

10.3.2 Security

In addition, security and integrity of data is very important. While it should be possible for anyone to view data (unless there is a good reason not to make certain data available to the public), there should be security mechanisms in place to prevent any unauthorised alteration of system data.

10.3.3 Accessibility

There are many different users of the proposed system, from local communities wanting to monitor their own water consumption or advocate for better service delivery to governments and researchers performing sophisticated analyses with external programs. This diverse user community adds additional non-functional requirements, as each type of user may need different information, and different mechanisms of data access. System design choices that could help to achieve this include:

- Requiring Modularity
- Maintaining Interoperability with external systems
- Involving users in requirements definition through a participatory software design approach

In South Africa, interoperability with the eWQMS system being rolled out to Water Services Authorities throughout the country is extremely important. This system's success has raised awareness of how IT systems can assist in drinking water quality management, which should increase the likelihood of additional IT systems in the area of drinking water quality being well received.

10.4 Technology Strategy

10.4.1 Appropriateness of Mobile Phone-based Reporting

Regular communication with, and monitoring of, community-managed supplies is hampered by the remote location of the supplies, literacy and skills challenges, frequent staff turnover and limited resources available to provide training and support to community operators. At the site of a rural supply,

landline connectivity and electricity are often not available. Mobile devices on the cellular network offer a possible solution where cellular network coverage is good, and this continues to expand in the developing world. Mobile devices can deliver an automated system in which a record is kept of all monitoring and fault reports submitted by the community-based water service providers. This information flow could strengthen accountability and trust between the water service provider, the overseeing authority and the community.

Customised data entry menus on a mobile phone are useful because they create a structure for monitoring activities. Ideally, data entry menus should be customisable by the organisation responsible for management of community-managed supplies. This would allow the information collected to be defined in accordance with standard water safety plans for the types of supply being monitored. In addition, it should be possible to collect data both as a set of compulsory, structured questions, and as free text.

A mobile phone-based system was seen to be appropriate in the rural Eastern Cape because mobile phones are already widely used by local communities. However, there is a strong need for language localisation, in this case into Xhosa. Because migrant labour patterns and HIV/AIDS cause frequent staff turnover in community-managed schemes, systems need to be usable, easy to learn and very simple.

10.4.2 Open Source Software and Open Standards

Because the source code is freely available and can be modified by any one with the necessary technical skills, Open Source Software is a good choice for building systems that are intended to be customised and localised. Open Source Software is also useful for prototype system development, as it is possible to modify pre-built components rather than building them from scratch.

It would be necessary to thoroughly investigate total cost of ownership for both proprietary and Open Source components before choosing a design for the final system. However, the Open Source components that were chosen for the prototype were evaluated as stable and suitable for the next system development iteration (development of a pilot system).

As there is no existing system for drinking water quality monitoring specifically in community-managed supplies, users would not need to migrate from an existing system. The introduction to an Open Source

system therefore offers a great opportunity for learning, without interrupting an existing work flow. The development of an Open Source community drinking water quality management system aligns with the strategic goal of the Government to increase the use of Open Source software throughout all government structures.

10.4.3 Entity-Attribute-Value Model for Data Storage

The Entity-Attribute-Value (EAV) model offers a flexible database schema, but increases the complexity of database queries. Given the need for customisability particularly with regard to the indicators collected, which may vary for each site, this flexibility is desirable and the EAV model should be used. Concerns around database query complexity could be mitigated by making use of database views and stored procedures to create an abstraction layer above the EAV model schema.

10.5 Need for Supportive Capacity-Building in the Local ICT Services Sector

Authorities responsible for monitoring programme design may not be proficient software developers, and should instead be able to buy software development and customisation services from the local IT sector. Similarly, training and support service providers are likely to be most cost effective and efficient if they are located in or near the area the system will serve. However, the capacity to provide these services may not be present in many rural areas in South Africa, and the sustainability of the system will be improved by finding ways to support and develop the local IT services sector. OpenMRS has adopted this approach, and provides support to service providers and implementers in the form of an implementers network (Seebregts et al, 2007).

10.6 Further Development of a Full Pilot System

The work described previously represents the first iteration of an iterative and incremental development process. As such, particular attention was given to the needs assessment component of the iteration, and a clear need was identified for a system that could assist with:

- Improving communication between community-based water service providers and the responsible water service authority

- Supporting communities so that they are able to carry out operational monitoring themselves
- Collecting reliable and up-to-date information about the water quality supplied to communities

The high-level functional and non-functional requirements for such a system, derived from a process of participatory design, should be refined in the next iteration to give a detailed system specification for a full pilot system that could meet these needs.

The prototype development process involved an investigation into available technologies to fulfil the high-level requirements, and many of the technology choices made are recommended for the full pilot system. Open Source Software, mobile devices on the cellular network and the Entity-Attribute-Value data model in particular show great promise. Combined with a thorough investigation of the operational context and system sustainability factors, these technologies could help to meet the information needs of rural communities, empowering them monitor and manage the quality of their drinking water.

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11 References

Abrams, L.J. (1996). Policy development in the water sector - the South African experience [online]. Proceedings of the Cranfield International Water Policy Conference, Cranfield University, United Kingdom, September 1996. Available from: <http://www.africanwater.org/sapolicy.htm> The Water Page. [cited 18 July 2007]

Alfred Nzo District Municipality (2007). Alfred Nzo District Municipality Report, 2006/7 [online]. Available from: <http://www.demarcation.org.za/>, Municipal Demarcation Board. [cited 13 June 2007].

Amatole District Municipality (2007). Amatole District Municipality Report, 2006/7 [online]. Available from: <http://www.demarcation.org.za/>, Municipal Demarcation Board. [cited 13 June 2007].

Anand, S. A. (2005). Development of a Cellphone Based Monitoring and Management-Support System for Anti-Retroviral Therapy. MSc(Eng) University of Cape Town.

Blake, E. (2002). How to Provide Useful ICT When Called Upon. ACM Interactions, [online]. 13 (5), Available from: <http://portal.acm.org/> ACM Portal. [cited 20 February 2007]

BOADICEA (2007). BOADICEA World Wide Web Interface Project [online]. Available from: http://www.srl.cam.ac.uk/genepi/boadicea/boadicea_interface.html. [cited 26 July 2007]

Bridges.org. (2005). The Real Access / Real Impact framework for improving the way that ICT is used in development [online]. Available from: <http://www.bridges.org>. [cited 16 January 2007]

Brikke, F. (2000). Operation and maintenance of rural water supply and sanitation systems: A training package for managers and planners [online]. Geneva: WHO. Available from: http://www.who.int/water_sanitation_health/hygiene/om/omruralsystems/en/index.html. [cited 21 July 2007]

Bruggink, M. (2003). Open Source in Africa: Towards Informed Decision-Making [online]. International Association for Communication and Development Research Brief 7. Available from: www.schoolnetafrica.net/index.php?id=897. [cited 8 January 2007]

Cacadu District Municipality (2007). Cacadu District Municipality Report, 2006/7 [online]. Available from: <http://www.demarcation.org.za/>, Municipal Demarcation Board. [cited 13 June 2007]

Carr, M. & Verner, J. (1997). Prototyping and Software Development Approaches [online]. Hong Kong: City University of Hong Kong. Available from: www.is.cityu.edu.hk/Research/WorkingPapers/paper/9704.pdf. [cited 26 July 2007]

Chipchase, J. (2005). Understanding Non-Literacy as a Barrier to Mobile Phone Communication [online]. Tokyo: Nokia Research Centre. Available from: <http://research.nokia.com/bluesky/non-literacy-001-2005/index.html>. [cited 15 June 2007]

Chris Hani District Municipality (2007). Chris Hani District Municipality Report, 2006/7 [online]. Available from: <http://www.demarcation.org.za/>, Municipal Demarcation Board. [cited 13 June 2007]

Codd, E.F. (1990). The relational model for database management: version 2 [online]. ACM Classic Book Series. New York, NY, USA: ACM Press. Available from: <http://portal.acm.org/> ACM Portal. [cited 29 July 2007]

Davison, A., Howard, G., Stevens, M., Callan, P., Fewtrell, L., Deere, D., Bartram, J. (2004). Water Safety Plans [online]. Geneva: World Health Organization. Available from: http://www.who.int/water_sanitation_health/dwq/wsp0506/en/index.html. [cited 15 September 2006]

De La Harpe, J. and Vermeulen, A. (2001). Community-based Organisations as Water Service Providers: Guidelines [online]. Pretoria: DWAF. Available from: <http://www2.irc.nl/pdf.php?file=pdf/manage/cboguidelines.pdf>. [cited 21 July 2007]

De Le Harpe, J. (2003). Scaling Up Community Management In South Africa: The Alfred Nzo District Municipality Case Study [online]. Delft: IRC International Water and Sanitation Centre. Available from: www.es.irc.nl/redirect/content/download/14277/192577/file/Alfred_Nzo-Case_Study.pdf. [cited 15 June 2007]

de Souza, P. F., Ramba, M. H., Wensley, A., Delpont, J. E. (2006). Implementation of an Internet Accessible Water Quality Management System for Ensuring the Quality of Water Services in South Africa. In WISA Biennial Conference and Exhibition – 2006. Pretoria: Water Institute of South Africa.

Donald, S., Rivett, U., Charissa, B. and Skinner, D. (2007). Evaluation of use of cellphones to aid compliance with drug therapy for HIV patients. *AIDS Care*, 19 (5).

DWAF (2003). Strategic Framework for Water Services [online]. Pretoria: DWAF. Available from: http://www.polity.org.za/attachment.php?aa_id=782. [cited 21 July 2007]

DWAF (2004). A History of the First Decade of Water Service Delivery in South Africa, 1994-2004: Meeting the Millenium Development Goals [online]. Pretoria: DWAF. Available from: <http://www.dwaf.gov.za/Documents/Publications/firstdecade.pdf>. [cited 25 July 2007]

DWAF (2005). A Drinking Water Quality Management Framework for South Africa [online]. Pretoria: DWAF. Available from: <http://www.wrc.org.za/downloads/watersa/2006/WISA%20special%20ed9.pdf>. [cited 20 February 2007]

DWAF (2005b). Drinking Water Quality Regulation Strategy [online]. Pretoria: DWAF. Available from: <http://www.dwaf.gov.za/Documents/Other/DWQM/DWQRegulationStrategySept05.pdf>. [cited 22 July 2007]

DWAF (2005c). Mid-term Review of Masibambane II Programme [online]. Pretoria: DWAF. Available from: <http://www.dwaf.gov.za/Masibambane/documents/monitoring-evaluation/2006-03-mid-term-evaluation.pdf>. [cited 15 June 2007]

DWAF (2006). Strategic Plan 2006-07 to 2010-11 [online]. Pretoria: DWAF. Available from: <http://www.dwaf.gov.za/Documents/Other/Strategic%20Plan/2006/StrategicPlan2006Part3.pdf>. [cited 22 July 2007]

Faysse, N. (2004). Challenges for Fruitful Participation of Smallholders in Large-Scale Water Resource Management Organisations: Selected Case Studies in South Africa. *Agrekon*, 43 (1).

Feinstein, W. P., & Hawker, S. J. (2000). A study of technologies for Client/Server applications [online]. Proceedings of the 38th annual on Southeast regional conference. New York, NY, USA: ACM Press. Available from: <http://portal.acm.org/> ACM Portal. [cited 27 July 2007]

Folifac, F. A. (2003). National Water Policies and Water Services at the extremes: What Challenges must be faced in bridging the gap? Learning from the South Africa Experience [online]. African Water Journal 1 (1). Geneva: United Nations Economic Commission for Africa. Available: http://www.uneca.org/awich/AWJ_Vol1_No1/2%20National%20Water%20Policies%20and%20Water%20Services%20at%20the%20extremes.pdf. [cited 15 July 2007]

Fynn, R. W., De Jager, D., Chan, H. A., Anand, S. and Rivett, U. (2006). Remote HIV/AIDS Patient Monitoring Tool Using 3G/GPRS Packet-Switched Mobile Technology [online]. IEE Appropriate Healthcare for Developing Countries Conference. London: IEE. Available from: www.cell-life.org, Cell-Life. [cited 15 January 2007]

G8 Digital Opportunities Task Force (2001). Digital Opportunities for All: Meeting the Challenge. [online]. Report of the Digital Opportunities Task Force including a proposal for the Genoa Plan of Action. Genoa: DOT Force. Available from: <http://www.g7.utoronto.ca/summit/2001genoa/dotforce1.html>. [cited 8 January 2007]

Gain, J.(2003). Software Engineering: Object-Oriented Analysis. Unpublished Lecture Slides for CSC201F at the University of Cape Town, April 2003.

Glance, D., Kerr, J. & Reid, R. (2003) . Factors Affecting the Use of Open Source Software in Tertiary Education Institutions [online]. First Monday, 9 (2). Available from:
http://firstmonday.org/issues/issue9_2/glance/index.html. [cited 22 August 2007]

Godfrey, S. and Howard, G. (2004). Water Safety Plans (WSP) for Urban Piped Water Supplies in Developing Countries [online]. Leicestershire: WEDC, Loughborough University. Available from:
<http://www.lboro.ac.uk/watermark/WEJX7/WSP%20book%2021104.pdf>. [cited 25 July 2006]

Gray, V. (2006). The Unwired Continent: Africa's Mobile Success Story [online]. Economía Exterior, 36. Available from: http://www.itu.int/ITU-D/ict/statistics/at_glance/Africa_EE2006_e.pdf [cited 30 July 2006]

GSM Association (2006). Universal Access – how mobile can bring communications to all [online]. GSM Association. Available from:
http://www.gsmworld.com/documents/universal_access_full_report.pdf. [cited 20 January 2007]

GSM World (2006). GSM Coverage Maps [online]. GSM Association. Available from:
<http://www.gsmworld.com/roaming/gsminfo/index.shtml>. [cited 25 July 2006]

Gundry et al (2006). Contamination of drinking water between source and point-of-use in rural households of South Africa and Zimbabwe: implications for monitoring the Millennium Development Goal for water. Proceedings of the 5th IWA World Water Congress, Beijing, September 2006. London: IWA Publishing.

Health Systems Trust (2007). ISDS Site: Alfred Nzo District [online]. Available from:
<http://www.hst.org.za/generic/43>. [cited 17 July 2007]

Heeks, R. (2005). Foundations of ICTs in Development: The Onion-Ring Model [online]. eDevelopment Briefing No. 4. Development Informatics Group, University of Manchester. Available from:
<http://www.sed.manchester.ac.uk/idpm/research/publications/wp/di/>. [cited 5 January 2007]

Heeks, R., and Bhatnagar, S. C. (1999). Understanding Success and Failures in Information Age Reform [online]. In Heeks, R. (Ed) Reinventing Government in the Information Age. London: Routledge. Available from: <http://www.sed.manchester.ac.uk/idpm/research/publications/wp/di/>. [cited 13 January 2007]

Hoadly, P. A. (2005). Waterfall Model [online]. Wikipedia. Available from:
http://en.wikipedia.org/w/index.php?title=Image:Waterfall_model.png&oldid=118077437. [cited 26 July 2007]

Hodgson, K. and Manus, L. (2006). A Drinking Water Quality Framework for South Africa [online]. Water SA, 32 (5). Available from: <http://www.wrc.org.za>. [cited 8 July 2007]

Howard, G. (2002). Water Supply Surveillance: A Reference Manual [online]. Leicestershire: WEDC, Loughborough University. Available from: <http://www.lboro.ac.uk/watermark/reference-manual/index.htm>. [cited 30 July 2006]

Illing, C. and Gibson, J. (2004). Rural water service provision by municipalities and CBOs: Performance milestones and KPIs [online]. Water SA, 30 (5). Available from: <http://www.wrc.org.za>. [cited 8 July 2007]

IRC (2002). Community Water Supply Management: Background Paper for “Beyond the Community”, An E-conference on Scaling Up Community Management of Rural Water Supply [online]. Available from: <http://www2.irc.nl/manage/debate/bgpaper.html>. [cited 30 June, 2007]

IRUS (2004). Application Software Development [online]. Virginia, USA: The IRUS Group inc. Available from <http://www.irusgroup.com/practices/software-development.aspvelopment>. [cited 26 July 2007]

Jacobson, I. (1987). Object oriented development in an industrial environment [online]. ACM SIGPLAN Notices, 22 (12). New York, NY, USA: ACM Press. Available from: <http://portal.acm.org/> ACM Portal. [cited 29 July 2007]

Jern, M. (1998). "Thin" vs. "fat" visualization clients [online]. Proceedings of the working conference on Advanced visual interfaces, Aquila, Italy, 1998. New York, NY, USA: ACM Press. Available from: <http://portal.acm.org/> ACM Portal. [cited 27 July 2007]

Kasrils, R. (2003). Water Service Achievements, Successes and Challenges [online]. Address given at the SALGA/DWAF Summit, 17 October 2003. Available from: <http://www.dwaf.gov.za/>. [cited 18 July 2007]

Kingston, P.A. (2004). Surveillance of Drinking Water Quality in the Pacific Islands: Situation Analysis And Needs Assessment [online]. Country Reports – Papua New Guinea. Geneva: WHO. Available from:

[www.wpro.who.int/NR/rdonlyres/AAD7989B-1AE6-49F3-A94B79F49D00D60B/0/Papua New Guinea.pdf](http://www.wpro.who.int/NR/rdonlyres/AAD7989B-1AE6-49F3-A94B79F49D00D60B/0/Papua%20New%20Guinea.pdf) [cited 5 January 2007]

Lockwood, H. (2001). Institutional Arrangements for Rural Communities: Municipal Promoter Program in Nicaragua [online]. Proceedings of the IRC Community Water Supply Management e-Conference, 2001. Available from: [http://www.ehproject.org/PDF/Strategic Papers/LACDEC/Nicaragua.pdf](http://www.ehproject.org/PDF/Strategic%20Papers/LACDEC/Nicaragua.pdf) [cited 20 June 2007]

MacDonald, L. H. (1994). Developing a Monitoring Project. *Journal of Soil and Water Conservation*, 49 (3). Soil And Water Conservation Society, Iowa. Available from: <http://www.warnercnr.colostate.edu/frws/people/faculty/macdonald/publications/Developing%20a%20Monitoring%20Project.pdf>. [cited 10 July 2007]

Mackintosh, G. S., Manxodidi, T., Wensley, A. Uys, F. M. (2004). Climbing South Africa's Water Services Ladder : Safe drinking-water through regulatory governance [online]. Proceedings of the Centre on Regulation and Competition International Conference. Manchester: Center on Regulation and Competition. Available from: <http://www.competition-regulation.org.uk/conferences/southafrica04/>. [cited 15 July 2007]

Mamlin B. W. & Biondich, P. G. (2006). OpenMRS: An EMR for Developing Countries [online]. Slides presented at the 2006 AIMA Spring Congress, Phoenix, AZ, USA. Available from: http://207.196.78.228/meetings/s06/post/mamlin_5-18_1030a.pdf. [cited 26 July 2007]

Marker, P., McNamara, K., and Wallace, L. (2002). The Significance of Information and Communication Technologies for Reducing Poverty, The Think! Programme [online]. United Kingdom: Development Policy Department, Department of International Development. Available from:

[http://en.wikibooks.org/wiki/Information and Communication Technologies for Poverty Alleviation/References](http://en.wikibooks.org/wiki/Information_and_Communication_Technologies_for_Poverty_Alleviation/References). [cited 17 January 2007]

Monyai, P. B. (2004). Health-related Water Quality and Surveillance Model for the Peddie District in the Eastern Cape. WRC Research Report 727/1/04. Pretoria: Water Research Commission.

MTN (2007). MTN Coverage Map [online]. South Africa: MTN. Available from:
<http://www.mtn.co.za/default.aspx?pid=11789>. [cited 25 June 2007]

Muller, M. (2002). The National Water and Sanitation Programme in South Africa: turning the “right to water” into reality [online]. Field Note 8. Water and Sanitation Programme – Africa Region. Available from:
<http://www.dwaf.gov.za/Communications/Articles/Other/2003/turning%20right%20of%20water%20into%20reality.pdf>. [cited 15 July 2007]

Mvula Trust (2006). Mvula Trust Annual Diary Chapter 9: Free Basic Water [online]. Johannesburg: Mvula Trust. Available from: <http://www.mvula.co.za/page/629>. [cited 18 July 2007]

Mvula Trust (2006). Supporting Water, Sanitation and Integrated Development. [online]. Available from: <http://www.mvula.co.za/page/518>. [cited 16 March 2007]

Nadkarni, P. (2000). The EAV/CR Model of Data Representation [online]. Available from: http://ycmi.med.yale.edu/nadkarni/eav_cr_frame.htm. [cited 29 July 2007]

National Advisory Council on Innovation Open Source Working Group, (2004). Free/Libre and Open Source Software in South Africa: A Critical Issue for Addressing the Digital Divide [online]. Available from: <http://www.naci.org.za/floss/>. [cited 30 June 2005]

Negussie, A. (2001). Institutionalising Community Management in Uganda [online]. Proceedings of the IRC Community Water Supply Management E-conference. Available from: <http://www2.irc.nl/manage/debate/uganda.html>. [cited 15 July 2007]

Netshiswinzhe , B. (2000). Strengthening Sustainability of Water Supply Projects [online]. Proceedings of the 26th WEDC Conference, Dhaka, 2000. Available from: <http://www.lboro.ac.uk/departments/cv/wedc/papers/26/W%20-%20Water%20Provision/netshiswinzhe.pdf>. [cited 21 July 2007]

Nichols, D. & Twidale, M. (2003). The Usability of Open Source Software [online]. First Monday, 8 (1). Available from: http://www.firstmonday.org/issues/issue8_1/nichols/. [cited 22 August 2007]

O. R. Tambo District Municipality (2007). O. R. Tambo District Municipality Report, 2006/7 [online]. Available from: <http://www.demarcation.org.za/>, Municipal Demarcation Board. [cited 13 June 2007]

O.R. Tambo District Municipality (2003). O.R. Tambo District Municipality Water Services Development Plan. O.R. Tambo District Municipality. Available from: <http://www.ortambodm.org.za>. [cited 15 June 2007]

OpenOffice.org (2007). I10n [online]. Available from: <http://i10n.openoffice.org/languages.html>. [cited 12 February 2007]

Parikh, T. S., and Lazowska, E. D. (2006). Designing an Architecture for Delivering Mobile Information Services to the Rural Developing World. Proceedings of the 15th International World Wide Web Conference, Edinburgh, 2006. New York, NY, USA: ACM Press. Available from: <http://www2006.org/programme/files/pdf/5507.pdf>. [cited 6 January 2007]

Pearlson, K. E. and Saunders, C. S. (2005). Managing and Using Information Systems: A Strategic Approach. (Third Edition). John Wiley & Sons.

PostgreSQL (2007). PostgreSQL: About [online]. Available from: <http://www.postgresql.org/about/>. [cited 29 July 2007]

Primo Braga, C. A., Daly, J. A., & Sareen, B. (2003). The Future of Information and Communication Technologies for Development [online]. UNDP Asia-Pacific e-Primers Series. Cambodia: UNDP. Available from: http://www.developmentgateway.org/download/221030/Future_ICT.pdf. [cited 16 January 2007]

Pruss, A., Kay, D., Fewtrell, L., and Bartram, J. (2002). Estimating the burden of disease from water, sanitation and hygiene at a global level [online]. *Environmental Health Perspectives* 110 (5). Available from: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1240845>. [cited 3 January 2007]

Rajiv Gandhi National Drinking Water Mission (2006). Guidelines for National Rural Drinking Water Quality Monitoring and Surveillance Programme [online]. Department of Drinking Water Supply. New Delhi: Government of India, Ministry of Rural Development. Available from: <http://megphed.gov.in/knowledge/standards/WQMSguide.pdf>. [cited 8 January 2007]

Redhouse, D., Abraham, T., Aw, K. Beaumont, N. Breslin, N. Calaguas, B., Chisanga, P., Gutierrez, E., Ziaul Kabir, A. B. M., Kapur, D. S., Mallé, Y., Maunder, T., Mohamed, A. N., Musaaazi, Y., Mwambwa, S., Napon, A. O., Nkongo, D., O'Connell, M., Rasolofomanana, L., Roberts, P., Shrestha, R. L., Sugden, S., Uwejamomere, T., de Waal, D. and Yiga, B. (2005). Getting to boiling point: Turning up the heat on water and sanitation [online]. London: Water Aid. Available from:

<http://www.wateraid.org/other/startdownload.asp?DocumentID=141&mode=plugin>. [cited 20 February 2007]

Robertson, W., Stanfield, D., Howard, G. and Bartram, J. (2003). Monitoring the Quality of Drinking Water During Storage and Distribution [online]. In Dufour, A., Snozzi, M., Koster, W., Bartram, J., Ronchi, E. and Fewtrell, L. (Eds), Assessing Microbiological Safety of Drinking Water: Improving Approaches and Methods. IWA Publishing, London. Available from:

http://www.who.int/water_sanitation_health/dwq/9241546301_chap6.pdf. [cited 10 July 2007]

Samoladas, I., & Stamelos, I. (2003). Assessing Free/Open Source Software Quality [online]. Thessaloniki, Greece: Department of Informatics, Aristotle University of Thessaloniki. Available from: <http://opensource.mit.edu/papers/samoladasstamelos.pdf> [cited 18 August 2007]

SATELLIFE (2005). Handhelds for Health: SATELLIFE'S Experiences in Africa and Asia [online]. Watertown, Massachusetts: SATELLIFE. Available from:

<http://pda.healthnet.org/download/pdapaper1.pdf>. [cited 5 January 2007]

Seebregts, C., Mamlin, B. W., Biondich, P. G., Fraser, H. S. F., Wolfe, B. A., Jazayeri, D., Allen, C., Miranda, J., Lesh, N., Baker, E., Fourie, C., Singh, Y., Song, S., Bailey, C., Yiannoutsos, C., Tierney, W. M. and The OpenMRS Implementers Group (2007). The OpenMRS Implementers Network [online].

Proceedings of HELINA 2007, Mali, January 2007. Available from:

<http://www.sim.hcuge.ch/helina/28.pdf>. [cited 15 July 2007]

Sinha, A. (1992). Client-Server Computing [online]. Communications of the ACM, 35 (7). New York, NY, USA: ACM Press. Available from: <http://portal.acm.org/> ACM Portal. [cited 27 July 2007]

Thakur, V., Khadanga, G., Venkatesh, D. S. and Shukla, D. R. (2004). Land Records Management System in India – Technical Framework [online]. GIS Development Geospatial Application Papers.

GISdevelopment.net. Available from:

<http://www.gisdevelopment.net/application/lis/overview/ma03188pf.htm>. [cited 10 June 2007]

The Economist (2005). The real digital divide [online]. The Economist, 10 March 2005. Available from:

http://www.economist.com/opinion/displayStory.cfm?story_id=3742817. [cited 20 January 2007]

Thomson, H., Stimie, C.M., Richters, E. and Perret, S. (2001) . Policies, legislation and organizations related to water in South Africa, with special reference to the Olifants river basin [online]. Working Paper 18 (South Africa Working Paper No. 7). Colombo, Sri Lanka: International Water Management Institute. Available from: <http://ideas.repec.org/p/iwt/worppr/h028253.html>. [cited 16 July 2007]

Turton, A. and Meissner, R. (2002). The hydrosocial contract and its manifestation in society: A South African case study. In Turton, A. and Henwood, R. (eds). Hydropolitics in the Developing World: A Southern African Perspective [online]. Pretoria: African Water Issues Research Unit. Available from:

<http://www.iwmi.cgiar.org/Assessment/files/Synthesis/River%20Basins/River%20basin%20management%20reconsidered%20WESTER.pdf>. [cited 21 July 2007]

UNICEF (2005). World Water Day 2005: 4,000 children die each day from a lack of safe water [online]. New York: UNICEF. Available from: http://www.unicef.org/wes/index_25637.html. [cited 30 January 2007]

United Nations (2007). Millennium Indicators Database [online]. Available from : <http://mdgs.un.org/unsd/mdg/>. [cited 21 July 2007]

United Nations Information and Communications Technologies Task Force (2005). Innovation and Investment: Information and Communication Technologies and the Millennium Development Goals [online]. United Nations ICT Task Force. Available from: <http://www.unicttaskforce.org/perl/documents.pl?id=1519>. [cited 8 January 2007]

Varghese, R. M. & Siddharth, S. M. (n. d.). Emergency Medical Communication System [online]. India: Amrita Institute of Technology and Science. Available from: <http://web.syr.edu/~ssmulcha/papers/paper2P.doc>. [cited 27 July 2007]

Vermeulen, A. (2001). Institutional Frameworks to Support Community Management in South Africa [online]. Proceedings of the IRC Community Water Supply Management e-Conference, 2001. Available from: <http://www2.irc.nl/manage/debate/za.html>. [cited 20 June 2007]

Vodacom (2007). Vodacom Coverage Map [online]. South Africa: Vodacom. Available from: <http://www.vodamap.net/3g/>. [cited 16 June 2007]

Water Services Act (Act. 108 of 1997). Government of the Republic of South Africa.

Wellman, P. (1999). Sustainability of South Africa's Water Miracle Questioned [online]. Africa Eye News Service, 9 May 1999. Available from: <http://www.africanwater.org/SAWSPProblems.html>. [cited 22 July 2007]

WHO (1997). Guidelines for drinking-water quality Volume 3: Surveillance and control of community supplies [online]. 2nd ed. Geneva: WHO. Available from: www.who.int/water_sanitation_health/dwq/gdwq2v1/en/index2.html. [cited 25 July 2006]

WHO (2004): Guidelines for drinking-water quality, Vol. 1 – Recommendations [online]. 3rd ed. Geneva: WHO. Available from: http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/. [cited 25 July 2006]

WHO/SIWI (2005). Driving Development by investing in Water and Sanitation: Five facts to Support the Argument [online]. Stockholm: Stockholm International Water Institute, Geneva: WHO. Available: http://www.siwi.org/downloads/Reports/Driving_Development.pdf. [cited 5 January 2007]

WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (2004). Meeting the MDG drinking water and sanitation target: a mid-term assessment of progress [online]. WHO/ UNICEF Joint Monitoring Programme. Available from: http://www.wssinfo.org/en/40_MDG2004.html. [cited 18 July 2006]

Zerfos, P., Meng, X., Wong S. H. Y., Samanta, V. and Lu, S. (2006). A study of the Short Message Service of a Nationwide Cellular Network [online]. ACM Internet Measurement Conference, Rio de Janeiro, 2006. Available from: <http://www.imconf.net/imc-2006/papers/p26-zerfos.pdf>. [cited 2 February 2007]

Appendix A: Questionnaire

1 Physical access to technology

1. How many people in your organisation use a desktop computer to perform their work?

all most around half few none

2. Does your organisation have access to:

a post office (how far away?)

a courier service (again, how far)

a telephone (party line)

a telephone (dedicated line), a broadband internet connection.

3. How many people in your organisation use cellphones for work purposes?

all most around half few none

4. How many people in your organisation use cellphones in their private time?

all most around half few none

5. If your cellphone was broken - how far away is the nearest place you could it repaired?

6. If you needed to buy a cellphone - how far away is the nearest place you could get one? Would this be from a shop?

7. How would you characterise the electricity supply to your organisation?

no generated power

generator providing intermittent power

mains power available but unreliable

mains power available but sometimes there are power failures

reliable mains power

8. How secure would a desktop computer / laptop be if you had to leave it in your place of work overnight?

Equipment has been stolen before, and this is likely to happen again.

I wouldn't do this – it would get stolen.

I would be anxious if I did this

I would feel comfortable doing this

My place of work is well-secured and would be the best place to leave something of value.

9. How secure would a cellphone be if you had to leave it in your place of work overnight?

Equipment has been stolen before, and this is likely to happen again.

I wouldn't do this – it would get stolen.

I would be anxious if I did this

I would feel comfortable doing this

My place of work is well-secured and would be the best place to leave something of value.

2 Appropriateness of technology

1. What language(s) are used to conduct the day-to-day business of your organisation?

2. In what language(s) do you report to DWAF?

3. Are there people in your organisation who might be resistant to technology use in their work, and prefer a supplementary paper-based system (e.g. printed reports, paper forms which are then captured into the system by someone else)?

no-one here sees the benefit of using technology

most people are opposed to technology

there is about an even split, most people would like to use technology

almost everyone would like to and be able to use the new technology

[Would also need to ask some specific questions about the suitability of the prototype system to local condition]

3 Affordability of Technology

1. In what ways could you see the system improving the service you provide? Are there cost savings that might result from its use?
2. [Presented with some kind of cost estimate for the system (installation, running costs) – Roughly R25 000 to start, for a simple system with one PC and a few phones, training, installation] Do you think the benefits you envisage from this system would justify these costs?
3. Is an IT system a cost-effective way to satisfy the reporting requirements imposed by
 - DWAF
 - your organisation's management processes
 - your consumers
4. Is this particular IT system cost-effective in your opinion? If not, why?

4 Human Capacity and Training

1. If there are already PCs in use at your organisation, who supports them?
 - How / where were the people who use these PCs trained?
 - How long does it take to get a PC fixed if it breaks?
2. What kind of technical expertise is available in the nearest town?
3. Is there a 'champion' in the organisation? Someone you might ask for help, who knows about computers.
4. Is there someone who could assist with training in your local language?
5. Are there local organisations that could provide training and support services?

5 Locally relevant content, applications, and services

1. How often do you monitor:

- Unprotected Sources (rivers, unprotected springs etc)
- Protected Point Sources (boreholes, protected springs, wells, handpumps)
- Piped Supplies

2. Please describe what happens during a visit to a source you will be monitoring:

- What parameters are monitored?

total coliforms faecal coliforms turbidity PH chlorine residual
others?

- Is a sanitary inspection carried out?
- If your results suggest the source is unsafe, what actions do you take on site?

3. Who within the organization is responsible for carrying out monitoring? (incl. job title)

4. Who within the organization is responsible for ensuring that monitoring is done? (incl. job title)

5. To whom do you report the results of water quality monitoring? In what format (paper, electronic) is this information made available? Specifically, please describe the information:

- Reported to other level of government
- Reported to consumers and the community
- Used internally in the running of the organization

6 Integration into daily routine

1. Who is currently responsible for preparing drinking water quality reports?

2. On average, how much time does this take each month?

less than an hour a few hours a few days a week

3. Does the prototype system we are demonstrating seem like it would save you time? Or, would it add to your workload, in reporting or in other areas?

7 Socio-cultural factors

1. Are there people within your organisation who might feel / be threatened by the introduction of an ICT-based system? What would you recommend doing to prevent this?

8 Trust in Technology

1. If a cellphone-based data capture system was implemented, how do you anticipate this being received by the community? For example, would there be trust issues if there is no physical form being filled out? [ref: previous e.cape study (Monyai, 2004) where communities asked for copies of sampling results, which they would use to lobby for better water quality]
2. How important is data security? Which of the following data security aspects would you consider very important?

Unauthorised people cannot edit or delete information from the system.

Unauthorised people cannot view data in the system (which data is sensitive? which is not? Think about making the system accessible to the public).

Unauthorised people cannot submit sample results.

The system is always accessible and is not prone to viruses and spyware

9 Local economic environment

[not sure all questions will be relevant to all areas – just want to get an idea of the area served so that it can be described in the report]

1. What percentage of people in your area drink from protected sources / unprotected sources?
2. What percentage of people in your area drink from safe sources / unsafe sources?
3. What are the main economic activities in the area?

4. What percentage of your customers would you classify as living in poverty?
5. Has HIV/AIDS had a noticeable impact on the local community?
6. Are there other development projects / NGOs that you know of in the area? What do they do?

10 Political will and public support

1. Do you consider ICTs a useful tool for drinking water quality monitoring?
2. Please suggest the benefits you anticipate from ICT use for drinking water quality monitoring.

Could these include:

- better data quality*
- better reporting*
- more accountability at local level*
- ability to act more quickly in the event of problems*
- better justification for budget requests*
- better HR management capacity.*

3. Please raise any areas of concern you have around ICT for drinking water quality monitoring.
4. Do you think that a system like the one being demonstrated would improve service delivery?

Appendix B: Interview Transcripts

1 List of Interviews

Date	Organisation	Interviewees
22 May 2007	Amatola Water, East London	Nosipo Gulwa
23 May 2007	Makana Municipality, Grahamstown	Pinkie Hermanus
23 May 2007	Buffalo City Municipality, East London	Deanne Karshagen
24 May 2007	Chris Hani District Municipality	Francois Nel
24 May 2007	O. R. Tambo District Municipality (Service Provider)	Booi Malgas
25 May 2007	O. R. Tambo District Municipality	Eric Mzayiya
25 May 2007	Alfred Nzo District Municipality	Mthetheleli Gcali, Nowthando Chongo, C. M. Qomto.

Copies of consent forms from participants are available on request.

Sarah Kiggundu, a fellow Masters student in Civil Engineering, was responsible for arranging the interviews in the Eastern Cape, and we conducted them together.

2 Interview with Nosipo Gulwa, Amatola Water

NG - Nosipo Gulwa

ML – Melissa Loudon

SK – Sarah Kiggundu

NG: You see in this area, which is like East London and around, there isn't really. Most of the places here have got potable water from the distribution system. Even in rural areas, even Amatola Water you know have got water works that they are managing, even in rural areas. So, there isn't that much problem here of water quality. But now, as you go to former Transkei – from East London, go to Butterworth – from

Butterworth, then you will find there's lots of rural communities who doesn't really have water supplies. In East London you not gonna see people from the municipalities, besides Deanne? Because deanne is just a laboratory manager. The people who work with communities are the people from – what's this name... Ey, they've changed all these names!

ML: We struggled with that too!

NG: Amatole. Amatole District Municipality.

SK: This is Amatola. The Amatole region is near to the coast.

NG: The head office is here in East London.

ML: Would you be able to give use a contact number by any chance? [To SK] Could you find a contact for them?

NG: Because my concern is that us at Amatola water, much as we are managing quality of water, we are managing the quality of the water that is produced from the water treatment works, and supplied to communities. Meaning we know about communities who have got water supply. Most of them have got water supply – I think 80% of the rural areas here have got water supply. But now, as you go, take this other direction and go to the former homelands you see, they don't.

SK: How do they get water? The ones who don't have water supply.

NG: They go to the rivers, or to natural sources like springs.

SK: Which is, clearly the water isn't tested

NG: Obviously, it's non-potable water.

SK: How come they haven't been supplied yet?

NG: I'm also asking that question.

ML: I'm sure they are, too.

NG: You see in South Africa now, water provision has become a political tool. But even then, I think the service delivery is too slow. We need to acknowledge that.

SK: Why do you think it is slow?

NG: If you go to the municipalities they will show you their IDPs and so on, all their plans. To do all this, provide water, sanitation, this and that. You will see that there, but it doesn't really happen for reasons I can't really understand. I don't know how municipalities spend their budget on services. But, we need to acknowledge that our current service delivery is too slow. And unfortunately, in the areas it's affecting the people.

ML: You said that in a lot of the municipalities, a lot of the communities in this area have their own water treatment works.

NG: In this area, these communities, Newlands and all, they are supplied by these water treatment works, so even if they have standpipes, they are getting treated water. An on the other side, the big township, Mthanzane, it's the second biggest township in South Africa, they've all got electricity, they've all got water supply. There are a few areas like squatter camps, but they've got standpipes as well. So, from my side and Amatola Water's side, as much as I would like to help.. So, I'm not saying that I can't help, but you see, my knowledge is quite limited...

ML: No, we understand. your opinion is still very valuable to us, you still know far more than we do about what might and might not work. Would you mind still having a look at the system?

NG: No, no fine.

ML: The system that we are demonstrating isn't necessarily targeted at the most rural areas either. If there were community-managed supplies, that maybe treat their own water – does that happen?

NG: Ah, I guess, yes.

ML: That might be someone who would use the system.

NG: You know, there are community organizations, which are called community-based organizations, and in some, they are called water committees, and those people there who serve in those committees, what they do they are there, they have been, I'm not sure if they are appointed through an election process or nominated or whatever, but they are there in the communities. If there is water supply in the communities, maybe there is a borehole, or there is a pump, even in some that are piped, pumps water to wherever,

they are taught to go check the diesel, to do all the minor operation and maintenance of the whole system. and I think they are getting a, like a stipend from the municipalities. And also you see in the rural communities in some there is vandalism.

And in cases where there are no water supply sources and people use rivers, that's where some municipalities, they will provide them maybe with chlorine tablets, to say, go get your water, maybe in a 25 liter bucket or whatever. Or say there is gonna be a big function, like weddings or funerals, where they must cart these large volumes of water, say a 50 liter drum, either they supply them with those tablet or they offer some kind of a service to say, use Jik, maybe pour so much of Jik and leave it overnight, just to make it a form of treatment, because you know that if water is not treated it can cause problems. But I know it is happening in rural areas and in some where there are no water committees or CBOs, there are local chiefs, people who look after the functioning of the area and then those people there are the ones who go maybe, because people like you do some research they come and they get together with them and they supply them – 'just try this maybe, we doing research.' Or if they offer what's this, Aquatest, so do this maybe every 15 liter drum. So then people get to know about these things. other than that, there is old ways of boiling water and some, if they can't boil the water, they use a clean cloth just to try and sieve through the water – just those old traditional ways, and I must say that they are really happy to get any assistance, in whatever form, to help them improve their water quality, because they are aware of the water quality problem. There are the ignorant ones, that will say Ah, we drink this water for years, and nothing has happened. So I think going out there, you could get a very broad picture, and get different opinions from different people. Political, cos some will tell you, I remember when we went to some village, some people there, they will tell you – that other village on the other side has got water supply, but they don't have. And then people start yelling at you and voicing their concerns. When you come and talk about water it's a political issue, it's a resource people need. Some voice their concerns, some are prepared to listen to what you have to say, some are not they just want to have water supply, that's all that they want.

SK: How can water be a political issue if the national water act they are saying that water is a basic human right?

NG: It goes further, the water services act says that we will provide water, you need to monitor the quality of that water. They don't do it, the municipalities are the government entity, they are part of government. Even those who provide water, the moment they put it in, a rural water source in, maybe it's a borehole source or whatever, that's the last time. They leave it for the people to drink, and they don't care about monitoring it. So, if you say, it's a good question that you are asking, but I must tell you I don't think you will have an answer. If you've got an answer, email me from Cape Town and say, somebody else managed to answer me convincingly. They will tell you that it's the budget, it's the money, it's the challenges that they have. Technical, human resources they don't have. You see all the stories that you'll get!

ML: I think maybe one of the things, one of the ways we could approach it is to say that, this kind of system, including a really low-cost, low-resource test for microbiological water safety, because it wouldn't test for very much else, it would just tell you whether the water was safe to drink or not

NG: Is it in the form of a tablet or what?

ML: It's a test in the form of a

NG: You don't have one?

ML: I don't have a prototype and it's not developed yet. Um, it's in the form of a kind of tube.

NG: So they have run trials?

ML: They haven't yet run trials, no. What we are involved in is a pre-study, and they are now hoping to get funding to develop the full test. Um, but what we would focus on asking I suppose is, If you had this test, and then you had a system that was, that helped you to manage the results, would they maybe, if they could give the community schemes with the borehole a phone to go through a sanitary inspection and they do it every month, and then every month those results would be received by sms, would it maybe help them to manage the process.

NG: Yes yes it would help. Because one of the things that you must understand, it's a pity there is no map here, is that the municipal office, head office or whatever is sitting here, and the area of their operation is so wide, you find that maybe it's in a radius of about 200km, and then it's not even physically possible for them to drive to those places every now and again. That's another thing, it's quite an expensive exercise

because they must claim back from the municipalities all of the kilometers traveled. And with an area so big, you can't really be in the same, at all these places, so that's also... So if now there's a system so that even the communities are able to say, yes we've used this and this is the result, then they would welcome that.

ML: That's great. Well then can I show you the prototype,

NG: Ok before we do a lot of taking!

ML: No, no talking is fantastic and you've already given us a much better definition of what the problem is than we could have come up with ourselves, so that is very helpful to us. Um, the first thing I have to show you (sorry that my phone rang, I had it on because I wanted to show you the little application on it). Um, this is a very rough prototype application. This is just the first screen telling you what it is. Just press ok to go – that's the ok button. It will now ask you to enter the name of the site – you can enter anything there – as far as I understand, if there's a borehole put in place it should have an identifier attached to it.

NG: Mm. It could be a code, and then there could be a full description.

ML: With the community name, or

NG: yes

ML: And then they would enter that [leaving out some demo bits here] And say now, you've done the test, and you've got a result, you could put in whatever numbers you get as the result.

NG: Does it do turbidity as well?

ML: Um, this test doesn't do turbidity, so I looked at some examples of what you could be measuring, I don't know how you do actually measure turbidity.

NG: You do actually get some portable tests

ML: The last thing on there is the sanitary inspection form, and this is one for a protected spring. So they would then go through all of these and hopefully check everything here, and say well yes we've got a problem um,

NG: What if this is a river?

ML: There'd need to be different ones for each source type, so if they have..

NG: How do you select them then?

ML: I've only written on for a spring, but it would be the same thing it would just have different questions. It would just have all the questions for a river.

NG: Ah ok.

ML: And then when you're finished, it doesn't do it, it just shows you what you've entered and then it'll send it over SMS into your central database.

NG: You've also developed that central database?

ML: Yes. So this is what's on the laptop, um... And then after that, the community would maybe get an SMS back saying um, your reading were successfully received, and what might also be possible is to then say, um your readings have been successfully received and we see that you've got a problem with one of the questions that was on the sanitary inspection and this might be some remedial action you could take. Like, put some chlorine in your water, you seem to have quite a high e.coli reading, or something like that so it could actually help the community.

NG: Who is funding this research

ML: The EU, the Aquatest project

NG: Why do they want to only do it with the University of Cape Town?

ML: I think because we're focusing on the data management aspect, and data collection.

NG: Is this a national project?

ML: No, we're actually just coming to the Eastern Cape for this pre-study, but for the followup project when they have actually developed the water test, then I think they'd like to look at other areas.

SK: [Explains why we chose the E.Cape, but she's too far away to hear her properly]

ML: This is the application that shows you the readings in the database that I've developed. And how it would get the readings in is that there would be just a little modem like the modem that connects to the phone line, except this modem would be receiving SMSs, so it would have a SIM card inside and received SMSs coming in from sites that would use the application on the phone. Um, and then this you can, these are all the samples that have been taken. This is the Northern Province up near Venda, because this is where a previous project took place and I have their data. Um, these are all their sample sites – they are quite close together because these are actually household samples. And then you can look at a site, click on the site and then see what the name of the site is, and have a look at the samples that have been taken there. These are colour-coded, so the samples that would be something to worry about are in red, so all these samples came out as something to be concerned about, they're quite high.

NG: This is what, here is e.coli, what test did they use?

ML: This is the data they gave me, it might not be correct. They randomized some of it.

NG: How did they measure it, for you to have a .65? Because even a lab, maybe the MPN method. No, that's impossible.

ML: Ok but the data in there isn't proper data, it's just to demonstrate how the system could work.

NG: Ok, ok.

ML: I did get their data, but I don't know how they got their results. And then this is some graphs of the same data so you can see also, with the same strange readings.

NG: What confused me, in most cases you'll find the total coliforms should always be greater than e.coli

NG: So you've developed the software.

ML: Yes

NG: Is it developed for this purpose only or?

ML: Yes it's using a free map viewer software and then I've written special modules for water quality management. Um, but to be used in practice by a municipality obviously it would need a few more features and we would need to do a lot more interaction with the people who would use it, asking them

what would be useful to them and what would help them, but this is just a prototype to show you the concept.

NG: It is a good one

ML: That's great to hear

NG: I'm actually impressed, it's similar to these other systems that you do find

ML: Ok, um cos what we were thinking of maybe doing with it was taking this then as a proposal to the water research commission, and saying we'd like to develop this system that could then be given to all the municipalities

NG: It's a pity I'm not, I wasn't there – there is a system that was developed for DWAF, but my understanding was that... I missed the presentation. In fact the reason why I didn't go is because we've got our own system LIMS here, but that one it is linked to the DWAF head office, so they do all their reporting of all their water quality data and all their results, it goes straight to the DWAF national database.

ML: Maybe what we should put in our project then as a better proposal, maybe we should say that we could develop a cellphone-based reporting tool that would link to that system

NG: The advantage of your system is the cellphones yes

SK: It would also help to get the community more involved in water quality. I would think that if you are supplying water to the community, especially a municipality for example that doesn't have the manpower to be able to track people up. That gets the community to believe more in the municipality

NG: Mm. And they aren't reliant on the laboratory, that would also help them. And there are no laboratory facilities.

SK: How long does it take to test your water samples on average.

NG: For e.coli and such? Lets say, overnight.

ML: I've just got a few more general questions about water quality. [Questionnaire].

Do you think security of a phone would be a problem in a rural community?

NG: No, most people have got cellphones now

ML: Language: for a local community, an English menu like that wouldn't be much use, it would be better to have it in Xhosa?

NG: No, not english

ML: Do you have any idea how much the two systems you've described, LIMS and the DWAF water quality system, could cost?

NG: I'm not sure about the DWAF one but LIMS is quite costly. It's a private system, i think even here to get it was about R76 000, and we're still paying annual fees, and every year there comes a new version, you must upgrade, and the support system they give is also not free. Although for us in the lab it is very useful.

ML: You saw that this was running on Ubuntu and not on windows. One of the things that we are quite focussed on is Open Source software. Because we would be developing this with research money, it wouldn't be right to sell it to people, you'd have to give it away for free. So that's something we would focus on is making it really affordable.

I've got quite a few questions on how often you monitor various sources, but you say it's mostly you monitor the distribution system.

SK: Do you monitor the dam and the treatment works?

NG: Yes

ML: Do you monitor at point of use – what comes out the taps?

NG: No. Reservoirs once a month, water treatment works at least 10 times a month. We are guided by SANS 241

ML: And household water:

NG: Not really, we take from the reservoirs and treatment works not from houses. [more questions about what is monitored – see standard]

ML: You obviously don't do a sanitary inspection, but would this be something that would be done at a borehole for example

NG: Only when there are problems, that would be part of your investigation.

ML: Have you ever had problems, where there has been for example a diarrhoea outbreak and someone has come to you?

NG: Not from this side, but it know it happens around. In rural areas often. There was a cholera outbreak.

SK: Andrew Lucas told me there were 3 cases of typhoid this year, 1 confirmed and 2 unconfirmed

NG: That could happen.

ML: But that would be more likely to happen when people were getting water from rivers, or from an unmonitored borehole too?

NG: No, I don't think boreholes.

ML: The other questions about reporting. Who do you report to – you said the DWAF water quality management system reports directly to their system in Pretoria.

NG: We report to DWAF, because DWAF has a system. We forward all out test results to DWAF

SK: So do all the municipalities in the Eastern Cape send it to the person who co-ordinates water quality for the Eastern Cape, and then they send it to DWAF?

NG: Mm. We go through DWAF

ML: So you don't spend a lot of extra time preparing results for DWAF?

NG: Us no, because we just extract it from our LIMS system. It's 2 minutes extracting and emailing.

ML: So the reporting in that system is very useful to you. So you would say that any system we develop would have to have quite good reporting?

NG: For those that don't have, yes.

ML: Is data security important?

NG: Yes, otherwise people might modify the data for whatever reason.

ML: Ok, so is the main reason for data security to stop people modifying your data. If people could see the data but not manipulate it, would that be a problem?

NG: It depends. I personally feel that it should be the way, people should know. But for some reason some people don't want that kind of transparency. I don't know.

ML: Ok so you would be more concerned about people getting in and modifying the data?

NG: Yes

ML: Has HIV/AIDS had an impact in the area that you've noticed?

NG: All social problems have got an impact. HIV/AIDS, poverty, drug abuse, all those things. If you go to communities you will see for yourselves, but really it does have a negative impact. You'll find that maybe those people who have been trained, to manage this operation they have, a borehole system or what. They fall sick – who is going to do this? Things like illiteracy in the rural areas. You are lucky to get people who can use the system, you would really love to keep those people, but due to those other things – poverty, maybe they leave to look for work, or maybe they fall sick due to HIV/AIDS, it would really be a problem.

ML: That's useful for us to know, because it means that any system we develop we would have to make very easy to learn.

NG: Yes, it must be a very user-friendly system. Very simple.

NG: The other place that you could target, I think you could target schools. Schoolkids are eager to learn. And it may be that the school you could give a cellphone for them, and then the kids could be given a project, say maybe this is July, the grade fives do all the water testing. It would be nice. Schoolkids are so enthusiastic, listening, asking questions, eager to learn wanting to do things themselves. In some villages, you find that even if they asked, you will give a date that you are coming to talk about water quality, and only 3 people turn up. If it was food parcels, then the whole area will be there. That's the reality of things, I'm not saying don't do your work, but these are the kinds of things you must be aware of. In that case it's easy to cover schools, you know you will find the kids at school.

ML: I don't really have any more questions, but you've been very helpful and you've answered most of them without me having to go through the questionnaire.

NG: Ah wonderful, good to know. I was really worried, I wondered if I would be of much help.

ML: No, very much help, We obviously still need to go to communities and go to local municipalities where there are boreholes in the area and that kind of thing, and in the followup to this we would have to do that, but as an introduction to the problems they face you've been very helpful, thank you

NG offers to help further if she can. ML says she'll send a copy of the report.

NG: Say for instance there is a municipality, they've got all their sampling points they've got everything, but they don't have a reporting system. Would you be able to assist them?

ML: Yes, I think in the followup project that is something we would need to do and would like to try and do.

NG mentions that there is someone in Barkly East looking for a system. She will email him and copy ML.

3 Interview with Pinkie Hermanus, Makana Municipality

PH: Pinkie Hermanus

ML: Melissa Loudon

SK: Sarah Kiggundu

Intro: Melissa introduces the project, the IT system and the aims of our research.

ML: You are Makana municipality and you supply water to Grahamstown. What other areas do you supply?

PH: We supply Grahamstown with water but from different sources

ML: Are they non-piped supplies like boreholes and or do people use springs?

PH: There are boreholes in Alicedale, Riebeck East.

ML: And as far as rural communities in the area? What water supply do they have?

PH: I'd say in terms of Grahamstown, we do comply but we still have a problem with Rub Riebeck in East. We are about to employ(can't make out what she says here).

ML: Does everyone in the area receive water from a supply that you manage or are there people who get water from rivers?

PH: In terms of Grahamstown, we have piped water supplies. We have the outside areas, like some farms, which specifically, we do not supply. There are farms that have water tankers and we fill the water tankers for them. There are other who don't have those tankers, which in the mean time, I would not be able to say. I think some of them use boreholes, according to the farmers. The farms are privately owned so we don't supply water for them.

ML: So it's not your responsibility to monitor those boreholes? Do you monitor private boreholes?

PH: We're not involved.

ML: In terms of community-managed supplies, are the community managed supplies in this area?

PH: No.

ML: As far as monitoring goes, do you manage your supply system and your distribution system? What monitoring do you do?

PH: In the meantime, we don't have a lab for chemical and biological testing. We have a small lab that we use for physical testing. We've got shifts, per day. If we're talking about the other reticulation, we're doing that once in a month. Then there is the Nelson Mandela Metro which is Port Elizabeth (PE), coming down once a month to test for chemical and biological.

ML: The people who don't get any water from your distribution system, like in the other towns, does as much monitoring take place there?

PH: We do monitor all of them.

ML: As far as reporting, what reporting to you do?

PH: We're doing reporting on the basis of the results- the physical and the chemical and micro. But there is a system now that we have to log onto. You input the data into the system. During the course of this

year, some members of DWAF came by to take some samples in our purification works, because they were no longer accepting the results. They came down to take the samples on their own and those samples are taken for testing wherever. Then at the end of the day, those results were recorded on the system. We're still struggling to get into the system. One guy was scheduled to come, last week from DWAF, to come and assist us to log onto the system, but they haven't come back to us. We have our results at hand, but we're still going to use the system.

ML: That system, have you seen it? Has anybody demonstrated it to you? What are your views on the system?

PH: I just know that we have to report on it. I tried to open it and it wanted a login password and unfortunately, we didn't have those until "this guy" (representative of DWAF) came in at the beginning of this month and he gave us a login. They had to come and give us the training and understanding of the system. We're unable to get into the system now!

SK: When exactly are you supposed to start reporting your results through the system?

PH: I'm not sure. We were supposed to start....I don't know but it's either towards the end of last year to the beginning of this year. We went to a meeting in PE and it was just an integrated water services meeting and that's where it was mentioned that the WSA are not reporting but according to us, here at Makana Municipality, we were not aware that we had to report because we were still waiting on the WSP to come back to us to say to us: "we've taken the information. The information has already been fed into the system. This is how you're going to get into the system." So we didn't have any information. What happened, is that they came here and told us that DWAF is trying to implement a system whereby all the municipalities are going to report into the system and they will be able to see those reports....but they didn't come back to us.

Melissa gives the demonstration.

ML: I don't know if it's in your area, but would you mind taking a look at it?

PH: It's not in my area since we at the municipality, don't have guys that are working on the(couldn't make that word out). We have a project that is coming up in one of the areas whereby we have a water purification worksite which is the one that is on the containers (not too sure that see saying at this part- it

does not seem coherent). In the meantime, i would not say that that (the IT system) is applicable because they areas of ours are not being served with anything at the moment. The planning that we have for the future: we're planning to have something like the container system. There is another one: its a pumping system.

ML: But it's a point source and someone from the municipality will monitor it?

PH: You'll find that this area consists of farms and you'll find that the people on these farms are not educated to be able to do some of the scientific work.

Melissa continues to demonstrate the system.

PH: Do you think that community take an interest in their water sources? Do you think the farmers are concerned?

PH: I think the farm workers are concemed and they are owners, specifically, of those boreholes. In terms of our community members- even if you can have a document in place where they receive information on their quality, it is not their main concem (that is paraphrased from what I understood about what she said- it what I could make out!). When time comes, that you have a problem, it becomes a concern.

ML: Most people drink from safe sources except those on farms, who drink from maybe unsafe boreholes? Would you say there is a significant amount of people that are poor?

PH: I'd say 45% of people in this area are poor. As I've already mentioned, we are surrounded by farms. People come here looking for jobs in the town.

ML: so unemployment is also a concern Is HIV/AIDS a problem?

PH: I won't lie, I don't know. If for example, you use this system, it has to be simple. Most of the people, are uneducated.

ML: Obviously not in English but in Xhosa?

PH: I think in English. You'll find others that can speak in Afrikaans. Grahamstown, way back, was quite Afrikaans. (explaining the history of Grahamstown with regard to the language and workers migrating here!) Even the old guys that we work with, they understand Afrikaans.

Melissa concludes and thanks Miss Pinkie Hermanus.

4 Interview with Deanne Karshagen, Buffalo City Municipality

DK – Deanne Karshagen

ML – Melissa Loudon

SK – Sarah Kiggundu

[Before recording, we discussed giving consent for the interview – consent form was not signed, but verbal consent was given provided we supply a copy of the research to Buffalo City municipality.]

ML: As far as resource constraints. What would you say the worst are?

DK: I don't think there's any place that doesn't have, but we always.. As your size of your area extends, it becomes increasingly difficult. You have the same resources that you now need to spread over a larger area. Budgets don't always increase, and you budgets don't always increase in line with say rising fuel costs, so that makes things slightly more difficult. Particularly when you want to collect a sample from somewhere far away then you have to justify sending a vehicle to one very remote site, whereas you have a number of closer sites that you could possibly monitor more often. But, not to exclude remote sites.

ML: Would you say having sites over a wide geographical area is a big challenge?

DK: It's not necessarily the size of the area. I think it's also that rural areas are sometimes not as easy to access, the terrain might not be so easy so it's not a case of any vehicle will get there, you need the right vehicle to get there, so that adds on some additional limitations. But I think there will always be financial implications, it just depends on the situation.

ML: And as far as community-managed supplies, do you have cases where communities manage their own supplies, or do you have boreholes that the municipality might put in and then leave the community to do the maintenance, make sure there's fuel in th pump or whatever

DK: That you would have to ask, finer details you would have to get that from the water department because we on our side have a monitoring programme that we follow. And as we can add on additional sites we do add on additional sites. But regarding the operational side of it, I can't answer that.

ML: What we, the system we developed, and it comes from another project also in civil engineering which was giving home-based carers who visit HIV-positive patients a cellphone. so that when they visit a patient they can record information about how a patient is doing on the phone, and then they can send that information to a central database so the doctor can see it. So now we have developed a kind of similar thing using a phone to collect information for water quality monitoring, with that the community or somewhere near to the sampling point could go and do a test if they had the field test kit, and could then report on a cellphone and send their results over SMS to the municipality rather than having to drive all the time. And also then helping the communities to take more control over their own water quality.

DK: Ok, so you're optimizing things

ML: Ja, and that idea came from the international consortium saying oh, you are doing this with home-based carers, could you maybe do it with water as well. So where're here asking people who are a bit closer to the reality of water quality monitoring, how they think it would work or what they think would work.

DK: Well if I think of where our water is treated, um, primarily we're dealing with water treatment works that are not too rural, it might have a lot more application where they are far more rural, but at the moment we deal with primarily 2, 3 water treatment works. But rurally speaking I can see its benefit.

ML: Ok. Can I show you the system anyway although it might not be that useful to you, just to get your thoughts on it. Before I do that actually, we've been hearing a lot about another DWAF system

DK: The EWQMS

ML: Yes, have you had any experience with that?

DK: Yes. We enter data on a weekly basis. Um no not weekly... well we do enter weekly but we have monthly reports that are generated from it. So that is something we do currently enter data into, and that is very much a data entry but also it can be used as a management tool, which one can use. So, it's a very

useful tool to then advise them on the water quality because they can then see provincially or nationally what the drinking water quality is like.

ML: And as far as being a management tool, DWAF use it as a management tool is it a useful management tool at your level as well

DK: Yes it is it's a very useful management tool because I believe it can send red flags when it picks up anomalous results. I believe, I don't know because I don't receive from them. It might depend on how you administer the system, I didn't go that far. It's very useful because you can see trends so a historical record. You can manipulate the data against certain parameters and then you can get a graphical output, so it does have a lot of advantages there. I actually think it's quite a good system.

ML: Um, knowing that the system exists and is working makes things a lot easier for us because we're not coming here saying, why don't you use an IT system when nobody has ever used one before and doesn't see the value in it. So it's nice to know that it's being used and being useful.

DK: I believe it will also grow into sanitation, but at the moment possibly only in the Eastern Cape it might have grown into sanitation in the other provinces I don't know, but in the Eastern Cape it's very much still in drinking water. Obviously the quality of your final effluents from your treatment works will impact on your drinking water quality downstream.

SK: When exactly did you start using the EWQMS system?

DK: We started using I would say about 1 year ago. I think it was also rolled out in stages in certain provinces, I don't know how far the Eastern Cape was in the rollout programme, but I have been involved with it myself for one year.

ML: I'm just going to let the laptop boot up, and can I show you the demo on my phone, and I'll show you the HIV one as well because that's much more finished, and is used in practice.

DK: Ok, this is what would now be issued to your operator?

ML: This is a very, very rough prototype of what would be issued, but ja – this is quite a cheap phone and we'd probably look at something a bit more rugged than this.

[demo]

DL: So site1 would have its information in the database, and they would then know where it is and..

ML: Ja, and which number they should be sending from maybe, so that people who aren't supposed to can't send results.

[demo]

ML: It might be possible also to get a reply by sms, saying say, I see you have a problem with the fence, you should fix it – some kind of feedback. And then, that's the reading that would be sent in to your central database. Then just the smarter phone, but also quite old, this is one of the much nicer looking applications, for collecting patient information during a home-based care visit.

[demo]

ML: For my thesis I developed this system also very much in prototype just to try out some technologies that could be used for reporting, one of them being open source software..

DK: Being..?

ML: You can see it's not running Microsoft windows, it's running a free operating system. Everything I've used to make this is available free, so also looking at ways that that could support resource-constrained areas. This system has some data for the Northern Province collected by other people involved in the project. Everyone else who has looked through it has said oh, those are totally wrong, it's quite likely that the readings are then totally strange..

DK: So then in other words you then would have you own site number, you would then feed information and you would then represent one of the dots.

ML: Yes, everyone with the phone would represent one of the dots.

DK: And that is your time delay between sending the information and being captured?

ML: 14 seconds, on average in the patient information system it would be 14 seconds

DK: It looks very good.

ML: One of the other things you can do that is quite nice is if you know what the normal range for a parameter is and you get a reading that looks totally wrong you can send it back to them and say, this looks wrong, check it again

DK: But then you'll have to have someone manning the system the whole time to do that? someone with a knowledge of what water quality should be, historically and whether it's in you acceptable limits for drinking water..?

ML: I think you could also have it serve as a warning, and have the acceptable limits as a starting point but still let them enter a reading that looks wrong if they're very sure.

[demo]

DK: I would say where your system has a lot of relevance or a lot of benefit would be in your rural areas, because they will not have a computer system or internet access. The DWAF system is internet based, so if you don't have access to the internet you cannot enter the data, so I can see it would have relevance there. Possibly you could even link onto that, as a service to DWAF even, or as well as to the municipality...

ML: We'd like to do that, maybe go to the water research commission and say we'd like to propose a project, for further development and to go to a municipality and find out what their requirements would be, and take it as a project. So that would be one way we could approach it. The idea of making it so that it can submit data to EWQMS is good

SK: Wouldn't you find that in the different communities in the rural areas, something like that would be better served towards the municipality, so they can compile it. Because I would think.. when we were speaking to the other people like Makhana Municipality for example, they told us how issues like that are usually handled by the municipality , and then they compile the water quality report and then they send them up for example to DWAF.

DK: Yes it would because the municipality also would have an obligation to supply potable water to the consumers, where the municipality is a water service authority, so yes it would have relevance, whether it was one level lower where you are now informing the municipality and the municipality then reports

some of the information to DWAF ultimately DWAF wants to know about the quality of the drinking water that is supplied by the municipality to dropping down one level over.

ML: I have a question that isn't on my questionnaire, just some thing we picked up this morning. If there's a private borehole say on a farm, and there's a farmer supplying water to the farmworkers on the farm, does anyone monitor the water that is supplied?

DK: At the moment we don't monitor private boreholes, but if there was a borehole that was being supplied to, say there was a borehole on municipal land, there are certain boreholes that we don analyse at the moment. The water is then obviously extracted from the borehole and fed to the reservoir and then it's chlorinated and supplied to consumers. As we make use of in buffalo city. But that information, because of its proximity we can get a sample there done on a weekly basis and brought to our lab for analysis. But if it is a far more remote one then yes it would have relevance as well. But we tend to test boreholes where consumers are not simply limited to one one farmer and his farm workers. We don't tend to test those boreholes because they are scattered everywhere. Where you have one that is supplying a number of consumers, then those we do try and bring on to our monitoring programme.

ML: And as far as reporting, I spose it is very standardised once you've got a DWAF system in place, but how often do you report, and is reporting an overhead?

DK: In terms of all our reservoirs etc? Well, our reservoirs are reported to the Water dept, we give them a report on a weekly basis of the reservoirs. There are certain daily reporting, that we can also react and respond to, because if you bear in mind that you cannot analyse bacteria every single day so you use indicator tests, like a turbidity, and a residual chlorine. You are then assuming that if you residual chlorine is sufficiently hight, that you then have adequate disinfection in your sample, therefore you're gonna have a reduced health impact. We do those analyses on a daily basis in and around the greater East London area, and then our supply reservoirs we do a full chemical analysis not just bacterial, weekly. Those results are copied to the water department, they're also copied to the water treatment works so they can see how they are treating their water. They will do their own minor testing as well, their process control testing within their own laboratory. We're more the compliance monitoring testing, and then we feed that

to water, we feed the drinking water results also to DWAF because they are our regulating authority, and we will then send those to them via the EWQMS system on a monthly basis.

ML: And communities in your area, do communities assume that their water is always safe? Is there any way for them to access those results. would they want to?

DK: That is something we should be doing, we should be advising consumers on the quality of the drinking water because they are entitled to that information. That is something that we do need to focus on doing, um, I'm not aware of too many systems in place that do do the feedback to the consumer. Usually when there is a complaint they'll react to that straight away, and they are given the results, but the routine programme, we don't often feed that information back but yes, we should be. And we have addressed that, we have discussed that.

ML: So maybe the system we develop could report, could be used to produce reports for the community.

DK: Well it's just how. Where would you present the information, where would you include it? Whether it goes on a water and lights account, but then you're going to reach only the folk that have water and lights and that pay it, are you going to put it in community centers, then you're relying on the person to actually go to the community center, there are some logistics there..

I think that is a shortfall, we do need to address that.

ML: Information security is kind of a related question I suppose. Previously people have told us that they don't mind other people seeing their results so long as they don't modify them. Is that the case here, is there any information that's really sensitive that you wouldn't want people to see?

DK: I don't see why they should modify at the moment, at the moment there is potential for it to be modified but there's no reason for it to modify. If you have an information management system, I know you can then not modify the data, so there you would have a protection on it which has obvious benefits. But at the moment we have one data capturer who captures the data and prepares the reports, they are then signed off for accuracy by the first-level managers, they do it visually, and then the reports come to me for signature for submission. So there's actually 2 checkings but then I don't physically go and check the accuracy of the typing, it is the.. The chemistry manager will check that first of all, then the

microbiologist will check this.. They will initial the report, confirming accuracy of typing and the feasibility of the results, and it then comes to me for signature so it can go off.

ML: Ok, so it's actually quite a process

DK: It's got a safety check built into it.

ML: I've got some general questions about the area, but I don't know if they apply. We were thinking we might be in more rural areas. Do you know what percentage of the people in the area drink from unsafe sources?

DK: There is information that comes through from time to time, benchmarking information but I don't know the most recent figures. There again that could be information that the water department could give you, and not necessarily that I would have to hand. We deal on the analytical side, we don't deal so much with the provision of the service and the backlog. So that sort of information you are welcome to confirm with Water Services, and I can refer you to somewhere to speak to.

ML: My other questions are, for example about HIV/AIDS,

DK: Would the water quality have an impact, you mean?

ML: Not the water quality on HIV, more HIV on a monitoring programme. People have told us it's difficult to set up a monitoring programme, often people that you train get sick

DK: That I could imagine could be a problem, it doesn't have as much of an impact where we sit over here. Our obligation then is to supply the water to the best standards you can, because you don't want to provide an additional risk to someone who is immunocompromised.

SK: Do you think it would be beneficial to have the software in a language other than English, for example in Afrikaans or Xhosa?

DK: I would see great benefit, but you're also going to have to have someone who is fairly literate to enter the information. It would have great regard - if you ask me in Xhosa what turbidity was, I wouldn't have a clue. There would be great benefit in putting it in a language even if you are using a whole sentence,

sometimes turbidity itself might not mean a whole lot but you ask them clarity or colour, if you gave a description of what it involved I think they would have a greater understanding of what it was. Unless you train the person doing the test, that eliminates the need a lot.

ML: I suppose it's a difficult line to draw with how much training you can do. [Describes cybertracker, picture-based]

ML: Hopefully we'll be back with something better, something we can actually try out in a community. It's easy to demonstrate but I think trying to implement it will be a lot more challenging.

DK: How will you then offer a system like that, because there must be certain royalties?

ML: No, one of the things that we would definitely do is release it as open source software, for people to use and modify. And that would be partly because it would be developed with research money and we therefore feel that it should belong to everyone, and partly because the research group we're involved in has always been very strong on open source software, and we used open source software to build the system. It wouldn't be a case so much of people needing to buy it, but we would need to have an infrastructure so that there would be support available, and DWAF I think would be the people who could help us with that.

DK: I'm just thinking, say we had an operator in little settlements that could do basic testing for us, and then feed the information for us, and then feed the information back to us, basically they would need to be issued with the cellphone, and it would then need to have your system to feed the data through to somewhere. So now what is that system, that it feed through to?

ML: There's a modem with a SIM card inside it, that works basically like a phone to receive SMSs, so then it will receive an SMS and passes it to the computer, so that basically receives the SMS that you've got and stores it in the database

DK: I'd like very much if you could leave me with your contact details, because I can see value in a system like that, and we were just discussing at a meeting yesterday how difficult it is to get through to some areas. So if you have an operator that you can train up, you might be even a n on-site reservoir, it need not even be a water treatment works but it could be an on-site reservoir, then we can at least get certain information coming through to us, where it reduces the need of our going out there to collect the

samples, which is what we are hamstrung by. We just need to make sure that the test that is used to generate that information is a verified / validated type of test, because we would need to advise whichever results are coming in, that they are using this test vs. the test that we use in the laboratory.

ML: Leaves details, offers to let DK know when the system is on the web.

5 Interview with Francois Nel, Chris Hani District Municipality

ML: Melissa Loudon

FN: Francois Nel

SK: Sarah Kiggundu

ML: We'd like to give an interview. We're Master students from the University of Cape Town, looking at drinking water quality monitoring specifically in more rural areas or community-managed supplies. The reason that we're doing the research, is because we're involved in an international project called Aquatest, funded by the EU and that project is to develop a low-cost test that can be used to test for e coli, without that much training. It is to be used in developing countries and more rural areas. Our part of the project, is to look at how this test can be used to improve water quality monitoring and improve the ability of the municipality to reach more out-lying areas to monitor sources that, for example, at the moment they may not be able to monitor. So most of my questions are around water quality monitoring and specifically drinking water quality. I've also got an IT system, issuing a cellphone to collect water quality readings. I'd like to show you this system and get input.

FN: Ya, that would be good!

ML: We need to ask you to sign a consent form to be interviewed.

FN: I don't have a problem with that!

ML: Generally, what is water service provision like in this area? Do you supply large towns?

FN: We consist of 8 local municipalities. I can give you a map so you can know exactly where they are. I don't deal directly with water provision, I focus particularly on environmental health. We're dealing

directly with the monitoring of water points. I'll tell you exactly what it is we do in terms of water monitoring. The supply is very well covered. We are a very rural area so there are areas that are not directly covered but you could speak to the Water Service Authority (WSA) about that! You can ask for access to their water service system and they could show you access to the areas. In terms of sampling, that is currently a discussion point with us because it falls within the spectrum of environmental health but it is also a core component of the WSA. At one stage, we wanted to take over that component of water quality monitoring in the area....we're looking at 600 schemes. That is a huge number of samples that must be taken. Currently, though, we have appointed a Water Service Provider (WSP). Amatola Water is working with the WSA in terms of water quality monitoring, maintenance and looking at the schemes. We do adhoc sampling. If we go to abattoirs, we take samples. If we go to food places, we take samples. We do not focus on river systems as such. I know some municipalities, for example, if you go to Ukahlamba (check the spelling) and Barkley....they went with the option of environmental health running the whole thing because you get the data first hand and can intervene immediately. There is a break in communication between the WSA and health. They get all the results, they are able to intervene but there is also a part that municipal health must play, for example, teaching health to people and showing people how to treat the water. All engineers do is throw in chlorine and then the water is right. They do not address the issues as to why the water is dirty. We have our own lab its not operational yet but we have all the equipment (nitrate, fluoride tests and bacteriological). I have a full set that I can use to do filtration as well (on the agar plates). I brought this stuff.....previously I was employed at one of our local municipalities. I have a fully-fledged lab. So that's basically how we run water samples at this stage. WSA run water quality sampling. They have a database in terms of an information system. There is also an information system, I don't know if they are working on it yet. It was developed by DWAF. I'm on the steering committee of that project. It's run by Amanti.

ML: Then we have a lot of questions for you on that.

FN: There is a little bit of a limitation on that programme for us. I think that there are one or two aspects that relate how we run it!

SK: With regard to the WSP, do they provide you with the information after they've tested the water?

FN: Yes. Amatola Water....I think they've started working already. Technical staff in the field analyse the samples and then the results go into the database. In terms of the results, they do their interventions etc.

SK: Can you access the information from the database?

FN: At this stage, they are supposed to supply us with the information and we discuss how we are going to make use of the information. I have my own system which has a water quality component in and it is a GIS system. The two systems don't talk to each other as such. My idea was: if I take a sample, this system must immediately update their database and vica versa. Otherwise, one will sit with two databases and one must dump information into one of the databases to get the bigger picture....but that is still in the pipeline and there's alot of work to be done on the information system.

ML: Do you have dial-up internet?

FN: No. We have fixed-line internet.

ML: Broadband.

FN: Each and every staff member has access to a computer. We're moving to a new phase where each and every Environmental Health Practitioner (EHP) (that's my proposal to the council) where each staff member can have a laptop when working onsite. They are placed in local municipal areas. IT infrastructure is an enormous expense. Broadband and 3G is so cheap....you can obtain access for R300. So they can take their samples and analyse them and immediately, it will be accessible on the system. We are moving in that direction, however, people do not always buy into that area because it is IT. I don't think the councilors always understand what IT is always about....even GIS. I thought GIS was a map with dots on it, until I took a course and I realised what an enormously powerful tool it is. We're putting these systems in place but everyone had their own system. We're moving into corporate GIS for Chris Hani, where all the information will be available on a central server. We will access the information via 3G. We're still struggling with reception in some of our towns....even in Queenstown. In certain areas, you don't get 3G.

SK: Don't you find that you'd have to train these people because the majority of them would not have the computer training?

FN: All my staff have a BTech degree. There are, however, people who come out of a university of technikon and don't know the basics of using a computer. We did a first-round training and at final implementation, the staff are trained again. IT progresses, thus the staff are trained regularly. Next month, we will have a final training session on the system. I now buy GPS for the workers to use. It helpful for them to see a visual picture of the area and prioritise where the critical areas are. They must get training on all these systems.

Melissa demonstrates the system.

FN: If they are sending information via sms (using the cellphone), what in systems must you have in place, in terms if in terms of infrastructure, to accept that information.

ML: On the receiving side, you'll need a database and the piece of hardware re you need is a GPRS/SMS modem. It's a little device, costing R1 500, with an aerial and it's got a simcard inside. It receives the SMSes and passes them to the computer. We're running everything on free software.

FN: How do you link you work with DWAF?

ML: We haven't at this stage. It's a pilot prototype system. It wouldn't work yet, we'd have to do more work on the system. What we're doing now, is a feasibility study. When we have the results, we'll then take this information to DWAF or WRC.

FN: I'm very system orientated and the more information you have available to make the work easier for the guys, the better for me but also, for us at management, that information is very important. I think that lacks in local government alot. They sit in the office and plan for thing one year and another the next. We didn't do anything about that. I ask my staff, if you go to site and test milk, for example, what will you do about the results? Whether they comply or don't comply, what are you doing about the results? If you have a guy in your area who does not comply, you write him a letter. If, however, you have 50 negative results, you have a big issue and you must plan and budget accordingly. These type of systems can help you to keep up-to-date and it's very very nice.

Melissa continues to demonstrate the IT system.

FN: One of my biggest issues, in terms of developing software like this, is how it will link up with the software in place. You must remember that this system (the system they use in DWAF) is not GIS based. This can be a component linking to that. I think you will easily get Water Research Funding for that. There is a need for such systems. It can save the guy outside a lot of time and it can save us a lot of money at the end of the day.

SK: Wouldn't it be easier to teach someone within a rural area, which might not be easily accessible, to use the cellphone and they test the water quality....

FN: You can do that as well. There are EHP in the rural areas. My view point, is that we have people in the field who are based in local municipal areas within the rural area. I know that sometimes, they want to fight with me because we have a 38 000 km² area. Some of the places are not even accessible by 4x4. I think it's a good idea, where there is no service but is not supposed to be the case, especially for environmental health. Adding to that, sometimes it's very difficult to get to these areas. I think I need another 30 EMPs to cover the national norm. Some of these guys are working in areas where there is a ratio of 1 EMP to 45 000 people. Council sometimes does not understand what environmental health is all about. It's water quality, its disposal of the dead - they then realise that it's an enormous field. That's why some of these guys get hooked onto projects that take up a lot of their time and they can't focus on their normal work. If they have the basics, and we have the basics, in terms of chemical, physical and bacteriological. Faecal coliforms is too broad a term to look at in any case. If you have a test like that you can input your data immediately. The test for me is very interesting. There was a test developed (hydrogen sulphide). If you can get a test that indicates the presence or absence of bacteria, it will be much more easier to intervene on the spot. It's a problem not only for water but for food as well.

SK: Once you know a source is contaminated, wouldn't you have to take need to take more samples, to identify what exactly is contaminating the water?

FN: That's unfortunately sampling. We do this sampling to get a rough indication of what's going on. If you look at the Water Quality Guidelines, things have slacked down a little bit. If I know there is 100 000 e.coli present in 1ml of the water, then I know that there's a big problem. It's really just a

presence/absence test. You must then send samples away and look at interventions. If ecoli is present, I already see it as a risk. We would have to intervene in any case. The biggest issue is : using a presence/absence test and something is present, the guy must intervene and locate the potential risk factors in the upstream or downstream conditions.

SK: How do you address the issue when you are intervening?

FN: It depends on where we get the contamination. In rural areas, we get contamination in water tanks. The first reason is birds. They don't close the tank properly or the pipeline is broken and remember, this is the deep rural area. There's a lot of animals. In terms of river systems or service water, there is a lot of animal and human activity around that water source. The cattle are drinking from there. We isolate the circumstances around the water source. If we see animals, even if the animals are not the source of problem we address it. People also use the river systems toilets. They've been doing it for 200 years and to get them to walk 100m to a toilet, they are not receptive of that. That's what we're focusing on: educating the people.(For example: there are cattle and these are the potential pollution sources.).....I went into water quality as my Masters. I didn't finish. It's a lot of work especially when you're working full-time, but in any case.....There are different things that you must look at. It does not help if you (if for example) you close the tank and the biofilm develops inside the tanks. A study on bio-film was done at the Free State Technikon. There are various aspects that we look at. We're not going to say: there's 1 e.coli, don't worry. They need to investigate where the potential contamination places are.

ML: Do you work with schools at all?

FN: Yes

ML: We were at Amatola Water and they suggested that if we want to try out the system, we should give the system to school children.

FN: That would be interesting. We're working with 6 six schools now on an Environmental Management Project. It's biodiversity, waste management etc. The schools like these types of initiatives. We have programmes in place that we want to establish and we can fund. Sometimes we can work together. I know there is a bio-monitoring system in George. The lady piloting that project was my previous director's wife. We wanted to implement a project whereby the river systems would be monitored. You can link that

directly to transferring of information to the children. Why mustn't you waste water? Why mustn't you throw things in water? And all the linkage in terms of waste pollution. You can go to Vodacom and ask them to sponsor your initiative.....they will give it to you. I promise you. For them, it becomes a national thing: being involved in this initiative. I think it's a good idea to go to schools, definitely. And environmental health people - give it to them and say "let's test it from a professional point of view". How do you find it and maybe you could change things on the system but with children, it must be very very user friendly. They must understand. That's where we can come in with what's ecoli, where is it coming from and why do we test for it? Why do we test for turbidity? Why do we test for all these other things? That becomes part of their curriculum. They are marked on that so immediately, you start targeting a lot of issues. You're targeting the curriculum, you're targeting water, you're targeting waste management - all of these things in a package. That can be a brilliant exercise!

ML: As far as language is concerned, I think that it's become very clear that English isn't the most used language out here?

FN: Afrikaans, you can forget in this area. In the Chris Hani area, it's Xhosa. Around the towns, yes, but when you move in rural areas, you can forget it! When you move around in rural areas, those people can't speak Afrikaans. Some of them can speak Afrikaans especially when they live near farms but in the Eastern Cape, it's more English-speaking people.

SK: When we googled the Eastern Cape, we were of the opinion that 80% were Xhosa-speaking!

FN: Definitely.

ML: As far as data security, you would probably want a system where people cannot modify the data.

FN: The only people that can modify data at the moment, is myself and a senior. We want the community to be aware of the issues and sometimes we get a little bit of flack about that but they will immediately put the pressure on politicians. It's supposed to work like that. I think we should put it out there and state why the issues are there. So politicians can see these are the problems.

ML: Not modifying it but reporting to the communities and important people.

FN: That's my personal view point. I don't know how my director would feel. I think she would feel the same. I think things (information) should be out there. To say "hey here is a problem". If it's the community that contributing then immediately, we must take responsibility and realise that? we're polluting our sources. What can we do- collaborations with the municipalities to address the issues.

ML: What we would like is for eventually communities to monitor their own water sources.

FN: That's one of the problems, to get communities involved. There's still this attitude: "If I do this, what do I get?". I've tried to change it now with my projects. What are they giving back to us? I think the government has spoilt our guys a little bit. The government has said they are going to do all these things, now people sit back and say " the government must provide". Our politicians are clued up and we are working very well with them. But I think some communities believe that it is the responsibility of government to give them everything. Like the last year's project, its R150 000 project. It's not alot of money, but 7 schools benefit out of the project and we had to cover one of the pieces of land, which we had to plough and they sent me an account of R350. I asked them what is your contribution to the project? They could not understand what I was talking about. You are making the project here, you must pay everything. It took a while but the community will cater R2 000 out of their own pocket. The children are working physically on the project. Previously, the municipality did everything and said "here is your project" and it failed. They must own the projects. This is our first big project at a school level. Our other projects, include the removal of alien vegetation from the area. It's because of over-grazing and there is no grazing land anymore. That's a big project but its a 6-month project where we pay them R2 000 per hectare to clear and the guy gets his R 2000 and the next year, we go to another area. This one is our first big project and we've been running it a for year now. The children are working and we're beautifying the schools. Other aspects, is to get the buy-in of the teachers. When I see the teachers that teach our children, it's scary. Teachers just sit there and don't do anything. The children will be committed because it's something new and something to get involved with....sometimes, we struggle with the principals.

SK: Would you say that poverty is accounts a little bit for what whether the community buy into the project or not? They will reap[benefit eventually, but not monetary benefits.

FN: That is a mindset that you must change. People must understand, it's not the monetary value that you get out of the thing but at the end of the day, it's a resource that is very scarce in our country that we must look after. I fight everyday with the politicians in the planning section, in terms of water resources. People should be aware that a project may not always benefit them financially but it will benefit the community in terms of water quality and immediately, when you address water quality, there are primary care issues, you address environmental issues and at the end of the day, you have a healthier community and it's cheaper to maintain for government, than an unhealthy population of people. I think that's where EHPs must come in - with awareness. Why are we doing this? Not for the sake of the law says, this must be done but the bigger picture and I don't think people always see the bigger picture.

ML: Has HIV/AIDS had a noticeable impact on the community?

FN: You just missed the HIV/AIDS co-ordinator. HIV/AIDS is a big problem in the country and the Eastern Cape. I made a presentation the other day to the HIV/AIDS council on the involvement of environmental health in HIV/AIDS because I think that's one thing that lacks. You have an HIV/AIDS department but there is not support from the departments. I think, like us that work with communities, it's the ideal time especially with their training in health, they have basic aspects of HIV/AIDS so you can use them. Why must you run HIV/AIDS on your own if you have support staff? Why can't engineering projects include a component for HIV/AIDS. I budget for HIV/AIDS awareness. We're the only department in the municipality that are doing HIV/AIDS awareness. On our posters, on our campaigns....everything, there's a message on HIV/AIDS. We're going to talk to the HIV/AIDS people to train EHP so that each component of a project will include HIV/AIDS. This project that we are running at the school, primary schools, but there will be a councillor there and they are going to be testing. We're not going to test the school children. The teachers will be tested. We'll give them some support in terms of that. We have a wellness day twice a year (Chris Hani District Municipality). All the officials test themselves, in terms of HIV/AIDS. The programme can become enormous with the impact of the other departments into the HIV/AIDS component. The HIV/AIDS guys made a brilliant proposal. They requested that 1% of each director's budget goes towards HIV/AIDS. I think it's a brilliant idea because then they have a lot of money and they're ploughing the money back into the departments. So that's how I see it. It's an enormous issue - it's an economic issue and we must change the mindset.

6 Notes from Interview with Booi Malgas, Service Provider to O.R. Tambo District Municipality

We met Mr Booi Malgas on the afternoon of 24 May 2007. We had been referred to him by the provincial water quality coordinator for the Eastern Cape, Mr Andrew Lucas.

Although Mr. Malgas reports on drinking water quality to DWAF using eWQMS, he is not part of the water service authority (O. R. Tambo District Municipality). His role is that of a water services provider, providing laboratory services to the municipality. He tests and report on water samples provided to him by the municipality, but is not involved in monitoring programme planning, or responsible for remedial action if water quality testing identifies a problem at a sampling site.

Mr Malgas assisted us by identifying Mr Eric Mzayiya at O. R. Tambo District Municipality as the correct person to speak to regarding drinking water quality monitoring in communities, and by helping to set up an interview with Mr Mzayiya for the following day. He also clarified the role of DWAF with regard to defining what tests can be used to monitor drinking water quality monitoring. Currently, the H2S presence/absence test is used by some Water Service Authorities (including Alfred Nzo District Municipality), but this test is not accepted by DWAF as proof that a source complies with SANS241. He stressed that any field testing method would need to be accepted as valid by DWAF if it was to be seen as fulfilling the legal requirement of WSAs to test water in accordance with SANS241.

7 Notes from Interview with Eric Mzayiya, O. R. Tambo District Municipality

We met Mr. Eric Mzayiya on the morning of 25 May 2007. He kindly agreed to be interviewed despite not having been contacted in advance with official details of the research. Because we had not followed the official process, it was not appropriate to use a dictaphone for this interview. However, we recorded the following notes:

- Have some water purification works, some boreholes, some protected springs. Monitored on a monthly basis, community members involved in operations and maintenance of the schemes and paid a stipend. Currently if there is a problem they might phone, or they might wait for the municipality's technicians (who come monthly to test the water) to come. In this case it is a

problem because people may drink unsafe water for a while before the municipality knows about it and can fix it.

- Water quality is a concern particularly after heavy rains – you might test a source and it is safe, but if it rains heavily it can become unsafe.
- Would support getting schools involved – the municipality is already involved in teaching about sanitation and hygiene in schools.
- Report to DWAF but are not yet using EWQMS. Mr Booi Malgas is contracted to do the reporting to DWAF as well as the testing of the samples they collect. Technicians are however involved in preventative maintenance.
- Likes the idea of a cellphone-based system and thinks it could be helpful particularly in the more remote areas. Does not see cost as the major barrier to such a system – water quality is a serious concern, and they would like to set aside budget if the system could help them monitor their schemes better. DWAF were also suggested as being able to help with this – they have paid for the development of EWQMS and are making it available at no cost to municipalities.
- Asked about the specs of the phone required – one of the only people to ask this.

At the end of the interview, Mr Mzayiya provided us with his contact details. He seemed enthusiastic about the possibility of implementing this kind of system in O. R. Tambo.

8 Interview with Mthetheleli Gcali, Nowthando Chongo, and C. M. Qomto, Alfred Nzo District Municipality

MG – Mthetheleli Gcali

CQ - C. M. Qomto

NC - Nowthando Chongo

ML – Melissa Loudon

SK – Sarah Kiggundu

ML: We were sitting in your office and we saw a map up on the wall about all the schemes that you have, could you tell us a bit about water supply in Alfred Nzo, and also a bit about how monitoring works?

MG: Ya, maybe we'll start by saying, most of our schemes are in rural areas. That have got sources as boreholes, or springs, or streams, and we've got a few schemes that supply the urban areas, Mount Ayliff, Mount Frere. We operate and maintain the schemes ourselves.

ML: Rural areas obviously present more challenges than a scheme in an urban area, what challenges do you face in operations and maintenance of those rural schemes?

MG: Well, maybe, basically the challenges in the rural schemes are with the maintaining part of it, we won't have our staff permanently there, we are relying on locals, local communities, community-based organizations. Who help us, but sometimes they don't report faults quickly enough and it takes some time to repair things. But ya, and the other thing is this water quality. Because some like during the rainy season there this a lot of runoff. That means the sources, there is high incidence of contamination by e.coli, total coliforms.

ML: More background to what we're doing is that the University of Cape Town is part of an international project called AQUATEST funded by the European Union. And what they want to do is develop a low-cost field test for e.coli. I know, we spoke Mr. Booi Malgas in O.R. Tambo, and he said that you were using a field test for e.coli, a presence/absence test

MG: Ja, ja

ML: Ok, this is designed to be not quite a presence/absence test, more of a banded test, like there could be say 3 bands for water quality. The test hasn't been developed yet, and the University of Cape Town is not involved in the development of the actual test, but more in the management of results and how we can help municipalities support schemes that are in rural areas when there are community-based organisations looking after the maintenance of the scheme, as happens in your area.

How much is the community involved in testing, is it mostly your technicians? Who tests the water?

MG: Oh, we've got Nowthando (sitting next to him), she is our chemist. And we've also got staff from the department of health, environmental health officers. They do the field testing, but I do the reporting.

ML: Are you, I know there's a system that DWAF is proposing, EWQMS, are you using that system?

MG: Yes, yes. It's a very very useful system. We started using it last year, some of data is already on the system, you can just go into it and have a look.

ML: The system that we have is something that is more intended for rural schemes to report to you, so that you could then report further to DWAF. And what we'd like to do with it is take it maybe to the water research commission, and say we've got this system that uses a cellphone for the community-based organization at the scheme to collect information about the work they're doing and the problems they are having, possibly the results of the test. We might want to go to the water research commission and say, would this be a good project to develop further. So what we are here doing is a feasibility study, asking people is it useful, would it be useful.

I'll show you the phone part of the system. If you imagine giving each of those community-based organizations looking after a scheme, maybe giving them a phone which they could then use to report information every time they did a test if they were using a field test kit, or every time they checked the fuel level or whatever

[demo]

ML: [...] so as soon as the SMS came in, you could then see that the person responsible for that scheme had done some tests, and had maybe done some maintenance. You would know exactly what was going on at that scheme.

MG: The challenge we would have with that, is that the people in the villages are either totally illiterate, or semi-literate, and we cannot really expect them to do these tests.

ML: I think the idea of this test they are developing is that it should be so easy to use that even a person who is semi-literate could use it. That they could be given instructions, or that you could maybe train the person in a local language rather than English, maybe in Xhosa. But the idea is that it should be simple enough that someone who is semi-literate could use it.

ML: Are these people payed at all?

MG: We currently give them a stipend, but they are not employees of the municipality.

[demo]

ML: [...] So that's an idea of what the system could look like, it obviously doesn't do everything you would need it to do in practice as this point, and we haven't tested it in practice either. What we are doing now is coming around and showing it to people, and asking do you think it is something that is worth testing, this cellphone-based reporting system, and should we go to the WRC and try and get a project together?

CQ: What does it cost to send an SMS?

ML: There are a lot of ways of doing it, one is you could put airtime on the phone, or you could use a reverse-billed line so they don't pay to send, in which case it could cost around 40c. The cost of the SMS isn't that high. The cost of a phone, also not that high – you don't need a particularly high-tech phone to do it, any phone would work. Any phone with Java, so any of the newer phones. The software, we have developed as Open Source software so it's all free software, and we give it away free and making it available for free because we would be developing it as a research project and with research money. Though we would maybe want to give it to DWAF to support and install it. But the municipalities would probably need to manage giving phones to people and making sure there is airtime, that kind of thing.

CQ: So, you can load the data from those maps?

ML: Um, the GIS files that I saw next door? Ja, we could load that.

CQ: So, they can report anything from the messages?

ML: Ja, you could maybe report text too. It's nice to have a kind of structure that they got through, so that you make sure that they check certain things every time. And then you would define what you want them to check every time, and then there would maybe also be space for them to put any other concerns that they have or things that are not working.

MG: Ya, I think it would be very useful if it could do that. Because now, we eliminate now this problem of not responding immediately when there is a problem. Cos now, the operator will send an SMS saying there is whatever problem with the scheme, and it would be picked up here in the office, and we would dispatch someone to fix it or whatever. Ja in that respect it would really really help us, we are battling with reporting. People are complaining we don't attend timeously to problems, they are for days without

water. But in fact we only now hear that there was a problem. But if someone had your system they could pick it up instantly. Sounds very very useful.

But like I was saying ja, even on the water quality side of it, the only problem that you would need, wither you would have to simplify the test, not like currently they are, so that those people there could do the test.

ML: I hope that the EU project will come up with a very simple test. They've got the prototype and they are going to be testing it, and I think it would help a lot of people if they could come up with a simple test.

MG: I think it would really help, it would be very, very welcome cos ja, the tests that we are currently using are complicated, needs people to do them, you cannot ask just anybody to do them. So if you can make a simpler test that will also be accurate.. Because ja water quality is very crucial, and we are battling to monitor it especially in the rural areas. There it can act up at any time, when we don't have the conventional water treatment works where we know we control the process.

ML: On way to use the system might also be to say, if you get a result that indicates a problem and you can't go immediately, then you can maybe send an SMS back saying, put this much Jik in your water or this much chlorine, or boil everything before drinking, until you can go there.

MG: It's good to know that there are people trying to simplify and help use deal with our responsibilities, but like you are saying you would have to develop it, let the WRC have a look at it, and most importantly DWAF because it is our regulator. And they also have this responsibility of giving us support, like this new reporting tool that we have got here (EWQMS), that was developed and we are getting for free. But ja it is good that you come to us, see how we feel about it.

ML: Thank you very much then.

MG: Thanks for coming.